Project Title: Wood Energy Demonstration Program

Project No: A-2400

Project Director: Mr. J.L. Birchfield

Sponsor: Georgia Office of Energy Resources; Atlanta, Ga. 30334

Agreement Period: From May 1, 1979 Until April 14, 1980

Type Agreement: OER Contract No. 164 (subcontract under DOE No. DE-FG05-79ET23076)

Amount: $793,810

Reports Required: Monthly Progress Reports

Sponsor Contact Person(s):

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<th>Contractual Matters (thru OCA)</th>
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<td>Mr. Mark Zwecker</td>
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</tr>
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<td>Office of Energy Resources</td>
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<tr>
<td>State of Georgia</td>
<td></td>
</tr>
<tr>
<td>270 Washington Street, S.W.</td>
<td></td>
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Defense Priority Rating: None

Assigned to: ERL/WEB (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director-EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)
SPONSORED PROJECT TERMINATION SHEET

Date 6/16/82

Project Title: Wood Energy Demonstration Program

Project No: A-2400

Project Director: Bulpitt

Sponsor: Georgia Office of Energy Resources; Atlanta, GA 30334

Effective Termination Date: 12/31/81

Clearance of Accounting Charges: 12/31/81

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/WEB (School/Laboratory)

COPIES TO:

Administrative Coordinator
Research Property Management
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Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services (OCA)
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EES Public Relations (2)
Computer Input
Project File
Other
A STATE DEMONSTRATION PROGRAM
IN WOOD ENERGY

Funded by the U.S. Department of Energy
through the Georgia Office of Energy Resources

VOLUME V
TECHNOLOGY TRANSFER

By
C. L. Aton, Task Director
William B. Himes, Jr.

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia
December 1981
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B. Wood Energy Financing
C. WOODTECH '81: An Industrial Wood Energy Exposition
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   Chips 'N Quips Vol. 2
G. Wood Energy for Nonforest Industries
H. Wood Energy Conversion: An Economic Analysis
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SUMMARY

The State Demonstration Program in Wood Energy was aimed at commercializing wood energy in nonforest products industries. While conducting feasibility studies, on-site demonstrations, and research into various aspects of wood energy implementation, the Georgia Tech team amassed a wealth of information and data with which industry could pursue its own approach to utilizing wood energy. The objective of the Technology Transfer Task was to transmit this information to industry.

Three seminars, one conference/trade show, and two dedication ceremonies were held during Phase II. The titles and locations were:

- Case Studies in Wood Energy, Atlanta
- Case Studies in Wood Energy, Savannah
- Wood Energy Financing, Atlanta
- WOODTECH '81: An Industrial Wood Energy Exposition, Atlanta
- Demonstration - Integrated Products, Inc., Aragon
- Demonstration - Gold Kist, Inc., Valdosta

A total of 422 participants from 18 states attended these events. Nonforest-related industries, forest products industries, consulting firms, equipment vendors, and government agencies were represented in these audiences.

A proceedings was published for each seminar. Full color six-page brochures were compiled for the demonstration sites and two newsletters were published and distributed throughout the Southeast.

An attractive, educational display was produced. It consists of a 4' x 4' detailed scale model depicting how a typical wood energy system would appear at a textile mill and ten 16" x 20" color prints of various wood energy activities.

An economic analysis model using the Georgia Tech computer was offered to businesses in Georgia. It computes the payback period using data supplied by the business and calculates the cash flow for 20 years that would result from installing a wood energy system.

Liaison between Georgia Tech research engineers and groups throughout the country was extensive. Our project team made 28 presentations at meetings, conferences, and workshops during Phase II of the program.

Over 45,000 copies of publications produced during Phase I and Phase II have been distributed and over 800 people have attended the workshops, seminars, trade show, and tours held during the two years this program has been active. Through these efforts more people than ever before are aware of the tremendous potential wood energy offers industry in the State of Georgia.
Lack of knowledge in wood energy is one of the barriers to the commercialization of wood as an alternate energy source. Few nonforest products industries realize the potential that exists in wood as an alternate energy source. An in-depth study by Georgia Tech showed that the energy wood potential in eight southern states is over half a quad per year. This potential could increase to as much as 1.2 quads by the year 2000. The equivalent of 340 million barrels of crude oil each year would be available for energy if an accelerated recovery program were implemented.

The State of Georgia alone produces the equivalent of nearly 30 million barrels of oil in potential energy wood today. That is enough energy to sustain 140 industrial boilers rated at 100,000 pounds per hour without competing with commercial timber markets.

The objective of this task is to make nonforest industries aware of wood as a fuel and to encourage consideration of wood as an alternate energy resource. There are five areas included under this task:

- Seminars
- Publications
- System Demonstrations
- Visual Displays
- Computer Aided Economic Analysis

Seminars

Three seminars and a conference/trade show were held under Phase II of this project:

- Case Studies in Wood Energy (November 5, 1980)

"Case Studies in Wood Energy" was presented twice in November 1980. The seminars were held in Atlanta and Savannah and featured speakers from Georgia Tech on:
Feasibility Case Studies
Feasibility Study Methodology and Detailed Analysis
Wood Fuel Drying
Wood-Fired Boiler Installation Procedure
Demonstration Projects in Georgia
Wood Fuel Processing Routes
A Demonstration in Wood Gasification

The seminar was attended by 23 people in Savannah and 35 people in Atlanta.

"Wood Energy Financing" featured speakers from outside agencies as well as Georgia Tech.

Topics covered and speaker affiliations were:

- Introduction to Wood Fuels
  Georgia Tech
- Overview of SSEC Wood Fuel Programs
  Southern Solar Energy Center
- Economics of Wood Fuels
  Georgia Tech
- Computer Modeling
  Georgia Tech
- Financial Considerations
  Arthur Andersen Co.
- How to Finance Wood Energy
  First National Bank of Atlanta

The number of registrants at this seminar totaled 41. They represented people from forest and nonforest products industries, government agencies, and equipment manufacturers.

"WOODTECH '81: An Industrial Wood Energy Exposition" was a two-day conference covering wood energy state-of-the-art technology and case studies of actual operating systems. A trade show displaying equipment from 26 manufacturers was held in conjunction with the conference.
Topics covered and speaker affiliations were:

- **Keynote Address**: Dr. Thomas E. Stelson, Vice President for Research
  Georgia Tech

- **Availability of Wood for Energy Use in Georgia**
  Georgia Forestry Commission

- **Wood Gasification System for the Northwest Regional Hospital, Rome, Georgia**
  Applied Engineering

- **A Survey of Georgia's Textile Industry for Wood Gasification Application**
  Georgia Tech

- **Construction and Startup of a Wood Gasification Pilot Plant**
  Georgia Tech

- **A New Quad-Fired Steam Generating Plant for the Jack Daniels Distillery**
  McGraw-Morgan, Inc.

- **Tennessee Valley Authority's Commercial and Industrial Biomass Program**
  Tennessee Valley Authority

- **Preparation of Wood Wastes for Firing Tunnel Kilns**
  Merry Companies

- **Application of Wood Gasifiers to the Cyanamid Complex**
  Georgia Tech

- **Experiences of a Wood Broker**
  Russell Lands, Inc.

- **Wood Energy Applications in the Textile Industry**
  Integrated Products, Inc.

- **An Economic Alternative Enjoying Success**
  Procter and Gamble

- **Utilization of Agricultural Waste Products for Process Steam Generation in a Soybean Extraction Facility**
  Gold Kist, Inc.

- **Feasibility Studies**
  Georgia Tech

This was our most popular seminar with 153 people from 18 states in attendance. After the conference, buses took attendees to Aragon, Georgia, for a tour of the demonstration site at Integrated Products.
Publications

A proceedings for each seminar was published. These were handed out to seminar attendees and sent to other interested parties around the country.

Full color brochures describing each demonstration site were very popular with over 3500 being distributed. They contained full color photographs of each site as well as detailed information on each system.

"Chips 'N Quips" is a wood energy newsletter published twice and distributed to over 6000 people. It kept people abreast of new developments in wood energy. There were 14 articles with numerous photographs describing research being conducted at Georgia Tech.

"Wood Energy for Nonforest Industries" was a full color brochure describing the display model built under this project. It gives an overview of a typical wood energy system for a textile industry.

"Wood Energy Conversion: An Economic Analysis" was printed to inform people about the computer analysis available through Georgia Tech. It explains all the information necessary to examine wood energy feasibility in their own plants.

Copies of all publications are included in the appendices.

System Demonstrations

A dedication ceremony was held at each of the demonstration sites completed under Task II of this project. Invitations were sent using our mailing list, and press releases inviting the general public were sent to all radio and TV stations, and newspapers in Georgia and the surrounding states. The installation at Aragon, Georgia, was dedicated in February 1981 and 95 people attended the ceremony. The site in Valdosta was dedicated in July 1981 and 75 people attended.

Two additional tours of Aragon were also held. These tours attracted over 70 guests to the demonstration site.

Visual Displays

"For many years, forest products industries have generated steam in wood-fired boilers. Today, these industries are no longer the only users of wood energy. Several nonforest products industries are already operating wood energy systems."
This message was extracted from our brochure entitled, "Wood Energy for Nonforest Industries." The brochure accompanies our scale model at trade shows, workshops, and other exhibits. It points out that wood energy is not only for the forest products industries but should be considered by other industries with substantial energy needs.

When combined, the brochure and model offer a straightforward, easy to understand approach to wood energy systems. A workshop attendee can stand in front of the model and "walk" through the wood energy fuel cycle as he/she reads about it in the brochure.

As in all wood energy systems, the fuel cycle begins with an unloading facility (see Figure 1). In the modeled system, a hydraulic truck dump is used to elevate tractor trailer trucks, allowing the wood chips to fall into a live bottom hopper. From there, the chips are conveyed to a covered storage area. Along the way, a number of important operations are completed: (1) tramp metal is removed, (2) chips are sized, and (3) oversized chips are hogged. Chips remain in the storage area until they are fed to the boiler by drag conveyor. Because the boiler's exhaust gases will contain a certain amount of ash and other particulate matter, the boiler is equipped with a scrubber. The wood energy cycle is completed as steam flows from the boiler house into the carpet mill for process heat.

The model is built to a scale of ¼-inch equals a foot. It is approximately 16 square feet and 1½ ft tall at its highest point. The four-piece frame is constructed out of wood and is taken apart and reassembled when the model is moved. The model's structures are made of a variety of materials. Plastic parts and sheeting were used to build all the wood handling equipment, covered wood storage area, and boiler house. The carpet mill is constructed from balsa wood and posterboard. It can be totally removed from the board during shipping. In addition, all of the tanks and the scrubber can also be removed to avoid damage during transportation.

When the model is not at a trade show or workshop, it is on display at Georgia Tech to introduce visitors to wood energy systems.

Ten 16 x 20 inch color prints were also made for use in trade show exhibits. They display the major accomplishments of the program and each photo has paragraph to accompany it explaining the scene. These too are on display at Georgia Tech when not on loan for an exhibit.
Covered Storage Area
Fuel Oil Storage Tank
Live Bottom Hopper
Drag Conveyor
Metal Detector
Bag Conveyor
Disc Screen
Entrainment Gas Scrubber
Boiler House
Steam Lines
Exhaust Gas Scrubber
Figure I. Wood Energy System Schematic
A wood fired boiler system can produce significant fuel cost savings compared to oil or natural gas fired boilers. The wood system typically pays for itself within five years. The Southern Solar Energy Center and the Engineering Experiment Station of the Georgia Institute of Technology, in cooperation with Arthur Andersen & Co., have developed an economic analysis model, based upon previous work by the New England Regional Commission, to compute a payback on a wood fuel system by comparing wood to alternative fuel sources.

The model computes annual costs for each of five years, a normal planning cycle for most businesses and a reasonable time frame for projecting fuel cost increases. Subsequent savings comparisons are grouped in five-year intervals because of the subjective nature of longer term price projections. A complete description of the program is presented on page 95 of Appendix B, and a user's guide is presented in Appendix I.

Evaluation of Technology Transfer

The technology transfer task was a very successful part of the overall program. The major events were attended by 422 people under this phase of the project which is a 56% increase in attendance over Phase I of the project.

"WOODTECH '81" was by far the most popular event. This was due to a combination of factors. The speakers and their topics were of interest to a broad spectrum of industry. The trade show held during the conference drew great interest, and the tour of the demonstration site was a feature with high appeal. "Wood Energy Financing" drew the second largest attendance. With high interest rates the financing of capital improvements in the area of energy cost reduction draws keen interest.

A profile of seminar registrants is shown in Table I.
Table I
SEMINAR REGISTRATION PROFILE

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<th>Audience Category</th>
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<th>Case Studies</th>
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<th>WOODTECH '81</th>
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<td>7</td>
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<tr>
<td>Nonforest-Related Firms</td>
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<td>6</td>
<td>14</td>
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<td>1</td>
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<td>3</td>
<td>1</td>
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<td>Other*</td>
<td>32</td>
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<td>1</td>
<td>4</td>
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<td><strong>TOTAL</strong></td>
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<td><strong>35</strong></td>
<td><strong>23</strong></td>
<td><strong>41</strong></td>
<td><strong>153</strong></td>
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</table>

*Includes utilities, entrepreneurs, researchers, and unknown classification

Figure II shows the responses to a questionnaire distributed at each seminar. Most of the responses were favorable and indicated that interest continues in the area of wood energy.

Our program also attracted the attention of the news media. Local newspaper and TV coverage has been excellent. NBC's "Today Show" covered the demonstration site at Gold Kist, Inc., in Valdosta on October 8, 1981, and several nationally distributed trade publications have discussed our work. Copies of these articles and the transcript of the "Today Show" are included in Appendix J.

Requests for research papers and speakers at meetings, conferences, and seminars came from all over the United States. Table II is a list of the liaison activities carried out by the research staff during the project. In addition to our regularly scheduled seminars, members of the project team prepared 28 presentations and papers on wood energy.

Table III summarizes the tremendous success of the technology transfer task. The results display the overwhelming acceptance of every facet of our program. Many of our publications are still available and requests are still being filled.
Figure II
PROGRAM EVALUATION FORM
(Based on 100 Responses)

1. Was the time spent worthwhile? YES 98 NO 0

2. Would you recommend our programs to business associates? YES 95 NO 2

3. This seminar is part of the State Demonstration in Wood Energy. The purpose is to stimulate commercialization of wood as an industrial fuel.

   A. Has the information presented at this seminar helped you evaluate wood energy feasibility? YES 92 NO 5

   B. What did you like best about the program? Seminar content was most often mentioned as the best aspect.

4. How would you evaluate the following?

   A. Speakers (S) & Content (C)

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<th>Fair</th>
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<td></td>
<td>S</td>
<td>C</td>
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<td>58%</td>
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<td>Wood Energy Finance</td>
<td>44%</td>
<td>43%</td>
<td>41%</td>
<td>46%</td>
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<td>WOODTECH '81</td>
<td>58%</td>
<td>55%</td>
<td>30%</td>
<td>39%</td>
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   B. Organization of Events: Excellent 39 Good 52 Fair 6 Poor 0

   C. Proceedings: Excellent 40 Good 53 Fair 1 Poor 0

5. How did you learn about this seminar? 84% Ga. Tech brochure 7% Press Releases, 9% misc.

6. Have you attended any other wood energy workshops? YES 38 NO 60
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<td>Paper &quot;A Wood Gasification Demonstration Project for the Northwest Georgia Regional Hospital&quot;</td>
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<td>Pollution Control Conference</td>
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<td>Presentation &quot;Gasification Technology&quot;</td>
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<td>Presentation &quot;Wood Combustion Systems and Equipment&quot;</td>
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AES - ICAES - University of Miami Conference on Alternate Energy Sources  
ARC - Appalachian Regional Commission  
ASME - American Society of Mechanical Engineers  
DOE - Department of Energy  
FPRS - Forest Products Research Society  
GFC - Georgia Forestry Commission  
IECEC - Intersociety Energy Conversion Engineering Conference  
SCEES - South Carolina Energy Extension Service  
TVA - Tennessee Valley Authority  
WEEC - World Energy Engineering Conference
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<td>200 requests for additional information</td>
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Appendix A
CASE STUDIES IN WOOD ENERGY
CASE STUDIES
IN
WOOD ENERGY
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FEASIBILITY CASE STUDIES -- AN OVERVIEW

by

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Senior Research Engineer
Technology Applications Laboratory

Georgia Institute of Technology
Engineering Experiment Station

Presented at

CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
1. INTRODUCTION AND BACKGROUND

The purpose of this task was to stimulate the widespread use of wood energy systems in the nonforest products industries of Georgia. The work was accomplished by investigating the technical and economic viability of wood energy through the preparation of eighteen feasibility studies. Fourteen of these studies are addressed to individual industrial plants that are potential users and four of the studies are addressed to companies who are potential suppliers of wood for energy.

The main body of this report is divided into the following topics:

- Candidate Selection Process
- Selection of Supplier-Users
- Feasibility Study Development
- Feasibility Studies - Users
- Feasibility Studies - Suppliers
- Results
2. SELECTION OF SUPPLIER-USER FEASIBILITY STUDY RECIPIENTS

The candidate identification process was based primarily on the active cooperation and assistance of the major Georgia industry trade associations. The groups that participated were:

- Georgia Textile Manufacturers Association
- Georgia Poultry Association
- Carpet and Rug Institute
- Georgia Forestry Association

Each of the associations contributed to the identification process by announcing the program at their meetings, mailing announcements to their membership, and through individual contact.

In addition to these efforts by the trade associations, other candidates were identified through an announcement published in a Georgia Tech newsletter received by over 2,000 Georgia industries.

The recipients of the user feasibility study were selected using these criteria:

- Recommendation by trade association
- Management interest
- Industry employment
- Opportunity for replication
- Geographical distribution
- Economic value of industry to Georgia
- Energy intensity of plant

Figure No. 2-1 is a listing of the selected companies together with some general data. The companies have a potential wood consumption of 480,843 tons per year and, at present, usage levels will displace 1,672,363 MCF of gas and 1,607,452 gallons of oil per year. Figure No. 2-2 shows the geographical distribution of the companies.

Candidates for the supplier studies were identified and selected in a similar manner to the user candidates. Figure 2-3 lists the companies selected and Figure No. 2-4 shows their geographical distribution.
<table>
<thead>
<tr>
<th>Company</th>
<th>Application</th>
<th>Steam boiler other firing system</th>
<th>Size</th>
<th>Potential Wood Consumption</th>
<th>Displacement Conventional Fuel-Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boiler</td>
<td></td>
<td>650 hp</td>
<td>29,983</td>
<td>#2 91,345 Gal-Oil 182,105 MCF-NG</td>
</tr>
<tr>
<td>2</td>
<td>Boiler</td>
<td></td>
<td>35,000 lb/hr</td>
<td>34,075</td>
<td>407,996 Gal-Oil 159,468 MCF-NG</td>
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<tr>
<td>3</td>
<td>Boiler</td>
<td></td>
<td>140 hp</td>
<td>3,115</td>
<td>18,461 MCF-NG 12,779 Gal-Oil</td>
</tr>
<tr>
<td>4</td>
<td>Boiler</td>
<td></td>
<td>525 hp</td>
<td>19,115</td>
<td>124,245 MCF-NG</td>
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<tr>
<td>5</td>
<td>Boiler</td>
<td></td>
<td>75,000 lb/hr</td>
<td>108,000</td>
<td>28,800 tons coal</td>
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<tr>
<td>6</td>
<td>Boiler</td>
<td></td>
<td>100 hp</td>
<td>3,188</td>
<td>850 tons coal</td>
</tr>
<tr>
<td>7</td>
<td>Boiler</td>
<td></td>
<td>20,700 lb/hr</td>
<td>27,743</td>
<td>119,194 MCF-NG 275,000 Gal-Oil</td>
</tr>
<tr>
<td>8</td>
<td>Boiler</td>
<td></td>
<td>770 hp</td>
<td>17,714</td>
<td>388,600 Gal-Oil 67,737 MCF-NG</td>
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<td>9</td>
<td>Boiler</td>
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<td>60,000 lb/hr</td>
<td>101,077</td>
<td>431,732 Gal-Oil 596,556 MCF-NG</td>
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<td>10</td>
<td>Boiler</td>
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<td>140 hp</td>
<td>6,502</td>
<td>43,345 MCF-NG</td>
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<tr>
<td>11</td>
<td>Dryer</td>
<td></td>
<td>33 MMBtu/hr</td>
<td>36,135</td>
<td>289,080 MCF-NG</td>
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<tr>
<td>12</td>
<td>Boiler</td>
<td></td>
<td>77 hp</td>
<td>1,873</td>
<td>12,172 MCF-NG</td>
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<tr>
<td>13</td>
<td>Boiler</td>
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<td>75,000 lb/hr</td>
<td>83,092</td>
<td>24,004 tons/year coal</td>
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<tr>
<td>14</td>
<td>Boiler</td>
<td></td>
<td>400 hp</td>
<td>9,231</td>
<td>60,000 MCF-NG</td>
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WOOD ENERGY USER
FEASIBILITY STUDY LOCATIONS

Figure 2-2
<table>
<thead>
<tr>
<th>Company</th>
<th>Present Business</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Association of area lumber manufacturers</td>
</tr>
<tr>
<td>2</td>
<td>Wood waste broker</td>
</tr>
<tr>
<td>3</td>
<td>Lumber manufacturer</td>
</tr>
<tr>
<td>4</td>
<td>Lumber manufacturer</td>
</tr>
</tbody>
</table>
WOOD ENERGY SUPPLIER
FEASIBILITY STUDY LOCATIONS

Figure 2-4
6
ANALYSIS OF SELECTED COMPANIES

The candidates selected to receive feasibility studies included both small and large firms in various types of manufacturing. The products they produced can be placed in four major categories:

- Textile Products—manufacture of yarn, fabric and carpet; dyeing and finishing of yarn and fabric

- Poultry Products—chicken processing and rendering

- Mineral Products—structural clay, kaolin, sorpture material and agricultural carriers

- Miscellaneous Products—marine recreational products

The poultry and textile products industries are among the state's largest and thus afford high potential for replication within the state. Furthermore, because of their size, these industries are very important to the state economy as a whole. The manufacturers of mineral products are intensive users of fossil energy and as such offer potentially huge reductions in the use of conventional energy sources. As illustrated in Figure 2-2, a wide geographic distribution of study recipients was reached. Eight selected companies are from the northern third of Georgia; five companies are in the central region, and one company is located in the southern third of the state.

Employment in the companies selected ranged from approximately 250 to 1,500. The energy systems considered for conversion to wood fuel ranged in size from $3.45 \times 10^6$ Btu/hr (3,450 lb steam/hr) to $100 \times 10^6$ Btu/hr (100,000 lb steam/hr). Energy consumption patterns varied widely between the companies. Both intensive and non-intensive energy users were among the recipients of studies. Tables 1 and 2 in Section 6, RESULTS, illustrate the energy consumption characteristic of each industry.

In general, location of adequate space for a wood energy system was not a major limitation; however, the lack of space placed constraint on the design of two of fourteen systems.

Other specific details associated with each plant are discussed in the individual feasibility studies and in Section 6, RESULTS.
3. FEASIBILITY STUDY DEVELOPMENT

The first work for each study involved a plant visit by a team of Georgia Tech engineers of the Wood Energy Systems Branch. The purpose of these visits was to collect engineering data on the energy-consuming equipment, the plant operation, and current energy consumption. Physical dimensions of the existing plant were taken with particular attention to space availability for new equipment that might be required and for wood storage and handling. Special conditions such as plant location (rural or urban) and highway and rail access were noted. Advice of plant management was sought.

To assist in the data gathering, a standard form was utilized. An example is shown in Figure 3-1. Each plant site was then analyzed individually. Wood system design elements include boiler size and type, emission controls, wood procurement and on-site handling, ash handling, and personnel requirements. Construction costs for each element of the system were tabulated. A plot plan and boiler layout, shown in Figure 3-2, was drawn for each site.

Each user feasibility study consists of these divisions:

- Introduction and Background
- Wood Fuel Information
- System Design
- System Economics

Early in the project it was determined that plant personnel would require more in-depth information on using wood for fuel than is usually found in a feasibility study. To meet this need, an extensive body of material was developed and appendixed to each report. The topics covered are:

- Georgia Wood Fuel Resources
- Wood Fuel Costs
- Wood Fuel Handling for Industrial Plants
- Wood Fired Boiler Emission and Control
- Safe Wood Storage
- Ash Disposal Methods
NAME OF COMPANY:

PRODUCT LINE: Textile manufacturing - processing and finishing woolen fabrics

NUMBER OF EMPLOYEES:

BOILER PLANT INFORMATION:

There are four boilers; three boilers are designed to burn coal and the other one burns on gas or oil. Two of the coal fired boilers are converted to burn gas or oil and the remaining one is idle. The description of the boilers are as follows.

Boiler No. 1:
Date of Installation: 1947
Steam Capacity: 35,000 lb/hr
Pressure: 163 psi
Heating Surface (boiler): 4,475 ft²
Heating Surface (water walls): 478 ft²
Fuel: Coal

Emission Control: Steam jet ash recovery
Ash Handling: Silo, approximately 15' dia. x 75' ht.
Fuel Storage: Not available
Boiler Efficiency: 81% (Approximately)

Boilers No. 2 & 3:
Specifications are the same as those of Boiler No. 1, but these have been converted to burn gas or oil.

Boiler No. 4:
Date of Installation: 1956
Steam Capacity: 60,000 lb/hr
Pressure: 250 psi

STEAM USAGE AND PLANT OPERATION:

Steam is used for processing and space heating as follows.

Summer: 65,000-75,000 lb/hr of steam 24 hrs/day, 6 days/week, 6-7 months/year
Winter: 110,000-120,000 lb/hr, 24 hrs/day, 6½-7 days/week, 5-6 months/year

ENERGY CONSUMPTION:
(Sept 1978 to Aug 1979)
Natural Gas: 4,529,948,000 cu. ft.
No. 6 Fuel Oil: 1,167,839 gallons

OTHER INFORMATION:

No. 1 coal fired boiler is remaining idle at the present time. The fuel handling system and storage (silo) that was designed for the three boilers, still exist. The company wants to burn wood on the third boiler.

Figure 3-1

SAMPLE FORMAT FOR DATA COLLECTION
EXISTING BOILER ROOM

EXISTING GAS METER

WOOD FUEL
COVERED STORAGE
4,300 SQ.FT.

OPEN STORAGE 10,500 SQ.FT.
CONCRETE PAD

FIGURE 3-2. SAMPLE PLOT PLAN AND BOILER LAYOUT FOR TASK 1
For the supplier feasibility studies, these sections were developed for each study:

- Introduction and Background
- Wood Supply Analysis
- Business Concept
- Business Costs

As with the user studies, appendixed background material was provided with each study:

- Georgia Wood Fuel Resources
- Wood Fuel Costs
- Wood Fuel Handling for Industrial Plants
- Safe Wood Storage
4. DESCRIPTION OF STUDIES FOR USERS

The purpose of this section is to give a detailed description of the user feasibility studies with comments on the development of specific components. The general format for each study is as follows:

INTRODUCTION AND BACKGROUND

This section provides a brief description of the program and the importance of this particular study. A general description of the location and operation of the plant is given together with an outline of the report.

WOOD FUEL INFORMATION

This section provides information on the supply, availability, and cost of wood material that could be available as fuel for the plant. In general, the wood supply is given for a 30-mile radius of the plant location and is organized by counties. Information is given on

- Standing timber resources
- Annual product drain and associated logging residues
- Wood supply residues from sawmills and other sources. The current weighted price average for the various categories of residue material is given: bark, sawdust, shavings, and other.

The final information given in this section is a listing by company name of all wood residue suppliers and whole tree chippers located within a 30-mile radius of the plant.

SYSTEM DESIGN

This section presents the conceptual system design. The topics addressed are component selection, system layout, site selection, fuel selection, emissions, ash handling, maintenance, installation schedule, and personnel requirements. Each of these topics are discussed in detail and frequent reference is made to the appendixed information. Each report has a site location drawing and a schematic drawing of the system layout.
As a review of the studies will show, most recommendations were positive to continue the work. For the majority of the studies, the environmental concerns were moderate, the fuel supplies were adequate and the system designs were proven. The studies that did not receive a positive recommendation were those where the economic analysis proved the wood fueled system to be uneconomic at this time.

SYSTEM ECONOMICS

This section presents an economic analysis of the proposed system and includes these topics: construction costs, operating costs, cost analysis (first year costs), and life cycle costs.

RESULTS AND CONCLUSIONS

This section summarized the findings of the feasibility study including wood fuel supply, system design, system economics, and environmental concerns. A recommendation for the next action is made.

APPENDIX TO USER STUDIES

The appended background material consists of six reports on topics that were found to be of special interest.

Georgia Wood Fuel Resources

This report provides an in-depth review of the wood and wood waste material that could be available for fuel. Quantities of material available from standing trees, harvesting residues, sawmill and manufacturing waste are identified. The present market for these materials is discussed.

Wood Fuel Costs

This report provides an overview of the present wood marketing system and identifies the costs of potential wood fuel. A supply curve for the various potential wood fuel materials is developed. The price and quantity relationships in the wood residue fuel marked is discussed.
5. DESCRIPTION OF STUDIES FOR SUPPLIERS

The purpose of this section is to provide a description of the supplier feasibility studies with comments on the development of specific components. The general format for each study is as follows:

INTRODUCTION

This section provides a basic description of the program and discusses the importance of this particular study. The present state of the use of wood for energy is given together with a listing of barriers that must be addressed.

WOOD FUEL SUPPLY INFORMATION

This section provides information on the supply, availability, and cost of wood material that could be available for marketing as fuel. In general, the wood supply is given for a 30-mile radius of the present business location and is organized by counties. Information is provided on:

- Standing timber resources
- Annual product drain and associated logging residues
- Wood supply residues from sawmills and other sources

POTENTIAL MARKET ANALYSIS

This section provides an overview of the wood energy market and, in particular, identifies industrial plants that are potential wood energy users. The identified plants are located in counties within a 30-mile radius and have a thermal load exceeding the equivalent of 100 tons of wood fuel per day.

APPROPRIATE FUEL HARVESTING, PREPARATION, AND DISTRIBUTION TECHNIQUES

This section addresses appropriate harvesting, preparation, and distribution techniques for wood fuel. As all of the candidates for the supplier studies are presently in the forest business, they are quite knowledgeable in this area. This report does not purport to
tell them about their own business, but rather emphasizes those factors that are important in meeting the needs of industrial plants.

**APPROPRIATE COSTS FOR HARVESTING, PREPARATION, AND HANDLING**

This section addresses the costs associated with the harvesting, preparation, and distribution of wood fuel. As noted in the previous section, the supplier study recipients are in the forest products industry and so are quite knowledgeable concerning costs. This section emphasized those costs that are of particular importance in the manufacture and delivery of wood in the forms suitable for fuel.

**RESULTS AND CONCLUSIONS**

This section summarizes the findings of the feasibility study including wood supply, market analysis, harvesting methods, fuel preparation, and distribution. A recommendation for the next action is made.

**APPENDIX TO SUPPLIER STUDIES**

The appended background material consists of four reports on topics that were found to be of special interest.

**Georgia Wood Fuel Resources**

This report provides an in-depth review of the wood and wood waste material that could be available for fuel. Quantities of material available from standing trees, harvesting residues, sawmill and manufacturing waste are identified. The present market for these materials is discussed.

**Wood Fuel Costs**

This report provides an overview of the present wood marketing system and identifies the costs of potential wood fuel. A supply curve for the various potential wood fuel materials is developed. The price and quantity relationships in the wood residue fuel market are discussed.

**Safe Wood Storage**

The purpose of this report is to discuss the various hazards associated with the storage of wood and to propose methods for safe storage. The topics discussed are: safety in relation to employees and neighbors, preservation of stored wood from catastrophic events, and preservation of the fuel energy values of wood.
Wood Fuel Handling for Industrial Plants

This report discusses the various elements of a wood fuel handling facility with applicability to an industrial plant. The report has these six topics: wood fuel properties, receiving, storage, transport, preparation, and typical designs. The report provides estimated costs for the various elements.

Wood Fired Boiler Emissions and Control

This report discusses the stack emissions from wood boilers and their control. The State of Georgia regulations on air quality control are given. For particulate emissions, the various control methods include: mechanical collectors, baghouses, wet scrubbers, dry scrubbers, and electrostatic precipitators. Installed and operating costs are given.

Safe Wood Storage

The purpose of this report is to discuss the various hazards associated with the storage of wood and to propose methods for safe storage. The topics discussed are: safety in relation to employees and neighbors, preservation of stored wood from catastrophic events, and preservation of the fuel energy values of wood.

Ash Disposal Methods

This report discusses the various disposal methods for wood ash. Wood ash is considered solid waste and is subject to the provisions of the Solid Waste Management Act, administered by the Environmental Protection Division, Department of Natural Resources. Various requirements of this act and methods of compliance are suggested.
Wood Fuel Handling for Industrial Plants

This report provides general background information for engineering and management operation and costs of on-site wood fuel handling systems. The topics discussed are wood fuel properties, receiving, storage, transport, preparation, typical system designs.
6. **RESULTS**

**INTEREST-GENERATED COOPERATION**

The program of providing wood energy feasibility studies to industrial plants was very well received. All of the major segments of the existing forest products industry were cooperative in providing data on resources and in sharing their own experience. Likewise the cooperation of industry trade associations was exceptional. These trade industry groups provided publicity to their membership and took an active part in identifying candidates. These associations that participated were:

- The Georgia Textile Manufacturers Association
- The Georgia Poultry Federation
- The Carpet and Rug Institute
- The Georgia Forestry Association

These groups were so successful in locating candidates for the program that more companies expressed interest in participating than could be accommodated. As a result, many companies had to be refused consideration at this time.

All of the companies studied cooperated fully by providing plant layouts, boiler data, operating and fuel costs. There was concern in some instances that proprietary information could be revealed with the publication of the reports, but we believe this has been handled correctly.

Another indication of the program's interest is that in most instances, the president or top managers were the initial contact and they requested the studies be sent to them.

**ENVIRONMENTAL CONCERNS**

In general, the environmental factors involved with the use of wood energy were moderate and manageable with known technology and control methods. Each site must be approved individually by the Georgia Department of Natural Resources, Division of Environmental Protection. The prime areas of concern were stack emission, ash disposal, and water runoff from outdoor stored wood fuel.
WOOD FUEL

The wood fuel supply and availability studies were accomplished for each location through identifying the quantities of standing timber, the growth and removal rates, logging residues, and manufacturing waste. This information was provided by counties within a radius of 30 miles.

The manufacturing wastes of sawdust, bark, and other residues from sawmills proved to be the lowest cost material and in most locations, should be in sufficient supply to meet the plant's need.

Cost of wood fuel material is site specific and varies over a considerable range. Transportation costs were a significant factor and averaged $1.50 per mile for a 23 ton van. On average, the prices of wood fuel material are as indicated:

- Bark, sawdust — $4.50/ton
- Shavings — $7.00/ton
- Chips — $16.00/ton

SYSTEM DESIGN CONCEPTS

Based on the study of existing wood energy systems and the development of proposed systems, useful concepts for the specification of individual components emerged. Generally the most important factor to be considered during design specifications is the system size. The information developed for various system components is presented below.

Boilers

For boilers, the first determination necessary is the practicality of converting the existing equipment. At present, boilers not designed for solid fuel firing cannot be converted to wood fuel. Boilers designed to burn solid fuel can probably be altered to wood firing; however, some de-rating of output may result.

If a new boiler is required, the largest influences on the selection of a given unit are output and operating pressure. For boilers of 1,000 bhp or less, the most economical choice is a horizontal return tubular (HRT) firetube boiler. If the boiler is 100,000 lb/hr or more, the usual
choice is a field erected watertube boiler. In the intermediate size ranges, boiler selection is affected by site factors, and the choice could be multiple firetube boilers, a modular watertube boiler, or a small field erected watertube boiler.

Emission Control

Emission control is another item influenced by boiler size. The smallest boilers (150 bhp and below) may require no emission control. Slightly larger systems (up to 45 bhp) will probably require a single mechanical collector (multi-cyclone). Boilers in the 450 to 1000 hp range will generally require two multi-cyclones in series. Boilers larger than this may require a multi-cyclone followed by a wet scrubber. The exact departure points between different control methods will be decided by local emission standards.

Fuel Specification

Two types of wood fuel, prepared and unprepared, were recommended in our studies. Prepared fuel requiring no site foreign object removal or size reduction was specified for small users of 800 hp and less. In larger installations where the cost of preparation equipment could be justified, unprepared residue use was recommended. In no instance was there a sufficient supply of dry wood waste material. Therefore, the capability to burn green wood fuel was recommended in each study.

Fuel Storage

Two types of fuel storage are recommended for each location. A three day supply of covered storage to offer some weather protection was suggested. For covered storage on new installations, an open shed extending off the boiler house was used where practical. In some instances, because of space limitations, a silo was recommended. For open storage, the choice is a poured concrete slab. Enough open storage is provided to contain a 28 day supply.

Fuel Receiving

The most economical receiving method is largely dependent on the amount of fuel to be unloaded. For small installations, investment in
a receiving system may not be justified, and the best method would be delivery in self-unloading (live bottom) vans. For receiving larger quantities of fuel, the expenditure for an unloading device is justifiable, and the choice becomes selecting between hydraulic truck dump or a mechanical unloader. The boiler size where investment in receiving becomes economical is determined by such factors as hours of operating, hauling distance, interest rates, labor cost, equipment life, equipment cost, and cost of live bottom delivery.

SUMMARY OF ECONOMIC ANALYSIS

The project studies include applications that vary in type and size of plant, energy consumption, fuels, and equipment. Most of the plants studied included boilers for producing process steam. One of them had a gas fired combustion unit for a drying process. The boilers included gas-oil fired package boilers, field erected coal fired boilers, and field erected coal fired boilers that had been converted to gas and oil firing. A few of the plants had idle coal fired boilers and these were considered for conversion to burning wood fuel. The capacities of the proposed systems ranged from approximately $0.27 \times 10^6$ Btu/hr output to about $75 \times 10^6$ Btu/hr output. The results of the economic analysis performed on these systems are summarized in Tables 6-1 and 6-2. For purposes of our study, these cases are classified as follows:

- Cases that involved a partial or complete replacement of the existing gas-oil fired system by an equivalent wood burning system (Table 6-1).
- Cases that involve the conversion of the existing coal fired system to wood firing by mechanical modifications (Table 6-2).

The conventional fuels used included 100% natural gas, gas and oil, or 100% coal. For purposes of comparison, the cost of conventional fuels per MMBtu output allowing for the efficiency associated with each fuel is listed in Table 6-3.
<table>
<thead>
<tr>
<th>Case No.</th>
<th>Wood System Capacity</th>
<th>Annual Energy Consumption Btu</th>
<th>Utilization %</th>
<th>Gas/Oil Cost $/MMBtu Output</th>
<th>Investment Capital ($1000)</th>
<th>First Year Savings ($1000)</th>
<th>Payback Period (Years)</th>
<th>Present worth of savings** ($1000)</th>
<th>Existing Fuel</th>
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<tr>
<td>(1)</td>
<td>650 hp</td>
<td>194.893 x 10^9</td>
<td>79.36</td>
<td>4.00</td>
<td>500.800</td>
<td>266.282</td>
<td>1.88</td>
<td>9,870.783</td>
<td>93.4% gas, 6.6% oil</td>
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<td>525 hp</td>
<td>24.246 x 10^9</td>
<td>63.28</td>
<td>3.75</td>
<td>414.000</td>
<td>130.982</td>
<td>3.20</td>
<td>5,606.004</td>
<td>100% natural gas</td>
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<tr>
<td>(7)</td>
<td>600 hp</td>
<td>149.700 x 10^9</td>
<td>66.04</td>
<td>4.76</td>
<td>428.016</td>
<td>291.172</td>
<td>1.47</td>
<td>9,641.012</td>
<td>74.3% gas, 25.7% oil</td>
</tr>
<tr>
<td>(8)</td>
<td>770 hp</td>
<td>115.141 x 10^9</td>
<td>39.60</td>
<td>5.60</td>
<td>539.920</td>
<td>270.809</td>
<td>1.99</td>
<td>8,955.791</td>
<td>52.8% gas, 47.2% oil</td>
</tr>
<tr>
<td>(9)</td>
<td>60,000 lb/hr</td>
<td>657 x 10^9</td>
<td>97.70</td>
<td>4.11</td>
<td>1,714,000</td>
<td>950.430</td>
<td>1.80</td>
<td>34,525.958</td>
<td>90.8% gas, 9.2% oil</td>
</tr>
<tr>
<td>(12)</td>
<td>77 hp</td>
<td>12.172 x 10^9</td>
<td>42.00</td>
<td>3.75</td>
<td>212.800</td>
<td>10.291</td>
<td>negative</td>
<td>376.238</td>
<td>100% gas</td>
</tr>
<tr>
<td>(11)*</td>
<td>45 MMBtu/hr</td>
<td>289.080 x 10^9</td>
<td>73.30</td>
<td>3.79</td>
<td>625.200</td>
<td>397.730</td>
<td>1.57</td>
<td>14,179.882</td>
<td>100% gas</td>
</tr>
<tr>
<td>(14)</td>
<td>400 hp</td>
<td>60 x 10^9</td>
<td>39.70</td>
<td>4.16</td>
<td>354.400</td>
<td>61.733</td>
<td>3.60</td>
<td>3,000.017</td>
<td>100% gas</td>
</tr>
</tbody>
</table>

*Wood combustion system for dryers
**20 year life

NOTES: 1. Wood fuel cost--$8.00 per ton ($1.00 MMBtu)
2. One boiler horsepower (hp) equals 34.5 lbs water evaporated from and at 212°F
<table>
<thead>
<tr>
<th>Case No.</th>
<th>Converted Capacity</th>
<th>Annual Energy Consumption Btu</th>
<th>Utilization %</th>
<th>Gas/Oil Cost $/MMBtu Output</th>
<th>Cost of Conversion ($1000)</th>
<th>First Year Savings ($1000)</th>
<th>Payback Period (Years)</th>
<th>Present Worth of savings* ($1000)</th>
<th>Existing Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2)</td>
<td>26,250 lb/hr</td>
<td>$221.484 \times 10^9$</td>
<td>76.80</td>
<td>$4.85$</td>
<td>$369,200$</td>
<td>$305,518$</td>
<td>1.21</td>
<td>$10,869.287</td>
<td>72% gas, 28% oil</td>
</tr>
<tr>
<td>(3)</td>
<td>140 hp</td>
<td>$20.247 \times 10^9$</td>
<td>38.32</td>
<td>$4.10$</td>
<td>$173,440$</td>
<td>$12,530$</td>
<td>5-6</td>
<td>$933.740</td>
<td>91.2 gas, 8.8 oil</td>
</tr>
<tr>
<td>(5)</td>
<td>75,000 lb/hr</td>
<td>$748.800 \times 10^9$</td>
<td>85.5</td>
<td>$1.89$</td>
<td>$1,110,400$</td>
<td>$52,940$</td>
<td>9</td>
<td>$1,705.332</td>
<td>100% coal</td>
</tr>
<tr>
<td>(6)</td>
<td>100 hp</td>
<td>$22.100 \times 10^9$</td>
<td>54.84</td>
<td>$3.28$</td>
<td>$155,680$</td>
<td>$8,054$</td>
<td>8</td>
<td>$247,911</td>
<td>100% coal</td>
</tr>
<tr>
<td>(10)</td>
<td>140 hp</td>
<td>$43.345 \times 10^9$</td>
<td>82.00</td>
<td>$3.75$</td>
<td>$995,600$</td>
<td>$44,311$</td>
<td>3.79</td>
<td>$1,962,565</td>
<td>100% gas</td>
</tr>
<tr>
<td>(13)</td>
<td>$2 \times 37,500$  lb/hr</td>
<td>$576.100 \times 10^9$</td>
<td>65.70</td>
<td>$2.20$</td>
<td>$151,331$</td>
<td>$151,311$</td>
<td>5</td>
<td>$2,979.695</td>
<td>100% coal</td>
</tr>
</tbody>
</table>

*20 year life

NOTES: 1. Wood fuel cost—$8.00 per ton ($1.00 MMBtu)
2. One boiler horsepower (hp) equals 34.5 lbs water evaporated from and at 212°F
## TABLE 6-3

COSTS OF FUELS

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Price</th>
<th>Heat Value</th>
<th>System Efficiency</th>
<th>$/MMBtu Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>$3.00/MCF</td>
<td>1,000 Btu/ft$^3$</td>
<td>80%</td>
<td>3.75</td>
</tr>
<tr>
<td>No. 2 Oil</td>
<td>$0.86/gal</td>
<td>140,000 Btu/gal</td>
<td>80%</td>
<td>7.68</td>
</tr>
<tr>
<td>Coal</td>
<td>$39/ton</td>
<td>13,000 Btu/lb</td>
<td>75%</td>
<td>2.00</td>
</tr>
<tr>
<td>Wood*</td>
<td>$8/ton</td>
<td>4,000 Btu/lb</td>
<td>65%</td>
<td>1.54</td>
</tr>
</tbody>
</table>
The approximate payback period and the annual savings before taxes are listed in Tables 6-1 and 6-2. The actual payback period and the net savings after taxes would depend on the tax situation associated with a project. However, a few general comments can be made on the results listed in Tables 6-1 and 6-2.

The savings resulting from the replacement of an existing gas only system with a wood system depend both upon system size and its utilization factor. Savings associated with small size systems are usually not significant on a short term basis. However, on a long term basis the savings improve as a result of the escalation of natural gas prices.

In larger systems, 400 hp and higher, the savings resulting from the use of a wood system are significant. The savings and the payback period before taxes are especially attractive in cases where more than 25% of the existing energy consumption is provided by fuel oil. In those cases where the existing system uses natural gas only, the annual savings are moderate.

For systems that are using coal, the conversion to burning wood fuel involves considerable investment capital. In view of the existing small differential between the effective costs of wood fuel and coal, the return on investment associated with conversion, is not attractive at the present time. However, on a long term basis, as indicated by the table of life cycle costs, the savings increase. More in-depth studies concerning the design and costs of conversion in the case of coal fired boilers would be desirable.

Conclusions

The results have shown that the utilization of wood energy in nonforest industries is economically feasible at current prices of gas and oil.

The annual savings realized from the replacement of existing systems by wood systems are very attractive where gas and oil are currently being used. The savings are not attractive at the present time if coal is replaced by wood.
DETAILED ANALYSIS OF A FEASIBILITY STUDY

by

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Georgia Institute of Technology
Engineering Experiment Station

Presented at

CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
A DETAILED ANALYSIS OF A FEASIBILITY STUDY

INTRODUCTION AND BACKGROUND

This paper presents the details of a study conducted for a chicken processing and rendering plant to investigate the feasibility of replacing the existing fossil-fuel fired boilers by a wood energy system. This plant is located in Georgia and is one of several plants owned by a major corporation in the United States. Visits to the plant were made by the personnel of the Engineering Experiment Station of the Georgia Institute of Technology to collect pertinent data on the plant and its operations. The plant uses steam from the boilers for chicken processing and rendering and the boilers are presently fired by natural gas and No. 2 fuel oil. The data on the plant are summarized in Table 1. Engineering personnel at the plant mentioned that the company wanted to increase the capacity of the steam plant as part of their future plans, and they were exploring the possibility of replacing their existing boilers by a wood energy system. The analysis that is presented here, addresses several aspects of the feasibility study and includes the following major topics:

- Wood fuel information
- Conceptual design of the wood energy system
- System economics
- Results and Conclusions

WOOD FUEL INFORMATION

Based on the existing energy consumption figures for the plant, it was estimated that the plant would require 17,700 tons of wood (50% moisture) per year or 340 tons per week. A study conducted by the University of Georgia (1) has provided information regarding the availability of wood in terms of standing timber resources, logging residues, and residues from sawmills within a 30 mile radius of where the plant is located. The data indicate that approximately 255,000 tons of soft wood residues and 175,000 tons of hardwood residues were generated from saw-log harvest, on an annual basis in neighboring counties. Also 10,000 tons of hardwood residues and 52,000 tons of softwood residues were generated from pulpwood harvest. Although these quantities represent a significant source of supply, the cost of transporting this material to
<table>
<thead>
<tr>
<th><strong>Table 1</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAME OF COMPANY:</strong></td>
</tr>
<tr>
<td>Firm &quot;X&quot;</td>
</tr>
<tr>
<td><strong>PRODUCT LINE:</strong></td>
</tr>
<tr>
<td>Chicken Rendering Plant</td>
</tr>
<tr>
<td><strong>BOILER PLANT INFORMATION:</strong></td>
</tr>
<tr>
<td>There are two boilers.</td>
</tr>
<tr>
<td><strong>Boiler No. 1:</strong></td>
</tr>
<tr>
<td>Firetube boiler</td>
</tr>
<tr>
<td>Capacity: 250 hp (- 8700 lb steam/hr)</td>
</tr>
<tr>
<td>Pressure: 110-120 psi</td>
</tr>
<tr>
<td>Fuel: Natural gas or oil</td>
</tr>
<tr>
<td>Efficiency: 80% (Approximately)</td>
</tr>
<tr>
<td><strong>Boiler No. 2:</strong></td>
</tr>
<tr>
<td>Firetube boiler</td>
</tr>
<tr>
<td>Capacity: 400 hp (- 14,000 lb/hr)</td>
</tr>
<tr>
<td>Pressure: 110-120 psi</td>
</tr>
<tr>
<td>Fuel: Natural gas or oil</td>
</tr>
<tr>
<td>Efficiency: 80% (Approximately)</td>
</tr>
<tr>
<td><strong>Emission Control Equipment:</strong></td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td><strong>Ash Handling:</strong></td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td><strong>STEAM USAGE:</strong></td>
</tr>
<tr>
<td>For cooking and drying</td>
</tr>
<tr>
<td><strong>PLANT OPERATION:</strong></td>
</tr>
<tr>
<td>24 hours/day, 5½-6 days/week</td>
</tr>
<tr>
<td><strong>ENERGY CONSUMPTION:</strong></td>
</tr>
<tr>
<td>1976-77: Natural Gas = 47,280,000 cu. ft No. 2 fuel oil = 438,000 gallons</td>
</tr>
<tr>
<td>1977-78: Natural Gas = 60,737 MCF No. 2 fuel oil = 388,600 gallons</td>
</tr>
<tr>
<td><strong>OTHER INFORMATION:</strong></td>
</tr>
<tr>
<td>They wish to expand the capacity of the plant and install a wood boiler.</td>
</tr>
<tr>
<td>There is sufficient yard area for wood handling and installation of wood</td>
</tr>
<tr>
<td>system.</td>
</tr>
</tbody>
</table>
the point of use requires further investigation. However, the survey also indicates that approximately 5,500 tons of wood residues in the form of sawdust, bark and shavings are generated on a weekly basis from sawmills currently operating in the county. The quantities and weighted average prices of wood residues and chips as of winter 1980 are shown in Table 2. Additionally about 25 potential suppliers of wood residue and chips in the county were identified in the survey.

Based on fuel prices and availability, wood residues in the form of sawdust, bark, shavings, and chips with moisture content up to 50% on a wet basis were recommended for the boiler. Modern HRT boilers can handle these varieties of wood fuel effectively.

SYSTEM DESIGN

The conceptual design of the system is based on the steam demand of the plant, the existing energy consumption, the quality and quantity of the fuel available near the plant location, space availability, and costs. The details of the system design include the following items:
- Wood Boiler Size and Selection
- Emission control
- Wood fuel handling
- Ash handling
- System layout
- Personnel requirements
- Maintenance
- Installation schedule.

Wood Boiler:

Based on the size of the existing boilers, the existing energy consumption and discussions with the plant engineers, a 770 hp wood boiler (26565 lb/hr) was found to be adequate to handle the load. An HRT boiler to burn sawdust, bark, and wood chips containing moisture up to 50% (wet basis) was recommended for this size.

A typical boiler of this size would measure approximately 13 ft wide, 38 ft long and 22½ ft high. To accommodate this boiler and the connected auxiliaries, a boiler house of approximately 40 ft x 60 ft with an eave height of 26 ft is recommended.
The boiler would be provided with combustion air fan, wood fuel metering bin, reinjection fan, induced draft fan, and other related equipment. The existing feedwater pumps, and water treatment system, would be used in the new wood system.

**Emission Control:**

The emission control system should be designed to conform to the standards set by the Environmental Protection Division in Georgia (1),(2). The emission control device was selected to control particulate emissions. Since wood fuel is low in sulphur content, SO₂ removal problems did not exist, unlike the case of coal fired boilers. For this system the design included two multicyclone mechanical collectors and a minimum stack height of at least 10 times the diameter past the last turn.

**Wood fuel handling:**

The wood fuel handling system includes fuel receiving, fuel storage, front end loader, and conveyor. The study assumes the use of prepared fuel and therefore no fuel preparation equipment is included in the system.

The boiler designed for this system -- 770 hp -- requires 130 tons or about 5½ truck loads per day when it runs at rated capacity. Studies on wood handling systems (1), indicate that the economical receiving method would be delivery by live bottom vans. This method eliminates the additional investment on an expensive unloading device, but the cost of delivered fuel would be slightly higher.

Fuel storage includes a 3-day covered storage close to the boiler and a 28-day open storage. The covered storage consists of a shed with a concrete floor and drag chain conveyors to transport fuel to the boiler hopper. The floor area of the covered storage was recommended to be 5,400 ft² based on a fuel pile height of 6 ft.

The open storage has an area of 25,000 ft² and assumes a fuel pile height of 12 ft to provide for a 28 day storage. The floor is made up of 4 inch thick concrete slab.

Fuel handling within the plant comprises the following functions.

- transfer fuel to the boiler hopper from the covered storage area
- transfer fuel from the open storage area to the covered storage
- other fuel movement -- unloading pile maintenance, etc.
Table 2
Potential Supply of Wood Residues Available from Sawmills and Other Industries*
Within 30 Mile Radius

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity (tons per week)</th>
<th>Weighted Ave. Price (dollars per ton)</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bark</td>
<td>1,956</td>
<td>6.59</td>
<td>99 (1%)</td>
</tr>
<tr>
<td>Sawdust</td>
<td>1,471</td>
<td>6.14</td>
<td>100 (100%)</td>
</tr>
<tr>
<td>Shavings</td>
<td>523</td>
<td>4.27</td>
<td>100 (100%)</td>
</tr>
<tr>
<td>Other</td>
<td>1,704 L</td>
<td>8.09</td>
<td>100 (100%)</td>
</tr>
<tr>
<td>Subtotal</td>
<td>5,654</td>
<td>14.14</td>
<td>100 (100%)</td>
</tr>
</tbody>
</table>

* The above sample represents 25 observations.

** The weighted average price was calculated as follows:

\[
\text{Weighted Ave. Price} = \frac{\sum (\text{quantity} \times \text{price per ton})}{\text{total quantity}}
\]

Source: University of Georgia Wood Fuel Survey Data. (Taken Winter 1980)
Fuel from the covered storage area can be transferred by means of drag chain conveyors or screw conveyors. Other functions such as transfer of fuel from the open storage area, and pile maintenance, are performed by a front end loader. For this system, a 65 hp unarticulated tractor with a 3 cubic yard low density material bucket is recommended.

Ash handling:

At the existing rate of energy consumption, the system consumes approximately 56 tons of wood per day and will produce approximately 1,120 pounds of ash per day. Ash handling for this system will consist of manually raking the grates once a shift and the removal of ash from the cyclone collection bin once per day. The recommended method of ash disposal is by landfill. The disposal of wood ash comes under the jurisdiction of the Georgia Department of Natural Resources, Environmental Protection Division; and industries that wish to operate their own disposal sites must obtain permits. Just as with boiler stack emissions, it is recommended that early contact be made with the Environmental Protection Division.

System Layout:

A plot plan of the existing layout and the proposed wood energy system consisting of the boiler house, covered storage and open storage areas are shown in Figures 1 and 2. The system has been located on the southwest end of the plant to provide adequate wood storage space and limit interference with existing plant functions. The new boiler has been located as near as possible to the existing boilers to reduce the cost of connecting into the steam system. The combination boiler house covered storage measures approximately 40 ft x 195 ft. The open storage measures about 130 ft x 195 ft and extends from the boiler house covered storage. Overall, the wood energy system will require a space of 170 ft x 195 ft.

Personnel requirements:

The wood boiler is semiautomatic and therefore requires periodic attention. The functions performed are water treatment, blowdown, raking the grates, assistance in fuel feed and storage, and general maintenance of the system. It is difficult to determine exactly the
Figure 1

- RENDERING PLANT
- BOILER HOUSE
- OPEN STORAGE (25,350 ft²)
- COVERED STORAGE (5400 ft²)
Figure 2

TYPICAL STORAGE LAYOUT

OUTDOOR STORAGE

CONCRETE SLAB

PITCH

COVERED STORAGE
extent of time spent in performing these functions. In practice a full-time attendant is necessary but he may do other jobs in addition to wood system maintenance.

Maintenance:

Wood-fired boiler maintenance presents no unusual problems; like any other boiler, it requires lubrication, blowdown, and water treatment. Because of the ash in wood and the possibility of soot formation, boiler heating surfaces may require more frequent cleaning than light oil or gas fired units. General maintenance guidelines recommend brushing of the heat transfer surfaces when ash accumulation exceeds 1/8 inch. The fuel handling equipment will require lubrication based on manufacturer's guidelines.

Installation Schedule:

For a wood energy system such as described in this report, the time between final order placement and start-up is approximately nine months. Installation of the boiler and associated equipment requires 14 to 18 weeks. Weather, equipment order backlogs, or other circumstances could alter these schedules. Application for a permit to construct the wood system should be made to the Air Quality Section, Environmental Protection Division of the Georgia Department of Natural Resources. Approval normally requires 90 days.

SYSTEM ECONOMICS

To evaluate the economic feasibility of the wood energy system, a cost comparison between the wood energy system and the existing system is required. Also, the expected savings to the user due to the use of wood fuel and the long term effects of the escalation of the various costs have to be examined. The economic analysis addresses the following topics:

- System construction and operating costs
- Cost analysis
- Life cycle costs

System Construction and Operating Costs:

The wood energy system includes major items such as the boilers, auxiliaries, and wood handling equipment that can be purchased from
vendors. It also includes items such as the boiler house and open storage area, that can be constructed by local contractors or by in-house labor. Some of the equipment such as the water treatment system and pumps of the existing system do not need to be replaced. Therefore, the total cost of the wood energy system can vary widely depending on how the project is managed. In arriving at the total cost of the wood system, the budget estimates of the vendors were studied with respect to details. The proposed system uses prepared fuel only and therefore the costs of the fuel preparation and receiving equipment are not included.

For purposes of the feasibility study, the federal investment and energy credits were taken into account to arrive at the final adjusted capital. The costs were based on Winter 1980 budget estimates. The system costs are shown in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Cost of the wood energy system = $674,900 including:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
</tr>
<tr>
<td>Emission control</td>
</tr>
<tr>
<td>Boiler house</td>
</tr>
<tr>
<td>Covered storage</td>
</tr>
<tr>
<td>Open storage</td>
</tr>
<tr>
<td>Conveyor and</td>
</tr>
<tr>
<td>Front end loader</td>
</tr>
<tr>
<td>Less Federal tax credits (20%) = $134,980</td>
</tr>
<tr>
<td>Adjusted capital cost = $539,920</td>
</tr>
</tbody>
</table>

(Continued)
Table 3 (Continued)

Operating costs:

The following data and assumptions were used to arrive at the operating costs.

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a) Wood system</strong></td>
<td>Capacity = 770 hp or 26,565 lb steam/hr</td>
</tr>
<tr>
<td></td>
<td>Wood fuel = Sawdust, bark, whole tree chips</td>
</tr>
<tr>
<td></td>
<td>Moisture content = 50% (wet basis)</td>
</tr>
<tr>
<td></td>
<td>Heat value = 4000 Btu/lb</td>
</tr>
<tr>
<td></td>
<td>Wood system efficiency = 65%</td>
</tr>
<tr>
<td><strong>b) Existing System</strong></td>
<td>Fuel consumption = 52.8% natural gas</td>
</tr>
<tr>
<td></td>
<td>47.2% No. 2 oil</td>
</tr>
<tr>
<td></td>
<td>Natural gas = 60,737,000 ft³/year</td>
</tr>
<tr>
<td></td>
<td>No. 2 fuel oil = 388,600 gal/year</td>
</tr>
<tr>
<td></td>
<td>Heat value of natural gas = 1000 Btu/ft³</td>
</tr>
<tr>
<td></td>
<td>Heat value of No. 2 oil = 140,000 Btu/gal</td>
</tr>
<tr>
<td></td>
<td>System efficiency = 80% (gas-oil)</td>
</tr>
<tr>
<td><strong>c) Other Assumptions</strong></td>
<td>Life of wood system = 20 years</td>
</tr>
<tr>
<td></td>
<td>Interest rate = 12%</td>
</tr>
<tr>
<td></td>
<td>Cost of elect. = $0.03/Kwh</td>
</tr>
<tr>
<td></td>
<td>Labor = $6/hour</td>
</tr>
<tr>
<td></td>
<td>Capital of existing system = Fully paid</td>
</tr>
</tbody>
</table>

**Fuel costs:**

Annual energy consumption = 115.141 x 10⁹ Btu/year (gas & oil)

Net energy output = 92.113 x 10⁹ Btu/year (80% eff)

Wood fuel consumption = \( \frac{92,113 \times 10^9}{400 \times 2000 \times 0.65} \) tons/year

= 17,714 tons/year

(Continued)
Wood fuel cost:
@ $8/ton = 17,714 tons x $8/ton = $141,712/year

Conventional fuel costs:
Cost of No. 2 fuel oil = 388,600 gallons x $0.86/gal = $334,196/year
Cost of natural gas = 60,737 MCF x $3.00/MCF = $182,211/year
Total cost of conventional fuels = $516,407/year

The cost of wood fuel is estimated on the basis of the information contained in Reference 1 and our estimates of the transportation costs, possible wood residue processing costs, and the availability of the given types of wood residue. Competitive bidding could alter these prices.

Cost Analysis (First Year Costs):
Table 4 presents the various costs associated with the proposed wood system and the existing system. The annual cost of capital was based on 12% interest rates and a 20-year life. The operating costs were calculated from average costs as given previously and are $0.436 per MMBtu output for the wood system and $0.122 per MMBtu for the existing system.

The property tax and insurance costs are estimates only. Specific tax information should be obtained from authorities having jurisdiction when the final design is made. Likewise, insurance costs can vary depending upon the particular insurance carrier and the rate classification of the final design. In this report, a figure of $0.042 per MMBtu output was used for the wood system and $0.028 per MMBtu output for the existing system. It should be noted that certain minor costs such as supervision and water treatment that are the same for both systems are not included.
Table 4

<table>
<thead>
<tr>
<th></th>
<th>Wood System</th>
<th>Existing System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual cost of Capital</td>
<td>$ 72,285</td>
<td>-----</td>
</tr>
<tr>
<td>(Amortization)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$ 40,161</td>
<td>$ 11,238</td>
</tr>
<tr>
<td>Electricity, labor,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>front end loader,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maintenance, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property Tax &amp; Insurance</td>
<td>$ 8,033</td>
<td>$ 5,355</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$141,712</td>
<td>$516,407</td>
</tr>
<tr>
<td></td>
<td>$262,191</td>
<td>$533,000</td>
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</table>

Cost Savings/Year = $533,000 - $262,191 = $270,809

Approximate Payback period (before taxes) = 1.99 years

Life Cycle Costs:

First year costs and savings that were calculated earlier are useful for preliminary estimates for the year 1980-81. However, in order to assess the economics of the system more accurately, the effects of specific cost increases and inflation will have to be taken into consideration. Therefore, life cycle costs were developed by using escalation rates for the various costs. The escalation rates were based on our own judgment and study of published reports (3),(4). The following annual escalation rates were used for the various costs.

- Operating costs (wood system): 7% per year
- Operating costs (conventional system): 7% per year
- Property Tax and Insurance: 6% per year
- Wood fuel: 9% per year
- Gas and oil: 17% per year for the first ten years
- 10% per year for the second ten years

Table 5 shows the various costs, the annual savings, and the present worth of the savings for each year over the life of the equipment.
## TABLE 5

<table>
<thead>
<tr>
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<th>WOOD SYSTEM</th>
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<tr>
<td></td>
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<td>($1000)</td>
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<td>20</td>
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8955.791
RESULTS AND CONCLUSIONS

The results of the study show that the expected annual savings to the user by the use of the wood energy system is $270,809 per year and an approximate payback period of 1.99 years. These figures are based on the assumptions made in the analysis with respect to the characteristics of wood fuel, the existing relative proportions, prices of gas and oil used, system efficiencies and the costs associated with operation and maintenance. Other real situations could vary. However, it is found that even if the non-fuel operating cost of the wood system is increased by 50%, the annual expected savings would be reduced by only 9% and the payback period increased by only two months. This is due to the influence of the high cost of conventional fuels used in the existing system. Allowing for the effects of specific cost increases and inflation, the present worth of the savings over the life of the equipment was found to be $8,955,791.

The feasibility study indicates that

1) The plant could benefit greatly by the use of the wood energy system, since the savings are significant.

2) The wood energy system is practical and is worthy of consideration.

3) The wood energy system would replace 60,737 MCF of natural gas and 9252 barrels of No. 2 fuel oil per year based on the existing energy consumption.

2. "Rules and Regulations for Air Quality Control," Environmental Protection Division, Georgia Department of Natural Services, Atlanta, Georgia, April 1979.


FEASIBILITY STUDY METHODOLOGY

by

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Presented at

CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
An engineer or manager who is interested in performing a feasibility study for wood energy is often aware of many of the aspects to be considered. However, the same person may be equally uncertain as to where to begin the study and in what order each aspect should be studied. The purpose of this paper is to present a methodology which organizes the data collection process in a flow that has been successfully used to perform many wood energy feasibility studies.

The step-by-step guide presented herein will be useful for those totally unfamiliar with wood energy as well as for those persons who have already been involved in studies. The flow of the data collection steps is set up as to improve the efficiency of the study by limiting the collection of data until certain go/no go indications have been passed. Thereby, effort expended in analyzing large amounts of unnecessary data is prevented.

This paper will cover only the broad steps required to complete a study and their respective order of processing. Details relating to individual systems and wood characteristics can be found in other publications.

The flow chart shown in Figure 1 depicts the order of the steps to be completed. The starting point must be a detailed assessment of the energy requirements. This assessment will be used to determine system characteristics, fuel type, fuel supply requirements, etc., and must therefore be detailed in both short term and long term aspects.

ENERGY REQUIREMENTS

Most often the energy requirements can be broken down into three general categories:

- Load Cycle
- Hours of Operation
- Annual Consumption
Each of these delineations will be used for different aspects of the study and any other abnormalities in energy demand should be equally detailed.

The load cycle has no defined time base and is peculiar to the operation. It can be as short as a few hours or as long as several months.

Consider a textile drying operation as might be represented by Figure 2. For simplicity, demand is shown as a percent of available capacity whereas in detailing your particular load cycle, a more quantitative form (such as pounds per hour of steam) should be used. In this example, a fairly constant base load is experienced with a periodic peak load from perhaps the opening and closing of a steam valve for a dryer.

Figure 3 depicts a demand cycle having a very long time base. This is a common situation for industrial processes where there is some peak modulation of a non-periodic form, but overall the average load remains relatively steady and greatly exceeds the peak fluctuations. In this case, the average load would be used to represent the load cycle.

Figure 4 is an iteration which could be typical for space heating loads. Here the load cycle occurs on a daily basis over a given season, but season to season it shifts over a wide range of demand.

Annual consumption could be directly extrapolated by integrating the load curve if the load cycle was uninterrupted. This brings us to considering the hours of operation. It must be defined not only for calculating fuel required, but must also be weighed for delivery schedules, materials handling, fuel storage, etc.

Having detailed the load curve and hours of operation and any other abnormalities peculiar to the operation, the total annual consumption is calculated. Often it will be necessary to proceed to the next step before being able to make a conclusive decision to discontinue investigations.
INDUSTRIAL PROCESS STEAM
WITH PEAK DEMANDS

AVAILABLE OUTPUT

DEMAND (% OF CAPACITY)

0 10 20 30 40 50 60 70 80 90 100

TIME (HOURS)

1 2 3 4 5 6 7 8 9 10
INDUSTRIAL PROCESS
STEADY DEMAND

DEMAND (% OF CAPACITY)

0 20 40 60 80 100

JAN APRIL JULY OCT DEC

TIME (MONTHS)

AVE. LOAD
SPACE HEATING / HOT WATER
SEASONAL DEMAND

DEMAND (% OF CAPACITY)

WINTER

SUMMER

SPRING / FALL

TIME (DAILY)

6am 6pm
SYSTEM AND FUEL REQUIREMENTS

The energy requirements can now be translated into the system and fuel requirements. If the investigator has little or no experience in wood fuel characteristics, he will need some assistance. The Wood Energy Systems Division has developed a great deal of information in this area and many publications are available. In particular, there are some "rule of thumb" calculations and charts to translate the energy requirements into fuel requirements and systems considerations. These approximations circumvent the laborious theoretical analyses and are practical for feasibility determination.

On the system side, a determination of the boiler or furnace size needed to meet the peak and annual energy requirements is needed. The type of unit must be able to respond to the load cycle and the fuel feeding requirements will also evolve in this step.

On the fuel side, the energy requirement details will be translated into annual wood consumption, daily and weekly requirements, and storage or standby requirements.

The completion of this step will yield some solid go/no go indicators. Perhaps a wood fueled system will not be able to efficiently respond to the load swings of the load cycle. Possibly the total energy demand is too small to generate significant cost savings in wood fuel. Or the wood fuel delivery requirements may not be compatible with the hours of operation or type of operation.

EXISTING SYSTEM AND SITE DATA

If the system and fuel requirements seem plausible, the next step is to examine the existing system and site in such detail to develop the options available to meet those requirements.

On the system side, the possibilities of boiler conversion is explored. The "derating" for wood firing is calculated, and space for materials handling and feeding and possibly fuel processing is examined. All possible options are being sought.

For the site data, such items of investigation are confirmation of the fuel supply, transportation alternatives, receiving areas
configuration, storage alternatives, and so on.

Any number of go/no go indicators may surface from these investigations and there is no defined order for the data collection during this step. Most investigators tend to examine fuel supply and storage areas first, probably out of greater concern for fuel availability. Also from a financial viewpoint, the wood supply and cost may provide an excellent benchmark in purely fuel cost savings to project a maximum capital outlay based on company R.O.I. and payback policies. This in itself is a good go/no go indicator.

**FACILITY LAYOUT**

If indications are good, it is now time to make selections from all of the options and prepare the proposed facilities layout. This scenario should have concrete reasons behind each option selected such that if a problem is encountered later in the study, a possible second alternative can be re-evaluated. A complete breakdown of hardware and implementation requirements will be needed for the following steps.

The facilities layout should cover every aspect of the system from wood supply through pollution control. With confirmation of a fuel supply, the delivery and receiving modes should be selected. This should cover transportation to the site as well as unloading equipment, transport to storage, etc.

If fuel processing is called for, the hogging and screening equipment and associated handling should be detailed. All storage areas should be located and sized to meet peak and contingency requirements, and materials handling in and out of storage should be specified.

The combustion system is detailed based on either a conversion of existing equipment or a new installation. Ash removal should not be overlooked, and plans and equipment should be selected.

Pollution controls, if needed, and alternate back-up fuels should also be incorporated into the proposed plan.

The facility layout will generate some go/no go indicators, but
most likely if the investigator has progressed to this step, the study will need to be completed through financial analysis to make a solid decision.

**OPERATIONAL REQUIREMENTS**

The operational plan will go hand-in-hand with the facilities layout and will include personnel additions or deletions, maintenance considerations, space parts, and back-up requirements.

**ECONOMIC ANALYSIS**

Barring any unusual problems in operational considerations, it is time to develop cost estimates of the proposed facility layout. Having assimilated all the costs, a full life cycle analysis can be made. This can be as simple or detailed as company policy dictates. The payback and R.O.I. generated will most likely be the most significant go/no go indicator along with the total capital required for the proposal.

**INSTALLATION PLANNING**

The final step which may or may not be necessary for the particular study, but which makes an excellent complement, is an installation timing investigation. Part of the facilities layout will have addressed various pollution control options, and approval of permits can require healthy lead time. The timing of permit applications, shutdown scheduling, construction time, and equipment delivery lead times will be important factors if the system is implemented.

It has been our experience that using this order of data collection and go/no go indications can improve the efficiency of performing wood energy feasibility studies by limiting the collection of data until certain checkpoints are passed.
WOOD FUEL DRYING

by

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Presented at
CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
INTRODUCTION

Criteria for Wood Fuel Drying

The goal of wood fuel drying with waste heat is a net decrease in the cost of power generation. Removal of moisture from fuel prior to the combustion phase yields savings as follows: pounds of water removed in the drying phase do not require heat input necessary to evaporate and then raise its temperature to that of the exiting flue gas. Evaporation of one pound of water requires approximately 1,065 Btus at 60°F during the drying stage. When green fuel is directly fired in the boiler, additional energy (1173 Btu/lb to raise water from 60°F to 400°F) is consumed in the combustion chamber to raise the temperature of the released water vapor to that of the flue gas exiting the boiler. Consider 200 pounds of wood fuel containing 50% moisture by weight. Contained therein is 100 pounds of bone-dry wood and 100 pounds of water. By reducing fuel moisture content to 25%, the original 200 pounds of fuel now weighs 150 pounds. These changes in the combustion scheme have occurred: decrease in fuel moisture content, reduction in load demand on the induced and forced draft fan, reduction in the excess air requirements, increase in boiler capacity, and increased boiler efficiency.

All of this is accomplished in one of three ways: by utilizing expensive Btu's that are presently being vented in the exiting flue gas, by the natural drying which may occur in many types of wood storage piles, or by using fossil fuel fired dryers. Drawbacks and benefits are associated with each method.

DRYING METHODS

Wood Piles

Research done by Mssrs. White and DeLuca (of Virginia Poly-Tech) several years ago yielded positive indications that the elevated temperatures associated with bulk storage wood piles resulted in significant moisture content reduction coupled with a probable net decrease
in pile heat content. Piles of different geometries were investigated. The piles were variously mixed green sawdust, hardwood bark, and pine bark. All piles exhibited a rapid increase in internal pile temperature with the greatest temperature near the geometric center at the base of the pile. The temperatures rapidly reached a threshold value and thereafter remained fairly steady—varying from steady state levels of 120°F to 170°F. Although some decrease in moisture content was observed, this research is not conclusive. Research on this question—especially regarding whole tree chips—is ongoing here at the Experiment Station, by the Georgia Forestry Service, and by Mark White. We hope to have more definitive results in hand next summer on this subject. As a footnote, gains in heating content due to moisture content decrease during open pile storage periods are tempered, and well may be offset by saturation of the surface layer by precipitation. Piles with large surface volume/total volume ratios (i.e. "small" piles) are particularly sensitive to surface saturation from precipitation.

Wood Drying Equipment

A wide range of gaseous, liquid, and solid fuel dryers have long been used in many industries. Single pass and triple pass fossil fuel fired, motor driven, rotary dryers are commonly used in fertilizer plants, grain and other process drying applications. Cascade dryers and flash type dryers are in widespread use in many processes. With the spiraling cost of energy, equipment vendors and biomass users have—in the last decade—adapted these existing technologies to drying wood. In applications where: exact moisture contents are not required by the process, the existing boiler has solid fuel firing capability, and is presently firing fossil fuel; flue gas derived waste heat is a demonstrated economical drying agent with short paybacks and good returns on investment. Paybacks on retrofitted waste heat dryers for systems already burning (high moisture content) wood will tend to be not so dramatic as those calculated for replacement of fossil fuel with dry wood fuel.
Rotary Dryers

Rotary dryers are of two types--single pass and triple pass. The single pass requires a smaller pressure drop, and consumes less fan horsepower. It has a consequently lower operating cost. Control of product moisture content is not so precise as in a triple pass dryer; however, this should not be a problem where the end goal of the dryer output is combustion. Both types are available from well known manufacturers. Koppers, Manufacturing Engineering Construction (MEC), and Rader are among the many vendors with waste heat fired single and triple pass dryers. A waste heat rotary dryer is under construction in Augusta, Georgia at the Merry Brothers Brick Co., Inc. for use on a wood fired kiln. The Rader single pass rotary dryer will process 6 Ton/hr., 50% moisture content mill residue in the waste heat drying mode.

Cascade Dryers and Flash Dryers

In cascade dryers, wood fuel is dried by falling through streams of hot gas--much like the path of light-weight sand would appear when tossed into a cascading fountain. Cascade dryers tend to be large as opposed to rotary units which are mid-size. No auxiliary fuel input or motor horsepower for rotation are required. Of course, the pressure drop demand across the unit must be taken up by the fan, so some energy input is necessary. Flash type dryers are simply several loops of duct work where the wet material and hot flue gas mingle and drying occurs. Successful cascade dryers have been reported from Sweden. The first American installation of a Swedish-designed cascade dryer was completed at a paper mill in upstate New York in mid-1980. The power plant superintendent reports he is satisfied with its operation even as the learning curve proceeds for tuning the controls and educating the operators. A very sophisticated flash drying system, incorporating a \( \frac{1}{4} \)" minus hogger in the middle of the drying loop, is being tested on two full size installations in Sweden, however, the vendor (Fläkt) has not placed the unit on the market. In addition, Fläkt has added a Sprout-Waldron pellet mill to the equipment train. The pelletizing capability enables the mill to store dry, pelletized wood which is ready for stoking or pulverized firing. At this time, any plant
decisions involving pelletization must recognize the high costs inherent therein.

All drying equipment previously described requires similar auxiliary equipment for material collection and fly ash removal. Systems of single cyclones, multiclones, and, where necessary, baghouses, scrubbers, and precipitators are common. Usually larger wood particles are collected in a pre-collection hopper while bark fines are separated in cyclones. The dried fuel is conveyed to a storage bin and then into a standard fuel feed system. Combustibles from the flyash are collected and mixed with the bark fuel while the remaining flyash is removed by the pollution control equipment.

**APPROPRIATE APPLICATIONS OF WOOD FUEL DRYERS FOR NONFOREST PRODUCTS INDUSTRIES**

**Retrofits**

Retrofitting waste heat wood fuel dryers to existing solid fuel boilers represents the largest market for drying equipment. The reasons for this are economic and are as follows. Boiler efficiency improvement is effected by decreasing the temperature of exiting flue gas from the neighborhood of 450°F to about 200°F. (Due to the SO₂ acid dewpoint problem, flue gas exit temperatures of 200°F are feasible only where no sulfur bearing fossil fuels are being combusted. Where fossil fuel is being combusted in conjunction with wood, flue gas exit temperatures must be maintained at greater than approximately 275°F). Flame temperature increases, less air is moved through the boiler by the fans, and ease of flue gas particulate collection improves. Often a plant with steam requirements greater than current operating capacity can gain enough capacity from burning lower moisture content fuel that installation of additional peak-load steam generating equipment can be avoided. Also, hogged wood or sawdust of greater than 65% moisture content will not normally sustain combustion. In the past, some plants have used fossil fuel fired dryers to dry this material so as to avoid storage and/or disposal problems. The advent of dryers fired by waste heat make this wet fuel a potentially attractive fuel source.

In processes where there are demands for high temperature off-gases (kilns, textile drying, etc.) increased flame temperatures can be achieved using dry fuel.
New Installations

Dryer manufacturers claim the following benefits are gained when a flue gas dryer is included in the scope of new power plant construction:

a) reduced dimensions of boiler heat transfer surfaces, air preheaters, and economizers
b) higher efficiency
c) improved load change response
d) overall lower costs for new plants incorporating waste heat wood dryers

Feasibility

Existing solid fuel boilers of at least 60,000 lbs/hr steam capacity are generally the least size boilers that should consider dryer retrofits. Of course, the larger the boiler and the more expensive the fossil fuel, the more attractive investment returns become. Installed costs for dryers are somewhat site specific. A very rough rule of thumb for pricing is $38,000 per ton/hr of moist fuel input—installed. Payback periods range from one to three years. Dryer installations are eligible for the 10% equipment investment benefit and may qualify for the 10% energy investment credit.

The inevitable growth of the wood densification (pelletization) industry represents an area where waste heat wood dryers should be of great value. At present, some pellet mills (still in the demonstration phase) are using conventional fossil fuel fired rotary dryers to sufficiently dry wood in preparation for pelletization.
WOOD FIRED BOILER INSTALLATION PROCEDURE

by

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Presented at
CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
WOOD FIRED BOILER INSTALLATION PROCEDURE

The design and installation of a wood boiler could present problems to an industry normally acquainted only with simple package systems. This presentation addresses the procedures involved in completing a wood system installation emphasizing aspects not encountered with package boilers.

Design Selection

The first decision to be made is how the design should be handled. The amount of engineering and construction handled "in house" is dependent on the resources available. Industries with limited resources usually elect to hire outside firms for design and construction. Others with larger more experienced staffs may develop their own design and select a suitable outside contractor or may handle all the design and construction internally. From our experience with nonforest-related industries, even those companies with large engineering resources do not have the necessary expertise with wood fuel and therefore must rely on outside consultants.

If a company decides to use the services of outside consultants, two basic types are available. The company can employ a design consultant for the purpose of completing a detail and design. Upon completion, bids from mechanical contractors responsible for the details of construction can be taken. Another option is to select a design and construction firm which serves not only as designer but contractor as well.

Feasibility

The first step in the design process is to firmly establish the technical and economic feasibility of such a venture. The current plant energy demands must be carefully reviewed. Energy data necessary in determining the technical feasibility includes:

- Average steam flow rate
- Peak steam demand
- Load swings
- Seasonal load variations
- Steam pressure

An economic analysis requires information on the hours of operation weekly and yearly, current fuel costs, a budget estimate of the new system cost, and a projection of the wood fuel cost. This data permits calculation of an estimated economic payback.

Fuel Procurement

An acceptable payback period is only one aspect in establishing the feasibility of a wood energy system; equally important is the location of an adequate fuel supply. A fuel survey will generally encompass the area within a 50-mile radius of the plant. During the feasibility study phase, sawmills, pallet, box and furniture plants, and wood chippers are contacted for wood residue and chip production, cost, and disposition information. Wood production and cost information are used to establish the fundamental feasibility of a system. The wood disposition information becomes important later during contractual negotiations with suppliers, unless most of the residue is already under firm contract.

Detailed Design

After establishing the feasibility of a wood system, the detailed design and specification phase begins. It is important to remember that no two wood systems are exactly the same and, unlike package boilers, will be tailored to fit specific plant requirements. Many factors such as those below, influence the final design:

- Fuel particle size and moisture content
- Space availability
- Emission codes
- Fuel delivery
- Secondary fuel capability
Of these, the fuel properties most strongly influence boiler design. After completion of the detailed design and specification, contractor bids are solicited. The bids are evaluated by both the designer and purchaser. Evaluation is based on factors other than cost alone. Other important factors are the ability to meet specifications, satisfactory delivery, and start-up schedules. The time period between solicitation of bids and a firm contract is usually 1 to 2 months.

**Emission Permit**

Soon after the decision to install a wood boiler has been made, an application for a permit to construct should be filed with the state air quality officials. This application contains information on the boiler size, location, fuel, and pollution control devices. Due to past operating data on wood boilers, environmental protection personnel can usually determine from the data supplied in the application if a proposed system will test in compliance. Therefore, under normal circumstances, permits are issued within 2 to 3 months of filing. If further information or assistance in completing an application is necessary, state personnel will meet with applicants. If desired, an outside consultant may complete the application as long as it is signed and submitted by an officer of the applying firm.

**Fuel Contracts**

Negotiations for the wood fuel supply usually begin about the same time as the detail design process. Potential suppliers are identified by the fuel survey performed earlier. Users are typically not interested in involvement with the daily procurement of fuel, but instead prefer to contract with a fuel broker for guaranteed deliveries. The fuel contract usually includes information on the weekly amounts of fuel required, daily minimum and maximum deliveries, fuel properties, fuel price, and payment schedule. Contracts can be effective for different lengths of time, but longer term contracts usually include a price escalation clause.
Installation

Once the construction contract is complete, the contractor is in a position to set up the delivery schedule and begin site preparation. The actual installation requires from 6 to 12 months depending upon the type and size of boiler. After completion of the installation, boiler start-up begins. During start-up, engineers check out all the boiler systems and fire the boiler. Operation training is the final part of the start-up process.
DEMONSTRATION PROJECTS UNDERWAY IN GEORGIA

by

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Presented at

CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
DEMONSTRATION PROJECTS UNDERWAY IN GEORGIA

In 1980, Georgia Tech has assisted in getting underway two wood demonstration projects in Georgia. One is Gold Kist, Inc., in Valdosta, Georgia. Gold Kist is Georgia's largest agricultural products company. The other is Integrated Products, Inc., a textile company in Aragon, Georgia. This paper highlights characteristics of each system and reports on the construction status of each project.

Gold Kist, Inc., in Valdosta, Georgia presently uses two 30,000 lb/hr gas-oil boilers to generate the steam heat required in the processing of soybean oil. The soybean oil production steps which require heat are heating the beans, heating the oil extraction chemical (hexane), separating oil-hexane-water in the mix, and drying the oil-free soybean flakes.

Gold Kist plans to burn both wood and peanut hulls. The hulls will come from the Gold Kist plant in Ashburn, Georgia. Wood will come from supplies in the general vicinity of Valdosta. The hulls will be ground and shipped by truck. The heating value of green hulls is 6,240 Btu/lb, and the estimated heating value of green wood is 3,800 Btu/lb.

Georgia Tech conducted the study of the individual supplies of wood residue within a 50-mile radius of Valdosta. The report showed over 2,300 tons/week of residue available at competitive prices. This would easily meet Gold Kist's demand of 430 tons/week of wood (2 days wood and 5 days hulls) and would also meet the demand of 1,500 tons/week if Gold Kist were to burn wood only. Peanut hulls will be produced only nine months out of the year; therefore, careful management of the supply and storage of fuel will be necessary. The suppliers will deliver the wood at $6 to $10 per ton, depending upon the hauling distance.

The wood fired boiler plant for Gold Kist is a turnkey project contracted with Wellons Company of Sherwood, Oregon. The storage system will consist of a 75 ft silo that is 38 ft in diameter. Level switches in the silo will control the feed to the silo.
The conveying system will require airlock seals due to the dust characteristics of the ground hulls. A chain conveyor will feed three metering bins which have screw feeds for three separate cell burners.

The three independent fuel cells are cylindrically shaped. The cell refractory is designed for both underfeed air and tangential air supply. The cyclonic effect produced in the cell allows for a turbulent mixing of air and fuel to promote complete combustion of the fuel. The hot gases release the unburned heavier particulates to the drop-out chamber while the finer ash particles remain entrained in the gas as it passes through the boiler. Combustion temperatures in the cells range from $2,500^\circ F$ to $3,000^\circ F$.

The boiler has a 60,000 lb/hr steam capacity and is designed for $660^\circ F$ superheat. Initially the plant will only use 150 psig steam for process, but eventually electricity generating steam turbines will be installed to use the full capacity of the plant. The boiler is single pass and has a U-type configuration. The Wellons boiler for Gold Kist differs from their ordinary systems in that the boiler is raised about 10 feet higher above the cell to reduce the velocity of the fine hull particles.

As the combustion gas exits the boiler, it enters an air-to-air heat exchanger which preheats the combustion air to about $250^\circ F$. The reduction in flue gas temperature is also necessary for prevention of material fatigue in the multi-clone pollution equipment.

A final decision has not been made on how the small particles that remain entrained in the flue after the multi-clone are going to be captured in order to meet environmental pollution codes. Gold Kist and Georgia Tech are both investigating the "Best Available Control Technology" on today's market and the feasibility of each.

Two different economic analyses of the Gold Kist project are shown in Tables 1 and 2 in order to demonstrate both the simple payback method and the cash flow method for determining the project's feasibility. The simple payback method in Table 1 disregards taxes
Table 1
ECONOMIC ANALYSIS USING SIMPLE PAYBACK METHOD

Given:

<table>
<thead>
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<th>Description</th>
<th>Value</th>
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<tbody>
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<td>System Cost</td>
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<tr>
<td>Natural Gas Price</td>
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<tr>
<td>Wood Price</td>
<td>$1.30/MMBtu</td>
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<td>Peanut Hull Price</td>
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<td>75%</td>
</tr>
<tr>
<td>Efficiency of New System</td>
<td>67%</td>
</tr>
<tr>
<td>Annual Operation Time</td>
<td>8,500 hours</td>
</tr>
<tr>
<td>Tax Credits and Grants</td>
<td>$874,000</td>
</tr>
</tbody>
</table>

Assume:

(a) Operation cost is equal and constant  
(b) Labor cost is equal and constant  
(c) Disregard taxes and depreciation  
(d) Fuel cost is constant

Calculate:

(a) Energy savings ($ per year)  
(b) Simple payback period

Present Annual Cost of Steam

\[47,500 \text{ lb/hr} \times 1,200 \text{ Btu/lb} \times $3.00/\text{MMBtu} \times 8,500 \text{ hrs} \times 1/\cdot.75 = $1,938,000/\text{yr}\]

Annual Cost of Proposed Wood-Hull Firing

\[47,500 \times 1,200 \times \left[(5/7 \times $1.00) + (2/7 \times 1.30)\right] /\text{MMBtu} \times 8,500 \text{ hrs} \times 1/\cdot.67 = $785,120/\text{year}\]

Energy Savings/Year = $1,938,000/year - $785,120 = $1,152,880

Simple Payback = ($3,640,000 - $874,000)/$1,152,880 = 2.40 years
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<td>3,640,000</td>
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<td></td>
<td>$2,655,75'</td>
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Salvage Value (20% of System Cost) 628,000

Net Present Value $2,655,75'

NOTE: The outlay is the 3,640,000 cost less the 874,000 tax credit and grant. Net Income and Operating Cost are assumed to rise 10% per year over the assumed ten year life of the plant. Net income before taxes and depreciation is the dollar fuel savings for using the alternative fuels in place of natural gas.
and depreciation as well as rising operation, labor, and fuel costs. The result was a simple payback period of 2.40 years. In contrast with Table 1, the cash flow method in Table 2 also assumes an annual inflation rate of 10% and cost of capital of 12%. The calculated results in Table 2 show the net cash flow becoming positive in about 6.0 years.

The difference in the results of the two methods, 2.40 years versus 6.0 years, indicates the necessity of taking all related factors into account. The 6.0 year payback is much longer than the 2.40 years; however, in Table 2, assumptions made on the equipment life, cost of capital, inflation rate, depreciation method, and the salvage value are reasonable and were not disregarded when analyzing a project's feasibility. It should be noted that these figures do not necessarily represent the actual figures used by the purchaser.

The construction of the wood fired system in Valdosta began in September 1980 and is expected to be completed and ready for startup in April 1981. At that time, Georgia Tech will begin its six months of data collection. This data will be made available to those companies that are considering a similar installation.

Integrated Products, Inc., is a textile manufacturing firm headquartered in Rome, Georgia. The plant in Aragon employs about 300 employees. The major product at the Aragon plant is "heat set" carpet yarn. "Heat set" carpet yarn is nylon yarn that has been twisted and subjected to heat which makes the twist permanent. The process requires large autoclaves that are filled with the yarn and then provided with steam heat from the existing boilers. After the heat set is complete, the yarn is transferred to steam dryers where it dries and retains its "fluffy" characteristic.

At present, the steam boilers in the Aragon plant burn natural gas 75% of the time and #2 oil the other 25%. Besides the heat set process, steam is also used in the winter for about 10% of the plant heating demand. The three existing boilers (650 hp of boiler capacity) will be put on standby when the new 400 hp wood-fired boiler, from Industrial Boiler, Inc., of Thomasville, Georgia, is completed. Construction began on the wood firing facility in August 1980 and is expected to be complete in November 1980.
The wood fuel is supplied to the plant by means of live bottom trailers. The trailers unload the wood into a 12,375 ft$^2$ (28-day) open storage area or a 72-hour covered storage area, 15,912 ft$^3$ in volume. The covered storage area serves as a fuel staging area for a concrete silo 24 ft in diameter x 48 ft high. The storage silo is filled by bucket elevator via a screw conveyor from the fuel staging hopper. From the silo, the wood is transferred to the metering bin via screw conveyors.

The combustion chamber is a refractory lined furnace with under-fire cast iron air grates and two overfire air sweep feeders. The fire on the grates will radiate heat to the bottom of the boiler, turn, enter the firetubes, and return to the front of the boiler where they exit through the stack.

The boiler is a horizontal return tube (HRT) type and is designed to produce 13,320 lb/hr (400 hp) of saturated steam at 130 psig. The feedwater supplied to this firetube boiler enters at 220°F.

The pollution control equipment will consist of two Zurn multiclon centrifugal dry collectors. This equipment alone has been adequate for other wood-fired installations in Georgia that are in this Btu range. Industrial Boiler Company guarantees the system will pass the Environmental Pollution Agency's criteria.

The cash flow diagram in Table 3 for the Integrated Products project indicates that the cash outlay of 1980 will be recovered in about 2.3 years. This is much better than the Gold Kist payback period of 6.0 years; however, if Gold Kist uses a faster depreciation method such as the double-declining balance method, the payback period will become more favorable.

Both the Gold Kist and Integrated Products wood-fired demonstration projects will serve those companies as an economic hedge against inflated gas and oil prices. Also, the data collected from these projects will be available to all of industry so that they will have more answers to the questions concerning the utilization of alternative fuels such as wood.
<table>
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<td>2,147,697</td>
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<td>1,288,620</td>
<td>1,748,620</td>
<td>$614,983</td>
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</table>

Salvage (20% of outlay) $658,983

Net Present Value

NOTE: These figures do not necessarily represent the actual figures used by the purchaser.
WOOD FUEL PROCESSING ROUTES AND ECONOMICS

by

T.F. McGowan, Research Engineer
J.L. Walsh, Jr., Research Engineer
Technology Applications Laboratory

Georgia Institute of Technology
Engineering Experiment Station

Presented at
CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
WOOD FUEL PROCESSING ROUTES AND ECONOMICS

by T.F. McGowan, P.E. and J.L. Walsh, Jr., P.E.

Introduction

The nonforest products industry is confronted with a wide variety of options when it decides to switch to wood fuel. Should wood residue be purchased as fuel, or are whole tree chips preferred? What type of boiler and burner are indicated? Is drying or pelletizing wood economically attractive? In order to resolve these issues and spur the commercialization of wood energy in industry, the Department of Energy funded a program to demonstrate the potential of wood energy in Georgia. This paper reports on the work done as a part of this project to quantify the total cost to the user for each wood fuel processing route as the cost of heat (typically as steam) in dollars per million Btu's delivered.

The major emphasis today is placed on commercialized processes such as direct combustion of wood in boilers. However, state-of-the-art topics like wood densification and gasification are approaching commercialization. These processes which are still in the experimental stage are dealt with briefly to assess market areas and provide rough cost estimates.

Economic Analysis

The bottom line for any fuel system is a combination of the capital, operating, and fuel costs. Each industrial company uses a different method to decide on the viability of an investment, dictated by their method of financing, tax liabilities, etc. It is difficult to compare fossil fueled systems using gas or oil with solid fueled systems using wood or coal. The capital investment and fuel costs are radically different. For these reasons, uniform annual cost and payback period are used in this paper. The uniform annual cost is
divided by the useful heat delivered to allow comparison of options over a range of size. Net present worth, another widely used method, is not presented, but can be developed using the costs contained in this paper.

Net present worth has a weakness in analyzing fuel systems in that fuel costs for the proposed system and its alternate must be projected over the lifetime of the equipment. The rate of inflation must be factored in for maintenance, taxes, etc., all of which are difficult to predict in the near future and impossible to predict 20 years from now.

Economic decisions must be made, however, and industry frequently uses as a rule of thumb a three-year payback period. This varies from 2 to 5 years depending on the market and type of industry.

The technique for calculation of system cost is the same for all systems. The total capital required for the system is computed by adding the cost of the components. An investment tax credit of 20% for wood systems and 10% for coal, gas, and oil systems is utilized. The difference between the total capital cost and the investment tax credit is the financed capital cost, or the amount of money which the user must borrow. The annual cost of capital is based on 15% interest rate and a loan period of 25 years. The maintenance cost, tax, and insurance are based on a fixed percentage of the total capital cost developed from existing installations (1)(2). The operating costs are estimated from existing installations and vary with size and type of system (3). The fuel cost is computed using the fuel consumption rates and the unit cost of the various fuels.

**Processing Routes**

Wood fuel can be used in a variety of ways. The simplest and most widely used processing route is the direct combustion of green (50% moisture content) wood chips for producing steam. This route has a minimum of intermediate steps, composed of unloading, storage, conveying, and burning. More complex routes include sizing, drying,
densification, gasification, and liquefaction before combustion. Direct combustion is the most viable route, and will be dealt with in detail. Other operations which show future promise are presented in a condensed form.

Wood Derived Fuels

The transformation of wood into a more usable form is technically feasible and rapidly approaching the time when it is economically viable. These processes include gasification, liquefaction, and densification. All these operations upgrade the form of the fuel by cutting the weight and volume and reducing the cost of transportation and combustion.

Wood gasifiers are under development by more than 30 companies and institutions in the United States, Canada, and Europe. Gasifiers fueled with wood and coal were used from the late 1800's through World War II when cheap oil and gas forced them from the market place. Their prime market at this time is the retrofit conversion of gas/oil boilers, dryers, and kilns. They can also be used to fuel internal combustion engines or turbines. Gasifiers produce a low-Btu gas which is used on site, and typically contains 150 Btu/ft³.

Wood can be used as a feedstock for producing ethanol, methanol, pyrolysis oil, and catalytic oil. Ethanol is made by converting cellulose into glucose followed by fermentation. The methanol route uses wood gasification to produce a CO/H₂ mixture followed by shift reaction. Pyrolysis oil, char, and gas are produced by thermal decomposition in the absence of air. Catalytic oil is made using alkaline catalysts at high pressures and temperatures. The alcohols can be used for transportation and may command higher prices, while the oils would be burned in place of fuel oils.

Densified wood is being produced in the form of wood pellets. This process includes drying, grinding, and producing pellets by forcing the finely ground wood through a die. This fuel can be substituted for coal in existing equipment and may find markets in
gasifiers and commercial installations.

The results of the economic analysis of wood derived liquid and gas fuels is found in Table 1. The total cost of each product is based on capital, operating, and fuel costs for typical plants. A more detailed analysis may be found in Reference 4.

Table 1

COST TO PRODUCE WOOD DERIVED LIQUID AND GAS FUELS

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<th>Fuel</th>
<th>Cost/Unit</th>
<th>Cost/Million Btu's</th>
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<td>Ethanol</td>
<td>$1.31/gal</td>
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<tr>
<td>Methanol</td>
<td>$0.84/gal</td>
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<td>Pyrolysis Oil</td>
<td>$0.60/gal</td>
<td>$5.17</td>
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<tr>
<td>Pyrolysis Char</td>
<td>$114./ton</td>
<td>$4.32</td>
</tr>
<tr>
<td>Catalytic Oil</td>
<td>$1.35/gal</td>
<td>$9.10</td>
</tr>
<tr>
<td>Low Btu Gas</td>
<td>$0.39/Mcf</td>
<td>$2.57</td>
</tr>
<tr>
<td>Wood Pellets</td>
<td>$45/ton</td>
<td>$2.94</td>
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</tbody>
</table>

The cost of the liquid fuels is higher than competing fossil fuels. The gap is closing rapidly, however, as gasoline and fuel oil prices increase. Wood pellets compete with natural gas, but are more costly than raw wood or coal. Low Btu gas is competitive with natural gas and less costly than oil; hence, the renewed interest in this technology.

Direct Combustion for Steam Generation

Wood presently supplies approximately 2% of the U.S. energy needs with many projections showing a possible contribution of 7% possible on a renewable basis. The majority of present use is in producing steam for industrial process heat in pulp and paper mills. Nonforest product industries located in the forested areas of the U.S. are now
turning to this resource. Typical new installations are wood fired boilers of 50,000 lb/hr steam capacity rated at 150 psig saturated steam.

The capacities of individual boilers and entire boiler plants span the ranges of 10,000 to 200,000 lbs/hr of steam. Five different boiler sizes are analyzed in this range, using seven different systems. These systems are a wood waste boiler, wood chip boiler, wood pellet boiler, wood fueled fluidized bed combustor, coal boiler, gas boiler with oil backup, and an oil boiler. The costs of the wood waste gasifier with gas/oil boiler are presented in the summary tables and charts. Five different sizes are analyzed for each of these systems; these are 10,000 lb/hr steam, 25,000 lb/hr steam, 50,000 lb/hr steam, 100,000 lb/hr steam, and 200,000 lb/hr steam. The systems have been configured for almost completely automatic operation although some applications may not require the degree of automation placed here.

The technique used to analyze each of the seven systems presented is the same. For each system, a process diagram is developed which shows the routing of the fuel from arrival at the plant to combustion. The cost of each piece of equipment is identified and entered in a system cost table.

The object of the system cost table is to determine a cost of steam in dollars per million Btu's delivered for each system analyzed. These costs are then compared to determine the attractiveness of the various systems. The cost of steam is computed by dividing the total annual cost of a system by the annual amount of heat delivered.

The design factors used in the analysis of each of the systems are presented in Table 2. Each of the boilers is assumed to generate 150 psig saturated steam with inlet feedwater at 220°F and efficiencies as shown. The fuel data presented is considered to be representative of current heat values and costs in Georgia. The plants analyzed are assumed to operate 24 hours per day, 345 days per year, and at an average load factor of 70%. This data can be modified as required for analysis of a particular installation.
Table 2

DESIGN FACTORS

Boiler Operating Conditions

Operating Pressure = 150 psig saturated
Inlet Feedwater Temperature = 220°F

Efficiencies

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<th>Efficiency</th>
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<td>Waste Wood Boiler</td>
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<tr>
<td>Wood Gasifier (with gas boiler)</td>
<td>85%</td>
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<tr>
<td>Wood Chip Boiler</td>
<td>65%</td>
</tr>
<tr>
<td>Coal Boiler</td>
<td>83%</td>
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<tr>
<td>Wood Pellet Boiler</td>
<td>80%</td>
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<tr>
<td>Gas Boiler</td>
<td>81%</td>
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<tr>
<td>Wood Fueled Fluidized Bed Combustor</td>
<td>68%</td>
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<tr>
<td>Oil Boiler</td>
<td>85%</td>
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Fuel Data

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<th>Heat Value</th>
<th>Unit Cost</th>
<th>Raw fuel cost/ $ per Million Btu</th>
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<td>$0.82</td>
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<tr>
<td>Wood Chips</td>
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<td>Wood Pellets</td>
<td>7,650 Btu/lb</td>
<td>$45.00/ton</td>
<td>$2.94</td>
</tr>
<tr>
<td>Coal</td>
<td>13,000 Btu/lb</td>
<td>$35.00/ton</td>
<td>$1.35</td>
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<tr>
<td>Gas</td>
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</tr>
<tr>
<td>#6 Oil</td>
<td>150,000 Btu/gal</td>
<td>$0.65/gal</td>
<td>$4.33</td>
</tr>
</tbody>
</table>

Plant Operation

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours/Day</td>
<td>24</td>
</tr>
<tr>
<td>Days/Year</td>
<td>345</td>
</tr>
<tr>
<td>Load Factor</td>
<td>70%</td>
</tr>
</tbody>
</table>

78
Waste Wood Boiler System

The process diagram of the waste wood boiler system is shown in Figure 1. The waste wood is delivered to the plant by truck, unloaded with a hydraulic truck dumper, and either immediately processed into the system or moved to and from outside storage using a front end loader. The wood enters the automatic system through a drag chain conveyor which feeds a belt conveyor having a 20 foot horizontal section for fuel transfer. The wood waste is processed over a disc screen where the rejects are further reduced in size by a hammermill. The fines are allowed to pass through without size reduction. Whole tree chips do not need this processing. The sized wood is transported by belt conveyor to a storage silo with sufficient capacity for 3 days of boiler operation. The fuel from the storage silo is transported to the boiler using a drag chain conveyor.

Figure 1
PROCESS DIAGRAM
WASTE WOOD BOILER SYSTEM
The system cost for the waste wood boiler system is shown in Table 3. Since the system utilizes wood, a 20% investment tax credit is used. The operating cost is a percentage of the total capital cost taken from operating experience. The maintenance cost is assumed to be 5% of the total capital cost, and the tax and insurance are assumed to be 2.5% of the total capital cost. The annual heat delivered is calculated by determining the amount of heat released for a 24-hour day operation, 345 days per year, at a 70% load factor.

Table 3
SYSTEM COSTS
WOOD WASTE BOILER SYSTEM

<table>
<thead>
<tr>
<th>Capacity (lbs/hr)</th>
<th>10,000</th>
<th>25,000</th>
<th>50,000</th>
<th>100,000</th>
<th>200,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Dumper</td>
<td>120,000</td>
<td>120,000</td>
<td>120,000</td>
<td>240,000</td>
<td>240,000</td>
</tr>
<tr>
<td>Front End Loader</td>
<td>16,000</td>
<td>22,000</td>
<td>57,000</td>
<td>120,000</td>
<td>240,000</td>
</tr>
<tr>
<td>Raw Wood Drag Chain Conveyor</td>
<td>18,000</td>
<td>25,000</td>
<td>38,000</td>
<td>65,000</td>
<td>116,000</td>
</tr>
<tr>
<td>Raw Wood Belt Conveyor</td>
<td>56,000</td>
<td>58,000</td>
<td>60,000</td>
<td>67,000</td>
<td>74,000</td>
</tr>
<tr>
<td>Disc Screen</td>
<td>7,000</td>
<td>13,000</td>
<td>23,000</td>
<td>37,000</td>
<td>66,000</td>
</tr>
<tr>
<td>Hammermill</td>
<td>22,000</td>
<td>30,000</td>
<td>43,000</td>
<td>71,000</td>
<td>125,000</td>
</tr>
<tr>
<td>Sized Wood Belt Conveyor</td>
<td>154,000</td>
<td>163,000</td>
<td>172,000</td>
<td>189,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Storage Silo</td>
<td>32,000</td>
<td>79,000</td>
<td>158,000</td>
<td>315,000</td>
<td>630,000</td>
</tr>
<tr>
<td>Boiler Feed Conveyor</td>
<td>41,000</td>
<td>43,000</td>
<td>47,000</td>
<td>53,000</td>
<td>68,000</td>
</tr>
<tr>
<td>Boiler</td>
<td>350,000</td>
<td>625,000</td>
<td>900,000</td>
<td>2,800,000</td>
<td>4,800,000</td>
</tr>
<tr>
<td>Total Capital Cost</td>
<td>816,000</td>
<td>1,178,000</td>
<td>1,618,000</td>
<td>3,957,000</td>
<td>6,319,000</td>
</tr>
<tr>
<td>Less Investment Tax Credit</td>
<td>163,000</td>
<td>236,000</td>
<td>326,000</td>
<td>791,000</td>
<td>1,264,000</td>
</tr>
<tr>
<td>Financed Capital Cost</td>
<td>653,000</td>
<td>942,000</td>
<td>1,295,000</td>
<td>3,166,000</td>
<td>5,055,000</td>
</tr>
<tr>
<td>Annual Cost of Capital</td>
<td>101,000</td>
<td>146,000</td>
<td>200,000</td>
<td>490,000</td>
<td>782,000</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>134,000</td>
<td>150,000</td>
<td>194,000</td>
<td>352,000</td>
<td>379,000</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>41,000</td>
<td>59,000</td>
<td>81,000</td>
<td>198,000</td>
<td>316,000</td>
</tr>
<tr>
<td>Tax and Insurance</td>
<td>20,000</td>
<td>29,000</td>
<td>40,000</td>
<td>99,000</td>
<td>158,000</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>74,000</td>
<td>186,000</td>
<td>370,000</td>
<td>741,000</td>
<td>1,480,000</td>
</tr>
<tr>
<td>Total Annual cost</td>
<td>370,000</td>
<td>568,000</td>
<td>885,000</td>
<td>1,880,000</td>
<td>3,115,000</td>
</tr>
<tr>
<td>Annual Heat Delivered (10^6 Btu)</td>
<td>59,000</td>
<td>146,000</td>
<td>292,000</td>
<td>585,000</td>
<td>1,168,000</td>
</tr>
<tr>
<td>Cost Per Million Btu's Delivered</td>
<td>$6.27</td>
<td>$5.89</td>
<td>$5.03</td>
<td>$3.21</td>
<td>$2.67</td>
</tr>
</tbody>
</table>
Wood Chip Boiler System

The process diagram for the wood chip boiler system is similar to Figure 1; however, the disc screen, hammermill, and raw wood belt conveyor are eliminated. Since the wood chips already have a somewhat uniform size, no size reduction equipment is required, and it is transported immediately to a storage silo with a capacity for 3 days boiler operation. Wood is transported from the storage silo to the boiler using a drag chain conveyor.

The costs for this system and the other systems which follow were computed in a similar manner to those for the waste wood system total fuel and capital costs are presented in Figures 2 and 3.

Wood Pellet Boiler System

Wood pellets are dumped directly into a bin which feeds a belt conveyor. One of the advantages of pellets is their low moisture content. Since it is not desirable to add moisture to the pellets, no outside storage is utilized. A drag chain conveyor would tend to break the pellets, therefore, a belt conveyor is used to feed the storage silo and then to feed the boiler.

Wood Fueled Fluidized Bed Combustor System

Fuel for the system, waste wood, is delivered to the plant by truck, unloaded by a hydraulic truck dumper, and transported to and from outside storage by a front end loader. The wood enters the system through a drag chain conveyor which feeds a belt conveyor. A disc screen is again utilized to separate oversized pieces of wood, and a hammermill is used for size reduction. A belt conveyor transports the wood to a storage silo, and a drag chain or screw conveyor is used to transport the wood from the storage silo to the fluidized bed combustor.
Coal Boiler System

Coal is delivered to the plant by truck, unloaded by a hydraulic truck dumper, and moved to and from outside storage with a front end loader. The coal enters the combustion system through a drag chain conveyor feeding a belt conveyor. It is assumed that the coal is already sized and thus no size reduction equipment is required. A belt conveyor will feed a storage silo, and the coal is then transported from the storage silo to the boiler with a drag chain conveyor.

While a hydraulic truck dump is specified for unloading, many plants would choose rail delivery of coal. A short spur line with bottom unloading via a trestle would cost approximately $235,000. Deleting the cost of the truck dump, this system would add $.03 per million Btu's delivered. Long spur lines might increase this cost considerably, and the choice of rail or truck delivery depends on availability of rail service, size of boiler, and distance to coal mines.

The capital and operating costs of SO₂ scrubbing equipment is not included. Relatively low sulfur coal (less than 2% sulfur) is available from Tennessee and Alabama, and SO₂ clean up is usually not required for boilers of up to 200,000 lbs/hr steam capacity. The addition of SO₂ scrubbers would add approximately $5 per lb/hr of steam capacity to the capital cost of the boiler plant. The annual cost for this capital, plus maintenance, would add approximately $.25 per million Btu delivered to the cost of a coal fired steam system.

Gas Boiler System

Due to the possibility of a curtailment of natural gas supplies to an industrial boiler, the system is designed to fire either gas or oil. The gas is supplied to the boiler directly from a pipeline; oil is delivered to the plant by truck. An outside oil storage facility is equipped with a transfer pump, which pumps the oil to a day storage
tank which in turn feeds the boiler.

The outside oil storage tank is sized for a 7-day emergency supply of oil; its pumps are designed to fill the day tank in one hour. The day tank and outside storage tank are equipped with heaters for the #6 fuel oil.

Oil Boiler System

Oil is delivered to the plant by truck, stored in an outside storage tank, and pumped by transfer pump to the day tank. The day tank transfers oil directly to the boiler with pumps.

The outside oil storage tank is designed for a capacity to provide 30 days of boiler operation. The oil transfer pumps are designed with a capacity to transfer oil to the day tank in one hour, both day tank and outside storage tank have heaters for the #6 fuel oil.

Wood Waste Gasifier with Gas/Oil Boiler

An updraft gasifier used to retrofit a gas/oil boiler is the basis for this system. It is fueled with whole tree chips and is close-coupled to the boiler. The total capital costs, fuel costs, and steam costs are presented in the summary table for comparison with other systems.

SUMMARY

Capital Costs

The capital cost of any steam generating system can be separated into boiler cost and fuel system cost. The latter can be found by subtracting the boiler cost from the total cost. Comparison of the cost data and the efficiency data indicates that boilers for gas and oil systems are efficient and low in cost, and fuel system costs are minimal. In contrast, solid fuel equipment is less efficient, par-
particularly when burning high moisture content fuels. The boiler cost and extensive solids handling and storage systems require a large capital investment. Solid fuel equipment is also considerably larger in size.

Figure 2 presents capital cost curves for boiler systems including fuel handling from 10,000 to 200,000 lb/hr steam for gas, liquid, and solid fuels. Solid fueled boiler systems are approximately 9 times the cost of gas/oil systems. Gasifier retrofit of existing boilers is somewhat less, at approximately 5 times the cost of gas/oil systems.

**Fuel Costs**

Figure 3 summarizes the fuel cost for the same systems based on a 345-day-per-year operation and a 70% load factor. Oil is the most costly fuel (No. 6 @ $0.65 per gallon) followed by natural gas, wood pellets, wood chips, coal (less than 2% sulfur) and wood waste. It is interesting to note that an oil fired boiler of 30,000 lb/hr capacity with an initial cost of $210,000 will consume $1 million worth of fuel oil in its first year of operation. The annual fuel cost for most solid fuel systems is about 1/3 of that for gas or oil systems.

The capital cost and fuel costs of the eight steam production systems are inversely proportional, i.e., the cheapest fuel requires the most costly handling and burning systems.

**Steam Costs**

The primary application in industry for wood fuel and competing fossil fuels is steam production. Using the costs for raw fuel and plant investment covered previously and adding operation costs as a percentage of plant investment, the total cost of producing steam can be found. This cost can be used to compare the economic merits of wood and fossil fueled systems for boiler replacement or plant expansion.
Figure 2

CAPITAL COST OF
STEAM GENERATING SYSTEMS

TURNKEY INSTALLATIONS
INCLUDING FUEL HANDLING

Figure 3

ANNUAL FUEL COST FOR
STEAM GENERATING SYSTEMS
The cost of steam for the individual systems is summarized in Table 4 and Figure 4. Cost is presented in dollars per million Btu's delivered of 150 psig saturated steam. This data indicates that the cost of steam goes down with increasing boiler size for all fuels, with the minor exception of a slight jump in price from package boilers to the larger field erected type over 50,000 lb/hr steam capacity. For the smallest boilers, 10,000 lb/hr capacity, natural gas is the least costly system. Interruptions and rising gas prices may change this position in the future. Coal is more costly, followed by oil, wood waste, wood chips, wood waste for a fluidized bed combustor, and wood pellet boiler in order of increasing cost. This analysis points out the fact that solid fuels are expensive to use for small industrial applications.

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>COST OF STEAM</td>
</tr>
<tr>
<td>(Dollars per Million Btu's Delivered)</td>
</tr>
<tr>
<td>System Rating</td>
</tr>
<tr>
<td>Wood Waste Boiler</td>
</tr>
<tr>
<td>Wood Chip Boiler</td>
</tr>
<tr>
<td>Wood Pellet Boiler</td>
</tr>
<tr>
<td>Wood Waste Fluidized Bed Combustion</td>
</tr>
<tr>
<td>Coal Boiler</td>
</tr>
<tr>
<td>Gas/Oil Boiler</td>
</tr>
<tr>
<td>Oil Boiler</td>
</tr>
<tr>
<td>Wood Waste Gasifier on Gas/Oil Boiler</td>
</tr>
</tbody>
</table>

The 25,000 lb/hr size range is perhaps more indicative of industrial boiler sizes. In this size, wood waste is the lowest cost, followed by coal, wood chips, and gas. Natural gas is more costly, followed by wood pellets and fuel oil.
Figure 4

TOTAL COST OF STEAM

$ / MILLION BTU DELIVERED

COST

$8.0$

$6.0$

$4.0$

$2.0$

0 50 100 150 200

STEAM DELIVERED 1000 LBS/HR

Oil

Wood Pellets

Gas

Wood Chips

Coal & Wood Waste

Gasified Wood Waste
The cost of wood gasifiers retrofitted to existing gas/oil boilers is also of interest. The economic analysis is complicated by the "existing" boiler which may already be fully depreciated. In order to keep the analysis on the same basis, the cost for delivered steam from a gasifier retrofit system includes the amortization, operational, and maintenance costs of a gas boiler. These costs, based on waste wood, are the least costly of any system in any size range. If wood chips are used as the fuel, the cost per million Btu's delivered as steam increases $0.61, making it the least costly option with the sole exception of the natural gas boiler at 10,000 lb/hr capacity. This economic advantage is countered by the lack of dependable hardware at present. Over 30 groups in the U.S. and Canada are developing wood gasifiers and availability problems may be alleviated in the next few years.

The economics of firing boilers with dry, densified wood pellets are competitive only with fuel oil in the 50,000 lb/hr size range and above. Cost reductions in pelletization technology or the emergence of compact, low cost gasifiers to convert pellets into a gas compatible with existing gas/oil equipment should greatly improve this competitive position.

The solid fuel systems with larger capital costs will be more sensitive to increases in loan interest rates than oil and gas systems. For example, changing from a 15% to 17% interest rate will increase the cost of steam for a 25,000 lb/hr wood waste boiler by $0.11 per million Btu's but only $0.03 per million Btu's for a 25,000 lb/hr gas/oil boiler.

Table 5 shows the payback period for wood waste, chip, and pellet fuel systems as compared to a conventional oil fired boiler. The cost data computed indicates that oil is a cheaper system in the 10,000 lb/hr size range. The cost of the wood systems could be reduced by removing some of the automation and storage designed into the system. Wood waste and chips will payoff within the five-year period which is generally considered to be a limit for industrial applications. Pellets are not competitive in the smaller capacities and have
unacceptably long payback periods in the larger sizes. As previously noted, pellets are not a viable fuel when analyzed by other economic methods. The jump between 50,000 lbs/hr and 100,000 lbs/hr is due to the increased capital cost of a field erected versus a packaged boiler. As capacities increase above 100,000 lbs/hr, the boiler costs and the resulting payback periods decrease due to economies of scale.

<table>
<thead>
<tr>
<th>Capacity (lb/hr)</th>
<th>Waste Payback Period (Years)</th>
<th>Chips Payback Period (Years)</th>
<th>Pellets Payback Period (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>Oil Cheaper</td>
<td>Oil Cheaper</td>
<td>Oil Cheaper</td>
</tr>
<tr>
<td>25,000</td>
<td>3.52</td>
<td>4.00</td>
<td>Oil Cheaper</td>
</tr>
<tr>
<td>50,000</td>
<td>1.77</td>
<td>1.99</td>
<td>6.90</td>
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<tr>
<td>100,000</td>
<td>2.63</td>
<td>3.30</td>
<td>27.90</td>
</tr>
<tr>
<td>200,000</td>
<td>1.69</td>
<td>2.20</td>
<td>8.20</td>
</tr>
</tbody>
</table>
REFERENCES


3. Cost Comparison Study Industrial Size Boilers 10,000 to 400,000 Pounds per Hour, Davy McKee Corporation, Cleveland, Ohio 44131, DOE Contract EX-77-C-01-2418, October 1979.

A DEMONSTRATION IN WOOD GASIFICATION

by

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Technology Applications Laboratory

Georgia Institute of Technology
Engineering Experiment Station

Presented at

CASE STUDIES IN WOOD ENERGY
November 5, 1980
Atlanta, Georgia
BACKGROUND

In 1978, the Georgia Forestry Commission and the Technology Applications Laboratory of Georgia Tech started a multi-task project to carry out demonstrations of wood energy use in the residential and institutional/commercial sectors. It was decided that the institutional demonstration should involve a state-owned institution and that a relatively new or unproven technology should be demonstrated.

The search for a suitable site was begun and the most promising possibilities included the Alto Correctional Facility at Alto, the Georgia Retardation Center near Atlanta, and the Northwest Regional Hospital in Rome, Georgia. The Alto facility was eliminated primarily due to the security difficulties which would be encountered in showing the wood energy system to tour groups, and the Georgia Retardation Center was eliminated due to its urban location and space limitations in the immediate area of the hot water plant.

The Northwest Regional Hospital was chosen as the demonstration site. The steam plant contains three Springfield watertube boilers rated at 19,000 lb/hr each, providing saturated steam at approximately 125 psi to the hospital for space heating and the institutional laundry. These boilers can be fired with natural gas obtained through a pipeline or with No. 6 fuel oil stored on the premises. In addition, an absorption air conditioning plant is located adjacent to the steam plant providing air conditioning to the hospital in the summertime. Thus, there is a year-round steam demand, and the peak demand never requires more than 1½ times the steam output of a single boiler, so one boiler is available on a "standby" basis.

There has been a great deal of interest recently in retrofit applications of wood gasifiers to provide low Btu gas (125 to 175 Btu/ft³) to gas/oil boilers. This concept, if feasible, could have many applications at industrial plants within the state, in addition to institutions and commercial buildings.

Georgia Tech and the Georgia Forestry Commission wrote a specification for a wood conversion of one of the hospital boilers. The basic criteria included—To provide the ability to burn green wood (50% moisture content); To use as much of the existing boiler equipment as possible; To achieve full boiler capacity on wood (19,000 lb of steam per hour), and to be operational a minimum of 3,000 hours per year.
A bidder's list of approximately fifteen companies was made up based on information available at that time on gasifier suppliers. A number of the suppliers visited the site but, for a variety of reasons, only three of the companies submitted proposals.

SYSTEM DESIGN

Based upon the designs submitted and subsequent negotiations, the Applied Engineering Company (APCO) in Orangeburg, South Carolina, was chosen to do the job. Applied Engineering has been working on wood gasification systems for several years and has also built many steam plants and processing plants for the forest products industries in the past. The company has a large manufacturing plant in Orangeburg and is fully capable of fabricating large pressure vessels and heavy industrial equipment. Although the Rome project is a research and development venture, a successful demonstration will probably result in the further marketing of wood gasifiers by APCO in a variety of market segments.

The overall wood gasification system is shown in Figure 1. The fuel for the gasifier will be green total tree chips (mixed hardwoods and softwoods) trucked in from North Georgia logging sites in standard chip vans. This material will be predominately chips of 2" by 2" mixed with some pine needles, leaves, twigs, and bark. It will have a moisture content of approximately 40% to 50% and a net heating value of 4,000 to 4,500 Btu/lb.

The chip trailers will be unloaded with a hydraulic tipping system into a live bottom pit. This pit will transfer the wood via drag chain to an inclined conveyor that will fill a storage silo. The silo (approximately 20,000 cubic feet) will allow for 3½ days operation, 24 hours per day at full boiler load. This will provide for long weekends or other temporary interruptions of chip delivery.

The silo will contain a bottom unloader, feeding a reclaim conveyor that will transport the chips to the top of the wood gasifier. The gasifier requires a maximum input of approximately 25 million Btu/hr which will provide enough energy to produce 19,000 lb/hr of steam when the losses within the gasifier and within the boiler are considered. Full load operation requires an infeed rate of approximately 3.1 tons of wood chips per hour.

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WOOD CHIP DELIVERY

LOADING CONVEYOR

LIVE BOTTOM HOPPER

WOOD STORAGE
(3.5 DAYS)

EXISTING 19,000 LB/HR GAS/OIL PACKAGE BOILER

LOW BTU GAS PIPE

LOW BTU BURNER

25 MILLION BTU/HR GASIFIER

RECLAIM CONVEYOR

COMBUSTION AIR SUPPLY

FIGURE 1
The gasifier is located just outside the boiler room in the open and is a large vessel approximately 10 feet in diameter and 30 feet high. Gas is transported to the burner from the gasifier outlet in an insulated pipe. The gas has a heating value of approximately 150 Btu/ft\(^3\) and is burned in an APCO designed burner designed to handle the tars and other hard to burn substances that are entrained in the producer gas.

Basically, the gasifier is typical of an updraft gasifier design as shown in Figure 2. In this design, a fire is started above the grate with approximately 25% of theoretical air supplied to this hot zone. The heat thus generated drives the volatiles from the wood and through several zones as shown in the figure, where the primary constituents of the gases are formed. A typical gas composition, based on APCO test data, is shown in Table I.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N(_2))</td>
<td>53%</td>
</tr>
<tr>
<td>Oxygen/Argon</td>
<td>2.4%</td>
</tr>
<tr>
<td>Carbon Dioxide (CO(_2))</td>
<td>9.5%</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>25%</td>
</tr>
<tr>
<td>Hydrogen (H(_2))</td>
<td>8%</td>
</tr>
<tr>
<td>Methane (CH(_4))</td>
<td>1.8%</td>
</tr>
</tbody>
</table>

Heating Value = 127 Btu/ft\(^3\)

The hot gases produced by the gasifier give up some of their heat to dry the infeed material as they leave the vessel, so that the exiting gas is relatively cool at 100° to 200°C.

The grate system used in this gasifier is of a design which allows the horizontal sections to rock in order to keep the ash flowing smoothly into the ash hopper. Ash can be removed automatically with an auger system. The infeed material is distributed with a rotating rake system to keep a relatively constant bed height.
FIGURE 2
Gasifier internal temperature and production of hydrogen is partially controlled through steam injection with the combustion air. The gasifier operates at a slight positive pressure (3 psi), and the ratio of steam to air under full load operation is typically about 0.25 on a volume basis. Control of the gasification system will depend on steam demand. It is anticipated that the gasifier-equipped boiler should be capable of 3:1 turndown ratio. Standby gas and oil changeover will be accomplished with some minor hardware changes. The flame temperature of the low Btu gas flame will be lower than that of natural gas or oil, so it is possible that some derating of the boiler will be necessary although it is hoped that the system will produce the full 19,000 lb/hr.

Full scale startup of the gasifier was made in Orangeburg in March 1980, and the unit was moved to Rome in August. Startup of the unit began in September and full scale operation is anticipated for October. Figure 3 shows the gasification unit as installed on the hospital site, and Figure 4 shows the overall relationship of the system to the existing steam plant.

ECONOMICS

At present, the hospital is supplied with interruptible gas and No. 6 oil. The economics of the system will change according to which fuel is available in the long run.

An analysis of the gasifier system payback can be made considering the cost of the system and the cost of the fuel alternatives as follows:

Description: The wood gasifier retrofit system consists of the wood fuel storage, feed system, unloading system, conveyors, fans, and other auxiliaries. The gasifier is coupled to an existing gas/oil fired boiler that is 18 years old. For depreciation purposes, the boiler will be considered paid for.
Wood Gasifier System

Assumptions:

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasifier thermal efficiency</td>
<td>85%</td>
</tr>
<tr>
<td>Gas/oil boiler efficiency</td>
<td>82.5%</td>
</tr>
<tr>
<td>Overall retrofit system efficiency</td>
<td>0.85 x .825</td>
</tr>
<tr>
<td>Capacity of system</td>
<td>550 hp</td>
</tr>
<tr>
<td>Capital cost of gasifier retrofit</td>
<td>$350,000</td>
</tr>
<tr>
<td>Expected life</td>
<td>20 years</td>
</tr>
<tr>
<td>Cost of wood</td>
<td>$15/ton</td>
</tr>
<tr>
<td>Net heat output (wood)</td>
<td>6,020,000 Btu/ton</td>
</tr>
<tr>
<td>Annual hours of operation</td>
<td>7,000 hours</td>
</tr>
</tbody>
</table>

Conventional System

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>0 (paid for)</td>
</tr>
<tr>
<td>Fuel</td>
<td>No. 6 oil</td>
</tr>
<tr>
<td>Cost of fuel</td>
<td>$26/barrel</td>
</tr>
<tr>
<td>Boiler efficiency</td>
<td>82.5%</td>
</tr>
<tr>
<td>Annual hours of operation</td>
<td>7,000</td>
</tr>
</tbody>
</table>

The annual cost comparison table follows.

<table>
<thead>
<tr>
<th>ANNUAL COST COMPARISON</th>
<th>Retrofit Wood Gasifier</th>
<th>Existing Gas/Oil Furnace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of Capital</td>
<td>$ 59,034</td>
<td>$ 0</td>
</tr>
<tr>
<td>(capital recovery factor 16% interest)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance (3% for gasifier)</td>
<td>$ 10,500</td>
<td>$ 2,250</td>
</tr>
<tr>
<td>Operation Cost (electricity and labor)</td>
<td>$ 48,290</td>
<td>$ 30,107</td>
</tr>
<tr>
<td>Cost of Fuel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood (Green chips @ $15/ton)</td>
<td>$331,395</td>
<td>$688,957</td>
</tr>
<tr>
<td>No. 6 fuel (@ $26/barrel)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL ANNUAL COST</td>
<td>$449,219</td>
<td>$721,314</td>
</tr>
</tbody>
</table>
Expected savings per year using wood (@$15/ton) = $721,314 - $449,219 = $272,095
Simple payback $350,000/$272,095 = 1.29 years

Admittedly, the above comparison oversimplifies the situation since the hospital is not required to burn No. 6 fuel oil year-round, but natural gas is expected to rise in price and become more interruptible over the next several years, so the payback will probably be less than 5 years in any event.

From an economic standpoint, the retrofit of wood systems to gas/oil fired boilers appears very attractive, but a major point that must be considered is the ease of operation. Maintenance of any solids handling system will require more manpower than a gas/oil system. Money spent on maintenance will be higher, unscheduled downtime of the system will probably be greater, and the amount of real estate necessary to dedicate to the system will also be greater.

CONCLUSIONS

The wood gasification demonstration of the Northwest Regional Hospital is behind schedule at this time due primarily to the contractual problems at the beginning of the project and due to the research and development nature of the gasifier. After full start-up of the system, the economics of the system will be closely monitored to verify that the gasifier meets expectations. It is anticipated that a successful demonstration in Rome will result in similar installations at other state institutions and in private industry.
Appendix B
WOOD ENERGY FINANCING
WOOD ENERGY

FINANCING
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A STATE DEMONSTRATION IN WOOD ENERGY

by

C. L. Aton, P.E., Technology Transfer Branch Chief

Presented at

WOOD ENERGY FINANCING
April 29, 1981
A STATE DEMONSTRATION IN WOOD ENERGY

As energy economics change to favor higher petroleum prices, alternative energy sources once considered too expensive to use become more attractive. Biomass sources in particular are beginning to show economic viability; and wood energy systems, a subset of biomass systems, show considerable potential for providing energy in the industrial and residential sectors.

Direct combustion wood energy systems have been used extensively in the forest products industry for many years, and that industry is familiar with technologies and procedures for both production of wood and conversion of wood to products including energy. Wood energy systems have had much less use in nonforest products industries, however. Few companies other than those having direct forest products interests have had the expertise or the need for considering wood fuel systems. Although many factors have worked against wood use in these industries, the major barrier was the low cost of readily available fossil fuels relative to the cost of wood energy. Now, however, with gas/oil supplies becoming more expensive and in shorter supply, companies without forestry expertise may derive benefits by converting to wood fuels and reducing the nation's dependence on premium fossil fuels.

Georgia Tech has undertaken a multi-year project directed toward accelerating the commercialization of wood energy for nonforest products industries. Funded by the Biomass Energy Systems Division of the U.S. Department of Energy through the Georgia Office of Energy Resources, the primary objective of this program is to encourage the replacement of oil and gas with wood fuel.

Georgia Tech is presently in the second year of a multi-year program designed to stimulate the use of wood energy by the industrial sector in the State of Georgia. The first year had as objectives the following:

1. Feasibility Studies. Eighteen feasibility studies for wood energy use have been conducted for nonforest product industrial plants in the state of Georgia.

2. Demonstration Plants. Georgia Tech personnel have worked on the actual construction of 2 wood energy plants in Georgia, chosen from among interested nonforest products industry industrial plants.

3. Technology Transfer. Four seminars concerned with wood energy (attended by some 300 representatives of industry, research, and government) have been held, and two slide/tape series on wood energy have been produced. In addition, various related proceedings and pamphlets have been published.

4. Wood Processing. An exhaustive study concerning wood fuel processing routes has been made, resulting in definite conclusions for the best alternate fuel coverage for various industrial situations.

Phase II of the project was started in July 1980 and consists of an expansion of the activities carried out in Phase I including the following:
1. Development of a Wood Energy Extension Service to provide widespread technical assistance to industry.

2. Continued supervision of the two demonstration projects begun under Phase I.

3. In-depth analysis of specific problems in supply, storage, and drying of wood fuels delineated in Phase I as well as better definition of fuel property standards.

4. Survey of potential wood gasification applications in Georgia and practical test programs on gasifier operational problems.

5. Technology transfer through seminars, publications, tours of demonstration sites, and presentations at national conferences.

The benefits of these efforts will be far reaching. Conversions from fossil-based energy systems to renewable resource energy systems will be accelerated. Economic activity on a local basis will be stimulated and dependence on foreign energy supplies reduced. And perhaps most importantly, a base of knowledge and a system of methodologies will be established that can be used not only in Georgia but as a model in other regions of the United States.
WOOD ENERGY AT THE SOUTHERN
SOLAR ENERGY CENTER

by

D. Gustashaw, Southern Solar Energy Center

Presented at
WOOD ENERGY FINANCING
April 29, 1981
SSEC WOOD PROGRAMS

Residential

The objective of the Center's residential wood program is to encourage the development of efficient wood supply systems and to continue to provide accurate consumer information on wood use and supply.

As residential use of wood for heating increases, existing supply techniques will not be adequate. Many people are already aware of the increasing difficulty and expense of obtaining wood for their stoves and fireplaces.

In addressing the needs of the residential sector, SSEC is encouraging the creation of more wood supply systems. Part of that effort involves the development of detailed analysis of existing residential wood-yard operations and providing small landowners with professional forestry consulting services. Those services to landowners include assistance in marking fuelwood for removal, development of forest management plans, advice on harvesting and stand regeneration, marketing advice, recommendations for timber stand improvement, and aid in locating producers for harvesting.

Past attempts by landowners to improve their forest land have been limited by their holdings of nonmerchantable stands of undesirable, small-diameter, or poorly formed species. The residential fuelwood program offers those landowners—and potential investors—the opportunity to use nonmerchantable stands as an energy source for an immediate economic return and also allows them to upgrade their stands for increased future returns through sound forest management practices.

Another part of the overall program effort provides assistance to producers. They are aided in locating sources of available fuelwood, furnished with information on fuelwood harvesting equipment, and are given suggestions related to environmental harvesting and the harvesting of small, nondescript hardwoods. Existing and potential dealers in fuelwood receive assistance in procurement activities, scaling procedures, weight conversions, and drying and storage techniques.

There are also environmental considerations in the widespread burning of wood, particularly in urban areas. SSEC is monitoring research into the environmental impact of wood combustion and tracking related state and local legislation. Eventually, the Center will serve as a clearinghouse for information on the residential use of wood, distributing publications on wood safety and on evaluations of the wood-yard concept.

Industrial

SSEC's industrial wood program has three major objectives. The first is to educate the nonforest industries about the wood energy potential and application through technical and economic assistance. The second objective is to assist the demonstration of new, promising technologies in such areas as the retrofitting of existing equipment, gasification, cogeneration, wood harvesting transportation and processing. The third objective is the development of an information base to provide technical data and expertise to the southern region's wood users.
In North Carolina, SSEC has established a prototype wood assistance team at the North Carolina State University. This team is composed of engineers, foresters and environmentalists who work with selected plants in their state to assess the potential for conversion to wood energy systems. This team has developed a self help information package that enables a potential wood energy user to do a preliminary in-house feasibility study on a total wood energy system. Currently, the wood assistance team is working on case studies which assess the feasibility of wood energy at four typical North Carolina Industries.

In an effort to expand the industrial information assistance, Virginia, Florida, and Alabama have been selected as the next three sites for five feasibility studies on the potential use of wood energy. Results of those studies, once completed, will be presented in a workshop for each state's industries.

More direct industrial assistance is provided for industries by the SSEC technical staff. Staff expertise ranges from engineering, economics and marketing to planning and finance. Conservation techniques, boiler sizing, materials handling design, economic analysis, market surveys and financial consideration are just some of the services provided by the SSEC staff to a wide variety of industry in the southern region.

Ongoing industrial wood program activities include information services utilizing the technical expertise of SSEC staff members and an SSEC-developed computer-modeled economic analysis. Other information support involves conducting workshops, publishing wood-energy articles, developing a wood energy handbook for industrial users, and maintaining a wood resource data base (including U.S. Forest Service, state forestry inventories, and privately compiled surveys) for industry support and planning purposes.

Beyond its current programs, SSEC is looking ahead to the identification and evaluation of new wood combustion systems with high potential for acceptance among and adoption by industries. To assist in making these evaluations, the Center will assemble an advisory group of specialists in industrial energy applications.

Many factors must be considered and explored in order to develop the potential of wood energy most efficiently. SSEC's wood programs are designed to evaluate those factors and respond with appropriate measures for the accelerated use of wood in filling our nation's energy needs.
WOOD FUEL SYSTEMS

by

J. L. Walsh, Jr., P.E., Research Engineer

Presented at

WOOD ENERGY FINANCING
April 29, 1981

Technology Applications Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
March 1981
INTRODUCTION

The objectives of this paper are to present an overview of the various wood fuel systems which might be utilized for an industrial application, and a general estimate of the requirements for the equipment for these systems. This overview will discuss the types of and general requirements for the combustion equipment and the fuel handling equipment. When an energy generation system utilizes a solid fuel, there is a significant increase in the amount of fuel handling equipment. In this paper the combustion equipment and the fuel handling equipment will be discussed for both solid and liquid systems.

Eight different systems are discussed. These systems are a wood waste boiler, wood chip boiler, wood pellet boiler, wood fueled fluidized bed combustor, wood waste gasifier with gas/oil boiler, coal boiler, gas boiler with oil backup, and an oil boiler. Five different sizes are analyzed for each of these systems; these are 10,000 lbs/hr steam, 25,000 lbs/hr steam, 50,000 lbs/hr steam, and 100,000 lbs/hr steam, and 200,000 lbs/hr steam. The systems have been configured for almost completely automatic operation although some applications may not require the degree of automation placed here. The system components are discussed in sufficient detail to permit removal of the automation if desired, for recalculation of system costs.

A process diagram will be presented for each of the eight systems discussed in this paper. A process diagram is a drawing which identifies the major equipment items required to process fuel into energy in the form of steam. The diagram shows the flow path of fuel to and from the major equipment items. Each system is analyzed to present sufficient information to permit a potential user to specify his own system. The technical specifications for the equipment presented in Appendix A are adequate for obtaining preliminary estimates of equipment costs. These specifications can be altered to meet the requirements of a particular facility.

Design Factors Analysis

The design factors used to generate the general equipment specifications for each of the systems are presented in Figure 1. Each of the boilers is assumed to generate 150 psig saturated stream with inlet
Figure 1

DESIGN FACTORS

Boiler Operating Conditions

Operating Pressure = 150 psig saturated
Inlet Feedwater Temperature = 220°F

Efficiencies

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Wood Boiler</td>
<td>65%</td>
</tr>
<tr>
<td>Wood Chip Boiler</td>
<td>65%</td>
</tr>
<tr>
<td>Wood Pellet Boiler</td>
<td>80%</td>
</tr>
<tr>
<td>Coal Boiler</td>
<td>83%</td>
</tr>
<tr>
<td>Gas Boiler</td>
<td>81%</td>
</tr>
<tr>
<td>Oil Boiler</td>
<td>85%</td>
</tr>
<tr>
<td>Wood Fueled Fluidized Bed Combustor</td>
<td>68%</td>
</tr>
<tr>
<td>Wood Gasifier</td>
<td>85%</td>
</tr>
<tr>
<td>(with gas boiler = 69%)</td>
<td></td>
</tr>
</tbody>
</table>

Fuel Data

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Heat Value</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Wood</td>
<td>4,250 Btu/lb</td>
<td>$7.00/ton</td>
</tr>
<tr>
<td>Wood Chips</td>
<td>4,250 Btu/lb</td>
<td>$10.50/ton</td>
</tr>
<tr>
<td>Wood Pellets</td>
<td>7,650 Btu/lb</td>
<td>$45.00/ton</td>
</tr>
<tr>
<td>Coal</td>
<td>13,000 Btu/lb</td>
<td>$35.00/ton</td>
</tr>
<tr>
<td>Gas</td>
<td>1,000 Btu/ft³</td>
<td>$0.30/10⁵ Btu</td>
</tr>
<tr>
<td>Oil #6</td>
<td>150,000 Btu/gal</td>
<td>$0.65/gal</td>
</tr>
</tbody>
</table>

Plant Operation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours/Day</td>
<td>24</td>
</tr>
<tr>
<td>Days/Year</td>
<td>345</td>
</tr>
<tr>
<td>Load Factor</td>
<td>70%</td>
</tr>
</tbody>
</table>
feedwater at 220°F, and efficiencies as shown. The fuel data presented is considered to be representative of current heat values and costs in Georgia. The plants analyzed are assumed to operate 24 hours per day, 345 days per year and at an average load factor of 70%. This data can be modified as required for analysis of a particular installation.

**Oil Boiler System**

The process diagram for the oil boiler system is shown in Figure 2. Oil is delivered to the plant by truck, stored in an outside storage tank with an internal heater, and pumped by transfer pump to the day tank. The day tank transfers oil directly to the boiler with pumps.

Specifications for the oil boiler system are shown in Appendix A1. The outside oil storage tank is designed for a capacity to provide 30 days of boiler operation and has an internal heater to keep the oil flowing. The oil transfer pumps are designed with a capacity to transfer oil to the day tank in 1 hour, both day tank and outside storage tank have heaters for the #6 fuel oil.

**Gas Boiler System**

The process diagram for the gas boiler system is shown in Figure 3. Due to the possibility of a curtailment of natural gas supplies to an industrial user, the system is designed to fire either gas or oil. The gas is supplied to the boiler directly from a pipe line; oil is delivered to the plant by truck. An outside oil storage facility is equipped with a transfer pump, which pumps the oil to a day storage tank which in turn feeds the boiler.

Specifications for the gas boiler system are shown in Appendix A2. The outside oil storage tank is sized for a 7 day emergency supply of oil; its pumps are designed to fill the day tank in one hour. The day tank and outside storage tank are equipped with heaters for the #6 fuel oil.

**Coal Boiler System**

The process diagram for the coal boiler system is shown in Figure 4. Coal is delivered to the plant by truck, unloaded by a hydraulic truck dumper, and moved to and from outside storage with a front end loader. The
Figure 2

PROCESS DIAGRAM
OIL BOILER SYSTEM

OIL DELIVERED BY TRUCK

OUTSIDE OIL STORAGE

OIL FEED PUMPS

OIL STORAGE DAY TANK

OIL TRANSFER PUMP

BOILER

STEAM SUPPLY
Figure 3

PROCESS DIAGRAM
GAS BOILER SYSTEM
WITH OIL BACKUP

OIL DELIVERED BY TRUCK

OUTSIDE OIL STORAGE

OIL FEED PUMPS

OIL STORAGE DAY TANK

OIL TRANSFER PUMP

NATURAL GAS FROM PIPELINE

BOILER

STEAM SUPPLY
Figure 4

PROCESS DIAGRAM
COAL BOILER SYSTEM

- COAL DELIVERED BY TRUCK
- TRUCK DUMPER
- DRAG CHAIN CONVEYOR
- BELT CONVEYOR
- BOILER
- BOILER FEED DRAG CHAIN CONVEYOR
- STORAGE SILO
- STEAM SUPPLY

TO AND FROM OUTSIDE STORAGE
coal enters the combustion system through drag chain conveyor feeding a belt conveyor. It is assumed that the coal is already sized and thus no size reduction equipment is required. A belt conveyor will feed a storage silo, and the coal is then transported from the storage silo to the boiler with a drag chain conveyor.

While a hydraulic truck dump is specified for unloading, many plants would choose rail delivery of coal. The choice of rail or truck delivery depends on availability of rail service, size of boiler, and distance to coal mines.

Specifications for the coal boiler system are shown in Appendix A3. All equipment upstream of the storage silo is designed to fill the silo in one 8 hour shift. The conveyor between the storage silo and the boiler is designed for a capacity equal to the boiler fuel consumption flow rate; the storage silo has a capacity for 3 days of boiler operation.

Sulphur dioxide (SO$_2$) scrubbing equipment is not included. Relatively low sulfur coal (less than 2% sulfur) is available from Tennessee and Alabama, and SO$_2$ clean up is usually not required for boilers of up to 200,000 lbs/hr steam capacity.

Waste Wood Boiler System

The process diagram of the waste wood boiler system is shown in Figure 5. The waste wood is delivered to the plant by truck, unloaded with a hydraulic truck dumper, and either immediately processed into the system or moved to and from outside storage using a front end loader. The wood enters the automatic system through a drag chain conveyor which feeds a belt conveyor having a 20 foot horizontal section for fuel transfer. The wood waste is processed over a disc screen where the rejects are further reduced in size by a hammermill. The fines are allowed to pass through without size reduction. Whole tree chips do not need this processing. The sized wood is transported by belt conveyor to a storage silo with sufficient capacity for 3 days of boiler operation. The fuel from the storage silo is transported to the boiler using a drag chain conveyor.

Specifications for each piece of equipment in the waste wood boiler system are shown in Appendix A4. The criterion for sizing the equipment upstream of the storage silo is that the wood for 3 days of operation must
Figure 5
PROCESS DIAGRAM
WASTE WOOD BOILER SYSTEM
be processed in one 8 hour working shift; this establishes the capacity for the conveyors, disc screen and hammermill on the upstream side of the silo. The drag chain conveyor between the storage silo and the boiler is sized to carry only the boiler fuel consumption rate. Although the system operates at an average load factor of 70%, all equipment must be sized for full load operation.

**Wood Chip Boiler System**

The process diagram for the wood chip boiler system is shown in Figure 6. Wood is delivered to the plant by truck, unloaded by hydraulic truck dumper, and either put directly into the system or moved to and from outside storage using a front end loader. The wood enters the system using a drag chain conveyor feeding a belt conveyor. Since the wood chips already have a somewhat uniform size, no size reduction equipment is required, and it is transported immediately to storage silo with a capacity for 3 days boiler operation. Wood is transported from the storage silo to the boiler using a drag chain conveyor.

Specifications for the wood chip boiler system are shown in Appendix A5. All capacities for equipment on the upstream side of the storage silo are based on the assumption that the storage silo must be filled in one 8 hour shift. The drag chain conveyor between the storage silo and the boiler is sized to carry the boiler fuel consumption rate.

**Wood Pellet Boiler System**

The process diagram for the wood pellet boiler system is shown in Figure 7. The wood pellets are delivered to the plant by truck and unloaded by a hydraulic truck dumper. The pellets are dumped directly into a bin which feeds a belt conveyor. One of the advantages of pellets is their low moisture content. Since it is not desirable to add moisture to the pellets, no outside storage is utilized. A drag chain conveyor would tend to break the pellets, therefore, a belt conveyor is used to feed the storage silo and then to feed the boiler.

Specifications for the wood pellet boiler system are shown in Appendix A6. The belt conveyor capacity is set to permit filling of the storage silo in one 8 hour shift. The belt conveyor between the storage
Figure 6

PROCESS DIAGRAM
WOOD CHIP BOILER SYSTEM
Figure 7

PROCESS DIAGRAM
WOOD PELLET BOILER SYSTEM

PELLETS DELIVERED BY TRUCK

TRUCK DUMPER → BELT CONVEYOR → STORAGE SILO

STEAM SUPPLY

BOILER → BOILER FEED BELT CONVEYOR
silo and the boiler is designed for a capacity equal to the boiler fuel consumption rate.

Wood Fueled Fluidized Bed Combustor System

The process diagram for the wood fueled fluidized bed combustor system is shown in Figure 8. Fuel for the system, waste wood, is delivered to the plant by truck, unloaded by a hydraulic truck dumper and transported to and from outside storage by a front end loader. The wood enters the system through a drag chain conveyor which feeds a belt conveyor. A disc screen is again utilized to separate oversized pieces of wood, and a hammermill is used for size reduction. A belt conveyor transports the wood to a storage silo, and a drag chain or screw conveyor, is used to transport the wood from the storage silo to the fluidized bed combustor.

Specifications for the wood fueled fluidized bed combustor system are shown in Appendix A7. All equipment upstream of the storage silo is designed to fill the storage silo in one 8 hour shift. The storage silo which has the capacity for 3 days of boiler operation. The capacity of the drag chain conveyor between the storage silo and the fluidized bed combustor is equal to the combustor fuel consumption flow rate.

Wood Waste Gasifier with Gas Boiler System

The process diagram for this system is shown in Figure 9. The operation of this system combines the operations of the wood waste and gas boiler systems. The operation of the wood fuel handling equipment up to the gasifier is identical to the wood waste boiler system. The wood waste boiler is replace with a gasifier which supplies low Btu gas to a conventional gas boiler system. The gas boiler system has an oil back-up due to the possibility of a natural gas curtailment. The operation of the gas boiler system with oil backup is identical to the system described earlier except that there is a secondary source of gas supply from the gasifier.

The gasifier system can be readily retrofitted to a conventional gas boiler system. An additional burner must be installed in the boiler to burn the low Btu gas. It should be noted that wood gasification is not a proven technology and thus these installations should be considered as experimental installations.
Figure 8
PROCESS DIAGRAM
WOOD FUELED FLUIDIZED BED COMBUSTOR SYSTEM

WOOD DELIVERED BY TRUCK

FRONT END LOADER

TO AND FROM OUTSIDE STORAGE

TRUCK DUMPER

RAW WOOD DRAG CHAIN CONVEYOR

RAW WOOD BELT CONVEYOR

SIZED WOOD BELT CONVEYOR

HAMMERMILL

DISC SCREEN

Fines

REJECTS

STORAGE SILO

COMBUSTOR FEED DRAG CHAIN CONVEYOR

FLUIDIZED BED COMBUSTOR

STEAM SUPPLY

p.
Figure 9

PROCESS DIAGRAM
WOOD WASTE GASIFIER WITH GAS/OIL BOILER SYSTEM

WASTE WOOD DELIVERED BY TRUCK

FRONT END LOADER

TO AND FROM OUTSIDE STORAGE

TRUCK DUMPER

RAW WOOD DRAG CHAIN CONVEYOR

RAW WOOD BELT CONVEYOR

SIZED WOOD BELT CONVEYOR

HAMMERMILL

OVERSIZED

DISC SCREEN

UNDERSIZED

STORAGE SILO

GASIFIER FEED DRAG CHAIN CONVEYOR

GASIFIER

OIL TRANSFER PUMP

OUTSIDE OIL STORAGE

OIL DELIVERED BY TRUCK

NATURAL GAS FROM PIPELINE

OIL STORAGE DAY TANK

OIL FEED PUMP

BOILER

STEAM SUPPLY

-24-
Summary

Wood fuel systems like all solid fuel systems require more equipment for fuel handling than oil or gas systems. The complexity grows as the amount of automation designed into the system increases. A careful selection of equipment is required to meet the particular requirements of an installation, and to design an economically viable wood energy system.
ECONOMICS OF WOOD FUEL

by

M. C. Ehrhardt, Research Engineer

Presented at

WOOD ENERGY FINANCING
April 29, 1981
I. The Energy Crisis

Since 1973 the expression "energy crisis" has become a regular topic of conversation the American public. It is often used interchangeably with the phrase "energy shortage." This substitution is not correct. In a free market where prices are allowed to change, there cannot exist a true economic shortage. As the price of a good increases, producers want to supply more of the good and consumers demand less of the good. If the price falls, then producers will want to supply less and consumers will demand more. The price will eventually reach an equilibrium in which the quantity producers want to supply matches the quantity consumers demand. This is the basic law of supply and demand.

What happens when a producer, like OPEC, increases the price? Demand for the good decreases until the quantity demanded by consumers matches the quantity supplied by producers. There is no energy shortage, since supply matches demand.

Fuels were once cheap and plentiful. As a consequence, American industries surged forward, automobiles became a way of life, and homes were built with no thoughts of conservation. Now that fuels are sky-rocketing in price, the ways Americans do business and pursue their life styles are drastically changing. The negative impact of these changes on America is the "energy crisis."

OIL

The history of world oil production is one of politics as well as economics. It is important to understand this background in order to understand the current energy situation.

In 1948, a change occurred that would have a tremendous impact on future U.S. policies - for the first time the U.S. imported more oil than it exported. The economic implications of this would not be fully recognized for another 22 years.

The years 1948 to 1960 were the golden years for American oil consumers. Domestic production increased each year and prices stayed low, between $2.60 and $2.70 per barrel. When inflation is considered, the real
price of oil fell in this period. Another important aspect was the excess capacity of domestic oil producers; that is, they were pumping out oil at less than the maximum rate.

International oil markets were dominated by seven major oil companies. They did the exploration, built the oil fields, and produced oil for the underdeveloped host governments. They essentially set the prices that they paid those countries for the oil. Imported oil remained very inexpensive, at $2.17 per barrel. Even though it was less expensive than domestic oil, input quotas limited it to about 20% of total U.S. consumption.

The United States government was also actively involved in the world oil market. Between 1951 and 1954, the CIA, with the economic muscle of the seven major oil companies, helped overthrow the government of Iran and reinstated the Shah. This led to greater stability in Iran and placed a friendly power in control. Local resentment from this action would have far-reaching, although delayed, effects. Other consequences of this move were to allow the Iran government to become the proprietor of their oil fields and to let smaller independent producers into the picture. These steps would eventually weaken the power of the seven major oil producers.

In 1960 the major oil producers reduced the price on imported oil to $1.79 per barrel. They did not negotiate with the host governments, they simply cut the price. The host countries were outraged and formed OPEC, the Organization of Petroleum Exporting Countries. Since U.S. domestic oil production was still increasing and excess capacity was still available, OPEC had very little power.

In 1966 the flow of oil through the Suez canal was interrupted. The U.S. met this crisis by utilizing some of its excess capacity. This reduction in excess capacity and the declining growth rate of domestic production set the stage for drastic future changes in the international oil market.

In 1970 two major events occurred. U.S. domestic oil production peaked and has been declining ever since. The second event was an accident - a bulldozer broke a pipeline carrying oil from the Persian Gulf to the Mediterranean. Colonel Muammer-el-Qaddafi, Libya's dictator, demanded an increase in the price of oil it was selling to Occidental, an independent producer. Occidental, with no other source of oil, quickly agreed to the higher price.
U.S. CONSUMPTION OF OIL

Million B/D*


*Million Barrels/Day
DOMESTIC OIL PRICES (1967 $'s)
IMPORTED OIL PRICES

$/BARREL

IMPORTED OIL PRICES (1967 $'s)
In 1971 OPEC began to flex its muscle. The U.S. had no more excess capacity and agreed to a 50¢ increase per barrel. By 1973 OPEC oil had increased to $2.60 per barrel. When the U.S. supported Israel in the 1973 war, Saudi Arabia placed a 25% embargo on sales to the U.S. Realizing the insatiable U.S. demand for oil, OPEC was able to increase oil prices to about $11.00 per barrel by 1974.

Oil prices remained fairly stable until 1978. Production in Iran was curtailed due to internal instability. Instead of increasing supplies, OPEC let prices increase and has continued this policy for the last three years. Current prices are now over $32 per barrel.

What is the future of oil prices? OPEC will certainly restrict supplies and let prices increase. Given their lack of any other resources, it is only sensible for them to make oil last as long as possible.

Both economic and technical experts disagree about domestic production. Oil companies want to explore Federal lands for new supplies of oil and claim that this will greatly increase production. They also claim deregulation of oil prices will increase their exploration and allow them to recover sources of oil that were once uneconomical. Now technologies, such as shale oil recovery, might also increase production. The most likely scenario, however, is one in which oil production declines less rapidly and prices continue to increase.

GAS

Before WW II natural gas was considered as primarily a byproduct of oil production. The creation of a national high pressure pipeline made gas readily available to industrial, commercial, and residential users. Because it had a high energy content, burned cleanly, and was kept at artificially low prices it developed into the first choice of fuel.

The distribution system of natural gas is considered a natural monopoly, like telephone and electric power utilities. With the advent of a national pipeline it become very difficult for an individual state to regulate this industry. In 1938 Congress passed the Natural Gas Act, creating the Federal Power Commission. As an effort to protect consumers, the FPC was authorized to regulate interstate gas prices and ensure that these prices were "just and reasonable."
U.S. CONSUMPTION OF NATURAL GAS

*2 Trillion Cubic Feet of Gas/Year = 1 Million Barrels/Day Oil Equivalent

-37-
INTERSTATE NATURAL GAS PRICES

$\$1000 \text{ CU. FT.}$

Before 1960, the FPC did not aggressively control prices. As gas prices rose from 7.3 cents per thousand cubic feet to 14 cents in the 1950's, production also increased at a rapid rate. It is interesting to note that the price that producers charged to interstate pipeline users came very close to being deregulated in 1950. Both the House and Senate voted to deregulate this wellhead price and President Eisenhower was in favor of signing the bill. But Senator Francis Case, who also favored deregulation, revealed that a gas lobbyist, pushing for passage of the bill, left him an envelope containing twenty-five $100 bills. President Eisenhower reacted against this blatant attempt at bribery by refusing to sign the bill.

In 1961 the FPC began holding down the interstate price of gas. In the next ten years prices increased from 15.1 cents to only 17.1 cents. This was just a 13 percent increase, and was quite small when compared with the 100% increase during the 1950's. Not surprisingly, production began to slow, and eventually peaked in 1973.

The 1978 Natural Gas Policy Act placed both interstate and intrastate gas prices in the hands of the Federal Energy Regulatory Commission (the FPC became the FERC when the Department of Energy was created.) There is a trend towards deregulation, but it will probably be implemented through stages during the next several years. Proponents of this deregulation claim that the higher prices will stimulate greater exploration and production, but experts are not in agreement. The most likely future is one of increasing prices and shrinking supplies.

COAL

The situation with coal is one of good news and bad news. The good news is that the U.S. has enormous reserves of coal. The bad news is that there are enormous problems with using coal.

The first problem is the existing distribution system. About 74 percent of the coal used for energy is consumed large by electric utilities. Many of these utilities are served by "unit trains." These trains are specifically designed to carry only coal and provide a direct link between the consumer and the producer. In some cases entire railroad lines have been built exclusively for this purpose. This distribution system makes it extremely difficult for smaller users in some regions to obtain coal.
U.S. CONSUMPTION OF COAL

*Million Barrels/Day Oil Equivalent

-41-
COAL PRICES

$/TON

25
20
15
10
5


-42-
Another distribution problem is one of transportation costs. Even when a distribution system exists it is often necessary to move the coal over a great distance. Coal is heavy, so the transportation costs are often very high.

Coal mining is a dirty and often dangerous profession. Problems with occupational safety are still a barrier to immediate expansion of coal production. Correcting safety problems typically increases production costs.

There are also environmental problems associated with coal. The costs of reclaiming strip mining lands are reflected in higher coal prices, and there is still some doubt if these lands can ever be fully reclaimed. Coal can be burned and contribute very little pollution to the atmosphere. But in most cases very expensive pollution control equipment is required, which increase the cost of using coal.

Coal prices were once very stable and relatively low. But since 1968 prices have been climbing each year.

Coal can make an increasingly important contribution to the energy demand of the U.S., but it will certainly not be a return to the days of cheap and clean fuel.

**ELECTRICITY**

From 1949 until 1968 electricity was the biggest bargain available to the American consumer: Prices actually fell from 1.86 cents per kilowat hour to 1.54 cents. When inflation is considered, the real cost of electricity fell drastically in this period.

There were several factors that helped make electricity such a bargain. The primary fuels that were converted to electricity all had very stable and low prices. Several economically attractive hydroelectric facilities were constructed. As the demand for electricity increased it was possible to build ever larger generating plants. Economics of scale made it possible to gently increase generating efficiencies.

During the 1970's electric utilities have been subjected to dramatic increases in fuel costs. It also appears that maximum levels of generating efficiency have been reached. In fact, additional regulations for occupational safety and environmental protection have added to the cost of producing electricity.
U.S. CONSUMPTION OF ELECTRICITY

% Share

100
50
0

Million B/DOE*

20 20

15
10
5

COAL

NUCLEAR

GEOTHERMAL

HYDRO

OIL

GAS

20 15 10 5 0


*Million Barrels/Day Oil Equivalent
ELECTRICITY PRICES

<table>
<thead>
<tr>
<th>Year</th>
<th>Price (c/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>1.5</td>
</tr>
<tr>
<td>1960</td>
<td>2.2</td>
</tr>
<tr>
<td>1965</td>
<td>2.9</td>
</tr>
<tr>
<td>1970</td>
<td>3.6</td>
</tr>
<tr>
<td>1975</td>
<td>4.3</td>
</tr>
<tr>
<td>1980</td>
<td>5.0</td>
</tr>
</tbody>
</table>
ELECTRICITY PRICES (1967 $'s)
Nuclear power was once thought to be a promising source of electricity. This industry has been beset by four major problems. First, there is a finite supply of Uranium 235, the primary feedstock for nuclear reactions. It has been increasingly difficult to obtain this fuel. Second, construction costs and time have increased dramatically. Nuclear plants have by far the greatest capital costs. Third, there are serious reservations about the safety of a nuclear plant. Both legislators and citizens are very concerned about the potential for a major catastrophe. Fourth, there are tremendous problems with waste disposal. Nuclear plants create radioactive wastes, which are very difficult and expensive to handle. To date there has been no adequate solution to this problem.

Prices for electricity will probably continue to increase. There will certainly be no return to the days of cheap electricity.
REFERENCES


II. WOOD FUEL COST AND SUPPLY

The cost of wood fuels varies widely from inexpensive wood waste to dry densified wood pellets. Price is also dependent on type of wood (softwood, hardwood), moisture content, hauling distance, local supply and demand situation, and quantity purchased.

This section emphasizes the user's considerations of purchase price and availability. The data given spans present use, availability, and cost to future availability on a renewable basis. Due to the large and unpredictable effect of supply and cost of competing fossil fuels, particularly coal, little is done to project costs of wood fuels into the future. Instead, estimates are concerned with future wood availability.

WOOD SUPPLY

Georgia is blessed with a productive commercial forest industry, and a Forestry Commission dedicated to forest management. The average growth rate is 1 cord per acre per year, with 24,839,000 acres classified as commercial forestland (1). Although the cost of wood fuel is of paramount importance, the supply of wood, particularly on a local level, must be proven in order to install a wood fired facility and insure a long term supply of wood at a reasonable cost. Table 1 gives an overview of wood production in Georgia, as well as an estimate of the amount of wood which may be available for use as an industrial fuel. A more complex breakdown by type of wood and region is included in the Appendix.

The use of wood as an industrial fuel in nonforest products industries is a recent development. Estimation methods of the wood available for fuel on a renewable basis are also in a developmental stage. The accuracy of assessing the wood available varies widely. Estimates of processing waste (mill residue) from sawmills and other forest products operations are highly accurate, while those of the wood which might be reclaimed from in-forest harvesting waste and cull (rough and rotten) trees are less dependable. One generally accepted method for estimating the potential wood fuel available breaks down the timber resource by categories and then multiplies these categories by the percent which may be economically recovered. The percent recoverable for fuel wood varies from 10% for in-forest resources to 50% for processing wastes concentrated at mill sites.
Table 1
Timber and Wood Residue Volumes for Georgia

<table>
<thead>
<tr>
<th>Georgia's Wood Supply*</th>
<th>Millions of Cords</th>
<th>Millions of Green Tons/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Annual Growth</td>
<td>24</td>
<td>64</td>
</tr>
<tr>
<td>Total Annual Tree Removal</td>
<td>14</td>
<td>38</td>
</tr>
<tr>
<td>Total Annual Excess Growth</td>
<td>10</td>
<td>27</td>
</tr>
</tbody>
</table>

Wood Available for Industrial Fuel

<table>
<thead>
<tr>
<th></th>
<th>Millions of Cords</th>
<th>Millions of Green Tons/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-forest logging residue</td>
<td>4.4</td>
<td>11.7</td>
</tr>
<tr>
<td>Wood processing mill residue</td>
<td>3.4</td>
<td>9.2</td>
</tr>
<tr>
<td>Annual excess growth</td>
<td>10.0</td>
<td>26.8</td>
</tr>
<tr>
<td>Cull timber</td>
<td>36.0</td>
<td>96.5</td>
</tr>
</tbody>
</table>

|                      | 53.8             | 144.2                       |

Estimate of Industrial Wood Fuel Available on a Renewable Basis

<table>
<thead>
<tr>
<th></th>
<th>Millions of Cords</th>
<th>Millions of Green Tons/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% of in-forest waste</td>
<td>0.48</td>
<td>1.17</td>
</tr>
<tr>
<td>50% of processing wastes</td>
<td>1.72</td>
<td>4.60</td>
</tr>
<tr>
<td>25% of excess growth</td>
<td>2.50</td>
<td>6.69</td>
</tr>
<tr>
<td>10% of cull trees</td>
<td>3.60</td>
<td>9.63</td>
</tr>
</tbody>
</table>

|                           | 8.3               | 22.1                        |

*(1975 Database) Reference 1

These figures do not include use of the large amount of standing wood which measures less than 5" diameter at breast height (dbh). Although harvesting of this material would raise the estimate of wood available for fuel, these small trees are part of growing stands and can be harvested only when the stand is cleared, i.e., every 25 to 30 years for softwood, and 50 to 60 years for hardwood (2). This small diameter, but high yield per acre material would be left as logging residue, but is not now included in logging residues estimates. Much of this material could be chipped in the field if the tops, limbs, and branches are harvested for fuelwood. This amount may be increased if these small trees are harvested during the thinning, and pulpwood harvesting on pine stands before sawtimber is harvested and the land cleared and replanted. To be viable this would require new machinery and harvesting methods.

Due to the uncertainty of its collection, it is difficult to estimate the availability of less than 5" dbh trees for use as an industrial fuel. Assuming
these small trees can be harvested when the mature stand is clearcut and replanted, and that 10% of the material will be reclaimed for fuel, an additional 493,000 green tons per year will be available for fuel. This would make a total of 22.6 million tons available per year, a 2.3% increase. A more detailed breakdown of this estimate is found in Appendix B.

Other recent estimates of wood availability for industrial fuel lie in the same range. The following table summarizes these estimates:

Table 2
Estimates of Annual Availability of Wood for Industrial Fuel

<table>
<thead>
<tr>
<th>Source</th>
<th>Reference</th>
<th>Trillion Btu's/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia Forestry Comm.</td>
<td>1</td>
<td>188</td>
</tr>
<tr>
<td>GFC, plus 2&quot; to 4&quot; trees,</td>
<td>Appendix B</td>
<td>192</td>
</tr>
<tr>
<td>Georgia Tech (1976)</td>
<td>3</td>
<td>132-169</td>
</tr>
<tr>
<td>Georgia Tech (2000)</td>
<td>3</td>
<td>183-245</td>
</tr>
<tr>
<td>Average of above</td>
<td></td>
<td>186</td>
</tr>
</tbody>
</table>

UNPROCESSED WOOD COST

Currently the predominant industrial wood fuels are mill residue and whole tree chips. A future potential is wood fuel from "energy plantations." Price and availability considerations of these fuels are considered below.

Mill Residue

The cheapest fuel wood for industrial use is wood residue available from sawmills and other forest products operations. This material varies in size from sawdust through chips and may include boards, blocks, and slabs. It is often largely composed of bark. Its non-uniform nature and high (50%) moisture content make handling, storage, and burning of this fuel costly and difficult. Its low price, however, (currently $4 to $10 ton, delivered) makes it an attractive fuel for large industrial users which require more than 100,000 lbs of steam per hour. This minimum size limitation is somewhat arbitrary, since having a supply of low cost mill residue close by would make feasible its use in boilers in the range of 20,000 lb/hr capacity. While this mill residue is widely available throughout
Georgia, only 8% is not used, and 35% is currently burned as boiler fuel (1). The remaining mill residue is consumed in making fiber products (42%) and miscellaneous (15%). The use of wood as an industrial fuel is almost entirely confined to generating steam in large boilers at pulpmills, with small amounts used as boiler fuel on site at furniture operations, sawmills, etc. It is worth noting that if only the 8% of wood residue which is presently unused (0.74 million tons per year) were to supply fuel for boilers, it would have an appreciable economic impact. It could supply fuel for 35 boilers of 20,000 lb per hour steam capacity (calculation shown in Appendix B).

One large industrial user may tie up the majority of mill waste available in a given locality, hence long term supplies are in question, and prices may rise to compete with whole tree chips, which are discussed below.

In summary, while mill residue is an inexpensive boiler fuel, the supply is dwindling rapidly as wood fired boiler plants go on line. Future plants should be designed to burn wood chips should residue prove unavailable or too costly.

Availability of mill residue in Georgia is 10,300,000 tons per year (1977 estimate), with 85% in South and 16% in North Georgia (1). North Georgia lags in production of wood and, therefore, wood waste due to undesirable species of trees and the higher cost associated with logging operations in mountainous terrain instead of the more level land found in South Georgia. The figure of 10.3 million tons per year includes small amounts of dry mill waste (approximately 13% moisture content) such as planer shavings and dry sawdust.

Table 3 shows cost and availability data collected for mill waste (sawdust and bark) within a thirty-mile radius of Atlanta, Georgia. The extremes are $4 to $10 per ton of mill residue, delivered, with averages of $6 to $7 per ton of residue, delivered within 100 miles.

Whole Tree Chips

Industrial users classify whole tree chips as clean or dirty, indicating respectively, those free of bark and dirt or those containing either or both. A quality grade of clean chips is also called pulp chips and is normally used to produce paper at pulp mills. Clean pine tree chips are the most costly type, typically selling at $17/ton, clean hardwood chips sell for $14/ton, dirty pine chips for $11, and dirty hardwood chips for $10. Chipping may be done in the forest or at a mill site from round wood logs.
TABLE 3
Cost & Availability of Mill Residue (Sawdust & Bark)
Metro Atlanta Area

<table>
<thead>
<tr>
<th>Questions Asked</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are wood chips sold</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Used as fuel</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Who is the major buyer</td>
<td>Pulp Mill (exclusively)</td>
<td>Anyone</td>
<td>Anyone</td>
<td>Anyone</td>
<td>Anyone</td>
<td>Anyone</td>
<td>---</td>
<td>Anyone</td>
</tr>
<tr>
<td>3. Amount produced per day</td>
<td>N/A</td>
<td>N/A</td>
<td>88 TPD</td>
<td>15-20 TPD</td>
<td>100 TPD</td>
<td>N/A</td>
<td>N/A</td>
<td>30 TPD</td>
</tr>
<tr>
<td>4. Wood Species</td>
<td>Hardwood &amp; Softwood</td>
<td>Hardwood &amp; Softwood</td>
<td>Hardwood only</td>
<td>Hardwood &amp; Softwood</td>
<td>Hardwood only</td>
<td>Softwood only</td>
<td>---</td>
<td>Softwood only</td>
</tr>
<tr>
<td>5. Price delivered and distance</td>
<td>$10/ton. within 100 mi.</td>
<td>$8/ton. within 100 miles</td>
<td>Residue available free if hauled away, no del. available</td>
<td>$4.25/ton within 20 miles</td>
<td>$8.50/ton within 30 miles</td>
<td>$4/ton within 30 miles</td>
<td>---</td>
<td>58/ton within 80 miles</td>
</tr>
<tr>
<td>6. Price less delivery</td>
<td>---</td>
<td>---</td>
<td>No charge</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7. Actual transportation cost</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>8. Is volume discount available</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data collected by Dee Bryson of EES, January 1980
Another source of chipped wood may be available in the future, namely logging operations which leave tops and limbs in the field to be burned before reforestation. It is expected that chipping crews will chip these wastes in the field for sale as "wood fuel chips" as the price rises and supply of mill residue tightens. The price of this type of fuel wood is unknown, but will probably be lower than that of dirty chips, but higher than that of mill residue.

Table 4 contains data on wood chip cost and availability within a 30-mile radius of Atlanta, Georgia. This spot check of eight sawmills yields an average price of $15.70 per ton for clean pine chips, $13.98 per ton for clean hardwood chips, and $10.84 per ton for dirty softwood chips and approximately $10.54 per ton for dirty hardwood chips containing bark; prices are per green ton, delivered. These are in general agreement with prices listed in Reference 4 of $16.70 and $13.50 per ton for clean softwood and hardwood chips, respectively, and $10 per ton for softwood or hardwood dirty chips in central Georgia. However, these reference prices are F.O.B. mill, and approximately $1.75 per ton would be added for each 25 miles of delivery.

Wood Fuel from Energy Plantations

Should the demand for industrial wood fuel skyrocket, or competing users outstrip local production, special tree farms might become economically feasible. These "tree farms" or "energy plantations" will use fast growing species, particularly those like sycamore which regenerate naturally from an existing stump. This system will have short crop rotations of 5 to 7 years, vs. 20 years for normal stands of pine. The energy plantation concept produces a high yield per acre, as much as 8 to 12 tons per acre per year, vs. 2 tons for normal stands (5). The land must be restricted to this concept for a long period of time, and the effects of short rotations on soil nutrient balance are as yet unknown. The concept may prove difficult to manage for large users, since 300 sq. miles of land is needed to supply a steam-electric plant in the range of 150 megawatt capacity. The cost of the wood fuel from this potential source is not established, but should be competitive with or somewhat below the price of clean chips.

PROCESSED WOOD COST AND AVAILABILITY

The two major processes used on wood to enhance its value as an industrial fuel are drying and densification. At the present time, no wood is being dried
### TABLE 4

Cost & Availability of Wood Chips

Metro Atlanta Area

<table>
<thead>
<tr>
<th>Questions Asked</th>
<th>Sawmill No. 1</th>
<th>Sawmill No. 2</th>
<th>Sawmill No. 3</th>
<th>Sawmill No. 4</th>
<th>Sawmill No. 5</th>
<th>Sawmill No. 6</th>
<th>Sawmill No. 7</th>
<th>Sawmill No. 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are wood chips sold?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3. Amount produced per day</td>
<td>60-65 TPD</td>
<td>35-40 TPD</td>
<td>100 TPD</td>
<td>42 TPD</td>
<td>90 TPD</td>
<td>60 TPD</td>
<td>50 TPD</td>
<td>50 TPD</td>
</tr>
<tr>
<td>4. Wood species</td>
<td>Hardwood &amp; Softwood</td>
<td>Hardwood &amp; Softwood</td>
<td>Hardwood only</td>
<td>Softwood only</td>
<td>Hardwood only</td>
<td>Softwood only</td>
<td>Softwood only</td>
<td>Softwood only</td>
</tr>
<tr>
<td>6. Price less delivery</td>
<td>$12.40 avg.</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7. Actual transportation cost</td>
<td>---</td>
<td>$0.06/ton per mile</td>
<td>---</td>
<td>$0.07/ton per mile</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>$0.07/ton per mile</td>
</tr>
<tr>
<td>8. Is volume discount available</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

* Dirty chips (mixed with sawdust & bark)

Data collected by Dee Bryson of EES, January 1980.
for sale as a wood fuel in Georgia. Dry waste is available, but only as a by-product of dry kiln furniture operations, usually as shavings, sawdust, and chips. These are frequently used in making fiberboard, particleboard, and for farm operations (such as animal litter). When used as an industrial fuel, it is burned with a suspension or cyclonic burner, much like pulverized coal. The moisture content is approximately 13%, and this dry material has 75% more heating value than wet residue at 50% m.c. Being a dry and fluffy material, its bulk density is low, 6 to 12 lbs/ft$^3$.

Densified wood is entering the market in states surrounding Georgia. There are wood pelletizing plants in Tennessee, North Carolina, and Alabama with a total plant capacity of about 500 tons per day. The feed material for these plants is waste wood. This wood is ground in hammermills, dried to approximately 15% moisture content, pelletized, cooled, and stored. The final product has approximately 10% moisture and has a higher heating value of 7,650 Btu/lb. The bulk density of the pellets is 35 lbs/ft$^3$, making handling and storage convenient and inexpensive.

The cost of wood pellets is not well established. Current prices average $40 per ton plus shipping. This yields an average cost per ton delivered (within 25 miles) of $42 per ton. As noted above, there are no mills operating in Georgia at this time; however, pellet mills in the surrounding states are interested in selling in Georgia, and if volume permitted, starting up wood pellet plants in the state.

SUMMARY

Georgia has a vast energy resource in its commercial forests. Present use for industrial fuel is more than 3 million green tons per year. Estimates of the renewable amount of wood available for fuel are approximately 185 trillion Btu's per year. A comparison of fuel cost in dollars per million Btu's is presented in Table 5.
### Table 5
Fuel Cost Comparison

<table>
<thead>
<tr>
<th></th>
<th>Cost, $ per ton</th>
<th>Cost, $ per million Btu's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet mill residue</td>
<td>7.00</td>
<td>0.82</td>
</tr>
<tr>
<td>Dry mill residue</td>
<td>7.00</td>
<td>0.47</td>
</tr>
<tr>
<td>Whole tree chips, dirty</td>
<td>10.50</td>
<td>1.24</td>
</tr>
<tr>
<td>Whole tree chips, clean</td>
<td>15.50</td>
<td>1.82</td>
</tr>
<tr>
<td>Wood pellets</td>
<td>42.00</td>
<td>2.75</td>
</tr>
<tr>
<td>Coal</td>
<td>35.00</td>
<td>1.46</td>
</tr>
<tr>
<td>No. 2 fuel oil</td>
<td>(at 85 cents per gal.)</td>
<td>6.07</td>
</tr>
<tr>
<td>No. 6 fuel oil</td>
<td>(at 65 cents per gal.)</td>
<td>4.33</td>
</tr>
<tr>
<td>Natural gas (Interruptible Supply)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small user</td>
<td>(30 cents per therm)</td>
<td>3.00</td>
</tr>
<tr>
<td>Large user</td>
<td>(28 cents per therm)</td>
<td>2.80</td>
</tr>
</tbody>
</table>

### REFERENCES

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2. Allen, Fred, private communication, January 22, 1980, Georgia Forestry Commission, Macon, Georgia

3. A Feasibility Study for Wood Energy Utilization in Georgia, Clifton, D.S., and Bulpitt, W.S., prepared by Georgia Tech for the Georgia Forestry Commission, funded by the Coastal Plains Regional Commission, Atlanta, Georgia, 1979

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5. USDA Forest Service, "Energy & Chemicals from Forests," Forest Products Laboratory, P.O. Box 5130, Madison, WI 53705
### III. CAPITAL REQUIREMENTS

Solid fuel combustion systems are generally more expensive than liquid or gas burning systems, and wood fueled combustion is no exception. In addition to a larger and more expensive boiler, there are material handling and preparation components that are not needed in oil or gas systems. Following are tables outlining costs for various systems. In Appendix A there are the equipment specifications from which the capital costs were derived.

#### SYSTEM COSTS

**WOOD WASTE BOILER SYSTEM**

<table>
<thead>
<tr>
<th>Capacity (lbs/hr)</th>
<th>10,000</th>
<th>25,000</th>
<th>50,000</th>
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<td><strong>Capital Costs</strong></td>
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<td></td>
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</tr>
<tr>
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<td><strong>WOOD PELLET BOILER SYSTEM</strong></td>
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-60-
# SYSTEM COSTS

**WOOD FUELED FLUIDIZED BED COMBUSTOR SYSTEM**

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### SYSTEM COSTS WOOD GASIFIER RETROFIT

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<td>120,000</td>
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<td>240,000</td>
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<tr>
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<td>57,000</td>
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<td>240,000</td>
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<td>58,000</td>
<td>60,000</td>
<td>61,000</td>
<td>74,000</td>
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<tr>
<td>Conveyor</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Disc Screen</td>
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<td>66,000</td>
<td>117,000</td>
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<td>163,000</td>
<td>172,000</td>
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<td>200,000</td>
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<td>Conveyor</td>
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### SYSTEM COSTS

**OIL BOILER SYSTEM**

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<td><strong>Capital Costs</strong></td>
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</tr>
<tr>
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<tr>
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<td>8,000</td>
</tr>
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### SYSTEM COSTS
#### GAS BOILER SYSTEM

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<td>74,000</td>
</tr>
<tr>
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<td>3,000</td>
<td>5,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Day Tank</td>
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### SYSTEM COSTS*
#### COAL BOILER SYSTEM

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<th>200,000</th>
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<tr>
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*Low sulfur coal, SO\(_2\) scrubbers not included in cost*
CAPITAL COST OF STEAM GENERATING SYSTEMS

TURNKEY INSTALLATIONS INCLUDING FUEL HANDLING

SYSTEM CAPACITY

1000 LBS/HR

WOOD CHIP & WASTE

WOOD PELLETS

WOOD WASTE FLUIDIZED BED

COAL

GASIFIED WOOD WASTE

GAS & OIL
IV. Life-Cycle Costing

Many potential projects have been analyzed using traditional financial yardsticks. Two widely used measures are simple payback and accounting rate of return on investment.

<table>
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<th>Simple Payback</th>
<th>First Years Return</th>
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<td>Payback = Initial Cost</td>
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<table>
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<th>Accounting Rate of Return</th>
<th>Annual Savings</th>
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<tbody>
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<td>= Initial Cost/2</td>
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</tbody>
</table>

Simple payback is inadequate because it does not consider returns after the initial payback period. Rate of return does not consider the timing of cashflows. Life cycle costing is an alternative that provides a better measure of project profitability.

In a lifecycle costing analysis the first step is to estimate cash flows for each year of the project life. Then it is necessary to compare the cash flowing for the two projects in question. This comparison will result in a series of cash flows that represent the effect of undertaking one project instead of the other. (It is possible for one project to be the status quo; that is, you can compare a project with the existing, or do-nothing, scenario.)

As an example, assume that a firm owns a piece of machinery, A. A has maintenance and fuel costs of $100 per year. A will last five more years and has no salvage. The firm has the option at replacing A with a newer piece of equipment, B. The installed cost of B is $75. B has maintenance and fuel costs at $50 per year; and will also last five years and will have no salvage value.
It is estimated that maintenance and fuel costs for both A and B will increase by 10% per year. Shown below over the cash flows for both alternatives.

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>-100</td>
<td>-100</td>
<td>-121</td>
<td>-133</td>
<td>-146</td>
</tr>
<tr>
<td>B</td>
<td>-125</td>
<td>-50</td>
<td>-55</td>
<td>-60.5</td>
<td>-66.5</td>
<td>-73</td>
</tr>
<tr>
<td>(B-A)</td>
<td>-125</td>
<td>+50</td>
<td>+55</td>
<td>+60.5</td>
<td>+66.5</td>
<td>+73</td>
</tr>
</tbody>
</table>

The next step in life-cycle costing is to consider the value of the cash flows. Suppose you have the option of receiving $100 today or $100 next year. You have only one investment opportunity, and that is a bank with a 10% interest payment. If you take the $100 today and invest it, you will have $110 next year \((100 \times (1.10) = 110)\). This is superior to $100 and demonstrates the time value of money - money received in the future is not as valuable as money received now.

Life-cycle decrease the value of future money by choosing an appropriate discount factor. This factor is the opportunity cost of your money; it is the rate your money could earn if invested somewhere else. This discount factor can be used to determine the value of future returns and compare them with the initial investment. For this example a discount factor of 20% was chosen. The present value of the future savings is:

\[
P_V = \frac{50}{(1.20)} + \frac{55}{(1.20)^2} + \frac{60.5}{(1.20)^3} + \frac{66.5}{(1.20)^4} + \frac{73}{(1.20)^5}
\]

\[
P_V = 176.3
\]

There was an initial cost of $150.00. Therefore, the net present value is:

\[
NP_V = 176.3 - 125
\]

\[
NP_V = 51.3
\]
Another way to evaluate this cash flow is through the internal rate of return (IROR). This is the discount factor that leads to a net present value of zero. For this example the IROR is 36%. If this number is above the rate of return you can achieve through other investment options, then this project is economically desirable.

There is no mystery to life-cycle costing. It simply involves looking at the cash flows over the entire length of a project and considering the timing at these cash flows. Using this simple method of evaluation can lend to higher profits for your firm.
WOOD ENERGY CONVERSION
AN ECONOMIC ANALYSIS

by

Arthur Andersen & Company
Mark R. Bell
Douglas Kirchhofer
Donald Lewis

Presented at
WOOD ENERGY FINANCING
April 29, 1981
WOOD ENERGY

I. Business Considerations

II. Economic Considerations

III. Tax Considerations

IV. Financial Statement Considerations
BUSINESS CONSIDERATIONS

I. The Mechanics of a Wood System

- The technology for environmentally acceptable wood fuel boiler systems is currently available.

- Technological assistance is available from:
  Engineering Experiment Station of The Georgia Institute of Technology; or Southern Solar Energy Center.

- Wood is not as efficient as natural gas or oil because it must be prepared for burning. This requires more manual and mechanical handling than natural gas or oil. The trade-off is the lower cost of wood.

- Wood storage and handling equipment require much more space than is required for a comparable natural gas or oil boiler system. Large stacks of chips can lead to excessive compression and, possibly, spontaneous combustion. The engineering solution is not to overstack wood chips.

- Wood does not burn completely; waste disposal must be considered.
BUSINESS CONSIDERATIONS

II. Cost Effectiveness of a Wood System

- A computerized economic model has been developed for the initial evaluation of wood as an alternative fuel. It is available from:

  Engineering Experiment Station of The Georgia Institute of Technology; or
  Southern Solar Energy Center.

- The initial investment in a wood system is much higher than a comparably-sized natural gas or oil system. This is more than offset by expected cost savings.

- The model allows a comparison of projected cost savings to the additional initial outlay to determine the amount of time between initial outlay and payback.

- If current trends in the price of natural gas and oil continue, the payback period can be very short (less than three years). Payback periods should be compared to alternative capital investments.
BUSINESS CONSIDERATIONS

III. Wood or Coal

- Costs of a comparably-sized wood and coal systems are similar.

- Efficiency, handling and waste problems are similar.

- Fuel costs of coal are more stable than natural gas or oil.

- Because coal is plentiful in this country, our government has written the tax laws to provide, essentially, the same tax incentives for wood and coal.

- The primary factors to evaluate between wood or coal include:
  - Which is more available to your plant now?
  - What do you believe/project about future availability?
  - What are current costs of wood vs. coal for your plant?
  - What do you believe/project about future cost increases?
  - How easily can a system be converted from wood to coal or vice versa?
IV. Planning for the Future

- How long do you believe that natural gas or oil will be available, in the quantities you need?

- Given the history of price increases, will natural gas or oil be affordable over the 20-30 year life of the boiler system?
V. The Environment

- Wood or coal systems require pollution control equipment for particulate emissions.

- The engineering for the pollution control equipment is currently available.

- Tax incentives, including rapid amortization and tax credits, are available for the pollution control equipment.

- The amount of equipment required is based on local regulations.
ECONOMIC CONSIDERATIONS

I. Cash Flow

- The initial cost of a wood fired boiler system is much higher than an oil or gas system due to the required wood handling equipment.

- The higher initial cost is partially offset by Federal and, in some instances, state tax credits that may be available to finance a portion of the system cost.

- Wood and coal systems generally qualify for Federal investment credit (10%) and business energy credit (10%).

- Borrowing or leasing will reduce the initial cash outlay and shorten the payback period.

- The economic model allows a comparison of various alternatives.
ECONOMIC CONSIDERATIONS

II. Considerations for the Present

- Tax incentives help cash flow.

- Financing costs in April 1981 are very high.

- The Company's ability to finance other capital needs may be impaired by significant borrowing to finance a wood or coal system.
III. The Future

- Oil and gas costs are increasing

- Average retail cost -- No. 6 fuel oil (per barrel)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>$11.49</td>
</tr>
<tr>
<td>1977</td>
<td>13.23</td>
</tr>
<tr>
<td>1978</td>
<td>12.75</td>
</tr>
<tr>
<td>1979</td>
<td>18.67</td>
</tr>
<tr>
<td>1980</td>
<td>25.03</td>
</tr>
</tbody>
</table>

- Compound five-year rate of increase -- 23%

- Current average retail -- $35.20
IV. Will Past Trends Continue

- Planning for the future is a management responsibility.

- The economic model allows the input of various assumptions related to:
  
  - Equipment cost
  - How much can be borrowed
  - Projected rates of increase in oil or gas costs
  - Projected rates of increase in wood costs
  - Projected rates of increase in labor costs for operating and maintenance
  - Varying depreciation lives and methods
  - Interest rates
  - Federal and state tax rates
  - Availability of Federal and state tax credits

- Savings will be significant if past trends continue.
V. Converting Existing Capacity

- The evaluation process is similar if the decision is to convert an existing oil or gas system to wood.

- Current costs must be balanced against future savings.

- The principal differences are that cash outlays could be deferred and scrap/salvage values must be considered.
I. Tax Incentives for Wood or Coal

- Our government has provided incentives to use plentiful resources: wood and coal.

- Investment credit, computed as 10% of qualifying assets, reduces taxes payable.

- Business energy tax credit, computed as an additional 10% of qualifying assets, further reduces taxes payable.

- The effect on cash flow is that the credits reduce the cash outlay for the system without reducing the depreciable cost. The full cost (before credits) is depreciated for tax purposes.
II. Tax Credits for Gas or Oil Systems

- Generally, none.

- Investment credit is not available unless coal is prohibited by law.

- Business energy credit is not available.
TAX CONSIDERATIONS

III. Depreciation Method

- The actual expected useful life of the equipment is similar to gas or oil.

- The most favorable depreciable life for tax purposes is a decision that can only be made based on your specific business and tax situation.

- Various alternatives are available:
  
  - System components may be depreciated over varying lives
  - Rapid amortization (60 months) is available for pollution control equipment
  - Accelerated methods (declining balance and sum-of-years digits) improve cash flow

- The economic model is flexible to allow different depreciation methods and lives to be computed.
IV. The Reagan Proposals

- Would allow depreciation of equipment over five years, regardless of actual economic life.

- The five-year life rule would be phased-in over five years -- from a nine-year guideline the first year, eight the second, etc.

- Full tax credits would be available using the five-year life compared to a minimum seven-year life to get full credits under current regulations.
V. What Qualifies for Credits?

- New equipment qualifies; only $100,000 of used equipment in any year can qualify.

- Federal tax credits are based on the eligibility of system components, as follows:

<table>
<thead>
<tr>
<th>Components (1)</th>
<th>Regular ITC</th>
<th>Business Energy Tax Credit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler, stack handling equipment</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pollution control equipment</td>
<td>Yes (3)</td>
<td>Yes</td>
</tr>
<tr>
<td>Wood fuel storage facilities</td>
<td>Yes</td>
<td>No (4)</td>
</tr>
</tbody>
</table>

(1) If the useful life assigned to any component is less than seven years, reduction in regular ITC and energy credit will result.

(2) Credit percentage is reduced from 10% to 5% if financed by Industrial Revenue Bond (IRB) or "subsidized energy financing". After 1982, credit percentage is reduced pro rata from 10% by ratio of IRB or subsidized energy financing to total qualified investment.

(3) Credit percentage is 5% rather than 10% if:
   a. Financed by IRB and
   b. Election made to amortize over 60-month period.

(4) If the wood fuel storage facility were self-contained unit capable of being moved such that it could be treated as a piece of equipment, energy credit would be available.
V. What Qualifies for Credits?

- Credits are subject to limits, based on taxable income.

- Credits may be lost if the equipment is sold or retired before the minimum credit period (3, 5 or 7 years) expires.
TAX CONSIDERATIONS

VI. The Theory of Credits

- Credits are a direct reduction of taxes payable. If no taxes are payable before credits, they may be carried back to reduce taxes previously paid or carried forward to reduce future taxes payable.

- Credits can be transferred if equipment is leased. Credits may be used by the owner of the equipment (lessor) or the user (lessee).

- There are limits on the amounts of ITC used in any year:

<table>
<thead>
<tr>
<th>Year</th>
<th>Tax Liability</th>
<th>Difference</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>($25,000)</td>
<td>Difference</td>
<td>$25,000 + Difference x 70%</td>
</tr>
<tr>
<td>1981</td>
<td>$25,000</td>
<td>Difference</td>
<td>$25,000 + Difference x 80%</td>
</tr>
<tr>
<td>1982 on</td>
<td>$25,000</td>
<td>Difference</td>
<td>$25,000 + Difference x 90%</td>
</tr>
</tbody>
</table>

- Business energy credits are limited to the remaining tax liability after ITC.

- Credits can be carried back, if taxes were paid and maximum credits were not used, for three years. This would result in recovery of taxes previously paid.

- Credits can be carried forward seven years to offset taxes payable in the future.
VII. Credit Regulations are Complex

- Financing can affect credit amount
  - industrial revenue
  - subsidized energy financing

- Useful life must be seven years or more to get maximum credit

- Recapture applies to early retirements
FINANCIAL STATEMENT CONSIDERATIONS

I. The Balance Sheet

- Capital spending normally reduces working capital by reducing cash.

- The current portion of long-term debt will also reduce working capital if equipment is financed.

- Future working capital is improved by cash savings.
FINANCIAL STATEMENT CONSIDERATIONS

II. The Income Statement

- Credits, which are available at the installation date, reduce the tax provision and increase income.

- The cost savings should exceed the additional depreciation of a more expensive system. Accordingly, expected savings, net of tax, improve net income.
I. Use of the Model

- The economic model is available, free of charge, to evaluate your situation.

- The economic model is flexible enough to allow your estimates to be used.

- The final decision rests with management, but the economic model is a useful tool to evaluate the key financial factors.
COMPUTER AIDED ECONOMIC ANALYSIS

by

M. C. Ehrhardt, Georgia Tech
D. Gustashaw, Southern Solar Energy Center

Presented at
WOOD ENERGY FINANCING
April 29, 1981
The first step in a financial analysis of a proposed wood energy system is to generate annual after tax cash flows that are a result of the project. The economic assessment, whether it is payback, net present value, or rate of return, is based upon the calculated cash flows.

There are several advantages of a computer aided analysis. Generating cash flows for a 20 year period by hand is very tedious. Calculating the internal rate of return by hand is also time-consuming and will usually require several iterations. These operations can be performed very quickly using the computer.

Sensitivity analysis is the systematic variation of any assumptions that will have an effect on the profitability of the proposed project. Because it calculates very rapidly, a computer is ideally suited to perform sensitivity analysis. This allows the user a chance to examine the project under different sets of conditions.

On the following page is a description of WOOD 4, a computer program developed by Georgia Tech and the Southern Solar Energy Center. This program is based upon work originally done by the New England Regional Commission. Arthur Andersen & Co. provided consultation on this project.
The Wood 4 computer program is a fast, versatile tool for determining the financial feasibility of a wood energy system. The program financially compares a wood energy system to any energy system fired with a conventional fuel, i.e., oil, gas or coal. This comparison can be made for the replacement of an existing system or between two proposed systems.

In either case, a required set of input is needed. It is convenient to think of these data in five groups:

- Analysis selection
- Boiler operating specifications
- Fuel data
- Financial parameters
- Optional input

The following describes the required user inputs. It is very important to enter the information in the units specified.

**Analysis Selection**

Select fuel comparison -- This allows the user to select one of three fuel comparisons, oil vs. wood, gas vs. wood or coal vs. wood. Once this selection is made, the program automatically adjusts for system federal tax credit eligibility.

Type of analysis -- This allows the user to choose one of two analyses: Replace Existing System or Compare Two Proposed Systems. When Replace Existing System is selected, the assumption is made that the existing system has either zero value or will be used for back-up purposes. When Comparing Two Proposed Systems, the assumption is made that the comparison will be made on two brand new, un-installed systems.

**Boiler Operating Specifications**

Size of boiler in pounds of steam per hour (unit: pounds of steam per hour) -- This is the rated size or capacity of the boiler. If boiler horsepower is known, this can be converted to pounds of steam per hour (pph) by multiplying the horsepower rating by 34.5. Thus, a 500 horsepower boiler has a capacity of 17,250 pph. If the BTU rating of the boiler is known, the capacity in pph can be estimated by dividing by 1000. For example, a 20 million BTU per hour boiler is a 20,000 pph boiler.

Number of hours of operation per year (unit: hours) -- This is the number of hours for which the boiler operates each year, and can be obtained from records or estimated. For example, if a boiler is operated two shifts per day, five days a week, 52 weeks per year, the number of hours of operation per year would be $2 \times 8 \times 5 \times 52 = 4160$.

Average utilization (unit: percent) -- Average utilization is the annual average percent of boiler capacity used. If a boiler has a rated capacity of 20,000 pounds of steam per hour but is operated at an average of 18,000 pounds per hour, the average utilization would be $18,000/20,000 = 0.9$ or $90\%$. 

-96-
Boiler efficiency (unit: percent) -- Boiler combustion efficiency depends upon boiler design, condition and operation. If the efficiency of a boiler is not known, the following is a list of efficiencies for well maintained and properly operated boilers.

- oil - 80%
- gas - 78%
- coal - 82%

Wood fuel combustion efficiency is a function of fuel moisture content in addition to the factors mentioned above. Efficiency is usually in the range of 50 to 78 percent.

Number of BTUs per pound of steam (unit: BTU) -- The amount of energy contained in a pound of steam varies with different boiler systems. In most low pressure applications such as space heating or dry kiln operation, it can be assumed that there are 1000 BTUs per pound of steam. This is appropriate up to about 55 psig pressure.

Annual operation and maintenance costs (unit: dollars) -- For an existing system, this value can be estimated from records. If the analysis is being conducted for a proposed rather than existing system, some manufacturers suggest that annual operation and maintenance (O&M) expenses can be assumed to be 5 percent of the system capital costs for an oil or gas system.

The O&M costs for a wood or coal fired system will be considerably greater than those for a similarly sized oil or gas system. It is roughly estimated that annual wood or coal system O&M costs are equal to about 10 percent of the system capital costs. Since the capital costs of a wood or coal system are also greater, these system O&M costs can be several times higher than an equivalent oil or gas system.

The program uses the boiler operating parameters to calculate the amount of energy required to meet demand. This is then combined with the comparison fuel and wood fuel data to arrive at the quantity and cost of both fuels. Unless the user has a specific reason for doing otherwise, it is very important to assume that the same amount of energy is demanded from the wood system as well as from the comparison system. Otherwise the fuel consumption and cost calculations, hence the financial analysis, may be misleading. This may create problems when the wood boiler under consideration is not exactly the same size as the comparison system. Usually it is simpler to assume that the two boilers will be of the same size and same average utilization. This assumption will produce accurate output figures.

Fuel Data

If a fuel oil comparison is made:

Type of oil (unit: numerical oil type, e.g., 2, 4, or 6) -- Type of oil refers to the grade of fuel oil used. The model assumes that light distillate (no. 2 oil) has 139,000 BTU per gallon; heavy distillate (no. 4 oil) has 145,500 BTU per gallon; and residual (no. 6 oil) has 150,000 BTU per gallon.
Dollars per gallon of oil (unit: dollars) -- This is the current delivered price per gallon of oil. Note that it is expressed in dollars per gallon not cents, so a decimal point must be used. If price is available only in dollars per barrel delivered, divide by 42. For example, oil at $20.00 a barrel = 20/42 = 0.476 dollars per gallon.

If a gas comparison is made:

Energy content of gas (unit: BTU per cubic foot) -- The higher heating value (HHV) of natural gas ranges from 900 BTU per cubic foot to over 1,300 BTU per cubic foot. If the HHV of natural gas is not known, a typical value for input would be 1,000 BTU per cubic foot.

Price per therm of gas (unit: dollars) -- This is the current price of gas. Note that it is expressed in dollars, so a decimal point must be used.

If a coal comparison is made:

Energy content of coal (unit: BTU per ton) -- The higher heating value (HHV) of coal ranges from 7,000 BTU per pound to over 14,000 BTU per pound (Bed Moisture Basis). If the HHV of coal is not known, a typical value for coal HHV would be 12,000 BTU per pound. In order to get this into the correct units, multiply by 2,000.

\[ 12,000 \times 2,000 = 24,000,000 \text{ BTU per ton}. \]

Price per ton of coal (unit: dollars) -- This is the current delivered price of coal.

Dollars per ton of wood (unit: dollars) -- The cost of wood fuel per delivered ton is entered here. Since the model accounts for moisture content, it is not necessary to express this as a cost per oven dry ton.

Oven dry energy content of wood fuel in million of BTU per ton (unit: million of BTU) -- The amount of energy in an oven dry ton of wood varies only slightly depending upon species, the part of the tree used and other factors. However, the model allows different values to be entered. An average energy content which is usually used is 16 million BTUs per dry ton (equivalent to 8,000 BTU per dry pound). If resinous softwoods are used extensively the energy content will be slightly higher, about 18 million BTUs per dry ton.

Wet basis moisture content of the wood fuel (unit: percent) -- Fuel moisture content is an extremely important variable and depends upon the source of wood, storage conditions and other factors. There are two methods of measuring moisture content: wet basis measure and dry basis which is normally used by the forest products industry. The wet basis measure is used here. Green wood usually has a wet basis moisture content of about 50 percent.
Financial Parameters

Inflation rates (unit: percent) -- The model allows for four different inflation rates: one for operation and maintenance expenses, one for the price of conventional fuels, one for the price of wood and one for the cogeneration of electricity. Experimenting with inflation rates allows the user to determine the effect of different price increases on the economics of conversion.

Tax rates (unit: percent) -- Since cost savings increase profits, state and federal taxes have been incorporated into the modeling. The tax rates entered here are not graduated; moreover, users should normally input the incremental tax rate rather than the average tax rate. State taxes are subtracted from taxable savings before federal taxes are calculated.

Tax credits (unit: percent) -- The model assumes utilization of the maximum available Federal tax credits. Because credits are earned for tax purposes when the equipment is placed in service, the model assumes credits are used at the completion of construction. Your company's taxable income and other property additions may affect the amount of credit you are able to use.

Federal tax credits are based on the eligibility of system components, as follows:

<table>
<thead>
<tr>
<th>Components (1)</th>
<th>Regular ITC</th>
<th>Business Energy Tax Credit (2)</th>
</tr>
</thead>
<tbody>
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<td>Yes</td>
</tr>
<tr>
<td>Pollution control equipment</td>
<td>Yes (3)</td>
<td>Yes</td>
</tr>
<tr>
<td>Wood fuel storage facilities</td>
<td>Yes</td>
<td>No (4)</td>
</tr>
</tbody>
</table>

(1) If the useful life assigned to any component is less than 7 years, reduction in regular ITC and energy credit will result.

(2) Credit percentage is reduced from 10% to 5% if financed by Industrial Revenue Bonds (IRB) or "subsidized energy financing." After 1982, credit percentage is reduced pro rate from 10% by ratio of IRB or subsidized energy financing to total qualified investment.

(3) Credit percentage is 5% rather than 10% if:
   a. Financed by IRB and
   b. Election made to amortize over 60-month period.

(4) If the wood fuel storage facility were a self-contained unit capable of being moved such that it could be treated as a piece of equipment, energy credit would be available.
State tax credits may also be available. Your tax advisor should be consulted to determine the maximum available credits.

Depreciation period (unit: years) -- Since the model calculates depreciation for tax purposes, it is necessary to enter a depreciation period. According to the IRS in most cases the allowable depreciation period is 20 years. If a firm can show that the equipment is not expected to last 20 years, a shorter period may be used. The model allows only one depreciation period for all new equipment.

Depreciation method -- The model allows the user to specify straight line, sum of years digits or double declining balance depreciation. Moreover, the user may change depreciation method at any time the opportunity to change input values arises. If an accelerated depreciation method is chosen, the program will automatically change to straight line depreciation at the most economically attractive time.

Loan period and interest rate (unit: years and percent, respectively) -- The model allows the user to use an appropriate loan period and interest rate. By using various loan terms on successive runs, the user can see the effect of financing options. The model assumes that installed cost minus equity equals the amount financed.

Tax exempt industrial revenue or subsidized energy financing may be available to your company. Industrial revenue bond interest is deductible to the company but is exempt from federal (and in some cases, state) income taxes. Consequently, the rates are normally lower than those otherwise available. A portion of the investment tax credit and business energy credit may be lost if industrial revenue or subsidized energy financing is used. Your tax advisor should be consulted to determine the tax effects of alternative financing sources.

Amount of equity (unit: dollars) -- In most cases a firm will be planning to invest some of its own money, as well as borrowed money, in the conversion. Equity, the firm's own share, is subtracted from the installed cost to determine the amount borrowed. This value is usually 20 to 25% of the installed cost of the system.

Installed cost of wood system (unit: dollars) -- The cost of the wood system equipment is one of the most important variables. The cost entered here would be the cost of the whole system: fuel storage and handling equipment, boiler, and necessary air pollution control devices. In other words, the total capital investment required for conversion to wood.

Operating life (unit: years) -- Equipment operating life is difficult to determine, but conventional boiler equipment can be expected to last at least 20 years with proper maintenance.

Discount rate (unit: percent) -- Discount rate is used to determine net present value. It accounts for the fact that a dollar saved (or spent) today is worth more than a dollar saved (or spent) at some future time, since the value of money accumulates over time.
Generated electricity (unit: dollars) -- This value is the amount of electricity produced in year 1. The amount of electricity produced is held constant for the entire life of the analysis. The model allows the user to account for any inflationary trend in the cost of electricity through the use of an inflation rate.

Cost of storage facilities (unit: dollars) -- Because the storage facilities are not eligible for the federal business energy tax credit, this value must be input separately. This value will reflect any costs associated with covered or outside storage.

Optional Input

The Wood 4 program can calculate the cost of a wood energy system if this value is not known. The following is a list of questions that must be answered for the calculation to be completed.

1. Days of open storage (unit: days)
2. Height of open storage (unit: feet)
3. Days of covered storage (unit: days)
4. Type of wood waste or other
5. Disc screen rate (unit: tons per hour)
6. Hammermill rate (unit: tons per hour)
7. Raw wood conveyor length (unit: feet)
8. Prepared wood conveyor length (unit: feet)
9. Boiler feed conveyor length (unit: feet)

The computer will give suggested values for these inputs but allows the user to input whatever value is needed.

Engineering and Accounting Assumptions

The following are assumptions and calculation procedures made when using the economic model.

Fuel Consumption and Cost

If an oil comparison is being made,

Annual oil consumption = (lbs. of steam per hr. x annual operating hrs. x average utilization x Btu per lb. of steam)/(Btu per gallon of oil x boiler efficiency)

Annual cost = annual oil consumption x price per gallon oil

If a gas comparison is being made,

Annual gas consumption = (lbs. of steam per hr. x annual operating hrs. x average utilization x Btu per lb. of steam)/(Btu per cubic foot of gas x boiler efficiency)
Annual cost = (price per therm of gas x annual gas consumption x Btu per cubic foot of gas)/100,000

If a coal comparison is being made,

Annual coal consumption = (lbs. of steam per hr. x annual operating hrs. x average utilization x Btu per lb. of steam)/(Btu per ton of coal x boiler efficiency)

Annual cost = annual coal consumption x price per ton of coal

Annual wood consumption = (lbs. of steam per hour x annual operating hrs. x average utilization x Btu per lb. of steam)/(dry wood energy content per ton x (1 - wood moisture content) x boiler efficiency)

Annual cost = annual wood consumption x price per ton of wood

Note: Annual fuel costs and value of electricity generated are adjusted by the respective inflation rates each year.

Financial Analysis (Cash Flow Table)

Fuel savings = conventional fuel costs - wood costs + value of electricity generated

Additional operating and maintenance costs = wood O&M - conventional fuel O&M

Note: O&M costs are adjusted by the O&M inflation rate each year.

Depreciation: Either straight line, sum of years digits or double declining balance depreciation can be selected. The model assumes zero salvage value.

Straight line = capital cost/depreciation period

Sum of years digits = [(operating life - previous number of depreciating years) x capital cost]/sum of years digits

Double declining balance = [(capital cost - previously claimed depreciation) x 2]/depreciation period

Loan repayment (principal) and interest: The model assumes uniform monthly payments.

Capital recovery factor = (loan interest rate/12) x [1 + (loan interest rate/12)]loan period x 12/[1 + (loan interest rate/12)]loan period x 12 - 1
Uniform monthly principal and interest = C.R.F. x loan proceeds

Monthly interest = (loan interest rate/12) x (loan proceeds - sum of the previously paid principal)

Monthly principal = uniform monthly principal and interest - monthly interest

Pretax income = fuel savings - additional O&M - depreciation - interest

Federal tax = federal tax rate x (pretax income - state tax)

State tax = state tax rate x pretax income

Tax credits:

Federal ITC = .10(Capital Costs)
Federal business energy credit = .10(Capital Costs - Cost of Storage)
State tax credit = .15(Capital Costs - Cost of Storage)

Net earnings after tax = pretax income - federal tax - state tax

Net cash flow: Installation year = -equipment cost + loan proceeds + tax credits

All other years = net earnings after tax + depreciation - loan repayment

Economic Values

Cash payback period of initial investment - The amount of time required to payback the net cash flow in the installation year.

Payback of total investment - The amount of time required for the cumulative cash flow to recover initial investment plus remaining loan balance.

Net present value - Sum of the discounted cash flows.

Internal rate of return - The discount rate at which the net present value = 0
THIS WOOD CONVERSION ECONOMIC MODEL WAS DEVELOPED AS A JOINT PROJECT BY THE ENGINEERING EXPERIMENT STATION OF GEORGIA TECH AND THE SOUTHERN SOLAR ENERGY CENTER, BASED UPON PREVIOUS WORK OF THE NEW ENGLAND REGIONAL COMMISSION.

SELECT FUEL COMPARISON: OIL VS. WOOD = 1, GAS VS. WOOD = 2, COAL VS. WOOD = 3

METHOD OF DATA INPUT: OLD = 1, NEW = 2, STANDARD = 3

TYPE OF ANALYSIS: REPLACE EXISTING SYSTEM = 1, COMPARE TWO PROPOSED SYSTEMS = 2

DO YOU WISH THE PROGRAM TO CALCULATE THE CAPITAL COSTS OF A WOOD SYSTEM? YES = 1, NO = 2

INPUT DATA:

LBS STEAM PER HOUR (OIL) ? 40000
LBS STEAM PER HOUR (WOOD) ? 40000
ANNUAL OPTG HRS (OIL) ? 6000
ANNUAL OPTG HRS (WOOD) ? 6000
AVERAGE UTIL (%) (OIL) ? 75
AVERAGE UTIL (%) (WOOD) ? 75
BOILER EFFIC (%) (OIL) ? 80
BOILER EFFIC (%) (WOOD) ? 63
BTUS/LB STEAM (OIL) ? 1000
BTUS/LB STEAM (WOOD) ? 1000
TYPE OF OIL (NO.) ? 6
PRICE/GAL OIL ($) ? .8
PRICE/TON WOOD ($) ? 12
DRY WOOD ENERGY (MMBTU) ? 16
WET BASIS M.C. (%) ? 50
### INPUTS TO CALCULATE CAPITAL COSTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days of Open Storage (28)</td>
<td>? 28</td>
</tr>
<tr>
<td>Height of Open Storage, ft. (12)</td>
<td>? 12</td>
</tr>
<tr>
<td>Days of Covered Storage (3)</td>
<td>? 3</td>
</tr>
<tr>
<td>Type of Wood: Wastes=1, Other=2</td>
<td>? 1</td>
</tr>
<tr>
<td>Tons/hour Disc Screen (53.57142857143)</td>
<td>? 53</td>
</tr>
<tr>
<td>Tons/hour Hammermill (53.57142857143)</td>
<td>? 53</td>
</tr>
<tr>
<td>Raw Wood Conveyor Length, ft. (Drag Chain, 100)</td>
<td>? 100</td>
</tr>
<tr>
<td>Prepared Conveyor Length, ft. (Belt Chain, 300)</td>
<td>? 300</td>
</tr>
<tr>
<td>Boiler Feed Conveyor Length, ft. (Drag Chain, 100)</td>
<td>? 100</td>
</tr>
</tbody>
</table>

### COMPONENT COSTS

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dumper</td>
<td>120000.00</td>
</tr>
<tr>
<td>Front End Loader</td>
<td>48000.00</td>
</tr>
<tr>
<td>Uncovered Storage</td>
<td>25799.087</td>
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<tr>
<td>Raw Wood Drag Chain Conveyor</td>
<td>79723.400</td>
</tr>
<tr>
<td>Disc Screen</td>
<td>15879.000</td>
</tr>
<tr>
<td>Hammermill</td>
<td>33490.000</td>
</tr>
<tr>
<td>Sized Wood Belt Conveyor</td>
<td>56184.429</td>
</tr>
<tr>
<td>Covered Storage</td>
<td>82954.990</td>
</tr>
<tr>
<td>Boiler Feed Conveyor</td>
<td>43129.762</td>
</tr>
<tr>
<td>Boiler</td>
<td>790000.00</td>
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<tr>
<td>Pollution Control</td>
<td>120000.00</td>
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### SYSTEM COSTS

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution Control</td>
<td>120000.00</td>
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<tr>
<td>Storage</td>
<td>108754.077</td>
</tr>
<tr>
<td>All Other</td>
<td>1186406.590</td>
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<td><strong>Total Capital Costs</strong></td>
<td><strong>1415160.667</strong></td>
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### Table

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Annual O&amp;M Costs (Oil)</td>
<td>42000</td>
</tr>
<tr>
<td>Annual O&amp;M Costs (Wood)</td>
<td>168000</td>
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<tr>
<td>O&amp;M Inflation Rate (%)</td>
<td>14</td>
</tr>
<tr>
<td>Oil Inflation Rate (%)</td>
<td>18</td>
</tr>
<tr>
<td>Wood Inflation Rate (%)</td>
<td>14</td>
</tr>
<tr>
<td>Fed Tax Rate (%)</td>
<td>46</td>
</tr>
<tr>
<td>Fed Tax Credit (%)</td>
<td>20</td>
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<td>6</td>
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<td>State Tax Credit (%)</td>
<td>0</td>
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<td>Deprec Period (yr)</td>
<td>20</td>
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<tr>
<td>Deprec Method</td>
<td>2</td>
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<tr>
<td>Loan Period (yr)</td>
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<td>Loan Interest Rate (%)</td>
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<tr>
<td>Equity Capital ($)</td>
<td>350000</td>
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<tr>
<td>Capital Cost ($)</td>
<td>1400000</td>
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<tr>
<td>Operating Life (yr)</td>
<td>20</td>
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<tr>
<td>Discount Rate (%)</td>
<td>25</td>
</tr>
<tr>
<td>Generated Electricity ($/yr)</td>
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<tr>
<td>Electric Price Infl Rate (%)</td>
<td>14</td>
</tr>
<tr>
<td>Cost of Storage Facilities</td>
<td>108000</td>
</tr>
</tbody>
</table>

**Data Loaded**

**Name of Facility (Up to 24 Chars.)**

? Example

**Next Choice**

? 2

**Output?** Terminal=0, Printer = 1

? 0
### Wood Conversion Economic Model Example

#### Base Case Data:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>LBS Steam per Hour (Oil)</td>
<td>40000.00</td>
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<tr>
<td>LBS Steam per Hour (Wood)</td>
<td>40000.00</td>
</tr>
<tr>
<td>Annual Optg Hrs (Oil)</td>
<td>6000.00</td>
</tr>
<tr>
<td>Annual Optg Hrs (Wood)</td>
<td>6000.00</td>
</tr>
<tr>
<td>Average Util (%) (Oil)</td>
<td>75.00</td>
</tr>
<tr>
<td>Average Util (%) (Wood)</td>
<td>75.00</td>
</tr>
<tr>
<td>Boiler Effic (%) (Oil)</td>
<td>80.00</td>
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<tr>
<td>Boiler Effic (%) (Wood)</td>
<td>63.00</td>
</tr>
<tr>
<td>BTUs/Lb Steam (Oil)</td>
<td>1000.00</td>
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<tr>
<td>BTUs/Lb Steam (Wood)</td>
<td>1000.00</td>
</tr>
<tr>
<td>Type of Oil (No.)</td>
<td>6.00</td>
</tr>
<tr>
<td>Price/Gal Oil ($)</td>
<td>0.80</td>
</tr>
<tr>
<td>Price/Ton Wood ($)</td>
<td>12.00</td>
</tr>
<tr>
<td>Dry Wood Energy (MMBTU)</td>
<td>16.00</td>
</tr>
<tr>
<td>Wet Basis M.C. (%)</td>
<td>50.00</td>
</tr>
<tr>
<td>Annual O&amp;M Costs (Oil)</td>
<td>42000.00</td>
</tr>
<tr>
<td>Annual O&amp;M Costs (Wood)</td>
<td>168000.00</td>
</tr>
<tr>
<td>O&amp;M Inflation Rate (%)</td>
<td>14.00</td>
</tr>
<tr>
<td>Oil Inflation Rate (%)</td>
<td>18.00</td>
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<tr>
<td>Wood Inflation Rate (%)</td>
<td>14.00</td>
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<tr>
<td>Fed Tax Rate (%)</td>
<td>46.00</td>
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<tr>
<td>Fed Tax Credit (%)</td>
<td>20.00</td>
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<tr>
<td>State Tax Rate (%)</td>
<td>6.00</td>
</tr>
<tr>
<td>State Tax Credit (%)</td>
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<tr>
<td>Deprec Period (Yr)</td>
<td>20.00</td>
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<tr>
<td>Deprec Method</td>
<td>Double-Declining Balance</td>
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<td>Loan Period (Yr)</td>
<td>7.00</td>
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<tr>
<td>Loan Interest Rate (%)</td>
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<tr>
<td>Equity Capital ($)</td>
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<tr>
<td>Capital Cost ($)</td>
<td>1400000.00</td>
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<tr>
<td>Operating Life (Yr)</td>
<td>20.00</td>
</tr>
<tr>
<td>Discount Rate (%)</td>
<td>25.00</td>
</tr>
<tr>
<td>Generated Electricity ($/Yr)</td>
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<tr>
<td>Elec Price Infl Rate (%)</td>
<td>14.00</td>
</tr>
<tr>
<td>Cost of Storage Facilities</td>
<td>108000.00</td>
</tr>
</tbody>
</table>

#### Estimated Annual Consumption & Costs

- **Annual Oil Consumption:** 1500000.00 Gallons
- **Annual Cost at $0.80 per Gallon:** $1200000.00

- **Annual Wood Consumption:** 35714.00 Tons
- **Annual Cost at $12.00 per Ton:** $428571.43
## COMPARISON OF ALTERNATIVE FUELS
### CASH FLOW ANALYSIS WITH FINANCING

(THOUSANDS OF DOLLARS)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>INSTALLATION</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>EQUIPMENT COST</td>
<td>1400.0</td>
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<td></td>
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<tr>
<td>LOAN PROCEEDS</td>
<td>(1050.0)</td>
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<tr>
<td>OIL COSTS</td>
<td>1200.0</td>
<td>1416.0</td>
<td>1670.9</td>
<td>1971.6</td>
<td>2326.5</td>
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<tr>
<td>WOOD COSTS</td>
<td>428.6</td>
<td>488.6</td>
<td>557.0</td>
<td>634.9</td>
<td>723.8</td>
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<tr>
<td>GENERATED ELECTRICITY</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>FUEL SAVINGS</td>
<td>771.4</td>
<td>927.4</td>
<td>1113.9</td>
<td>1336.7</td>
<td>1602.7</td>
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<tr>
<td>ADDITIONAL O&amp;M</td>
<td>126.0</td>
<td>143.6</td>
<td>163.7</td>
<td>186.7</td>
<td>212.8</td>
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<tr>
<td>DEPRECIATION</td>
<td>140.0</td>
<td>126.0</td>
<td>113.4</td>
<td>102.1</td>
<td>91.9</td>
<td></td>
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<tr>
<td>INTEREST</td>
<td>151.4</td>
<td>136.6</td>
<td>119.5</td>
<td>99.6</td>
<td>76.5</td>
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<td>PRETAX INCOME</td>
<td>354.1</td>
<td>521.2</td>
<td>717.3</td>
<td>948.4</td>
<td>1221.5</td>
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<tr>
<td>TAXES PAYABLE</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STATE</td>
<td>21.2</td>
<td>31.3</td>
<td>43.0</td>
<td>56.9</td>
<td>73.3</td>
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<td>FEDERAL</td>
<td>153.1</td>
<td>225.4</td>
<td>310.2</td>
<td>410.1</td>
<td>528.2</td>
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<tr>
<td>TAX CREDITS</td>
<td>(269.2)</td>
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<td>NET EARNINGS-AFTER TAX</td>
<td>179.7</td>
<td>264.6</td>
<td>364.1</td>
<td>481.4</td>
<td>620.0</td>
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<td>ADD DEPRECIATION</td>
<td>140.0</td>
<td>126.0</td>
<td>113.4</td>
<td>102.1</td>
<td>91.9</td>
<td></td>
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<tr>
<td>DEDUCT LOAN PAYMENT</td>
<td>91.8</td>
<td>106.5</td>
<td>123.7</td>
<td>143.5</td>
<td>166.6</td>
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<tr>
<td>NET CASH FLOW</td>
<td>(80.8)</td>
<td>227.9</td>
<td>284.0</td>
<td>353.8</td>
<td>439.9</td>
<td>545.3</td>
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</table>

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## Subsequent Planning Cycles

(Thousands of Dollars)

<table>
<thead>
<tr>
<th>Years</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Costs</td>
<td>19640.5</td>
<td>44932.7</td>
<td>102795.2</td>
</tr>
<tr>
<td>Wood Costs</td>
<td>5454.5</td>
<td>10502.2</td>
<td>20221.1</td>
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<tr>
<td>Generated Electricity</td>
<td>0.0</td>
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<tr>
<td>Fuel Savings</td>
<td>14186.0</td>
<td>34430.6</td>
<td>82574.2</td>
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<tr>
<td>Additional O&amp;M</td>
<td>1603.6</td>
<td>3087.6</td>
<td>5945.0</td>
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<tr>
<td>Depreciation</td>
<td>338.5</td>
<td>244.1</td>
<td>244.1</td>
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<tr>
<td>Interest</td>
<td>68.4</td>
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<td>0.0</td>
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<tr>
<td>Pretax Income</td>
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<td>31098.8</td>
<td>76385.1</td>
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<td>Taxes Payable</td>
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<td>State</td>
<td>730.5</td>
<td>1865.9</td>
<td>4583.1</td>
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<td>Federal</td>
<td>5264.7</td>
<td>13447.1</td>
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<td>Net Earnings-After Tax</td>
<td>6180.3</td>
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<td>38773.1</td>
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<td>Add Depreciation</td>
<td>338.5</td>
<td>244.1</td>
<td>244.1</td>
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<tr>
<td>Deduct Loan Payment</td>
<td>417.9</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Net Cash Flow</td>
<td>6100.9</td>
<td>16029.8</td>
<td>39017.1</td>
</tr>
</tbody>
</table>
ECONOMIC VALUES OF WOOD FUEL ALTERNATIVE

CASH PAYBACK PERIOD OF INITIAL INVESTMENT = .4 YEARS

PAYBACK OF TOTAL INVESTMENT = 2.9 YEARS (CUMULATIVE CASH FLOW IS SUFFICIENT TO RECOVER INITIAL INVESTMENT AND REMAINING LOAN BALANCE)

NET PRESENT VALUE = 3322.9 (DISCOUNTED AT 25.000%)

INTERNAL RATE OF RETURN = 307.3%

NEXT CHOICE
? 5
  OUTPUT? TERMINAL=0, PRINTER = 1
  ? 0
  VARIABLES & VALUES?
  ROUND 1 CHANGES FROM BASE CASE:
  ? 19 14
  ? 0 0
  ROUND 2 CHANGES FROM BASE CASE:
  ? 19 14
  ? 18 8
  ? 20 11
  ? 0 0
  ROUND 3 CHANGES FROM BASE CASE:
  ? 0 0

TYPE OF ANALYSIS:
ENGINEERING ONLY = 1
FULL ENGINEERING, FINANCIAL, & ECONOMIC = 2
FULL ANALYSIS, BUT SUPPRESS FINANCIAL TABLE = 3
FINANCIAL & ECONOMIC, SUPPRESS COMPARATIVE CONSUMPTION = 4
ECONOMIC VALUES ONLY = 5
? 5
WOOD CONVERSION ECONOMIC MODEL

EXAMPLE

CHANGES FROM BASE CASE DATA:
--------------------------------------
OIL INFLATION RATE (%) : 14.00

ECONOMIC VALUES OF WOOD FUEL ALTERNATIVE
----------------------------------------

CASH PAYBACK PERIOD OF INITIAL INVESTMENT = .4 YEARS
PAYBACK OF TOTAL INVESTMENT = 3.0 YEARS (CUMULATIVE CASH FLOW IS SUFFICIENT TO RECOVER INITIAL INVESTMENT AND REMAINING LOAN BALANCE)
NET PRESENT VALUE = 2029.4 (DISCOUNTED AT 25.000%)
INTERNAL RATE OF RETURN = 297.7%

WOOD CONVERSION ECONOMIC MODEL

EXAMPLE

CHANGES FROM BASE CASE DATA:
--------------------------------------
O&M INFLATION RATE (%) : 8.00
OIL INFLATION RATE (%) : 14.00
WOOD INFLATION RATE (%) : 11.00

ECONOMIC VALUES OF WOOD FUEL ALTERNATIVE
----------------------------------------

CASH PAYBACK PERIOD OF INITIAL INVESTMENT = .4 YEARS
PAYBACK OF TOTAL INVESTMENT = 3.0 YEARS (CUMULATIVE CASH FLOW IS SUFFICIENT TO RECOVER INITIAL INVESTMENT AND REMAINING LOAN BALANCE)
NET PRESENT VALUE = 2417.6 (DISCOUNTED AT 25.000%)
INTERNAL RATE OF RETURN = 301.7%
ITERATIVE ANALYSIS PARAMETERS
? 13 6 2
? 1 20

WOOD CONVERSION ECONOMIC MODEL

<table>
<thead>
<tr>
<th>PRICE/TON WOOD ($)</th>
<th>OIL CONS (GAL/YR)</th>
<th>WOOD CONS (TON/YR)</th>
<th>FUEL SAVGS ($/YR 1)</th>
<th>NPV ($)</th>
<th>IRR (%)</th>
<th>PAYBACK (YR)</th>
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<tbody>
<tr>
<td>6.00</td>
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<td>35714.</td>
<td>985714.</td>
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<td>1500000.</td>
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<td>35714.</td>
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<td>1.0</td>
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</tbody>
</table>
WOOD ENERGY FINANCING

by

M. Whitmire, First National Bank of Atlanta

Presented at

WOOD ENERGY FINANCING
April 29, 1981
Wood Energy Financing

A decision to implement a wood energy system will probably be contingent upon securing adequate financing for the system. The financing arrangement between the borrower and the lender will be completely dependent upon the specific characteristics of that particular situation. There are, however, several key issues that are common to most financial evaluations.

It is important to educate the lender. He must be given enough background information to assure him that the company is well managed and the industry is stable. Most bankers will not be familiar with wood energy systems, so evidence must be presented to demonstrate the technical feasibility of the proposed system. The anticipated impact of the proposed system on the financial performance of the company must be evaluated and presented to the banker.

Each bank uses a variety of criteria for evaluation of a loan. Determine from your banker the criteria that will be used to evaluate your loan request.

There are numerous types of financing arrangements, each with a different level of risk and cost. Discuss these with your banker to determine the one that is best for your particular situation.

Following is an outline of topics that you will need to consider when you are trying to secure financing for a wood energy system.
Wood Energy Financing

I. Education of Lender
   A. Background Information
      1. Company history
      2. Management resumes
      3. Industry characteristics
   B. Technological Material
   C. Financial Information
      1. Historic financial performance
      2. Energy costs and expense data
      3. Projected balance sheets, income statements, and cash budgets
      4. Personal financial statements
      5. Plant, property, and/or equipment appraisals

II. Evaluation Criteria
   A. Historical earnings performance
   B. Historical cash flow data
   C. Leverage
   D. Industry Evaluation

III. Types of Credit Facilities
   A. Accounts receivable financing
      1. Largest potential source of asset-based loans
2. Variety of techniques and procedures dependent on risk-taking attitude

3. Factoring as an alternative to accounts receivable financing

4. Interest rate and maturity structure

B. Inventory Financing

1. Variety of techniques and procedures dependent on risk-taking attitude

2. Generally higher degree of risk involved

3. Use of external third-parties for information and control

4. Interest rate and maturity structure

C. Equipment Financing

1. Types of equipment typically financed

2. Uncertainty of liquidation value

3. Use of outside service for information and control

4. Interest rate and maturity structure

D. Real Estate and Improvement Financing

1. Long-term/Institutional lenders

2. Industrial Revenue Bonds

3. Interest rate and maturity structure

E. Government Guaranteed Lending Activities

1. Small Business Administration programs

2. Farmers Home Administration programs

3. Economic Development Administration programs

4. Urban Development Action grants
### GENERAL EQUIPMENT SPECIFICATIONS

**Oil Boiler System**

#### Outside Oil Storage

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Tank Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 $\times$ 10^3 lbs/hr</td>
<td>40 $\times$ 10^3 gals</td>
</tr>
<tr>
<td>25 $\times$ 10^3 lbs/hr</td>
<td>99 $\times$ 10^3 gals</td>
</tr>
<tr>
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<tr>
<td>200 $\times$ 10^3 lbs/hr</td>
<td>797 $\times$ 10^3 gals</td>
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#### Oil Transfer Pump

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Pump Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 $\times$ 10^3 lbs/hr</td>
<td>22.3 gals/min</td>
</tr>
<tr>
<td>25 $\times$ 10^3 lbs/hr</td>
<td>55.2 gals/min</td>
</tr>
<tr>
<td>50 $\times$ 10^3 lbs/hr</td>
<td>110.7 gals/min</td>
</tr>
<tr>
<td>100 $\times$ 10^3 lbs/hr</td>
<td>221.5 gals/min</td>
</tr>
<tr>
<td>200 $\times$ 10^3 lbs/hr</td>
<td>772.7 gals/min</td>
</tr>
</tbody>
</table>

#### Oil Storage Day Tank

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Tank Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 $\times$ 10^3 lbs/hr</td>
<td>1.4 $\times$ 10^3 gals</td>
</tr>
<tr>
<td>25 $\times$ 10^3 lbs/hr</td>
<td>3.3 $\times$ 10^3 gals</td>
</tr>
<tr>
<td>50 $\times$ 10^3 lbs/hr</td>
<td>6.6 $\times$ 10^3 gals</td>
</tr>
<tr>
<td>100 $\times$ 10^3 lbs/hr</td>
<td>13.3 $\times$ 10^3 gals</td>
</tr>
<tr>
<td>200 $\times$ 10^3 lbs/hr</td>
<td>26.6 $\times$ 10^3 gals</td>
</tr>
</tbody>
</table>

#### Oil Feed Pumps

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Pump Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 $\times$ 10^3 lbs/hr</td>
<td>0.9 gals/min</td>
</tr>
<tr>
<td>25 $\times$ 10^3 lbs/hr</td>
<td>2.3 gals/min</td>
</tr>
<tr>
<td>50 $\times$ 10^3 lbs/hr</td>
<td>4.6 gals/min</td>
</tr>
<tr>
<td>100 $\times$ 10^3 lbs/hr</td>
<td>9.2 gals/min</td>
</tr>
<tr>
<td>200 $\times$ 10^3 lbs/hr</td>
<td>18.4 gals/min</td>
</tr>
</tbody>
</table>

**Boiler Capacities = As Previously Stated**
Appendix A2

GENERAL EQUIPMENT SPECIFICATIONS
Gas Boiler System

**Outside Oil Storage**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Tank Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$9.4 \times 10^3$ gals.</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$23.2 \times 10^3$ gals.</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$46.5 \times 10^3$ gals.</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$93.0 \times 10^3$ gals.</td>
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<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$185.9 \times 10^3$ gals.</td>
</tr>
</tbody>
</table>

**Oil Transfer Pump**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Pump Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>22.3 gals/min</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>55.2 gals/min</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>110.7 gals/min</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>221.5 gals/min</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>442.7 gals/min</td>
</tr>
</tbody>
</table>

**Oil Storage Day Tank**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Tank Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$1.4 \times 10^3$ gals.</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$3.3 \times 10^3$ gals.</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$6.6 \times 10^3$ gals.</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$13.3 \times 10^3$ gals.</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$26.6 \times 10^3$ gals.</td>
</tr>
</tbody>
</table>

**Oil Feed Pumps**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Pump Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>0.9 gals/min</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>2.3 gals/min</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>4.6 gals/min</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>9.2 gals/min</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>18.4 gals/min</td>
</tr>
</tbody>
</table>

**Boiler**

Capacities = As Previously Stated
Appendix A3

GENERAL EQUIPMENT SPECIFICATIONS
Coal Boiler Systems

Truck Dumper
Length = 60 ft. (Lifts Tractor plus Trailer)
Weight of Cargo = 25 tons of Coal

Front End Loader

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>No. of Loaders</th>
<th>Bucket Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$1.5 \text{ yds}^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$1.5 \text{ yds}^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$1.5 \text{ yds}^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$3.0 \text{ yds}^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$5.0 \text{ yds}^3$</td>
</tr>
</tbody>
</table>

Drag Chain Conveyor
Length = 60 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>4.2 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>10.5 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>21.1 tons/hr</td>
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<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>42.0 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>84.1 tons/hr</td>
</tr>
</tbody>
</table>

Belt Conveyor
Length = 500 ft.
Height = 60 ft.
Capacity = Same as Drag Chain

Storage Silo

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Silo Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$1.4 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$3.4 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$6.8 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$13.5 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$26.9 \times 10^3 \text{ ft}^3$</td>
</tr>
</tbody>
</table>

Boiler Feed Drag Chain Conveyor
Length = 100 ft.
Height = 10 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>0.5 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>1.2 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>2.3 tons/hr</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>4.7 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>9.3 tons/hr</td>
</tr>
</tbody>
</table>

Boiler
Capacities = As Previously Stated; Includes Equipment for Particulate Cleanup, but No SO2 Scrubbing Equipment
Appendix A4

GENERAL EQUIPMENT SPECIFICATIONS
Wood Waste Boiler System

Truck Dumper
Length = 60 ft. (Lifts Tractor plus Trailer)
Weight of Cargo = 25 tons of Wet Wood Waste

Front End Loader

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>No. of Loaders</th>
<th>Bucket Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>1.5 yds$^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>3.0 yds$^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>5.0 yds$^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>12.0 yds$^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>2</td>
<td>12.0 yds$^3$</td>
</tr>
</tbody>
</table>

Raw Wood Drag Chain Conveyor
Length = 40 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>16.5 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>41.1 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>82.1 tons/hr</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>164.2 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>328.1 tons/hr</td>
</tr>
</tbody>
</table>

Raw Wood Belt Conveyor
Length = 70 ft.
Height = 20 ft.
Capacity = Same as Drag Chain

Disc Screen
Maximum Outlet Wood Size = 2"
Capacity = Same as Drag Chain

Hammermill
Maximum Outlet Wood Size = 2"
Capacity = Same as Drag Chain

Sized Wood Belt Conveyor
Length = 500 ft.
Height = 60 ft
Capacity = Same as Drag Chain

Storage Silo

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Silo Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$10.5 \times 10^3$ ft.$^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$26.3 \times 10^3$ ft.$^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$52.5 \times 10^3$ ft.$^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$105.1 \times 10^3$ ft.$^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$210.0 \times 10^3$ ft.$^3$</td>
</tr>
</tbody>
</table>
Boiler Feed Drag Chain Conveyor

Length = 100 ft.
Height = 10 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 ( \times 10^3 ) lbs/hr</td>
<td>1.8 tons/hr</td>
</tr>
<tr>
<td>25 ( \times 10^3 ) lbs/hr</td>
<td>4.6 tons/hr</td>
</tr>
<tr>
<td>50 ( \times 10^3 ) lbs/hr</td>
<td>9.1 tons/hr</td>
</tr>
<tr>
<td>100 ( \times 10^3 ) lbs/hr</td>
<td>18.2 tons/hr</td>
</tr>
<tr>
<td>200 ( \times 10^3 ) lbs/hr</td>
<td>36.5 tons/hr</td>
</tr>
</tbody>
</table>

Boiler Capacities = As previously stated
Appendix A5

GENERAL EQUIPMENT SPECIFICATIONS

Wood Chip Boiler System

**Truck Dumper**

Length = 60 ft. (Lifts Tractor plus Trailer)

Weight of Cargo = 25 tons of Wood Pellets

**Front End Loader**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>No. of Loaders</th>
<th>Bucket Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>1.5 yd$^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>3.0 yd$^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>5.0 yd$^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>12.0 yd$^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>2</td>
<td>12.0 yd$^3$</td>
</tr>
</tbody>
</table>

**Drag Chain Conveyor**

Length = 40 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>16.5 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>41.1 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>82.1 tons/hr</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>164.2 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>328.1 tons/hr</td>
</tr>
</tbody>
</table>

**Belt Conveyor**

Length = 500 ft.

Height = 60 ft.

Capacity = Same as Drag Chain

**Storage Silo**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Silo Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$10.5 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$26.3 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$52.5 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$105.1 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$210.0 \times 10^3$ ft$^3$</td>
</tr>
</tbody>
</table>

**Boiler Feed Drag Chain Conveyor**

Length = 100 ft.

Height = 10 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1.8 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>4.6 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>9.1 tons/hr</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>18.2 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>36.5 tons/hr</td>
</tr>
</tbody>
</table>

**Boiler**

Capacities = As Previously Stated

-125-
Appendix A6

GENERAL EQUIPMENT SPECIFICATIONS
    Wood Pellet Boiler System

Truck Dumper
Length = 60 ft. (Lifts Tractor plus Trailer)
Weight of Cargo = 25 tons of Pellets

Belt Conveyor
Length = 500 ft.
Height = 60 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 x 10^3 lbs/hr</td>
<td>7.5 tons/hr</td>
</tr>
<tr>
<td>25 x 10^3 lbs/hr</td>
<td>18.5 tons/hr</td>
</tr>
<tr>
<td>50 x 10^3 lbs/hr</td>
<td>37.1 tons/hr</td>
</tr>
<tr>
<td>100 x 10^3 lbs/hr</td>
<td>74.2 tons/hr</td>
</tr>
<tr>
<td>200 x 10^3 lbs/hr</td>
<td>148.1 tons/hr</td>
</tr>
</tbody>
</table>

Storage Silo

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Silo Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 x 10^3 lbs/hr</td>
<td>3.4 x 10^3 ft^3</td>
</tr>
<tr>
<td>25 x 10^3 lbs/hr</td>
<td>8.5 x 10^3 ft^3</td>
</tr>
<tr>
<td>50 x 10^3 lbs/hr</td>
<td>17.0 x 10^3 ft^3</td>
</tr>
<tr>
<td>100 x 10^3 lbs/hr</td>
<td>33.9 x 10^3 ft^3</td>
</tr>
<tr>
<td>200 x 10^3 lbs/hr</td>
<td>67.7 x 10^3 ft^3</td>
</tr>
</tbody>
</table>

Boiler Feed Belt Conveyor
Length = 100 ft.
Height = 10 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 x 10^3 lbs/hr</td>
<td>0.8 tons/hr</td>
</tr>
<tr>
<td>25 x 10^3 lbs/hr</td>
<td>2.1 tons/hr</td>
</tr>
<tr>
<td>50 x 10^3 lbs/hr</td>
<td>4.1 tons/hr</td>
</tr>
<tr>
<td>100 x 10^3 lbs/hr</td>
<td>8.2 tons/hr</td>
</tr>
<tr>
<td>200 x 10^3 lbs/hr</td>
<td>16.5 tons/hr</td>
</tr>
</tbody>
</table>

Boiler
Capacities = As Previously Stated
Appendix A7

GENERAL EQUIPMENT SPECIFICATIONS
Wood Fueled Fluidized Bed Combustor Systems

Truck Dumper
Length = 60 ft. (Lifts Tractor plus Trailer)
Weight of Cargo = 25 tons of wood

Front End Loader

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>No. of Loaders</th>
<th>Bucket Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$1.5 \text{ yds}^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$3.0 \text{ yds}^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$5.0 \text{ yds}^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>$12.0 \text{ yds}^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>2</td>
<td>$12.0 \text{ yds}^3$</td>
</tr>
</tbody>
</table>

Raw Wood Drag Chain Conveyor
Length = 40 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>15.7 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>39.2 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>78.5 tons/hr</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>157.0 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>313.8 tons/hr</td>
</tr>
</tbody>
</table>

Raw Wood Belt Conveyor
Length = 70 ft.
Height = 20 ft.
Capacity = Same as Drag Chain

Disc Screen
Maximum Outlet Wood Size = 4"
Capacity = Same as Drag Chain

Hog
Maximum Outlet Wood Size = 4"
Capacity = Same as Drag Chain

Sized Wood Belt Conveyor
Length = 500 ft.
Height = 60 ft.
Capacity = Same as Drag Chain

Storage Silo

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Silo Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$10.1 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$25.1 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$50.2 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$100.5 \times 10^3 \text{ ft}^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$200.8 \times 10^3 \text{ ft}^3$</td>
</tr>
</tbody>
</table>
Appendix A7 (Continued)

**Combustor Feed Drag Chain Conveyor**

- **Length** = 100 ft.
- **Height** = 10 ft.

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1.8 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>4.4 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>9.1 tons/hr</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>17.4 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>34.9 tons/hr</td>
</tr>
</tbody>
</table>

**Fluidized Bed Combustor**

- Capacities = As Previously Stated
Appendix A8

General Equipment Specifications
Wood Waste Gasifier with Gas/Oil Boiler System

Truck Dumper

Length = 60 ft (lifts tractor plus trailer)
Weight of Cargo = 25 tons of wet wood waste

Front End Loader

<table>
<thead>
<tr>
<th>Gasifier Capacity</th>
<th>No. of Loaders</th>
<th>Bucket Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>1.5 yds$^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>3.0 yds$^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>5.0 yds$^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>1</td>
<td>12.0 yds$^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>2</td>
<td>12.0 yds$^3$</td>
</tr>
</tbody>
</table>

Raw Wood Drag Chain Conveyor

Length = 40 ft

<table>
<thead>
<tr>
<th>Gasifier Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>15.5 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>38.7 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>77.3 tons/hr</td>
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<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>154.7 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>309.2 tons/hr</td>
</tr>
</tbody>
</table>

Raw Wood Belt Conveyor

Length = 70 ft
Height = 20 ft
Capacity = Same as drag chain

Disc Screen

Maximum Outlet Wood Size = 2"
Capacity = Same as drag chain

Hammermill

Maximum outlet wood size = 2"
Capacity = Same as drag chain
Appendix A8 (Continued)

Sized Wood Belt Conveyor

Length = 500 ft
Height = 60 ft
Capacity = Same as drag chain

Storage Silo

<table>
<thead>
<tr>
<th>Gasifier Capacity</th>
<th>Silo Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$9.9 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$24.7 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$49.5 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$99.0 \times 10^3$ ft$^3$</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$197.9 \times 10^3$ ft$^3$</td>
</tr>
</tbody>
</table>

Boiler Feed Drag Chain Conveyor

Length = 100 ft
Height = 10 ft

<table>
<thead>
<tr>
<th>Gasifier Capacity</th>
<th>Conveyor Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>1.7 tons/hr</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>4.3 tons/hr</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>8.6 tons/hr</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>17.2 tons/hr</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>34.4 tons/hr</td>
</tr>
</tbody>
</table>

Boiler

Capacities = As previously stated

Outside Oil Storage

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Tank Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$9.4 \times 10^3$ gals</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$23.2 \times 10^3$ gals</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$46.5 \times 10^3$ gals</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$93.0 \times 10^3$ gals</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$185.9 \times 10^3$ gals</td>
</tr>
</tbody>
</table>
### Appendix A8 (Continued)

**Oil Transfer Pump**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Pump Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>22.3 gals/min</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>55.2 gals/min</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>110.7 gals/min</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>221.5 gals/min</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>442.7 gals/min</td>
</tr>
</tbody>
</table>

**Oil Storage Day Tank**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Tank Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>$1.4 \times 10^3$ gals</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>$3.3 \times 10^3$ gals</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>$6.6 \times 10^3$ gals</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>$13.3 \times 10^3$ gals</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>$26.6 \times 10^3$ gals</td>
</tr>
</tbody>
</table>

**Oil Feed Pumps**

<table>
<thead>
<tr>
<th>Boiler Capacity</th>
<th>Pump Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 \times 10^3$ lbs/hr</td>
<td>0.9 gals/min</td>
</tr>
<tr>
<td>$25 \times 10^3$ lbs/hr</td>
<td>2.3 gals/min</td>
</tr>
<tr>
<td>$50 \times 10^3$ lbs/hr</td>
<td>4.6 gals/min</td>
</tr>
<tr>
<td>$100 \times 10^3$ lbs/hr</td>
<td>9.2 gals/min</td>
</tr>
<tr>
<td>$200 \times 10^3$ lbs/hr</td>
<td>18.4 gals/min</td>
</tr>
</tbody>
</table>

**Boiler**

Capacities = As previously stated
APPENDIX B
(Wood Fuel Cost)

Estimate of trees less than 5" in diameter available for industrial fuel in Georgia.

Assumption:

1) That trees from 2" to 4.9" in diameter are harvestable and that trees less than 2" in diameter are brush and are unlikely to be harvested by large in-field whole tree chippers.

2) That only desirable species will be harvested on a significant basis, i.e., undesirable stands are infrequently harvested, and only the best mature trees are selected without clearing the site.

3) A 30 year rotation for softwoods and 60 years for hardwoods, with clear cutting and harvest of logging waste and 2" to 4.9" diameter trees at that time.

4) That 10% of the available material is actually harvested.

5) Calculation of annual yield; volume shown is 2" + 4" standing timber of desirable species:
   
   A. Softwoods:
   
   37,800,000 standing cords x 1/30-year rotation x 10%
   x 5,350 lbs/cord/2,000 lbs/ton = 337,000 tons/year

   B. Hardwoods:

   32,200,000 x 1/60 x 10% x 5,800/2,000 = 156,000 tons/year

   TOTAL = 493,000 tons/year

---

*Georgia's Wood Energy Program, Ref. 1
Calculation of wood fuel consumption for boiler fuel

Assumption:

1) Mill residue used for fuel, 50% moisture content, higher heating value, 4,250 Btu/lb at 50% moisture content.
2) Boiler efficiency for HRT boiler, 65%.
3) Load factor (percent of rated capacity for normal operation) 70%
4) Steam output rated from and at 212° F, 970 Btu required per pound of steam
5) Assume 10 days per year plant shutdown, 355 days operation
6) Assume boiler is a 20,000 lb/hr steam capacity, low pressure firetube boiler for process heating
7) Calculation

\[
20,000 \text{ lb/hr steam} \times 0.70 \text{ load factor} \times 970 \text{ Btu/lb steam} \\
\times 355 \text{ days/year} \times 24 \text{ hr/day} \times \frac{1}{0.65} \text{ efficiency} \\
\times \frac{1}{4,250} \text{ Btu/lb of fuel} \times \frac{1}{2,000} \text{ lb/ton} = 20,900 \text{ tons/year per boiler}
\]

Fuel wood available; 8% of processing wastes

\[
9,200,000 \text{ tons/year} \times 0.08 \times \frac{1}{20,900} \text{ tons/year per boiler} = 35 \text{ boilers}
\]
The increasing cost of industrial fuel and raw material has made many wood residues more attractive as substitutes. The 1978 survey of wood-using industries indicated that 86 percent of all bark was being used in some form. This includes bark that was shipped to pulp mills in dirty chips.

Each primary manufacturer in Georgia was questioned about production and disposal of residue items such as bark, sawdust, shavings, and veneer clippings. This information has been entered into a computer program, and disposal by volume, species, and residue type can be printed for any selected group of Georgia counties.

Table B-1: Residue Disposal by Primary Processors*

<table>
<thead>
<tr>
<th>Use of Residue</th>
<th>Deleted</th>
<th>Deleted</th>
<th>Deleted</th>
<th>Deleted</th>
<th>Deleted</th>
<th>Deleted</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Percent</th>
<th>By Region</th>
</tr>
</thead>
</table>

|删 | 32% |

|删 | 18% |

|删 | 34% |

|删 | 10% |

|删 | 6% |

17 Data compiled by Southeastern Forest Experiment Station, USFS
18 Includes bark from pulp mills.

** Reference (3) Georgia's Wood Energy Program

** See map next page
Figure B-1

Forest Survey Units and Mill Residue Availability

Total Mill Residue Available
10.3 Million tons/year (1977)
### STUMPAGE PRICE MART

#### Standing Timber

**State:** GEORGIA  
**Date:** DECEMBER 1979

<table>
<thead>
<tr>
<th>Item</th>
<th>Trade Area</th>
<th>Price/rd. cord (Round Wood only-No-Chip-N-Haul)</th>
<th>Demand</th>
<th>Demand Est.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulpwood</strong></td>
<td>Pine</td>
<td>1</td>
<td>8.50</td>
<td>12.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>10.00</td>
<td>22.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>17.00</td>
<td>26.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>St. Avg.</td>
<td>11.50</td>
<td>23.00</td>
</tr>
<tr>
<td><strong>Pulpwood</strong></td>
<td>Soft Hwd.</td>
<td>1</td>
<td>2.00</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>3.00</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>2.75</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>St. Avg.</td>
<td>2.75</td>
<td>4.75</td>
</tr>
<tr>
<td><strong>Pulpwood</strong></td>
<td>Pulp Hwd.</td>
<td>1</td>
<td>2.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>2.50</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>2.75</td>
<td>4.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>St. Avg.</td>
<td>2.50</td>
<td>4.00</td>
</tr>
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</table>

### F.O.B. MILL PRICE MART

#### Delivered Product

**State:** GEORGIA  
**Date:** DECEMBER 1979

<table>
<thead>
<tr>
<th>Item</th>
<th>Trade Area</th>
<th>Price/Std. F.O.B. Yard (Less Freight—See Notes)</th>
<th>Demand</th>
<th>Demand Est.</th>
<th>Wood Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulpwood</strong></td>
<td>Pine</td>
<td>1</td>
<td>34.00</td>
<td>37.90</td>
<td>36.42</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>35.55</td>
<td>41.22</td>
<td>40.67</td>
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<tr>
<td></td>
<td></td>
<td>3</td>
<td>37.12</td>
<td>44.80</td>
<td>41.93</td>
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<tr>
<td></td>
<td></td>
<td>St. Avg.</td>
<td>36.29</td>
<td>41.50</td>
<td>40.60</td>
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<tr>
<td><strong>Pulpwood</strong></td>
<td>Mix. Hwd.</td>
<td>1</td>
<td>25.40</td>
<td>28.90</td>
<td>28.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>26.07</td>
<td>30.80</td>
<td>29.79</td>
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<td>32.87</td>
<td>30.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>St. Avg.</td>
<td>26.15</td>
<td>31.92</td>
<td>30.17</td>
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</table>

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<table>
<thead>
<tr>
<th>Pulpwood</th>
<th>S</th>
<th>Pine</th>
<th>1</th>
<th>85</th>
<th>120</th>
<th>115</th>
<th>fair</th>
<th>fair</th>
<th>R/L Chip. Logs</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2</td>
<td>90</td>
<td>130</td>
<td>120</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>3</td>
<td>95</td>
<td>138</td>
<td>124</td>
<td>fair</td>
<td>fair</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>St. Avg.</td>
<td>90</td>
<td>132</td>
<td>117</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Pulpwood</th>
<th>D</th>
<th>Mix. Hwd.</th>
<th>1</th>
<th>N-A</th>
<th>2</th>
<th>65</th>
<th>100</th>
<th>85</th>
<th>poor</th>
<th>poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>3</td>
<td>65</td>
<td>110</td>
<td>90</td>
<td>fair</td>
<td>fair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>St. Avg.</td>
<td>65</td>
<td>103</td>
<td>87</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Price/Ton F.O.B. Mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp chips</td>
</tr>
<tr>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
</tr>
</tbody>
</table>

| Pulp chips | Hwd. | 1 | 13.00 | 14.50 | 14.00 | good | good | Chips-Clean |
| "          | "    | 2 | 12.00 | 14.40 | 13.50 | good | "    |
| "          | "    | 3 | 11.30 | 14.30 | 13.60 | good | "    |
| "          | "    | St. Avg. | 12.35 | 14.42 | 13.70 | "    |

| Pulp chips | Pine | 1 | 8.00 | 10.50 | 10.00 | fair | fair | Chips-Dirty |
| "          | "    | 2 | 8.00 | 11.00 | 10.00 | fair | fair |
| "          | "    | 3 | 9.00 | 13.50 | 11.00 | fair | "    |
| "          | "    | St. Avg. | 8.75 | 11.75 | 10.50 | "    |

| Pulp chips | Hwd. | 1 | N-A | 7.50 | 11.00 | 10.00 | fair | fair |
| "          | "    | 2 | 8.00 | 12.25 | 10.00 | fair | fair |
| "          | "    | 3 | 7.90 | 11.75 | 10.00 | "    |

N.A. ............... Little or no activity
NOTES

Prices will vary greatly within a given area and are determined by: Grade and size of timer, damage, logging conditions, length of haul, volume per acre, total volume, competition and demand. However, all of these are reflected in the price column by including as broad a cross section in field sampling as possible to give an average figure.

The Hardwood market is very complex and prices can vary greatly by set factors such as species, size and grade. The purpose here is to report an average market price on delivered logs that reflect grouping by price range. For lower grades, such as pallet, chipping, etc., deduct 20% of listed price. For higher grades, such as furniture stock, etc., add 25% to the listed price.

Rare Hwds are mostly: Walnut, Cherry, Chestnut, some species and grades of cypress, certain prime grades, Northern Red Oak, Cherry Bark Oak and White Oak. Occasionally exceptional high grade Hwds of some of the "Mixed Hwds" (especially if running a high percentage of veneer) will be so classified.

Mixed Hwds are mostly: Ash, Beech, Cottonwood, Willow, Elm, Gums, Locust, Hackberry, Magnolia, Maples, Pecan, Hickory, Sassafras, Sycamore, Tupelo and Birch.

In Stumpage reporting: Round wood, tree length, and chipping logs are reflected in the overall pulpwood price columns—only the logging method varies.

Soft Hwds are species used mostly for mechanical process as: Cottonwood, Willow, Poplar and Gum.

Pulping Hwds are species used mostly for chemical process and includes most all other species.

Pole prices are based on average per board foot using classes 1 through 10 and lengths 16' through 80.' American Stand, Assoc.

Cross ties, for stumps purposes, are reflected in saw-timer price column—mostly in oak and mic. hwds.

Cross tie prices are based on an average tie grade of 1 through 5, stand. gauge, and 6' and 8' lengths.

U.S. Forest Service timber sales prices will be reported separately on a quarterly basis along with your regular mailing. This is done in order that a more normal "open market" report be maintained. U.S. Forest Service sales more often reflect the sale of heavy, old growth, prime timber not generally found on the "open market."

Basis of Data:

- Ala. 1 (2) Ark. 1 (3) Fla. 1 (3) Ga. 1 (3) La. 1 (2) Miss. 1 (2)
- 2 (3) 2 (2) 2 (2) 3 (2) 2 (2) 2 (2)
- 3 (3) 3 (2) 3 (2) 3 (5) 3 (3) 3 (3)

Reporters 8 7 7 11 7 7

N. C. 1 (5) S. C. 1 (2) Tenn. 1 (2) Tex. 1 (2) Va. 1 (2)
- 2 (4) 3 (2) 3 (2) 3 (2) 3 (3)

Reporters 11 7 6 4 7

Total 82 paid Reporters: Each of these Reporters, in turn, take approx. 66 sample prices in their respective areas each month for a total sampling of approx. 5,412 prices. These figures are then compared with the findings of other sources, if available.

Log Rule Conversions and Factors: Scribner—Doyle 15% Diff./.85 Doyle to Scribner/1.17 Scribner to Doyle. International—Doyle 24% Diff./.76 Doyle to International/1.32 International to Doyle. International—Scribner 11% Diff./.89 Scribner to International/1.12 International to Scribner. Based on average size logs on today's average market. These are Dollar Value Conversions.

Log Rule and Weight Equivalents: Pine & Hwd Stumpage & Delivered Products are purchased on Scribner Doyle, International, per cu. ft., per ton, per M lbs., Std. Cord, and Cunit basis. Therefore, for the purpose of this reporting, prices for Pine are based on Scribner 15,000 lbs./MBF (Range 13,000-17,000 lbs.) Hwd prices based on Doyle 17,500 lbs./MBF (Range 15,000-19,000 lbs.) States and areas using these other measurements are adjusted to read on this basis for comparative purposes.

Pine pulpwood is by the Std. Cord/12 Cu. Ft./5350 lbs. (Range 5000-5620 lbs.) Hwd pulpwood is by the Std. Cord/12 Cu. Ft./5800 lbs. (Range 5400-6075 lbs.)

Some Converting Factors used are:

- 2.8 cd. MBF for Pine
- 8.75 Tons/MBF for Hwd.
- 3.0 cd. MBF for Hwd.
- 2.5 Tons/cd. for Chigs
- 7.5 Tons/MBF for Pine
- 1 Cunit=100 Cu. ft./Solid Wood

Pricing Point—Pulpwood—Roundwood—Prices are based on price at Loading Points—No freight included—F.O.B. car.

Data published herein is gathered with diligence and from sources considered reliable. However, we are not responsible for errors or omissions. Information is gathered and published as it exists and no attempt to set or influence prices is intended. Specific prices, because of variations in field work and time element, sometimes result in prices which are somewhat lower or higher than those published. These are not absolute Highs or Lows; but Average of Lows and Average of Highs.
JOODTECH '81

JULY 13-14, 1981 • DUNFEY HOTEL • ATLANTA, GEORGIA

An Industrial Wood Energy Exposition

SPONSORS

Georgia Institute of Technology Engineering Experiment Station
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Georgia Office of Energy Resources
WOODTECH '81
An Industrial Wood Energy Exposition

July 13-14, 1981
Atlanta, Georgia

Sponsored by

Georgia Institute of Technology
Engineering Experiment Station

Southern Solar Energy Center

United States Department of Energy
Biomass Energy Systems Division

Georgia Office of Energy Resources
Monday, July 13, 1981

<table>
<thead>
<tr>
<th>Time</th>
<th>Subject</th>
<th>Speaker/Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30</td>
<td>Welcome</td>
<td>BILL BULPITT, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia.</td>
</tr>
<tr>
<td>8:35</td>
<td>Introductory Remarks</td>
<td>MARK ZWEEKER, Georgia Office of Energy Resources, Atlanta, Georgia.</td>
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<tr>
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<td>JERRY BIRCHFIELD, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DAN SMITH, Southern Solar Energy Center, Atlanta, Georgia.</td>
</tr>
<tr>
<td>9:00</td>
<td>Keynote Address</td>
<td>DR. THOMAS E. STELSON, Vice President for Research, Georgia Institute of Technology, Atlanta, Georgia.</td>
</tr>
<tr>
<td>9:40</td>
<td>Coffee Break and Exhibit</td>
<td></td>
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<tr>
<td></td>
<td>Visit</td>
<td></td>
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<tr>
<td>10:10</td>
<td>Availability of Wood for Energy</td>
<td>FRED ALLEN, Georgia Forestry Commission, Macon, Georgia.</td>
</tr>
<tr>
<td></td>
<td>Use in Georgia</td>
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<tr>
<td>10:25</td>
<td>Georgia Forestry Commission</td>
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<tr>
<td></td>
<td>Movie</td>
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<td></td>
<td>for the Northwest Regional</td>
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<td></td>
<td>Hospital, Rome, Georgia</td>
<td></td>
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<tr>
<td>11:20</td>
<td>A Survey of Georgia's Textile</td>
<td>TOM MCGOWAN, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia.</td>
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<td>Industry for Wood Gasifier</td>
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<tr>
<td></td>
<td>Application</td>
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<tr>
<td>11:45</td>
<td>Luncheon</td>
<td></td>
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<tr>
<td>1:15</td>
<td>Construction and Startup of a</td>
<td>TONY JAPE, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia.</td>
</tr>
<tr>
<td></td>
<td>Wood Gasification Pilot Plant</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td>Presenter</td>
</tr>
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<td>---------------------------------------------------------------------------</td>
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<tr>
<td>2:05</td>
<td>The Tennessee Valley Authority's Commercial and Industrial Biomass Program</td>
<td>MELINDA WIECK, Tennessee Valley Authority, Chattanooga, Tennessee.</td>
</tr>
<tr>
<td>2:30</td>
<td>Exhibit Visit</td>
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<tr>
<td>5:30</td>
<td>Reception</td>
<td></td>
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<tr>
<td></td>
<td><strong>Tuesday, July 14, 1981</strong></td>
<td></td>
</tr>
<tr>
<td>8:30</td>
<td>Preparation of Wood Wastes for Firing Tunnel Kilns</td>
<td>PIERCE MERRY, Merry Companies, Augusta, Georgia.</td>
</tr>
<tr>
<td>8:55</td>
<td>Application of Wood Gasifiers to the Cyanamid Complex</td>
<td>BILL BULPITT, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia.</td>
</tr>
<tr>
<td>10:10</td>
<td>Coffee Break and Exhibit Visit</td>
<td></td>
</tr>
<tr>
<td>10:40</td>
<td>An Economic Alternative Enjoying Success</td>
<td>DAN MULLIGAN, Procter and Gamble, Albany, Georgia.</td>
</tr>
<tr>
<td>11:05</td>
<td>Utilization of Agricultural Waste Products for Process Steam Generation in a Soybean Extraction Facility</td>
<td>MITCHELL TEAGUE, Gold Kist, Inc., Atlanta, Georgia.</td>
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<tr>
<td>11:30</td>
<td>Feasibility Studies</td>
<td>GRANT CURTIS, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia.</td>
</tr>
<tr>
<td>11:55</td>
<td>Luncheon</td>
<td></td>
</tr>
<tr>
<td>1:15</td>
<td>Closing Remarks</td>
<td></td>
</tr>
<tr>
<td>1:30</td>
<td>Tour of Aragon Wood-Fired Boiler System</td>
<td></td>
</tr>
</tbody>
</table>
AVAILABILITY OF WOOD FOR ENERGY USE IN GEORGIA

by

J. Fred Allen
Wood Energy Specialist

Georgia Forestry Commission
Forest Research

Presented at
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia
J. FRED ALLEN

Mr. Allen is a registered forester. He graduated from the University of Georgia, School of Forest Resources in 1970. He was employed with the Georgia Forestry Commission in 1972 as a field forester in the Augusta area. He transferred to Atlanta serving in the capacity of wood energy specialist under the Forest Management Department. In January, 1980, he transferred to Macon to work as wood energy specialist in the Research Department. Mr. Allen is a member of the Georgia Forestry Association and the Forest Products Research Society.
ABSTRACT

Our forests have played a vital role in the establishment and development of our nation. Experts are currently predicting that the South will become the wood producing area in the future. Wood as an energy source has not been used as such since the introduction of the relatively cheap and available fossil fuels, but since the oil embargo of 1973, it has become a viable alternate energy source. The overall wood energy program in Georgia has the potential to develop new markets, become less dependent on imported fuels and upgrade our forest to meet future demands.

INTRODUCTION

Georgia, the largest state east of the Mississippi River, is truly blessed with its abundant forest land. At present, there are 24 million acres of commercial forest land in the state, averaging one cord per acre per year growth. The total standing volume of all timber in Georgia is estimated to be about 383 million cords. In 1979, Georgia Tech estimated that an equivalent of 48 million barrels of #2 oil annually could be produced from wood on a continuous basis within the state. This paper will address three areas in which wood is available for use in the energy field.

FOREST

Approximately 640,000 acres are harvested annually in the state with a removal of some 14 million cords of timber. With an annual growth of 24 million cords, a surplus of 10 million cords exists within the state. In that it is not practical to utilize all the reserve, it has been estimated that 25 percent or 2.5 million cords could be used in energy production on a continuous basis.

In most conventional logging operations, cull trees and trees less than five inches dbh are not economical to harvest. In most instances, small and cull stems are destroyed during logging practices or in site preparation. In addition, only the main stem to a merchantable top is utilized with crown material remaining in the woods. An estimation of average green tons of logging residue and trees left standing following a conventional harvesting operation in Georgia is as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Tons/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine Type</td>
<td>22</td>
</tr>
<tr>
<td>Pine/Hardwood Type</td>
<td>38</td>
</tr>
<tr>
<td>Hardwood Type</td>
<td>42</td>
</tr>
</tbody>
</table>

These figures are a statewide average and may vary in specific locations.
While the harvesting of small diameter stems may not be economical at the present, thirty percent of the total standing volume is categorized as five inches or less in diameter. The potential as an energy source exists when the market demand increases. The harvesting of small diameter timber offers one method of improving existing forest stands.

An estimated 35 million cords of cull timber exist in the state and can be classified as non-merchantable due to form or species except for energy use.

PLANT RESIDUE

The increasing cost of industrial fuel has made many wood residues more attractive as fuel substitutes. A 1978 survey of wood using industries in the state indicated that 78 percent of all bark was being utilized as a fuel source.

Based on data collected, approximately 10.3 million tons of residue --bark, slabs, sawdust, shavings, etc.--were produced at primary wood-using plants in Georgia. The survey indicated that 3.7 million tons were utilized as fuel, 5.7 million tons were used in other products such as particleboard, charcoal, and fiber products. The remaining residue --approximately 900,000 tons--was classified as not used. The unused residue is available for use in the energy field and one could expect that as price and demand dictate, the residue in other categories could become available as energy wood. Sawmills as well as various wood-using industries can be found throughout the state offering access to the various mill residue.

URBAN LANDFILL WASTE RESIDUE

The urban landfill offers another source of wood residue that has the potential in the energy area. In the summer of 1977 and 1978, a survey was conducted by the Georgia Forestry Commission personnel to determine the amount of urban wood residue going into the landfills in the Atlanta metropolitan area.

Wood material coming into the landfills was categorized as junkwood, brush, roundwood, stumps and chips. It was observed during the study that approximately 1,500 tons of wood material came to the various landfills with 57 percent classified as junkwood.

Granted that problems exist when considering this type material, such as contamination, scattered sites, fluctuation in volume, but it can
play its role in the overall energy program. In addition to providing a small energy source, this material, if utilized, can reduce landfill area required to bury this bulky material.

SUMMARY

Wood has played a significant role in the development of our nation and state and will continue to do so in the utilization of wood as an energy source. The availability of wood for energy can be found in our forest, wood-using industries, as well as urban areas. To what extent the material is available will depend upon our "supply and demand" theory.

It is evident that the resource exists now. Also, there is no reason to doubt that the resource will be available in the future. By upgrading our existing stands, reforestation of idle acres, and sound forestry practices, we can meet the future demands of the pulp industries, sawmills, various wood related industries, and the energy field.
WOOD GASIFICATION SYSTEM
FOR THE
NORTHWEST REGIONAL HOSPITAL

by

James F. Jackson
Department Manager
Wood Energy Systems

Applied Engineering Company

Presented at
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia
Mr. James F. Jackson is a West Point graduate with over five years active military duty. His industrial experience includes an eight year tenure with Combustion Engineering working on heat recovery and thermal oxidation products. Presently he is the Department Manager for Wood Energy Systems at Applied Engineering Company. His department performs feasibility studies determining the best alternative energy system for a particular application and designs and develops advanced gasifier systems.
WOOD GASIFICATION SYSTEM
FOR THE
NORTHWEST REGIONAL HOSPITAL

ABSTRACT

The demonstration report of a wood gasification system providing the heat energy for a water tube boiler is the subject of this paper. The project, undertaken jointly by the Georgia Forestry Commission, the Georgia Institute of Technology, and Applied Engineering Company, was designed to demonstrate a "state of the art" technology for the use of wood energy at a state installation. This site, a 19,000 lb/hr gas/oil boiler at the Northwest Georgia Regional Hospital in Rome, Georgia, was retrofitted with a 25 million Btu/hr fixed bed updraft wood gasification system. The unit was in a test run mode of operation beginning in March of 1980. When fully operational in the summer of 1981, it began to lower the hospital's dependence on oil and natural gas while helping to provide a new market for low-grade hardwood chips in North Georgia. The evolution of the project design, start-up details, operational history, and projected economics of the system are discussed.

PROJECT BACKGROUND

In 1978, the Georgia Forestry Commission initiated a program to demonstrate the value of wood as a practical and economical energy source for commercial and institutional applications. The Commission retained the Technology Applications Laboratory of the Georgia Institute of Technology to provide engineering assistance, and following feasibility studies and site surveys, it was decided to construct a wood gasification system to fuel a boiler at the Northwest Regional Hospital in Rome, Georgia.

The hospital steam plant has three 19,000 lb/hr watertube boilers to provide steam for space heating, the institutional laundry, and for an absorption-type air conditioning system. There is a constant annual steam demand at the facility with peak demand never more than 30,000 lb/hr--leaving one boiler always on standby status. The boilers were able to burn either natural gas or No. 6 fuel oil, depending on cost and availability.

The specifications prepared by the Forestry Commission and Georgia Tech called for the conversion of one 18-year old boiler to wood gas fuel, based on the following criteria: the system has to utilize green wood (50% moisture) as a feedstock, existing boiler equipment was to be retained as far as possible, full 19,000 lb/hr steam output was to be achieved, and the
system was to be operational at least 3,000 hours per year. A bidders list was prepared and several proposals were submitted by interested firms. Following design reviews and subsequent negotiations, a contract was awarded in the spring of 1979 naming Applied Engineering Company (APCO), of Orangeburg, South Carolina, as the designer and manufacturer for the project.

WHY GASIFICATION?

Gasification was chosen over more conventional direct firing of wood for a number of important reasons:

1. Space considerations
2. Absence of pollution control problems
3. Flexibility of fuels used
4. Advancement of the "state of the art" of wood gasification

Space, in an existing installation, is often something that is at a premium. Such was the case at the N. W. Regional Hospital. There was no way that any of the boilers could be retrofitted with an enlarged or add-on combustion chamber. There was, however, adequate space outside the facility for the gasifier vessel and fuel handling system.

Direct firing also required particulate collection equipment to satisfy pollution control laws. The expense and operating problems of this equipment could be eliminated with the use of gasification.

SYSTEM DESIGN

The overall wood gasification system is shown in Figure 1. The fuel for the gasifier is green total tree chips (mixed hardwoods and softwoods) trucked in from North Georgia logging sites in standard chip vans. This material is predominately chips of 2" by 2" mixed with some pine needles, leaves, twigs, and bark. It has a moisture content of approximately 40% to 50% and a net heating value of approximately 4,000 to 4,500 Btu/lb.

The chip trailers are unloaded with a hydraulic tipping system into a live bottom pit. This pit transfers the wood via drag chain to an included conveyor that fills a storage silo. The silo (approximately 20,000 cubic feet) will allow for 3½ days operation, 24 hours per day at full boiler load. This will provide for long weekends or other temporary interruptions of chip delivery.
WOOD GASIFICATION SYSTEM
NORTHWEST REGIONAL HOSPITAL
ROME, GEORGIA

Figure 1
The silo contains a bottom unloader, feeding a reclaim conveyor that transports the chips to the top of the wood gasifier. The gasifier requires a maximum input of approximately 25 million Btu/hr, which provides enough energy to produce 19,000 lbs/hr of steam when the losses within the gasifier and within the boiler are considered. Full load operation requires an infeed rate of approximately 3.1 tons of wood chips per hour.

The gasification equipment is located outside the boiler house and is composed of the following equipment items (see Figure 1 and Figure 2 for equipment locations):

**Vessel**

The reactor vessel itself is cylindrical in shape, insulated with firebrick and enclosed in a carbon steel shell. The area around the grate is water cooled and there is a two foot diameter pressure relief port at the top of the reactor which functions in the unlikely event of an overpressurization of the vessel.

When in operation, air is injected into the bottom of the reactor and fuel is added into the top. The gases produced by this reaction exit from the top and the ash is discharged from the bottom of the vessel.

**Chip Fuel Distribution**

A rotary valve on top of the reactor vessel meters fuel into the vessel as well as forming a seal preventing the gases from escaping to atmosphere. A rake system is used to continuously stir the top layer of chips to insure even distribution and eliminate channeling and other irregularities within the vessel.

**Grate**

The grate which is located above the ash hoppers serves the dual purpose of uniformly injecting air into the reactor vessel and breaking up any clinkers that the gasification reaction might produce. The grate is of a proprietary design and is based on proven gasification technology.

**Ash Removal**

The ash is removed by activating a grate/ash hopper which causes ash to dump into a pressurized storage compartment for subsequent removal. Temperature profiles in the ash bed are used to determine when ash should be dumped. A decreasing temperature in the bed indicates an ever higher
Figure 2
C-15
ash bed and dumping is initiated until grate temperatures rise to a preset point.

Flare

During start-up, shutdown or a flame failure, a flare is used to safely dispose of the gas that is produced by the gasifier.

Generally, the flare is used when starting up the gasifier until a quality gas is produced and then the gas is put on-line and effectively burned to supply heat to the boiler.

During shutdown, gas is diverted to the flare and all lines that had been carrying the gas are safely purged.

Burner

The APCO system is a fully integrated one and comes complete with a burner capable of burning the low Btu gas and any condensed tars/oils/liquids that are produced. The burner will also burn natural gas as an auxiliary fuel. A collection tank is located ahead of the burner to separate the entrained liquids from the wood gas. The liquids are pumped separately to the burner and atomized, achieving complete combustion with the wood gas flame.

PERFORMANCE

The gasifier vessel is a fixed bed updraft design which is the easiest to operate and the most reliable. As shown in Figure 2, wood chip fuel is fed in at the top with process air piped in at the bottom through the grate system.

In this design, a fire is started above the grate with approximately 25% of theoretical air supplied to this hot zone. The heat thus generated drives the volatiles out of the wood and through several zones as shown in the figure, where the primary constituents of the gases are formed. A typical gas composition based on actual unit test data is shown below:
N₂ (Nitrogen & N Compounds) 50% by Volume
CO 30%
CO₂ 7%
HC (Oils & Tars) 3%
H₂ 10%
Heat Content (Dry Basis) 150-165 Btu/ft.³
H₂O (Vapor) Variable depending upon moisture content of feedstock

The hot gases produced by the gasifier give up much of their heat to dry the infeed material as the gases leave the vessel. The exiting gas is relatively cool, typically 200°F., making it easy to transport the gas and separate the gas and liquid phases.

The system has been successfully fired at rates of from 6,000 lb/hr steam to 20,000 lb/hr steam, demonstrating that there is no de-rating of a conventional boiler when retrofitted to fire wood gas. Continuous monitoring of the boiler stack oxygen levels confirms that the combustion of wood gas may be closely controlled. Typical readings indicate an excess oxygen range of from ½% to 2%, corresponding to 5%-15% excess air rates. This represents combustion efficiencies comparable to a conventionally fired boiler. There is a significant improvement over the general efficiencies of a direct fired system which typically operates at a 50% excess air ratio.

ECONOMICS

A typical wood gasifier retrofit system consists of both gasification and fuel handling equipment. The gasifier is coupled to an existing boiler requiring only a burner modification or replacement. Current costs of both equipment and fuel are used for the evaluation. Tax credit allowances are factored in.
Asumptions:

Overall Retrofit System Efficiency 70%

Capacity 25MM Btu/hr (Gross) = 19,000 #/hr Steam

Retrofitted System Cost $600,000
Less Tax Credit (20%) 120,000
Net Cost To Owner $480,000

Conventional Fuel Cost $0.90/Gal.
Yearly Expense (7000 Hrs @ an Average 60% Load) $605,000

Wood Chip Fuel Cost $16/Ton
Yearly Expense (7000 Hrs @ an Average 60% Load) $212,000

Additional Gasification Costs
Cost of Capital ($600,000 18.5% for 10 Years) $132,000
Maintenance 36,000
Electricity 12,000
Labor (1/2 Man Yr.) 12,500

Total Yearly Gasification Operating Costs Including Fuel Cost: $404,500

Yearly Savings $200,500
Payback $600,000 = Less Than 3 Years
$200,500
CONCLUSIONS

Wood gasification has been proven to be a viable and cost effective alternate energy system. Its economic benefit will improve as the cost of conventional fuels increases due to inflation and deregulation.

The combustion characteristics of an integrated wood gas system allows full boiler capacity to be maintained and provides turn down capabilities of 3:1.

Second and third generation units will increase the mechanical integrity while lowering the overall costs of the system. Wood gasification will be a definite part of our Nation's changeover to alternative fuels.
A SURVEY OF GEORGIA'S TEXTILE INDUSTRY FOR WOOD GASIFIER APPLICATIONS

by

Thomas F. McGowan
Michael L. Brown
R. Lynnard Tessner
Technology Applications Laboratory

Georgia Institute of Technology
Engineering Experiment Station

Presented at
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia
Mr. McGowan received both his bachelor's and master's degrees in Chemical Engineering from the Manhattan College. As a research engineer at Georgia Tech, he has been actively involved in residential, commercial, and industrial wood combustion systems. Specific projects included the design and construction of a half million Btu/hr wood gasifier, production of training manuals and seminars on safe installation and use of wood stoves and furnaces, and production of a study on industrial wood fuel processes. Other projects included the production of a manual and lecture series on energy conservation and marketing energy conserving homes for builders and contractors. Mr. McGowan was also the founder of Sunbelt Technology, a consulting firm specializing in energy and solar energy projects.
INTRODUCTION

Wood appears to offer considerable potential as an energy source in regions where it is plentiful. Studies have indicated that between 69% and 92% of the 1977 industrial energy consumption for the State of Georgia could be met with wood if timberlands were managed properly. In this situation, the problem would not be finding wood fuel but utilizing it correctly for a particular process. Past experience has shown that industrial users are more likely than commercial or residential users to tolerate the minor inconveniences created and use wood because of the highest cost saving potential. In Georgia, because they use over 16% of the total industrial energy consumption, textiles offer a valid standard by which to study the potential impact of industrial wood energy consumption. The purpose of this study is to determine the size of the market for indirect wood utilization methods like gasifiers by surveying the dryers and boilers currently in use. Additionally, a case study of wood energy equipment for a typical plant was performed.

TEXTILE INDUSTRY ENERGY USAGE

Like most other industries, the textile industry has developed a number of wasteful energy habits during the era of cheap oil and gas. It seems universal that everyone in the textile industry wants a dryer to be ready for use almost at the instant it is turned on, even when it is started up only once a week. Insulation is skimpy and poorly used. One dryer manufacturer stated that only enough insulation was used to drop the temperature of the outer surface to around 220°F because this prevented condensation from forming which could rust out the insulation panels. While it does save the panels, the energy costs associated with the insufficient insulation are very large. Another waste of energy is the nearly universal practice of exhausting all of the hot, humid air resulting from dryer use to the atmosphere instead of running it through a heat exchanger. Reasons for this are given as lint problems and cost. However, as the cost of the most common dryer energy source - natural gas - continues to increase, the cost of dumping heat in any form will increase to the point that heat recovery will become an economic necessity. The days of cheap energy are rapidly drawing to a close, and the wasteful habits fostered by cheap energy must be replaced by strong conservation measures. It appears that the technology is available; it only remains for the wise to put it to use.
Conservation, while certainly a step in the right direction, may not be sufficient to solve all of the textile industries energy problems. Textile firms use vast quantities of energy for dyeing and drying textiles. In most of the southeast, the main source of that energy is natural gas because it is very clean and in the past was reasonably priced and readily available. It now appears, however, that gas will remain in tight supply and cost more due to deregulation. The causes are at least twofold: seasonal shortage of gas and inadequacy of the distribution network.

The time appears right for the investigation of alternate to natural gas for fabric dyeing and drying. As of early 1981, no oil or natural gas has been produced in the State of Georgia, although oil does seep to the surface in the state. From time to time, Georgia has produced small quantities of coal but, the only sizable source of energy in Georgia is the wood grown in its forests and some hydroelectric power. Low Btu producer gas made from wood or other biomass feedstocks offer a solution to the problems of natural gas cost and availability.

GASIFIER TYPES AND APPLICATIONS

While there are many types of gasifiers capable of producing low Btu gas, the most common ones are the downdraft and the updraft gasifier. A new concept that appears to offer a number of potential improvements is the fluidized bed gasifier. A final bed geometry seen in some instances is the crossdraft configuration. The four different gasifier types are illustrated in Figure 1.

The fluidized bed gasifier offers the advantage of a smaller reactor size with a high throughput. The gas produced also has a higher Btu content than do the older up-or-down draft gasifiers. The tars normally produced by older designs are present in much smaller quantities because a large percentage are cracked. Disadvantages of fluidized beds include the large amount of energy which must be used to fluidize the bed, and the bed container itself is also subjected to abrasion and high temperatures. While the technology of the fluidized bed gasifier appears to be developed, extensive application has not occurred. Downdraft gasifiers are more compact and produce gas with less tars, but they are limited to operation on wood with less than 30% moisture. Crossdraft gasifiers also have high outputs per
Figure 1

BED GEOMETRY IN WOOD GASIFIERS

UPDRAFT

FUEL

GAS

AIR

ASH

DOWNDRAFT

FUEL

AIR

GAS

ASH

CROSSDRAFT

FUEL

AIR

GAS

ASH

FLUIDIZED BED

FUEL

GAS

ASH

AIR

C-24
square foot of grate area, but they have not received wide application due to problems encountered from the burnout of the inlet nozzle from overheating. As a result, Georgia Tech's efforts are and have been along the line of the more widely tested and used updraft gasifier.

If the textile industry of Georgia is to successfully tap the forest energy reserve, a technically and economically feasible energy system must be found. One method for the utilization of wood is developed to a commercial level - wood fired boilers. Wood boilers, produce steam, and are not always compatible with equipment fired directly with gas and oil. While they may be the proper equipment choice if a new boiler is planned, wood boilers are not suitable for interfacing with direct fired dryers. A wood gasifier retrofit would be able to fire an existing gas/oil package boiler with a modified burner, and they may be able to supply low Btu gas for use in direct fired dryers.

The cost of a retrofit wood gasifier system is clouded by variables that are unique to wood gasification. These include existing system age, gas Btu content, gasifier location, and other variables common to any energy system, such as fuel cost, supply and demand interaction, cost of capital, insurance and equipment. Past studies have shown that wood gasifiers have the potential of being cheaper than wood boilers in many instances.

The market for a retrofit gasifier is, like any other industrial product, controlled by cost. The exception would occur only if all other forms of energy were unavailable. During the energy shortage of the 70's, many companies found that payback and cost have little meaning when the choice was to find an energy source or shutdown. Companies now have equipment that can use oil, natural gas or propane so that the shortage or lack of one fuel will not close down the plant.

SYSTEM CONFIGURATION

The major markets which this survey addressed as potential gasifier applications were dryers and boilers. Several configurations for the utilization of gasifiers for these applications are possible (Figure 2). For reasons of efficiency, a gasifier should be close-coupled to a dryer or boiler whenever possible. Close-coupling of a gas producer and consuming appliance allows the gas to be used directly without cleaning. If the gasifier cannot be close-coupled to the burner, the producer gas must be cleaned. Cleaning the gas also cools it so
Figure 2

TEXTILE GASIFIER SYSTEM CONFIGURATIONS

A) Direct Fired - CloseCoupled

B) Direct Fired - Remote, With Cold, Clean Gas

C) Indirect Fired - Via Heat Exchanger

D) Indirect Fired - Via Steam Boiler
some efficiency is lost. Another arrangement permits use of gas without cleaning by employing a heat exchanger to warm the air going to a dryer. A last method of using gasifiers indirectly is firing a boiler and using the steam in a dryer.

In order to use producer gas on a dryer of, say, 120-foot length, the gas would have to be cleaned and manifold-fed to the six burners that normally heat such a dryer. If the company desired to have almost instant start on the dryer, the burners would have to be started on natural gas or propane because it may require 30-45 minutes to start up a cold gasifier. Also because of the slow response time (3 to 4 minutes) of a gasifier, it may be necessary either to feed the dryer at a lower rate when changing throughput, or some type of anticipator signal may have to be supplied to the gasifier controls. Of course, the gasifier could be used to supply the dryer base load with natural gas used to respond to the swings in demand.

Steam-heated dryers may prove to be easier to control and operate with a gasifier since the thermal lag in such a system more closely approaches that of a gasifier. The steam-heated dryer would normally allow a gasifier to be close-coupled which would raise the system efficiency.

TEXTILE INDUSTRY SURVEY

The textile firms of Georgia listed in the Georgia Manufacturing Directory were screened to remove the very small firms (less than 10 employees). The remaining firms were then sampled to determine their interest in a wood gasifier retrofit system.

An overview of the survey is presented in Table 1. The majority of the firms included in the survey were involved in fabric production. They were followed by carpet and rug, yarn, sheet, spread, and drape manufacturers. Though the product range of the firms was wide, Table 1 also illustrates that the equipment they use is similar. All the firms surveyed have a boiler in their plant and almost half have dryers or ovens.
### TABLE 1. SURVEY OVERVIEW

**Classification of Surveyed Companies by Product**

<table>
<thead>
<tr>
<th>Product</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparel Fabric</td>
<td>36%</td>
</tr>
<tr>
<td>Carpet and Rug</td>
<td>19%</td>
</tr>
<tr>
<td>Yarns</td>
<td>15%</td>
</tr>
<tr>
<td>Sheets, Spreads, &amp; Drapes</td>
<td>15%</td>
</tr>
<tr>
<td>Underwear &amp; Hosiery</td>
<td>10%</td>
</tr>
<tr>
<td>Other</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Equipment in Use**

- Boilers - 100%
- Dryers - 49%
The survey yielded in-depth data on energy consumption at the selected plants. The distribution of boiler sizes found at the plants is shown in Figure 3. This quantity represents a sum of the total nameplate rating for each location. Almost half, 43%, of the plants had installed boiler capacities in the range between 5,000 and 25,000 lb/hr. A second large size category was the 25,000 to 50,000 lb/hr range which included 23% of the surveyed plants. The remaining 34% of the plants had installed boiler capacities distributed in four other size range categories. Table 2 presents the primary fuel used by boilers included in the survey.

TABLE 2. PRIMARY BOILER FUEL CURRENTLY IN USE

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>84%</td>
</tr>
<tr>
<td>Coal</td>
<td>10%</td>
</tr>
<tr>
<td>Oil</td>
<td>5%</td>
</tr>
<tr>
<td>Wood</td>
<td>1%</td>
</tr>
</tbody>
</table>

As expected, the fuel used in the majority of the boilers surveyed was natural gas. In addition to gas, fuels used to a lesser extent were coal, fuel oil, and wood.

Data developed for dryers used in the textile industry is shown in Table 3. Most of the dryers and ovens currently in use were found to be direct fired with natural gas. The plant total heat input for those firms with gas dryers is shown in Table 3B. Over half of the plants with gas dryers had inputs of 5 million Btu/hr or less. The second largest class of dryers with 28% of the plants had consumption of over 15 million Btu/hr.

The data obtained on boiler size, dryer type and size, and energy consumption in the textile industry in Georgia can be used to develop marketing information for wood gasifiers. The largest potential use for gasifiers would be to supply alternate gaseous fuel to gas/oil package boilers. The optimum size of such a unit would be in the 5,000 to 75,000 lb/hr range. This segment includes approximately 78% of the textile boiler population. Most of the dryers in the survey were found to be direct fired with natural gas. Thus, a wood gasifier could potentially supply fuel to a large portion of the dryers used in the textile industry. The optimum size of gasifier units for dryers would be sized either small (below 5 million Btu/hr) or large (over 15 million Btu/hr). Since the mid-range size accounts for only 15% of the
Figure 3

BOILER SIZE DISTRIBUTION

<table>
<thead>
<tr>
<th>SIZE</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>6%</td>
</tr>
<tr>
<td>5-25</td>
<td>43%</td>
</tr>
<tr>
<td>25-50</td>
<td>23%</td>
</tr>
<tr>
<td>50-75</td>
<td>12%</td>
</tr>
<tr>
<td>75-100</td>
<td>8%</td>
</tr>
<tr>
<td>&gt;100</td>
<td>8%</td>
</tr>
</tbody>
</table>

Boiler Steam Capacity - 1,000 lbs/hr

TABLE 3. DRYER DATA

A. Type Dryers Used

Gas Fired (Direct) 84%
Steam Heated (Indirect) 16%

B. Gas Dryer Heat Input

Below 5,000,000 Btu/hr 57%
5 to 15,000,000 Btu/hr 15%
Over 15,000,000 Btu/hr 28%
Based on the quantity of boilers and dryers uncovered in the study and their associated size, insight into the potential market and optimum output of gasifiers is provided.

Further insight into the potential gasifier market was developed from the survey. The firms were sampled to determine their interest in a wood gasifier retrofit system. Some companies, while interested, did not have a wood storage area and thus could not consider using wood. Other firms did not want to even consider using wood because of preconceived wood shortages or fire hazards.

A sincere interest in using wood in some manner was expressed by 70% of the firms screened. One company, in fact, had purchased 5.7 acres of land adjacent to the plant for the express purpose of having a woodyard for a wood gasifier. This same company is equipped to use oil, natural gas, and propane.

If the percentage of those firms contacted which expressed an interest in wood gasification is applied to the total from which the sample was taken, it appears that 331 companies in Georgia may be interested in installing a wood gasifier. The same percentage was applied to the manufacturers in Alabama, South Carolina, and Florida, and it appears that possibly as many as 395 companies in these adjacent states may be potential users of wood gasifiers.

Because of location and local competition for waste wood, some areas of the four-state area may not have available mill waste which would normally be considered the "ideal" low cost wood fuel. In such cases, the use of higher value wood fuels would be required. The high cost of this wood is balanced by its more predictable availability which, in times of energy shortage, may mean the difference between being in business and having to close for lack of energy.

The price of mill waste is usually low but such waste may require sizing before use in a gasifier. Generally, whole tree chips will not require the use of sizing equipment. Once the chips are delivered to the plant, they must be handled with a minimum of labor and minimal exposure to weather. Small, low-capital systems may manage with a front-end loader on a concrete pad running a single shift gasifier, but such systems would have only limited application. Most industrial plants will require a more capital intensive system which would allow 24-hour boiler operation seven days a week.
CASE STUDIES

Since the range of boilers and dryers which can be retrofitted with a gasifier is large, two companies have been selected for detailed case studies. The case studies include data on wood storage, wood system cost, and energy savings. The wood storage requirement was formulated based on the particular plant's operating schedule and energy usage. The capital cost of the wood gasifier and ancillary equipment can be estimated with fair accuracy from information on similar systems. Interest rates and tax credits used in the economic evaluation are in a state of flux and as such are subject to wide change. For this study, a capital cost of 16% will be used. Since tax credits occur after the fact, they will not be included in the calculations, but will be noted as a shelter of capital.

While many combinations of wood storage, handling, and gasification equipment are available, the study represents the selections that best fit the needs of each of the companies. Other plants may require different sets of equipment.

CASE I

Stratton Industries in Cartersville, Georgia, is a manufacturer of carpets. The Stratton plant has a 1,500 hp Keystone watertube boiler. The boiler normally runs at approximately 900 hp. At present, the boiler can be fired with natural gas or with No. 5 oil. The boiler is located close to an outside wall allowing the use of a close-coupled gasifier. At present, there are two large 20,000 gallon and 30,000 gallon oil tanks on a 22' x 44' pad located in such close proximity that it may be necessary to relocate them or install a firewall to separate them from the gasifier.

Adjacent to the building site is a 5.7 acre lot which can be used for wood storage and wood processing; in fact, the land was purchased for the express purpose of serving as a wood storage yard. The tract is covered with small bushes and young, 2" to 4" trees. Presently the western end of this lot is used as a turnaround for the oil delivery truck. The company was hard pressed by the energy shortages of the early 70's and has sought to prevent a recurrence of shortages experienced at that time. The addition of the ability to use wood to power the plant is added insurance against being closed down by another energy shortage.
If the use of wood also makes it possible to reduce energy costs, the company's competitive position will be improved as well.

Stratton's work schedule is normally 6 days per week. Because of their schedule, automatic silo storage can be limited to 18 hours of supply. A wood supply operator could fill the silo to last through the night. Additional fuel could be held in an uncovered open storage area. It would seem reasonable to store from a 3 to 5 day supply of chips in summer. Normally, chips would not be delivered on Saturday—a company work day—which would then leave only a 2 to 4 day supply. Since 2 days of rain is a very common occurrence, a full 5 days' supply would seem necessary to avoid frequent outages. In the winter months which are frequently wet also, a larger supply would seem appropriate as that is when the use of oil is most frequent. In the months of November through February, a 10 day supply would make more sense as the cost of using oil is much higher than the cost of gas.

At an average output of 900 hp, the gasifier will consume 86 tons in 18 hours. A 10,000 ft$^3$ capacity silo holds approximately 100 tons of fuel which is slightly over 18 hours of storage. An area 10,000 ft$^2$ with a pile height of 12 feet can store a 10 day supply. Therefore, a 10,000 ft$^2$ concrete pad has been specified for open storage. These two storage options are considered the minimum amount which would be adequate for day-to-day operation. Frequently, 3 days of wood fuel are kept in covered storage for 7 day operation of the boiler to allow for 3 day weekends. Some companies use 30 to 90 day open storage which increases inventory costs but allows more freedom in purchasing fuel. The major equipment needed for this system and its associated cost is shown in Table 4.

**TABLE 4. CAPITAL EQUIPMENT FOR STRATTON INDUSTRIES GASIFIER**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasifier, 900 hp size</td>
<td>$600,000</td>
</tr>
<tr>
<td>Pit and screw conveyor</td>
<td>35,000</td>
</tr>
<tr>
<td>Bucket conveyor</td>
<td>25,000</td>
</tr>
<tr>
<td>Silo, 10,000 ft$^3$</td>
<td>60,000</td>
</tr>
<tr>
<td>Gasifier feeder conveyor</td>
<td>30,000</td>
</tr>
<tr>
<td>Concrete pad, 100' x 100'</td>
<td>13,000</td>
</tr>
<tr>
<td>Front-end loader</td>
<td>25,000</td>
</tr>
<tr>
<td>Truck dumper</td>
<td>100,000</td>
</tr>
<tr>
<td>Ash containers</td>
<td>25,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$890,000</td>
</tr>
</tbody>
</table>

C-33
Because the company does not have separate meters on the natural gas used for heating the plant and firing the boiler, it must be assumed that the boiler is run approximately one-half the time on oil and one-half the time on gas. The assumption is conservative because the consumption amounted to more than half the total energy input needed to run the boiler and oil is used exclusively in the boiler.

If the boiler is run at 900 hp from the gasifier and oil or natural gas is used to shave the peaks, then the 900 hp load would require:

\[
900 \text{ hp} \times 34.5 \text{ lb/hr/hp} \times 1,000 \text{ Btu/lb/hr} \times 24 \text{ hr/day} \\
\times 6 \text{ day/week} \times 50 \text{ weeks/year} = 2.23 \times 10^{11} \text{ Btu/year}
\]

Assuming that the efficiency of the boiler is 80%, the energy requirement is \(2.78 \times 10^{11}\) Btu/year. If half of the energy input is oil:

\[
1.39 \times 10^{11} \text{ Btu} = 992,800 \text{ gallons oil and 138,000 MCF of natural gas}
\]

The cost at mid-1981 prices would be:

\[
\begin{align*}
992,400 \text{ gallons} & \times .871\%/\text{gallon} = \$ \, 864,000 \\
139,000 \text{ MCF} & \times \$3.20/\text{MCF} = \$444,000 \\
\text{TOTAL} & = \$1,308,000
\end{align*}
\]

If the same amount of energy is supplied by a gasifier operating at 90% efficiency, the requirement of energy would rise to:

\[
1.39 \times 10^{11}/.90 = 1.54 \times 10^{11} \text{ Btu}
\]

The energy would be contained in

\[
1.54 \times 10^{11} \text{ Btu}/4,500 \text{ Btu/1b} \times 2,000 \text{ lb/ton} = 17,100 \text{ tons/year}
\]

Whole tree chips sell for $14/ton to $15/ton, depending on tree type and handling distance. Thus the cost of wood chips would amount to:

\[
17,100 \text{ tons/year} \times \$15/\text{ton} = \$256,500
\]
The fuel savings that would result should amount to:

- Oil and gas $1,308,000
- Less whole tree chips $256,500
  $1,051,500

Since the wood gasifier would cost more to operate than a conventional boiler, the resulting savings will be reduced somewhat. Operating costs include system maintenance, electricity, and labor to operate the gasifier. Yearly operating costs for the gasifier were calculated to be $176,600/year. Based on these factors, the simple payback for the system is about 1.25 years. The gasifier economics are summarized in Table 5.

<table>
<thead>
<tr>
<th>TABLE 5. GASIFICATION SYSTEM ECONOMIC SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood required                                  17,000 tons/year</td>
</tr>
<tr>
<td>Wood fuel cost                                $256,000/year</td>
</tr>
<tr>
<td>Gasifier operating cost                       $177,000/year</td>
</tr>
<tr>
<td>Net yearly savings                            $869,000</td>
</tr>
<tr>
<td>Yearly cost of capital (16%, 15 years)         $160,000</td>
</tr>
<tr>
<td>Simple payback                                1.25 years</td>
</tr>
</tbody>
</table>

CASE II

The Modern Fiber-Plant Jay in Fitzgerald, Georgia, has a 300 hp boiler supplying process steam that is used in the production of carpet yarn. The boiler operates on natural gas with oil as backup fuel. Energy consumption figures for this boiler indicate an average steam production of over 200 hp. The company has expressed an interest in using wood if it is economical.

The Jay Plant has a parking lot located next to the boiler which would make an ideal wood storage yard. Because the boiler is small and requires only 1.76 tons/hour of wood, a truck dump would be too costly for this case. A small, skidder-type front-end loader would be used to move all the needed materials and
to unload delivery trucks with the use of a ramp-type truck dock. Since the parking lot is paved, there will be no added costs for open storage.

The nominal 5 day work week at this plant means that a silo capable of holding 18 hours of fuel is adequate. A 300 hp boiler operating at full load will consume approximately 2 tons/hour of fuel; thus, the silo must store about 36 tons of fuel. A 5,000 ft steel silo is capable of holding 50 tons of fuel and would be adequate for this application. The major equipment that must be purchased is shown in Table 6. Because the boiler is heavily loaded in winter due to an increase in demand of steam for heating, a gasifier capable of supplying 300 hp was selected.

<table>
<thead>
<tr>
<th>Table 6. CAPITAL EQUIPMENT FOR MODERN FIBERS GASIFIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood gasifier, 300 hp</td>
</tr>
<tr>
<td>Silo, 5,000 ft$^3$</td>
</tr>
<tr>
<td>Conveyor from pit to silo screw (50')</td>
</tr>
<tr>
<td>Conveyor from silo to gasifier (50')</td>
</tr>
<tr>
<td>Front end loader</td>
</tr>
<tr>
<td>Two (2) ash containers</td>
</tr>
<tr>
<td>Unloading ramp</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
</tbody>
</table>

During 1980, the company did not have to rely on oil at all. Natural gas costs for the plant were approximately $89,120. Gas prices rose at a rate of over 25% during the year from $3.30 in January to $4.25 per million Btu in November. Although gas was used primarily to fire the plant's boiler, a small amount of gas was used in direct fired heaters. For this study, all of the gas purchased will be assumed to be used in the boiler. Based on the 1980 consumption of $2.7 \times 10^{10}$ Btu, the amount of wood necessary would be:
\[ 2.7 \times 10^{10} \text{ Btu} \times \frac{1}{4,500} \text{ Btu/lb} \times \frac{1}{2,000} \text{ lb/ton} \]

= 3,000 tons of wood

The yearly cost of this wood at $15/ton is:

\[ 3,000 \text{ tons} \times $15/\text{ton} = $45,000 \]

Yearly savings from wood fuel become:

\[
\begin{array}{c}
$89,120 \\
-45,000 \\
$44,120
\end{array}
\]

The gasifier operating and maintenance costs are estimated to be $53,000/year. For this case, the wood gasifier operating costs exceed those of the conventional system.

In conclusion, the case studies demonstrate that wood gasification systems can be practical in the right situation. Important factors to keep in mind when considering a wood system include equipment size, yearly hours of operation, the cost of capital, and the relative prices of conventional and alternate fuel. Generally, the larger the system and the greater the utilization, the shorter will be the payback. It must be kept in mind that a reliable long lasting gasifier is paramount in conversions such as this, and given the shortage of commercially proven units, the location of a suitable one may still be a barrier.
CONSTRUCTION AND STARTUP
OF A WOOD GASIFICATION PILOT PLANT

by

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Research Engineer

Thomas F. McGowan
P.E., Senior Research Engineer

Technology Applications Laboratory
Georgia Institute of Technology
Engineering Experiment Station

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WOODTECH '81
July 13-14, 1981
Atlanta, Georgia
Mr. Jape received both his bachelor's and master's degrees in Mechanical Engineering from the Georgia Institute of Technology. As a research engineer at Georgia Tech he has participated in a variety of projects, including the acoustic testing and analysis of industrial process plant noise and the mechanization of poultry processing. Mr. Jape is currently engaged in the design, development, and testing of a pilot scale wood gasifier used at a textile drying facility. He has also compiled a manual for the selection and use of low Btu producer gas burners.
Many industries throughout the Southeast, particularly the more energy intensive ones, are seeking a dependable and more cost effective fuel to replace oil and natural gas. Wood is widely available as a replacement fuel, but it cannot be directly substituted in existing gas and oil fired equipment.

The commercialization of wood gasification technology provides the opportunity to utilize wood in equipment originally designed for gas and oil. Gasifiers convert wood into a clean burning and easy-to-handle fuel gas which can be used to retrofit boilers and other equipment which otherwise could not utilize a solid fuel. Potential applications include boilers, kilns, furnaces, fueling of gasoline and diesel engines, use as a chemical feedstock for methanol production, and power production with gas turbines.

With these applications in mind, Georgia Tech undertook the development of a pilot plant for wood gasification research in March 1979. The major goal of the project was to further the state-of-the-art of gasifiers for industrial use. The gasifier and auxiliaries were sized and designed to provide flexible operation and data acquisition to produce design data for later application to industrial equipment. The unit is equipped with a variety of temperature and flow monitoring instrumentation to record important operating parameters during experimental runs. The project was jointly funded by Georgia Tech, the Georgia Forestry Commission, and the Tennessee Valley Authority.

Successful startup of the gasifier took place in May 1980, about fifteen months after the commencement of design work. This paper contains a description of the equipment and experimental procedures employed in the project as well as an analysis of the data collected during the first two experimental runs. It has been condensed from an earlier report which contains much more detailed documentation and raw data.

---

Gasifier Design

The pilot plant was designed as an updraft gasifier with a nominal output of 1 million Btu/hr. The updraft configuration was chosen for its ability to utilize high moisture content fuel, its proven suitability for scale-up to large sizes, and the high probability that many of the proposed industrial size units will be of this type. The unit was sized to provide sufficient energy to operate the various pilot scale test devices that have commercial applications. Examples are burners, boilers, ovens, dryers, kilns, and engines.

The cylindrical carbon steel vessel is lined with 1" of high temperature ceramic insulating blanket and 4 1/2" of insulating firebrick. The interior dimensions are 18" diameter and 70 1/2" high. Figure 1 shows a three dimensional view of the pilot plant layout. Multiple thermocouple ports have been provided to measure peak temperature, study gradients, and extract samples at various positions within the bed.

Principal Features

Air Supply Grid

The gasifier uses an innovative air cooled grid design which uses no grate of any kind. The air necessary for gasification is admitted to the bed through three carbon steel tubes fitted with upturned nozzles. Figure 2 is a construction drawing of the grid section of the vessel. The lower section of the gasifier is filled with ash to a point just below the startup ports, several inches above the grid. The ash is supported by the uninsulated bottom plate and the fuel bed rests directly on the ash layer. The air flow from the grid tubes comes up through the ash and into the bed, allowing combustion to take place at the interface between ash and fuel. During normal operation, the grid tubes are cooled from the air flow and insulated from the combustion zone by the ash. The location of the combustion zone is held constant by the ash extraction system, which removes ash at approximately the same rate as it is produced.

Ash Extraction System

A stainless steel auger, mounted to the bottom plate of the vessel, extends from the vessel centerline radially outward a short distance past the outside diameter of the vessel. A removable tank is mounted to the outboard end of the auger casing to collect and store the ash during operation of the unit. A slowly turning spoked wheel, mounted just above the auger, provides maximum filling of the auger and assures that the ash is removed uniformly so the top surface of the ash layer remains relatively flat. The ash auger drive is actuated by a percentage timer coupled to the feed system so that ash is extracted continuously at the rate it is being produced.
GEORGIA TECH GASIFIER

THERMOCOUPLE LOCATION
0 Vessel, second plug from bottom (left of center)
1 Vessel, upper head
2 Air supply grid, center tube
3 Vessel, bottom plug (right of center)
4 Vessel, fifth plug from bottom (left of center)
5 Gas outlet pipe
6 Inlet air pipe
7 Burner flame

Figure 1
GRID SECTION OF GASIFIER

Figure 2
Feed System

The rate that the gasifier consumes feed is directly controlled by the air flow into the combustion zone. The feed system is completely independent and uses an automatic control system to maintain the bed height at a constant level.

The feed is stored in an unpressurized cone shaped hopper of about 28 cubic feet capacity. The feed is transferred to the gasifier vessel by a 4" agricultural screw auger. As it is currently geared, the auger capacity is about 450 lb/hr of wood pellets. A gas disengaging space of 6 to 8 inches between the top head and the bed is provided to reduce carryover of pellets and particulates into the gas exit piping. This space is maintained by the design of the feed pipe and level detection system. The feed pipe extends vertically about 8½" below the top head of the vessel. When the feed reaches the mouth of the pipe, it backs up the pipe instead of filling the vessel further. The feed system is graphically illustrated in Figure 3.

A radio frequency type level detector is mounted outside the vessel, about 18 inches from the mouth of the pipe, and when the feed reaches the detector, the auger automatically stops. An automatic knife-gate valve is mounted between the level detector and the feed auger to prevent gas from escaping through the feed auger. The valve opens automatically when the auger starts and closes when the auger stops. When the gasifier is operating at 1 million Btu/hr, the auger runs about 30% of the time. The gas leakage when the auger is running is expected to be small due to the long flow path and head pressures of only 1" to 2" w.g. A motor driven stirrer with the blade mounted about 1½" to 2" below the feed pipe maintains a relatively flat top surface on the bed and prevents the downward propagation of voids into the bed. A second radio frequency level detector, mounted about 2" below the stirrer blade, provides a low bed warning signal in the event of a malfunction of the automatic system and allows the feed system to be operated on manual control if necessary.

Feedstock

Wood pellets are currently being used as the fuel for gasification due to their uniformity, ease of handling, and low moisture content. The feed system will handle wood chips up to 1" without modification, and future testing will involve a wide variety of biomass fuels. Table 1 provides data and analysis of the wood pellet fuel.

Steam Addition System

The admission of steam into the high temperature combustion zone of the gasifier provides two beneficial results; the reaction of the steam greatly increases the percentage of hydrogen in the fuel gas being produced, and the endothermic nature of this reaction makes it possible to use the steam to control the maximum temperatures in the combustion zone and improve gasifier efficiency. The hydrogen increases the heating value and the flammability limits of the gas and
FEED SYSTEM DETAIL

FEED AUGER DRIVE MOTOR

4" FEED AUGER

RADIO FREQUENCY LEVEL DETECTOR

KNIFE GATE VALVE

FEED PIPE

STIRRER DRIVE MOTOR

REFRACTORY WITH RETAINER PLATE

STEEL VESSEL

1" THICK CERAWOOL BLANKET

4 1/2" FIRE BRICK INSULATION

STIRRER BLADE

WOOD PELLETS

Figure 3
Table 1
TYPICAL WOOD PELLET FUEL DATA

<table>
<thead>
<tr>
<th>Proximate Analysis</th>
<th>Ultimate Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Volatile</td>
<td>Carbon 44.90%</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>Nitrogen .10%</td>
</tr>
<tr>
<td>Ash Content</td>
<td>Oxygen 39.87%</td>
</tr>
<tr>
<td>Water Content</td>
<td>Hydrogen 4.96%</td>
</tr>
<tr>
<td></td>
<td>Water 9.68%</td>
</tr>
<tr>
<td></td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>99.51%</td>
</tr>
</tbody>
</table>

- 35 lb/ft³
- 7610 Btu/lb
- 8430 Btu/lb
the cooling effect of the steam extends the life of the firebrick lining. To produce the best results, the steam should be dry and its addition rate should be readily adjustable over the necessary range. To achieve optimum results, the system is designed to admit dry steam independently of other control variables. This system is illustrated in Figure 4. Saturated steam at moderate pressure (about 55 to 60 psi) is piped from the boiler to a steam trap which is just upstream of the solenoid control valve. Placing the steam trap as close as possible to the control valve insures that the steam going to the metering valve is saturated and does not contain significant amounts of condensate. When the solenoid valve is activated, the steam passes through the metering valve and into a manifold where it is piped to three nozzles fitted to the bottom head of the vessel. The purpose of the metering valve is to control the rate of steam addition and to further dry the steam. Other than small piping losses, all of the pressure drop from boiler pressure to gasifier pressure (3" to 10" water) occurs across the calibrated metering valve. This pressure drop is sufficient to cause sonic flow in the throat of the valve so the calibration of the valve is not affected by pressure changes in the gasifier vessel and considerable super heat is produced, insuring that dry steam is admitted to the bed.

Temperature Measurement

A variety of ports are located on the vessel for mounting thermocouples or extracting samples from the bed. Figure 1 depicts the location of the ports and the thermocouple locations as used in the initial test runs. The ports are fitted with type k thermocouples and all thermocouple outputs are displayed and recorded by a multiple channel data logger. Probes extending into the high temperature regions of the bed were burned out during the first test run. High purity Alumina thermowells have been fitted to all probes in the high temperature region and tungsten-rhenium thermocouples will be used for future tests.

Safety Devices

The gasifier vessel was designed to be operated at up to 15 psig pressure and is protected by two safety relief devices to provide protection from possible pressure surges. As currently operated, the vessel is pressurized to about 1/3 psig. A 1½" stainless steel pressure relief valve is provided to vent small pressure surges without interruption of the operation of the unit. This valve is currently set to open at 7 psig. A 4" graphite rupture disk, calibrated to rupture at 15 psig, provides pressure relief in the event of a severe pressure surge.

A continuously monitoring carbon monoxide detection system with four remote sensors provides protection against the build-up of poisonous gas around the unit or control station. The four remote sensors are mounted in key areas where personnel are stationed and provide an audible warning in the event that a build-up of carbon monoxide should occur. The gasifier is mounted out-of-doors with all instrumentation
STEAM INJECTION SYSTEM

Figure 4
and controls inside the lab to minimize the possibility of exposure to carbon monoxide.

An annunciator system has been fitted to the control station to alarm any malfunction of the major operating systems to provide safer and easier automatic operation of the unit.

**Initial Startup**

Upon completion of construction, all electrical and instrumentation systems were tested and calibrated and the vessel was hydrostatically tested for leakage and strength. Pressure drop versus flow rate for the empty vessel and grid system was determined. To simulate the presence of ash, the section of the vessel from the bottom plate to the centerline of the grid tubes was filled with dry sand and the space from the centerline of the grid tubes to the bottom edge of the startup ports was filled with vermiculite. Approximately 2" of charcoal was added and the vessel was then filled with wood fuel and the operation of the level detector and automatic feed system verified. A relatively low cost, capacitive type level detector was used, but subsequent use during the initial test run showed it to be inoperative at the working temperature of the gasifier. It has been replaced with a radio frequency type that is not temperature sensitive.

Pressure drop versus flow rate was measured for the full vessel to provide baseline data to later evaluate possible plugging of the grid ports or slagging and caking of the ash.

Theoretical calculations were made relating air flow to gasifier output to provide a starting point for setting the controls. It was decided to operate the unit at about 300,000 Btu/hr for the initial test run and the controls were set accordingly.

The gasifier is started by inserting a lighted safety flare into each startup port. A small airflow through the gasifier is obtained by operating the combustion air blower which creates a draft of ½" to 1" w.g. on the gasifier via the burner. The flares are removed and the ports capped after 3 to 5 minutes. The gas valve is then closed, the vent valve opened, and the process air blower is started. During the warmup period, an Orsat analyzer was used to monitor the gas composition at 15-minute intervals. The carbon monoxide level rapidly exceeded the 10% limit for the single contact pipet, but the tests were continued to monitor the oxygen content. The continuously decreasing oxygen content showed that the reaction was proceeding properly and the burner was lighted when the oxygen level dropped to 2%. The vent valve was closed while simultaneously opening the gas valve and the flame was lighted with a standard natural gas pilot.

The gas burned with a stable flame that was almost completely invisible in the daylight. The unit operated very well overall, and the grid system required almost no adjustments during the test and the bed pressure drop remained essentially constant. Approximately 4 hours after starting the unit, shutdown procedures were initiated. The gas valve was closed and the vent valve opened to extinguish the flame. The feed system and the blowers were shut down, causing gas production to decrease to a very low level within a few minutes.
Bottled nitrogen was fed into the grid system to prevent heat soakback from overheating the tubes. This was maintained at a low flow rate for approximately 2 hours.

**Results**

A total of 3 test runs of about 4 hours duration each have been successfully completed. These have proved that all systems operate properly, the unit is easily started and shutdown, and have provided some gas samples for analysis. Table 2 provides gas compositions and analysis of the first two test runs.

The temperature measured at the interface between the firebrick and the combustion zone of the bed rose rapidly after startup and became stable at 1500°F to 2000°F, depending on gasifier output. The temperatures inside the combustion zone were too high to measure with type k thermocouples.

**Current and Future Work**

The gasifier is currently being configured for a series of textile drying tests to determine its suitability for the direct firing of textile drying ovens. A hot gas takeoff and automatic control system has been designed, constructed, and fitted to the gasifier. The system will power a small batch type drying oven. A variety of fabric samples, chosen to be representative of regionally produced materials, will be tested for color variation, particulate deposits, and mechanical properties against electrically dried control specimens.

Future projects include a thorough evaluation of the effects of varying operating parameters such as steam addition rate, bed temperature, air rates, fuel composition and fuel moisture content on output, testing and evaluation of internal combustion engines operated on producer gas, and pressurized operation of gasifier for gas turbine operation.
## RESULTS AND ANALYSIS OF TEST RUNS

### Feed Consumption:

<table>
<thead>
<tr>
<th></th>
<th>Run 1</th>
<th>Run 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed added during run</td>
<td>152 lbs</td>
<td>389 lbs</td>
</tr>
<tr>
<td>Feed required to refill vessel</td>
<td>145 lbs</td>
<td>(unknown, assumed small)</td>
</tr>
<tr>
<td>Total feed consumed</td>
<td>297 lbs</td>
<td>389 lbs</td>
</tr>
<tr>
<td>Total length of run</td>
<td>4.75 hr</td>
<td>4.95 hr</td>
</tr>
<tr>
<td>Steam addition rate (intermittent)</td>
<td>13.5 lb/hr</td>
<td>13.5 lb/hr</td>
</tr>
<tr>
<td>Average feed consumption</td>
<td>62.5 lb/hr</td>
<td>78.6 lb/hr</td>
</tr>
<tr>
<td>Maximum feed consumption (EST)</td>
<td>----</td>
<td>138 lb/hr</td>
</tr>
<tr>
<td>Average energy input (wet basis)</td>
<td>475,000 Btu/hr</td>
<td>598,000 Btu/hr</td>
</tr>
<tr>
<td>Maximum energy input (wet basis)</td>
<td>----</td>
<td>1.05 million Btu/hr</td>
</tr>
<tr>
<td>Average airflow (startup to shutdown)</td>
<td>14.8 SCFM</td>
<td>20.4 SCFM</td>
</tr>
</tbody>
</table>

### Air to wood ratio averaged over run length:

- Air/100 lb/hr wood: 24 SCFM, 26 SCFM
- Air/100 lb wood: 108 lbs, 117 lbs
- Air/million Btu wood: 142 lbs, 153 lbs

### Ratio of air required for gasification to air required for complete combustion: 19.4%, 20.9%

### GAS CHROMATOGRAPH ANALYSIS OF GAS SAMPLES

<table>
<thead>
<tr>
<th>Component</th>
<th>Run 1 (% Volume)</th>
<th>Run 2 (Steam Off) (% Volume)</th>
<th>Run 2 (Steam On) (% Volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂</td>
<td>55.200</td>
<td>50.140</td>
<td>44.800</td>
</tr>
<tr>
<td>CO</td>
<td>24.900</td>
<td>24.130</td>
<td>26.560</td>
</tr>
<tr>
<td>CO₂</td>
<td>5.820</td>
<td>8.640</td>
<td>7.710</td>
</tr>
<tr>
<td>H₂</td>
<td>9.620</td>
<td>8.150</td>
<td>12.770</td>
</tr>
<tr>
<td>O₂</td>
<td>2.330</td>
<td>3.070</td>
<td>1.150</td>
</tr>
<tr>
<td>CH₄</td>
<td>1.640</td>
<td>2.590</td>
<td>3.450</td>
</tr>
<tr>
<td>C₂ 's</td>
<td>.440</td>
<td>.830</td>
<td>.950</td>
</tr>
<tr>
<td>C₃ 's</td>
<td>.120</td>
<td>.290</td>
<td>.260</td>
</tr>
<tr>
<td>C₄ 's</td>
<td>.003</td>
<td>.006</td>
<td>.007</td>
</tr>
</tbody>
</table>

Calculated Heating Value (Dry basis): 138 Btu/ft³, 150 Btu/ft³, 184 Btu/ft³
NEW QUAD-FIRED STEAM GENERATING PLANT
FOR
JACK DANIEL DISTILLERY
LYNCHBURG, TENNESSEE

by

Arthur S. McGraw
President
McGraw-Morgan, Incorporated

Presented at
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia
ARTHUR S. MCGRAW

Mr. McGraw received a degree in Mechanical Engineering from Virginia Tech. While employed with Massey, Wood and West, Incorporated and Boiler Brick and Refractory, Incorporated, both of Richmond, Virginia, Mr. McGraw was involved with all aspects of industrial steam generating plants. Presently he is the President of McGraw-Morgan, Incorporated, located in Richmond, Virginia. His recent accomplishments include the construction of several wood burning plants, ranging in capacity from 10,000 to 100,000 pounds per hour.
NEW QUAD-FIRED STEAM GENERATING PLANT
FOR
JACK DANIEL DISTILLERY
LYNCHBURG, TENNESSEE

FEASIBILITY

In the early spring of 1977, Jack Daniel began working on the design of a new steam generating plant. Their plant consisted of two packaged type water tube steam boilers capable of generating a maximum of 100,000 pounds per hour of saturated steam at 175 psig, when fired with No. 2 fuel oil or natural gas. Their needs to build a new boiler plant were manyfold. Present equipment was nearly 12 years old and was being operated at about 75% of maximum continuous rating. They wanted to increase production in the distillery, but had no room to add another boiler. They were completely dependent upon increasingly expensive oil and gas and the risk of supply interruption. If they continued to burn No. 2 fuel oil, their storage tanks would have to be replaced.

PLANT SELECTION

Their original plan was to locate a modern coal burning facility with oil as a back-up some 2200 feet from and out of sight of the distillery, and to retain the present plant as a back-up. The new plant would have one 80,000 and one 55,000 pound per/hour boiler and would provide for nearly a 50 percent increase in production. After a thorough study into the availability and cost of wood residue, it was decided to build a modern wood unloading and handling system and to burn wood as a primary fuel in the boilers. In order to continue enforcement of their contract, gas was added, thereby making this a four fuel plant—wood, coal, oil and gas.

WOOD SUPPLY

A contract was signed with Econ, Incorporated of Alexander City, Alabama, to furnish wood fuel. Initially, this would consist of old sawdust and bark piles in the immediate area, gradually working out to a 50 mile hauling radius, until eventually whole tree chips would be the primary fuel. Moisture content ranges from 35 to 50 percent. Wood is brought in on truck trailers; weighed; unloaded with a hydraulic dumper; conveyed through a metal remover, disc classifier, a hog which reduces larger pieces to about 2 inches in size, and then on to a 1400 ton storage pile under roof. Additional open ground storage is provided for approximately 2000 tons. All fuel is sized before storage. A live bottom hydraulic reciprocating
reclaimer moves the fuel from storage to a concrete silo from which it is metered and conveyed to the boilers in proportion to steam demand.

SYSTEM DESCRIPTION

The boilers are E. Keeler Company, Type MKB water tube and are capable of 20 percent overloads. The wood stokers are Detroit Stoker Company swing spout type, which are located in the front wall of the boiler, approximately 8 feet above the traveling grates. Combustion air is preheated to approximately 300°F. Wood fines burn in suspension while the heavier pieces burn on the grates. Collected carbon is reinjected to the furnaces from the rear boiler soot hoppers, the economizer hoppers and from the classifiers located below the multiclone collector hoppers. Wood ash from the grate dumps and sifting hoppers is pneumatically conveyed to an overhead storage silo. Ash from the classifiers and bag house hoppers is continuously augered to large receptacles to be trucked away to landfill. This material cannot be stored in the ash silo.

OPERATING EXPERIENCE

Other than the usual type of problems encountered in starting up a new plant with new personnel, we have had no serious problems to date. Some field modifications had to be made to conveyor transfer points. Loading of trucks from old ground storage sawdust piles initially produced a quantity of unwanted rocks and dirt which had to be diverted. Other than these the system works well.

ECONOMICS

Total cost of this plant was approximately $6.1 million. Currently wood is costing $1.39 per million Btu; coal costs $1.77; oil $5.69; and gas approximately $4.00. These are all delivered prices. The plant intends to burn wood as a primary fuel and gas as a back-up and for ignition purposes. The four fuel flexibility provides a hedge against inordinate price fluctuations and supply interruptions.
TVA'S COMMERCIAL AND INDUSTRIAL
BIOMASS PROGRAM

by

Joan M. Wood
Project Manager
Tennessee Valley Authority
C&I Biomass Program

Tennessee Valley Authority

Presented at
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia

C-56
Ms. Wood received a B.S. in Electrical Engineering from Polytechnic Institute of New York and an M.S. in Industrial Management from the Georgia Institute of Technology. In previous employment with the Engineering Experiment Station of Georgia Tech, the Southern Solar Energy Center, and the U.S. Department of Energy, she has managed projects in many fields of alternate energy, including solar, geothermal, and biomass. She is presently the Project Manager for Commercial and Industrial Biomass Applications for the Tennessee Valley Authority. This program is designed to encourage the growth of an environmentally sound self-sustaining biomass energy industry in the TVA area.
TVA'S COMMERCIAL AND INDUSTRIAL BIOMASS PROGRAM

INTRODUCTION

Wood played an important role in the early industrial development of the United States and the Tennessee Valley. Direct combustion of wood provided heat that generated steam to power industrial machinery and heat buildings. In the late 1800's, coal replaced wood as the primary source of industrial energy and chemical feedstocks. Coal was, in turn, replaced by petroleum and natural gas which were abundant and inexpensive. Petroleum and natural gas are no longer inexpensive, and burning coal in an environmentally acceptable manner requires expensive pollution control equipment. The rapidly increasing costs of energy produced from fossil fuels have had a devastating impact on our economy, and energy costs are expected to continue to increase in the foreseeable future. It is, therefore, imperative that we seek alternate, renewable sources of energy to decrease our dependence on fossil fuels and stabilize our energy costs. Wood can, once again, play an important role in our region, not as a cure-all for our energy woes but as a dependable, renewable source of fuel that could supply a substantial part of our total industrial demand. It is estimated that there is 0.4 quads of energy available annually in the TVA region from biomass. This is over and above the projected raw material requirements of the forest products industries. The technologies developed during our earlier, wood-fueled years are reappearing, and the TVA Biomass Program is helping them to find wide acceptance throughout our region.

C&I BIOMASS

The Tennessee Valley Authority, in addition to being the nation's largest producer of electric power (123 billion kilowatt hours in 1980), is also an agency dedicated to improving the economic well-being of the Tennessee Valley Region. In the late 1970's TVA began an indepth look at alternate energy technologies which could benefit the Valley. Among the conservation and solar technologies which appeared feasible was the use of biomass in commercial and industrial applications. The Division of Energy Conservation and Rates' Solar Applications Branch then set up a program to assist the implementation of biomass energy systems in the Valley.

The C&I Biomass Program is designed to encourage the development of an economically viable, environmentally sound biomass energy industry in the Tennessee Valley. This is being done through a program of information and education for industry officials in decision-making roles and architect/engineers who design the heating systems and industrial boilers used in the region. Technical assistance is available to selected firms considering conversion to biomass fuels. Limited financial incentives
are offered to encourage demonstrations of innovative applications. This assistance allows us to monitor actual installations to determine the full impact on the power system and the environment.

Typically, a firm requests an energy audit from one of TVA's seven district offices. The auditors have been trained to recognize a site that has the potential to utilize a biomass fuel. The auditor refers sites to the C&I Biomass Program Staff. The sites are screened and those that meet the program goals are offered a TVA-sponsored feasibility study. The sites which are feasible are evaluated, and TVA cost-shares engineering drawings with selected firms. At this point we believe that most firms will construct systems without additional TVA assistance. However, nonprofit institutions and those firms with innovative applications are considered for construction incentives.

All firms that receive TVA assistance are asked to allow TVA to publicize the project and to monitor the project for a period of one year.

As of June 1, 1981, 101 potential sites have been identified, 57 sites have been screened, 18 feasibility studies have been completed, 5 more feasibility studies are underway, 3 sets of design specifications are underway, and 1 project is under construction. The goals for FY 1981 are to identify 125 sites, screen 90 sites, perform feasibility studies for 35 sites, prepare specifications for 15 sites and begin construction on 8 projects.

A typical project which has been supported involves a commercial greenhouse in middle Tennessee. The seven greenhouses involved have a floor area of 23,080 ft² and cost $15,000 to heat in 1980. With fuel prices continuing to rise the owner realized that to remain competitive he would need to reduce his energy costs. With TVA's assistance, he installed a system utilizing a used wood-fired boiler. The greenhouse is located in an area of plentiful mill residues and it is estimated that his fuel cost for the 1981-1982 heating season will be about $900.

In addition to technical assistance to users, TVA is analyzing the supply of available biomass in the Valley. Preliminary analysis indicates that biomass in the Valley can supply 0.4 quads (10¹⁵ Btu's) of energy annually without depleting our existing forests (see Table 1). We have also analyzed the mill residues on a county-by-county basis and can provide users with data on the potential supply in their area.
TABLE 1
ANNUAL BIOMASS AVAILABLE FROM
WOOD RESOURCES IN THE TVA REGION

<table>
<thead>
<tr>
<th></th>
<th>Million Green Tons</th>
<th>Quads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging Residue</td>
<td>16.4</td>
<td>0.1312</td>
</tr>
<tr>
<td>Salvageable Dead Timber</td>
<td>14.0</td>
<td>0.1120</td>
</tr>
<tr>
<td>Cull Trees</td>
<td>9.6</td>
<td>0.0768</td>
</tr>
<tr>
<td>Surplus Growing Stock</td>
<td>10.9</td>
<td>0.0872</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>50.9</strong></td>
<td><strong>0.4072</strong></td>
</tr>
</tbody>
</table>

TVA is working jointly with the Environmental Protection Agency to ensure that the use of biomass does not adversely affect the environment. Air, water, and soil quality are being studied both at the harvesting site and at the end-use site.

The use of wood and other biomass fuels is attractive to Valley firms, since this proven technology offers payback periods ranging from two to five years. Its use in commercial and industrial applications also has the potential to directly benefit the power system by reducing the peak load demand and by providing cogenerated electricity to the grid. It will stimulate the Valley economy by diverting money now spent on imported fuels to locally produced fuels which in turn will result in additional employment.

Support of this project demonstrates one of the ways TVA encourages the development of natural and human resources within the Valley region.

ABSTRACT

TVA has an active program of resource assessment information, education and technical assistance designed to enable Valley firms to convert to biomass fuels. The program is being supported by TVA power revenue funds and by funds appropriated by Congress for national energy demonstrations.

Once systems are installed they are monitored in order to determine their operational characteristics and to ensure that they meet environmental regulations. TVA is working with EPA on a Biomass Integrated Environmental Assessment designed to look at all possible impacts of biomass fuels on the environment.
PREPARING WOOD WASTE FOR
SOLID FUEL FIRING

by

Pierce Merry, Jr.
Executive Vice President
Production

Merry Companies, Inc.
Augusta, Georgia

Presented at
WOODTECH '81
July 14, 1981
Atlanta, Georgia
Approximately two years ago I told a similar group about Solid Fuel Firing. We discussed the new plant, Merry Brothers Plant 5, and that its only fuel was wood waste. Slides of the plant, the firing system, and wood preparation were shown. It was pointed out that our source of fuel was wood shavings from many sources and that all of it was dry. Our objective was to construct a wood waste handling system that would handle any wood waste up to about 30% bark and prepare a solid fuel at 12% moisture (wet weight) with the desired particle size.

Since my last visit to Tech the demand for dry wood waste has increased sizeably in Merry's area and a resultant increase in cost occurred. This demand was created by the needs of Merry Companies and that the new plant could not operate without wood waste. This need increased the pressure on the construction of the Green Waste Preparation Facility and it was completed within the last 60 days.

The Wood Fuel Preparation Facility for dry wood waste was installed with the plant during 1979 and provided the dumper, screening, hog, stacking conveyor, silos with disc feeder and arch breaker. The new facility that was completed in May involved reclaiming facilities, the dryer, and support equipment.

The two reclaiming operations from the green wood waste storage were built, one to feed the dryer and one to grind and screen wet wood waste to be used as an additive in our brick to reduce weight. The use of wood waste as an additive is a different story than the one today.

The use of wood fuel was projected because of the sizeable increase in the cost of oil as a standby fuel and the rapidly mounting price of gas. For a quick example of the effect of wood fuel on Merry Brothers Division of our company, Table I shows what has happened to the consumption of No. 2 Fuel Oil during this period.

The criteria established for the design of the dryer were based on the use of products of combustion as the heat source for drying the wood waste. This figure was established from the kiln contractor at 100,000 cfm at 2500°F. The volume was the maximum available from the exhaust fan and the temperature was the minimum expected. This sounds contradictory, but no brick manufacturer runs anything at half speed and they will never admit exhaust temperatures are high.
Designs were submitted from several vendors and the selection of a single pass dryer 14 ft. x 30 ft. was selected that would furnish 3-1/2 tons per hour at 12% moisture with a maximum of 15 tons per hour with supplemental heat. The dryer met these requirements easily, in fact, the minimum requirements have been met with the kiln running at one-third its capacity of 150 million brick per year.

The use of the exhaust gases as a drying medium is not new but close controls had to be established so that the rotary dryer system did not impose any fluctuation of the kiln draft. If this did occur, changes in the kiln atmosphere would result and the resultant brick will be variable in color with physical changes in the brick a possibility. The resulting design on stack and duct damper controls has been excellent and the kiln has not been affected by the dryer installation.

The resulting ground wood waste was expected to have certain characteristics and these are shown on Table II.

A more detailed example of the sized wood waste is shown on Table III.

The following slides will show the development of the Wood Waste Processing Facility and will demonstrate its operational capabilities.

From 12 to 15 slides will be shown with extemporaneous presentments.

We have reviewed the use of wood waste, we have seen the development of the facility to produce dry wood fuel from green waste and we have looked at the results. Now let us conclude by observing the effect wood fuel had on the fuel costs for the last four years ending September 1980 on three plants. Plant A - is the prototype installation with the wood waste starting in 1977. Plant B - is the second plant that started firing in 1978, and Plant C - is still fring gas with oil standby. Plants A and B are top fired kilns. Plant C is side fired. All installations were built during the early 70's.

The introduction of wood waste at Merry has been most beneficial as an additive and as a fuel. The 100,000 tons we use of wood waste will increase as our total fuel requirements are met by solid fuel. The use of wood waste has made a significant contribution towards the profitability of our company.
<table>
<thead>
<tr>
<th>Winter</th>
<th>Oil Consumption (Gals.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976 - 1977</td>
<td>2,041,257</td>
</tr>
<tr>
<td>1977 - 1978</td>
<td>1,411,147</td>
</tr>
<tr>
<td>1978 - 1979</td>
<td>190,607</td>
</tr>
<tr>
<td>1979 - 1980</td>
<td>6,268</td>
</tr>
</tbody>
</table>
### TABLE II

**WOOD FUEL CHARACTERISTICS**  
**PARTICLE SIZE DISTRIBUTION**

<table>
<thead>
<tr>
<th>Mesh</th>
<th>Range</th>
<th>Percent Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4 + 20</td>
<td>25 - 35</td>
<td></td>
</tr>
<tr>
<td>-20 + 50</td>
<td>35 - 45</td>
<td></td>
</tr>
<tr>
<td>-50 +100</td>
<td>20 - 40</td>
<td></td>
</tr>
</tbody>
</table>

**MOISTURE**

<table>
<thead>
<tr>
<th>Minimum</th>
<th>Desired</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>12%</td>
<td>20%</td>
</tr>
</tbody>
</table>

**BULK DENSITY**

14.0 lbs. per cu. ft. at a Fineness Modulus of 3.33 and Moisture Content of 12%.

A more detailed example of the sized wood waste is shown in Table III.
# TABLE III

GROUND AND SIZED WOOD FUEL

**Fineness Modulus**

<table>
<thead>
<tr>
<th>Opening Inches</th>
<th>U. S. Screen Size</th>
<th>Percentage Retained</th>
<th>Cumulative</th>
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<tbody>
<tr>
<td>.187</td>
<td>4</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>.0937</td>
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<tr>
<td>.0469</td>
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<td>.0234</td>
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<td>.0117</td>
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<td>.0059</td>
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<td>98.0</td>
</tr>
<tr>
<td>Pan</td>
<td></td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

100.0

**Fineness Modulus** 3.33
APPLICATION OF WOOD GASIFIERS
TO THE AMERICAN CYANAMID COMPLEX

by

William S. Bulpitt
Chief, Wood Energy Systems Division
Technology Applications Laboratory

Thomas F. McGowan
Senior Research Engineer
Technology Applications Laboratory

Georgia Institute of Technology
Engineering Experiment Station

Presented at
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia

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WILLIAM S. BULPITT

Mr. Bulpitt received both his bachelor's and master's degrees in Mechanical Engineering from the Georgia Institute of Technology. As Chief of the Wood Energy Systems Division, he has directed numerous wood and biomass energy programs. These programs include inventories of resources, review of biomass conversion systems, improvement of residential heater performance, design and construction of wood gasification systems, commercial applications of wood energy systems to industrial plants, and transfer of wood energy technology to industry as a whole. As a field office director for KVB Engineering, Inc., he was active in fields of air pollution control and energy conservation for various clients, including pulp and paper plants and electric utilities.
INTRODUCTION AND BACKGROUND

In July, 1980, a research contract was awarded by the Department of Energy to the project team at the American Cyanamid Company and the Georgia Tech Engineering Experiment Station to perform a feasibility study under the Public Law 96-126 Alternate Fuels Program. This study had the following overall objectives:

- The identification and assessment of wood gasification and wood pyrolysis systems and equipment that are ready for commercial application at an industrial facility such as the American Cyanamid plant.
- The detailed analysis of the wood resource in the region surrounding the Cyanamid plant, with a complete assessment of total availability and cost.
- The preparation of a preliminary multiphase plan and design for converting the Cyanamid plant to alternate fuel use with wood gasification or wood pyrolysis.

At the time of this writing, the study is drawing to a close and it is expected that the final report will be complete at the end of July, 1981. The following sections deal briefly with the results of the study.

THE CYANAMID PLANT

The American Cyanamid Plant at Savannah, Georgia, is located on the south bank of the Savannah River and employs approximately 650 people, contributing significantly to the economic base of the region. The plant produces approximately 85,000 tons per year of white titanium dioxide pigment, 75,000 tons per year of sulfuric acid, and, as a by-product of acid neutralization processes, 180,000 tons per year of gypsum. The gross annual sales of these products result in revenues of over $100 million.

The plant processes are quite energy intensive and the facility as a whole requires about 3.1 x 10^12 Btu per year of clean, high quality thermal energy and 150,000 MWH per year of electrical power. The thermal energy is provided predominantly by natural gas with a distillate fuel oil or propane backup. Approximately one-third of the thermal energy is used to generate process steam and the remainder is consumed by direct-fired process heaters. Electric power is purchased from the local electric utility (Savannah Electric Company) and the distillate oil is obtained from national suppliers through local terminals. The natural gas is supplied by pipeline from a local distributor.
Special product quality or equipment requirements restrict the direct fire fuel options on thermal energy to either natural gas or distillate oil. Energy used for steam generation is consumed by a multiplicity of small package boilers designed with only gas/oil capabilities which include high sulfur residual oils. There is no solid fuels capability.

There are presently seven gas/oil package boilers and one heat recovery boiler (acid plant) supplying steam for the titanium dioxide processing plant. Three large boilers are usually in operation at once, and under normal conditions, there will be four small boilers on standby. Overall, the Cyanamid plant has an average steam load of $250 \times 10^6$ Btu/hr. On annual basis about 80% of the steam is obtained by natural gas firing and 20% by fuel oil which is used when gas is seasonally curtailed.

Another major use of energy can be found in the titanium dioxide processing facility. Here the major users are the two rotary kilns which each consume $45 \times 10^6$ Btu/hr when in operation. These units are fired directly with gas or oil and are normally run 8200 hours per year. Proper firing is important for product quality in these kilns and the effects of using alternate fuels will therefore be most critical in this part of the TiO$_2$ plant.

Figure 1 diagrams the general energy use at the plant. About one third of the total gas/oil fuel is used for steam generation; another third is used in the direct-fired calciners; and the remaining third in spray dryers and other small direct fired heaters. The boilers supply about 75% of the steam used and the remaining 25% comes from a heat recovery unit in an acid plant on site.

Overall, the use of wood gas or wood pyrolysis fuels for just one boiler could result in the replacement of about $22 \times 10^{10}$ Btu of fossil fuel energy annually, with a potential of replacing about $305 \times 10^{10}$ Btu of fossil fuels if wood gasifiers were fitted to all the boilers and all the processes requiring thermal energy.

The American Cyanamid Complex at Savannah is spread out over several hundred acres and receipts and shipments are normally made by barge, rail, or truck. It is not anticipated that the shipment of large amounts of wood would create any special problems, although allowances would have to be made for scheduling. The handling of liquids and solids is a major part of the overall design of the plant, and Cyanamid personnel see no particular new problems in going to solid fuel.
WOOD FUEL SUPPLY

The area of Southeast Georgia in which the American Cyanamid plant is located is an area of intense forest product industry activity. The Union Camp complex in Savannah is the largest pulp and paper plant in the world. Thus, there was some concern about the availability of wood as a feedstock for a gasification or pyrolysis system.

As part of the study team, F. & W. Foresters were brought in as consultants to examine the availability of wood in the Savannah area. They examined the twenty county area within 75 miles of Savannah which was considered a reasonable hauling distance. The following conclusions were drawn:

- 2,700,000 tons of biomass are grown annually within a 75 mile radius of Savannah.
- 3,000,000 tons of wood residue and chips are produced by the forest products industry within the same area.
- 522,000 tons of wood would be required for the Cyanamid Plant to meet its annual energy needs.
- Cyanamid is willing to pay 1/3 to 1/2 the equivalent price of natural gas for wood.
- At the upper limit of the above cost, there could be as much as 1,600,000 tons of wood available annually to Cyanamid in 1984.
- Four different companies have expressed an interest in entering relatively long term energy contracts with Cyanamid for wood supply.

In light of the above information it has been concluded that there is certainly enough wood available at an attractive enough price to allow Cyanamid to start the construction of a wood-fired system without being overly concerned about wood supply.

SYSTEM DESIGN

Air blown wood gasifiers produce low Btu gas which generally has an energy density of 80-180 Btu/ft$^3$. In addition, pyrolysis processes can produce oils with heating values approximately 70% of that of fuel oil and char containing 10-12,000 Btu/lb.
The lower energy density of wood gas requires higher mass flow rates to produce the same energy in combustion systems, and this fact can cause problems. Gas lines for low Btu gas must be much larger than natural gas lines and de-rating of some combustion systems may be necessary.

Another critical factor in direct fired applications such as part of the American Cyanamid plant is the possible detrimental effects of combustion products on the product being produced. The production of pure white paint pigment could be considered a very critical process in terms of product contamination, and it was decided after examining the available information on discharges from wood gasifiers that the successful system would probably incorporate a scrubbing system to remove tars, liquids, and ash from the gas system before introducing the gas into the kilns.

Based upon these requirements and an overall energy requirement of 370 million Btu per hour, a conceptual process diagram was produced as shown in Figure 2.

This system will require 60 tons per hour of green wood infeed, producing 41,000 SCFM of wood gas, 5 GPM of tar and 120 GPM of water (separated from the gas).

In addition, if it is decided that electricity production should be included, Figure 3 depicts an outline of such a system. In this system, low Btu gas would be used to fire gas turbines and heat recovered from the turbines would assist in steam generation.

The above diagrams have been included to give an idea of the scope of a complete energy conversion for the plant. It is quite likely that a first phase would begin with a smaller wood gasification plant (of the 100 MMBtu/hr size range) that could be used to fire one or more boilers. Later phases would then result from an expansion of this first gasification plant.

WOOD GASIFICATION AND PYROLYSIS SYSTEMS

A major portion of this study included a survey of the state-of-the-art of wood gasification and pyrolysis systems. Initial inquiries were sent to approximately twenty-five companies engaged in the manufacture and marketing of gasification/pyrolysis systems. These companies were identified through an extensive literature search. After some initial screening, many of the companies were eliminated for various reasons, including lack of interest, size limitation of the process, lack of sound financial base for the company, etc.
Figure 2
ATMOSPHERIC UPDRAFT GASIFIER CONFIGURATION
FOR THE PHASE III TOTAL THERMAL PLANT
370 X 10^6 Btu/hr Capacity
Figure 3
PRESSURIZED UPRIGHT GASIFIER CONFIGURATION FOR THE PHASE IV COGENERATION COMPLEX
570 x 10^6 Btu/hr Capacity
During the course of evaluation many field trips were made to various gasification system installations. Based upon these trips and the information supplied by the vendors, the companies listed in Table 1 were considered to have systems which appeared workable under the constraints of the American Cyanamid plant. It must be stressed that this table does not constitute an endorsement of the companies, but rather indicates those companies that Cyanamid would be interested in pursuing for a final design.

It should be noted here that many systems were considered during the course of the study which at first appeared promising but upon closer scrutiny did not demonstrate that they were commercially ready for the marketplace.

CONCLUSIONS AND FUTURE PLANS

As this is being written, the economic analysis of the Cyanamid project is still being carried out. It appears that the overall thermal gasification plant would have a first cost of $12,000,000 and would have a simple payback of 3 years. The thermal/cogeneration plant would cost $35,000,000 and pay back in 3 years.

A preliminary construction schedule is being drawn up which would result in a complete wood conversion for the plant's energy needs by 1986. It is anticipated that a "demonstration" plant would be constructed first for one or more boilers and there would be a later expansion to a complete system if it performs well.
### TABLE 1

**FINAL VENDOR ASSESSMENT**

<table>
<thead>
<tr>
<th>Gasifier Process Vendors</th>
<th>Proposal Submitted</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERCO</td>
<td>Yes</td>
<td>Turnkey Capability</td>
</tr>
<tr>
<td>Omnifuel</td>
<td>Yes</td>
<td>Turnkey Capability</td>
</tr>
<tr>
<td>American Carbons</td>
<td>Yes</td>
<td>Contract Supplier</td>
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</table>

**Gasifier Equipment Vendor**

<table>
<thead>
<tr>
<th>Applied Engineering</th>
<th>Yes</th>
<th>Updraft Units</th>
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</thead>
<tbody>
<tr>
<td>Lamb-Cargate</td>
<td>No</td>
<td>Grate Design Only</td>
</tr>
<tr>
<td>Lurgi</td>
<td>No</td>
<td>Site Visit Pending</td>
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</tbody>
</table>

**Architect/Engineer Firms**

<table>
<thead>
<tr>
<th>D. M. International</th>
<th>No</th>
<th>Unit Under Cost for Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₂M Hill/INTEG</td>
<td>No</td>
<td>Access to Westwood Polygas Knowhow</td>
</tr>
<tr>
<td>Simons Eastern/Halcyon</td>
<td>No</td>
<td>Wood Handling</td>
</tr>
</tbody>
</table>

**GAS Turbine/Electrical Generation**

| Solar Turbines International | Yes | Experience in Medium Btu Gas, Working on Low Btu Gas Turbines |

Note: This assessment is preliminary and should not be considered an endorsement of the companies by Georgia Tech or American Cyanamid.
WOOD ENERGY APPLICATIONS
IN THE TEXTILE INDUSTRY

by

Hardin C. Byars
Vice President of Engineering and Development
Integrated Products

Presented at
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia

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HARDIN C. BYARS

Hardin C. Byars, holder of a B.S. degree in Agricultural Engineering from the University of Georgia, also received special training in Industrial Engineering and Statistical Quality Control while employed with Burlington Industries where he served in Industrial Engineering positions as well as Management.

For the past 19 years he has served in Manufacturing, Management, Purchasing and Engineering positions during the growth of Integrated Products from 40 employees to the current 1800. He now serves as Vice President of Engineering and Development, and was responsible for the wood-fired boiler installation at the Aragon plant.
It is a pleasure to be here today to share with you some of the knowledge we have received in our wood energy project and also to give you some observations that seem pertinent to the use of wood energy in the textile industry.

Let me take this opportunity to thank the Engineering Experiment Station of Georgia Tech for taking the lead in promoting wood energy conferences that helped us gain valuable information on this subject.

We had a number of questions to be answered before we attempted this project. First, we needed to find out if there was sufficient fuel in our area for long term. For us, this information came from the Georgia Forest Commission and the Forest Department at the University of Georgia. Also, we made a personal survey of suppliers in our area. After you get the basic information from government sources I strongly recommend that a thorough personal survey is most important.

Second, a feasibility study was needed to see if the project was practical. We were most fortunate in having a study made for us by the Wood Energy Systems Division of the Engineering Experiment Station at Georgia Tech. This was a program that was co-sponsored with the Georgia Department of Energy Resources and the U. S. Department of Energy Biomass Energy Systems Division. I do not think this program is still in effect but Mr. Bill Bullpit and his department have the basic format for you to follow.

Third, would wood-fired boilers handle the swing in loading that we had in our process? We have 3 large 72" x 231" Turbo Autoclaves and 4 large Challenge Cook Steam Tumblers. The Autoclaves fill and exhaust about 4 times every hour as well as intermittent loading of the steam tumblers. We have had no problems with this swing loading; in fact, it is much better than with our conventional boilers.

Integrated Products, Inc. was pleased to be selected to participate in a joint wood energy demonstration project by the Engineering Experiment Station Wood Energy Systems Division of Georgia Tech, sponsored by the U. S. Department of Energy Biomass Energy Division. We probably would not have undertaken this program because of so little knowledge on the subject. With our success in this venture we will continue to pursue the use of wood energy for our operation in the future.

I will try to answer any of your questions after we go through a short slide presentation of the construction of our project. Also, if you are interested, there will be a field trip to our plant in Aragon later. Check your program for the time.

The Textile Industry is fortunate to be located in the same region with a large forest products industry. We can both benefit if we use
the waste products such as sawdust and bark along with the cull hardwood whole tree chips so as not to compete with each other in the market place for wood.

The Textile Industry has been faced with oil embargos, natural gas shortages, coal strikes, along with ever increasing prices of each. With our industry being one of the top 5 energy consumers, it is my hope that we can utilize wood energy to take a little of the pressure off other fuels, especially since it is a home-grown product.
APPENDIX

TECHNICAL DETAILS OF THE DEMONSTRATION PROJECT
AT INTEGRATED PRODUCTS, INC., ARAGON PLANT

Reference: Final Report on Project A-2400,
1980
3. DEMONSTRATION PLANT--Integrated Products, Inc.

Integrated Products, Inc., is a textile manufacturing firm headquartered in Rome, Georgia. The company manufactures yarn for the carpet industry and has several plants located in Rome, Villa Rica, and Aragon, Georgia. The company employs 1,800 people and supplies products to domestic and international customers. The demonstration project discussed here is being conducted at the Aragon plant located 60 miles northwest of Atlanta. The Aragon plant produces carpet yarn and has approximately 450 employees. The plant uses steam from the boilers to "heat set" and dry the carpet yarn in order to provide a permanent twist to the yarn. This process is accomplished in "auto claves" and steam dryers, and in winter, steam is also used for space heating. Presently the plant boilers run on natural gas and oil; approximately 85% of the energy consumption is provided by natural gas and 15% is provided by No. 2 fuel oil.

Visits to the plant by Georgia Tech personnel and meetings with the vice-president and plant engineers of the company indicated that the Aragon plant could be a prime candidate for a wood energy demonstration project. The potential for success was based on the following considerations:

- A preliminary economic analysis performed on the basis of the energy usage data indicated that a wood energy system would be economically feasible and that the company had a strong potential for conservation of scarce gas and oil fuels.

- Meetings with the engineering and plant personnel revealed that the company had a competent technical staff and all of them were interested in the conversion to wood.

- A survey of the local wood supply situation indicated that wood fuel in the form of sawdust, bark, and wood chips would be available at economical prices.
Financial records of the company revealed that the company was stable and the management had a positive attitude with respect to participating in a demonstration project.

Integrated Products, Inc., is a nonforest industry, and its success in the demonstration project would serve as a model for other industries to follow.

CONCEPTUAL DESIGN

The primary goals of the conceptual design study of the proposed wood energy system were to determine boiler size, determine the wood fuel storage volume required, determine the optimum wood handling system, and to develop plans for the plant layout.

In order to perform this task, information on the energy use of the existing plant, specifications of the existing boilers, characteristics of the steam consuming equipment, and available space for the installation of the wood system was collected. The engineering staff and plant personnel of the company provided a considerable amount of information and assistance in these efforts. Information on the existing boiler plant is summarized in Table 1. Monthly energy consumption data is shown in Table 2, and a plot plan of the area adjacent to the boiler house is shown in Figure 2.

Size of the Boiler

In sizing of the boiler, the existing energy consumption, the size and utilization of the existing boilers, characteristics of the steam consuming equipment, and the future plans of the company were taken into consideration. It was required that the wood boiler supply all of the process heating and space heating requirements and no backup (except in emergencies) by the fossil fuel boilers was to be employed. There were no steam flow charts to indicate the total instantaneous demand on the boilers. However, steam flow charts connected with the major steam consuming equipment such as the auto claves and steam dryers indicated the cyclical nature of the steam demand by the equipment. Discussions were held with the engineering and plant personnel concerning the loading of the existing boilers and the addition of
INTEGRATED PRODUCTS INC.
Wood-Fired Boiler Plant
| NAME OF COMPANY: | Integrated Products, Inc.  
Aragon, Georgia |
| PRODUCT LINE: | "Heat Set" nylon carpet yarn for the carpet industry |
| NUMBER OF EMPLOYEES: | 450 |
| BOILER PLANT INFORMATION: | There are three boilers with descriptions as follows: |

**BOILER NO. 1:**
- **Date of Installation:** 1972
- **Capacity:** 200 hp (= 6900 lbs steam/hr)
- **Pressure:** 100 psig
- **Fuel:** Gas or oil
- **Emission Control:** Chimney
- **Ash Handling:** None
- **Boiler Efficiency:** 82.5% (Approximately)

**BOILER NO. 2:**
- **Date of Installation:** 1972
- **Capacity:** 350 hp (= 12,100 lbs steam/hr)
- **Other specifications** are the same as those of Boiler No. 1.

**BOILER NO. 3:**
- **Date of Installation:** 1920
- **Capacity:** 100 hp
- **Fuel:** Gas or oil

**STEAM USAGE:**
Steam is used in auto claves for the "heat set" process. This process provides a permanent twist to the yarn. During winter, approximately 10% of the space heating demand is met by steam.

**PLANT OPERATION:**
24 hours/day, 6 days/week, 50 weeks/year

**ENERGY CONSUMPTION:**
- Natural Gas: 51,934 cu. ft/year
- No. 2 Fuel Oil: 53,464 gals/year

**OTHER INFORMATION:**
There is sufficient yard area available for wood handling, storage, and installation of the wood fired boiler.

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### Table 2

ENERGY CONSUMPTION: INTEGRATED PRODUCTS, INC.

<table>
<thead>
<tr>
<th>Period</th>
<th>Month</th>
<th>Natural Gas</th>
<th></th>
<th></th>
<th>Total Btu</th>
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<td>May 78</td>
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<td>4.9955 \times 10^9</td>
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<td>4.9955 \times 10^9</td>
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<tr>
<td>5/30 - 6/28/78</td>
<td>June 78</td>
<td>45,093</td>
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<td>4.5093 \times 10^9</td>
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<tr>
<td>6/28 - 7/28/78</td>
<td>July 78</td>
<td>36,710</td>
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<td>7/28 - 8/29/78</td>
<td>Aug 78</td>
<td>46,868</td>
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<td>5.2253 \times 10^9</td>
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<tr>
<td>10/31 - 12/1/78</td>
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<td>12/1/78 - 1/3/79</td>
<td>Dec 78</td>
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<td>8,000</td>
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<td>3/1/79 - 4/1/79</td>
<td>Mar 79</td>
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<td>7,500</td>
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<td>4/1/79 - 4/30/79</td>
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<td>45,123</td>
<td>4.5123 \times 10^9</td>
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<td>4.5123 \times 10^9</td>
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<tr>
<td><strong>ANNUAL CONSUMPTION</strong></td>
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<td></td>
<td></td>
<td></td>
<td><strong>59.4198 \times 10^9</strong></td>
</tr>
</tbody>
</table>


another dryer. Based on these considerations, a 400 hp boiler was judged to be adequate by the engineering and plant personnel of Integrated Products, Inc., and Georgia Tech personnel.

Wood Fuel Storage and Handling

To estimate the size of the storage and the wood handling equipment, the following assumptions were made with regard to wood fuel properties and system efficiency.

Wood fuel: Sawdust, bark, and chips
50% moisture

Heat value: 4,000 Btu/lb

Bulk density: 24 lb/ft$^3$

System thermal efficiency: 65%

Heat required to generate 1 lb of steam: 1,000 Btu

Calculations

Output of Boiler at rated capacity: $400 \times 34.5 \times 1,000 \text{ Btu/hr} = 13.8 \times 10^6 \text{ Btu/year}$

Wood fuel consumption/hr: $\frac{13.8 \times 10^6}{4,000 \times 0.65} = 5,308 \text{ lb/hr}$

$= 2.654 \text{ tons/hr}$

Volume flow rate of wood: 221 ft$^3$/hr

Covered Storage

Storage volume for 72 hours (rated capacity): 15,912 ft$^3$

A storage silo of this size or a covered storage shed of floor area of approximately 2,600 ft$^2$ (assuming average of 6' of pile depth) can be used.

Open Storage Area

Concrete floor area for 28 days storage, assuming avg. of 12' pile depth: 12,376 ft$^2$

Wood Requirements

Wood required/hour: 2.654 tons/hr

$= 3 \text{ truckloads/day at rated capacity}$

$= 2 \text{ truckloads/day at 60% to 70% capacity}$

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Wood required/year at 100% capacity: = 19,000 tons/year
Wood required/year at 70% capacity: = 13,300 tons/year

Wood fuel handling. For a plant of this size, preliminary feasibility studies indicated that an automatic fuel receiving hydraulic truck dump would be an expensive investment. Simpler systems such as the use of front loaders or fuel delivery by live bottom delivery vans were considered to be economical alternatives.

Other fuel handling equipment such as conveyors, elevators, etc., designed to handle volume of wood (design speed 221 ft$^3$/hr) should be included in the system.

Space requirements. Based on manufacturer's data for wood fired boilers, wood handling equipment, and our own calculations, it was found that a 400 hp wood system including a storage silo would require approximately 7,200 ft$^2$ of space for the boiler house, silo fuel unloading, and driveway for trucks to enter the fuel staging area.

Contractor Selection

Based on our discussions with the engineering staff of the company and our study of the fuel supply situation, it was decided that the selected boiler should be capable of burning sawdust, bark, wood chips, and other kinds of wood waste up to 50% moisture content on a wet basis. An HRT (Horizontal Return Tube) boiler was considered to be a good choice, but various other types were also considered. A number of boiler manufacturers were contacted based on Georgia Tech experience with previous projects in the wood energy area. The following firms actually visited the plant site:

- Applied Engineering Co.
  Atlanta, Georgia
- Wellons Inc.
  Sherwood, Oregon
- Kincaid Engineering Company, Inc.
  Gastonia, N.C.
- Industrial Boiler Co., Inc.
  Thomasville, Georgia
- Energy Systems, Inc.
  Chattanooga, Tennessee
During the visits, the representatives from these firms investigated the details of the existing boiler plant, including space availability and use. Some of the vendors explained the details of the systems they were going to propose including details of similar systems supplied to other companies. Based on their examinations of the plant site and the requirements of the proposed wood energy plant, four of the companies sent their budget estimates as proposals. There were some variations in the components of the systems proposed by these firms. The equivalent costs of the complete systems varied from approximately $460,000 to $600,000. In the selection of the contractor, the following factors were taken into consideration:

- The cost of the wood energy system quoted by the vendor
- The type of wood boiler and the details of the wood energy system
- The reliability and the service that would be furnished by the vendor or determined by previous experience and reputation
- Contractors' guarantees on system performance and emission characteristics

Based on these considerations, the proposal from the Industrial Boiler Company was accepted by the management of Integrated Products, Inc. Before arriving at this decision, the vice president for engineering at Integrated Products had visited a similar wood energy system in Rome, Georgia, that was built by Industrial Boiler Company. Georgia Tech personnel also visited this plant.

The decision by the Integrated Products Co. was agreeable to Georgia Tech personnel since the Industrial Boiler Company is a reputable firm and has installed satisfactorily a number of wood energy systems in Georgia and other parts of the United States. Additionally, all of the functions of design, manufacture, installation, and startup of the entire wood system would be borne by the same contractor.

**Contract Document Preparation**

The proposal submitted by the Industrial Boiler Company included details of the wood energy system and budget prices for the various components. The proposal was reviewed by the engineering staff of
Integrated Products Co., and by Georgia Tech personnel with respect to the costs of the system components, the optional equipment, and the system layout. Meetings were also held with representatives from Industrial Boiler Company and the final contract includes the following items:

**Fuel Storage System**
- Poured concrete silo
- Supreme unloader

**Fuel Feeding System (Unloader to Boiler)**
- Conveyor--unloader to metering bin
- Metering bin
- Transfer conveyor--metering bin to air sweep feeders
- Air sweep feeders
- Fuel receiving area--sheltered

**Steam Generating System**
- Industrial horizontal tubular boiler, Model 3-2600-158*
- Cast iron pin hole grates
- Combustion air system
- Steel casing
- Refractories
- Rear arch
- Pre-wired automatic control panel
- Primary air pollution control equipment

**Exhaust Gas Handling System**
- Exhaust gas duct
- Secondary air pollution control equipment
- Clean gas duct
- Draft inducer (fan)
- Exhaust gas stack

*From Bulletin of Industrial Boiler Co.*
Auxiliary Equipment and Services

- Boiler feed water system
- Chemical feed system
- Steam flow meter
- Piping material for installation of the system within boiler room
- Electrical materials for field wiring of system
- Labor— for installation of system

The boiler house and foundation, the sheltered fuel staging area, and the open storage area will be built by a local construction company under a separate purchase order from Integrated Products, Inc.

A purchase order for the system was signed by Integrated Products, Inc., in a meeting on May 19, 1980 at Rome, Georgia. The vice president for sales and chief engineer from Industrial Boiler Company, and Georgia Tech personnel were present at the meeting. The final system layout is shown in Figure 1.

System Description

The system as shown in Figure 2 consists of the following major components:

- Horizontal return tube boiler (HRT)
- Wood storage
- Wood fuel handling

Each one of these components is described briefly in the following sections.

Horizontal return tube boiler. The HRT boiler is a firetube boiler designed to produce 13,320 lb/hr of saturated steam (400 hp) at 130 psig from feed water supplied to the unit at 220°F. The boiler is designed to burn wood fuel up to 50% moisture content (wet basis) such as sawdust, bark, and chips. Wood fuel enters the grate area by means of air sweep feeders.

Wood storage. A poured concrete silo, 24 ft diameter x 48 ft high, provided with a supreme unloader, is used for storage. The usable storage
capacity of this silo is 14,464 cu. ft. and is sufficient to store wood fuel for approximately 72 hours, when the boiler is operating at 70% load. For long term storage, an open storage of approximately 10,000 ft$^2$ provided with a concrete floor and sufficient to store wood for approximately 28 days is proposed. This will be built in an adjacent land owned by the company.

**Wood Fuel Handling**

Wood fuel is supplied to the plant by means of live bottom trailers. They can unload the fuel in the open storage area or in the fuel staging area which is located close to the wood storage silo. The wood fuel in the fuel staging area is transferred to the receiving hopper located in the corner by means of a front end loader. The receiving hopper is approximately 4 ft wide, 8 ft long, and 6.5 ft high, and the fuel received in this hopper is delivered to the storage silo by means of a screw conveyor and bucket elevator. Fuel from the silo to the metering bin and from the metering bin to the air sweep feeders is transferred by means of screw conveyors.

**FEASIBILITY STUDIES**

A preliminary economic analysis was performed on the basis of budget estimates for the equipment and wood fuel costs. This was done prior to the acceptance of the Aragon plant as a candidate for the demonstration project. A refined feasibility study based on the quoted prices for the equipment was later prepared and it addresses the major items such as economic analysis and the wood supply situation.

**Economic Analysis**

The economic analysis includes the costs associated with the wood system and the existing system, the first year savings, and the payback period. Life cycle costs based on escalation rates for the costs and the present worth of savings over the life of the equipment were calculated using the computer. The items used in the analysis include the following:
Total costs including operating costs, etc.
Total annual savings due to the installation of the wood system
Approximate payback period
Life cycle costs and savings allowing for escalation rates

Costs

Costs were based on the information obtained from the manufacturers, plant engineering personnel, and our own experience and discussion with professionals in the field. Current prices of conventional fuels were obtained from Integrated Products.

In computing the capital cost, the federal investment and alternative energy property tax credits amount to 20% of the investment is allowed. Additionally, the DOE grant to the company toward the demonstration is subtracted to arrive at the final adjusted capital investment.

Cost of the system: $460,000
Less 20% Federal Tax Credits: $92,000
Less DOE Grant: $146,000
Adjusted Capital: $222,000

The system includes the boiler and related equipment described earlier, building, storage, etc.

In arriving at the nonfuel operating costs and fuel costs, the following data and assumptions are used:

Operating Costs

a) **Wood system**: Capacity = 400 hp or 13,800 lb steam/hr
Wood fuel = Sawdust, bark, whole tree chips
Moisture content = 50% (wet basis)
Heat value = 4,000 Btu/lb
Wood system efficiency = 65%
b) **Existing System:**

<table>
<thead>
<tr>
<th>Fuel consumption</th>
<th>87.4% natural gas</th>
<th>12.6% No. 2 oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>51,934,400 ft$^3$/year</td>
<td></td>
</tr>
<tr>
<td>No. 2 fuel oil</td>
<td>53,464 gals/year</td>
<td></td>
</tr>
<tr>
<td>Heat value of natural gas</td>
<td>1,000 Btu/ft$^3$</td>
<td></td>
</tr>
<tr>
<td>Heat value of No. 2 oil</td>
<td>140,000 Btu/gal</td>
<td></td>
</tr>
<tr>
<td>System efficiency</td>
<td>80% (gas-oil)</td>
<td></td>
</tr>
</tbody>
</table>

c) **Other Assumptions:** Life of wood system = 20 years

- Interest rate = 12%
- Cost of electricity = $0.03/Kwh
- Labor = $5.62/hour
- Capital of existing system = Fully paid

d) **Fuel costs:**

- Annual energy consumption: $59.42 \times 10^9$ Btu/year (gas & oil)
- Net energy output = $47.536 \times 10^9$ Btu/year (80% eff)

Wood fuel consumption = \(\frac{47.536 \times 10^9}{4000 \times 2000 \times 0.65}\) tons/year

\[= 9,142 \text{ tons/year}\]

Cost of wood fuel @ $8/ton = 9,142 \times 8 = 73,136/year

Conventional fuel costs:

- Cost of No. 2 fuel oil = 53,464 gallons \times $0.86/gal = $45,979/year
- Cost of natural gas = 51,934.8 MCF \times $3.00/MCF = $155,804/year

Total cost of conventional fuels = $201,783/year

The various costs are summarized in Table 3.
AN ECONOMIC ALTERNATIVE
ENJOYING SUCCESS

By

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Plant Utilities Manager

The Procter and Gamble Paper Products Company
Albany, Georgia

Presented At
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia
Mr. Mulligan holds a B.S. degree in Naval Engineering from the U.S. Naval Academy, Annapolis, Maryland and an M.S. degree in Mechanical Engineering from the U.S. Naval Post Graduate School, Monterey, California. Dan is presently the Plant Utilities and Environmental Manager for the Procter and Gamble Paper Products Company, Albany, Georgia. He has been actively involved in energy reduction for the Albany plant for the past two years. He has been with Procter and Gamble four years; prior to that time he was a member of the U.S. Navy.
Proctor and Gamble took another major step forward in its continuing energy conservation effort with the March 2, 1981 start-up of a new waste fuel boiler at the Albany, Georgia, paper products plant.

This project is noteworthy because the new boiler facility is the company's first attempt to generate plant steam using waste wood as the only fuel source. The major success of this project is that it started up six months ahead of schedule with a boiler reliability greater than 99 percent.

During the first year of Albany Plant operation, it spent $500,000 for fossil fuel and this number has escalated to a staggering $8,000,000 during the last fiscal year. The impact of high fuel prices was certainly being realized by Procter and Gamble and in the late 1970's the Company began to explore economic alternatives to its existing method of operation. The concept of an independent waste wood boiler was unique to Procter and Gamble. The necessary boiler reliability was questionable. The Company had experience operating waste fuel units, but only in the role of a back-up boiler. The economics of such a concept at the Albany Plant was most attractive, so the decision was made to move ahead with the project. From the date of the project approval to the date of start-up was 18 months. During that period the project was designed, engineered, purchased, constructed and finally started up. On the start-up date the previous gas/oil fired boiler was shut down.

The new boiler, when operating at maximum capacity, reduces the Company's dependence on fossil fuel by the equivalent of 225,000 barrels of fuel oil per year. That is enough fuel to heat 35,000 homes annually.

Waste wood is purchased from approximately 20 Georgia suppliers; this will increase the Company's impact on the South Georgia economy by about $1,500,000 annually. The new boiler will burn more than 500 tons of waste wood per day and will generate 120,000 pounds of steam per hour. The latest environmental control technology was used in the boiler design to comply with Federal and Georgia clean-air regulations.

The waste fuel boiler start-up was unique in that the process was not dependent on a production schedule. The start-up focus was generating steam from wood as soon as possible.

The start-up was dependent on a number of critical variables of which delays in any would impact the start-up date of August, 1981. These variables included system engineering, design reviews, equipment purchase, equipment delivery, construction staffing, plant utilities staffing, technician training, construction, and pre-start-up inspections.

The boiler was the most critical piece of equipment in regard to schedule impact. By thorough planning, the boiler was selected, reviewed, purchased and delivered three months early. At this same time woodyard
equipment was being installed in order to support wood stockpiling in the event of an early start-up. With those key areas well in progress, we were able to focus on other significant schedule impact areas. It was recognized that by increasing the Utilities Department staffing early, the initial training would be completed earlier so that additional people would be made available for the construction support. The early staffing proved to be very successful. The new personnel completed an aggressive training plan on the existing utilities systems and qualified to assume shift responsibilities within four months. Five additional people were then freed to support the start-up team. These additional resources supported the development of the organizational and operational requirements which would support a successful start-up. It was an objective to complete these requirements prior to the boiler's scheduled construction completion.

Within nine months of the authorization of the project appropriation, construction was underway on the boiler support structure and woodyard equipment. Review of the progress of the project indicated that the August, 1981, start-up date could be improved, and start-up was revised to May, 1981. Our focus remained at generating steam from wood as soon as possible. The Project Group continued to look for ways to improve the schedule.

During the early stages of construction those members of the Department assigned to the project were able to review drawings, specifications and technical manuals in order to become more familiar with the project. During this period the operating technical manuals, equipment training manuals, operator training programs, preventive maintenance program, spare parts inventory, calibration, and operational file systems were prepared. These were all completed utilizing department personnel. As construction drew closer to completion this experience was extremely beneficial in aiding in decisions regarding field changes. At this point 40 percent of the department was involved in the project with the remaining 60 percent supporting the plant utilities operation.

In order to support the loss of experience to the project, the plant provided experienced temporary people to support the utilities operation. The training of the people operating utilities in the new system was accomplished by rotating them to the Project Group for training. Each person was provided four weeks of training.

In the early summer, the truck dumping system was ready and wood was being received. The woodyard system was completed and successfully tested by October, 1980. We were confident that we had a reliable wood feed system for the boiler. Construction was continuing at a fast rate. The boiler completion was firm at December, 1980.

In order to improve on the May start-up, consolidation of the time from construction completion to start-up would need to be reduced. The
decision was then made to eliminate a formal process definition period. The pre-start-up inspections were completed in conjunction with construction completion of subsystems. The objective was to have all systems ready and personnel trained when the boiler construction was completed. We were successful in meeting that objective. In January the boiler was completed, support systems operational and people trained. When this revised strategy was developed, the schedule was changed to move start-up to March 2, 1981--six months ahead of the original date. January and February were devoted to boiler inspections, hydrostatic testing, boil-out, flushing and test firing.

The strategy was to test fire on oil to ensure header control and reliability of the automatic combustion controls. With the boiler successfully operating on oil, wood firing began. After two days of testing on wood the plant steam load was shifted to the waste wood boiler at 100 percent wood. The date was March 2, 1981. The risk associated with this was low. With a gas fired boiler as a back-up, any interruptions in operation could be quickly picked up with that unit minimizing disruptions in steam service.

The reliability of the boiler has been greater than 99 percent during each month since start-up. This can be attributed to the attention to detail during construction, obtaining excellent operational control during oil firing, and early operation involvement and training.

The savings associated with this project are substantial. The dependence on the most abundant renewable Georgia resource benefits Procter and Gamble and the State of Georgia, thereby significantly reducing the dependence on fossil fuel. This has truly been an economical alternative enjoying success.
UTILIZATION OF AGRICULTURAL BIOMASS WASTE PRODUCTS FOR PROCESS STEAM GENERATION IN A SOYBEAN OIL EXTRACTION FACILITY

by

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Presented at
WOODTECH' 81
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MITCHELL L. TEAGUE

Mr. Teague received both his bachelor's and master's degrees in Mechanical Engineering from the Georgia Institute of Technology. As a member of the Corporate Engineering group of Gold Kist, he has worked extensively on the wood fired boiler system project located at the Valdosta facility. He has also worked on heat recovery systems for poultry by-products plants.
Gold Kist, Incorporated, an agricultural cooperative, owns and operates a 2000 ton per day soybean oil extraction facility in Valdosta, Georgia. The facility was designed by Blaw-Knox and Gulf States working under Gold Kist engineering supervision and constructed in 1968. The soybean oil extraction process requires 45,000 to 55,000 pounds per hour of 150 PSIG saturated steam. The steam is used primarily for soybean meal drying and toasting, and solvent distillation. Some portions of the steam are throttled to lower pressures before being used for the heating purposes. Additionally, approximately 4000 pounds of steam per hour is sold to an adjacent Gold Kist facility.

The facility also uses natural gas (or fuel oil) in three grain driers on the site. The grain driers use approximately twenty percent of the total fuel consumed by the plant. The grain driers will continue to be fueled with the conventional fuels.

In order to reduce steam costs, Gold Kist has installed a waste fuel boiler, manufactured by Wellons, Incorporated, that will be fired with wood waste and agricultural biomass waste products generated by Gold Kist owned processing facilities.

### AVAILABLE BIOMASS WASTE PRODUCTS

Gold Kist operates a peanut processing facility in Ashburn, Georgia, which shells peanuts. The Ashburn facility is about 70 miles from Valdosta. The peanut shells are primarily a waste product of limited commercial value. The peanut hulls are used in the production of commercial animal litter, residential fire logs, and as a filler for bulk in cattle diets. In the past, teepee type burners were used to dispose of excess hulls that could not be sold. Some hulls were also disposed in land fills. Environmental restrictions have limited the use of the teepee burners, and as a result, a considerable quantity of excess peanut hulls is occasionally available.
Peanut hulls have good potential as a solid fuel. The heating value of peanut hulls is approximately 8000 Btu's per pound. The hulls are relatively dry, because the peanuts must be dried to below 10% moisture content to satisfy USDA requirements for safe storage before the shelling operation. The ash content of peanut hulls is normally between 3% and 4%, with the initial deformation temperature occurring at 2160°F, softening temperature occurring at 2210°F, and fluid temperature occurring at 2310°F. The heating value and ash content of the peanut hulls are similar to other cellulosic materials used for fuel, such as wood waste and bark. The moisture content is generally lower than other typical biomass fuels, due to the required drying process. Refer to Table 1 for a comparison of cellulosic fuel properties.
<table>
<thead>
<tr>
<th>Fuel</th>
<th>Peanut Hulls</th>
<th>Pecan Hulls</th>
<th>Pine Bark*</th>
<th>Pine Wood*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximate Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile Matter %</td>
<td>75.7</td>
<td>76.5</td>
<td>72.9</td>
<td>79.4</td>
</tr>
<tr>
<td>Fixed Carbon %</td>
<td>20.6</td>
<td>21.2</td>
<td>24.2</td>
<td>20.1</td>
</tr>
<tr>
<td>Ash %</td>
<td>3.7</td>
<td>2.3</td>
<td>2.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Heating Value,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Basis, Btu/km</td>
<td>8,573</td>
<td>9,170</td>
<td>9,030</td>
<td>9,130</td>
</tr>
</tbody>
</table>

The Ashburn facility processes a large quantity of peanuts every year. There are approximately 20,000 tons of peanut hulls available for fuel use after local feed sales during the processing season. The season starts in early fall when the first peanuts are harvested and continues for about nine months.

Peanut hulls are also available from a Gold Kist facility in Tifton, Georgia, about fifty miles from the Valdosta facility. This facility has approximately 4700 tons of peanut hulls available for fuel use, after local feed sales.

Pecan hulls are also available as a biomass boiler fuel from a Gold Kist facility in Waycross, Georgia. This facility generates approximately 1000 tons per year of pecan hulls, after local sales. The pecan hulls also have a value as an abrasive cleaning agent in some blast cleaning operations, as a packing in oil field drilling operations, and as a garden mulch. The pecan hulls have a burned heating value of about 8500 BTU's per pound and a moisture content of about 7.5%. The ash content is 2%, with an initial deformation temperature of 2660°F, a softening temperature of 2700°F, and a fluid temperature of 2740°F.

The peanut and pecan hulls will provide approximately 4.3 x 10^6 Btu's per year. A boiler efficiency of 80% means that there are 3.4 x 10^6 Btu's per year available from the agricultural biomass products produced from the three Gold Kist facilities. The boiler system will require a fuel input of approximately 6.6 x 10^6 Btu's per year. Therefore, the agricultural biomass waste available within the Gold Kist organization will supply the waste fuel boiler with approximately 65% of its biomass fuel requirements.

In order to supply the remaining fuel required for the boiler, Gold Kist has made arrangements to purchase wood waste products from the forest products industries in the area. These products include bark, sawdust, chips, and sanderdust. South Georgia and North Florida produce a considerable quantity of forest products, and Gold Kist is fortunate in being able to purchase the waste products from companies in the wood industry. In some instances, the forest products industries have trouble disposing of their waste products and they are glad to have a means of disposal.

TRANSPORTATION AND RECEIVING

All biomass fuel for the boiler must be shipped to the soy processing facility by truck. Gold Kist will use a company owned fleet of two tractor-trailers to transport the peanut hulls from Ashburn and Tifton to Valdosta. Wood waste products are received in trucks operated or leased by the forest products processors in the area. Each truckload of fuel is
weighed on truck scales as the truck enters the plant. The scales are also used for receiving soybeans and shipping soy meal and soy oil.

Provisions for future rail receiving were incorporated into the design of the receiving system. Current rail shipping prices are so high as to favor shipping the boiler fuel by truck.

The trailers are unloaded using a Kewanee hydraulic truck dumper. The boiler fuel falls into a hopper with two screw conveyors in the bottom. The screw conveyors can be run individually or simultaneously, depending upon the desired unloading rate. The screw conveyors discharge into a Tramco drag chain conveyor. The drag chain conveyor, inclined at an angle of forty-five degrees, conveys the boiler fuel to the top of two storage silos.

There is a discharge spout about half way up the drag chain conveyor. An air operated slide gate can be opened to allow boiler fuel to fall into a bulk storage pile under the drag chain conveyor. Only wood waste products and pecan shells are stored in the outside storage pile. All of the peanut hulls will be stored in the storage silos. A reversing leveling screw distributes the wood waste products in the storage pile. A front end loader is also used to distribute the pile. The outside wood storage pile has a storage capacity of approximately 700,000 cubic feet of wood waste products.

Wood is recovered from the storage pile using the front end loader. The front end loader deposits the wood waste into the truck dump hopper for reclamation.

Boiler fuel is deposited directly into one silo from the forty-five degree drag chain, or transferred to the other silo with another Tramco drag conveyor, mounted horizontally between the tops of the silos.

The two storage silos are Piedmont silos, constructed of reinforced concrete. The silos were constructed utilizing the jump form process. The silos are equipped with explosion vents, because of the hazardous nature of peanut hull dust. The silos are thirty feet in diameter and eighty feet high. The silos will contain enough peanut hulls or wood waste to operate the boiler for about seven days. Provisions have been made for the installation of a third storage silo if operating experience determines that a third silo is necessary.
SILO RECLAIM

The boiler system starts with the reclaim system in the storage silos. Located in the bottom of each silo is a "Flying Dutchman Unloader" arrangement, consisting of a pipe centered in the silo with a series of chain welded to the pole. The pole rotates whenever there is a call for fuel, the chains agitate the boiler fuel, and a small paddle discharges the boiler fuel through the discharge opening in the bottom of the silo. The boiler fuel drops into Tramco drag chain conveyors, located in a tunnel under the silos. The drag chain conveyors are equipped with variable speed drivers, so that the boiler operator can blend the desired proportions of fuel from each silo. Fuel blending might be used in case the boiler operator desires to burn peanut hulls and wood waste simultaneously. The Tramco drag chain conveyors discharge into the main boiler fuel feed conveyor manufactured by Wellons. This drag chain conveyor conveys fuel into the boiler house and deposits the fuel into three metering bins. The silo unloaders, tunnel drag chain conveyors, and Wellons main feed conveyor operate on demand by fuel level in the metering bins.

METERING BINS

Each of the three metering bins has two screw feeders in the bottom of the bin. The screw feeders are driven by variable speed A.C. motors. There is one variable speed motor per metering bin. The motor speed is controlled by the boiler steam pressure controller, which also controls the position of the forced draft air dampers. The steam pressure controller sends an electrical signal to the programmable controller, which in turn calculates the appropriate metering screw speed and sends an appropriate signal to the metering bin motors' speed controller.

The metering bins deliver fuel to feed screws, which conveys the fuel to chutes where the boiler fuel drops into the combustion section of the boiler. There is one feed screw at each metering bin. Each feed screw is double-flighted, to provide an even fuel feed to the boiler.

COMBUSTION SECTION

Each feed screw delivers fuel into a "fuel cell" where combustion takes place. There are three fuel cells, each being about six feet in diameter and about twelve feet high. The cells are equipped with water-cooled grates. Preheated combustion air is introduced into each cell in three locations; undergrate air, circumferential air, and overfin air. The undergrate air enters the cell through slots in the water-cooled grates and
assists in drying any high moisture content fuel. The circumferential air enters the cell tangentially, creating a cyclonic action within the cell. The overfire air is introduced near the top of the cell, and provides additional air required for complete combustion of any pyrolysis gases generated in the cells.

The amount of combustion air introduced into each portion of the cell can be ratioed as desired by adjusting the forced air dampers. Boiler fuel with a high moisture content may require more undergrate air, for example, than a very dry fuel such as planer shavings, or peanut hulls. The dry fuels may require little or no undergrate air for proper combustion. Of course, the correct total quantity of combustion air must be supplied in all cases.

FURNACE SECTION

A large furnace section, ten feet high, ten feet wide, and thirty-seven feet long, is located directly above the fuel cells. The volume of the furnace section is large enough to allow complete combustion of any pyrolysis gases or sparklen that comes out of the fuel cells. The large volume of the furnace section also allows the velocity of the combustion gases to decrease so that any heavy ash carried out of the fuel cells drops out. A large drop-out chamber at one end of the furnace section catches the ash that may have been entrained in the combustion gases.

WATER SECTION

The water section of the boiler consists of an A-type, water tube Nebraska boiler. The boiler is shop-assembled, with two mud drums and one steam drum, typical of the A-type boiler. The boiler has a design pressure of 700 PSIG, and an operating pressure of 600 PSIG. The boiler is equipped with a superheater section that will provide superheated steam at 750°F. The boiler is designed to produce 80,000 pounds of steam per hour when fired with natural gas or fuel oil, and is derated to 60,000 pounds per hour for the waste fuel application. Currently, the boiler is operated at 150 PSIG. The boiler will be operated at the higher pressure when cogeneration equipment is installed.

The water section of the boiler is mounted on top of the furnace section. Due to the arrangement of the A-type boiler, additional furnace volume is available between the boiler tubes. The boiler tubes are located far above the combustion section of the boiler, so that the possibility of clinkers and slag getting on the tubes is almost non-existent.

The boiler has a total heating surface area of 7928 square feet. The superheater has a heating surface of 850 square feet. The radiant section
of boiler tubes are finned, and the convective section of boiler tubes are bare.

The water section of the boiler is equipped with two fixed Diamond soot blowers. Each soot blower is mounted in the bank of tubes connecting the mud drums to the steam drum.

There are ash hoppers mounted on each mud drum. The hoppers collect ash that drops out in the convective section of the boiler.

COMBUSTION AIR

Combustion air is supplied to the boiler by a seventy-five horsepower Chicago airfoil fan. The fan is rated at 36,000 CFM at 7.5 inches of water static pressure. The combustion air flows from the fan through an air-to-air heat exchanger, and then through the previously discussed forced draft damper. There is an air bypass installed around the combustion air preheater to allow the operator to control the temperature of the combustion air. Full air flow through the heat exchanger will heat the combustion air to about 350°F, depending upon the boiler load.

The air enters the fuel cells through the forced draft dampers and travels through the convection section of the boiler. The combustion gases exit the boiler and flow through an economizer and then the combustion air preheater. After the air heater, the combustion gases flow through a multi-cone dust collector, and then into the induced draft fan. The combustion gases then flow up the stack.

The induced draft fan is a Chicago radial-tipped, single wheel, single inlet fan. The fan is rated at 67,000 ACFM at 12 inches of water static pressure and is driven by a 250 horsepower D.C. motor. The D.C. motor is variable speed. The motor speed is controlled by the draft pressure in the furnace section of the boiler, through the programmable controller. The speed of the fan is varied so that a negative one-half inch water column pressure is maintained in the combustion chamber. The variable speed system was installed based upon potential energy savings occurring during periods of time the draft fan is operating below its rated capacity.

ECONOMIZER

The economizer is a Trenten Kentube model with 1418 square feet of effective surface area. The economizer is equipped with two Diamond soot blowers. The economizer is designed to preheat boiler feedwater from 225°F to 289°F and decrease the combustion gas temperature from 675°F to 498°F, at design condition. The economizer has a design pressure of 900 PSIG.
AIR HEATER

The combustion air heater is installed in the combustion gas stream after the economizer. Combustion gases flow through three inch diameter tubes, while combustion air flows around the outset of the tubes. Access doors are provided for clean-out purposes.

The air heater increase boiler efficiency by as much as ten percent and allows the use of boiler fuels with moisture contents as high as fifty percent moisture.

COEN GAS-OIL BURNER

The boiler is equipped with a Coen gas-oil burner rated at 86 MMBtu/hr. The gas-oil burner is mounted on the Nebraska water section of the boiler. It is equipped with its own 40 HP forced draft fan. The gas-oil burner is hardwired, and not controlled through the programmable controller for safety purposes.

The boiler can be fired solely by the gas-oil burner, or the boiler can be fired by base-loading with wood waste or peanut hull fuel and using the gas-oil burner to take the boiler swings. If base loaded on biomass, the forced draft dampers and fuel metering screws are set manually at the desired firing rate and the boiler firing rate controller governs the gas-oil burner oxenation. It may be desirable to operate the boiler in this mode in case of a shortage of wood waste products and peanut hulls.

POLLUTION CONTROL

Emissions from the boiler are controlled using a mechanical multi-cone type duct collector and a fabric filter baghouse.

The dust collector is manufactured and supplied by Wellons. The dust collector is located after the air heater, in order to minimize its size. It is an effective device, removing nearly all of the large sized particles reaching it, with a relatively low pressure drop through the collector. The low pressure drop through the collector corresponds to low energy requirements for its operation. The Wellon boiler systems normally meets all emissions requirements while burning wood waste with just the multi-cone dust collector installed.

Unfortunately, the burning of peanut hulls requires additional pollution control equipment. This is due to several factors, including the chemical composition of the hulls, the dryness of the hulls, and the size of the hulls and the ash contained within the hulls. After considerable investigation by Gold Kist, including test firing of peanut hulls in a Wellons
boiler, it was determined that a fabric filter was the best solution to the pollution control problem.

A fabric filter baghouse has been ordered from Eastern Controls, Incorporated. The fabric filter will be installed during July and August, 1981. Prior to that time, the boiler was fired only with wood waste products, so that emissions limitations could be met with the dust collector. The fabric filter is a reverse air type, with four sections of filters. Each section contains 182 bags. The design air to cloth ratio is less than 3.0. Fiberglass bags are used in the filter.

FEEDWATER SYSTEM

The feedwater system consists of a water softener, a Stickley spray-type deaerator, and two boiler feedwater pumps.

The water softener is a typical zeolite type regeneration softener, rated for full make-up capacity, in case condensate is not returned to the boiler for some reason. The softener provides adequate water treatment for operation of the boiler at 150 PSIG. When the boiler is operated at 600 PSIG, a demineralizer will have to be installed, because of the high silica content of the make-up water. The demineralizer will be installed to prevent turbine problems due to impurities being carried out of the boiler in the steam.

The deaerator is also rated for full make-up capacity, and it provides fifteen minutes of feedwater storage capacity.

The boiler feedwater pumps are Goulde horizontal split case two stage pumps. The pumps are driven by fifty horsepower motors. One pump is operated as the primary feed pump, and the other pump is in stand-by. The feedwater pumps also supply water for a Coper-Vulcas desuperheater. Saturated steam is required in the soy processing facility for heating purpose, so all steam going to the facility must be desuperheated. There is also a recirculation orifice for feedwater pump protection that recirculates water to the deaerator.

Cooling water for the grates in the boiler is also supplied from the deaerator. A Goulde end suction circulation pump pumps water through the grate. The cooling water is recirculated to the deaerator.

PROGRAMMABLE CONTROLLER

Every motor or electro-mechanical device in the receiving system or in the boiler system, with the exception of the gas-oil burner controls, is controlled by a Gould Modicon 584 programmable process controller. The
control logic for the receiving system was designed and programmed by Gold Kist. The control logic for the boiler was designed by Wellons and programmed by Gold Kist.

The programmable controller allows convenient changes in the operating logic to be made, in case of design changes or oversights in the initial operating logic. Additionally, it can be programmed to perform calculations upon input signals and provide a corresponding output signal for devices. Presently, calculations are performed to control the metering screws, determine the volumetric quantity of fuel introduced into the boiler, blend fuels from the two storage silos, and control the speed of the induced draft fan. The programmable controller also controls the annunciation on the boiler and receiving system control panels.

ENGINEERING AND CONSTRUCTION

Engineering and construction of the boiler house and boiler system was the responsibility of Wellons, Incorporated. Gold Kist provided some components of the boiler system, according to Wellons specifications, including the forced draft and induced draft fans, boiler feedwater pumps, and all electric motors. Gold Kist also provided the electrical design, with the exception of the boiler control logic, and contracted to have the electrical system installed.

Gold Kist provided the engineering and design for the site work and utilities connections and contracted for the work. Gold Kist provided the design and some of the engineering for the receiving system. Simone-Eastern provided the additional engineering for the receiving system and Gold Kist contracted for the work.

COSTS AND FUNDING

The total cost of the project, including engineering, utilities and site work, the receiving system, and the boiler and boiler house, was approximately $4,000,000. The boiler and boiler house cost approximately $1,500,000. The additional pollution control equipment required for firing peanut hulls cost approximately $300,000. Research funds in the amount of $146,000 were provided through the Georgia Tech Engineering Experiment Station and the Georgia Office of Energy Resources, by the Biomass Energy System Division of the U. S. Department of Energy.
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PREPARATION OF FEASIBILITY STUDIES

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INTRODUCTION

The purpose of this paper is to provide guidelines for the preparation of wood energy feasibility studies for industrial plants. It addresses the principal elements that should be included in the studies and particularly those items that may be unique to the use of wood for energy.

The topics are:

1. Report Organization
2. Wood Fuel Supply
3. System Design
4. Construction, Operating and Maintenance Costs
5. Economic Evaluation
6. Summary and Recommendations

REPORT ORGANIZATION

A wood energy feasibility study should be characterized by its completeness, clarity and presentation. In other words, it should contain all of the elements that go to make up any good feasibility study. If a wood energy feasibility study has any special requirements, they are that it should contain extensive background information, for it is likely that the report will be reviewed by management people who have little knowledge of certain phases of the report. For example, there may be few people in the company who have any knowledge of the combustion of wood aside building a camp fire or burning logs in a fireplace. They will bring these prejudices to the reading of the feasibility study, so it is essential that the feasibility study present sufficient information for its understanding. Another area of the feasibility study which will require special emphasis is the presentation of the wood fuel supply. Again, there are few people who have an understanding of the methods of determining fuel availability and its marketing organization. This means, as stated previously, that a good wood energy study should include more background type of information.

There are several ways of organizing a feasibility study and there is no one correct presentation. The study should follow good organizational practice and reflect any special local needs. Among the essential elements of the study are sections on:
WOOD FUEL SUPPLY

Though all sections of a feasibility study are important, the one that is usually most critical is the work that is done to establish the availability of wood fuel at a particular site and its cost. In many locations, a study will show an overwhelming supply of wood fuel available for the project but it is a fact that this is not always the case. Information is available on the wood supply and market conditions in any given area. Fuel costs can be determined and its future cost ascertained as well as it is possible to anticipate the future cost of any of the common fuels.

A wood fuel supply study should encompass these seven elements:

- Growth and removals
- Forest waste and quantity availability
- Manufacturing waste, its quantity and availability
- Present wood fuel marketing structure
- Proposed marketing structure
- Economic analysis of proposed wood fuel
- Specific supplier identification

The first two items establish the size of the basic resource that is possibly available for wood fuel. What is the present mass of the trees growing in a given area? How much new growth is expected each year? How much of this growth is presently harvested? What is the amount of this growth that is left in the forest in the forms of tops and limbs and undesirable species? This information is available in publications from the U.S. Forest Service and can often be obtained from the state forest service. For instance, in the State of Georgia, this information is on a computer tape at the Georgia Forestry Commission headquarters in Macon and they will be happy to print out this information for you for any given
area of the state. During many of the past surveys, the U.S. Forest Service was looking at forests only in terms of timber production and paper industry. In some cases, this has led to significant undercounts of the total biomass that is available for fuel. The U.S. Forest Service recognizes this problem and has begun a program to update their surveys.

The next item is manufacturing waste. This is sawdust, chips, slabs, and bark that comes primarily from the manufacture of lumber. This can often be the most economical source of wood fuel. The technique for determining the quantity of manufacturing waste varies, but it generally involves telephone contacts or, preferably, actually going to visit the sawmills in the area and discussing with them the quantity of material that they would have available for fuel. In many locations, this material has had such little economic value in the past that determining accurate quantities available may be a little difficult. But it has been most people's experience that the sawmills quickly determine the quantity of material they have when they find that there is a market.

The next item listed concerns the present marketing structure for fuel. It needs to be known whether there are a few or many people engaged in the forest products industry, are they independent or are they captive to larger organizations? How is the price structure set for wood products? After determining this information, the next item listed proposed marketing structure follows logically. If a new significant demand for wood fuel entered the market, what would be its effect? You may find that there is such a large supply of wood fuel available and the demand relatively low that no significant effect will be felt.

The next item--Economic Analysis of Proposed Wood Fuel--will probably contain several scenarios. In many locations the base price is established by the cost of whole tree chips because the quantity is practically unlimited. For the manufacturing waste material (sawdust, slabs, and bark) there could be several different prices depending upon the location, quantity available, and the existing market. In addition to cost there are always a number of other important market factors to consider in this economic analysis. How reliable is the source of supply? How clean is the fuel? How much preparation is needed for the system being considered?

The next item is the identification of specific suppliers. This recommends listing the actual names and addresses of people contacted who are interested in supplying wood fuel. There is no set expectation. The supplier could be a sawmill, landowner, harvester, or, as is becoming common today for the larger installations, the use of a wood fuel broker.
SYSTEM DESIGN

- Analysis of Company Energy Requirements
- Applicability of Proposed Wood Energy System
- Evaluation of System Components
  - Fuel storage
  - Fuel handling
  - Combustion system
  - Stack emissions
  - Ash handling
- Maintenance Requirements
- Operating Requirements
- Environmental Impacts

The analysis of the energy requirements for wood energy systems follows conventional practice with the special consideration that solid fuel systems are more capital intensive. As solid fuel energy systems can have construction costs five to ten times that of natural gas systems, it is important to apply best efforts to determine the minimum size system that will meet the project's requirements. The natural gas systems were so low in cost that many designers adopted sizing practices which are little more than sophisticated guesses. Wood systems are comparatively expensive, so it is prudent to spend the necessary effort to make an accurate determination.

Another factor that needs to be evaluated regarding the size selections of a wood fired system is the duty cycle of the equipment. That is an evaluation of the number of hours of operation taken together with the percent of full load operation. For example, the ideal situation would be a power plant that operated 24 hours a day, 7 days a week, 365 days a year at 100% load. Except for certain special applications this ideal is never achieved in practice. So the question must be addressed whether or not to size the wood burning system to take the maximum peak load or to size the wood system to take care of the base load with the peak load taken by some other means. For example, the load requirements could be seasonal. The plant could operate with an essentially flat load for most of the year with a high peak occurring for only a few days. In this instance it may be economically prudent to size the wood fired system to handle the base load.
only and supply the peak requirements with a standby gas or oil fired unit. Though the gas or oil fuel should cost more than the wood fuel this difference could be more than made up by the interest charges associated with the higher capital costs of the wood system sized to take care of the peak load. If there is a significant difference between the base load and the peak load, the wood energy feasibility study should include an evaluation of this fact.

The next item under system design is to consider the applicability of the proposed wood energy system. In addition to the usual factors which apply to all systems, the special characteristics of wood systems need to be considered. For example, some wood systems cannot follow rapid load changes. If the load suddenly drops there may be so much fuel in the firebox that excessive steam pressure results. The reverse situation can also be true and can result in some operating problems. If the steam load should suddenly sharply increase the steam pressure could drop for several minutes until the system responded to the new load.

The feasibility study should include an evaluation of the system's components. How does the fuel storage system match up to the system requirements and any fuel supply interruptions which may occur? How automated is the fuel handling system? How much labor is required? Should a failure be experienced in the fuel handling system, what back-up method of fuel handling is provided? Is the combustion system proven or somewhat experimental? Can it readily handle the expected type of wood fuel? Is the design of the pollution control system adequate to meet the stack emission requirements of the federal, state and local authorities? What type of ash handling system is proposed? What will be the disposal procedure for the ash?

The feasibility study should address the special maintenance requirements of wood fired system. Especially in the area of fuel handling, maintenance requirements can be significant. Another factor can be the requirement to clean the boiler heating surfaces. With gas or oil fired systems it is seldom necessary to clean the heating surfaces because the fuels are so clean-burning. But even with the best of firing practices soot and fly ash accumulate and must be removed periodically. The feasibility study should also address the special operating requirements of wood fuel systems. As a general statement most wood fired systems require the full time attention of a boiler operator. Additionally many systems require the services of one or more people for the management of the fuel.

The feasibility study should consider the various issues which may be of environmental concern. In addition to stack emissions and ash handling there could be environmental impacts from water run off from outdoor wood storage piles or machinery noise. In some locations the noise, traffic and pavement damage from fuel delivery trucks has been questioned.
CONSTRUCTION OPERATING AND MAINTENANCE COSTS

- Equipment Costs
- Construction Costs
- Operating Costs
- Maintenance Costs

The costing procedure for a wood energy feasibility study is essentially the same as other construction projects which are of the same order of magnitude. A full variety of construction procedures have been employed, ranging from a 100% turn key installation to purchase of equipment with the installation being handled in-house. The method to employ is the one which is deemed most favorable to the purchaser. As there is generally more equipment and more field labor involved in the installation of a wood system as compared to a gas or oil system, special care should be taken to insure that all costs have been included. This is especially true in the instance of operating costs and maintenance costs. The normal operating costs associated with gas-oil systems should be adjusted to cover the increased horsepower required by the larger combustion air fans. The pollution control equipment can have a high pressure drop which is reflected in increased horsepower for the induced draft fan. There are operating costs associated with the conveyor system and with a front end loader which is frequently employed. Likewise the maintenance costs associated with wood systems are generally higher than the maintenance costs of conventional gas-oil systems. Maintenance costs of the fuel handling system can be significant. It is not unusual to have $750,000 to $1,000,000 invested in the fuel preparation, storage and retrieval system. With this much active machinery the maintenance costs can be substantial.

The essential ingredient in the preparation of the costs section of the feasibility study is to be thorough and to include all important costs, whether associated with construction, operation, maintenance or other costs which may apply to any particular installation.

ECONOMIC EVALUATION

This section of the feasibility study addresses all issues that affect the economic viability of the project. The most important principal to use in developing this section is to be complete. Essentially this section provides guidelines which aid the decision making process. The section should compare the cost of using wood as a prime fuel source to other energy options that may be available. In addition to the facts that are gathered, this section will require that certain assumptions be made.
Among the assumptions that will be required are:

- Future fuel costs
- Percent of full load operation
- Interest rates
- Inflation factors

The values that are assigned to these various assumptions will greatly influence the economic evaluation. It has been the experience of many that the single most important assumption is the percent of full load capacity that is utilized. Systems that are utilized to near full capacity on a continuous basis almost invariably have an excellent economic return. It is also true that systems which are underutilized both in hours of operation and percent of capacity will have a poor rate of return. The reason for these results is the high capital investment required by a solid fuel facility. In any event, the assumptions made should be clearly indicated so the final result of the calculations can be evaluated in light of these assumptions.

The actual economic analysis can be as elaborate or simple as desired. It may be adequate to perform a simple payback analysis; but as there is usually a substantial amount of money involved, it is more likely that some form of life cycle analysis will be desired or even required by company policy.
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Appendix D

ARAGON: AN ALTERNATIVE
ARAGON: AN ALTERNATIVE

Georgia Institute of Technology
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AN OLD SOLUTION TO A NEW PROBLEM

As energy economics change to favor higher petroleum prices, alternative energy sources once considered too expensive to use become more attractive. Biomass sources in particular are beginning to show economic viability; and wood energy systems, a subset of biomass systems, show considerable potential for providing energy in the industrial and residential sectors.

Direct combustion wood energy systems have been used extensively in the forest products industry for many years, and that industry is familiar with technologies and procedures for both production of wood and conversion of wood to products including energy. Wood energy systems have had much less utility in nonforest products industries, however. Few companies other than those having direct forest products interests have had the expertise or the need for considering wood fuel systems. Although many factors have worked against wood use in these industries, the major barrier was the low cost of readily available fossil fuels relative to the cost of wood energy. Now, however, with gas/oil supplies becoming more expensive and in shorter supply, companies without forestry expertise may derive benefits by converting to wood fuels and reducing the nation's dependence on premium fossil fuels.

Georgia Tech has undertaken a multi-year project directed toward accelerating the commercialization of wood energy for nonforest products industries. Funded by the Biomass Energy Systems Division of the U.S. Department of Energy through the Georgia Office of Energy Resources, the primary objective of this program is to encourage the replacement of oil and gas with wood fuel.

Phase I of this project ran from July 1979 to June 1980. Eighteen feasibility studies were conducted--14 studies determined the economics for potential wood users while 4 studies conducted economic analysis for potential wood suppliers. Three actual demonstration sites were planned, and Integrated Products, Inc. in Aragon, Georgia is the first to be completed. Four seminars were held during the year and an exhaustive study detailing wood fuel processing routes was completed.

Under Phase II, which runs from July 1980 through June 1981, the feasibility studies were expanded to include potential wood users who might benefit from wood energy systems involving cogeneration, space heating, and boiler conversions. The demonstration projects begun during Phase I are continuing. An in-depth analysis of specific problems in supply, storage, and drying of wood fuels as well as better definition of fuel property standards is underway. A survey of potential wood gasification applications in Georgia and practical test programs on gasifier operational problems is being conducted. Technology transfer through seminars, publications, tours of demonstration sites, and presentations at national conferences completes the activities of Phase II.

The benefits of these efforts will be far reaching. Conversions from fossil-based energy systems to renewable resource energy systems will be accelerated. Economic activity on a local basis will be stimulated and dependence on foreign energy supplies reduced. And perhaps most importantly, a base of knowledge and a system of methodologies will be established that can be used not only in Georgia but as a model in other regions of the United States.
Self-unloading trailers bring the wood chip fuel to the plant. They can unload the fuel in the open storage area or in the fuel staging area, located close to the storage silo. The wood fuel in the staging area is moved to the receiving hopper by means of a front end loader. From the 4' x 8' x 6.5' high hopper, a screw conveyor delivers the fuel to a bucket elevator, which raises it into the 24' diameter x 48' high storage silo. Screw conveyors transfer the fuel from the silo first to the metering bin and then to the air sweep feeders. Operating at 70% load, the wood boiler has sufficient fuel to last 2 hours stored in the full 14,464 cubic feet of the storage silo. For longer term storage, there is a concrete pad of about 6,000 square feet which holds enough fuel for 15 days of operation.

The boiler has the following specifications:

<table>
<thead>
<tr>
<th>Type</th>
<th>HRT Firetube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>13,320 lb/hr</td>
</tr>
<tr>
<td>Capacity</td>
<td>400 HP</td>
</tr>
<tr>
<td>Pressure</td>
<td>130 psig</td>
</tr>
<tr>
<td>Feedwater</td>
<td>220 °F</td>
</tr>
<tr>
<td>Fuel Moisture</td>
<td>50% Wet Basis</td>
</tr>
<tr>
<td>Combustion Grates</td>
<td>Fixed</td>
</tr>
<tr>
<td>Operation</td>
<td>Fully Automated</td>
</tr>
<tr>
<td>Emission Control</td>
<td>Cyclones</td>
</tr>
</tbody>
</table>

Two tons of wood per hour or 40 tons per day are consumed to meet existing steam demand on the boiler. Neighboring sawmills and other sources supply wood fuel at reasonable prices.

In wood-burning systems, sulfur dioxide emissions are not produced during combustion; thus, wood has an additional advantage over coal and high-sulfur petroleum fuels. The only air pollutant of primary concern is particulate matter. Since wood is low in ash (around 2%), two centrifugal dry collectors (cyclones) were employed for removal of particulate matter.
THE WOOD-FIRED SYSTEM

The wood energy system at Integrated Products' Aragon mill evolved from the initial screening through feasibility study, system design, contracting, and construction. The feasibility study included a conceptual design of the system, the calculations of the financial and economic considerations, and the investigation of wood fuel availability. Work on the feasibility study began in early Spring, 1980.

After exact equipment requirements were established, the selection of vendor and installation contractors followed. Four companies submitted bids, and the contract for construction and installation was awarded to the Industrial Boiler Co. of Thomasville, Georgia. Mass Construction Co. of Rome, Georgia, was contracted for the construction of the boiler house and the fuel staging area.

Construction began in May, 1980 and the installation was completed by the beginning of December, 1980. The boiler is now in operation, supplying steam for all plant requirements, including process heat and space heating. The main system components are

- Wood storage silo
- Fuel staging area
- Horizontal return tube (HRT) boiler
- Related wood handling and emission control equipment
INTEGRATED PRODUCTS, INC.

Integrated Products, Inc. is a textile manufacturing firm headquartered in Rome, Georgia. The company manufactures yarn for the carpet industry and has plants located in Villa Rica, and Aragon, Georgia. The company employs 1800 people and supplies products to domestic and international customers. The demonstration project described here has been constructed at the Aragon plant, located 60 miles northwest of Atlanta. The employees of the Aragon plant produce carpet yarn, using steam from the boilers to set and dry the yarn to provide a patent twist. In winter, steam is also used for space heating. Previously the plant boilers ran on natural gas and oil. The old boilers are used for emergency backup.

The installation of the wood energy system at the Integrated Products plant marks an important step in demonstrating the feasibility of using wood fuel in non-forest industries. Integrated Products, Inc., was chosen for a demonstration project from a list of potential candidates based on visits by Georgia Tech personnel and meetings with the vice-president and the plant management of the Aragon facility. The selection was based on the following:

- A preliminary economic analysis performed on the basis of the energy usage data indicated that a wood energy system would be economically feasible and that the company had a strong potential for conservation of scarce gas and oil fuels.
- Meetings with the engineering and plant personnel revealed that the company had a competent technical staff, and all of them were interested in the conversion to wood fuel.
- A survey of the local wood supply situation indicated that wood fuel in the form of sawdust, bark, and wood chips would be available at economical prices.
- Financial records of the company revealed that the company was stable and that the management had a positive attitude with respect to participating in a demonstration project.
- Integrated Products, Inc., is a non-forest products industry, and its success in the demonstration project would serve as a model for other industries to follow.

Integrated Products' new wood-fired system is designed to produce 400 HP.
THE ECONOMICS OF WOOD

An investment in a wood-fired system balances low fuel costs against high initial capital costs, with payback periods as low as one year in some applications. At the Aragon mill of Integrated Products, the economic analysis looks like this:

The actual value of the investment can be calculated only over its life cycle, taking account inflation, escalation of fuel prices, interest rates, property taxes, and insurance. Conservative assumptions about the expectancy of the system and the rate of increases for alternative fuels result in a present value of over $3 million for savings that will be realized by using wood-fired boiler system.

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Wood System</th>
<th>Existing System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of Capital Amortization (20 years @ 12%)</td>
<td>$29,721</td>
<td>$0</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>40,552</td>
<td>20,744</td>
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<tr>
<td>Electricity, labor, front end loader, maintenance</td>
<td>4,500</td>
<td>4,000</td>
</tr>
<tr>
<td>Insurance and Taxes</td>
<td>4,500</td>
<td>4,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood fuel @ $8/ton</td>
<td>73,136</td>
<td>201,783</td>
</tr>
<tr>
<td>Gas @ $3/MCF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil @ $0.86/gal</td>
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</tr>
<tr>
<td>TOTAL COST PER YEAR</td>
<td>$147,909</td>
<td>$226,527</td>
</tr>
</tbody>
</table>

Cost savings per year = $226,527 - $147,909 = $78,618
Approximate payback period (before taxes) = 2 to 3 years.

WOOD ENERGY SYSTEMS DIVISION
TECHNOLOGY TRANSFER BRANCH
GEORGIA INSTITUTE OF TECHNOLOGY

Funded By
Biomass Energy Systems Division
United States Department of Energy
Through
Georgia Office of Energy Resources
Appendix E

VALDOSTA: BIOMASS VERSATILITY
A VIABLE ALTERNATIVE

As energy economics change to favor higher petroleum prices, alternative energy sources once considered too expensive to use become more attractive. Biomass sources in particular are beginning to show economic viability; and wood energy systems, a subset of biomass systems, show considerable potential for providing energy in the industrial and residential sectors.

Direct combustion wood energy systems have been used extensively in the forest products industry for many years, and that industry is familiar with technologies and procedures for both production of wood and conversion of wood to products including energy. Wood energy systems have seen much less use in nonforest products industries, however. Few companies other than those having direct forest products interests have had the expertise or the need for considering wood fuel systems. Although many factors have worked against wood use in these industries, the major barrier was the low cost of readily available fossil fuels relative to the cost of wood energy. Now, however, with gas/oil supplies becoming more expensive and in shorter supply, companies without forestry expertise may derive benefits by converting to wood fuels and reducing the nation's dependence on premium priced fossil fuels.

Georgia Tech has undertaken a multi-year project directed toward accelerating the commercialization of wood energy for nonforest products industries. Funded by the Biomass Energy Systems Division of the U.S. Department of Energy through the Georgia Office of Energy Resources, the primary objective of this program is to encourage the replacement of oil and gas with wood fuel.

Phase I of this project ran from July 1979 to June 1980. Eighteen feasibility studies were conducted—14 studies determined the economics for potential wood users while 4 studies conducted economic analyses for potential wood suppliers. Two demonstration sites, one at Integrated Products in Aragon, Georgia, and this site at Gold Kist in Valdosta, Georgia, were begun during Phase I. Four seminars were held during the year, and an exhaustive study detailing wood fuel processing routes was completed.

Under Phase II, which runs from July 1980 through December 1981, the feasibility studies have been expanded to include potential wood users who might benefit from wood energy systems involving cogeneration, space heating, and boiler conversions. The demonstration projects begun during Phase I are being completed. An in-depth analysis of specific problems in supply, storage, and drying of wood fuels as well as better definition of fuel property standards is underway. A survey of potential wood gasification applications in Georgia and practical test programs on gasifier operational problems is being conducted. Technology transfer through seminars, publications, demonstration site tours, national conferences, and presentations completes the activities of Phase II.

The benefits of these efforts are far reaching. Conversions from fossil-based energy systems to renewable resource energy systems are being accelerated. Economic activity on a local basis is being stimulated and dependence on foreign energy supplies reduced. And perhaps most importantly, a base of knowledge and a system of methodologies has been established that can be used not only in Georgia but as a model in other regions of the United States.
three screw feeders which feed fuel to the boiler through a ceramic chute.

The wood fired boiler designed by Wellons is unique in that its firebox consists of three separate cell" burners. Each cell is cylindrically shaped and designed for both underfeed and tangential air supply. The cyclonic effect produced in the cell allows for a turbulent mixing of air and fuel to promote complete combustion of the fuel. The hot gases release the unburned heavier particulates to the dropout chamber while the finer ash particles are removed by downstream collection devices. Combustion temperatures in the cells range from 500°F to 3000°F.

After the gases pass through the boiler, they proceed through an economizer, the air reheater, multiclone collector, the I.D. fan, a gashouse, and then to the stack. The economizer reheats water entering the boiler. An air reheater is used to heat the combustion air which aids drying and promotes the combustion of green wood.

In wood burning systems, sulfur dioxide emissions are not produced during combustion; thus, wood has an additional advantage over coal and high-sulfur petroleum fuels. The only air pollutant of primary concern is particulate matter. Since wood is low in ash (approximately 2%), a centrifugal dry collector (multiclone) and a gashouse are employed for removal of particulate matter.

The boiler capacity when fired on wood is 60,000 lb/hr of steam. Nebraska Boiler Company manufactured the boiler according to Wellons specifications. The boiler will also have the capability of producing high pressure steam up to 650 psig. This feature will allow electricity to be cogenerated in the near future.

Georgia Tech conducted the study of the individual supplies of wood residue within a 50-mile radius of Valdosta. The report showed efficient residue available in the area. The prices of the residue ranged from $6 to $14 per ton or $.75 to $1.75 per million Btu's delivered. By comparing these alternative fuel prices to $3.45/MMBtu for natural gas, the new boiler proved to be a feasible capital investment.
After exact equipment requirements were established, the selection of vendor and installation contractors followed. The contract for construction and installation was awarded to Wellons Company of Sherwood, Oregon.

Construction began in October 1980 and the installation was completed at the end of April 1981. The boiler is now in operation, supplying steam for all plant requirements. The main system components are:

- Wood storage silos
- Watertube boiler
- Related wood handling and emission control equipment

The boiler has the following specifications:

- Type: Watertube
- Output: 60,000 lb/hr
- Pressure: 200 psig
- Max. Pressure: 650 psig
- Feedwater: 250°F
- Combustion Sys.: "Cell" burners
- Emission Control: Cyclone/baghouse
- Baghouse inlet temperature: 300°F

The two silos are 80 feet high and 30 feet in diameter. The volume is 56,500 ft³ each. The two silos and open storage together have a total storage capacity of 750,000 ft³ of green wood. The boiler burns nine tons of green wood per hour when it is producing 60,000 lbs/hr of steam. If the boiler load remains constant at 60,000 lbs/hr, a full inventory of wood will last 38 days.

The feed system for the boiler starts at the controlled chain conveyor. From the bottom of the silos, the chain conveyor brings the fuel to one of...
GOLD KIST, INC.

Gold Kist, Inc., is the largest agricultural products firm in Georgia and one of the largest in the country. Corporate headquarters are located in Atlanta, Georgia. The company employs approximately 10,000 people and supplies products to domestic and international customers. The described wood energy demonstration project is located at Gold Kist’s soy plant in Valdosta, Georgia. The Valdosta plant employs over 200 people.

Steam is used to process soybeans into soybean oil. Steam supplies the heat required in three processing steps: heating of the extraction chemical (hexane), separating oil from the extraction chemical and water, and drying oil-free soybean flakes.

The installation of the wood energy system at the Gold Kist plant marks an important step in demonstrating the feasibility of using wood fuel in nonforest industries. This and other demonstration projects are intended to serve as models for other businesses in nonforest products. This type of wood energy technology will be able to replace expensive fossil fuels while at the same time reducing operating costs.

Gold Kist was chosen for a demonstration project from a list of potential candidates based on visits by Georgia Tech personnel and meetings with the corporate management and the plant management of the Valdosta facility. The selection was based on the following:

- A preliminary economic analysis performed on the basis of the energy usage data indicated that a wood energy system would be economically feasible and that the company had a strong potential for conservation of expensive gas and oil fuels.
- Meetings with the engineering and plant personnel revealed that the company had a competent technical staff, and all of them were interested in the conversion to wood fuel.
- A survey of the local wood supply situation indicated that wood fuel in the form of sawdust, bark, and wood chips would be available at economical prices.
- Financial records of the company revealed that the company was stable and that the management had a positive attitude with respect to participating in a demonstration project.
- Gold Kist, Inc., is a nonforest products industry, and its success in the demonstration project would serve as a model for other industries to follow.

THE WOOD-FIRED SYSTEM

The wood fuel boiler is designed to utilize biomass sources of fuel such as wood waste, peanut hulls, and pecan shells. The peanut hulls come from Gold Kist peanut processing plants in the Valdosta area.

The fuel is brought to the site in trucks and unloaded into a receiving pit using a hydraulic truck dump. From the pit the fuel is conveyed to either of the two storage silos or the open storage areas.

The heating value of hulls is approximately 7,800 Btu/lb, and the estimated heating value of green wood is 3,800 Btu/lb. The new boiler also has the capability of burning coal, oil, and natural gas.
THE ECONOMICS OF WOOD

The actual value of the investment for the first year is shown in the Financial Analysis. Due to the lack of space, all twelve years are not shown. However, the overall results of the project are given.

Using a 20% cost of capital rate, operating cost escalation of 12%, current fuel escalation rate of 18%, a wood cost escalation rate of 15%, and a life of 12 years, the discounted return on investment is calculated to be 38.1%. This type of cash flow analysis is now available to industry through a computer program developed by the engineers in the Wood Energy Systems Division of the Georgia Tech Engineering Experiment Station.

SYSTEM FINANCIAL ANALYSIS

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Wood System</th>
<th>Existing System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of Capital Amortization (12 years @ 20%)</td>
<td>$684,900</td>
<td>$0</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>134,000</td>
<td>64,000</td>
</tr>
<tr>
<td>Electricity, labor, front end loader, maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurance and Taxes</td>
<td>22,000</td>
<td>14,000</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>672,000</td>
<td>2,604,750</td>
</tr>
<tr>
<td>Wood fuel @ $8/ton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas @ $3.45/MCF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL COST PER YEAR</td>
<td>$1,512,900</td>
<td>$2,682,750</td>
</tr>
</tbody>
</table>

Before tax savings, first year = $2,682,750 - $1,512,900 = $1,169,850
Approximate payback period (before taxes) = 2 to 3 years.
Appendix F

CHIPS 'N QUIPS VOL. 1
CHIPS 'N QUIPS VOL. 2
Georgians lead the nation in forested acreage and this acreage is increasing. The number of new trees consistently exceeds the number of removal of trees from the land. Some energy researchers estimate that wood wastes alone could meet as much as 25% of the state's energy demands, if these wastes are harnessed to their fullest potential. Despite the reports, however, comparatively few Georgia industries and businesses are aware of the potential of wood as an alternative energy source.

Georgia Tech has undertaken a multi-objective project directed toward accelerating the commercialization of wood energy products. Funded by the Biomass Energy Systems Division of the U.S. Department of Energy through the Georgia Office of Energy Resources, the primary objective of this program is to encourage the replacement of oil and gas with wood fuel. A Wood Energy Extension Service has been organized as a part of this project to explore all aspects of wood energy and to determine where the best opportunities for wood conversion lie. Feasibility studies, demonstration projects, and research activities are all part of the activities of this service.

Findings from all of these activities are made available to the public through written materials, seminars, tours of demonstration plants, system models, and this newsletter.

Other Georgia Tech initiatives in wood energy are focusing on wood stove use for home heating purposes. Tech engineers are helping clarify safety codes for stove installations and have compiled handbooks to guide installations. In addition, Tech has worked in conjunction with the Georgia Forestry Commission on a mobile woodstove exhibit which toured small communities throughout the state.

ed harvest equipment, such as the whole tree chipper shown here, has greatly increased the possibilities of using wood for energy. Georgia Tech engineers are also helping to train energy auditors to inspect stove installations for the Tennessee Valley Authority.

WOOD ENERGY PROCESSING NETWORK

A number of processing routes are available to the energy user when he considers using wood to produce energy. These multiple paths and options can be confusing to the newcomer in the wood energy field, and without adequate explanation, can give the impression that the use of wood for fuel is fraught with difficulties. To clarify the situation, Georgia Tech engineers have developed a Wood Energy Processing network.

The network has three major phases: source processing, fuel processing, and site processing. The network shows the various routes involved in each phase of wood energy processing. For example, the network indicates the steps required to process the raw source (wood) from the source site. Each block indicates a major process involving capital equipment and manpower. Each process has a cost which must be added to the base price of the raw source itself. The cost of waste and chips after the transport process has been completed is the wood price that is quoted for delivered fuel.

The network is designed to serve as a roadmap for showing the relationship of individual processing steps to the overall conversion of wood to energy. Two areas currently under investigation during Phase II of the Georgia Tech wood program, for example, are fuel standards and supply. These areas relate directly to the wood sources shown under source processing. The wood fuel supply and the standards applied to the fuel will affect the cost and availability of the basic fuel source. Obviously, a change in this area will affect every part of the network.

The network will provide a means of relating the many areas being investigated as part of the Georgia Tech wood demonstration project. For further details contact Jim Walsh, 404-894-3623.
WOOD ENERGY
MEASUREMENT

How much energy can be obtained from a pound of wood? The answer to this question would seem simple enough to determine: send a sample of the wood to a laboratory and tell the chemist to run the same tests used to determine the energy in coal. Unfortunately, due to the large percentage of volatile matter in wood, the procedures used for coal do not work well for wood.

Georgia Tech is working with the American Society for Testing and Materials (ASTM) to develop testing standards for wood. The two key standards used to determine the energy in a pound of wood are the gross caloric value test and the moisture content test. The gross caloric value test will determine the total amount of energy (heat) released from the wood, and the moisture content test will determine the amount of this energy that is lost by vaporizing the moisture in the wood.

The moisture content of the wood is measured by drying the wood sample in an oven for a specified period of time and determining the weight difference between the wet and dry sample.

The gross caloric value is determined with a bomb calorimeter. (See illustration.) The sample is dried and placed inside the bomb chamber (small container). Ignition wires are attached to the sample and the bomb chamber is sealed. Then the chamber is pressurized with oxygen, and the chamber is closed to seal the complete assembly. A fuel sample is ignited by electric current through the ignition wires, and the released heat is measured by the increase in temperature of the water in the bucket. By adding the energy required to heat the bomb and bucket (data provided by manufacturer), the energy released from the wood is determined.

Moisture content and gross caloric value are two of the most important wood measurements. The data are used by designers of boilers, gasifiers, pyrolysis units, dryers and other equipment. This information also is valuable to the operator in determining the fuel requirements for his facility and any needs for storage or drying equipment.
A wood-fired boiler system at Integrated Products in Aragon, Georgia, has been in operation since December 1980.

**WOOD FIRED BOILER DEMONSTRATION SITES**

Demonstration sites selected under the Georgia Tech wood project are Integrated Products at Aragon and Gold Valdosta.

The Integrated Products plant is in the manufacture of carpet. A 400 hp (13,800 lb/hr.) boiler, manufactured by Industrial Boiler ofville, Georgia, was the system at this plant. The boiler consumed approximately 250 tons of wood. Construction was started in 1980. In early September, the boiler was set in place and the boiler was built. The system was completed in December and is now fully functional.

The second demonstration site is Gold soybean processing plant in Valdosta. A 1740 hp. (60,000 lb/hr.) manufactured by Weldon's Inc. of Oregon, is being installed. To supplement the wood fuel, this unit will also burn waste hulls from a nearby peanut plant. The system will consume an average of 1s of wood per week. Completion of this system is scheduled for June 1981.

Additional information on these sites can be arranged by contacting Mike Brown at 404-894-3636.

**WOOD ENERGY SYSTEMS FINANCE WORKSHOP**

Managers can learn how to locate and secure financing for wood energy systems at a workshop on the Georgia Tech campus April 29.

The session will run from 8:30 a.m. to 12:30 p.m. at the Space Science and Technology Building. Pre-registration is urged but participants also may register on the day of the workshop beginning at 8:00 a.m. A course fee of $10 will be charged.

Sponsored by the Georgia Office of Energy Resources and conducted by engineers from Georgia Tech's Engineering Experiment Station (EES), the workshop will be the first public session of its kind in Georgia. Speakers will include experts from Georgia Tech, the Arthur Andersen & Co. accounting firm, the First National Bank of Atlanta and Southern Solar Energy Center.

The workshop will be geared to company executives and planners as well as executives of financial institutions, industrial consultants and government agency personnel.

Participants will receive credit evaluation criteria used by bankers and investment alternatives for introducing wood fuel into a firm's production processes.

Additional information is available from Susan Lynskey at the Technology Applications Laboratory, Engineering Experiment Station, Georgia Tech, Atlanta, Georgia 30332.

**WOOD ENERGY PUBLICATIONS**

Six publications currently available from the Wood Energy Division are:

<table>
<thead>
<tr>
<th>Publication</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Wood: An Alternate Energy Resource&quot;</td>
<td>No charge for single copy</td>
</tr>
<tr>
<td>&quot;Wood Fuel Processing&quot;</td>
<td>$20.00 per copy</td>
</tr>
<tr>
<td>&quot;Technology Transfer&quot;</td>
<td>$25.00 per copy</td>
</tr>
<tr>
<td>&quot;Case Studies in Wood Energy&quot;</td>
<td>$6.00 per copy</td>
</tr>
<tr>
<td>&quot;Aragon: An Alternative&quot;</td>
<td>No charge for single copy</td>
</tr>
<tr>
<td>&quot;Safe and Warm Wood Heat&quot;</td>
<td>No charge</td>
</tr>
</tbody>
</table>

Additional information is available from Susan Lynskey at the Technology Applications Laboratory, Engineering Experiment Station, Georgia Tech, Atlanta, Georgia 30332.
Research on an experimental wood gasifier will determine the viability of using wood gas to dry fabric in the textile industry.

WOOD GASIFICATION RESEARCH

Wood gasifiers can be used to convert solid wood into a more versatile fuel gas. This wood gas can be substituted for fuel oil or natural gas in existing boilers, dryers, and kilns. During World War II, wood gas was used to power cars and trucks, as well as for stationary engines driving pumps or making electricity. This technology is making a comeback due to increased cost and decreased availability of fossil fuels.

Georgia Tech's Engineering Experiment Station currently is engaged in a wood gasification research program. This program has two objectives. The first objective is to assess the market for these updated gasifiers in the textile industry. Applications include boiler retrofits for process steam and the substitution of wood gas for natural gas in direct fired textile dryers. The survey is investigating the type and capacity of typical boiler and dryer systems, their yearly fuel usage and cost, and technical constraints on gasifier conversion such as space limitations and product contamination.

The second objective of the program is an experimental test project on the Georgia Tech campus. A pilot plant gasifier, rated at approximately 1 Btu/hr., successfully started up in 1980. This experimental gasifier is used to dry and cure textiles to gate any detrimental effects on and carpet from contaminants combusted wood gas. The experiment dilutes hot burned gas with air and gas stream to heat a batch dryer. Fabric test samples are placed in oven, withdrawn, and compared for and other properties with a sample heated by an electric heat source.

Results of the experiments presented at a seminar in Atlanta 1981. Questions regarding the should be addressed to Tom Mc 404–894-3636.

Wood Energy Systems Division
Georgia Institute of Technology Engineering Experiment Station
Atlanta, Georgia 30332

Funded by the U. S. Department of Energy Through the Georgia Office of Energy Reso
How much energy is in a wood pile? When the pile is first built, this question can be easily answered. A representative sample of the pile is analyzed for moisture content and gross caloric value and the weight of the wood is determined by weighing delivery trucks. The gross caloric value is multiplied by the pile mass to determine the total pile energy.

However, determination of pile total energy two months after construction is not so simple. Internal heating caused by the sun and heat absorbed from the air have increased the gross caloric value such that it varies through the pile. Studies by Marshall White of the Polytechnic Institute and Ed Eder of the Forest Products Research Laboratory have documented the variations in gross caloric value with time and pile position. Unless the bulk density is known for an area with a specific gross caloric value, the total energy cannot be determined. A suitable technique has not yet been determined for measuring this bulk density.

Georgia Tech engineers are experimenting with a nuclear depth probe in an attempt to measure the bulk density of the wood. The probe is a device used by engineers to determine soil composition at a building construction site. The probe contains a very low level of source material which emits a signal on the density of the surrounding material. The probe measures the amount of signal returned and the ratio of the signal emitted to signal returned gives the bulk density. Experiments conducted with several wood piles verify the use of the probe for measuring bulk density. For more information, contact Jim Walsh, Georgia Tech, Atlanta, Georgia, 30332, or 404-894-3623.

GOLD KIST INSTALLS WOOD ENERGY SYSTEM

Gold Kist, Inc., is the largest agricultural products firm in Georgia and one of the largest in the country. Corporate headquarters are located in Atlanta, Georgia. The company employs approximately 10,000 people and supplies products to local and international customers. The described wood energy demonstration project is located at Gold Kist's soy plant in Valdosta, Georgia.

Steam is used to process soybeans into soybean oil. Steam supplies the heat required in three processing steps: heating of the extraction chemical (hexane), separating oil from the extraction chemical and water, and drying oil-free soybean flakes.

The installation of the wood energy system at the Gold Kist plant marks an important step in demonstrating the feasibility of using wood fuel in nonforest industries. This and other demonstration projects are intended to serve as models for other businesses in nonforest products. This type of wood energy technology will be able to replace scarce fossil fuel while reducing operating costs for the firms at the same time.

The boiler is designed to utilize biomass sources of fuel such as wood waste, peanut hulls, and pecan shells. The peanut hulls come from Gold Kist pean...
WOODTECH '81
July 13-14, 1981
Atlanta, Georgia

EXPERTS TO SPEAK ON WOOD ENERGY

The WOODTECH '81 Conference/Trade Show will feature eight hours of intensive exposure to the latest technical information on the utilization of wood or waste fuels. Experts from private industries and from the public sector will speak on a variety of topics, ranging from the supply of wood in Georgia to descriptions of actual working systems. Following is a schedule of speakers and topics for the two day conference. For more information, contact Bill Himes, Georgia Institute of Technology, EES/TAL, Atlanta, Georgia 30332 or call 404-899-3412.

Monday, July 13, 1981

Time Subject

8:30 Introductory Remarks:

10:30 Availability of Wood Energy Use in Georgia

10:55 Wood Gasification for the Northwest Hospital, Rome, Ga.

11:20 Retrofit of Gasification Equipment in Text

11:45 Luncheon

Session I

Speaker/Organization

Bill Bulpit, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia; Beverly Berger, U.S. Department of Energy, Washington, D.C.; Mark Zwecker, Georgia Office of Energy Resources, Atlanta, Georgia; Jerry Birchfield, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia; Dan Smith, Southern Solar Energy Center, Atlanta, Georgia

1:15 Construction and Testing of a Wood Gasification Pilot Plant

1:40 A New Quad-Fired Generating Plant for Jack Daniels Distillery

2:05 The Tennessee Valley Authority's Commercial and Industrial Blot

2:30 Exhibit Visit

5:30 Reception

LATEST EQUIPMENT ON DISPLAY AT WOODTECH '81

An integral part of the WOODTECH '81 Conference/Trade Show will be displays of the latest available technologies. Manufacturers of boilers, pollution control equipment, material handling equipment, wood pulverizers, and wood storage systems will exhibit all the components of a successful wood energy system.

Following is a partial list of equipment suppliers participating in the trade show. The list is growing daily, but space is still available. For more information, contact John Adams, Georgia Institute of Technology, EES/TAL, Atlanta, Georgia 30332, or call 404-899-3636.

Guaranty Performance Company, Inc.
Independence, Kansas

Aeroglide Corporation
Raleigh, North Carolina

Avco Industries
Abilene, Texas

Konus Systems, Inc.
Atlanta, Georgia

Industrial Technology, Inc.
Fort Wayne, Indiana

Industrial Boiler Company, Inc.
Thomasville, Georgia

Heil Company
Knoxville, Tennessee

Thermotech Systems
Orlando, Florida

Wellons, Inc.
Sherwood, Oregon

Energy Resource Systems
Minneapolis, Minnesota

Rader Systems, Inc.
Memphis, Tennessee

TOUR OF WOOD FIRED SYSTEM PLANNED

After hearing presentations by experts and viewing displays by wood energy system suppliers, participants at WOODTECH '81 will have an opportunity to visit an actual working energy system. Integrated Products, Inc., is a textile firm 61 miles north of Atlanta that produces a required steam from a boiler fired with wood waste.

The Integrated Products plant is engaged in the manufacture of yarn. A 400 hp (13,800 lb/hr.) boiler, manufactured by Industrial Boiler Company, is selected at this plant. The boiler produces approximately 250 tons of steam per week.
Tuesday, July 14, 1981

Session V

8:30 Preparation of Wood Wastes for Firing Tunnel Kilns
   Pierce Merry, Merry Companies, Augusta, Georgia

8:55 Application of Wood Gasifiers to the Cyanamid Complex
   Bill Bulpitt, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia

9:20 Experiences of a Wood Broker
   Jerry Scott, Russell Lands, Inc., Alexander City, Alabama

9:45 Wood Energy Applications in the Textile Industry
   Hardin Byars, Integrated Products, Inc., Rome, Georgia

10:10 Coffee Break and Exhibit Visit

10:40 An Economic Alternative Enjoying Success
   Dan Mulligan, Procter and Gamble, Albany, Georgia

11:05 Utilization of Agricultural Waste Products for Process Steam Generation in a Soybean Extraction Facility
   Mitchell Teague, Gold Kist, Inc., Atlanta, Georgia

11:30 Feasibility Studies

11:55 Luncheon

1:15 Closing Remarks

1:30 Tour of Aragon Wood-Fired Boiler System

Session VI

10:40 An Economic Alternative Enjoying Success
   Dan Mulligan, Procter and Gamble, Albany, Georgia

11:05 Utilization of Agricultural Waste Products for Process Steam Generation in a Soybean Extraction Facility
   Mitchell Teague, Gold Kist, Inc., Atlanta, Georgia

11:30 Feasibility Studies

11:55 Luncheon

1:15 Closing Remarks

1:30 Tour of Aragon Wood-Fired Boiler System

OLD KIST continued

Processing plants in the Valdosta area. The heating value of hulls is approxi-

mately 7,800 Btu/lb, and the estimated value of green wood is 3,800

Btu/lb. The new boiler also has the capability of burning coal, oil, and natural gas.

Exact equipment requirements were established, the selection of vendor and construction contractors followed. The main system components are:

1. Storage silos
2. Water tube boiler
3. Chain conveyor and emission control equipment
4. Heating value of hulls is approximately 7,800 Btu/lb, and the estimated value of green wood is 3,800 Btu/lb.

Each cell is cylindrically shaped and designed for both underfeed and tangential air supply. The cyclonic effect produced in the cell allows for a turbulent mixing of air and fuel to promote complete combustion of the fuel. The hot gases release the unburned heavier particulates to the dropout chamber while the finer ash particles are removed at downstream collection devices. Combustion temperatures in the cells range from 2500°F to 3000°F.

After the gases pass through the economizer, they proceed through the economizer, the air preheater, the multicone collector, the I.D. fan, the baghouse, and then to the stack. The economizer preheats water entering the boiler. An air preheater is used to heat the combustion air which aids drying and promotes the combustion of green wood.

In wood burning systems, sulfur emissions are not produced during combustion; thus, wood has an additional advantage over coal and high-sulfur petroleum fuels. The only air pollutant of primary concern is particulate matter. Since wood is low in ash (around 2%), a centrifugal dry collector (multicone) and a baghouse are employed for removal of particulate matter.

The boiler capacity when fired on wood is 60,000 lb/hr of steam. Nebraska Boiler Company manufactured the boiler according to Wellons specifications. The boiler will also have the capability of producing high pressure steam up to 600 psig. This feature will allow electricity to be cogenerated in the near future.

For additional information, contact David Harris, Georgia Institute of Technology, EES/TAL, Atlanta, Georgia 30332, or call 404-894-3636.
WOOD FUEL COMBUSTION CHARACTERISTICS

The combustion characteristics of fuels such as coal, natural gas, or oil are determined by test procedures approved by the American Society for Testing and Materials (ASTM). Fuels are generally classified by proximate analysis, ultimate analysis, and gross caloric value. The gross caloric value is determined by a single test procedure while the ultimate and proximate analysis require the running of several separate test procedures.

There are currently no approved standards specifically designed for wood fuels. ASTM subcommittee E44.12 for biomass fuels conversion is developing standards for determining wood fuel properties. The subcommittee is developing a standard for determining moisture and volatile content. An approved standard will be used to determine ash content. Standards being developed by Subcommittee E38.01 on Refuse Derived Fuels will be used for determining the gross caloric value and the remaining ultimate analysis tests. Finally, subcommittee E44.12 will generate an overall reference for all applicable standards required to determine fuel properties.

A list of the standards and draft standards for biomass fuels is contained in the Table. For more information contact ASTM Information Center, 1916 Race Street, Philadelphia, Pennsylvania 19103.

Wood Energy Systems Division
Georgia Institute of Technology Engineering Experiment Station
Atlanta, Georgia 30332

W O O D H E A T E R S AND BUILDING CODES

Along with the rapid increase in the installation and use of wood heaters for supplemental heating in recent years, there has come an alarming increase in the number of home fires caused by improper installation or use of these appliances. Preliminary results from a study conducted by Georgia Tech indicate that the majority of these fires are caused by unsafe installation practices, most often with respect to chimneys and the connectors.

Because widespread use of wood heaters is a fairly recent phenomenon, many building codes do not add specific requirements for wood appliances in sufficient detail. Inspectors and firemen, who are receiving an increasing number of calls from homeowners for safety inspections of their installations, often have had little special training on the subject. In an attempt to fill this gap, the Tennessee Valley Authority has conducted training sessions and is preparing a manual for safety inspectors. Georgia Tech has been contracted to evaluate the needs of the individuals in this area to define the content and subject matter of the forthcoming programs.

Georgia Tech engineers will conduct a telephone survey of approximately 200 fire chiefs and inspectors. On-campus computer facilities will be used to analyze the results of this survey. Additional information obtained from Doug Moore, Georgia Tech, EES/TAL, Atlanta, Georgia; or call 404-894-3412.
Appendix G

WOOD ENERGY FOR NONFOREST INDUSTRIES
NONFOREST INDUSTRIAL WOOD ENERGY

Model Designed And Constructed By
Steve Coursey, Research Engineer, Technology Transfer Branch
Engineering Experiment Station, Georgia Institute of Technology

Endorsed By
Biomass Energy Systems Division, United States Department of Energy

Doug
Georgia Office of Energy Resources
Wood is fast becoming a significant industrial energy source. For many years, forest products industries have generated steam in wood-fired boilers. Today, these industries are no longer the only users of wood energy. Several nonforest products industries are already operating wood energy systems.

This scale model has been constructed to display the essential elements of a wood energy system envisioned for a large textile mill. Such a system would be custom designed to match the needs of the mill.

Each wood energy system begins with some type of unloading facility for trucks or rail cars. In the modeled system, a hydraulic truck dump is used to elevate tractor trailer trucks, allowing the wood chips to fall into the live bottom hopper.

Several very important operations are then conducted. As the model displays, wood chips are loaded out of the live bottom hopper onto a belt conveyor, which passes through a series of magnetized rollers. Any metal that is mixed with the wood chips is attracted to the rollers and is then easily removed from the system. Because no system is foolproof, the belt also passes under a metal detector. If any additional metal is found, the belt is automatically stopped so the metal can be removed by hand.

A disc screen is then used to separate wood chips that are the proper size for burning. This screen consists of a series of rotating discs having a staggered pattern. Properly sized chips fall through the screen, while oversized chips roll into a hog where they are reduced to an acceptable size.

A front-end loader moves the wood fuel from the screening operation to the covered storage area, where it is stored until needed.

As fuel is required by the boiler, wood chips are loaded onto a drag chain conveyor that leads from the storage area to the boiler house. A drag chain conveyor allows better control over the fuel feed rate than a belt conveyor. Once inside the boiler house, the chips fall into chutes that feed the boiler. The chips are burned with excess air to achieve nearly complete combustion. Because the exhaust gases contain a certain amount of ash and other particulate matter, the boiler is equipped with a scrubber.

Steam is piped from the boiler house to the carpet mill for process heat. Although most of the steam used for live injection, a small amount of condensate from other processes is returned to the boiler house where it is mixed with boiler make-up water.
Appendix H

WOOD ENERGY CONVERSION: AN ECONOMIC ANALYSIS
WOOD ENERGY CONVERSION
AN ECONOMIC ANALYSIS

Prepared by
SOUTHERN SOLAR ENERGY CENTER,*
ENGINEERING EXPERIMENT STATION OF THE
GEORGIA INSTITUTE OF TECHNOLOGY**
and ARTHUR ANDERSEN & CO.

*Southern Solar Energy Center is operated for the U.S. Department of Energy under Contract DE-AC02-79CS30166.
**Funded by the U.S. Department of Energy through the Georgia Office of Energy Resources.
INTRODUCTION

Many businesses are frustrated by fuel costs that are rising more rapidly than price increases can be passed on to customers. One way to control these cost increases is through the use of wood fuel.

A wood fired boiler system can produce significant fuel cost savings compared to oil or natural gas fired boilers. The wood system typically pays for itself within five years. The Southern Solar Energy Center and the Engineering Experiment Station of the Georgia Institute of Technology, in cooperation with Arthur Andersen & Co., have developed an economic analysis model, based upon previous work by the New England Regional Commission, to compute a payback on a wood fuel system by comparing wood to alternative fuel sources. Representatives are available to demonstrate the model, at no charge to you, using your cost data to determine the feasibility of a wood fuel system.

WOOD IS AN ALTERNATIVE

The technology for environmentally acceptable wood fuel boiler systems is currently available. The primary financial considerations include:

- Current cost and availability of wood fuel vs. alternative fuels in a particular plant location.
- Projected future cost increases and availability of wood fuel vs. alternative fuels.
- Initial cost of the conversion to a wood system.

The initial cost of a wood fired boiler system is much higher than an oil or gas system due to the required wood handling equipment. Also, additional space is required for wood fuel storage.

TAX CREDITS

The higher initial cost is partially offset by Federal and, in some instances, state tax credits that may be available to finance a portion of the system cost. Federal tax credits are normally available for up to 20% of the system cost. Federal tax credits include an investment tax credit (ITC), a 10% direct reduction of taxes payable, which is generally available for new additions to tangible personal property. In most circumstances, ITC is not available for an oil or natural gas fired boiler system. However, it is available for a coal fired system.

An advantage of the wood fired system is that substantially all of the cost of the system may qualify for both Federal ITC and business energy credits. Business energy credits are available for equipment that operates on fuels produced from sources other than petroleum and gas fuels. The business energy credit rate for a wood or coal fired boiler system is, generally, 10% of the equipment cost.

The decision on whether equipment qualifies for Federal and/or state tax credits must be based on your tax situation. The amount of available credit can be affected by the type of property, the method of financing, the depreciable life assigned to the property and the amount of your Company’s taxable income. You should consult your tax advisor before making an investment decision.
## COMPARISON OF ALTERNATIVE FUELS
### CASH FLOW ANALYSIS WITH FINANCING

<table>
<thead>
<tr>
<th>LIFE (000)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20 YEARS</th>
</tr>
</thead>
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<td></td>
<td>$1,200,000</td>
<td>$1,416,000</td>
<td>$1,670,880</td>
<td>$1,971,638</td>
<td>$2,326,533</td>
<td>$19,640,000</td>
<td>$44,933,000</td>
<td>$102,795,000</td>
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<td>428,571</td>
<td>486,571</td>
<td>556,971</td>
<td>634,947</td>
<td>723,840</td>
<td>5,455,000</td>
<td>10,502,000</td>
<td>20,221,000</td>
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<td>771,429</td>
<td>927,429</td>
<td>1,113,909</td>
<td>1,336,691</td>
<td>1,602,693</td>
<td>14,185,000</td>
<td>34,431,000</td>
<td>82,574,000</td>
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<td>126,000</td>
<td>143,640</td>
<td>163,750</td>
<td>186,675</td>
<td>212,810</td>
<td>1,604,000</td>
<td>3,088,000</td>
<td>5,945,000</td>
</tr>
<tr>
<td></td>
<td>140,000</td>
<td>126,000</td>
<td>113,400</td>
<td>102,060</td>
<td>91,854</td>
<td>338,537</td>
<td>244,075</td>
<td>244,074</td>
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<tr>
<td></td>
<td>151,360</td>
<td>136,606</td>
<td>119,480</td>
<td>99,602</td>
<td>76,527</td>
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<td>-</td>
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<td>354,069</td>
<td>521,183</td>
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<td>31,098,25</td>
<td>76,384,926</td>
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<td>153,100</td>
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<td>310,151</td>
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<td>21,244</td>
<td>31,271</td>
<td>43,037</td>
<td>56,901</td>
<td>73,290</td>
<td>730,000</td>
<td>1,866,000</td>
<td>4,583,000</td>
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<td></td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td></td>
<td>179,725</td>
<td>264,552</td>
<td>364,091</td>
<td>481,385</td>
<td>620,034</td>
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<td>102,060</td>
<td>91,854</td>
<td>338,537</td>
<td>244,075</td>
<td>244,074</td>
</tr>
<tr>
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<td>143,537</td>
<td>166,612</td>
<td>417,880</td>
<td>-</td>
<td>-</td>
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<tr>
<td>3000</td>
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<td>$284,019</td>
<td>$353,832</td>
<td>$439,908</td>
<td>$545,276</td>
<td>$6,100,721</td>
<td>$16,030,000</td>
<td>$39,017,000</td>
</tr>
</tbody>
</table>

- **Cash payback period of initial investment = .4 years**
- **Payback of total investment = 2.8 years** (Cumulative cash flow is sufficient to cover initial investment plus remaining loan balance.)
- **Net present value, discounted at 25% = $3,320,000**
- **Internal rate of return = 302%**

### THE MODEL

The comparison of wood to an alternative fuel depends on data that can only be determined by specific analysis. The economic analysis model is designed to evaluate the data for your plant location. The table demonstrates an application of the economic model for a 40,000 lb/hr boiler system. The model computes annual costs for each of five years, a normal planning cycle for most businesses and a reasonable time frame for projecting fuel cost increases. Subsequent savings comparisons are grouped in five year intervals because of the subjective nature of longer term price projections.
EXPLANATION OF CASH FLOW ANALYSIS

OIL COST
Current costs of No. 6 fuel oil ($0.80 per gallon) are assumed to escalate at 18% per year. The amount of oil to fuel a 40,000 lb/hr boiler remains constant over the expected 20-year life of the equipment.

WOOD COST
Current costs of dirty green wood chips ($12 per ton) are assumed to escalate at 14% per year. The amount of wood to fuel a 40,000 lb/hr boiler remains constant over the expected 20-year life of the equipment.

OPERATING AND MAINTENANCE
Additional operating and maintenance costs for a wood fired system consist principally of labor for handling wood fuel. These costs are assumed to escalate at 14% per year.

DEPRECIATION
Depreciation is computed over the 20-year useful life of the equipment. A double-declining balance method is used, switched to straight-line after the tenth year. No salvage value is assigned.

Various accelerated depreciation methods are available under the Internal Revenue Code. Rapid amortization (60 months) is available for pollution control equipment. Shorter taxable lives may be available to your Company. Your tax advisor should be consulted on the optimal election in your circumstances.

INTEREST
Financing will be a major consideration due to the high initial purchase cost of a wood fired system. The accompanying analysis assumes a seven-year installment loan at 15% interest can be obtained for 75% of the equipment cost.

Tax exempt industrial revenue or subsidized energy financing may be available to your Company. Industrial revenue bond interest is deductible to the Company but is exempt from Federal (and in some cases, state) income taxes. Consequently, the rates are normally lower than those otherwise available. A portion of the investment tax credit and business energy credit may be lost if industrial revenue or subsidized energy financing is used. Your tax advisor should be consulted to determine the tax effects of alternative financing sources.

INCOME TAXES
Federal and state income taxes are computed at 46% and 6%, respectively. The model has the flexibility to consider various combinations of Federal and state tax rates.

TAX CREDITS
The model assumes utilization of the maximum available Federal tax credits. Because credits are earned for tax purposes when the equipment is placed in service, the model assumes credits are used at the completion of construction. Your Company’s taxable income and other property additions may affect the amount of credit you are able to use.

Federal tax credits are based on the eligibility of system components, as follows:

<table>
<thead>
<tr>
<th>Components (1)</th>
<th>Regular Energy Tax Credit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler, stack, handling equipment</td>
<td>Yes</td>
</tr>
<tr>
<td>Pollution control equipment</td>
<td>Yes (3)</td>
</tr>
<tr>
<td>Wood fuel storage facilities</td>
<td>Yes</td>
</tr>
</tbody>
</table>

(1) If the useful life assigned to any component is less than 20 years, reduction in regular ITC and energy credit will result.

(2) Credit percentage is reduced from 10% to 5% if financed by Industrial Revenue Bond (IRB) or “subsidized energy financing”.

After 1982, credit percentage is reduced pro rata from 10% by ratio of IRB or subsidized energy financing to total qualified investment.

(3) Credit percentage is 5% rather than 10% if:
   a. Financed by IRB and
   b. Election made to amortize over 60-month period

(4) If the wood fuel storage facility were a self-contained unit capable of being moved such that it could be treated a piece of equipment, energy credit would be available.

State tax credits may also be available. Your tax advisor should be consulted to determine the maximum available credits.

FOR MORE INFORMATION
The model provides a basis for the initial evaluation of wood as a fuel alternative. For an analysis of your Company’s situation, call or write:

Technology Transfer Branch
Georgia Institute of Technology
Engineering Experiment Station/TAL
Atlanta, Georgia 30332
(404) 894-3412
Appendix I

WOOD ENERGY CONVERSION COMPUTER PROGRAM USER'S GUIDE
WOOD ENERGY CONVERSION COMPUTER PROGRAM
A USER'S GUIDE

The wood energy conversion computer program presently resides in the Georgia Tech Cyber 74 computer system. The permanent files are always required to run this program. These files are stored under the user number Q0 243** and are public; they may be accessed by any Cyber system user.

The first is named RUNWOOD. This is the compiled file, ready to be run. The user may examine the coding, written in Fortran IV, by getting the file WOOD 4, also a public access file stored under QO 243**.

The second file is named FORMAT. This file contains printing commands used during data prompting.

The user may wish to input data from another file, rather than input the data on a line-by-line basis. If this option is chosen, then the data file, named OLD, must also be in the local working space.

In this report all user responses will be underlined. Following is an example of a typical runstream for signing on and getting the necessary permanent files.

Figure 1.

*DIALUP LINE 074-21XX PORT 06*
*GT CYBER ADDRESS M2/F0*

1/11/78, 08.33.33.
GEORGIA TECH CYBER 74.
FAMILY: USER NUMBER: Q0243**
PASSWORD: ********
TERMINAL: 110, TTY
RECOVER /SYSTEM: BATCH
$RFLY0.

NEWS FOLLOWS...
LAST NEWS RUN ON 1/11/78, 08.31.34.

NEWS COMPLETE.
/GET, RUNWOOD, WOOD4, FORMAT
The program is initiated by typing "RUNWOOD." Since this program is designed to evaluate the economics of using wood instead of a conventional fuel, it is necessary to specify the conventional fuel being compared.

In this example the data will be input from another local file. A later example will show interactive data input. The standard data can be used to demonstrate program capabilities.

The program is capable of analyzing a replacement of an existing system or comparison of a two proposed systems. In the replacement analysis, it is assumed that the existing system has no salvage value or will be maintained on premise as a back-up system. In either case, the only benefits derived by replacement are the reduction in fuel costs and operating costs associated with the system. When two proposed systems are compared, all incremental costs are compared, including differences in financing and depreciation. When a comparison analysis is selected, the computer will offer to calculate the capital costs of the conventional system. Otherwise, the user must supply this data.

When data is input interactively, the computer will offer to calculate the capital costs of the wood system. An example will be shown later.

Following is an example of choosing the type of analysis and inputting data.

Figure 2

```
RUNWOOD

THIS WOOD CONVERSION ECONOMIC MODEL WAS DEVELOPED AS A JOINT PROGRAM BY THE ENGINEERING EXPERIMENT STATION OF GEORGIA TECH AND THE SOUTHERN SOLAR ENERGY CENTER, BASED UPON PREVIOUS WORK OF THE NEW ENGLAND REGIONAL COMMISSION.

SELECT FUEL COMPARISON: OIL VS. WOOD = 1, GAS VS. WOOD = 2, COAL VS. WOOD = 3
?

METHOD OF DATA INPUT: OLD = 1, NEW = 2, STANDARD = 3
?

TYPE OF ANALYSIS: REPLACE EXISTING SYSTEM = 1, COMPAR E TWO PROPOSED SYSTEMS = 2
?
```

I-2
At this point the computer will respond "NEXT CHOICE?" There are eight choices.

1. The program will perform an engineering analysis by calculating the annual consumption of conventional fuel and wood. It will then give the annual fuel cost.

2. The program will perform the engineering analysis. It will also perform a financial analysis, consisting of a table of annual cash flows. It will then use those cash flows to perform an economic analysis.

3. This option is the same as "2", except the financial table is not printed.

4. This allows the user to make changes in the data. The program will offer to print a variable list. Then the program elicits the new values. The data will reflect these changes throughout the remainder of the computer session.

5. This option allows the user to make temporary changes in the data. The user may change up to 10 variables in 10 different rounds. The user enters the variable number and the new value. Each round is terminated by entering zero twice. The session is terminated by entering zero twice in response to the request for changes in base case data.
6. This allows the user to perform an iterative analysis. For example, the user may wish to see the effect of varying the cost of wood. In response to a request for iterative analysis parameters, the user enters the variable number, the initial value, the size of the incremental change, and a carriage return. Then the user either enters "1" and the final value or "2" and a specified internal rate of return. If this option is chosen, the program will continue iterating until the specified internal rate of return is achieved.

7. This will display the data.

8. This terminates the session.

The user has the option of printing output at the terminal or of having it written into a local file named PRINT. If the local file option is chosen, the file must be rewound after the session is completed.

Following is a typical runstream.

Figure 3.

NEXT CHOICE

? 2
OUTPUT? TERMINAL=0; PRINTER = 1
? c

WOOD CONVERSION ECONOMIC MODEL
OUR EXAMPLE

CHANGES FROM BASE CASE DATA:
Figure 3 Continued

**ESTIMATED ANNUAL CONSUMPTION & COSTS**

**ANNUAL OIL CONSUMPTION:** 1500000. GALLONS  
**ANNUAL COST AT $.800 PER GALLON:** $ 1200000.00

**ANNUAL WOOD CONSUMPTION:** 35714. TONS  
**ANNUAL COST AT $12.00 PER TON:** $ 428571.43

**COMPARISON OF ALTERNATIVE FUELS**

**CASH FLOW ANALYSIS WITH FINANCING**  
(THOUSANDS OF DOLLARS)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INSTALLATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EQUIPMENT COST</td>
<td>1400.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AN PROCEEDS</td>
<td>(1050.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>1200.0</td>
<td>1416.0</td>
<td>1670.9</td>
<td>1971.6</td>
<td>2326.5</td>
</tr>
<tr>
<td>OD COSTS</td>
<td>423.6</td>
<td>488.6</td>
<td>557.0</td>
<td>634.9</td>
<td>723.8</td>
</tr>
<tr>
<td>GENERATED ELECTRICITY</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
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<td>927.4</td>
<td>1113.9</td>
<td>1336.7</td>
<td>1602.7</td>
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<td>126.0</td>
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<td>163.7</td>
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<td>212.8</td>
</tr>
<tr>
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<td>102.1</td>
<td>91.9</td>
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<td>INTEREST</td>
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<td>119.5</td>
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<td>76.5</td>
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<td>RETAX INCOME</td>
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<td>521.2</td>
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<td>1221.5</td>
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<td></td>
<td></td>
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<td>STATE</td>
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<td>310.2</td>
<td>410.1</td>
<td>528.2</td>
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<tr>
<td>TAX CREDITS</td>
<td>(268.0)</td>
<td></td>
<td></td>
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<td>NET EARNINGS-AFTER TAX</td>
<td>179.7</td>
<td>264.6</td>
<td>364.1</td>
<td>481.4</td>
<td>620.0</td>
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<td>102.1</td>
<td>91.9</td>
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<td>91.8</td>
<td>106.5</td>
<td>123.7</td>
<td>143.5</td>
<td>166.6</td>
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<tr>
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<td>(82.0)</td>
<td>227.9</td>
<td>204.0</td>
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<td>439.9</td>
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**SUBSEQUENT PLANNING CYCLES**

**(THOUSANDS OF DOLLARS)**

<table>
<thead>
<tr>
<th>YEARS</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20</th>
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<tbody>
<tr>
<td>OPERATING COSTS</td>
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<td>44932.7</td>
<td>102795.2</td>
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<td>DD COSTS</td>
<td>5454.5</td>
<td>10502.2</td>
<td>20221.1</td>
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<td>GENERATED ELECTRICITY</td>
<td>0.0</td>
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<td>0.0</td>
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I-6
Figure 3 Continued

<table>
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<th>Description</th>
<th>Year 1</th>
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<th>Year 3</th>
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<td>FUEL SAVINGS</td>
<td>11136.0</td>
<td>31430.6</td>
<td>22574.2</td>
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<td>ADDITIONAL O&amp;M</td>
<td>1603.6</td>
<td>3087.6</td>
<td>5945.0</td>
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<td>DEPRECIATION</td>
<td>338.5</td>
<td>244.1</td>
<td>244.1</td>
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<tr>
<td>INTEREST</td>
<td>68.4</td>
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<td>0.0</td>
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<td>PRETAX INCOME</td>
<td>12175.4</td>
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<tr>
<td>STATE</td>
<td>730.5</td>
<td>1865.9</td>
<td>4583.1</td>
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<td>FEDERAL</td>
<td>5264.7</td>
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<td>NET EARNINGS-AFTER TAX</td>
<td>6180.3</td>
<td>15785.8</td>
<td>38773.1</td>
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<td>ADD DEPRECIATION</td>
<td>338.5</td>
<td>244.1</td>
<td>244.1</td>
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<tr>
<td>DEDUCT LOAN PAYMENT</td>
<td>417.9</td>
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<tr>
<td>NET CASH FLOW</td>
<td>6100.9</td>
<td>16029.8</td>
<td>39017.1</td>
</tr>
</tbody>
</table>

ECONOMIC VALUES OF WOOD FUEL ALTERNATIVE

CASH PAYBACK PERIOD OF INITIAL INVESTMENT = 0.4 YEARS

PAYBACK OF TOTAL INVESTMENT = 2.9 YEARS (CUMULATIVE CASH FLOW IS SUFFICIENT TO RECOVER INITIAL INVESTMENT AND REMAINING LOAN BALANCE)

NET PRESENT VALUE = 3321.7 (DISCOUNTED AT 25.000%)

INTERNAL RATE OF RETURN = 303.2%
After displaying data and consumption figures, the computer generates a financial table. Fuel savings is the difference in fuel costs plus any cogenerated electricity. Pretax income is fuel savings less additional O & M, depreciation, and interest. It is assumed that the loan will be paid off in equal monthly payments over the entire life of the loan. It is assumed that any reduction in taxes, through the investment credits or pretax losses, can be claimed in the year of occurrence. Finally, depreciation and principal payments on the loan are considered and a net cash flow is calculated.

The results are printed on an annual basis for the first five years. Subsequent results are grouped in 5-year intervals, reflecting normal business planning cycles.

The economic values are based upon the after tax cash flow. As such, they are a reflection of return on initial investment (cash flow at installation) and not a measure of return on assets.

Following is a demonstration of the multiple edit feature, choice 5.

![Figure 4.](image)
**WOOD CONVERSION ECONOMIC MODEL**

**OUR EXAMPLE**

**BASE CASE DATA:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBS STEAM PER HOUR (OIL)</td>
<td>40000.00</td>
</tr>
<tr>
<td>LBS STEAM PER HOUR (WOOD)</td>
<td>40000.00</td>
</tr>
<tr>
<td>ANNUAL OPTG HRS (OIL)</td>
<td>6250.00</td>
</tr>
<tr>
<td>ANNUAL OPTG HRS (WOOD)</td>
<td>6000.00</td>
</tr>
<tr>
<td>AVERAGE UTIL (%) (OIL)</td>
<td>75.00</td>
</tr>
<tr>
<td>AVERAGE UTIL (%) (WOOD)</td>
<td>75.00</td>
</tr>
<tr>
<td>BOILER EFFIC (%) (OIL)</td>
<td>80.00</td>
</tr>
<tr>
<td>BOILER EFFIC (%) (WOOD)</td>
<td>71.00</td>
</tr>
<tr>
<td>BTUS/LB STEAM (OIL)</td>
<td>1000.00</td>
</tr>
<tr>
<td>BTUS/LB STEAM (WOOD)</td>
<td>1000.00</td>
</tr>
<tr>
<td>TYPE OF OIL (NO.)</td>
<td>6.00</td>
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<tr>
<td>PRICE/GAL OIL ($)</td>
<td>8.80</td>
</tr>
<tr>
<td>PRICE/TON WOOD ($)</td>
<td>12.50</td>
</tr>
<tr>
<td>DRY WOOD ENERGY (MMBTU)</td>
<td>16.00</td>
</tr>
<tr>
<td>WET BASIS M.C. (%)</td>
<td>50.00</td>
</tr>
<tr>
<td>ANNUAL O&amp;M COSTS (OIL)</td>
<td>42000.00</td>
</tr>
<tr>
<td>ANNUAL O&amp;M COSTS (WOOD)</td>
<td>168000.00</td>
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<tr>
<td>O&amp;M INFLATION RATE (%)</td>
<td>14.00</td>
</tr>
<tr>
<td>OIL INFLATION RATE (%)</td>
<td>18.00</td>
</tr>
<tr>
<td>WOOD INFLATION RATE (%)</td>
<td>14.00</td>
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<tr>
<td>FED TAX RATE (%)</td>
<td>46.00</td>
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<tr>
<td>FED TAX CREDIT (%)</td>
<td>20.00</td>
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<tr>
<td>STATE TAX RATE (%)</td>
<td>6.00</td>
</tr>
<tr>
<td>STATE TAX CREDIT (%)</td>
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<tr>
<td>DEPREC PERIOD (YR)</td>
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<tr>
<td>DEPREC METHOD</td>
<td>DOUBLE-DECLINING BALANCE</td>
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<tr>
<td>LOAN PERIOD (YR)</td>
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<td>LOAN INTEREST RATE (%)</td>
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<td>EQUITY CAPITAL ($)</td>
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<td>CAPITAL COST ($)</td>
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<tr>
<td>OPERATING LIFE (YR)</td>
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<tr>
<td>DISCOUNT RATE (%)</td>
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<tr>
<td>GENERATED ELECTRICITY ($/YR)</td>
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<tr>
<td>ELEC PRICE INFL RATE (%)</td>
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<tr>
<td>COST OF STORAGE FACILITIES</td>
<td>120000.00</td>
</tr>
</tbody>
</table>
Figure 4 Continued

ESTIMATED ANNUAL CONSUMPTION & COSTS

ANNUAL OIL CONSUMPTION: 1562500. GALLONS
ANNUAL COST AT $ .000 PER GALLON: $ 1250000.00

ANNUAL WOOD CONSUMPTION: 31690. TONS
ANNUAL COST AT $12.50 PER TON: $ 396126.76

WOOD CONVERSION ECONOMIC MODEL
OUR EXAMPLE

CHANGES FROM BASE CASE DATA:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ANNUAL OPEH HRS (OIL)</td>
<td>62500.00</td>
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<tr>
<td>BOILER EFFIC (%) (WOOD)</td>
<td>68.00</td>
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<tr>
<td>PRICE/TON WOOD ($)</td>
<td>12.80</td>
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</table>

ESTIMATED ANNUAL CONSUMPTION & COSTS

ANNUAL OIL CONSUMPTION: 15625000. GALLONS
ANNUAL COST AT $ .800 PER GALLON: $12500000.00

ANNUAL WOOD CONSUMPTION: 33088. TONS
ANNUAL COST AT $12.90 PER TON: $ 423529.41

I-10
Following is an example of the iterative analysis feature, choice 6. Shown also is the termination option, choice 8.

![Figure 5.](image)

<table>
<thead>
<tr>
<th>いる</th>
<th>10.00</th>
<th>10.50</th>
<th>11.00</th>
<th>11.50</th>
<th>12.00</th>
<th>12.50</th>
<th>13.00</th>
<th>13.50</th>
</tr>
</thead>
<tbody>
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<td>1500000.</td>
<td>1500000.</td>
<td>1500000.</td>
<td>1500000.</td>
<td>1500000.</td>
<td>1500000.</td>
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<tr>
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<td>35714.</td>
<td>35714.</td>
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<tr>
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<td>825000.</td>
<td>807143.</td>
<td>789286.</td>
<td>771429.</td>
<td>753571.</td>
<td>735714.</td>
<td>717857.</td>
</tr>
<tr>
<td>FUEL SAVGS ($/YR 1)</td>
<td>3599101.</td>
<td>3529755.</td>
<td>3460410.</td>
<td>3391064.</td>
<td>3321710.</td>
<td>3252372.</td>
<td>3183027.</td>
<td>3113681.</td>
</tr>
<tr>
<td>NPV ($)</td>
<td>346.</td>
<td>335.</td>
<td>324.</td>
<td>314.</td>
<td>303.</td>
<td>292.</td>
<td>282.</td>
<td>271.</td>
</tr>
<tr>
<td>IRR PAYBACK (YR)</td>
<td>3.</td>
<td>3.</td>
<td>3.</td>
<td>3.</td>
<td>3.</td>
<td>3.</td>
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</table>

WOOD CONVERSION ECONOMIC MODEL

OUR EXAMPLE

<table>
<thead>
<tr>
<th>RICE/TON WOOD (%)</th>
<th>OIL CONS (GAL/YR)</th>
<th>WOOD CONS (TON/YR)</th>
<th>FUEL SAVGS ($/YR 1)</th>
<th>NPV ($)</th>
<th>IRR PAYBACK (YR)</th>
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<tr>
<td>10.00</td>
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<td>346.</td>
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<td>1500000.</td>
<td>35714.</td>
<td>825000.</td>
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<tr>
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<td>1500000.</td>
<td>35714.</td>
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<td>3460410.</td>
<td>324.</td>
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<tr>
<td>11.50</td>
<td>1500000.</td>
<td>35714.</td>
<td>789286.</td>
<td>3391064.</td>
<td>314.</td>
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<tr>
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<td>1500000.</td>
<td>35714.</td>
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<td>3321710.</td>
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<td>12.50</td>
<td>1500000.</td>
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<td>753571.</td>
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<td>1500000.</td>
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<td>735714.</td>
<td>3183027.</td>
<td>282.</td>
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<tr>
<td>13.50</td>
<td>1500000.</td>
<td>35714.</td>
<td>717857.</td>
<td>3113681.</td>
<td>271.</td>
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</tbody>
</table>

NEXT CHOICE

2.166 CP SECONDS EXECUTION TIME.
Following is an example of a run stream demonstrating interactive input and the capability of the program to calculate capital costs. The requests for inputs to calculate the capital costs of a wood system are followed by numbers in parentheses. These numbers are typical values, based upon examinations of existing systems.

Figure 6.

```
RUNW
RUNW COMPLETE.
/RUNWOOD
```

This wood conversion economic model was developed as a joint project by the Engineering Experiment Station of Georgia Tech and the Southern Solar Energy Center, based upon previous work of the New England Regional Commission.

Select fuel comparison: Oil vs. Wood = 1, Gas vs. Wood = 2, Coal vs. Wood = 3

? 1
Method of data input: Old = 1, New = 2, Standard = 3

? 2
Type of analysis: Replace existing system = 1, Compare two proposed systems = 2

? 1
Do you wish the program to calculate the capital costs of a wood system? Yes = 1, No = 2

? 1
Input data:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(Oil)</th>
<th>(Wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs steam per hour</td>
<td></td>
<td>40000</td>
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<tr>
<td>Annual optg hrs</td>
<td></td>
<td>6000</td>
</tr>
<tr>
<td>Boiler effic (%)</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Average util (%)</td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Boiler effic (%)</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>BTUs/lb steam (OIL)</td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>BTUs/lb steam (WOOD)</td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>Type of oil (no.)</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Price/gal oil ($)</td>
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<td>.80</td>
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<tr>
<td>Price/ton wood ($)</td>
<td></td>
<td>12,00</td>
</tr>
<tr>
<td>Dry wood-energy (MMBTU)</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Wet basis M.C. (%)</td>
<td></td>
<td>50</td>
</tr>
</tbody>
</table>
Figure 6 Continued

INPUTS TO CALCULATE CAPITAL COSTS

DAYS OF OPEN STORAGE (28)
? 28
HEIGHT OF OPEN STORAGE, FT. (12)
? 15
DAYS OF COVERED STORAGE (3)
? 3
TYPE OF WOOD: WASTES=1, OTHER=2
? 1
TONS/HOUR DISC SCREEN (53.57142857143)
? 55
TONS/HOUR HAMMERMILL (53.57142857143)
? 55
RAW WOOD CONVEYOR LENGTH, FT. (DRAG CHAIN, 100)
? 105
PREPARED CONVEYOR LENGTH, FT.
(BELT CHAIN, 300)
? 295
BOILER FEED CONVEYOR LENGTH, FT.
(DRAG CHAIN, 100)
? 100

COMPONENT COSTS

DUMPER 120000.000
FRONT END LOADER 48000.000
UNCOVERED STORAGE 20639.269
RAW WOOD DRAG CHAIN CONVEYOR 36405.500
DISC SCREEN 16365.000
HAMMERMILL 34150.000
SIZED WOOD BELT CONVEYOR 55633.010
COVERED STORAGE 82954.990
BOILER FEED CONVEYOR 43129.762
BOILER 720000.000
POLLUTION CONTROL 120000.000

SYSTEM COSTS

POLLUTION CONTROL 120000.000
STORAGE 103594.260
ALL OTHER 1193683.280

TOTAL CAPITAL COSTS 1417277.539
Figure 6 Continued

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual O&amp;M Costs (Oil)</td>
<td>$42000.00</td>
</tr>
<tr>
<td>Annual O&amp;M Costs (Wood)</td>
<td>$168000.00</td>
</tr>
<tr>
<td>O&amp;M Inflation Rate (%)</td>
<td>12%</td>
</tr>
<tr>
<td>Oil Inflation Rate (%)</td>
<td>16%</td>
</tr>
<tr>
<td>Wood Inflation Rate (%)</td>
<td>15%</td>
</tr>
<tr>
<td>Fed Tax Rate (%)</td>
<td>46%</td>
</tr>
<tr>
<td>Fed Tax Credit (%)</td>
<td>20%</td>
</tr>
<tr>
<td>State Tax Rate (%)</td>
<td>6%</td>
</tr>
<tr>
<td>State Tax Credit (%)</td>
<td>0%</td>
</tr>
<tr>
<td>Deprec Period (YR)</td>
<td>20</td>
</tr>
<tr>
<td>Deprec Method</td>
<td>Double-Declining Balance</td>
</tr>
</tbody>
</table>

DO < ERROR, RETYPE RECORD AT THIS FIELD

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loan Period (YR)</td>
<td>7</td>
</tr>
<tr>
<td>Loan Interest Rate (%)</td>
<td>15%</td>
</tr>
<tr>
<td>Equity Capital ($)</td>
<td>$350000</td>
</tr>
<tr>
<td>Capital Cost ($)</td>
<td>$1417277.54</td>
</tr>
<tr>
<td>Operating Life (YR)</td>
<td>20</td>
</tr>
<tr>
<td>Discount Rate (%)</td>
<td>25%</td>
</tr>
<tr>
<td>Generated Electricity ($/YR)</td>
<td>0</td>
</tr>
<tr>
<td>Electric Price Infl Rate (%)</td>
<td>12%</td>
</tr>
<tr>
<td>Cost of Storage Facilities</td>
<td>$103594.26</td>
</tr>
</tbody>
</table>

DATA LOADED

Name of Facility (Up to 24 Chars.)

Our Example
Following is a demonstration of the edit function, choice 4. All variables that are changed will remain changed for the entire session.

Figure 7.

Next Choice

? 4
VARIABLE LIST? YES = 1, NO = 0

? 1

- 1 LBS STEAM PER HOUR (OIL)
- 2 LBS STEAM PER HOUR (WOOD)
- 3 ANNUAL OPTG HRS (OIL)
- 4 ANNUAL OPTG HRS (WOOD)
- 5 AVERAGE UTIL (%) (OIL)
- 6 AVERAGE UTIL (%) (WOOD)
- 7 BOILER EFFIC (%) (OIL)
- 8 BOILER EFFIC (%) (WOOD)
- 9 BTUS/LB STEAM (OIL)
- 10 BTUS/LB STEAM (WOOD)
- 11 TYPE OF OIL (NO.)
- 12 PRICE/GAL OIL ($)
- 13 PRICE/TON WOOD ($)
- 14 DRY WOOD ENERGY (MMBTU)
- 15 WET BASIS M.C. (%)
- 16 ANNUAL O&M COSTS (OIL)
- 17 ANNUAL O&M COSTS (WOOD)
- 18 O&M INFLATION RATE (%)  
- 19 OIL INFLATION RATE (%)  
- 20 WOOD INFLATION RATE (%)  
- 21 FED TAX RATE (%)  
- 22 FED TAX CREDIT (%)  
- 23 STATE TAX RATE (%)  
- 24 STATE TAX CREDIT (%)  
- 25 DEPREC PERIOD (YR)  
- 26 DEPREC METHOD  
- 27 LOAN PERIOD (YR)  
- 28 LOAN INTEREST RATE (%)  
- 29 EQUITY CAPITAL ($)  
- 30 CAPITAL COST ($)  
- 31 OPERATING LIFE (YR)  
- 32 DISCOUNT RATE (%)  
- 33 GENERATED ELECTRICITY ($/YR)  
- 34 ELEC PRICE INFL RATE (%)  

STOP = 0, CONTINUE = 1
Figure 7 Continued

? 1
VARIABLE NUMBER
? 13
NEW VALUE
? 12.50
STOP = 0, CONTINUE = 1
? 1
VARIABLE NUMBER
? 17
NEW VALUE
? 42500
STOP = 0, CONTINUE = 1
? 1
VARIABLE NUMBER
? 30
NEW VALUE
? 1417500
STOP = 0, CONTINUE = 1
? 0

I-16
Output may be printed at the terminal or written into a local file, PRINT. Following is an example of using the local file option.

Data that is input interactively may be saved for later analysis. The data is written into a local file, SAVE. Remember, before the data can be used it must be copied into a new file named OLD or attached to an existing file named OLD.

Figure 8.

NEXT CHOICE
? 3
OUTPUT? TERMINAL=0, PRINTER = 1
? 1
TABLES SENT TO PRINTER

NEXT CHOICE
? 8
SAVE THIS DATA SET? YES = 1, NO = 0
? YES
Y < ERROR, RETYPE RECORD AT THIS FIELD
? 1
.939 CP SECONDS EXECUTION TIME.

Following is an example of a permanent file, OLD, containing data for several facilities. The format for each facility is:

Line 1: Name of facility (3A8)

Line 2: Annual operating hours, conventional (F5.0); Annual operating hours, wood (F5.0); Average utilization, conventional (F6.2); Average utilization, wood (F6.2); LBS steam per hour, conventional (F7.0); LBS steam per hour, wood (F7.0); Boiler efficiency, conventional (4.0); boiler efficiency, wood (F4.0); BTUS/LB steam, conventional (F6.0); BTUS/LB steam, wood (F6.0); Annual O & M costs, conventional (F7.0); Annual O & M costs, wood (F7.0).

Line 3: Price per gallon, oil (or price per therm, gas; or price per ton, coal; F6.2); Price per ton, wood (F6.2); Capital costs (F9.0); Conventional fuel inflation rate (F4.1); wood fuel inflation rate (F4.1); Dry wood energy content (F5.1); Wet basis moisture content (F4.0); Discount rate (F4.0); O & M inflation rate (F5.1); Federal
tax rate (F4.1); State tax rate (F4.1); Depreciation period (F4.0); Operating life of system (F4.0); Federal investment tax credit (F4.0); State investment tax credit (F4.1).

Line 4: Loan period (F3.0); Loan interest rate (F4.1); Oil type (or BTUS per therm gas, or BTUS per ton coal; (I8); Equity capital (F8.0); Depreciation method (I2); Value of cogenerated electricity (F9.2); Electricity inflation rate (F5.1); Cost of storage facilities (F9.0).

Figure 9.
Appendix J

NEWS MEDIA PRESENTATIONS
Ga. Firm Fuels Boiler With Peanut Shells

By BOB DEANS

VALDOSTA, Ga.—Weary of shelling out nearly $2 million a year for natural gas and residual oil, the management of Gold Kist Inc. is switching to peanut hulls and pecan shells to fuel a new boiler that came on-line at its soybean processing plant here last week.

The boiler—which will also burn wood waste such as chips, bark and sawdust—and fuel-handling equipment cost the company approximately 5 tons of hulls and wood in fuel savings in less than three years, according to Mickey Teague, mechanical engineer for Gold Kist.

Teague, the company's mechanical engineer, described Gold Kist's handling operations:

Peanut hulls are transported to the plant in 40,000-pound loads delivered to two silos 80 feet that will hold "several days" supply of hulls, according to Teague.

The hulls will be stored in two silos 80 feet that will hold "several days" supply of hulls, according to Teague.

Construction of the facility began last July, Teague said, and that careful attention to environmental and engineering considerations during the planning stages contributed to the unit's coming on-line in only ten months.

Peanut hulls will be available from September to June each year, from Gold Kist's peanut shelling operations in Ashburn, Ga., 70 miles from here, Reed said. The company bought three trucks, each capable of hauling 40,000 pounds of hulls, Teague said. Each truck will make several runs a day, five days a week to keep the plant supplied. The hulls will be stored in two silos 30 feet by 80 feet that will hold "several days" supply of hulls, according to Teague.

While the Ashburn plant is not charging for the peanut hulls, Teague said the hulls will cost the Valdosta plant between $8 and $12 a ton for the trucks and drivers.

The company's mechanical engineer, described Gold Kist's handling operations: A truck is unloaded by being tipped back with hydraulic lifts. Wood waste is dumped into a 750,000-cubic-foot outside storage lot and hulls are stored in the two silos. The fuels are fed into a hopper, then conveyed to metering bins where measured amounts of fuel are fed into the combustion chamber on demand.

The conveyor/metering system is controlled by a Gould Modicon 584 microprocessor-based programmable process control system, Teague said.

"Our primary reason for going to the waste-fired boiler is economics, and we'll also reduce our dependence on fossil fuels," he said.

The boiler will supply the plant with approximately 72 percent of its total energy needs, Reed said. Natural gas for soybean dryers accounts for roughly 18 percent of the plant's energy requirements, he said, with the remaining 10 percent being electricity to operate the plant's machinery, lights and HVAC equipment.

Besides peanut hulls, pecan shells and wood waste, Teague said, the boiler can burn natural gas or fuel oil should supply or delivery problems occur with the solid fuels. The boiler was manufactured by the Nebraska Boiler Co., Lincoln, Neb., and was fitted with a firebox, controls and pollution equipment by Wellons Inc., Portland, Ore., according to Bryce Adkins, project engineer for Wellons.

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One of the major considerations in burning any type of cellulose-based fuel, such as hulls or wood waste, is handling the large volumes of the bulky material, sources agree.

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Peanut hulls are light, Teague explained, and unlike wood waste which is more dense, peanut hulls burn suspended in the atmosphere inside the combustion chamber: This creates a large amount of fly-ash that goes up the exhaust stack.
Stack emissions, in the form of the fly-ash particulates, necessitated the use of a two-stage pollution control system, consisting of a multi-cone dust collector and fiberglass filter, Teague said.

The pollution controls account for approximately 5 percent of the total cost of the project, he said.

The ash is in demand as a fertilizer additive, Teague said, adding that Gold Kist will use the ash in its agricultural fertilizer blending and distribution operations.

The plant operates three shifts a day, seven days a week, Teague said. To extract oil from soybeans, he explained, the beans are dried, sized, squeegeed and ground into meal or flakes. Some oil comes off during the squeezing process but most remains in the bean until the meal is mixed with hexane, a chemical solvent.

The oil dissolves in the hexane and the resultant solution then goes into a “desolventizer” where steam is used to boil off the hexane, leaving the crude soy oil, Teague said.

Desolventization is the most energy-intensive step in the extraction process, he said, noting that the new boiler will supply all of the steam needed for that process, roughly 40,000 lbs/hr.

Approximately 20,000 lbs/hr of steam will be used to dry the soy meal, a byproduct of the soy oil extraction process, according to Teague.

Gold Kist received a $146,000 grant for the new boiler project from the federal Energy Department, Reed, the firm’s energy manager, said. The grant is being administered through the Georgia Institute of Technology in Atlanta.

In exchange for the grant, Reed said, Gold Kist agreed to open the plant for tours and inspections by groups authorized by Georgia Tech, provide Georgia Tech with performance data on the boiler’s operation and to burn strictly wood for six months to collect data on the use of the fuel.

David Harris, research engineer in the wood energy systems branch of Georgia Tech, is in

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Firm Fuels Boiler With Peanut Shells

Continued from Page 8 school and Gold Kist on the project.

In an analysis he performed two months ago, Harris projected that switching from burning natural gas to burning the hull/chip mixture will net savings in the magnitude of $55.5 million over 12 years. Harris cautioned that while his figures were arrived at by using the best information available and are sound in theory, they are not actual figures and may vary from the plant’s actual operating figures.

In Harris’s analysis, he used $3.45 per thousand cubic feet as the price for natural gas, “an average price now being paid by industrial users in Georgia,” he said. He calculated the plants’ fuel cost last year to have been $2,604,000. Reed estimated that actual use was roughly 20 percent less than Harris calculated.

At $15 a ton for the hull/chip fuel mix, Reed said, the plant’s annual fuel costs for the new boiler will be approximately $840,000. At that price, he said, the boiler will have a simple payback of three years, or a discounted payback, that includes an inflation factor, of 4.6 years. Harris said that his figures include $70,000 a year in additional operating costs for handling the hull/chip fuel at the plant, and annual escalation rates of 12, 15 and 18 percent, respectively, for the costs of fuel handling, hull/chip fuel and natural gas.

An additional benefit of the new boiler is that it has sparked enthusiasm among plant employees in saving energy, Reed said. Additional savings have been achieved at the plant through an aggressive maintenance effort to detect steam leaks in lines and faulty steam traps, Reed said. The plant is also considering cogeneration, he added, but that it is not now economically attractive.

In anticipation of future cogeneration possibilities, Teague said, the firm spent an additional $200,000 for the new boiler to be rated at 600 psig at 750 degrees F. to ensure adequate steam supplies for a turbine generator. The plant currently uses steam at 150 psig, he said.
Carpet Plant Turns To Wood Energy

ROME, Ga. — A ribbon was burned — not cut — at a Feb. 5 dedication of an innovative wood energy system at a federal demonstration site near here. The public attended the 10 a.m. “ribbon burning” ceremony at Integrated Products, Inc., a carpet yarn manufacturer in the northwest Georgia community of Aragon.

State and federal energy officials were in attendance, including Dr. Beverly Berger, director of the Biomass Energy Systems Division of the Department of Energy, and Mark Zwecker, director of Georgia’s Office of Energy Resources.

On display for the program was a 400 horsepower wood-fueled boiler and wood handling system designed and installed with the assistance of engineers from Georgia Tech’s Engineering Experiment Station.

The system cost $460,000 to build and the present worth of the expected energy savings over the next 20 years will exceed $3 million. The Department of Energy is sponsoring this and two other wood energy demonstration projects in Georgia. The aim of the DOE’s effort is to show manufacturers in non-forest industries that wood can be used for fuel economically.

Tech engineers selected Integrated Products as a demonstration site because of the company’s potential for fossil fuel conservation through wood conversion.
Wood energy is very real for at least one non-forest products industry in Georgia. Integrated Products, Inc., an Aragon, GA carpet yarn manufacturer, dedicated a 400-HP wood-fired boiler and wood handling system in a "ribbon burning" ceremony this past February. The wood boiler at Integrated Products, which will supply the plant's steam and space heating needs, is the first tangible result of an active wood energy program sponsored by the Engineering Experiment Station of Georgia Institute of Technology (Atlanta, GA).

The wood program is aimed at convincing non-forest products industries in northern Georgia to use the state's plentiful supply of wood wastes. Carol Aton, a research engineer with the program, estimates that as much as 25% of Georgia's industrial boiler capacity could be fueled by wood waste without altering current practices. And the non-forest products industries in Georgia, a state that imports some 97% of its fuel, are listening, especially now that there's some concrete evidence of the program's practicality at Integrated Products.

Cost savings from the Integrated Products boiler system are expected to be quite substantial—some $3 million over the 20-year life expectancy of the system. With fuel costs reduced by some $128,000/year, the payback period for the system is expected to be only two to three years—even with high initial capital costs of $460,000. The bright financial picture comes from the switch from oil (53,000 gal/year of No. 2 fuel oil at $0.86/gal) and natural gas (52 million cubic ft/year at $3.00/1000 cubic ft) to wood (9,142 ton/year at $8/ton). Wood comes from nearby sawmills and other forest products industries.

The Integrated Products project is one of three demonstration projects expected to be in operation by the end of this year. The other two are a 1800-HP boiler system at Goldkist Co., a soybean processing plant in Valdosta, GA, and a 125-HP system at Graniteville Textile Co. in Augusta, GA.

The high installation costs of a complete wood-fired boiler system have made some manufacturers a bit shy, but the wood energy program includes something for the wary too—a retrofit, gasification system. This system involves adding a wood gasifier to a good oil/natural gas boiler. The close-coupled gasification systems are considerably cheaper, especially for plants that have recently installed a new oil/gas boiler system.

In all probability, the trend toward local solutions to local energy problems will pick up steam in the following year, given the current energy budget-cutting mood that prevails in Washington.
Textile Plant Switches Boilers To Wood

By BOB DEANS

ARAGON, Ga.—Induced by a package of financial incentives that include approximately $100,000 a year in reduced energy costs, approximately $92,000 in federal tax credits and $146,000 in federal grant money, a textile plant here has replaced its gas/oil-fired boilers with one that will burn wood residue, according to a company representative.

Current data show that, at $8 a ton for sawdust, Integrated Products Inc. (IPI) will spend approximately $4,000 a month on boiler fuel, compared to between $12,000 and $13,000 a month which it would have been paying for natural gas and fuel oil, the spokesman said.

Although payback figures will vary with the cost of sawdust, the yarn-weaving firm expects the installation in three and a half years, the spokesman said.

The price and availability of fuel oil and natural gas prompted IPI to begin looking for an alternate fuel about four years ago, according to Hardin Byars, vice president of engineering for the company.

The firm was assisted in its feasibility analysis and in locating sources of wood residue by the Georgia Institute of Technology's Engineering Experiment Station, (EES) in Atlanta, according to William S. Bulpitt, chief of the EES' wood energy systems branch.

Bulpitt said that a year and a half ago the EES contacted the Georgia Textile Manufacturers Association Inc. to find textile firms interested in using wood as an alternate fuel and willing to participate in a demonstration project that would give wood use public exposure.

IPI was selected as one of the demonstration projects and received $146,000 in financial assistance for the project. The U.S. Department of Energy allocated the money through the Georgia state energy office to Georgia Tech for demonstration projects, Bulpitt said.

The total cost of the system was approximately $470,000, Byars said, noting that 10 percent federal tax credits for both energy conservation equipment and purchases of new equipment would reduce the cost by 20 percent.

Byars said that that price included a new boiler, a silo that will store a three-day supply of wood residue (sawdust, chips, bark), a feed system, a covered unloading ramp area, an outside storage ramp, a front-end loader to load the feed system hopper, and the boiler itself.

Byars said that without the grant money the project may still have been economically feasible but that his company would have been reluctant to be the first to try a process as yet unproven in the textile industry. He said that the IPI installation will serve as a "guinea pig" for a wood-burning operation and that other industries will benefit from the actual payback data the firm receives.

"We might not have done it without the grant because it was so new...We would have been able to swing it without the grant if we knew what this equipment would really do," Byars said. "But for us to go in and spend a half-million dollars and still have a lot of questions about the equipment, we probably would have backed off."

Byars said that in exchange for the grant money "we're making our facility completely available to Georgia Tech and the DOE for one year." He said that IPI will conduct tours, speak at seminars, and make cost-comparison figures available so that other industries may benefit from IPI's experience.

The boiler was manufactured by the Industrial Boiler Corp. (IBC), Thomasville, Ga. Byars said. He said it is rated at 400 horsepower and will produce up to 13,000 pounds of steam an hour at a pressure of 115 pounds per square inch gauge.

Byars said that it replaced two boilers, of 200 and 300 hp, and has been delivering adequate levels of steam since it came on-line the first week in January.

Byars said that the IBC boiler was selected after IPI reviewed bids from six other boiler manufacturers. He said that while price was a primary factor, IBC's expertise in the wood-burning field weighed heavily in the decision.

Bulpitt said that IBC has 60 or 70 units of the same size in the wood-waste field."

Bulpitt said that he intends to fire the boiler with sawdust because it costs roughly half as much as wood chips, even though both sources have about the same Btu-value per ton.

One reason for the difference in price, Byars explained, is that the chips are bought by paper manufacturers as a source of cellulose, hence the wood fiber that is the basic ingredient of paper. "I don't want to compete with something that has value to it, so I'd rather stick to sawdust," Byars said.

He said that he based his economic analysis on a price of $8 a ton for sawdust, though it is often available for as little as $6 a ton. Wood chips, he said, now sell for between $14 and $15 a ton.

The IPI plant produces approximately 65,000 pounds of finished heat-set nylon carpet yarn a day, Byars said, and is considered a medium-sized operation. He said that steam is used to heat-set the twist in the yarn the company makes and sells to carpet manufacturers.

Byars said that steam is also used to heat the building, though generally "our machinery heat keeps our buildings pretty warm." He said that on days when production usually slackens, such as on weekends, when the weather is cold, the plant's heating load peaks at between 3,000 and 5,000 pounds of steam an hour.

He said that the steam boiler accounts for roughly 30 percent of the plant's total energy consumption, with most of the other 70 percent being electric motors that operate the spinning process.

Bulpitt said that the IPI installation represents a significant breakthrough in the use of wood residue as an industrial boiler fuel because up until now most such applications have been confined to the wood products manufacturing industries.

One drawback to burning wood residue, Byars said, is that handling the fuel takes more labor than operating a gas- or oil-fired boiler. "It takes about two and a half people to operate this boiler," whereas before, one person would spend half of his time operating the other two gas/oil-fired boilers.
Go Slow On Wood Switch, Industries Told

By BOB DEANS

ATLANTA—In the hope of saving big dollars in fuel costs, southeastern industries are taking a hard look at wood as a boiler fuel. But those hopes are tempered by concern over the future price and availability of wood, according to William S. Bulpitt, chief of the wood energy systems (WES) branch of the Georgia Institute of Technology here.

Speakers at a recent Georgia Tech seminar on wood energy agreed that the feasibility of burning wood for industrial, commercial and agricultural users must be evaluated on a site-specific basis with wood availability being the first consideration since it affects both the fuel's supply and its price.

One study delivered at the workshop, for example, showed that transportation of wood residue adds approximately 6.5 cents per ton to its cost over each mile. Unless a potential user is located near a supplier, the switch to wood probably would not be cost-effective.

B.S. Dixit, senior research engineer for WES said that the use of wood as an industrial fuel has heretofore been largely confined to the wood products manufacturing industry. He cited the brick industry and a few textile mills as notable exceptions, and pointed to increased interest in wood burning among other users.

Bulpitt said the reason for users' reluctance to invest in wood-burning equipment is the uncertainty of the future supply. "The average man still doesn't feel confident enough in the supply to take that jump. What is lacking is a network of wood-procurement businesses that will sign a long-term (3-year) contract that will assign a guaranteed price for wood," he said.

Bulpitt later indicated that a lack of confidence in the future supply of wood is justified. He acknowledged that the amount of sawdust, shavings, bark, chips and other residue the wood products manufacturers can produce is limited. If demand for that residue outstrips the supply in a given region, the "waste wood" becomes a valuable commodity whose price would rise with competition. Bulpitt explained.

He said that in some areas, such as Brunswick and Savannah in Georgia, much of the timberland is owned or leased by pulp and paper companies which use wood residue and are not encouraging its use as a fuel by other industries. "I don't really advocate pushing for a company to use wood in an area where they will be in competition for the wood residue," Bulpitt said.

He said that despite competition considerations, there are areas in Georgia where wood waste is available as a low-cost industrial fuel.

The recent wood energy workshop at Georgia Tech, aimed at demonstrating the feasibility of wood energy for industrial, commercial and agricultural users, drew about 50 attendees, and Bulpitt and other speakers told those interested in investing in wood-burning equipment to first investigate thoroughly the wood market in their area.

Feasibility Report

A feasibility study of a chicken-rendering plant in Georgia, showed that the plant could save nearly $9 million over a 20-year projected life-cycle by using wood fuel instead of its present mix of 52.8 percent natural gas and 47.2 percent No. 2 fuel oil. The study, made by the Georgia Tech Engineering Experiment Station (EES), estimated that the plant could replace its annual requirement of 60.737 million cubic feet of natural gas and 388,500 gallons of No. 2 fuel oil with 17,700 tons of wood residues having a moisture content of up to 50 percent.

The workshop at Georgia Tech was funded by the Department of Energy through the Georgia Office of Energy Resources. Another seminar will be held in Savannah on Nov. 23 at the Downtownier, 201 West Oglethorpe Ave.
Do You Know That

. . . . wood wastes are being seriously looked at as possible sources of industrial fuel? Rising fuel costs and concerns about available supplies have helped create that interest. Since natural gas prices have risen, comparative costs with wood have become more equal. And the reason that more manufacturers aren't opting for wood right now is that capital costs for installation and maintenance are 5 to 10 times higher than those necessary for oil or natural gas. The attraction of wood wastes is that they already exist in usable form—as discarded sawdust in lumber yards or fragments of trees left in the forest when woodlands are cleared.

Grant Curtis, an engineer in Georgia Tech's Wood Energy Group, estimates that Georgia alone could meet around 20% of its annual energy requirements by using its wood wastes more thoroughly. The group is offering help to industries seeking dependable sources of wood wastes or advice on conversion. The group also helps forest-product companies locate markets.

Anyone interested should write; Wood Energy Group, Engineering Experiment Station, Georgia Tech, Atlanta, GA 30332.
Maynard Eaton: Wood is the first fuel man used, then we got tired of using oil and gas. Now those fuels are expensive and in short supply; the solution - use wood again.

Bonnie Erbe: This cargo of sawdust is being used as fuel for a soybean oil plant in South Georgia. As the cost of fuels continue to rise, a few pioneering companies are turning to wood. Gold Kist, a large agricultural cooperative, and Georgia Tech University converted the plant as an experiment with the help of a small federal energy grant. It cost $3½ million to convert from oil and gas to wood; it will take 3 years to recover that investment. But once recovered, the company expects to save $2 million a year. The plant burns sawdust, peanut shells, and other wood waste much of which is produced by Gold Kist. These fuels are one-fourth the cost of coal or gas and they cause less pollution, but there are limitations. It's expensive to ship bulky wood products; large supplies must be within 75 miles of the plant site to make wood burning plants economical.

Bill Bulpitt: Wood is not the cure-all for the nation's industrial energy problems, but in certain site-specific locations, it can significantly help out the energy picture for a specific industrial plant, particularly in areas in the Southeast and some parts of the Northeast and also the Pacific-Northwest.

Bonnie Erbe: Scientists say as much as 7% of the country's industrial energy needs could someday be supplied by wood wastes, saving the U.S. $28 billion a year at current oil prices.