

TECHNOLOGY & COSTS**Biorenewable Insights****Ethylene, Ethylene Oxide, and Ethylene Glycol**

Table of Contents

A Report by **NexantECA, Inc.**

Published Date: November 2020

www.nexanteca.com/subscriptions-and-reports**Contents**

1	Executive Summary	1
1.1	Overview.....	1
1.2	Introduction.....	1
1.3	Technology.....	3
1.4	Economics.....	3
1.4.1	Ethylene	3
1.4.2	Ethylene Oxide	4
1.4.3	Ethylene Glycol	4
1.5	Capacity Analysis	5
1.6	Implications for the Conventional Industry	6
1.6.1	Bioethylene.....	6
1.6.2	Bioethylene Oxide	7
1.6.3	Bioethylene Glycol.....	7
2	Introduction.....	8
2.1	Overview.....	8
2.1.1	The Conventional Ethylene Value Chain	9
2.2	Strategic and Business Considerations	12
2.3	Biobased versus Renewable versus Sustainable	13
3	Technology.....	14
3.1	Overview.....	14
3.2	Ethylene.....	15
3.2.1	Ethanol to Ethylene	15
3.2.2	Steam Cracking of Bio-Naphtha.....	22
3.2.3	Methanol to Olefins	57
3.2.4	Oxidative Coupling of Methane	70
3.2.5	Fermentation	71
3.2.6	Plants as Plants.....	71
3.3	Ethylene Oxide	72
3.3.1	Ethylene Oxidation	72
3.4	Ethylene Glycol	73
3.4.1	Ethylene Oxide Hydration	74

	3.4.2	Sugar to Ethylene Glycol.....	83
	3.4.3	Glycerine to Ethylene Glycol.....	87
	3.4.4	Developmental Routes to MEG.....	92
4		Economics.....	98
	4.1	Economic Analysis Methodology.....	98
	4.1.1	Sources.....	98
	4.1.2	Costing Basis.....	98
	4.1.3	Capital Cost Elements.....	98
	4.1.4	Operating Cost Elements.....	102
	4.1.5	Price of Ethylene in Derivative Steps.....	105
	4.2	Comparative Economics.....	106
	4.2.1	Ethylene.....	106
	4.2.2	Ethylene Oxide.....	111
	4.2.3	Ethylene Glycol.....	111
	4.3	Cost of Production Models.....	116
	4.3.1	Bioethylene.....	116
	4.3.2	Bioethylene Oxide.....	132
	4.3.3	Bioethylene Glycol.....	136
5		Capacity Analysis.....	152
	5.1	Overview.....	152
	5.1.1	Types of Developments Considered.....	152
	5.2	Existing Capacity.....	152
	5.2.1	Ethylene Capacity for Polyethylene.....	152
	5.2.2	Ethylene Oxide Capacity.....	153
	5.2.3	Ethylene Glycol Capacity.....	153
	5.3	Announced Project Listing.....	154
	5.4	Closed Capacity.....	154
	5.4.1	Reliance.....	154
	5.4.2	Historical Ethanol to Ethylene.....	154
	5.5	Conclusion.....	154
6		Implications for the Conventional Industry.....	156
	6.1	Scale and Market Penetration.....	156
	6.1.1	Scale of Production.....	156
	6.1.2	Market Penetration.....	156
	6.1.3	Feedstock Issues: Carbon 14 Issues and Cellulosics.....	158
	6.1.4	Market Pull.....	159
	6.2	Impact of Oil and Gas Prices on Biofeedstocks.....	160
	6.3	Strategic Implications.....	161
	6.3.1	Bioethylene.....	161
	6.3.2	Bioethylene Oxide.....	162
	6.3.3	Bioethylene Glycol.....	162
Appendices			
A		References.....	163

Figures

Figure 1	Routes to Bio-Ethylene, Bio-Ethylene Oxide, and Bio-Ethylene Glycol	2
Figure 2	Comparative Economics for Bioethylene in the USGC	3
Figure 3	Comparative Economics for Bioethylene Oxide via Bioethylene Oxidation	4
Figure 4	Comparative Economics for Bioethylene Glycol Production in the USGC	5
Figure 5	Raw Material Feeds for Ethylene	9
Figure 6	Routes to Bio-Ethylene, Bio-Ethylene Oxide, and Bio-Ethylene Glycol	14
Figure 7	Routes to Bio-Ethylene	15
Figure 8	Bio-Ethanol to Green Ethylene: Conceptual Process Flow	16
Figure 9	Braskem Ethanol Dehydration Process	18
Figure 10	Ethylene from Ethanol	20
Figure 11	Comparison of Hummingbird and Conventional Ethanol-to-Ethylene Catalysts	21
Figure 12	TechnipFMC Hummingbird® Technology Simplified Block Flow Diagram	22
Figure 13	TechnipFMC Hummingbird® Technology Process Diagram	22
Figure 14	Steam Cracking Process Overview	25
Figure 15	NGL Cracking (Cracking and Compression) Simplified Process Flow Diagram	26
Figure 16	NGL Cracking (Fractionation and Recovery) Simplified Process Flow Diagram	27
Figure 17	Typical Cracking Furnace Process Flow	32
Figure 18	Typical Dual Radiant Cell Cracking Furnace Design	33
Figure 19	Water Quench System Simplified Process Flow Diagram	36
Figure 20	Oil and Water Quench System Simplified Process Flow Diagram	37
Figure 21	Demethanizer-First Simplified Process Flow Diagram	46
Figure 22	Deethanizer-First Simplified Process Flow Diagram	47
Figure 23	Depropanizer-First Simplified Process Flow Diagram	48
Figure 24	UOP Advanced MTO Process: Reaction and Olefins Recovery	65
Figure 25	UOP Advanced MTO Process: Olefins Cracking Process	68
Figure 26	Routes to Bio-Ethylene Glycol	74
Figure 27	Dow METEOR™ Glycol Reaction and Evaporation System	76
Figure 28	Glycol Reaction and Separation via SD Process	78
Figure 29	Shell OMEGA Process	81
Figure 30	Shell OMEGA Ethylene Glycol	82
Figure 31	IPCI Sugar to Polyols Process	85
Figure 32	UOP PG Process Block Flow Diagram	90
Figure 33	GBT Glycerine to Propylene Glycol Process Flow Diagram	93
Figure 34	Biomass to MEG Process (Illustrative)	94
Figure 35	Block Flow Diagram for Liquid Light's CO ₂ to Chemicals – Electrochemical Cell	96
Figure 36	Block Flow Diagram for Liquid Light's CO ₂ to Chemicals – Second Reactor	96
Figure 37	Comparative Economics for Bioethylene in the USGC	106
Figure 38	Comparative Economics for Bioethylene in China	107
Figure 39	Comparative Economics for Bioethylene in Brazil	107
Figure 40	Comparative Economics for Bioethylene in Western Europe	108
Figure 41	Comparative Economics for Bioethylene via Ethanol Dehydration	108

Figure 42	Comparative Economics for Bioethylene via Bionaphtha Cracking	109
Figure 43	Comparative Economics for Bioethylene via Bio-Methanol MTO	110
Figure 44	Comparative Economics for Bioethylene via OCM of RNG	110
Figure 45	Comparative Economics for Bioethylene Oxide via Bioethylene Oxidation	111
Figure 46	Comparative Economics for Bioethylene Glycol Production in the USGC	112
Figure 47	Comparative Economics for Bioethylene Glycol Production in China	112
Figure 48	Comparative Economics for Bioethylene Glycol Production in Brazil	113
Figure 49	Comparative Economics for Bioethylene Glycol Production in Western Europe	113
Figure 50	Comparative Economics for Bioethylene Glycol Production via Oxidation and Hydration	114
Figure 51	Comparative Economics for Bioethylene Glycol Production via Glucose Hydrogenation	114
Figure 52	Comparative Economics for Bioethylene Glycol Production via Glycerine Hydrolysis	115
Figure 53	Comparative Economics for Bioethylene Glycol Production via Liquid Light	115
Figure 54	Global Breakdown of Ethylene Production	157
Figure 55	Global Breakdown of MEG Production	157

Tables

Table 1	Bioethylene Capacity	5
Table 2	Bioethylene Oxide Capacity	5
Table 3	Bioethylene Glycol Capacity	5
Table 4	Strategic/Business Considerations	12
Table 5	Steam Cracking of Naphtha – Once Through Yields	29
Table 6	Steam Cracking of Naphtha – Effect of Variables on Once Through Yields	30
Table 7	Typical Pyrolysis Heater Characteristics	34
Table 8	Comparison of Ethylene Cracking Tube Alloys	43
Table 9	Licensors and Technology Holders for Steam Cracking Routes to Ethylene	57
Table 10	UOP Advanced MTO Process Material Balance	69
Table 11	UOP Advanced MTO Process Utilities Consumption	69
Table 12	S2G Biochem Product Slate	86
Table 13	ADM Nickel-on-Alumina Catalyst Composition	88
Table 14	UOP PG Process Conditions	91
Table 15	Cost of Production Estimate for Bioethylene via Ethanol Dehydration in the USGC	116
Table 16	Cost of Production Estimate for Bioethylene via Ethanol Dehydration in China	117
Table 17	Cost of Production Estimate for Bioethylene via Ethanol Dehydration in Brazil	118
Table 18	Cost of Production Estimate for Bioethylene via Ethanol Dehydration in Western Europe	119
Table 19	Cost of Production Estimate for Bioethylene via Bio-Naphtha Cracking in the USGC	120
Table 20	Cost of Production Estimate for Bioethylene via Bio-Naphtha Cracking in China	121
Table 21	Cost of Production Estimate for Bioethylene via Bio-Naphtha Cracking in Brazil	122
Table 22	Cost of Production Estimate for Bioethylene via Bio-Naphtha Cracking in Western Europe	123
Table 23	Cost of Production Estimate for Bioethylene via Bio-Methanol MTO in the USGC	124
Table 24	Cost of Production Estimate for Bioethylene via Bio-Methanol MTO in China	125
Table 25	Cost of Production Estimate for Bioethylene via Bio-Methanol MTO in Brazil	126
Table 26	Cost of Production Estimate for Bioethylene via Bio-Methanol MTO in Western Europe	127
Table 27	Cost of Production Estimate for Bioethylene via OCM of RNG in the USGC	128
Table 28	Cost of Production Estimate for Bioethylene via OCM of RNG in China	129
Table 29	Cost of Production Estimate for Bioethylene via OCM of RNG in Brazil	130
Table 30	Cost of Production Estimate for Bioethylene via OCM of RNG in Western Europe	131
Table 31	Cost of Production Estimate for Bioethylene Oxide in the USGC	132
Table 32	Cost of Production Estimate for Bioethylene Oxide in China	133
Table 33	Cost of Production Estimate for Bioethylene Oxide in Brazil	134
Table 34	Cost of Production Estimate for Bioethylene Oxide in Western Europe	135
Table 35	Cost of Production Estimate for Bioethylene Glycol via Oxidation and Hydration in the USGC	136
Table 36	Cost of Production Estimate for Bioethylene Glycol via Oxidation and Hydration in China	137
Table 37	Cost of Production Estimate for Bioethylene Glycol via Oxidation and Hydration in Brazil	138
Table 38	Cost of Production Estimate for Bioethylene Glycol via Oxidation and Hydration in Western Europe	139

Table 39	Cost of Production Estimate for Bioethylene Glycol via Glucose Hydrogenation in the USGC	140
Table 40	Cost of Production Estimate for Bioethylene Glycol via Glucose Hydrogenation in China	141
Table 41	Cost of Production Estimate for Bioethylene Glycol via Glucose Hydrogenation in Brazil.....	142
Table 42	Cost of Production Estimate for Bioethylene Glycol via Glucose Hydrogenation in Western Europe	143
Table 43	Cost of Production Estimate for Bioethylene Glycol via Glycerine Hydrolysis in the USGC	144
Table 44	Cost of Production Estimate for Bioethylene Glycol via Glycerine Hydrolysis in China.....	145
Table 45	Cost of Production Estimate for Bioethylene Glycol via Glycerine Hydrolysis in Brazil	146
Table 46	Cost of Production Estimate for Bioethylene Glycol via Glycerine Hydrolysis in Western Europe	147
Table 47	Cost of Production Estimate for Bioethylene Glycol via Liquid Light in the USGC	148
Table 48	Cost of Production Estimate for Bioethylene Glycol via Liquid Light in China.....	149
Table 49	Cost of Production Estimate for Bioethylene Glycol via Liquid Light in Brazil	150
Table 50	Cost of Production Estimate for Bioethylene Glycol via Liquid Light in Western Europe	151
Table 51	Bioethylene Capacity	155
Table 52	Bioethylene Oxide Capacity	155
Table 53	Bioethylene Glycol Capacity.....	155



TECHNOLOGY & COSTS

Biorenewable Insights

The NexantECA Subscriptions' Biorenewable Insights program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. Biorenewable Insights reports are available as a subscription program or on a single report basis.

Contact Details:

Americas:

Marcos Nogueira Cesar, Vice President, Global Products, E&CA: NexantECA Subscriptions
Phone: + 1-914-609-0324, e-mail: mcesar@nexant.com

Erica Hill, Client Services Coordinator, E&CA-Products
Phone: + 1-914-609-0386, e-mail: ehill@nexant.com

EMEA:

Anna Ibbotson, Director, NexantECA Subscriptions
Phone: +44-207-950-1528, aibbotson@nexant.com

Asia:

Chommanad Thammanayakatip, Managing Consultant, Energy & Chemicals Advisory
Phone: +66-2793-4606, email: chommanadt@nexant.com

NexantECA (www.nexantECA.com) is a leading management consultancy to the global energy, chemical, and related industries. For over 38 years, NexantECA has helped clients increase business value through assistance in all aspects of business strategy, including business intelligence, project feasibility and implementation, operational improvement, portfolio planning, and growth through M&A activities. Nexant has its main offices in White Plains (New York), and London (UK), and satellite offices worldwide.

Copyright © by NexantECA 2020. All Rights Reserved.