MASTER

METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

Attachment VIII

The Wood-Fueled Gasification System Evergreen Energy Corporation's Final Engineering Report

June 1982

**Prepared by
Biomass Energy Systems, Inc.
Lakeland, Florida**

**For the
U.S. Department of Energy
Office of Alcohol Fuels
Under Grant No. DE-FG07-80RA50316**

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Attachment VIII

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METHANOL PRODUCTION FROM
EUCALYPTUS WOOD CHIPS

Working Document 8

The Wood-Fueled Gasification System -
Evergreen Energy Corporation's
Final Engineering Report

Principal Investigator:
Henry H. Fishkind

June 1982

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For the
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THE WOOD-FUELED GASIFICATION SYSTEM -
EVERGREEN ENERGY CORPORATION'S
FINAL ENGINEERING REPORT

BIOMASS ENERGY SYSTEMS INC.
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"HARVESTING RENEWABLE ENERGY RESOURCES NOW"

EVERGREEN ENERGY CORPORATION

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May 28, 1982

Dr. Henry H. Fishkind
Biomass Energy Systems, Inc.
1337 Gary Road
Lakeland, FL 33801

Re: Gasifier Redesign; DOE Grant No. DE-FG07-80RA-50316

Dear Dr. Fishkind:

Evergreen has now completed the project referenced above and authorized per your letter of November 13, 1981, George W. Cornwell to John P. Libbey, and we are pleased to enclose our final report on this study.

We appreciate the opportunity to provide Biomass Energy Systems, Inc. with estimated technical, economic and process information relating to the Evergreen/Texaco eucalyptus wood-to-methanol entrained-bed gasification system as an alternative to the fixed bed method considered earlier by BESI.

All dollar figures have been adjusted to be comparable with the Davy McKee Report.

Very truly yours,

EVERGREEN ENERGY CORPORATION

John P. Libbey ^{Sab}

John P. Libbey
International Marketing Manager

ENCLOSURE

BIOMASS ENERGY SYSTEMS, INC.

1337 Gary Road
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PROJECT NO. 810101

GASIFIER REDESIGN

DOE GRANT NO. DE-FG07-80RA-50316

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May 27, 1982

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EXECUTIVE SUMMARY

Biomass Energy Systems, Inc. requested Evergreen Energy Corporation to provide projected cost and operating data on the Evergreen/Texaco entrained-bed wood gasification system currently under development as an alternative to the state-of-the-art fixed-bed wood gasification system proposed by Davy McKee in their report "Feasibility Study - Eucalyptus to 1000 STPD Methanol Plant in South Central Florida" dated August, 1981.

A preliminary engineering analysis performed by Evergreen based on data furnished by Badger America Inc., Sandwell and Company Limited and Texaco Development Corporation indicates that the Evergreen/Texaco wood gasification system will offer the following advantages over the fixed-bed system:

1. Significant increases in overall plant thermal efficiency, 49.7% vs. 33.3%.
2. Reduction of total wood consumption by 34%, from 3047 dry tons per day down to 1990 dry tons per day.
3. Reduction in electric power consumption by better than 50%, from 21500 KW to 9600 KW.
4. Significant decrease in environmental problems--waste water treatment problems are reduced and total waste water discharge is cut in half, from 1050 GPM down to 550 GPM.
5. 46% less makeup water required: 1500 GPM vs. 2800 GPM.

Overall capital costs for the total plant remain about the same at approximately \$250 million. The Evergreen/Texaco system will provide significant capital cost savings in the gasifiers, gas cleanup, and waste water treatment sections, and eliminate the need for a large off-site wood-fired power boiler. These reductions are offset by higher investments in the feedstock preparation, drying, and feeding section plus the need for a larger air separation plant and compressor to supply oxygen at high pressure to the gasifier.

It should be noted that these conclusions are based on preliminary engineering and cost estimates which have an overall accuracy of $\pm 35\%$. More accurate information will not be available until Evergreen and Texaco complete their testing of the prototype gasification system at Texaco's Montebello, California facility during 1983.

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BIOMASS ENERGY SYSTEMS, INC.
Lakeland, Florida

Project No. 810101

DATE: May 27, 1982

Gasifier Redesign;
DOE Grant No. DE-FG0-7-80RA-50316

I. INTRODUCTION

Biomass Energy Systems, Inc. (BESI) has prepared, under a grant from the Department of Energy, a feasibility study for the conversion of plantation eucalyptus wood to methanol. The plant would be installed in south central Florida adjacent to a stand of some 10,000 acres of eucalyptus trees. BESI's report was based on a technical study for a complete plant by Davy McKee in August of 1981 featuring relatively small log gasifiers working at low pressures and high retention times.

BESI has retained Evergreen Energy Corporation to provide an optional production process using the Evergreen wood-to-methanol system which features Evergreen's proprietary technology for introducing wood feedstock into the Texaco high-pressure gasifier. Under a cooperative agreement with Texaco, Inc., and its subsidiary, Texaco Development Corporation, Evergreen and Texaco are presently working together to adapt the Texaco coal gasifier to accept wood for the production of synthesis gas.

By gasifying at high pressure and high temperature, the Texaco process yields excellent conversion efficiencies while producing

a minimum of undesirable by-products. Because the feedstock residence time in this gasifier is very short, the particle size of the feedstock must be substantially reduced from conventional logs or pulpwood chip size.

Evergreen has retained Sandwell and Company Limited of Montreal, Canada, to prepare capital and operating costs for the eucalyptus wood fibre handling and preparation facilities needed to meet the Evergreen/Texaco gasification process requirements.

Badger America, Inc. of Cambridge, Massachusetts has been retained to determine equipment and operating cost differentials downstream from the proposed Texaco gasifier vs. the Davy McKee system originally designed for BESI.

II. SCOPE OF THE STUDY

This report addresses the technology and cost differences from the BESI/Davy McKee Report of August, 1981 in these specific units:

- Unit 1: Wood Preparation and Storage
 - a. Log feeding and chipping systems
 - b. Storage and reclaim system
 - c. Drying facilities
 - d. Feedstock preparation facilities
 - e. Prepared feedstock storage
- Unit 2: Gasifier Feeder System
- Unit 3: Gasifier
- Unit 4: Shift Conversion
- Unit 5: Acid Gas Recycle
- Unit 6: Methanol Synthesis and Distillation
- Unit 7: Air Separation
- Unit 8: Wastewater Treatment
- Unit 9: Utilities and Ancillary Systems

III. TECHNICAL SUMMARY

The objective of this work has been to develop the capital costs for a plant to produce 1000 short tons per day of methanol from wood using Evergreen/Texaco gasification technology and ICI methanol synthesis technology. The design and cost estimating techniques are intended to be comparable to those employed by Davy McKee in the original report submitted to BESI dated August, 1981. Sandwell Ltd. has developed a cost estimate for the wood reception, storage and preparation sections, Evergreen for the high pressure feeder, Texaco for the gasification section and Badger America for the process downstream of the gasifier.

The salient design characteristics are listed below:

Table S-1: Plant Design Characteristics

Feedstock

Wood Feed Rate (Eucalyptus), STPD (MF)1990

Product

Methanol, STPD (fuel grade)1000

Plant Investment - \$ millions 243

Thermal Efficiency - Percent 50
(Based on HHV of Methanol Product)

The process design involves wood preparation, gasifier feeder system, wood gasification and heat recovery, shift conversion, acid gas removal, methanol synthesis and refining.

This design is noteworthy for a number of reasons:

- Overall thermal efficiency is calculated to be 49.7% as compared to 33.3% for the fixed bed gasifier design.
- Texaco gasification technology produces synthesis gas at pressures well suited for the ICI low pressure methanol synthesis process.

- Synthesis gas produced by Texaco gasification technology does not require any additional reforming or partial oxidation step.
- Water consumption is only 1500 GPM as compared to 2,500 GPM for the Davy McKee design.
- Electric power consumption is estimated at 9,600 KW as compared to 21,500 KW for the Davy McKee design.
- The operating cost of catalysts and chemicals is \$4.10 per ton of methanol as compared to \$5.66.

IV. BASIS OF DESIGN

The same basis of design as Davy McKee has been retained in this study. The plant capacity is 1000 STPD of fuel grade methanol.

Sandwell has specified the wood preparation and drying units.

The yields associated with gasifying wood were furnished by the Texaco Development Company upon request by Evergreen Energy Corporation. Texaco has included in their design the heat recovery and ash disposal systems.

The gasifier feeding system has been designed by Evergreen Energy Corporation and is considered proprietary.

Badger America, Inc. has developed the process design and has chosen the Rectisol process for the removal of acid gases from the methanol synthesis gas. Badger has retained the ICI low pressure methanol synthesis process of the Davy McKee study.

Costs are installed costs FOB U. S. Gulf Coast in 1st quarter 1982 dollars.

V. PLANT CONFIGURATION

The selection of the Texaco process for wood gasification has been made by Evergreen Energy Corporation.

The selection of the Rectisol process by Badger for acid removal was based upon the need for a process which has demonstrated the capability of reducing residual sulfur concentration to extremely low levels to protect the methanol synthesis catalyst from sulfur poisoning.

The overall energy balance, including electric power and steam, is dictated by the large amount of high-level process heat that is recovered as 1500 psig saturated steam in both the gasification and the shift units. A natural gas fired superheater is required to furnish superheated steam for mechanical drive of the process equipment.

Medium pressure steam and purge gas are used for drying the feedstock to 15% moisture content.

The design of the Evergreen Feeding System and the Texaco gasification system are proprietary. The effluent gas compositions, temperature and pressure exiting the heat recovery system were given by Texaco.

A nominal 50 atmosphere methanol synthesis unit was selected so that the methanol synthesis loop will operate at somewhat lower pressure than the gasifiers thus eliminating the need for further feed gas compression.

Key processing units and sequence of operation are illustrated in Drawing No. 810101-A, Appendix F.

VI. DESCRIPTION OF UNITS

Unit 1: Wood Preparation and Storage

a. Log Feeding and Chipping:

Logs, without crowns, of an average length of 50'-0" and average diameter of 6.5" would be loaded on two receiving decks, unscrambled and slashed to $\pm$ 10'-0" length. All logs would pass under a washing station to remove sand and grit, and then drop feed to two (2) chippers. Design rates and operating periods take into consideration the daily downtime for chipper knife changes which is expected to be high due to the high level of silica content in this type of wood species.

The chips produced by the chippers can be selected for a nominal chip size of 3/8". The size of chip selected will be based on an optimum minimum size while not restricting the maximum rated capacity of each chipper.

The chips would be blown from each chipper to an equalizing bin with metering screw conveyor. Each of the two chipper bin arrangements would discharge to a common belt conveyor transporting the chips to a screening facility where oversized chips would be removed and re-chipped, and sent to an outside storage pile.

b. Storage and Reclaim:

The storage pile would consist of a 15-day supply of raw material and be formed by two tripper conveyors with some dozing required. One tripper conveyor

would be located directly over the automatic reclaim system so that production may be maintained without dozing. The second tripper would be positioned parallel and approximately 200 feet from the main tripper so that a main pile can be formed by dozing, between the two storage tripper conveyors.

Crown chips arriving by truck from the wood plantation which will now be used as part of the feedstock supply, would be unloaded, screened and shredded by the facilities described in BESI's report of August 1981 and discharged onto the conveying system going to the storage pile and mixed with the feedstock wood chips leaving the chipping facility.

The feedstock chips would be reclaimed by means of a double travelling screw extractor, feeding a belt conveyor that would carry the chips to the feedstock drying and preparation plant.

c. Drying:

At the drying plant, the chips would pass to a surge bin of sufficient size to allow the plant to continue operation during short interruptions to reclaim operation.

Chips extracted from the bin would be split into three (3) separate controlled conveying systems each feeding a separate feedstock drying line.

The drying process would consist of first pass or primary drying using steam as a heat source and second pass or secondary drying using process purge gas and natural gas as a fuel source.

Each drying line will consist of one primary steam dryer capable of reducing the moisture content of the fiber from 50% to approximately 28% and a secondary rotary drum dryer to reduce the moisture to a final level of 15%.

Normal plant operating conditions would require only two (2) drying lines in operation. From time to time when prepared feedstock storages are depleted, all three (3) lines would be in operation at the higher design rate to build up the necessary storages.

d. Feedstock Preparation:

The same operating principle would apply for the preparation facilities. Feedstock chips leaving the dryers would be conveyed in three (3) separate flows on belts to three air classification systems designed to remove dense materials such as rocks and metal items. It is anticipated that an additional 2 to 3% of moisture would be lost from the warm chips during this process.

The flow of clean chips leaving each of the air classifiers would discharge directly to a fines screen allowing the oversized material to be separated from the finer acceptable material, and conveyed to a final shredder producing a uniform grind of approximately 3/16".

e. Prepared Feedstock Storage:

Accepted fine feedstock material would be conveyed to the prepared feedstock enclosed storage building. This storage building would be of the "A" frame style, with a pile building shuttle conveyor and a travelling screw reclaimer.

Reclaimed Feedstock would be conveyed by belt to the gasifier feed distributing bin. Material would be extracted and metered to two conveying systems to the gasifier feeder system.

Feedstock process flow diagram illustrated in Appendix F. Drawing 810101-B. List of major equipment for wood preparation is shown in Appendix A.

Unit 2: Evergreen Energy Feeder System

A key requirement has been the design of a feeder system to interface with the Texaco gasifier and accomplish injection of the specially prepared wood feedstock into the gasifier itself which is pressurized up to 1000 psi at process temperatures in excess of 2400°F. A feeder/injector system ("high pressure dry feeder") is being developed by Evergreen. It is essentially a mechanical injector pump that can feed appropriately prepared dry solids such as wood, coal, peat and petro-coke into a pressurized chemical processing system or reactor uniformly, continuously, and safely without loss of pressure or loss of transfer gas. The flow rate for a single representative unit is 12 dry (10% to 15% or less moisture content) tons of feedstock per hour, but the machine can be sized to accommodate a smaller or somewhat larger flow rate according to process requirements. Projected energy requirements for feeding wood are less than 15 KWH/dry ton.

Unit 3: Gasifier

The "gasifier" includes the heat recovery and ash removal systems. The Texaco gasifier is a refractory-lined vert-

ical vessel in which gasification takes place at high pressure (up to 1000 psi) and temperature (around 2400°F) where the ash is molten. The feedstock is chemically converted via oxidation to a gaseous mixture (syngas) consisting (only) of H_2 , CO, CO_2 and H_2O . Two gaseous streams are produced by the Texaco gasifier: a high temperature (unquenched) stream from which a large amount of high level heat is recovered and a quenched stream containing sufficient water vapor to furnish the chemical needs of the shift operation.

A heat recovery system recovers high level heat from the gas, producing 1500 psig saturated steam.

Each stream is processed for the removal of finely divided solids in quenching vessels.

Ash is withdrawn as inert slag from the gasifiers, then sent to disposal. Aqueous blowdown from the gasification unit is processed to an environmentally acceptable effluent.

Unit 4: Shift Conversion

The purpose of this unit is to convert part of the CO in the raw syngas to H_2 in order to meet the required H_2 /CO ratio in the methanol synthesis feed.

The saturated syngas from the Texaco gasifier at around 900 psi and 500°F is split into two parts. One part goes through shift reaction in a single bed reactor. The reactor effluent at a high temperature due to the exothermic shift reaction generates HP steam and preheats the reactor feed before combining with the other part which bypasses the reactor. This combined stream provides the required ratio of H_2 to CO for the methanol synthesis.

Waste heat is further recovered from this combined gas stream by generating MP and LP steam. Low level heat is then utilized to preheat boiler feed water before final cooling down to 100°F. The bulk of this cooled gas is sent to the Acid Gas Removal Unit.

Condensate collected from the medium temperature knock-out stages is recycled to the gasifier as quench water. Condensate from the final cooling, which contains dissolved gases, is sent to the Wastewater Treatment Unit.

Unit 5: Acid Gas Removal

This unit removes most of the CO_2 present in the syngas from the Shift Conversion Unit before methanol synthesis. The Rectisol process has been selected due to its advantages as a physical system for a high feed acid gas partial pressure (about 340 psi) and the ready availability of methanol as its solvent.

After injection of methanol into the feed gas to prevent ice formation, the feed gas is cooled against cold product streams and fed into the absorber column. The purified gas from the top of the absorber is warmed by cooling the feed steam and fed to the Methanol Synthesis/Distillation Unit.

The CO_2 -rich methanol stream from the absorber is flashed and stripped of CO_2 with nitrogen. The CO_2 -rich tail gas from the CO_2 stripper is warmed by the incoming feed gas and vented to atmosphere.

The condensate produced by feed gas cooling is separated into methanol and water in a distillation column. The separated water is sent to the Wastewater Treatment Unit.

Unit 6: Methanol Synthesis & Distillation

As per Davy McKee Report.

Unit 7: Air Separation

A single unit with a nominal capacity of 1,200 ST/D of O_2 is provided to supply the oxidant to the Texaco gasifier. Oxygen is 99.5% pure and compressed to 950 psi by a combination of centrifugal and reciprocating compressors. All the compressors in the unit are driven by steam turbines.

Nitrogen separated from air is used for stripping CO_2 from the rich solvent stream in the Rectisol process and for purging throughout the plant.

Unit 8: Wastewater Treatment

Process wastewater and condensates are generated in the gasification, shift, and methanol synthesis processes. Due to the high operating temperatures and pressures of the Texaco gasifier, the resulting gasifier wastewaters are judged to be relatively free of complex organic pollutants. Gasifier purgewater is clarified to remove ash solids before combining with the shift and methanol synthesis wastewater streams and being stripped of organics and volatile gases in a steam stripper. The vapor stream is directed to a fired heater where the organics and volatile gases are oxidized, and the stripped wastewaters are directed to an aerated stabilization basin. In the aerated stabilization basin,

the wastewaters are cooled and the dissolved oxygen level restored prior to discharge at the battery limits.

The major source of non-process wastewaters are the blowdown streams for the cooling tower and steam systems. A low chromate chemical treatment of the circulating cooling water is considered for corrosion control, with shock chlorination used to control the growth of bio-slime. Therefore, the cooling tower blowdown is treated with an electrochemical chromate reduction system, permitting the removal of the resultant metallic hydroxides in a subsequent clarifier. The clarifier also removes solids from the boiler blowdown system, with the clarifier overflow being pumped through a sand filter before being discharged at the battery limits. Clarifier sludges are conveyed to sludge storage before being dewatered and trucked to landfill disposal.

Unit 9: Utilities and Ancillary Systems

a. Water Supply and Treatment

Well water is assumed as the source of raw water which is pumped to raw water storage and fire water storage tanks. Pumps draw water from the raw water storage tank to supply cooling water makeup, boiler feedwater makeup, gasifier quench water makeup, and water to the potable water treatment system.

Boiler feedwater is pumped through ion exchange beds for demineralization before joining the condensate return. The entire stream is pumped through ion-exchange polishing beds prior to entering the boiler feedwater storage tank. Subsequently, boiler feedwater is pumped through the deaerator, followed by the chemical addition of oxygen scavengers and solids dispersants, before entering the steam system.

The raw water supply to the potable water system is filtered through activated carbon beds and chlorinated prior to entering the potable water storage tank.

b. Boiler Systems

HP Steam

All the 1,500 psig steam needed is produced as saturated steam by waste heat recovery in the Gasifier and Shift Conversion Units. This steam is then superheated in a natural gas-fired superheater for use in the condensing steam turbines throughout the plant. A package boiler fired on natural gas is proposed to produce 100,000 lbs./hr. of superheated HP steam for startup only.

MP Steam

All the MP (285 psig) steam required for drying raw wood is produced by waste heat recovery in the Shift Conversion Unit.

LP Steam

LP (30 psig) steam is generated in the Shift Conversion Unit and from flashing of the blowdowns from the HP steam generators. This LP steam is used for reboiler duties and other miscellaneous usages in the plant.

c. Ancillary Facilities

Davy McKee's design bases were retained for the miscellaneous units such as product and intermediate storage, instrument air system, flare system and nitrogen system.

VII. SUMMARY OF MATERIALS AND ENERGY QUANTITIES

Overall Process Material, Evergreen/Texaco System

- a) Feedstock: Eucalyptus Wood1990 STPD
- b) Total Solids from Texaco Gasifier
Components	STPD
Ash	27.9
Unconverted carbon	20.1
- c) O₂ to Texaco Gasifier
Flow rate	1095 STPD
Purity	99.5%
Pressure	950 psig
- d) CO₂ Vent from Acid Gas Removal
Flow Rate	2117 STPD
- e) Methanol Product
Flow Rate	1000 STPD
Quality:	Fuel Grade, same specifications as in Davy McKee's Report.

VIII. UTILITY SUMMARY

	Lbs./Hr.
a) Steam Consumption	
1500 psig superheated (880°F)	225,000
285 psig superheated	161,000
30 psig saturated	<u>106,300</u>
Total	492,300
b) Electric Power Consumption	9600 KW
c) Well Water Make-up	1500 GPM
d) Treated Water Discharge	550 GPM
e) Natural Gas	

Natural gas firing is required for superheating the 1500 psig saturated steam exiting the heat recovery system. The consumption of Natural gas, based on 1000 Btu/SCF is 2.2 MMSCFD.

f) Catalysts and Chemicals

The same requirements as proposed by Davy McKee have been retained with the exception of hydrogenation catalyst. This catalyst is not needed with the Texaco gasification process.

The consumption of lime for water treating is substantially reduced in view of the lower water makeup, 1500 GPM versus 2800 GPM.

IX. MANPOWER REQUIREMENTS

The same operating labor estimates as in the Davy McKee report have been retained in this study.

X. CAPITAL COST ESTIMATES

The basis of evaluation adopted by Davy McKee has been retained in this study.

The total installed cost for the plant is estimated as follows:

<u>Process Unit</u>	<u>Installed Cost (\$000)</u>
Wood Preparation and Drying	\$ 43,600
Gasifier Feeding System	7,300
Wood Gasification, Heat Recovery and Ash Disposal	58,200
Shift Conversion	8,500
Acid Gas Removal	26,700
Methanol Synthesis and Distillation	25,700
Air Separation	45,500
Boiler System	1,900
Methanol Storage Facility	4,000
Raw Water and Waste Water Treatments	22,000
Total Installed Cost	\$243,400

XI. CATALYST AND CHEMICALS REQUIRED

Catalyst and chemicals have been estimated to cost approximately \$4.10/ton of methanol produced.

XII. CONCLUSIONS

The Evergreen/Texaco entrained-bed wood gasification process is well-suited to generating a high pressure gas with low inerts for use as methanol synthesis gas.

Most of the steps employed in the design, including wood preparation, wood drying, shift conversion, acid gas removal and methanol synthesis, represent proven technology.

The costs of the gasification and heat recovery units have been determined by Texaco. The important design parameters will be firmly established after completion of the wood gasification tests by Texaco at their Montebello, California facilities.

As presented in Appendix E, the entrained-bed Texaco/Evergreen Energy wood gasification system has several advantages over the fixed-bed process:

- o Wood consumption is 1990 STPD
- o Well water consumption is 1500 GPM
- o Treated waste water is 550 GPM
- o Electric power consumption is 9600 KW
- o Thermal efficiency is 49.7%

LIST OF MAJOR EQUIPMENT FOR UNIT 1

Wood Preparation and Storage

Sandwell has designed and estimated the cost of the Feedstock Preparation Unit. The plant consumption of wood is 1990 STPD of moisture-free wood.

Block diagram Drawing No. 810101-B describes the feedstock preparation and estimated mass flows. The preliminary design criteria of the wood preparation unit is included in Appendix

A list of major equipment as proposed by Sandwell is as follows:

Log Sorting and Slashing

Loading deck No. 1
Loading deck No. 2
Breakdown deck No. 1
Breakdown deck No. 2
Slasher deck No. 1
Slasher Deck No. 2
Slasher discharge conveyor No. 1
Slasher discharge conveyor No. 2
Log conveyor No. 1
Log conveyor No. 2
Washing station No. 1
Washing station No. 2
Distributing gate No. 1
Distributing gate No. 2
Log Conveyor No. 3
Log conveyor No. 4
Chipper infeed conveyor No. 1
Chipper infeed conveyor No. 2
Scraper wagon
Scraper wagon
Bark and debris conveyor

Sawdust and bark flight conveyor

Saw servicing equipment

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Log Chipping

Chip collecting conveyor
Log chipper No. 1
Log chipper No. 2
Chip surge bin No. 1
Chip surge bin No. 2
Magnetic Detector No. 1
Magnetic Detector No. 2
Chipper knife grinding equipment

Screening and Rechipping

Rechipper by-pass conveyors
Storage conveyor No. 1
Storage conveyor No. 2
Scalping screen No. 1
Scalping screen No. 2
Scalping screen No. 3
Scalping screen No. 4
Rechipper No. 1
Rechipper No. 2
Transfer auger
Magnetic Separator

Raw Fiber Storage

Storage tripper conveyor No. 1
Storage tripper conveyor No. 2
Chip dozer

Raw Fiber Reclaim

Reclaim conveyor
Transfer conveyor
Distributing conveyor
Feedstock reclaimer
Magnetic Separator

Drying Plant

Dry feedstock collecting conveyor No. 1
Dry feedstock collecting conveyor No. 2
Dry feedstock collecting conveyor No. 3
Transfer conveyor No. 1
Transfer conveyor No. 2
Transfer conveyor No. 3
Steam primary dryer No. 1
Steam primary dryer No. 2
Steam primary dryer No. 3
Rotary drum dryer No. 1
Rotary drum dryer No. 2
Rotary drum dryer No. 3
Raw fiber surge bin
Dryer feed conveying system No. 1
Dryer feed conveying system No. 2
Dryer feed conveying system No. 3
Dryer emergency by-pass conveyor No. 1
Dryer emergency by-pass conveyor No. 2
Dryer emergency by-pass conveyor No. 3

Feedstock Preparation

Storage conveyor
Rocks & Tramp metal evacuation conveyor
Shredder discharge air sweep No. 1
Shredder discharge air sweep No. 2
Shredder discharge air sweep No. 3
Shredder No. 1, Screen No. 1
Shredder No. 2, Screen No. 2
Shredder No. 3, Screen No. 3
Air classifier No. 1
Air classifier No. 2
Air classifier No. 3
Magnetic Separator

Prepared Feedstock Storage

Reclaim conveyor

Shuttle conveyor

Feeder conveyor No. 1

Feeder conveyor No. 2

Feedstock storage and reclaim system

Gasifier feed distributing bin

FEED AND PRODUCT FLOW TABLE

Feed and Product Flow Rates

<u>Feed Streams</u>	<u>STPD</u>
Wood (MF Basis)	1990
Oxygen (at 99.5 percent purity)	1095
 <u>Product Stream</u>	 <u>STPD</u>
Methanol	1000
Ash & unconverted Carbon	48
Carbon dioxide	2117

WOOD ANALYSIS TABLE

<u>Ultimate Analysis (Dry)</u>	<u>Weight Percent</u>
Carbon	50.6
Hydrogen	6.0
Nitrogen	0.3
Sulfur	0.0
Oxygen	41.7
Ash	<u>1.4</u>
	100.0
Moisture Content, Wt. %	15.0

THERMAL EFFICIENCY TABLE

The overall thermal efficiency of the plant is calculated to be 49.7 %. Wood, natural gas and electric power are taken as heat inputs, and methanol as heat output. These calculations are for higher heating value. In addition, it takes 3 1/3 units of primary fuel energy to produce one unit of electrical energy.

Thermal Efficiency Calculation

	Fixed Bed Gasification Davy McKee Process	Entrained Bed Gasification Texaco-Evergreen Energy Process
<u>Heat Input</u>	10 ⁶ Btu/hr	10 ⁶ Btu/hr
Wood (MF), 8580 Btu/lb	2178.7	1422.9
Natural gas, 1000 Btu/SCF	0	91.7
Electric Power	244.7	109.2
<u>Heat Output</u>		
Methanol, 9692 Btu/lb	807.7	807.7
Efficiency	33.3%	49.7%

APPENDIX E

ENGINEERING DATA COMPARISON TABLE

	<u>Fixed Bed Gasification</u> <u>Davy McKee Process</u>	<u>Entrained Bed Gasification</u> <u>Texaco-Evergreen Process</u>
<u>A. Raw Materials and Utilities In</u>		
1. Eucalyptus Wood (Dry Basis)		
Feedstock	1995 STPD	1990 STPD
Fuel (wood)	1052 STPD	0
2. Well Water Makeup	2800 GPM	1500 GPM
3. Electrical Power	21500 KW	9600 KW
4. Natural Gas	0	2.2 MMSCFD
<u>B. Products Out</u>		
1. Fuel Grade Methanol	1000 STPD	1000 STPD
2. Treated Waste Water	1050 GPM	550 GPM
3. Ash & Unconverted Carbon	14.8 STPD	48.0 STPD
C. <u>Total Installed Cost of Plant</u> (million dollars)	250	243.6
<u>D. Catalysts and Chemicals</u>		
Cost per ton of methanol	\$5.66	\$4.10
E. Manpower Requirements	186	186
F. Thermal Efficiency (see Appendix D)	33.3%	49.7%

APPENDIX F DWG. No. 810101-A

EVERGREEN ENERGY CORPORATION

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OVERALL BLOCK FLOW DIAGRAM

WOOD TO METHANOL

Waltham 5-25-82
DWG. 810101-A

APPENDIX G

FEEDSTOCK PREPARATION

PRELIMINARY DESIGN CRITERIA

EVERGREEN ENERGY CORPORATION

PROJECT M5048
EUCALYPTUS/METHANOL
CONVERSION PLANT

EVERGREEN ENERGY CORPORATION
WALTHAM MASSACHUSETTS

FEEDSTOCK PREPARATION - PRELIMINARY
CAPITAL COST SUMMARY

DATE 13 APRIL 1982
REVISION 1 13 MAY 1982

APPENDIX 4 - PRELIMINARY DESIGN CRITERIA

		<u>Unit</u>	<u>Amount</u>	
			<u>Normal</u>	<u>Design</u>
1.	<u>METHANOL YIELD FACTOR</u>			
	Wood to Methanol Yield	BDT Wood/ 1000T Methanol	1 990	-
2.	<u>PLANT CONSUMPTION</u>			
	Fiber moisture content	%	50	-
	Fiber consumption	TPD	3 980	-
		BDTPD	1 990	-
	Losses	%	3	-
		BDTPD	60	-
	Annual consumption	BDT/A	676 500	-
3.	<u>OPERATING PERIOD</u>			
	Annually	days/A	330	-
	Weekly	days/week	7	-
	Daily	hours/day	24	-
	Available	hours/day	20	-
4.	<u>CHIPPING RATE</u>			
	Weekly	days/week	7	-
	Daily	hours/day	16	-
	Available	hours/day	12	-
	Daily consumption (inc. crown chips)	tons/day	4 100	6 150
	Average mean diameter of log	ins	6.5	
	Average length of log, crown removed	ft	50	
	Density (solid green wood)	lbs/cuft	46	
	Average weight of log (85% of total tree)	lbs/log	530	-

	<u>Unit</u>	<u>Amount</u>	
		<u>Normal</u>	<u>Design</u>
No of logs	logs/day	13 200	19 800
	logs/hr	1 100	1 650
Chipping Rate	Tons/hr	290	435
5. <u>MAIN FIBRE STORAGE PILE</u>			
Surge capacity	day	15	-
(4100 x 15)	Tons	61 500	-
	* FT ³	5 350 000	-
Assumed compaction factor	%	15	-
6. <u>RECLAIM RATE</u>			
- Plant consumption $\frac{(4100)}{24}$	Tons/hr.	170	-
	BDT/hr.	85	-
- Prepared Feedstock storage	hrs.	14	-
(50% moisture)	tons	2 400	-
	FT ³	210 000	-
- Fill time	hrs.	35	35
- Required reclaim rate			
Design: $\frac{2400}{35} + 170$	Tons/hr.	-	240
	BDT/hr.	-	120
7a. <u>FEEDSTOCK PRIMARY DRYING</u>			
Moisture content of incoming fiber	%	50	-
Maximum moisture of primary dried fibre	%	28	-
Capacity (infeed) per dryer	Tons/hr	56	80
	BDT/hr	28	40
Dryer Preliminary Selection:			
Dryer size, length	ft	69	-
heat exchangers	No.	4	-
tubes	No.	55	-
Number of driers required	No.	3	-

* Fiber average green bulk density 20 to 23 lbs/cu ft.

		<u>Unit</u>	<u>Amount</u>	
			<u>Normal</u>	<u>Design</u>
7b.	<u>FEED SECONDARY DRYING</u>			
	Moisture content of incoming fiber	%	28	-
	Maximum moisture of dried fiber	%	15	-
	Drum dryer preliminary selection:			
	Dryer size	length(FT.)	30	
		diameter(FT.)	14	
	Capacity (infeed)	Tons/hr.	40	56
		BDT/hr.	28	40
	Units Required	units	3	3
8a	<u>PRIMARY DRYING FUEL REQUIREMENTS</u>			
	Total steam required (saturated)	pph	160 000	233 000
	Steam, available from process	pph	160 000	-
		psig	285	-
	Steam, from package boiler (by others)	pph	-	73 000
		psig	-	285
8b.	<u>SECONDARY DRYING FUEL CONSUMPTION</u>			
	Total fuel consumption	10 ⁶ BTU/hr	58.4	84.0
	By-product purge gas available	10 ⁶ BTU/hr	52.9	52.9
	Natural gas consumption	10 ⁶ BTU/hr	5.5	31.1
		ft ³ /hr	5 500	31 100
9.	<u>FEEDSTOCK PREPARATION</u>			
	a. <u>Air Classifiers</u>			
	Total capacity required (15% moisture)	Tons/hr.	100	140
	Capacity per unit (15% moisture)	Tons/hr.	33	47
		BDT/hr.	28	40
		FT ³ /hr.	4 900	7 000
	Number of units required (3 lines of 1 classifier each)	Number	3	

		<u>Unit</u>	<u>Amount</u>	
			<u>Normal</u>	<u>Design</u>
b. Shredders				
Total shredding capacity	(15% moisture)	Tons/hr.	100	141
Design capacity per line	(15% moisture)	Tons/hr.	33	47
		BDT/hr.	28	40
		FT ³ /hr.	4 900	7 000
Nominal capacity per shredder		BDT/hr.	-	47
		FT ³ /hr.	-	7 000
Total number required		Number	3	3
c. Fines screens				
Total infeed rate		FT ³ /hr.	15 000	21 000
Design rate per screen		FT ³ /hr.	-	8 700
Total number of screens		Number	3	3

10. PREPARED FEEDSTOCK STORAGE

*Surge capacity	(15% moisture)	Tons	1 400	-
		BDT	1 200	-
		FT ³	200 000	-
	(Plant Prod.)	hrs	14	-
Average required extraction rate	(15% moisture)	Tons/hr	98	-
		BDT/hr	83	-
Maximum required extraction rate (to fill gasifier feed bin)	(15% moisture)	Tons/hr	-	120
		BDT/hr	-	102

11. GASIFIER FEED BIN

Surge capacity	(15% moisture)	Tons	70	-
		BDT	60	-
		FT ³	10 000	-
	(Plant Prod.)	min.	45	-
Extraction rate	Total	Tons/hr	98	-
		BDT/hr	83	-
	Per system	Tons/hr	49	-
	(2 Systems)	BDT/hr	42	-

* It is usual to experience an additional 2% to 3% reduction in feedstock moisture content after the driers due to flash drying occurring during the handling and preparation of the feedstock.