



**Managing O&M Risk
for offshore windfarm
by Predictive maintenance**

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Who are we?

- ✕ ONYX InSight **is a global leader** in predictive maintenance for wind energy
- ✕ We provide **unbiased predictive maintenance** analytics underpinned by **real-world engineering expertise**, enabling clarity and control over your O&M decisions
- ✕ **Global reach:** Engineering offices in UK, USA, South Korea and India

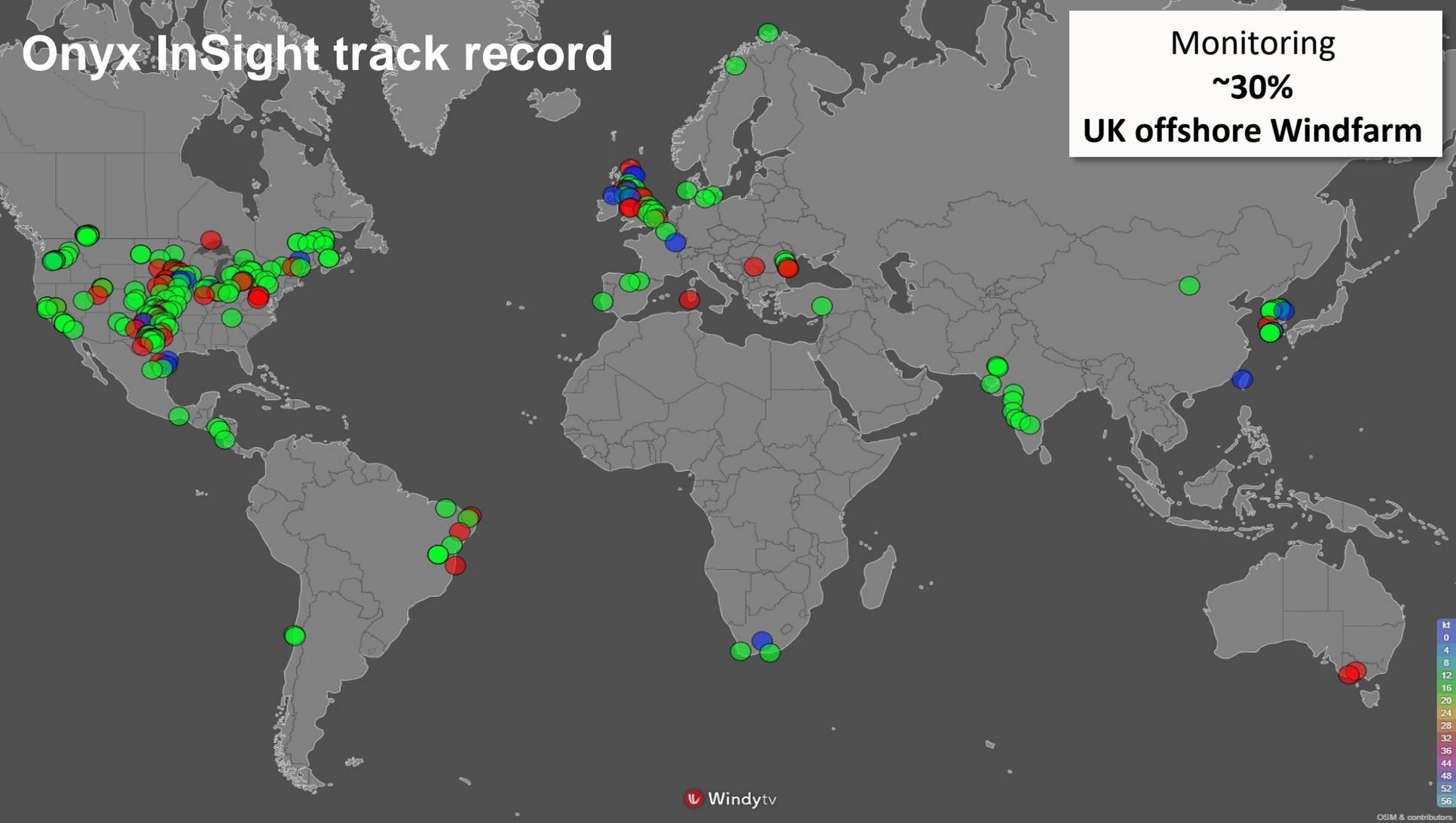


Our Track Record :

- ✕ **5000+** wind turbine monitoring services
- ✕ **2000+** gearbox teardowns and inspections
- ✕ **3.4 GW** of installed offshore wind turbine types covered
- ✕ Due diligence services for more than **26GW** of assets worldwide
- ✕ **10+ patents** on our technology

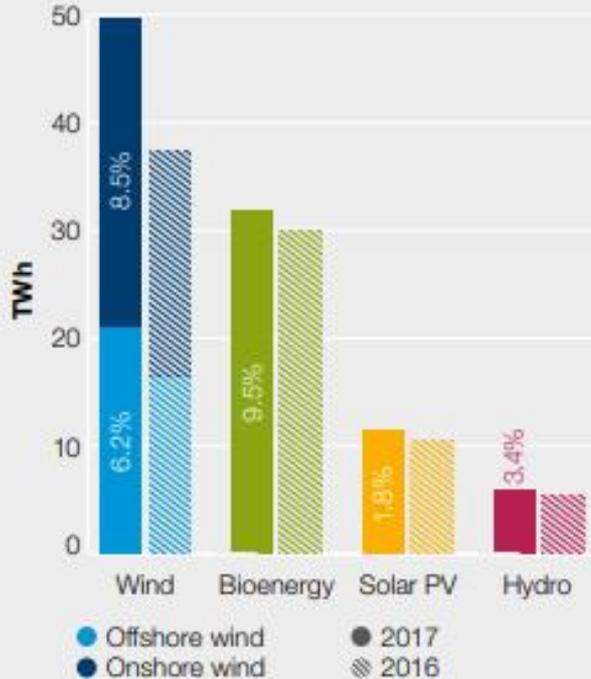
Onyx InSight track record

Monitoring
~30%
UK offshore Windfarm



Overview of UK Offshore

Renewable energy represented 29.4% of the UK's electricity generation mix in 2017, of which 6.2% was provided by offshore wind.



UK offshore wind generated over **20.8 TWh** last year, that's enough to supply the electricity needs of **5.3m homes**, around **20%** of the UK total

UK Offshore Wind Farm O&M Target

- UK Past Target:
 - Cost of Energy: £150 per MWh
 - O&M Practice: - 1 planned visit / turbine / year (6 days/year – Servicing)
- **5~12 unplanned visits per turbine per year**

- UK Round 3 Target:
 - Cost of Energy: £100 per MWh
 - O&M Target: - 1 planned visit / turbine / year: 2-5 people; 2-4 days
- **2 to 3 unplanned visits per turbine per year**

UK's Round 1 windfarm case study

60MW Offshore Wind Farm, Scroby Sand, UK

- UK Round 1 off shore wind farm
 - Operation since 2004 March
 - Vestas V80 – 60 MW
- **E.On's O&M STRATEGY**
 - 5 year Warranty Operations and Maintenance Agreement
 - `Hands off ` Approach
- **Windturbine Reliability Issue**
 - Initially had a history of poor performance, this has improved dramatically



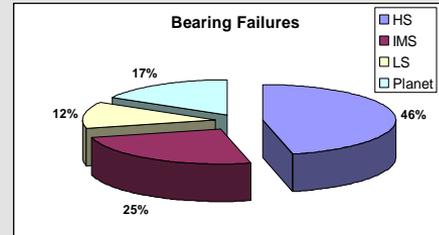
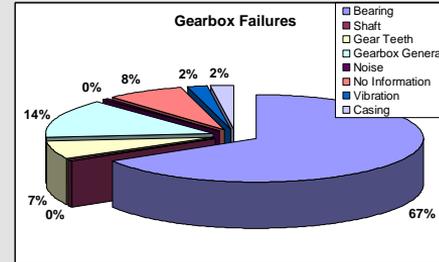
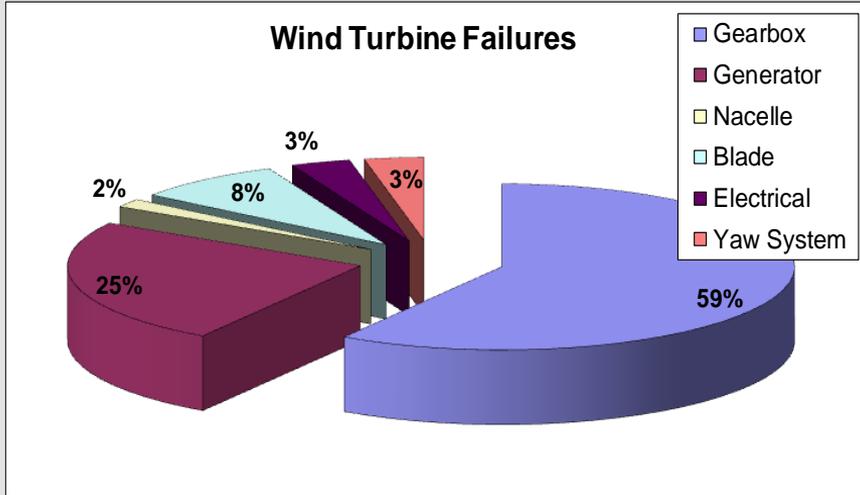
* Wind Power Monthly, vol. Dec 2010

UK's Round 1 windfarm case study

60MW Offshore Wind Farm, Scroby Sand, UK

Wind Farm Failure Distributions

- Example failure distribution from 6 years operation of offshore wind farm.
- Gearbox had highest failure rates.



UK's Round 1 windfarm case study

60MW Offshore Wind Farm, Scroby Sand, UK



Scroby Sands, built by E.ON in 2004 with 30 Vestas V80 turbines, was one of the first offshore wind farms to be built and for the first five years of

operation, the O&M activity was largely managed under the terms of the warranty agreement with Vestas.

As this warranty approached expiry, E.ON reviewed its options and decided to take much of the O&M activity

in-house. This required a significant up-skilling of staff and a steep learning curve as E.ON sought to move to a much more proactive strategy, investing in a new service vessel and managing logistics. E.ON also tendered for a maintenance contract and, after receiving a number of bids, chose Vestas. In addition, Vestas was retained on a technical support agreement covering software upgrades, design changes and major repairs.

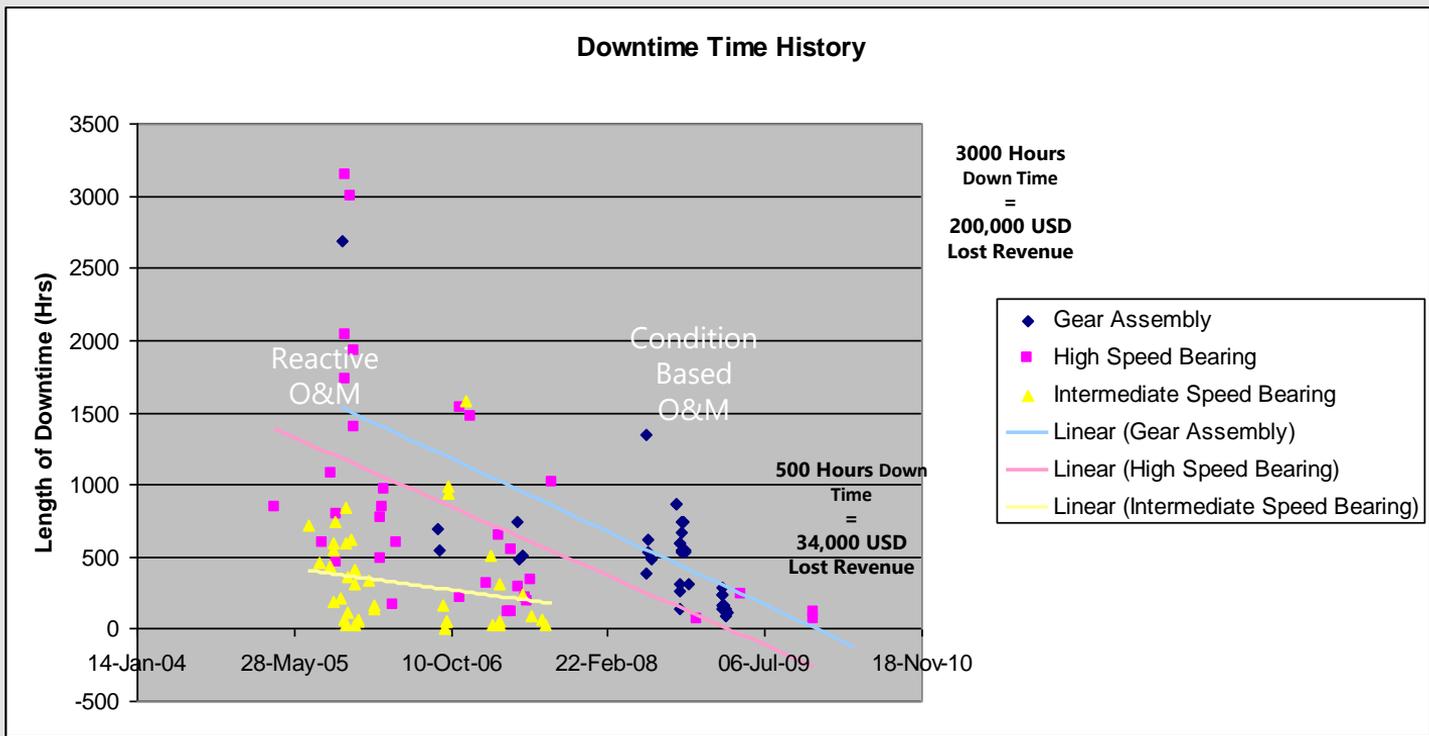
In 2013, the Vestas contract will expire and E.ON has decided to take on all of the maintenance activities internally, with all technical staff, including the technicians E.ON employs. This will complete the transition from a hands-off owner to a fully hands-on owner.

“If you’re proactive and you detect a bearing failing, you may be able to shut that turbine down for two days, change that bearing and it has cost you a few thousand pounds. If you fail to pick up the bearing failing, drive it to destruction and destroy the gearbox, the costs can be enormous. You could be waiting 12-14 weeks for a jack-up barge at tens of thousands of pounds a day.”

JON BERESFORD, OPERATIONS MANAGER SCROBY SANDS, E.ON

UK's Round 1 windfarm case study

60MW Offshore Wind Farm, Scroby Sand, UK



UK's Round 1 windfarm case study

Kentish Flats Offshore Wind Farm

Overview

- Round 1 windfarm, Vestas V90 x 30

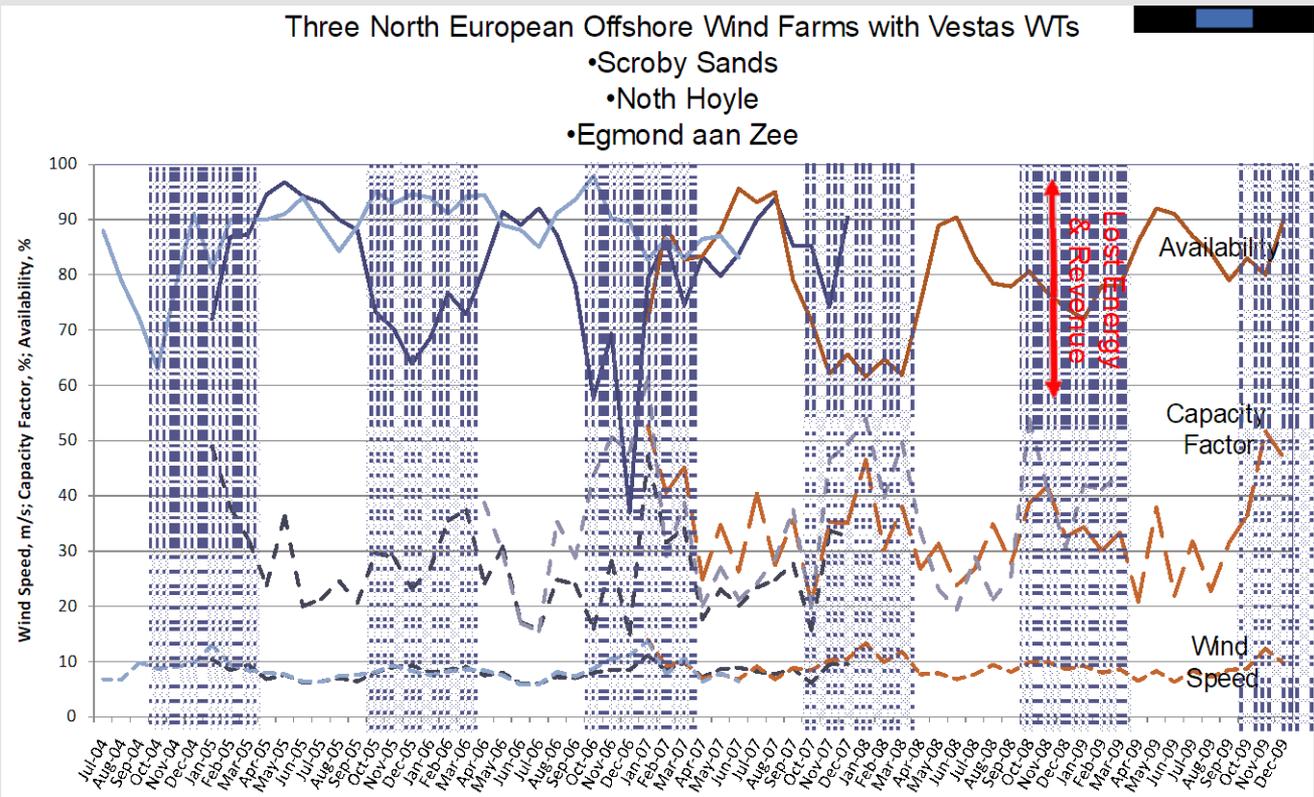
Availability

- **Average contractual availability for 2008 was 89.2 %, compared to 73.5% in 2007 and 87% in 2006.**
- Turbine availability has been affected mainly due to
 - bearing failures in the planetary gear stage, resulting in 20 gearbox exchanges.
 - Generator exchange

<i>Task</i>	<i>Year To Date</i>	<i>Project</i>
Gearbox Changes	20	CIM Upgrade
Gearbox Commissioned	17	Scheduled
Hub Re-alignment	20	Scheduled
DE Ground Brush Installation	18	CIM Upgrade
DE Bearing Replaced	18	CIM Upgrade
NDE Bearing replaced	20	CIM Upgrade
Internal Rotor Cable Changes	20	CIM Upgrade
External Rotor Cables	20	CIM Upgrade
Prop V/Vs	1	Scheduled
Accumulators	16	Scheduled
Hub Door Changes	1	CIM Upgrade
Oil Samples	37	Scheduled
6 month Lift Checks	60	Scheduled
Nav Light checks	8	Scheduled
TX Brackets	9	CIM Upgrade
Pitch Upgrades	2	CIM Upgrade
Fire Extinguishers	30	Scheduled
Yearly Service	30	Scheduled
Generator Exchange	20	CIM Upgrade
Voltage Contactor	30	CIM Upgrade
Roof Brackets	30	CIM Upgrade
Hydraulic Coupling	29	CIM Upgrade
Safety Key Boxes	30	CIM Upgrade
Hub Door Locks	30	CIM Upgrade
Skii Pack Exchange	26	CIM Upgrade
Encoder Change	4	CIM Upgrade
Rotor Lock Bolt Change	31	CIM Upgrade
Capacitor Cable Exchange	29	CIM Upgrade
Logo Exchange	12	Project
Numeric ID Lights	15	Project

Table 8: Component Improvement Management (CIM) and Scheduled works

UK Windfarm Performance in Round 1 (2004-2009)



Availability Varies significantly from 60% ~ 95% because of failures

Source : Trends in wind turbine reliability and availability in Europe & China, Peter Tavner



Commissioning stage performance

Figure 8: 2009

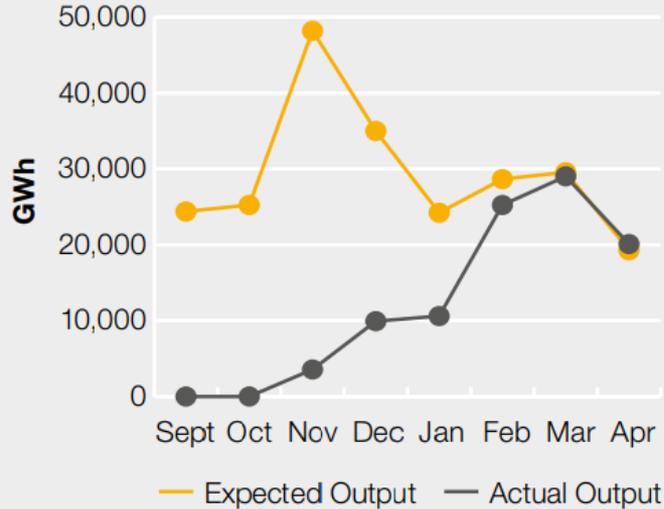
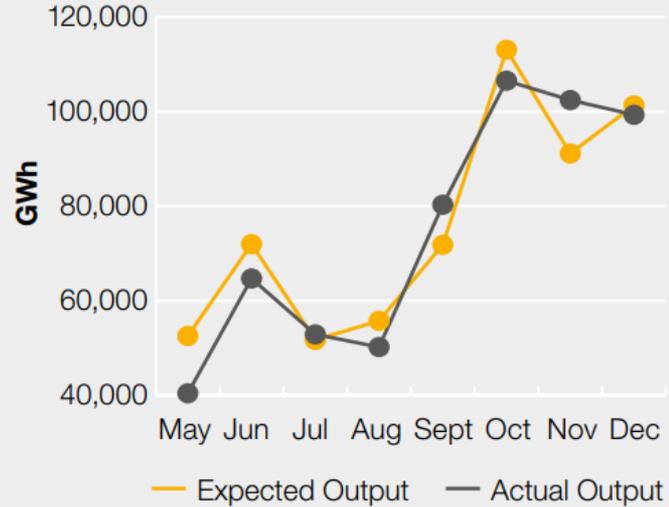
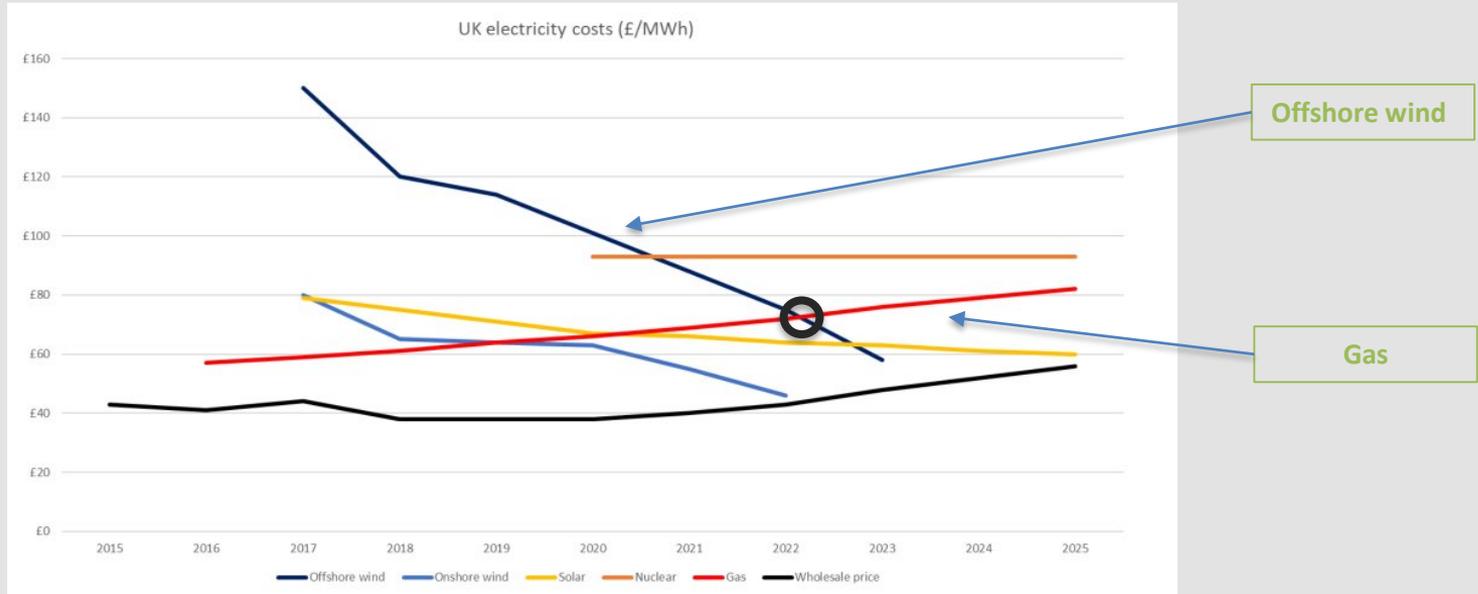


Figure 9: 2017



Capacity factor trend

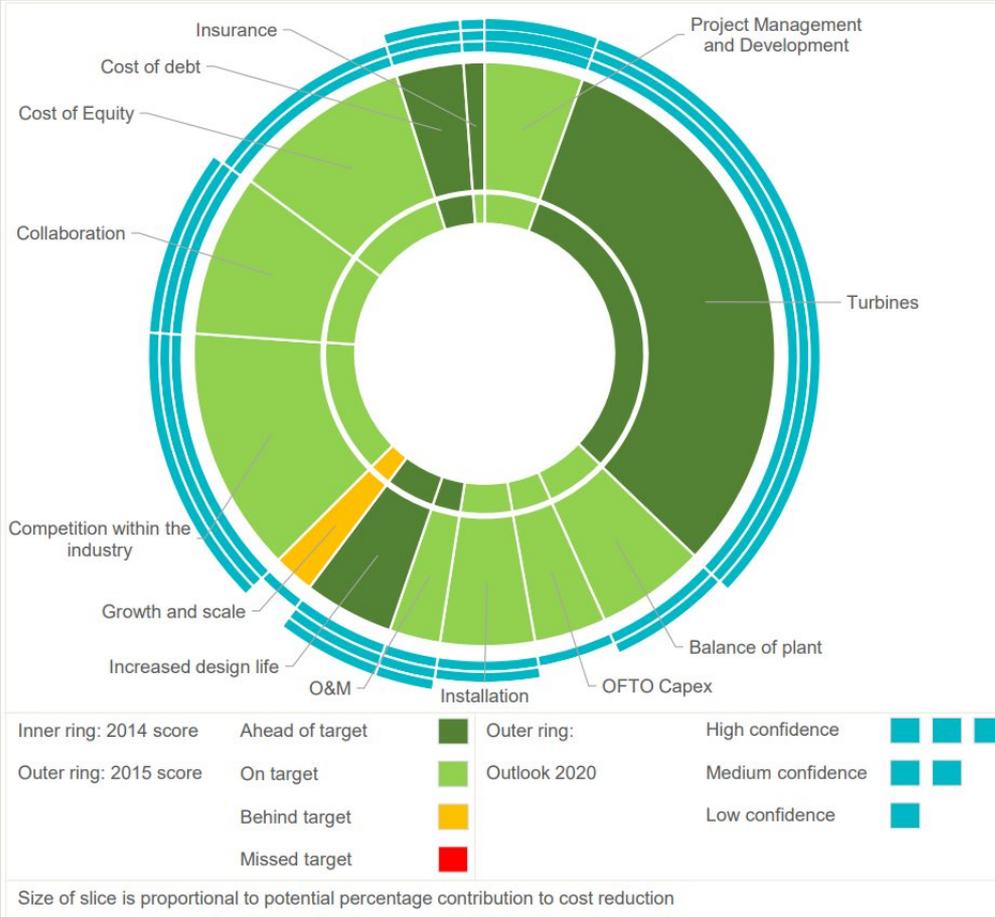


UK electricity costs (source: DBEIS CfD results, Carbon Brief)

Costs are falling rapidly

- Awarded strike prices in 2015 were 117/MWh on average (projects due for construction in 2018-2019).
- Awarded strike prices in 2017 were 63.25/MWh on average (projects due to be constructed in 2021-2022).
- This represents a 46% drop in 2 years.
- This compares favourably to the industry target of 100/MWh by 2020.

Current progress

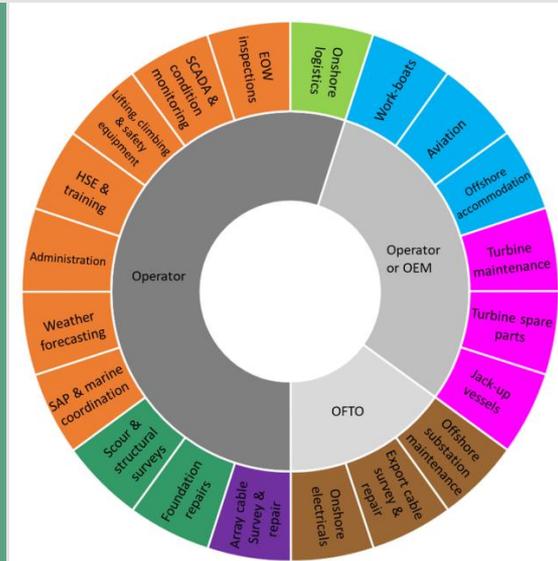
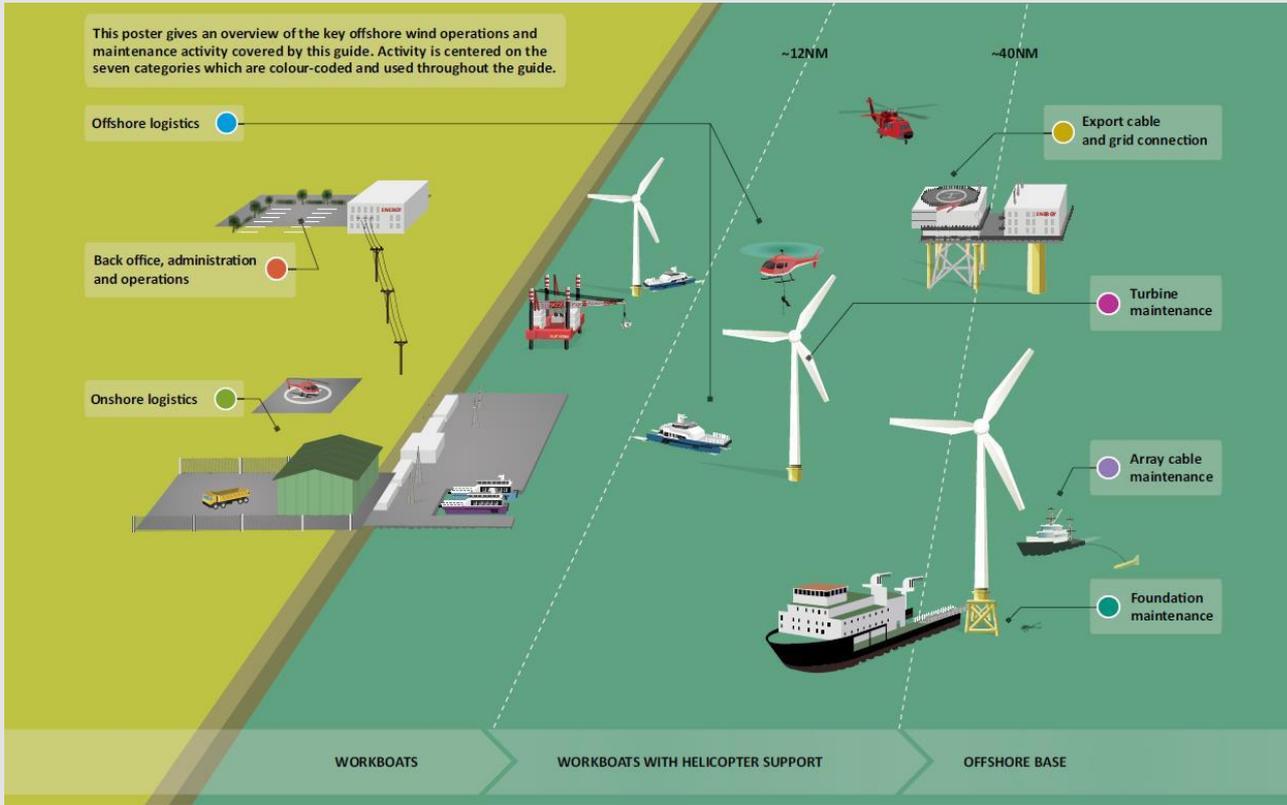


How cost target in O&M could be achieved?

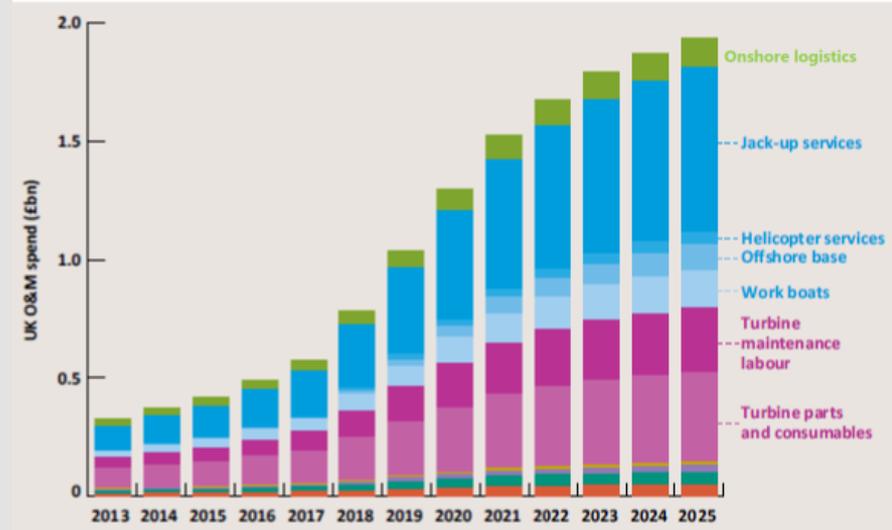
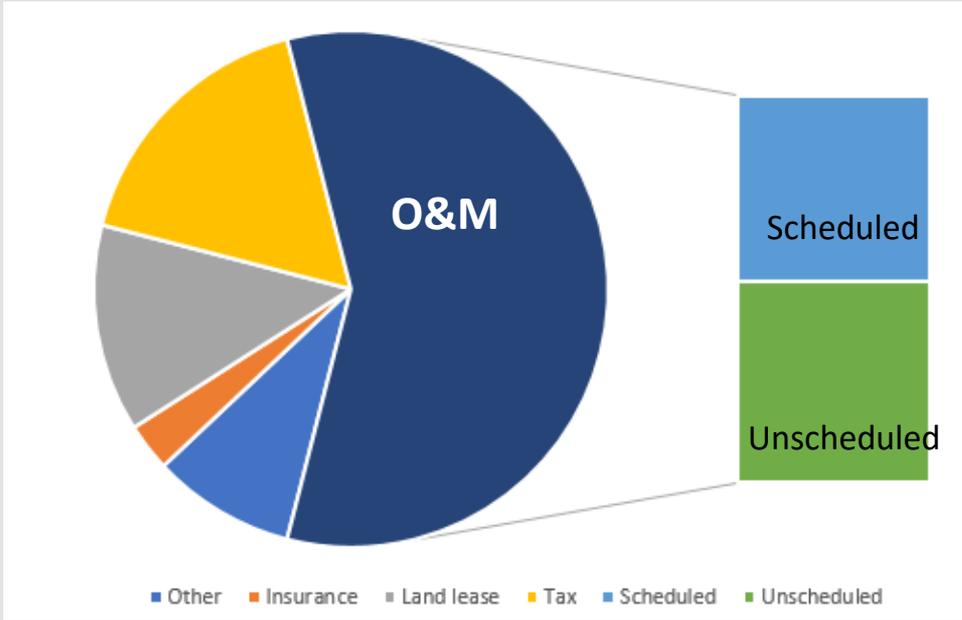
“Implementation of condition monitoring equipment and the resulting increased understanding of asset performance

Operations and Maintenance (O&M)		
There is significant progress in development of condition monitoring techniques and innovative maintenance strategies. Implementation of condition monitoring equipment and the resulting increased understanding of asset performance is valuable, but tracking the implementation of truly condition-based maintenance strategies should be considered.	Undertake a review of the use of condition-based maintenance strategies across the industry to establish best practice. The ORE Catapult O&M case study publications are a potential route to dissemination.	OWPB O&M Group

Areas of O&M



O&M cost breakdown



UK O&M spend by category
 (Source : A guide to UK Offshore Wind Operations and Maintenance, The Crown Estate, 2013)

How PdM reduce the cost?

Total cost saving for this single operation ~ €490k on two turbines

Main sources of ROI:

- Reduced crane cost
- Reduced downtime/ increased power production



- Main bearing fault detected on one offshore turbine

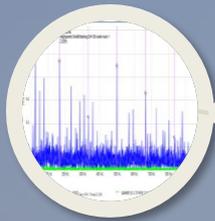
- Main bearing fault detected on another turbine

- Repair both turbines simultaneously during low wind season

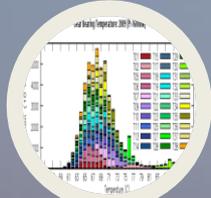
PdM Technologies



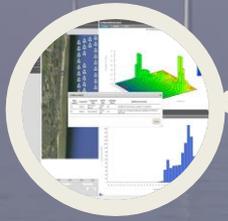
Digital Machine for condition monitoring



Vibration



Temperature



SCADA



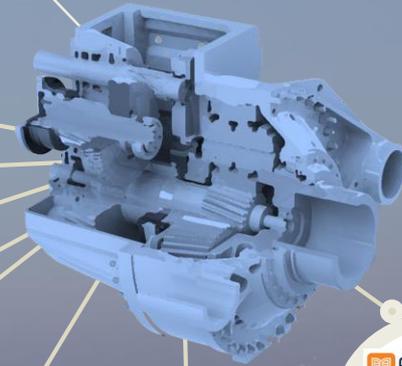
Lubrication



Particle Counter



Inspection Report

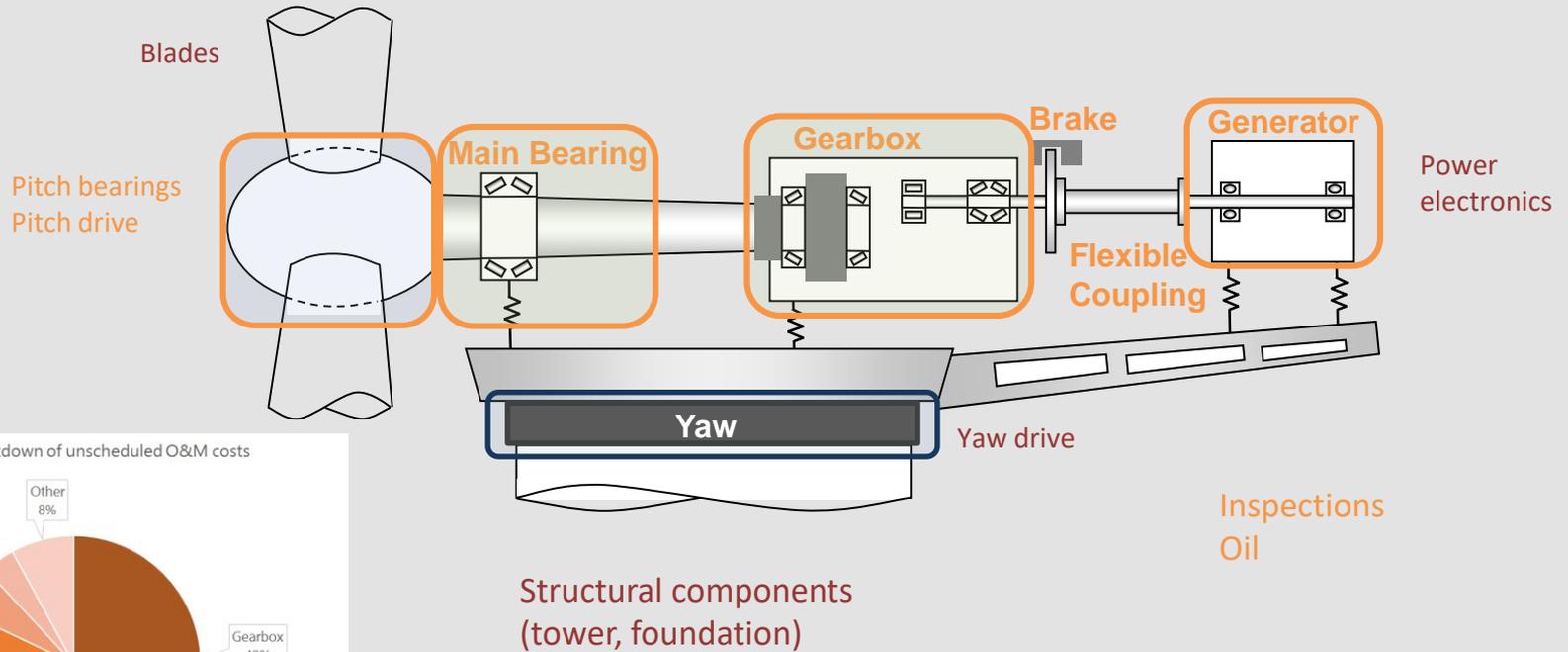


Field Pro
Mobile App

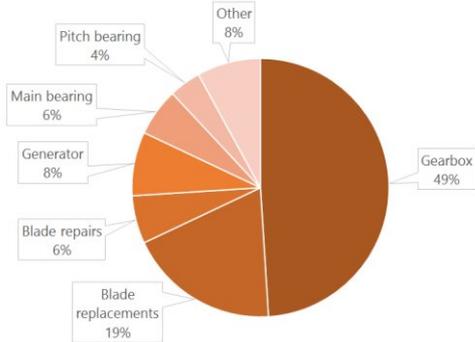


Failure Database

Condition monitoring - Scope of analysis

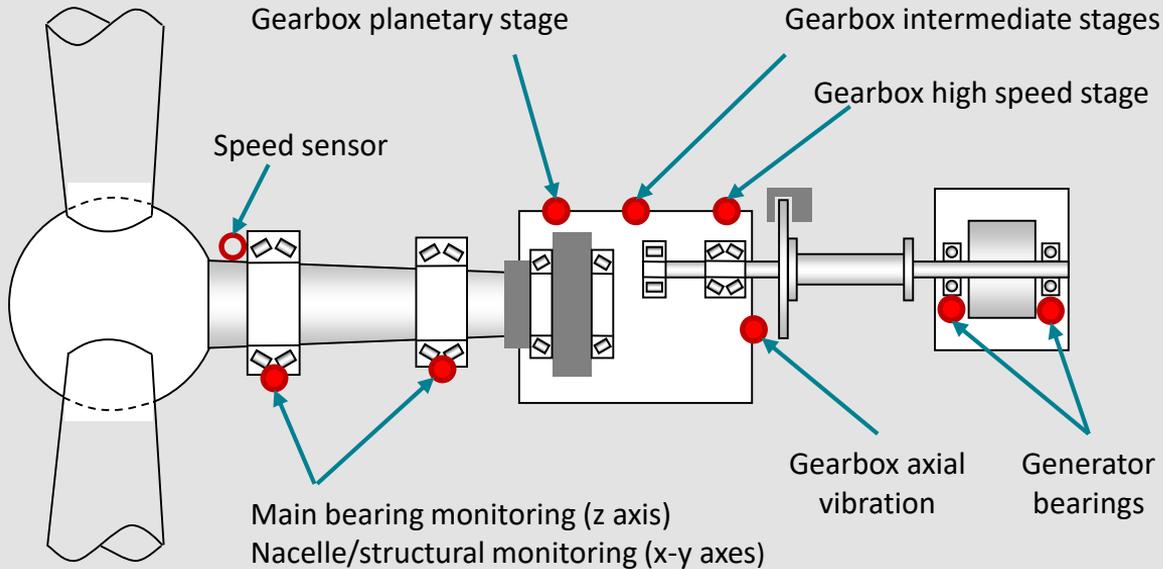


Example breakdown of unscheduled O&M costs



Vibration data collection (CMS)

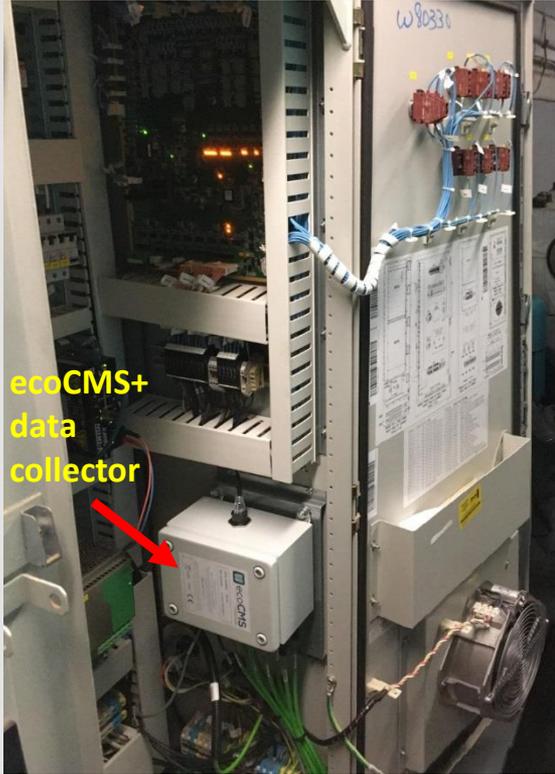
Typical installation:



Features of a modern CMS system:

- **Reliable solid state memory**
- **No fan or Hard Drive to fail**
- **Low cost tri-axial MEMS accelerometers**
- **Integrated temperature sensors**
- **Easy IT**
- **Ports for optional sensors (Oil debris)**

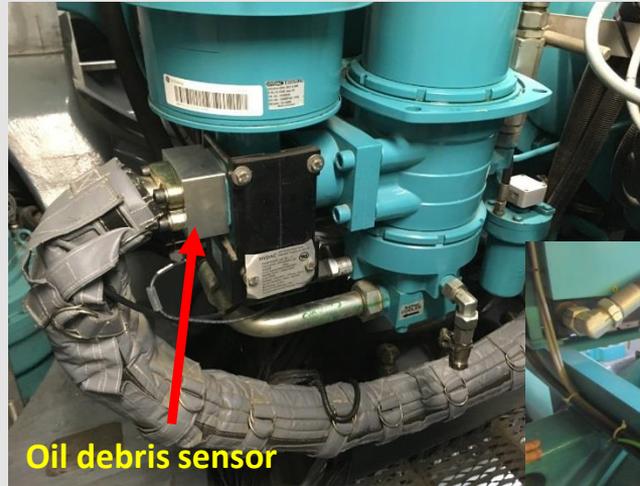
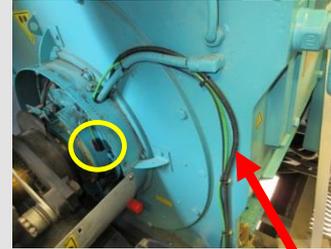
CMS Installation



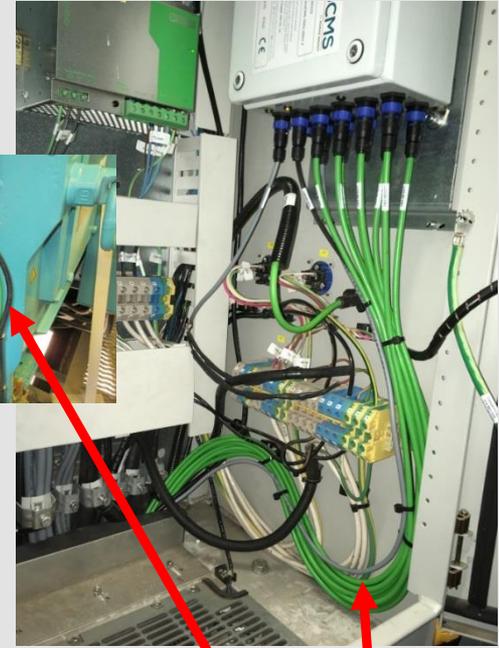
ecoCMS+
data
collector



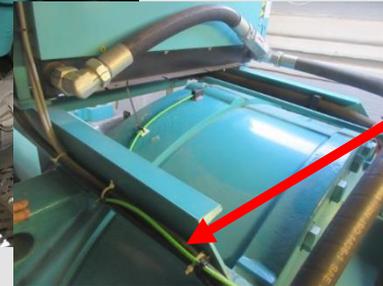
IP configuration



Oil debris sensor



Accelerometer
cables routed to
drivetrain



Two installations per day is typical

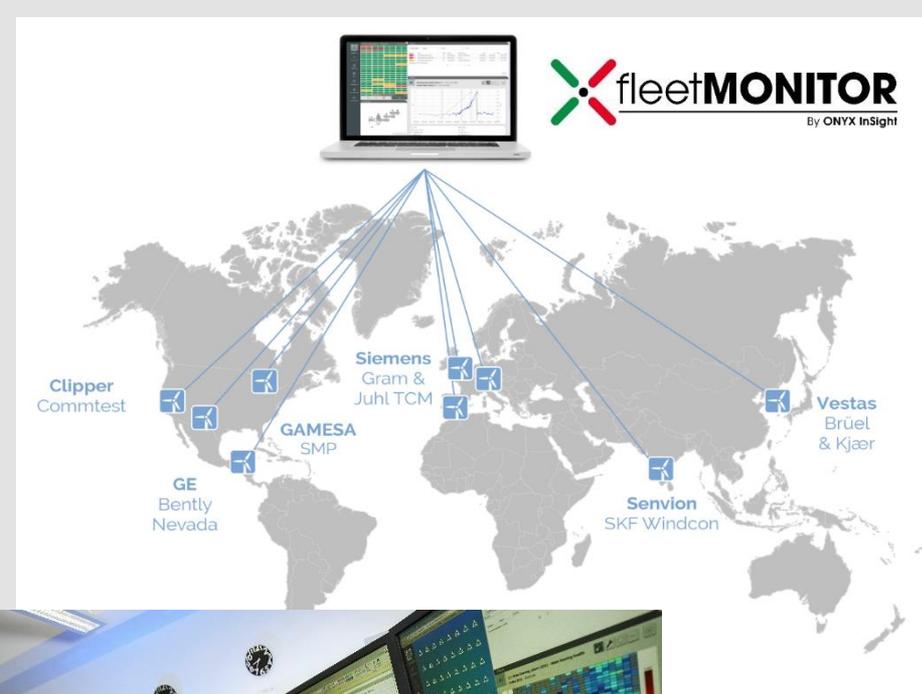
© Copyright 2018

Vibration data is only as good as the analysis

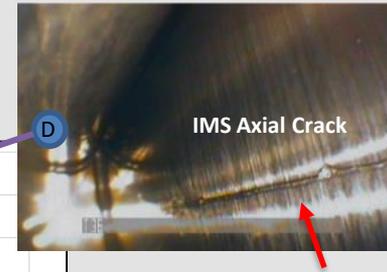
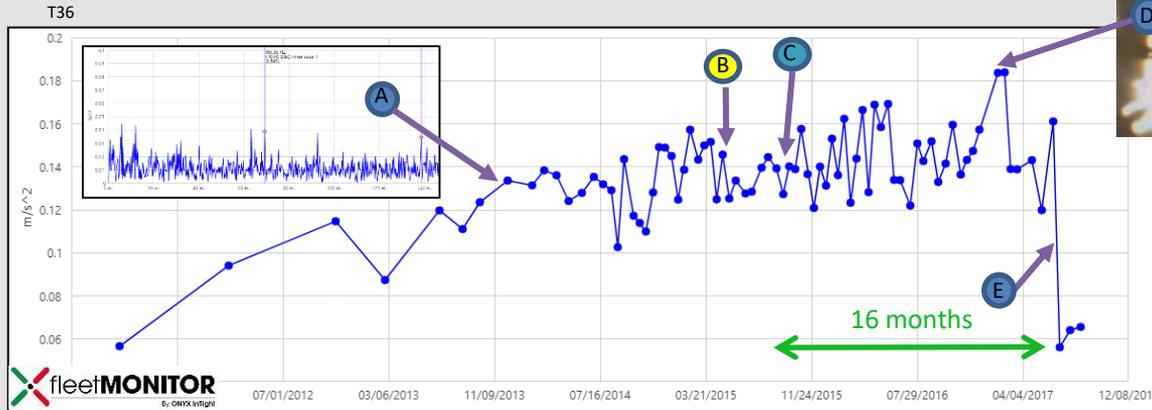
Accurate, long lead time warning is accomplished by automation and Analyst expertise. What is required?

- High end IT infrastructure
- Spectrum analytics engine
- Concise reporting
- Experience with a wide range of rotating equipment
- Relationship between owner and analyst
- Continuous detection improvement program

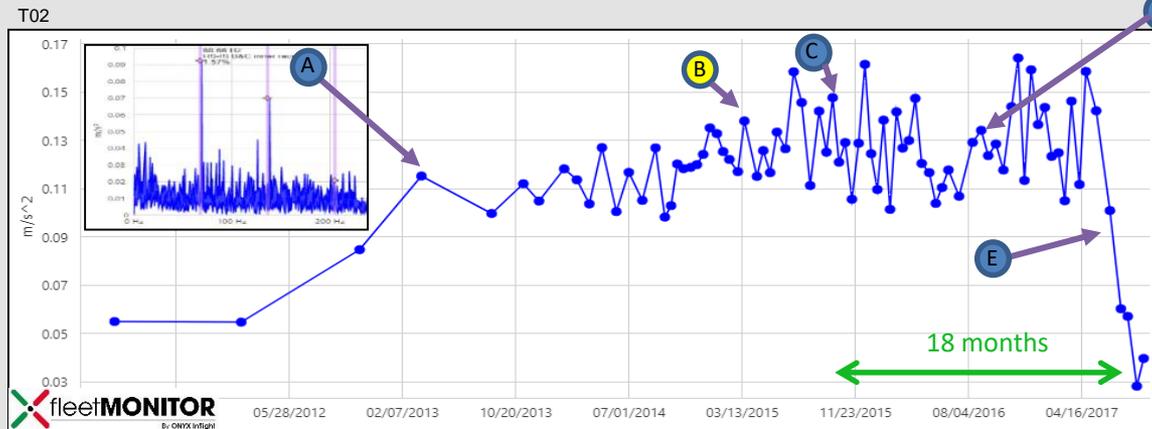
Machine learning will advance the field of vibration analytics in the near future



PdM for Gearbox IMS Bearings

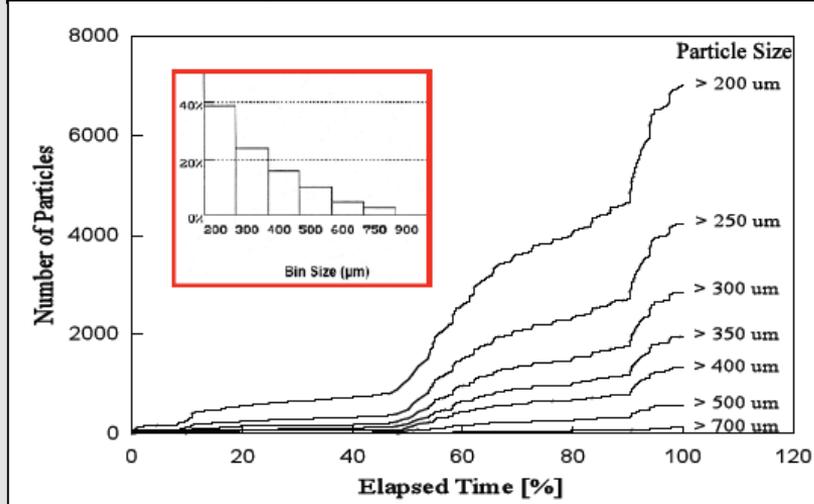
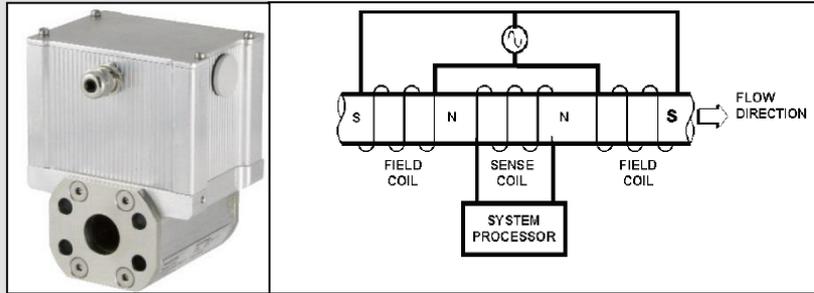


	Activity
A	First detectable trend prior to contract
B	Contract started
C	Crack detection rules optimized
D	Inspection confirmed cracked IMS bearing
E	IMS bearing replaced, healthy signal

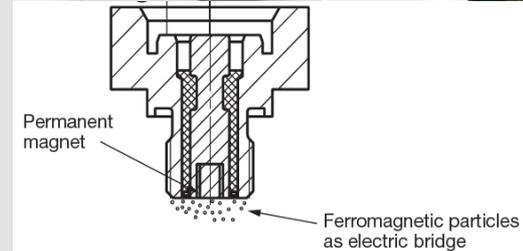
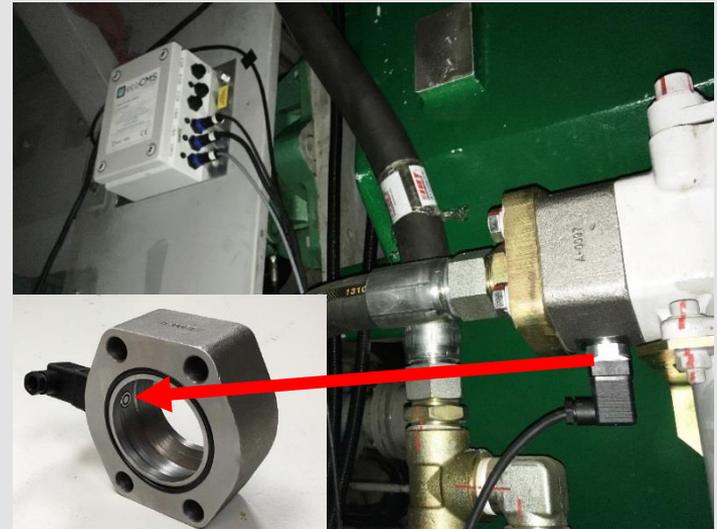


Oil debris monitoring

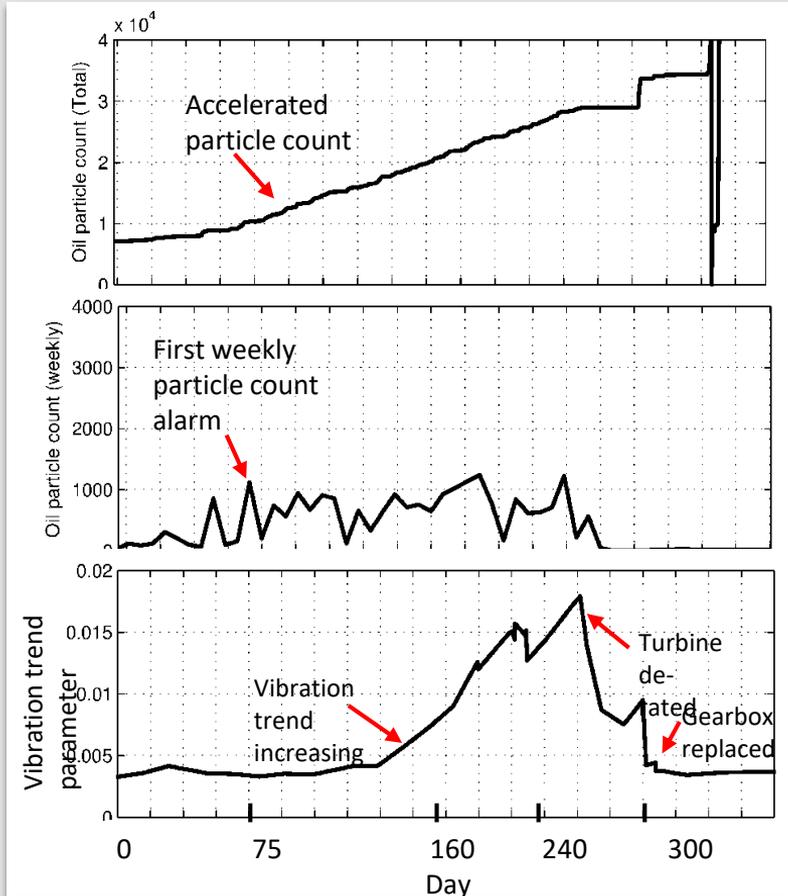
Continuous monitoring, side stream



Chip detector, inline

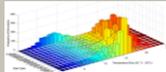


Oil debris monitoring



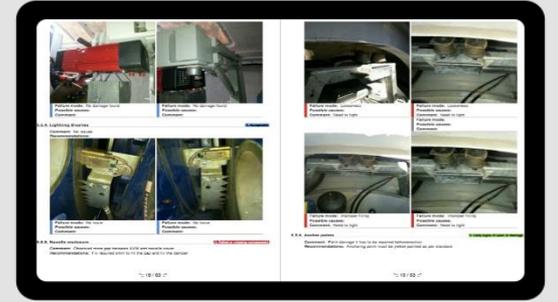
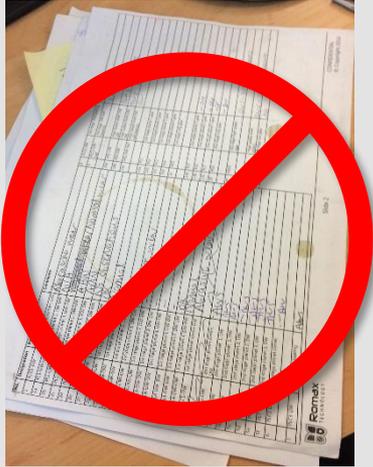
Bearing raceway spalling releases a significant amount of ferrous debris which can easily be detected by the debris monitoring system. Often this warning comes before vibration levels begin to rise.

Effectiveness of various PdM technologies

	Main bearings	Planet tooth	Planet bearings	Parallel gears	Parallel bearings	Gear oil health	Gen bearing	Gen stator	Yaw system	Pitch system	Blade imbalance	Tower
Vibration analysis 	Excellent 12 – 18 Months	Excellent 6 – 12 Months	Analysis difficult 3 – 12 Months	Excellent 6 – 12 Months	Excellent 6 – 12 Months	N/A	Excellent – experience required to avoid false alarms	Analysis difficult 1 – 2 Months	N/A	N/A	Excellent	Possible Requires correct sensor
Oil debris 	NA (unless oil lubricated)	Moderate Little debris produced	Excellent 6 – 12 Months	Moderate Little debris produced	Excellent 6 – 12 Months	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lubricant analysis 	Moderate Sampling difficult	Poor Late warning	Poor Late warning	Poor Late warning	Poor Late warning	Excellent	Moderate Sampling difficult	N/A	N/A	N/A	N/A	N/A
Controller analysis 	Moderate 6 Months	Poor	Poor	Poor	Moderate Few bearings measured	N/A	Excellent	N/A	Excellent	Excellent	Moderate	N/A

Multiple CMS technologies are required for foolproof drivetrain health diagnostics!

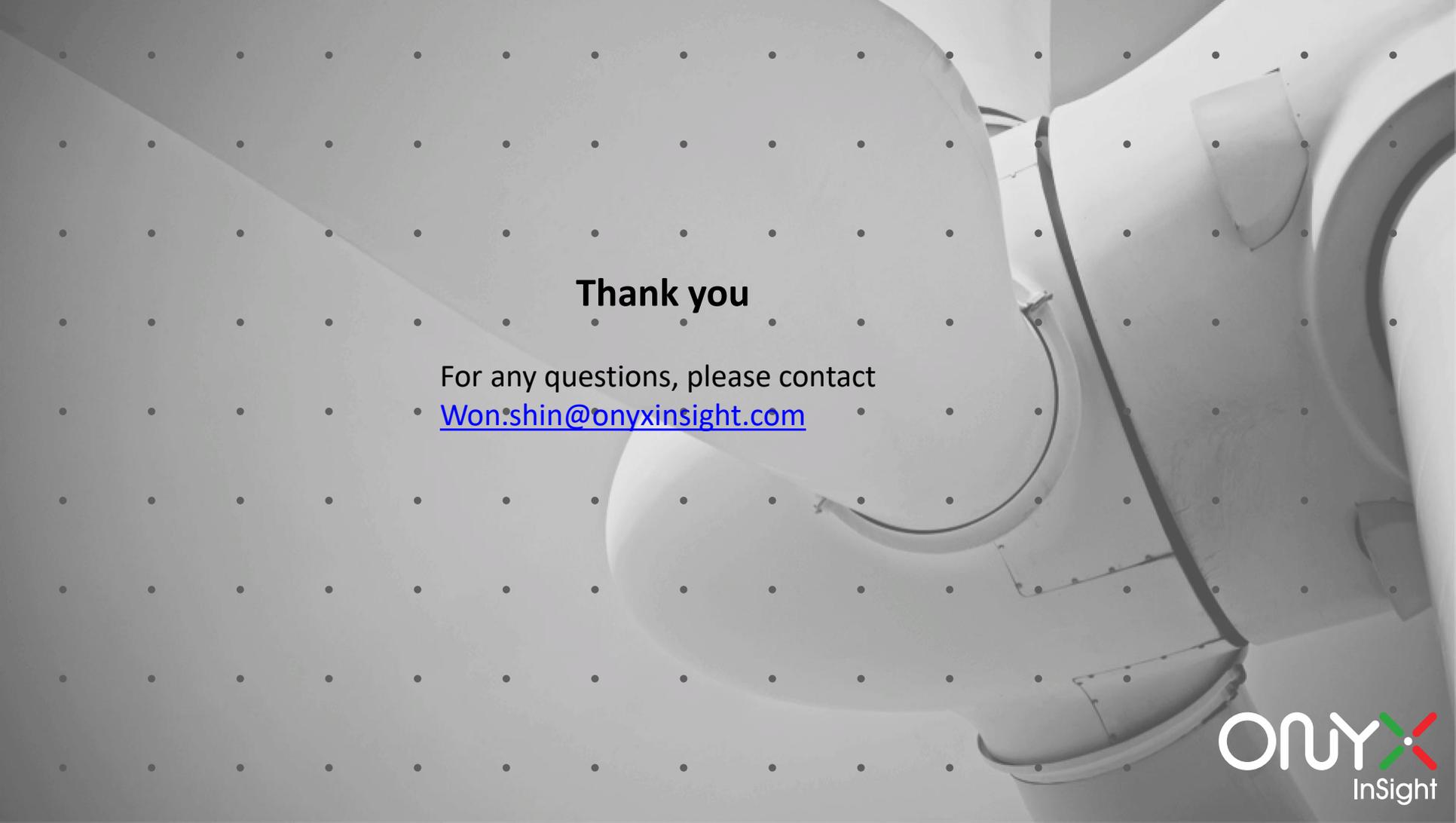
Digital work tracking



Paper checklist are time consuming and do not provide data in a format for trending

Implement digital work tracking tools

Upload maintenance actions and inspection photos to Reliability database



Thank you

For any questions, please contact

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