Offshore Wind Turbine Reliability

Peter Tavner

Professor of New & Renewable Energy

Energy Group

Durham University
School of Engineering and Computing Sciences

Overview

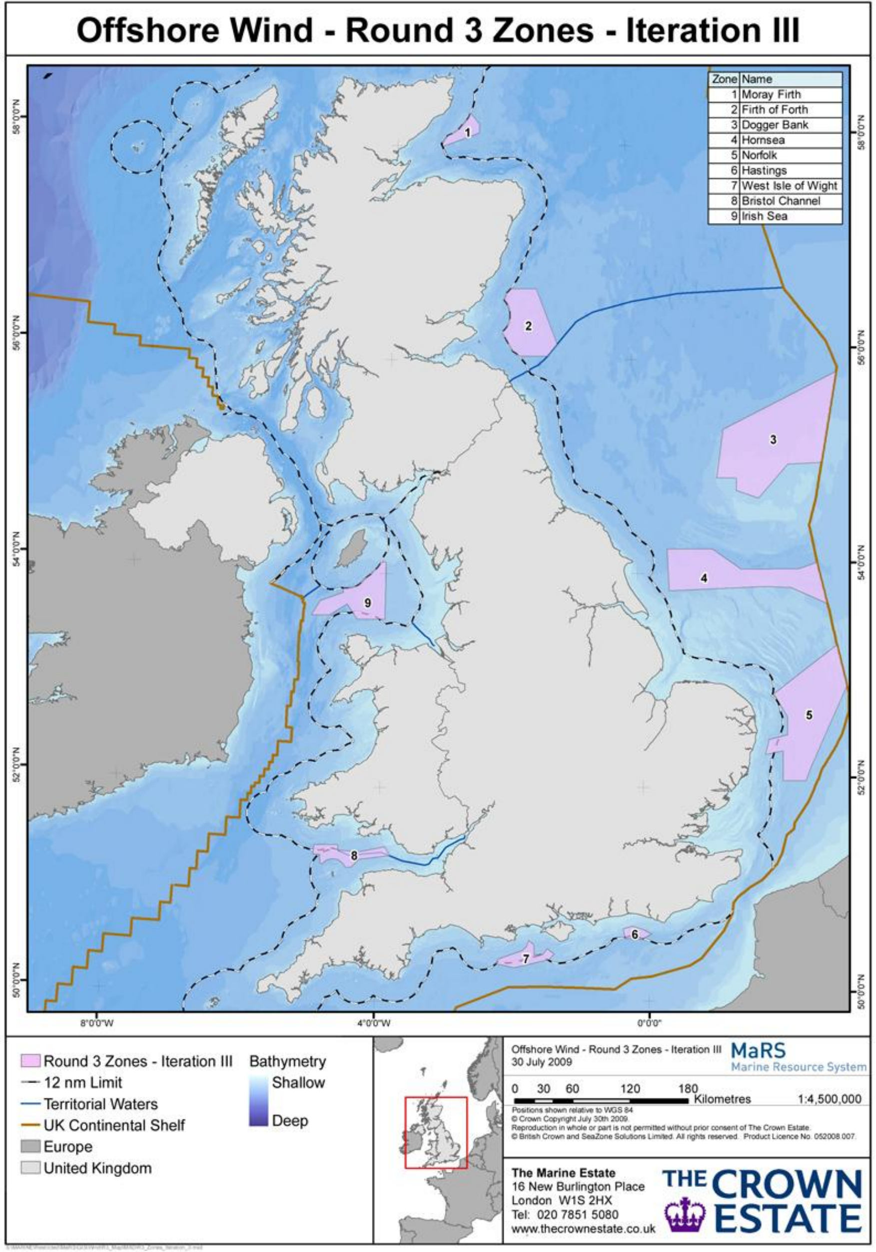
- Brief update on UK offshore wind power
- What we know about wind turbine availability and reliability, onshore
- More detail on reliability of components
- Conclusions and future challenges

UK Offshore Rounds 1 & 2

European Offshore Wind Farms

Wind farm	MW Capacity	Country	WT No.	Maker	Type	Rating	Commissioned
Thanet	300	United Kingdom	100	Vestas	V90	3 MW	2010
Horns Rev II	209	Denmark	91	Siemens	SWT-2,3-93	2.3 MW	2009
Rødsand II	207	Denmark	90	Siemens	SWT-2,3-93	2.3 MW	2010
Lynn and Inner Dowsing	194	United Kingdom	54	Siemens	SWT-3.6-107	3.6 MW	2009
Walney Phase I	184	United Kingdom	51	Siemens	SWT-3.6-107	3.6 MW	2011
Robin Rigg	180	United Kingdom	60	Vestas	V90	3 MW	2010
Gunfleet Sands	173	United Kingdom	48	Siemens	SWT-3.6-107	3.6 MW	2010
Nysted I	166	Denmark	72	Siemens	SWT-2,3-82	2.3 MW	2003
Horns Rev I	160	Denmark	80	Vestas	V80	2 MW	2002
Princess Amalia	120	Netherlands	60	Vestas	V80	2 MW	2008
Lillgrund	110	Sweden	48	Siemens	SWT-2.3-	2.3 MW	2007
Egmond aan Zee	108	Netherlands	36	Vestas	V90	3 MW	2007
TOTAL	**2111 MW**		790				

UK Offshore Round 3



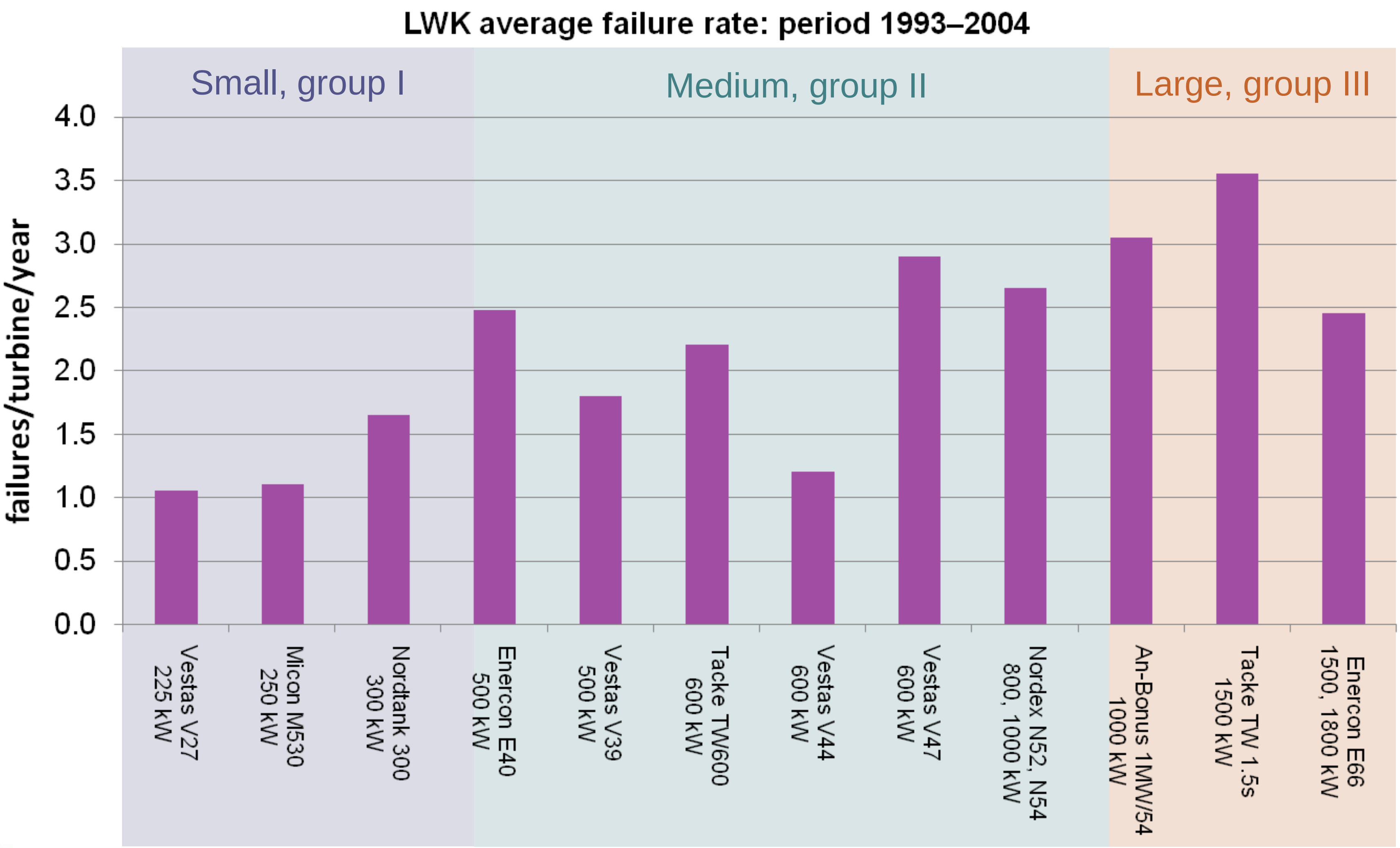
UK Onshore & Offshore in Context

Operational wind farms			
Onshore			**MW Capacity**
	England	103	812.09
	Northern Ireland	27	309.73
	Scotland	111	2,364.18
	Wales	33	382.55
		274	**3,868.55 MW**
Offshore Round 1 & 2			
	England	10	1,181.20
	Scotland	1	10.00
	Wales	2	150.00
TOTAL		**13**	**1,341.20 MW**

Offshore Round 3 Wind Zones

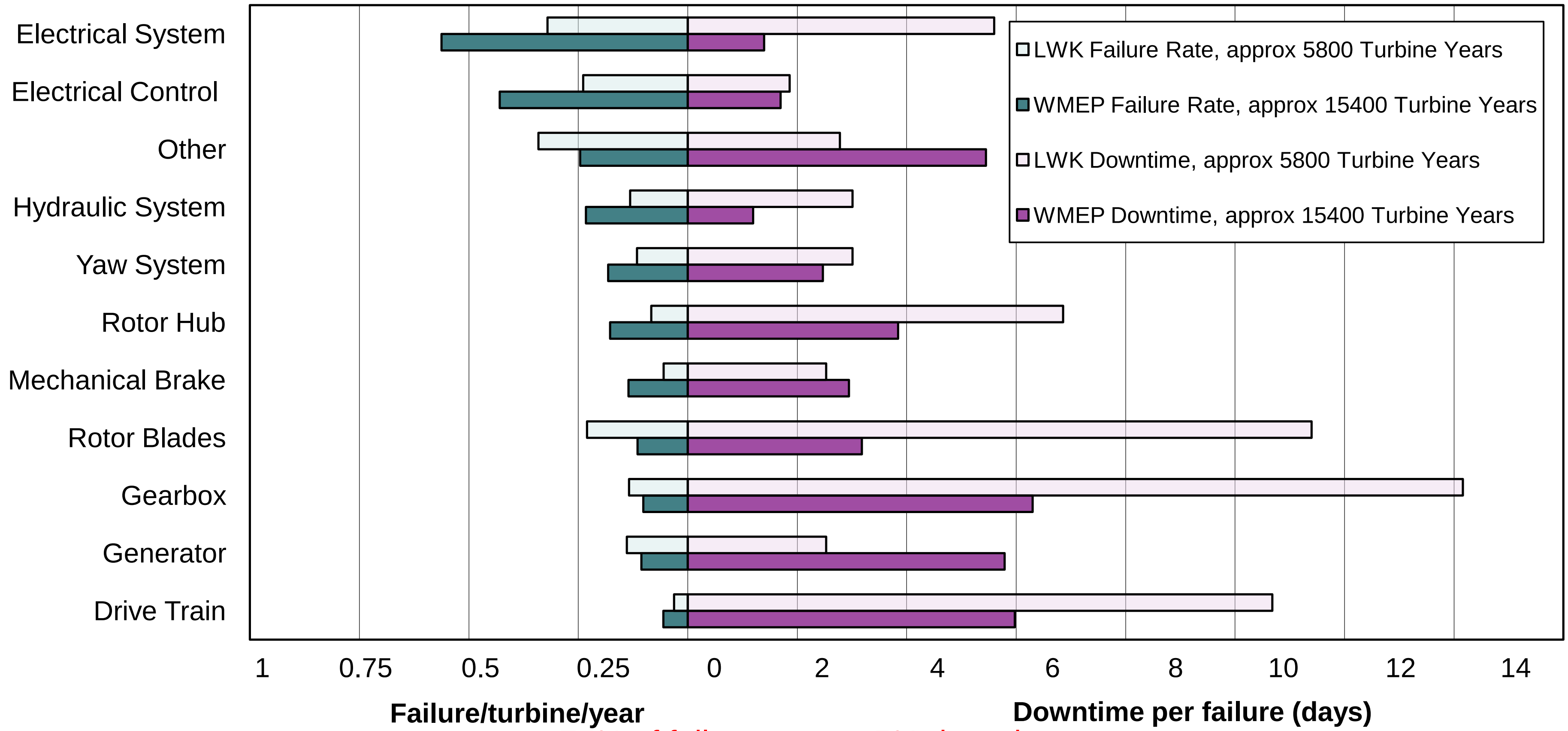
Wind farm	Region	MW Capacity	Developer (owner)
Bristol Channel	South West	1500	RWE Npower Renewables
Dogger Bank	North Sea	9000	Forewind Consortia (SSE Renewables, RWE Npower Renewables, Statoil and Statkraft)
Firth of Forth	Scotland	3500	SeaGreen Wind energy Ltd (SSE Renewables, Fluor)
Hastings	South	600	E.On Climate and Renewables
Hornsea	North Sea	4000	Mainstream Renewable Power, Siemens Project Ventures
Irish Sea	Irish Sea	4200	Centrica
Moray Firth	Scotland	1300	EDP Renovaveis, Seaenergy Renewables
Norfolk Bank	Southern North Sea	7200	East Anglia Offshore Wind Ltd (Scottish Power Renewables and Vattenfall)
West of Isle of Wight	South	900	Eneco New Energy
TOTAL		**32,200 MW**	

Reliability and Size , EU Onshore



Reliability, Downtime and Subassemblies, EU Onshore

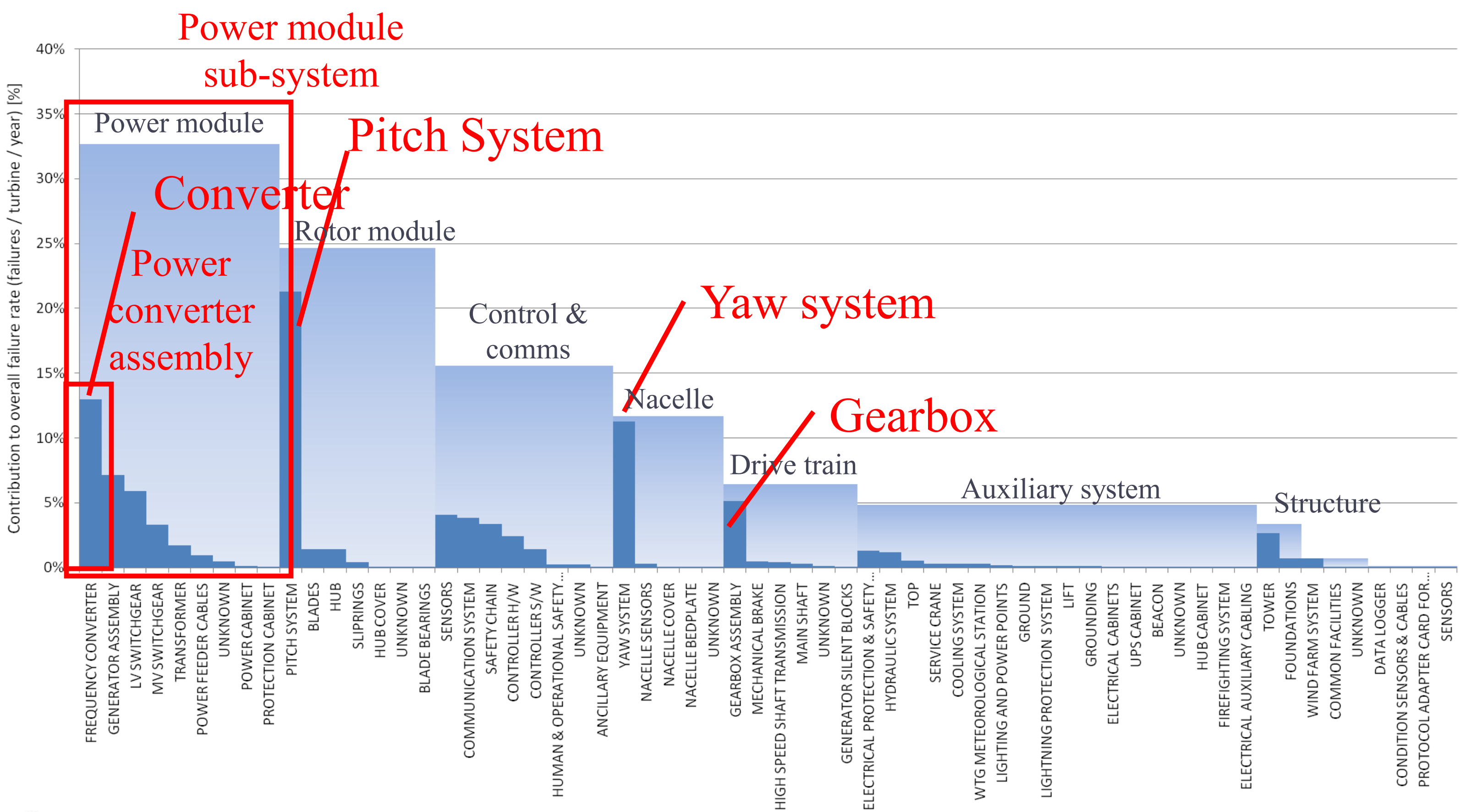
Failure/turbine/year and Downtime from 2 Large Surveys of European Onshore Wind Turbines over 13 years



75% of failures cause 5% downtime

25% of failures cause 95% of downtime

Reliability, Downtime and Subassemblies, EU Onshore



Percentage contribution to overall failure rate

Data source: turbines from multiple manufacturers

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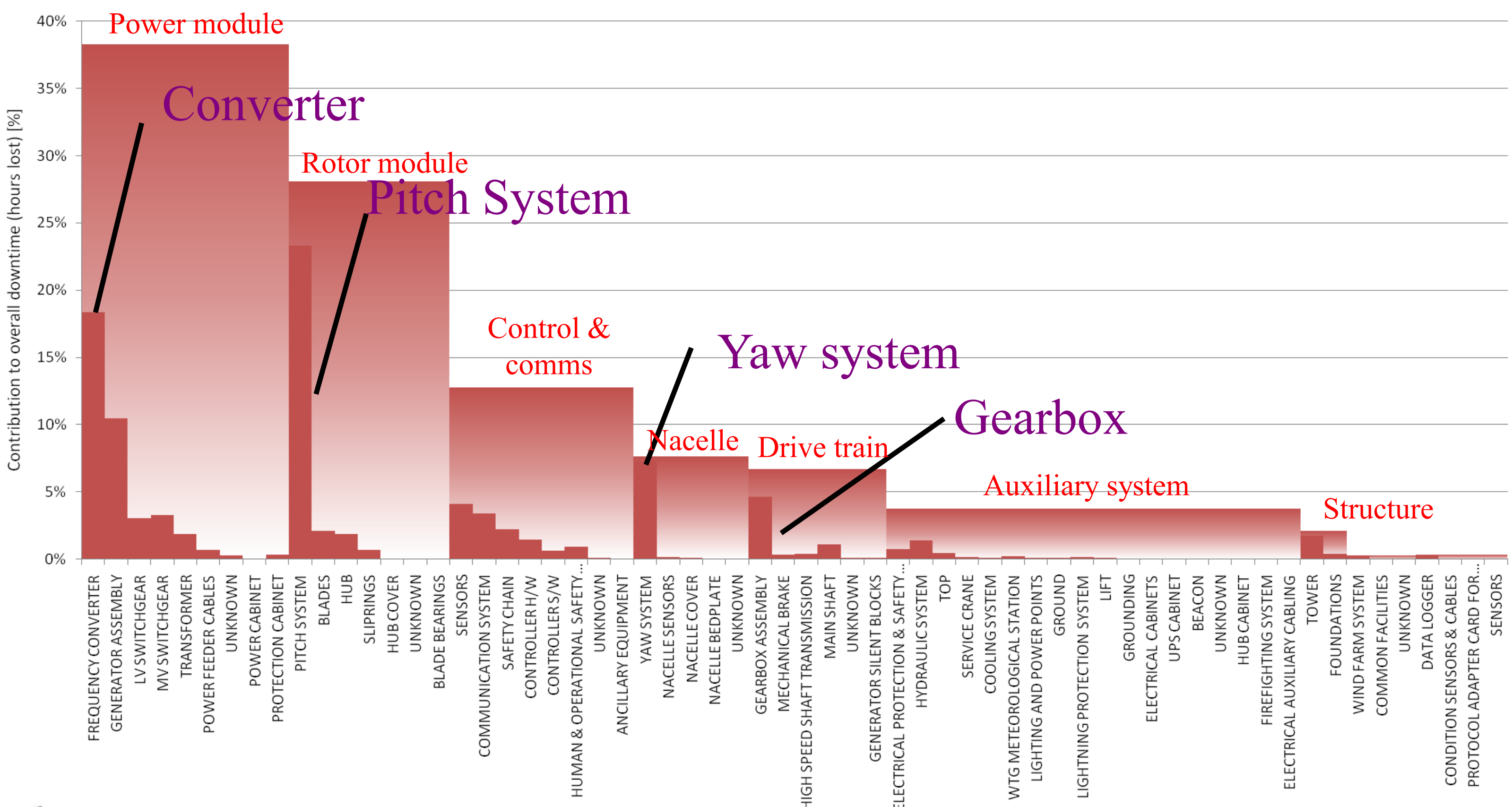
Reliability, Downtime and Subassemblies , EU Onshore

ReliaWind



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Percentage contribution to overall failure rate

Data source: turbines from multiple manufacturers

Capacity Factor & Availability

Energy generated in a year = C x Turbine rating x 8760

Capacity Factor, *C*

8760: number of hours in a year

Therefore:

C = Energy generated in a year / Turbine rating x 8760

C incorporates the Availability, *A*

Availability, *A=1-MTTR/MTBF*, where *MTBF=1/*λ

	Capacity Factor, *C*	**Availability, *A***
Typical UK values		
Onshore	27.3%	97%
Early offshore	29.5%	80%
Typical EU values		
Offshore	36%	90%

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Cost of Energy, *COE*

- *COE*, £/kWh=

  $(ICC \times FCR + O\&M)/AEP$
  - *ICC*=Initial Capital Cost, £
  - *FCR*=Fixed Charge Rate, interest, %
  - *O&M*=Annual Cost of Operations & Maintenance, £
  - *AEP*=Annualised Energy Production, kWh
- *COE* , £/kWh =

  $(ICC \times FCR + O\&M(1/\lambda, 1/MTTR))/AEP(A(1/\lambda, 1/MTTR)\}$
- Reduce failure rate λ, Reliability MTBF $1/\lambda$ improve and Availability *A* improve, O&M cost reduces;
- Reduce Downtime MTTR, Availability *A* improve, O&M cost reduces;
- Therefore *COE*, reduces

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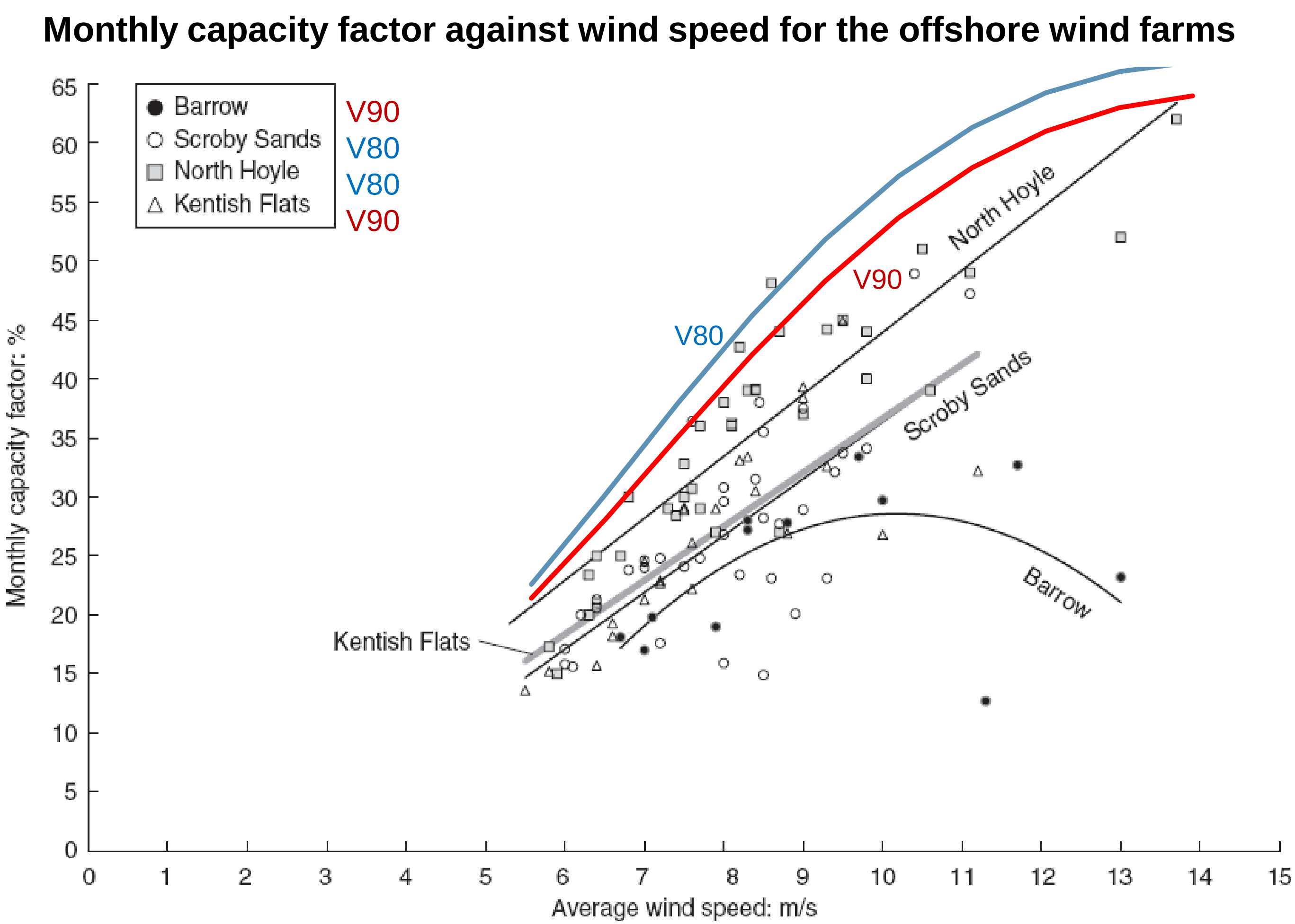
Offshore Capacity Factor and Wind Speed, UK



Offshore Availability and Wind Speed, UK

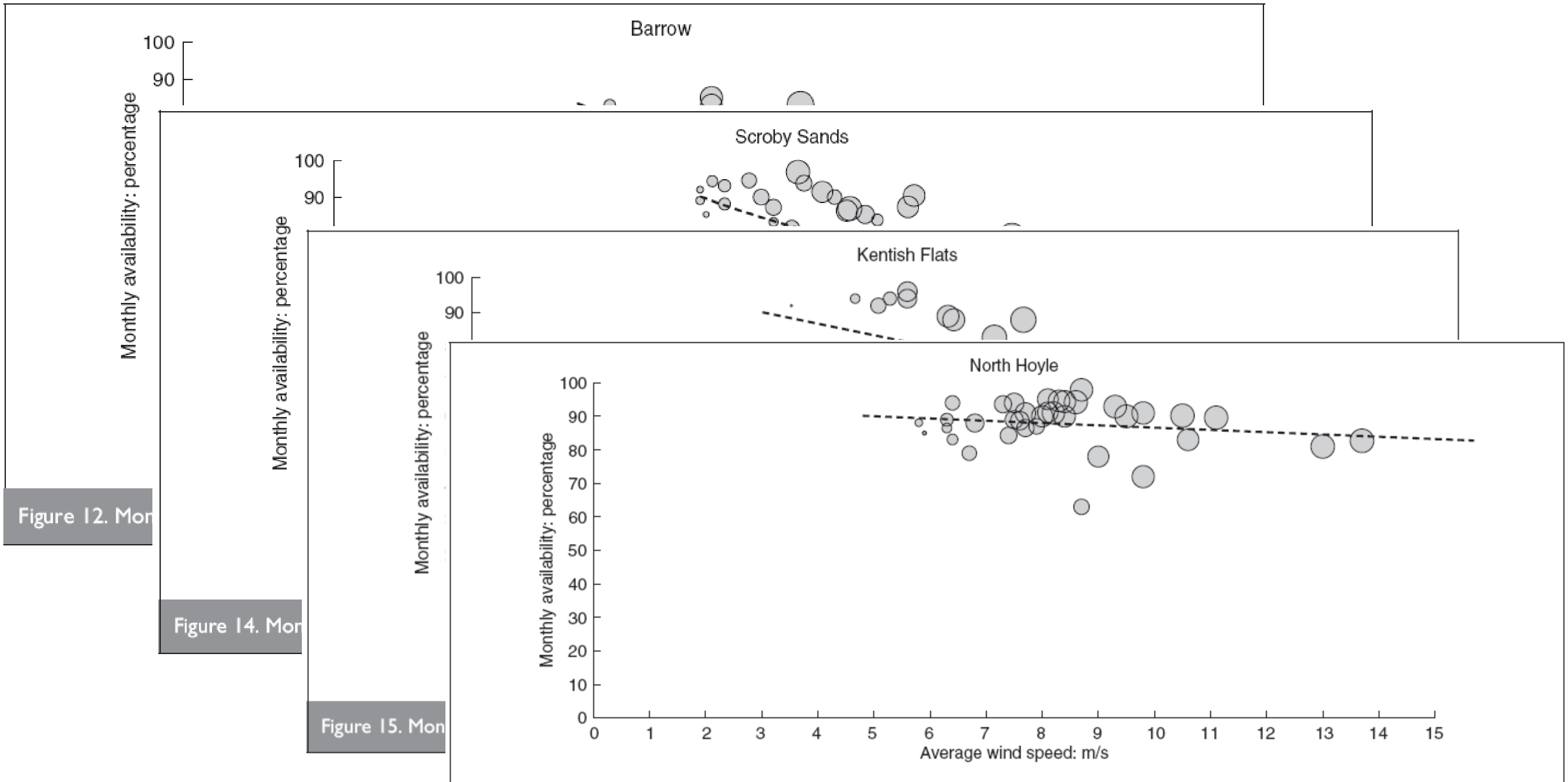
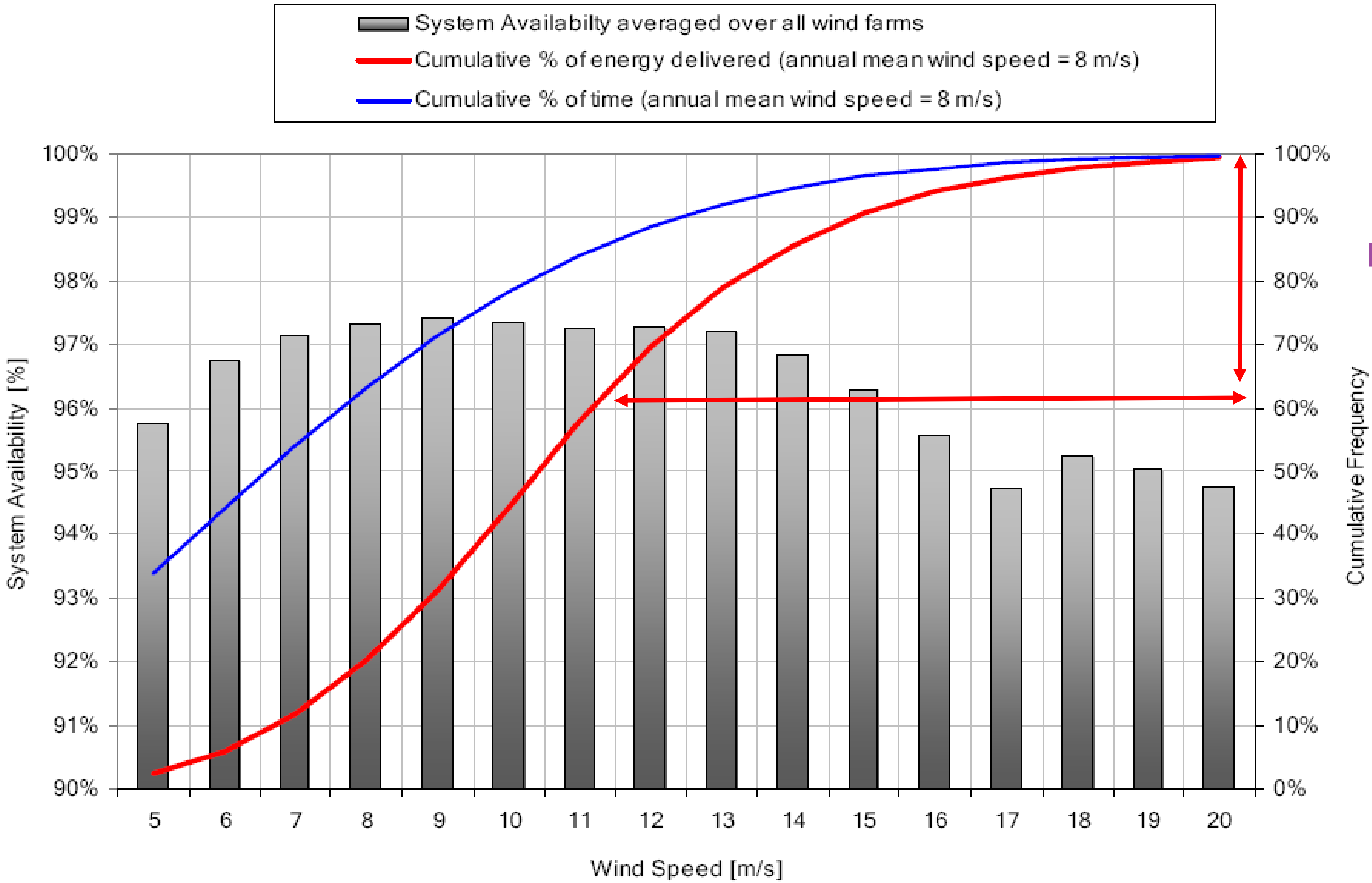


Figure 13. Monthly availability against wind speed for North Hoyle offshore wind farm

Onshore Availability and Wind Speed, World



40% energy produced at wind speeds >11m/s

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Supergen Wind Training
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ReliaWind

Wind Turbine Reliability Analysis

Root Causes → Condition Monitoring Signals → SCADA Signal Analysis → Failure Modes And Effects Analysis, FMEA → Failure Location

Wind condition
Weather
Faulty design
Faulty materials
Poor maintenance

Results of WP3 analysis

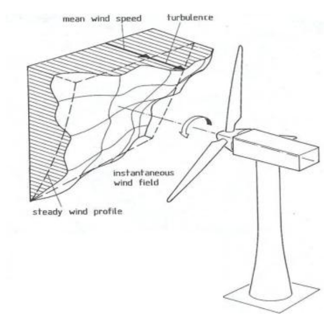
Results of WP2 analysis

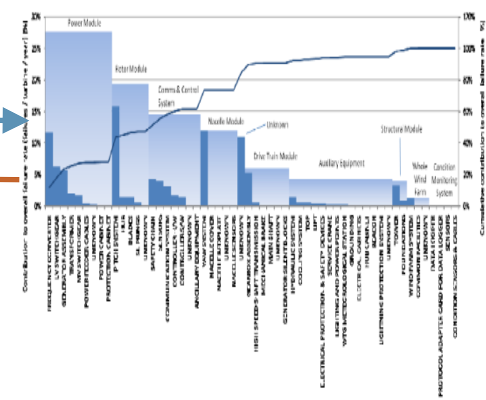
Results of survey data WP1

How?

SCADA Analysis

& Diagnosis





Why?

Root Cause Analysis

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Conclusions

- WT reliability is improving
- WT concepts have different reliabilities
- Larger WTs have higher failure rates
- Generally failure rates are constant & subassemblies with high failure rates are consistent
- Downtime or *MTTR* and Cost of Energy are also important
- Failure rates of subassemblies can improve with time
- Offshore availability A_i is worse than onshore
- Offshore availability reduces with wind speed

What is the Value of this Information

- It gives us baselines for WT and subassembly λ (*1/MTBF*) and MTTR
- It makes clear the difference between onshore and offshore
- It shows us that we need to use standardised Availability and Reliability definitions
- It shows us that we need to standardise subassembly definitions if we are to interpret results

What is the Value of this Information

- It shows us that there is a lot to learn about Root Causes and valid Detection Methods by interpreting this information
- It shows us that there is a lot we can do to improve our Wind Turbines but that we need hard data to do it
- However data from turbines is useless if we cannot relate it to failures and repairs

Thank you

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