

IHS CHEMICAL

Propylene by Olefin Conversion Processes

Process Economics Program Report 267C

August 2017

ihc.com

PEP Report 267C

Propylene by Olefin
Conversion Processes

Girish Ballal
Principal Analyst



PEP Report 267C

Propylene by Olefin Conversion Processes

Girish Ballal, Principal Analyst

Abstract

Propylene is second only to ethylene in worldwide production. Steam cracking of various hydrocarbon feeds is the largest source for both ethylene and propylene. The amount of propylene produced from these traditional sources is limited. However, the demand for propylene is increasing at a rate higher than that for ethylene. Hence, there exists a need to produce more propylene than is obtainable from a typical steam cracker. Some of the additional demand can be met from on-purpose, standalone propylene production facilities. Olefins interconversion processes provide another option for converting lighter or heavier olefins generated from a cracker, in order to increase net propylene production.

With the above in perspective, we present in this report a review and technoeconomic analysis of some of the olefins interconversion processes, mostly in a steam cracker environment. The processes analyzed in this report include the Omega™ process by Asahi Kasei to produce propylene from C₄ olefinic raffinate by catalytic conversion, and the metathesis process by LyondellBasell to produce polymer-grade propylene starting from ethylene. This process also produces 1-butene as by-product in addition to propylene. The third process is the olefins conversion process (OCP™) by Total/UOP, which converts C₄ olefinic raffinate to produce propylene by catalytic conversion. The processing capacity for all processes is 110 million lb/year (~50,000 MT/year) of propylene production per year.

The production economics assessment in this report is based on a US Gulf Coast location. However, an iPEP Navigator module (an excel-based computer costing model developed by IHS) is attached with this report to allow a quick calculation of the process economics for three other major regions also—Germany, Japan, and China. For every process, the module also allows production economics to be reported in English or metric units in each region.

The technological and economic assessment of the processes is PEP's independent interpretation of the companies' commercial processes based on information presented in open literature, such as patents or technical articles, and may not reflect in whole or in part the actual plant configuration. We do believe that they are sufficiently representative of the processes and process economics within the range of accuracy necessary for economic evaluations of the conceptual process designs.

Contents

| | | |
|----------|--|-----------|
| 1 | Introduction | 8 |
| 2 | Executive summary | 10 |
| | Commercial overview | 10 |
| | Sources | 10 |
| | End uses | 11 |
| | Capacities, supply, and demand | 11 |
| | Technology overview | 13 |
| | Process economics | 14 |
| | Capital costs | 15 |
| | Production costs | 16 |
| | Environmental footprint | 17 |
| | Summary and conclusions | 18 |
| 3 | Industry status | 19 |
| | Sources and uses | 19 |
| | Capacities | 20 |
| | Top producers | 25 |
| | Feedstock and by-products | 25 |
| | Propylene product | 25 |
| | 1-Butene by-product | 26 |
| | Ethylene feedstock | 26 |
| | C4 raffinate feedstock | 27 |
| | Price differentials | 28 |
| 4 | Technology | 29 |
| | Olefins interconversion | 29 |
| | Process chemistry and catalysis | 30 |
| | Metathesis | 30 |
| | Olefins catalytic cracking | 31 |
| | Ethylene-to-propylene (ETP) process by Mitsubishi | 35 |
| | Commercial interconversion processes | 36 |
| | Omega™ process by Asahi Kasei | 36 |
| | Superflex™ process by KBR/LyondellBasell | 37 |
| | Mobil Olefins Interconversion process (MOI™) | 40 |
| | Propylur™ process by Lurgi/Linde | 41 |
| | Olefins Cracking Process (OCP™) by Total Petrochemicals/UOP | 42 |
| | Olefins Conversion Technology (OCT™) by CB&I/Lummus | 43 |
| | Propylene and 1-butene production via metathesis by LyondellBasell | 44 |
| | Ethylene-to-propylene (ETP) process by Mitsubishi | 45 |
| | Patent review | 45 |
| | Asahi Kasei | 45 |
| | Mitsubishi | 46 |
| | LyondellBasell | 46 |
| | Total Petrochemicals/UOP | 47 |
| | Axens | 48 |
| | CB&I/Lummus | 49 |

IHS™ CHEMICAL

COPYRIGHT NOTICE AND DISCLAIMER © 2017 IHS. For internal use of IHS clients only.

No portion of this report may be reproduced, reused, or otherwise distributed in any form without prior written consent, with the exception of any internal client distribution as may be permitted in the license agreement between client and IHS. Content reproduced or redistributed with IHS permission must display IHS legal notices and attributions of authorship. The information contained herein is from sources considered reliable, but its accuracy and completeness are not warranted, nor are the opinions and analyses that are based upon it, and to the extent permitted by law, IHS shall not be liable for any errors or omissions or any loss, damage, or expense incurred by reliance on information or any statement contained herein. In particular, please note that no representation or warranty is given as to the achievement or reasonableness of, and no reliance should be placed on, any projections, forecasts, estimates, or assumptions, and, due to various risks and uncertainties, actual events and results may differ materially from forecasts and statements of belief noted herein. This report is not to be construed as legal or financial advice, and use of or reliance on any information in this publication is entirely at client's own risk. IHS and the IHS logo are trademarks of IHS.



| | | |
|----------|---|------------|
| 5 | Omega™ process by Asahi Kasei | 50 |
| | Process description | 50 |
| | Section 100—Reactors | 50 |
| | Section 200—Product recovery | 50 |
| | Process discussion | 53 |
| | Feedstock | 53 |
| | Reaction and product recovery | 53 |
| | Catalyst | 53 |
| | Process waste effluents | 54 |
| | Materials of construction | 54 |
| | Cost estimates | 56 |
| | Fixed-capital costs | 56 |
| | Production costs | 57 |
| | Environmental footprint | 64 |
| 6 | Metathesis process by LyondellBasell | 65 |
| | Process description | 65 |
| | Section 100—Dimerization section | 65 |
| | Section 200—Metathesis section | 65 |
| | Process discussion | 68 |
| | Feedstock | 68 |
| | Reaction and product recovery | 68 |
| | Catalyst | 68 |
| | Process waste effluents | 69 |
| | Materials of construction | 69 |
| | Cost estimates | 71 |
| | Fixed-capital costs | 71 |
| | Production costs | 72 |
| | Environmental footprint | 79 |
| 7 | Olefins Conversion Process (OCP™) by Total/UOP | 80 |
| | Process description | 80 |
| | Section 100—Reactors | 80 |
| | Section 200—Product recovery | 80 |
| | Process discussion | 83 |
| | Feedstock | 83 |
| | Reaction and product recovery | 83 |
| | Catalyst | 84 |
| | Process waste effluents | 85 |
| | Materials of construction | 85 |
| | Cost estimates | 87 |
| | Fixed-capital costs | 87 |
| | Production costs | 87 |
| | Environmental footprint | 94 |
| | Appendix A—Cited references | 95 |
| | Appendix B—Patent summaries | 99 |
| | Appendix C—Design and cost basis | 105 |
| | Design conditions | 106 |
| | Cost bases | 106 |
| | Capital investment | 106 |
| | Production costs | 107 |
| | Effect of operating level on production costs | 107 |
| | Appendix D— Process flow diagrams | 109 |

Tables

| | |
|---|----|
| Table 2.1 Comparison of production economics | 15 |
| Table 2.2 Comparison of environmental footprints | 17 |
| Table 3.1 Top 25 global propylene (polymer/chemical) grade producers | 25 |
| Table 5.1 Design basis and assumptions—Asahi Kasei Omega™ process | 51 |
| Table 5.2 Feedstock composition—Asahi Kasei Omega™ process | 51 |
| Table 5.3 Stream summary—Asahi Kasei Omega™ process | 52 |
| Table 5.4 Major equipment—Asahi Kasei Omega™ process | 55 |
| Table 5.5 Utilities summary—Asahi Kasei Omega™ process | 56 |
| Table 5.6 Total capital investment—Asahi Kasei Omega™ process | 58 |
| Table 5.7 Total capital investment by section—Asahi Kasei Omega™ process | 59 |
| Table 5.8 Production costs—Asahi Kasei Omega™ process | 60 |
| Table 5.9 Production costs (metric units)—Asahi Kasei Omega™ process | 62 |
| Table 5.10 Environmental performance factors—Asahi Kasei Omega™ process | 64 |
| Table 6.1 Design basis and assumptions—LyondellBasell metathesis process | 66 |
| Table 6.2 Stream summary—LyondellBasell metathesis process | 67 |
| Table 6.3 Major equipment—LyondellBasell metathesis process | 70 |
| Table 6.4 Utilities summary—LyondellBasell metathesis process | 71 |
| Table 6.5 Total capital investment—LyondellBasell metathesis process | 73 |
| Table 6.6 Total capital investment by section—LyondellBasell metathesis process | 74 |
| Table 6.7 Production costs—LyondellBasell metathesis process | 75 |
| Table 6.8 Production costs (metric units)—LyondellBasell metathesis process | 77 |
| Table 6.10 Environmental performance factors—LyondellBasell metathesis process | 79 |
| Table 7.1 Design basis and assumptions—Total/UOP OCP™ process | 81 |
| Table 7.2 Feedstock composition—Total/UOP OCP™ process | 81 |
| Table 7.3 Stream summary—Total/UOP OCP™ process | 82 |
| Table 7.4 Major equipment—Total/UOP OCP™ process | 85 |
| Table 7.5 Utilities summary—Total/UOP OCP™ process | 86 |
| Table 7.6 Total capital investment—Total/UOP OCP™ process | 88 |
| Table 7.7 Total capital investment by section—Total/UOP OCP™ process | 89 |
| Table 7.8 Production costs—Total/UOP OCP™ process | 90 |
| Table 7.9 Production costs (metric units)—Total/UOP OCP™ process | 92 |
| Table 7.10 Environmental performance factors—Total/UOP OCP™ process | 94 |

Figures

| | |
|---|----|
| Figure 2.1 World 2016 PG/CG propylene production by feedstock | 10 |
| Figure 2.2 2016 PG/CG propylene demand | 11 |
| Figure 2.3 PG/CG propylene supply and demand | 12 |
| Figure 2.4 PG/CG propylene production by feedstock | 12 |
| Figure 2.5 PG/CG propylene demand | 13 |
| Figure 2.6 Comparison of capital costs | 16 |
| Figure 2.7 Comparison of production costs | 16 |
| Figure 2.8 Carbon footprint of the three processes | 17 |
| Figure 2.9 Water footprint of the three processes | 18 |
| Figure 3.1 World 2016 PG/CG propylene production by feedstock | 19 |
| Figure 3.2 2016 PG/CG propylene demand | 20 |
| Figure 3.3 PG/CG propylene supply and demand | 20 |
| Figure 3.4 PG/CG propylene production by feedstock | 21 |
| Figure 3.5 PG/CG propylene demand | 22 |
| Figure 3.6 On-purpose propylene production as percentage of total world propylene | 23 |
| Figure 3.7 Global PDH additions | 23 |
| Figure 3.8 World PC/PG propylene demand by region | 24 |
| Figure 3.9 World PG/CG propylene demand year-on-year growth | 24 |
| Figure 3.10 Polymer-grade propylene prices | 26 |

| | |
|--|-----|
| Figure 3.11 1-Butene by-product prices | 26 |
| Figure 3.12 Ethylene prices | 27 |
| Figure 3.13 C ₄ raffinate prices | 27 |
| Figure 3.14 (Propylene-C ₄ raffinate) price differential | 28 |
| Figure 3.15 Propylene-ethylene price differential | 28 |
| Figure 4.1 Olefins interconversion processes | 29 |
| Figure 4.2 Olefins catalytic cracking reaction scheme | 31 |
| Figure 4.3 Olefins cracking catalyst performance | 32 |
| Figure 4.4 Olefins proton-free cracking catalyst structure | 33 |
| Figure 4.5 Deactivation of proton-free catalyst | 34 |
| Figure 4.6 Olefins cracking propylene selectivity | 34 |
| Figure 4.7 Olefins cracking reactivity | 35 |
| Figure 4.8 Omega™ process by Asahi Kasei | 36 |
| Figure 4.9 KBR/ARCO Superflex™ process chemistry | 37 |
| Figure 4.10 Phosphorous bonding to zeolite | 38 |
| Figure 4.11 KBR/KBR Superflex™ process scheme | 39 |
| Figure 4.12 Olefins conversion reaction scheme | 40 |
| Figure 4.13 ExxonMobil MOI™ KBR/KBR process scheme | 41 |
| Figure 4.14 Total/UOP OCP™ process scheme | 42 |
| Figure 4.15 CB&I/Lummus OCT™ process scheme | 43 |
| Figure 4.16 LyondellBasell olefins interconversion process | 44 |
| Figure 5.2 Effect of plant capacity on capital costs—Asahi Kasei Omega™ process | 63 |
| Figure 5.3 Effect of plant capacity on production costs—Asahi Kasei Omega™ process | 63 |
| Figure 5.4 Effect of feedstock price on production costs—Asahi Kasei Omega™ process | 64 |
| Figure 6.2 Effect of plant capacity on capital costs—LyondellBasell metathesis process | 78 |
| Figure 6.3 Effect of plant capacity on production costs—LyondellBasell metathesis process | 78 |
| Figure 6.4 Effect of feedstock price on production costs—LyondellBasell metathesis process | 79 |
| Figure 7.2 Effect of plant capacity on capital costs—Total/UOP OCP™ process | 93 |
| Figure 7.3 Effect of plant capacity on production costs—Total/UOP OCP™ process | 93 |
| Figure 7.4 Effect of feedstock price on production costs—Total/UOP OCP™ process | 94 |
| Figure 5.1 Process flow diagram—Omega™ process by Asahi Kasei | 110 |
| Figure 6.1 Process flow diagram—Metathesis process by LyondellBasell | 111 |
| Figure 7.1 Process flow diagram—Olefins Conversion Process (OCP™) by Total/UOP | 112 |

IHS Customer Care:

Americas: +1 800 IHS CARE (+1 800 447 2273); CustomerCare@ihs.com
Europe, Middle East, and Africa: +44 (0) 1344 328 300; Customer.Support@ihs.com
Asia and the Pacific Rim: +604 291 3600; SupportAPAC@ihs.com

