

TECHNOLOGY & COSTS**Biorenewable Insights****Propylene**

Table of Contents

A Report by **NexantECA**, the Energy and Chemical Advisory company

Published Date: August 2023

www.nexanteca.com/subscriptions-and-reports**Contents**

1	Executive Summary	1
1.1	Overview.....	1
1.2	Technologies	1
1.3	Economics	3
1.3.1	Comparative Economics by Region	3
1.4	Capacity.....	7
1.5	Implications for the Conventional Industry	7
2	Introduction.....	8
2.1	Background	8
2.2	Value Chain.....	8
2.3	Conventional Propylene Technology	10
2.4	Renewable Propylene Technology	12
3	Technology	13
3.1	Steam Cracking.....	13
3.1.1	HVO.....	13
3.1.2	Fischer-Tropsch Technologies.....	14
3.1.3	ATJ	15
3.1.4	Pyrolysis Technologies.....	15
3.1.5	Steam Cracking of Renewable Naphtha	17
3.2	PDH	20
3.2.1	Biopropane	20
3.2.2	Propane Based.....	20
3.2.3	PDH	20
3.3	MTP	22
3.3.1	Renewable Methanol.....	22
3.3.2	MTP	23
3.4	Metathesis	28
3.4.1	Renewable Ethylene Technologies	28
3.4.2	Bio-Butene Technologies	32

3.4.3	Metathesis	40
3.5	Developmental Routes	41
3.5.1	Enhanced FCC	41
3.5.2	Gevo ATH	44
3.5.3	Glycerine Dehydration	47
3.5.4	Direct Fermentation	48
3.5.5	Propanol Dehydration	52
4	Economics	64
4.1	Methodology	64
4.1.1	Basis of Economics	64
4.1.2	Sources	64
4.1.3	Capital Cost Elements	64
4.1.4	Contractor Charges	66
4.1.5	Contingency Allowance	66
4.1.6	Other Project Costs	67
4.1.7	Start-up/Commissioning Costs	67
4.1.8	Miscellaneous Owner's Costs	67
4.1.9	Operating Cost Elements	68
4.2	Key Modelling Assumptions	71
4.3	Comparative Economics	72
4.3.1	Comparative Economics by Region	72
4.3.2	Comparative Economics by Process	76
4.4	Cost of Production Models	81
4.4.1	HVO Naphtha Cracking	81
4.4.2	FT Naphtha Cracking	85
4.4.3	ATJ Naphtha Cracking	89
4.4.4	rPDH	93
4.4.5	rMTP	97
4.4.6	Ethanol-based Metathesis	101
4.4.7	Enhanced FCC	105
4.4.8	Gevo ATH	109
4.4.9	Glycerine Dehydration	113
4.4.10	Direct Fermentation	117
5	Capacity	121
5.1	Existing Capacity	121
5.1.1	INEOS	121
5.1.2	Neste and Borealis	121
5.1.3	Neste and LyondellBasell	121
5.2	Announced Projects	121
5.2.1	Mitsui Chemicals and Kasei Inc.	121
5.2.2	Global Bioenergies	122
5.2.3	Gevo Inc.	122

5.2.4	Genomatica	122
5.3	Cancelled Projects	123
5.4	Conclusions	123
6	Implications for the Conventional Industry	124
6.1	Markets and Scales	124
6.1.1	Global Supply, Demand, and Trade	124
6.2	Strategic Implications	125
Appendices		
References		126

Figures

Figure 1	Routes to Bio-Propylene.....	2
Figure 2	Comparative Economics for Propylene, USGC.....	3
Figure 3	Comparative Economics for Propylene, China.....	4
Figure 4	Comparative Economics for Propylene, Brazil	5
Figure 5	Comparative Economics for Propylene, Western Europe	6
Figure 6	Propylene Value Chain.....	9
Figure 7	Conventional Routes to Propylene	10
Figure 8	Routes to Bio-Propylene.....	12
Figure 9	Triglyceride-based Conversion Technologies	13
Figure 10	Transportation Fuels via Pyrolysis Process	16
Figure 11	Block Flow Diagram of HVO Followed by Propane Dehydrogenation	20
Figure 12	Paraffin Dehydrogenation: Thermodynamic Conversion at 1.0 Bara.....	21
Figure 13	Primary Bio-based Routes to Methanol.....	22
Figure 14	Air Liquide Lurgi MTP™ Process Simplified Process Flow Diagram	27
Figure 15	Block Flow Diagram: Sugar Fermentation, Ethanol Dehydration, Dimerization, and Metathesis	29
Figure 16	Bio-Ethanol to Bio-Ethylene: Conceptual Process Flow.....	31
Figure 17	Cobalt Simplified Process Flow Diagram from US Patent US20100330633	33
Figure 18	Schematic of Guerbet Ethanol Condensation	36
Figure 19	Reaction Network of Ethanol Conversion.....	37
Figure 20	Butene 1 via Ethylene Dimerization (Axens Alphabutol Process).....	39
Figure 21	RxCat™ Technology.....	42
Figure 22	Vegetable Oil FCC Cracking Configuration	43
Figure 23	Gevo's ATH Product Slates for High Propylene Yield Case and High Isobutylene Yield Case	46
Figure 24	Reactor Effluent Hydrocarbon Composition	47
Figure 25	Global Bioenergies' Bio-Propylene Process Diagram	50
Figure 26	Solventogenesis Metabolic Pathways	54
Figure 27	Fermentation Propanol Pathway Genome Sources and Augmentations.....	55
Figure 28	Plastid Augmentation.....	56
Figure 29	Schematic Flowsheet of Batch Gevo Patent Application U.S./2009 0246842 A1 Fermentation Propanol Production Process.....	57
Figure 30	Block Flow Diagram for the Production of Propylene from Glycerin	59
Figure 31	Reactor Effluent Hydrocarbon Composition	61
Figure 32	Comparative Economics for Propylene, USGC.....	72
Figure 33	Comparative Economics for Propylene, China.....	73
Figure 34	Comparative Economics for Propylene, Brazil	74
Figure 35	Comparative Economics for Propylene, Western Europe	75
Figure 36	Comparative Economics for Propylene, HVO Naphtha Cracking	76
Figure 37	Comparative Economics for Propylene, FT Naphtha Cracking.....	76
Figure 38	Comparative Economics for Propylene, ATJ Naphtha Cracking.....	77
Figure 39	Comparative Economics for Propylene, rPDH	77

Figure 40	Comparative Economics for Propylene, rMTP	78
Figure 41	Comparative Economics for Propylene, Ethanol-based Metathesis	78
Figure 42	Comparative Economics for Propylene, Enhanced FCC	79
Figure 43	Comparative Economics for Propylene, Gevo ATH	79
Figure 44	Comparative Economics for Propylene, Glycerine Dehydration	80
Figure 45	Comparative Economics for Propylene, Direct Fermentation	80

Tables

Table 1	Overall Cracking Yields at Moderate Severity	19
Table 2	Estimated Green Olefins Yield	44
Table 3	Fermentation Propanol Patent Matrix.....	52
Table 4	Material Balance: Glycerin to Propylene Process	60
Table 5	Cost of Production Estimate for HVO Naphtha Cracking for Propylene, USGC	81
Table 6	Cost of Production Estimate for HVO Naphtha Cracking for Propylene, China	82
Table 7	Cost of Production Estimate for HVO Naphtha Cracking for Propylene, Brazil	83
Table 8	Cost of Production Estimate for HVO Naphtha Cracking for Propylene, Western Europe	84
Table 9	Cost of Production Estimate for FT Naphtha Cracking for Propylene, USGC	85
Table 10	Cost of Production Estimate for FT Naphtha Cracking for Propylene, China	86
Table 11	Cost of Production Estimate for FT Naphtha Cracking for Propylene, Brazil	87
Table 12	Cost of Production Estimate for FT Naphtha Cracking for Propylene, Western Europe	88
Table 13	Cost of Production Estimate for ATJ Naphtha Cracking for Propylene, USGC	89
Table 14	Cost of Production Estimate for ATJ Naphtha Cracking for Propylene, China	90
Table 15	Cost of Production Estimate for ATJ Naphtha Cracking for Propylene, Brazil	91
Table 16	Cost of Production Estimate for ATJ Naphtha Cracking for Propylene, Western Europe	92
Table 17	Cost of Production Estimate for rPDH for Propylene, USGC	93
Table 18	Cost of Production Estimate for rPDH for Propylene, China	94
Table 19	Cost of Production Estimate for rPDH for Propylene, Brazil	95
Table 20	Cost of Production Estimate for rPDH for Propylene, Western Europe	96
Table 21	Cost of Production Estimate for rMTP for Propylene, USGC	97
Table 22	Cost of Production Estimate for rMTP for Propylene, China	98
Table 23	Cost of Production Estimate for rMTP for Propylene, Brazil	99
Table 24	Cost of Production Estimate for rMTP for Propylene, Western Europe	100
Table 25	Cost of Production Estimate for Ethanol-Based Metathesis for Propylene, USGC	101
Table 26	Cost of Production Estimate for Ethanol-Based Metathesis for Propylene, China	102
Table 27	Cost of Production Estimate for Ethanol-Based Metathesis for Propylene, Brazil	103
Table 28	Cost of Production Estimate for Ethanol-Based Metathesis for Propylene, Western Europe	104
Table 29	Cost of Production Estimate for Enhanced FCC for Propylene, USGC	105
Table 30	Cost of Production Estimate for Enhanced FCC for Propylene, China	106
Table 31	Cost of Production Estimate for Enhanced FCC for Propylene, Brazil	107

Table 32	Cost of Production Estimate for Enhanced FCC for Propylene, Western Europe	108
Table 33	Cost of Production Estimate for Gevo ATH for Propylene, USGC	109
Table 34	Cost of Production Estimate for Gevo ATH for Propylene, China	110
Table 35	Cost of Production Estimate for Gevo ATH for Propylene, Brazil	111
Table 36	Cost of Production Estimate for Gevo ATH for Propylene, Western Europe	112
Table 37	Cost of Production Estimate for Glycerine Dehydration for Propylene, USGC	113
Table 38	Cost of Production Estimate for Glycerine Dehydration for Propylene, China	114
Table 39	Cost of Production Estimate for Glycerine Dehydration for Propylene, Brazil	115
Table 40	Cost of Production Estimate for Glycerine Dehydration for Propylene, Western Europe	116
Table 41	Cost of Production Estimate for Direct Fermentation for Propylene, USGC	117
Table 42	Cost of Production Estimate for Direct Fermentation for Propylene, China	118
Table 43	Cost of Production Estimate for Direct Fermentation for Propylene, Brazil	119
Table 44	Cost of Production Estimate for Direct Fermentation for Propylene, Western Europe	120



TECHNOLOGY & COSTS

Biorenewable Insights

The NexantECA Subscriptions' Biorenewable Insights program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. Biorenewable Insights reports are available as a subscription program or on a single report basis.

Contact Details:

Americas:

Steven Slome, Principal, Biorenewable Insights

Phone: + 1-914-609-0379, e-mail: sslome@NexantECA.com

Erica Hill, Client Services Coordinator, Subscriptions and Reports

Phone: + 1-914-609-0386, e-mail: ehill@NexantECA.com

EMEA:

Anna Ibbotson, Vice President, Sales and Marketing

Phone: +44-207-950-1528, aibbotson@NexantECA.com

Asia:

Chommanad Thammanayakatip, Managing Consultant

Phone: +66-2793-4606, email: chommanadt@NexantECA.com

NexantECA Subscriptions and Reports provide clients with comprehensive analytics, forecasts and insights for the chemicals, polymers, energy and cleantech industries. Using a combination of business and technical expertise, with deep and broad understanding of markets, technologies and economics, NexantECA provides solutions that our clients have relied upon for over 50 years.

Copyright © 2000-2023. NexantECA (BVI) Limited. All rights reserved