

Coal-to-MEG - Changing the Rules of the Game

Volume II - Technology Evaluation

January 2011



Griffin House, 1st Floor South, 161 Hammersmith Road, London W6 8BS, UK
Tel: +44 20 7950 1600 Fax: +44 20 7950 1550

This Report was prepared by Nexant, Inc ("NEXANT") and is part of the CSOL SPECIAL REPORT. 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. Aforesaid information has not been independently verified or otherwise examined to determine its accuracy, completeness or financial 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 should not be reproduced, distributed or used without first obtaining prior written consent by NEXANT. Each Subscriber agrees to use reasonable effort to protect the confidential nature of the Report.

Copyright © by Nexant Inc. 2011. All rights reserved.

Contents

Section	Page
1 Executive Summary	1-1
1.1 INTRODUCTION.....	1-1
1.1.1 Raw Materials	1-2
1.1.2 MEG Consumption	1-4
1.1.3 Technology.....	1-6
1.2 SIMPLIFIED PROCESS OVERVIEW	1-8
1.2.1 Coal Based Platform	1-8
1.2.2 Alternative Syngas Platforms.....	1-9
1.3 COST COMPETITIVENESS	1-11
1.4 STRATEGIC TECHNOLOGY CONSIDERATIONS	1-12
1.5 CONCLUSIONS.....	1-13
2 Introduction.....	2-1
2.1 OVERVIEW	2-1
2.1.1 Raw Materials	2-2
2.1.2 MEG Consumption	2-5
2.1.3 Technology.....	2-7
2.2 STRUCTURE OF THE REPORT	2-10
2.2.1 Report Coverage	2-10
3 Coal-to-MEG Technology.....	3-1
3.1 OVERVIEW	3-1
3.2 PROCESS CHEMISTRY	3-3
3.2.1 Coal Gasification.....	3-3
3.2.2 CO to Dimethyl Oxalate.....	3-4
3.2.3 Dimethyl Oxalate to MEG	3-5
3.2.4 Implications for Syngas Ratio.....	3-6
3.3 PROCESS DESIGN AND OPERATION.....	3-7
3.3.1 Coal Gasification and Syngas Clean-Up.....	3-7
3.3.2 CO Conversion to Dimethyl Oxalate	3-20
3.3.3 Dimethyl Oxalate Conversion to MEG	3-24
3.3.4 Coal-to-MEG as an Integrated Complex Coal-to-MEG as an Integrated Complex	3-25
4 Syngas to MEG Technology based on Alternative Syngas Platforms	4-1
4.1 OVERVIEW	4-1

4.2	NATURAL GAS AS ALTERNATIVE SYNGAS FEEDSTOCK.....	4-2
4.2.1	Natural Gas to MEG as an Integrated Complex.....	4-2
4.2.2	Natural Gas Purification.....	4-3
4.2.3	Syngas from Natural Gas	4-3
4.2.4	Purification and Recovery	4-5
4.3	BIOMASS GASIFICATION AND MEG PRODUCTION	4-7
4.3.1	Overview	4-7
4.3.2	Biomass to MEG as an Integrated Complex	4-7
4.3.3	Biomass Gasification	4-9
4.3.4	Mass Balance for Biomass to MEG Process.....	4-13
5	Capital Costs and Operating Costs.....	5-1
5.1	OVERVIEW	5-1
5.2	INVESTMENT COSTS (CAPEX)	5-2
5.2.1	Inside Battery Limits (ISBL) Investments	5-3
5.2.2	Outside Battery Limit (OSBL) Investments.....	5-3
5.2.3	Other Project Costs	5-5
5.2.4	Working Capital.....	5-6
5.2.5	Location Factor	5-7
5.2.6	Impact of Scale Economics.....	5-8
5.2.7	Capital Cost Analysis for Coal-to-MEG Technology	5-8
5.3	OPERATING COST FACTORS	5-11
5.3.1	Mass Balance	5-11
5.3.2	Utility Requirements	5-11
5.3.3	Manning Requirements and Fixed Costs Considerations	5-11
6	Cost of Production Analysis	6-1
6.1	BACKGROUND AND METHODOLOGY	6-1
6.1.1	Introduction.....	6-1
6.1.2	Cost of Production Terminology.....	6-1
6.1.3	Location Factors.....	6-2
6.1.4	Plants Considered.....	6-3
6.1.5	Location and Market Coverage	6-3
6.2	FEEDSTOCK PRICES	6-4
6.2.1	Naphtha Price.....	6-4
6.2.2	Gas Prices.....	6-4
6.2.3	Coal Price in China	6-4
6.2.4	Biomass Prices	6-5

6.3	SHIPPING & TARIFF COSTS	6-6
6.3.1	Shipping Costs	6-6
6.3.2	Tariff	6-6
6.4	DELIVERED COST COMPETITIVENESS COMPARISON.....	6-7
6.4.1	Domestic Cost of Production Analysis	6-7
6.4.2	Delivered Cost Competitiveness Analysis	6-8

Appendix		Page
A	Review of Conventional MEG Technology	A-1
B	Review of Conventional Coal Gasification Technology and Syngas Clean-Up	B-1
C	Review of Conventional Syngas and Water Gas Shift Technology	C-1
D	Support Cost of Production Estimate Tables	D-1

Figure	Page
1.1 Conventional and Non-Conventional Routes to Ethylene Glycol (MEG)	1-1
1.2 Regional Coal Reserve Share	1-3
1.3 Global MEG Consumption, 2009.....	1-4
1.4 Global MEG Demand and Supply by Region, 2009	1-5
1.5 MEG Trade in China, 2009.....	1-5
1.6 Three Major Chemical Steps in Coal-to-MEG.....	1-8
1.7 Alternative Syngas Platforms to Coal Gasification in MEG Production	1-9
1.8 MEG Domestic Cost of Production, 2009	1-11
2.1 Conventional and Non-Conventional Routes to Ethylene Glycol (MEG)	2-1
2.2 Regional Coal Reserve Share	2-3
2.3 Global MEG Consumption, 2009.....	2-5
2.4 Global MEG Demand and Supply by Region, 2009	2-6
2.5 MEG Trade in China, 2009.....	2-7
2.6 Three Major Chemical Steps in Coal-to-MEG.....	2-7
3.1 Three Major Chemical Steps in Coal-to-MEG.....	3-1
3.2 Simplified Process Diagram From CO to MEG.....	3-3
3.3 Major Gasification Reactions.....	3-4
3.4 Dimethyl Oxalate Synthesis Reaction Mechanism	3-5
3.5 ChevronTexaco Gasifier	3-11
3.6 ConocoPhillips E-Gas Gasifier	3-12
3.7 Shell Gasification Process.....	3-13
3.8 Coal-to-MEG.....	3-22
3.9 Integrated Coal-to-MEG Complex.....	3-25
3.10 Syngas composition	3-26
4.1 Alternative Syngas Platforms to Coal Gasification in MEG Production	4-1
4.2 Natural Gas to MEG Process	4-2
4.3 Biomass to MEG Process.....	4-8
4.4 Process Schematic - CHOREN Syngas Production from Biomass.....	4-10
4.5 Simplified Mass Balance for Straw to MEG.....	4-13
5.1 Steel Producer Price Indexes.....	5-2
6.1 Components of Cost Delivery to Market	6-1
6.2 MEG Domestic Cost of Production, 2009	6-7
6.3 MEG Domestic Cost of Production, 2015	6-8
6.4 MEG Delivered Cost into China, 2009	6-9
6.5 MEG Delivered Cost into China, 2015	6-9
A.1 Dow METEOR™ EO/MEG Process Overview.....	A-5

A.2	Dow METEOR™ EO Reaction System.....	A-7
A.3	Dow METEOR™ CO2 Removal System	A-8
A.4	Dow METEOR™ Glycol Reaction and Evaporation System	A-10
A.5	EO Reaction, Scrubbing, and EO Purification via SD Process.....	A-12
A.6	Ethylene Oxide Reaction and Scrubbing via SD Process	A-14
A.7	Glycol Reaction and Separation via SD Process.....	A-17
A.8	Shell MASTER Process	A-19
A.9	Shell Ethylene Oxide Reaction and Recovery with CO2 Removal	A-21
A.10	Shell OMEGA Process.....	A-25
A.11	Shell OMEGA Ethylene Glycol Section.....	A-26
B.1	Three Main Gasification Processes16	B-3
B.2	200 T/D Gasifier – View 1.....	B-9
B.3	200 T/D Gasifier – View 2.....	B-9
B.4	Fixed-Bed Slagging Gasifier.....	B-10
B.5	BGL Gasifier Heat Balance.....	B-12
B.6	The BGL Process	B-13
B.7	Transport Gasifier	B-17
B.8	Transport Gasifier Isometric	B-17
B.9	Raw Lower Heating Values	B-21
B.10	Commercially Projected Gasifier Lower Heating Values	B-22
B.11	Projected Turbine Inlet Lower Heating Values.....	B-22
B.12	Carbon Conversions	B-23
B.13	Freedom Lignite Carbon Conversion and Temperature.....	B-24
B.14	Levelised COE – 500 MW Power Plant.....	B-25
B.15	Typical GE Energy Installation.....	B-26
B.16	GE Energy Gasifier	B-31
B.17	E-GAS Gasifier	B-33
B.18	Shell Gasification Process.....	B-35
B.19	Lurgi Dry-Ash Gasifier	B-36
B.20	Prenflow Entrained Flow Gasifier.....	B-38
B.21	SFG Entrained Flow Gasifier	B-38
B.22	HT Winkler Fluidised Bed Gasifier	B-40
B.23	U-GAS® Fluidised-Bed Gasifier	B-43
B.24	MPG-Quench Configuration	B-45
B.25	MPG-Quench Configuration	B-47
B.26	Metals Ash Recovery System	B-48
B.27	Material & Heat Balance – Westinghouse Plasma Gasification Reactor.....	B-57
B.28	Westinghouse Plasma Gasifier.....	B-58

B.29 IGCC System Sheet 1 of 2	B-61
B.30 IGCC System Sheet 2 of 2	B-62
B.31 Overall Heat Balance of 500 MW IIGCC Plant.....	B-65
C.1 Selected Reformer Options	C-4
C.2 Steam-Methane Reforming	C-7
C.3 Reformer Layouts SMR	C-10
C.4 Combined Reforming.....	C-13
C.5 UHDE’S Combined Autothermal Reformer	C-15
C.6 Partial Oxidation	C-18
C.7 Hydrogen from Natural Gas (PSA Route)	C-21

Table	Page
1.1 Key Coal-to-MEG Technology Providers in China	1-7
2.1 Major Proven Coal Reserves, by Country (1).....	2-3
2.2 Key Coal-to-MEG Technology Providers in China	2-9
3.1 Gasifier Technology Suppliers.....	3-10
3.2 Salient Characteristics of Major Gasification Technologies	3-16
3.3 Entrained Coal Gasification Processes – Syngas Compositions	3-16
3.4 Fluid and Moving Bed Coal Gasification Processes – Syngas Compositions	3-17
4.1 Syngas Characteristics by End-Use Application.....	4-4
5.1 Capital Investment Location Factors.....	5-7
5.2 Representative Plants Modelled	5-9
5.3 Capital Investments Comparison of Different MEG Production Routes	5-9
5.4 Raw Materials Consumption.....	5-11
5.5 Utilities Consumption	5-11
5.6 Number of Personnel Required.....	5-12
6.1 Capital Investment Location Factors.....	6-2
6.2 Representative Plants Modelled	6-3
6.3 MEG Freight Costs Delivered to China	6-6
A.1 Typical Properties of Monoethylene Glycol	A-1
A.2 Typical Fibre Grade Monoethylene Glycol Specifications	A-1
A.3 MEG – Specification - Transmission in Ultraviolet.....	A-2
A.4 Typical Diethylene/Triethylene Glycol Specifications	A-2
B.1 Gasifier Types	B-4
B.2 Gasifier Typical Characteristics2	B-4
B.3 Syngas Compositions for Entrained-Flow Gasifiers1	B-5
B.4 Syngas Compositions for Moving and Fluid-Bed Gasifiers1	B-5

B.5	Syngas Composition before Shift Adjustment	B-6
B.6	Typical Product Gas Composition	B-10
B.7	Feedstocks Gasified	B-13
B.8	Test Runs.....	B-19
B.9	GE Energy Experience	B-27
B.10	CO ₂ Removal	B-28
B.11	GE Energy IGCC Experience	B-29
B.12	MPG Feedstock Flexibility	B-49
B.13	MPG – Selection Criteria for Quench Configuration vs. Boiler Configuration.....	B-50
B.14	Comparison between Westinghouse Plasma Gasifier and Conventional Gasifier	B-56
B.15	Composition of Lignite Coal.....	B-59
B.16	Preliminary Material Balance for Individual Plasma Gasification Reactor	B-64
C.1	Syngas Characteristics by End-Use Application.....	C-1
C.2	Typical Steam Methane Reforming Operating Conditions	C-8
C.3	Partial Oxidation Operating Conditions(1)	C-19
D.1	Cost of Production for MEG in Saudi Arabia	D-1
D.2	Cost of Production for MEG in Canada	D-2
D.3	Cost of Production for MEG in Kuwait	D-3
D.4	Cost of Production for MEG in South Korea	D-4
D.5	Cost of Production for MEG in Japan	D-5
D.6	Cost of Production for MEG in Western Europe	D-6
D.7	Cost of Production for MEG in South-East Asia	D-7
D.8	Cost of Production for MEG in China	D-8
D.9	Cost of Production for MEG in Qatar	D-9
D.10	Cost of Production for MEG in Western Europe	D-10