LyondellBasell Technology: Advancing Possible

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Presentation overview

- Introduction to LyondellBasell’s Technology Business
- Market update / sustainability concepts
- Process technology update
- Catalyst technology update
- Conclusions
**LyondellBasell delivers innovative products and solutions in five key areas**

<table>
<thead>
<tr>
<th>CHEMICALS</th>
<th>POLYMERS</th>
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<tr>
<td>We produce the chemical building blocks for:</td>
<td>Our versatile plastic resins are used to create a variety of products including:</td>
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<tr>
<td>- automotive fluids</td>
<td>- automotive parts</td>
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<tr>
<td>- furniture, household goods</td>
<td>- packaging</td>
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<tr>
<td>- coatings, adhesives, cleaners</td>
<td>- piping</td>
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<td>- cosmetics, personal care products</td>
<td>- textiles</td>
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<td></td>
<td>- renewable energy technologies</td>
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<td></td>
<td>- agricultural films / irrigation</td>
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<td>- healthcare</td>
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<td>- food supply products</td>
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| ADVANCED POLYMERS                              | FUELS                                                                     |
|------------------------------------------------|                                                                          |
| Our diverse portfolio is used to create customizable products including: | Our refinery in the U.S., produces:                                       |
|   - automotive parts                          |   - gasoline, fuel components                                            |
|   - differentiated packaging                  |   - low-sulfur diesel                                                    |
|   - electronics / appliances                   |   - jet fuel                                                             |
|   - construction materials                    |   - lubricants                                                           |
|   - roofing                                    |   - oxyfuels that help improve air quality                               |
|   - flooring                                  |                                                                          |
|   - geomembranes                               |                                                                          |
|   - specialty pipe                             |                                                                          |

| TECHNOLOGIES                                   |                                                                          |
|------------------------------------------------|                                                                          |
| We license our state-of-the-art manufacturing and process technologies: |                                                                          |
|   - technologies that are used by chemical and plastics companies around the globe |                                                                          |
Leading Catalyst Producer and Technology Licensor

Catalysts for PP and PE
- Leading provider of PP and PE polymerization catalysts
- More than 60 different Avant catalysts for broad set of applications
- Manufacturing locations in Italy, Germany, and USA

Licensing
- Process technologies for Polyolefins and Chemicals
- More than 280 polyolefin Licenses sold
- Introducing innovative technologies

Technology Services
- High-level support in training, start-up, and safety reviews
- Continuous support for plant optimization and troubleshooting
- Supported by R&D sites in Italy, Germany, and USA

Continuous improvement of catalyst and process technology through innovation
LyondellBasell operates some of the safest, most reliable facilities in the industry

**LYB Total Recordable Incident Rate**

**LYB Indexed Process Safety / Environmental Incidents**

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(1) Injuries per 200,000 hours. Includes employees and contractors. ACC is American Chemistry Council

(2) LYB 2017 Benchmark survey. Excludes the impact of scheduled and unscheduled external shutdowns.
Global Macro Trends - Demographics Driving Demand

Upper/Middle Class Households

World PE and PP Demand

2016 Polyolefins Consumption

China Polyolefin Trade Deficit(1)

Source: IHS.
1. China polyolefin trade deficit is production less domestic demand.
Key factors within the circular economy for plastics

**Circular Economy**

- In a circular economy, resources remain in use for as long as possible to extract their highest potential value

**Market Drivers**

- **Legislation (EU)**
  - 2018 EU Plastics Strategy
  - Packaging and Packaging Waste Directive which sets a plastics packaging recycling target of 55% by 2030 which may include an element of reuse
  - 2019 EU Single Use Plastic Products

- **Retailers, brand owners & consumers**
  - World Economic Forum: Companies working towards using 100% reusable, recyclable or compostable packaging by 2030
  - Evolving consumer consciousness concerning waste and recycling

Source: European Commission
LyondellBasell: Advancing the circular economy

- Cooperation with KIT for chemical recycling to feedstock: “MoReTec”
- Cooperation with Covestro:
  - Circular steam – incineration of production waste for energy

- Quality Circular Polymers
  - Suez-LyondellBasell JV
  - Capture value from post-consumer material

- Trend from single-use to multi-use application solutions
- Design for end of life – circular economy
- Inter-material replacement to simplify designs
- Downgauging

Technology selection will play a strong role in the ability to deliver improved material properties required for the applications of the future
LYB licensing - A comprehensive portfolio of technologies for license

Polyolefins Technologies

- **Spheripol** Benchmark PP process
- **Spherizone** Differentiated PP process
- **Lupotech** LDPE/EVA processes
- **Spherilene** LL/HDPE process
- **Hostalen** Multimodal HDPE process

Chemicals Technologies

- **Olefins Recovery and Conversion** Trans4m for Butadiene, Butenes, Isoprene, DCPD
- **Aromatics Extraction** From Coke Oven / Pygas Benzene, Toluene, Xylenes
- **Acetyl** Glacido acetic acid process, Vacido vinyl acetate monomer (VAM) process
- **Oxiranones & Derivatives** Propylene oxide, Styrene, Butenes, MTBE/ETBE, Butanediol
**Spherizone** – 20 lines licensed with a total capacity of 6.6 million MT/a

Unrivalled industry experience with recent licenses such as Zhejiang Petroleum (ZPCC) and Liaoning Bora
### Spherizone – The breakthrough PP technology

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<th>Added Value Portfolio</th>
<th>Performance Products</th>
<th>Operational Excellence</th>
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<td>&quot;N&quot; in 1 Multizone Circulating reactor</td>
<td>3 Unique families Homo-Raco, dual-Raco, Soft HeCo</td>
<td>45% Weight Reduction for novel Pipe grades</td>
<td>97% Average Prime</td>
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<td>Lowest CAPEX &amp; OPEX for multi-modal products</td>
<td>Inter-material Replacement (IMR)</td>
<td>Increased value in use</td>
<td>&gt;200 average transitions per year</td>
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<td>Reliable with efficient transitions</td>
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- **Unique Platform**
  - "N" in 1 Multizone Circulating reactor
  - Lowest CAPEX & OPEX for multi-modal products

- **Added Value Portfolio**
  - 3 Unique families Homo-Raco, dual-Raco, Soft HeCo
  - Inter-material Replacement (IMR)

- **Performance Products**
  - 45% Weight Reduction for novel Pipe grades
  - Increased value in use

- **Operational Excellence**
  - 97% Average Prime
  - >200 average transitions per year
  - Reliable with efficient transitions
Examples of customer benefits:

- Better fluidity: less energy consumption in converting and higher efficiency
- Better processability: multi-layers, multi-functional and bigger dimensions of products
- Better impact/stiffness balance: replacement of engineering plastics, such as ABS and PC
- Better transparency: clean products for medical applications; replacement of PVC, PET and glass
- Better low temperature impact: extending to elastomer

Enabling product differentiation to meet current and future customer requirements
Spheripol – 115 lines licensed with a total capacity over 25 MM t/a

Recent licenses include: Qingdao Jinneng New Material and Ulsan Polypropylene Co., Ltd. (UPP)

Incl. LYB captive, scrapped lines not included
**Spheripol – The Benchmark PP Technology**

### Advantaged Economics
- **Best class monomer efficiency**
- **12% Lower electricity consumption**

### Benchmark Products
- **1st installed capacity**

### World Scale
- **600 kta Largest single line capacity**

### Operational Excellence
- **Robust & Reliable**
- **>100 Production lines in operation**

**Leadership Through Five Generations – Optimized for the Future**

Source: 2014 Industry consultant data / LYB analysis. Calculation vs. average
Hostalen – 49 lines licensed with a total capacity over 11 MM t/a

Recent licenses include: Sinopec SK Wuhan and Zhejiang Petroleum (ZPCC)
**Hostalen ACP - Providing products for high-performance HDPE applications**

- Multimodal HDPE platform
- High Performance products
- Robust Process
- Operational Excellence

Enhanced stiffness/impact balance allows higher efficiency in HDPE applications

- Downgauge – weight reduction in packaging, SBM & film
- Higher performance – PE 100 pipe
- Extended territory – PERT for heating system

Added value through

- Downgauge – reduced material and energy cost
- Higher performance – PE 100 pipe and PERT
- Improved processability – higher productivity

**Flexible and versatile technology for high-performance HDPE products**
Lupotech T&A – 69 lines licensed with a total capacity over 11 MM t/a

Including latest licenses for Xinjiang Tianli Gaoxin, PT Chandra Asri Perkasi and ZPCC

North America: 9 lines
South America: 1 line
Europe & CIS: 23 lines
AFME: 8 lines
Asia Pacific & India: 28 lines

Incl. LYB captive, scrapped lines not included
**Lupotech – At the Forefront of LDPE and LDPE/EVA Technology**

**The Foremost Process**
- Tubular reactor weight savings up to 40%
- Maximizing energy recovery
- Innovative peroxide dosing
- Lowest CAPEX

**Leading Economics**
- Lowest energy consumption
- Lowest utility consumption
- Lowest chemical consumption
- Lowest OPEX

**Configuration Differentiation**
- *Lupotech T* Tubular process VA% up to 30%
- *Lupotech A* Autoclave process VA% up to 40%
- Product differentiation
  - Acrylic-modified copolymer available

**Operational Excellence**
- Market leader 11mln tons of licensed capacity and >40 lines in operating
- RTO to ensure emission meeting the strictest requirement
- Reliable, Safe and Environmental friendly
LyondellBasell Avant Catalysts

- Long tradition of investment and innovation combined with latest innovations:
  - High yield & high H2 response production
  - Covering from narrow to broad MWD
  - Full range of PE and PP products
  - Available for broad range of slurry, gas phase and bulk technologies

Avant catalysts enable customers to improve and differentiate, in LYB and in 3rd party technology
**Avant catalysts – Phthalate alternatives**

- LyondellBasell has introduced a new family of Avant PP catalyst: non-phthalate, but phthalate-like
- They exhibit strongly improved activity, hydrogen, and donor response
- Products are rheologically very similar to phthalate based-products

**Comparison of Molecular Weight Distribution**

- Customers use the new catalyst as a drop-in replacement of incumbent solutions, taking advantage of reduced C-emissions, and a widened product window
- In 3 years time, the majority of the European PP market converted to this non-phthalate solution

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**Strong increase in non-phthalate in EU**

- Americas market is following the increasing trend in non-phthalate catalyst usage driven by brand owners and converters
LyondellBasell 5th Generation Catalysts - Enabling cleaner, higher value products

- **Oligomers and volatile organic compounds (VOC) reduced by 40-65% with use of 5th generation catalyst**
  - Example of as-polymerized impact copolymer 50 MFR, 18% rubber

- **Higher MFR targets without need for peroxides deliver improved organoleptics**
  - Improved hydrogen response of 5th generation catalysts as enabler
  - Higher stiffness maintained

- **High catalyst yields for reduced ash content and efficient production**
  - Enabling additive optimization

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Source: LyondellBasell
Innovation - Delivering Cleaner and Better Polypropylene resins

- LyondellBasell launches a new family of Avant catalysts
  - Highly stereospecific homopolymers (4m pentads via NMR around 99%)
  - Unprecedented Ziegler-Natta randomization in random copolymers
  - Strong reduction in C-emissions in impact copolymer (ICP) grades
  - Increased melt flow, improved impact/stiffness balance ICP grades

- Industrially launching in 2019

![XS/C2 balance in random copolymers](chart1)

![Strong reduction C-emissions in ICP](chart2)
Summary

- Robust polymer demand anticipated globally driven by demographic megatrends
- Application design for life cycle: inter-material replacement and new material requirements
- Improving the end of life value chain: higher value recycling, chemical recycling
- LyondellBasell’s process technologies
  - More sophisticated manufacturing platforms such as Spherizone will best position companies to deliver innovative grades to meet the challenges of the future
  - Improvements in efficiency and reliability
- LyondellBasell’s catalyst technologies
  - Proven 5th-Generation catalyst families with differential performance
  - A new innovative catalyst family which will deliver breakthrough performance for cleaner products
- Long term technical support to licensees under Technical Service Agreement (TSA)
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