IET/CSEE Workshop

Offshore Wind
Experiences in Northern Europe and Opportunities in China

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TPJ2

Antoine de Saint Exupery,
French pilot, writer & poet (d1944)

"The machine does not isolate man from the great problems of nature but plunges him more deeply into them"

Slide 1

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Overview

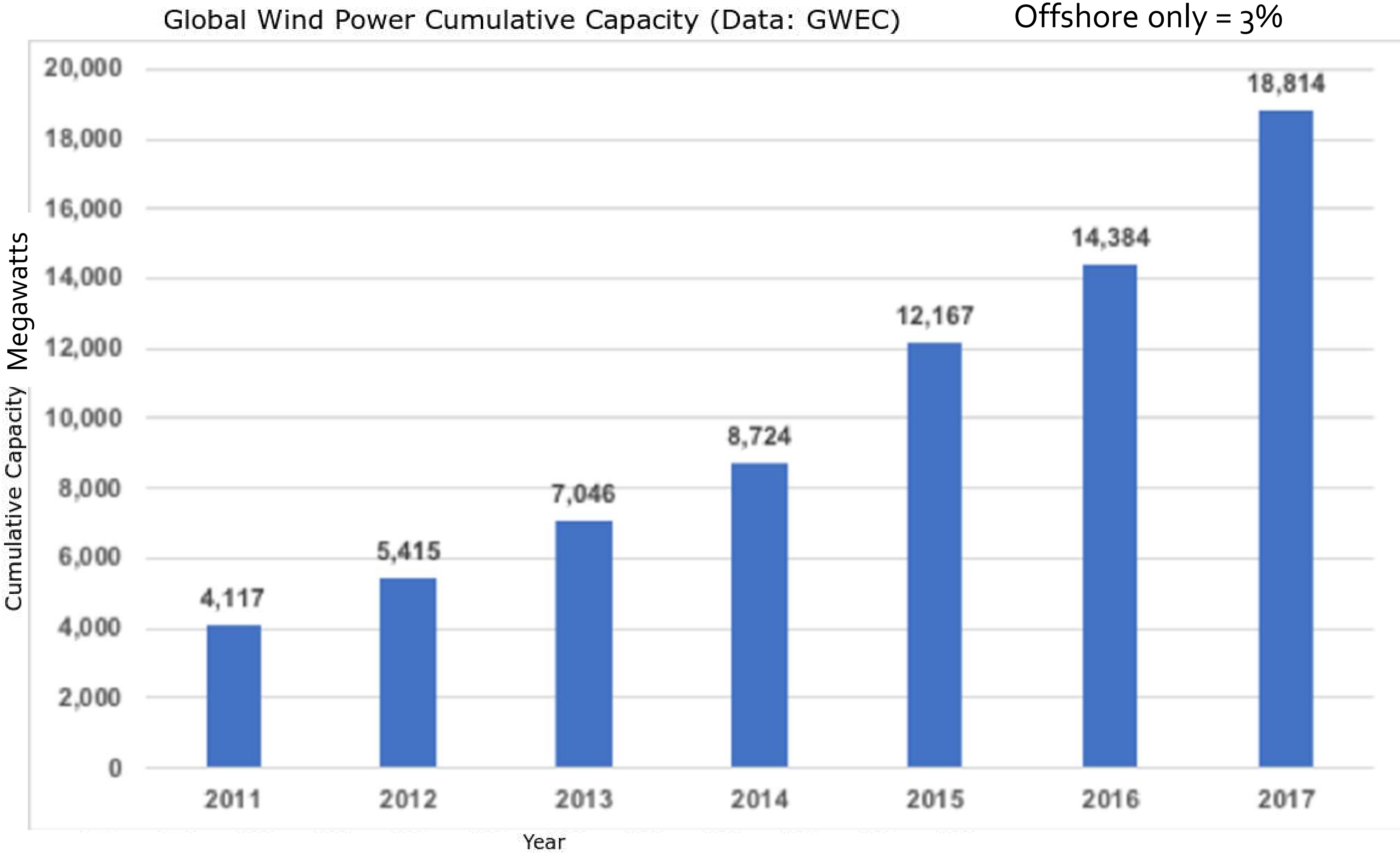
- Background to causes & effects of wind turbine unreliability & Capacity Factor;
- Understand basic reliability information;
- Examples of current WT reliability data & how it is changing with time:
  - Onshore;
  - Offshore Fixed;
  - Offshore Floating.
- Compare China & Europe wind experience
- What's needed to make Offshore Fixed & Floating more reliable and more successful.

Wind Reliability Transitions: Onshore-Offshore-Offshore Floating

Musial, W, Beiter, P, Spitsen, P, Nunemaker, J, Gevorgian, V (2018) Off-shore wind technologies market report, US Department of Energy, USA.

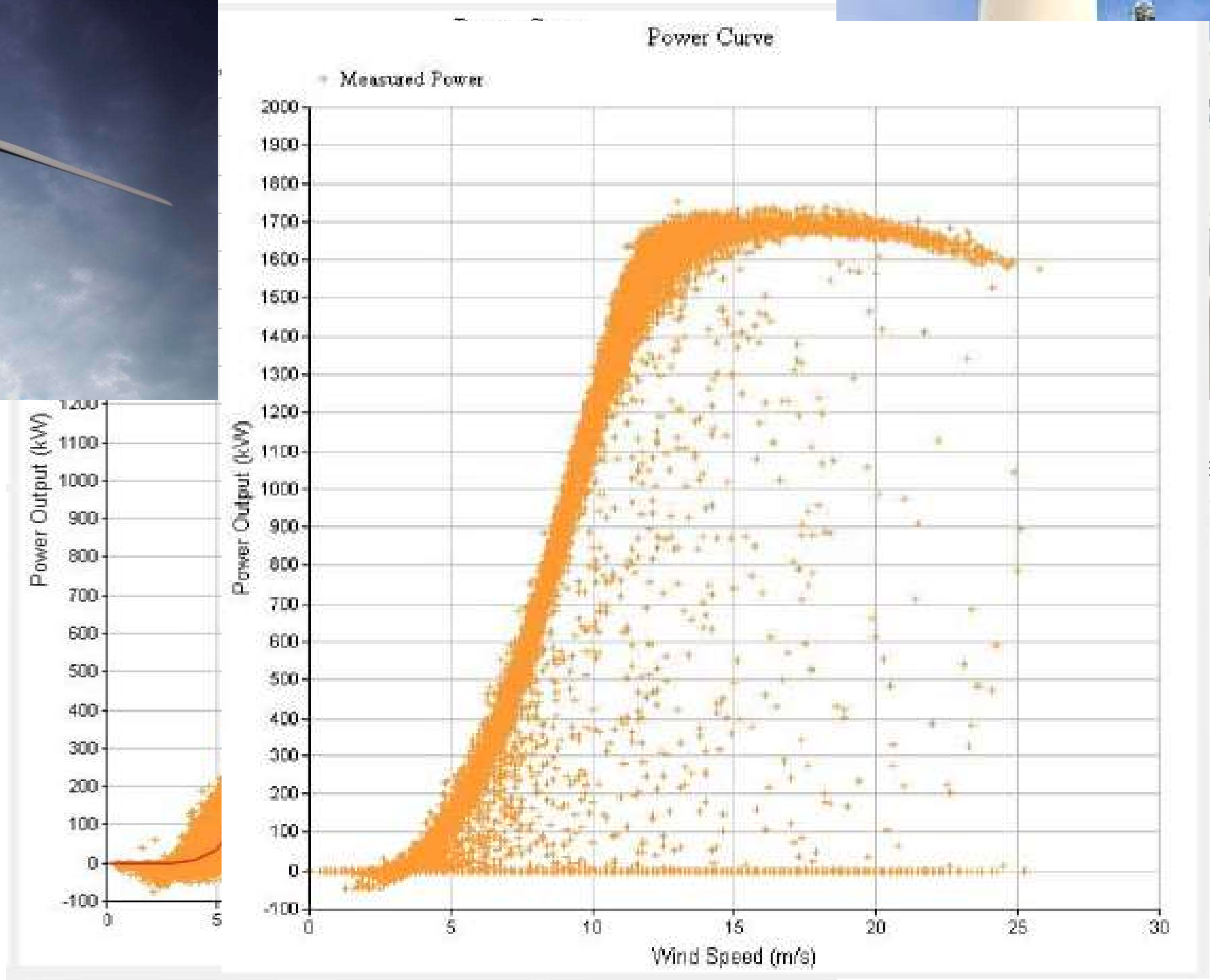
Growth of Onshore & Offshore Wind

Offshore only = 3%



Wind Turbine Power Curves

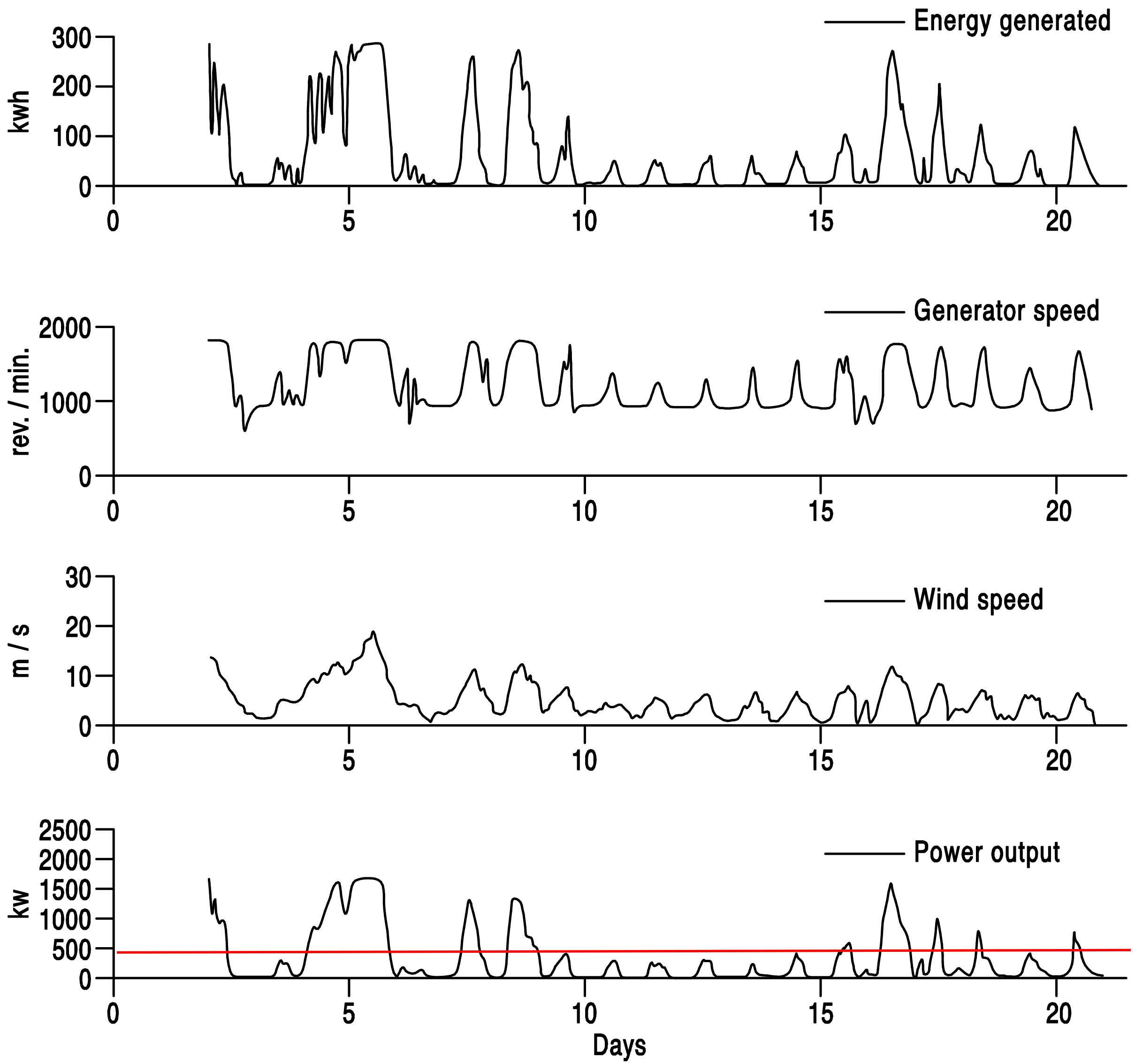
Eco80 Pitch-regulated,
Variable speed,
1.67 MW



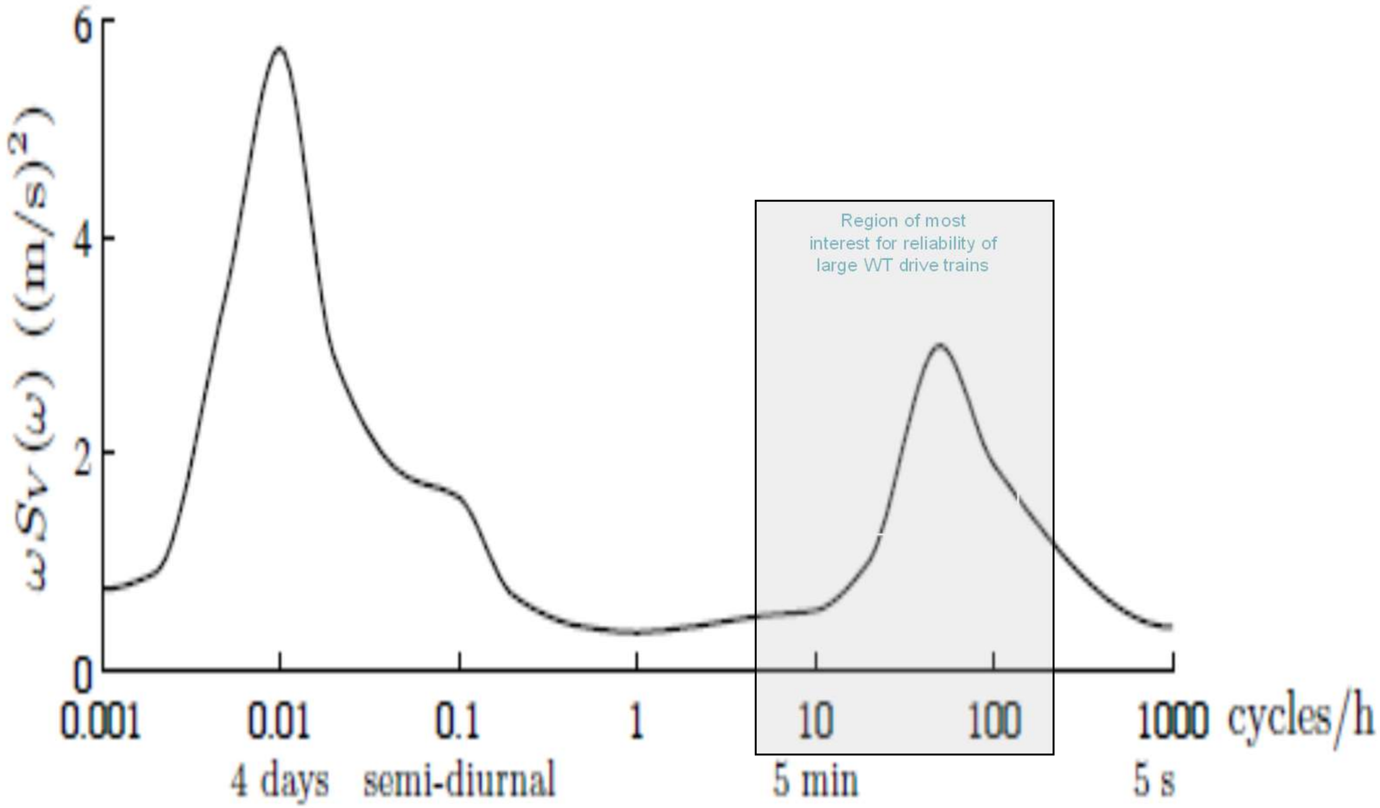
Stall-regulated,
ed speed,
1 MW

Wind Turbine Operation- 18 days

WT rating= 1.67MW
Average output=480kW
Capacity Factor =480/1670=29%



Wind Turbulence & WT Data

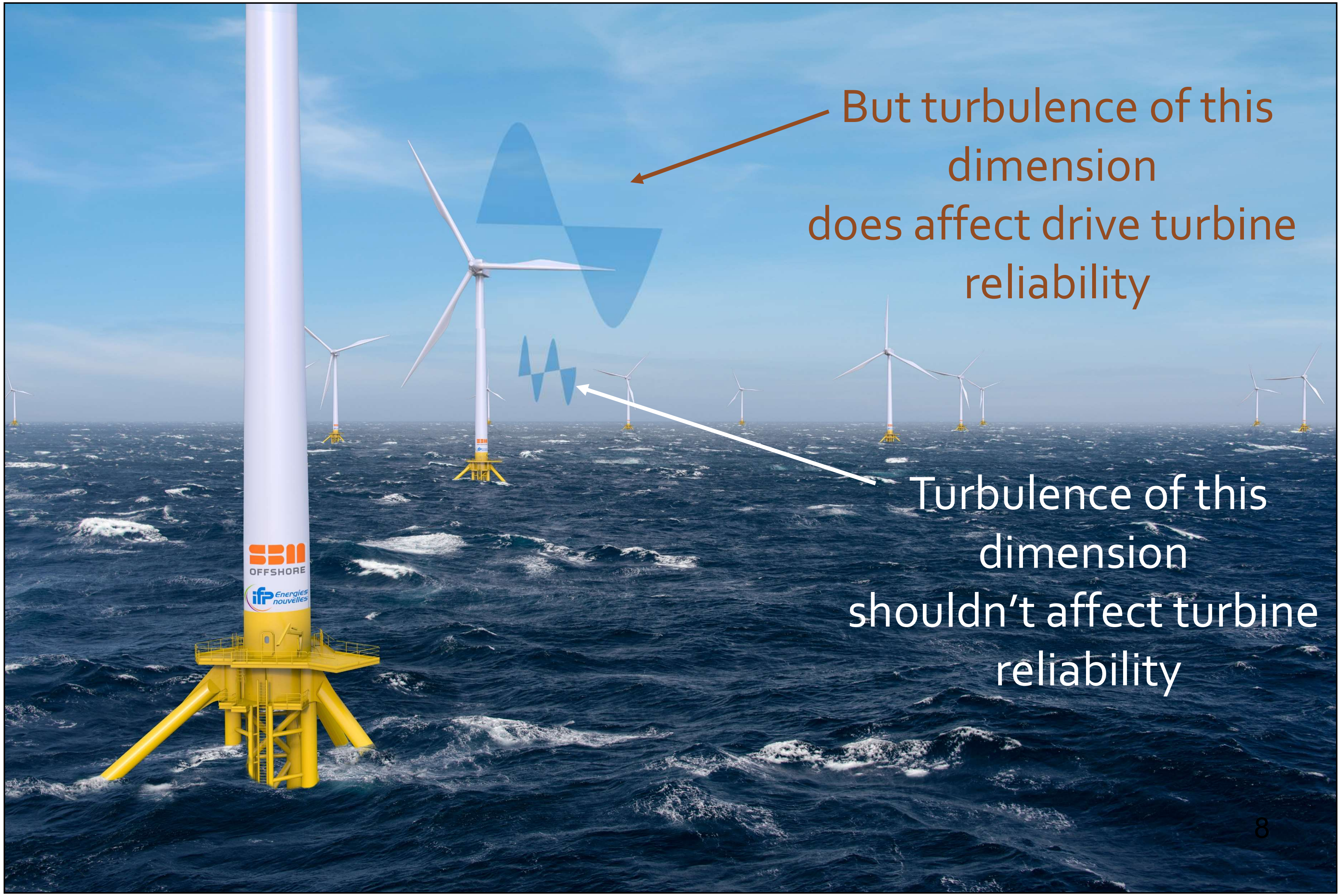


van der Hoeven, I (1957) Power spectrum of horizontal wind speed in the frequency range from 0.0007 to 900 cycles per hour. *Journal of Atmospheric Sciences*, **14**(2): 160-164.

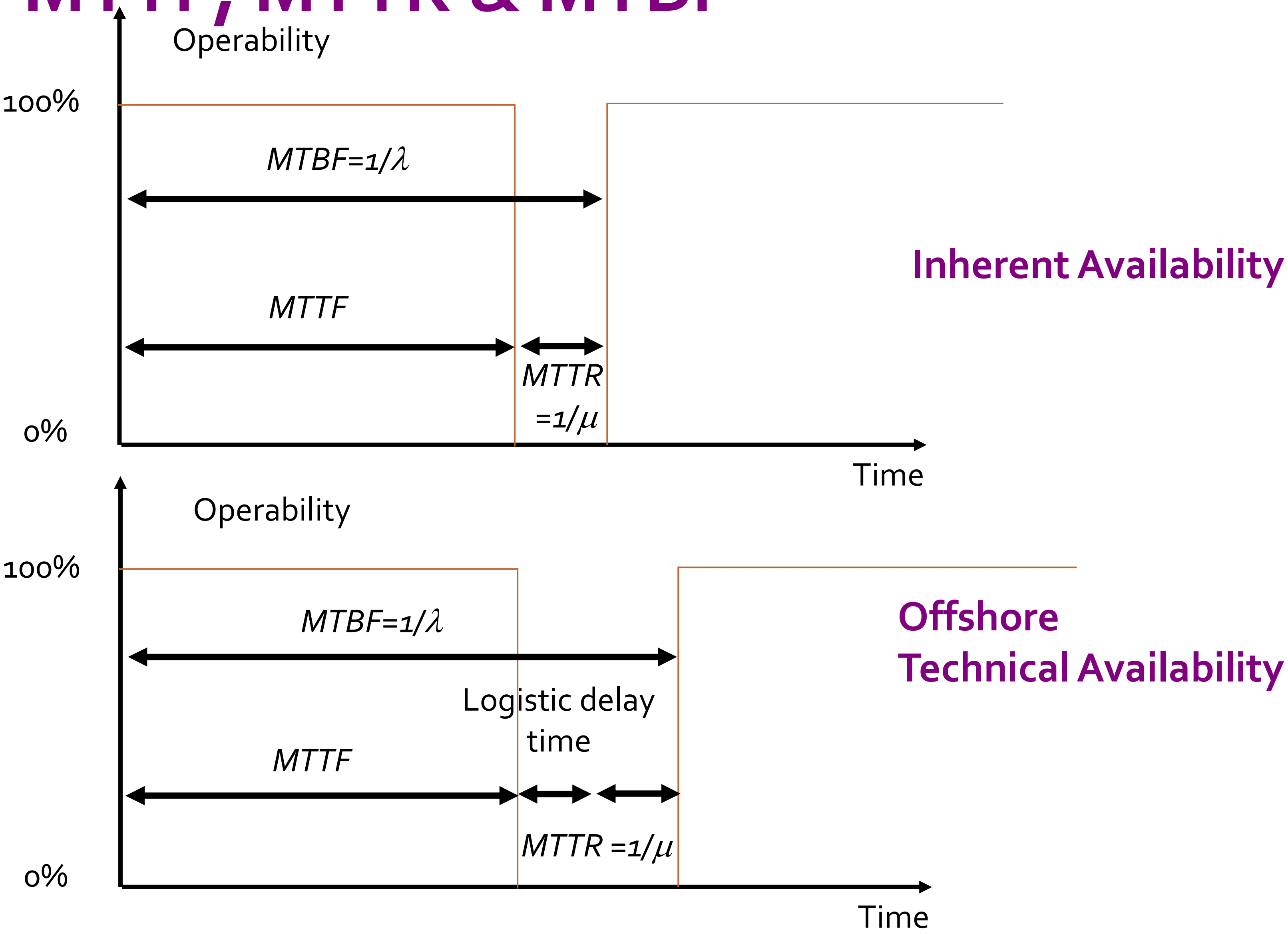
Lavely, A W (2017) Effects of Daytime Atmospheric Boundary Layer Turbulence on the Generation of Non-steady Wind Turbine Loadings and Predictive Accuracy of Lower Order Models, , Doctoral Thesis, Pennsylvania State University.

Nandi, T N, Herrig, A, Brasseur, J G (2017) Non-steady wind turbine response to daytime atmospheric turbulence. Phil. Trans. R. Soc. Lond A; 375(2091).

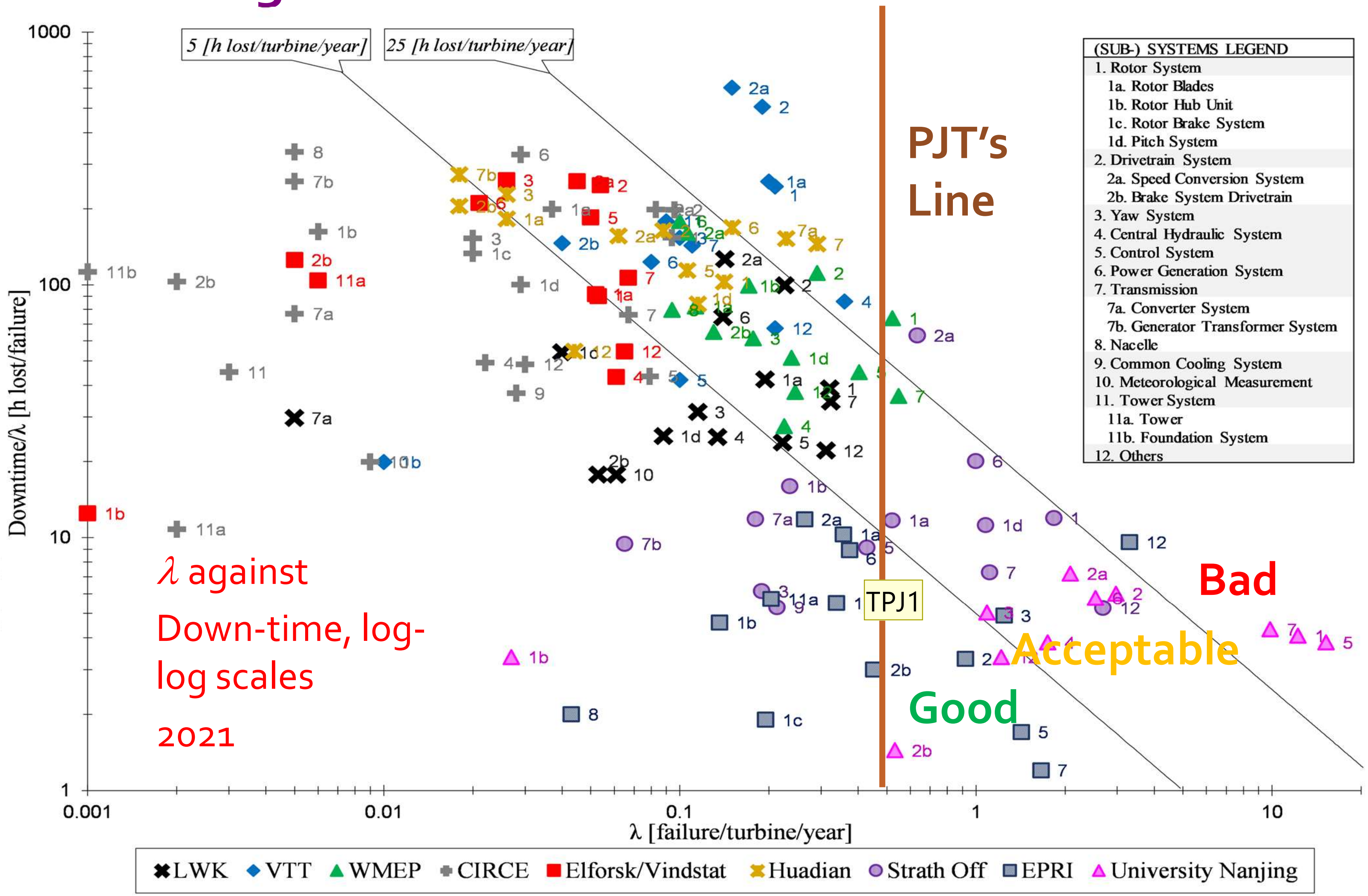
Offshore Wind Turbulence in Context



Availability, MTTF, MTTR & MTBF



WT Failure Rates λ (1/MTBF) & Down-time MTTR ($1/\mu$), Trends against different variables



Cevasco, D, Koukoura, S, Kolios, A.J (2021) Reliability, availability, maintainability data review for the identification of trends in off-shore wind energy applications, *Renewable and Sustainable Energy Reviews*, 136, Feb, 110414

Slide 10

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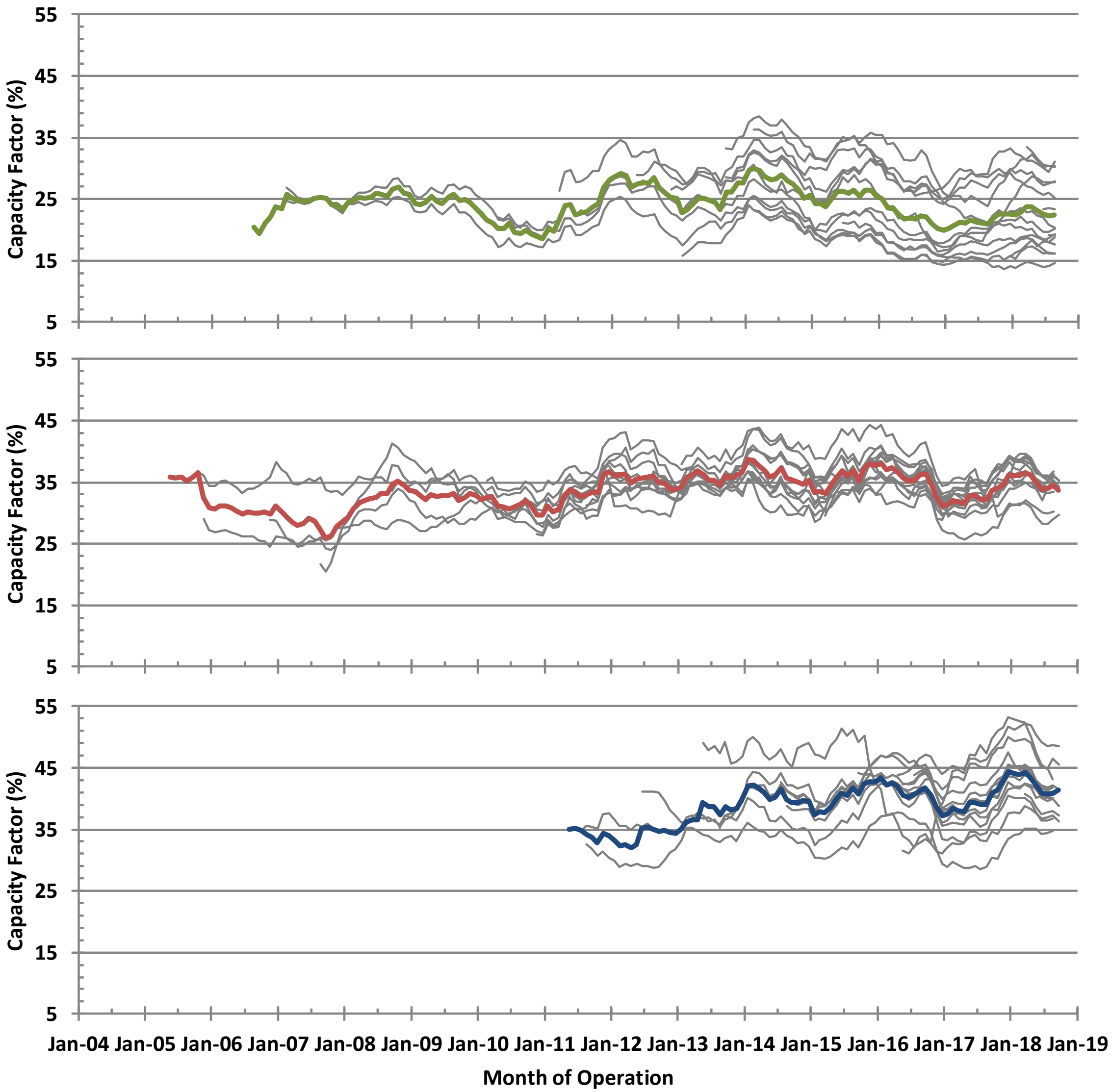
Capacity Factor, UK Onshore & Offshore Wind Experience



Onshore >100 MW
1013 WTs
2.5 GW

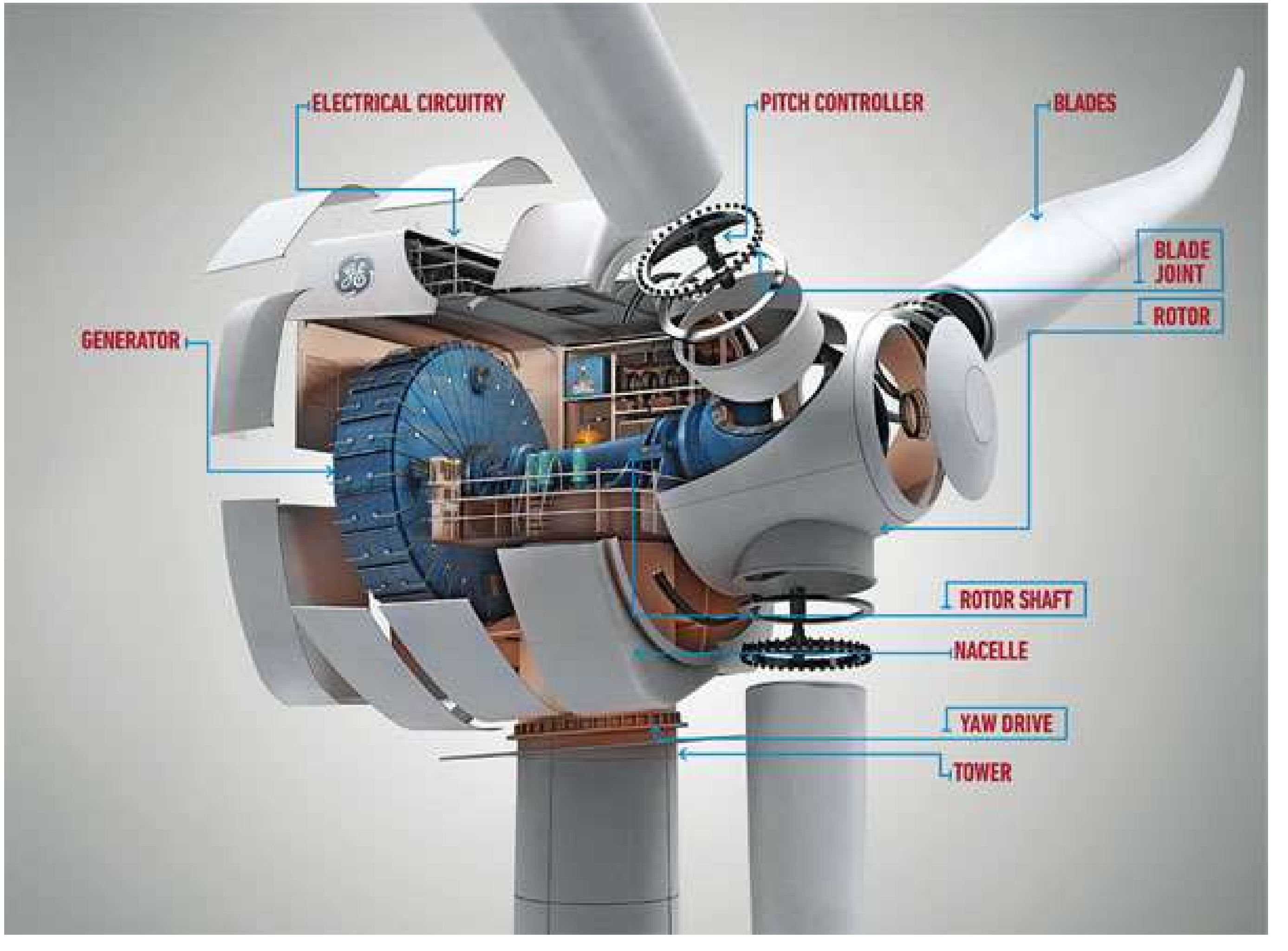
Offshore R1
371 WTs
1.2 GW

Offshore R2
1456 WTs
5.9 GW

2020

Crabtree, C J, Zappala´ , D, Hogg, S I (2015) Wind energy: UK experiences and off-shore operational challenges, Proc IMechE Part A: J Power and Energy; 0(0): 1–20

Offshore WT Fault Monitoring in Context



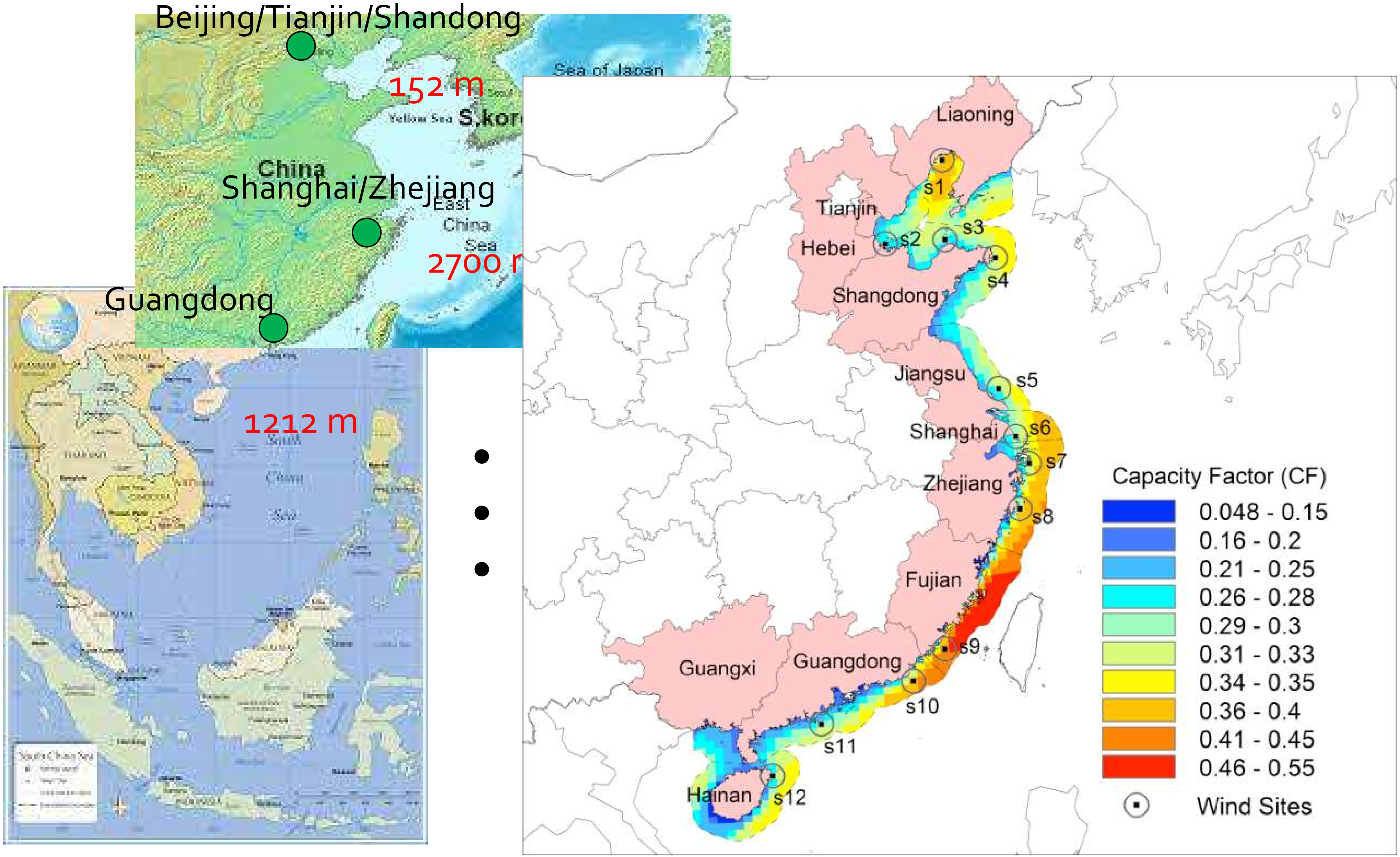
Example of UK Offshore Monitoring Issues London Array, Offshore Wind Farm, UK Round 2 175 x 3.6 MW WTs, 630 MW

- 175 WTs, 400 I/O per WT;
- Total Wind Farm I/O > 80000 items/10min
- Onshore 75% of faults cause
  5 % of downtime;
- Offshore 75% of small faults become critical;
- Alarm rates at onshore Ops are overloaded;
- Consuming O&M time & money.

Best Offshore Wind, Fixed or Floating

- Long Onshore Wind experience has proven turbines are reliable;
- Early Offshore Wind experience has proven fixed Offshore Turbines;
- Offshore Wind Capacity Factors are better than Onshore;
- Offshore Wind CAPEX/MW/turbine falls with increased MW rating;
- Higher rated Floating Offshore Wind Turbines will have lower CAPEX/MW/turbine because:
  - Cost savings on unit numbers;
  - Build Floating Offshore Wind turbines onshore;
  - Float them out to avoid high offshore erection costs.
- Need Offshore Fixed & Floating to be more reliable & reduce OPEX, therefore become more successful.

China Wind Conditions in Yellow, East & South Seas



China Offshore Wind, Fixed or Floating Transitions

Conclusions

- **Offshore wind has proved its capability but improved reliability needed**, differing subassemblies have high failure rates but are consistent & known;
- Failure rate, $\lambda = 1/MTBF$, generally constant;
- Downtime, $MTTR = 1/\mu$, variable and

  OPEX cost very important for fixed & floating offshore wind;
- Capacity Factor, *C*, consistently better offshore than onshore **floating offshore wind is the best**;
- However, availability, ***A*, worse offshore than onshore** because of repair mobilisations;
- **Over-instrumentation a major problem for reducing *A***;
  - Too much data, too little analysis & planning;
  - Turn WT Data into Wind Farm Data, gives better offshore WT availability & lower CoE:
  - More efficient maintenance schedules reduce offshore cost & deliver lower cost/MWh floating wind farms.
- **Recommendations for China:**
  - Move towards floating offshore in Yellow, East & South China Seas;
  - Improve *MTTR*.

Thank you

1. Tavner, P J, Xiang, J P, Spinato, F (2007) Reliability analysis for wind turbines, *Wind Energy*, **10**(1): 1–18;
2. Spinato, F, Tavner, P J, van Bussel, G J W, Koutoulakos, E (2009) Reliability of wind turbine subassemblies, *IET Renew Power Gen*, **3**(4): 387-401;
3. Faulstich, S, Hahn, B, Tavner, P J (2011) Wind turbine downtime and its importance for offshore deployment, *Wind Energy* **14**(3): 327-337;
4. **Tavner, P J (2012) Offshore Wind Farms, Availability & Maintenance, *IET Energy*, UK, 2nd Ed due end 2021;**
5. Musial, W, Beiter, P, Spitsen, P, Nunemaker, J, Gevorgian, V (2018) Off-shore wind technologies market report, *US Department of Energy*, USA.
6. Cevasco, D,Koukoura, S, Kolios, A.J (2021) Reliability, availability, maintainability data review for the identification of trends in off-shore wind energy applications, *Renewable and Sustainable Energy Reviews*, 136, Feb, 110414