

TECHNOLOGY & COSTS**Technoeconomics - Energy & Chemicals (TECH)****TECH 2022-1 Ethylene Oxide/Ethylene Glycol**

Table of Contents

A Report by **NexantECA, the Energy and Chemical Advisory company**

Published Date: September 2022

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

1	Executive Summary	1
2	Business Overview	4
2.1	Introduction.....	4
2.2	Technology Overview	6
2.2.1	Ethylene Oxide	6
2.2.2	Ethylene Glycol	6
2.3	Technology Licensors and Major Producers.....	9
2.3.1	Licensors	9
2.3.2	Producers	10
2.4	Historical Development	11
2.4.1	Ethylene Oxide Hydrolysis	12
2.4.2	Coal to MEG via DMO	12
2.4.3	JM Davy Process	13
2.5	Recent Developments	14
2.5.1	Demand Landscape	14
2.5.2	Capacity Development	15
2.6	Physical Properties.....	17
2.6.1	Ethylene Oxide	17
2.6.2	Ethylene Glycol	17
2.7	Specifications	18
2.7.1	Ethylene Oxide	18
2.7.2	Ethylene Glycol	18
2.8	Health Hazards.....	19
2.9	Storage and Transportation	19
2.9.1	Ethylene Oxide	19
2.9.2	Ethylene Glycol	19
3	Commercial Technologies.....	20
3.1	Conventional Ethylene Glycol Technology.....	21
3.1.1	Process Chemistry	21

3.1.2	Catalysts.....	22
3.1.3	Dow	22
3.1.4	Scientific Design.....	37
3.1.5	Shell.....	47
3.2	Coal to MEG via DMO.....	60
3.2.1	Technology Licensors	60
3.2.2	Process Overview	61
3.2.3	Process Chemistry	63
3.2.4	Recent Developments in Coal to MEG	64
3.2.5	Coal Gasification	65
3.2.6	CO to Dimethyl Oxalate.....	76
3.2.7	Dimethyl Oxalate to MEG.....	79
3.3	Johnson Matthey Davy Technology	80
3.3.1	Catalyst Improvements.....	80
3.3.2	Formaldehyde Raw Material	80
3.3.3	Chemistry	81
3.3.4	Process Description	81
3.4	Comparison of Technologies	83
3.4.1	Conventional and OMEGA Process.....	83
3.4.2	Coal to MEG via DMO and Conventional Process	83
3.4.3	Coal to MEG via DMO and JM Davy Process	84
4	Developing Technologies	85
4.1	Key Findings.....	85
4.2	Patent Developments	85
4.2.1	US20210309624 - Method of Producing Ethylene Oxide and Ethylene Glycol	88
4.2.2	US20210130309 - Process for the Production of Ethylene Oxide	88
4.2.3	US20220024841 - Process for the Preparation of Ethylene Glycol.....	88
4.2.4	US20190330134 - Method for Improving the Manufacture of Ethylene Glycol	89
4.2.5	US20200216377 - Process for the Purification of Ethylene Glycol.....	89
4.2.6	Numerous Patents by Chinese Companies	89
4.3	Renewable Pathways to MEG	90
4.3.1	Bio-ethylene to Ethylene Glycol	91
4.3.2	Sugar to Ethylene Glycol.....	104
4.3.3	Glycerine to Ethylene Glycol	108
4.3.4	Developmental Routes to Ethylene Glycol.....	115
5	Process Economics	118
6	Carbon Intensity	131
7	Commercial Applications	137
7.1	Ethylene Oxide	137
7.2	Monoethylene Glycol.....	138

8	Regional Markets	139
---	------------------------	-----

Appendices

A	Appendix – Cost of Production Models	186
B	Definitions of Capital Cost Terms Used in Process Economics.....	199
C	Definitions of Operating Cost Terms Used in Process Economics.....	204
D	TECH Program Title Index (2012-2022)	207
E	References	210

Figures

Figure 1	Global MEG Demand, 2022-e	1
Figure 2	Conventional Ethylene Glycol Production	1
Figure 3	WIPO Patent Development by Date Published and Assignee Region, Ethylene Glycol.....	3
Figure 4	Cost of Production Summary for Conventional MEG, Shell OMEGA and Coal to MEG via DMO.....	3
Figure 5	Chemical Formulas for Ethylene Oxide and Monoethylene Glycol	4
Figure 6	Ethylene Oxide Value Chain.....	4
Figure 7	Ethylene Oxide Consumption, 2022-e.....	5
Figure 8	Ethylene Oxide Production from Ethylene.....	6
Figure 9	Conventional Ethylene Glycol Production	6
Figure 10	Coal to MEG via DMO	7
Figure 11	Five Major Steps in Coal to MEG via MTO	8
Figure 12	Global Ethylene Oxide and MEG Capacity Share by Producer, 2022-e	10
Figure 13	Timeline of Ethylene Glycol Technology Development	11
Figure 14	Dow's EO Catalyst Advantages.....	23
Figure 15	Comparison of CO ₂ Production of METEOR™ EO 200 Catalyst versus METEOR™ EO-RETRO Catalyst.....	24
Figure 16	Dow METEOR™ EO/MEG Process Overview	27
Figure 17	Dow METEOR™ EO/EG Process EO Reaction Section	28
Figure 18	Dow METEOR™ EO Reactor Design.....	29
Figure 19	Dow's Single EO Reactor Concept in a Two Reactor Plant	31
Figure 20	Dow METEOR™ EO/EG Process Purified EO and Aqueous EO Production	34
Figure 21	Dow METEOR™ EO/EG Process Glycol Reaction and Separation Section	36
Figure 22	SD Purified EO Production	41
Figure 23	SD EO Reaction and Recovery for EG.....	44
Figure 24	SD Glycol Reaction and Separation Simplified Process Flow Diagram.....	46
Figure 25	SC&T EO Catalyst Selectivity Developments	49
Figure 26	Shell MASTER Process.....	51
Figure 27	Shell Ethylene Oxide Reaction and Recovery Section with CO ₂ Removal	54

Figure 28	Shell OMEGA Process	58
Figure 29	Shell OMEGA Ethylene Glycol Section	59
Figure 30	Three Major Steps in Coal-to-MEG via DMO	61
Figure 31	Simplified Block Flow Diagram for MEG Production from CO	62
Figure 32	Dimethyl Oxalate Synthesis Reaction Mechanism	63
Figure 33	Major Coal Gasification Reactions	66
Figure 34	Types of Coal.....	67
Figure 35	Coal Gasification and Syngas Recovery	69
Figure 36	Moving Bed Gasifier Diagram.....	70
Figure 37	Fluidized Bed Gasifier Diagram.....	71
Figure 38	Entrained Flow Gasifier Diagram.....	72
Figure 39	Coal-to-MEG	77
Figure 40	JM Davy/Eastman Block Flow Diagram	82
Figure 41	WIPO Patent Development by Date Published and Assignee Region, Ethylene Oxide	86
Figure 42	WIPO Patent Development by Date Published and Assignee Region, Ethylene Glycol.....	86
Figure 43	WIPO Patent Development by Company for Ethylene Oxide	87
Figure 44	WIPO Patent Development by Company for Ethylene Glycol.....	88
Figure 45	Routes to Bio-Ethylene Glycol.....	91
Figure 46	Routes to Bio-ethylene	92
Figure 47	Bioethanol to Green Ethylene: Conceptual Process Flow	94
Figure 48	Braskem Ethanol Dehydration Process.....	96
Figure 49	Ethylene from Ethanol	98
Figure 50	Comparison of Hummingbird and Conventional Ethanol-to-Ethylene Catalysts.....	99
Figure 51	TechnipFMC Hummingbird® Technology Process Diagram	100
Figure 52	IPCI Sugar to Glycols Process	106
Figure 53	UOP PG Process Block Flow Diagram.....	112
Figure 54	GBT Glycerin to Propylene Glycol Process Flow Diagram	114
Figure 55	Biomass to MEG Process.....	116
Figure 56	Regional Cost of Production Summary – Purified EO	122
Figure 57	Regional Cost of Production Summary – Conventional MEG	124
Figure 58	Regional Cost of Production Summary – Shell OMEGA.....	126
Figure 59	Cost of Production Summary for Conventional MEG, Shell OMEGA and Coal to MEG via DMO.....	127
Figure 60	MEG Byproduct Value Sensitivity.....	128
Figure 61	Conventional MEG Capital Cost Sensitivity versus Coal-Based MEG.....	129
Figure 62	Raw Material Price Sensitivity, Ethylene and Coal.....	130
Figure 63	Process Carbon Balance	131
Figure 64	Ethylene Capacity in the United States	133
Figure 65	Ethylene Capacity in China	133
Figure 66	Ethylene Oxide Derivatives and Downstream Markets	137
Figure 67	Global Ethylene Oxide Consumption by End Use, 2022-e.....	139

Figure 68	Global Ethylene Oxide Consumption by Region, 2022-e	140
Figure 69	Global Ethylene Oxide Capacity Share by Region, 2022-e	141
Figure 70	Global Ethylene Oxide Capacity Share by Producer, 2022-e	141
Figure 71	Global Ethylene Oxide Supply and Demand	142
Figure 72	North America Ethylene Oxide Consumption, 2022-e.....	144
Figure 73	North America Ethylene Oxide Supply, Demand, and Trade	147
Figure 74	Western Europe Ethylene Oxide Consumption, 2022-e.....	148
Figure 75	Western Europe Ethylene Oxide Supply, Demand, and Trade	150
Figure 76	Middle East Ethylene Oxide Consumption, 2022-e.....	152
Figure 77	Middle East Ethylene Oxide Supply, Demand, and Trade	154
Figure 78	Asia Pacific Ethylene Oxide Consumption, 2022-e	156
Figure 79	Asia Pacific Ethylene Oxide Supply, Demand, and Trade	161
Figure 80	Global MEG Consumption by End-Use, 2022-e.....	162
Figure 81	Global MEG Consumption by Region, 2022-e	163
Figure 82	MEG Capacity Share by Region, 2022-e	164
Figure 83	MEG Capacity Share by Producer, 2022-e	165
Figure 84	Global MEG Supply and Demand	166
Figure 85	North America MEG Consumption, 2022-e	167
Figure 86	North America MEG Supply, Demand, and Trade	169
Figure 87	Western Europe MEG Consumption, 2022-e.....	170
Figure 88	Western Europe MEG Supply, Demand, and Trade	172
Figure 89	Middle East MEG Consumption, 2022-e	173
Figure 90	Middle East MEG Supply, Demand, and Trade	175
Figure 91	Asia Pacific MEG Consumption, 2022-e	177
Figure 92	Asia Pacific MEG Supply, Demand, and Trade.....	184

Tables

Table 1	Commercial Production of MEG	2
Table 2	Licensors and Technology Holders of Petroleum-Derived Ethylene to MEG	9
Table 3	Ethylene Oxide Key Physical and Thermodynamic Properties	17
Table 4	MEG Key Physical and Thermodynamic Properties	17
Table 5	Ethylene Oxide Commercial Specification	18
Table 6	MEG Commercial Specification	18
Table 7	Characteristics of Each Coal Type	68
Table 8	Licensor and Gasifier Types.....	72
Table 9	Gasifier Typical Characteristics	73
Table 10	Process Conditions for MEG Production Technologies	84
Table 11	Licensors and Technology Holders for Steam Cracking Routes to Ethylene	101
Table 12	S2G Biochem Product Slate.....	108
Table 13	ADM Nickel-on-Alumina Catalyst Composition	110
Table 14	UOP PG Process Conditions	111
Table 15	Prices of Raw Materials, Products, Utilities and Labor.....	119
Table 16	Regional Cost of Production Summary – Purified EO	122
Table 17	Regional Cost of Production Summary – Conventional MEG	124
Table 18	Regional Cost of Production Summary – Shell OMEGA.....	125
Table 19	Global Ethylene Oxide Consumption by Derivative.....	140
Table 20	Global Ethylene Oxide Consumption by Region	140
Table 21	Global Ethylene Oxide Supply and Demand	142
Table 22	North America Ethylene Oxide Consumption by Derivative	144
Table 23	Ethylene Oxide Capacity in North America	146
Table 24	North America Ethylene Oxide Supply, Demand, and Trade	147
Table 25	Western Europe Ethylene Oxide Consumption by Derivative	148
Table 26	Ethylene Oxide Capacity in Western Europe	149
Table 27	Western Europe Ethylene Oxide Supply, Demand, and Trade	150
Table 28	Middle East Ethylene Oxide Consumption by Derivative	152
Table 29	Ethylene Oxide Capacity in the Middle East	153
Table 30	Middle East Ethylene Oxide Supply, Demand, and Trade	154
Table 31	Asia Pacific Ethylene Oxide Consumption by Derivative	156
Table 32	Ethylene Oxide Capacity in China	157
Table 33	Ethylene Oxide Capacity in Asia Pacific (excluding China)	159
Table 34	Asia Pacific Ethylene Oxide Supply, Demand, and Trade	161
Table 35	Global MEG Consumption by End Use	162
Table 36	Global MEG Consumption by Region.....	163
Table 37	Global MEG Supply and Demand	166
Table 38	North America MEG Consumption by End Use	167
Table 39	MEG Capacity in North America.....	168
Table 40	North America MEG Supply, Demand, and Trade	169
Table 41	Western Europe MEG Consumption by End Use	170

Table 42	MEG Capacity in Western Europe.....	171
Table 43	Western Europe MEG Supply, Demand, and Trade	172
Table 44	Middle East MEG Consumption by End Use.....	173
Table 45	MEG Capacity in the Middle East.....	174
Table 46	Middle East MEG Supply, Demand, and Trade	175
Table 47	Asia Pacific MEG Consumption by End Use	177
Table 48	MEG Capacity in China	179
Table 49	Asia Pacific MEG Supply, Demand, and Trade.....	184
Table 50	Cost of Production Estimate: Purified Ethylene Oxide, Ethylene Oxidation, USGC	186
Table 51	Cost of Production Estimate: Purified Ethylene Oxide, Ethylene Oxidation, Middle East	187
Table 52	Cost of Production Estimate: Purified Ethylene Oxide, Ethylene Oxidation, China Coast	188
Table 53	Cost of Production Estimate: Purified Ethylene Oxide, Ethylene Oxidation, Western Europe.....	189
Table 54	Cost of Production Estimate: Ethylene Glycol, Coal-based via DMO, China Inland	190
Table 55	Cost of Production Estimate: Ethylene Glycol, Ethylene Oxidation and EO Hydrolysis, USGC	191
Table 56	Cost of Production Estimate: Ethylene Glycol, Ethylene Oxidation and EO Hydrolysis, Middle East	192
Table 57	Cost of Production Estimate: Ethylene Glycol, Ethylene Oxidation and EO Hydrolysis, China (Coast)	193
Table 58	Cost of Production Estimate: Ethylene Glycol, Ethylene Oxidation and EO Hydrolysis, Western Europe	194
Table 59	Cost of Production Estimate: Ethylene Glycol, Shell OMEGA Process, USGC	195
Table 60	Cost of Production Estimate: Ethylene Glycol, Shell OMEGA Process, Middle East	196
Table 61	Cost of Production Estimate: Ethylene Glycol, Shell OMEGA Process, China Coast	197
Table 62	Cost of Production Estimate: Ethylene Glycol, Shell OMEGA Process, Western Europe.....	198



TECHNOLOGY & COSTS

Technoeconomics - Energy & Chemicals (TECH)

The NexantECA Subscriptions' Technoeconomics - Energy & Chemicals (TECH) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. Technoeconomics - Energy & Chemicals (TECH) reports are available as a subscription program or on a single report basis.

Contact Details:

Americas:

Marcos Nogueira Cesar, Vice President, Global Subscriptions and Reports
Phone: + 1-914-609-0324, e-mail: mcesar@NexantECA.com

Erica Hill, Client Services Coordinator, Subscriptions and Reports
Phone: + 1-914-609-0386, e-mail: ehill@NexantECA.com

EMEA:

Anna Ibbotson, Vice President, Sales and Marketing
Phone: +44-207-950-1528, aibbotson@NexantECA.com

Asia:

Chommanad Thammanayakatip, Managing Consultant
Phone: +66-2793-4606, email: chommanadt@NexantECA.com

NexantECA Subscriptions and Reports provide clients with comprehensive analytics, forecasts and insights for the chemicals, polymers, energy and cleantech industries. Using a combination of business and technical expertise, with deep and broad understanding of markets, technologies and economics, NexantECA provides solutions that our clients have relied upon for over 50 years.

Copyright © 2000-2021 NexantECA (BVI) Limited. All rights reserved