

Let's energize
wind innovation
together!



Next generation wind turbines made possible with PU solutions from Covestro

The wind energy industry plays a crucial role in achieving the goals of the Paris Climate Agreement. However, the industry is facing several challenges that must be addressed in order to continue its growth. One of the biggest challenges is the need for more durable, reliable, and sustainable materials for wind turbine components that help reduce costs and maximize productivity.

A systematic reduction in the Levelized Cost of Energy (LCoE) can be achieved by increasing Annual Energy Production (AEP) through larger, more productive wind turbines and decreasing investment and operating costs through more advanced manufacturing processes and reduced maintenance.

Polyurethane (PU) raw materials enable longer, lighter, more durable wind turbine blade designs which increase turbine capacity and extend lifetime and therefore add years of energy production to a wind farm. Reducing the frequency of blade repairs and cable failures reduces the total cost over the entire lifetime of a turbine as well.

Covestro has developed a range of PU solutions from PU hybrid infusion and pultrusion resins for blades, to Leading Edge Protection (LEP), to Cable Protection Systems (CPS) to increase the energy output of a wind farm and reduce the cost of energy.

The impact of our PU solutions:

8%

reduction in blade manufacturing costs
(pultrusion and infusion resins)

30%

reduction in maintenance & repair costs (LEP coating)

2 years
life time extension

2.4% reduction in cost of energy

Blade composite resins and coatings reduce LCoE by 2.4% and increase AEP by 1%.

- Lower blade manufacturing cost: combining PU infusion resins with prefabricated pultruded PU spar caps can reduce the total cost of blade production by up to 8%
- Less operational blade maintenance: PU based Leading Edge Protection (LEP) coatings and shells reduce repair and maintenance costs by 30%
- Lighter blades: the expected 5% blade weight reduction extends the overall blade lifetime by at least 2 years thanks to reduced stress on the bond lines and turbine components

These high performance results with Covestro's PU hybrid vacuum infusion and pultrusion resins were achieved thanks to its significant processing and performance advantages compared to the widely used epoxy resin process.

Along with their processing advantages, PU systems enable the production of parts with excellent mechanical properties and an increased stiffness-to-weight ratio, allowing for a lighter blade design with even less deflection of the blades. Simulations show that lighter blades reduce bond line stress and the overall loading of the blades' roots.

Even more from Covestro:

- To withstand the harsh conditions in which turbines need to operate, Covestro offers high performance coating ingredients that provide durable protection at offshore installations, subsea cables are subject to natural forces. Covestro PU based elastomers deliver up to 30% cost savings, from raw materials to manufacture cable bend stiffeners and restrictors.
- As the wind industry matures, recyclability and circularity become high priorities. The chemical structure of PU allows a selective cleavage of bonds and therefore offers a superior recyclability over most other thermosets. Covestro strives to leverage recycling solutions from adjacent PU based applications for use in wind blade composites.
- Vacuum infusion equipment is recommended to create the optimal process conditions for PU infusion resin. Covestro's Baulé equipment has been designed to infuse the PU resin for the production of blade composites.

Contact: Dirk Soontjens,
Global Director Wind Industry

dirk.soontjens@covestro.com

Find out more in our whitepaper:



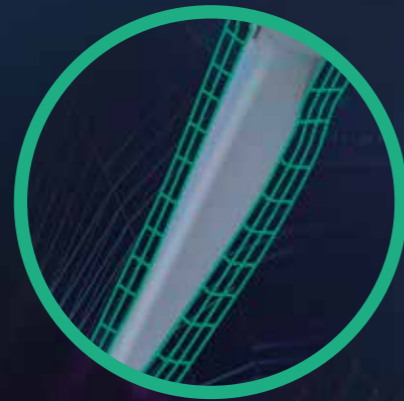
Covestro commissioned bewind GmbH to evaluate the impact of their PU solutions for wind turbine applications. Three PU products were evaluated: pultrusion resin, infusion resin, and coating raw materials for LEP. Results are based on internal data processed by Bewind using a proprietary simulation tool.

Our Portfolio

Solution: High performance composites

Products:

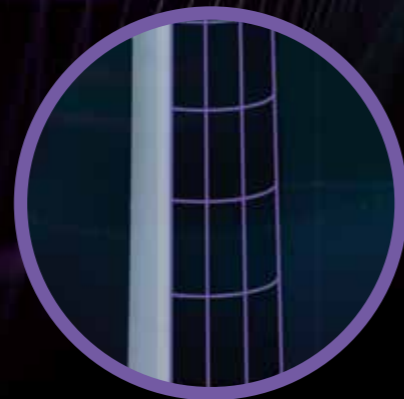
- Baydur®, Desmodur® high-strength infusion resin
- Baule® PU direct infusion machine
- Baydur® PUL, Desmodur® PUL for pultruded spar caps



Solution: Surface protection for blades and towers

Products:

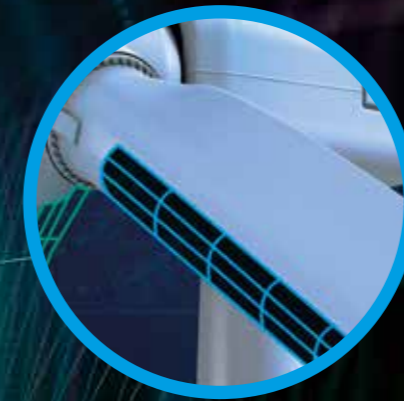
- Pasquick® gelcoat for manufacturing productivity of wind blades (raw material)
- Top coats and primers for water and UV protection of blades and towers (raw material)
- Pasquick® for corrosion protection of towers (raw material)



Solution: Leading edge protection

Products:

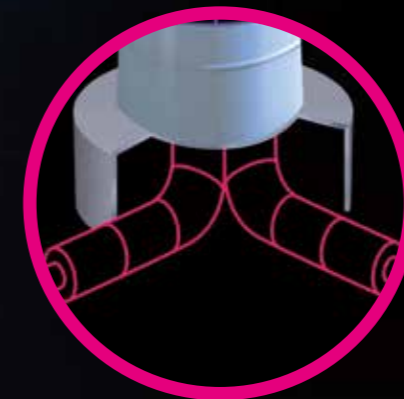
- Leading edge protection (by coatings)
- Bayfol® adhesive films for fixation of PU LEP soft shells
- Dureflex® aliphatic TPU film for surface protection
- Desmodur® Elastomer soft shells
- Desmopan® TPU granules for leading edge protection solutions



Solution: Cable protection

Product feature:

- Subsea cable protection using Desmodur®

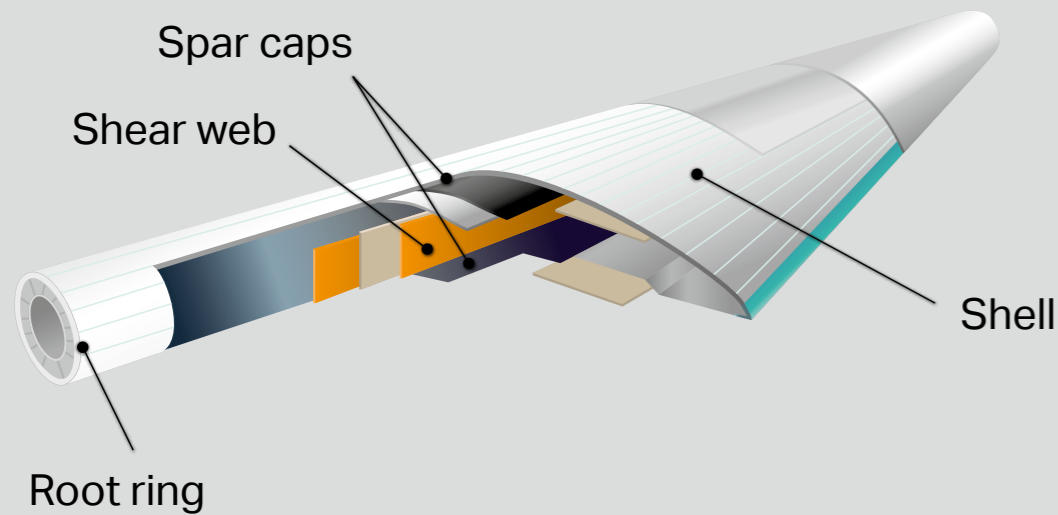


Find out more:



Solution: High performance composites

“PU resin for longer, lighter, more durable wind blades”



Application Areas:

Wind blade composite parts

Polyurethane resin for the manufacturing of structural components in wind turbine blades

Wind turbines are expected to generate more energy. This has led to larger blade designs, putting higher demands to their structural design and their use of materials. Moreover, increased market demand for wind blades drives the need for faster manufacturing and better use of CAPEX. With Covestro PU resins we offer a reduction of up to 8% in blade manufacturing costs by combining the advantages of both our infusion and pultrusion solutions.

Covestro has developed dedicated polyurethane resins tailored to the demands of producing wind blades in vacuum infusion and pultrusion processes. They are characterized by a very low viscosity combined with high reactivity and offer outstanding mechanical properties. This combination allows longer and lighter blades to be designed, while improving manufacturing efficiencies. For spar caps, pultruded pre-fabricated parts make a perfect solution that can be centrally produced and integrated into wind blades.

Advantages of Covestro PU infusion resins:

- Up to 20% shorter production cycles thanks to faster infusion and curing; enhanced capacity utilization
- Good impregnation of glass and carbon fibers, resulting in higher quality parts with lower porosity and fewer defects
- Good compatibility with PET and PVC core materials and other thermoset resins, to meet the processibility requirements with other emerging materials
- Low exotherm, enabling production of thicker parts with lower internal stress in the composite

Advantages of Covestro PU pultrusion resins:

- Quick wetting of fibers and fast curing for higher line speeds saving up to 14% on production costs for spar caps
- Extra high stiffness-to-weight ratio allows for building larger blades with lower blade deflection and improved twist angle distribution
- Good compatibility with other thermoset resins, carbon fibers, glass fibers and peel ply
- High product quality due to a robust production process with low amount of defects, leading to lower scrap rates in production and lower downtime costs during operation

Products:

Infusion Resins:

- Baydur® 78BD085 + Desmodur® 44CP20 (Asia)
- Baydur® 120V2 + Desmodur® 44CP23 (Europe, Americas)

Pultrusion Resins:

- Baydur® 18BD251, Baydur® 18BD252 + Desmodur® 44CP24 (Asia)
- Baydur® PUL 20PL10, Baydur® PUL 20PL20 + Desmodur® PUL 10PL01, Desmodur® PUL 10PL02, Desmodur® PUL 10PL03 (Europe, Americas)

Contact: Jens van Haag,
Market Development Manager PU Composites
jens.vanhaag@covestro.com

Find out more:



Solution: Leading edge protection of wind turbines

"Versatile solutions to protect the leading edge"



Application Areas:

- Protection of the leading edge of wind turbine blades by LEP coatings
- Protection of the leading edge of wind turbine blades by LEP shells
- Adhesive films for LEP blade shell application
- Protective films for wind blade surfaces

Leading edge protection to enable a long service life for wind turbine blades

The leading edge of a wind turbine blade is exposed to harsh impacts from the environment, such as rain, UV-light or hail, therefore they have to be safeguarded with leading edge protection. Ideally, an LEP lasts for the entire service life of a wind turbine, so that maintenance costs and downtime are reduced. Covestro offers different technologies to protect the leading edge, so that customized solutions can be used.

1. Leading edge protection using coatings

One measure to protect the leading edge of the blade is the use of LEP coatings. Covestro has developed different raw materials for LEP coatings, which makes it possible to develop tailor made solutions. These materials provide ease of application, increased productivity in painting operations and long lasting performance.

Advantages of Covestro raw materials for LEP coatings:

- Ease of application for in-shop as well as maintenance
- Increased productivity in painting operations due to fast cure with Pasquick® technology
- Reduced solvent emissions with low to Near Zero VOC coatings
- Reduced maintenance and downtime cost due to long lasting LEP coatings

Most common products:

- LEP coatings based on Pasquick® technology (Desmophen® NH and Desmodur® ultra product family)

Contact: Thomas Baeker,
Marketing Manager Industrial Metal and Plastic Coatings

thomas.baeker@covestro.com

Find out more:



2. Leading edge protection by shells

A proven concept to protect leading edges of wind blades are shell solutions, which are developed to last the full lifetime of wind turbines. As rotor blades get longer, leading edge are submitted to higher tip speed requiring increased performance of the shells. Covestro offers high performance cast polyurethane for soft shells providing protection against leading edge erosion.

Advantages of Covestro polyurethane elastomer for LEP shells:

- Flexible polyurethane to facilitate the installation at the leading edge
- Durability against erosion, drop impact and UV
- Good thermal stability

Most common products:

- Desmodur® Elastomer shells

Contact: Manon Manaranche,
Marketing Specialist & Business Developer

manon.manaranche@covestro.com

Find out more:



Solution: Leading edge protection of wind turbines

"Versatile solutions to protect the leading edge"



3. Leading edge protection using films

Adhesive films for PU soft shell

Only outstanding adhesive solutions can be used to create a durable bond between the protective shells and wind blades. Covestro offers custom tailored blade adhesive films which keep protective shells in place optimally over the full lifetime of the wind turbine. This solution is a latent reactive adhesive, either formed as a closed homogeneous film or from a pattern which forms structured coatings in any format. Adhesive films are heat activated to achieve the necessary high bonding properties.

Advantages of Covestro blade shell adhesive films:

- Combination of thermoplastic processing with characteristics of a crosslinkable PU adhesive
- Adhesive film is non-sensitive to atmospheric moisture
- Storage and transport capabilities:
Non-blocking / non-tacky at room temperature
- Excellent adhesion to various substrates

Surface protection films

Another state of the art concept to increase the longevity of wind blades is to use surface protection films. Covestro's film products aim to provide tailor-made solutions, which we always develop hand-in-hand with our customers.

**Contact: Dirk Pophusen,
Global Segment Manager,
Specialty Films**

dirk.pophusen@covestro.com

Find out more:



Advantages of Covestro surface protection films:

- Outstanding abrasion resistance to protect leading edge of wind turbine
- Exhibits excellent impact and high temperature resistance
- Color matching of the film product
- Tailor-made-film to create the best solution for our customer

Most common products:

- Bayfol® adhesive film for shell fixation
- Dureflex®/Plation® aliphatic TPU films

4. Leading edge protection using Thermoplastic Polyurethane (TPU)

Advantages of Covestro TPU for wind blades:

- Flexible TPU material for easy installations
- Durability against drop impact, UV and erosion
- No solvents due to thermoplastic
- processing (recyclability), means no VOC
- long lasting TPU solution means less maintenance and lower costs

**Contact TPU: Mark Scheller,
Segment Manager, TPU**

mark.scheller@covestro.com

Find out more:



Most common products:

- Desmopan® UP® line for ultimate protection

Solution: Surface protection

“Coating solutions for the surface protection of wind turbines”



Application Areas:

Protection of wind turbines by:

- Topcoats for steel and concrete towers
- Gelcoat, primer & topcoat for blades

Coating raw materials for the protection of wind turbines

Wind turbines are exposed to extreme weather conditions. To protect them against influences such as rain and UV light, the structures have to be protected with coatings. Ideally, a coating lasts for the entire service life of a wind turbine, so that maintenance costs and downtime are reduced. Covestro has developed raw materials for coatings

that can be used for different applications, such as protective coatings for towers and coatings for the blades. A wide range of raw materials makes it possible to develop customized solutions for different applications both for on-shore and off-shore. These materials provide increased productivity in painting operations and long lasting performance.

Advantages of Covestro raw materials for coatings:

- Versatile product range allows customized solutions for different applications:
- Topcoat for towers and other steel components
- Gelcoat, primer, topcoat for wind blades
- Increased productivity in painting operations due to fast cure with Pasquick® technology
- Reduced solvent emissions with low to Near Zero VOC coatings
- Reduced maintenance and downtime cost due to long lasting PUR coatings
- Proven track record

Most common products:

For towers

- Topcoats based on Pasquick® technology (Desmophen® NH and Desmodur® ultra product family)

For blades

- Gelcoats, primers and topcoats based on Pasquick® technology (Desmophen® NH and Desmodur® ultra product family)
- Topcoats based on waterborne PUR (Bayhydrol® and Bayhydur® product family)

Contact: Thomas Baeker,
Marketing Manager Industrial Metal
and Plastic Coatings

thomas.baeker@covestro.com

Find out more:



Solution: Cable Protection

“Cast polyurethane solutions for subsea cable protections”



Bend restrictor



Bend stiffener

Long-lasting cable bending protection solutions

Installation and maintenance of subsea cables involve significant costs because the task typically requires the intervention of professional divers and, once installed, cables are continuously exposed to strong currents and tidal action. Such conditions have a direct impact on cable lifetime and cost of operation. To prevent any issue, cable protection systems are used to protect cables & pipes. Ideally, long-lasting materials should be used – such as our cast PU elastomer systems.

Covestro offers a range of cast polyurethane for cable protection systems capable of withstanding extreme

offshore environmental conditions and solutions specifically designed for bend restrictors and bend stiffeners.

Components made with Desmodur® boast a long service life and low maintenance costs – powerful attributes for the offshore wind energy industry, which is heavily focused on reliability, efficiency and cost management. In addition to the cast PU portfolio, Covestro offers a range of machines and peripheral equipment to industrialize all scales of cast PU part production.

Cable protection – Bend restrictor:

Advantages:

- Lifetime extension of Bend restrictors: improved thermal behaviour, high hydrolysis resistance, stiffness and elongation
- Weight reduction of Bend restrictors: The 85 Shore D grade reduces the weight by 30% while keeping high performance. This helps to lower the loading on the pipe and facilitate the installation.
- Easy casting process
- Available in mass balanced grade using sustainably sourced renewable feedstocks leading to reduced carbon footprints

Products:

- Desmodur® B9M10 + Baytec® BR-P100 85D
- Desmodur® B9M10 + Baytec® BR-P100 82D
- Desmodur® B9M10 + Baytec® CG9 9086 82D

Cable protection – Bend stiffener:

Advantages:

- High overbending protection and good control of the minimum bend radius thanks to good stiffness with optimized modulus, tensile strength and elongation
- Meeting requirement for rigid and floating structures: High performance grades for different bend stiffener designs (static or dynamic environment) and sizes
- Track history of successfully installed projects
- Available in mass balanced grade using renewable feedstocks leading to reduced carbon footprints

Products:

- Desmodur® MTX6076 + Baytec® T4X + Baytec® XLB
- Desmodur® LU-T 60D + Baytec® XL1705

Contact: Manon Manaranche,
Marketing Specialist & Business Developer
manon.manaranche@covestro.com

Find out more:



Solution: Machinery

"Polyurethane processing machines for the wind industry"



Baulé® machines for optimal polyurethane processing

Covestro offers a range of Baulé® machines to process cast polyurethane elastomers as well as other resins for offshore wind applications. With decades of experience and detailed knowledge in chemistry and processing, Baulé® alpha and omega machines are developed to provide the highest levels of efficiency, ease of use and processing functionality.

Machines are designed to fit with your requirements regardless of the chemicals processed and the application field. Indeed, in addition to the range

of low pressure dispensing machines for hot cast elastomers, Covestro specially developed an innovative Baulé® machine for the direct infusion of polyurethane blades. In order to achieve the perfect infusion of the polyurethane resin into the wind blade, this core Baulé® technology allows to produce high-quality and larger blades with faster infusion times, combined with specific characteristics derived from the resin specifications and the wind blade process.

Advantages of Covestro direct infusion machine for blade manufacturing:

- Wide range of output that can be adjusted all along wind blade production and excellent metering accuracy
- Smart flow rate control
- Performant degassing at high flow rate and accurate temperature control
- Innovative software design and powerful data management system

Products:

- Baulé® machines for cast Polyurethane
- Baulé® machine technology for direct infusion of wind turbine blades

**Contact: Manon Manaranche,
Marketing Specialist & Business Developer**
manon.manaranche@covestro.com

Find out more:



Speeding up to Circularity



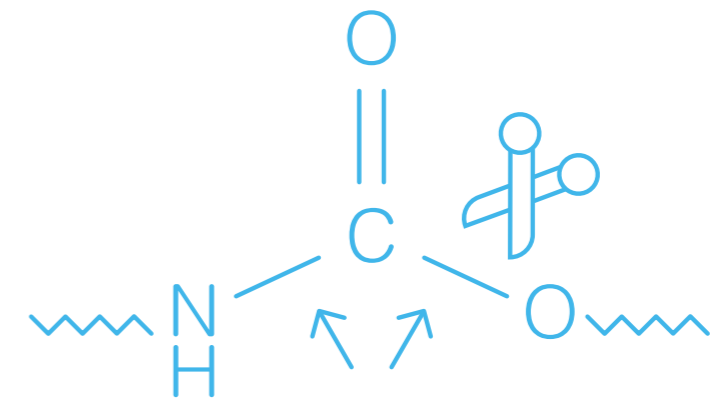
OUR GOAL: Embed the principles of Circular Economy into the fabric of our operations. Alternative raw materials such as biomass or End-of-Life (EoL) materials, renewable energy, and innovative recycling solutions are our key levers for shifting the previously linear use of resources in our industry toward circularity and regeneration. In the wind industry, recycling is an emerging requirement. The largest impact is yet to be delivered from the blade composite components.

OUR APPROACH: Innovative recycling processes based on years of experience. Covestro strives to leverage recycling process options from other PU applications, which are tailored to multiple outcomes and aim to achieve full circularity. Our core technical competence is the development and application of complex chemical processes. In particular, we want to use this expertise to establish innovative chemical recycling and production processes for a Circular Economy. We want to create processes that enable us to reclaim the chemical precursors needed to produce used materials. These can in turn be used as raw materials in our production activities.

On the whole, chemical recycling processes are an important tool to help Covestro gradually replace the use of fossil-based materials and contribute to the introduction of circularity in the wind industry with our polyurethane (PU) solutions. The benefits of the new processes will be verified through a life cycle assessment (LCA), which considers effects and contributions throughout the part life cycle by applying the “cradle to gate” approach.

OUR ADVANTAGE: PU has unique and almost contrasting benefits for use in blade composites. While it is fully certified for its lasting mechanical performance in wind blades, it can also be cleaved and separated from the fibers under specific process conditions.

A sustainable and climate-neutral Circular Economy is not just a vision; it already presents a multitude of opportunities for action. One example is mass balancing, which allows the proportion of alternative raw materials in production to be gradually increased and allocated to selected products. By applying this principle to the entire value chain and certifying it according to the ISCC PLUS standard, the proportion of renewable raw materials increases and products become more sustainable. By pursuing this approach, Covestro’s aim is to gradually switch its global production to certified mass-balanced products and thereby significantly expand its alternative raw material base. Currently, we offer PU raw materials such as MDI products, TDI products and polyols from renewable feedstocks with significantly reduced carbon footprints as a drop-in solution.



**Contact: Michael Weinkraut,
Circular Economy Platform Manager**
michael.weinkraut@covestro.com



Covestro Deutschland AG
Kaiser-Wilhelm-Allee 60
51373 Leverkusen
Germany

solutions.covestro.com
info@covestro.com

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