

Refinery-Petrochemical Integration

Table of Contents

A Report by **NexantThinking™**

Process Evaluation/Research Planning (PERP) Program

PERP Report 2015S3 – Published December 2015

www.nexantthinking.com

Section	Page
1 Executive Summary	1
1.1 INTRODUCTION	1
1.1.1 The Refinery – Petrochemical Interface	1
1.2 INTEGRATION OPTIONS	3
1.3 REGIONAL ANALYSIS	5
1.4 INCREMENTAL ECONOMIC ANALYSIS	6
1.4.1 Impact on the Refinery	7
1.4.2 Incremental Revenues and Margins	7
1.5 OWNERSHIP STRUCTURES	9
2 Introduction	10
2.1 INTRODUCTION	10
2.1.1 Crude Oil Refining	11
2.1.2 Petrochemical Production	12
2.1.3 The Refinery – Petrochemical Interface	16
3 Technical Integration Considerations	22
3.1 INTRODUCTION	22
3.2 REFINERY INTEGRATED WITH A STEAM CRACKER	22
3.2.1 Background	22
3.2.2 Feedstock Influence on Steam Cracking Technology	24
3.3 REFINERY INTEGRATED PROPYLENE PRODUCTION	36
3.3.1 Background	36
3.3.2 Refinery Propylene	38
3.3.3 Purification of Refinery Grade Propylene	39
3.4 REFINERY-INTEGRATED AROMATICS PRODUCTION	44
3.4.1 Background	44
3.4.2 Integrated Aromatics Complex	44

3.5	REFINERY-INTEGRATED STEAM CRACKER AND AROMATICS PRODUCTION	51
3.5.1	Background	51
4	Regional Analysis	53
4.1	BACKGROUND	53
4.2	REFINERY-INTEGRATED ETHYLENE PRODUCTION	53
4.2.1	Global Analysis	53
4.3	REFINERY INTEGRATED PROPYLENE PRODUCTION	71
4.3.1	Background	71
4.3.2	Global Analysis	72
4.3.3	Regional Analysis	73
4.4	REFINERY INTEGRATED AROMATICS PRODUCTION	74
4.4.1	Global Analysis	74
4.4.2	Regional Analysis	75
5	Economic Analysis	76
5.1	INTRODUCTION	76
5.2	MODELING BASIS	78
5.2.1	Refinery Configuration	78
5.2.2	Western Europe	83
5.2.3	U.S. Gulf Coast and Asia	86
5.3	INCREMENTAL ECONOMIC ANALYSIS	87
5.3.1	Introduction	87
5.3.2	Western Europe	87
5.3.3	U.S. Gulf Coast	89
5.3.4	Asia	90
6	Ownership Structures	93
6.1	INTRODUCTION	93
6.2	OWNERSHIP STRUCTURES	94
6.2.1	Model A - Separate Ownership	94
6.2.2	Model B - Single Site – Separate Ownership	94
6.2.3	Model C - Single Site – Same Ownership	94
6.2.4	Governance	95
6.2.5	Exchanges and Transfers	96
6.3	COMPANY PROFILES	101
6.3.1	Singapore Integrated Manufacturing Site	101
6.3.2	OMV	104
6.3.3	PetroRabigh	106
7	References	108
Appendix		Page

A	Definitions of Capital Cost Terms Used in Process Economics.....	A-1
B	Definitions of Operating Cost Terms Used in Process Economics	B-1
C	PERP Program Title Index (2006 - 2015)	C-1

Figure	Page
1.1 Global Ethylene Production by Feedstock Type	1
1.2 Summary of Refinery Petrochemical Interface Options	3
1.3 Refinery Integrated Steam Cracker	4
1.4 Refinery – Aromatics Interface	4
1.5 Refinery – Aromatics-Steam Cracker Interface.....	5
1.6 Regional Refinery Integrated Ethylene Production	6
1.7 Refinery-Petrochemical Integration - Changes in Product Tonnage.....	7
1.8 Overall Revenue – Standalone Refinery and Integrated Complex	8
1.9 Comparative Gross Margins.....	9
1.10 Refinery Petrochemical Integration Models	9
2.1 Historical Refinery Throughput and Petrochemical Production	10
2.2 Steam Cracker Yields by Feedstock Type	13
2.3 Global Ethylene Production by Feedstock Type	14
2.4 Refinery Streams Produced by Fractional Distillation	15
2.5 Basic Petrochemicals and Fuel Prices	16
2.6 Feedstock Effect on Co-Product Yield	18
2.7 Summary of Refinery Petrochemical Interface Options	21
3.1 Global Ethylene Production by Process.....	22
3.2 Regional Variation in Steam Cracker Feedstock	23
3.3 Furnace and Separation Section Overview.....	25
3.4 Typical Mixed Feed Cracker Furnace Layout	26
3.5 Refinery Integrated Steam Cracker.....	27
3.6 Consumption Factors for Different Feedstocks.....	27
3.7 Alternative Value of Refinery Dry Gas	28
3.8 Refinery Dry Gas Feed to Ethylene Complex	29
3.9 Quarterly Propane and Naphtha Prices	30
3.10 Ethylene Yield and Hydrogen Content of Feedstock	32
3.11 Comparative Coking Rates	33
3.12 Simplified Once Through Hydrocracking Flow Scheme.....	34
3.13 Ethylene Yields as a Function of BMCI	35
3.14 Light Naphtha Paraffin Content for Various Crude Oils	36
3.15 Global Propylene Production by Process.....	37
3.16 Propylene Yield from Various Refinery Process Units	38
3.17 Propylene Purification	41

3.18	Price Differentials between Polymer and Chemical Grade Refinery Grade	42
3.19	Representative Aromatics Complex.....	46
3.20	Refinery – Aromatics Interface	48
3.21	Refinery – Aromatics Interface	48
3.22	Refinery – Aromatics Interface	49
3.23	Octane Balance – Aromatics Production	50
3.24	Refinery – Aromatics- Steam Cracker Interface.....	52
4.1	Global Ethylene Production by Technology	53
4.2	Global Ethylene Capacity by Feedstock	54
4.3	Extent of Refinery Petrochemical Integration	55
4.4	West European Ethylene Production	56
4.5	Refinery Integrated Ethylene Production in Western Europe	56
4.6	Pressures Facing West European Ethylene Production	57
4.7	West European Ethylene Pipeline Network	58
4.8	Middle East Ethylene Production	59
4.9	Refinery Integrated Ethylene Production – Middle East	60
4.10	Pressures on Middle East Ethylene Production	61
4.11	North America Ethylene Production	61
4.12	Refinery Integrated Ethylene Production – North America	62
4.13	U.S. Unconventional Domestic Crude Production	63
4.14	USGC Propylene Prices.....	64
4.15	Pressures Facing Refinery Integrated Ethylene Producers	64
4.16	South American Ethylene Production	65
4.17	East European Ethylene Production	67
4.18	South and South-East Asian Ethylene Production.....	68
4.19	Refinery Integrated Ethylene Production – South Asia and South-East Asia.....	68
4.20	East Asian Ethylene Production	69
4.21	East Asian Refinery-Integrated Ethylene Analysis.....	70
4.22	Refinery Integrated Ethylene Production	70
4.23	Global Propylene Capacity (<i>By Technology – 2014</i>)	72
4.24	Global Propylene Capacity (<i>Approx. 100 000 tons per year</i>).....	72
4.25	Extent of Refinery Integration – Propylene Capacity	73
4.26	Global <i>para</i> -Xylene Capacity.....	74
4.27	<i>para</i> -Xylene to Feedstock Differential	75
4.28	Extent of Refinery Petrochemical Integration – <i>para</i> -Xylene Capacity	75

5.1	Global Refining Margins	76
5.2	West European Cash Margin Index	77
5.3	West European Refinery and Petrochemicals Indices	77
5.4	Refinery Configuration.....	79
5.5	Refinery – Steam Cracker	80
5.6	Refinery Fuel System	81
5.7	Refinery Production – FCC/Visbreaking Refinery	83
5.8	Naphtha Disposition	84
5.9	Available Gasoline Blending Components	84
5.10	Changes in Gasoline Blend Components	85
5.11	Refinery – Petrochemical Yields	85
5.12	Changes in Product Tonnage.....	86
5.13	Overall Revenue – Standalone Refinery and Integrated Complex	87
5.14	Revenue Breakdown for Integrated Complex	88
5.15	Comparative Gross Margins.....	89
5.16	Revenue – Refinery and Integrated Complex	89
5.17	Revenue Breakdown – Integrated Complex	90
5.18	Comparative Gross Margins.....	90
5.19	Overall Revenue – Standalone Refinery and Integrated Complex	91
5.20	Revenue Breakdown – Integrated Complex	91
5.21	Comparative Gross Margins.....	92
6.1	Refinery Petrochemical Integration Models	94
6.2	Governance Models	96
6.3	Naphtha Pricing Variation.....	98
6.4	Transfer Stream Revenue	99
6.5	Transfer Stream Revenue	100
6.6	Feedstock Transfer Price – Effect on IRR.....	101
6.7	Singapore Integrated Manufacturing Complex.....	103
6.8	Schwechat and Burghausen	105
6.9	PetroRabigh.....	107

Table	Page
1.1 Select Refinery Streams and Alternative Uses	2
2.1 Select Refinery Streams and Alternative Uses	16
2.2 Mixed C ₄ Fraction Composition	19
2.3 Pyrolysis Gasoline Composition (mol%)	19
2.4 Pyrolysis Fuel Oil Composition and Properties	20
3.1 Sources of Propylene Production	37
3.2 Typical FCC Process Yields	39
3.3 Propylene Grade Specifications	40
3.4 Cost of Production – Polymer Grade Propylene	43
3.5 Most Common Aromatics and their End Uses	44
3.6 Aromatics Complex Yields	47
3.7 Gasoline Blend Details	50
4.1 Comparison of Conventional and Non-Conventional U.S. Crudes	63
5.1 Major Refinery Process Unit Capacities	81
5.2 Refined Products and Petrochemicals Pricing Basis	83
6.1 Potential Exchange Stream Pricing Guidelines	97
6.2 Singapore Refinery Process Units	102
6.3 Petrochemicals Products	102

Nexant Thinking™

Process Evaluation/Research Planning



The NexantThinking™ Process Evaluation/Research Planning (PERP) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. PERP reports are available as a subscription program or on a single report basis.

Contact Details:

New York: Marcos Nogueira Cesar, Vice President, Global Products, E&CA: Nexant Thinking™
Phone: + 1-914-609-0324, e-mail: mcesar@nexant.com

New York: Heidi Junker Coleman, Global Programs Support Manager
Phone: + 1-914-609-0381, e-mail: hcoleman@nexant.com

Nexant, Inc. (www.nexant.com) is a leading management consultancy to the global energy, chemical, and related industries. For over 38 years, Nexant 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 San Francisco (California), White Plains (New York), and London (UK), and satellite offices worldwide.

Copyright © by Nexant Inc. 2015. All Rights Reserved.