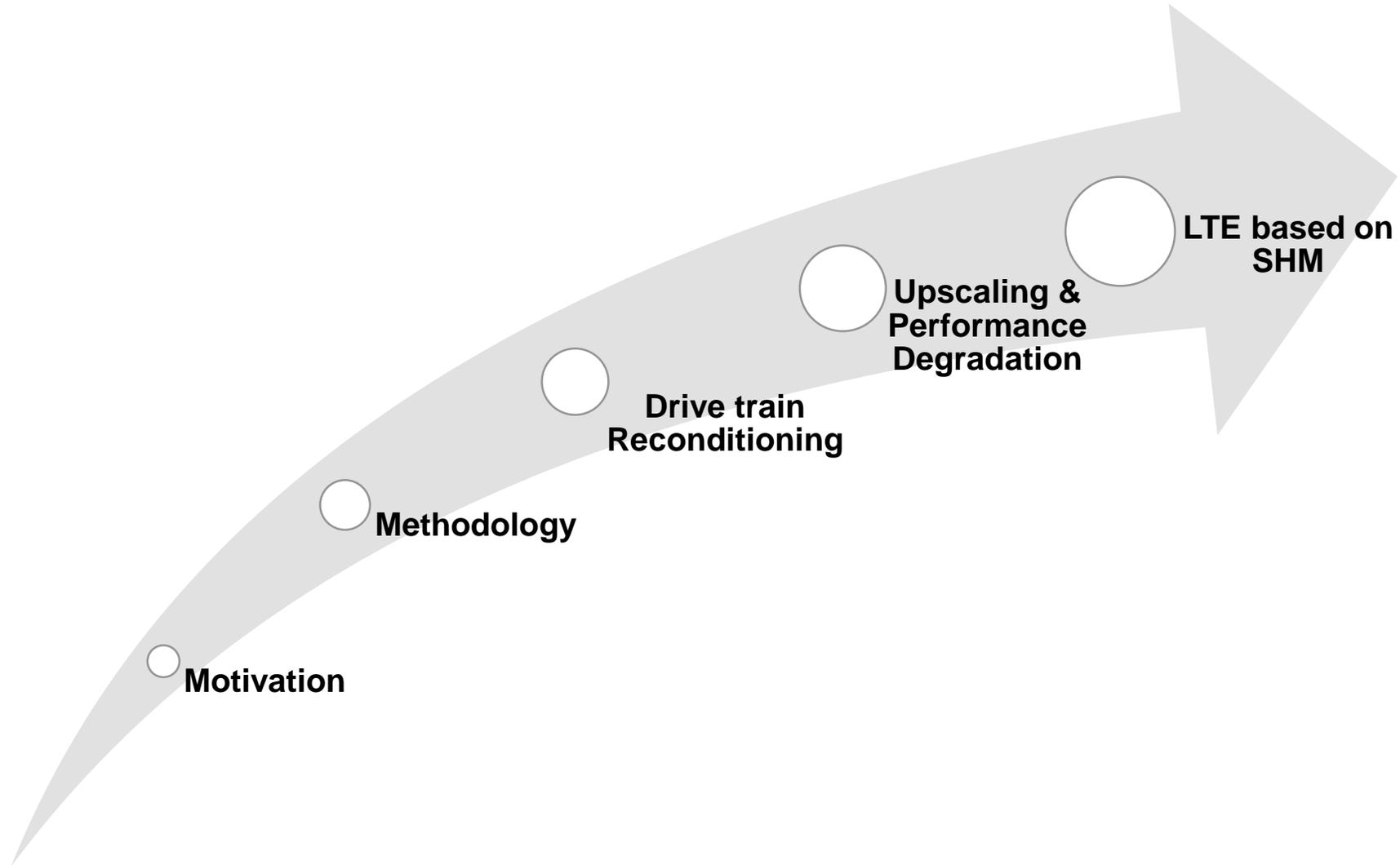


# Lifetime Extension of Wind Turbines

Tim Rubert, David McMillan, Pawel Niewczas et al.

Industrial Partner: SSE & SPR

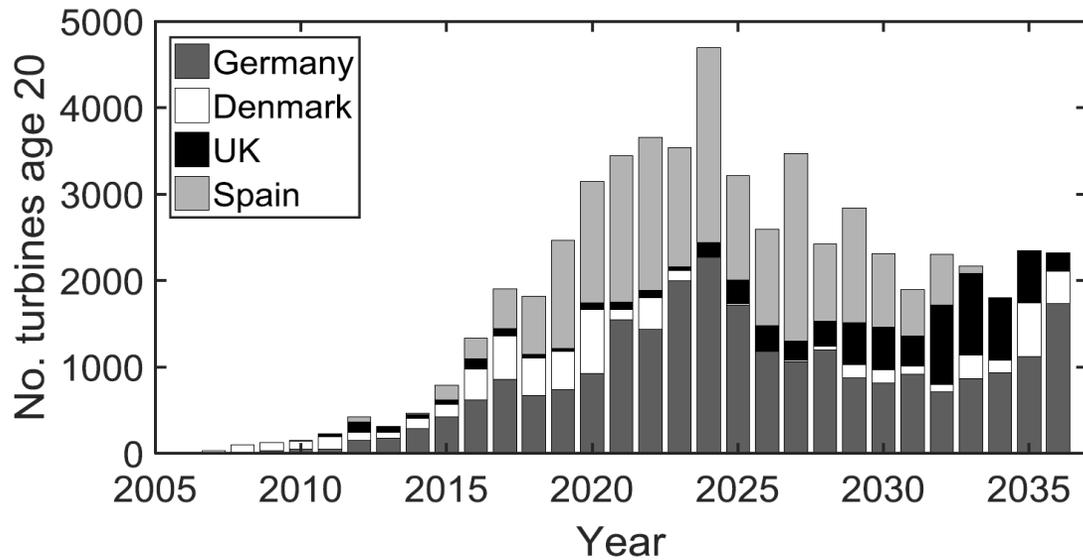
# Agenda



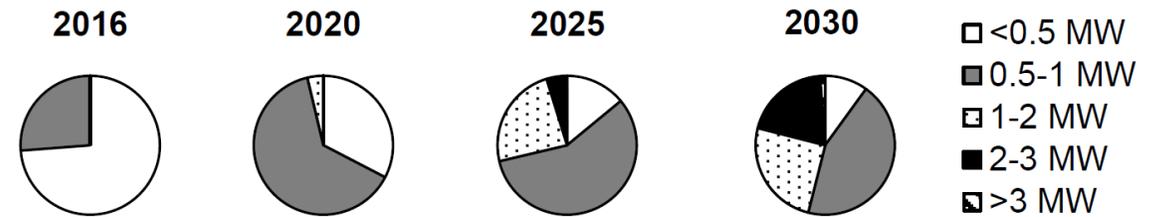
# Motivation

## Marked Development

LTE Market

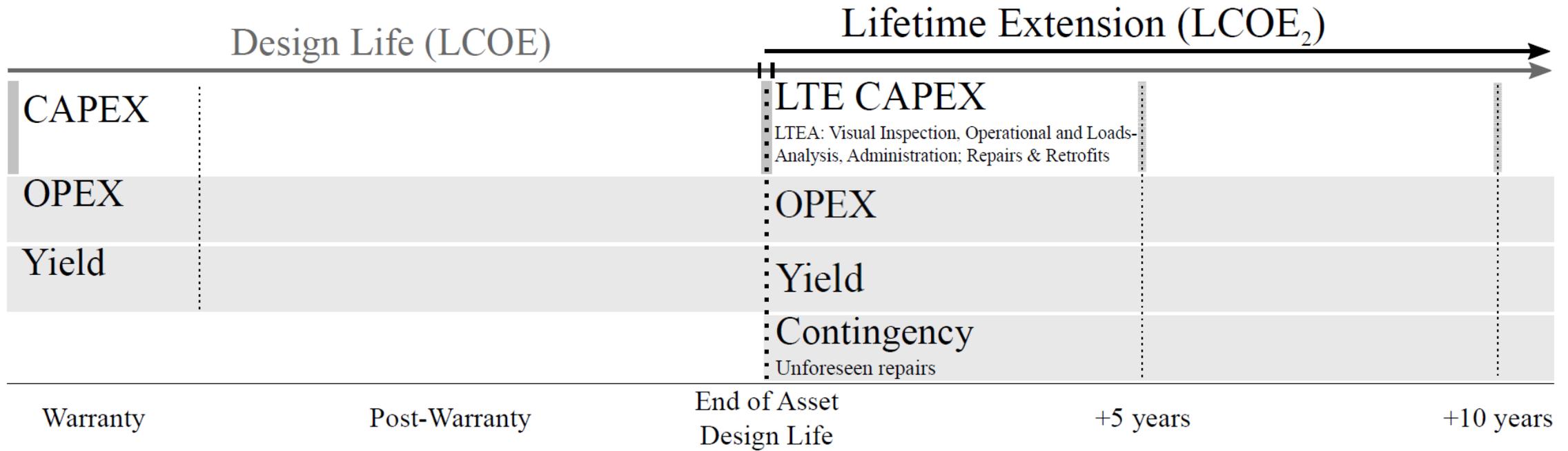


Future Capacity Distribution



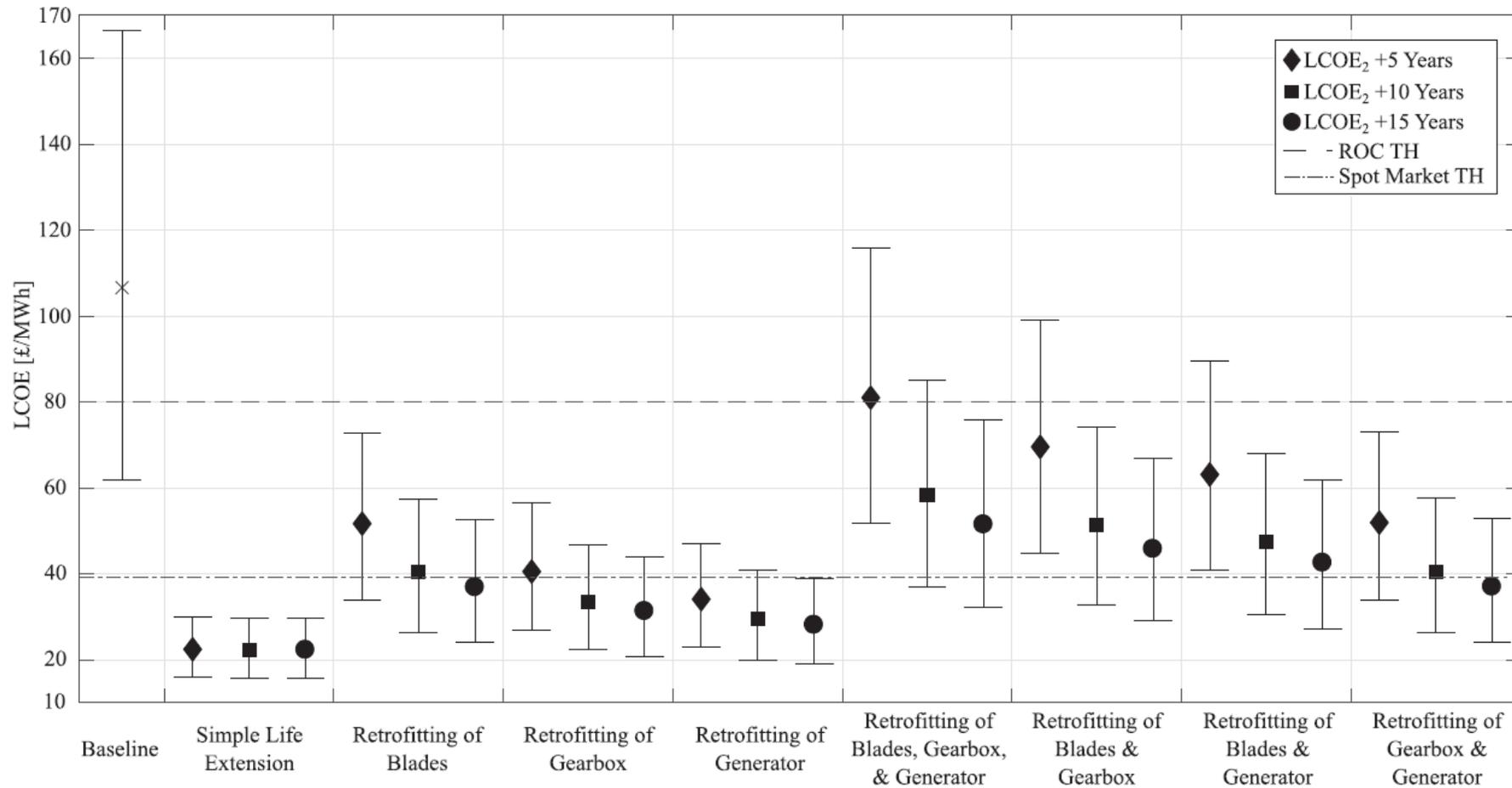
# Methodology

## LCOE-Based Analysis & Contingency Approach



# Results

## Under varying reconditioning

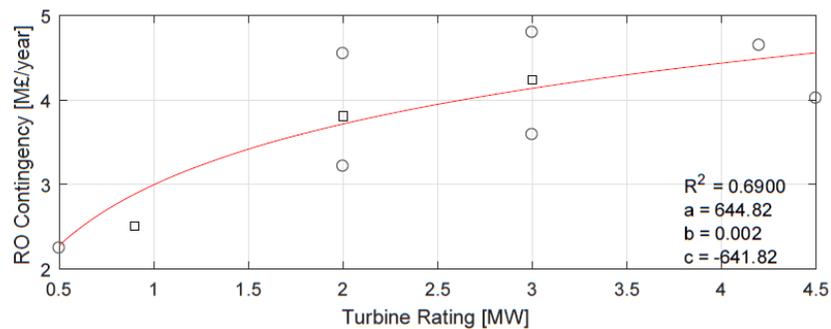
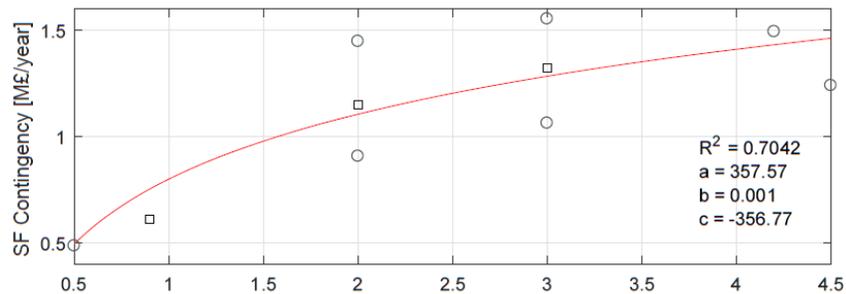
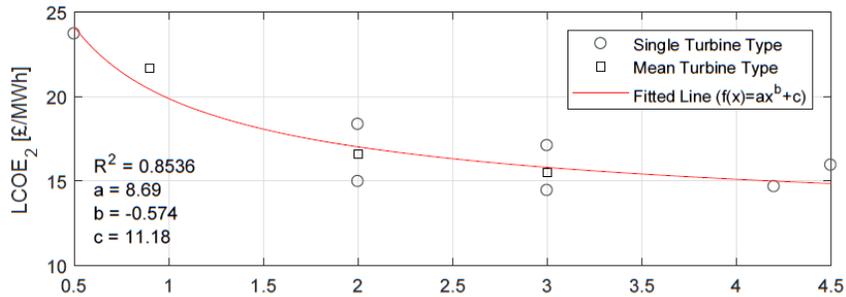


# Methodology

## Sensitivity Analysis

Case [-10%]	Gearbox retrofit [+10 years]		No retrofit [+10 years]	
	LCOE <sub>2</sub> [£]	Δ Baseline [%]	LCOE <sub>2</sub> [£]	Δ Baseline [%]
Mean wind speed	40.89	22.03	26.83	20.05
OPEX	31.36	-6.42	20.19	-9.62
C <sub>p,max</sub>	35.40	5.66	23.50	5.16
CAPEX (spares)	32.42	-3.24	N/A	N/A
Weibull shape factor	33.14	-1.08	22.12	-0.98
CAPEX LTE	33.42	-0.25	22.26	-0.38

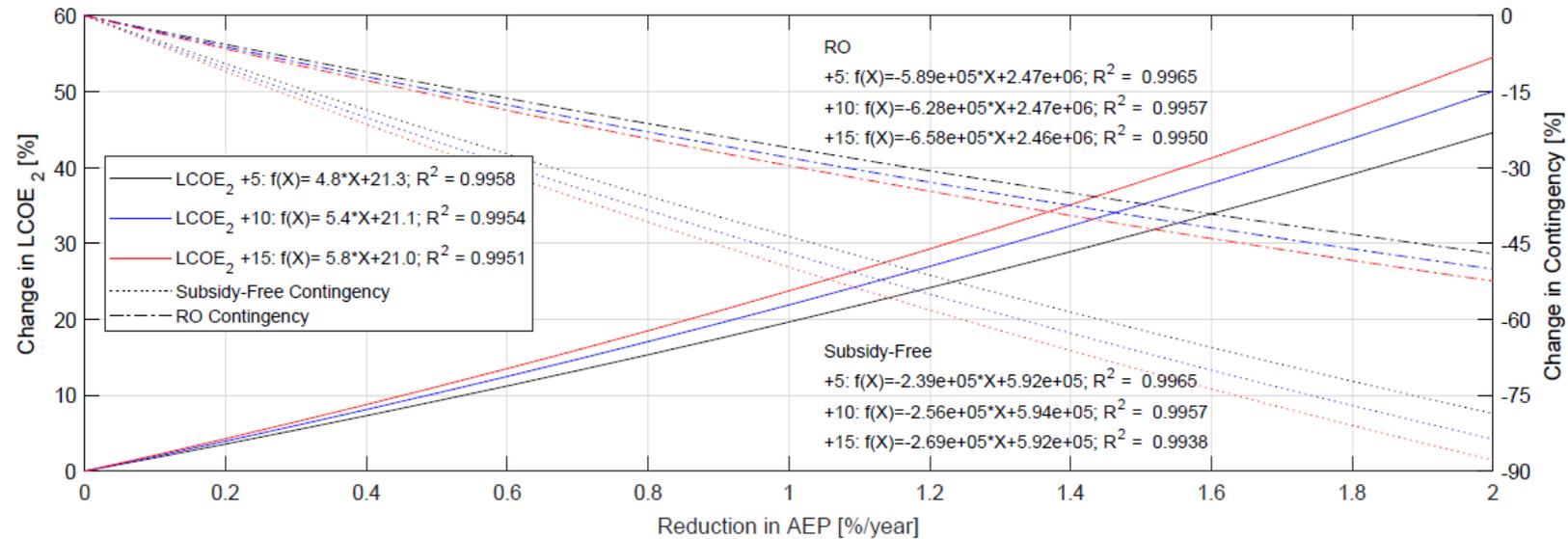
# Results Upscaling



- Goodness of fit indicators illustrate the great variance within turbine classes (some turbines have comparatively upscaled rotors, presumably for low wind speed regimes).
- Reductions in costs are most prominent sub 2MW installations.
- Size matters

# Results

## Performance Degradation



- **Methodology:** a reduction in AEP reduces yield and variable OPEX. Greater impact on yield, increasing the cost of energy.
- **Design life:** results indicate that an annual PD of 1.6% (0.2%) increases LCOE by 11.8% (1.4%).
- **LCOE<sub>2</sub>:** results indicate that an annual PD of 1.6% (0.2%) elevates LCOE<sub>2</sub> by 34-41% (3.6-4.3%).

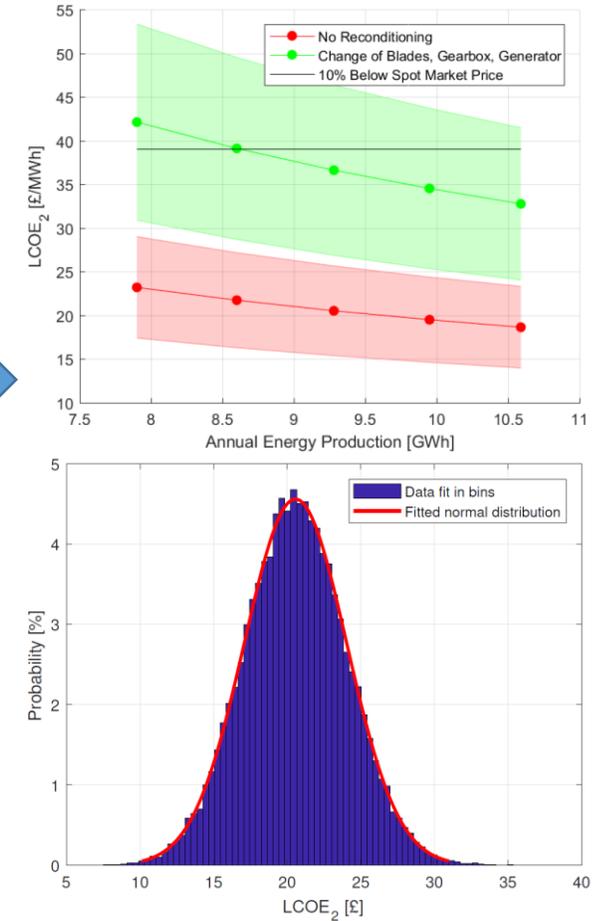
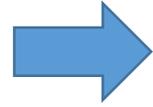
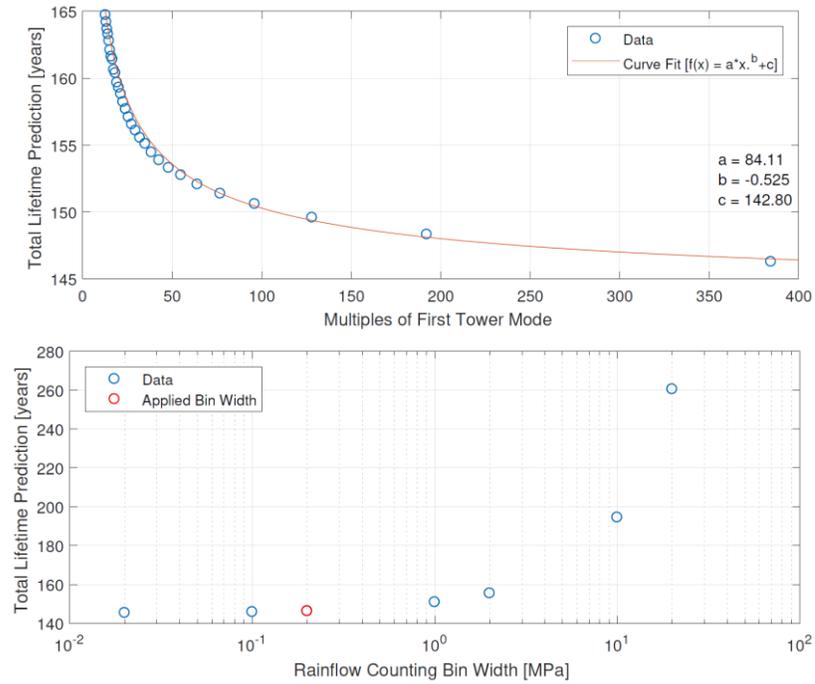
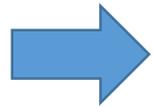
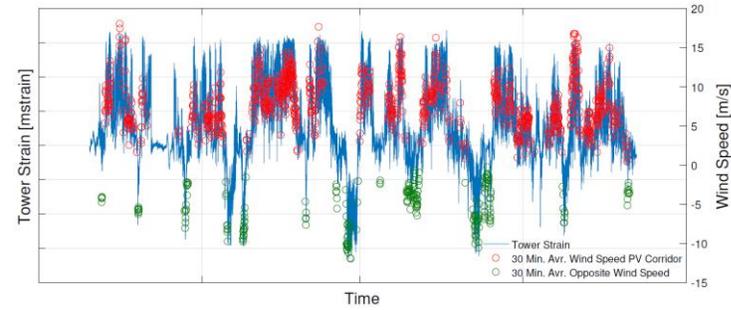
# Results

## LTE based on SHM

Strain Data

Component RUL

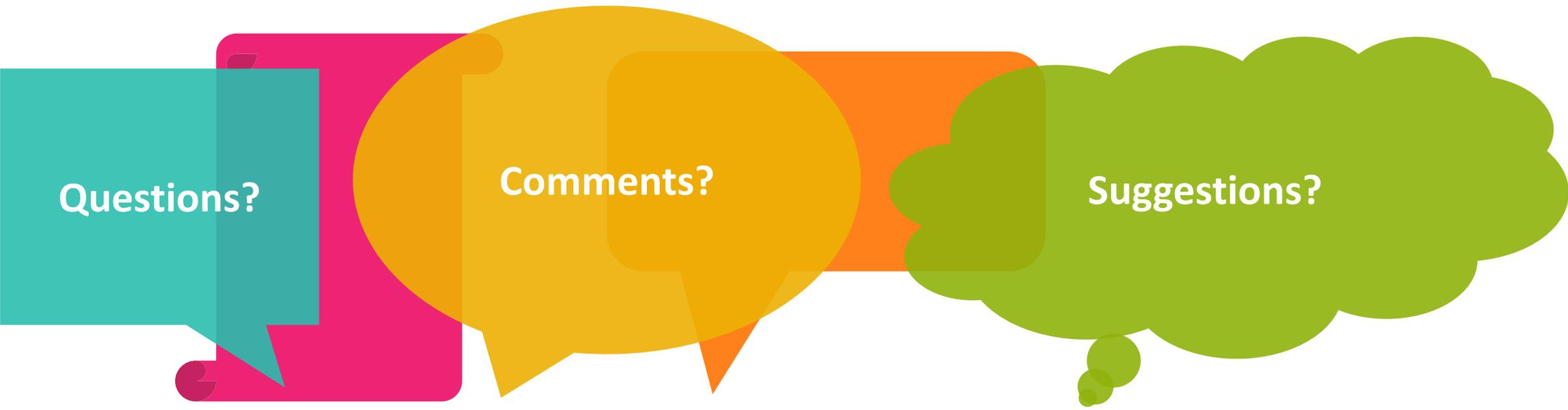
Commercial Strategy



# Conclusion

- LTE period requires a technical and economic analysis
- Size matters ( $P = \frac{1}{2} \rho \pi r^2 C_p v^3$ ) – so does **curtailment**
- For greater turbines ( $x > 0.5$  MW) a more strategic LTE decision making is expected
- There is room for manoeuvre in a subsidy-free environment
- SHM can confirm the commercial LTE strategy

# Thank You for your Attention



Questions?

Comments?

Suggestions?



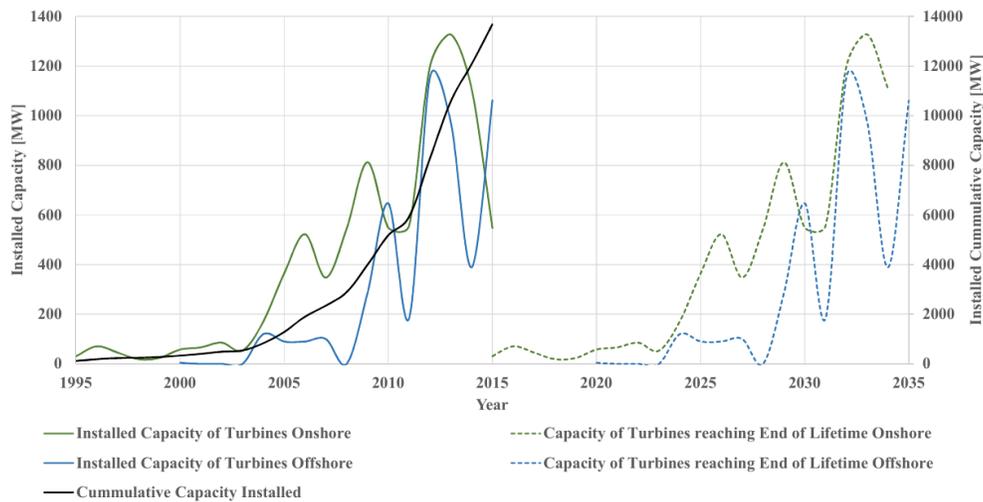
# futureWind 2018 & Marine



# UK Motivation

## Marked Development

### LTE Market



### Future Capacity Distribution

