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ADVANCED SYSTEM DEMONSTRATION FOR UTILIZATION OF
BIOMASS AS AN ENERGY SOURCE

Executive Summary

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October 1980

Work Performed Under Contract No. AC06-77ET20055

Wheelabrator Cleanfuel Corporation
Washington, D. C.

U.S. Department of Energy

Solar Energy

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DESIGN REPORT

DEPARTMENT OF ENERGY
FUELS FROM BIOMASS SYSTEMS BRANCH

ADVANCED SYSTEM
DEMONSTRATION
FOR UTILIZATION OF BIOMASS
AS AN ENERGY SOURCE

CONTRACT EG-77-R-06-1036

EXECUTIVE SUMMARY

Prepared By
WHEELABRATOR CLEANFUEL CORPORATION

OCTOBER, 1980

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I. INTRODUCTION

A. PURPOSE

This document summarizes the findings of an extensive investigation to determine the technical and economic viability of a biomass fueled 510,000 lb/hr boiler and related facilities to generate steam and/or electricity. Several special studies appraised biomass availability, environmental impact, and site selection in order to more fully substantiate the feasibility of this effort.

B. PARTICIPANTS

This document and others that detail the study have been prepared for the U.S. Department of Energy, Fuels from Biomass Systems Branch, Washington, D.C. by the Wheelabrator Cleanfuel Corporation of Washington, D.C., and The Rust Engineering Company of Birmingham, AL under DOE Contract EG-77-R-06-1036.

Portions of the study investigations were completed by the organizations listed below.

Biomass Study Report -- Wood Energy Institute

Environmental Impact Statement -- Dartmouth College

Site Selection Report -- The Rust Engineering Company

Design Report -- The Rust Engineering Company

The Wheelabrator Cleanfuel Corporation directed, reviewed, and coordinated all aspects of this report.

C. SCOPE

The basic goals of this study were to:

1. Determine the availability and cost of biomass for use as a continuous fuel source for a steam/electricity co-generation facility sized to burn 1,000 oven dry tons of biomass per day;
2. Select a suitable site for construction of such a facility;
3. Prepare a draft Environmental Impact Statement for the facility at the selected site;
4. Prepare an engineering design package for the facility, including flowsheets, P&I diagrams, general arrangement drawings, engineering and architectural specifications, and a scope and design criteria document;
5. Prepare an estimate of the cost of the facility based on information obtained in tasks outlined above; and
6. Develop a selling price for the energy produced.

The project as originally conceived by the DOE consisted of three phases to be completed in 64 months. The original overall project schedule was as follows:

PHASE I. System Design	19 months (Completed June, 1979)
EVALUATION PERIOD	4 months after Phase I
PHASE II. Construction and Start-up	29 months
PHASE III. Operation and Evaluation	12 months after Phase II

The Phase I work has now been completed and the documents have been submitted to the DOE by the Wheelabrator Cleanfuel Corporation. Further work has not been authorized. As presently planned, the DOE will not participate in the construction and operation of the plant.

The design package is based upon a specific site in the State of Maine. However, the design is generic in nature and could serve as a model for other biomass conversion facilities located anywhere biomass is available in adequate quantities.

D. SUMMARY

The results of the study investigations confirm the feasibility of collecting 1,000 oven dry tons of biomass per day to fuel a 510,000 lb/hr boiler operating in a cogeneration mode and producing steam and electricity.

This study was based on the supply of a significant portion of the facility's biomass fuel by tree harvesting and collection operations within a 50 mile radius of the plant site. These operations, including transporting biomass to the conversion plant, would pose no threat to the environment if good forestry practice is carefully maintained, as described in the reference documents.

Other environmental factors relating to air and water discharges from the conversion plant pose no significant technological problems in complying with federal, state, and local regulations at a cost that is competitive with similar costs associated with fossil fueled facilities.

The technology for the conversion facility design and its operation including chip handling, boiler feeding, combusting the biomass, and treating emissions and wastes is described in the reference documentation and is available for implementation.

The facility has been designed to adjust the level of electricity production to the steam available after process steam consumption requirements have been met. Under average conditions, approximately 258,000 lb/hr of steam will be available while about 20 megawatts of electricity will be sold to a utility grid.

Based on the results of this study, biomass is an economically viable and technically feasible boiler fuel for the cogeneration of steam and electricity. Our confidence in this statement is supported by our investigations, as reported in the reference documentation. We recommend the development of a fully detailed facility design and further investigations into the economic parameters of the facility's construction and operation.

II. KEY DESCRIPTIONS

A. BIOMASS ENERGY FLOW CONCEPTS

1. Energy Source

The biomass energy flow concept is illustrated on the following page. The energy source is biomass--which includes harvested forest biomass and biomass mill residues. The harvested biomass consists largely of standing timber that has no commercial value at present--rough-and-rotten wood, non-marketable species, dead and diseased trees, thinnings and culls, overage stands, and other biomass presently unused by the forestry industry. The second source is mill residue, which includes bark from paper mills; slabs, trimmings, and sawdust from sawmills; shavings and trimmings from furniture plants; and other industrial and commercial wood waste materials.

All of these materials represent energy sources that are not fully utilized. Additionally, the forest continues to produce an abundant amount of this material each year. If this material were removed, it would improve the remaining growing stock. Our forests are renewable energy sources that can provide a continual supply of fuel. Thus, the use of biomass as a fuel is a viable and attractive alternative and will help us become less dependent on imported fuels.

Biomass Energy Flow Concepts

2. Harvesting and Collection

The existence of the biomass supply is beyond question. The methods available for economical harvesting and collection of biomass from the woods are under investigation and development. Mechanical equipment is now available that reduces manual labor and increases productivity to the point where biomass fuel costs can be competitive. Many types of machines such as fellers, feller-bunchers, grapple skidders and forwarders are on the market to assist the logger in his complicated tasks and greatly increase daily production. These methods are covered in detail in the Fuelwood Availability Report.

3. In-Woods Processing

The economics of delivering biomass to the plant requires full consideration of every potential method that can reduce costs and improve efficiency. The concept of in-woods processing can now be implemented by machines that take whole trees and reduce them rapidly to chips. Some forestry operations now utilize these in-woods chippers along with mechanical fellers, feller-bunchers, skidders, or combinations of this mechanical equipment to provide a complete chipping operation on wheels that can be easily relocated as needed in the forest. The chips produced are then loaded into a truck or van for transport to the conversion plant, where they can be handled more easily than logs and can be routed directly to a furnace for combustion.

Other methods of biomass harvesting include topping and delimbing to produce shortwood (lengths up to 8 or 10 feet) and longwood (tree-length logs). These approaches require transport as roundwood with appropriate unloading, handling, and chipping at the consuming facility. Studies of the economics favor in-woods chipping and this approach has been incorporated into the design of the biomass conversion facility.

4. Transportation

Two basic approaches to the transport system have been explored--truck and rail. Trucks will invariably be used for the trip out of the woods. Railroads offer possibilities for low-cost transport, especially if distances are long enough to warrant an extra loading-unloading operation. A mechanical means of loading and unloading biomass is essential for an efficient transportation system and several methods have been investigated for incorporation into the design.

B. SITE SELECTION

A comprehensive site selection study revealed a number of locations in the State of Maine that offered desirable characteristics for selection as the prime site for the proposed facility. The initial list of potential sites included 22 localities where a large industrial concern could become a customer for the steam produced by the facility. (The location of an electricity buyer was not a problem in Maine.) This list was reduced to five prime sites by careful analysis of the most critical elements required to meet the precise conditions set forth in the contract. Any of the five sites would be suitable for a demonstration project.

C. PLANT AND PROCESS

The plant is designed as a nominal 50 megawatt cogeneration steam and electric power plant using biomass as the principal fuelstock. Oil is available as a back-up fuel and a small amount of oil is burned continuously to keep the lines, pumps, and control system ready for immediate switchover, if necessary.

Using the cogeneration principle, the plant produces both steam and electricity for sale to nearby customers. High pressure steam is generated and passed through a turbine-generator for electricity generation, with extraction of steam at lower pressure levels for process and heating uses. The boiler and turbine-generator have been matched to the industrial process steam requirements; electrical generation will vary slightly with steam demand. This design approach achieves a high level of efficiency.

The plant consists essentially of biomass receiving, handling, and storage facilities, and a boiler house with its associated facilities. The biomass handling facilities include truck dumpers to unload trailers carrying whole-tree chips and mill residue, the necessary conveyors and processing equipment for size reduction, and a storage area for a 30 day supply of fuelstock. Fuel reclaimed from storage is conveyed to the boiler house, where it is dried and delivered to the furnace. The boiler generates steam at 1500 psig and 925 °F for delivery to the turbine-generator. The hot exhaust gases are used as a drying medium for the incoming fuelstock as well as to pre-heat the combustion air. Exhaust gases are processed for air pollution control to meet all applicable

regulations. A double-basin ash pond is provided for receiving ash sluiced from the furnace. At any given time, one section of the pond is being used to receive ash, while the other section is drying for removal of the settled ash, which is then disposed of in a landfill.

The overall external appearance of the facilities will be that of a simple, uncluttered, functional industrial complex designed in keeping with modern industrial architectural practice.

D. ENVIRONMENTAL IMPACT STATEMENT

An Environmental Impact Statement has been prepared for the proposed facility as required by applicable laws and regulations. The study revealed that the biomass conversion plant will have environmental impacts, both beneficial and adverse. These impacts on the environment fall into four general categories--(1) plant construction, (2) plant operation, (3) biomass harvesting, and (4) the transportation of biomass.

Plant construction will provide approximately 1,000 jobs, direct and indirect, over the two year construction period. There will be a significant increase in the ambient noise levels in the area during this period.

Plant operation will change the overall emissions to the atmosphere from the Westbrook complex, decreasing particulates and sulfur dioxide considerably, and increasing the emission of nitrogen oxides and carbon monoxide. The water quality in the Penobscot River should be improved. Landfilling of the residual ash should not pose any hazards to the environment.

The environmental effects of harvesting are dependent upon good forestry management. With the use of sound harvesting systems and well-managed silvicultural practices, both the economic and aesthetic values of the residual forestry stands can be improved.

The transportation of biomass supplies to the plant will increase the traffic in the area, and will tend to increase noise levels. With good dispersal of traffic throughout the working hours, this effect will not be significant.

The project will contribute to several goals of our National Energy Plan, including the replacement of approximately 766,000 barrels of oil annually. It will also provide a significant demonstration of appropriate technologies and environmental standards for the development of wood as a sustainable, renewable energy source for industry.

E. CONCEPT OF OPERATION

The facility is designed for continuous operation, 24 hours a day, 7 days a week, for 340 days a year. The shut-down period is for scheduled maintenance and repair to assure continuous operation for the following scheduled period.

It will operate upon a fixed fuel supply rate of 1,000 oven dry tons per day of biomass fuelstock, converting the energy in the fuel by direct combustion into steam for process uses and electrical generation.

The operation will control the production of electrical energy so the steam user will receive his needs first and then, the remainder of the energy will be converted to electricity for

sale to the utility company. Under average conditions, approximately 258,000 lb/hr of steam will be sold to the industrial user while approximately 20 megawatts of electricity will be sold to the utility grid. This balance will vary from season to season and at various times due to the fluctuations in steam requirements.

F. PROCUREMENT AND CONSTRUCTION SCHEDULE

The procurement and construction schedule is presented in Volume I, Section III and identifies the key milestones and activities required for construction of the facility. The key information from that schedule is summarized below:

<u>ACTIVITY</u>	<u>DURATION--COMPLETION TIME</u>
Final Engineering	7 months
Procurement	Months 1 through 27
Construction	Months 13 through 36
Start-up	Month 36

2-11

TURBINE-GENERATOR

2-13

AIR POLLUTION CONTROL WITH BIOMASS DRYER

III. FEASIBILITY AND ECONOMIC EVALUATIONS

A. FUEL AVAILABILITY

The Fuelwood Availability Study concluded that there is enough unutilized biomass feed stock within a 50 mile radius of the model site to sustain operations on a long term basis. The growth of the tops and limbs of the trees alone is almost three times the amount required to operate the plant. Mill residues, that are currently wasted, offer an attractive potential for reduced fuel costs.

B. ENVIRONMENTAL IMPACT

The Environmental Impact Study that was completed for the model site indicates no significant threat to the environment. This applies to the harvesting, collecting and transporting of fuelstock and to the operation of the facility. However, it is based on the use of the recommended forestry procedures and the construction of the facility per the conceptual design.

C. PRODUCT COST COMPETITIVENESS

Based on the harvesting and collection system recommended and the conceptual design for the conversion facility, the cost of the energy products, (process steam and electricity) from the use of biomass as a feedstock is a competitive, viable alternative to coal.

D. TOTAL INVESTMENT COSTS

Total investment cost for the proposed biomass conversion facility is \$64,500,000 in mid-1979 dollars. The components are:

Total installed capital, with engineering	\$55,000,000
Startup, checkout and testing	800,000
Land	300,000
Working capital	1,140,000
Interest during construction	6,860,000
Bond sale cost	400,000

The capital cost estimate has been prepared for the proposed biomass conversion facility based upon a nominal 50 megawatt steam and electric generating plant using biomass as fuelstock. This cost estimate includes final engineering, equipment, direct and indirect labor costs, materials, subcontractor costs, tools, construction supplies, equipment, and overhead, taxes and insurance, and profit. These are the costs normally encountered for any major industrial construction project. The estimate is based upon flow-sheets, drawings, specifications, equipment lists and prices, and other details provided in the design package.

E. TOTAL OPERATING COSTS

The annual operating costs in mid-1979 dollars were estimated as follows:

Fuel

Mill residue	\$ 2,850,000
Forest biomass	6,020,000
Oil	587,400

Labor

Operating	\$ 570,400
Maintenance	119,700
Maintenance materials and services	1,327,100
Local taxes	1,371,400
G&A expenses	<u>371,900</u>
Total	\$ 13,217,900

F. ECONOMIC ANALYSIS

A computer model based on discounted cash flow methods of analysis was used to determine the economic feasibility of the proposed project. The model considers the project as being constructed over a construction period in which capital is input, and operated over an economic life in which the facility generates revenues and incurs operating expenses, tax obligations and debt service requirements.

In this case the model determines the annual revenues and energy prices required to generate a given after tax rate of return on equity.

The base case energy prices in mid-1979 dollars and the major economic assumptions are as follows:

	<u>Electricity</u> <u>\$ kWh</u>	<u>Steam</u> <u>\$/MBtu</u>
Energy Prices	0.040	3.88
Economic Assumptions:		
After tax return on equity	15%	
Debt/equity ratio	75%/25%	
Debt interest rate	10%, 20 years	
Economic life	20 years	

Effective tax rate	46%
Tax depreciation	20 years, double declining balance
Inflation rate	10% per year to start-up 8 per year over economic life
Investment tax credit	73% of investment at 20% 17% of investment at 10% 10% of investment at 0%

The required energy prices for a coal fired facility equivalent in size to the biomass facility and with the above economic parameters are \$0.040 per kWh and \$4.26 per million Btu.

The required plant revenues were plotted against the major variables such as fuel wood price, capital cost, operating costs and debt interest rate. The sensitivity of the required revenues to changes in the major variables was also measured.

The full economic analyses are presented in Volume I, Scope and Design Criteria.

IV. REFERENCE DOCUMENTATION

The documents listed below form the study package for the biomass fueled facility. These documents provide full details of the areas they address and can be ordered through the DOE. A description of the contents of each follows the listing.

- A. Fuelwood Availability (Wood Energy Institute)
- B. Draft Environmental Impact Statement (Dartmouth College)
- C. Site Study Report (The Rust Engineering Company/Wheelabrator Cleanfuel Corporation)
- D. Design Report (The Rust Engineering Company/Wheelabrator Cleanfuel Corporation) consisting of:
 - 1. Volume I--Scope and Design Criteria
 - 2. Volume II--Technical Specifications
 - 3. Volume III--Equipment Specifications (2 books)
 - 4. Volume IV--Design Drawings
 - 5. Volume V--Electrical and Instrumentation Elementary Diagrams and Instrument Indices

A. FUELWOOD AVAILABILITY

This document was prepared by the Wood Energy Institute of Camden, Maine. It characterizes potential sources of biomass such as mill residue and forest residues and assesses the availability of each. It also details the possible means for harvesting forest residues and evaluates the cost of those operations. In Section IV, it address the transportation of forest and mill residues, compares the available equipment, and provides a supply and transportation plan.

B. DRAFT ENVIRONMENTAL IMPACT STATEMENT

This is a series of documents prepared by the Resource Policy Center, Thayer School of Engineering, Dartmouth College of Hanover, New Hampshire. It addresses specific areas of environmental concern as described below.

Draft Environmental Impact Statement (Summary of Conclusions and Findings)

Appendix A: Project Description

Appendix B: Air Quality Studies

Appendix C: Water Quality Studies

Appendix D: Terrestrial Ecosystem Studies

Appendix E: Socioeconomic Studies

Appendix F: Transportation Studies

Appendix G: Land Use Studies

Appendix I: Historic, Archaeological, and Cultural Studies

Appendix J: Alternative Studies

C. SITE STUDY REPORT

This document, prepared by The Rust Engineering Company under the auspices of the Wheelabrator Cleanfuel Corporation, presents the criteria used to determine possible sites and the subsequent evaluation of the sites that isolated the most promising location.

D. DESIGN REPORT

These documents, five volumes, were prepared by The Rust Engineering Company under the auspices of the Wheelabrator Cleanfuel Corporation. A description of the contents of each is provided on the following page.

1. Volume I--Scope and Design Criteria

This volume presents detailed scope information, procurement and construction schedules, technical design data, descriptions of each generalized site area, the general project requirements, a discussion of alternatives studied, and a full economic evaluation.

2. Volume II--Technical Specifications

This volume presents, in complete form, all the technical specifications relating to materials and construction for the proposed facility.

3. Volume III--Equipment Specifications (2 Books)

This volume, 2 books, presents the equipment specifications and information relating to vendor performance for the biomass facility.

4. Volume IV--Design Drawings

This volume presents design drawings for the proposed facility and is segmented for each plant area as described in Volume I, Scope and Design Criteria.

5. Volume V--Electrical and Instrumentation Elementary Diagrams and Instrument Indices

This volume is comprised of two sections, one for electrical and instrumentation elementary diagrams and the other for instrument indices.