



SUPERGEN Wind 2011 General Assembly

**How are we going to make offshore
wind farms more reliable?**

Peter Tavner

20th March 2011, Durham University

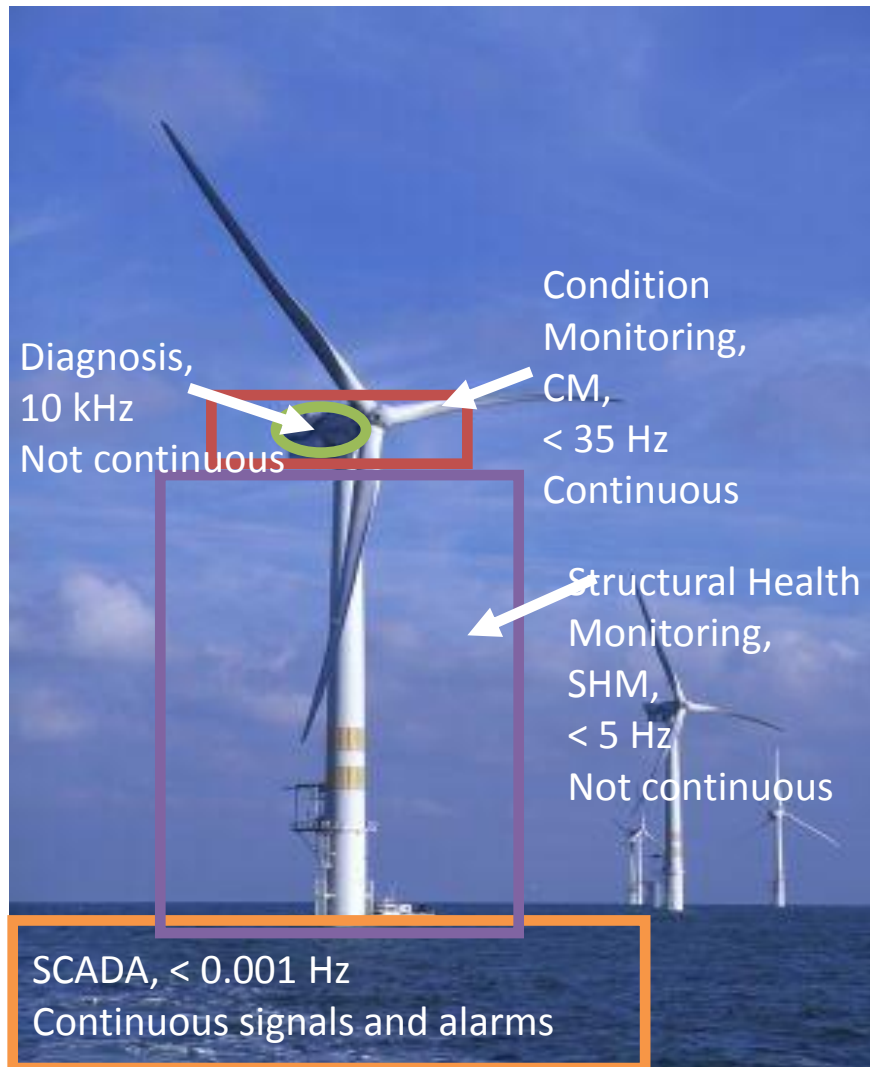


Summary

- **This research addresses issues of raising offshore wind farm Availability and lowering Cost of Energy**
- **What are we monitoring**
- **What reliability and availability are we getting**
- **What is it going to be like offshore**

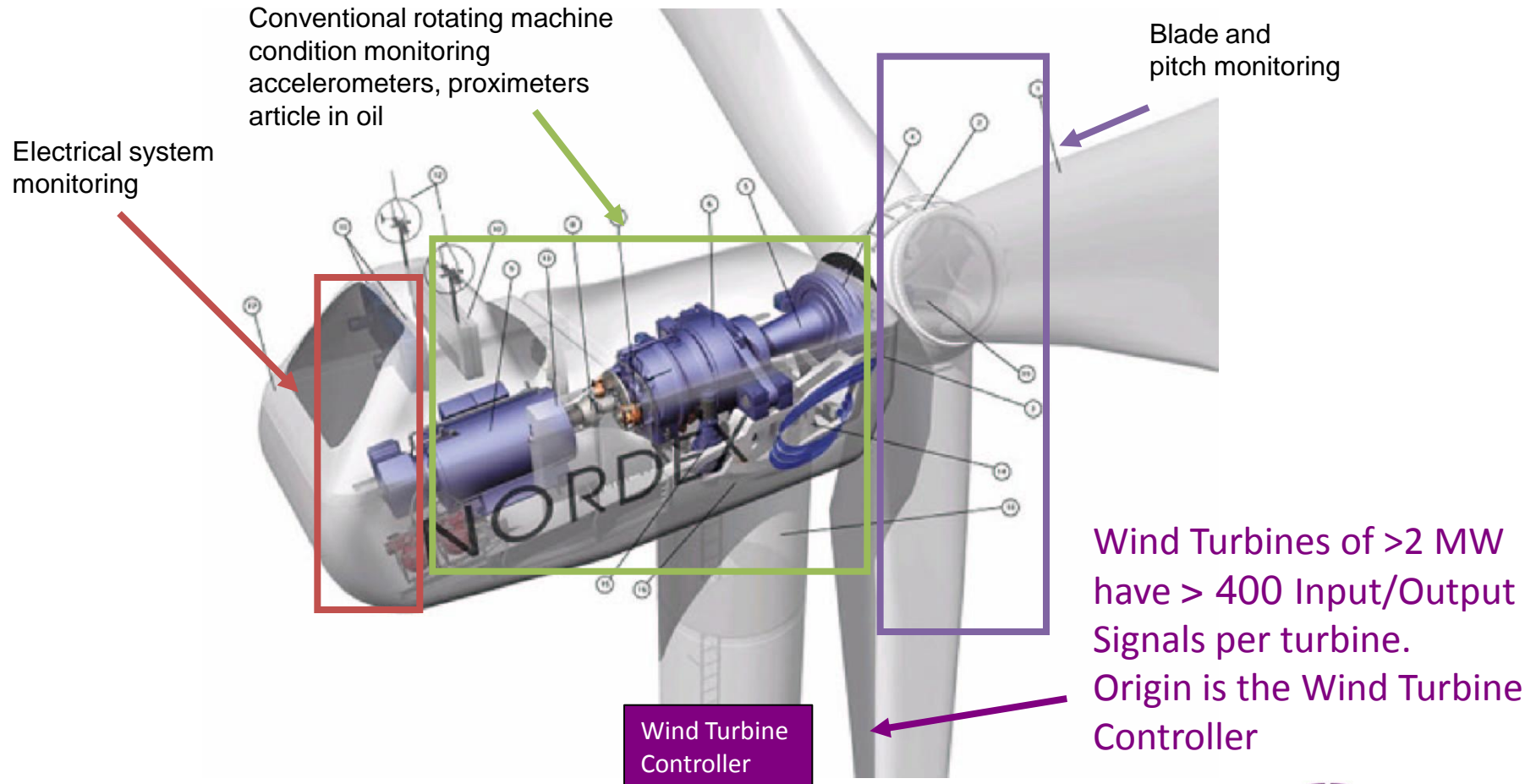


SCADA & Condition Monitoring in Context





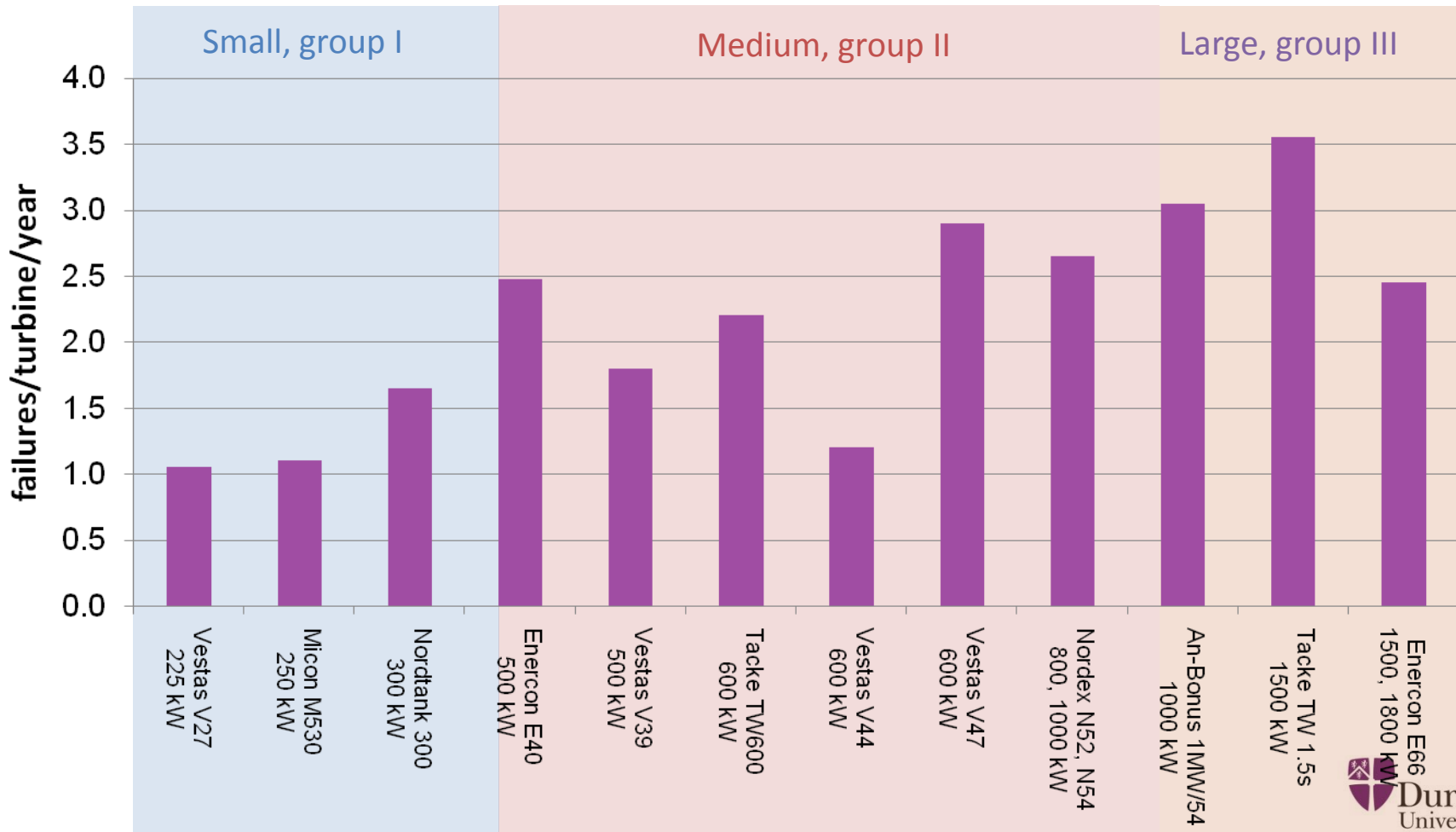
SCADA & Condition Monitoring in Context





Reliability & Size Onshore, EU

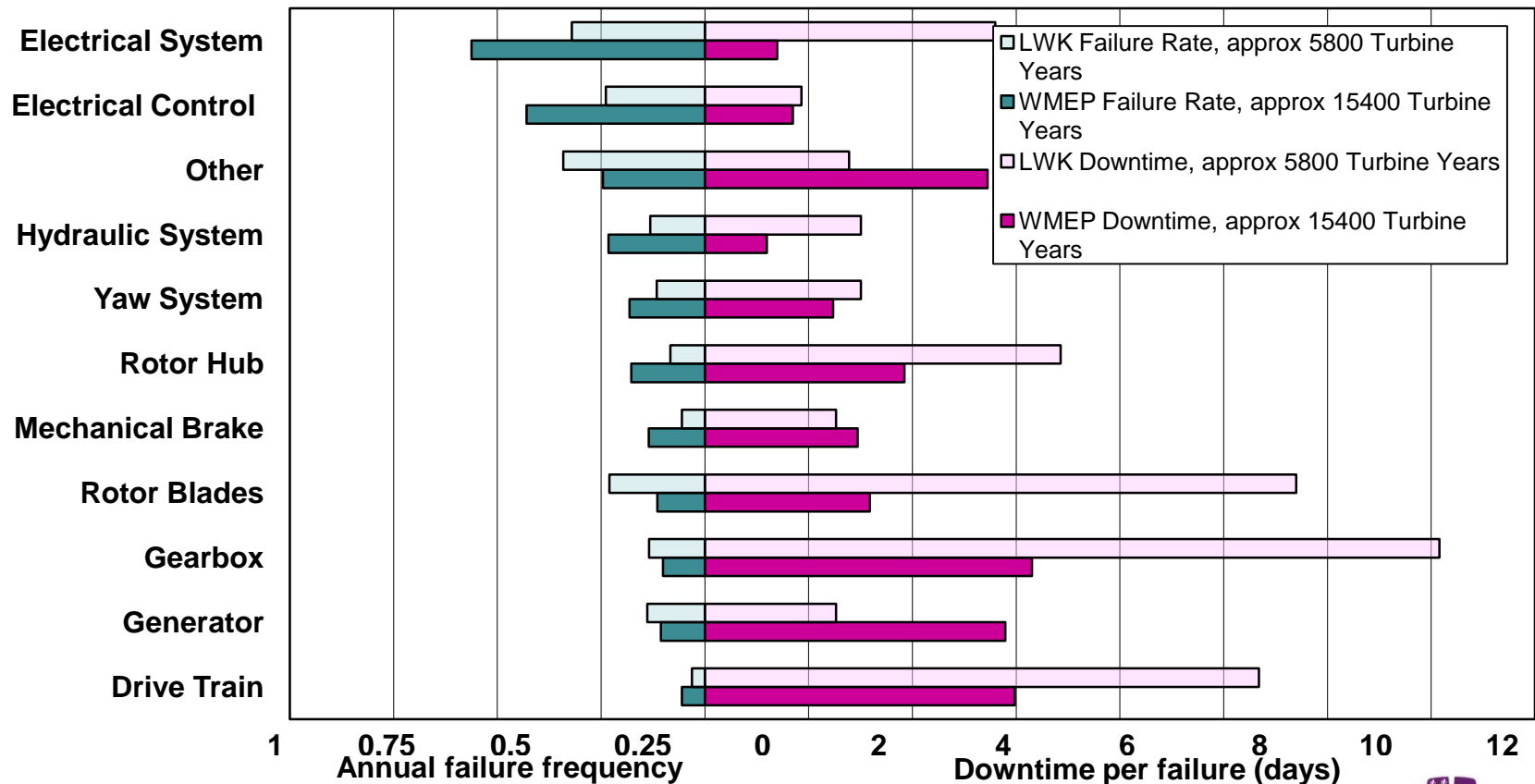
LWK average failure rate: period 1993–2004





Reliability & Subassemblies Onshore, EU

Failure Rate and Downtime from 2 Large Surveys of onshore European Wind Turbines over 13 years

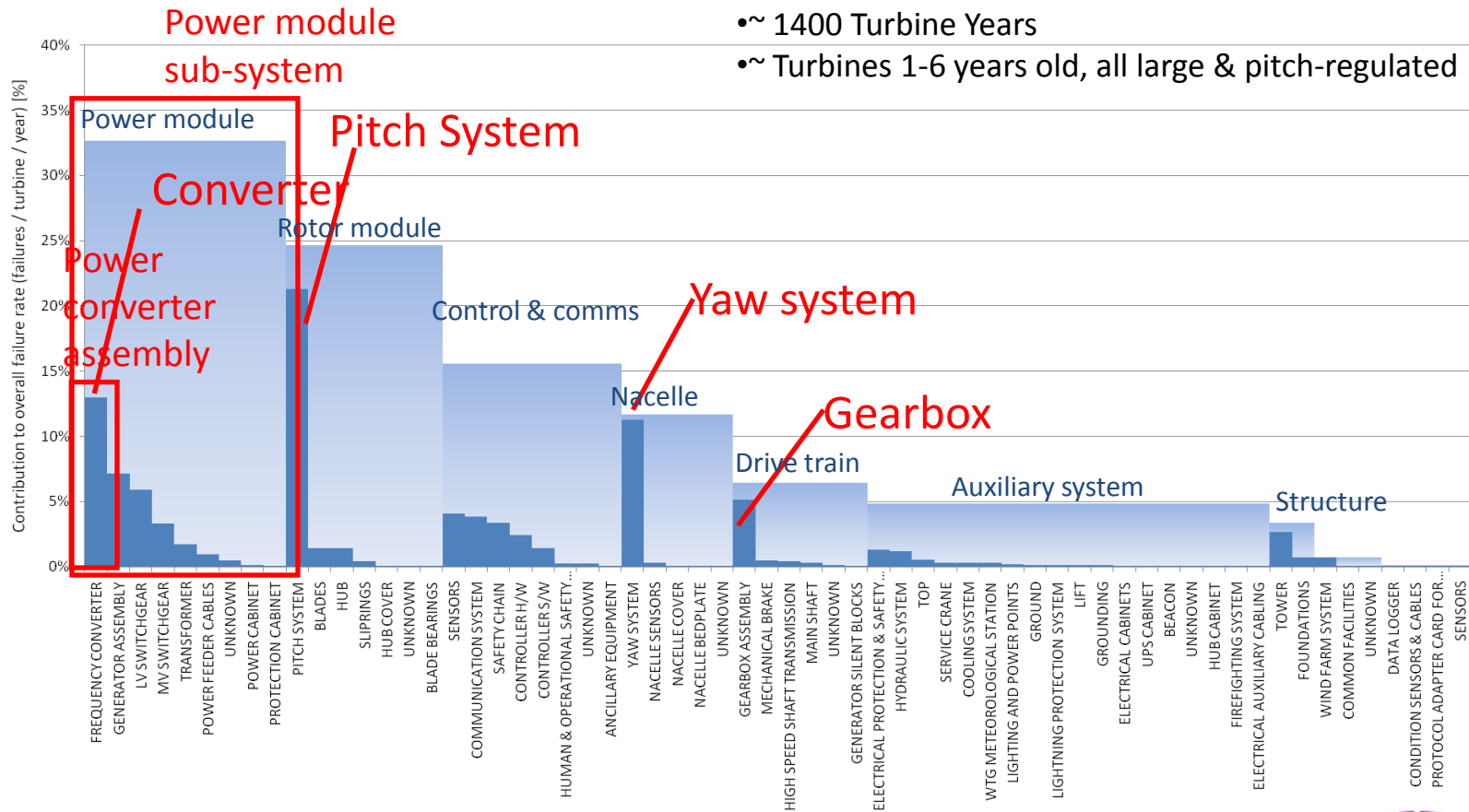


Overall availability 97%, WT $\lambda_f = 1-3$ failures/turbine/year
 75% of faults cause 5% of downtime
 25% of faults cause 95% of downtime

Reliability & Subassemblies

Onshore EU

- ~ 35,000 Downtime Events
- ~ 1400 Turbine Years
- ~ Turbines 1-6 years old, all large & pitch-regulated

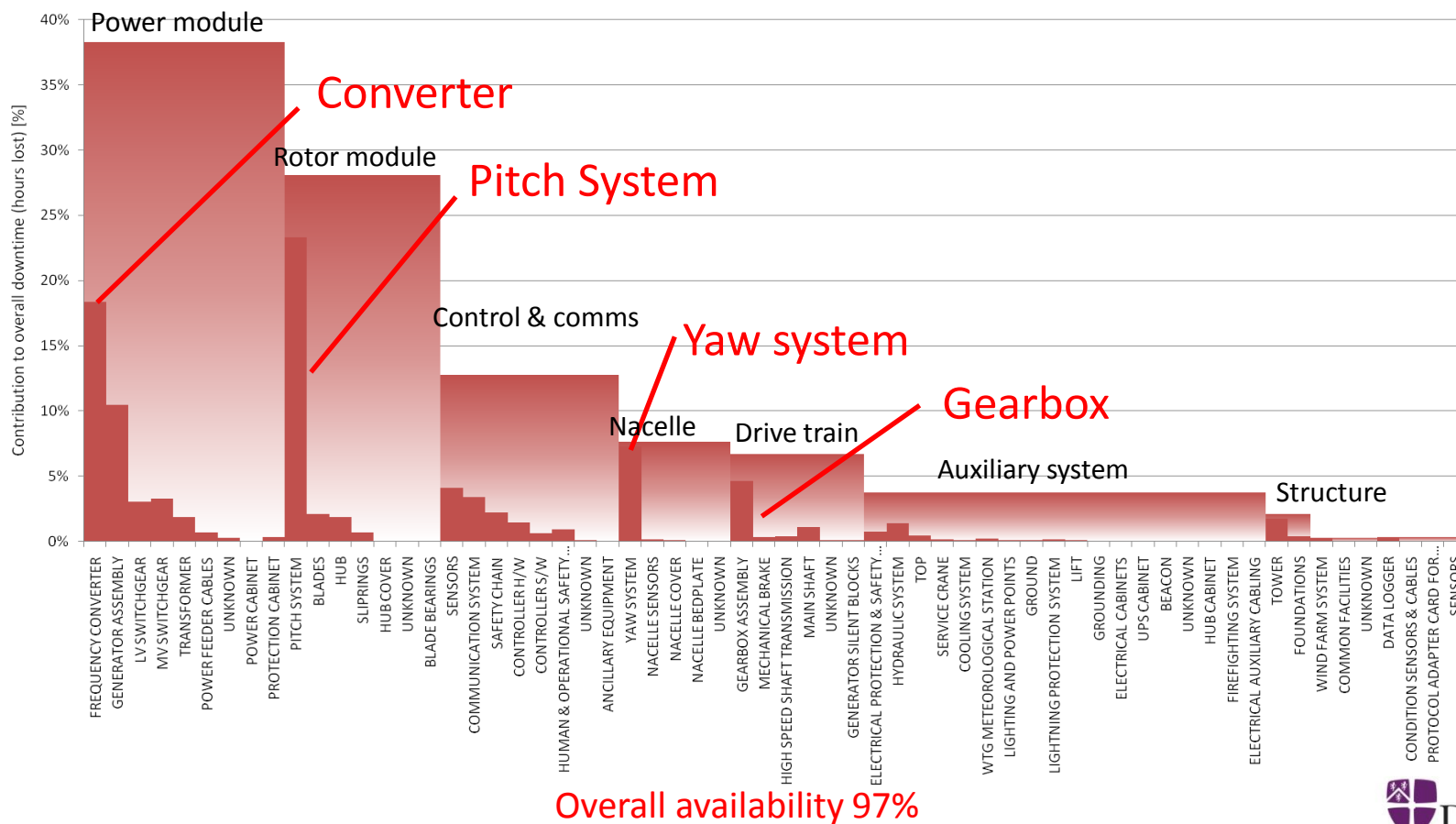


Overall availability 97%

Percentage contribution to overall failure rate

Data source: turbines from multiple manufacturers

Downtime & Subassemblies Onshore EU

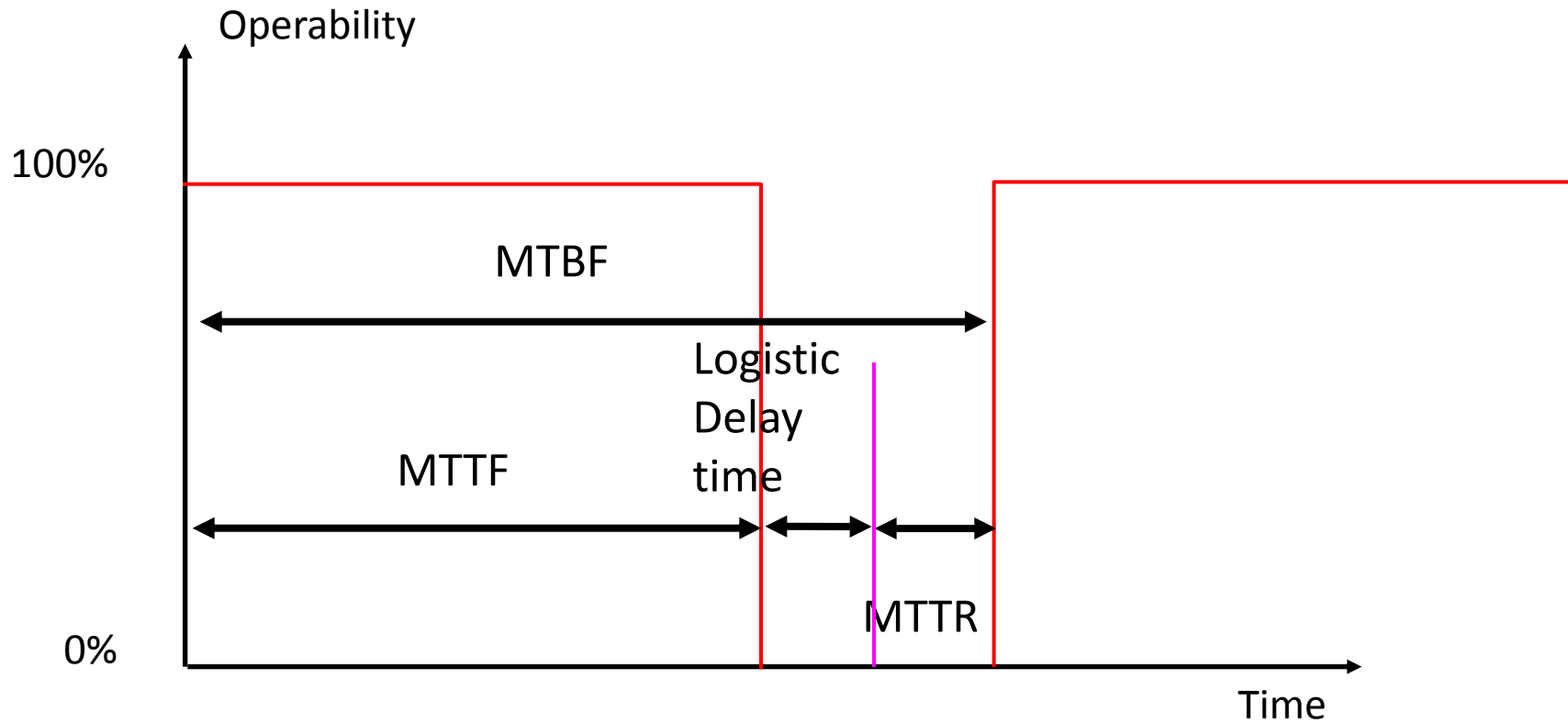


Percentage contribution to overall failure rate

Data source: turbines from multiple manufacturers



Inherent Availability





What were the failure criteria?

- Mean Time To Failure $MTTF$
- Mean Time to Repair, or downtime $MTTR$
- Mean Time Between Failures $MTBF$
- WMEP & LWK failure MTTR $> 24\text{hr}$
- ReliaWind failure MTTR $> 1\text{hr}$
- Failure rate, λ $\lambda = 1/MTBF$
- Repair rate, μ $\mu = 1/MTTR$
- Availability $A = (MTBF - MTTR) / MTBF$
 $= 1 - (\lambda / \mu)$
- If $A=97\%$ in both cases λ depends on μ , which is $1/24$ or $1/1$
- Therefore $\lambda_1=1-3$ failures/turbine/yr, $\lambda_2=24-72$ failures/turbine/yr

Summary of ReliaWind WP1 Data: Critical Subassemblies

Sub-system / Assembly	Total Failure Rate %	Medium Time Lost %
Pitch System	16%	20%
Frequency Converter	12%	13%
Yaw System	12%	10%
Control System	14%	9%
Generator Assembly	6%	11%
Gearbox Assembly	5%	4%



Summary of ReliaWind WP1 & WP2: Critical Subassemblies & Failure Modes

Sub-system / Assembly		Failure Mode 1	Failure Mode 2	Failure Mode 3	Failure Mode 4	Failure Mode 5
Pitch System	Electrical (5 out of 13)	Battery Failure	Pitch Motor Failure	Pitch Motor Converter Failure	Pitch Bearing Failure	Temperature or Humidity Sensor Failure
	Hydraulic (5 out of 5)	Internal leakage of proportional valve	Internal leakage of solenoid valve	Hydraulic cylinder leakage	Position sensor degraded or no signal	Pressure control valve sensor degraded signal
Frequency Converter (5 out of 18)		Generator-side or Grid-side Inverter Failure	Loss of Generator Speed Signal	Crowbar Failure	Converter Cooling Failure	Control Board Failure
Yaw System (5 out of 5)		Yaw gearbox & pinion lubrication out of specification	Degraded wind direction signal	Degraded guiding element function	Degraded hydraulic cylinder function	Brake operation valve does not operate
Control System (5 out of 5)		Temperature sensor modules malfunction	PLC analogue input malfunction	PLC analogue output malfunction	PLC digital input malfunction	PLC In Line Controller malfunction
Generator Assembly (5 out of 11)		Worn slip ring brushes	Stator winding temperature sensor failure	Encoder failure	Bearing failure	External fan failure
Gearbox Assembly (5 out of 5)		Planetary Gear Failure	High Speed Shaft Bearing Failure	Intermediate Shaft Bearing Failure	Planetary Bearing Failure	Lubrication System Malfunction

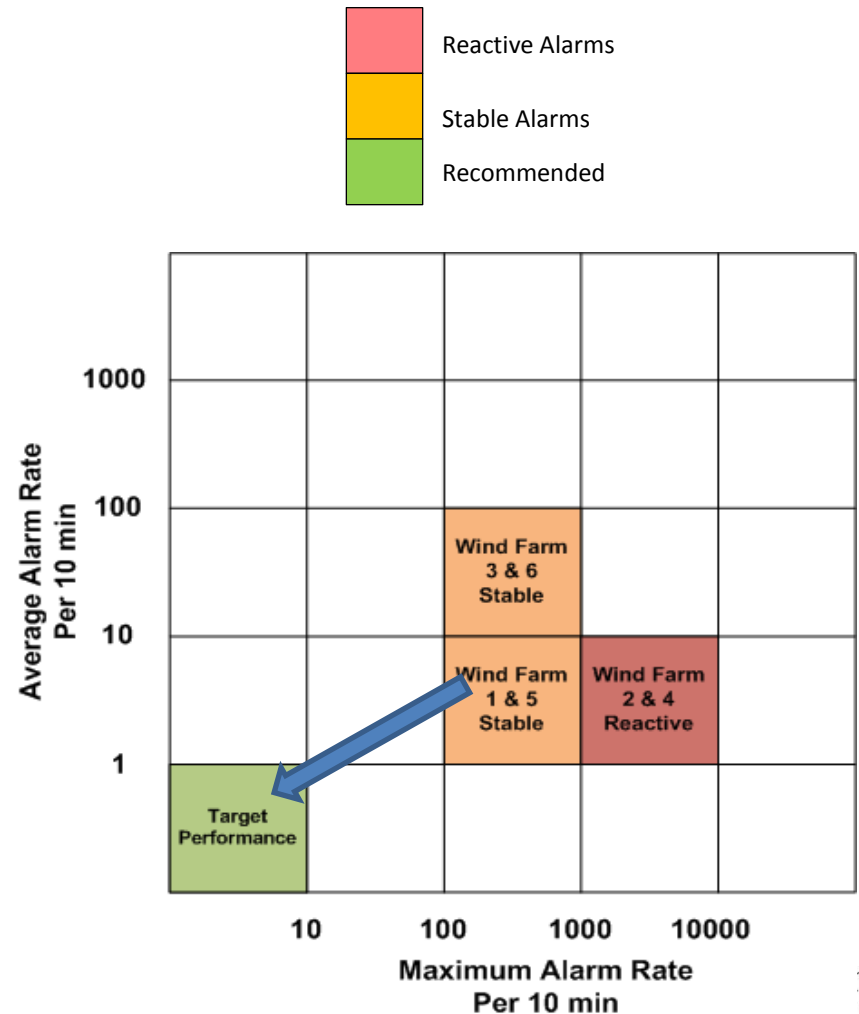
Alarm KPIs for 4 Wind Farms

KPIs	Wind Farm 1	Wind Farm 2	Wind Farm 3	Wind Farm 4	
Total WT Numbers	30-35				
Ave. Alarm Rate Per 10 min	11	10	10	21	
Max. Alarm Rate per 10 min	636	1570	439	541	
Percentage of Time Alarm Rates are within these ranges	0	24%	19%	20%	7%
	1-10	47%	50%	48%	34%
	11-50	27%	30%	31%	54%
	>51	2%	1%	1%	5%
	In Total	100%	100%	100%	100%

30-35 WTs per Wind farms with each WT having 2-300 I/O
9000 I/O per Wind Farm

Alarm System Performance Levels

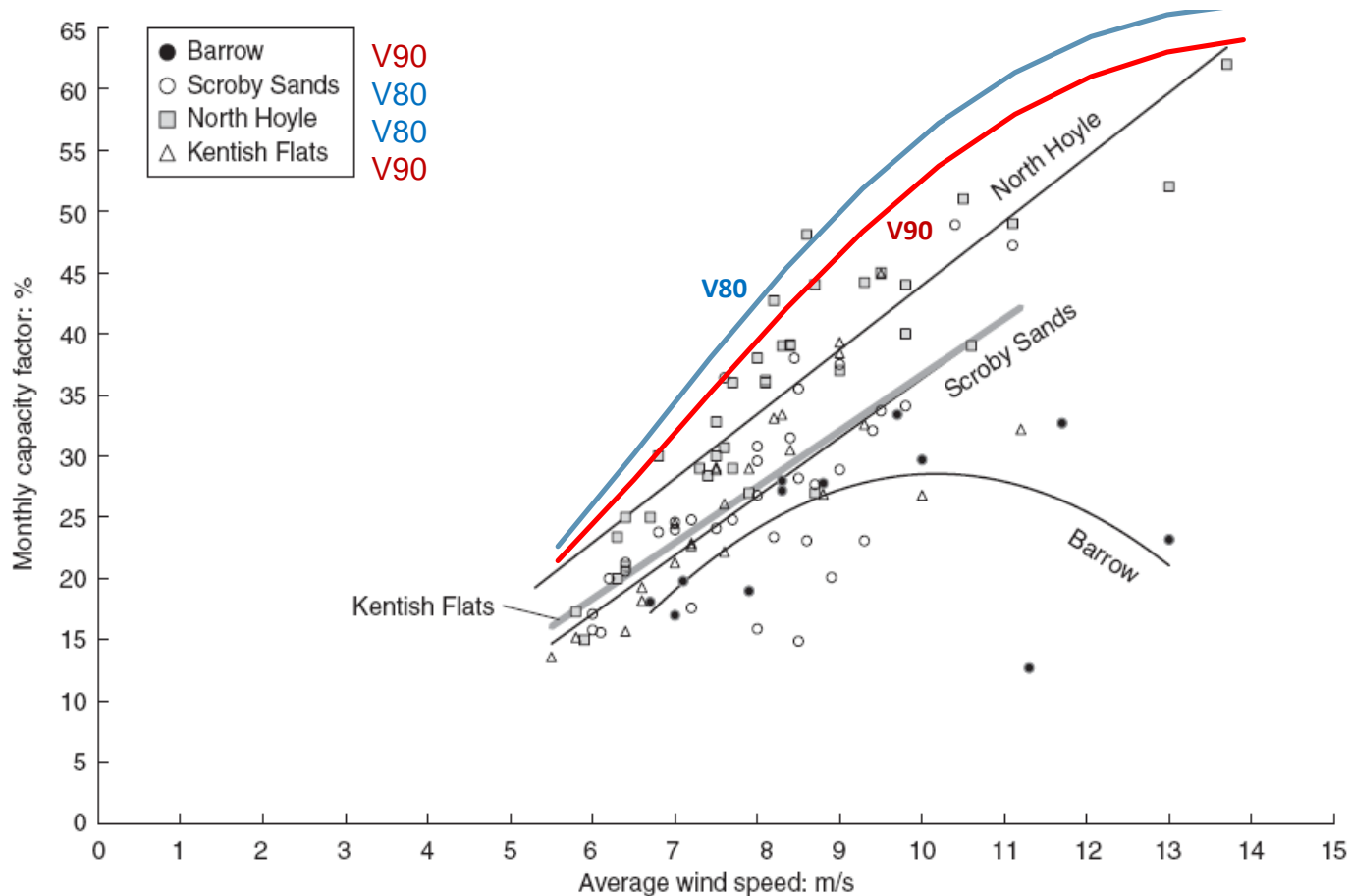
- Matrix for Alarm System Performance Evaluation*
 - **Reactive:** peak alarm rate during upset is unmanageable and alarm system will continue to present an unhelpful distraction to the operator for long period
 - **Stable:** alarms have been well defined for normal operation, but the system is less useful during plant upset



* Alarm systems, a guide to design, management and procurement No. 191 Engineering Equipment and Materials Users Association 1999 ISBN 0 8593 1076 0

Offshore Capacity Factor & Wind Speed, UK

Monthly capacity factor against wind speed for the offshore wind farms





Offshore Availability & Wind Speed, UK

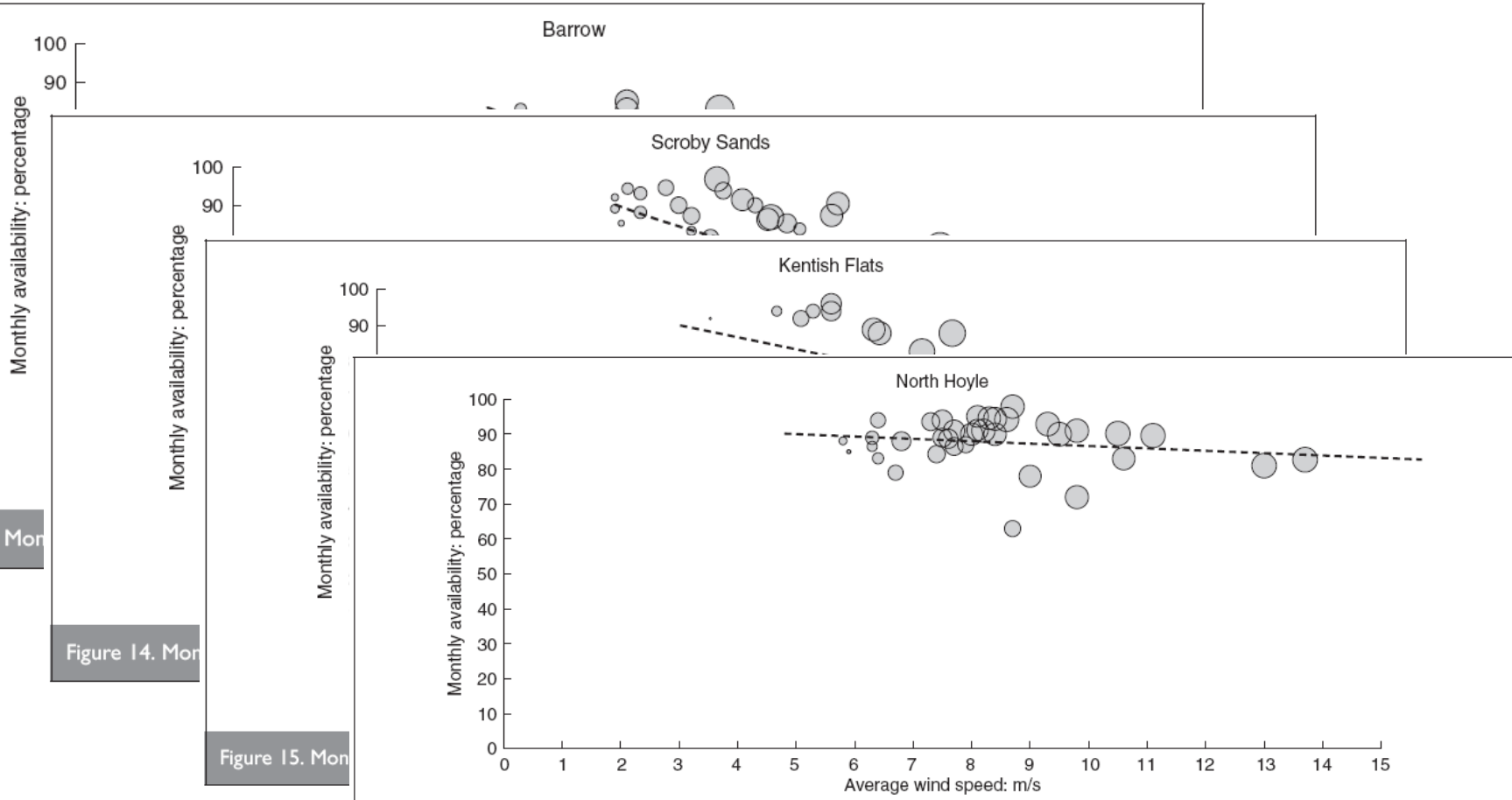


Figure 12. Mon

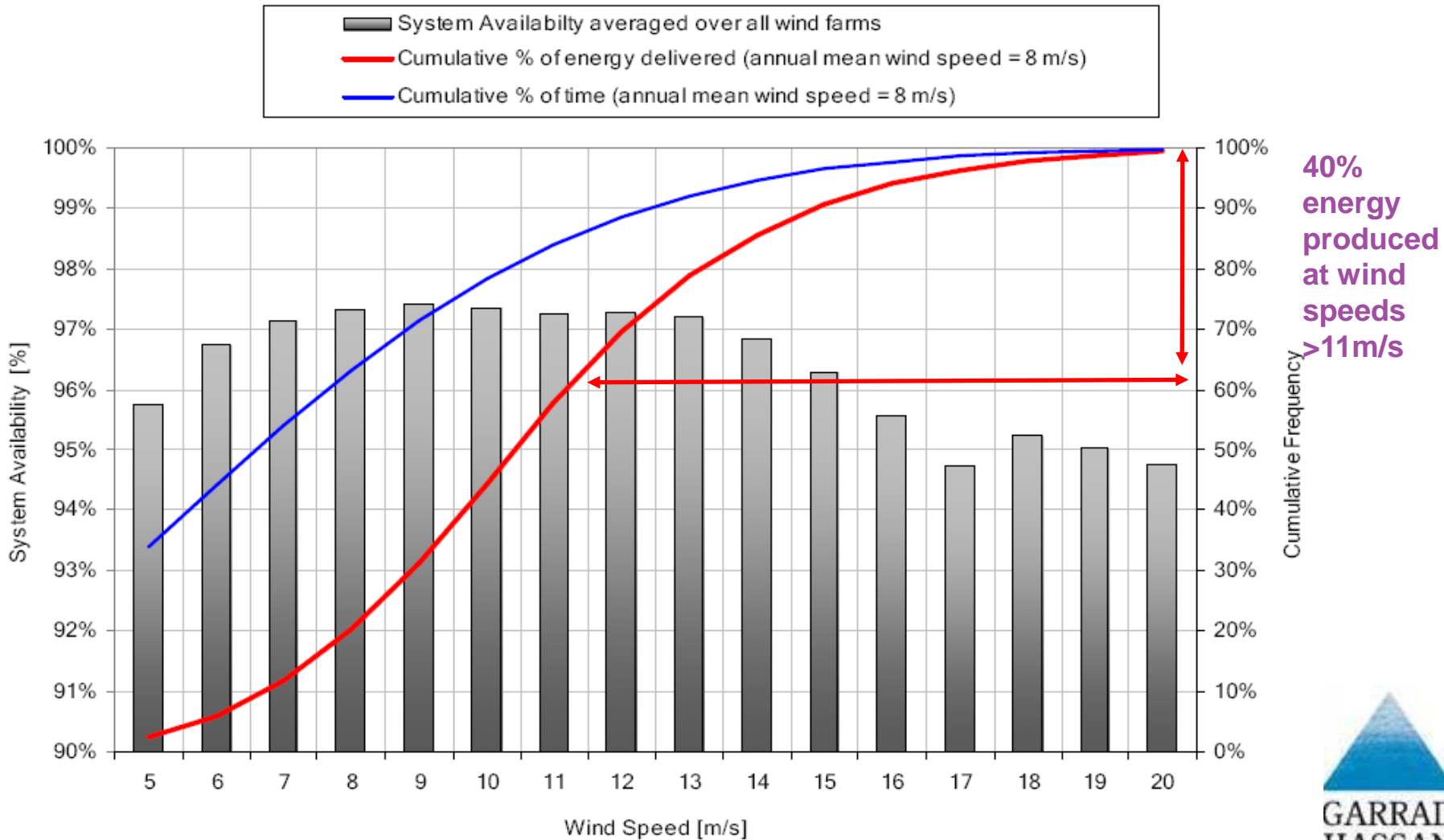
Figure 14. Mon

Figure 15. Mon

Figure 13. Monthly availability against wind speed for North Hoyle offshore wind farm



Onshore Availability & Wind Speed, World





The Problem: Offshore Rounds 2 & 3



Wind Farms of 100-500 WTs

400 I/O per WT

20000 WT I/O per Wind Farm

Excluding substation, cables & connection

Total Wind Farm I/O > 30000

Onshore 75% of faults cause 5 % of downtime

Offshore this 75% of small faults will be critical

Because they will consume O&M time & money



The Solution: A Wind Farm Knowledge Management System

Integrated SCADA & CMS

Controlled concentration of Wind Farm I/O

Classification of faults per WT

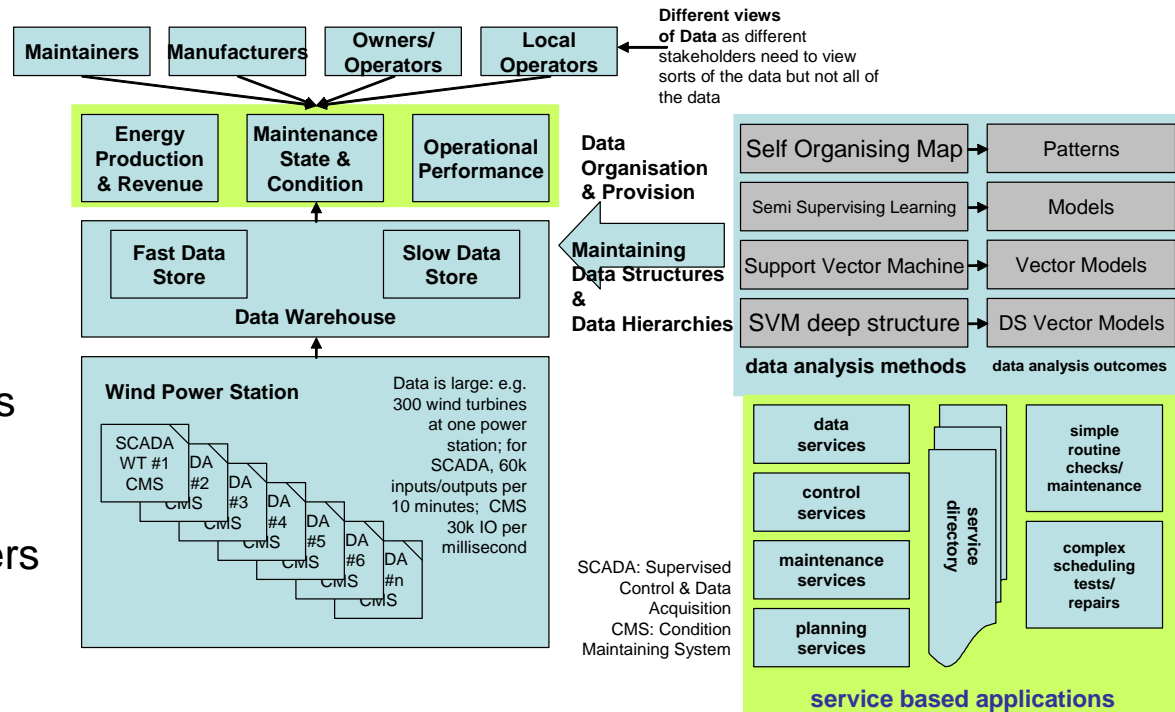
Automatic Alarm Handling

Clear GUI for Operational Managers showing key faults

Clear GUI for Maintenance Managers classifying key faults

Drill down from GUI for Maintainers to diagnose and prognose faults

Lengthen the prognostic horizon





What issue does this research address?

- **Lack of clarity in SCADA and CMS data**
- **Problem of data overload**
- **Importance of eliminating this problem offshore**



Impact of this research on the Wind Industry

- **Serious but solvable issue for Offshore Wind Farm O&M**
- **Clear measured failure rate and downtime results to benchmark future developments**
- **Clear methods that could be applied**
- **Clear structure for the future**