Wind turbine design drivers

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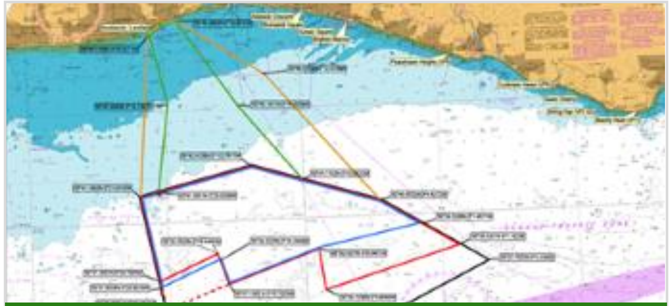
ONE PARTNER. WORLDWIDE SUPPORT.

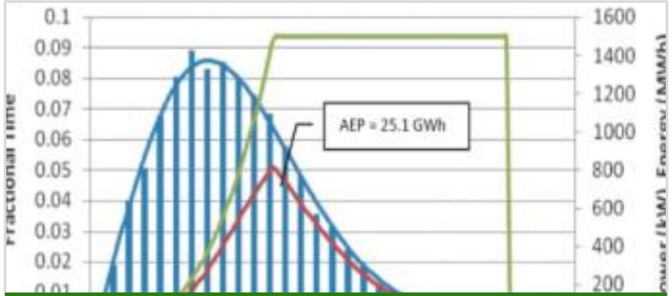
Skillset

- Naval Architects
- Master Mariners
- Civil & Structural Engineers
- Marine Engineers
- Mechanical Engineers
- Geotechnical Engineers
- Metocean Engineers
- Hydrodynamicists
- Subsea, Cable & Pipeline Engineers

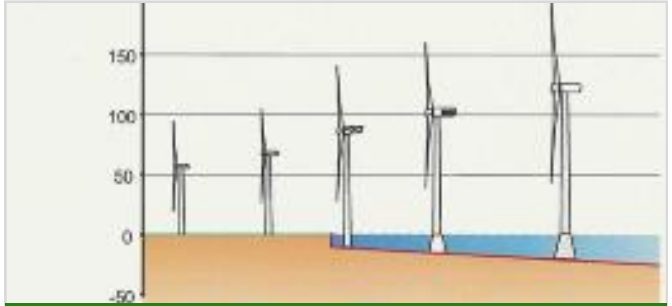
Technical Services Overview



Planning & Permitting



Wind Resource Assessment



Turbine Review, Selection & Procurement

Design engineering

Transport & Installation

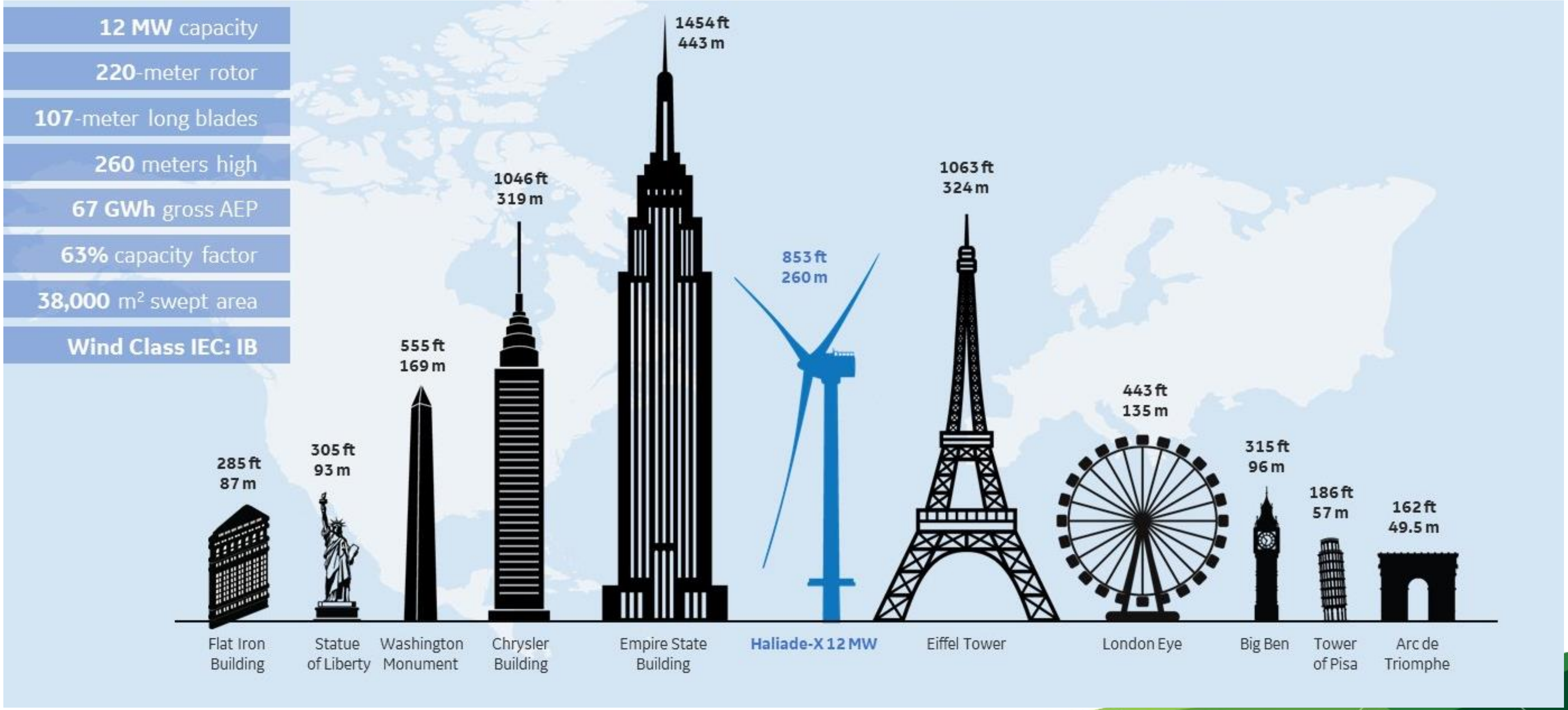
Operational Services

Outline

- Wind turbine scale
- Design drivers:
    - Fatigue loading
    - Extreme loading
- Design standards
- Drivers for SHM & NDT

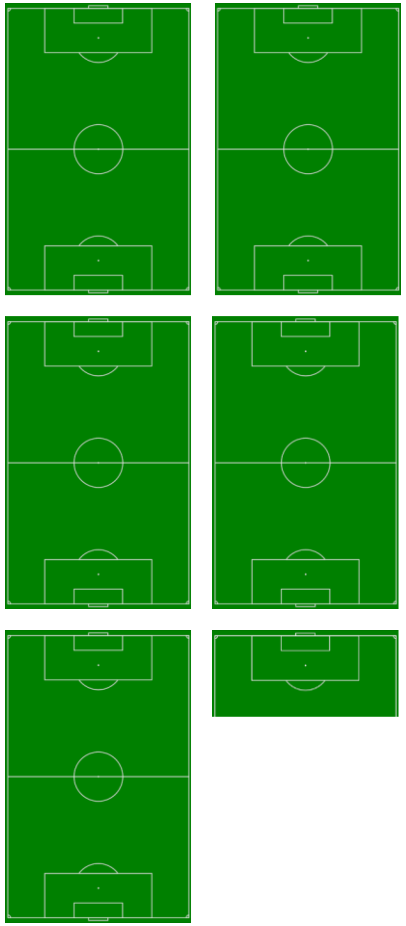
Wind turbine scale

GE Haliade-X 12MW



GE Haliade-X 12MW

GE Haliade-X 12MW



5.3 football pitches

GE Haliade-X 12MW

Mass flow rate through rotor disk at rated wind speed: 373 tonnes/s

50 Routemaster buses

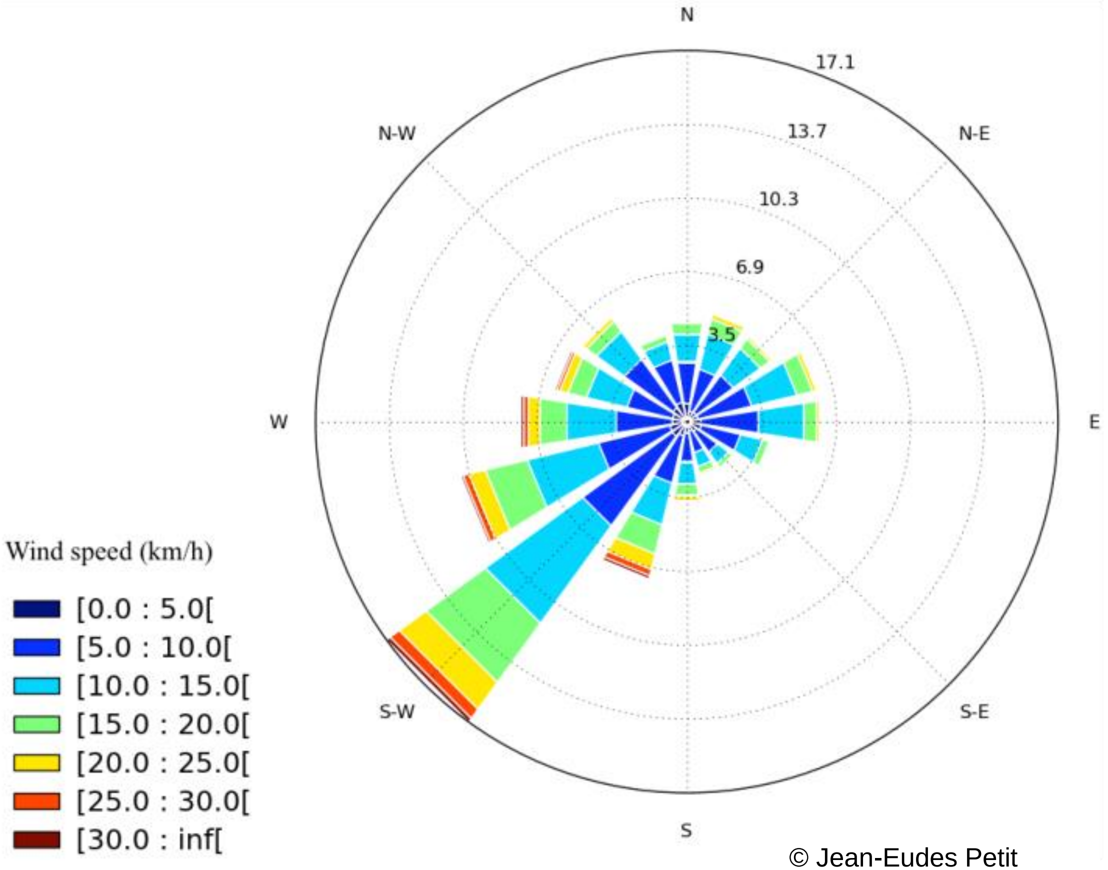
Design drivers

External Conditions + Design Situation = Design Load Case

Normal External Conditions + Normal Operation

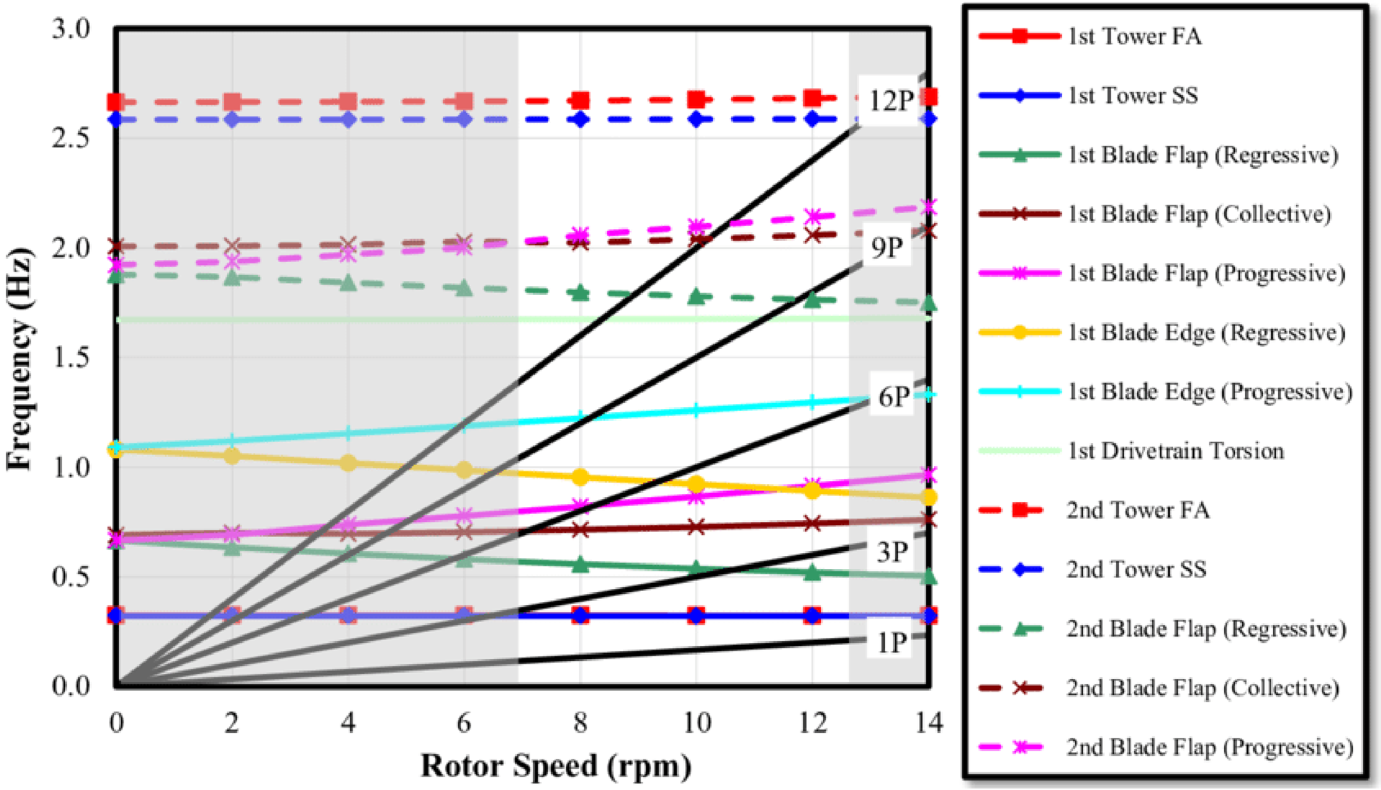
Fatigue loading

- Wind turbines are fatigue machines!
- Flexible / dynamic structures – multiple modes of vibration
- Stochastic aerodynamic & hydrodynamic loads
- Drives design of:
  - Hub
  - Mainframe
  - Tower welds
  - Grouted joints
  - Support structure joints
  - Rolling elements (gears & bearings)



Dynamically active structure

- Campbell diagram reveals complex interaction between excitation frequencies & modal frequencies of the structure.
- Drives design of:
  - Support structure stiffness
  - Blade mass / stiffness
  - Control system



External Conditions	+	Design Situation	=	Design Load Case
Normal External Conditions	+	Normal Operation		
Extreme External Conditions	+	Normal Operation		

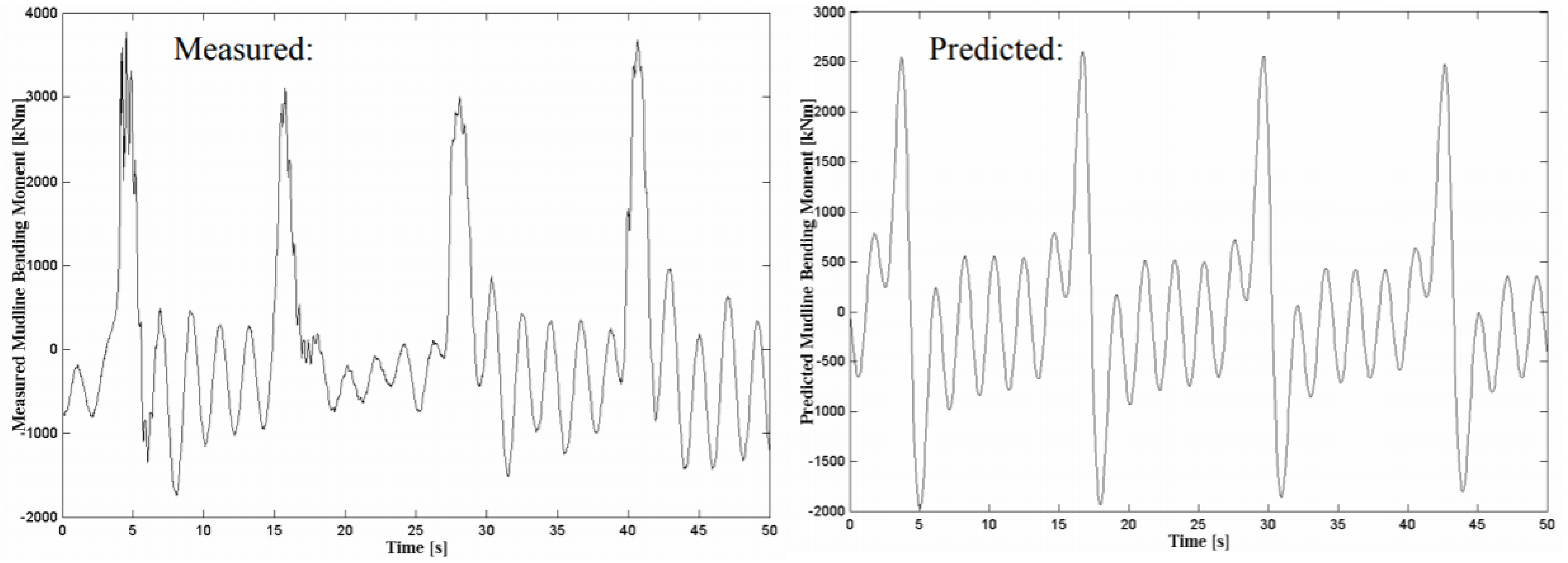
Extreme loads – extreme environmental conditions

- Design standards specify the combination of 50-year return environmental conditions with a normally operating / idling turbine.

Damage caused by typhoon Maemi in 2003 (Ishihara et al, 2005)

- Blade / tower clearance, tower buckling & foundation design (& others) are driven by extreme loads

Extreme loads – extreme environmental conditions



Blyth V66 monopile subjected to 8m waves

- Extreme waves drive air-gap requirements & (possibly) foundation strength

External Conditions	+	Design Situation	=	Design Load Case
Normal External Conditions	+	Normal Operation		
Extreme External Conditions	+	Normal Operation		
Annual External Conditions	+	Fault States		

Extreme loads – fault conditions

- Consequences of sensor & actuator faults are analysed in combination with 1-year return environmental conditions

Nordex N80/2500 at Screggagh wind farm

Some other design drivers

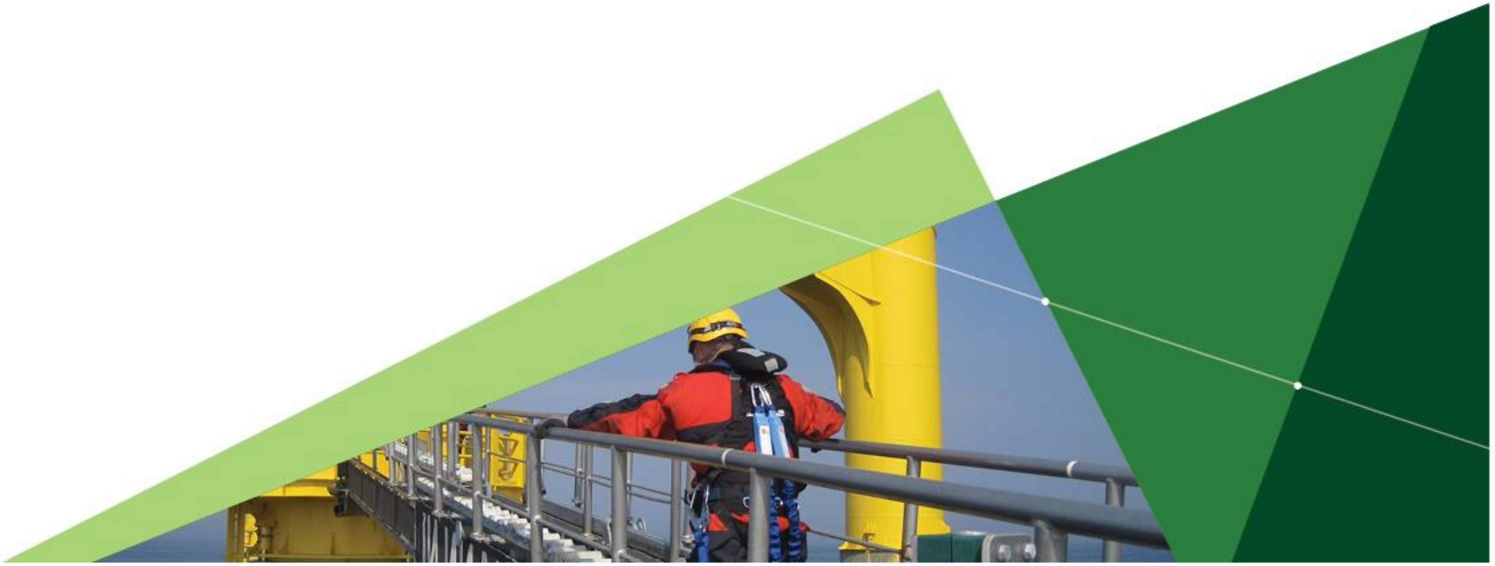
Corrosion

Scour

Lightning strike

Leading edge erosion

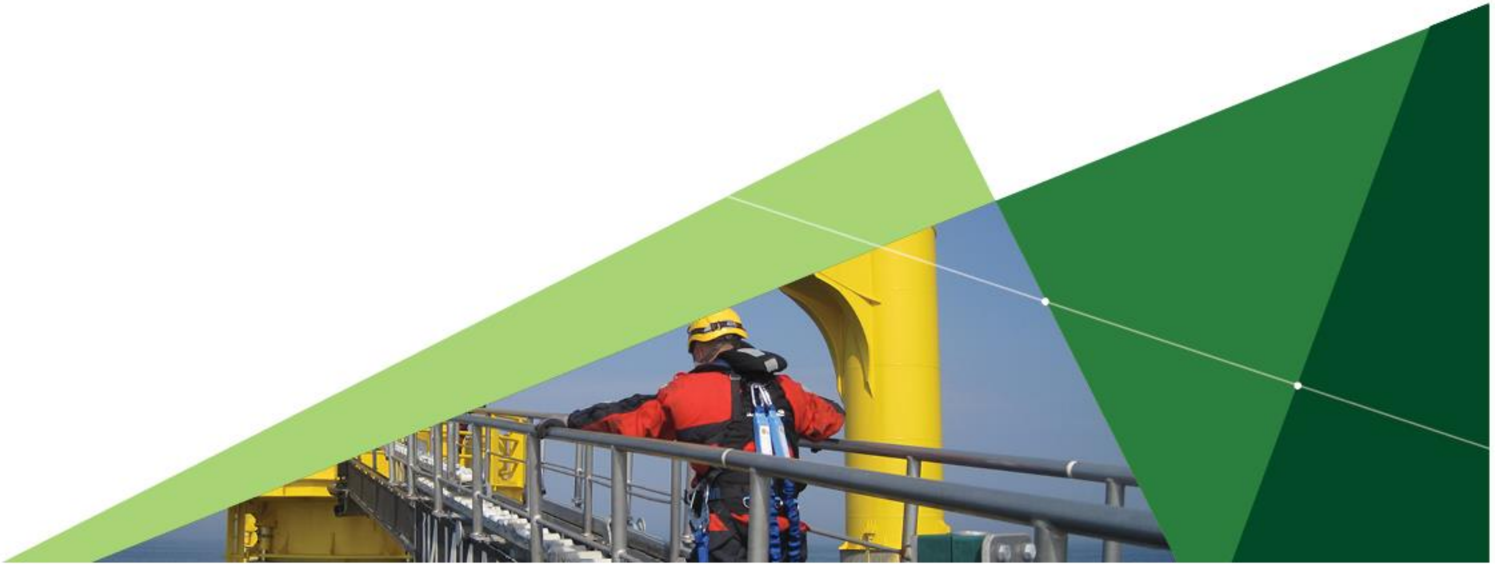
Design standards



Design standards for wind turbines

- IEC 61400-1 “Wind turbines – part 1: Design requirements”
- IEC 61400-3-1 “Wind turbines – part 3-1: Design requirements for offshore wind turbines”
- DNVGL-ST-0437 “Loads and site conditions for wind turbines”
- DNVGL-ST-0126 “Support structures for wind turbines”
- DNVGL-ST-0361 “Machinery for wind turbines”
- Deutsche Institut für Bautechnik (DIBt) “Guidelines for loads on wind turbine towers and foundations.”
- DS472 “Load and Safety for Wind Turbine Structures”
- NEN6096 “Safety Requirements for Wind Generators”
- ABS “Guide for Building and Classing Offshore Wind Turbine Installations”
- & others…

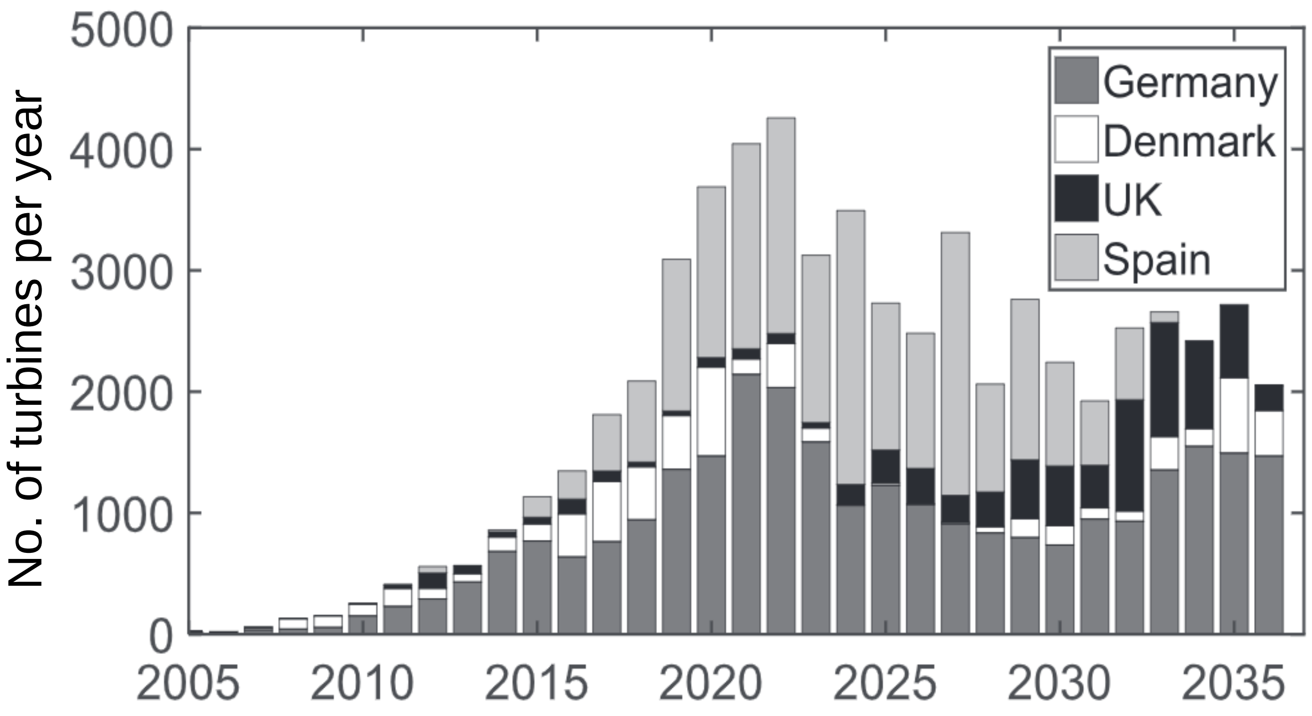
Drivers for SHM & NDT



Drivers for SHM & NDT

- Owners need to understand the residual life of their turbines as they prepare for:
  - Lifetime extension
  - Adaptions
  - Decommissioning / repowering
- SHM should begin well before year 20 (!) but best practice is not well defined in the wind industry.

Number of onshore turbines per year reaching 20 years old



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