

TECHNOLOGY & COSTS

Technoeconomics - Energy & Chemicals (TECH)

TECH 2018-3 Vinyl Chloride Monomer/Ethylene Dichloride (VCM/EDC)

Table of Contents

A Report by **Nexant, Inc.**

Published Date: September 2018

www.nexantsubscriptions.com**Contents**

1	Executive Summary	1
1.1	Overview	1
1.2	Process Overview.....	2
1.2.1	Acetylene-based VCM.....	2
1.2.2	Ethylene-based VCM	3
1.2.3	Bio-based VCM.....	4
1.2.4	Ethane-based VCM	4
1.3	Process Economics	5
1.3.1	VCM Capacity	5
1.3.2	EDC Cost of Production Summary.....	6
1.3.3	VCM Cost of Production Summary	7
1.4	Commercial Analysis	7
1.4.1	Global Overview.....	7
2	Introduction	10
2.1	Value Chain and Technology Overview.....	10
2.2	Business Developments	11
2.3	Technology Holders and Licensing Status.....	13
2.4	Strategic and Business Considerations	13
2.5	Physical and Thermodynamic Properties	13
2.6	Specifications	14
2.7	Health Hazards.....	15
2.7.1	Safety	15
2.7.2	Health Risks.....	16
2.7.3	Environmental Risks.....	17
2.8	Storage and Transportation	18
3	Commercial Technologies	19

3.1	Acetylene-Based VCM	19
3.1.1	Acetylene via the Calcium Carbide Process.....	21
3.1.2	VCM via the Acetylene Process.....	28
3.1.3	Developments in Acetylene-based VCM Technology	30
3.2	Davy VCM Process.....	33
3.2.1	Process Description	34
3.3	Ethylene-based VCM.....	36
3.3.1	Chemistry.....	36
3.3.2	Process Description	37
3.4	INEOS Process	45
3.4.1	Technology Features.....	46
3.4.2	Process Description	46
3.5	LG Chem Process	51
3.5.1	EDC Production	51
3.5.2	VCM Production.....	52
3.6	Oxyvinyls.....	53
3.7	Tosoh	53
3.8	Vinnolit	53
3.8.1	Technology Features.....	54
3.8.2	Process Description	54
4	Developing Technologies	61
4.1	Green Chemistry and Biotechnology	61
4.1.1	Ethanol-based EDC Processes	61
4.2	Ethane-based Process for VCM.....	66
4.2.1	Chemistry.....	68
5	Process Economics.....	74
5.1	Cost Basis	74
5.1.1	Investment Basis.....	74
5.1.2	Pricing Basis	74
5.1.3	Cost of Production Basis	76
5.1.4	Capacity.....	76
5.2	Cost of Producing VCM via Acetylene Process	78
5.3	Cost of Producing VCM via Davy VCM Process	78
5.4	Cost of Producing EDC via INEOS Direct Chlorination Process.....	82
5.5	Cost of Producing EDC via Vinnolit CNC Process	82
5.6	Cost of Producing EDC via Vinnolit Oxychlorination Process.....	86
5.7	Cost of Producing EDC via Generic Direct Chlorination Process	86
5.8	Cost of Producing VCM via INEOS Balanced Oxychlorination Process	86
5.9	Cost of Producing VCM via Vinnolit Balanced VCV Process.....	90

5.10	Cost of Producing VCM via Generic Balanced VCM Process	90
5.11	Cost of Producing “Green” VCM/PVC	93
5.12	Regional Cost of Production Estimates for EDC and VCM.....	96
5.12.1	Middle East	96
5.12.2	USGC	96
5.12.3	Western Europe	96
5.13	Speculative Cost of Producing VCM from Ethane.....	115
5.14	Comparison of Commercial EDC and VCM Processes.....	115
5.15	Sensitivity Analyses	119
5.15.1	Feedstock Price	119
5.15.2	Economies of Scale.....	120
5.15.3	Capital Investment Costs.....	122
6	Commercial Applications	123
7	Regional Market Analysis	124
7.1	Global Overview	124
7.2	North America.....	127
7.2.1	Demand	127
7.2.2	Supply.....	128
7.2.3	Supply, Demand, and Trade.....	131
7.3	Western Europe.....	132
7.3.1	Demand	132
7.3.2	Supply.....	133
7.3.3	Supply, Demand, and Trade.....	136
7.4	Asia Pacific.....	137
7.4.1	Demand	137
7.4.2	Supply.....	141
7.4.3	Supply, Demand, and Trade.....	150
7.5	Rest of World.....	152

Appendices

A	Definitions of Capital Cost Terms Used in Process Economics	157
B	Definitions of Operating Cost Terms Used in Process Economics.....	161
C	TECH Program Title Index (2008-2018).....	164

Figures

Figure 1	Global Vinyl Chloride Monomer Capacity by Feedstock.....	1
Figure 2	Average VCM Plant Capacity in China by Process	6
Figure 3	EDC Cost of Production for INEOS, Vinnolit, and Generic Process Technology.....	6
Figure 4	VCM Cost of Production via Petroleum Derived Ethylene, Bio-sourced Ethylene and Acetylene Based Process.....	7
Figure 5	Global EDC Demand by Region, 2017	8
Figure 6	Global VCM Demand by Region, 2017	9
Figure 7	Vinyl Chloride Monomer Value Chain	11
Figure 8	Global Vinyl Chloride Monomer Capacity by Feedstock.....	12
Figure 9	Average VCM Plant Capacity by Country - 2018	20
Figure 10	Number of Vinyl Chloride Monomer Plants by Country - 2018.....	21
Figure 11	Calcium Carbide Acetylene Process	23
Figure 12	VCM via Acetylene Process	29
Figure 13	VCM via Davy VCM Process.....	35
Figure 14	VCM via C_2H_4/Cl_2 Chlorination/Oxychlorination Process	38
Figure 15	INEOS Balance VCM Process	47
Figure 16	Vinnolit Balanced VCM Process	55
Figure 17	Vinnolit VCM Process Direct Chlorination: CNC Boiling Reactor Process	57
Figure 18	Block Flow Diagram for the Production of Bioethanol from Cane Juice or Molasses	61
Figure 19	Bio-Ethanol to Green Ethylene: Conceptual Process Flow.....	64
Figure 20	Ethylene from Ethanol (Chematur Route)	65
Figure 21	Comparison of Ethylene and Ethane based VCM Processes.....	67
Figure 22	Reactions in EVC Oxychlorination and Hydrogenation Reactors.....	68
Figure 23	EVC's Novel Concept of Catalytic Oxychlorination of Ethane to VCM	69
Figure 24	EVC Ethane to VCM Process: Ethane Chlorination Section.....	70
Figure 25	EVC Ethane to VCM Process: Chlorination, Purification and Hydrogenation Section	71
Figure 26	Evolution of Average Chinese Vinyl Chloride Monomer Plant Capacity by Production Process.....	77
Figure 27	EDC Production Costs for INEOS, Vinnolit and Generic Process Technology.....	115
Figure 28	Cost of Production for EDC in USGC	117
Figure 29	Regional Cost of Production Comparison for VCM	118
Figure 30	VCM Production Costs via Petroleum Derived Ethylene, Bio-sourced Ethylene and Acetylene Based Processes.....	118
Figure 31	Sensitivity of EDC Costs of Production to Ethylene Pricing	119
Figure 32	Sensitivity of VCM Costs of Production to Acetylene Pricing.....	120
Figure 33	Sensitivity of VCM Costs of Production to Ethylene Pricing.....	120
Figure 34	Sensitivity of EDC Cost of Production + 10 Percent ROCE to Plant Scale	121
Figure 35	Sensitivity of VCM Cost of Production + 10 Percent ROCE to Plant Scale	121

Figure 36	Sensitivity of EDC Cost of Production + 10 Percent ROCE to Capital Investment	122
Figure 37	Global EDC Demand by Region, 2017	124
Figure 38	Global VCM Demand by Region, 2017	126
Figure 39	EDC Demand by End Use in North America, 2017	127
Figure 40	VCM Consumption in North America by Region, 2017	128
Figure 41	Western Europe EDC Demand by End Use - 2017	132
Figure 42	Western Europe VCM Consumption by End Use - 2017	133
Figure 43	Asia Pacific EDC Consumption by Country - 2017	140
Figure 44	Asia Pacific VCM Consumption by Country - 2017	141

Tables

Table 1	Average Capacity of VCM Plants by Location	5
Table 2	Number of Operating VCM Plants by Location.....	5
Table 3	Global EDC Supply, Demand, and Trade	8
Table 4	Global VCM Supply, Demand, and Trade	9
Table 5	VCM Licensors and Technology Holders	13
Table 6	Key Physical and Thermodynamic Properties of EDC and VCM	14
Table 7	Commercial Specifications for EDC.....	14
Table 8	Commercial Specifications for VCM	15
Table 9	Analysis of Illinois No. 6 Coal, as Received.....	22
Table 10	Limestone Feed Composition, Dry Basis	22
Table 11	Lime Feed Composition to Carbide Furnace, Dry Basis.....	24
Table 12	Coke Composition, Dry Basis.....	25
Table 13	Purified Coke Oven Gas, Dry Basis.....	25
Table 14	Carbide Furnace Offgas, Dry Basis	26
Table 15	Impurities in Carbide Acetylene	27
Table 16	Activity Comparison of Various Catalysts in LG Chem's EDC Process.....	52
Table 17	Raw Materials, Products, Utilities, and Labor Costs.....	75
Table 18	Average Capacity of VCM Plants by Country/Region	76
Table 19	Number of VCM Plants by Country/Region	77
Table 20	Cost of Production Estimate for: Acetylene Process: Hydrolysis of Calcium Carbide, China	79
Table 21	Cost of Production Estimate for: Vinyl Chloride Monomer Process: Acetylene based VCM Process, China.....	80
Table 22	Cost of Production Estimate for: Vinyl Chloride Monomer Process: DAVY VCM Process, China.....	81
Table 23	Cost of Production Estimate for: Ethylene Dichloride Process: INEOS Direct Chlorination, China.....	83
Table 24	Cost of Production Estimate for: Ethylene Dichloride Process: Vinnolit Compact Natural Circulation Reactor for Direct Chlorination, China.....	84
Table 25	Cost of Production Estimate for: Ethylene Dichloride Process: Vinnolit EDC (Integrated with VCM Operation), China.....	85
Table 26	Cost of Production Estimate for: Ethylene Dichloride Process: Vinnolit Oxychlorination, China.....	87
Table 27	Cost of Production Estimate for: Ethylene Dichloride Process: Direct Chlorination, China	88
Table 28	Cost of Production Estimate for: Vinyl Chloride Monomer Process: INEOS Balanced VCM Process, China	89
Table 29	Cost of Production Estimate for: Vinyl Chloride Monomer Process: Vinnolit Balanced VCM Process, China.....	91

Table 30	Cost of Production Estimate for: Vinyl Chloride Monomer Process: Conventional Balanced VCM Process, China	92
Table 31	Cost of Production Estimate for Bioethylene Process: Ethanol Dehydration (Fixed-Bed), China	94
Table 32	Cost of Production Estimate for Vinyl Chloride Monomer Process: Generic Balanced VCM Process from Bioethanol-based Ethylene, China.....	95
Table 33	Cost of Production Estimate for Ethylene Dichloride Process: INEOS High Temperature Chlorination, Middle East	97
Table 34	Cost of Production Estimate for Ethylene Dichloride Process: Vinnolit Compact Natural Circulation Reactor for Direct Chlorination, Middle East	98
Table 35	Cost of Production Estimate for Ethylene Dichloride Process: Direct Chlorination, Middle East	99
Table 36	Cost of Production Estimate for Vinyl Chloride Monomer Process: INEOS Balanced VCM Process, Middle East.....	100
Table 37	Cost of Production Estimate for Vinyl Chloride Monomer Process: Vinnolit Balanced VCM Process, Middle East	101
Table 38	Cost of Production Estimate for Vinyl Chloride Monomer Process: Conventional Balanced VCM Process, Middle East	102
Table 39	Cost of Production Estimate for Ethylene Dichloride Process: INEOS High Temperature Chlorination, USGC	103
Table 40	Cost of Production Estimate for Ethylene Dichloride Process: Vinnolit Compact Natural Circulation Reactor for Direct Chlorination, USGC	104
Table 41	Cost of Production Estimate for Ethylene Dichloride Process: Direct Chlorination, USGC	105
Table 42	Cost of Production Estimate for Vinyl Chloride Monomer Process: INEOS Balanced VCM Process, USGC	106
Table 43	Cost of Production Estimate for Vinyl Chloride Monomer Process: Vinnolit Balanced VCM Process, USGC	107
Table 44	Cost of Production Estimate for Vinyl Chloride Monomer Process: Conventional Balanced VCM Process, USGC	108
Table 45	Cost of Production Estimate for Ethylene Dichloride Process: INEOS High Temperature Chlorination, Western Europe	109
Table 46	Cost of Production Estimate for Ethylene Dichloride Process: Vinnolit Compact Natural Circulation Reactor for Direct Chlorination, Western Europe	110
Table 47	Cost of Production Estimate for Ethylene Dichloride Process: Direct Chlorination, Western Europe	111
Table 48	Cost of Production Estimate for Vinyl Chloride Monomer Process: INEOS Balanced VCM Process, Western Europe.....	112
Table 49	Cost of Production Estimate for Vinyl Chloride Monomer Process: Vinnolit Balanced VCM Process, Western Europe	113
Table 50	Cost of Production Estimate for Vinyl Chloride Monomer Process: Conventional Balanced VCM Process, Western Europe	114

Table 51	Cost of Production Estimate for Vinyl Chloride Monomer Process: EVC VCM Process, USGC	116
Table 52	Global EDC Supply, Demand, and Trade	125
Table 53	Global VCM Supply, Demand, and Trade	126
Table 54	EDC Capacity in North America - 2017	130
Table 55	VCM Capacity in North America - 2017	131
Table 56	North America EDC Supply, Demand, and Trade.....	131
Table 57	North America VCM Supply, Demand, and Trade	132
Table 58	EDC Capacity in Western Europe - 2017	134
Table 59	VCM Capacity in Western Europe - 2017	135
Table 60	Western Europe EDC Supply, Demand, and Trade.....	136
Table 61	Western European VCM Supply, Demand, and Trade	137
Table 62	Asia Pacific EDC Capacity - 2017	143
Table 63	Asia Pacific VCM Capacity - 2017	146
Table 64	Asia Pacific EDC Supply, Demand, and Trade.....	150
Table 65	Asia Pacific VCM Supply, Demand, and Trade	152
Table 66	Rest of World EDC Capacity - 2017	153
Table 67	Rest of World VCM Capacity - 2017	155

Nexant Inc.

TECHNOLOGY & COSTS

TECHNOECONOMICS - ENERGY & CHEMICALS (TECH)

Vinyl Chloride Monomer/Ethylene Dichloride (VCM/EDC)

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.