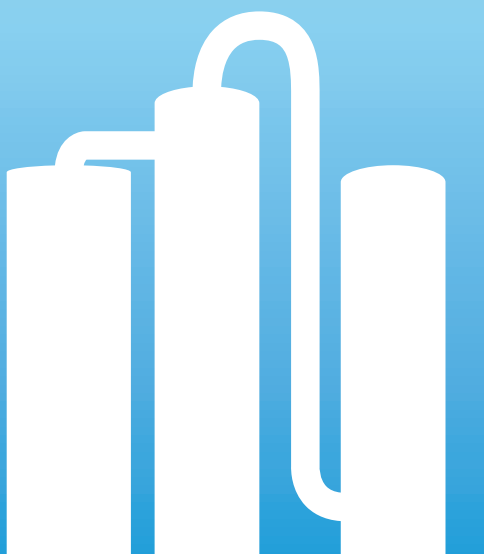
NexantThinking™
PERP PROGRAM

Ethylene

PERP 2013-4



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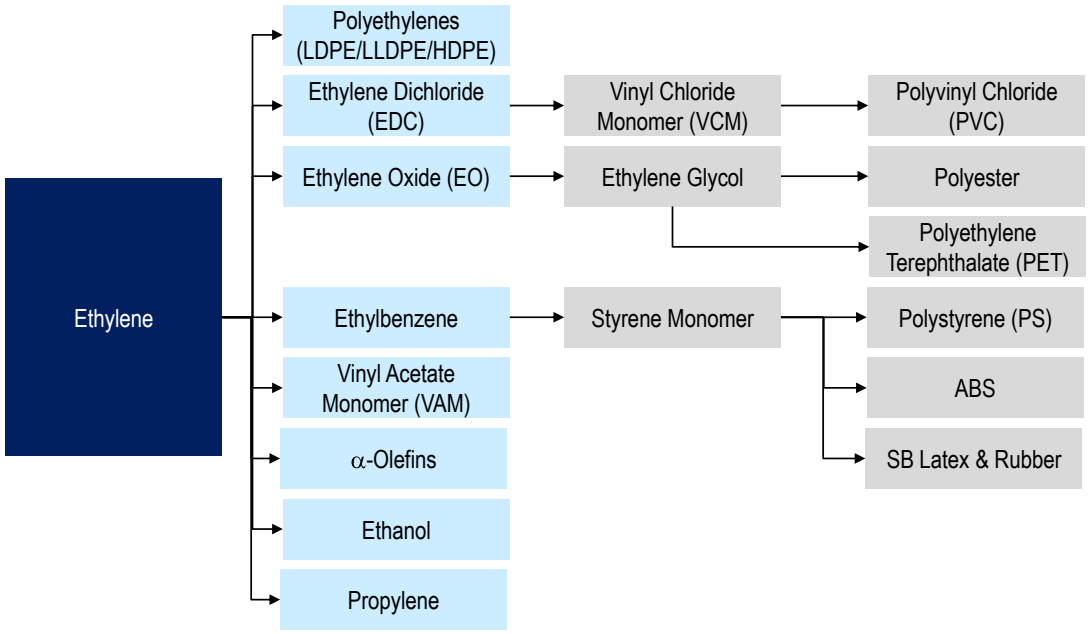
INTRODUCTION

Ethylene is the most widely used olefin building block for petrochemicals derivatives. Its carbon-carbon double-bond, $H_2C=CH_2$, provides inherent characteristics for chemical reactivity to form saturated hydrocarbons, their derivatives, as well as polymers. As such, ethylene serves as a key starting material for many of the petrochemicals in the industrial and consumer markets such as: packaging, transportation, electronic, textile and construction.

Figure 1 Key Ethylene Derivatives



This NexantThinking™ Process Evaluation/Research Planning (PERP) report includes:

- An overview of the licensing technology and other proprietary technology holders status
- Strategic business considerations for a new entrant into the Ethylene business
- A detailed discussion of established/conventional process technologies (hydrocarbon feed-based routes – e.g. ethane, propane, butane, naphtha, gas oil), as well as alternative routes to ethylene (e.g. methanol to olefins, bio-ethanol dehydration, etc.)
- A critical review of emerging technological advances in the ethylene technology space
- Process economics for conventional steam cracking technology as well as alternative routes to ethylene (MTO, bio-ethanol dehydration).
- Regional process economics for established leading capacities and speculative capacities for alternative technologies.
- Commercial end-use applications as well as global and regional (supply/demand/trade) market analysis

TECHNOLOGY ANALYSIS (COMMERCIAL & DEVELOPING)

This report provides a thorough review of ethylene technology, reviewing and evaluating commercial technologies which hold significant market relevance. The report evaluates the following commercial technologies:

- **Pyrolysis (steam cracking) of hydrocarbons** for various feeds: ethane, propane, butane, naphtha, and atmospheric gas oils. Technology performance claims from key licensors (Technip, Linde AG, Lummus, and KBR) are also provided.
- **Methanol to olefins** (UOP's Advanced MTO process and DICP's DMTO process)
- **Dehydration of bio-ethanol to ethylene**

Although the steam cracking of hydrocarbons remains the dominant method to produce ethylene – accounting for the large majority of global capacity – alternative technologies are becoming more and more relevant as feedstock volatility and availability become strong drivers in capturing advantaged economic profit in cracker operations. There are notable developing technologies which have the potential to provide key alternative routes to producing ethylene. The evaluated developing technologies in this report are:

- **Hydrogenation of Acetylene via Natural Gas** (Synfuels International GTE process)
- **Oxidative Coupling of Methane** (Siluria)

An overview of the recent research and technology efforts (at the lab or pilot scale) for improving ethylene production technology is also included.

A detailed analysis of the critical factors affecting steam cracker operations, efficiency, and profitability is also provided. Some of the factors reviewed in this report include:

- **Steam cracker flexibility and limitations**
  - **Hot end:** furnace convection section limitations, furnace radiant section limitations, transfer line exchangers, quench section
  - **Cold end:** compressor section, cold box, demethanizer, deethanizer, debutanizer, acetylene conversion and ethylene purification, depropanizer and MAPD conversion, propylene purification, etc.
- **Cracker optimization**
  - **Cracking Severity**: high, low, total olefins maximizing
  - **Cracking Coil Design**: performance parameters, advancements in coil design, twin cell furnace designs, impact of coil diameters, single-pass vs multi-pass and split-coil designs, transfer line exchangers, furnace tube materials, etc.

PROCESS ECONOMICS

Nexant has developed detailed cost of production models for various ethylene processes in commercial operations. For process comparison purposes, a single location – the U.S. Gulf Coast – has been used as a benchmark location. Evaluations for steam cracking technology have been modeled at plant capacities of 1.5 million tons per year, MTO/DMTO cost of production models have been carried out at plant capacities of 300 000 tons per year, and an ethylene via bio-ethanol dehydration model has been carried out for a plant capacity of 350 000 tons per year.

The cost of production estimates included in this report are:

- **Ethylene via steam cracking** – for various feedstocks: Ethane, Ethane/Propane (80/20), Propane, Butanes, Naphtha (high severity, low severity, and low severity with C_4s recycle), Atmospheric Gas Oil
- **MTO/DMTO** – for UOP's Advanced MTO process and DICP's DMTO process.
- **Bio-ethanol dehydration**

Regional cost competitiveness analysis has also been performed using developed cost models for a total of 11 regional plants. Cost of production estimates for a steam cracker have been modeled for 8 different facilities in 4 different regions – USGC, WE, SEA, and ME – , with varying capacities of 1.0 to 1.5 million tons per year of ethylene. Two facilities for the production of ethylene via coal-based methanol have also been modeled at 300 000 tons per year capacities. A cost of production model for ethanol dehydration using bio-Ethanol as the feed has also been evaluated.

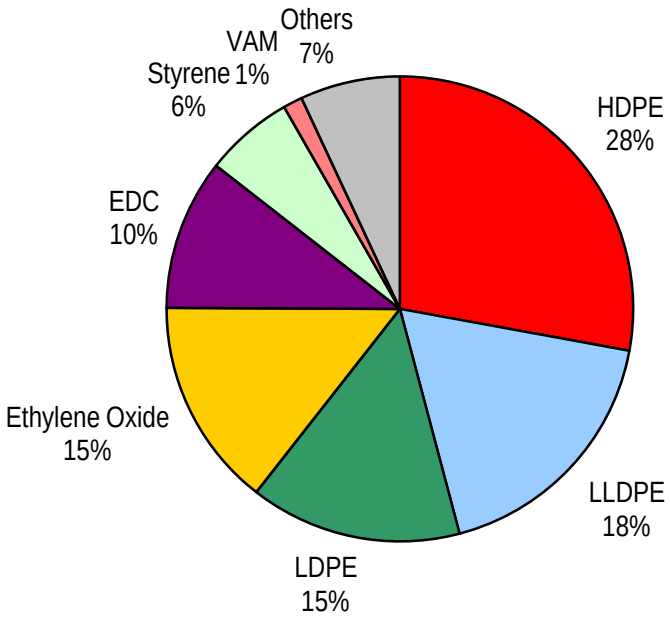
Sensitivity analyses have been performed based on variations in feedstock price and capital investment. The magnitudes of impact as well as drivers of these factors have been analyzed.

COMMERCIAL MARKET REVIEW

The global ethylene market reached an estimated 153 million tons in 2013, serving a wide-ranging end-use market, from automotive, construction, general industrial, and agriculture sectors via polyethylene, to rigid and flexible foams via PVC, to synthetic rubbers via styrene monomer.

Polyethylene continues to be the dominant consumer of ethylene. Almost all new steam crackers have been built with polyethylene units integrated on-site to directly off-take the ethylene, allowing for profit margin sharing. Polyethylene consumption has slowed in developed regions due to slower economic growth and the maturity of many application areas. Growth in developing regions is a much greater contributor to the global total due to generally higher GDP growth and the rapid development of key end-use sectors such as packaging and construction.

Figure 2 Ethylene End-Uses
(2013)



- Commercial end-use analysis for ethylene is provided, discussing the major derivative petrochemicals that can be produced form ethylene as well as their relevant product sectors.
- Global and regional (North America, Western Europe, Asia Pacific, and Middle East) supply, demand, and trade data is provided for 2010-2012 actuals, 2013 estimate, and 2014-2018 forecasts.
- Capacity listings from Nexant's database for each region are also included as part of the analysis, specifying plant capacities, owning capacity, location, and annual tonnage produced.

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