Vietnam Wind Power Conference, Hanoi

O&M to optimize turbine output

June 2019

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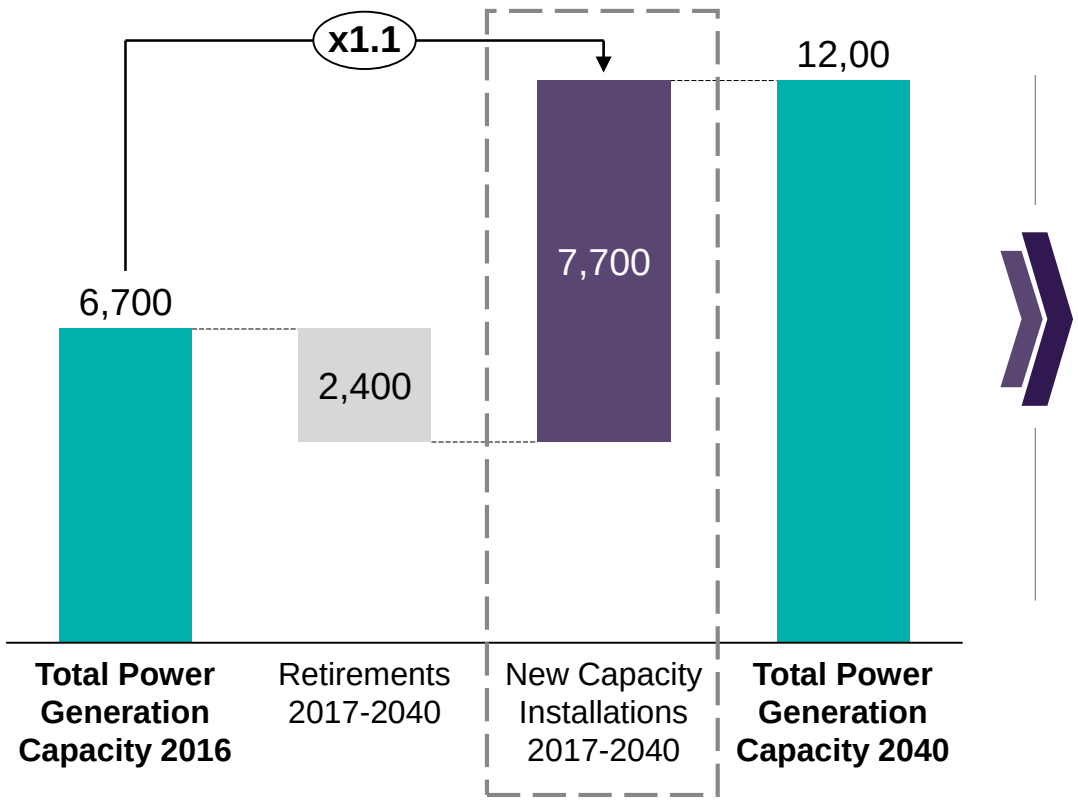
Global power generation additions until 2040 to exceed total existing installed base

Global power generation capacity (in GW)[1]



Fundamentals

Global population and **GDP growth** driving **higher energy consumption**

Retirements of old capacity triggering need of additional new installations

Clear **electrification trends**, e.g. transportation

Implications

New installations to **surpass existing accumulated capacity**

Global **investment** until 2040: ~**10 $T**[2]

1 IEA WEO 2017 (New Policies Scenario)

2 BNEF NEO 2017, in real $T

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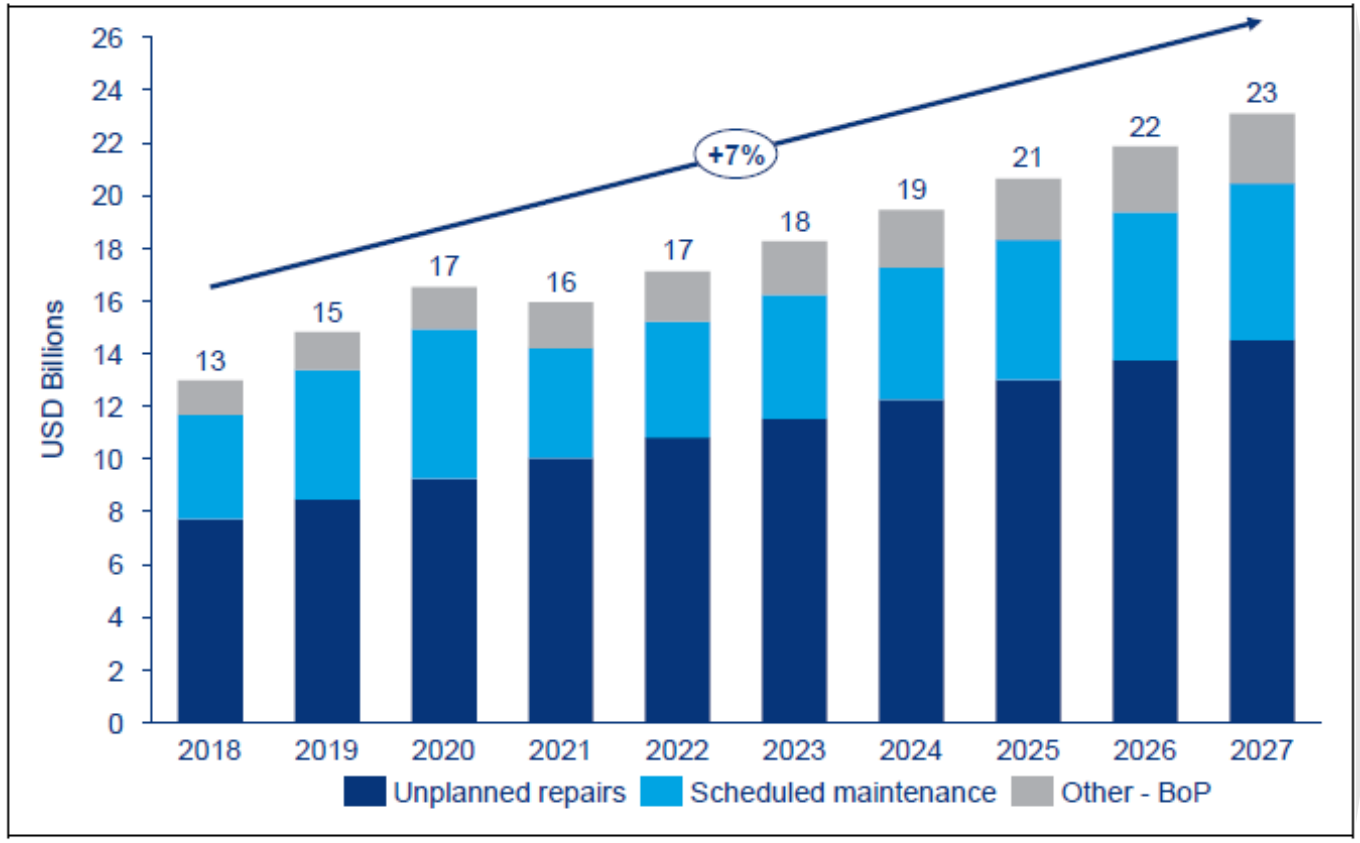
Wood Mackenzie: Unplanned repairs will cost the global wind power industry more than $8 billion in 2019

Figure 1.1 Global onshore wind power O&M spend estimates to 2027



Source: Wood Mackenzie 1

- Component failures are a fact of life for every asset owner
- Global onshore wind O&M costs will reach nearly $15 billion in 2019. Of that number, 57% - or $8.5 billion – will be spent on unplanned repairs and correctives caused by component failures.
- OEMs and asset owners increasingly dedicate resources and strategy to reduce the frequency of unplanned failures

1 Wood Mackenzie May 2019: "Digital technology in wind power operations and maintenance"

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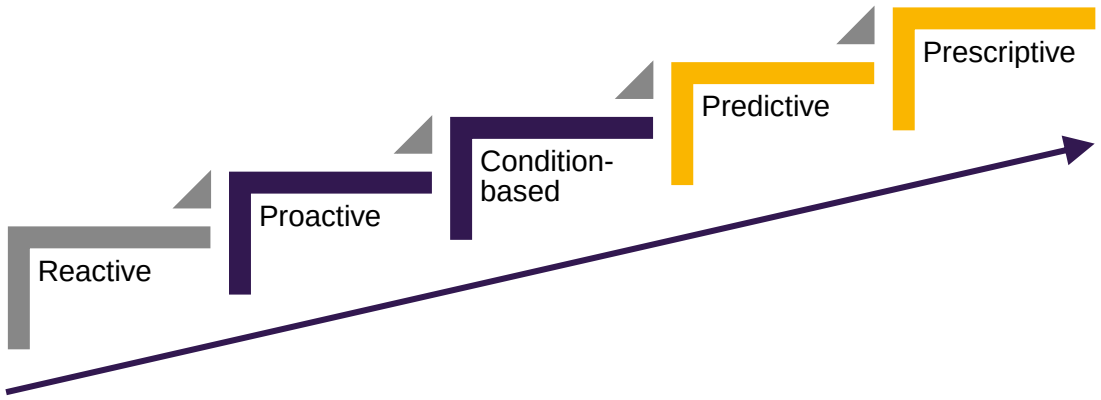
Evolution of digital asset management

The Digital Services are focused on Remote Services and Upgrades, and are designed to support the evolution of maintenance strategies…



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Wood Mackenzie: Digital technologies may be a solution to reducing O&M costs

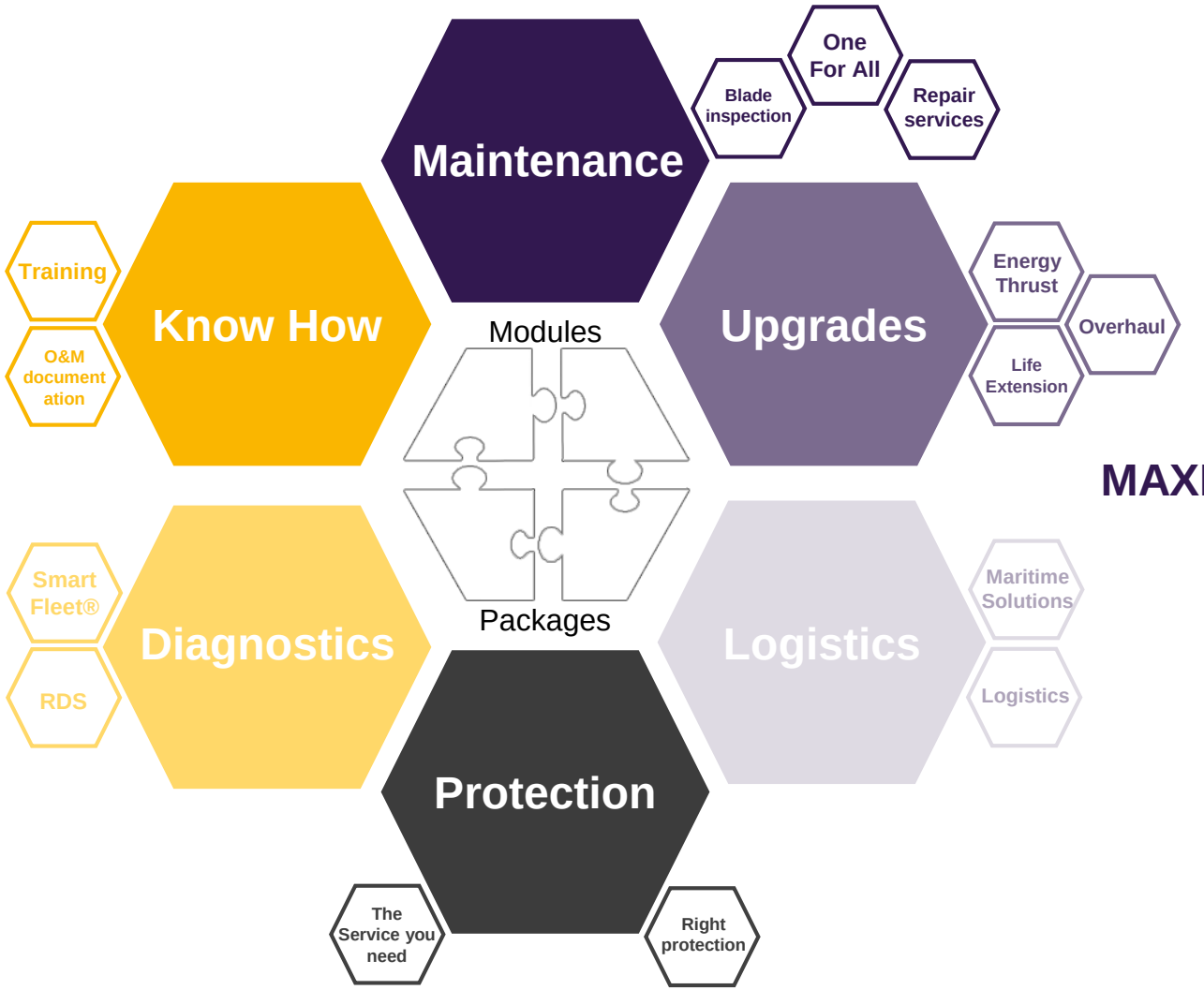
Figure 2.2 Summary of the 7 key digital technology types for wind O&M [1]

Technology	Use of examples	Technological readiness	Commercial readiness
ERP	Spares and logistics optimization, technician dispatch	◕	◔
Machine learning	Artificial intelligence based yaw and blade-pitch misalignment correction	◑	◔
Data analytics platforms	Component, turbine, and site performance analysis	◑	◑
Digital twins	Physics based simulations of components or entire turbine models	◕	◑
Production forecast	Energy production forecasts, revenue forecasting	◕	●
Autonomous inspection	UAV inspection drones, blade repair bots	◕	◕
CMS	Component early failure detection and remote monitoring	●	◕

1 *Wood Mackenzie May 2019: "Digital technology in wind power operations and maintenance"*

The objective is to improve and secure your business case

CONTROL YOUR COST



MAXIMIZE YOUR REVENUE

MITIGATE YOUR RISKS

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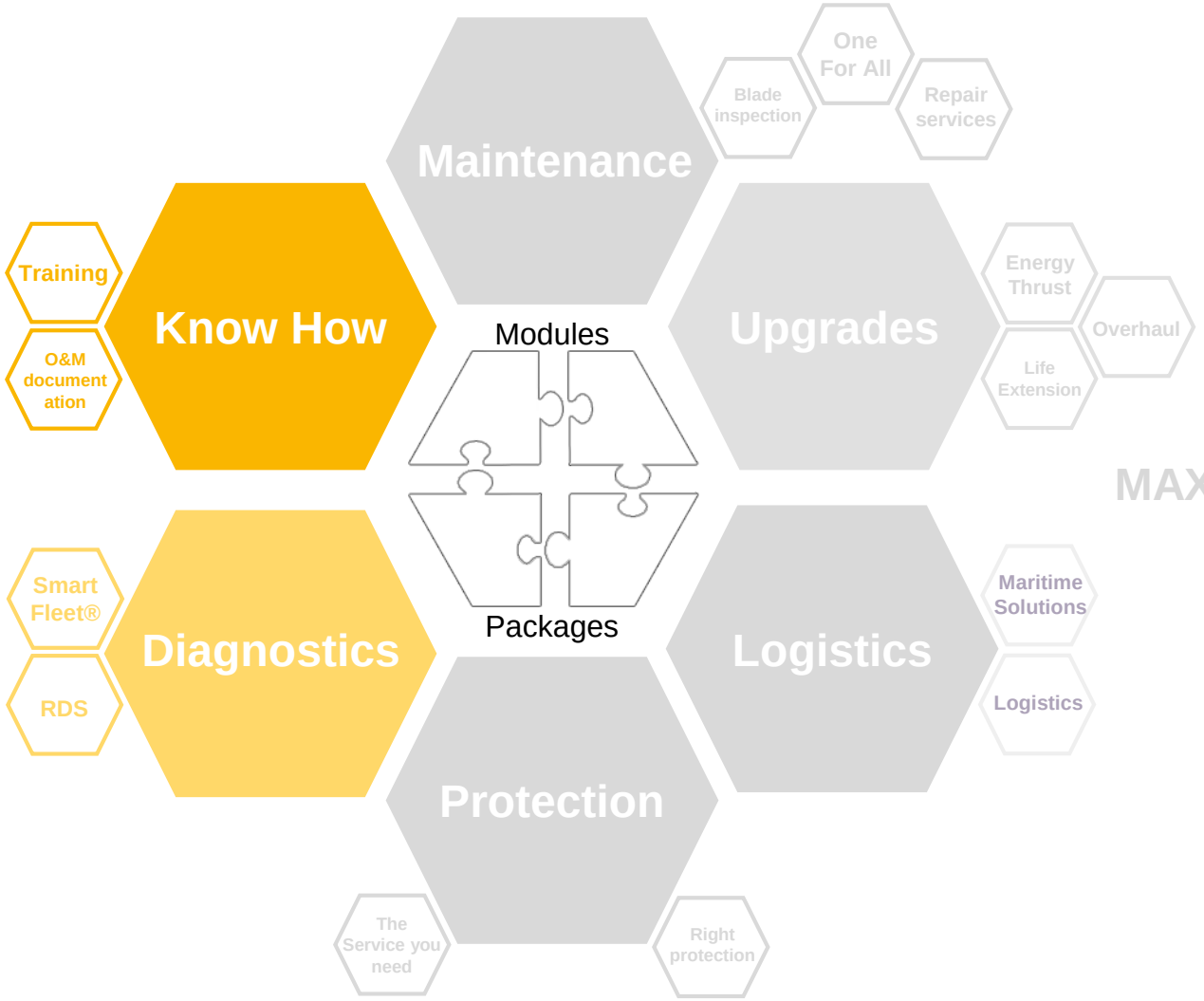
Examples of solutions to CONTROL YOUR COST

CONTROL YOUR COST



MAXIMIZE YOUR REVENUE

MITIGATE YOUR RISKS

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Example: WindCommand

Combining data with know-how

- Structural fatigue assessment (knowledge-driven)
- Wind turbine health assessment through CMS (data-driven)
- Reliability assessment based on Operational experience (statistical-driven)
- Condition assessment based on local inspections (empirical evidence)

Understand your assets

1 *RUL: Remaining Useful Lifetime*

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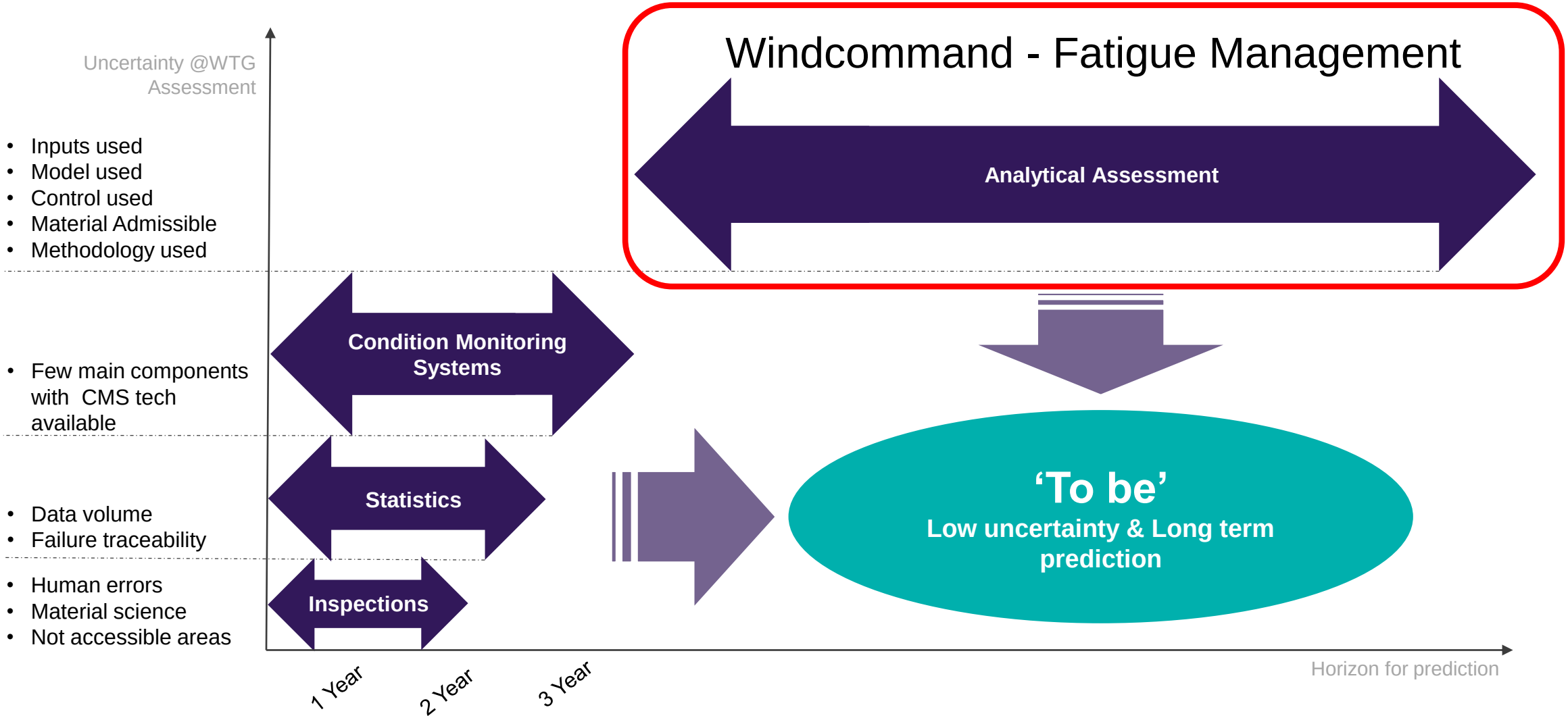
How to assess the RUL (Remaining Useful Lifetime) according to SGRE



Uncertainty Management

Wind Field Characterization

- Main Wind characteristics estimators; Turbulence Intensity, Wind Speed, Air Density

Aerolastical Code and WTG Control

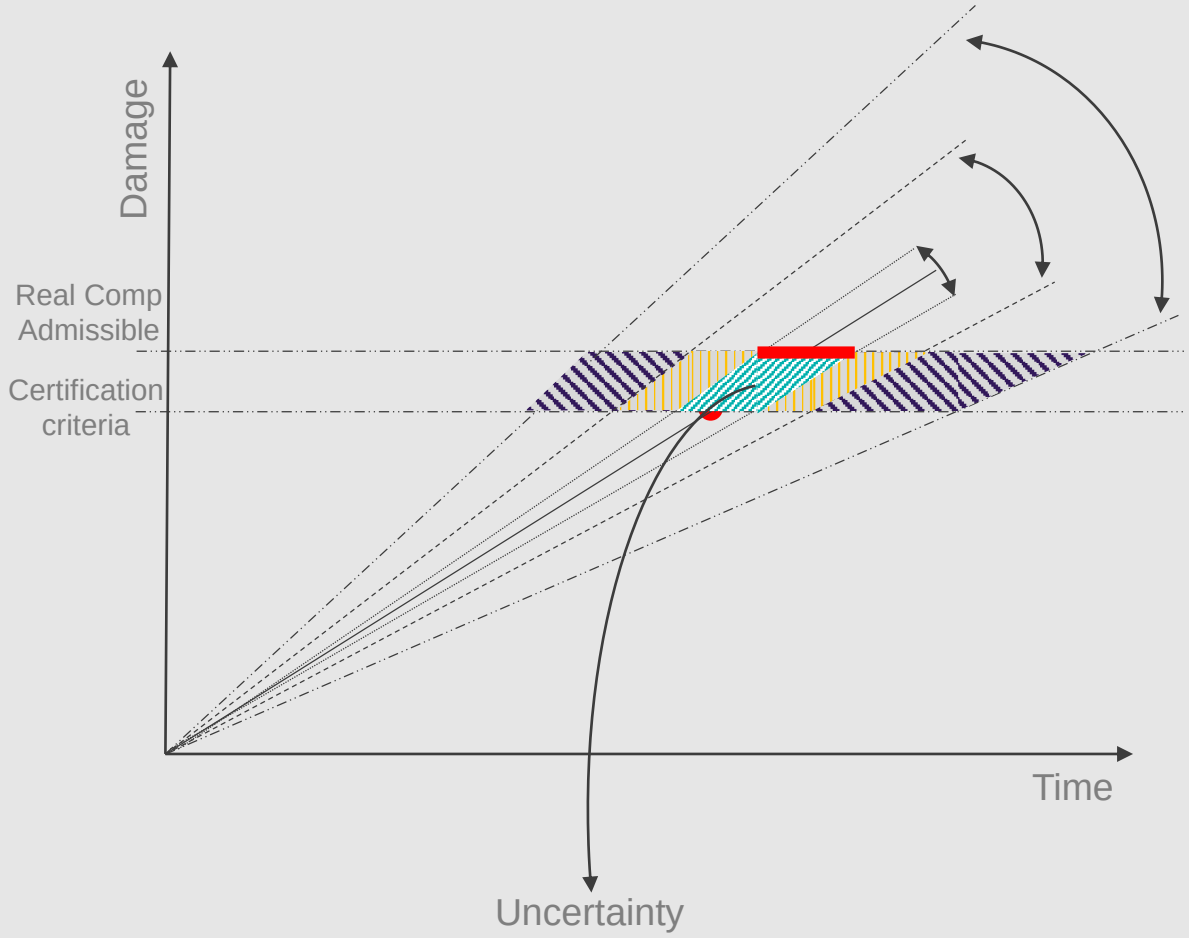
- State of art in modeling, used for original design creation

Admissible limit for material used

- New S-N Curves based on real tests

Methodology for the assessment

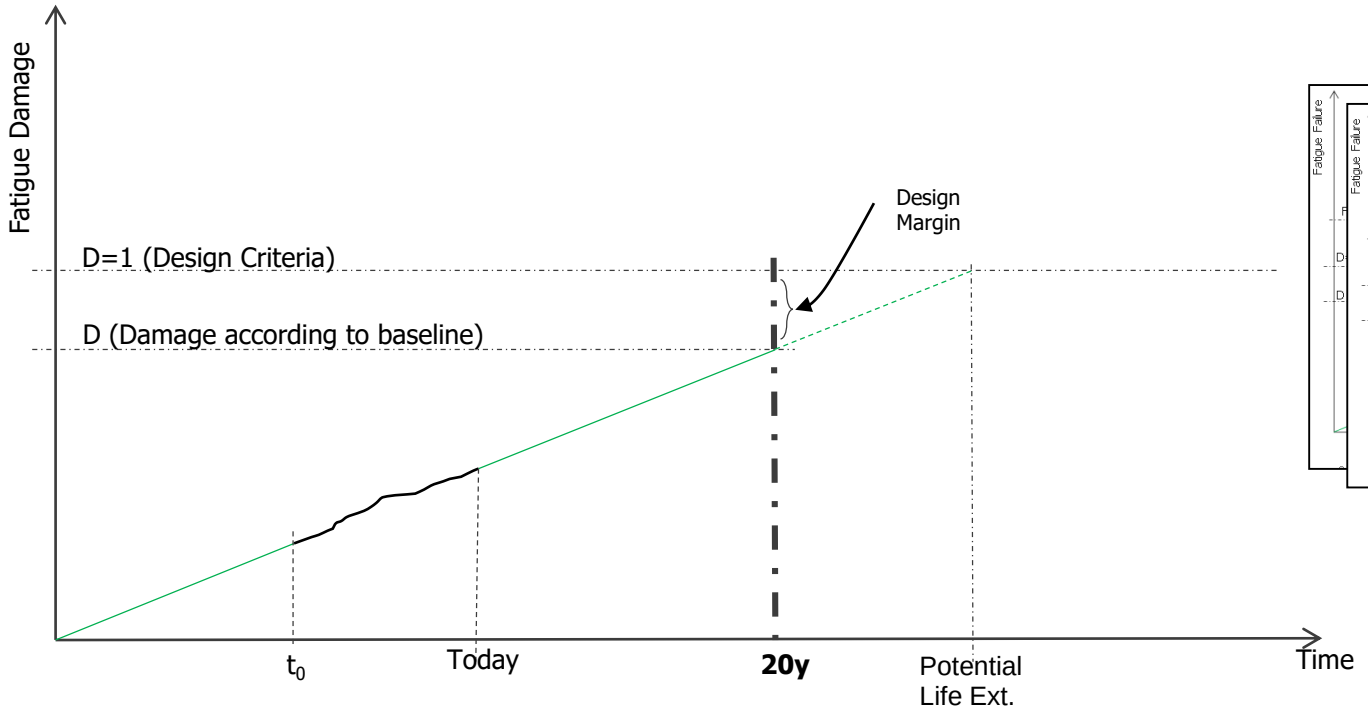
- Damage assessment real time

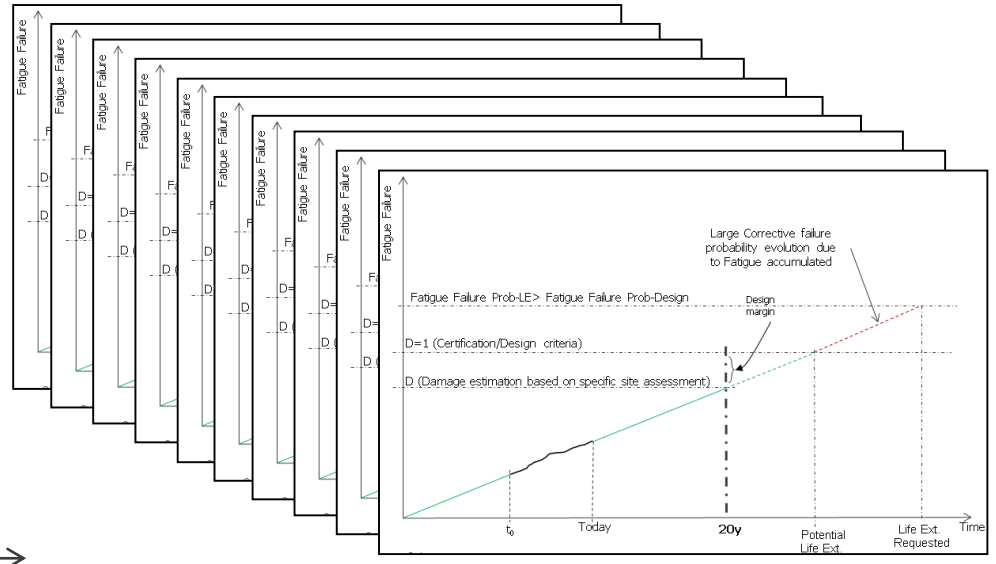


WindCommand – General Vision

MVP (Minimum Viable Product) description:

- The system will be able to track the fatigue damage evolution, in recurrent basis (on-line), without impact in CAPEX for the assets.

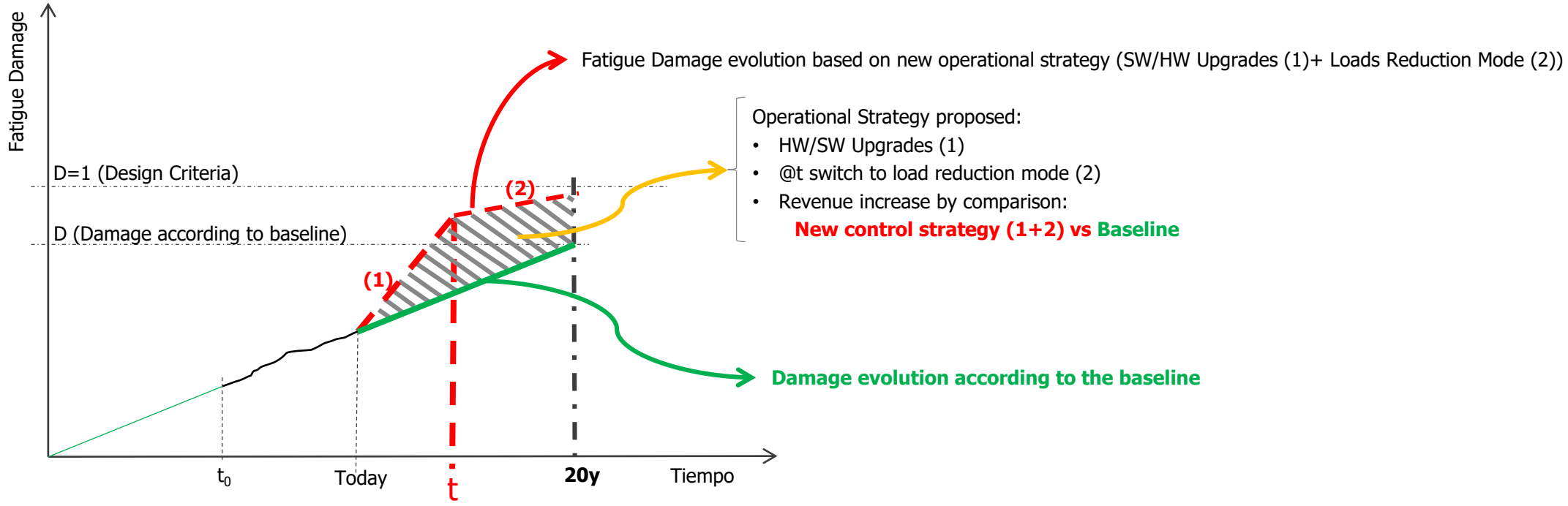




WindCommand – General Vision

Advanced functionality description:

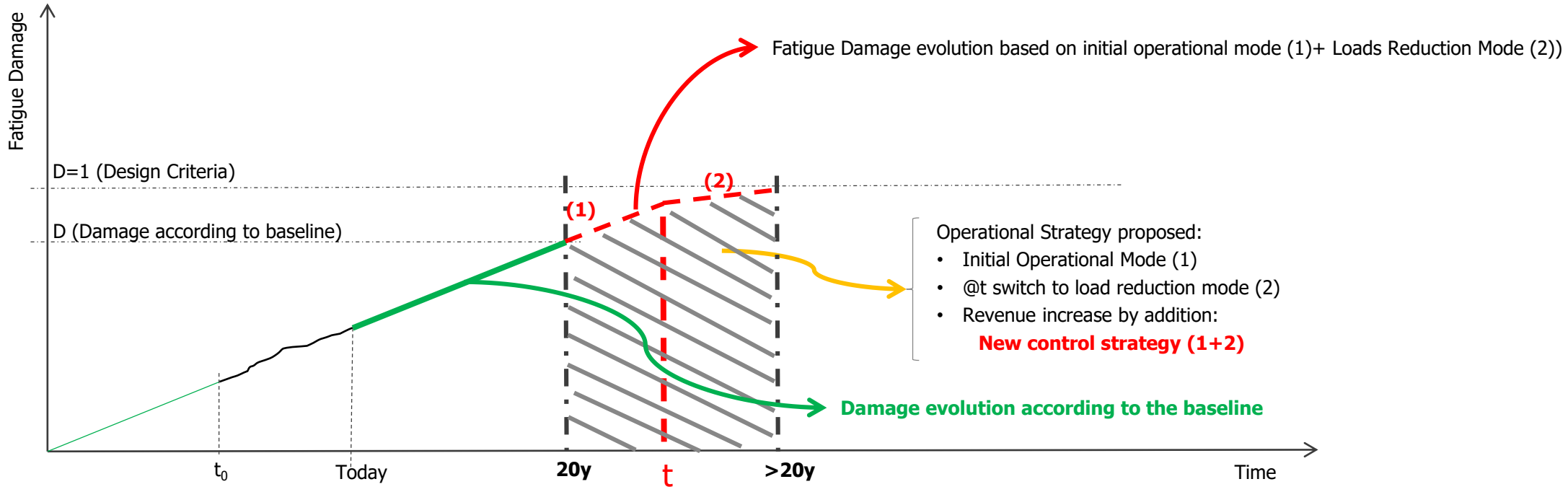
- The system will be able to identify the time (t) when, after a performance improvement applied, it will be needed to switch to a fatigue reduction mode in order to keep the original design risk, achieving the end of the predefined operational period.



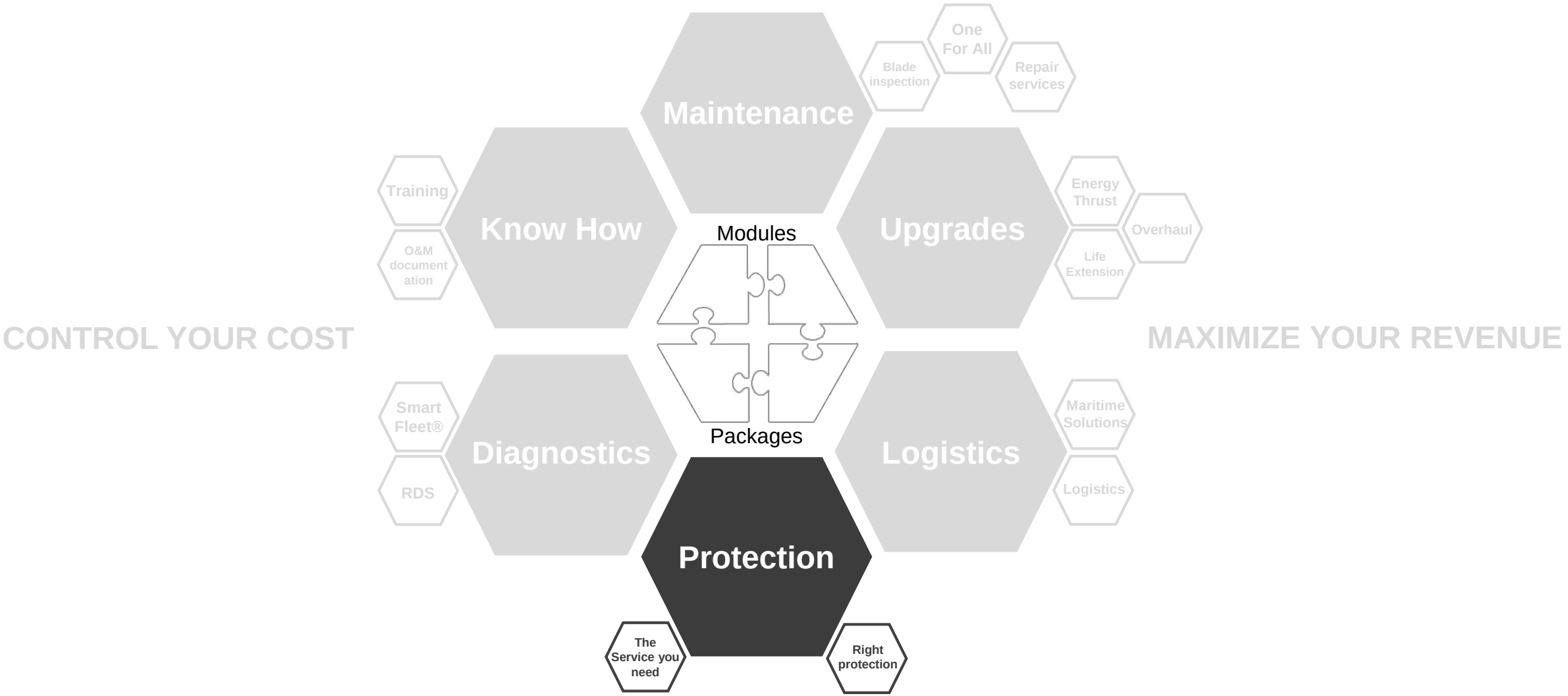
WindCommand – General Vision

Advanced functionality description:

- The system will be able to identify the time (t) when a load reduction mode should be applied in order to keep the original design risk, achieving the end of a new lifetime required.



Examples of solutions to MITIGATE YOUR RISKS



MITIGATE YOUR RISKS

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Fleet Analysis: Advanced data-driven digitalization

SGRE Diagnostic Center in DK and Remote Monitoring Centers in UK and ES

~28,000
Globally monitored wind turbines

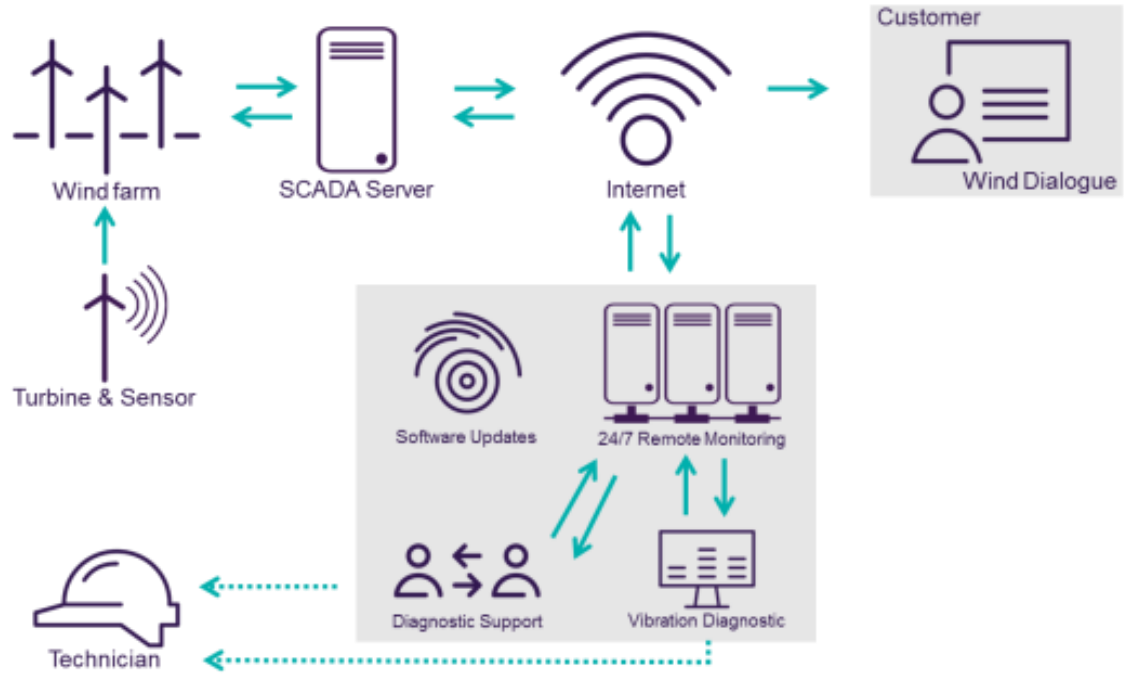
>200 GB/day
received data from numerous sensors

24/7
center manned all day – every day

>85%
of issues can be resolved remotely

98%
of serious component failures detected in advance

Domain
Wind farm insights and more than two decades of experience



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Example: Vibration Based Condition Monitoring

SGRE offering world-class vibration diagnostic capabilities

SGRE Vibration Based CMS carries out **early detection** of **slow developing damage** allowing for **optimized service planning** (e.g. mobilization of crane) reducing downtime, service cost and increases turbine output.

SGRE Vibration Based CMS carries out **early detection** of **fast developing damage**, resulting in preventive repair of components and **prevention of fatal breakdown** and consequential downstream damage.

SGRE can provide quick **scan of global fleet** of SGRE turbines as a preventive measure for fleet wide irregularities/early damage detections.

With an SGRE Vibration Based CMS service in place insurance companies will often allow for **better insurance conditions** for your wind farm.

SGRE TCM and Vibration Based CMS is certified by Germanischer Lloyd providing you with a **3rd party quality stamp** of our capabilities.

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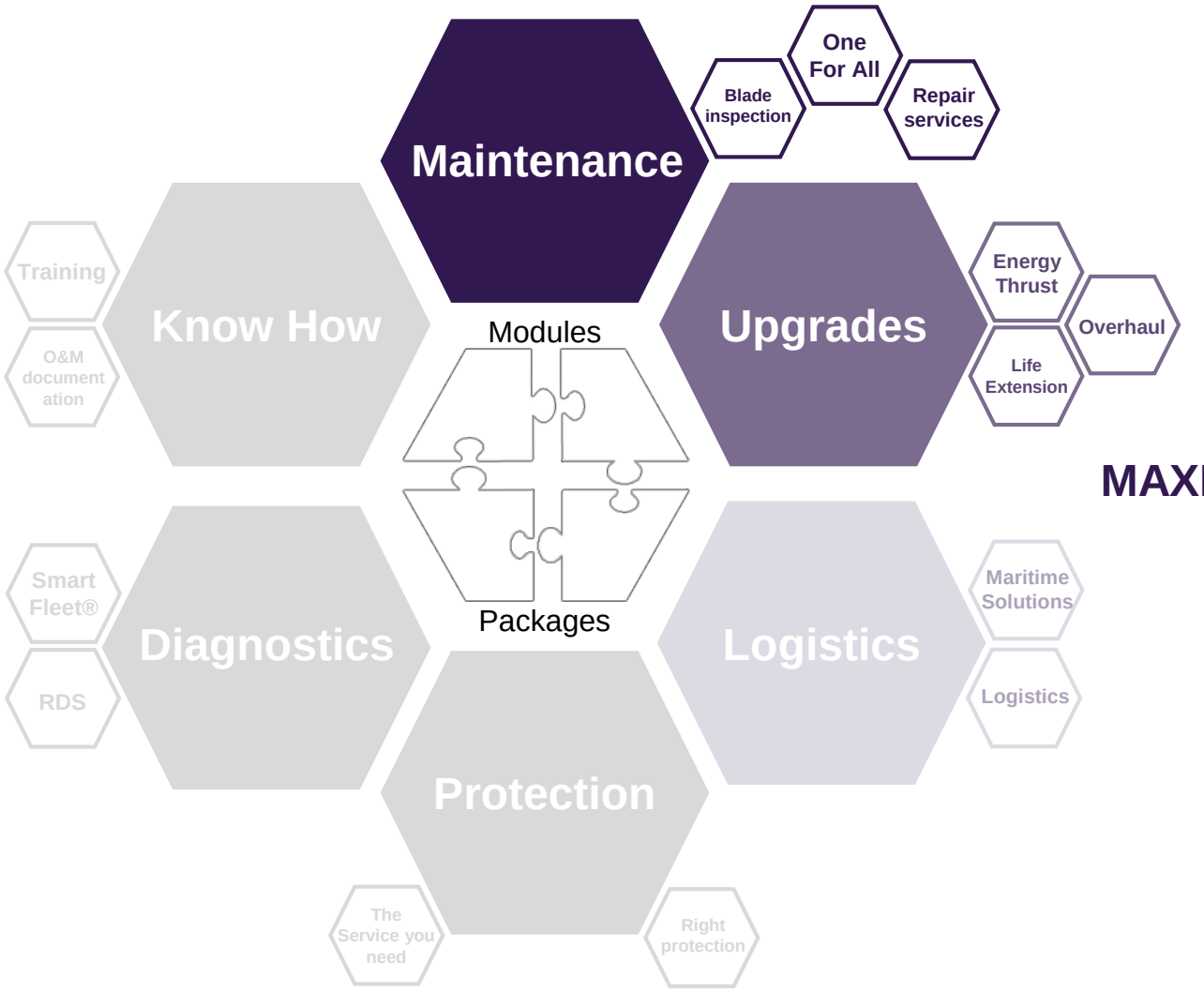
Examples of solutions to MAXIMIZE YOUR REVENUE



CONTROL YOUR COST

MAXIMIZE YOUR REVENUE

MITIGATE YOUR RISKS

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Example: Adaptive Control Strategy

Intelligent software feature

- Software functionality that can be **installed remotely** on each turbine in the wind farm, and **operated and controlled at turbine level**
- The technology assesses the turbine's loads and can **provide load alleviation in all wind directions**. It is only activated if conditions are exceeding design limitations
- This leads to **lower curtailment level** compared to the standard fixed curtailment, hence less production loss
- ACS **can be used to extend the lifetime** of the turbine under site-specific conditions

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How it improves the business case: ACS Power curve

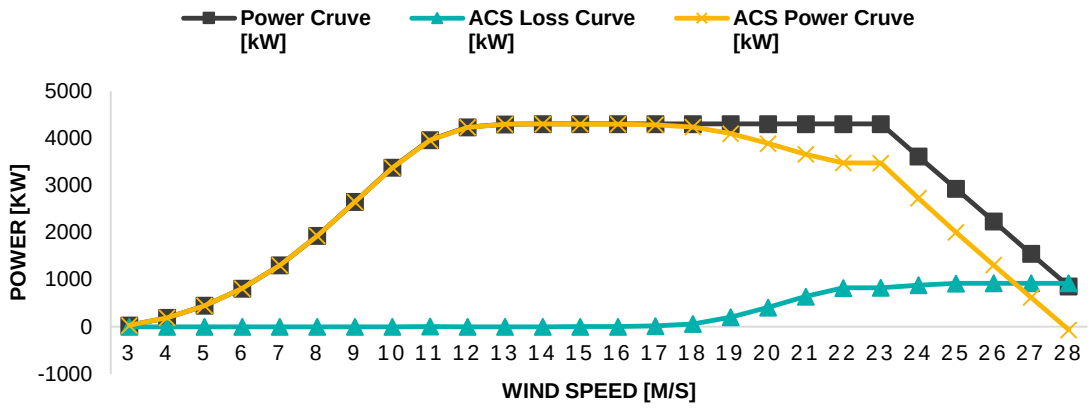
- ACS loss curve being estimated during site assessment.
- The ACS reduction in a given moment will depend on the loads (as deducted from the accelerations) and the loads in turn depend on the wind speed, TI, shear, veer etc. in that particular moment.
- In practice this will mean different reductions for a specific wind speed e.g. depending on wind direction.
- The loss curve(s) express the long term average power reduction at the different wind speeds.

~7.5% Customer Gain Using ACS

Annual Energy Production - Net : 14293 MWh

Traditional Sector Management	Adaptive Control Strategy
AEP: 13121 MWh & Loss : 8.2%	AEP: 14189 MWh & Loss : 0.73%

Turbine Model – SWT-DD-130 | Number of turbines – 22



Empowering your business case

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Thank you!

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