Appendix A:A

Oregon Biomass-to-Ethanol Project:
Pre-feasibility Study and Modeling Results

MODEL INPUTS AND ASSUMPTIONS

Process Summary - Base Case Biomass to Ethanol Feasibility Study Oregon Site		
Biomass feedrate	1369 BDT/day	
Dilute Acid Model:	A9912H2	** Estimated; information not given in A
	Feedstock Composition (% Dry Weight)	**Reference/ Source**
Cellulose	43.3%	Chemical Analysis and
Xylan	7.4%	Homogeneity Testing on
Galactan	2.8%	Quincy Library Group Mixed
Arabinan	1.5%	Softwood Samples; Figure 4 ;
Mannan	10.2%	GLG Mixed Average
Lignin	28.6%	
Ash	0.9%	
Acetate **	0.3%	
Extractives	5.0%	
Total	100.0%	Normalized by ASPEN PLUS to 100%
	1st Stage Acid Hydrolysis	
Pressure	12.2 atm (179 psia)	Evaluation of a Two-Stage
Temperature	190 °C	Dilute Sulfuric Acid Hydrolysis
Acid Concentration	0.7%	Process; C-milestone Report;
Residence Time	3 minutes	Completed by Q. Nguyen, 2/11/98
		Table 3.
Sugar Yields:		
Glucose	21%	
Xylose	70%	
Mannose	79%	
Galactose	79%	
Arabinose	90%	
	2nd Stage Acid Hydrolysis	
Pressure	22.4 atm (329 psi)	Preliminary Design of an Ethanol
Temperature	210 °C	Demonstration Plant Based on Two-
Acid Concentration	2.5%	Stage Dilute Acid Hydrolysis
Residence Time	3 minutes	Technology; C-milestone Report;
		Completed by Q. Nguyen, 7/15/99
Sugar Yields:		Table B3, Appendix B.
Glucose	34%	
Xylose	5%	Also See C-milestone, 2/11/98
Mannose	11%	
Galactose	3%	
Arabinose	0%	
	Overall Hydrolysis Yield	
Glucose	55%	
Xylose	75%	Based on C-milestone work by
Mannose	90%	Q. Nguyen; 2/11/98 and 7/15/99
Galactose	82%	
Arabinose	90%	
	Counter-Current Washing	
		Based on experiment by Dan Schell, et.al. on batch extraction; 3.5:1 L/S ratio
Sugar Recovery	95.2%	
Insoluble Solids lost to Sugar Stream	0.0%	Q. Nguyen Assumption
Wash Water Quantity	255 gpm	3.5:1 L/S ratio
	Fermentation	
1st Stage Fermentation Yield:		
Glucose--> Ethanol	63%	Designed for 63% sugar conversion
Xylose --> Ethanol	63%	to limit time spent in stationary
Galactose-->Ethanol	63%	growth phase
Mannose -->Ethanol	63%	
Arabinose-->Ethanol	0%	
2nd Stage Fermentation Yield:		
Glucose--> Ethanol	27%	Used to bring overall conversion
Xylose --> Ethanol	12%	of C6 to 90% and xylose to 75%
Galactose-->Ethanol	27%	
Mannose -->Ethanol	27%	
Arabinose-->Ethanol	0%	
Overall Fermentation Yield:		
Glucose--> Ethanol	90.0%	Based on memo: Requirements for
Xylose --> Ethanol	75.0%	High Ethanol Yield Fermentation of
Galactose-->Ethanol	90.0%	SW Hydrolysates; 31 March 99;
Mannose -->Ethanol	90.0%	Fred Keller; Notebook reference:
Arabinose-->Ethanol	0.0%	#2247-021
Overall Ethanol Yield	**58 Gal/BDT**	
(Denatured) Ethanol Production	**29 MM Gal/yr**	

Process Economic Assumptions

Product Selling Prices:

Ethanol	$1.25 / gal
Lignin-rich Residue	$2.00 / MMBTU
Hauling Cost / Distance	$1.25/truck/mile@10 miles
Electricity	$0.04/kWh

Required Purchasing Prices:

Feedstock	varies
Electricity	$0.025 / kWh
Natural Gas	$2.50 / MMBTU
Wastewater Treatment	$1.60 / 1000 gallon
Process Water	$4 per initial 1000 gal + $1.60 per each additional 1000 gal

Economics:

40% Equity
10 year loan @ 8.0% interest rate
Equipment Depreciation Period = 7 years

General Process:

Feedrate	varies
Feedstock	varies
Plant On-line Time	95.9% (8400 hrs/yr)
Plant Life	20 years
Construction Period	2.5 years
Startup	6 months

Ethanol Production Process Engineering Analysis
Base Case Summary

Forest Residue Feedstock - Natural Gas Boiler, $2.00/MMBTU for Lignin Residue
2-Stage Dilute Acid Hydrolysis
All Values in 1997$

(Denatured) Ethanol Selling Price $1.25
Internal Rate of Return 19.0% (After Tax)

(Denatured) Ethanol Production (MM Gal. / Year)	29.2
Pure Ethanol Yield (Gal / Dry Ton Feedstock)	57.8
Feedstock Cost ($/Dry Ton)	28.0

Capital Costs	
Feed Handling	$4,400,000
Pretreatment/Detox	$11,900,000
Fermentation	$2,700,000
Distillation	$4,400,000
WWT	$5,500,000
Storage	$1,400,000
Boiler	$1,200,000
Utilities	$2,900,000
Total Equipment Cost	$34,400,000
Added Costs	$15,700,000
(% of TPI)	31%
Total Capital Investment	$50,100,000

Theoretical Yields	Ethanol MM Gal/year
Cellulose	35.8
Xylan	6.3
Mannan	8.4
Galactan	2.3
Total Maximum (MM Gal/yr)	54.1
Maximum Yield (Gal/ton)	112.8
Current Yield (Actual/Theor)	51%

Operating Costs (cents/gal ethanol)	
Feedstock	46.0
Lignin Credit	**-35.3**
CSL	2.1
Denaturant	2.7
Natural Gas	**23.5**
Other Raw Materials	13.5
Waste Disposal	6.3
Electricity	7.0
Fixed Costs	13.3
Capital Recovery	46.0
	125.0

Operating Costs ($/yr)	
Feedstock	$13,400,000
CSL	$600,000
Denaturant	$800,000
Other Raw Matl. Costs	$10,800,000
Waste Disposal	$1,800,000
Electricity	$2,000,000
Fixed Costs	$3,900,000
Capital Recovery	$13,400,000
	$46,700,000

Revenue ($/yr)	
Ethanol	$36,400,000
Lignin	$10,300,000
	$46,700,000