

PERP Report

***Benefits of Refinery/Petrochemical
Integration***

06/07S7

September 2007



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

Copyright© by Nexant, Inc. 2007

This Report was prepared by Nexant, Inc. ("Nexant") and is part of ChemSystems Process Evaluation/Research Planning (PERP) Program. 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. The aforesaid information has not been independently verified or otherwise examined to determine its accuracy, completeness, or 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 shall not be reproduced, distributed, or used outside Subscriber's organization 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 Summary	1
1.1 INTEGRATION DISCUSSION AND ANALYSIS	1
1.1.1 Capital Investment	4
1.1.2 Operating Costs.....	4
1.1.3 Other Savings.....	5
1.1.4 Eliminating Steps and/or Close-Coupling Units.....	5
1.2 ECONOMIC ANALYSIS	6
1.2.1 Investment.....	6
1.2.2 Cost of Production	8
1.3 COMMERCIAL ANALYSIS.....	11
1.3.1 United States	11
1.3.2 Western Europe.....	13
1.3.3 Asia	14
1.4 CONCLUSIONS.....	16
2 Integration Discussion and Analysis	18
2.1 OVERVIEW	18
2.1.1 Introduction.....	18
2.1.2 Outline of Study	18
2.2 INTEGRATION - GENERAL	19
2.2.1 Capital Investment	19
2.2.2 Operating Costs.....	19
2.2.3 Other Savings.....	20
2.2.4 Eliminating Steps and/or Close-Coupling Units.....	20
2.3 REFINERY – PETROCHEMICAL INTERFACE	24
2.3.1 Overview.....	24
2.3.2 Flexibility	29
2.4 REFINERY/OLEFINS/AROMATICS SYNERGIES.....	31
2.4.1 Synergies.....	31
2.4.2 Recovery from Refinery Streams.....	33

2.4.3	Steam Cracker Feedstocks	36
2.4.4	Ethylene Plant Products	38
2.4.5	Aromatics Plant Products	38
2.5	DOWNSTREAM SYNERGIES	39
2.5.1	Olefins	39
2.5.2	Aromatics	41
2.6	OTHER OPPORTUNITIES FOR INTEGRATION	41
2.7	CONCLUSIONS	43
3	Economic Analysis	44
3.1	BASIS	44
3.1.1	Pricing Basis	44
3.1.2	Investment Basis	45
3.1.3	Cost of Production Basis	45
3.2	INVESTMENT	47
3.2.1	ISBL	47
3.2.2	OSBL	47
3.2.3	Other Project Costs	49
3.2.4	Cost Curves	49
3.3	ECONOMICS	53
3.3.1	Cost of Production of Ethylene	53
3.3.2	Cost of Production of <i>para</i> -Xylene	57
3.3.3	Cost of Production of Ethylene Glycol	57
3.3.4	Cost of Production of Styrene	57
3.3.5	Cost of Production of PTA	65
3.3.6	Cost of Production of PET	65
3.3.7	Intangibles	74
3.4	CONCLUSIONS	74
4	Commercial Analysis	75
4.1	INTRODUCTION	75
4.2	UNITED STATES	76
4.2.1	Overview	76

4.2.2	ExxonMobil	77
4.3	WESTERN EUROPE	79
4.3.1	Overview	79
4.3.2	Total	79
4.4	ASIA	81
4.4.1	Overview	81
4.4.2	Reliance.....	82
Appendix		Page
A	Elements of Nexant's ChemSystems Capital Cost Estimates	A-1
B	PERP Program Title Index	B-1

Figure	Page
1.1 Refinery Petrochemical Integration Opportunities	3
1.2 Ethylene Cost of Production	9
1.3 Styrene Cost of Production	9
1.4 PET Cost of Production	10
1.5 MEG, PTA, and PX Cost of Production	10
2.1 Refinery Petrochemical Integration Opportunities	26
2.2 Refinery/Olefin/Aromatics Integrated Streams	32
2.3 Simplified Flow Diagram – Aromatics Facility.....	34
2.4 Ethylene Plant Block Flow Diagram Naphtha Feed Case Plus Cat Cracker Offgas .	35
2.5 Simplified Flow Diagram – Downstream Facilities	40
3.1 Flat Bottom Storage Tank Cost Curves	50
3.2 Pressure Sphere Cost Curves	50
3.3 Recirculating Cooling Water System Cost Curves.....	51
3.4 Steam Boiler Cost Curves.....	51
3.5 Buildings Cost Curves	52
3.6 Ethylene Cost of Production Scenarios.....	53
3.7 Styrene Cost of Production Scenarios.....	65
3.8 PET Cost of Production	66
4.1 Reliance.....	83

Table	Page
1.1 Refineries Streams Used for Petrochemicals.....	2
1.2 OSBL Savings.....	7
2.1 Refineries Streams Used for Petrochemicals.....	25
2.2 KBR Case Studies Overall Material Balances.....	28
2.3 Refinery Petrochemical Products Flexibility	30
2.4 Value Chain for Olefin Feedstocks.....	39
2.5 Value Chain for Aromatic Feedstocks.....	41

3.1	Price and Utility Basis	44
3.2	OSBL Savings.....	48
3.3	Cost of Production Estimate for: Ethylene Process: Steam Cracking, Stand-alone	54
3.4	Cost of Production Estimate for: Ethylene Process: Steam Cracking, Integrated with Refinery	55
3.5	Cost of Production Estimate for: Ethylene Process: Steam Cracking with CCOG, Integrated with Refinery	56
3.6	Cost of Production Estimate for: <i>para</i> -Xylene Process: Naphtha Hydrotreater/CCR Reformer/Adsorption/Isomerization EB Dealkylation)/Toluene Disproportionation, Stand-Alone.....	58
3.7	Cost of Production Estimate for: <i>para</i> -Xylene Process: Naphtha/Hydrotreater/CCR Reformer/Adsorption/Isomerization EB Dealkylation/Toluene Disproportionation, Integrated with Refinery	59
3.8	Cost of Production Estimate for: Ethylene Glycol Process: Ethylene Oxidation/EO Hydration – Scientific Design, Stand-Alone	60
3.9	Cost of Production Estimate for: Ethylene Glycol Process: Ethylene Oxidation/EO Hydration – Scientific Design, Integrated with Steam Cracker	61
3.10	Cost of Production Estimate: Styrene Monomer Process: Liquid Phase Alkylation (Zeolite Catalyst)/Catalytic Dehydrogenation, Stand-Alone	62
3.11	Cost of Production Estimate for: Styrene Monomer Process: Liquid Phase Alkylation (zeolite Catalyst)/Catalytic Dehydrogenation, Integrated with Steam Cracker.....	63
3.12	Cost of Production Estimate for: Styrene Monomer Process: Reactive Distillation with Dilute Ethylene, Integrated with Refinery.....	64
3.13	Cost of Production Estimate for: PTA Process: Oxidation/Hydrogenation, Stand-Alone	67
3.14	Cost of Production Estimate for: PTA Process: Oxidation/Hydrogenation, Integrated.....	68
3.15	Cost of Production Estimate for: PET Melt-Phase Chip, with Comonomer Process: Conventional, Non-integrated	69
3.16	Cost of Production Estimate for: PET Melt-Phase Chip, with Comonomer Process: Conventional Integrated with PTA.....	70
3.17	Cost of Production Estimate for: PET Melt-Phase Chip, with Comonomer Process: Conventional, Integrated with EG	71

3.18	Cost of Production Estimate for: PET Melt-Phase Chip, with Comonomer Process: Conventional Integrated with PTA and EG.....	72
3.19	Cost of Production Estimate for: PET Melt-Phase Chip, with Comonomer Process: Conventional, Integrated with PTA and EG (both further back integrated)	73
4.1	ExxonMobil Petrochemical Capacity – Baytown, TX	78
4.2	Total Petrochemical Capacity – Gonfreville, France.....	80
4.3	Reliance Petrochemical Capacity – Gujarat, India	84