O&M optimization

The key to managing wind power operational costs

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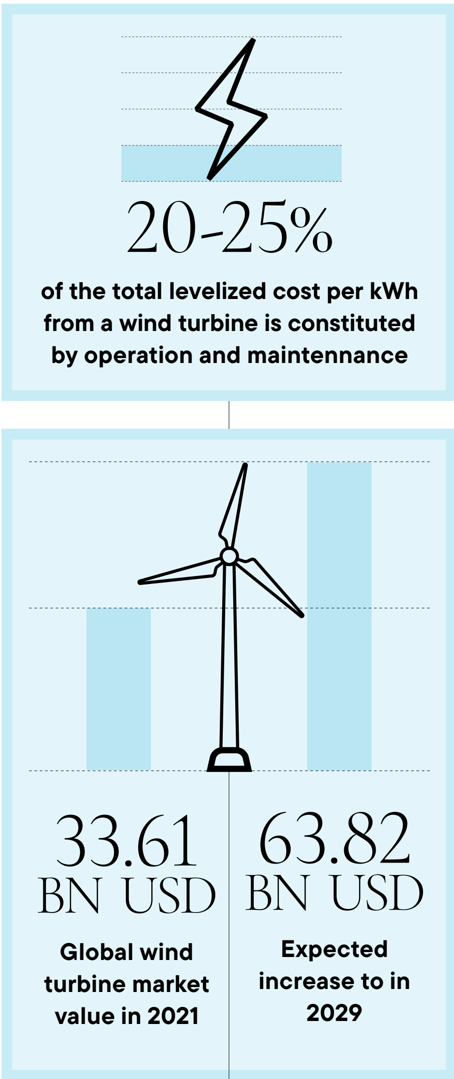
Upswing in wind power operational expenditures

Operation and maintenance (O&M) costs constitute a sizeable share of wind turbine's total annual costs. For a new turbine, they may easily make up 20-25% of the total levelized cost per kWh produced over the turbine's lifetime. It is expected from this year (2024) that OPEX costs will exceed CAPEX[i].

In 2021, the global wind turbine O&M market was valued at USD 33.61 billion and is expected to increase to USD 63.82 billion by 2029, exhibiting a CAGR of 8.4% during the forecast period. The market is expected to be driven by the growing investment in installing and operating wind energy[ii].



The growth indications emphasize the issues at stake here. Given that the projected growth might be even higher when considering political goals, the challenge the market faces will be operating and maintaining the many assets efficiently.

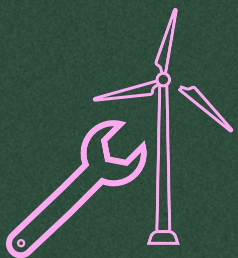
One has to ask if the operational costs of wind power are manageable at all? And if they are, what optimization strategies and business models prioritizing cost-efficiency will do the trick? At DIS/CREADIS we believe optimization is key as well as further consolidation within the industry, as both self-performing entities and those operating under OEM service contracts seek more efficient ways to manage these costs.

[i] Wood Mackenzie, 2019

[ii] https://www.fortunebusinessinsights.com/wind-turbine-operation-and-maintenance-market-102757

Operating and maintaining versus building wind turbines

When OEMs are designing wind turbines, O&M considerations play a crucial role in ensuring their long-term performance, reliability, and cost-effectiveness. From an engineering perspective, a holistic approach to wind turbine design that considers O&M factors from the outset is essential to ensure reliable and sustainable energy production throughout the turbine's lifecycle. Key design aspects related to O&M include:



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Component reliability and durability

Wind turbines operate in variable and harsh conditions, unattended, and in remote locations, which means certain design considerations need to be taken into account, including:

- Selecting robust materials for components (e.g., gearbox, generator, blades) to withstand wear, temperature extremes, and contamination.
- Optimizing component layouts to facilitate maintenance access and minimize downtime.

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Predictive maintenance

Unplanned downtime due to component failures can be costly. Considerations could include:

- Integrating sensors for real-time condition monitoring.
- Implementing predictive algorithms to anticipate maintenance needs.

3

Documentation and reporting

Accurate record-keeping is essential for effective O&M. Design considerations could therefore include:

- Implementing data loggers and reporting systems.
- Documenting maintenance activities, failures, and repairs.

Effective maintenance of wind turbines is crucial for their efficient operation and extended lifespan. Typically, for planning and execution purposes, maintenance activities within the wind turbine sector are categorized into two main types.

Preventive maintenance	Predictive maintenance

Each category addresses specific aspects of turbine upkeep, ensuring comprehensive care and management:

Preventive maintenance

This involves routine operational planning to conduct regular inspections and check mechanical and electrical parts, typically every 6 and 12 months. The goal is to keep turbines running smoothly and avoid breakdowns by addressing potential issues proactively. It can include tasks such as:

Retightening: Checking and adjusting the bolts and screws that hold the turbine components together to prevent loosening and vibration that can damage the turbine.

Lubrication and filter change: Applying grease or oil to the quality monitoring systems combined with improved filtration, i.e. offline filtration or fine filtering, will prolong the lifetime of lubricants and components.

Turbine inspection: Using various tools to inspect the blades, nacelle, tower, and generator to identify cracks, damage, corrosion, and malfunction.

Turbine cleaning: Removing debris from the blades, nacelle, tower, and generator, among other areas to improve the turbine's aerodynamics and efficiency.

Turbine monitoring: Continuous monitoring of critical components to enable early fault detection. Understanding failure development will improve the maintenance planning capability.

Predictive maintenance

This approach leverages real-time data and machine learning techniques to foresee potential component failures. It involves operational planning that not only predicts when a component might fail but also ensures the availability of resources and spare parts for timely corrective actions. This method helps in minimizing unexpected downtimes and extends the lifespan of the turbine. Some of its benefits include:

Improved planning and operational efficiency: By analyzing data from sensors and SCADA systems, predictive maintenance can detect changes in the physical condition of components and identify signs of failure. This enables timely maintenance activities, maximizes component life, and reduces unnecessary shutdowns.

Reduced equipment malfunction and damage: By monitoring and adjusting to weather and wind conditions, this data can enable predictive maintenance to prevent equipment damage caused by atmospheric conditions. Using computer vision or robotics can also reveal defects that are easily overlooked by human inspectors.

Lowered construction and installation costs: By using AI-driven tools to optimize design, construction, and installation, predictive maintenance can reduce the cost of wind energy systems and wind farms. Using generative construction simulators and optimizers can also help to recover from delays and resequencing tasks.

The principle of "availability"

When it comes to maximizing both the annual energy production (AEP) and revenue of wind turbines while ensuring efficient operations, the term "availability" is an important aspect to consider. However, measuring the availability is a bit more complicated and often a critical subject for discussion. There are two forms or metrics to consider:

Yield-based availability measures the proportion of time a wind turbine is capable of generating electricity within a specific timeframe, relative to the total duration of that period. This metric accounts for variations in wind speed and underscores the significance of maintaining a turbine's operational availability.

Time-based availability is determined by the ratio of operational periods to the total time, without accounting for wind speed fluctuations. This approach might not fully reflect the critical importance of a turbine's availability in varying wind conditions.

Three main drivers for optimal "availability"

Availability

Enhancing reliability	Improving maintainability	Optimizing support
• Ensure equipment quality. • Implement quality-focused maintenance. • Guarantee fit-for-purpose designs. • Promote correct usage of turbines. • Foster strategic planning. • Encourage continuous improvements. • Maintain thorough documentation.	• Simplify data acquisition and diagnostics. • Enhance access for maintenance tasks. • Streamline repair and testing processes. • Focus on modularization for easier servicing.	• Ensure ready availability of parts and tools. • Facilitate access for service teams. • Invest in training and develop competencies. • Provide specialist support as needed. • Maintain clear documentation and instructions. • Evaluate the balance between in/outsourcing.

Reliability: Ensuring each component is ideally suited for its application enhances overall turbine reliability.

Maintainability: Efficient data and structure management are crucial for optimizing turbine performance.

Maintenance support: Proactive component monitoring and availability of necessary parts play a key role. Early detection of potential issues can reduce downtime, thereby optimizing energy production.

High availability enhances **uptime**, which boosts energy production (kWh). Conversely, **downtime** equates to lost production, ultimately reducing overall production. Implementing predictive maintenance can effectively minimize downtime and potentially augment uptime.

For instance, consider a 5 MW wind turbine that generates approximately 2,400,000 kWh. Targeted interventions that increase production by 1%, will translate into an additional 24,000 kWh annually. This increment could power 4 extra households for a year, based solely on the increased output from this single wind turbine.

This tells us that diagnosing errors through fault detection or troubleshooting to predict adverse events is paramount when it comes to O&M. Not surprisingly, many industry service entities have established diagnostic centers to support operational staff in their endeavors to ensure smooth operations.

At DIS/CREADIS our experience is that diagnostics plays a crucial role in managing operational costs effectively, but that the combination of data from SCADA systems and wind turbines together with expert knowledge will deliver the optimal results. The human element – the expertise of engineers and technicians in interpreting data and applying it contextually – should not be undermined as the practical wind turbine experience is as vital as having accurate data for making informed decisions.

The value of knowledge and experience

The man-machine duality is often viewed as a contradiction. However, at DIS/CREADIS, we see it as a harmonious relationship where both elements complement each other. We believe that the engineer's intuition, particularly in troubleshooting and fault detection, is significantly enhanced when paired with AI tools. AI's adaptability and learning capabilities are the perfect complement for engineers aiming to broaden their O&M skills, creating a powerful blend of human insight and machine intelligence.

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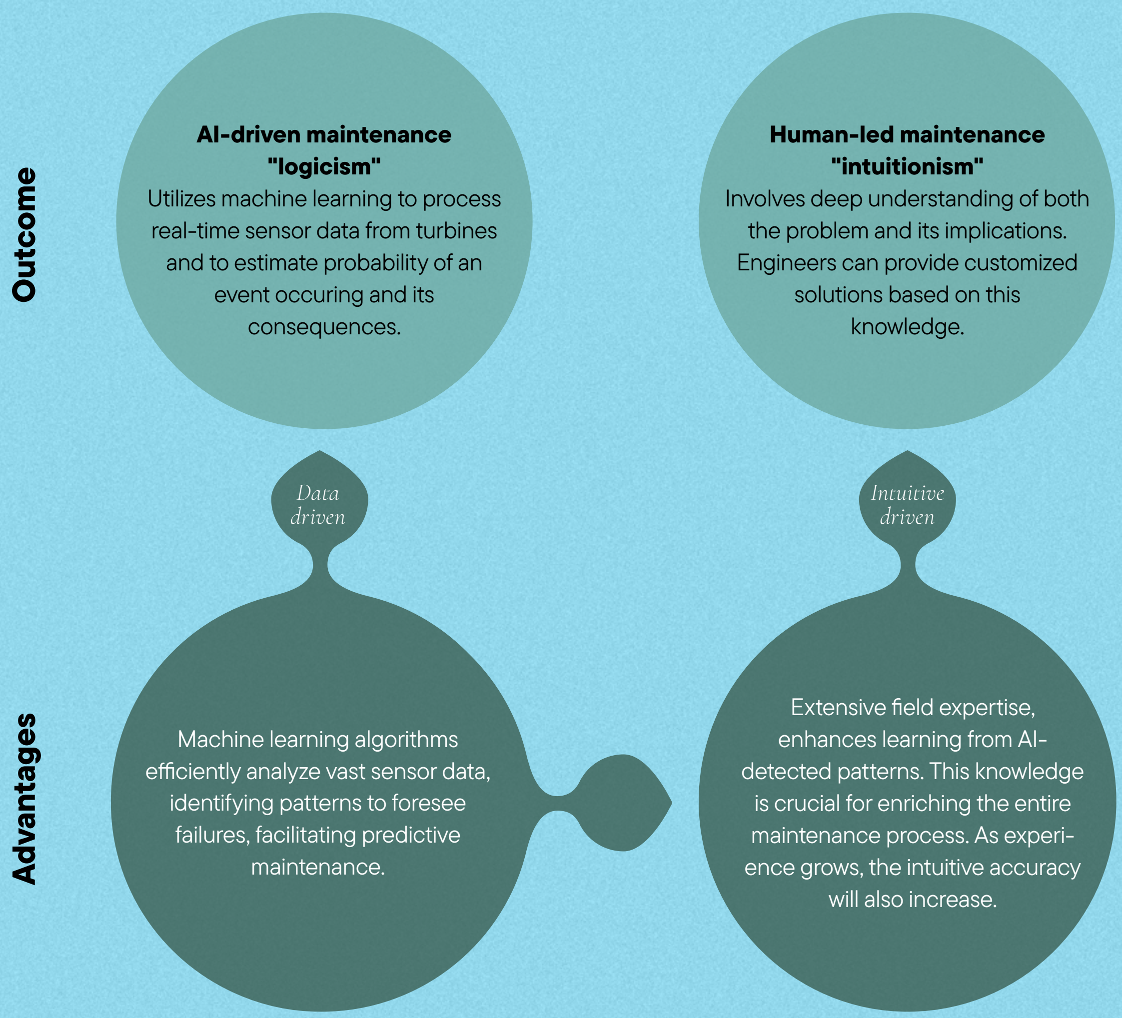
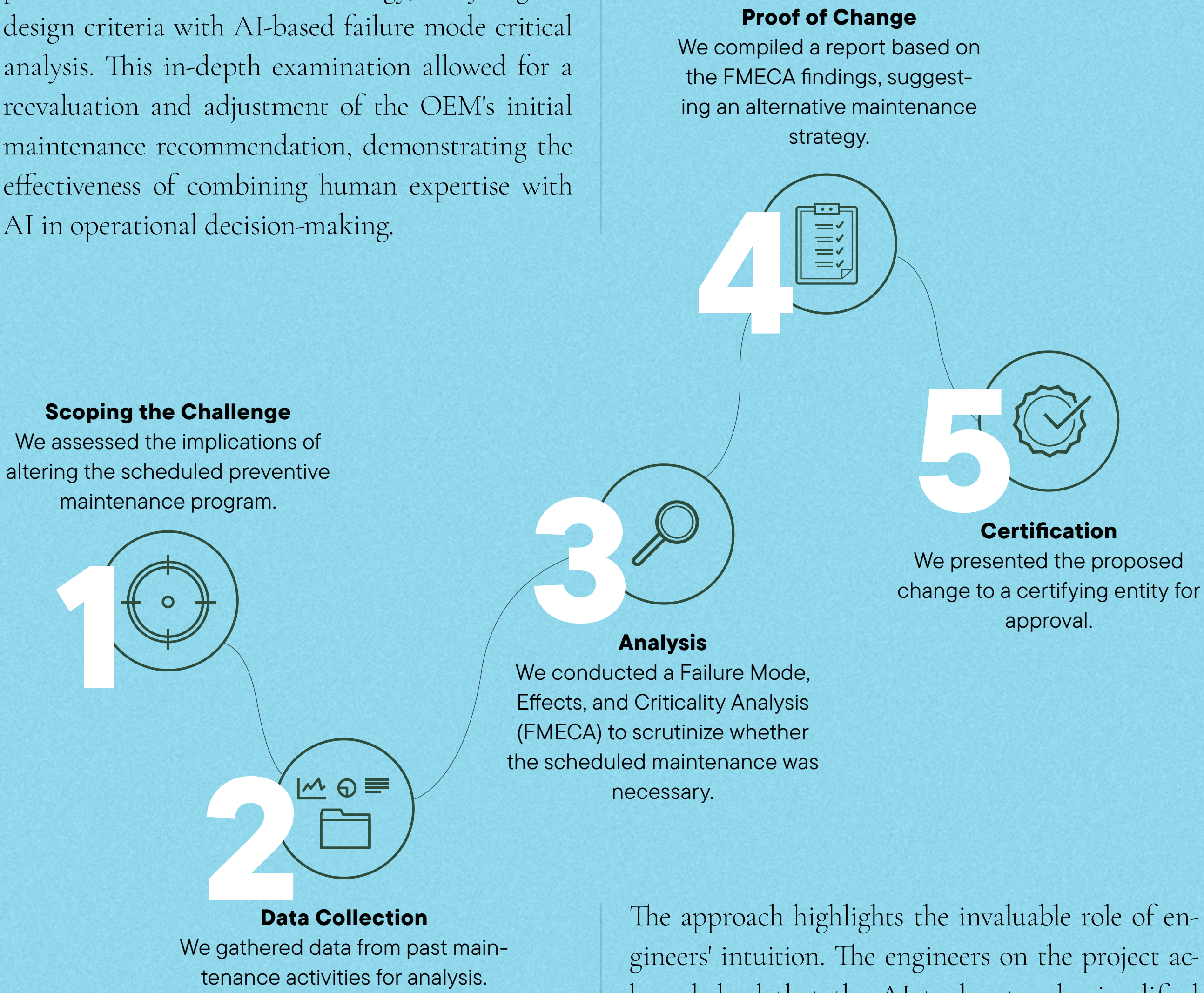
Synergizing AI and human expertise for predictive maintenance



In a real-world case from a client, our engineers questioned the necessity of a six-month maintenance activity scheduled by a wind turbine OEM for an offshore site. Their intuition, backed by experience, suggested that the maintenance might be unnecessary and costly. They approached the problem with a data-driven strategy, analyzing the design criteria with AI-based failure mode critical analysis. This in-depth examination allowed for a reevaluation and adjustment of the OEM's initial maintenance recommendation, demonstrating the effectiveness of combining human expertise with AI in operational decision-making.



The approach highlights the invaluable role of engineers' intuition. The engineers on the project acknowledged that the AI tool not only simplified the problem-solving and documentation process but also reinforced their confidence in their intuitive judgments. The data provided by the AI tool played a crucial role, adding a logical foundation to their decisions. Without this data, the learning outcomes would have been more uncertain, and the intuitive approach might not have been as effectively engaged. This synergy of intuition and AI-driven logic underscores the strength of combining human insight with technological advancements in problem-solving.

Bringing it all into perspective: **Are operational costs manageable at all?**

Yes, they are. Provided the right tools are utilized.

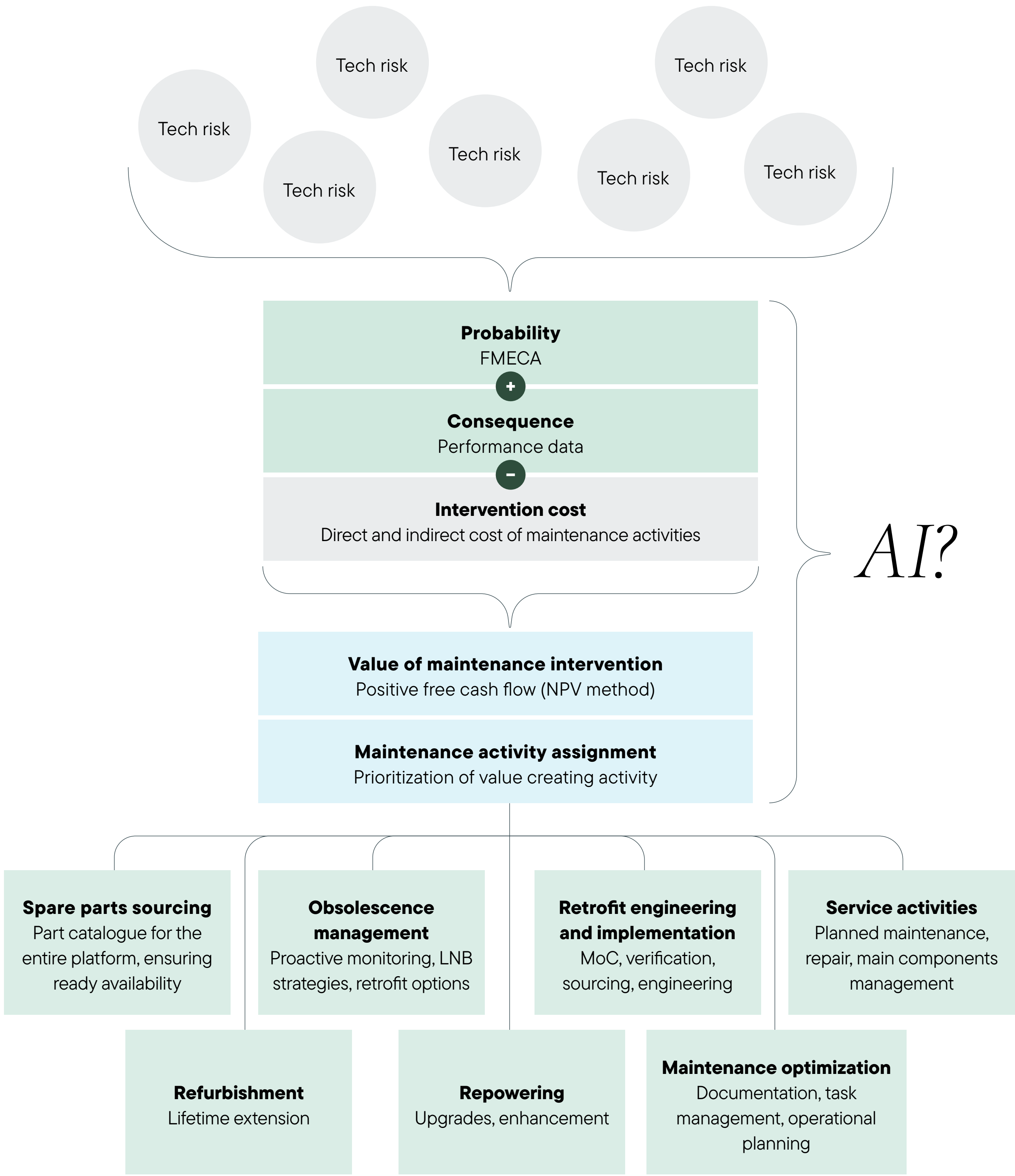
AI contributes significantly to the wind energy sector by addressing challenges, optimizing operations, and ensuring sustainable energy production. As the industry evolves, AI-driven technologies will continue to play a crucial role in wind-power innovation.

Some wind energy providers already use AI to predict maintenance needs and optimize turbine performance through:

- Monitoring of wind conditions and cross-references environmental data with records of past maintenance.
- Identifying patterns that may indicate future maintenance or repair needs. Continuous optimization of maintenance schedule, specifying when and how often maintenance should be performed.

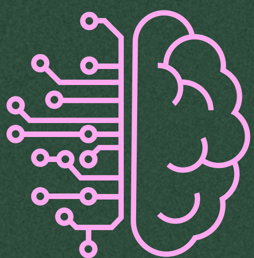
Integrating AI for initial technical risk assessments and further refining these analyses with experienced engineers ensures that maintenance and repair become value-adding activities, rather than just routine tasks. With this dual approach we argue that operational costs can be managed.

The below model exemplifies how wind farm owners and operators can efficiently manage their assets. Here, technical risks are integrated into analytical processes, balanced against maintenance costs, and considered in free cash flow calculations, prioritizing, and executing essential maintenance activities.



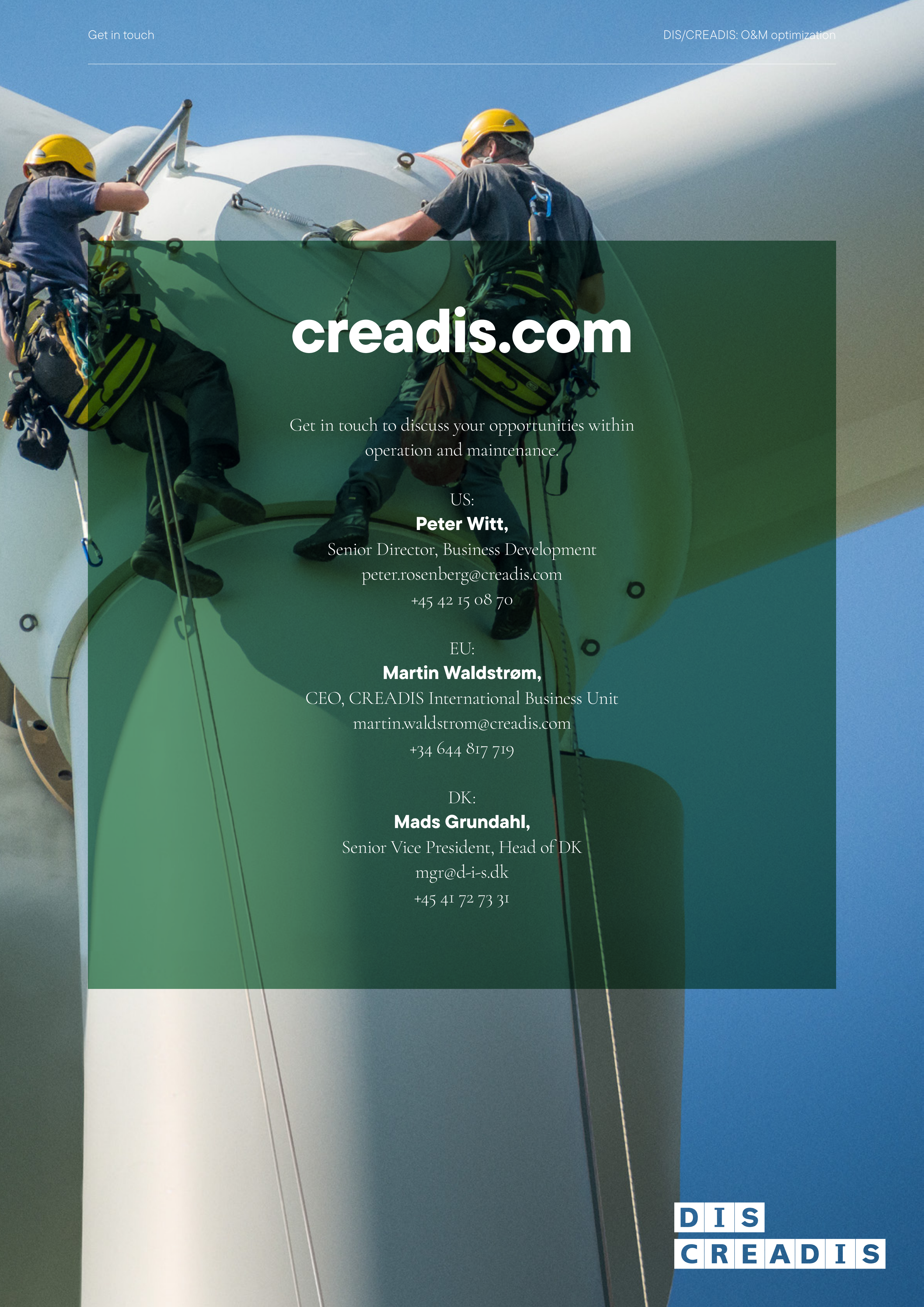
Conclusion

As the wind energy sector navigates the rising tides of operational expenditures, the imperative for efficient, cost-effective O&M strategies is clear. Advanced technologies like AI and machine learning are pivotal in this journey towards cost management. Yet, the ultimate success hinges on the synergy between these technologies and the seasoned expertise of wind engineers. Their deep understanding of the sector's unique challenges ensures the practical applicability of tech-driven solutions. This approach is not just about maintaining operational efficiency; it's a strategic move towards enhancing the longevity and profitability of wind energy assets, embracing a future where technology and human expertise drive sustainable growth in the wind energy sector.



About DIS/CREADIS

With over 25 years of wind engineering experience, DIS/CREADIS is well-positioned to help you overcome the unique challenges of the wind industry. We acknowledge the intricate nature of grid integration and the design of electrical infrastructures and offer our expert advice to ensure your wind farm is effectively incorporated into the grid. We also support your operations & maintenance across its entire lifecycle. From aiding in equipment selection to implementing predictive maintenance planning, we utilize state-of-the-art digitalization tools, including advanced analytics, AI, and machine learning. The end goal is to bring significant reductions in downtime, operational expenditure (OPEX), and the Levelized Cost of Energy (LCOE).



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