Wind Turbine Reliability: A View From the Field

Design for Reliability: Economic Optimization

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Albuquerque, NM
June 18, 2009

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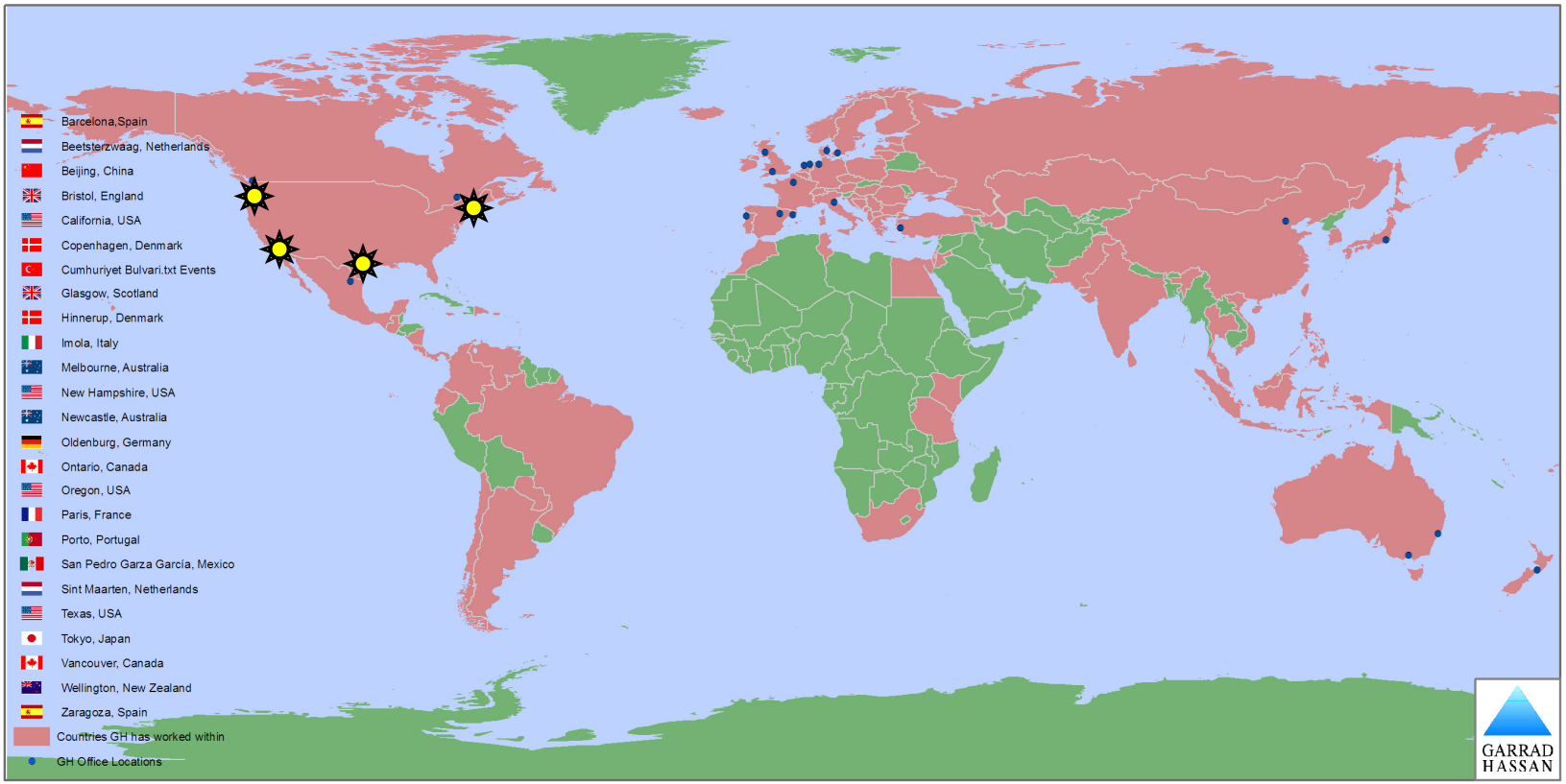
Countries where Garrad Hassan has worked and global office locations



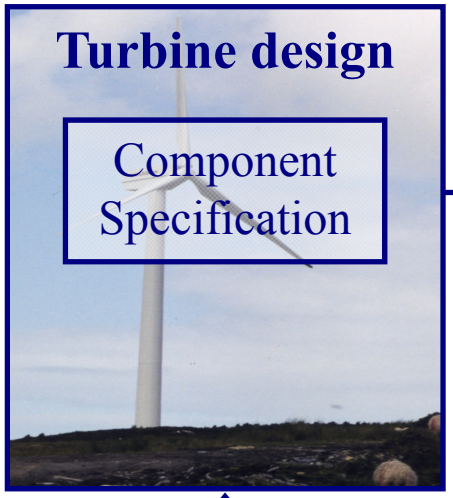
Overview:

- An increased need for reliability
- Reliability in the various project phases
- Designing machines for reliability
- Operating and maintaining machines for reliability
  - Operations and Maintenance (O&M) Analysis
  - Case study: A view from the field
  - Calculation method and input
  - Results
- Conclusions

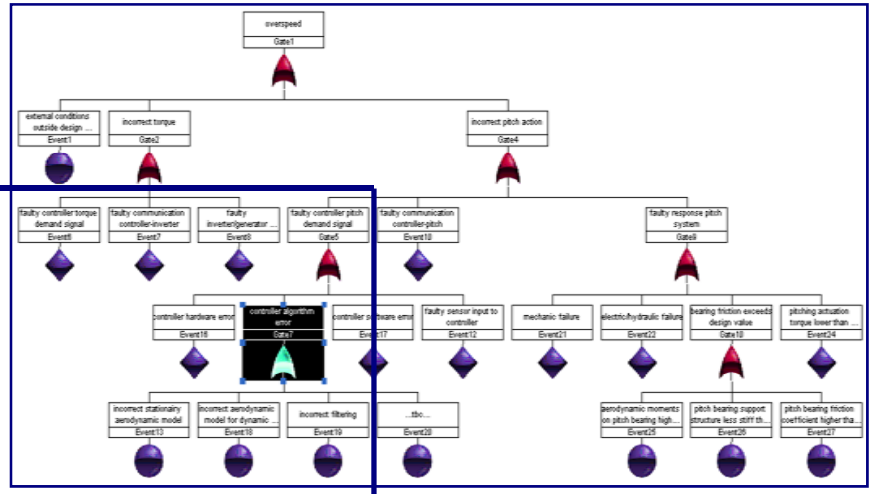
Reliability in the various project phases:

PHASE	ACTIVITY	GH SERVICES AND SOFTWARE
Wind Turbine Design	Quantified analysis of cost of energy: Integrating reliability aspects in the design of a turbine.	Turbine Design
Project Development Onshore	Reliable prediction of expected energy production from any wind farm	Energy Development
Project Development Offshore	Site evaluation and analysis of availability and O&M costs for offshore farms, and optimization of maintenance strategies	Offshore Wind Farms
Operational Phase	Monitoring wind farm Assessing wind farm operating performance Forecasting	SCADA Asset Management and Optimization Services (AMOS) Forecaster

Reliability analysis in the design:



Reliability Analysis



Critical failure modes (FMECA*)

Fault Trees of critical events

Maintainability/ time to repair

Failure rates

Optimize/ Redesign

* Failure Mode Effect and Criticality Analysis

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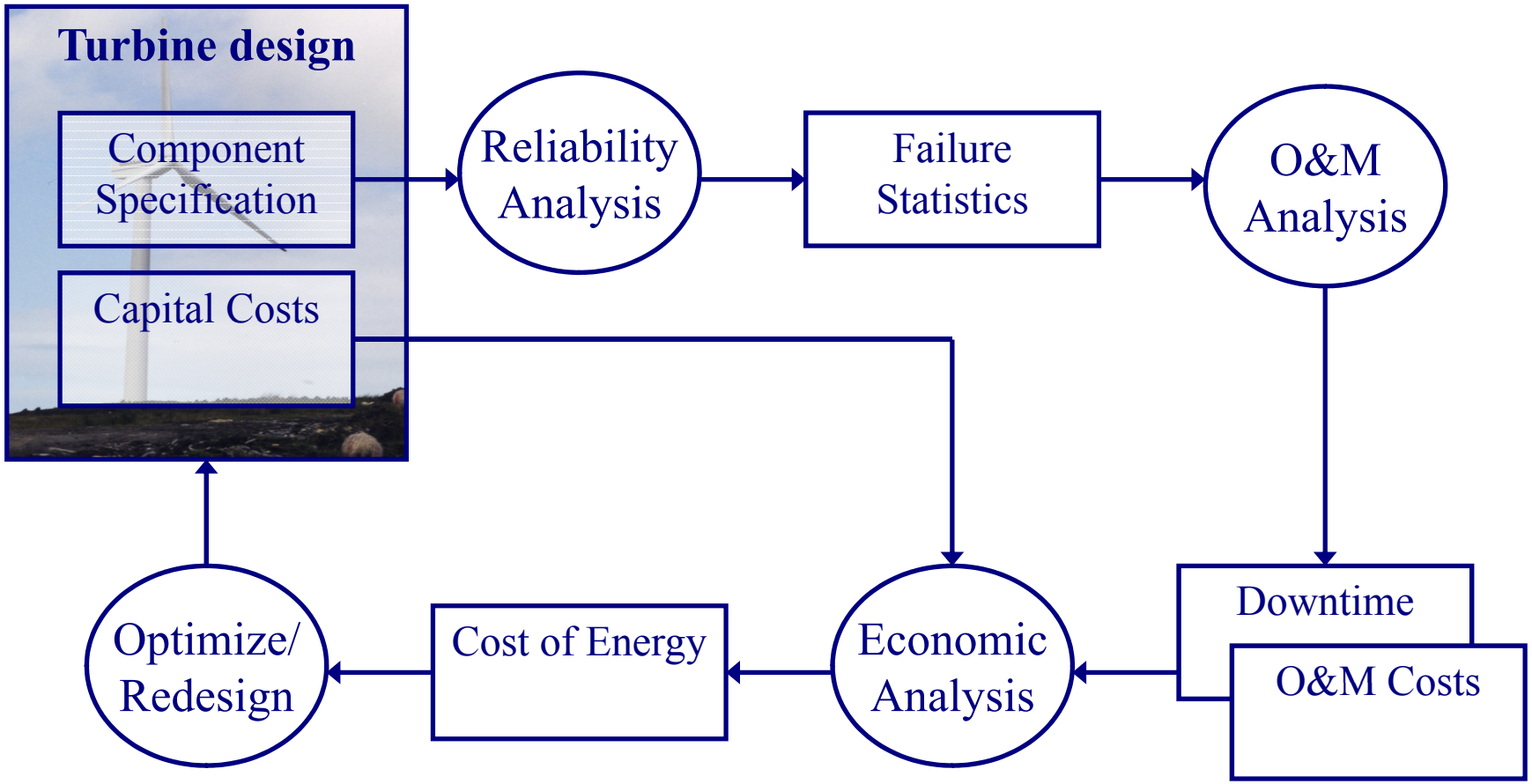
Approach in this field case study (offshore):



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Why O&M analysis for offshore projects?

- Additional operational risks compared to onshore projects:
  - Weather / access risk
  - Equipment risk
  - Export system risk

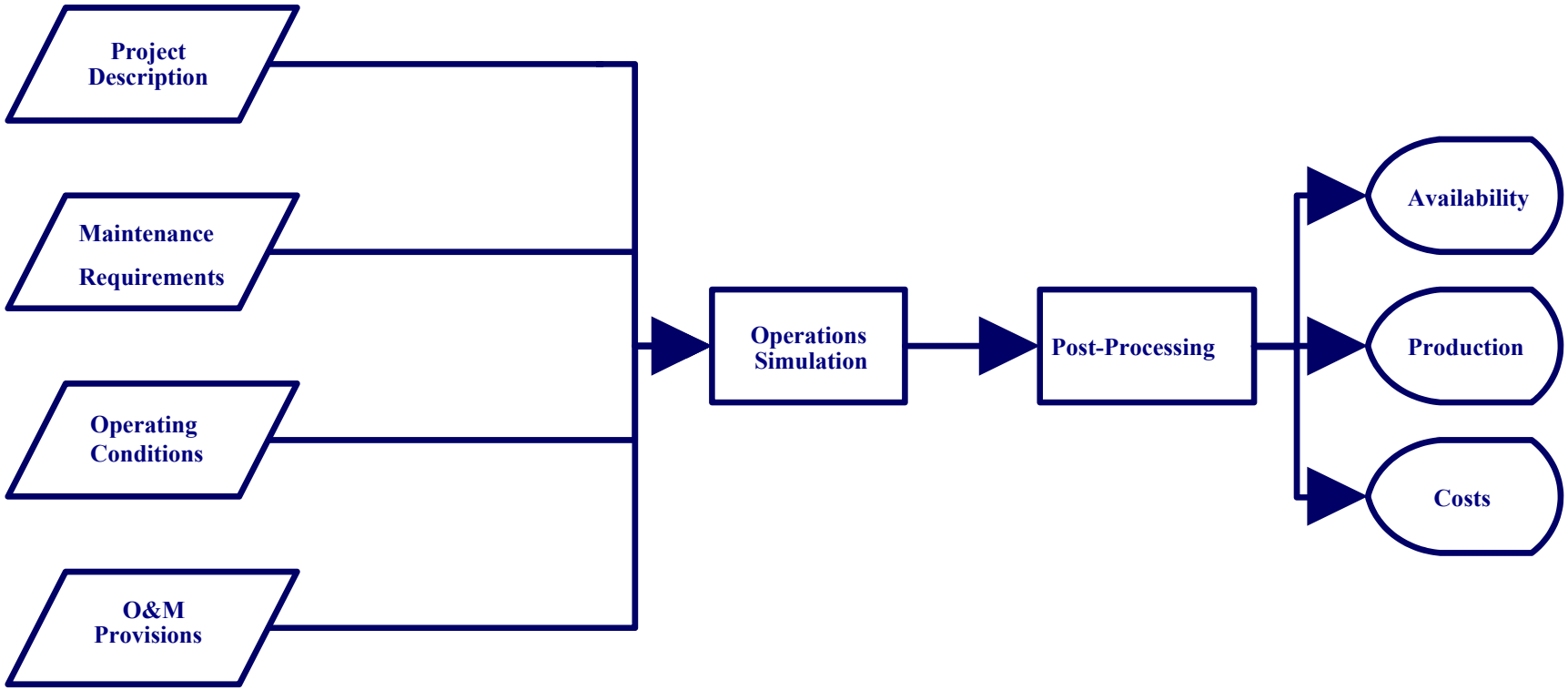
- Assess these risks
- Eliminate, reduce or transfer risks
- Minimize the impact through adequate O&M resources and operating strategies
- Integrate O&M in the optimization of the turbine design (integrated design)

Calculation method and input:

- O2M Software: Optimization of Operations & Maintenance Approach
- Maintenance strategies
- Failure data
- Cost data
- Levelized production costs

O&M analysis – O2M modelling structure:

- Optimization of Operations & Maintenance: "O2M" software
  - Based on work by Bossanyi and Strowbridge (ETSU 1994)



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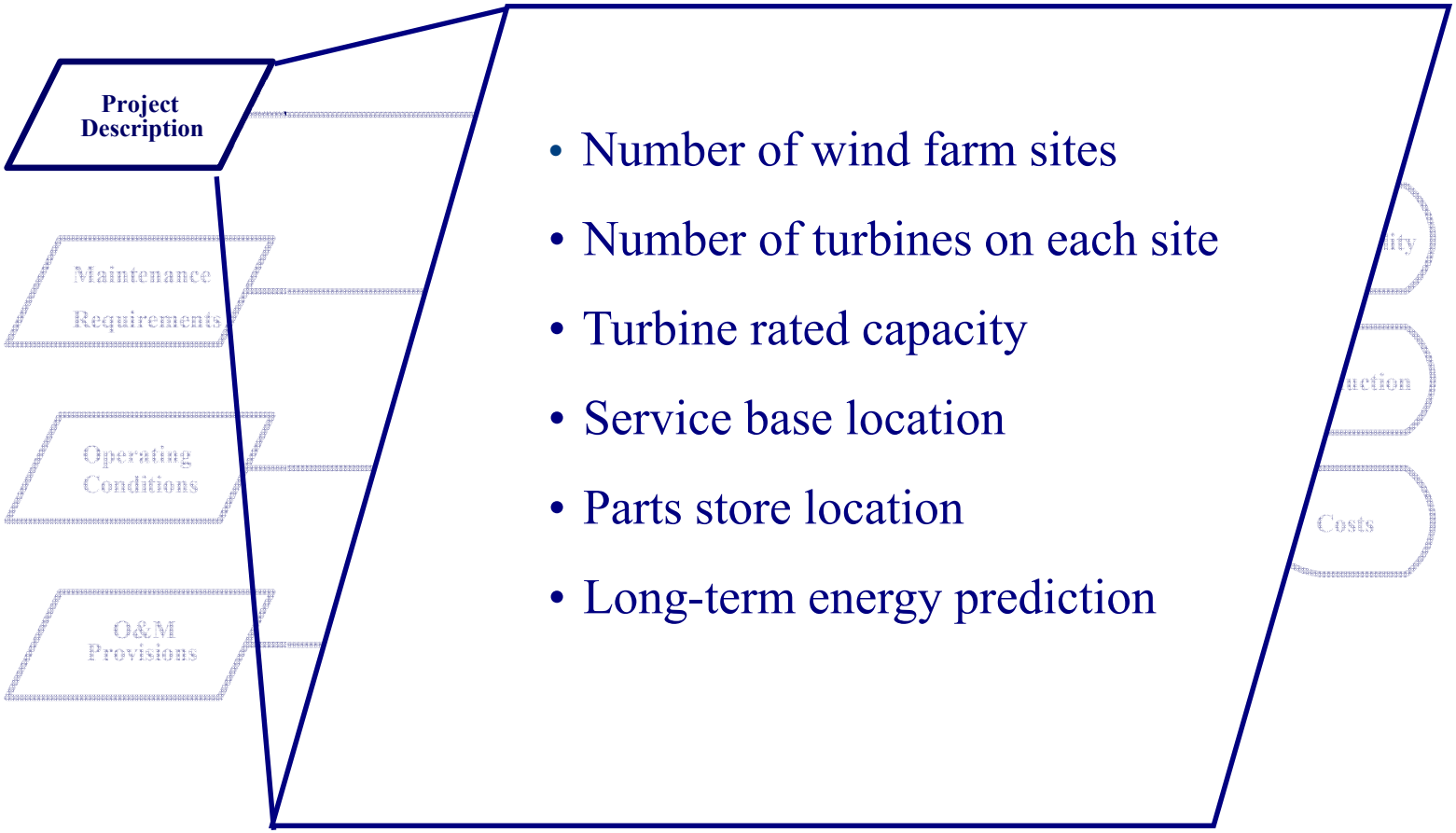
O&M Analysis - Modelling Structure:



- Number of wind farm sites
- Number of turbines on each site
- Turbine rated capacity
- Service base location
- Parts store location
- Long-term energy prediction

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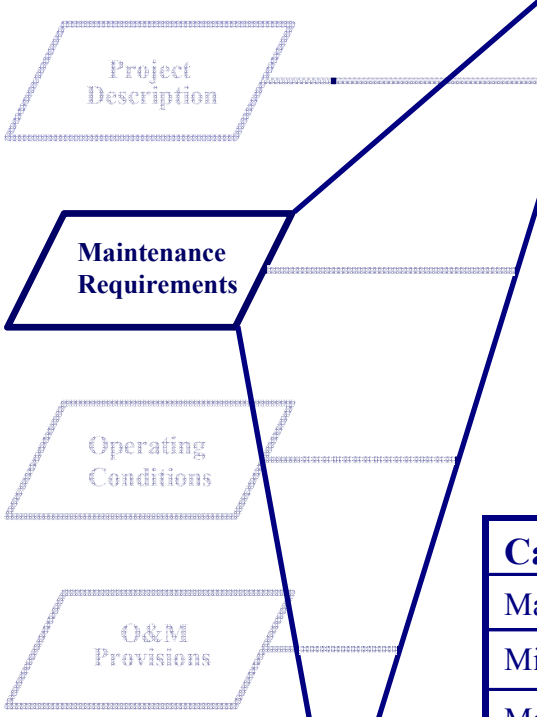
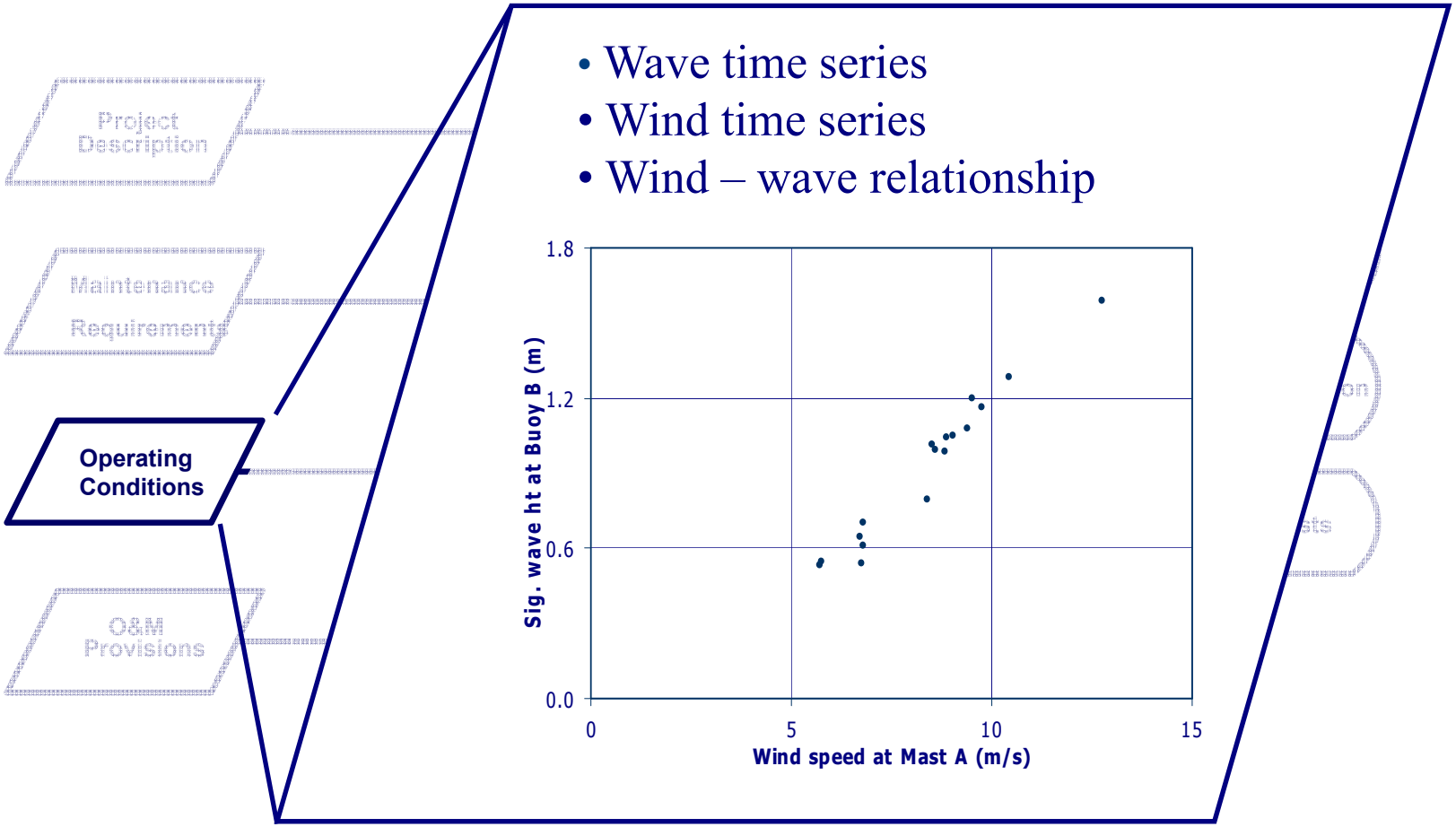
O&M Analysis - Modelling Structure:



- Scheduled maintenance
- Unscheduled maintenance
- Several failure categories defined by
  - Failure Rate (MTBF)
  - Direct Time To Repair (DTTR)
  - Spares and equipment requirements
- Example WTG reliability profile:

Category	MTBF (hrs)	DTTR (Labor-hours)
Manual restart	1,500	4
Minor change-out	2,500	8
Major repair	20,000	70
Major change-out	50,000	90

O&M Analysis - Modelling Structure:



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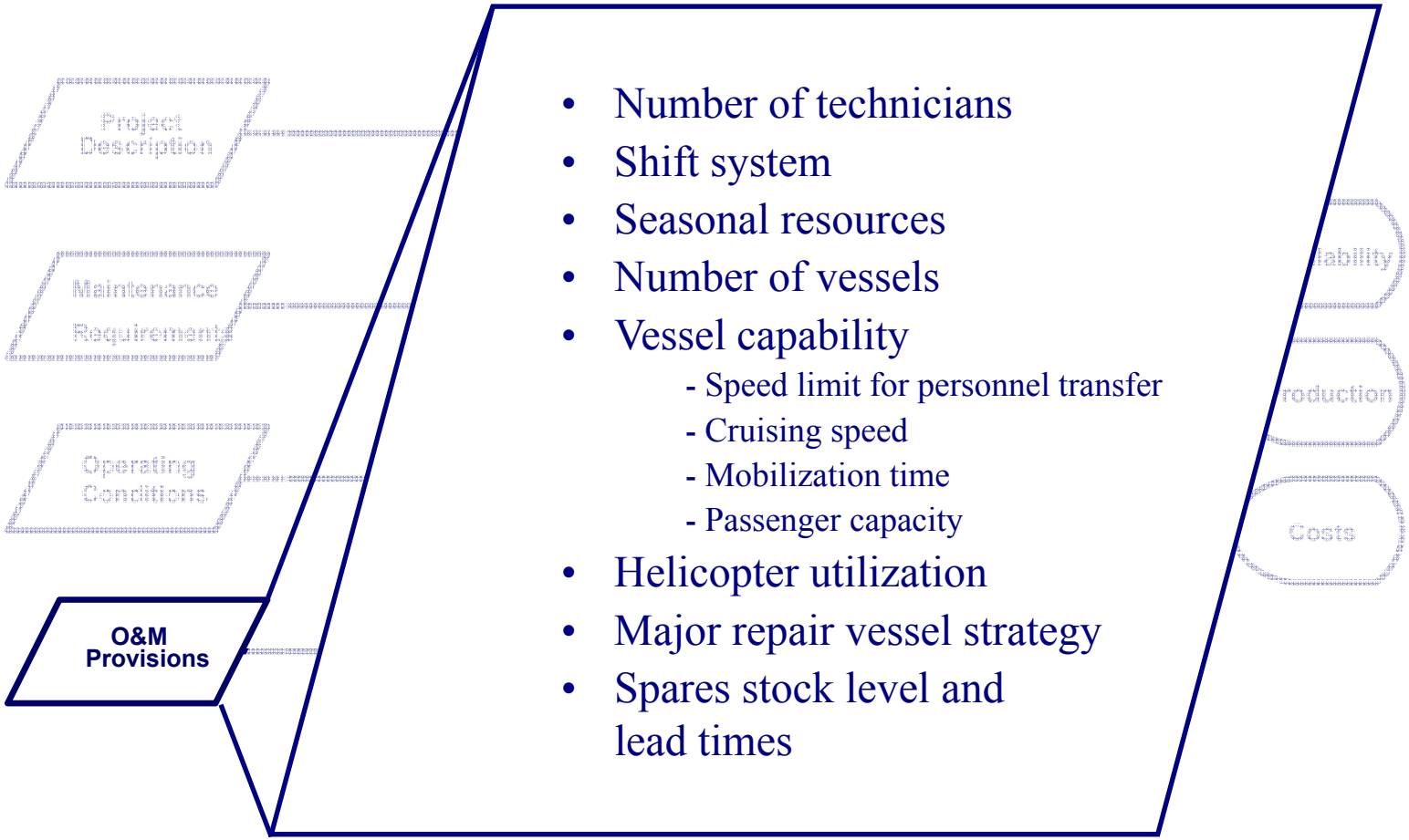
O&M Analysis - Modelling Structure:



- Number of technicians
- Shift system
- Seasonal resources
- Number of vessels
- Vessel capability
  - Speed limit for personnel transfer
  - Cruising speed
  - Mobilization time
  - Passenger capacity
- Helicopter utilization
- Major repair vessel strategy
- Spares stock level and lead times

Input Data - Offshore Field Case Study:

Failure Rates

Component Failures	Manual Restart	Minor repair	Major repair	Major replacement	All cat
Blade	0.0000	1.4800	0.0800	0.0400	**1.600**
Pitch system	0.6800	0.0800	0.0320	0.0080	**0.800**
Hub	0.0000	0.1850	0.0100	0.0050	**0.200**
Main shaft and bearings	0.0000	0.1850	0.0100	0.0050	**0.200**
Gearbox	0.6800	0.0800	0.0200	0.0200	**0.800**
High-speed shaft	0.0000	0.1900	0.0100	0.0000	**0.200**
Mechanical Brake	0.3400	0.0400	0.0200	0.0000	**0.400**
Generator (high speed)	0.6800	0.0800	0.0200	0.0200	**0.800**
Control System	2.1600	0.2400	0.0000	0.0000	**2.400**
Yaw System	1.0200	0.1200	0.0480	0.0120	**1.200**
Hydraulic Services	1.0200	0.1200	0.0600	0.0000	**1.200**
Power Electrics	2.0400	0.2400	0.1200	0.0000	**2.400**
Transformer	0.1700	0.0200	0.0080	0.0020	**0.200**
Tower	0.0000	0.1900	0.0100	0.0000	**0.200**
	8.7900	**3.2500**	**0.4480**	**0.1120**	

Failure Rates per Year

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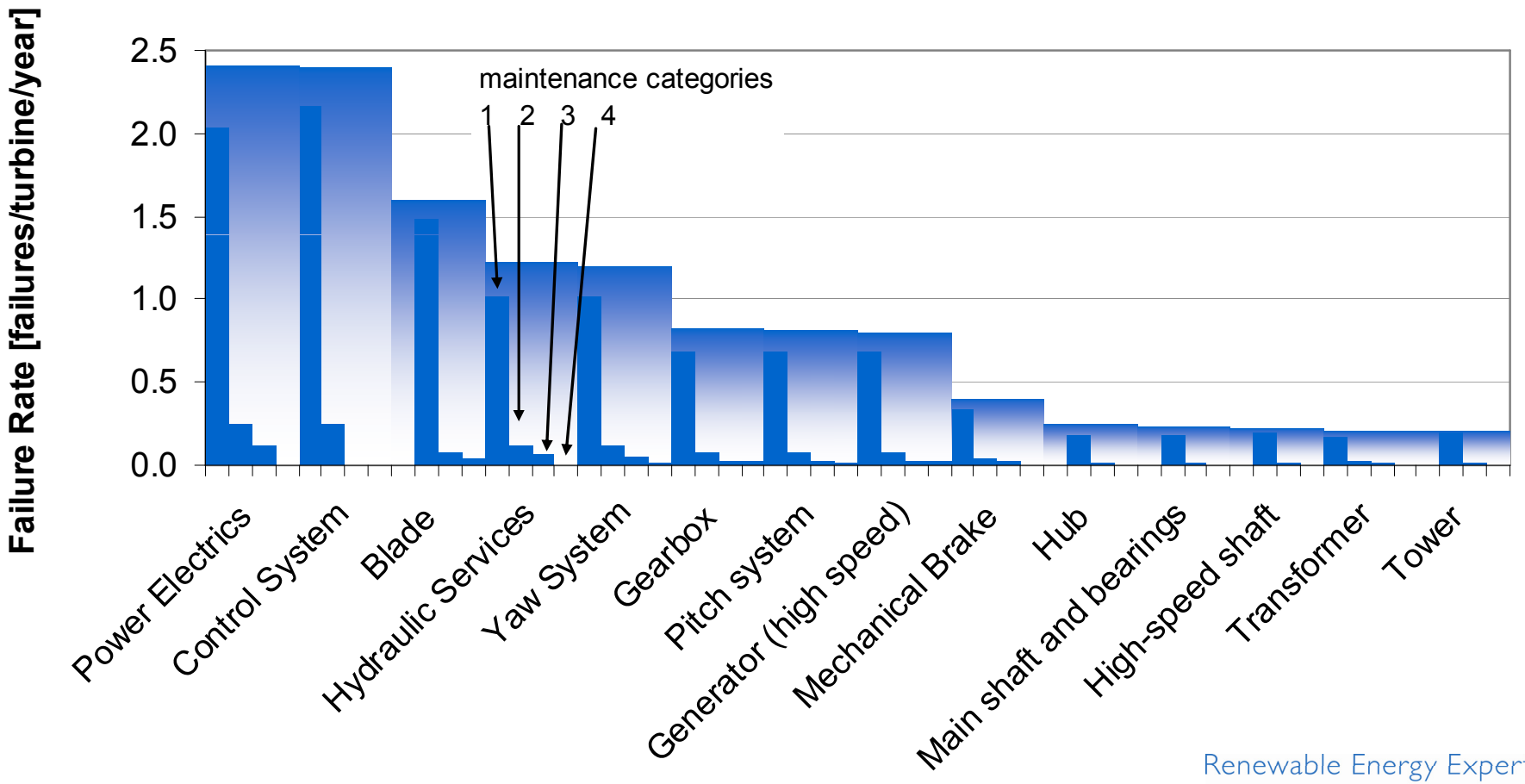
Input Data - Offshore Field Case Study:

Failure Rates



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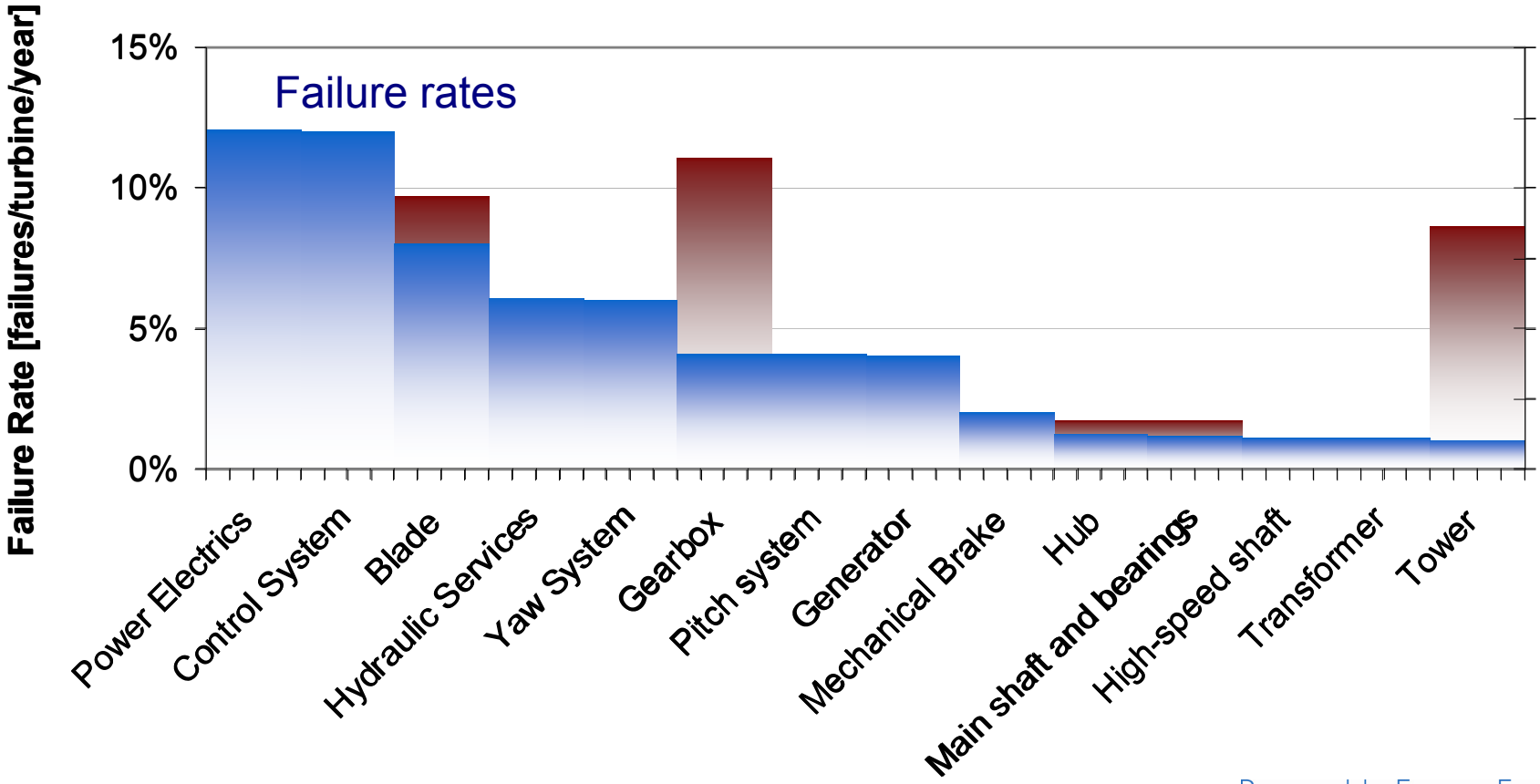
Input Data - Offshore Field Case Study

Capital Costs



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Input Data Case Study

Levelized Production Costs

$$\mathrm{CoE} = \frac{\mathrm{ICC} \times \mathrm{FCR} + \mathrm{O\,\&\,M}}{\mathrm{AEP_{Net}}}$$

$\mathrm{CoE} = \text{Cost of Energy (costs per kWh)}$

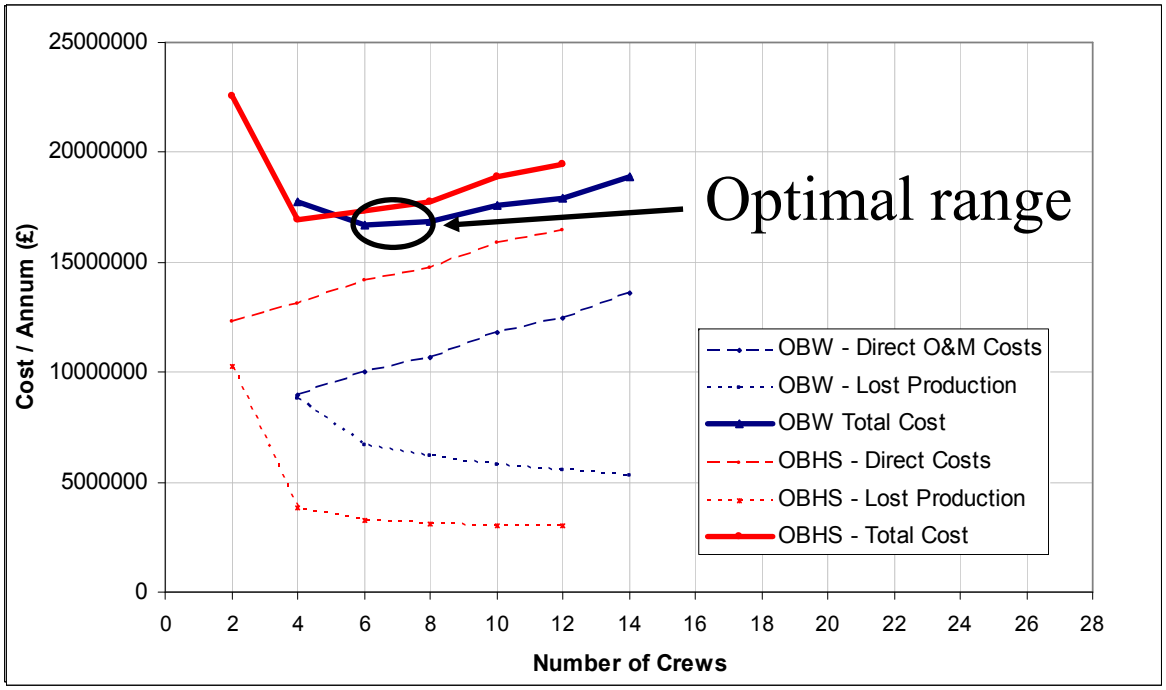
$\mathrm{FCR} = \text{Fixed Charge Rate (\% per year)}$

$\mathrm{O\,\&\,M} = \text{Operations \& Maintenance costs (costs per year)}$

$\mathrm{AEP_{Net}} = \text{Annual Energy Production (kWh per year)}$

Example Results

- 100 WTGs in "benign" climate, located close to shore
- Comparison of two O&M strategies:
  - Onshore based workboats
  - Onshore based workboats with helicopter support



O&M

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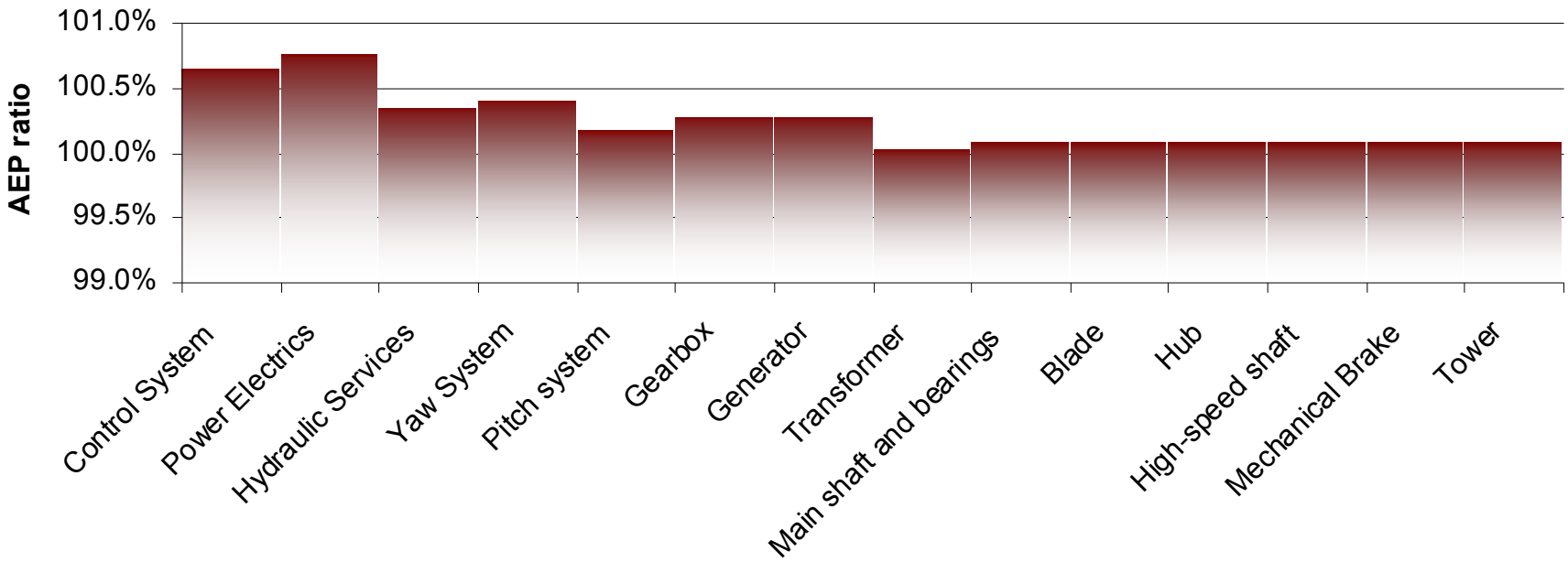
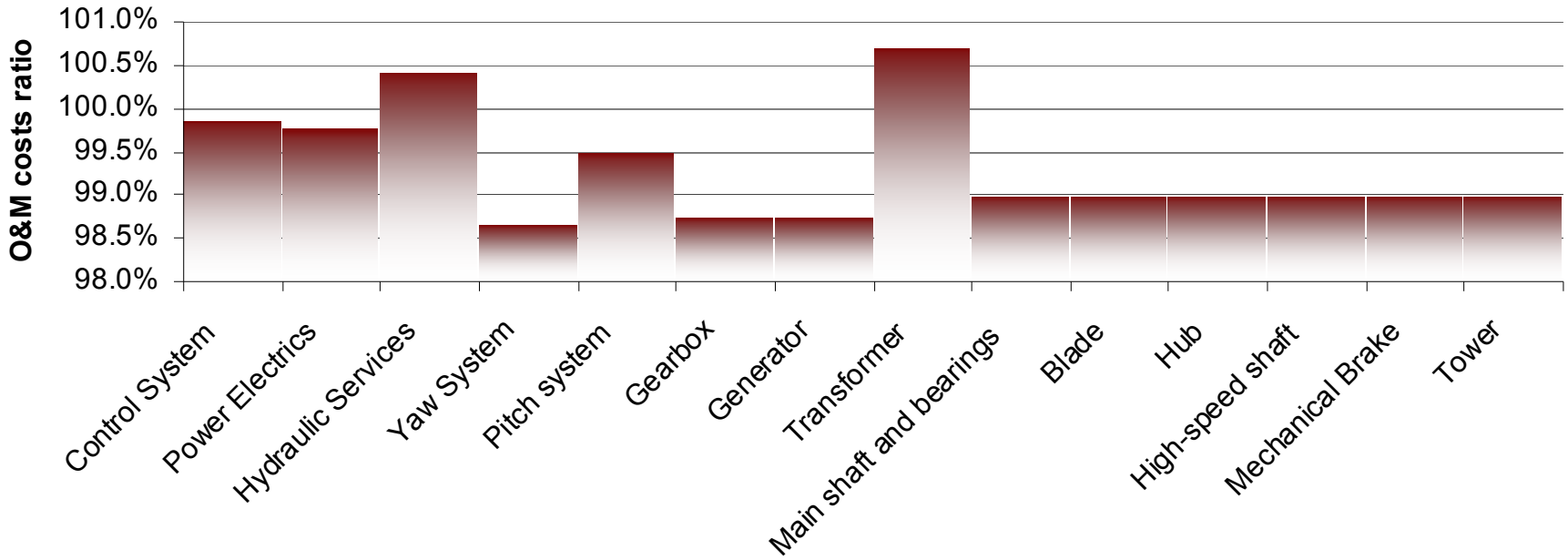
Example Results

Reduced Failure Rates (50%): Effect on Annual Energy Production (AEP)



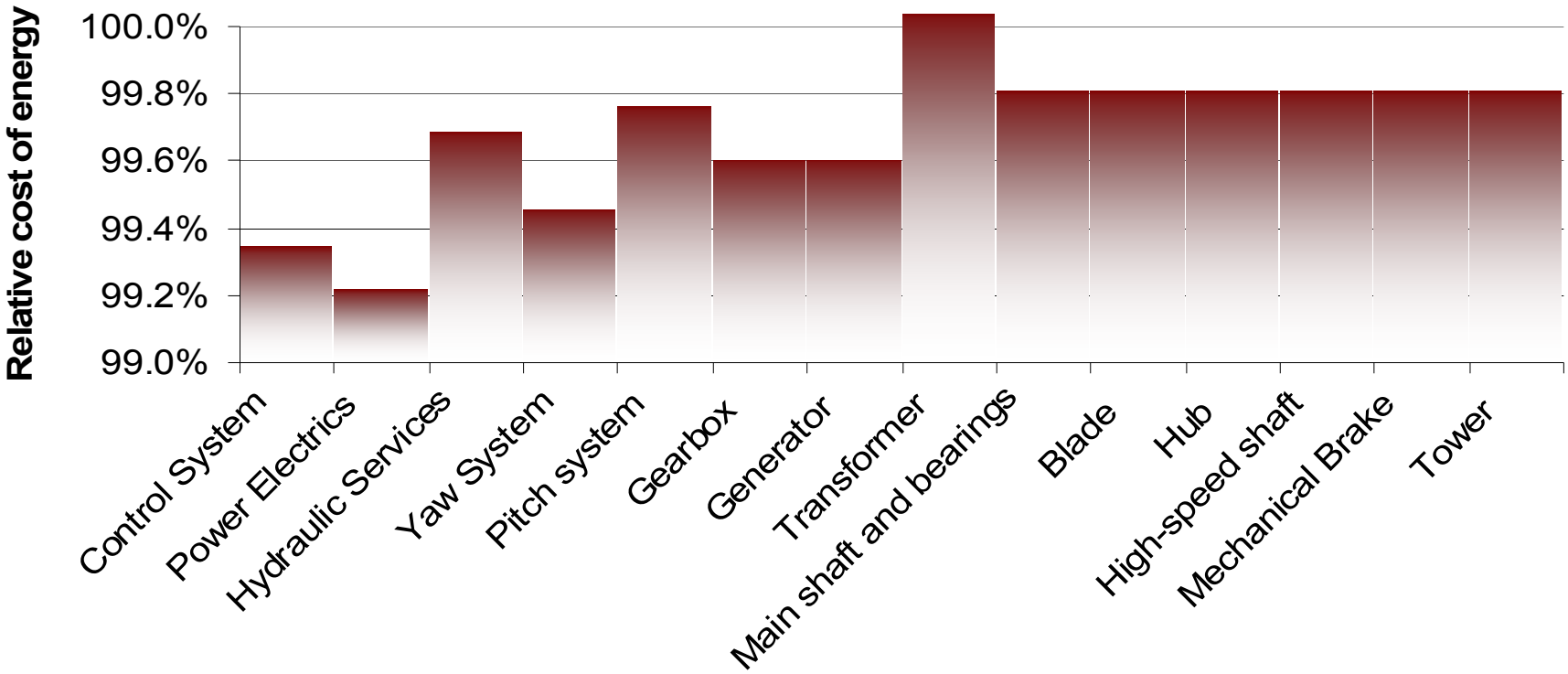
Example Results

Reduced Failure Rates (50%): Effect on Direct O&M Costs



Example Results

Reduced Failure Rates (50%): Effect on Cost of Energy



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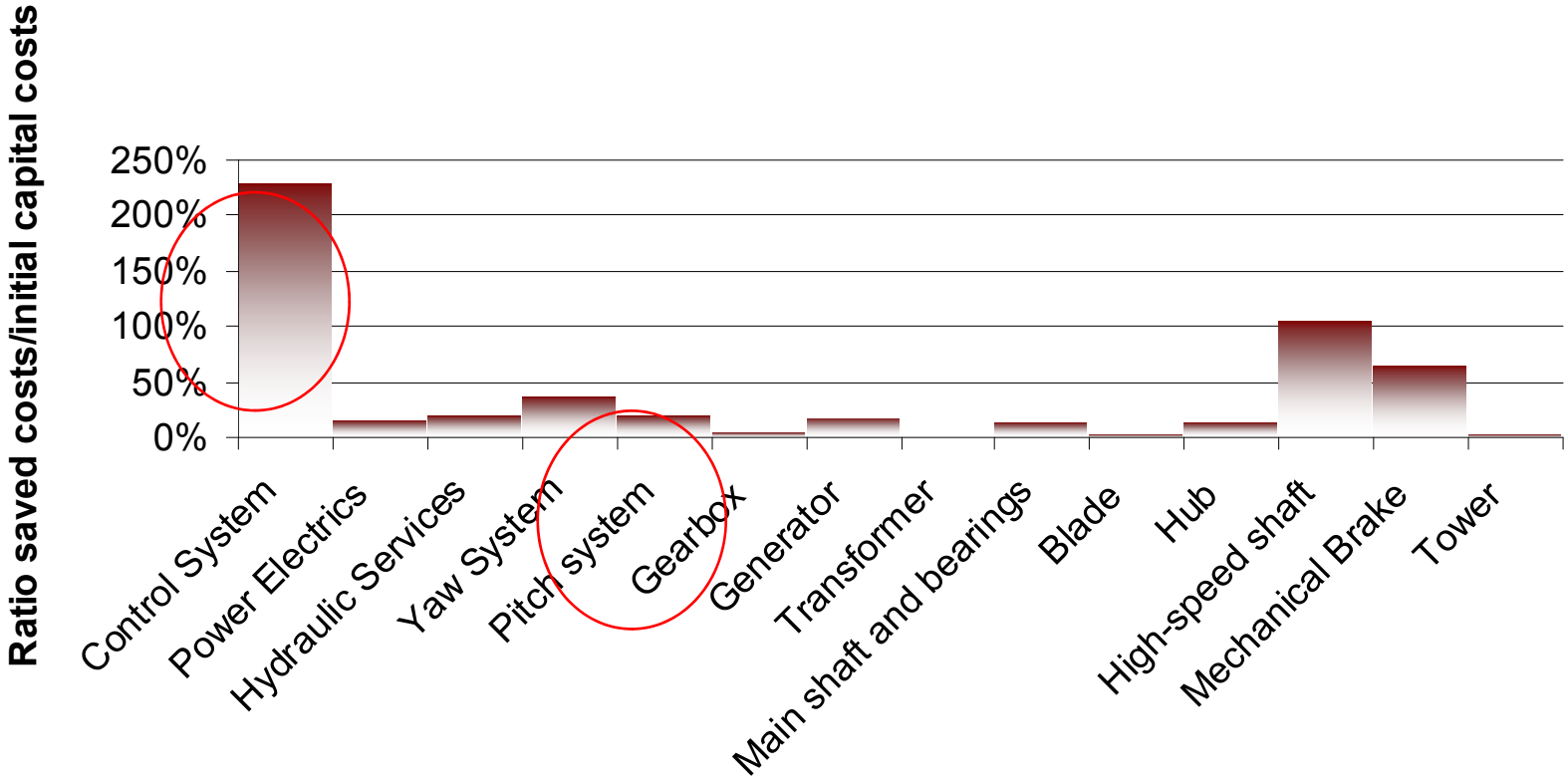
Example Results

Reduced Failure Rates (50%):

Saved revenue losses and O&M costs have been capitalized and compared with the initial capital costs for the component



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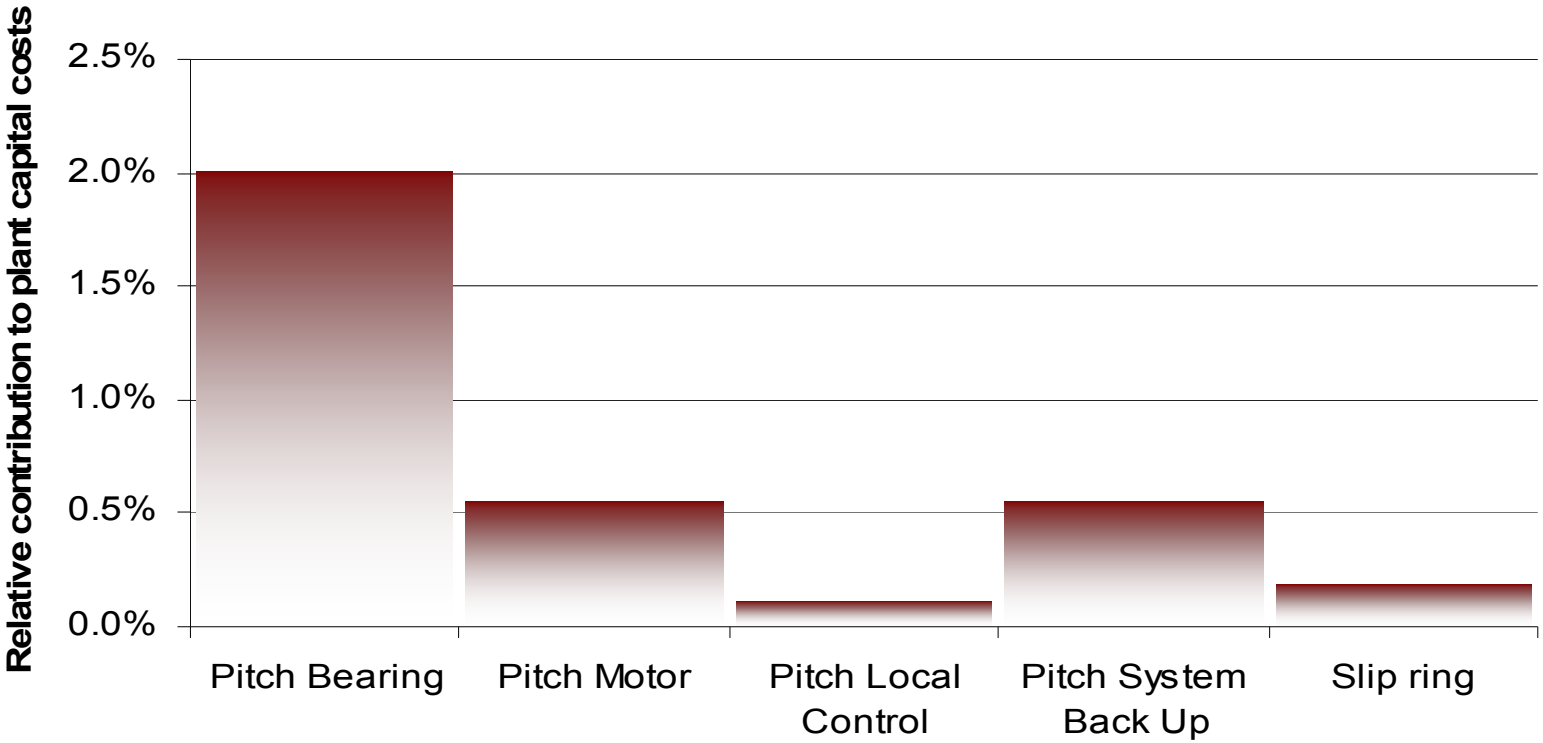
Example Results

Reduced Failure Rates (50%):

Further breakdown of pitch system, contribution to plant capital cost



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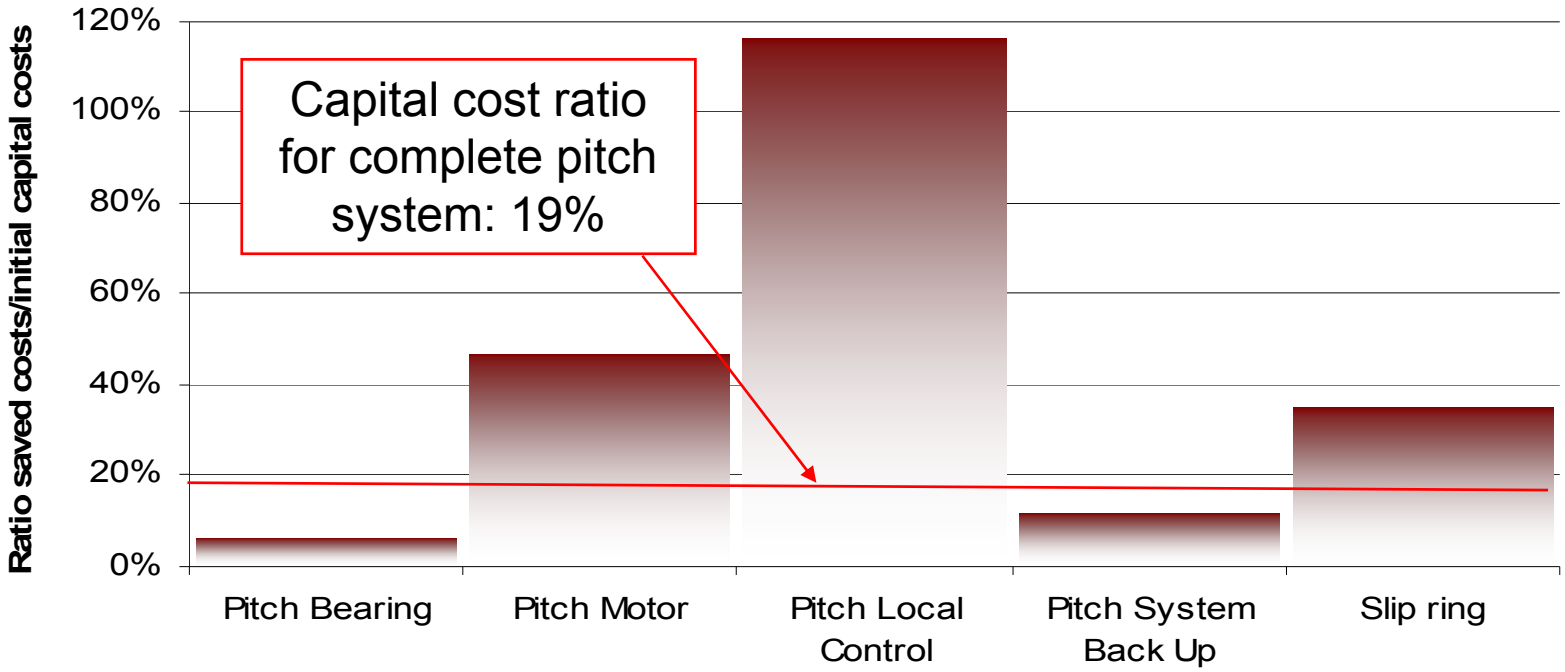
Example Results

Reduced Failure Rates (50%):

Further breakdown of pitch system, ratio of saved capital costs over initial capital cost



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Concluding Remarks

- It has been shown that reliability analysis and modelling of O&M can be used in an integrated design approach to optimize the economics of a wind turbine design.

- O&M analysis is important in assessing operational risk of offshore wind projects. O2M software is a good tool for evaluating the cost benefit of various O&M strategies.

- Method is also applicable to the optimization of onshore designs.

Thank you!

For more information
please contact:

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