CHEMSYSTEMS

PERP PROGRAM

# Linear Low Density Polyethylene (LLDPE)

# Process Technology (including Comparison of Gas Phase, Solution & Slurry: Conventional Innovene-Unipol-Dowlex-Compact-Sclairtech, Metallocene/Single-Site mPact, and Easy-Processing Resin Evolue-Borstar-LD LPE), Production Costs (COP), Regional Supply/Demand Forecasts

PERP07/08-1

Report Abstract

November 2008

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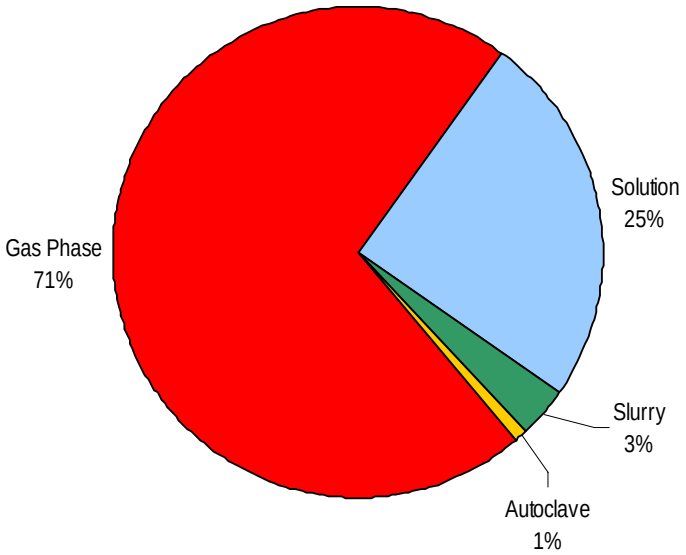
For further information about these reports contact Dr. Jeffrey S. Plotkin, Vice President and Global Director, PERP Program, phone: 1-914-609-0315; fax: 1-914-609-0399; e-mail: jplotkin@nexant.com; or Heidi Junker Coleman, phone: 1-914-609-0381, e-mail address: hcoleman@nexant.com, Website: http://www.chemsystems.com.

## Introduction

Global polyethylene demand continues to grow, driven by continued substitution of traditional materials such as paper, glass, and wood, as well as gains within the polymers sector at the expense of PVC and some higher cost polymers. The increasing demand for polyethylene will assure the need for new build in the industry, and with it, demand for technology licenses. The three primary forces that drive technology development and progress are product performance, process technology, and process chemistry.

The LLDPE technology licensing market is very competitive. The number of technologies available for license has grown, with numerous technologies competing for each new plant. The dominance of the gas phase process is illustrated below.

Installed LLDPE Capacity by Process - 2007




Q308_00101.0008.4101_Section 1 Figures.xls\LLDPE by Process

The strong growth in polyethylene leads to parallel growth in demand for ethylene. Decisions on the location of polyolefin plants are influenced by two main factors – proximity to the end use customer or proximity to the hydrocarbon raw material. The inherent difficulty in transporting ethylene has led to the co-location of ethylene production and derivative plants.

Location of future polyethylene plants will have an impact on polyethylene technology. Where the main motivation for a new plant is feedstock, the technology selected is likely to be suited to high volume commodity grades of polymer, with the key driver being high volume and low cost per ton of installed capacity. For a market-driven application, the key requirement of the technology is to match local market grade requirements, so the technology selected is most likely to be one with a more differentiated product slate. However, there are likely to be exceptions to these scenarios.

## PROCESS TECHNOLOGIES

For this report, Nexant *ChemSystems* evaluated many state-of-the-art LLDPE processes that are available for license. This evaluation provides:

- Recent developments highlighting key developments relating to each process technology.
- Background on the technology, including general product capabilities and a list of licensees, where applicable.
- Process description including simplified flow sheets.
- Investment and cost of production (COP) estimates for a grassroots facility. This is a generic plant constructed by a third party and does not reflect special situations that could result in a lower or higher capital investment. It is generally believed that a licensor can build its own plant for a lower capital cost relative to a third party company.

The focus of Section 2 is on the various gas phase, solution, and slurry processes that are well-established, commercially practiced technologies for the production of LLDPE resin and are generally available for license. The recent developments, background, and process descriptions for many LLDPE technologies are covered in this section.

The economic analysis for the technologies is presented in Section 3. The pricing basis and cost of production estimates are included. Estimates for cost of production were developed for conventional film grade resins, metallocene/single-site film grade resins, and easy processing film grade resins, depending on the technology. Detailed data is presented in Appendix A for conventional LLDPE and Appendix B for metallocene/single-site and easy processing LLDPE. A comparison of LLDPE versus LDPE economics is also presented in Section 3.

### Gas Phase Technologies

Since its development over thirty years ago, the gas phase process has dominated plant capacity additions. The process offers the capability of producing both LLDPE and HDPE resins.

Developments in gas phase technologies available for license are discussed in Section 2.2, along with full process descriptions. The processes comprise:

- INEOS Technologies' unimodal INNOVENE G swing process, which offers its condensing mode Enhanced High Performance (EHP) technology.
- LyondellBasell's bimodal and unimodal SPHERILENE process developed for LLDPE and now capable of producing HDPE products, including a discussion of the LUPOTECH G process.
- Mitsui's bimodal EVOLUE process developed for metallocene LLDPE products.
- Univation's unimodal UNIPOL swing process, which offers its Super Condensing Mode Technology (SCM-T), and its new bimodal HDPE process based upon a single reactor and novel catalyst system.
- Westlake's ENERGX technology developed for installation in gas phase LLDPE plants.

### Solution Phase Technologies

The solution process is particularly suited to the production of high quality LLDPE film resin based on octene-1 comonomer. Additionally, these processes are known for very short reactor residence times thus allowing them significant flexibility in producing a wide product slate in a short production cycle.

While one disadvantage inherent to solution processes is their somewhat higher investment cost, producers have been improving their competitiveness through process simplification, the employment of low cost high activity catalysts, and economy of scale.

### Slurry Loop (Swing) Processes

Historically, the polyethylene slurry process based on a loop reactor was developed and dedicated to the production of MDPE and HDPE resins above a certain minimum density. As such, these processes dominated globally, especially with respect to quality and performance of broad MWD resins for blow molding and pipe applications. The process is also known for its high quality medium MWD film resins.

Two process disadvantages have been: relatively high investment cost associated with a process requiring many polymer and hydrocarbon recovery steps, and an inherent limitation to produce low density materials because of polymer solubility problems in the reactor. As such, producers have focused on process streamlining and the expansion of the product portfolio to include a full range of LLDPE and HDPE products. The slurry loop processes are discussed in Section 2.4.

## ECONOMIC & COMMERCIAL ANALYSIS

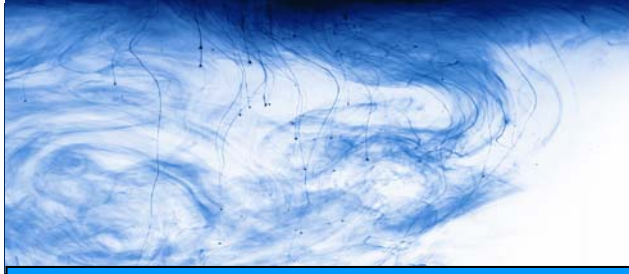
One major aspect of technology selection is economics. This includes not only the initial investment but the operating costs as well. In this time of rapidly advancing developments, where many technologies are available for license, the choice between a low pressure LLDPE process and a high pressure LDPE process is becoming less obvious. Since the inception of the gas phase LLDPE process, there has always been the question of which process is less expensive. Based on the global proliferation of LLDPE technology, it was generally found that an LLDPE plant was the least expensive to build and operate, but history has shown that this did not directly correlate to the highest profitability.

Cost of production estimates are presented in section 3 for various types of LLDPE film. The economics do not include post-plant costs such as licensing fees, which are believed to have a significant impact on total costs. These must be considered when carrying out a full technology comparison. The economic basis used by Nexant *ChemSystems* for the cost of production estimates presented in this report is described.

Cost of production economics for the production of LLDPE film were developed for all of the processes discussed based on a typical world scale plant, as well as alternative capacities for some technologies. The analysis for conventional LLDPE is presented in Section 3.3.1 and the analysis for the production of metallocene/single-site and easy processing LLDPE is presented in Section 3.3.2.

It should be noted that cost of production is only one factor in technology selection. In addition to the cost analysis, a full technology evaluation must consider the revenue (value) of the product slate corresponding to the production costs. In other words, it may be possible that a higher cost process may have better overall profitability due to the realization of a higher value and sales revenue.

Detailed Supply/Demand and Trade data for USA, Western Europe, and Asia Pacific are given in section 4.



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