

MARKETS AND PROFITABILITY

(Formerly Quarterly Business Analysis Supplement) **(Formerly Quarterly Business Analysis Supplement)**

Petrochemicals, Polymers, C1 Chemicals and
Fertilizers

Western Europe

May 2022



This Report was prepared by NexantECA, the Energy and Chemicals Advisory company ("NexantECA"). Except where specifically stated 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 and belief of NexantECA. The information has not been independently verified or otherwise examined to determine its accuracy, completeness or financial feasibility. Neither NexantECA, Subscriber nor any person acting on behalf of either shall have any liabilities for any loss or damage arising from or connected to the use of any information contained in this Report. NexantECA does not represent or warrant that any assumed conditions will come to pass.

The Report is for Subscriber's internal use only and shall be kept strictly confidential. The Report should not be otherwise reproduced, distributed or used without first obtaining prior written consent by NexantECA. Each Subscriber agrees to use reasonable effort to protect the confidential nature of the Report.

Copyright © by NexantECA (BVI) Ltd. 2022. All rights reserved.



Contents

1	Executive Summary	1
2	Methodology	2
2.1	Leader Laggard Plant Concept	2
2.2	Cost of Production Definition and Basis	4
2.2.1	Variable Costs	5
2.2.2	Direct Fixed Costs	7
2.2.2.1	Direct Plant Manpower	8
2.2.2.2	Direct Overhead	8
2.2.2.3	Maintenance	8
2.2.3	Allocated Fixed Costs	8
2.2.3.1	General Plant Overheads	9
2.2.3.2	Tax and Insurance	9
2.2.4	Technical Support/Royalty	9
2.2.5	Cash Costs	10
2.2.6	Corporate Overheads	10
2.2.7	Working Capital	11
2.2.8	Energy Taxation	11
2.3	Investment Costs	12
2.3.1	Inside Battery Limits	13
2.3.2	Outside Battery Limits	13
2.3.3	Miscellaneous Owner's Costs/Other Project Costs	14
2.4	Pricing Basis	15
2.5	Profitability Analysis and Basis	17
2.5.1	Variable Cost Margin	17
2.5.2	Cash Cost Margin	17
2.5.3	Integrated Costs and Margins	18
2.5.4	Return on Replacement Capital	19
3	Crude Oil, Refining and Petrochemical Feedstocks	20
3.1	Introduction	20
3.2	Refinery Configurations and Product Yields	21
3.2.1	Hydroskimming Refinery Configuration	21
3.2.2	Complex Cracking Refinery Configuration	22
3.2.3	Refinery Yields	24
4	Olefins	27
4.1	Ethylene	27
4.2	Propylene	38
4.3	Butadiene	41
5	Polyolefins	43
5.1	Low Density Polyethylene (LDPE)	43
5.2	Linear Low Density Polyethylene (LLDPE)	46



5.3	High Density Polyethylene (HDPE)	49
5.4	Polypropylene (PP)	54
6	Vinyls.....	57
6.1	Chlor-alkali / Ethylene Dichloride (EDC) / Vinyl Chloride Monomer (VCM)	57
6.2	Polyvinyl Chloride (PVC)	68
7	Aromatics.....	71
7.1	Reformate, Benzene, Toluene and Xylenes	71
7.1.1	Feedstocks and Processing	71
7.1.2	Valuation of Aromatics	72
7.1.2.1	Gasoline Valuation for Aromatics.....	72
7.1.3	Valuation of Pyrolysis Gasoline.....	75
7.1.4	Reformate.....	76
7.1.4.1	Reformer Models.....	76
7.1.5	Benzene	79
7.1.5.1	Pyrolysis Gasoline.....	79
7.1.5.2	Toluene Dealkylation Costs	80
7.1.6	Mixed Xylenes	83
7.1.6.1	Mixed Xylenes from Reformate.....	83
7.1.6.2	Mixed Xylenes from Toluene Disproportionation (TDP)	83
7.2	Cyclohexane.....	87
8	Styrenics	90
8.1	Styrene	90
8.2	Polystyrene.....	93
9	Butadiene Derivatives.....	96
9.1	Styrene Butadiene Rubber (SBR)	96
9.2	Acrylonitrile Butadiene Styrene (ABS)	98
9.3	Butadiene Rubber (BR)	100
10	Polyester and Intermediates	102
10.1	Ethylene Oxide (EO)/Mono Ethylene Glycol (MEG)	102
10.1.1	Ethylene Oxide	102
10.1.2	Mono-Ethylene Glycol (MEG)	103
10.2	Para-Xylene and Ortho-Xylene	108
10.2.1	Xylene Isomers.....	108
10.2.2	Integrated Xylenes Separation.....	110
10.3	Purified Terephthalic Acid (PTA)	115
10.4	Polyethylene Terephthalate (PET)	117
11	Propylene Derivatives.....	120
11.1	Acrylonitrile	120
11.2	Cumene/Phenol.....	123
11.3	Bisphenol-A (BPA)	130
11.4	Polycarbonate	132
11.5	Propylene Oxide	136
11.6	Oxo-Alcohols: Butanols and 2-Ethylhexanol (2EH)	142



12	Isocyanates	145
12.1	Methylene Diphenyl Diisocyanate (MDI) and Toluene Diisocyanate (TDI)	145
13	Methanol.....	158
13.1	Methanol.....	158
13.2	Methyl Tertiary Butyl Ether	161
14	Ammonia & Urea	163
14.1	Ammonia	163
14.2	Urea.....	166

Figures

Figure 1	Schematic Cost Curve	3
Figure 2	Production Cost Elements	4
Figure 3	Simplified Flow Diagram of a Typical Hydroskimming Refinery	21
Figure 4	Simplified Flow Diagram of a Typical Complex Refinery	22
Figure 5	Typical Refinery Yields	24
Figure 6	Octane Valuation – Western Europe Annual Average	74
Figure 7	Typical Xylenes Separation Scheme.....	109
Figure 8	<i>para</i> -Xylene Economics.....	110
Figure 9	MDI and Intermediate Production Costs	146
Figure 10	TDI and Intermediate Production Economics.....	148

Tables

Table 1	Refinery Configuration Assumptions	24
Table 2	Typical Refinery Product Yields	25
Table 3	Typical Atmospheric and Vacuum Distillation Yields for Brent Crude.....	25
Table 4	Major Refinery Process Units - Yield Summary	26
Table 5	Cost of Production for Ethylene – Leader Plant Process: Standard Steam Cracker – (Naphtha Feed, Standard Severity).....	30
Table 6	Cost of Production for Ethylene – Leader Plant Process: Basic Steam Cracker – (Naphtha Feed, Standard Severity).....	31
Table 7	Cost of Production for Ethylene – Leader Plant Process: Basic Steam Cracker (Ethane Feed).....	32
Table 8	Cost of Production for Ethylene – Leader Plant Process: Standard Steam Cracker - (Gas Oil Feed, Standard Severity)	33
Table 9	Cost of Production for Ethylene – Leader Plant Process: Standard Steam Cracker (Naphtha/Propane Flexible Feed)	34
Table 10	Cost of Production for Ethylene – Leader Plant Process: Standard Steam Cracker - (Mixed Butanes Feed)	35
Table 11	Cost of Production for Ethylene – Laggard Plant Process: Basic Steam Cracker – (Naphtha Feed, Intermediate Severity)	36
Table 12	Influence of Naphtha Cracker Severity on Yield Slate	37
Table 13	Cost of Production for Propylene Process: Propane Dehydrogenation	39
Table 14	Cost of Production for Propylene Process: Refinery Propylene Splitter - Alkylate Value Refinery C ₃ Feedstock	40
Table 15	Cost of Production for Butadiene Process: Extraction from Mixed C ₄	42



Table 16	Cost of Production for LDPE Liner Grade – Leader Plant Process: Tubular Reactor	44
Table 17	Cost of Production for LDPE Liner Grade – Laggard Plant Process: Autoclave Reactor	45
Table 18	Cost of Production for LLDPE – Leader Plant Process: Gas Phase.....	47
Table 19	Cost of Production for LLDPE – Laggard Plant Process: Gas Phase.....	48
Table 20	Cost of Production for HDPE Injection Moulding – Leader Plant Process: Gas Phase	50
Table 21	Cost of Production for HDPE Injection Moulding – Laggard Plant Process: Slurry	51
Table 22	Cost of Production for HDPE Blow Moulding – Leader Plant Process: Slurry	52
Table 23	Cost of Production for HDPE Blow Moulding – Laggard Plant Process: Slurry	53
Table 24	Cost of Production for Polypropylene – Leader Plant Process: Bulk	55
Table 25	Cost of Production for Polypropylene – Laggard Plant Process: Slurry.....	56
Table 26	Cost of Production for Chlorine – Leader Plant Process: Membrane (Net Basis Spot Caustic).....	60
Table 27	Cost of Production for Chlorine – Illustrative Laggard Plant Process: Mercury Cell (Net Basis Spot Caustic)	61
Table 28	Cost of Production for Chlor-alkali – Leader Plant Process: Membrane (ECU Basis).....	62
Table 29	Cost of Production for Chlor-alkali – Illustrative Laggard Plant Process: Mercury Cell (ECU Basis)	63
Table 30	Cost of Production for Ethylene Dichloride – Leader Plant Process: Direct Chlorination (Chlorine on Net Basis)	64
Table 31	Cost of Production for Ethylene Dichloride – Laggard Plant Process: Direct Chlorination (Chlorine on Net Basis)	65
Table 32	Cost of Production for Vinyl Chloride – Leader Plant Process: Balanced Oxy-Chlorination (Chlorine on ECU Basis)	66
Table 33	Cost of Production for Vinyl Chloride – Laggard Plant Process: Balanced Oxy-Chlorination (Chlorine on ECU Basis)	67
Table 34	Cost of Production for PVC – Leader Plant Process: Suspension Polymerisation	69
Table 35	Cost of Production for PVC – Laggard Plant Process: Suspension Polymerisation	70
Table 36	Typical BTX Compositions from Pygas and Reformate	71
Table 37	Cost of Production for Reformate – Leader Plant Process: CCR Reforming.....	77
Table 38	Cost of Production for Reformate – Laggard Plant Process: SR Reforming	78
Table 39	Pyrolysis Gasoline and Aromatics Yields in Steam Crackers	80
Table 40	Effect of Severity on Pyrolysis Gasoline and Aromatics Yields.....	80
Table 41	Cost of Production for Benzene – Leader Plant Process: Extractive Distillation of Pygas.....	81
Table 42	Cost of Production for Benzene – Laggard Plant Process: Toluene HDA (Gasoline Value Toluene)	82
Table 43	Cost of Production for Mixed Xylenes – Leader Plant Process: CCR Reformate Extraction.....	84
Table 44	Cost of Production for Mixed Xylenes – Laggard Plant Process: SR Reformate Extraction.....	85
Table 45	Cost of Production for Mixed Xylenes – Leader Plant Process: Toluene Disproportionation (Gasoline Value Toluene)	86
Table 46	Cost of Production for Cyclohexane – Leader Plant Process: Benzene Hydrogenation	88



Table 47	Cost of Production for Cyclohexane Laggard Plant Process: Benzene Hydrogenation	89
Table 48	Cost of Production for Styrene – Leader Plant Process: Liquid Phase Alkylation/Dehydrogenation.....	91
Table 49	Cost of Production for Styrene – Laggard Plant Process: Gas Phase Alkylation/Dehydrogenation.....	92
Table 50	Cost of Production for Polystyrene – Leader Plant Process: Mass (Purchased Styrene)	94
Table 51	Cost of Production for Polystyrene – Laggard Plant Process: Mass (Purchased Styrene)	95
Table 52	Cost of Production for SBR Process: Emulsion (Purchased Butadiene & Styrene)	97
Table 53	Cost of Production for ABS Process: Emulsion (Purchased Acrylonitrile, Butadiene & Styrene).....	99
Table 54	Cost of Production for Butadiene Rubber Process: Ni Catalyst (Purchased Butadiene)	101
Table 55	Cost of Production for Ethylene Oxide – Leader Plant Process: Direct Oxidation.....	104
Table 56	Cost of Production for Ethylene Oxide – Laggard Plant Process: Direct Oxidation.....	105
Table 57	Cost of Production for Mono Ethylene Glycol – Leader Plant Process: Direct Oxidation and Ethylene Oxide Hydrolysis	106
Table 58	Cost of Production for Mono Ethylene Glycol - Laggard Plant Process: Direct Oxidation and Ethylene Oxide Hydrolysis	107
Table 59	Xylene Isomer Distribution in Feedstocks and Products	108
Table 60	Cost of Production for Para-Xylene – Leader Plant Process: Isom/Separation (Purchased Mixed-Xylenes)	112
Table 61	Cost of Production for Para-Xylene – Laggard Plant Process: Isom/Separation (Purchased Mixed Xylenes).....	113
Table 62	Cost of Production for Para-Xylene Process: Integrated Aromatics Complex (Reformer, TDP Transalkylation).....	114
Table 63	Cost of Production for PTA – Leader Plant Process: Para-xylene Oxidation	116
Table 64	Cost of Production for PET Bottle Grade – Leader Plant Process: PTA Polycondensation and Solid Stating.....	118
Table 65	Cost of Production for PET Bottle Grade – Laggard Plant Process: PTA Polycondensation and Solid Stating.....	119
Table 66	Cost of Production for Acrylonitrile – Leader Plant Process: Propylene Ammonoxidation	121
Table 67	Cost of Production for Acrylonitrile – Laggard Plant Process: Propylene Ammonoxidation	122
Table 68	Cost of Production for Cumene – Leader Plant Process: Benzene Alkylation.....	124
Table 69	Cost of Production for Cumene Laggard Plant Process: Benzene Alkylation.....	125
Table 70	Cost of Production for Phenol – Leader Plant Process: Cumene Oxidation	126
Table 71	Cost of Production for Phenol – Laggard Plant Process: Cumene Oxidation	127
Table 72	Cost of Production for Phenol – Leader Plant Process: Integrated Cumene/Phenol	128
Table 73	Cost of Production for Phenol – Laggard Plant Process: Integrated Cumene/Phenol.....	129
Table 74	Cost of Production for BPA Process: Ion Exchange Resin	131
Table 75	Cost of Production for Polycarbonate Process: Interfacial.....	133
Table 76	Cost of Production for Polycarbonate Process: Melt Phase (non-phosgene)	134
Table 77	Cost of Production for 1:1Syngas Process: Fuel Oil Partial Oxidation	135



Table 78	Cost of Production for Propylene Oxide Process: Chlorohydrin Propylene Oxide (CHPO)	138
Table 79	Cost of Production for Propylene Oxide Process: Propylene Oxide Styrene Monomer (POSM)	139
Table 80	Cost of Production for Propylene Oxide Process: Hydrogen Peroxide Propylene Oxide (HPPO)	140
Table 81	Cost of Production for Hydrogen Peroxide Process: Anthraquinone Auto Oxidation	141
Table 82	Cost of Production for <i>n</i> -butanol Process: Oxo Selector 30.....	143
Table 83	Cost of Production for 2EH Process: Oxo Selector 30.....	144
Table 84	Cost of Production for MDI Process: Aniline Condensation and MDA Phosgenation.....	149
Table 85	Cost of Production for Aniline Process: MNB Hydrogenation	150
Table 86	Cost of Production for Mono Nitro Benzene Process: Benzene Nitration	151
Table 87	Cost of Production for Toluene Dilsocyanate Process: DNT Hydrogenation and Phosgenation.....	152
Table 88	Cost of Production for DiNitroToluene Process: Toluene Nitration	153
Table 89	Cost of Production for Nitric Acid Process: Ammonia Oxidation (60% Acid)	154
Table 90	Cost of Production for Sulphuric Acid Process: Contact Process (98% Acid)	155
Table 91	Cost of Production for Hydrogen and Carbon Monoxide (HYCO) Process: Natural gas reforming, PSA & Cryogenic separation.....	156
Table 92	Cost of Production for Formaldehyde (38%) Process: Methanol Oxidation.....	157
Table 93	Cost of Production for Methanol Process: Natural Gas Reforming	159
Table 94	Cost of Production for Methanol Process: Vacuum Residue	160
Table 95	Cost of Production for MTBE Process: Butylene ex FCC	162
Table 96	Cost of Production for Ammonia – Leader Plant Process: Natural Gas Reforming	164
Table 97	Cost of Production for Ammonia – Laggard Plant Process: Natural Gas Reforming	165
Table 98	Cost of Production for Urea – Leader Plant Process: Ammonia Stripping.....	167
Table 99	Cost of Production for Urea – Laggard Plant Process: Ammonia Stripping.....	168