

Final Topical Report

Polygeneration from Coal

Integrated Power and Fuels

May 2008



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

This report was prepared by Nexant, Inc ("Nexant") and is part of the ChemSystems Topical 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.

Contents

Section	Page
1 Liquid Fuels Executive Summary	1-1
1.1 INTRODUCTION	1-1
1.2 COMPARISON BASIS	1-1
1.2.1 Chemicals.....	1-3
1.2.2 Liquid Fuels	1-4
1.3 COST OF PRODUCTION COMPARISONS	1-5
1.3.1 High Crude Oil Price (Base Case) Forecast.....	1-9
1.3.2 High Crude Oil Price Production Cost Sensitivity	1-21
1.4 DELIVERED COST COMPARISONS	1-34
1.4.1 Base Case Crude Oil Forecast.....	1-34
1.4.2 High Crude Oil Price Delivered Cost Sensitivity	1-42
2 Introduction.....	2-1
2.1 OVERVIEW	2-1
2.1.1 Overall Value Premise	2-1
2.2 BACKGROUND	2-3
2.2.1 Coal Liquefaction.....	2-3
2.2.2 Direct Coal Liquefaction (DCL).....	2-3
2.2.3 Indirect Coal Liquefaction (ICL).....	2-4
2.2.4 U.S. Energy Policy Act of 2005.....	2-6
2.3 ABSTRACT OF STUDY	2-7
3 Approach and Methodology.....	3-1
3.1 OVERALL APPROACH.....	3-1
3.2 OTHER ASPECTS OF APPROACH FOR THIS STUDY.....	3-2
4 Coal Gasification Technology	4-1
4.1 INTRODUCTION	4-1
4.2 GASIFIER OVERVIEW	4-1
4.3 COAL GASIFICATION.....	4-5
4.3.1 Overview.....	4-5
4.4 GASIFIER TECHNOLOGY	4-6

4.4.1	Advantica BGL Gasifier	4-6
4.4.2	KBR Transport Gasifier	4-15
4.4.3	GE Energy	4-27
4.4.4	E-GAS Entrained-Flow Gasifier	4-35
4.4.5	Shell Entrained Flow Gasifier	4-36
4.4.6	Lurgi Dry Ash Gasifier	4-38
4.4.7	Prenflow Entrained Bed Gasifier	4-40
4.4.8	Siemens (formerly Sustec-Group) GSP Entrained Flow Gasifier	4-41
4.4.9	High Temperature Winkler Gasifier	4-42
4.4.10	Lurgi Multi Purpose Gasification (MPG)	4-43
4.4.11	Westinghouse Plasma Gasification Technology	4-53
5	Liquid Fuels from Synthesis Gas Technologies	5-1
5.1	GASOLINE	5-1
5.1.1	Haldor Topsoe TIGAS	5-1
5.1.2	Integration of IGCC and TIGAS - Case Study	5-5
6	Liquid Fuels from Competing Conventional Feedstock Technologies	6-1
6.1	REFINING TECHNOLOGY	6-1
6.1.1	Product Upgrading and Sulfur Removal	6-1
6.2	MAJOR REFINERY PROCESSES	6-4
6.2.1	Introduction	6-4
6.3	BASIC REFINING PROCESSES	6-4
6.3.1	Fractionation	6-4
6.4	BASIC REFINERY CONFIGURATIONS – COMPLEXITY AND YIELDS	6-29
6.5	PRO-FORMA USGC REFINERY	6-31
6.5.1	Processing Configuration	6-31
6.6	SUMMARY AND CONCLUSIONS	6-32
6.6.1	Summary	6-32
6.6.2	Conclusions	6-34
6.7	DIESEL (FISCHER-TROPSCH GAS-TO-LIQUIDS)	6-34
6.7.1	Introduction	6-34
6.7.2	BP Process	6-34

6.7.3	ExxonMobil AGC-21 Process	6-36
6.7.4	Rentech Process	6-43
6.7.5	Sasol Slurry Phase Distillate (SPD) Process.....	6-46
6.7.6	Shell Middle Distillates Synthesis (SMDS II) Process.....	6-50
6.7.7	Statoil/PetroSA Process	6-54
6.7.8	Syntroleum Process.....	6-59
6.8	METHANOL	6-62
6.8.1	Large-Scale Methanol Background	6-62
6.8.2	Toyo Engineering Corporation (TEC) Methanol Technology.....	6-63
6.8.3	Lurgi Large-Scale Methanol Process.....	6-67
6.8.4	Foster Wheeler Starchem Methanol Process	6-74
6.9	DIMETHYL ETHER.....	6-76
6.9.1	Introduction.....	6-76
6.9.2	Conventional Methanol Dehydration.....	6-79
6.9.3	Air Products Liquid Phase DME (LPDME™) Process	6-82
6.9.4	Haldor Topsøe One Step Syngas to DME Process	6-86
7	Economic Bases	7-1
7.1	CONCEPT	7-1
7.2	COMPARISON BASIS	7-2
7.2.1	Chemicals.....	7-2
7.2.2	Liquid Fuels	7-3
7.3	COST OF PRODUCTION WORKSHEETS.....	7-4
7.3.1	Gasifier Island.....	7-4
7.3.2	Gasifier Capital Cost.....	7-8
7.3.3	Gasifier Syngas Production.....	7-8
7.3.4	Gasifier Island Capital Cost	7-9
7.3.5	Power Production; IGCC (Integrated Gasification Combined Cycle).....	7-10
7.4	ECONOMIC BASIS	7-12
7.4.1	Capital and Operating Costs	7-14
7.4.2	Inside Battery Limits Investment.....	7-20
7.4.3	Outside Battery Limits Investment	7-21

7.4.4	Contractor Charges	7-22
7.4.5	Project Contingency Allowance	7-22
7.4.6	Other Project Costs	7-22
7.4.7	Working Capital	7-24
7.4.8	Shipping Costs	7-24
7.4.9	Forecast Years.....	7-25
7.5	PRICING BASIS	7-25
7.5.1	Crude Oil.....	7-25
7.5.2	Coal in China	7-37
8	Liquid Fuels and Power from Polygeneration Economics	8-1
8.1	UNITED STATES	8-1
8.1.1	Syngas from Polygeneration	8-1
8.1.2	Methanol	8-1
8.1.3	DME.....	8-4
8.1.4	FT Liquids.....	8-4
8.1.5	Gasoline	8-7
8.2	CHINA.....	8-9
8.2.1	Syngas from Polygeneration	8-9
8.2.2	Methanol	8-11
8.2.3	DME.....	8-11
8.2.4	FT Liquids.....	8-14
8.2.5	Gasoline	8-14
8.3	EASTERN EUROPE/EURASIA.....	8-17
8.3.1	Syngas from Polygeneration	8-17
8.3.2	Methanol	8-17
8.3.3	DME.....	8-20
8.3.4	FT Liquids.....	8-20
8.3.5	Gasoline	8-23
9	Conventional Feedstock Liquid Fuels Economics	9-1
9.1	UNITED STATES	9-1
9.1.1	Methanol	9-1

9.1.2	DME.....	9-1
9.1.3	FT Liquids.....	9-4
9.2	CHINA.....	9-4
9.2.1	Methanol	9-4
9.2.2	DME.....	9-7
9.2.3	FT Liquids.....	9-7
9.3	EASTERN EUROPE/EURASIA.....	9-10
9.3.1	Methanol	9-10
9.3.2	DME.....	9-10
9.3.3	FT Liquids.....	9-13
10	Regional Economics and Comparisons.....	10-1
10.1	ECONOMICS COMPARISONS.....	10-1
10.1.1	United States	10-4
10.1.2	China	10-8
10.1.3	Eastern Europe/Eurasia	10-12
10.2	REGIONAL COMPARISONS.....	10-16
10.2.1	Methanol	10-16
10.2.2	Dimethyl Ether.....	10-21
10.2.3	F-T Liquids	10-25
10.2.4	Gasoline	10-30
10.3	HIGH OIL PRICE PRODUCTION COST SENSITIVITY	10-34
10.3.1	United States	10-35
10.3.2	China	10-39
10.3.3	Eastern Europe/Eurasia	10-43
10.4	HIGH OIL PRICE DELIVERED COST SENSITIVITY	10-47
10.4.1	Methanol	10-47
10.4.2	Dimethyl Ether.....	10-51
10.4.3	F-T Liquids	10-55
10.4.4	Gasoline	10-59
11	Liquid Fuels Markets	11-1
11.1	UNITED STATES.....	11-1

11.1.1	Gasoline	11-1
11.1.2	Naphtha.....	11-2
11.1.3	Diesel	11-3
11.1.4	Fuel Oils.....	11-4
11.2	WESTERN EUROPE	11-5
11.2.1	Gasoline	11-5
11.2.2	Naphtha.....	11-6
11.2.3	Diesel/Gas Oil.....	11-7
11.2.4	Fuel Oils.....	11-8
11.3	ASIA PACIFIC	11-9
11.3.1	Gasoline	11-9
11.3.2	Naphtha.....	11-10
11.3.3	Diesel/Gas Oil.....	11-11
11.3.4	Fuel Oils.....	11-12

Figure	Page
1.1 Overall Production Scheme	1-1
1.2 Gas Island Schematic	1-2
1.3 Nexant's Crude Oil Price Scenarios	1-6
1.4 Methanol Cost of Production Comparison, U.S.	1-9
1.5 DME Cost of Production Comparison, U.S.	1-10
1.6 F-T Liquids Cost of Production Comparison, U.S.	1-11
1.7 Gasoline Cost of Production Comparison, U.S.	1-12
1.8 Methanol Cost of Production Comparison, China	1-13
1.9 DME Cost of Production Comparison, China	1-14
1.10 F-T Liquids Cost of Production Comparison, China	1-15
1.11 Gasoline Cost of Production Comparison, China	1-16
1.12 Methanol Cost of Production Comparison, Eastern Europe/Eurasia	1-17
1.13 DME Cost of Production Comparison, Eastern Europe/Eurasia	1-18
1.14 F-T Liquids Cost of Production Comparison, Eastern Europe/Eurasia	1-19
1.15 Gasoline Cost of Production Comparison, Eastern Europe/Eurasia	1-20
1.16 Crude Oil Scenario Price Comparison	1-21
1.17 High Crude Price Methanol Cost of Production Comparison, U.S.	1-22
1.18 High Crude Price DME Cost of Production Comparison, U.S.	1-23
1.19 High Crude Price F-T Liquids Cost of Production Comparison, U.S.	1-24
1.20 High Crude Price Gasoline Cost of Production Comparison, U.S.	1-25
1.21 High Crude Price Methanol Cost of Production Comparison, China	1-26
1.22 High Crude Price DME Cost of Production Comparison, China	1-27
1.23 High Crude Price F-T Liquids Cost of Production Comparison, China	1-28
1.24 High Crude Price Gasoline Cost of Production Comparison, China	1-29
1.25 High Crude Price Methanol Cost of Production Comparison, Eastern Europe/Eurasia	1-30
1.26 High Crude Price DME Cost of Production Comparison, Eastern Europe/Eurasia ..	1-31
1.27 High Crude Price F-T Liquids Cost of Production Comparison, Eastern Europe/Eurasia	1-32
1.28 High Crude Price Gasoline Cost of Production Comparison, Eastern Europe/Eurasia	1-33

1.29 Methanol Delivered Cost Comparison, U.S., 2007	1-34
1.30 Methanol Delivered Cost Comparison, Western Europe, 2007.....	1-35
1.31 DME Delivered Cost Comparison, U.S., 2007	1-36
1.32 DME Delivered Cost Comparison, Western Europe, 2007	1-37
1.33 F-T Liquids Delivered Cost Comparison, U.S., 2007.....	1-38
1.34 F-T Liquids Delivered Cost Comparison, Western Europe, 2007	1-39
1.35 Gasoline Delivered Cost Comparison, U.S., 2007.....	1-40
1.36 Gasoline Delivered Cost Comparison, Western Europe, 2007.....	1-41
2.1 U.S. Historical Crude/Gas/Coal Prices	2-5
2.2 China Historical Crude/Fuel/Coal Prices.....	2-6
2.3 Polygeneration	2-7
2.4 Regional Coal Reserve Share by Percent of Global Coal Resource.....	2-9
4.1 Three Main Gasification Processes1.....	4-2
4.2 200 T/D Gasifier – View 1.....	4-8
4.3 200 T/D Gasifier – View 2.....	4-8
4.4 Fixed-Bed Slagging Gasifier.....	4-9
4.5 BGL Gasifier Heat Balance	4-12
4.6 The BGL Process	4-13
4.7 Transport Gasifier	4-16
4.8 Transport Gasifier Isometric	4-17
4.9 Raw Lower Heating Values	4-21
4.10 Commercially Projected Gasifier Lower Heating Values	4-22
4.11 Projected Turbine Inlet Lower Heating Values	4-23
4.12 Carbon Conversions.....	4-24
4.13 Freedom Lignite Carbon Conversion and Temperature	4-25
4.14 Levelized COE – 500 MW Power Plant.....	4-26
4.15 Typical GE Energy Installation	4-27
4.16 GE Energy Gasifier.....	4-34
4.17 E-GAS Gasifier.....	4-35
4.18 Shell Gasification Process.....	4-37
4.19 Lurgi Dry-Ash Gasifier.....	4-39

4.20 Prenflow Entrained Flow Gasifier	4-40
4.21 GSP Entrained Flow Gasifier.....	4-41
4.22 HT Winkler Fluidized Bed Gasifier.....	4-43
4.23 MPG-Quench Configuration.....	4-45
4.24 MPG-Quench Configuration.....	4-48
4.25 Metals Ash Recovery System	4-49
4.26 Material & Heat Balance – Westinghouse Plasma Gasification Reactor	4-57
4.27 Westinghouse Plasma Gasifier	4-58
4.28 IGCC System Sheet 1 of 2	4-61
4.29 IGCC System Sheet 2 of 2	4-62
4.30 Overall Heat Balance of 500 MW IIGCC Plant	4-65
5.1 The Methanol-to-Gasoline (MTG) Process: Two Steps via Raw Methanol.....	5-1
5.2 The Topsøe Integrated Gasoline Synthesis (TIGAS) process	5-2
5.3 Equilibrium Conversion.....	5-3
5.4 H ₂ /CO Ratio vs. Distribution	5-4
5.5 TIGAS Process Demonstration Unit.....	5-5
5.6 Integration of an IGCC Plant with TIGAS	5-6
5.7 Summary of the Study Cases	5-7
6.1 Typical Simplified Refinery Process Flow Diagram	6-2
6.2 BP GTL Process.....	6-35
6.3 Diagram of the Compact Reformer.....	6-36
6.4 ExxonMobil AGC-21 Flowsheet	6-38
6.5 ExxonMobil AGC-21 Advanced Gas Conversion.....	6-42
6.6 Rentech Process Scheme.....	6-45
6.7 Sasol Slurry Bed Reactor	6-48
6.8 Shell Gasification Process.....	6-51
6.9 Simplified Flow Diagram SMDS Process	6-52
6.10 Simplified Block Flow of Statoil/PetroSA GTL Process	6-55
6.11 Statoil/PetroSA Slurry Bubble Column Reactor.....	6-58
6.12 Syntroleum Process Gas-to-Liquids Conversion.....	6-61
6.13 5,000 Metric Tons per Day Methanol/Process Flow Scheme (1 of 3).....	6-64

6.14 5,000 Metric Tons per Day Methanol Plant/Process Flow Scheme (2 of 3)	6-65
6.15 5,000 Metric Tons per Day Methanol Plant/Process Flow Scheme (3 of 3)	6-66
6.16 Lurgi MEGA Methanol Process	6-68
6.17 Lurgi MEGA Methanol Process – Reforming Section	6-69
6.18 Lurgi MEGA Methanol/Process – Methanol Synthesis and Distillation Section	6-70
6.19 Lurgi Water and Gas-Cooled Methanol Synthesis Reactor	6-72
6.20 Foster Wheeler Starchem Methanol Process	6-75
6.21 Carbon Monoxide and Carbon Dioxide Conversion as a Function of Pressure	6-78
6.22 Equilibrium Conversion of Syngas	6-78
6.23 Catalyst Activity for Methanol Dehydration	6-80
6.24 DME Synthesis via Methanol Dehydration	6-81
6.25 Air Products LPDME™ Process	6-83
6.26 LPDME™ Slurry Bubble Column Reactor	6-85
6.27 LPDME™ Syngas Conversion versus CO ₂ Feed Concentration	6-85
6.28 Haldor Topsøe DME Process	6-87
7.1 Overall Production Scheme	7-1
7.2 Gas Island Schematic	7-2
7.3 Gasifier Configuration	7-10
7.4 Polygeneration Chemical Production	7-12
7.5 Conventional Chemical Production	7-13
7.6 Polygeneration Liquid Fuels Production	7-13
7.7 Conventional Liquid Fuels Production	7-14
7.8 Nexant’s Crude Oil Price Scenarios	7-15
7.9 Production Volume of Different Crude Oil Types	7-26
7.10 Crude Oil Price	7-29
7.11 Real Price of Crude Oil	7-33
7.12 Crude Oil Price Scenarios	7-34
7.13 Historical Chinese Coal Production	7-38
7.14 Coal production by Coal Mine Type in China	7-39
7.15 Historical Chinese Coal Consumption	7-40
7.16 Coal Sales Price of key State-owned Mines	7-42

7.17 Key State-run Coal Mines Coal Sales Price Forecast.....	7-43
7.18 Historical Thermal Coal Market Price	7-45
7.19 Forecast Chinese Thermal Coal Prices	7-46
10.1 United States Raw Material Prices	10-2
10.2 China Raw Material Prices	10-2
10.3 Methanol Cost of Production Comparison, U.S.	10-4
10.4 DME Cost of Production Comparison, U.S.....	10-5
10.5 F-T Liquids Cost of Production Comparison, U.S.	10-6
10.6 Gasoline Cost of Production Comparison, U.S.	10-7
10.7 Methanol Cost of Production Comparison, China.....	10-8
10.8 DME Cost of Production Comparison, China	10-9
10.9 F-T Liquids Cost of Production Comparison, China	10-10
10.10 Gasoline Cost of Production Comparison, China	10-11
10.11 Methanol Cost of Production Comparison, Eastern Europe/Eurasia.....	10-12
10.12 DME Cost of Production Comparison, Eastern Europe/Eurasia	10-13
10.13 F-T Liquids Cost of Production Comparison, Eastern Europe/Eurasia.....	10-14
10.14 Gasoline Cost of Production Comparison, Eastern Europe/Eurasia.....	10-15
10.15 Methanol Delivered Cost Comparison, U.S., 2007	10-16
10.16 Methanol Delivered Cost Comparison, U.S., 2010	10-17
10.17 Methanol Delivered Cost Comparison, U.S., 2015	10-17
10.18 Methanol Delivered Cost Comparison, Western Europe, 2007.....	10-18
10.19 Methanol Delivered Cost Comparison, Western Europe, 2010.....	10-19
10.20 Methanol Delivered Cost Comparison, Western Europe, 2015.....	10-20
10.21 DME Delivered Cost Comparison, U.S., 2007	10-21
10.22 DME Delivered Cost Comparison, U.S., 2010	10-22
10.23 DME Delivered Cost Comparison, U.S., 2015	10-22
10.24 DME Delivered Cost Comparison, Western Europe, 2007	10-23
10.25 DME Delivered Cost Comparison, Western Europe, 2010	10-24
10.26 DME Delivered Cost Comparison, Western Europe, 2015	10-24
10.27 F-T Liquids Delivered Cost Comparison, U.S., 2007.....	10-25
10.28 F-T Liquids Delivered Cost Comparison, U.S., 2010.....	10-26

10.29 F-T Liquids Delivered Cost Comparison, U.S., 2015.....	10-26
10.30 F-T Liquids Delivered Cost Comparison, Western Europe, 2007.....	10-27
10.31 F-T Liquids Delivered Cost Comparison, Western Europe, 2010.....	10-28
10.32 F-T Liquids Delivered Cost Comparison, Western Europe, 2015.....	10-29
10.33 Gasoline Delivered Cost Comparison, U.S., 2007.....	10-30
10.34 Gasoline Delivered Cost Comparison, U.S., 2010.....	10-31
10.35 Gasoline Delivered Cost Comparison, U.S., 2015.....	10-31
10.36 Gasoline Delivered Cost Comparison, Western Europe, 2007.....	10-32
10.37 Gasoline Delivered Cost Comparison, Western Europe, 2010.....	10-33
10.38 Gasoline Delivered Cost Comparison, Western Europe, 2015.....	10-33
10.39 Crude Oil Scenario Price Comparison.....	10-34
10.40 High Crude Price Methanol Cost of Production Comparison, U.S.	10-35
10.41 High Crude Price DME Cost of Production Comparison, U.S.....	10-36
10.42 High Crude Price F-T Liquids Cost of Production Comparison, U.S.	10-37
10.43 High Crude Price Gasoline Cost of Production Comparison, U.S.	10-38
10.44 High Crude Price Methanol Cost of Production Comparison, China	10-39
10.45 High Crude Price DME Cost of Production Comparison, China	10-40
10.46 High Crude Price F-T Liquids Cost of Production Comparison, China	10-41
10.47 High Crude Price Gasoline Cost of Production Comparison, China	10-42
10.48 High Crude Price Methanol Cost of Production Comparison, Eastern Europe/Eurasia.....	10-43
10.49 High Crude Price DME Cost of Production Comparison, Eastern Europe/Eurasia.....	10-44
10.50 High Crude Price F-T Liquids Cost of Production Comparison, Eastern Europe/Eurasia.....	10-45
10.51 High Crude Price Gasoline Cost of Production Comparison, Eastern Europe/Eurasia.....	10-46
10.52 High Crude Price Methanol Delivered Cost Comparison, U.S., 2010	10-47
10.53 High Crude Price Methanol Delivered Cost Comparison, U.S., 2015	10-48
10.54 High Crude Price Methanol Delivered Cost Comparison, Western Europe, 2010...	10-49
10.55 High Crude Price Methanol Delivered Cost Comparison, Western Europe, 2015...	10-50
10.56 High Crude Price DME Delivered Cost Comparison, U.S., 2010.....	10-51

10.57 High Crude Price DME Delivered Cost Comparison, U.S., 2015.....	10-52
10.58 High Crude Price DME Delivered Cost Comparison, Western Europe, 2010	10-53
10.59 High Crude Price DME Delivered Cost Comparison, Western Europe, 2015	10-54
10.60 High Crude Price F-T Liquids Delivered Cost Comparison, U.S., 2010.....	10-55
10.61 High Crude Price F-T Liquids Delivered Cost Comparison, U.S., 2015.....	10-56
10.62 High Crude Price F-T Liquids Delivered Cost Comparison, Western Europe, 2010.....	10-57
10.63 High Crude Price F-T Liquids Delivered Cost Comparison, Western Europe, 2015.....	10-58
10.64 Gasoline Delivered Cost Comparison, U.S., 2010.....	10-59
10.65 Gasoline Delivered Cost Comparison, U.S., 2015.....	10-60
10.66 Gasoline Delivered Cost Comparison, Western Europe, 2010.....	10-61
10.67 Gasoline Delivered Cost Comparison, Western Europe, 2015.....	10-62
11.1 USGC and NWE Premium Gasoline Prices	11-1
11.2 Gasoline & Light Virgin Naphtha Prices.....	11-2
11.3 Gasoline & Diesel Prices	11-3
11.4 No. 2 Heating Oil & Fuel Oil Prices.....	11-4
11.5 USGC & NWE Premium Gasoline Prices.....	11-5
11.6 Premium Gasoline & Naphtha Prices	11-6
11.7 Premium Gasoline & Diesel Prices.....	11-7
11.8 Gas Oil & Fuel Oil Prices	11-8
11.9 USGC & Singapore Premium Gasoline Prices.....	11-9
11.10 Premium Gasoline & Naphtha Prices	11-10
11.11 Premium Gasoline & Diesel/Gas Oil Prices	11-11
11.12 Singapore Upgrading Incentive High Sulfur Fuel Oil & Gas Oil.....	11-12

Table	Page
1.1 Chemicals Cost of Production Capacities.....	1-3
1.2 Liquid Fuels Cost of Production Capacities	1-4
1.3 Price Values – Used in Report Analysis	1-7
1.4 Prices of Feedstocks, on \$ per Million Btu Basis	1-7
1.5 Prices of Feedstocks, on \$ per Million Btu Basis	1-7
2.1 Major Proven Coal Reserves, by Country	2-8
4.1 Gasifier Types.....	4-3
4.2 Gasifier Typical Characteristics.....	4-3
4.3 Syngas Compositions for Entrained-Flow Gasifiers.....	4-4
4.4 Syngas Compositions for Moving and Fluid-Bed Gasifiers	4-5
4.5 Syngas Composition before Shift Adjustment.....	4-5
4.6 Typical Product Gas Composition	4-10
4.7 Feedstocks Gasified	4-12
4.8 Test Runs	4-19
4.9 GE Energy Experience.....	4-28
4.10 CO ₂ Removal	4-29
4.11 GE Energy IGCC Experience	4-30
4.12 MPG Feedstock Flexibility	4-49
4.13 MPG – Selection Criteria for Quench Configuration vs. Boiler Configuration	4-50
4.14 Comparison between Westinghouse Plasma Gasifier and Conventional Gasifier	4-56
4.15 Composition of Lignite Coal	4-59
4.16 Preliminary Material Balance for Individual Plasma Gasification Reactor.....	4-64
5.1 Summary of the Study Cases	5-6
6.1 Typical Vacuum Distillation Yields	6-6
6.2 Thermal Cracking and Visbreaking Yields.....	6-8
6.3 Direct Effect of Visbreaking on Reducing Residual Fuel Oil Production.....	6-8
6.4 Catalytic Reforming – Indicative Yield Data	6-11
6.5 Fluid Catalytic Cracking.....	6-15
6.6 Fluid Catalytic Cracking of Vacuum Distillates Typical Product Yields.....	6-16
6.7 Octane Improvement from Isomerization Process.....	6-17

6.8	Hydrocracking of Vacuum Distillates - Typical Product Yields	6-18
6.9	Alkylation versus Polymerization Yields	6-20
6.10	Typical Coking Yields for Different Crude Sources Feedstock Vacuum Tower Bottoms	6-23
6.11	Residual Catalytic Cracking Yields	6-24
6.12	Shell HYCON Process Yields	6-25
6.13	Vacuum Residue Desulfurization Yields and Product Qualities	6-25
6.14	H-Oil Process Yields.....	6-26
6.15	LC-Fining Yields	6-27
6.16	Typical Refinery Configurations	6-30
6.17	Product Slate with Qualities.....	6-31
6.18	Overview of Principal Petroleum Refining Processes	6-33
6.19	ExxonMobil FBSG Operating Conditions.....	6-39
6.20	ExxonMobil GTL Product Slate	6-43
6.21	Finished Product Makeup	6-46
6.22	Typical Product Slates of Sasol Reactors	6-49
6.23	Middle Distillate Product Split after Hydrocracking	6-53
6.24	Shell HPS and Hydrotreating Operating Conditions	6-54
6.25	SMDS Fuel Combustion Properties.....	6-54
6.26	Typical Statoil/PetroSA GTL Product Properties.....	6-55
6.27	F-T Catalyst Performance	6-57
6.28	Typical Properties of Statoil GTL Base Oil.....	6-59
6.29	Physical Properties of DME.....	6-79
7.1	Chemicals Cost of Production Capacities.....	7-3
7.2	Liquid Fuels Cost of Production Capacities	7-3
7.3	Pittsburgh #8 Coal Properties	7-9
7.4	Values as Used in Report Analysis.....	7-16
7.5	Prices of Feedstocks, on \$ per Million Btu Basis	7-17
7.6	Price of Feedstocks, on \$ per Million Btu Basis.....	7-17
7.7	Regional Coal Prices.....	7-18
7.8	Regional Utility and Wage Unit Costs.....	7-19
7.9	Capital Investment Location Factors, Relative to USGC	7-20

7.10 Shipping Costs for Chemicals.....	7-24
7.11 Shipping Costs for Liquid Fuels	7-25
7.12 Historical Crude Oil Prices	7-28
7.13 Crude Oil Price Scenarios.....	7-35
7.14 Coal Consumption by Sector, 1985-2005.....	7-40
7.15 Comparison of Salable Coal Cost and Thermal Coal Sales Price (Key State-owned Mines)	7-44
7.16 Comparison of Thermal Coal Market Price and Planned Contract	7-45
8.1 Cost of Production Estimate for: Syngas	8-2
8.2 Cost of Production Estimate for: Methanol	8-3
8.3 Cost of Production Estimate for: DME.....	8-5
8.4 Cost of Production Estimate for: FT Liquids.....	8-6
8.5 Cost of Production Estimate for: Gasoline	8-8
9.1 Cost of Production Estimate for: Methanol	9-2
9.2 Cost of Production Estimate for: DME.....	9-3
9.3 Cost of Production Estimate for: FT Liquids.....	9-5
9.4 Cost of Production Estimate for: Methanol	9-6
9.5 Cost of Production Estimate for: DME.....	9-8
9.6 Cost of Production Estimate for: FT Liquids.....	9-9
9.7 Cost of Production Estimate for: Methanol	9-11
9.8 Cost of Production Estimate for: DME.....	9-12
9.9 Cost of Production Estimate for: FT Liquids.....	9-14