



Vestas[®]

Blade Services

Expert blade service solutions for all your turbines

Wind. It means the world to us.[™]

Safety is in our DNA

Safety matters

Wind turbines operate at heights of more than one hundred meters, with the tip of the turbine blade often turning at over 200 km/h. The weight of each blade can reach up to 10 tonnes and the turbine itself is a high-voltage electrical machine with output ratings reaching multiple megawatts. These are all factors that can lead to severe incidents if not handled properly.

At Vestas, we firmly believe that all hazards can be managed. Our market-leading position and 40 years of industry experience enable us to develop world-class standards and solutions that help protect human life, the environment and the integrity and business continuity of your assets.

By choosing Vestas you are partnering with an industry expert that keeps teams safe and your fleet up and running.



All-round service solutions for your blades

Blades are your turbine's most expensive component

Blades are crucial to revenue generation, but often neglected. Damages are often discovered too late. As a result, repair is extensive and costly with the risk of longer downtimes. A heavy lightning activity site for example, coupled with lack of protection systems can lead to costly unexpected damages. Even erosion, minor damages and dirt can cause reduced efficiency and productivity losses of up to 5 percent.

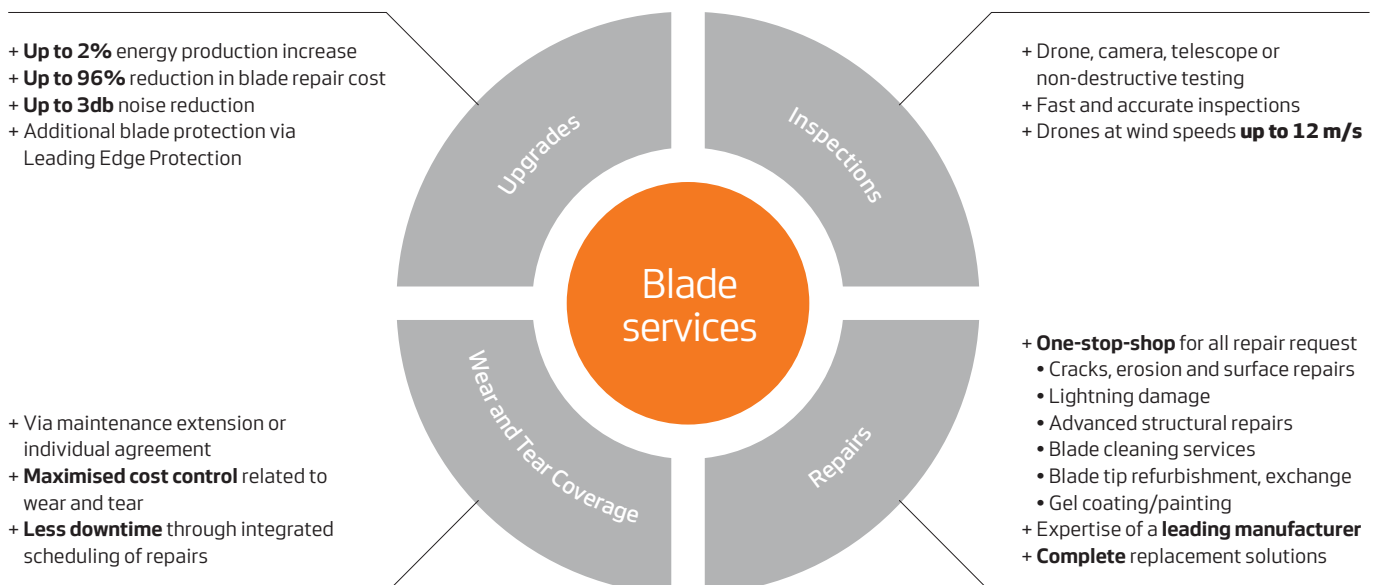
All-round solutions from the blade expert

With a combination of 40 years of experience, our manufacturing know-how, a global team of dedicated blade engineers and the data gathered from the largest global multibrand fleet, we develop leading solutions for the early discovery of defects and state-of-the-art repairs and upgrades.

Our blade service offer includes:

- **Inspections:** All platforms
- **Minor repairs:** All platforms
- **Structural repairs:** Vestas®, Gamesa®, LM® (GE®, Siemens® etc.), other as per individual agreement
- **Upgrades:** Vestas, other as per individual agreement
- **Wear and tear coverage:** All platforms

In the following pages, you can read more about each of the elements and how they can be combined to minimise lost production factor and increase your annual energy production.



Minimise risk and reduce costs with **blade inspections**

Intervene early, reduce costs

Inspecting your blades is less than 0.001 percent of the cost of replacement, not to mention the potential cost of lost production. Identifying defects and addressing them before they develop into serious, failure-causing damages can save you significant costs and unnecessary downtime. This is why Vestas has developed comprehensive inspection methods that provide a solution for every situation. We offer drone, camera, telescope and Non-Destructive Testing (NDT) for both Vestas and non-Vestas turbines.

Drone inspections increase speed, safety and accuracy

Our cutting-edge drone inspection solution is fast, accurate and operational at wind speeds of up to **12 m/s**. It can be conducted by a team of **1-2 people*** and the data is evaluated against a unique and large database of classified damages. With drone inspection, you get:

- Minimal downtime
- Online reporting
- Still images and video
- Increased safety
- Purpose-built drone

In addition to drone inspections, Vestas offers the latest, camera, telescope or Non-Destructive Testing (NDT) inspection methods. Our solution can always be tailored in close dialogue with your local service team to cover site-specific requirements.

Detailed reporting directly to you

Once we have conducted inspections, our technical experts analyse the collected data to identify potential concerns. The results are delivered in a comprehensive report that includes a clear outline of any damage, recommendations on the most economically sensible repair solutions, and engineering suggestions for improving your fleet's conditions. These will, in many cases, eliminate the root causes of defects.

This customised report is delivered directly to you, so you can assess your different options. The report will also include detailed images of all blade areas and detailed defect clarifications. We store reports and images to help monitor the development of blade conditions over time.

Blade Asset Management

To support you in your development of cost-efficient blade management strategies, we offer a Blade Asset Management system. The system provides a digital overview of your blade inspection data and recommended actions across sites and turbines regardless of the wind turbine brand. Blade Asset Management is available on Vestas' online customer platform, VestasOnline®, and builds on Vestas' extensive experience inspecting, assessing, maintaining and repairing blades for 40 years. You can read more about the application here: vestas.com/bam.

* Depending on local legislation

FREQUENT ISSUES FOUND DURING INSPECTIONS

- Leading edge erosion
 - Lightning damage
 - Broken or missing Vortex Generators
 - Cracks
 - Severe contamination
-

Blade service inspection process

1. Blades are inspected by Vestas using drones or high resolution camera and telescope.
2. Damages are evaluated and compared to a historical database of tens of thousands of inspections. They are then classified into damage categories ranging from one to five.
3. Possible repair solutions are generated and evaluated.
4. Repair is conducted as required.
5. Based on the analysis of the collected information, a detailed report with recommended action is submitted to you.





Case study

" In recent months, we have been informed of total blade losses on several competitor turbines in Italy. Due to a bonding failure the blades cracked (broke) at approximately rad 6 to 8. The lack of structural inspections meant the initial cracks where never discovered and addressed.

We have the same type of turbines on a service contract in Germany. Because of the regular maintenance cycles, we discovered these cracks at an early stage. The blades where repaired up-tower and have been working properly ever since."

Marcel Bruins
Blade Engineer, Vestas





Our blade solutions include both cosmetic and structural repairs

- Cracks, erosion and surface repairs
- Leading and trailing edge
- Lightning damage repairs
- Advanced structural repairs
- Blade tip refurbishment/exchange
- Gel coating/painting
- Blade cleaning services

We are experts in blade engineering and manufacturing. Our solutions and materials knowledge enables us to approach even the most complex repairs with confidence. Put us to the test and let us help you take advantage of our know-how.

State-of-the-art repair solutions

A partner with expert repair capabilities

Blades are a part of Vestas' core business, and our dedication to each stage in a blade's operating lifetime means that we know blades better than anyone. A partnership with Vestas gives you and your assets industry-leading care with innovative and economical repair solutions.

High quality and timely blade repairs are critical for your turbines' performance. With Vestas as your service partner, you can be sure that your blades will be back in optimal operating mode as quickly as possible after any repair.

We are continuously developing multibrand solutions, and we already offer inspections, cosmetic repairs and leading and trailing edge repair of all leading turbine brands.

Cut your costs with preventive repairs

A major part of caring for your blades is repairing developing damage as early as possible. With our extensive experience in inspection and repair, Vestas knows that preventive solutions are the most effective method to reduce your operational and maintenance costs related to blades and increasing turbine uptime. Early intervention can reduce your repair costs by **up to 75 percent**.

Intervene early, reduce costs

Addressing damages as early as possible in the least serious damage classifications is the key to reducing blade repair costs. We recommend our partners to always repair damaged blades as early as possible. In doing so, we have in example seen the number of damages requiring turbine downtime reduced by 30 percent from 2009 to 2016.

We understand that not all blade damage can be prevented, and occasionally urgent repairs are required to put the turbine back into operation. To facilitate these situations, Vestas offers extensive on-site repair capabilities.

Damage classifications

To determine the urgency of intervention and the needed repair level, we classify damage into five categories:

1. Cosmetic

No intervention needed

2. Similar to cosmetic

Intervention only if other damage exists

3. Non-serious damage

Intervention done during planned wind turbine inspection

4. Serious damage

Intervention done within three months

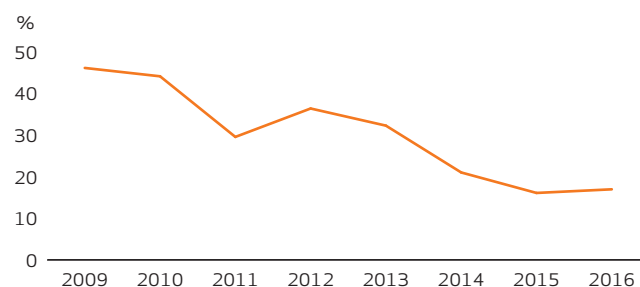
5. Very serious damage

Intervention required immediately

Blades as parts

In addition to inspections, repairs and upgrades, Vestas also offers complete blade replacements, new or refurbished, demonstrating our commitment to fulfill your every need.

% of blade damage category 4 and 5



Full turbine stop due to blade repair has been reduced by 30 percent from 2009 to 2016 at turbines taken over by Vestas services.

Blade Services Repair Capabilities

Repair type	Service type
Service	<ul style="list-style-type: none"> Inspections (drone, camera, telescope, NDT) Wear and Tear program
Cosmetic	<ul style="list-style-type: none"> Lightning marks at screw receptor Cosmetic paint tip ends with contrasting colours Repair of Mankiewich ALEXIT Coating Recoating of surface on site Leading edge repairs Leading edge erosion repairs Mounting and reading routines for reg. Card for lightning sensor Replacement and mounting of lightning implant (PPT Blades) Wear and Tear Replacement of bladecollar Replacement of Lightning Receptor Repair of 3M Tape Repair blisters on coat surfaces
Medium	<ul style="list-style-type: none"> LE Protection Lightning Protection Copper Caps Lightning Protection Copper Strips Repair of Internal short circuit with down conductor cable severed Balancing of blade on site Open Tip end Repair of tip ends Shell repairs Repair of external impact on glass layer only Edgewise vibration Repair of cracks and damages to the leading edge Lightning Protection System repairs Repair of lightning damage due to bad cable isolation Lightning sensor replacement (V90 3MW) Trailing edge repairs Open trailingedge at the drain hole (V90/V100) Open trailingedge at the tip area Repair of cracks and damages during transport Repair of open trailing edge of Prepreg blades (VE/GA) Repair of trailingedge cracks at root end (V47/V66) Replacement of blade controller and blade load sensor Mounting of oscillation damper (PPT > V80)
Structural	<ul style="list-style-type: none"> Root Repairs Tip End repairs Replacement of 3M tip end (Only PPT) Repair of external impact on core material 3M shell replacement due to lightning impact (Only PPT) Repair of damaged alu mesh due to crack (V1.26-V1.10) Renovation of decomposed LE Spar Repairs (All PPT Blades) Repair of lightning damage at Carbon spar <1.6m from tip end · V90/V100/V112/V117 Repair of lightning damage at Carbon spar >1.6m from tip end · V90/V100/V112/V117 Open trailingedge
Upgrades Vestas & multi-brand	
Upgrade	<ul style="list-style-type: none"> Vortex Generators (multi-brand) Lightning Monitoring System (multi-brand) ICE Detection System (multi-brand) Vortex Generators (Vestas) Gurney Flaps (Vestas) Serrated Trailing egde (Vestas & multi-brand)

Blade exchange subject to blade availability
 Inquire information regarding blade availability with your SBU.

Upgrades for **complete blade protection**

It is impossible to stop nature's assault on your blades. Lightning, dirt, insects and ice are just some of the enemies blades face in their daily operation. To address nature's threats to your blades Vestas has developed a range of high-quality upgrades.

Protecting the surface

Turbine blades are exposed to a variety of harsh environmental conditions. Rain, hail, sand, dirt and salty sea water all gather on the blade surface, which can lead to deterioration of paint and coating systems, especially on blade leading edges. This leads to material abrasion and crack formation caused by erosion and ultimately to lost aerodynamic characteristics. Vestas offers a range of retrofit and refurbishment solutions that protects and strengthens blade's resistance against harsh weather. Choosing the right blade protection is highly site specific and often dependent on a combination of factors. Therefore, Vestas provides support in analysing site conditions to determine the best suited blade protection for your site.

- Coating: Vestas offers a retrofit polyurethane coating that protects blades' leading edge against chemical, UV, abrasion and mechanical influencers. The most exposed area is painted, usually the outer third of the blade, along the blade's leading edge in three layers of 100-125 microns Dry Film Thickness (DFT). Each of the layers can be applied in different colours to allow for visual inspection of wear and tear. The coating can be applied uptower, preventing dismantling of the blades, and can be performed in conjunction with a scheduled service visit. The coating is recommended for sites with low erosion or as a lifetime extension solution for blades with limited remaining operational capacity. All Vestas blades from V110 and up are manufactured with a protective coating under the topcoat paint.

- Tape: Vestas also offers an exceptionally tough, polyurethane elastomer tape resistant to puncture, erosion and UV that provides a high, even layer of protection along the leading edge of the blade. Requiring a high level of skill and blade surface preparation to achieve a good

application quality, the tape can both be applied during blade manufacturing and as a retrofit solution. Its tolerance to humidity during application makes it especially suitable for sites with high humidity.

- Shell: Furthermore, Vestas offers an elastomeric polyurethane casted shell designed to specifically fit the aerodynamic profile of individual blade types. Mounted with a pressure sensitive tape, the shell provides a strong, even level of erosion protection, as the thickness of the shell is quality assured during manufacturing. Shell protection is especially effective on high erosion sites, where severe erosion can drastically affect the annual energy production of turbines.

Lightning protection

One of the greatest dangers for blades is lightning. In worst case scenarios, lightning can cause structural damages requiring costly repairs and unnecessary downtime.

Installing copper caps on the tip of turbine blades provides a significant improvement to lightning protection. The conductive shield provided by the copper cap, and its ability to control electrical field enhancement, has proven to provide solid protection against lightning damage.

For turbines in high lightning density areas, Vestas also offers copper strips to enhance the protection given by the copper.



Copper cap before surface finishing



Copper strip



REDUCE DAMAGES BY 88 %

Lightning Protection field tests in Greece and Spain have shown an **88 percent** reduction in lightning-related damages following copper cap installation. That translated to a **96 percent** reduction in blade repair costs.

BENEFITS

- + Removal of wear and tear cost uncertainty
 - + Comprehensive inspections and detailed customer reports
 - + Minimised Lost Production Factor caused by suboptimal blade conditions
 - + Full integration into a streamlined repair process
 - + Life-cycle tracking
-

Reduce risk exposure with **Wear and Tear Coverage**

What's included in Wear and Tear Coverage?

- Coverage for your wear and tear damages (parts and repair)
- Comprehensive inspection with thorough reporting following Vestas' inspection processes
- Clearly outlined descriptions of damages and classification levels to help you prioritise what needs to be addressed and when
- Ongoing monitoring of early-stage damages that do not need immediate attention
- Integrated scheduling of repair activities into other service activities performed by Vestas to minimise turbine downtime
- All repairs performed by expert engineering and support teams

Blades are constantly exposed to challenging environmental conditions. The tip of an 80 meter diameter turbine blade turns at 240 km/h and can travel a distance equal to 40,000 km in one week. Imagine driving your car through rain, hail, snow, sand, dirt and salty sea water at 240 km/h day in and day out.

Wear and tear on blades varies depending upon site-specific conditions, which makes forecasting maintenance costs subject to great uncertainty. If neglected, even damages like erosion can lead to an AEP loss of up to 5 percent.

Typically, repairs related to wear and tear are not part of a standard service agreement. Our Blade Wear and Tear program provides a cost-effective means of addressing business uncertainty by offering parts and repair coverage for a flat fee along with comprehensive inspections. The program is available both as an extension of your existing maintenance contract and as a standalone solution.

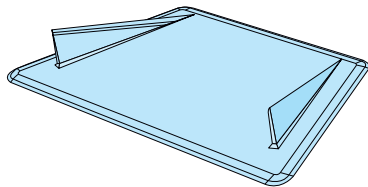
Optimise power production with Aerodynamic Upgrades

Our Aerodynamic Upgrades provide the latest development in wind turbine blade technology to increase your fleet's profitability. Vortex Generators and Gurney Flaps optimise the blade's ability to capture the wind.

Vortex generators

Placed strategically along the leeward side of the blade, vortex generators reduce the separation of air flow in the root-region of the blade and increase lift. Vestas' vortex generators are specifically designed for Vestas blades to improve the aerodynamic performance of wind turbines and increase total energy output by up to 0.8 percent*.

Figure 2: Example of a counter rotating vortex generator



Gurney flaps

Gurney flaps are small, flat plates fitted at a right angle to the windward side of the blade along the trailing edge. They effectively change the camber of the aerofoil near the trailing edge and increase lift. In combination with vortex generators, gurney flaps will increase annual energy production by up to 2 percent*.

These Aerodynamic Upgrades are a part of PowerPlus™ which is Vestas' range of products dedicated to improving the performance of existing wind power plants. All products, including Aerodynamic Upgrades, come with an **Investment Guarantee****, offering you maximum security in your investment.

Figure 3: Example of a gurney flap on a wind turbine blade

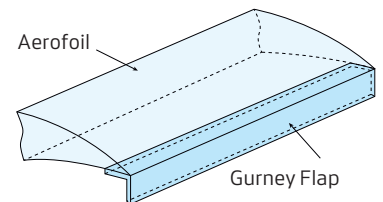
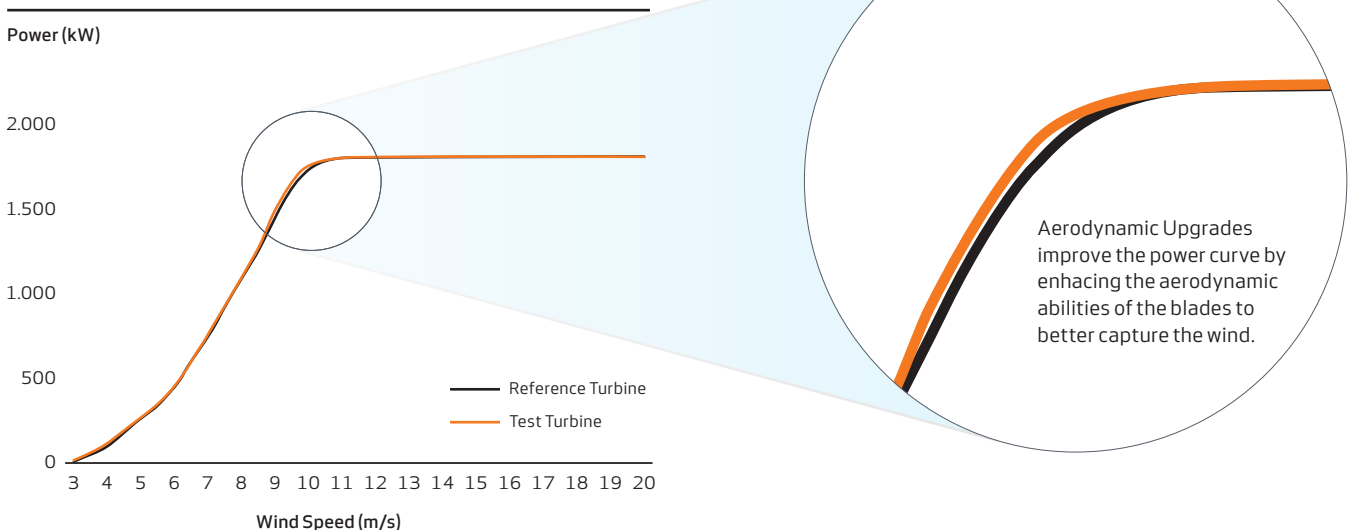


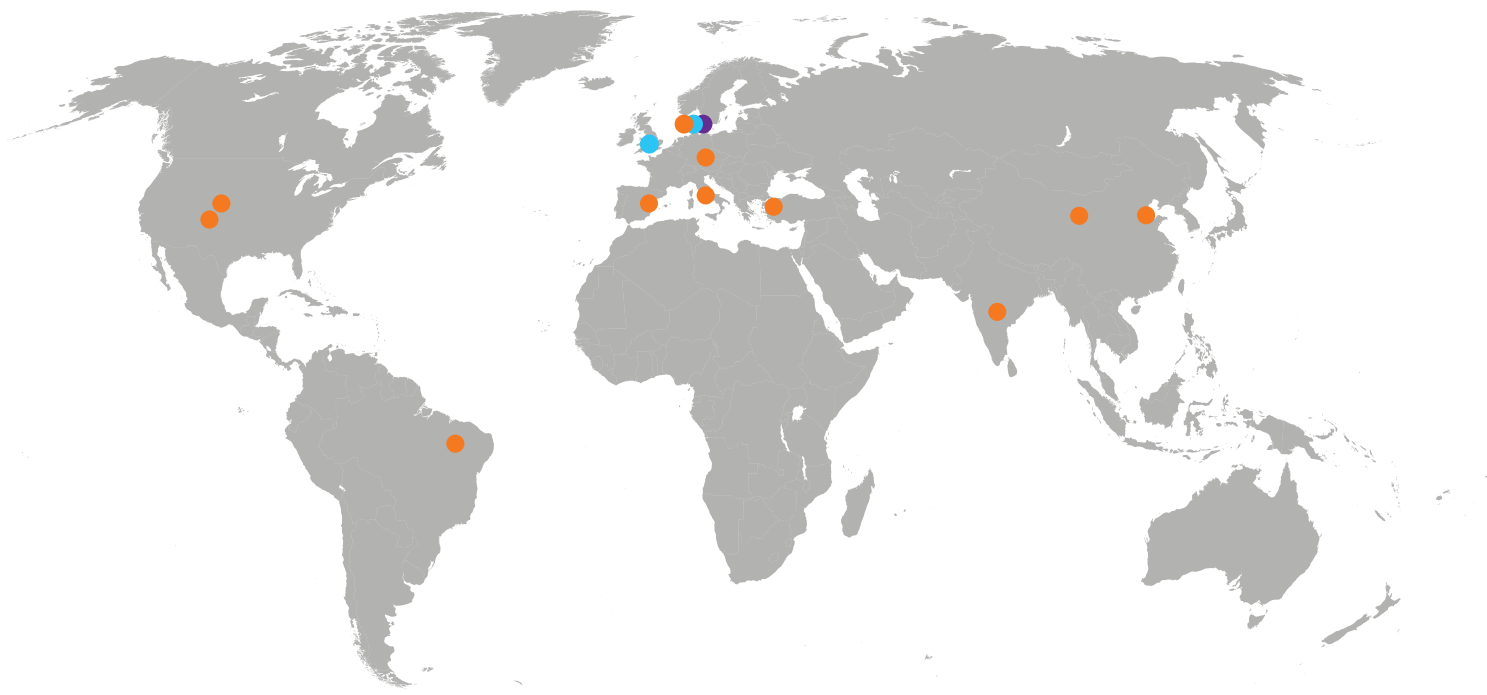
Figure 4: Aerodynamic Upgrades improve the power curve on the slope, delivering up to 2 percent* increase in annual energy production.



* In IEC III conditions. Site specific research is required for more accurate estimation.
 ** Subject to specific agreement.

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Global dedication to blades



- = Blade production site
- = Dedicated blade R&D facility
- = Dedicated blade repair shop

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