Borealis Sirius catalyst technology – enabling factor for sustainable growth

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Borealis at a glance

2nd largest polyolefin producer in **Europe**

Borouge operates **world's largest** integrated PO site in Ruwais, UAE

6,600 employees

+3,500 in Borouge

EUR 7.5 billion sales revenue in 2017 (**>EUR 9 billion** with Borouge)

Operates in over **120 countries** on **5 continents**

EUR 1.095 million net profit for 2017

Production and sales of **polyolefins**, **base chemicals** and **fertilizers**

Head office in **Vienna**, Austria

Ownership structure

Mubadala, UAE
OMV, Austria

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Our values guide our business decisions and drive every action we take

Responsible

We strive for zero incidents in health and safety

We consider our local and global responsibility for the environment in our decisions

We do business according to high ethical standards and lead by example

Respect

We trust and involve people and communicate openly, respectfully and in a timely manner

We collaborate, support and help each other to develop for the best of Borealis

We build on diversity for better results as “One Company”

Exceed

We win through Excellence and deliver beyond expectations

We commit to making joint decisions and follow through

We give feedback and make “Connect–Learn–Implement” and “Continuous Improvement” a natural way of working

Nimblicity™

We are fit, fast and flexible and seek smart and simple solutions

We encourage decisions on all levels of the organisation to increase ownership and speed to realisation

We welcome change and manage it to shape our future

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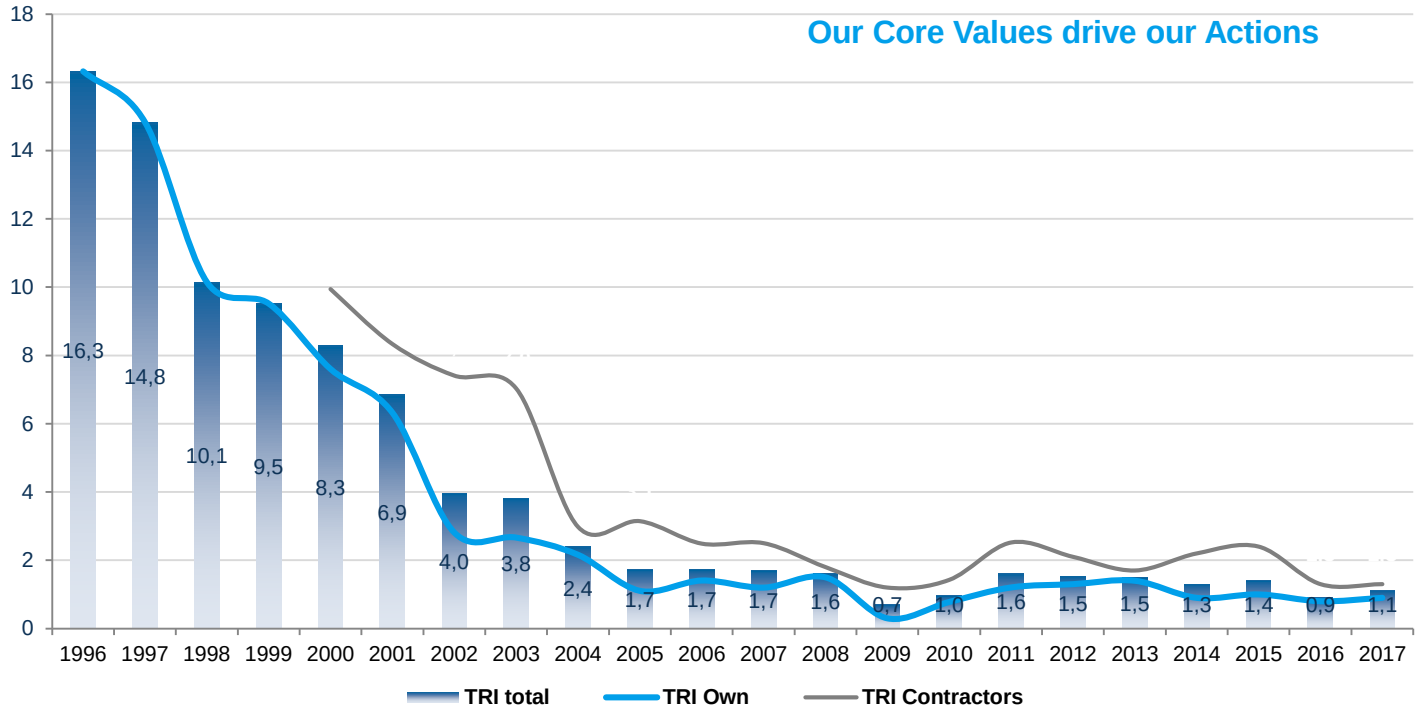
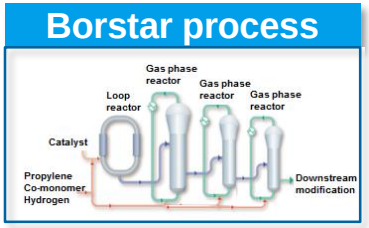
World class safety standards

TRI frequency - Own vs. Contractors 1996 – 2017



Note: TRI being defined as total recordable incidents per million hours worked

Multimodality of Borstar® PP
Key feature to tailor end product properties



Borstar® PP – A unique technology platform

- Borstar® process gives freedom in molecular design resulting in highly differentiated PP
- Multimodality for advanced properties (e.g.: strength and processability, clarity and toughness)
- Stiffness control through MWD design, Borealis nucleation technology and catalyst
- High EPR incorporation (RTPO's)

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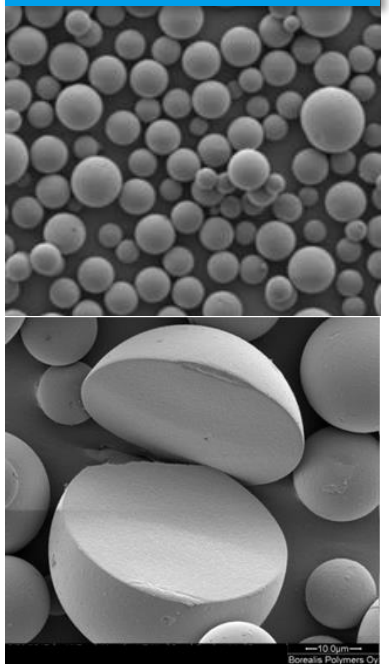
Borealis Sirius catalyst technology – Key to advanced PP products with Borstar®

- High degree of control on the catalyst nano and micro structure allowing fine-tuning of polymer properties
- Excellent control of internal and external morphology for an optimal polymerisation behaviour
- Versatile catalyst chemistry allowing flexibility in the choice of modern donor technology

Catalyst Macrostructure



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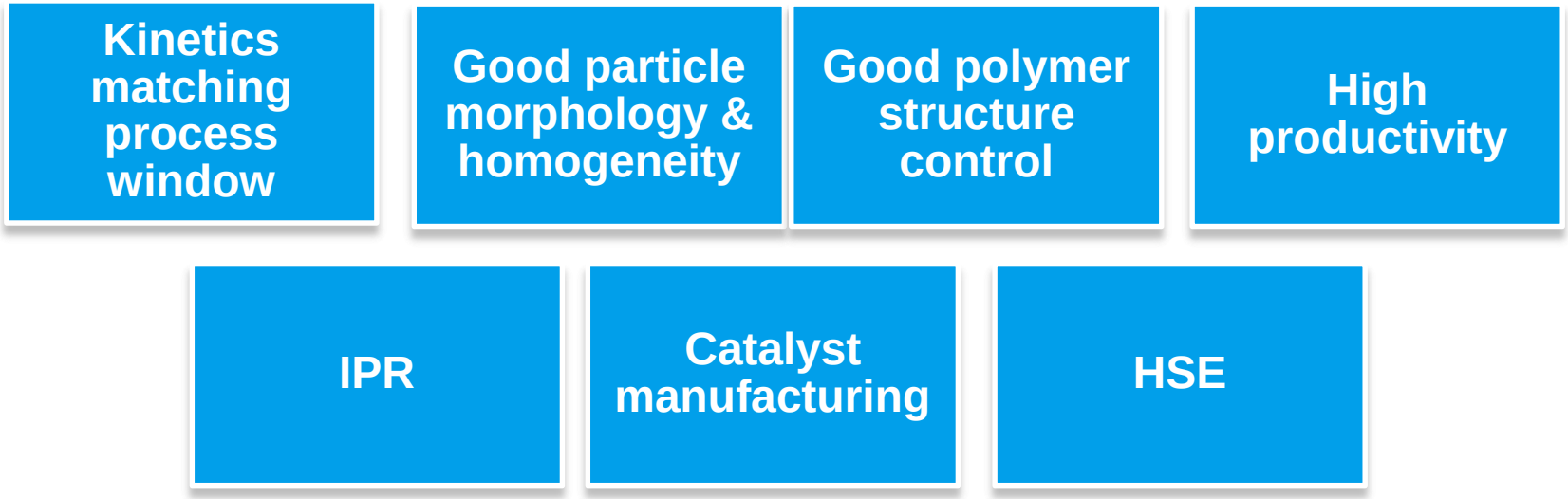
Requirements for a Catalyst used in Borstar®



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Borealis Sirius: Sustainable Basics

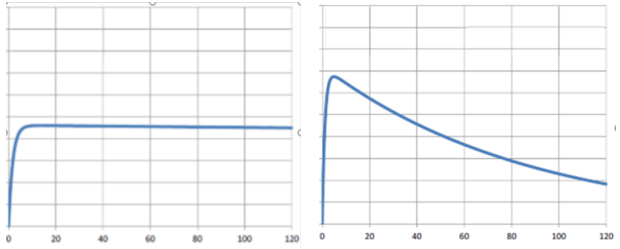
1. Borealis Proprietary Sirius technology: IPR in place

2. No phthalates – No other questionable chemicals either

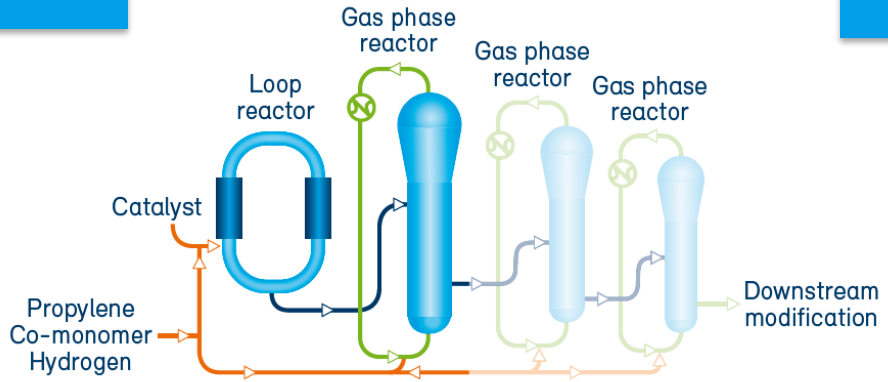
3. Catalyst manufacture designed to be highly contolled for reproducibility of quality – Still flexible enough for making several types of Borealis Sirius catalysts

Borealis Sirius – Meeting Borstar® operability requirements

Catalyst kinetics matching process
- Flexibility to adjust the reactor split to get different products



Good morphology and homogeneity of catalyst and polymer
- Operability in different reactors & conditions



PP powder from Borstar® PP plant

High enough catalyst productivity
- Different reactors and conditions

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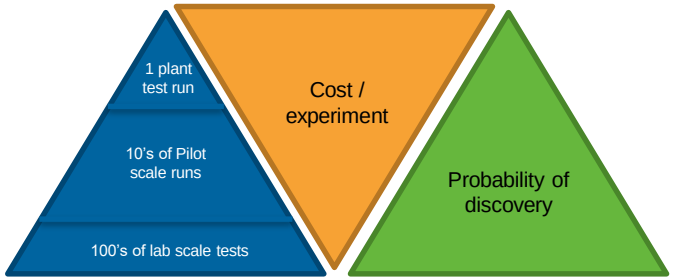
The Catalyst Value Chain



Catalyst Scale-Up

PO Catalyst R&D

Catalyst Design

Catalyst Performance

Cat Scale-Up

Process Development

Process Development

Polymer development

Pilot Scale

Catalyst Pilot

Polymerisation Pilots

Cat Scale-Up

Process Development

Process Development

Polymer development

Commercial Scale

Catalyst Plant

Full Scale Plants

Polymerisation Scale-Up

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Catalyst scale-up from lab to plant

Laboratory reactor	• **Catalyst development** • Screening, DoE for conditions	Batch < 1,5 g
Laboratory reactor	• **Catalyst development** •Polymerisation, analytics	Batch < 5 g
Catalyst Pilot reactors	• **Scale up** • Combining chemistry with engineering practices → process optimisation	Batch kilograms
Production Sirius catalyst Plant	• **Catalyst production for PO plants**	Batch hundreds kg

Polymerisation scale-up from lab to plant

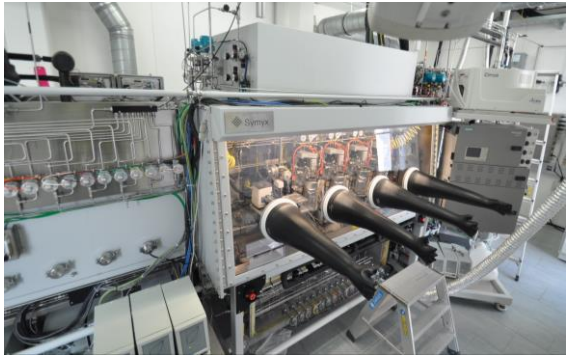
Laboratory HTE	• **Catalyst screening** •High Throughput **Polymer: 300 mg – 100g**
Laboratory bench reactors	• **Catalyst Evaluation, Product Development** • Polymerisation, Polymer Analysis **Polymer: 0,5 - 3 kg**
Polymerisation Pilots	• **Polymer Production at Pilot Scale** • Validation, Pre-marketing testing, Operating windows, Demonstration **Production Rate: 60 – 120 kg/hr**
Full Scale Plants	•**Production Plants** • Several **Borstar®** in the World **Up to 700 kt/a**

Borealis Catalyst R&D

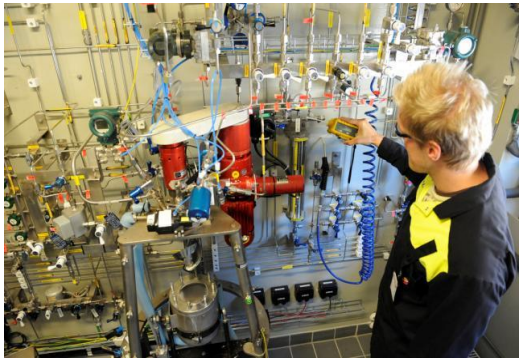
Parallel Catalyst Synthesis

Advanced Catalyst Characterisation

High Throughput Experimentation



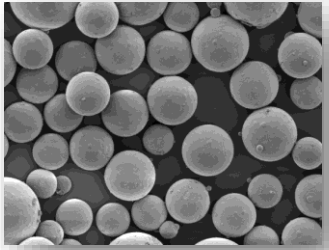
Bench Scale Polymerisation



- Located in Finland, Europe
- Target is to develop new catalyst systems that meet the PO product and process targets
- Supported by broad polymerisation capability and analytical tools

Borealis Sirius Catalyst Technology – Mastering polymer structure and polymerization behaviour

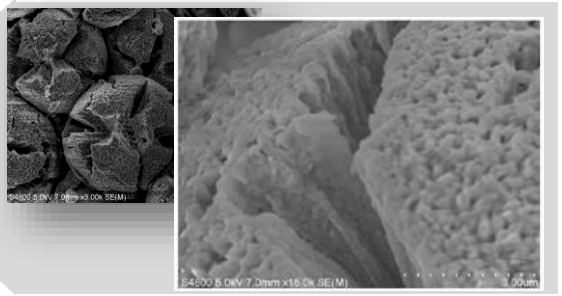
Macrostructure



Intra- and inter-particle homogeneity

Particle morphology

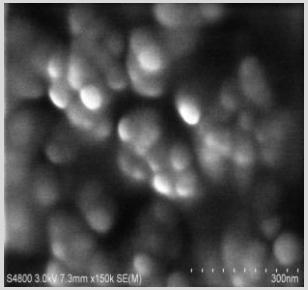
Microstructure



Assembly of $MgCl_2$ nanoparticles

Porosity

Nanostructure Chemistry



$MgCl_2$ nano-crystals with active sites

External / internal donor chemistry

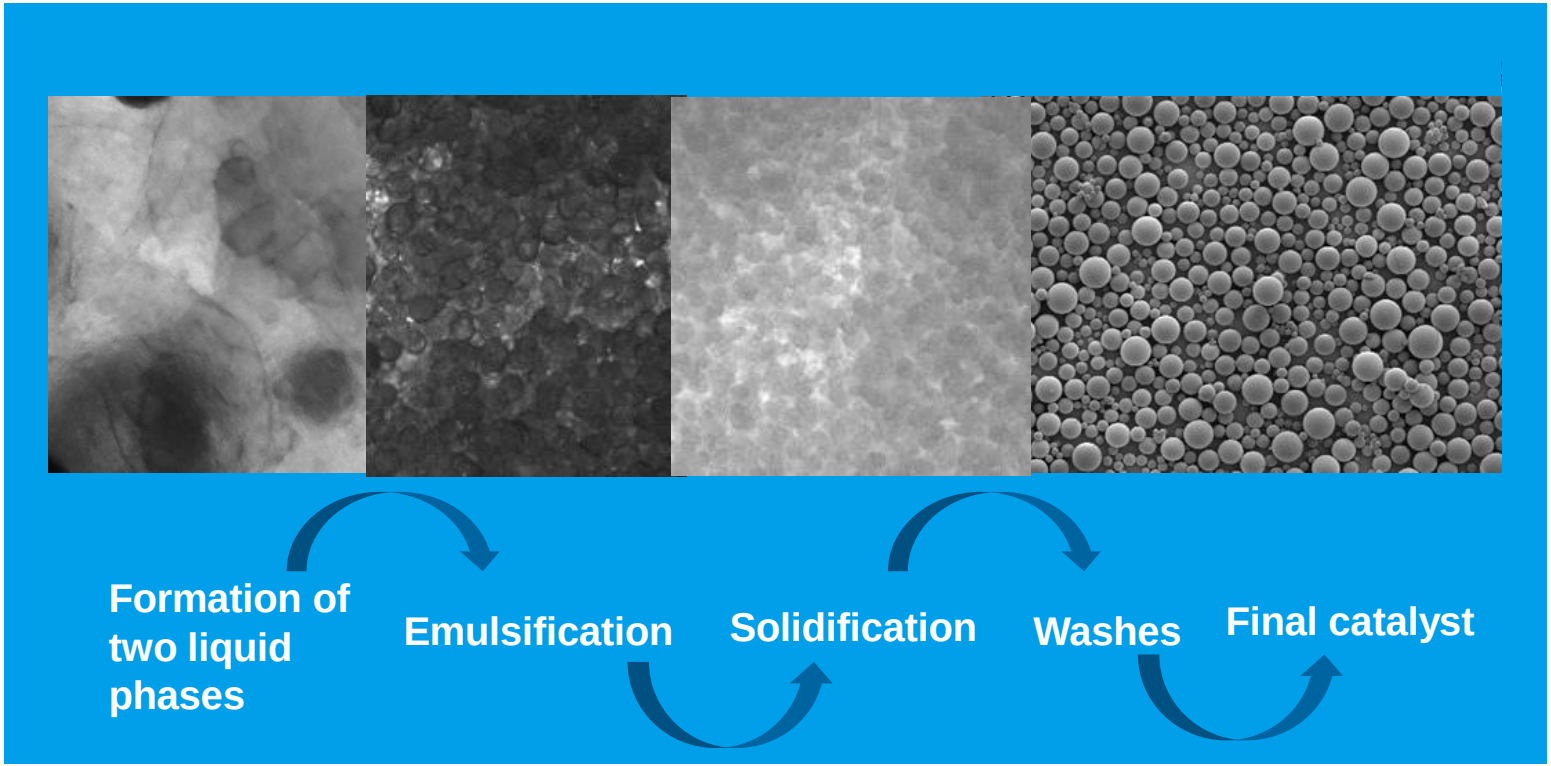
Polymerization process behavior

Polymer structure / product properties

Borealis Catalyst Pilot Plant

- Located in Finland, Europe
- Own proprietary technology
- Scope is catalyst development including Borealis Sirius technology
- Several types of catalysts has been piloted
- High level of flexibility with a wide variety of reactors and equipment combinations

Borealis Sirius Catalyst Technology – Inside the reactor



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Borealis Sirius Catalyst Plant

- Located in Austria, Europe
- Own proprietary technology
- Start up year 2012
- Non-phthalate Ziegler-Natta PP catalyst manufature since 2014
- So far proven for different Borealis Sirius catalysts at the plant
  - Broad range of particle sizes
  - Different chemical compositions
  - Different morphologies

Key messages

- Borealis' Borstar® process gives freedom in molecular design resulting in highly differentiated polymers
- The Borstar® process sets a variety of demands for the catalyst capability
- Borealis' Sirius catalyst technology is fulfilling these demands and enables broad product property capability
- Sirius is platform technology for all kind of Ziegler-Natta and Single Site catalysts
- Sirius emulsion catalyst technology allows unique possibilities in tailoring particle size and morphology

Thank you

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