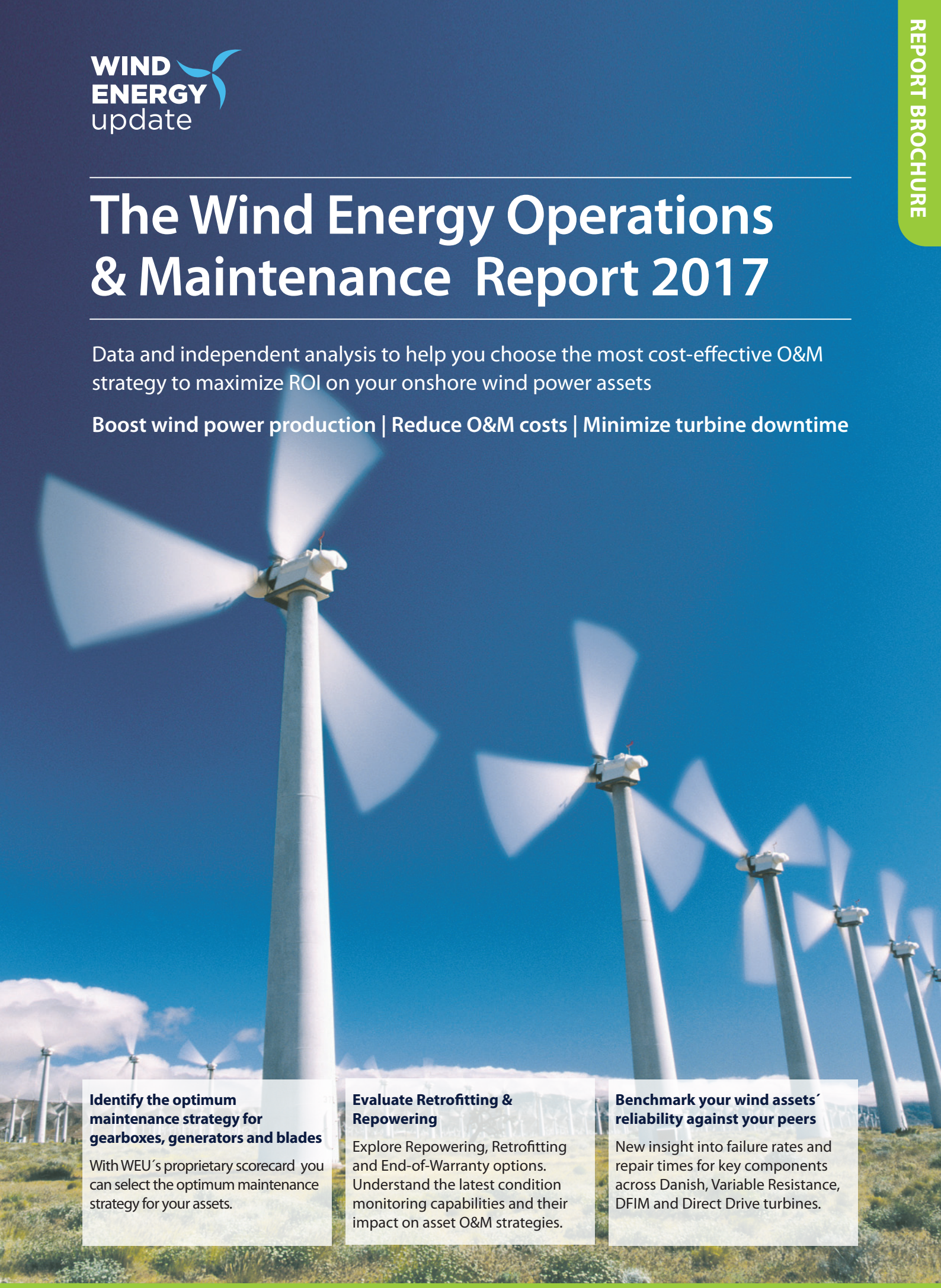
WIND ENERGY update

REPORT BROCHURE

The Wind Energy Operations & Maintenance Report 2017

Data and independent analysis to help you choose the most cost-effective O&M strategy to maximize ROI on your onshore wind power assets

Boost wind power production | Reduce O&M costs | Minimize turbine downtime



Identify the optimum maintenance strategy for gearboxes, generators and blades

With WEU´s proprietary scorecard you can select the optimum maintenance strategy for your assets.

Evaluate Retrofitting & Repowering

Explore Repowering, Retrofitting and End-of-Warranty options. Understand the latest condition monitoring capabilities and their impact on asset O&M strategies.

Benchmark your wind assets´ reliability against your peers

New insight into failure rates and repair times for key components across Danish, Variable Resistance, DFIM and Direct Drive turbines.

To purchase the full copy of the report click here

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KEY REASONS TO BUY

Operations and maintenance is key to maximizing profitability of your wind energy assets

Once a wind farm is operational, adopting an effective operations and maintenance strategy is the main path for operators to maximize ROI on wind energy. The Wind O&M Report 2017 provides access to the latest updates on the O&M wind market enabling you to:

- **Explore Repowering and Retrofitting as well as End-of-Warranty options.**
- **Deep dive into comprehensive analysis on key component reliability and asset optimization.**
- **Understand the latest condition monitoring capabilities and their impact on asset O&M strategies.**

The **WEU Wind Energy O&M Report 2017** provides data and analysis to help you formulate the most cost-effective O&M strategy for your wind power assets.

Some of the leading companies who have previously secured our O&M reports

Invenergy
KEPCO
NEXTera ENERGY
Statoil
acciona
DUKE ENERGY
edp renewables powered by nature
e·on
GDF SUEZ
HITACHI Inspire the Next
Brookfield Renewable Energy Partners
CATAPULT Offshore Renewable Energy
MITSUBISHI ELECTRIC RESEARCH LABORATORIES
Omega energia renovável
Castrol
WIND PROSPECT

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This report will enable you to…

- **Maximize energy yield**
- **Identify the failure types that have the biggest impact on your bottom line**
- **Quantify the costs and benefits of adopting predictive O&M compared to scheduled and reactive approaches**
- **Identify components most at risk of failure and estimate repair times**
- **Benchmark against global leaders in Operations and Maintenance**
- **Find out whether it is more cost-effective to leave O&M to a turbine manufacturer, outsource it to an independent service provider or bring it in-house**
- **Identify the O&M strategy most suitable to each market**
- **Weigh up the costs and benefits of CMS**
- **Evaluate the costs and benefits of re-powering vs retrofitting**

Questions addressed…

- What are the failure rates of key components on different turbine types and capacities?
- When is it more cost effective to carry out O&M in-house rather than working with OEMs or ISPs?
- How are other companies reducing their O&M costs whilst delivering better wind farm performance?
- Under which circumstances is it cost-effective to invest in condition monitoring systems, rather than carry out scheduled O&M?
- What is the O&M market size?
- What is the re-power market size?
- What is the retrofit market size?
- What are the end of warranty options for operators, when should they consider repowering or retrofitting?

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Who needs this report?

Owners and operators of wind power assets will benefit from unique failure rate data on the performance of different turbine types.

The following functions will benefit

- **Asset managers:** get a deeper understanding of the costs and performance implications of each O&M approach so you can maximize return on investment on your wind power assets.
- **O&M directors:** optimise your wind farm performance and benchmark against your peers, by drawing on exclusive quantitative analysis.
- **Business Development Managers O&M**: measure the O&M, repower and retrofit market size, evaluate opportunities in key markets globally and compare your technologies performance with your peers.

Five reasons to buy

1. **Make your investment in O&M count,** scheduled and predictive O&M have their own cost and performance implications, use this report to choose the most cost-effective approach for your assets
2. **Save time and money**, we have already provided the data and analysis you need to optimise your wind O&M strategy
3. **Predict, plan and prevent:** Avoid unplanned downtime that could wipe-out your ROI on wind power assets by identifying failure rates and repair times for key components for different turbine technologies and capacities
4. **Stay ahead of your competitors** by applying O&M learning's which leading wind energy companies have shared in this report
5. **Plan your investment strategy:** Evaluate the benefits of re-powering, retrofitting & CMS.

Access exclusive failure rate and repair time analysis for key components including:

- Yaw System
- Turbine Transmission System
- Structure and Machinery Enclosure System
- Control and Protection System
- External Lighting Protection System
- Central Hydraulics System
- Blade Adjustment System
- Generator System
- Rotor System
- Drive Train System
- Turbine

Covering several turbine types and capacities:

- DFIM
- Direct Drive
- Variable Resistance
- Danish Concept
- Under 1MW
- Over 1MW

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An alternative to full repowering could be to simply replace the worn-out machines, without the full potential of repowering. This is often referred to as partial repowering, where selected turbines are replaced, or key components overhauled to extend the life of the asset. According to NREL, a partial repowering approach where the rotor and drivetrain are replaced can yield a 30 to 37% increase in the net cash flow, at a cost 15% lower than a greenfield project and 10% lower than a repowered project.

2.2.2. European Repowering Market

While life extension may delay the onset of the "Repowering Era", it is imminent in northern Europe. Upon reaching the operational lifespan of the asset of 25 years, turbines will either be decommissioned, life extended, or repowered (full or partial). Repowering may even be considered within the viable lifespan of the turbine, depending on the cost-benefit ratio of the project. The repowering landscape resulting from an early (20 year) and late (30 year) repowering scenario is depicted in Figure 58 for the EU-27/28 countries.

While the first instances of repowering in the northern European market focused on the replacement of sub-MW turbines, which often times were obsolete, of poor reliability and efficiency, the wind market today is looking at a much larger scale of repowering as established market see their assets passing the 15 year of operation mark. A good example is Germany's central registers, which corroborates this repowering trend.

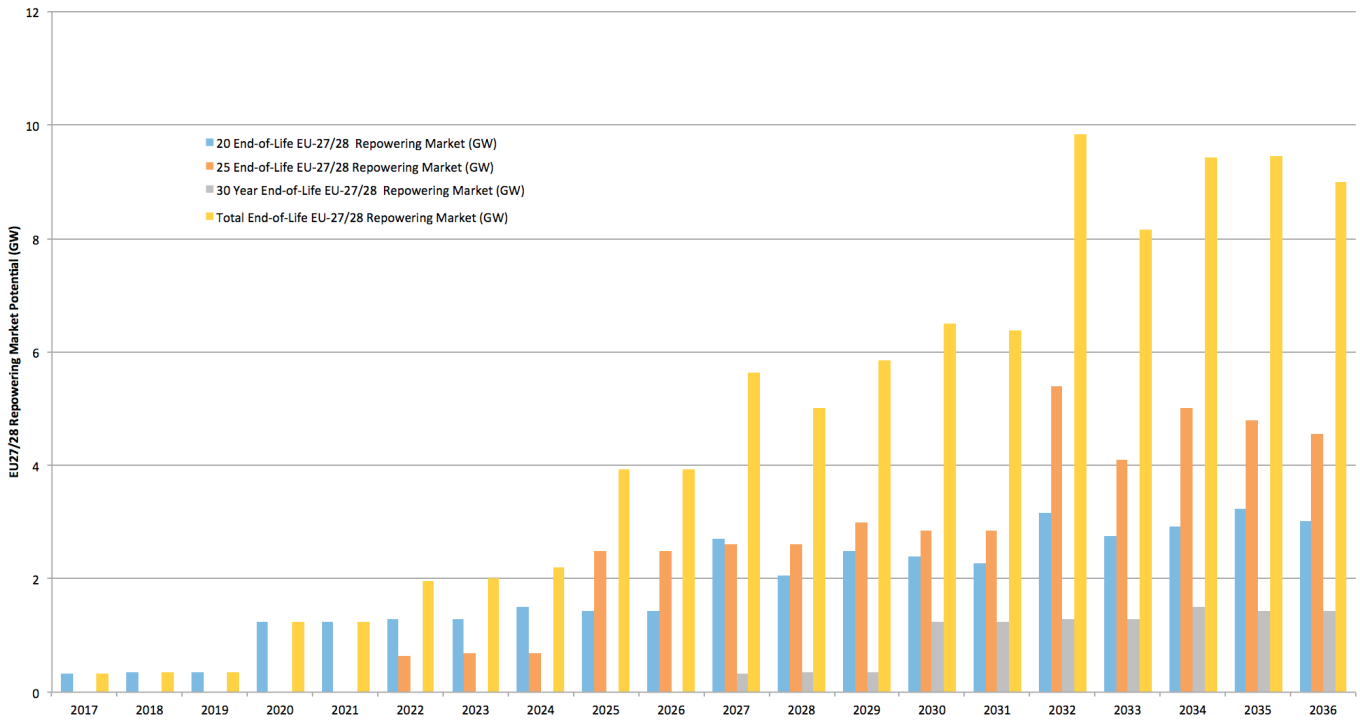
Northern Europe, meanwhile, will rely on offshore capacity for 34% of its growth and repowering 16%. (Lee, A., 2017)

2.2.2.1. Germany

Prior to the EEG 2014 revision, developers could benefit from a bonus of 0.49c/kWh in addition to its degressive feed -in tariff (8.9c/kWh – 0.4%/quarter). Since August 2014, Germany's blueprint for growth now excludes repowering capacity, making for a more difficult business case to repowering investors.

Germany's central wind turbine register is also an interesting database which resulted from the 2014

Figure 58: Cumulative EU-27/28 Repowering Market Potential (GW)



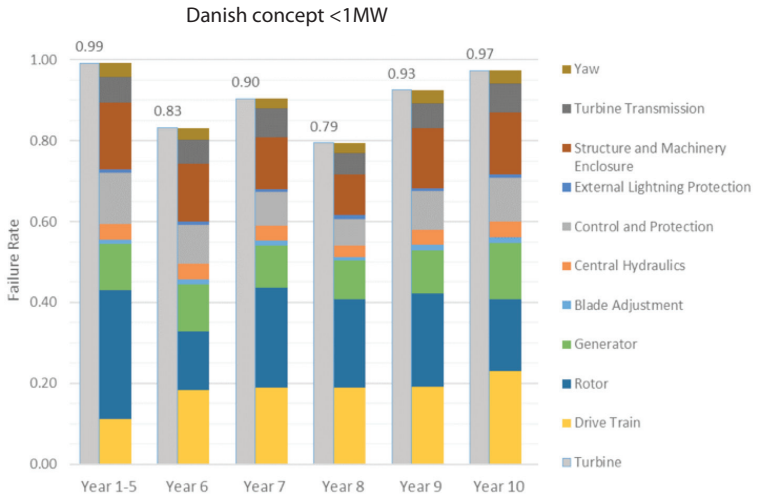
3.2.2 Type A - Danish Concept

Data for the <1MW Danish Concept machines in Figure 72 and Figure 73 shows that the failure rate decreases in the post-warranty period, which indicates that the majority of issues are covered within the warranty period, especially, especially failures in the Rotor System. In year 6, MTTR decreases as well as failure rate, indicating both fewer and less severe failures. However, for subsequent years 7 and 8, MTTR lengthens mainly because of more severe and time-consuming repairs caused by the Drive Train System.

Figure 72 and Figure 73 also show that the Danish Concept is a robust technology with a relatively low failure rate and MTTR. It is interesting to note that the Drive Train System, which has a low failure rate for the first five years, is doubling its failure rate for year 6 and keeps a stable rate at around 0.2 failures per year after the 6th year. Although such a failure rate in the Drive Train System is not unusual, MTTR is by far the most important, reaching up to 4.8 days in year 8. Fixed speed operation of this technology causes high torque as well as fatigue loads on the Drive Train system as detailed in Section 3.1.1.1, which explains the increasing fatigue-induced failures with longer repair times due to their catastrophic failure mode.

These early wind turbines were typically installed without a power converter. This means that they were more susceptible to local grid conditions. This effect can explain the high Transmission System failure rates recorded for Danish Concept turbines, while variable resistance turbines experience a lower failure by regulating power fluctuations through power electronics.

Figure 72: Failure Rate of <1MW Danish Concept Turbines

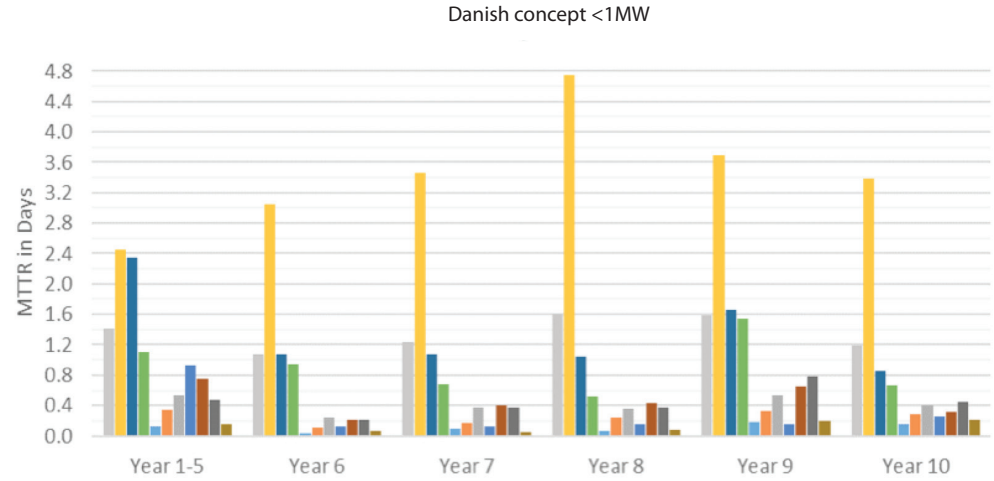


Source: WEBS, 2017

3.2.3 Type B - Variable Resistance

Analysis of the trends observed for the <1MW and ≥1MW Variable Resistance turbines documents the initial reliability problems encountered while increasing the turbine size and capacity. As shown in Figure 74

Figure 73: MTTR of <1MW Danish Concept Turbines



Source: WEBS, 2017

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Methodology

Wind Energy Update's (WEU) O&M Report 2017 responds to the evolving onshore wind O&M industry, representing over four months of primary and secondary research.

At the core of WEU's research process is a multi-disciplinary team, in-depth research and constant analysis of the changing landscape of the onshore wind sector, identifying:

- Key industry trends
- Challenges and opportunities currently facing wind industry executives
- Shifting O&M practices
- The maturing presence of CMS
- The growth of retrofit and O&M solutions
- The emergence of repowering
- An O&M strategy outlook, and scorecards

The methodological approaches adopted in this report have been framed by the pursuit to meet the information needs outlined in the original in-depth industry interviews. The 2017 edition delves deeper in the after-market owner/operators options and strategies throughout the lifecycle of their asset, providing an outlook on the repowering potential of key markets in Europe and the US.

Market Data: Data has been collated from a combination of proprietary and published sources, and verified and analyzed by our expert authors to provide the most comprehensive, up-to-date and digestible facts and figures on market sizing and trends, company share and O&M market sizing.

WEU Onshore O&M Survey (March 2017): Targeted stakeholders across the O&M space providing unparalleled insight into project and component level reliability experiences, downtime rates and failure causes, maintenance strategy trends and monitoring system deployment rates. Information is also filtered by location and company type adding exceptional nuance to the analysis.

Quantitative Analysis

WEBS: Wind Energy Benchmarking Services provided the detailed failure rate and performance data utilised in the report analysis.

CMS Wind: Provided Comments on the CMS systems chapter.

Secondary Sources: Additional analysis includes secondary research conducted by our expert analysts. A comprehensive review of industry and academic journals, conference presentations, online publications, news articles, government policy documents, company press releases, and proprietary literature and materials providing a strong foundation from which to contextualize the report findings and highlight points of corroboration and departure. Where applicable, all secondary research sources are appropriately cited within the report.

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Expert Knowledge:

This report has been researched and written by a team of highly-qualified and impartial industry experts and reviewed by highly-regarded industry specialists to ensure that only the highest quality and most relevant information is published.

Learn more about each aspect of the methodology…

Contact Louis Vye at: lvye@windenergyupdate.com

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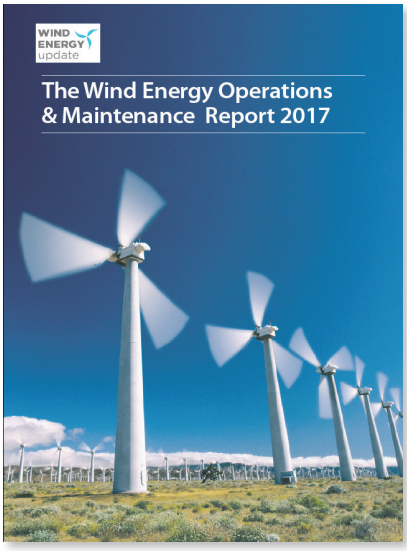

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Our impartial perspective allows us to comment freely and express views on what's happening and why. Our international vents explore industry opportunities, challenges and emerging best practices tailored for executives working in wind energy.