

TECHNOLOGY & COSTS**Technoeconomics - Energy & Chemicals (TECH)****TECH 2019-8 Hydrogen Peroxide**

Table of Contents

A Report by **Nexant, Inc.**

Published Date: September 2019

www.nexantsubscriptions.com**Contents**

1	Executive Summary	1
1.1	Introduction.....	1
1.2	Business and Strategic Considerations	2
1.3	Technology Overview.....	3
1.3.1	Historical Technology.....	3
1.3.2	Commercial Technologies.....	3
1.3.3	Developing Technologies.....	7
1.4	Process Economics.....	8
1.5	Commercial Applications.....	10
1.6	Global Market Analysis.....	11
1.6.1	Demand.....	11
1.6.2	Supply and Trade.....	12
2	Introduction.....	17
2.1	Business and Strategic Considerations	18
2.2	Physical and Thermodynamic Properties.....	19
2.3	Specifications	19
2.4	Health Hazards.....	20
2.5	Explosion Risk.....	21
2.6	Regulatory Requirements.....	21
2.7	Environmental Issues.....	21
2.8	Storage and Transportation.....	21
3	Commercial Technologies.....	23
3.1	Introduction.....	23
3.2	Anthraquinone Auto-Oxidation Process.....	24
3.2.1	First Developments	25
3.2.2	Chemistry	25
3.2.3	Process Description	29
3.2.4	Solvay's Large-Scale Plants	38
3.2.5	Solvay's Satellite Peroxide Production "myH2O2™"	40
3.2.6	Latest Patents Concerning the Auto-Oxidation Process.....	41

3.3	Dow Electrochemical Process.....	43
3.3.1	Technology Status.....	44
3.3.2	Chemistry	44
3.3.3	Process Description	44
3.4	The Isopropanol Oxidation Route	50
3.4.1	Technology Status.....	50
3.4.2	Chemistry	50
3.4.3	Process Description	50
3.5	Technology Holders and Licensing Status.....	51
3.5.1	EB Nuberg.....	52
3.5.2	Chematur Engineering AB (CEAB)	53
3.5.3	3V Tech Group and Consito.....	53
3.5.4	Hubei Sanli Fenxiang Technology Co. (SL TEC).....	53
3.5.5	Liming Research Institute of Chemical Industry (LRICI)	54
3.5.6	Edison/Experson	54
3.5.7	Evonik.....	54
3.5.8	Mitsubishi	54
3.5.9	Solvay.....	55
3.5.10	Nouryon.....	55
4	Developing Technologies	56
4.1	Direct Synthesis Process	56
4.1.1	Solvay.....	58
4.1.2	Nippon Oil.....	59
4.1.3	Evonik Headwaters	59
4.1.4	Arkema	62
4.1.5	LyondellBasell	63
4.2	Alternatives Electrochemical Processes	63
4.2.1	HPNow	63
4.2.2	Voltachem	64
4.2.3	King Saud University.....	65
4.3	The Methyl Benzyl Alcohol Oxidation Route (Abandoned).....	65
4.3.1	Chemistry	66
4.3.2	Process Description	67
5	Process Economics.....	70
5.1	Costing Basis	70
5.1.1	Investment Basis	70
5.1.2	Pricing Basis.....	70
5.1.3	Cost of Production Basis	72
5.2	Cost of Producing Hydrogen Peroxide via Anthraquinone Auto-Oxidation Process.....	73
5.2.1	Material Balance.....	73
5.2.2	Cost of Production Estimate – EAQ	73
5.2.3	Cost of Production Estimate – AAQ	76
5.3	Speculative Cost of Producing Hydrogen Peroxide via Direct Synthesis	80
5.3.1	Material Balance.....	80

	5.3.2	Cost of Production Estimate - Direct Route	80
5.4		Comparison of Commercial and Speculative Processes to Produce Hydrogen Peroxide	82
5.5		Sensitivity of Cost of Production to Plant Scale	83
5.6		Regional Cost of Production Estimates	83
6		Commercial Applications	86
6.1		Bleaching	88
6.2		Chemical Synthesis	89
6.3		Environmental	90
	6.3.1	Water/Waste and Effluent Treatment	90
	6.3.2	Chemical Purification	91
6.4		Electronics	92
6.5		Mining/Metallurgy	93
6.6		Food Industry	93
6.7		Cosmetics and Personal Care	93
6.8		Aquaculture	93
6.9		Pharmaceuticals	94
6.10		Detergents	94
6.11		Space and Aeronautics	94
7		Regional Market Analysis	95
7.1		Global	95
	7.1.1	Demand	95
	7.1.2	Supply and Trade	96
7.2		North America	100
	7.2.1	Demand	100
	7.2.2	Supply and Trade	101
7.3		Western Europe	102
	7.3.1	Demand	102
	7.3.2	Supply and Trade	103
7.4		Middle East	105
	7.4.1	Demand	105
	7.4.2	Supply and Trade	105
7.5		Asia Pacific	107
	7.5.1	Demand	107
	7.5.2	Supply and Trade	107
7.6		Rest of the World	112
	7.6.1	Demand	112
	7.6.2	Supply and Trade	112
8		Glossary	115

Appendices

A	Regional Cost of Production Estimates.....	117
B	Definitions of Capital Cost Terms Used in Process Economics.....	126
C	Definitions of Operating Cost Terms Used in Process Economics	131
D	TECH Program Title Index (2009-2019)	134
E	References	138

Figures

Figure 1	Hydrogen Peroxide Value Chain	1
Figure 2	Simplified Overview of Historical Hydrogen Peroxide Technology	3
Figure 3	Simplified Overview of Commercial Hydrogen Peroxide Technology	3
Figure 4	Direct Synthesis Route for Hydrogen Peroxide.....	7
Figure 5	Comparison of Hydrogen Peroxide Costs Depending on Capacity, Product Concentration and Process (U.S. Gulf Coast, 2Q 2019).....	8
Figure 6	Summary of Economics of Processes Producing Hydrogen Peroxide	9
Figure 7	Global Hydrogen Peroxide Demand by End Use, 2019.....	10
Figure 8	Hydrogen Peroxide Consumption by Region, 2019	12
Figure 9	Global Hydrogen Peroxide Capacity Share, 2019.....	14
Figure 10	Global Supply and Demand.....	15
Figure 11	Hydrogen Peroxide Value Chain	17
Figure 12	Simplified Overview of Commercial Hydrogen Peroxide Technology	23
Figure 13	Hydrogen Peroxide Chemistry: Anthraquinone Auto-Oxidation Process	26
Figure 14	Anthraquinone Auto-Oxidation Process Block Diagram.....	30
Figure 15	Hydrogen Peroxide via Alkylanthraquinone Process	31
Figure 16	Sulzer Multi-Functional Concentrator for Hydrogen Peroxide.....	36
Figure 17	2-Amyl Anthraquinone (AAQ)	39
Figure 18	Dow Alkaline Peroxide Process.....	45
Figure 19	Peroxide Cell Schematic	47
Figure 20	Integrated Pulp Bleaching Schematic	49
Figure 21	Direct Synthesis Route for Hydrogen Peroxide.....	56
Figure 22	Direct Synthesis.....	57
Figure 23	Conceptual Direct Synthesis Hydrogen Peroxide Process (US6919065 B2 to Hydrocarbon Technologies)	61
Figure 24	Hydrogen Peroxide Lyondell Process	68
Figure 25	Comparison of Hydrogen Peroxide Costs, U.S. Gulf Coast, 2Q 2019.....	82
Figure 26	Variation in Cost of Hydrogen Peroxide (70 Weight %) for the Anthraquinone Processes with Plant Scale	83
Figure 27	Summary of Economics of Processes Producing Hydrogen Peroxide	84
Figure 28	Global Hydrogen Peroxide Demand by End Use, 2019.....	86
Figure 29	Hydrogen Peroxide Consumption by Region, 2019	95

Figure 30	Global Hydrogen Peroxide Capacity Share, 2019.....	97
Figure 31	Global Supply and Demand.....	99
Figure 32	North America Supply, Demand, and Trade	101
Figure 33	Western Europe Supply, Demand, and Trade	103
Figure 34	Middle East Supply, Demand, and Trade.....	106
Figure 35	Asia Pacific Supply, Demand, and Trade.....	109
Figure 36	Rest of the World Supply, Demand, and Trade.....	113

Tables

Table 1	Strategic/Business Considerations.....	2
Table 2	Key Features of the Commercial Hydrogen Peroxide Routes	4
Table 3	Hydrogen Peroxide Licensors	6
Table 4	Hydrogen Peroxide Technology Holders – Possible License via JV.....	7
Table 5	Typical HP Concentration in Applications/Storage.....	11
Table 6	Top 10 Producers Overview	13
Table 7	Strategic/Business Considerations.....	18
Table 8	Key Physical and Thermodynamic Properties.....	19
Table 9	Typical HP Concentration in Applications/Storage.....	19
Table 10	Commercial Specification	20
Table 11	Key Features of the Commercial Hydrogen Peroxide Routes	24
Table 12	Exemplary Anthraquinone Working Solution Composition.....	28
Table 13	Hydrogen Peroxide Licensors	51
Table 14	Hydrogen Peroxide Technology Holders – Possible License via JV.....	52
Table 15	Prices of Raw Materials, Products, Utilities and Labor.....	71
Table 16	Key Mass Balance Considerations.....	73
Table 17	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Soln.) - U.S. Process: EAQ Standard Auto-Oxidation Technology, 100 kT/Yr Capacity.....	74
Table 18	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 43 % Soln.) - U.S. Process: EAQ Standard Auto-Oxidation Technology, 100 kT/Yr Capacity.....	75
Table 19	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Solution) - U.S. Process: AAQ High Productivity Auto-Oxidation Technology, 260 kT/Yr Capacity	77
Table 20	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Solution) - U.S. Process: AAQ High Productivity Auto-Oxidation Technology, 100 kT/Yr Capacity	78
Table 21	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 40 % Solution) - U.S. Process: AAQ High Productivity Auto-Oxidation Technology, 100 kT/Yr Capacity	79
Table 22	Key Mass Balance Considerations	80
Table 23	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 9 % Solution) – U.S. Process: Direct Synthesis in Methanol Reaction Medium, 100 kT/Yr Capacity.....	81
Table 24	Regional Cost of Production for the EAQ Process.....	84
Table 25	Regional Cost of Production for the AAQ Process.....	85
Table 26	Regional Cost of Production for the Direct Process	85
Table 27	Typical HP Concentration in Applications/Storage.....	87

Table 28	Summary of Hydrogen Peroxide Chemistry: Organic Compounds.....	90
Table 29	Summary of Hydrogen Peroxide Chemistry: Inorganic Compounds.....	91
Table 30	Top 10 Producers Overview	97
Table 31	Global Supply and Demand.....	99
Table 32	North America Supply, Demand, and Trade	101
Table 33	North America Capacity List – 2019	102
Table 34	Western Europe Supply, Demand, and Trade	104
Table 35	Western Europe Capacity List – 2019	104
Table 36	Middle East Supply, Demand, and Trade.....	106
Table 37	Middle East Capacity List – 2019	106
Table 38	Asia Pacific Supply, Demand, and Trade	109
Table 39	Asia Pacific Capacity List – 2019	110
Table 40	Rest of the World Supply, Demand, and Trade.....	113
Table 41	Rest of the World Capacity List – 2019	114
Table 42	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Soln.) – NW Europe Process: EAQ Standard Auto-Oxidation Technology, 100 kT/Yr Capacity	117
Table 43	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Solution) – NW Europe Process: AAQ High Productivity Auto-Oxidation Technology, 100 kT/Yr Capacity	118
Table 44	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 9 % Solution) – NW Europe Process: Direct Synthesis in Methanol Reaction Medium, 100 kT/Yr Capacity	119
Table 45	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Soln.) – China Process: EAQ Standard Auto-Oxidation Technology, 100 kT/Yr Capacity	120
Table 46	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Solution) – China Process: AAQ High Productivity Auto-Oxidation Technology, 100 kT/Yr Capacity	121
Table 47	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 9 % Solution) – China Process: Direct Synthesis in Methanol Reaction Medium, 100 kT/Yr Capacity	122
Table 48	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Soln.) – Middle East Process: EAQ Standard Auto-Oxidation Technology, 100 kT/Yr Capacity	123
Table 49	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 70 % Solution) – Middle East Process: AAQ High Productivity Auto-Oxidation Technology, 100 kT/Yr Capacity	124
Table 50	Hydrogen Peroxide Cost of Production (100 % Basis, Produced as 9 % Solution) – Middle East Process: Direct Synthesis in Methanol Reaction Medium, 100 kT/Yr Capacity	125

Nexant Inc.

TECHNOLOGY & COSTS

Technoeconomics - Energy & Chemicals (TECH)

The Nexant Subscriptions' Technoeconomics - Energy & Chemicals (TECH) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. Technoeconomics - Energy & Chemicals (TECH) reports are available as a subscription program or on a single report basis.

Contact Details:

Americas:

Marcos Nogueira Cesar, Vice President, Global Products, E&CA: Nexant Subscriptions

Phone: + 1-914-609-0324, e-mail: mcesar@nexant.com

Erica Hill, Client Services Coordinator, E&CA-Products

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

EMEA:

Anna Ibbotson, Director, Nexant Subscriptions

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

Asia:

Chommanad Thammanayakatip, Managing Consultant, Energy & Chemicals Advisory

Phone: +66-2793-4606, email: chommanadt@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. 2018. All Rights Reserved.