

Ethylene

Steam Cracking (Naphtha, Ethane/Propane), MTO, from ethanol Processes. Developing Technologies: Gas To Ethylene, FCC, Alkanes To Alkenes etc. Cost of Producing Ethylene from Ethane, Propane, E/P, Butane, Gas Oil, MTO, Naphtha, Ethanol. Regional Supply/Demand.

PERP 08/09-5

Report Abstract

October 2009

CHEMSYSTEMS PERP PROGRAM

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For further information about these reports, please contact the following:

New York, Dr. Jeffrey S. Plotkin, Vice President and Global Director, PERP Program, phone: + 1-914-609-0315, e-mail: jplotkin@nexant.com; or Heidi Junker Coleman, Multi-client Programs Administrator, phone: + 1-914-609-0381, e-mail: hcoleman@nexant.com.

London, Dr. Alexander Coker, Manager, PERP Program, phone: + 44-(20)-709-1570, e-mail: acoker@nexant.com.

Bangkok, Maoliosa Denye, Marketing Manager, Energy & Chemicals Consulting: Asia, phone: + 66-2793-4612, e-mail: mdenye@nexant.com.

Website: www.chemsystems.com

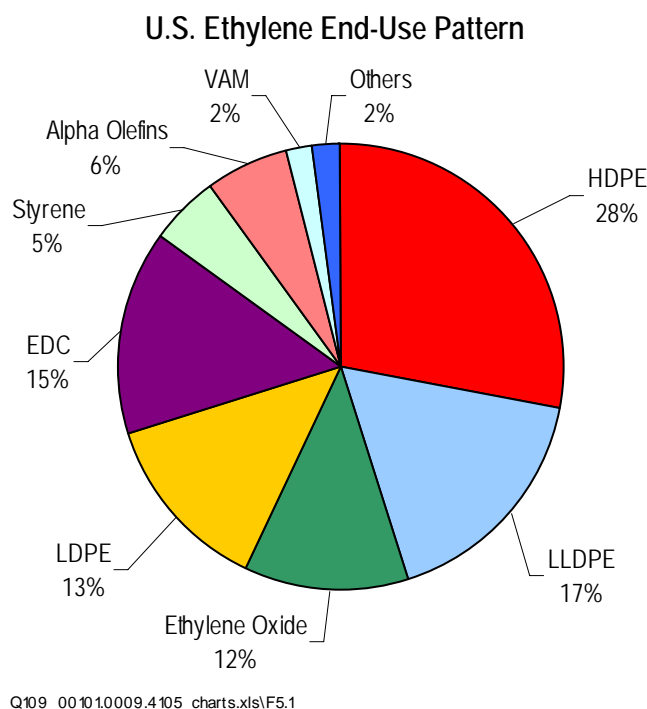
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INTRODUCTION

Ethylene end use markets are diverse, owing to the wide spectrum of derivatives. These end use markets include: wire and cable insulation; consumer, industrial and agricultural packaging; woven fabrics and assorted coverings; pipes, conduits and assorted construction materials; drums, jars, containers, bottles and the racks in which to hold them; antifreeze; and solvents and coatings.

Some examples of the major chemicals and polymers that are produced from ethylene include low, linear low and high density polyethylenes (LDPE, LLDPE and HDPE respectively), ethylene dichloride (EDC), vinyl chloride (VCM), polyvinyl chloride (PVC) and its copolymers, alpha-olefins (AO), ethylene oxide (EO) used primarily to make mono ethylene glycol (MEG) for use in polyester and antifreeze production, vinyl acetate (VAM), ethyl alcohol (ethanol), ethylene propylene diene monomer (EPDM), a co-monomer for polypropylene, ethylbenzene (EB), styrene (SM), polystyrene (PS) and its copolymers.

Polymers represent the major end use for ethylene, as exemplified by the Figure below showing ethylene end-use for the United States.



This PERP report discusses commercial and near commercial technology for producing ethylene, developing technologies, cost of production estimates for the manufacture of this olefin, and analysis of the commercial market.

COMMERCIAL AND NEAR COMMERCIAL TECHNOLOGY

Having originally been developed in refineries in the United States, steam cracking technology has been around since the 1920s; (heat treatment of crude oil streams was happening previously to enhance the yield of light components).

Although the cracking process is simple in principle, with no catalysts or initiators needed, practical application has been constrained by:

- Material properties – in particular tube temperature limits in the furnaces, limiting feedstock conversion
- Controllability – immeasurably improved by the advent of automatic and now computer control systems
- Scale – compressors and turbines and now able to efficiently work at the sizes needed for million ton crackers

Some other specific developments that are helping transform cracker configurations include:

- Short residence coils that greatly improve olefin selectivity
- Significantly larger furnaces with efficient floor burners allowing crackers with 4-8 furnaces instead of 12 +
- Structured packing/high efficiency trays in columns to improve separation efficiency
- Integration techniques to reduce specific power consumption

This section discusses the various feeds employed in each region and the conventional technologies (i.e., steam cracking) employed to produce olefins. In addition, a discussion of alternative technologies such as methanol-to-olefins (MTO) and ethylene from renewable sources is included.

Steam Cracking

Naphtha cracking remains the dominant source of ethylene globally; however gas cracking has been gathering more and more significance. Naphtha crackers took the brunt of the pressure after overbuilding in the late 1970s, with significant closures in the United States. Ethane cracking has come from nowhere to be a significant source of ethylene, principally as a result of capacity developments in the Middle East. The LPG cracker segment (albeit chiefly comprising ethane/propane crackers) has increased steadily since the late 1980s.

Global ethylene developments are discussed - Nexant's capacity database allows us to analyze ethylene capacity information all the way back to the mid 1970s. Regional capacity split over the last 30 years, overlaid with a broad description of petrochemical industry profitability (as portrayed by ChemSystems Cash Margin Index) is given as well as various other analyses

- Specifically, North American, European, Asia Pacific and Middle East developments are discussed.

Process variables - The cracking of a single hydrocarbon or a complex mixture of hydrocarbons into vastly different compounds involves complex reaction kinetics, which are influenced by a

number of different process variables. In practice, however, only a few of these are under the control of the cracking-heater designer. The key parameters that have the greatest effect on pyrolysis and which the designer can manipulate are discussed in the report

Process description - Steam cracker feeds can be separated into two categories: natural gas liquids (ethane and LPG) and heavy liquids (i.e., naphtha and gas oils).

- Natural gas liquids (NGLs) are composed essentially of ethane, propane and butanes. The process description and process flow diagrams given in the report are based on an ethane/propane feedstock.
- Full range naphtha (FRN) is thought of as any hydrocarbon that boils in the gasoline boiling range, which generally means the C₅-430 °F (C₅-221 °C) boiling range; however, many olefin units operate on lower end-point (e.g., 350 °F or 177 °C) light naphtha (LVN). In the description given in the report, only the steps that differ from the NGL flow scheme are discussed.
- Gas oils are classified as either atmospheric or vacuum according to their origin, either from an atmospheric crude tower or a crude bottoms vacuum column. Atmospheric gas oil material boils in the range 400-800 °F (204-427 °C); vacuum gas oil boils at 800-1,000 °F (427-538 °C) and higher. Since vacuum gas oils are not cracked commercially to any significant degree, only the processing scheme for an atmospheric gas oil facility is discussed in relation to naphtha cracking.
- A significant amount of licensor time is spent optimizing the recovery section (i.e., back end) of the ethylene plant. Rearranging and optimizing the tower configuration is another approach taken by the major licensors of ethylene technology. The different arrangements fall into three categories depending on the first fractionation tower in the recovery scheme (i.e., demethanizer-first, deethanizer-first, or depropanizer-first). In this section, a qualitative analysis of these three tower configurations is presented for full range naphtha (FRN) feed case, pertinent process flow diagrams are given.
- An efficient means of separating acetylene from the ethylene product is essential and technology for achieving this is discussed in the report, pertinent process flow diagrams are also given.

Trends in the ethylene industry and various approaches to dealing with these are discussed in the report (furnace tube materials, curtailing coke formation etc.).

The report includes a section which addresses flexibility for a “demethanizer first” configuration – details for other configurations may differ, although overall impacts can be similar (hot end, cold end).

The global ethylene industry is generally dependent on the expertise and experience of a limited number of licensors/contractors that own proprietary ethylene technology and have been responsible for designing and building most of the world ethylene production plants. This topic is briefly discussed.

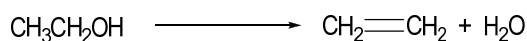
Methanol To Olefins (MTO)

Methanol-to-olefins (MTO) was first developed by Mobil (now ExxonMobil) in the mid-1980s as part of its methanol-to-gasoline (MTG) process that was developed in New Zealand. The Mobil workers found that, by altering operating conditions, high levels of ethylene, instead of gasoline-range hydrocarbons, could be made by passing methanol over a ZSM-5 catalyst. This technology lay dormant until the mid-1990s, when UOP teamed with Norsk Hydro to build an MTO pilot plant in Norway. Since then, Lurgi has developed its own version of this process, methanol-to-propylene (MTP). The Chinese have also been active in this field. Dalian Institute of Chemical Physics (DICP) has recently developed their own process (DMTO).

- Process flow diagrams and descriptions for UOP, ExxonMobil and Dalian Institute of Chemical Physics (DICP) technologies are given

Ethylene From Renewable Sources

The use of ethanol to make ethylene on a comparatively small scale is well established in developing countries not having ready access to hydrocarbons. The chemistry of ethylene production via dehydration of ethanol can be represented by the following reaction:



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Process description and process flow diagrams for the use of ethanol to make ethylene are given in the report.

DEVELOPING TECHNOLOGY

The following developing technologies are discussed in the report:

- Gas To Ethylene (GTE)
- Olefins Via Enhanced Fluid Catalytic Cracking (FCC)
- Syngas To Ethanol Followed By Dehydration To Ethylene
- ConocoPhillips Two-Zone Reactor For Converting Alkanes To Alkenes
- Olefins Via Catalytic Naphtha Cracking

ECONOMIC ANALYSIS

In this section the costs of ethylene production have been estimated using steam crackers with the following feedstocks and world scale capacities:

- Ethane
- Propane
- Ethane/Propane (80/20)
- n-Butane
- i-Butane
- Light Naphtha (A-180)
- Atmospheric Gas Oil

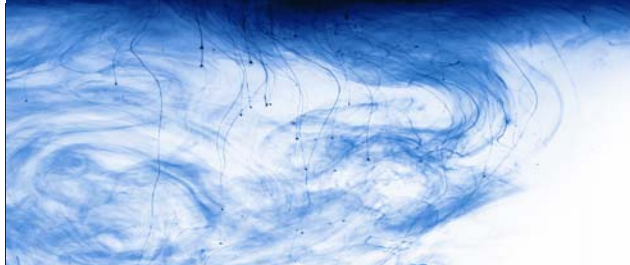
In addition, costs of ethylene production have been estimated for the following:

- A methanol-to-olefins plant (employing methanol at spot market value)
- Ethanol dehydration plant (employing ethanol derived from corn)

Pertinent sensitivity analyses have also been carried out and discussed. Plant flexibility for handling various feedstocks is also briefly outlined.

COMMERCIAL ANALYSIS

- Supply, demand and trade for the United States, Western Europe, and Asia Pacific are discussed.
- Extensive listings detailing plant capacity, specific company, plant location, and production process employed are given for the regions denoted above are given.



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