English

Lupotech T Process
and Services
Production of LDPE

basell
Polyolefins

A True Polyolefin Perspective

1. An Introduction to Basell

Basell develops, produces and markets polypropylene, polyethylene, advanced polyolefin materials and polyolefin catalysts, and also develops and licenses polyolefin processes.

Formed in October 2000, Basell is owned equally by BASF and Shell. Basell and its joint ventures serve customers in more than 120 countries with materials produced in 18 countries. The company's network of joint ventures expands Basell's technology and market base and enables the company to follow key customers as they expand and globalise their operations.

With research and development centres in Europe, North America and the Asia-Pacific region, Basell is continuing and expanding a technological heritage that dates back to the start of the polyolefins industry. The company is committed to continuously extending the property profile of its polyolefins portfolio and to developing with its customers a shared agenda for bringing new products to market as quickly as possible.

Basell is committed to a strong Health, Safety and Environmental (HSE) performance. The company's products are used in countless consumer and industrial goods from food and drink packaging to car components, and from household products to underground piping.

Basell's corporate centre is located in Hoofddorp, The Netherlands, near Amsterdam. The company has regional offices in Brussels, Belgium; Mainz, Germany; Elkton, Maryland, USA; Sao Paulo, Brazil, and Hong Kong, as well as sales offices in the major markets around the world.

For further information on Basell, please see separate leaflets in the pocket-page in the back of this brochure.

2 Your Partner in the World of Polyolefins Technology

2.1 Leading the Technology Race

The history of Basell and its predecessors is one of continuing achievements and breakthroughs in catalysts, process and product developments in the field of polyolefins.

It began with the discoveries in polyolefins technology and catalysts by Karl Ziegler and Giulio Natta, rewarded with the Nobel Prize in 1963, and has continued through five revolutionary generations of Ziegler-Natta catalysts to the development of new metallocene-based polypropylene catalyst family and products.

From the first industrial polypropylene and polyethylene processes to our latest multi-zone circulating reactor developments, Basell and its predecessors have delivered state-of-the-art polyolefin catalysts, technologies, and products to customers world-wide.

For us, creating innovative polyolefin products is a way of life, delivering both superior performances and cost-effective solutions that meet the changing requirements of our customers.

Thanks to the close integration between our marketing, R&D and manufacturing, new developments of catalysts, processes and products are always focused on meeting market demands and commercialised quickly in a responsible manner.

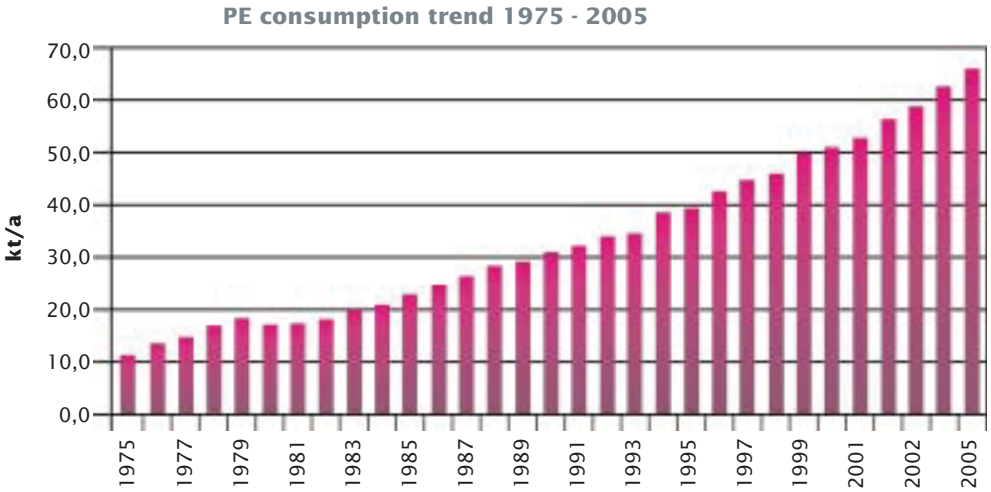
2.2 A Licensing Portfolio for Any Producer's Needs

Basell is the only licensor offering process technologies for production of all PP and PE product families. Our technologies are some of the most reliable, efficient and cost-effective in the world, and can meet both the diverse needs of performance plastics manufacturers and those of commodity-oriented polyolefin producers.
Basell's licensing portfolio of processes and services includes the following technologies:

- *Spheripol,* the world's leading technology for the production of polypropylene homopolymer plus random and heterophasic copolymers
- *Spherizone*, a new manufacturing platform with a multi-zone circulating reactor system that creates polypropylene and novel, propylene-based polyolefinic materials with outstanding quality
- *Hostalen*, the leading low-pressure slurry process technology for the production of bimodal HDPE
- *Spherilene*, a dual reactor swing gasphase process technology for the production of LLDPE and HDPE
- *Lupotech* G, a fluidised bed gasphase technology for the production of chromium type HDPE and MDPE or ZN based HDPE / LLDPE
- *Lupotech* T, a high pressure tubular reactor process technology for the production of LDPE homopolymers and EVA-copolymers

Some of the processes can be easily upgraded in capacity and capability to produce more sophisticated products, if required.

Basell's *Avant* catalyst range covers titanium, chromium and zirconium-based polymerisation and is the optimal solution for the process technologies we offer. *Avant* catalysts can also be used in most other types of polyethylene and polypropylene process technologies.



Source: TECNON, Basell

3 Technology

3.1 Introduction to *Lupotech* T

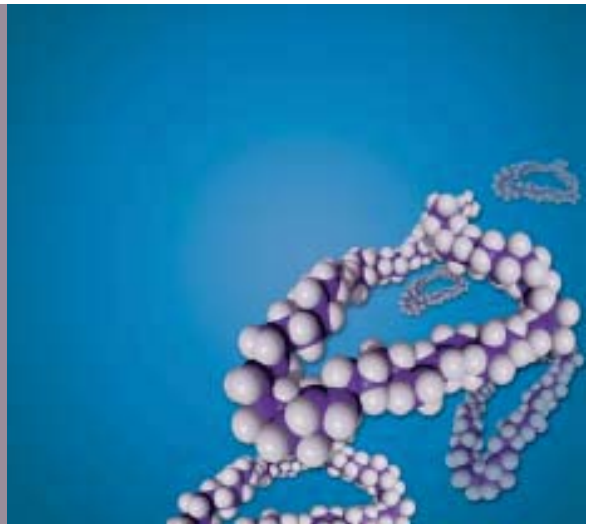
Global demand for polyethylene (PE) has grown quickly over many decades. There are three major reasons for this:

- As a well-established plastic resin with a broad application range, PE use has grown in line with the overall economy.
- During their transition phase, developing countries typically experience a rapid growth in per capita PE consumption.
- There is a huge untapped technical potential in PE resins, which continues to extend their use into market segments of conventional materials like glass, wood, paper, metal, etc.

The *Lupotech* T process for the production in tubular reactors of low density polyethylene (LDPE) has been successfully licensed all over the world. Over 50 years of manufacturing experience combined with modern tools such as process simulation, advanced control, polymer research and material/equipment optimization makes the *Lupotech* T process the most attractive technology with tubular reactors for LDPE production.

The *Lupotech* T process is being continuously improved and upscaled and capacities up to 400 kt/a per single line are now feasible. Products from the *Lupotech* T process cover the whole MFR and density range including High Ethylene Vinylacetate copolymers (HEVA) and can be used for all LDPE applications including the wide range of vinyl acetate copolymers.

Basell's current *Lupotech* T process is the result of decades of development based on a strong R&D program focusing on all key features of the technology (Process, Equipment, Products and Application).



3.1.1 An overview of *Lupotech* T Development

LDPE was discovered in 1933 and attained commercial importance because of its electrical insulation, optical and mechanical properties. The first commercial plants based on Basell technology became operational in the 1950s.
Since then, a series of R&D programs have achieved significant advances, which have established the *Lupotech* T process as a world class technology.

In the 1970s, a major breakthrough in terms of process safety, plant reliability and operating windows was the introduction of modified high pressure steels with increased toughness as base material for the reactor piping. This resulted in superior plant integrity and also enabled higher operating pressures, which expanded the LDPE product portfolio with higher density LDPE grades and an increase in film quality.

In the 1980s, organic peroxides were introduced as radical initiators leading to both higher conversion rates and more efficient process control.
In the 1990s, R&D refocused on process upscaling, process simulation and modeling and advanced control.
The introduction of *Luposim* T, Basell's proprietary simulation program for high-pressure tubular reactors, created a powerful tool for process and product development/improvement.

In terms of scale up, *Lupotech* T technology achieved a breakthrough in January 2001 with the start up of the world's largest LDPE plant at Aubette, France, with a single line capacity of 320 kt/a. The successful operation of this unique plant is an impressive showcase for the process technology.

Based on advanced process simulation, which has been validated in existing plants and has proven its capabilities with the scale up of the 320 kt/a LDPE plant, Basell is now in the position to offer plant capacities up to 400 kt/a single line with dedicated customer design.

3.2 Key Characteristics

The *Lupotech* T process is the high-pressure tubular reactor technology developed for the whole range of LDPE products, including HEVA copolymers.

Safety and Loss Prevention
Polymerisation of ethylene under high pressure in a tubular reactor takes place in supercritical ethylene as diluent. Therefore no additional solvent is required.
Plants using the *Lupotech* T process are operated in full compliance with environmental and safety requirements. Worldwide, over 50 million metric tons have been produced with *Lupotech* T technology without major incidents.

Reducing Resource Intensity
In the *Lupotech* T process unreacted monomers are constantly recovered and recycled. If necessary, discontinuous hydrocarbon purges can be sent for "thermal recovery" or to a flare system.
Since hydrocarbons as solvent are not needed, there are no major effluent streams.

Design Capability/Flexibility
Single line capacities up to 400 kt/a can be provided covering the whole range of LDPE products.

Process Versatility
Related to specific process features *Lupotech* T technology can produce the whole range of LDPE products including EVA and N-butylacrylate modified LDPE.
Fast grade changes ensure the amount of Off Grade material is kept very low, allowing a broad grade slate to run on one reactor.

Product Quality
Lupotech T technology delivers a very homogenous product quality with a low gel level, which means blending/homogenizing silos are not required.

Economical
Capital costs for the *Lupotech* T process are low, as a result of highly efficient design.
Based on low raw material and energy consumption figures, *Lupotech* T technology is characterized by competitive operating costs, while the final product is sold at a premium over other PE products.
The combination of low investment and low operating costs makes the *Lupotech* T process the most attractive high-pressure PE process.

3.3 Process Description

In the *Lupotech* T process, ethylene is polymerised to LDPE at temperatures above 150°C and pressures between 2000 and 3100 bar. For the production of copolymers, specific comonomers such as vinyl acetate or butylacrylate are used.
The overall manufacturing process can be divided into the following steps/process units:

- ❑ Precompression of ethylene
- ❑ Compression to reaction conditions
- ❑ Polymerisation reaction
- ❑ Polymer/gas separation
- ❑ Recycling of unreacted gases
- ❑ Extrusion, pelletizing
- ❑ Degassing
- ❑ Storage and packaging

Precompression of ethylene

Polymer grade ethylene and recycled ethylene are compressed by a primary compressor to approx 300 bar. A modifier to control the molecular weight is added.

Compression to reaction conditions

The ethylene stream together with the recycled ethylene out of the high-pressure recycle loop is further compressed by the hyper-compressor up to 3100 bar.
The hyper compressor is a symmetric two stage compressor.In the first stage the compressor feed gas is compressed from about 270 bar to approximately 1250 bar.
The gas is compressed in the second stage to pressures up to 3200 bar.
After each stage the gas passes through a discharge pulsation dampener. The ethylene finally discharged has to be further heated up for the reaction to take place.

Polymerisation reaction

The reaction mixture leaving the hyper-compressor is fed to a tubular reactor.
High pressure tubular reactors are offered in two generally different forms, shown in figure 1 and 2.
In a TS reactor the total ethylene flow from the hyper-compressor is preheated to 150-180°C and fed to the inlet of the first reaction zone. Reaction is initiated by injection of organic peroxides. As the reaction mixture cools after the first reaction peak, additional peroxide initiator is added to start a second reaction zone. There can be further peroxide injection points giving a total of three to five reaction zones.

In a TM reactor (multiple cold gas injection) the compressed ethylene is split into several streams and fed into the reactor at a number of positions. 40 to 70% of the total ethylene is preheated to 150-180°C before addition of peroxide which, together with the oxygen, sets off the first reaction zone. The other 30-60% of the ethylene is cooled and further split into more or less equal quantities which are injected at different locations along the reactor. Together with addition of initiator this results in the desired number of reaction zones. Additional reaction zones can be created by dosing of peroxide directly to the reactor. The TM reactor can

Lupotech TS process

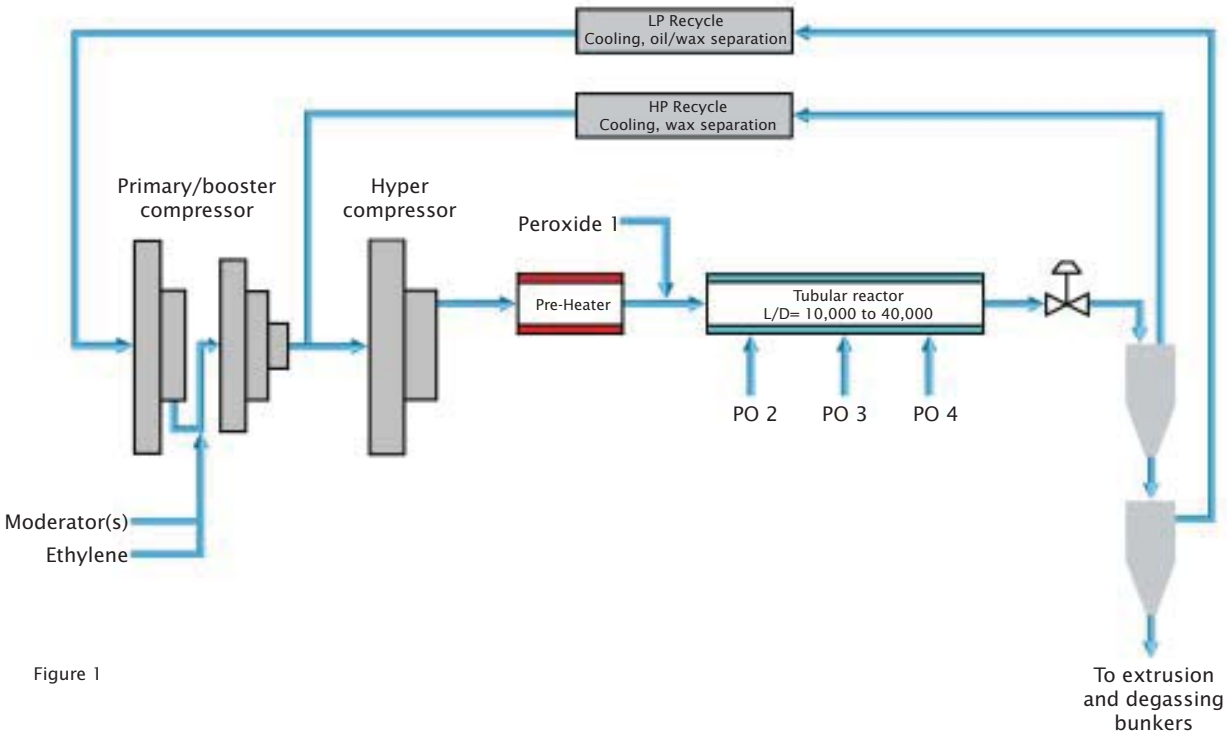


Figure 1

Lupotech TM process

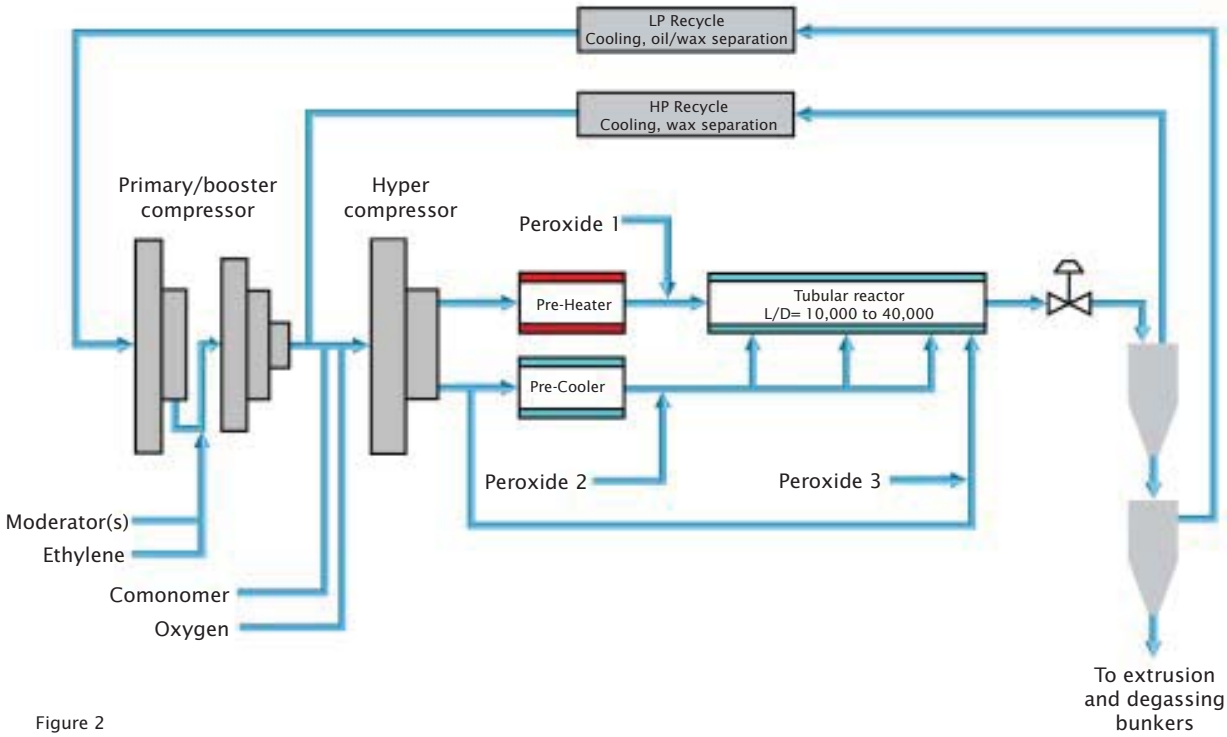
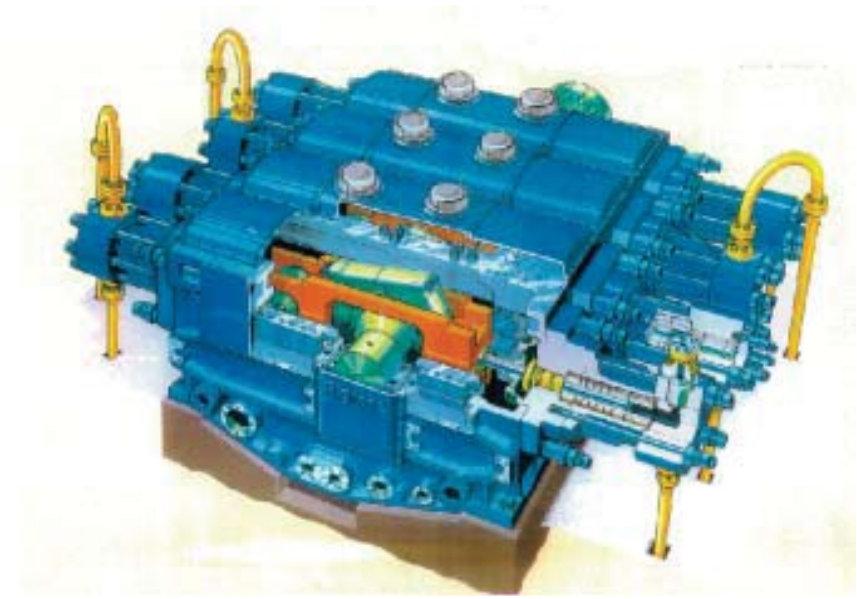


Figure 2

have a stepwise increase in reactor diameter and the reaction mixture flow velocity can change significantly due to the additional gas feeds.

In the reaction zones, the polymerisation is initiated by adding the polymerisation initiator (oxygen or peroxide). Due to the exothermic nature of the ethylene polymerisation, the reaction mixture heats up, and the resulting polyethylene product is in a molten state. Temperature is controlled by the concentration and type of added initiators as well as by the hot water circuit. Side streams of cooled fresh ethylene can be used for a fast cool down of the reaction mixture and restart of the initiation. The conversion of more than 35% per pass can be achieved by this procedure.



Polymer gas separation

At the end of the reactor, the mixture of polymer and unreacted ethylene is depressurised, passes a post reactor cooler and enters the high-pressure product separator. The unreacted ethylene is separated from the polymer melt at approx. 300 bar. The polymer melt is let down through the product valve into the low-pressure product separator (approx. 0.2 - 2.0 bar g) to remove the remaining ethylene from the resin.

Recycling of unreacted gases

Ethylene streams from both separators are recycled to the respective compressors by stepwise cooling. The high-pressure stream is recycled to the hyper compressor and the low-pressure stream to the booster stage of the primary compressor. To avoid accumulation of impurities and inerts in the loops, a minor quantity of ethylene is withdrawn as a purge gas stream and sent to the ethylene recovery at Battery Limits.

Extrusion, pelletizing

The melt, still containing minor quantities of ethylene, is passed from the low pressure product separator into the extruder for further degassing, for the incorporation of additives, if demanded, and for pelletizing by an underwater face cutter system.

Degassing

After passing the extruder the pellets still contain traces of ethylene, and are sent to the degassing silos, which are purged by a constant flow of air. Within a certain period of time the remaining hydrocarbons diffuse out of the pellets. Airflow is designed to keep the concentration level of ethylene safe.

Storage, bagging

Pellets are conveyed pneumatically into storage silos, from where the products can be shipped in bulk, or bagged.

3.4 Safety and Environment

Basell has a safety record unmatched in the industry. By 2003, Basell technologies have achieved nearly 7 million operating hours without any major incident.

Lupotech T process plants are built according to the Basell Safety Design Criteria and must undergo Safety Audits prior to commissioning and start-up. All licensed sites receive visits from a team of specialists with experience in diverse fields, including:

- ❑ Safety and Loss Prevention
- ❑ Health & Environmental
- ❑ Process Operations
- ❑ Instrument/Electrical/Mechanical design

This team verifies and ensures that the plant is built according the Basell Safety Design Criteria, and assists the licensee with any safety, health or environmental concerns regarding the process and related facilities.

Automatic Reactor Safety Relief System

The polymerization process is secured by up-to-date safety systems, installed independently in addition to the DCS.
This safety system is hardwired and therefore extremely reliable. It fulfills all standards for such production plants.
This Reactor Shut Down (RSD) program transfers the reactor unit into a safe condition by depressurizing the compressors and the reactor. Shortly after, the reactor system is ready for another start-up.

Environmental Protection from Noise, Gaseous, Liquid and Solid Pollution

The *Lupotech* T process causes no air, soil or water pollution under normal operating conditions. Special equipment is installed to collect minor quantities of liquids and solids, discontinuously received at compressors and recycle gas loops. Following the initiation of the RSD program the reactor content (ethylene/polyethylene) is released via the Emergency Vent System (EVS) into the atmosphere. Emissions of noise and polymer particles are considerably reduced by the integrated Emergency Vent Vessel (EVV).

Specific Safety Features

1. Fast acting safety chain (thermocouples, pressure transmitters, hydraulic system)
2. Fast depressurisation of the reactor system in case of a reactor safety shut down (RSD-program) to safe levels.
3. Autofrettage of HP-reactor equipment manufactured of K 10 X-steel material.
   Result: Leak before break.
4. TV-cameras for an overall view of reactor and plant area.
5. Inertisation system for pellet degassing silos in case of elevated ethylene concentrations in the silo atmosphere, or additional spare blowers for air.

3.5 Process Capability

3.5.1 Design Capability

Basell's *Lupotech* T process technology covers single train capacities up to 400 kt/a based on 8000 operating hours per year.
The *Lupotech* T process system offered is dependent on the required products.

3.5.2 Versatility

A wide range of products can be obtained using the *Lupotech* T process, ranging from standard LDPE grades to EVA copolymers or N-butylacrylate modified copolymer. The process has no limitations to the number of reactor grades and the product mix can be adjusted to match market demand and economical product ranges. Reactor grades from MFR 0.15 to ≥ 40 and from density 0.917 to 0.934 g/cm^3 can be prepared accordingly. Commonly available additives, as used around the world in the LDPE business, can be easily directly incorporated into the product to yield the final product.

3.5.3 Simulation / operator training program

The *Luposim* T tubular reactor simulation program is a powerful tool for process and product quality simulation and monitoring for any high pressure tubular reactor system, and can be made available to *Lupotech* T licensees or other interested parties. Separately, a new operator training program is currently under development.

3.6 Process Economics

Lupotech T process plant capital and operating costs compare favourably with other technologies. This is a result of:

- ❑ Efficient reactor design and plant layout
- ❑ High conversation rates
- ❑ Low monomer consumption
- ❑ Very short transition time
- ❑ High process reliability
- ❑ Waste heat integration concept

Typical specific consumption (per 1000kg of PE produced)

	LDPE
Monomers (kg)	1010
Initiator (kg)	0.25
Product additives (kg) (1)	2.5
Electric power (kWh) (1)(2)	700-1000
Steam (kg) (1)(2)	-1200 (=export)
Cooling water (m^3) (1)(2)	75 -100
Boiler feed water (m^3) (1)(2)	1.4
Nitrogen (Nm^3)	4
Instrument air (Nm^3)	25

(1) Typical, may vary depending on grade slate

(2) Extrusion included, depending on grade slate and plant capacity

3.7 Product Range & Applications

3.7.1 Overview

Lupolen is the tradename for the Basell line of polyethylene low density resins, which includes homopolymers and copolymers. The range of applications consists of products for film, injection mouldings, blow mouldings, sheathings for cables and wires and steel pipes, profiles and sheets. Special features of *Lupolen* LDPE are the large scope, easy processing, good resistance to environmental stress cracking, well-balanced property combination of good mechanics/opticals/draw down and an overall excellent product consistency.
By means of variation of process conditions a large variety of products with different densities and melt flow rate can be produced. By these two parameters the key product parameters of homopolymers are determined.
For copolymers the fraction of comonomer may range from 3% up to 28% and has the most important influence on the key product parameters.
For EVA grades rubber-like properties are a key feature with the related applications.

3.7.2 Applications of LDPE

Depending on the kind of application and demanded property mix, the specific *Lupolen* grade can be selected, including an appropriate additive mix (e.g. slip, antiblock and stabilizers for specific applications).
EVA grades are especially suited for low temperature applications. Other outstanding properties are enhanced stress crack resistance, flexibility and transparency.

Film

The wide range of products for both homopolymers and copolymers enables all kinds of film applications including shrink and heavy-duty packing films, films for laminates, carrier bags, composite and crack films, deep freeze bags and agricultural films like mulch and greenhouse films.

Injection moulding & blow moulding

Both homopolymers and copolymers are used for many standard applications. For parts in the medical and pharmaceutical sector, *Lupolen* LDPE homopolymers are especially suitable due to their high purity.
The product line matches the technical properties required, namely flowability, rigidity and stress cracking resistance.
The range of grades includes specialty products of pharmaceutical applications and products with good organoleptic properties.

Pipe Coating

Lupolen grades for coating steel pipes provide effective corrosion protection with a well balanced property profile: good long term properties, excellent processing, high mechanical strength and good chemical resistance.

Cable & Wire

Lupolen LDPE homopolymers cover the area of cable applications from power cables, insulation for coaxial cables and telephone cable cores to sheathing material with very high resistance to environmental stress cracking.
Lupolen copolymers are best suited to be filled with carbon black and used for insulation for 1 kV overhead cables and for conductive compounds.

4 Licensing Customer Services

During the development of a project and throughout the operation of the plant, experts from the Licensing department and the Technology Transfer Centre will be dedicated to the licensee's needs in the following areas of activity:

Licensing process

Prior to the granting of a license, Basell will actively participate in the definition of the project, based on the product and marketing expectations from the customer. This stage defines the optimal technology and particular design features - such as capacity, reactor configuration, catalyst system, etc. - under a confidentiality agreement.

Once the scope of the plant has been jointly identified, a draft License Agreement will be prepared and negotiated; the agreement will contain articles that define the type and capacity of the plant, the product grade slate, etc. The supply of the Process Design Package, the extent of the granting of the license, the license fee and the payment conditions are also described. Payment conditions vary from lump sums to running royalties, or an appropriate combination of both these elements.

Further sections of the License Agreement stipulate the project assistance, particularly during commissioning and start-up of the plant and the performance testruns, by Basell experts in process design, polymerisation, extrusion and quality control.

Other more formal chapters cover secrecy, liability, patent issues, force majeure, applicable law, etc.

Business start-up support

Basell is open to discuss possible supply of resins from Basell production for pre-marketing of resins by the licensee, and use the Basell marketing and sales organisations to support the licensee in the development of the polyolefins business, by agreement on defined off-take volumes of resins until the licensee can market the entire production volume itself.

Process Design Services - Engineering

The Process Design Package (PDP) provided by Basell Process Design contains a comprehensive technical description of the entire process, and is adequate to allow for the preparation of the engineering of the plant, application to authorities for environmental licenses, and the preparation of the operating manual. Typical PDP content is:

- ❑ Process description
- ❑ Process flow diagram (PFD) with heat and material balances
- ❑ Piping and instrument diagrams (PIDs)
- ❑ Equipment list + data sheets
- ❑ Instrument list + data sheets
- ❑ Safety valve list + data sheets
- ❑ Plot plans
- ❑ Safety design criteria
- ❑ Emergency flaring load
- ❑ Fluid list and piping classes
- ❑ Environmental information
- ❑ Guidelines for the operating manual
- ❑ Etc.

Ideally the Basic Engineering may be provided by a contractor with a proven record of the Basell technology. Alternatively this can be done by another contractor on the basis of the PDP.

The Detailed Engineering – at least in part - is typically done by a local engineering company in the region of the license plant.

Experts from Basell Process Design can assist the engineering activities.

Technology Transfer:
Besides some initial support during the licensing process, the main services provided to the Licensees by Technology Transfer are in agreement with the Licensing Agreement, and consist of the following:

Training
Prior to the start-up, highly experienced trainers at Basell's training centres (Ferrara, Italy / Bayport, Texas, USA / Aubette, France) will train licensees' experts on Operations, Quality Control, Maintenance, Applications and Safety. Computerised dynamic process simulators are available to enable licensees' personnel to train for start-up, steady state, grade-change and shutdown operations.
Courses are tailored to fit the specific needs of the customer, not only with regard to content, but also in areas such as accommodations, interpretation, transportation, visas, etc.

Start-up support and guarantee testruns
A start-up team, consisting of Basell expert operators, will provide assistance during pre-commissioning and commissioning of the plant.
After completion of the commissioning, Basell HSE experts will participate in a Plant Safety Audit to verify the adherence to the Safety Design Criteria, with special attention to health and environmental concerns.
The start-up team will assist during the start-up, in order to obtain a safe and reliable start-up, and normally remain until the performance guarantee testruns have been finalised.

Technical support after start-up

While the full commercial operation of the plant will soon become a routine business of the licensee, developments in the world of polyolefins will continue.
Safety information about Basell, JVs and/or licensees will be directly shared unconditionally, in order to continue to improve the safety standard of our technologies.
In order to further benefit from Basell's technical knowledge and developments, licensees can enter into a Technical Support Agreement (TSA) with Basell, typically comprising the following elements:

- ❑ Explanation and details of technical improvements within the scope of the original License Agreement
- ❑ Non-confidential information on Basell's R&D progress that goes beyond the current license
- ❑ Further training sessions
- ❑ Optimisation of plant efficiency: trouble shooting / trial for new products / new catalyst implementation, provided with technical assistance at the customer's site
- ❑ Advice on maintenance and quality control procedures
- ❑ Marketing exchange
- ❑ New product development or adjustments to local markets
- ❑ Periodical Technical Exchange Meetings with focus on licensee's issues
- ❑ Periodical seminars / conferences with focus on safety, best practice and breakthrough in process and catalysts

Engineering services

If market conditions change, and the capacity of the plant needs to be increased, or a variation in the product grade slate needs to be made, Basell can assist in the engineering activities needed to upgrade the plant accordingly.

Source: Nasa

Basell Technology Licensing – Conclusion

Basell is unique in providing excellent process technologies for all polyolefin production for all fields of product applications. This, together with our drive for customer satisfaction, continuing R&D developments, and the support from the organisation of the world leader in polyolefins, will make Basell technology the optimum choice for your polyolefin production, now and in the future.

Corporate Centre

Basell N.V.
Hoeksteen 66
2132 MS Hoofddorp
The Netherlands
Tel. +31 20 4468 644
Fax +31 20 4468 649

Technology Business
Licensing and Technology Transfer

Basell Poliolefine Italia S.p.A.
Via Pergolesi 25
20124 Milano
Italy
Tel. +39 02 6712 4631
Fax +39 02 6712 7397

For more information on Basell licensing services, *Lupotech* T technology, or engineering, technical and marketing services, please contact : licensing@basell.com

You can find out more about Basell by visiting our website at : www.basell.com

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