Wind Turbine Life Extension

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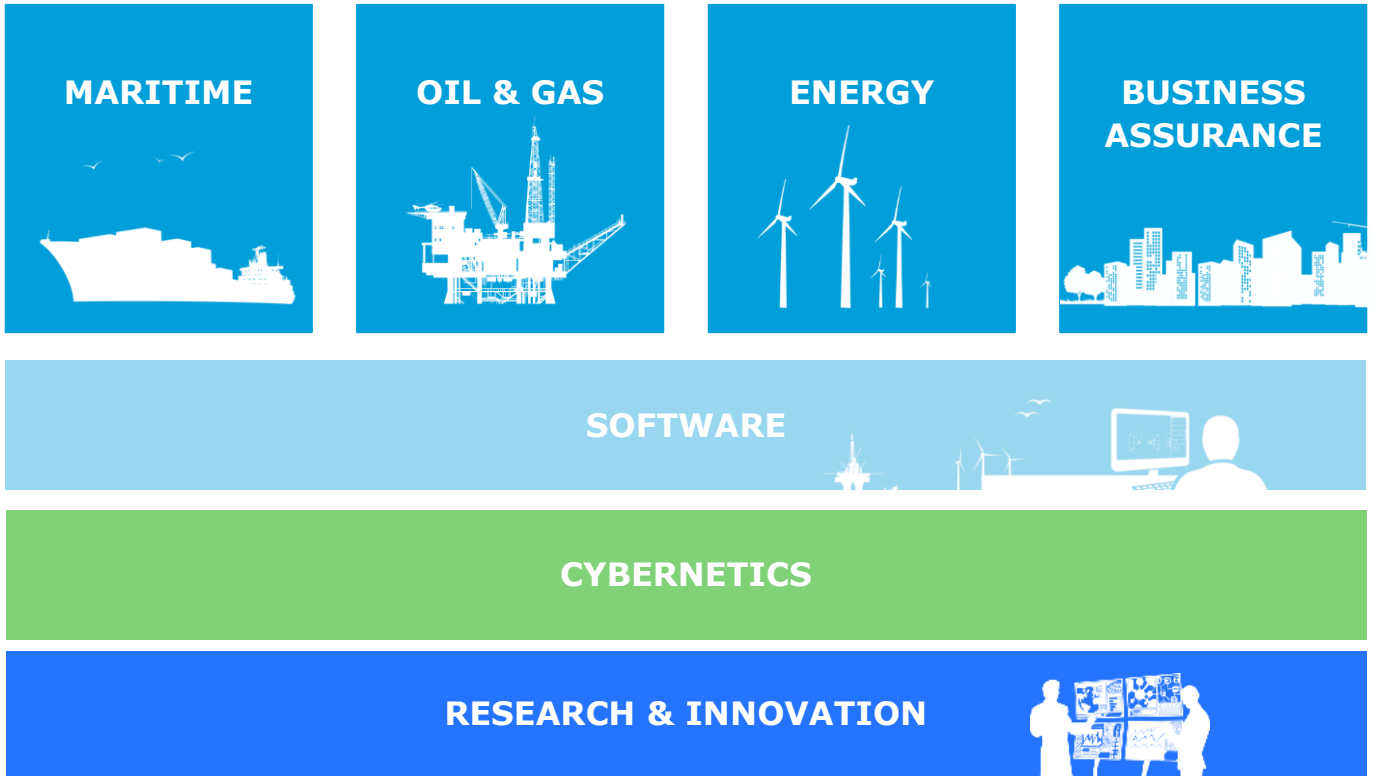
DNV GL: Organized to maximise customer value



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The risks of extending turbine life

Image source: www.renewableenergyworld.com

DNV GL: "Guideline for Continued Operation of Wind Turbines (2009)
DNV GL-ST-0262: Lifetime extension of wind turbines (2016)
DNV GL-SE-0263: Certification of lifetime extension of wind turbines (2016)

New DNV GL Renewables Certification standard

- DNVGL-ST-0262 Lifetime extension of wind turbines
- DNVGL-SE-0263 Certification of lifetime extension of wind turbines

Table A-1 Methods for lifetime extension assessment

Method	*Service*	*Main deliverables*	*Result*
Lifetime extension inspection (LEI)	Lifetime extension inspection (LEI)	Report "Lifetime extension inspection"	Suitability for lifetime extension
Simplified approach for lifetime extension	Analytical part Lifetime extension inspection (LEI)	Statement of compliance "Analytical part lifetime extension, simplified approach" Certificate "Lifetime extension, simplified approach"	Proof of strength and stability
Detailed approach for lifetime extension	Analytical part *) Lifetime extension inspection (LEI)	Statement of compliance "Analytical part lifetime extension, detailed approach" Certificate "Lifetime extension, detailed approach"	
Probabilistic approach for lifetime extension	Analytical part *) Lifetime extension inspection (LEI)	Statement of compliance "Analytical part lifetime extension, probabilistic approach" Certificate "Lifetime extension, probabilistic approach"	

*) Remark:

The analytical part may be performed in two steps:

Step 1: Wind turbine type specific, performed e.g. by the wind turbine manufacturer

Step 2: Wind farm site specific, performed e.g. be the wind farm operator

Wind turbine life assessment – combined knowledge

Turbine Engineering Support (TES)

Asset & Operations Management (AOM)

Project Engineering & Development (PE & PD)

Engineering assistance to new wind energy and marine renewables technology

Key services:

- Technology evaluation
- Design load analysis
- Control system development
- Mechanical engineering design support
- Bladed software for analysis of wind turbines

Targeted inspections:

- Visual inspections, blade inspection
- Gearbox inspections, videoscope, vibrations
- Review of hystorical failure rate
- SCADA condition monitoring

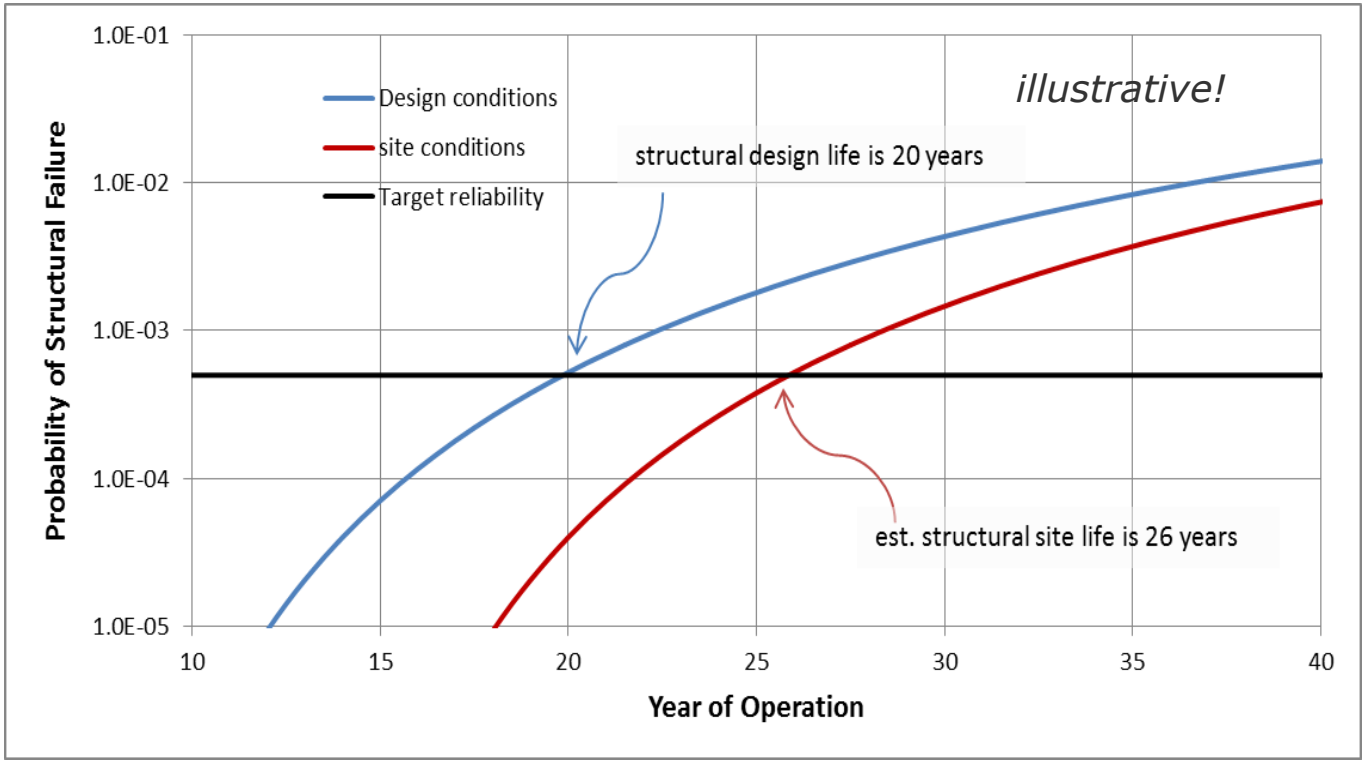
The risks of extending turbine life

Lifecycle strategies:	Continued operation:	Operation optimization:
▪ Continued operation ▪ Decommissioning ▪ Repowering	▪ Business as usual ▪ Retrofits ▪ Aero upgrades	▪ Turbine control ▪ Operational modifications ▪ Inspections & monitoring

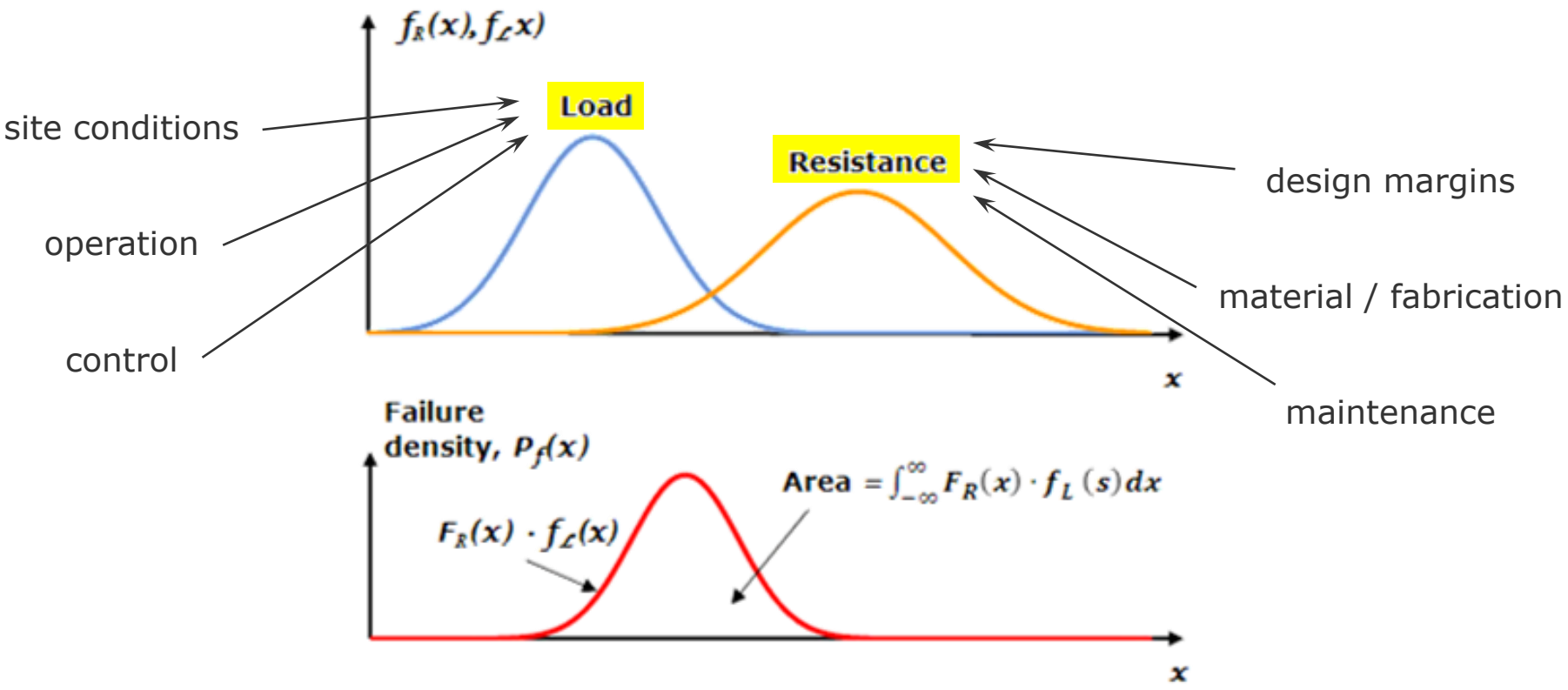
- **Costs**:
  - O&M
  - retrofits or modifications
  - additional inspections and monitoring
- **Technology**:
  - availability of OEM technical support
  - supply chain vulnerabilities
- **Energy sale & regulatory framework**:
  - terms of PPA or interconnection agreements
  - permits

What is turbine life?

- **Economic** or **useful life** (considers all factors impacting project costs and revenues)
- **Structural design life** vs. **structural site life** (driven by fatigue loads, probabilistic)



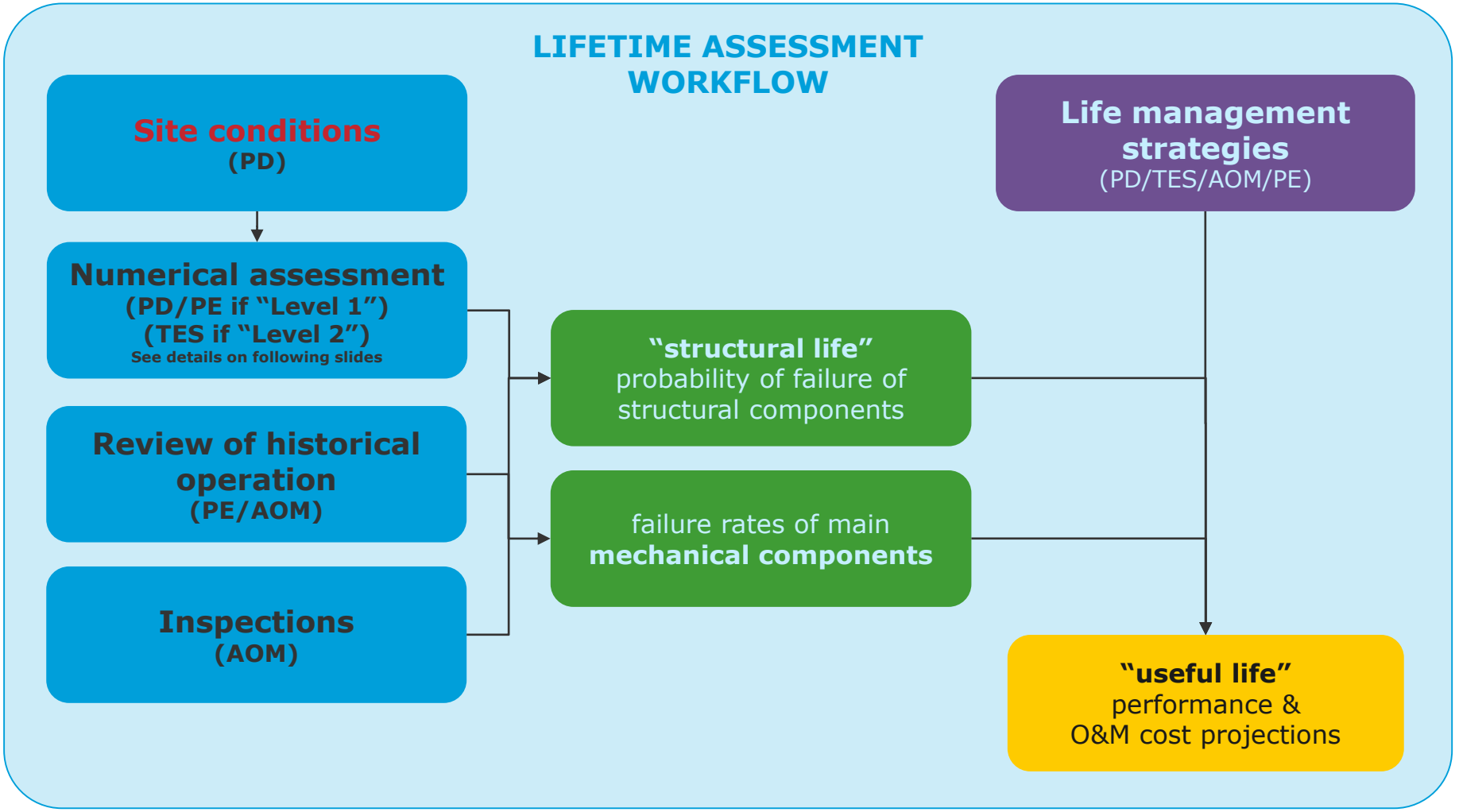
Key factors driving structural site life



Typical target reliability for wind turbines:

Annual probability of failure $\mathbf{P_f < \sim 10^{-4}}$

DNV GL's holistic approach to assessing turbine life



Approaches to the Numerical Assessment: "LEVEL 1"

"Level 1" Site Suitability Tool

Performs comparison of

site condition parameters

vs.

turbine design class parameters (IEC)

to provide a rough estimation of

load margins

in order **to confirm turbine suitability** from a structural & mechanical perspective.

Possible outcomes:

1) Suitability can be confirmed with comfort;
or
2) Confirmation subject to quality of inputs;
or
3) Suitability cannot be confirmed.

Therefore **conclusion on lifetime** is limited and can only be:

1) Design lifetime (typically 20 or 25 years) is expected to be achieved or exceeded;
or
2) Design lifetime cannot be confirmed.

In general, Level 1 serves only to form an opinion on expected lifetime.

Typically used for *Technical Due Diligence high level review* where available information and/or budget are limited.

Approaches to the Numerical Assessment: "LEVEL 2"

"Level 2" Site Suitability Tool

Assesses impact of the difference between

site condition distributions

vs.

turbine design class distributions (IEC)

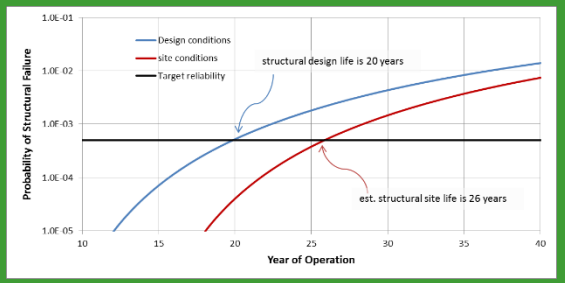
on
load margins

to estimate **annual probability of failure** of main structural components considering specific failure modes.

Outcome:

Annual probability of failure of
- tower
- nacelle main frame
- blades

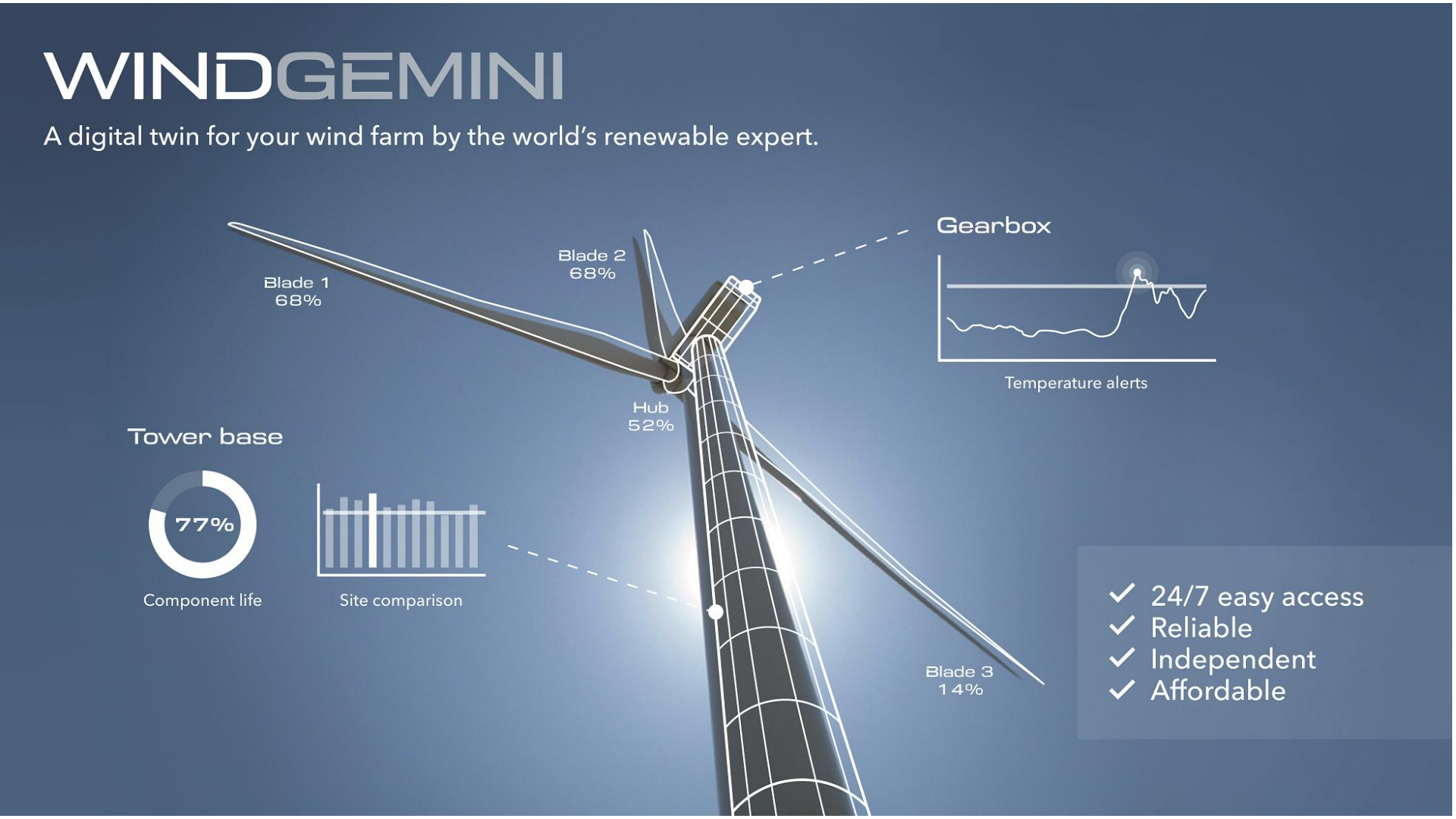
(Standard target reliability is typically 10^{-4} annual probability of failure in year 20, see eample figure – zoom in!)



Level 2 serves to provide a solid conclusion on expected lifetime.

Typically used for *Technical Due Diligence* of large portfolios, or for *Asset Lifetime Management* to enable implementation of a life extension strategy at a particular wind farm.

WIND Gemini – wind farm digital twin model



WIND Gemini – wind farm digital twin model

- Uses turbine and wind farm sensor data
- OEM agnostic
- "Near" real time

- Turbine life estimator
- Predictive maintenance
- Detection of sub-optimal performance

Drivetrain condition monitoring	Use 10-minute SCADA data for measuring component health and predicting failures
Structural integrity analysis	Online analysis of ~1 second SCADA data for tracking tower and rotor frequency
Turbine life estimator	Uses operational data to model wind field / site conditions data, model loads from matrix of loads from Bladed database and quantifies uncertainty
Performance watch-dog	10-minute SCADA data for real time identification of under performance

DNV GL's 'Life Assessment' track record

Level 1 analysis (high-level)	• More than 17 500 MW analysed worldwide
Level 2 analysis (detailed)	• More than 500 MW analysed worldwide
Several wind turbine models	• Vestas, Gamesa, Nordex, Enercon, among others

Thank you

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