Borstar® PE for blown film applications
Borealis: A leading provider of innovative, value creating plastics solutions

Borealis is a leading provider of innovative, value creating plastics solutions. With more than 40 years of experience in the polyethylene (PE) and polypropylene (PP) business, we focus on pipe systems, energy and communications cables, automotive and advanced packaging markets. We are strong in Europe and growing in the Middle East and Asia-Pacific through Borouge, our joint venture with the Abu Dhabi National Oil Company (ADNOC). Our technology shapes plastic products that make an essential contribution to the society in which we live. We are committed to lead the way in ‘Shaping the Future with Plastics’.

With EUR 5 billion revenue in sales and 4,500 employees, Borealis is headquartered in Vienna, Austria with innovation centres, customer service centres, and main production sites in Europe and the Middle East. Borealis has representative offices and operations in Asia, North and South America.

At its heart, the company’s four values of Responsible, Respect, Exceed and Nimblacity™, define its way of doing business. For Borealis, success is achieving value creation through innovation.

Borstar® is Borealis’ proprietary technology supporting differentiated PE and PP products. Borstar and is a registered trademark of Borealis A/S.

Learn more about us at www.borealisgroup.com
Contents

02 Your success is our motivation
03 Borstar polyethylene
04 Enhanced Borstar LLDPE products
05 Enhanced Borstar HDPE products
06 Processing properties of Borstar PE
11 Properties of Borstar LLDPE films
13 Typical needs in packaging
14 Market success and positive feedback
16 Borstar PE conversion and packaging performance
19 Application examples of Borstar Enhanced PE
22 Borealis provides film solutions
25 Applications
32 Summary
Your success is our motivation

In the polyolefin industry, production cost has always been included as a main element of product pricing, and hence the marketing approach. Cost minimisation has been seen as the preferred route to success. Even if cost effectiveness is of major importance to Borealis, as to any other polyolefin producer, we are convinced that we can and do contribute in many ways to value creation for our customers – and their customers, present in the value chain.

We extend our added-value by developing solutions to enhance the recovery, reuse or recycling of end-of-life advanced plastics applications. Lighter, more durable and recoverable, Borealis advanced materials reduce consumption and waste of resources through the entire value chain.

We have a long tradition at Borealis of providing differentiated products for many industries with high quality, consistency and reliability. This is a result of the high level of technical expertise and competencies of our support teams. But equally important is our co-operation with customers and other market leaders in application development, which has brought us numerous success stories. This is facilitated by our well-equipped application facilities and an extended network of industrial contacts. We strive to better understand the needs of the different Value Chain members with the high ambition to provide even better customer satisfaction for our partners.

This brochure profiles how we view the film and fibre market, its challenges and what we can do to help our customers’ businesses become even more successful. If you have questions or require further information, please contact our sales representative in your area. See www.borealisgroup.com for contact details.
**Borstar polyethylene**

Conventional polyethylene can not really be compared with Borstar polyethylene, because the Borstar process makes it possible to combine the good properties of various conventional PE’s into one product and hence create new products that set new standards. The fundamental feature of the Borstar technology is its dual reactor operation which allows us to produce materials for film extrusion in a wider range of densities and MFR, with a broad (bimodal) molecular weight distribution and tailored comonomer distribution. Unlike conventional bimodal processes, which are limited to HDPE and MDPE products, Borstar can also produce bimodal LLDPE resins.

This is made possible by the unique patented process configuration. Borstar technology is suited to a very wide range of PE product properties and applications, and offers new materials with enhanced performance.

![Figure 1: A bimodal PE is a mixture of two different molecular weights, as can be seen from this MWD curve. Two important features result from this: good processability and good mechanical strength.](image-url)
Enhanced Borstar LLDPE products

The enhanced Borstar LLDPE product mix exhibits today an extended list of products for blown film. These grades are all very well suited for extrusion on most blown film lines including coextrusion and blends, as well as coextrusion with HDPE in high neck HD extrusion lines. In the extended list of products, Borealis has also developed a Borstar grade with lower haze, FB4250T (T=transparent) with transparency similar to fractional melt MFR LDPE.

Borstar PE film products are indeed different from conventional LLDPE due mainly to the very broad molecular weight distribution (MWD), as shown in figure 2.

All Borstar grades exhibit enhanced physical properties combined with very good processing properties. With the broad MWD, all Borstar grades have excellent homogenization with most other types of PEs.

FB2230, FB4230 and FB4250T are through their lower density, exhibiting the best sealing performance. FB2310 and FB4370 have increased stiffness combined with high toughness, which makes them excellent products for core layers in coextrusion and providing stiffness modification for PE blown films.

FB4230 and FB4370 have been developed to provide improved output and improved extrusion properties, resulting in reduced pressure and also lower power consumption.

FB4250T provide good optical properties on the level of LDPE with MFR=0.3 g/10 min.

The FB4370G is especially developed for cast process geo-membrane applications with an enhanced additive package to meet the demand for higher thermal resistance which is required for these applications.

<table>
<thead>
<tr>
<th>Basic properties</th>
<th>FB2230</th>
<th>FB4230</th>
<th>FB4250T</th>
<th>FB2310</th>
<th>FB4370</th>
<th>FB4370G</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFR2 (190°C) [g/10 min]</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>MFR5 (190°C) [g/10 min]</td>
<td>0.9</td>
<td>2</td>
<td>2</td>
<td>0.9</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>MFR21 (190°C) [g/10 min]</td>
<td>0.9</td>
<td>2</td>
<td>2</td>
<td>0.9</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Density [kg/m³]</td>
<td>923</td>
<td>923</td>
<td>925</td>
<td>931</td>
<td>937</td>
<td>937</td>
</tr>
<tr>
<td>DSC melting point [°C]</td>
<td>124</td>
<td>124</td>
<td>124</td>
<td>127</td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>Vicat softening point [°C]</td>
<td>103</td>
<td>104</td>
<td>106</td>
<td>112</td>
<td>114</td>
<td>114</td>
</tr>
</tbody>
</table>
**Enhanced Borstar HDPE products**

The enhanced Borstar HDPE product mix today includes an extended list of grades for blown HDPE film as well as a one cast grade. These grades are very well suited for extrusion on most high neck blown film lines including coextrusion and blends. With the introduction of FB7400, intended for hygienic film applications, Borealis has also entered the cast film area with the Borstar PE technology.

FB1350 and FB1460 are mainly intended for high neck film extrusion. These grades are with their broad MWD easy to extrude and perform well in conventional HDPE blown film lines. In addition FB1350 and FB1350G show excellent extrusion properties for blown geo-membranes. FB1350G is especially developed for blown process for geo-membrane application with an enhanced additive package to meet the demand for higher thermal resistance which is required for these applications.

FB3450 is especially developed for blends in film made from LDPE (or LLDPE mix) for enhancement of stiffness and conversion processes. With a mix of 10-30% FB3450 one achieves improved process properties as well as increased stiffness. The benefits can be measured in higher retention force which is a very important property in shrink films and collation shrink films.

FB7400 is especially developed for cast film intended for hygienic film production, but has also proven to be an excellent alternative for other HDPE cast film solutions.

<table>
<thead>
<tr>
<th>Basic properties</th>
<th>FB1350</th>
<th>FB1350G</th>
<th>FB3450</th>
<th>FB7400</th>
<th>FB1460</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFR2 (190°C) g/10 min</td>
<td></td>
<td>0.3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MFR5 (190°C) g/10 min</td>
<td></td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MFR21 (190°C) g/10 min</td>
<td>15</td>
<td>15</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>935</td>
<td>935</td>
<td>945</td>
<td>940</td>
<td>946</td>
</tr>
<tr>
<td>DSC melting point (°C)</td>
<td>128</td>
<td>128</td>
<td>129</td>
<td>130</td>
<td>131</td>
</tr>
<tr>
<td>Vicat softening point (°C)</td>
<td>117</td>
<td>117</td>
<td>120</td>
<td>119</td>
<td>125</td>
</tr>
</tbody>
</table>

*Figure 4: Table of Borstar HDPE film grades*
**Processing properties of Borstar PE**

It is very important for the film converter that the processing operation is smooth, efficient and trouble-free. High output is a must, the bubble must not break and cause production delay, and the thickness profile of the film should be stable. The downgauging flexibility of the film is important for cost reduction, as is the flexibility to use both mono and coextrusion processes. For the packer, the film consistency on a high-speed packaging line is crucial.

The very broad Molecular Weight Distribution (MWD) of Borstar LLDPE, together with the linear molecular structure, provide improved trouble free extrusion and stable film bubble behaviour. The zero shear viscosity is high, resulting in very good bubble stability. The shear thinning behaviour is close to LDPE and provides convenient extrusion conditions. The linear molecular structure also provides practically unlimited draw down ability. With the introduction of the extended Borstar PE product mix PE film producers have more options and more flexibility when selecting the best grade for their application and production / conversion equipment.

The similarity of shear thinning behaviour to LDPE, as can be seen in figure 4, is also very beneficial with respect to melt fracture, often referred to as shark skin. This is practically absent for Borstar LLDPE products even at die gaps of 1.0 mm.

Borstar LLDPE products can therefore be processed most beneficially with narrow die gaps, in contrast to conventional LLDPE.

Furthermore, the combination of excellent bubble stability and extremely low tendency to bubble breaks provides a stable production at high efficiency.

![Figure 5: Viscosity behaviour of Borstar LLDPE shows a high similarity to LDPE, in contrast to conventional LLDPE.](image-url)
**Processing guideline**

Borstar LLDPE can be conveniently processed on state-of-the-art LD/LLD blown film extrusion lines. The processing conditions will influence the final film properties. Therefore, we do recommend to follow our general guideline which is outlined in figure 6.

**Draw down ability**

With Borstar you can cover a thickness range from below 10 µm to more than 200 µm, while maintaining good bubble stability. The bubble stability of unimodal LLDPE is often too low for the extrusion of thick as well as thin films, while LDPE has the traditional problem of figure 7 versus MFR.

<table>
<thead>
<tr>
<th>Extruder temperature</th>
<th>LDPE</th>
<th>LLDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>190-210°C</td>
<td>&lt; 200°C</td>
<td>200°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Die gap</th>
<th>LDPE</th>
<th>LLDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0-1.8 mm</td>
<td>0.8 - 1.5 mm</td>
<td>1.8 - 2.3 mm</td>
</tr>
<tr>
<td>narrow</td>
<td>narrow</td>
<td>wide</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cooling ring</th>
<th>LDPE</th>
<th>LLDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>mono lip</td>
<td>mono lip</td>
<td>dual lip</td>
</tr>
<tr>
<td>dual lip</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blow up ratio (BUR)</th>
<th>LDPE</th>
<th>LLDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:1 - 4:1</td>
<td>1.5:1 - 3:1</td>
<td>2:1 - 4:1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frost line height (FLH)</th>
<th>LDPE</th>
<th>LLDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>medium - higher</td>
<td>low - medium</td>
<td>low</td>
</tr>
<tr>
<td>3xD - 6xD</td>
<td>3xD - 5xD</td>
<td>2xD - 3xD</td>
</tr>
</tbody>
</table>

Figure 6: Recommended processing parameters for Borstar LLDPE.

**Figure 7:** The best flexibility to produce a large span of film thickness is achieved with Borstar LLDPE.
Processability is of vital importance to the film producer, in order to effectively produce a high quality film with good consistency. This may be measured in several ways. Figure 8 combines into one ranking the most important processing parameters of Borstar LLDPE – extrusion, output, bubble stability and thickness profile –, and compares them to other linear PE’s, with LDPE as a reference.

Films for most packaging applications are normally extruded as a blend of PE’s in either mono or coextrusion, in order to tailor to the customer’s needs, whether these are performance related (e.g. mechanical strength, cost, thickness, stiffness) or marketing related (surface characteristics, printing or stiffness). This means that the processability of Borstar LLDPE cannot be seen in isolation.

Our experience in the market has proven that Borstar LLDPE can:

- be processed at highest extrusion rates
- be easily processed on most blown film machinery
- improve bubble stability
- reduce waste production
- improve production efficiency
- easily be coextruded with other PE’s.
The achievable film line output will depend on many different factors including the polymers’ processing behaviour, winding capability, film thickness, die construction, extruder pressure and cooling capacity, to mention some of the important ones. For instance, the output is limited by the winding speed for relatively thinner films and on the other hand the cooling capacity is limiting the output for thicker films. Conventional LDPE is generally regarded as the most convenient PE to process, yielding the highest output rates in most instances. It is a common understanding in the market that pure LLDPE films or their rich blends with LDPE can only be produced at lower extrusion rates due to limitations either in bubble stability, pressure or cooling capacity.

Borstar LLDPE do not behave in this way. On the contrary, an equally high or only marginally lower output can be expected, contrary to conventional LLDPE, when extruded pure or in rich blends with LDPE.
A typical example in heavy duty films is a loss of up to 30% output with a rich LLD/LDPE blend compared to LDPE. Several examples have shown us that Borstar LLDPE can be processed pure at the same output rates or maximum 10% lower than pure LDPE.

Borstar HDPE products, FB1350 and FB1460, should be processed under normal conditions in high neck extrusion. Due to their bimodal nature our experience is that when a lower temperature profile setting is applied a better result is achieved. Both these products are also commonly processed in coex lines, e.g. core layers, or in blends with other PE’s to improve the film stiffness.

Borstar FB3450 is especially designed to be used in blends with LDPE in ratios of 5-25% HDPE. It has excellent homogenization capability with LDPE and will result in greatly improved draw down, higher stiffness and beneficial heat shrink properties.
Properties of Borstar LLDPE films

Based on the bimodal polymer design concept, Borstar LLDPE products offer the flexible extrusion quality of traditional LDPE, combined with the superior mechanical properties of higher alpha olefin linear products. The combination of these properties facilitates increased production efficiency with value generating potential both in the blown film extrusion and in converting and packaging.

The unique combination of stiffness and mechanical properties such as tear, impact and yield strength offers a genuine downgauging potential for packaging film. Features traditionally obtained by coextruded structures, combining blends of different PE’s in each structure, may be achieved with a single material and in most cases with thinner film.

The controlled comonomer distribution results in low taste and odour levels and improved low temperature properties, compared to traditional PE’s.

Furthermore, films made from Borstar polyethylene grades have a high seal strength and hot tack force.

Due to the linear structure, in combination with a rather low MFR of these materials, a high blow-up ratio and/or higher frost line height may further improve the mechanical properties.

Compared to conventional products like LDPE and C4-LLDPE, which represent the most commonly used PE types for extruded blown films, Borstar PE products offer significant improvement potential in properties, leading to cost advantages.

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Figure 10: Improved performance of Borstar LLDPE.

Figure 11: Borstar PE holds a unique balance of properties which are normally not associated with LLDPE. This property balance is highlighted in this figure.
The Dart drop index can further illustrate the mechanical performance, in comparison to conventional PE products (figure 12).

If any single property should be emphasised, it is the superior low temperature impact performance, which exceeds conventional materials in the market today. This makes Borstar PE well suited for the production of any packaging material that needs to be tough and resistant at frozen conditions (figure 13).

For more details see the separate brochure “Borstar LLDPE Frozen Food Packaging Films”.

Figure 12: Dart drop index (F50) [g] of 40 µm films processed on a LD/LLDPE mono extrusion line.

Figure 13: Impact total energy measured at −20°C by dynamic falling weight, according to DIN53373.
Typical needs in packaging

The packaging industries represent a strong need for economical, effective and innovative packaging solutions, and demand package consistency as well as good product quality.

This is the reason why the packers of food and nonfood products have continuously invested in effective Form-Fill-Seal machines for their packaging operations. These modern packaging operations demand easy processability from the film, as well as good sealing behaviour. Furthermore the package integrity, limiting product spoilage, the cost and the appearance of the packages plays an important role in the way package specifications are defined.

Some basic requirements for packaging films are listed below:

- balance between toughness and stiffness
- mechanical resistance
- low temperature resistance
- high temperature resistance for hot filling of food or industrial goods
- grease resistance
- excellent sealing behaviour
- low blocking force, “easy opening”
- optical properties
- film appearance
- moisture barrier
- oxygen and gas barrier
- light barrier
- low migration levels
- good printability
- environmentally friendly
- balanced surface friction on FFS-equipment
- distinct layflat of the film, easy to run on high speed conversion lines.
After several years in the marketplace we see a strong and increasing demand for these enhanced Borstar PE products. Feedback from our customers has highlighted many positive characteristics of Borstar PE:

- good processing and mechanical properties
- homogenises well with regrain
- competitive properties to C8-LLD
- excellent yield and tensile strength
- outperforms LD/LLD blends for carrier bags
- unique side-fold impact
- no pinholes during cross-lamination
- high output and excellent bubble stability
- excellent mechanical properties allow up to 40% downgauging
- outstanding toughness/stiffness balance is basis for downgauging potential in mono- and coex – film solutions
- better drawdown ability than LDPE
- 25 µm monofilm/FB2230 liners are competitive with more expensive coex alternatives
- low CoF that changes slowly by slip addition makes it easy to control surface properties e.g. in critical lamination applications
• no addition of antiblock is needed to get antiblocking effect
• Borstar LLDPE gives >25% higher output than CB-LLD due to better bubble stability e.g. when running 150 µm sack film
• good optical properties, low CoF and high dart impact when a slip containing LDPE / Borecene Metalloocene blend is used as surface layer in an ABA coextruded film
• extremely good processability over a wide range of film thickness; a 6 µm film can be run on a LD/LLD line at full speed; no need for blends any more
• excellent matt surface properties
• higher melt strength than conventional LLDPE
• possible to use the narrow LDPE die gaps
• Borstar LLDPE gives the best result in deep freeze packaging applications
• 15–25% downgauging can be achieved in FFS shipping sacks
Borstar PE conversion and packaging performance

Borstar PE products have demonstrated their converting and packaging performance on a wide range of machines and in a broad spectrum of applications, such as high speed bag making, collation shrink, FFS packaging, in-line liner production and other highly efficient packaging operations. Increased stiffness, in combination with toughness, is one of the main reasons why films produced with these materials have proven successful in such high speed conversion and packaging. Another benefit of Borstar PE in packaging processability terms is the fact that these products provide a matt and non-blocking surface. Films with such surface properties will be easy to open and run well on high speed packaging machines (controlled, suitable friction against metal surfaces). Furthermore, the matt surface, together with a balanced stiffness, provides excellent unfolding behaviour, which makes installation of bag-in-box and other liners very convenient, “easy to handle”.

The sealing and hot tack behaviour of Borstar LLDPE products is characterised by a beneficial balance of high hot tack force and seal strength, as well as broad sealing window. The hot tack force is higher than LDPE, it’s copolymers and standard C4-LLDPE.

Figure 14: Seal strength and hot tack behaviour of Borstar LLDPE products
The seal strength, which is correlated to tensile strength, is higher than other low density materials. Seal initiation temperature, which depends on viscosity and density, is similar to low MFR LDPE for FB2230 and FB4230, but about 10°C higher for FB2310. Sealing performance also depends on the conversion and packaging equipment, their speed, and the film thickness. Market experience in a variety of applications confirms the convenient sealing behaviour of FB2230 and FB4230. When sealing FB2310, the higher SIT should reflect in the machine settings.

Conversion and packaging operations involve operations like film cutting in machine- and transvers- direction or cutting/punching holes in the film, according to the design of the package, bag or pouch. Due to the high toughness of Borstar LLDPE products, problems might occur in such operations when this equipment is of simple design or not well maintained or if cutting devices have been intended for LDPE films, which are normally very easy to cut.

![Tensile strength of Borstar versus other PE](image)

**Figure 15: Tensile strength of Borstar versus other LDPE products**
Migration levels, as well as taste and odour problems, with films produced with Borstar LLDPE is very low and all products meet the specific food packaging regulations in European countries, regulation EC No 1935/2004 and Commission Directives 2002/72/EC, 2004/1/EC, 2004/19/EC and 2005/79/EC as well as the FDA, CFR in the US. This is due to the beneficial molecular structure and low additive levels. Also, processing of Borstar LLDPE does not require any sort of processing aids.

Coextrusion technology is becoming increasingly common for the production of PE blown films of all kinds. The major suppliers of film extrusion equipment are reporting that more than 70% of all new extrusion lines are based on coex technology, mainly with a 3 extruder ABC construction. Using Borstar LLDPE in one or more layers of such coex films will provide advantages in terms of the balance of properties of the final films. The selection of the grade and in which layer to use it, will depend on the final application. Several examples are described in detail in the last section of this brochure.

In general below mentioned guide-formulations for 3 layer Coex films as well as Mono films meet the demanding requirements of modern packaging solutions.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Borecene mLLDPE-rich layer (incl. LDPE)</td>
</tr>
<tr>
<td>B</td>
<td>Borstar LLDPE as preferred core layer material</td>
</tr>
<tr>
<td>A</td>
<td>Borecene mLLDPE-rich layer (incl. LDPE)</td>
</tr>
</tbody>
</table>

*Figure 16: 3 layer Coex film solutions*
Application examples of Borstar Enhanced PE

Our Borstar Enhanced PE Film products hold a significant position in the marketplace as being versatile products for a very wide range of film and flexible packaging applications.

The technical performances of these products are highly appreciated for the contributions in various recipes for such films.

The range of applications for PE films is certainly very wide today, but not only technical issues are decisive in the choice of the raw material recipe. The decision is also affected by market expectations, competition, benefits, trends, design features, etc. in areas such as industrial packaging, food and non-food consumer packaging, and agriculture.

Current and potential application areas for Borstar Enhanced LLDPE products.
Several of these applications are discussed in detail in the next section.
Borstar applications

The customer’s choice of Borstar product is dominated by the specific need for stiffness in the product.

- Films for lamination
- Deep freeze applications
  - domestic roll pouches
  - FFS vegetable packs
  - box liners/sheet for fish and meat
  - ice cube bags
- Stand up pouches
- Consumer and Industrial Shrink films
- Diaper packs
- Bread bags
- Water bags/pouches
- FFS packs for peat moss and soil
- Carrier bags for retail and fashion boutiques
- Courier mail envelopes
- Money bags
- Shipping sacks
- Geomembranes and other sheets
- Liners in paper sacks, boxes and semi-bulk
- Refuse sacks, specified types e.g. for hospitals
- Insulation packs
- Coextrusion with ‘skin’ layers of glossy LDPE or Borecene mLLDPE

Several of the below listed applications are discussed in detail in the next section.
- Masking films for painting of cars
- Blend component for recycled plastics
- Blend component for HDPE films ~20%
- Inner or middle layer in coextrusion with HDP
- Medical packaging
- Hygienic applications
- Breathable films for diaper barriers

Good physical properties even at thinner gauges.

Borstar PE film offers superior cold temperature behaviour.

Good printability on the matt surface, a strong film with strong seals.

Borstar PE film gives superior physical properties even at low thicknesses.

Higher stiffness gives easy conversion and faster bag filling, leading to higher production rates.
Borealis provides film solutions

The market for PE films in packaging and other applications is today dominated by the needs for application specific raw material recipes being produced as mono or co-extruded combinations. This has resulted in improved packaging performance and consumer appeal and at the same time helped to reduce costs in various parts of the value chain.

Borealis offers a wide range of both standard and differentiated PE and PP products which enables us to fully cooperate with and assist our customers and the value chain in further development and improvement of film solutions and recipes. In this paragraph some of these concepts will be discussed.

Product mix

Our products allow for a wide range of opportunities when these are combined as specific recipes. The key product families are illustrated in fig. 17 and within each of these product families Borealis usually offers several products. Borstar is a key technology for us in Borealis and our Borstar Enhanced PE film products play an important role in film recipe modification and optimization due to the properties and benefits discussed before in this brochure.

Figure 17: Borealis product mix for blown film
Mono films

Extrusion of single layer mono-films is still commonplace in the industry and will remain important for several applications and includes high volumes. By using a Borstar product with suitable stiffness and toughness for the specific application or end use pure or in a variety of blends a beneficial balance of the film properties and processing regularity and economics can be obtained. Some general guidelines are highlighted below:

- Pure Borstar products are extensively used in liners, roll pouches, fashion carrier bags, wrapping films, protection films and agricultural applications.
- Pure Borstar FB4250T can and will replace LDPE in several applications.
- Blending FB4250T with Borecene mLLDPE products results in very good clarity and sealing performance, as well as film toughness.
- LDPE with an addition of between 10-40% of Borstar products have improved draw down properties, stiffness, tensile strength and with the higher stiffness products improved shrink performance.
- Blends of Borstar products with Borecene mLLDPE result in better balance of stiffness, toughness and sealing performance.
- Triple blends of Borstar grades with Borecene mLLDPE and LDPE gives very desirable combinations and can easily be designed for monofilms to give extraordinary balance of toughness, stiffness, optics and sealing properties which can be optimized by the specific choice of products. Additionally the processing performance of such triple blends are outstanding.
Coex films

Co-extrusion has become a preferred choice, in particular 3-layer films, and offers much greater flexibility in how the film properties can be balanced and optimized in terms of specific properties like sealing or optics and when utilizing Borstar products in one or more layer take advantage of their high strength, toughness and processing benefits. Co-extruded films are better suited for more demanding applications within consumer packaging and laminated films due to the better ability for tailoring of performance.

Coextruded films are normally designed after 3 main principles of layer distribution and polymer composition: symmetric ABA layer or non symmetric ABC or ABB constructions. In the 3 layers Borealis products will be used pure or in blends.

Our competence of our products and film solution possibilities together with our customers complementary knowledge have resulted in numerous recipes that helps the value chain to improve packaging and cost performance of their operations.

Blends of products, as described in previous paragraph, can be used in these various layers. However, one of the key solutions brought by our product mix is the combination of Borstar core layers with surface layers of Borecene mLLDPE and LDPE.

By our extensive product mix of Borstar, Borecene and LDPE products with a range of density and MFR’s it is possible to produce films with higher or lower stiffness while toughness, sealability, optical performance and processability are at the same time optimized. When selecting this solution it brings also another very significant cost benefit; recipes can be standardized and and much more easily modified with extremely short transition times in production.
Applications

Industrial shrink films

The total shrink film market in Western Europe consumes more than 900 kt of PE per year (AMI 2004) and is the classic application, where LDPE with its good shrinkage behaviour is the dominating material used. Borstar LLDPE exhibits significant benefits over LDPE and its blends with LLDPE or HDPE for collation and pallet shrink applications.

Key advantages with Borstar:

- Very low hot shrink force → no hole burning
- Very high cold shrink force → collation and holding forces
- Balance of strength, toughness and stiffness → stability during transport and handling, improved film integrity, less film puncture with sharp edges, possibility to downgauge, improved film integrity
- Matt surface → easy to open film, easy to apply onto e.g. pallets

Film structures with Borstar:

- Mono films made from pure FB2310 or with up to 25% LDPE will take the advantages of the full property range in mechanical and shrinkage properties.
- Blend of FB2310 into LDPE provides enhanced shrinkage properties but less improvement of mechanical properties.
- Coex films with FB2310 together with LDPE or LD/LLDPE blends result in a property enhancement combined with high gloss and transparency.
- Blend of LDPE with 5-15% FB3450.

Key shrink film properties for 120 µm film samples processed on a coex line with BUR=3.8:1. Borstar F2310 is compared to an LDPE with MFR2 = 0.3, processed as mono and coextruded films. The coextruded film is an ABA construction of LDPE/FB2310/LDPE in a layer ratio of 30/40/30%.
Collation Shrink Films

The use of shrink film for multipacks for bottles and cans have been growing steadily recent years. Such packs are practical to carry home and give the product enhanced customer appeal through high quality printing, especially when printed on the reverse side. Such films have undergone a continuous development due to increasing needs for higher optical performance, higher packaging line speeds and cost reductions through downgauging. For these reasons, co-extruded films where Borstar FB2310 or FB4370 are combined with Borecene mLLDPE and LDPE have proven to give a particularly beneficial balance of properties.

Film structures with Borstar:
- The best balance of properties are achieved with ABA Coex films
  A = FM5276+20-40%LDPE
  B = FB2310 + 30-50% LDPE
- FB4370 can be used on core layer for higher stiffness.

Key advantages with Borstar:
- Very low hot shrink force \(\rightarrow\) no hole burning
- Very high cold shrink force \(\rightarrow\) collation and holding forces
- Balance of strength, toughness and stiffness \(\rightarrow\) stability during transport and handling, improved film integrity, less film puncture with sharp edges, possibility to downgauge
- High clarity and gloss \(\rightarrow\) surface layers of Borecene/LDPE blends \(\rightarrow\) excellent display and visibility

![Diagram showing property improvement](image-url)

*Property improvement achievable by a coextruded film with a combination of Borstar/Borecene/LDPE vs. a monofilm of LDPE/LLDPE blend.*
Lamination films

Through lamination it is possible to add other functionalities into the packaging substrate than by extrusion alone. Some of these advantages are stiffness, rigidity and barrier properties. This has made lamination a success and the overall market is growing. When using lamination it is possible to add different substrates to the PE film like layers of BOPP, PET, PA or Alu. It is also becoming more common to join two PE films with a sandwiched print for aesthetic reasons.

**Key advantages with Borstar:**

- Increased stiffness ➔ rigidity and handling
- Toughness/seal strength ➔ less product spoilage
- Extremely low amount of gels ➔ very high quality
- Matt surface ➔ easy treated and good adhesion
- Low migration and additive level ➔ low taste and odour
- High ESCR ➔ compliance to food packaging
- Processability ➔ cost efficiency
- Low migration ➔ low taste and odour
- Low additive levels ➔ compliance in food packaging

Stand up pouches

PE films, mono and coextruded, are being used for a variety of stand up pouches as the main component in duplex and triplex laminated structures. PE based stand up pouches are typically used for packaging of beverages, non-retorted food and non-food products.

**Key advantages with Borstar LLDPE:**

- Increased stiffness ➔ pouch rigidity and handling
- High ESCR ➔ shelf life and no breakage
- High toughness ➔ cost savings, design freedom
- High seal strength ➔ less risk of product spoilage
- Matt surface ➔ ease of conversion and filling
- Processability ➔ cost efficiency
- Low migration ➔ low taste and odour
- Low additive levels ➔ compliance in food packaging

Film structures with Borstar:

- Mono films made from blends of Borstar + LDPE or Borecene or triple blends thereof.
  **Example:** 40% FB2230 + 40% Borecene FM5226 + 20% LDPE.
- Coex films with Borstar products, Borecene and LDPE selected in order to meet the needs of the specific application.
  **Example:** ABA film where A=Borecene FM5226 + 20% LDPE B=Borstar FB4370.

Film structures with Borstar:

- Mono films of FB2230, FB2310 and FB4230.
- Coex films with FB2230, FB2310 and FB4230 in one or more layers.
Film structures with Borstar:
- Mono films of FB2230 give the best toughness and sealing properties alternatively blended with Borecene.
- In coex films with dual colour a stiffer Borstar FB2310 or FB4370 would be used in the core layer and tougher Borstar grade, FB2230 or FB4230, in one or both surfaces or alternatively FB4250T for better gloss. FB2230, FB4250T and FB4230 can be combined with LDPE or Borecene to tailor stiffness, toughness, surface gloss and sealability in any of the surface layers.

Courier and security envelopes
Plastic envelopes and pouches have been successfully implemented for courier shipments, direct mail and money bags. This is due to the beneficial properties of plastics like water repellence, toughness, security aspects, efficient production, etc. providing high performance at a beneficial cost.

Key advantages with Borstar LLDPE:
- Increased stiffness ➔ pouch rigidity and handling ➔ potential for downgauging
- High toughness ➔ high protection/security
- High seal strength ➔ less risk of breakage
- Matt surface ➔ ease of conversion and opening ➔ facilitates write-on ➔ reduced transparency
- Processability ➔ cost efficient film production

Liners
Liners are used in various formats ranging from sheets and pouches to converted bags in sacks, boxes, barrels and containers. The key purpose is to provide a protection and barrier between the product and e.g. the corrugated box.

Film structures with Borstar:
- Mono films of any of the Borstar LLDPE products where choice of product depends on property requirements like stiffness or sealability.
- Coextruded films for tailoring the balance of properties like surface, stiffness, strength, penetration resistance, barrier, etc. with the chosen Borstar LLDPE in the desired layer(s). Borecene mLLDPE can be used to improved sealing properties of inner layer.

Key advantages with Borstar LLDPE:
- Increased stiffness ➔ film rigidity and handling ➔ potential for downgauging
- High toughness ➔ improved product protection
- High seal strength ➔ less risk of product spoilage
- Matt surface ➔ ease of installation and opening
- Processability ➔ cost efficient film production
Carrier bags

Shoppers and carrier bags represent a high consumption for PE film with a variety of formats ranging from thin and cheap T-shirt bags to solid and highly printed fashion bags.

Key advantages with Borstar LLDPE:
- Film processability ➔ production efficiency
  ➔ well suited for coex on HDPE lines
- Increased stiffness ➔ good load bearing
- Toughness ➔ less risk of breakage
  ➔ downgauging
- Matt surface ➔ provides a frosted appearance
  ➔ conversion speed

Bags for garden products

Garden products like seeds, fertilisers, soil and peat are packed in various types of converted and FFS bags, ranging from 1–2 kg carry-out bags to 50 litre compact bags.

Key advantages with Borstar LLDPE:
- Bubble stability ➔ efficient film production
- Stiffness ➔ good packaging machineability
- Matt surface ➔ easy opening/filling
- Impact/puncture resistance ➔ package integrity
- Stiffness/impact balance ➔ downgauging

Film structures with Borstar:
- Thicker mono films for printed fashion bags, providing an exclusive printed surface.
  - Monofilms of FB4250T gives a simple and reliable solution.
  - Monofilms of triple blend gives opportunity to optimize properties vs. requirements.
- Coex films of Borocene+LD/Borstar/Borocene+LD for high gloss shoppers will make it possible to downgauge.
- Coex films of HDPE with Borstar in one layer will increase toughness. If used as inner layer, sealability will also be improved.
Medical packaging and hygienic films

The packaging needs of the medical industry are characterised by high demands for safety and protection of the packed product. These packaging needs are met through coextruded and laminated films, which have to fulfil the requirements both regarding physical properties as well as regulatory aspects.

**Key advantages with Borstar LLDPE:**
- Drug master filings ➔ ease of approvals
- Stiffness ➔ good behaviour on packaging machine
- Impact/puncture resistance ➔ package integrity
- Matt surface ➔ easy opening/filling
- Low additive levels ➔ compliance to regulations ➔ low migration
- Low migration

Food packaging

The food packaging sector needs effective packaging solutions for fresh, processed and frozen food products. A wide variety of formulations, mainly coextruded and laminated films, provide a range of attributes to ensure product protection, shelf life and good display properties of the product.

**Key advantages with Borstar LLDPE:**
- Stiffness ➔ packaging speed
- Matt surface ➔ easy opening/filling
- Impact/puncture resistance ➔ package integrity
- Low temp. resistance ➔ high integrity at frozen conditions
- Stiffness/impact balance ➔ downgauging
- Low additive levels ➔ compliance to food packing regulations ➔ less problems in lamination
- Low migration ➔ low taste and odour

Film structures with Borstar:
- Coextruded films with Borstar LLDPE in one or more layers. FB2310 or FB4370 are well suited for core layers and provide high strength and stiffness. When combined with Borecene mLLDPE an improved surface gloss, print appearance or sealing performance can be achieved.
Oriented PE films

Biaxially oriented PE films have traditionally been serving packaging markets like high transparency shrink films, barrier films and candy twist wrap. Other technologies are emerging in the market, like monoaxial orientation of PE blown films, suitable for producing oriented films beyond 100 µm. This allows for the penetration of OPE into new applications.

Key advantages with Borstar LLDPE:

- Bubble stability ➔ film production output
- Flexible orientation ➔ tailoring of properties
- Very high mechanical ➔ significant downgauging
- High stiffness ➔ good behaviour on packaging machine
- Impact/tear resistance ➔ package integrity

Potential applications:

- Shipping sacks
- Compression package
- Magazine wraps
- Twist films
- Labels
- Breathable films

Film structures with Borstar:

- Mono films based on FB2230, FB2310 or FB4230.
- Coextruded films combining Borstar LLDPE with HDPE or Borecene mLLDPE.
- Coextruded films based on Borstar LLDPE with inner layer of EMA or EVA for lamination of thick substrates before stretching into films of thickness > 60 µm.
Borealis has developed its range of enhanced Borstar PE products for blown films, based on the growing need for demanding packaging solutions in the market. Our Borstar products are well suited for a wide range of packaging applications, combining good blown film processability with high mechanical properties. This brochure demonstrates that Borstar Borstar LLDPE and HPPE products provide a unique balance of properties, resulting in improved performance in blown film extrusion and a variety of PE film applications. In order to supply high performance PE films for any application, it is important to understand the demands of this market. A number of benefits have been emphasised, required to meet the challenging demands of the packaging industry. These excellent properties ultimately lead to a range of benefits for all parts of the value chain involved in PE film applications.

### Summary

Borealis has developed its range of enhanced Borstar PE products for blown films, based on the growing need for demanding packaging solutions in the market. Our Borstar products are well suited for a wide range of packaging applications, combining good blown film processability with high mechanical properties. This brochure demonstrates that Borstar Borstar LLDPE and HPPE products provide a unique balance of properties, resulting in improved performance in blown film extrusion and a variety of PE film applications. In order to supply high performance PE films for any application, it is important to understand the demands of this market. A number of benefits have been emphasised, required to meet the challenging demands of the packaging industry. These excellent properties ultimately lead to a range of benefits for all parts of the value chain involved in PE film applications.

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<tr>
<th>Converter</th>
<th>Packer</th>
<th>Retailer</th>
<th>Consumer</th>
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| - Bubble stability  
  - Production regularity & output | - Downdragging  
  - Packaging integrity  
  - High mechanical properties | - Good handling  
  - Packaging integrity  
  - Innovative design solutions | - Attractiveness  
  - High mechanical properties  
  - Less product spoilage |
| - Film thickness range  
  - High mechanical properties | - Packaging efficiency  
  - Cost efficiency | - No off-taste or flavour  
  - Less product spoilage | - No off-taste or flavour  
  - Packaging integrity |

### Three other brochures elaborate further on specific applications:

- Borstar LLDPE for Frozen Food Packaging Films
- Borstar PE in Heavy Duty Shipping Sacks
- MDO Film Orientated PE and PP packaging film
Borealis specialises in supplying advanced polyolefin plastics for the manufacture of film, fibre, coating and thermoforming solutions. Through the introduction of technologies and solutions such as Borstar®, Borclear™, Borflow™ and Borseal™, Borealis has, over 40 years established a leading position in the film and fibre market across Europe.

Borealis believes that customer-driven innovation is the only way to achieve and sustain progress. In the film and fibre industry, Borealis has pioneered the development of innovative solutions. Borseal advanced biaxially oriented polypropylene (PP) film with higher gloss and transparency has opened up new opportunities for film producers. For meltblown, nonwoven applications, Borflow has set a new standard in barrier performance in applications such as diapers. Daploy™ HMS is a new generation of long chain branched PP for low weight foam and high speed coating applications. Through foresight and focus on customer needs, Borealis continues to provide innovative polypropylene (PP) and polyethylene (PE) solutions for the film and fibre industry that add real value throughout the value chain.

We also know the high value that our customers in the film and fibre industry place on product consistency and processability. We pride ourselves on the performance of our products, and through ongoing investment in upgrades and new plant programmes, we continue to set new records for output efficiency and product reliability. Borealis believes that responsiveness is the foundation of fruitful customer partnerships.

Film & Fibre ensures this through highly skilled and experienced technical, marketing and product development people, located in Borealis hubs across Europe: Central Europe, Belgium, Scandinavia and Finland. In addition we have a strong sales force around Europe and close cooperation with our joint venture Borouge in the Middle East and Asia.