

# Epichlorohydrin

## Table of Contents

A Report by Nexant's CHEMSYSTEMS  
Process Evaluation/Research Planning (PERP) Program  
PERP Report 09/10S1– Published August 2011

[www.chemsystems.com](http://www.chemsystems.com)

| Section                                                                       | Page |
|-------------------------------------------------------------------------------|------|
| <b>1 Executive Summary</b> .....                                              | 1    |
| 1.1 COMMERCIAL TECHNOLOGY OVERVIEW .....                                      | 2    |
| 1.1.1 Allyl Chloride Route (“Conventional” Chlorination).....                 | 2    |
| 1.1.2 Allyl Alcohol Route .....                                               | 3    |
| 1.1.3 Glycerol Route .....                                                    | 4    |
| 1.2 POTENTIAL ROUTES RECEIVING ATTENTION IN THE LITERATURE .....              | 5    |
| 1.2.1 Electrochemical Route .....                                             | 5    |
| 1.2.2 Acetone Route.....                                                      | 5    |
| 1.2.3 Acrolein Route .....                                                    | 5    |
| 1.2.4 Ethane Conversion Route .....                                           | 6    |
| 1.3 BUSINESS DEVELOPMENTS .....                                               | 6    |
| 1.4 TECHNOLOGY LICENSING STATUS .....                                         | 7    |
| 1.5 PROCESS ECONOMICS.....                                                    | 8    |
| 1.5.1 Epichlorohydrin Production Routes Evaluated.....                        | 9    |
| 1.5.2 Regional Competitiveness of the Glycerol to Epichlorohydrin Route ..... | 13   |
| 1.5.3 Concluding Remarks.....                                                 | 15   |
| 1.6 GLOBAL MARKET DYNAMICS .....                                              | 16   |
| 1.6.1 Global Summary .....                                                    | 16   |
| <b>2 Introduction</b> .....                                                   | 19   |
| 2.1 COMMERCIAL TECHNOLOGY OVERVIEW .....                                      | 20   |
| 2.1.1 Allyl Chloride Route (“Conventional” Chlorination).....                 | 20   |

|          |                                                                            |           |
|----------|----------------------------------------------------------------------------|-----------|
| 2.1.2    | Allyl Alcohol Route .....                                                  | 20        |
| 2.1.3    | Glycerol Route .....                                                       | 20        |
| 2.2      | POTENTIAL ROUTES RECEIVING ATTENTION IN THE LITERATURE .....               | 21        |
| 2.2.1    | Electrochemical Route .....                                                | 21        |
| 2.2.2    | Acetone Route .....                                                        | 21        |
| 2.2.3    | Acrolein Based Route .....                                                 | 21        |
| 2.2.4    | Ethane Conversion Route .....                                              | 22        |
| 2.3      | BUSINESS DEVELOPMENTS .....                                                | 22        |
| 2.4      | TECHNOLOGY LICENSING STATUS .....                                          | 23        |
| 2.5      | PHYSICAL PROPERTIES .....                                                  | 24        |
| 2.6      | HEALTH HAZARDS .....                                                       | 24        |
| 2.7      | STORAGE AND HANDLING .....                                                 | 24        |
| <b>3</b> | <b>Commercial Process Technologies .....</b>                               | <b>26</b> |
| 3.1      | ALLYL CHLORIDE ROUTE .....                                                 | 26        |
| 3.1.1    | Allyl Chloride from Propylene .....                                        | 26        |
| 3.1.2    | Epichlorohydrin from Allyl Chloride .....                                  | 28        |
| 3.2      | ALLYL ALCOHOL ROUTE .....                                                  | 34        |
| 3.2.1    | Process Description .....                                                  | 34        |
| 3.3      | GLYCEROL ROUTE .....                                                       | 42        |
| 3.3.1    | Process Chemistry .....                                                    | 43        |
| 3.3.2    | ASER .....                                                                 | 45        |
| 3.3.3    | CONSER S.P.A. ....                                                         | 45        |
| 3.3.4    | Dow .....                                                                  | 46        |
| 3.3.5    | Hanwha Chemical .....                                                      | 51        |
| 3.3.6    | Samsung .....                                                              | 51        |
| 3.3.7    | Solvay .....                                                               | 52        |
| 3.3.8    | Spolek pro chemickou a hutní výrobu, akciová společnost (Spolchemie) ..... | 62        |
| 3.3.9    | Closing Remarks on the Glycerol to ECH route .....                         | 62        |
| <b>4</b> | <b>Potential Routes Mentioned in the Literature .....</b>                  | <b>64</b> |

|       |                                                                              |     |
|-------|------------------------------------------------------------------------------|-----|
| 4.1   | ELECTROCHEMICAL DEHYDROCHLORINATION OF<br>DICHLOROPROPANOL.....              | 64  |
| 4.2   | ACETONE ROUTE.....                                                           | 64  |
| 4.3   | ACROLEIN ROUTE.....                                                          | 66  |
| 4.3.1 | Process Description.....                                                     | 67  |
| 4.4   | ETHANE CONVERSION.....                                                       | 69  |
| 5     | <b>Process Economics</b> .....                                               | 71  |
| 5.1   | COSTING BASIS.....                                                           | 71  |
| 5.1.1 | Investment Basis.....                                                        | 71  |
| 5.1.2 | Pricing Basis.....                                                           | 71  |
| 5.1.3 | Cost of Production Basis.....                                                | 72  |
| 5.2   | ALLYL CHLORIDE ROUTE.....                                                    | 73  |
| 5.2.1 | Sensitivities.....                                                           | 79  |
| 5.3   | ALLYL ALCOHOL ROUTE.....                                                     | 83  |
| 5.4   | GLYCEROL ROUTE.....                                                          | 86  |
| 5.5   | ACROLEIN ROUTE.....                                                          | 89  |
| 5.6   | COMPARISON OF PRODUCTION ROUTES TO<br>EPICHLOROHYDRIN.....                   | 93  |
| 5.7   | REGIONAL COMPETITIVENESS FOR GLYCEROL BASED ROUTE<br>TO EPICHLOROHYDRIN..... | 97  |
| 5.8   | CONCLUDING REMARKS.....                                                      | 104 |
| 6     | <b>Commercial Overview</b> .....                                             | 105 |
| 6.1   | APPLICATIONS.....                                                            | 105 |
| 6.1.1 | Epoxy Resins.....                                                            | 105 |
| 6.2   | MARKET DYNAMICS.....                                                         | 107 |
| 6.2.1 | North America.....                                                           | 107 |
| 6.2.2 | Western Europe.....                                                          | 108 |
| 6.2.3 | Asia.....                                                                    | 110 |
| 6.2.4 | Rest of the World.....                                                       | 113 |
| 6.2.5 | Global Summary.....                                                          | 115 |
| 7     | <b>Glossary</b> .....                                                        | 118 |
| 8     | <b>References</b> .....                                                      | 120 |

| <b>Appendix</b>                                                 | <b>Page</b> |
|-----------------------------------------------------------------|-------------|
| <b>A Supporting Cost of Production Estimates .....</b>          | <b>A-1</b>  |
| <b>B Capital Cost Estimates .....</b>                           | <b>B-1</b>  |
| <b>C Operating Cost Elements .....</b>                          | <b>C-1</b>  |
| <b>D PERP Program Title Index (2000/2001 – 2009/2010) .....</b> | <b>D-1</b>  |

| Figure                                                                            | Page |
|-----------------------------------------------------------------------------------|------|
| 1.1 Global Epichlorohydrin Net Trade .....                                        | 18   |
| 3.1 Allyl Chloride via Propylene Chlorination .....                               | 29   |
| 3.2 Epichlorohydrin via Allyl Chloride .....                                      | 31   |
| 3.3 Allyl Acetate/Allyl Alcohol Synthesis and Purification .....                  | 36   |
| 3.4 Allyl Alcohol Chlorination and Purification.....                              | 39   |
| 3.5 Epichlorohydrin via 2,3-Dichloro-1-Propanol.....                              | 40   |
| 5.1 Propylene Price Effect on Epichlorohydrin Cost for Allyl Chloride Route ..... | 80   |
| 5.2 Investment Effect on Epichlorohydrin Cost for Allyl Chloride Route .....      | 81   |
| 5.3 Effect of Capacity on Epichlorohydrin Cost for Allyl Chloride Route .....     | 82   |
| 5.4 Comparison of Epichlorohydrin Costs.....                                      | 94   |
| 5.5 Glycerol Process Regional Cost of Production Comparison .....                 | 102  |
| 6.1 Epichlorohydrin Value Chain .....                                             | 105  |
| 6.2 U.S. Epichlorohydrin Demand, 2010.....                                        | 108  |
| 6.3 West European Epichlorohydrin Demand, 2010 .....                              | 109  |
| 6.4 Asian Epichlorohydrin Demand, 2010 .....                                      | 110  |
| 6.5 Global Epichlorohydrin Demand .....                                           | 115  |
| 6.6 Global Epichlorohydrin Capacity .....                                         | 116  |
| 6.7 Global Epichlorohydrin Net Trade .....                                        | 117  |

| Table                                                                                                                                                                                                                                                       | Page |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1.1 Epichlorohydrin Product Cost Summary, 100 kta .....                                                                                                                                                                                                     | 10   |
| 1.2 Relative Epichlorohydrin Production Processes Evaluation.....                                                                                                                                                                                           | 11   |
| 1.3 Regional Comparison of Glycerol to Epichlorohydrin Costs .....                                                                                                                                                                                          | 14   |
| 1.4 Comparison of Relative Regional Economics for Glycerol to ECH Process .....                                                                                                                                                                             | 15   |
| 1.5 Global Epichlorohydrin Demand .....                                                                                                                                                                                                                     | 17   |
| 1.6 Global Epichlorohydrin Capacity .....                                                                                                                                                                                                                   | 17   |
| 2.1 Physical Properties.....                                                                                                                                                                                                                                | 24   |
| 5.1 Prices of Epichlorohydrin Raw Materials, Byproducts, and Other Inputs .....                                                                                                                                                                             | 72   |
| 5.2 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Allyl Chloride Hypochlorination, (2) Alkaline Epoxidation (Allyl<br>Chloride Route, 63.5 kta - assuming Supply from 55.3 kta Allyl Chloride Plant)....                                 | 76   |
| 5.3 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Propylene Chlorination, (2) Hypochlorination, (3) Alkaline<br>Epoxidation (Allyl Chloride Route from Propylene, 63.5 kta).....                                                         | 77   |
| 5.4 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Propylene Chlorination, (2) Hypochlorination, (3) Alkaline<br>Epoxidation (Allyl Chloride Route from Propylene, 100 kta).....                                                          | 78   |
| 5.5 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Propylene Oxidation (2) Hydrolysis (3) Chlorination (4) Alkaline<br>Epoxidation (Allyl Alcohol (Showa Denko/Daiso) Route, 63.5 kta) .....                                              | 84   |
| 5.6 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Propylene Oxidation (2) Hydrolysis (3) Chlorination (4) Alkaline<br>Epoxidation (Allyl Alcohol (Showa Denko/Daiso) Route, 100 kta) .....                                               | 85   |
| 5.7 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Glycerol Hydrochlorination, (2) Alkaline Epoxidation (Glycerol<br>Route, 100 kta).....                                                                                                 | 88   |
| 5.8 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Acrolein Chlorination, (2) Hydrogenation, (3) Alkaline Epoxidation<br>(Acrolein Route, 63.5 kta - assuming Supply from 56.5 kta Acrolein Plant).....                                   | 91   |
| 5.9 Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Acrolein Chlorination, (2) Hydrogenation, (3) Alkaline Epoxidation<br>(Acrolein Route, 100 kta - assuming Higher Selectivity and Supply from Larger<br>106.5 kta Acrolein Plant) ..... | 92   |
| 5.10 Epichlorohydrin Product Cost Summary .....                                                                                                                                                                                                             | 93   |
| 5.11 Relative Epichlorohydrin Production Processes Evaluation.....                                                                                                                                                                                          | 95   |

|      |                                                                                                                                                                        |     |
|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 5.12 | Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Glycerol Hydrochlorination, (2) Alkaline Epoxidation (Glycerol<br>Route, 100 kta China) .....         | 98  |
| 5.13 | Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Glycerol Hydrochlorination, (2) Alkaline Epoxidation (Glycerol<br>Route, 100 kta Thailand).....       | 99  |
| 5.14 | Cost of Production Estimate for: Epichlorohydrin<br>Process: (1) Glycerol Hydrochlorination, (2) Alkaline Epoxidation (Glycerol<br>Route, 100 kta Western Europe)..... | 100 |
| 5.15 | Regional Comparison of Glycerol to Epichlorohydrin Costs .....                                                                                                         | 101 |
| 5.16 | Relative Regional Glycerol to ECH Production Costs .....                                                                                                               | 102 |
| 6.1  | U.S. Epichlorohydrin Producers, 2010 .....                                                                                                                             | 107 |
| 6.2  | North American Epichlorohydrin .....                                                                                                                                   | 108 |
| 6.3  | West European Epichlorohydrin Producers, 2010.....                                                                                                                     | 109 |
| 6.4  | West European Epichlorohydrin Supply/Demand Balance.....                                                                                                               | 110 |
| 6.5  | Asian Epichlorohydrin Producers, 2010 .....                                                                                                                            | 111 |
| 6.6  | Asian Epichlorohydrin Announced Capacity Additions. 2011-2015 .....                                                                                                    | 112 |
| 6.7  | Asian Epichlorohydrin Supply/Demand .....                                                                                                                              | 113 |
| 6.8  | Rest of World Epichlorohydrin Demand .....                                                                                                                             | 113 |
| 6.9  | Rest of the World Epichlorohydrin Capacity.....                                                                                                                        | 114 |
| 6.10 | Rest of the World Epichlorohydrin Supply/Demand.....                                                                                                                   | 114 |
| 6.11 | Global Epichlorohydrin Demand .....                                                                                                                                    | 115 |
| 6.12 | Global Epichlorohydrin Capacity .....                                                                                                                                  | 116 |

# CHEMSYSTEMS

## PERP PROGRAM



[www.chemsystems.com](http://www.chemsystems.com)

The ChemSystems Process Evaluation/Research Planning (PERP) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. PERP reports are available as a subscription program or on a single report basis.

### Contact Details:

**London:** Dr. Alexander Coker, Manager, PERP Program  
Phone: + 44-(20)-7950-1570, e-mail: [acoker@nexant.com](mailto:acoker@nexant.com)

**New York:** Heidi Junker Coleman, Global Programs Support Manager  
Phone: + 1-914-609-0381, e-mail: [hcoleman@nexant.com](mailto:hcoleman@nexant.com)

**Shanghai:** Dr. Y. Larry Song, General Manager, Nexant China  
Phone: +86 21 6182 6791, e-mail: [ylsong@nexant.com](mailto:ylsong@nexant.com)

Nexant, Inc. ([www.nexant.com](http://www.nexant.com)) is a leading management consultancy to the global energy, chemical, and related industries. For over 38 years, ChemSystems 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. 2011. All Rights Reserved.