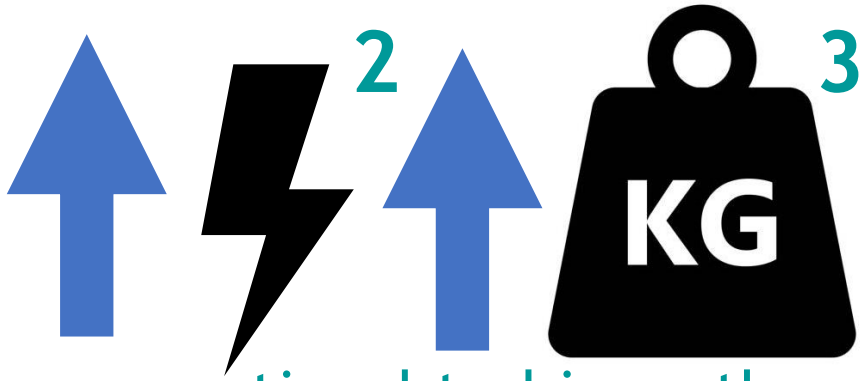
MULTI ROTOR WIND TURBINE SYSTEMS: *an exploration of failure rates and failure classification*

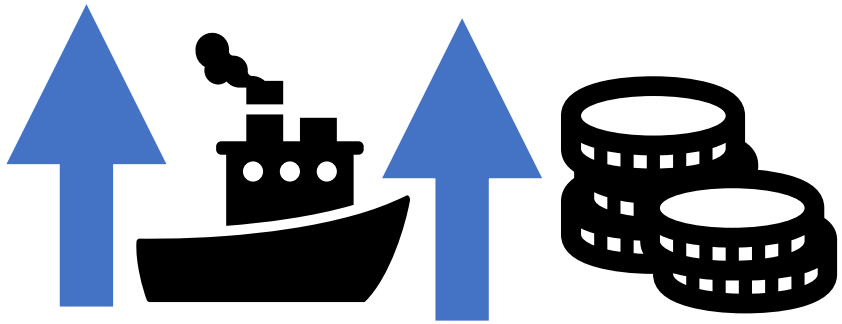
Jade McMorland, Abdullah Khisraw, Peter Dalhoff, Sven Störtenbecker & Peter Jamieson

jade.mcmorland@strath.ac.uk

The Problem with ‘Traditional’ Offshore Wind



In conventional turbines, the output power varies as the **square** of the radius. However, the weight of the turbine scale **cubically**



Increase **demand** for expensive Jack Up Vessels (**JUVS**) expected to increase the charter price

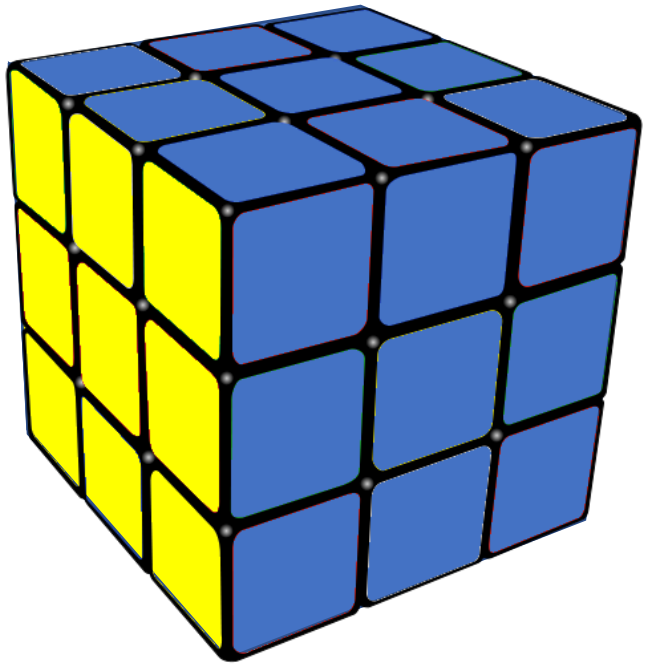
The Solution?

BENEFITS

- Scaling Laws
- Redundancy
- Potential modular systems
- Standardisation of parts

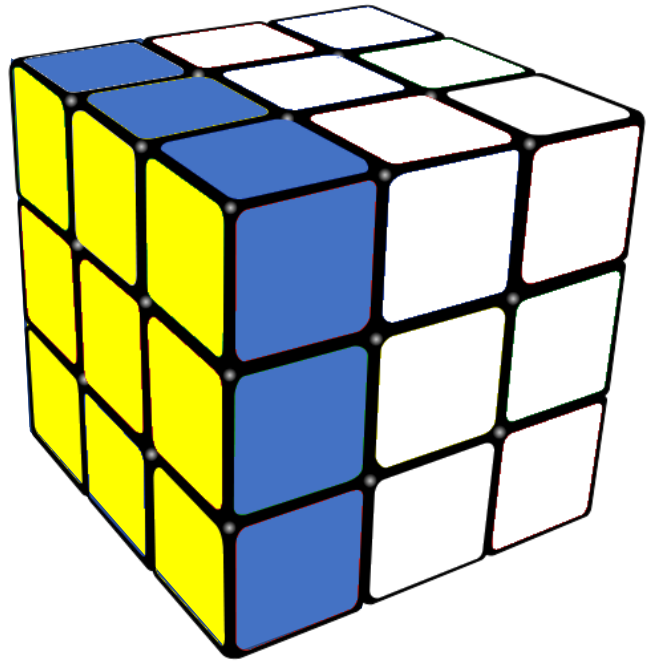
Multi Rotor Systems (MRS)

Scaling Laws



Power

weight



Traditional Turbine

Multi Rotor System

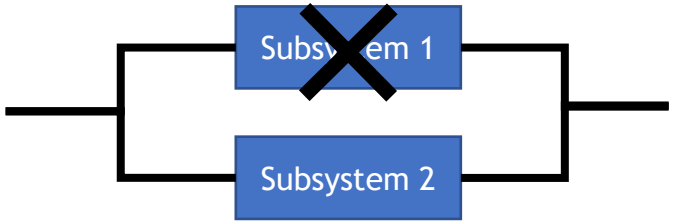
Why O&M?

O&M costs can be up to 30% of total LCOE*[1]

MRS increase in components means more transfers?

Harsher conditions and increased distance means weather windows are more critical

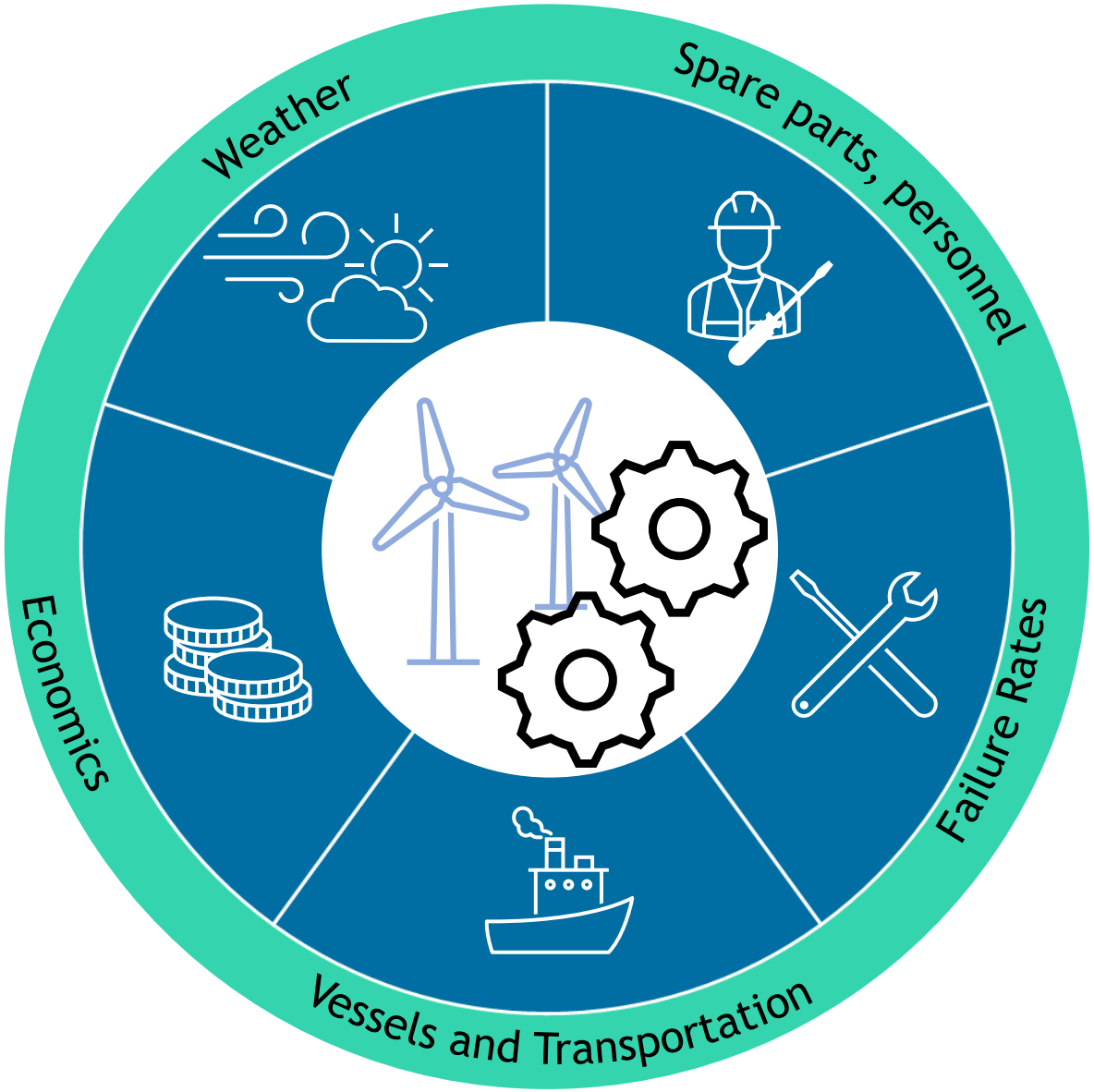
Additional requirements needed for safety of asset and personnel

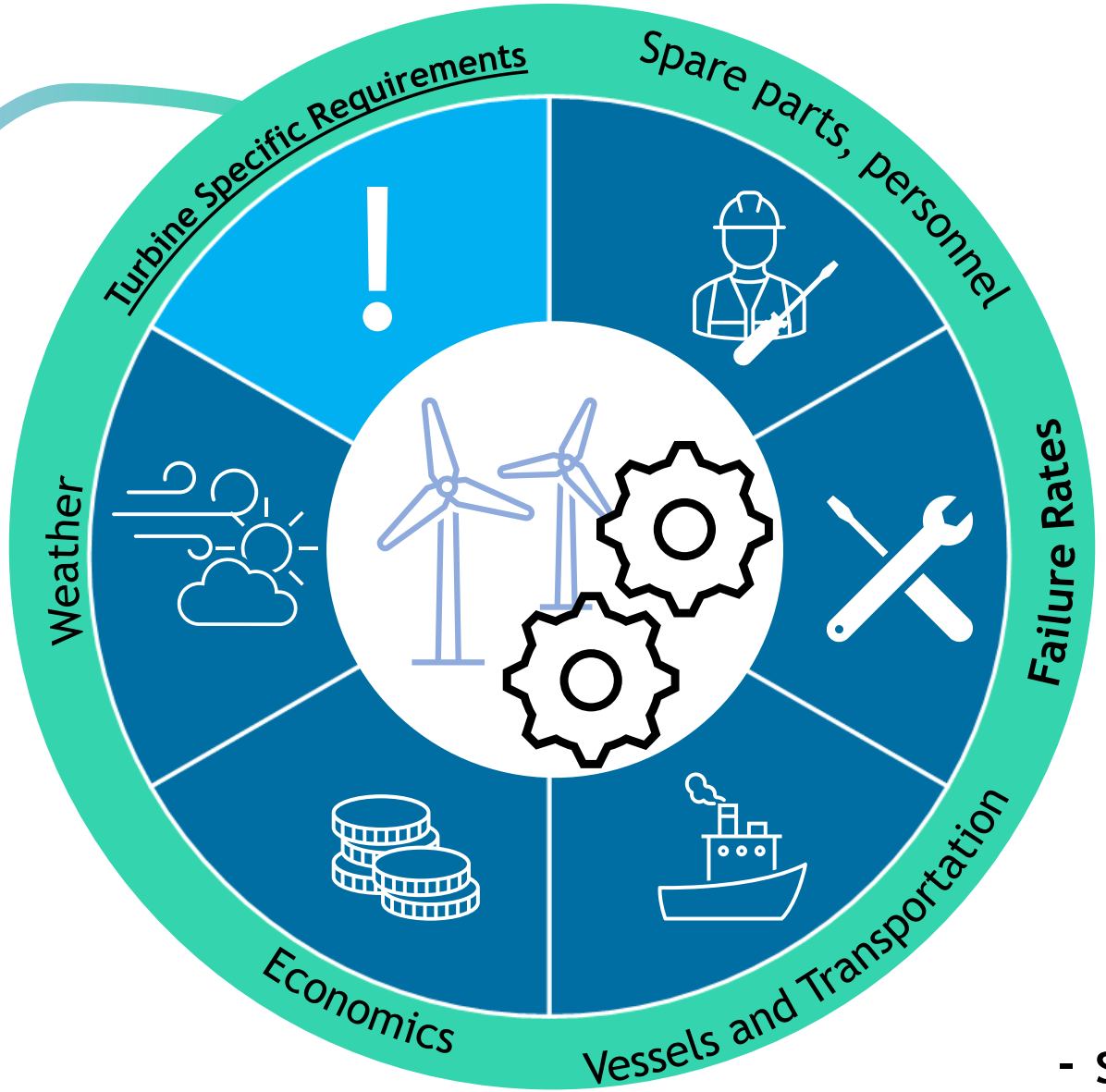


How does redundancy impact O&M operations?

LCOE – Levelised Cost of Energy

Offshore Wind O&M Influential Factors [2]





Multi Rotor Wind

MRS Influential Factors

- redundancy
- component scaling
-global vs local failures
- small scale components

Case Study: ScotWind

ScotWind Allocated Zone **E3**

34 km from selected port

CTV based approach

Various scales of deployment

20 MW 500 MW 1GW

Component Selection

= failure rate x cost

Repair cost + lost revenue

£/MWh + downtime

waiting time + time to repair

Component Selection

Dao et al. [3]

= failure rate x cost

Carroll et al. [4]

Repair cost + lost revenue

UK Round 4 Strike Price

£/MWh + downtime

Site Specific Strath Tool *Dao et al. [3], McMorland et al.[5]*

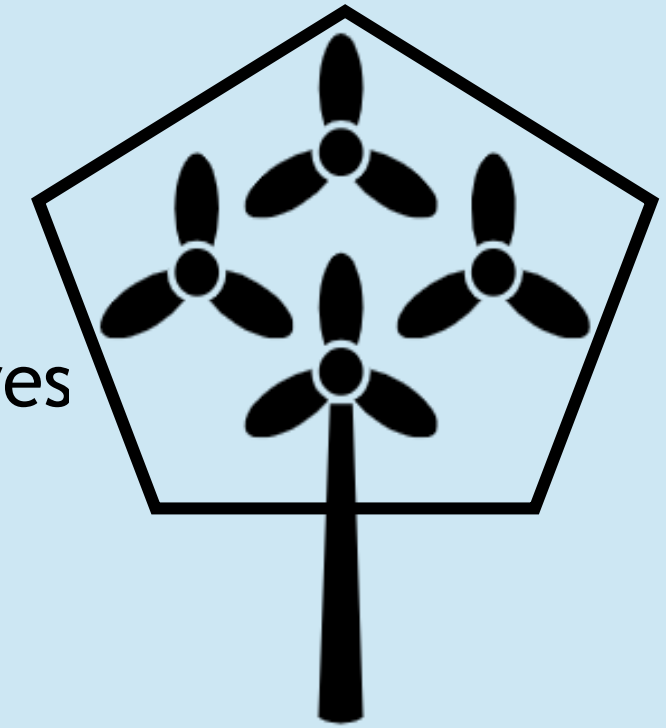
waiting time + time to repair

Turbine Comparison

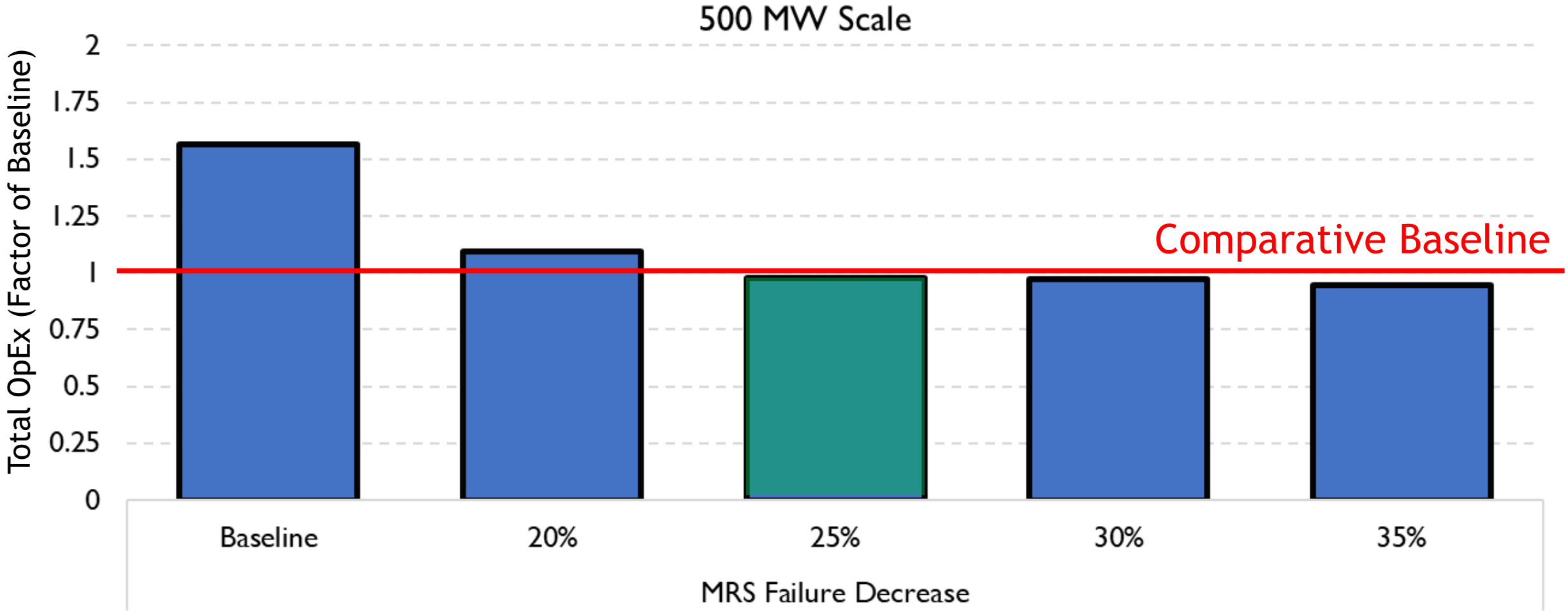
Monte Carlo based Strath OW O&M Adapted Tool

Blades & hub pitch generator gearbox electrical control

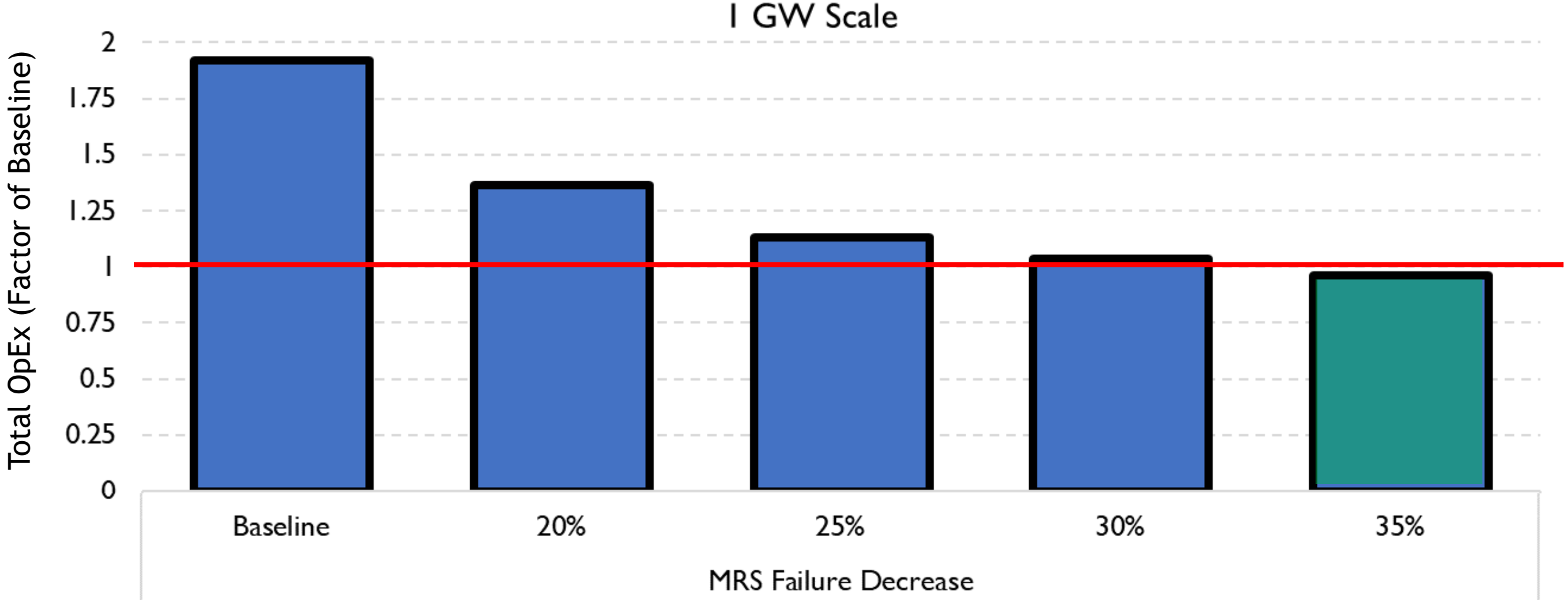
10 MW Rating	45 x 500kW
Use of JUV for failures	CTV for all failures
Baseline Operational Expenditure (OpEx)	Global vs local failures



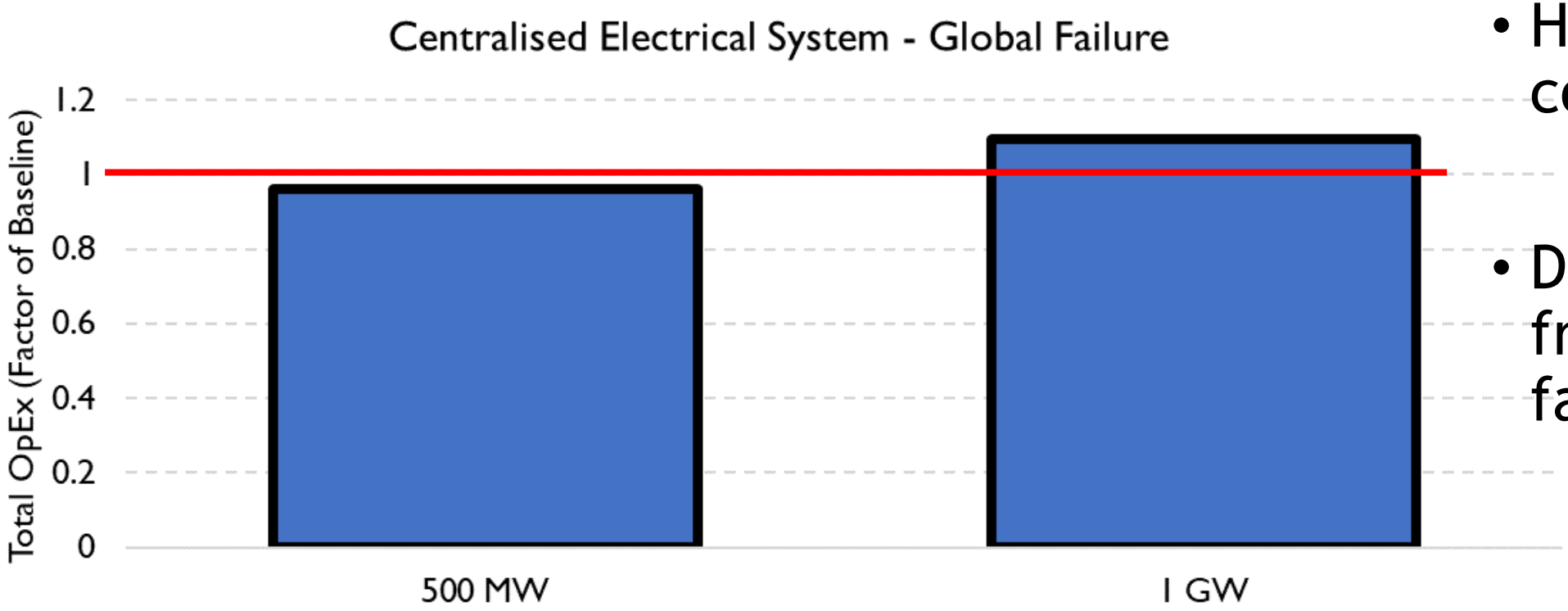
Sensitivity Analysis – Failure Rate



Sensitivity Analysis – Failure Rate



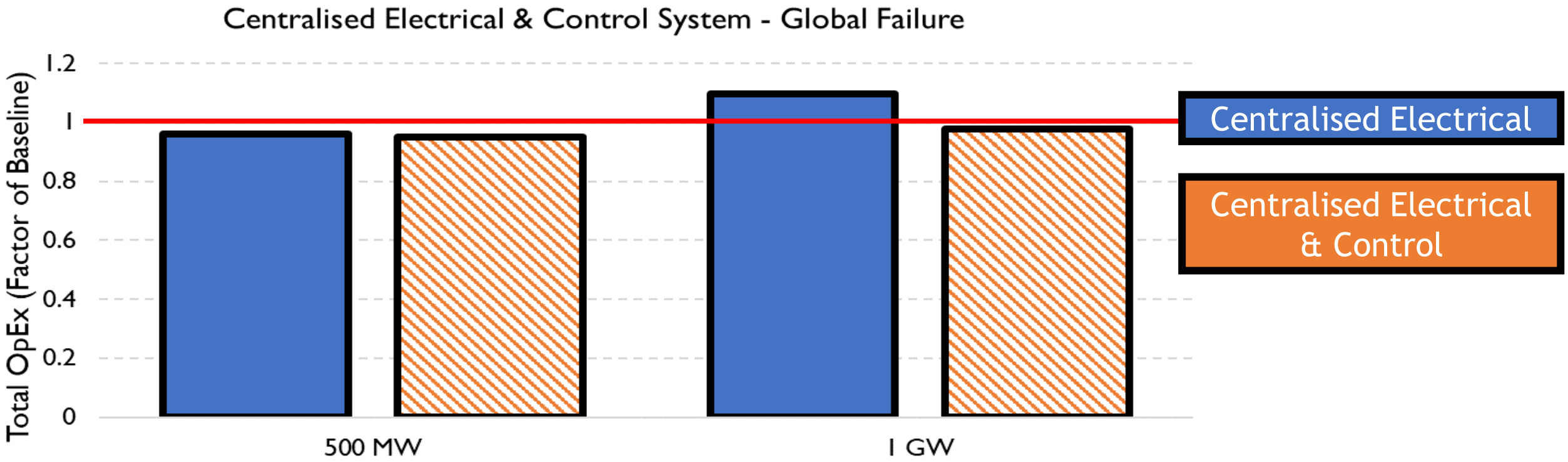
Global Failures
centralised electrical system



- High number of components
- Decrease in frequency of failure
  - Increase in impact

Global Failures

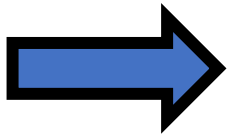
centralised electrical & control system



Fatigue Strength Analysis

Size Effects:

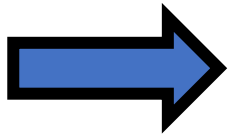
- Technological size effect
- Stress-mechanical size effect
- Surface technological size effect
- Statistical size effect



Considered in Detail Classes (EC3, DNV, IIW) or Knock Down Factors (FKM) in Fatigue Calculation Guidelines

What about Failure Rates and Scaling?

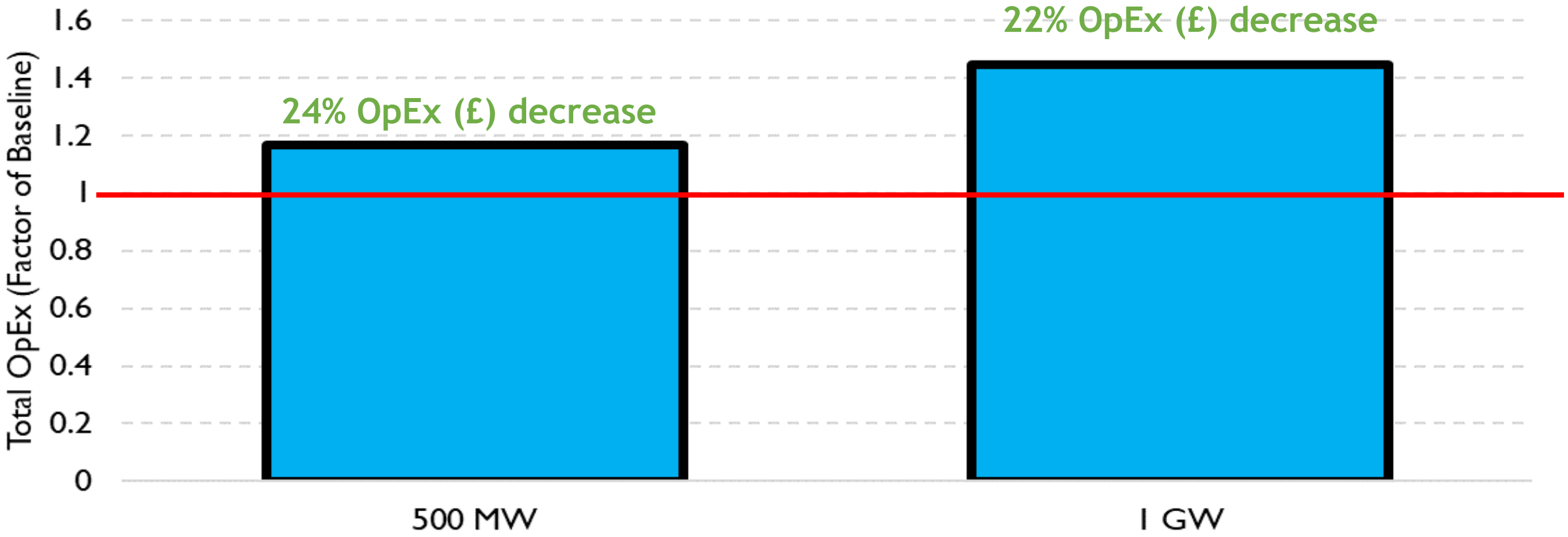
- Fatigue Crack Initiation at Surface
- Considering Square-Cube-Law



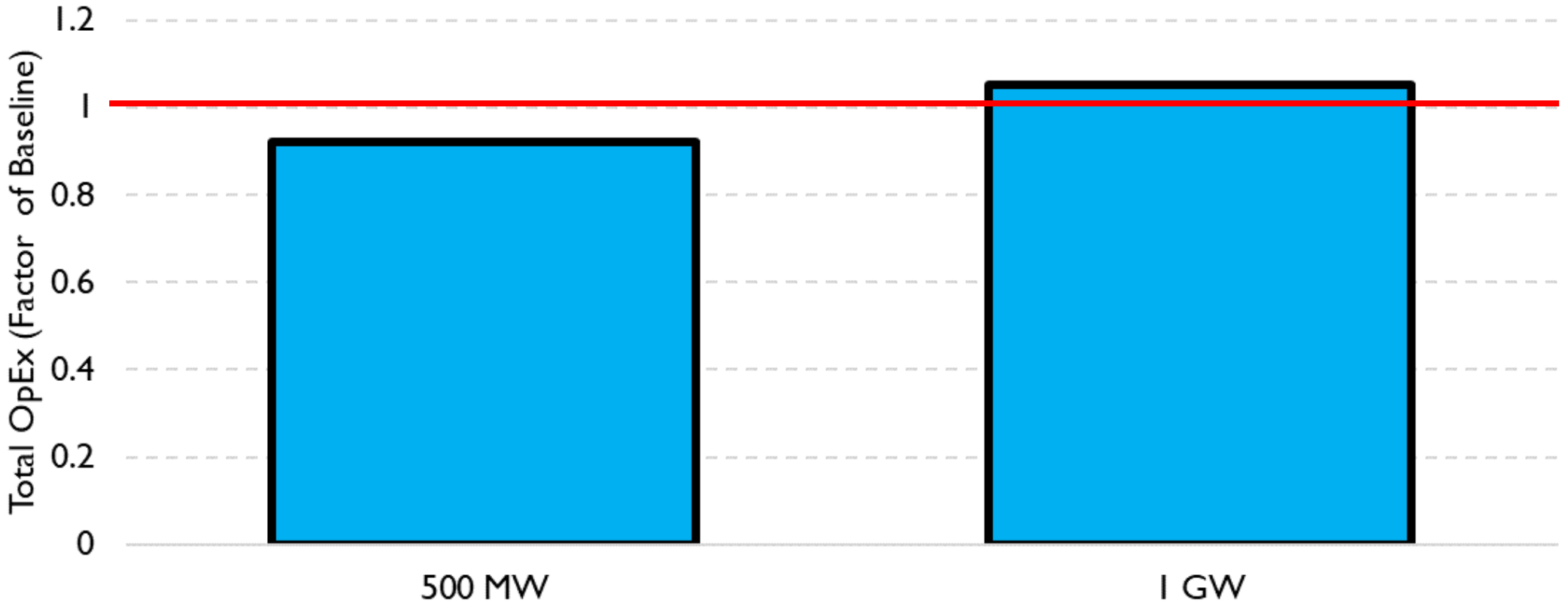
- Equal overall SR and MRS Surface Area
- Failure Rate F of RNA Component on MRS:

$$F_{SR} = F_{MRS} = n * F$$

RNA Results


22% OpEx (£) decrease
24% OpEx (£) decrease
Total OpEx (Factor of Baseline)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
500 MW
1 GW

RNA + 20% decrease across other failures



Conclusions and Further Work

- Similar results for small scale sites between baseline turbine and 20MW MRS turbine
- Key cost components are **lost revenue** and **vessel utilisation**
- **Availability: 92-98%**
- **Capacity Factor: 50.7-53%**

- Root cause analysis of failures
  - What % are fatigue based?
- Classification of MRS components
  - Global vs local systems
    - Additional risk?
- Exploration of repair strategies

[1] I. A. Dinwoodie et. al “Development of a combined operational and strategic decision support model for offshore wind”, Energy Procedia, 35, pp. 157-166, (2013).

[2] Seyr, Helene, and Michael Muskulus. "Decision support models for operations and maintenance for offshore wind farms: a review." Applied Sciences 9.2 (2019): 278.

[3] Dao, Cuong, Behzad Kazemtabrizi, and Christopher Crabtree. "Wind turbine reliability data review and impacts on levelised cost of energy." Wind Energy 22.12 (2019): 1848-1871.

[4] Carroll, James, Alasdair McDonald, and David McMillan. "Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines." Wind Energy 19.6 (2016): 1107-1119.

[5] McMorland, J., Pirrie, P., Collu, M., McMillan, D., Carroll, J., Coraddu, A., & Jamieson, P Operation and maintenance modelling for multi rotor systems: bottlenecks in operations. In Journal of Physics: Conference Series (Vol. 2265, No. 4, p. 042059). IOP Publishing. . (2022, May).