

CHEMSYSTEMS PERP PROGRAM

Competing Feedstocks for Vinyl Chloride Monomer (VCM)

Process Technology & Costs for Producing VCM from Coal-Based Acetylene in China, Sugar fermentation (Ethanol)-Based Ethylene in Brazil, Ethane/Propane Cracker Derived Ethylene in USGC, Naphtha Cracker Derived Ethylene in Western Europe; & VCM Regional Supply/Demand Forecasts.

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Report Abstract

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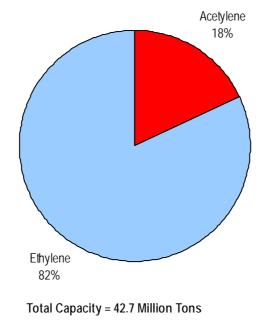
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INTRODUCTION

Vinyl chloride monomer (VCM) was first produced by reacting acetylene with hydrogen chloride. Until the early 1950s, acetylene-based technology predominated. Due to the energy input necessary to produce acetylene and the hazards of handling it thereafter, ethylene-based routes have since become predominant.

Currently, VCM capacity can be categorized based on the feedstocks acetylene and ethylene. The figure below shows the VCM capacity share of these two feedstocks.



Global VCM Capacity by Feedstocks, 2008

This report examines the competitiveness of VCM produced from different routes and sources of feedstocks. The costs of production of VCM from acetylene (derived from coal/coke), as well as from ethylene using balanced oxychlorination from various feedstocks in selected locations are compared.

• The majority of VCM in China is produced from the coal route due to the shortage of oil resources and the abundance of coal in the country. It has been believed that when oil prices surpass certain levels the coal to chemicals alternative could become more advantageous. However, the current constant rise of coal prices in China may also make the production from this route less competitive than the conventional process.

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For the balanced oxychlorination process, the costs of production of commercial VCM production based on ethylene from an ethane/propane gas cracker in the United States and naphtha cracker in Western Europe are included in the analysis.

• The alternative/developing ethylene production derived from bioethanol in Brazil is also featured in the analysis.

CHEMISTRY AND TECHNOLOGY

Acetylene-Based VCM

Acetylene can be produced by a number of high temperature processes. The classical commercial route is the calcium carbide route in which acetylene is generated by the reaction of calcium carbide and water. In this process, lime is first reduced by carbon (in the form of coke) in an electric furnace to yield calcium carbide:

$$CaO + 3C \longrightarrow CaC_2 + CO$$

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The calcium carbide is then hydrolyzed to produce acetylene:

 $CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2 H = -129 kJ/mol$ C408_00101.0008.4120.cdx

• This process (acetylene from calcium carbide) is described in detail in the report.

The oldest and simplest commercial route to VCM is via the vapor phase addition of anhydrous hydrogen chloride (HCl) to acetylene (C_2H_2) over a mercuric chloride (HgCl₂) catalyst supported on activated carbon.

$$HC \equiv CH + HCI \xrightarrow{HgCl_{2}/} CH_{2} = CHCI$$

$$VCM$$
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- This process (VCM from acetylene) is described in detail in section 3 of the report.
- Acetylene-based VCM is an important process route in China, both currently and in the future: The report discusses coal, coke, calcium carbide, acetylene and VCM from a specific Chinese perspective.

Ethylene-Based VCM

The majority of commercial VCM technology utilizes direct chlorination of ethylene to produce ethylene dichloride (EDC), followed by pyrolysis to VCM and hydrogen chloride (HCl). In the oxychlorination step, the HCl released by the subsequent pyrolysis of EDC is reacted with ethylene and oxygen to yield additional ethylene dichloride and water. The commercialization of oxychlorination technology paved the way for the so-called "balanced process", combining direct chlorination, oxychlorination, and EDC pyrolysis reactions. This widely used commercial process utilizes the HCl stream and produces only vinyl chloride and water. The individual chemical reactions are direct chlorination of ethylene to produce ethylene dichloride (EDC), followed by pyrolysis to VCM and HCl and the final reaction shown (immediately below) is the oxychlorination step where hydrogen chloride released in pyrolysis is reacted with ethylene and oxygen to yield EDC and water. The EDC produced in this step is subsequently converted to VCM.

Direct Chlorination	
$H_2C=CH_2 + CI_2$	\rightarrow CH ₂ CICH ₂ CI
Ethylene	1,2 - Dichloroethane (EDC)
EDC Pyrolysis	
$CH_2CICH_2CI \longrightarrow H_2C=CHCI + HCI$	
EDC	VCM
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$H_2C=CH_2 + 2HCI + \frac{1}{2}O_2 \longrightarrow CH_2CICH_2CI + H_2O$	
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The overall reaction is:

 $2H_2C=CH_2 + CI_2 + \frac{1}{2}O_2 \longrightarrow 2CH_2=CHCI + H_2O$

• This process is described in detail in the report.

A high proportion of VCM production capacity is based on this technology. However, a number of producers operate unbalanced schemes drawing HCl from other chlorination operations in an adjacent plant. A further variation runs in part on EDC brought in from other sources. Nevertheless, the balanced process is representative of the majority of the industry.

The primary source of ethylene is from steam crackers i.e., by thermal pyrolysis of saturated hydrocarbons in the presence of steam. A variety of feedstocks can be cracked to ethylene, with each yielding a different slate of co-products. In general, the choice of feedstock is dependent on location, and there are considerable regional disparities. Cracker feedstocks can be hydrocarbon gases such as ethane and propane, or oil derived feedstocks such as naphtha and gas oil.

Ethylene production from bioethanol is being planned for use as a feedstock for VCM production. In fact, ethylene has for many years been produced by dehydration of ethanol in Brazil and India, and the Australian chemical industry initiated ethylene-based chemistry by this route before it was feasible to build crackers.

• This report section details an extensive discussion on current ethanol technologies particularly from fermentation of sugar as in the case of Brazil. In addition, a discussion of the Scientific Design (SD) ethanol dehydration technology to produce ethylene (the rights to which are currently owned by Chematur) is included.

ECONOMIC ANALYSIS

Nexant has modeled the process economics of the major existing and emerging VCM technologies in selected important locations i.e., the United States Gulf Coast (USGC), Western Europe, China, and Brazil, using the leading feedstocks in each venue. The costs for ethylene based VCM are also examined via ethanol dehydration and via conventional steam cracking.

The cases considered for the cost of production analysis are depicted in the table below:

Process Region Route Feedstock Process Route USGC Ethylene Ethane/Propane Steam cracking to Ethylene Balanced Oxychlorination Western Europe Naphtha Steam Cracking to Ethylene Balanced Ethylene Oxychlorination Brazil Ethylene Bioethanol Sugarcane fermentation to ethanol, Ethanol dehydration to ethylene Balanced Oxychlorination China Acetylene Coal Coal to calcium carbide,

Matrix for VCM Cost of Production Analysis

Commentary on the selected feedstocks used in developing the economic assessments for each region is provided in the report.

Calcium Carbide to VCM

- Sugarcane in Brazil including microeconomic and macroeconomic factors affecting the price of sugarcane
- Ethane and Propane in USGC
- Naphtha in Western Europe
- Coal in China including commentary on the thermal coal price

Chinese producers have continued to build new acetylene based VCM/PVC plants near its coal producing regions in the South and West. The report includes the following Cost of Production Estimate Tables, from which **Cost of Production Estimates for ACETYLENE-based VCM in China** have been developed:

- Coke from Coal (Low Coal Price Case)
- Calcium Carbide from Coal (Low Coal Price Case) using Closed Furnace Process
- Acetylene from Coal (Low Coal Price Case) via Calcium Carbide Process
- VCM from Coal (Low Coal Price Case) via Acetylene Process
- Coke from Coal (High Coal Price Case)
- Calcium Carbide from Coal (High Coal Price Case) via Closed Furnace Process
- Acetylene from Coal (High Coal Price Case) via Calcium Carbide Process
- VCM from Coal (High Coal Price Case) via Acetylene Process

Two coal price cases were modeled in order to represent the range of production costs of the acetylene route, because the coal prices fluctuated so much during the first half of 2008.

The report includes the following Cost of Production Estimate Tables, from which **Cost of Production Estimates for ETHYLENE-based VCM in the USGC, Western Europe and Brazil** have been developed:

- Ethylene from Ethane/Propane in the USGC via Steam Cracking Process
- VCM from Ethylene in the USGC via Balanced Oxychlorination Process
- Ethylene from Naphtha in Western Europe via Steam Cracking (Medium Severity) Process
- VCM from Ethylene in Western Europe via Balanced Oxychlorination Process
- Ethanol in Brazil via Sugarcane Fermentation Process
- Ethylene from Ethanol in Brazil via Ethanol Dehydration Fixed Bed Process
- VCM from Ethylene (from sugarcane-based ethanol via dehydration process) in Brazil via Balanced Oxychlorination Process

The production cost estimates are based on 2Q, 2008 when the Brent crude oil price was high. However, the economic for these alternative routes may be less favorable than the conventional production at lower crude oil price.

To test the impact of crude oil and consequently other raw material prices on VCM production costs, the sensitivity analysis was performed for both acetylene and ethylene production routes. Costs of production were estimated on a series of these material prices as follows. This represents the past raw material price and the potential price in the future.

- Crude oil price: ethane/propane and other byproduct prices were varied with the crude oil prices by using the historical relationship between Brent crude oil and these product prices
- Coal: coking coal price was varied with thermal coal price for power varied at the same ratio to current price, while keeping other production costs constant
- Sugarcane: sugarcane price was varied, while other production costs are kept constant

Utilities costs are adjusted along with the change of the crude oil price, while other costs remain unchanged.

The results of this analysis are illustrated and discussed.

MARKET ANALYSIS

VCM is used almost exclusively to produce PVC. PVC can be used in a multitude of applications by employing a number of fabrication methods including extrusion, calendaring, injection molding, blow molding, and coating. Most PVC is processed by extrusion to make pipe, siding and window or door profiles, wire and cable insulation and rigid film or sheet.

Other applications include chlorinated solvents and polyvinylidene chloride, however the volumes involved are insignificant relative to PVC production.

The market section provides a detailed understanding of regional dynamics (U.S., Western Europe, and Asia Pacific).

- Supply, Demand and Trade data are given for the US, Western Europe and Asia Pacific.
- For the U.S. and Western Europe, VCM plant capacity by producer and specific location are given.
- An extensive listing of VCM plant capacity by producer, specific location and feedstock for Asia Pacific (including Japan, India, Pakistan, Indonesia, Thailand, Malaysia, Taiwan, South Korea and China).





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