

PERP Report

"Green" Polyethylene 06/07S11

March 2008



44 South Broadway, White Plains, New York 10601, USA
Tel: +1 914 609 0300 Fax: +1 914 609 0399

Copyright© by Nexant, Inc. 2008

This Report was prepared by Nexant, Inc. ("Nexant") and is part of ChemSystems Process Evaluation/Research Planning (PERP) Program. Except where specifically stated otherwise in this Report, the information contained herein is prepared on the basis of information that is publicly available, and contains no confidential third party technical information to the best knowledge of Nexant. The aforesaid information has not been independently verified or otherwise examined to determine its accuracy, completeness, or feasibility.

Neither Nexant, Subscriber, nor any person acting on behalf of either assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information contained in this Report. Nexant does not represent or warrant that any assumed conditions will come to pass.

The Report is submitted on the understanding that the Subscriber will maintain the contents confidential except for the Subscriber's internal use. The Report shall not be reproduced, distributed, or used outside Subscriber's organization without first obtaining prior written consent by Nexant. Each Subscriber agrees to use reasonable effort to protect the confidential nature of the Report.

Contents

Section	Page
1 Summary	1
1.1 INTRODUCTION	1
1.2 ETHANOL.....	2
1.2.1 Feed Compositions.....	2
1.2.2 Sugarcane Fermentation.....	3
1.2.3 Grain Fermentation	6
1.3 ETHYLENE VIA DEHYDRATION OF ETHANOL	14
1.4 POLYETHYLENE VIA BIOMASS GASIFICATION	16
1.5 ECONOMICS	17
1.6 ETHANOL FEEDSTOCK SUPPLY.....	19
2 Technology Analysis	21
2.1 INTRODUCTION	21
2.2 ETHANOL.....	22
2.2.1 Background	22
2.2.2 Molecular Biology for Fermentation	23
2.2.3 Feedstock and Process Diversity	27
2.2.4 Sugarcane Fermentation.....	27
2.2.5 Fermentation of Other Sugar and Starch Substrates.....	31
2.2.6 Grain Fermentation	31
2.2.7 Biomass Fermentation (Cellulose/Hemicellulose)	50
2.3 ETHYLENE VIA DEHYDRATION OF ETHANOL	58
2.3.1 Chemistry.....	58
2.3.2 Process Description.....	59
2.4 POLYETHYLENE VIA BIOMASS GASIFICATION	63
2.4.1 Background	63
2.4.2 Feed Preparation	64
2.4.3 Gasification	64
2.4.4 Syngas Cleanup.....	65
2.4.5 Methanol	67

2.4.6 Methanol-to-Olefins (MTO)	70
3 Economic Analysis	76
3.1 BASIS	76
3.1.1 Pricing Basis	76
3.1.2 Investment Basis	77
3.1.3 Cost of Production Basis.....	77
3.2 ECONOMICS.....	78
3.2.1 Ethanol Cost of Production.....	78
3.2.2 Ethylene Cost of Production	85
3.2.3 Green Polyethylene Cost Comparison.....	92
3.2.4 Conclusions.....	97
4 Commercial Analysis	98
4.1 ETHANOL FEEDSTOCK SUPPLY.....	98
4.1.1 United States	99
4.1.2 Brazil.....	103
4.1.3 Canada.....	104
4.1.4 The European Union	105
4.1.5 India	105
4.1.6 China	106
4.1.7 Australia	106
4.1.8 Central and Latin America.....	107
5 References	108

Appendix	Page
A Elements of Nexant's ChemSystems Capital Cost Estimates	A-1
B PERP Program Title Index	B-1

Figure	Page
1.1 Composition of Biomass Materials.....	2
1.2 Industrial Fermentation Processes to Ethanol Production	3
1.3 Block Flow Diagram of Ethanol Production from Sugarcane	5
1.4 Material Balance of Ethanol Production from Sugarcane and Bagasse	6
1.5 Wet Milling versus Dry Milling	7
1.6 Polyethylene via Biomass Gasification	16
1.7 Comparison of Cost of Production of “Green” and Conventional Polyethylene.....	17
1.8 Sensitivity of Cost of Production of LLDPE versus Biofeed Price	18
1.9 Global Ethanol Production, 2006.....	20
2.1 Composition of Biomass Materials.....	22
2.2 Industrial Fermentation Processes to Ethanol Production	28
2.3 Block Flow Diagram of Ethanol Production from Sugarcane	30
2.4 Material Balance of Ethanol Production from Sugarcane and Bagasse	30
2.5 Wet Milling versus Dry Milling	32
2.6 Corn Receiving, Storage, and Milling Whole Kernel Milling.....	34
2.7 Milling and Hydrolysis Whole Kernel Milling.....	35
2.8 Saccharification Whole Kernel Milling.....	36
2.9 Fermentation Whole Kernel Milling.....	37
2.10 Beer Still Corn Dry Milling	38
2.11 Rectifier and Dehydration Corn Dry Milling.....	39
2.12 DDGS Drying Whole Kernel Milling.....	40
2.13 Ethanol Pasteurization and Vent Recovery Whole Kernel Milling.....	41
2.14 Safe Corn Storage Life.....	42
2.15 Conceptual Structure of Cellulose in Plants	51
2.16 Site View of Abengoa’s BCyL Biomass Plant	54
2.17 BC International Process.....	55
2.18 Ethylene from Ethanol (Chematur Route)	60
2.19 Ethylene from Ethanol – Lummus Fluid Bed Process.....	62
2.20 Polyethylene via Biomass Gasification	63

2.21 Syngas Cleanup Scheme	66
2.22- Selected Methanol Reformer Options.....	68
2.23- Methanol Technology Licensors.....	69
2.24 UOP/Hydro MTO Process Simplified Flow Diagram	71
3.1 Recent U.S. Corn Price History	83
3.2 Recent U.S. DDGS Price History	84
3.3 Sensitivity of Ethanol from Corn Cost of Production to DDGS Price	85
3.4 Ethylene Dehydration Cost of Production Sensitivity to Investment Capital.....	88
3.5 Sensitivity of Syngas Economics to Capital Investment	90
3.6 Comparison of Cost of Production of "Green" and Conventional Polyethylene.....	96
3.7 Sensitivity of Cost of Production of LLDPE versus Biofeed Price	96
4.1 Global Ethanol Production, 2006.....	99
4.2 United States Ethanol Biorefineries.....	103

Table	Page
1.1 Typical Corn Analysis	8
2.1 Typical Corn Analysis	33
2.2 Gas Cleanup Requirements for Methanol Synthesis	66
2.3 Component Yield from UOP/Hydro MTO Process (SAPO-34).....	73
2.4 UOP/Hydro MTO Flexibility.....	74
3.1 Price and Utility Basis	76
3.2 Ethanol Conversion Factors for Sugar Feedstock per Unit of Feedstock.....	80
3.3 Cost of Production Estimate for: Ethanol Process: Sugarcane Fermentation	82
3.4 Cost of Production for: Ethanol Process: Corn Dry Milling	86
3.5 Cost of Production Estimate for: Ethylene Process: Ethanol Dehydration Fixed Bed	87
3.6 Cost of Production Estimate for: Ethylene Process: Steam Cracking (Ethane).....	89
3.7 Cost of Production Estimate for Syngas Process: Gasification Biomass (Purchased Oxygen)	91

3.8	Cost of Production Estimate for: Methanol Process: Syngas (2:1 H ₂ :CO)	93
3.9	Cost of Production Estimate for: Ethylene Process: MTO	94
3.10	Cost of Production Estimate for: LLDPE Films Process: Dowlex.....	95
4.1	2007 Energy Act RFS Mandated Schedule of Use.....	100
4.2	Ethanol Capacity by State.....	101
4.3	Ethanol Capacity by Province.....	104
4.4	European Union Bioethanol Production	105