A Sensitivity Analysis of Offshore Wind Turbine Failure Rates Subject with Different Failure Definitions

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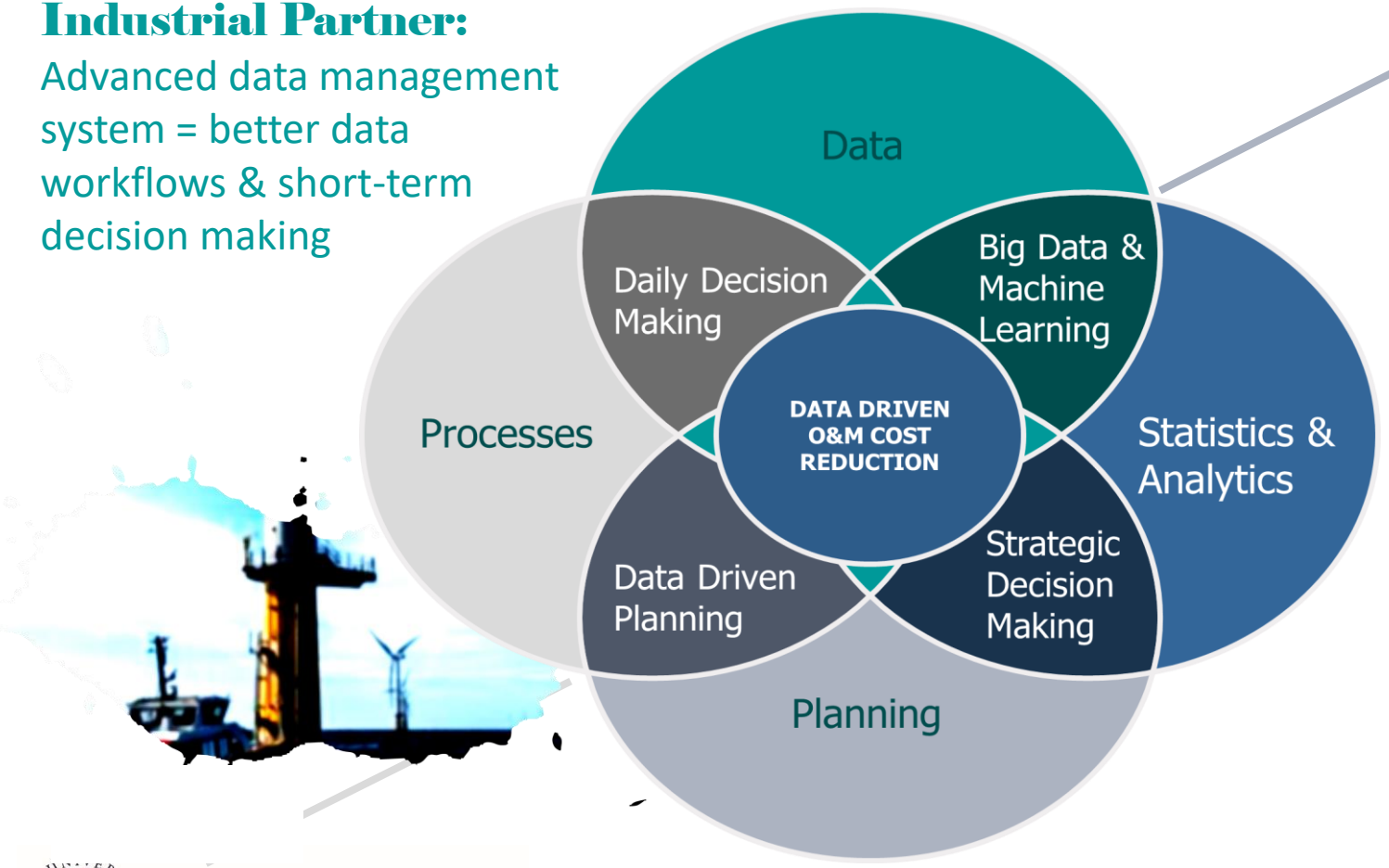
Research Context - Motivations of the Project

Industrial Partner:

Advanced data management system = better data workflows & short-term decision making



This Project:

- Improved data workflows = accessible database for statistics & analytics
- An opportunity to link turbine performance to a myriad of factors at once
- In doing so we can inform operational/strategic decision making

Reliability Data

O&M Data Type	Information Derived	Disadvantages
A. Maintenance logs	• Accurate failure info • Information for downtimes • Cost of repair	• Sometimes available only in hard copies • Can be difficult to read or incomplete
B. Operation and alarm logs	• Failures and duration	• Unknown alarm codes • Numerous stops for the same failure • No environmental conditions info
C. 10-min SCADA and alarms	• Failure data • Information for further analysis (e.g., root cause analysis) • Environmental parameters • Comparison/verification of logs (if both available)	• Large amount of data, require time-consuming processing • Not all alarms indicate failures • No maintenance activity described
D. Service provider bills	• Maintenance cost • Indications for the kind of failures	• Less detailed info about failures
E. Component purchase bills	• Information for component replacements	• No downtime information • No failure information

Data Sources & Failure Definitions

There is no standard definition of a failure in the wind industry. The definition used often depends on the data available to the researcher.

1. Reliability analyses for wind turbines are valuable

2. Failure rate estimates seem to have a huge uncertainty due to inconsistent data treatment

3. We want to:
   (a) Perform a reliability analysis with the available data
   (b) Explore sensitivity of results to failure definition

Available Dataset

O&M Data Type	Information Derived	Disadvantages
A. Work Procedures	• Type of work carried out	• Sometimes difficult to map to assembly/subsystem
B. Tasks/Task types	• Task descriptions • Task categories (corrective, inspection, annual service etc.)	• Most task descriptions for corrective works only contain alarm code – not always indicative of failure
C. SCADA	• Turbine unavailability • Downtime	• No maintenance activity description • Large amount of data
D. Operations Planned Movements	• Manual acknowledgement/card swipe times for technician transfer of control on/off turbine • Repair times	• Incomplete: some pick-ups have to drop-off and vise-versa • Some transfers are 'planned', but not acknowledged.

- Single offshore wind farm
- Geared HAWT
- 2-4MW power rating
- ~600 turbine years of data

Turbine-Level Failures – Possible Failure Definitions

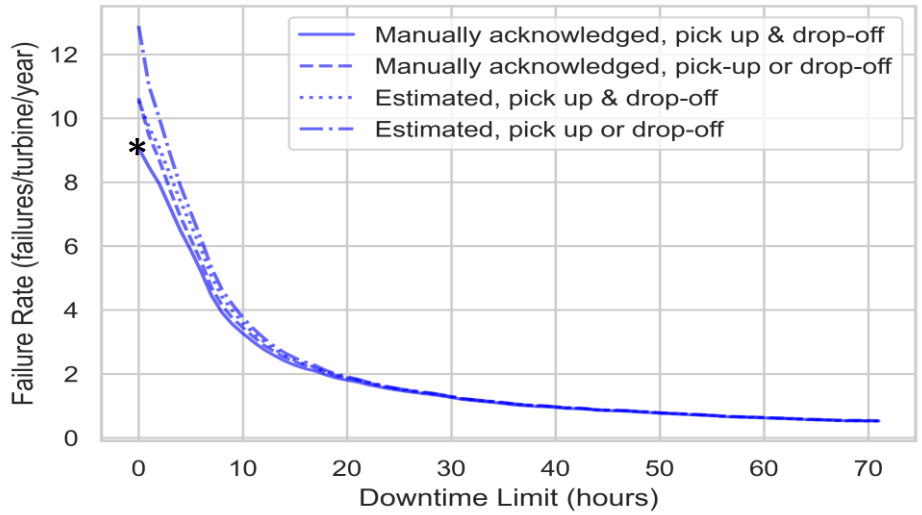
WT Failure: a downtime event accompanied by an unscheduled visit to a turbine.

- Total duration of downtime event > some lower threshold *Downtime limit*
- How much time between failures constitutes the same failure? *Grouping Limit*

- Unscheduled visit = manually acknowledged transfers OR estimated transfers as well?
- Visit = a drop off/pick up pair OR is only one of the two necessary?

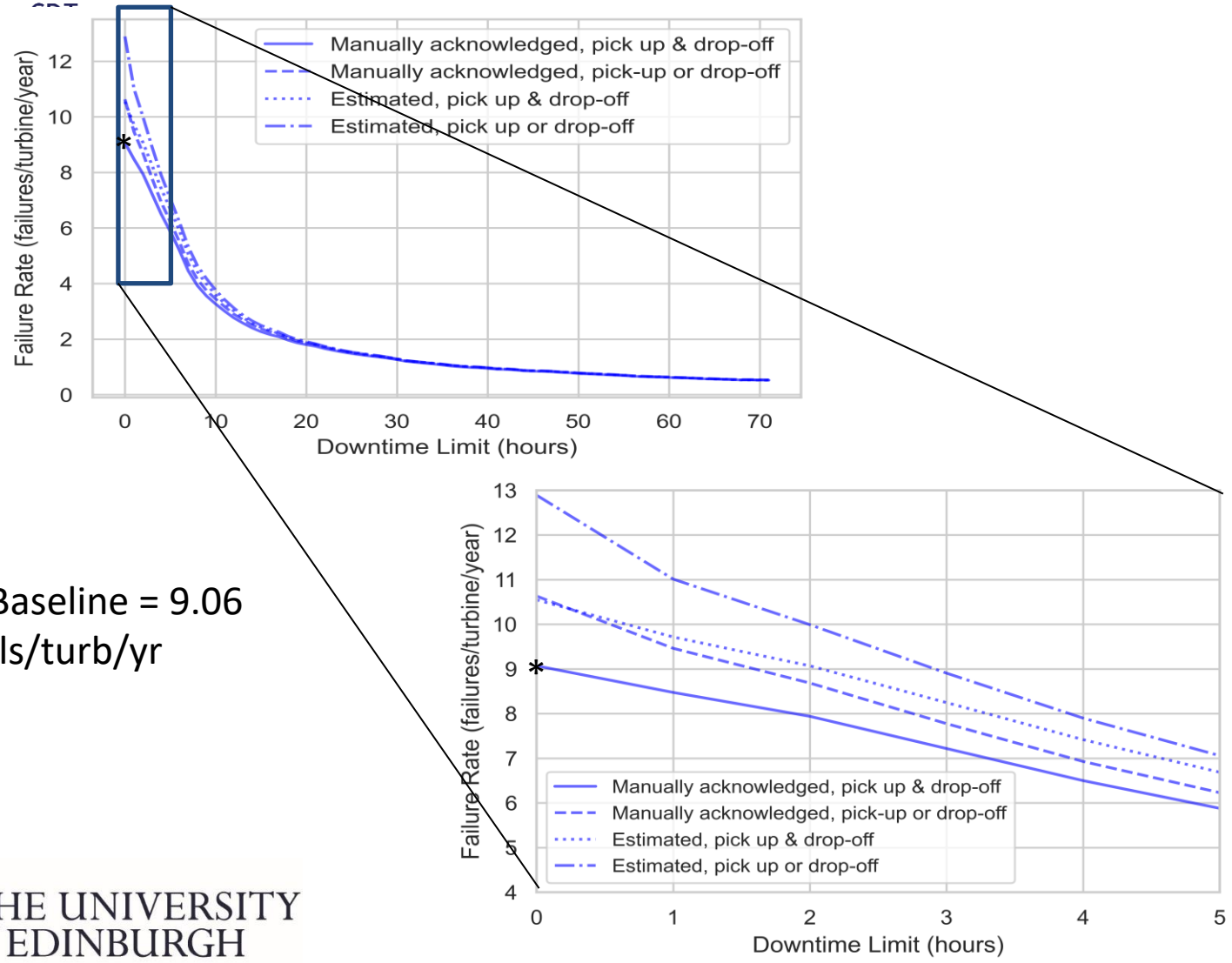
Baseline: no limit on downtime, each DT event is it's own failure, only events with a manually acknowledged pick-up AND drop-off considered.

Turbine-level Failures – Sensitivity of Failure Rate



* Baseline = 9.06 fails/turb/yr

Turbine-level Failures – Sensitivity of Failure Rate



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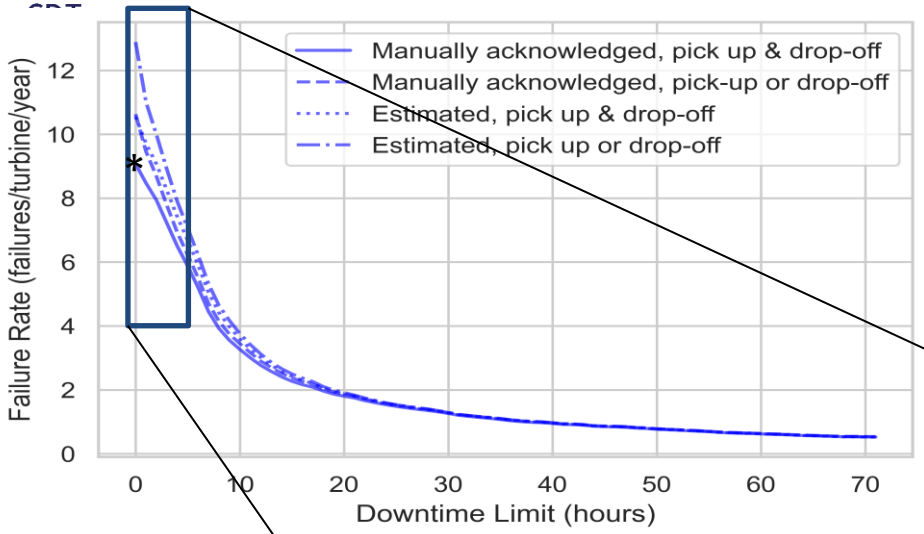
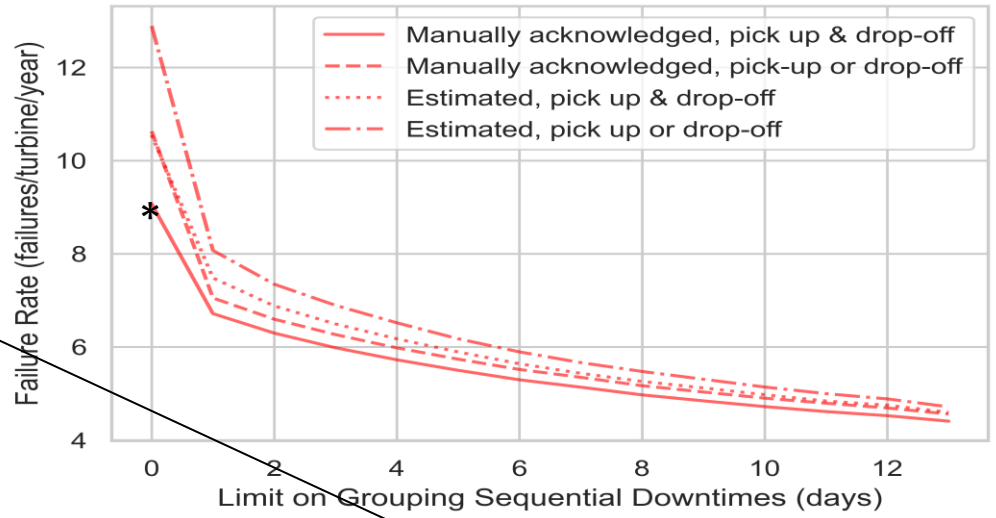
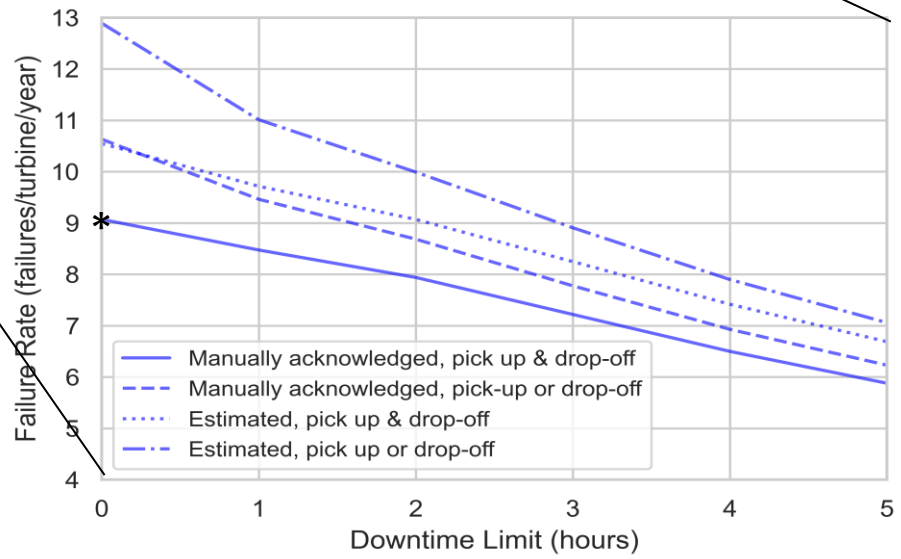
Turbine-level Failures – Sensitivity of Failure Rate







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Additional Filters from Work Procedures/Task Types

PLUS OPPORTUNISTIC JOBS – Add all tasks undertaken throughout duration of turbine downtime

PLUS RETROFITTING – add events that contained ‘retrofitting’ in task description

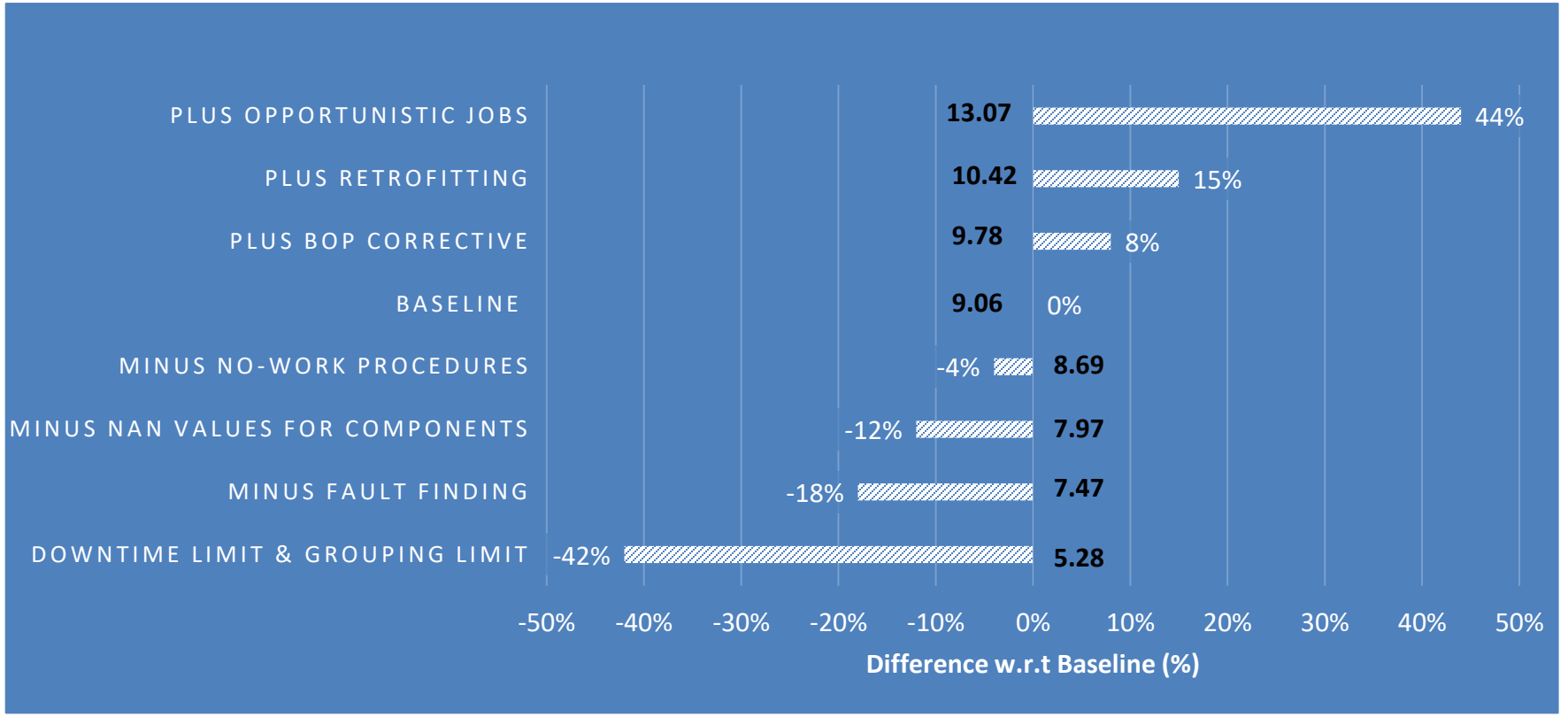
PLUS BOP CORRECTIVE – Add task types ‘Corrective – BoP’ to Baseline

MINUS NO-WORK PROCEDURES – Minus events where no work procedure is recorded

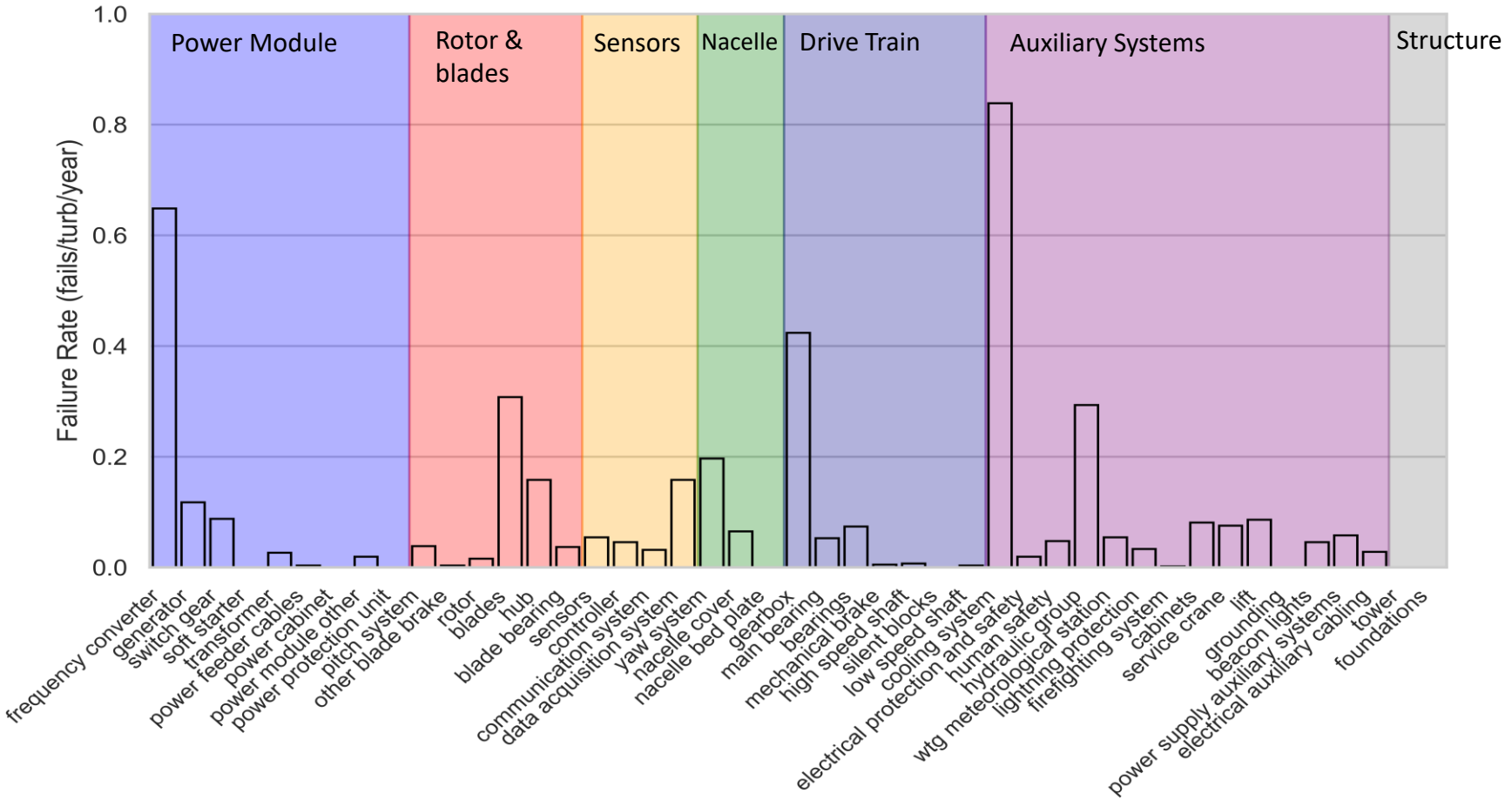
MINUS NAN VALUES FOR COMPONENTS – Minus events that weren’t categorizable into taxonomy

MINUS FAULT FINDING – Minus events that had work procedures ‘fault finding’

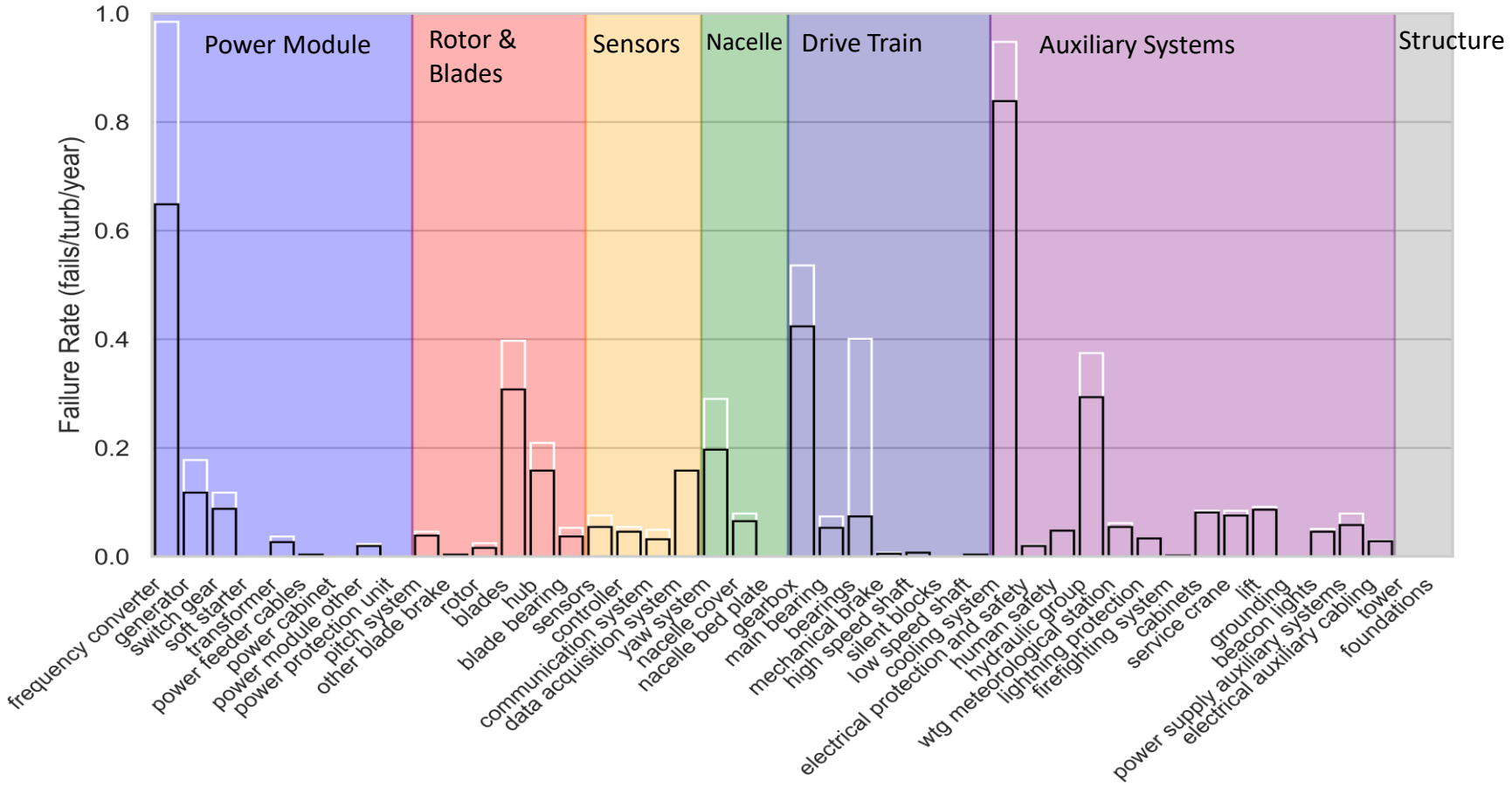
DOWNTIME LIMIT & GROUPING LIMIT – Apply a 1 hour lower limit on downtime and a 24 hour grouping limit



Assembly-Level Failures – Baseline



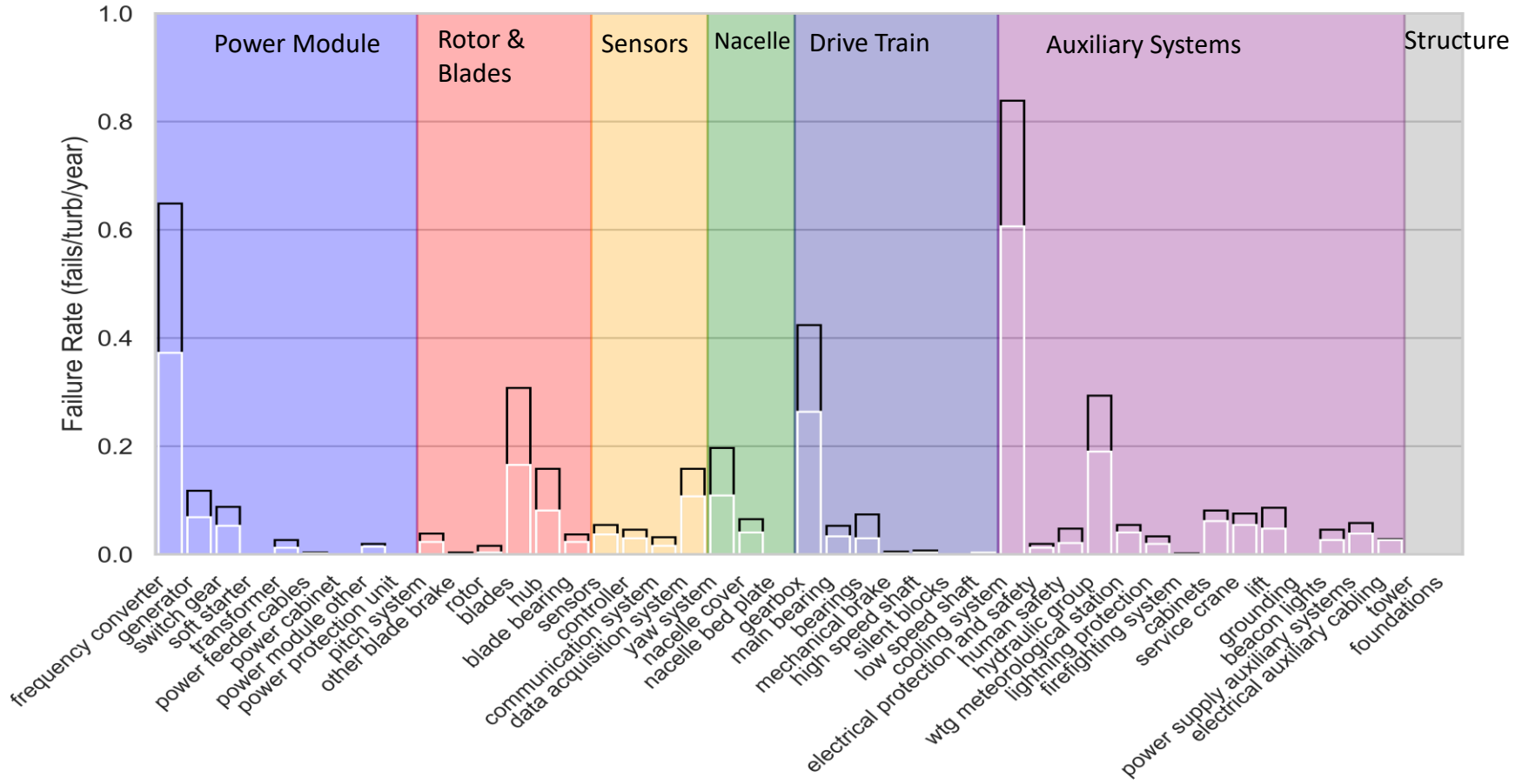
Assembly Level Failures – Sensitivity of Opportunistic Jobs



Baseline

Opportunistic Jobs

Assembly Level Failures – Sensitivity of Downtime & Grouping Limit



Baseline

Downtime & Grouping Limit Applied

Conclusions

1. Lack of a standard definition of a failure & inconsistency in data treatment -> significant uncertainty in failure rate figures

2. Failure rates are sensitive to how you define a failure

3. A lot of value can be added to reliability analyses by defining exactly what a failure is

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Thanks for listening, Any Questions?

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