

# Bladena

Experts in blades

## Advisory services

Catalogue

**Bladena** Stronger blades, More energy

BLADE ENABLER



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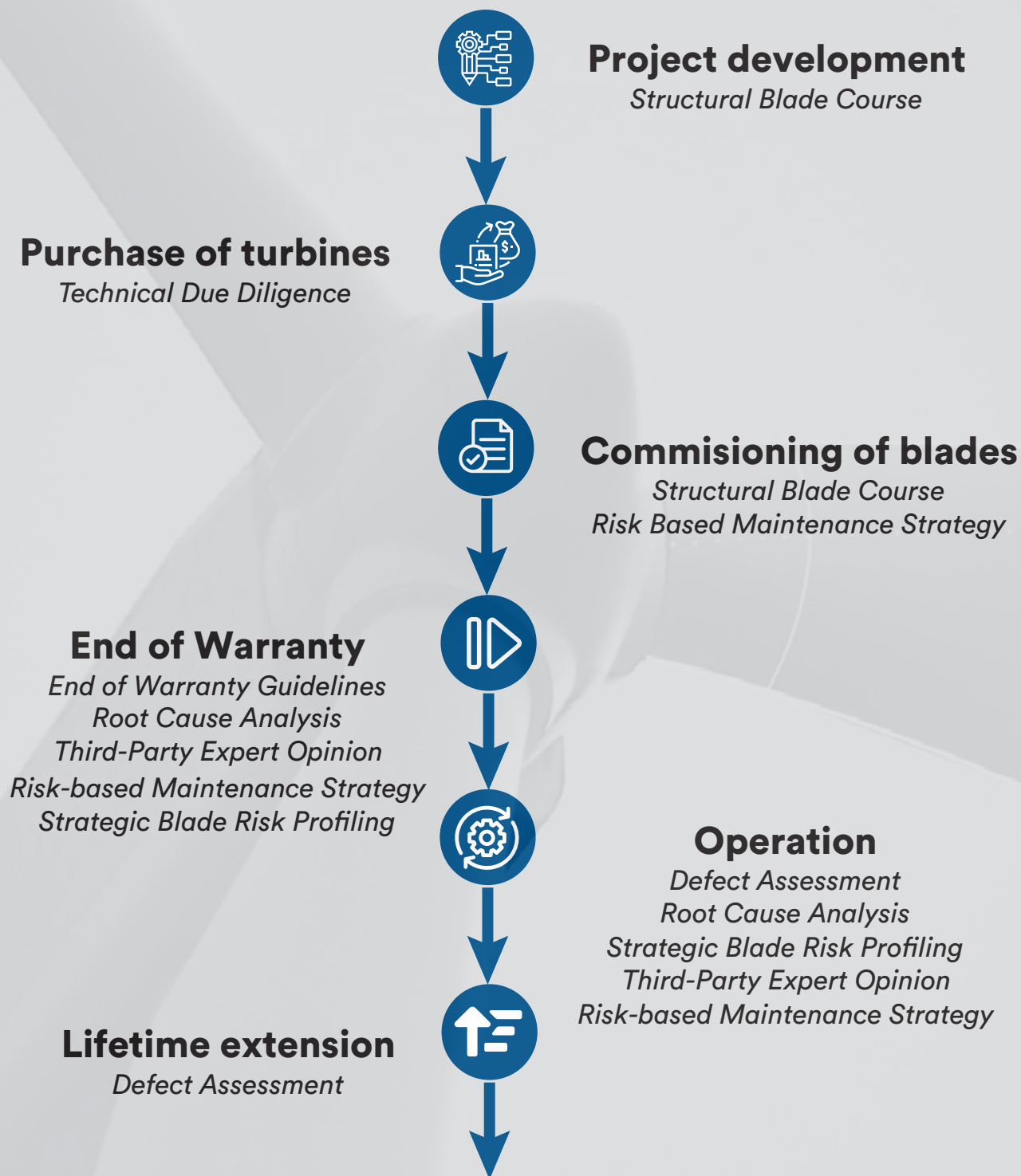
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## **We are your blade experts.**

*In Bladena we are passionate about blades. Our business is based on advanced blade data achieved through field experience and science. We use our expertise to help you optimize your blade asset strategy, by lowering your operation costs (OPEX) and decreasing downtime periods, hence higher AEP (annual energy production).*

## When can you use our Advisory services?

Bladena during the blade's lifecycle:



*Advisory Services allocation in the blade's lifetime is indicative and a number of advisory services are relevant/crucial on many stages of the blade's lifecycle.*

# Structural Blade Course

by Bladena

## Customer Benefit

**Better understanding of blades:** Understand wind turbine blades from both WTO and ISP perspectives.

**Better understanding of loads:** Understanding loads acting on a blade in operation.

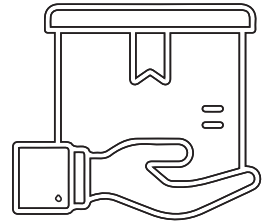
**Better understanding of damages and failure modes:** Classification of structural damages and their corresponding risk.

**Better understanding of testing and certification:** Deep dive in testing methods and certification requirements.

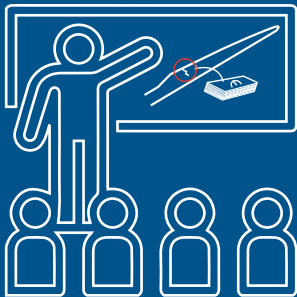
**Better understanding of inspection methods:** Deep dive in inspection and monitoring techniques.

**Better understanding of LEE and Lightning Damages:** Lectures about the root cause of Leading Edge Erosion and Lightning Damages with their possible consequences.

**Understanding risk-based maintenance strategies:** Familiarize with risk-based maintenance for decision making optimization.



## What it offers



- Blade Course Focusing on Specific Needs
- Lectures held by in-field experts
- State-of-the-art knowledge in every module
- Offered as webinar, in-house or at Bladena's office

Bladena offers both light and advanced blade course where knowledge regarding structural aspects of wind turbine blades, leading edge erosion, and lightning protection systems is given. The course is specifically developed for either Asset Managers or Individual Service Providers. The knowledge in all modules is streamlined in such way that any unnecessary information is stripped out, making the course easy to follow and understand.





# Technical Due Diligence

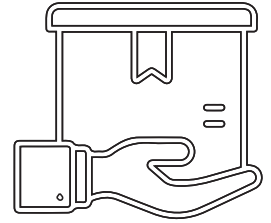
by Bladena

## Customer Benefit

**Confidence in Procurement:** WTOs can be assured that blades meet technical expectations and are backed by rigorous testing and certifications.

**Thorough Insight:** Acquire a complete understanding of your blade's design and operational practices, uncovering potential areas of improvement as well as limitations in certification and testing methodologies.

**Confidence in Operation:** With a thoroughly assessed blade design and operational strategy, WTOs can be more assured in their investment and operational decisions.



## What it offers



**Structural Evaluation:** Dive deep into the blade's structural integrity, utilizing our state-of-the-art understanding of blade structure. Identifying limitations in certification and testing methodologies, we help WTOs understand and manage risks better.



**Full-Scale and Sub-component Testing Evaluation:** Complete analysis of the entire testing program, ensuring if tests mimic the real-world conditions. Recommendations to ensure testing fully captures potential structural design weaknesses.

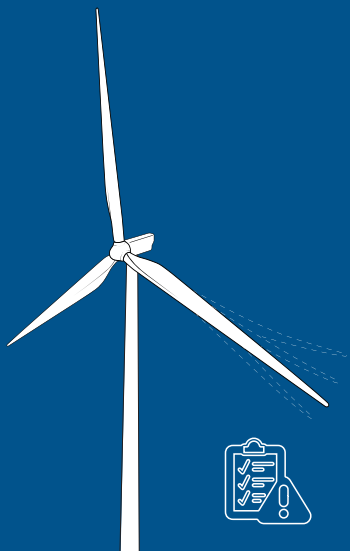
**Certification and Implications:** Review of certifications specifically targeted at structural integrity and testing process (especially Full-Scale and Sub-component Testing).

**Recommendations & Improvements:** Suggestions on areas of improvement for testing methodologies. Recommendations for supplemental tests.

**Lightning Assessment:** Understand the effectiveness of the blade's lightning protection system and potential improvements.

**Leading Edge Erosion:** Evaluate potential risks and solutions related to leading edge erosion.

**Operation & Maintenance Review:** Assess operational practices and maintenance schedules to ensure they align with best practices.



Bladena's Technical Due Diligence service is an assessment of a wind turbine blade design. For Wind Turbine Owners (WTOs), choosing the right blades during procurement is crucial. This advisory service focuses on the technical details, placing a strong emphasis on the full-scale testing methodologies and certification also highlighting the lapses in certification and testing. While blade certifications are essential, they often only meet the bare minimum. Established OEMs test more rigorously than the minimum and have the chance to separate themselves from the competitors. This service also aims to present this difference, guiding WTOs towards the best procurement decisions. The service ensures that WTOs are equipped with the knowledge, potential risks and insights needed to make well-informed, strategic decisions.



# Defect Assessment

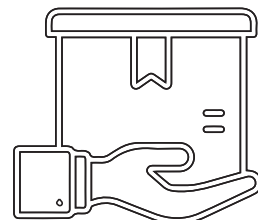
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## Customer Benefit

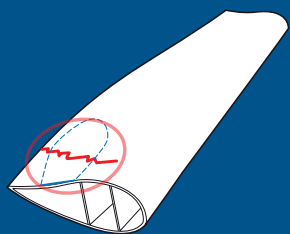
**Comprehensive Knowledge Base:** Leverage Bladena's Blade File and Guide2Defect database. Over the past 12 years Bladena has gained extended, industry-leading knowledge and built a strong reputation of understanding blade structural issues. Backed up with an extensive database of blade damages and details about numerous blade types. The database includes damages on large modern blades, provides insights on both common and severe, often catastrophic blade failures.

**Benchmark:** Gain insight into whether the defect is an isolated issue within your fleet or a more widespread concern in the industry. This benchmarking provides a strategic understanding of the defect's significance.

**Expertise and Experience:** Benefit from Bladena's deep structural knowledge and vast field experience. This ensures that the advice and recommendations you receive are established in both data and real-world experience, paving the way for optimal decision-making.



## What it offers

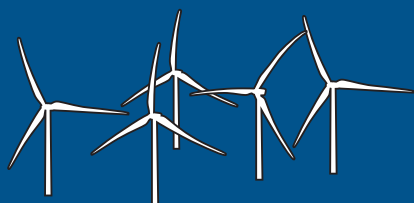


**Defect Overview:** A thorough assessment of specified defects observed in your fleet, compared against Bladena's extensive structural blade database. This offers clarity on the type of defect, its length, and blade location (Primary or Secondary structure). Such identification subsequently categorizes the defect.

**Trend Identification:** Utilizing Bladena's vast defect database, trends associated with the specific defect characteristics can be identified. This data-driven approach ensures that your fleet's defects are compared to known issues in the industry, providing a more comprehensive understanding of the problem.

**Risk and Cause Overview:** A detailed description of the defect trend, the probable cause, representation of associated risks, and its frequency in the industry.

**Actionable Insights:** After a thorough assessment, the service offers clear steps and recommendations on the best course of action. This ensures that you are equipped with the knowledge to make informed decisions on the next



Bladena's Defect Assessment Advisory Service offers comprehensive insight into the structural integrity of wind turbine blades. This service is particularly designed to provide a clear understanding of observed blade defects, and analysing how it fits with the larger picture of known issues in blades.



# Root Cause Analysis

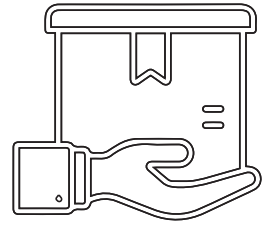
by Bladena

## Customer Benefit

**Negotiation Advantage:** Armed with a Bladena RCA, customers are better positioned in cost negotiation dialogues related to blade repairs/collapse.

**Contract Discussions:** The insights can significantly aid negotiations with OEMs.

**Precise Insights:** Understanding the true root cause before repair solution ensures appropriate solutions are chosen.



## What it offers

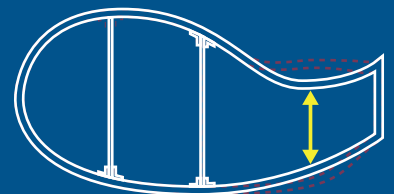
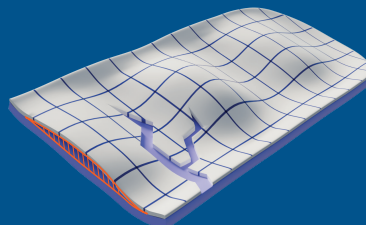
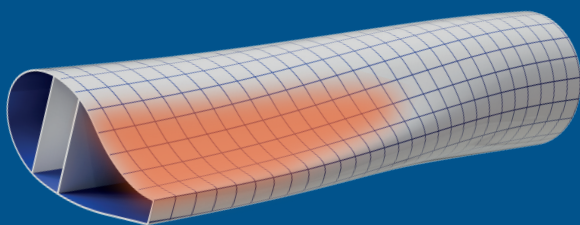
**Holistic Analysis:** Comprehensive assessment into why structural damages occurred on a blade, offering deep insights.

**Mitigation Impact Assessment:** In addition to identifying causes, the service evaluates the effects of proposed solutions to mitigate these damages, ensuring that proposed solutions are effective.

**Focus on Critical Aspects:** Unlike traditional RCAs that majorly focus on material science, Bladena emphasizes a four-fold approach considering materials science, structural understanding, manufacturing, and blade operational loading.

**Understanding Blade Behaviour:** The service provides an understanding of blade structural behaviour, including insights e.g. on how bondlines are stressed during operations, and other core competencies that are integral to blade operations.

**Reliability:** Built on the expertise of the Technical University of Denmark and in-house knowledge, Bladena ensures the RCA is reliable and accurate.



Bladena's RCA Advisory Service dives deep to find out why wind turbine blades get damaged. We use International standards and expert knowledge to pinpoint the problems and suggest the best solutions.



# Third-Party Expert Opinion

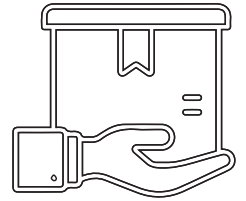
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## Customer Benefit

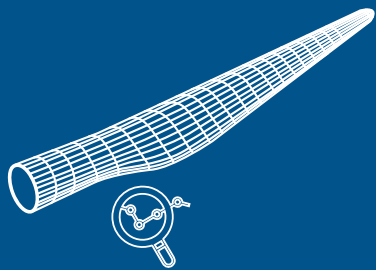
**Simple Insights:** Get complex information extracted into simple, actionable insights.

**Reduced Failures:** Understand potential vulnerabilities in design, leading to proactive measures and fewer blade issues.

**Increased Level of Understanding:** By understanding how come a specific catastrophic failure or serial issue has occurred, appropriate actions can be taken by the management.



## What it offers



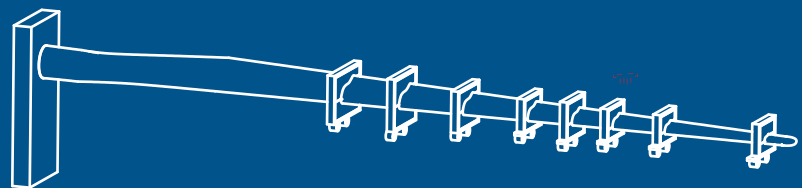
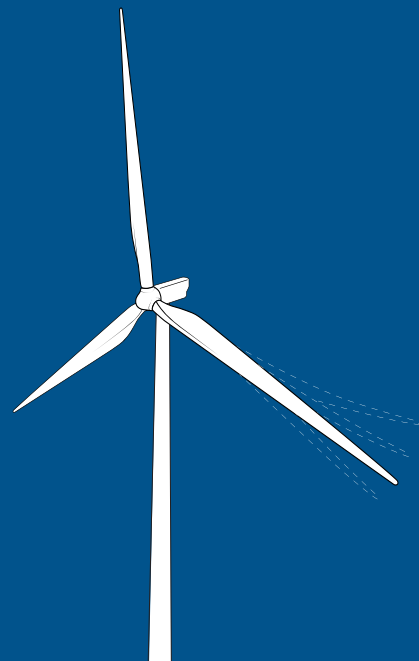
**Certification Analysis:** Evaluate current certification standards and their real-world implications. Determine if certifications capture all design-related vulnerabilities.

**Testing Review:** Analyse existing testing practices for their comprehensiveness. Identify potential gaps in testing that might overlook design flaws.

**Deep Dive Into Blade Structural Design:** Explore the details of wind turbine blade design. Assess how design choices can impact the blade's durability.

**Document Review:** Thoroughly analyze OEM documents to determine whether the solution proposed is sufficient in solving an issue.

**Non-Technical Opinion:** Translate complex design, manufacturing, certification, and testing details into easy-to-understand insights. Provide clear recommendations on how to ensure blade reliability.



As wind turbine blades have grown longer, a questioning trend has emerged: some OEMs are facing unexpected challenges and losses at early operational phases of modern blades. These problems often relate to blade design, lack of requirements from the certification bodies, and testing. Through our advisory service, we dive into these areas, aiming to explain the complexities. Presented in a non-technical manner, our insights guide Wind Turbine Owners (WTOs) to navigate this situation, ensuring they're equipped with knowledge that's both comprehensive and easily understandable. This will explain how come a specific catastrophic failure has occurred.



# End-of-Warranty Guidelines & Evaluation

by Bladena

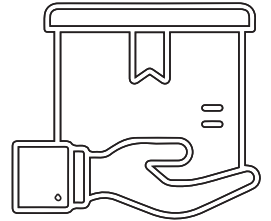
## Customer Benefit

**Operational Efficiency and Risk Mitigation:** By identifying hotspots and failure modes, WTOs can prevent catastrophic failures. The service helps WTOs to better understand and manage their operational risk for improved decision making.

**Cost Savings:** Early detection of potential issues can result in significant cost savings.

**Extended Blade Lifetime:** Implementing the strategies and recommendations provided by the service can result in longer blade life.

**Strengthened Negotiations with OEMs:** The technical support provided can help WTOs with their negotiations with OEMs. By understanding the criticality and root causes of damages, WTOs are better equipped to navigate warranty claims.



## What it offers

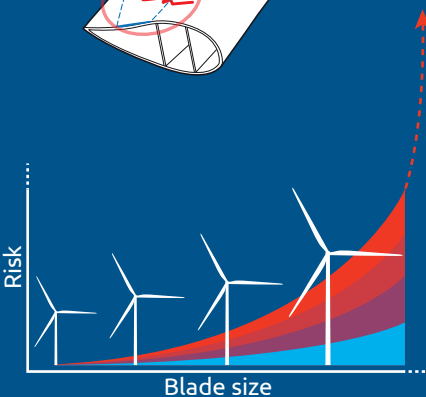
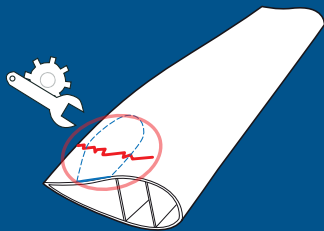
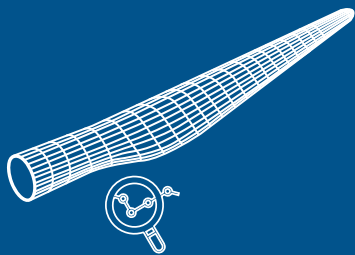
**Hotspot Identification:** Utilizing historical data, we provide the hotspots that are most susceptible to damage. The detailed report will include hotspot locations, potential reasons for their vulnerability, and predictive insights.

**Failure Mode Identification:** Analyzing Bladena's extensive data on common failure modes for specific blade types, Bladena will provide WTOs with a breakdown of the potential failure modes they can anticipate. This includes descriptions of each failure mode, its indications and its impact on the wind turbine blade.

**Risk Analysis:** Bladena will conduct a risk analysis for each failure mode at the identified hotspots, evaluating likelihood of occurrence and potential consequences. This provides WTOs a clear understanding of the risks they face and allowing them to prioritize their maintenance efforts effectively.

**Damage Criticality Assessment Guidelines:** Bladena will provide clear guidelines for assessing damage criticality. These guidelines will include all the factors to consider when evaluating the severity of the damage including location, size, depth and impact on blade.

**Mitigation Actions and Repair Recommendations:** For each identified hotspot and failure mode, Bladena will recommend appropriate mitigation measures to tackle the root causes of the damages.



The advisory service aims to guide Wind Turbine Owners in understanding, evaluating and mitigating the risks associated with their wind turbine blades as their warranty period comes to an end.



# Risk-Based Blade Maintenance

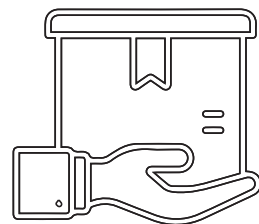
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## Customer Benefit

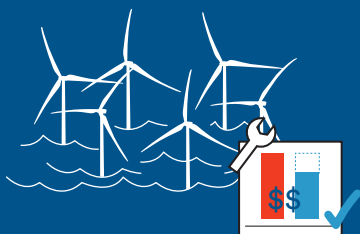
**Cost Savings:** Achieve substantial cost savings and/or mitigate risk by avoiding potential high-cost failures.

**Confidence in Decision-Making:** Make educated decisions backed by data-driven insights.

**Optimal Return On Investment:** With a thoroughly assessed blade design and operational strategy, WTOs can achieve optimal Return On Investment (ROI) on blade maintenance and repair tasks.



## What it offers



**Monitoring Solutions:** We guide clients in identifying optimal placement in the blade for condition monitoring installations. It can provide early warnings of potential issues, reducing downtime and repair costs.

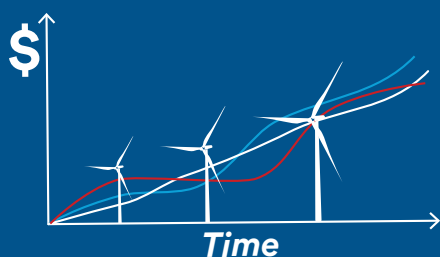
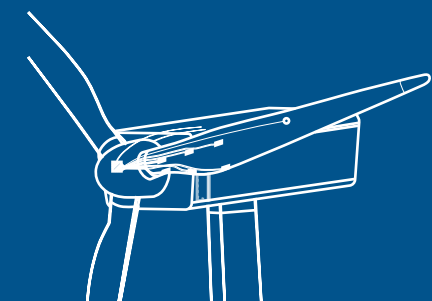
**Damage Categorization:** With our expertise, damages are systematically sorted into high-risk/low-risk and structural/non-structural categories. This precise classification aids in decision-making, helping customers to effectively allocate their repair budgets.

**Lightning Protection Guidance:** Navigate the complexities of Lightning Protection System (LPS). We indicate both site-specific and blade model associated risks, giving insights on potential upgrades and regular LPS maintenance.

**Leading Edge Erosion Assessment:** Our service involves detailed site assessments to estimate risks associated with this. Following a comprehensive review of site-specific risks, blade type, and weather conditions, we suggest cost-optimal Leading-Edge Protection (LEP) applications.

**Repair and Upgrade Advising:** Benefit from our expert advisory on blade repair and upgrade strategies. Established in an understanding of structural damages and specific blade models, we advise on the timings - when a repair is necessary, when it can wait, and when a blade replacement is the more optimal choice.

**Analysis of Blade Design:** The fleet specific blade design is analyzed, with emphasis on re-occurring failure modes and risk of recognized failure modes.



Adopt a forward-thinking approach to blade maintenance with our Risk-Based Maintenance Strategy. This service is a proactive approach to blade maintenance that uses risk assessment to prioritize maintenance activities. It considers the probability of failures, the potential cost or implications of those failures, and the specific operational budgets parameters. The goal is to reduce the potential for costly failures and improve the reliability of blade assets.





# Strategic Blade Risk Profiling

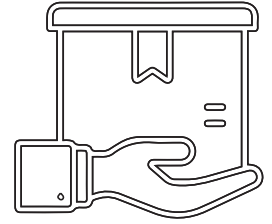
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## Customer Benefit

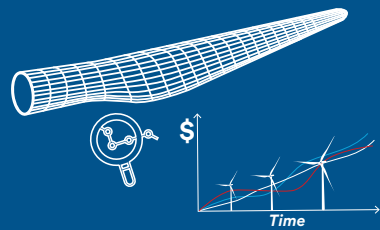
**Cost Savings:** Proactive strategies lead to significant maintenance savings.

**Blade Longevity:** Implement our strategies for a longer blade life.

**Decisions:** Our detailed risk profiles enable sharper operational choices.



## What it offers



### Blade Selection and Review:

- **Identification:** Using our vast database, we pinpoint at-risk blades in your fleet.
- **Design Insights:** Deep dive into your blades' design principles.
- **Hotspots & Failures:** We highlight vulnerable regions and common failures.
- **Hotspot Assessment:** Hotspots are assessed by comparing certification loads with operational loads, and any disparity is translated into a measure of risk.

### Risk Profiling:

- **Categorization:** Parameters to classify damages and their risks.
- **Load Regions:** Differentiating primary from secondary load areas.
- **Criticality:** A qualitative and/ or quantitative analysis of identified hotspots.

### Monitoring and Maintenance Guidance:

- **Inspection Guidelines:** Tailored methods targeting identified hotspots.
- **Mitigation:** Strategies to reduce damage initiation and progression.

This advisory service takes a strategic approach to enhance wind turbine blade performance. We identify vulnerable blades and offer guidance for smarter decisions, which ultimately reduce costs, increase Annual Energy Production (AEP), and boost blade reliability.

Wind turbine blades vary in design and face unique operating conditions. A one-size-fits-all strategy can lead to excessive costs and risks. The Strategic Blade Risk Profiling emphasizes the importance of tailored solutions, ensuring that operators make cost-effective choices suited to their specific needs.



# Other competences & toolset

by Bladena



## Other completed assignments

- **Measurement/Monitoring Assessment:** Advice on specific measurement/monitoring techniques that aim the detection of specific structural failure modes.
- **Fleet Performance Analysis:** Qualitative analysis on the possible influence of leading edge erosion and structural damages on the operational blade efficiency.
- **Assessment on Material Composition and Modular Blades:** Technical documentation regarding modular blades and material distribution along the blade layout for blade models.
- **FEM Education:** Technical documentation sharing knowledge on the type of analysis that must be followed for specific FEM studies.
- **Asset Lifetime Estimation:** Loads analysis combined with FEM for specific critical structural damages and sub-component testing to estimate the possible lifetime of a blade.
- **Owner's Requirements:** Set of additional specifications added on top of existing certification requirements found in standards today, aiming in managing technical risks better.
- **Investment Analysis:** Business case analysis studying the possible economic and risk benefit of specific O&M strategies making use of Bladena's CAR Tool.



## Bladena's unique toolset

- **Bladena's Blade File (BBF) and Guide2Defect:** Database with 60000+ damages and structural knowledge about different blades. The database includes knowledge regarding small, medium and large blades.
- **CAR Tool:** Cost and Risk analysis tool for the most optimal O&M planning.
- **State-of-the-art FEM Analysis Tool**
- **Structural Knowledge and Field Experience**
- **Partnerships all around the industry**

