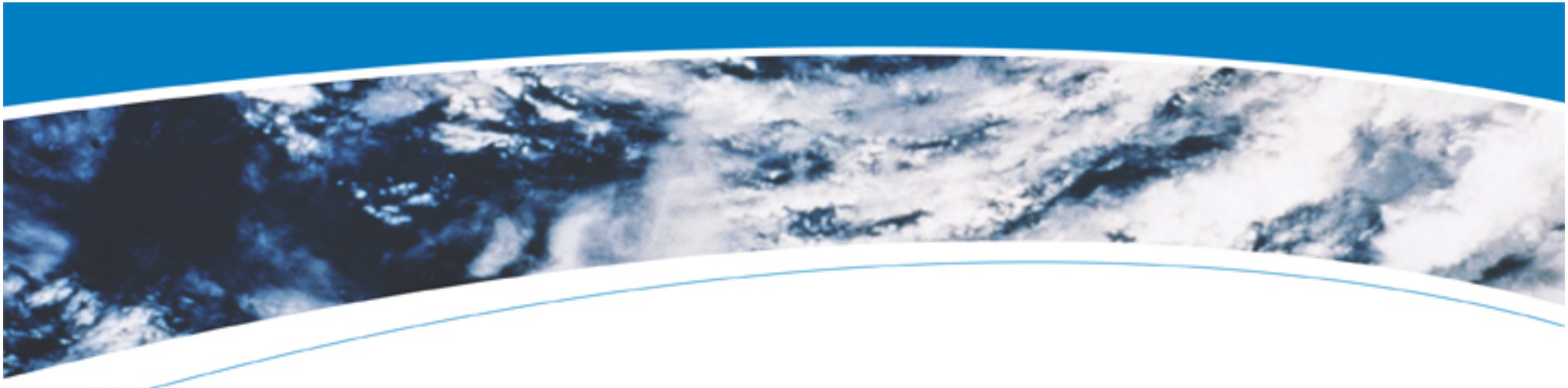

Understanding uncertainties in energy production estimates for offshore wind farms - examining operational risks through simulation

Copenhagen Offshore Wind, 27 October 2005

Joe Phillips < joe.phillips@garradhassan.com >

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Summary

- Background and Motivation
- Offshore O&M Simulation
- Example Applications

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Background and Motivation (1)

- O&M Experience to date….

LT Availability	
O&M Costs	(ma

- Offshore Operational Risks:
  - Poor accessibility => low availability
  - Higher costs (than anticipated)
- => Modelling capability required to examine O&M risks
  - Closely based on work of Bossanyi and Strowbridge (ETSU 1994)
  - Model dubbed O2M,“Optimisation of Operations & Maintenance”

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Background and Motivation (2)

- Some key questions that a modelling approach helps to answer….
  - Banks and Owners:
    - *Probability of warranty failure ?*
    - *Wind farm availability after warranty period ?*
    - *Is it worth investing more / less in O&M resource ?*
  - O&M Contractors / Turbine Manufacturers:
    - *Is our O&M strategy adequate to meet warranted availability level ?*
    - *What is the value of our O&M contract ?*
  - How should the Operational Risks be divided ?

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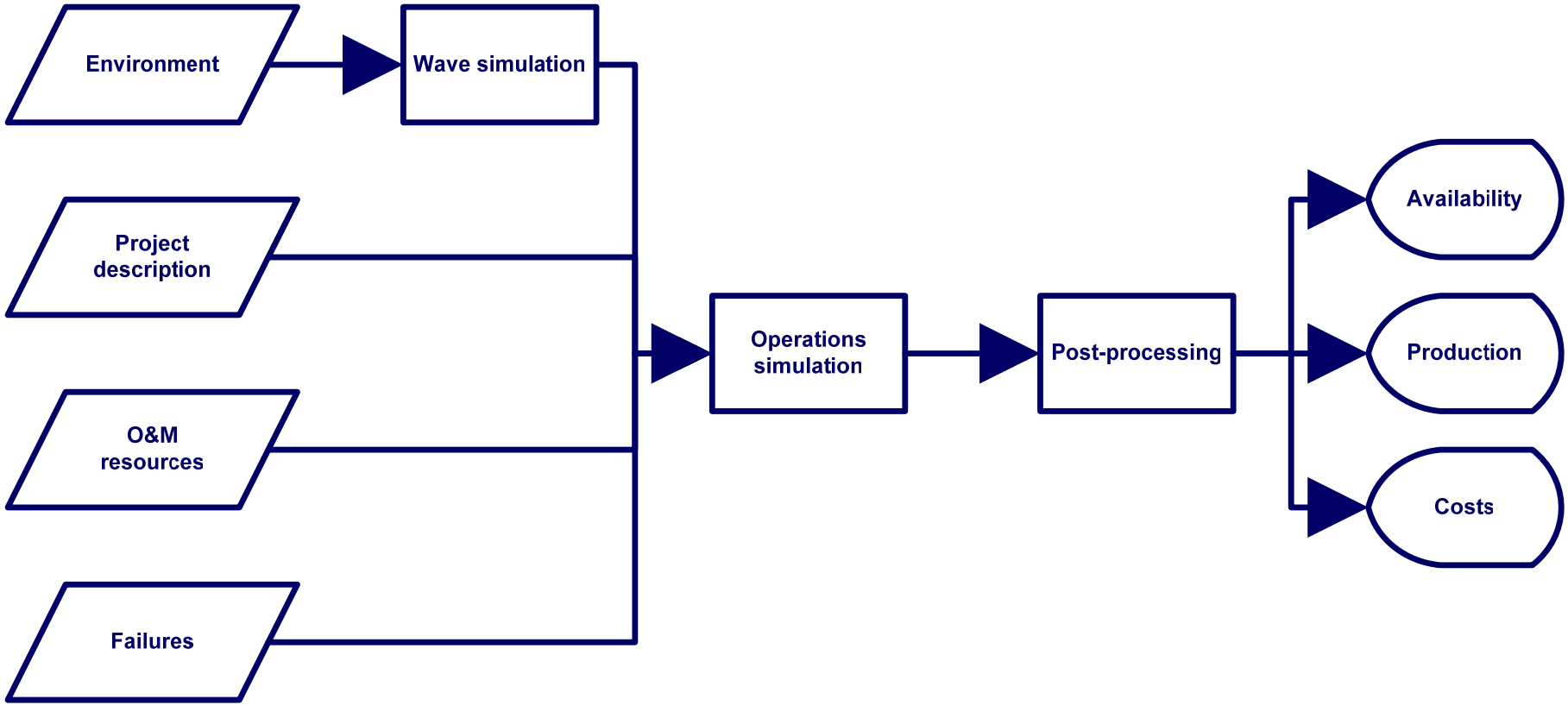
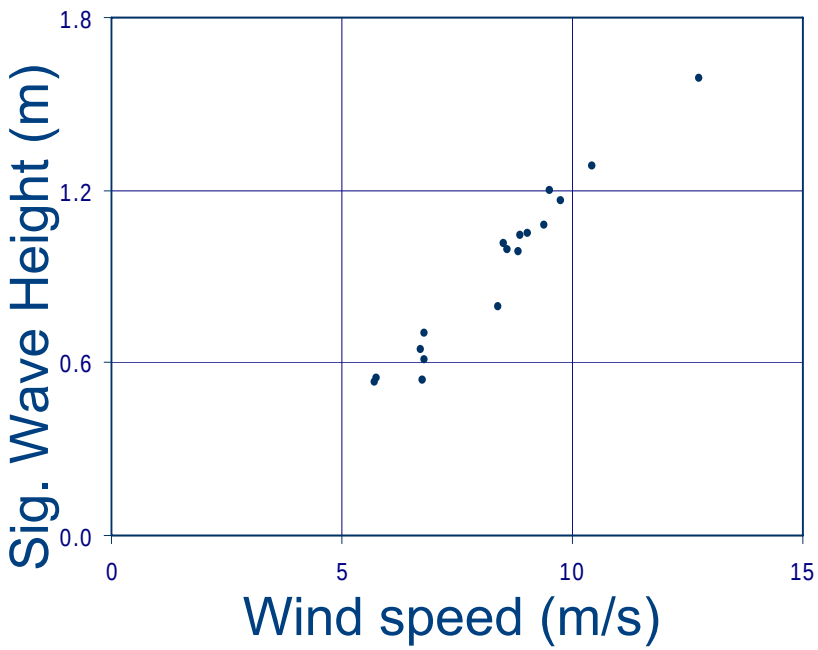
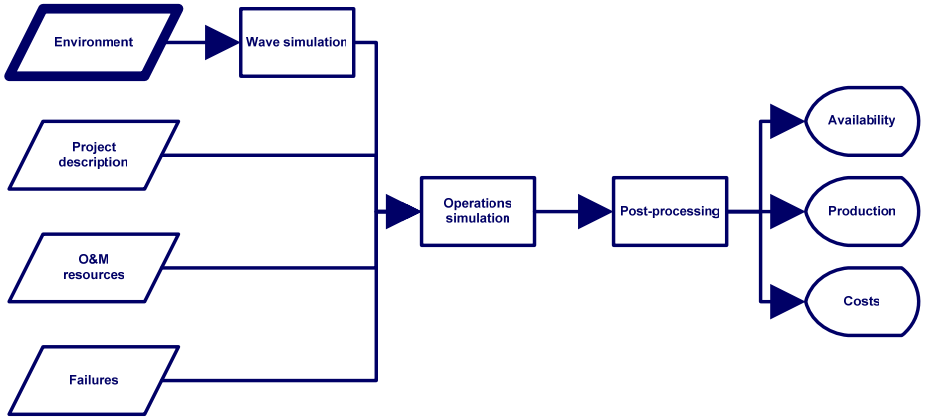
O2M Structure



Inputs: Environment

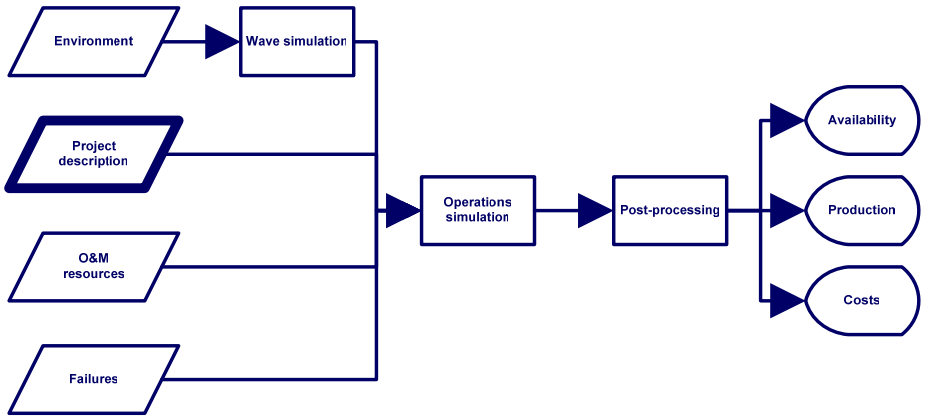
- Wave time series, if available
- Wind – wave relationship





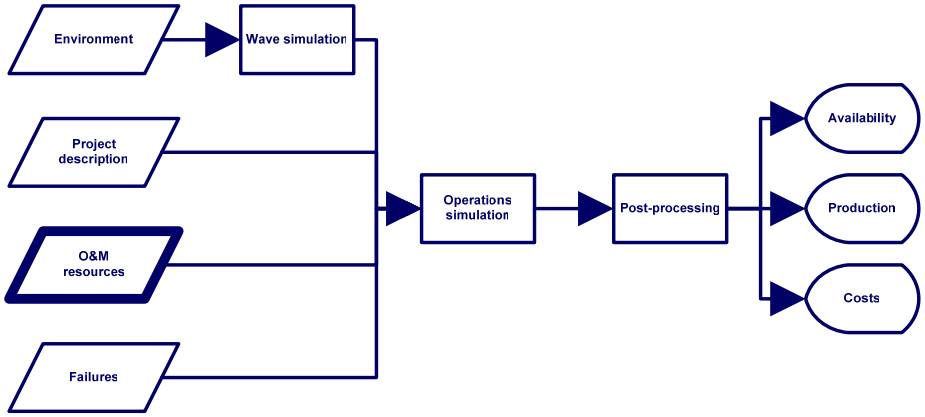
Inputs: Project Description

- No. of wind farm sites
- No. turbines on each site
- Stores and service locations
- Mobilisation + Travel times
- LT energy prediction
    - (seasonal breakdown)



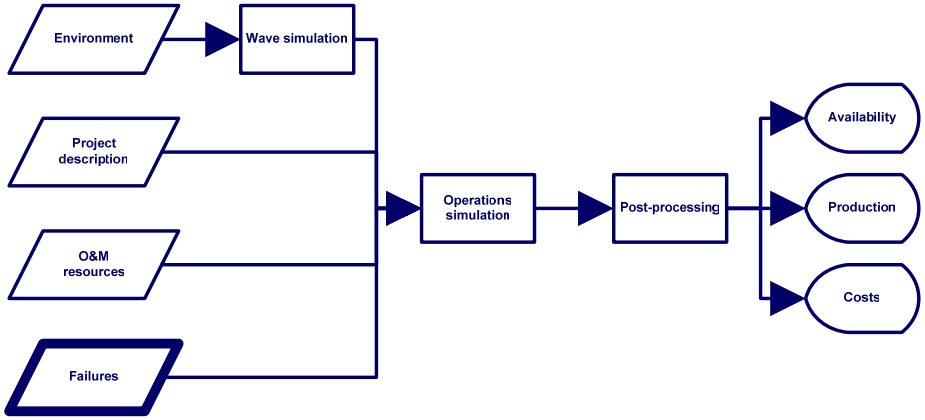
Inputs: O&M Resources

- Staffing
- Shift system
- Vessel capability
- Spares holding
- Spares lead times
- Decision logic



Inputs: Turbine Reliability

- Define several failure categories
- For each category define
  - Mean Time Between Failure (MTBF)
  - Mean Time To Repair (MTTR)
  - Spares requirement
- Example schedule of faults:



	DESCRIPTION	MTBF (HRS)	MTTR (HRS)
1	Manual restart	4000	2
2	Small component change-out	2500	8
3	Major component repair	15000	30
4	Major component change-out	50000	45

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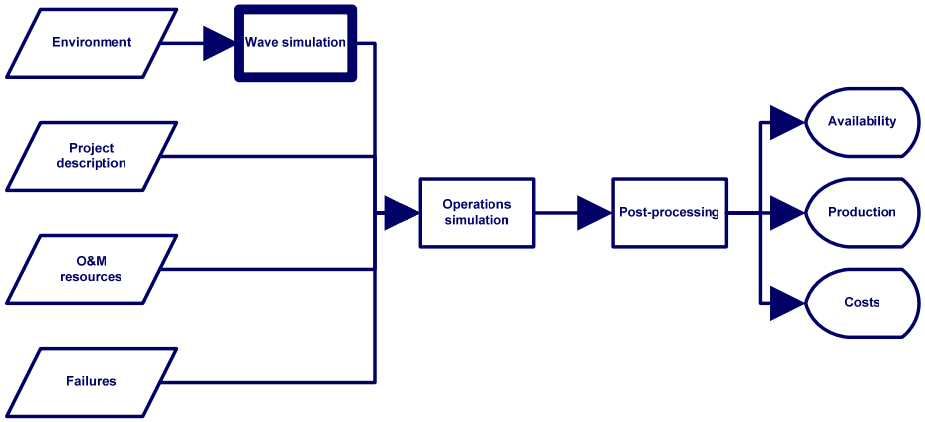
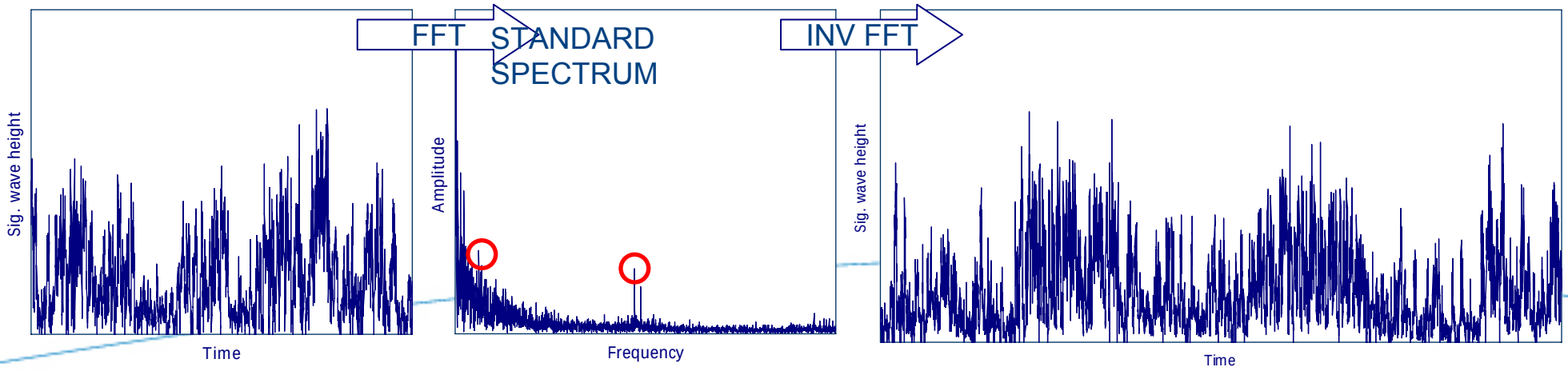
Wave Synthesis

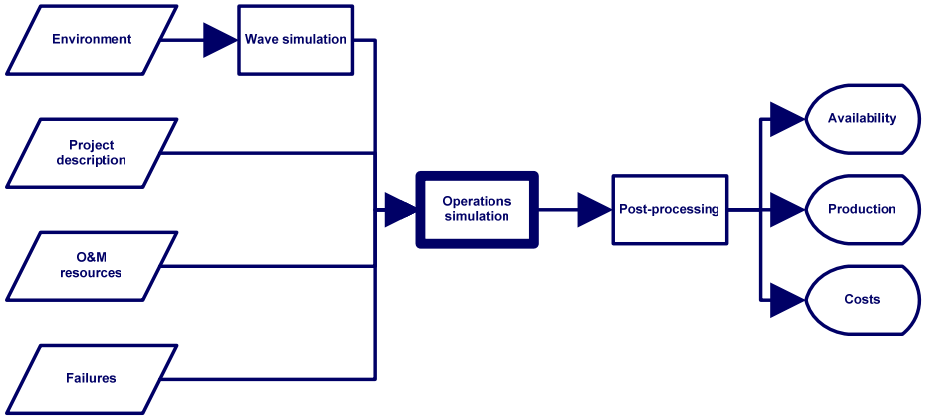
- Input time series
- Fast Fourier Transform (FFT)
- Wave Spectrum, includes
  - Seasonal phasing
  - Tidal phasing
- Inverse FFT
- Synthesised time series of desired length





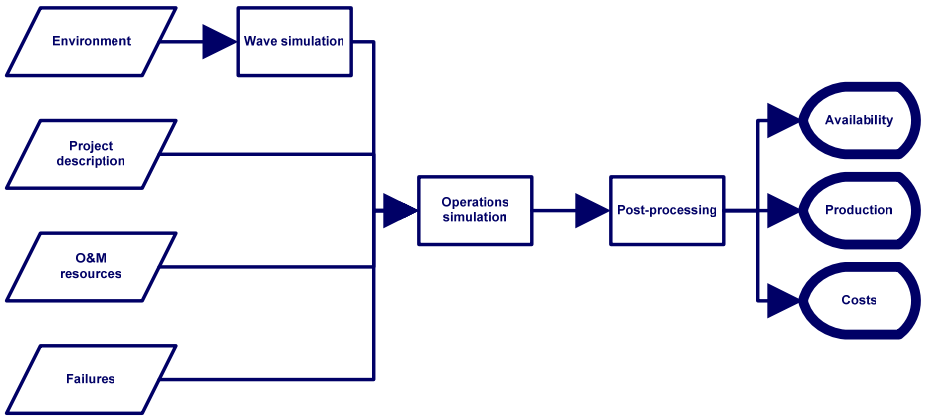
Operations Simulation

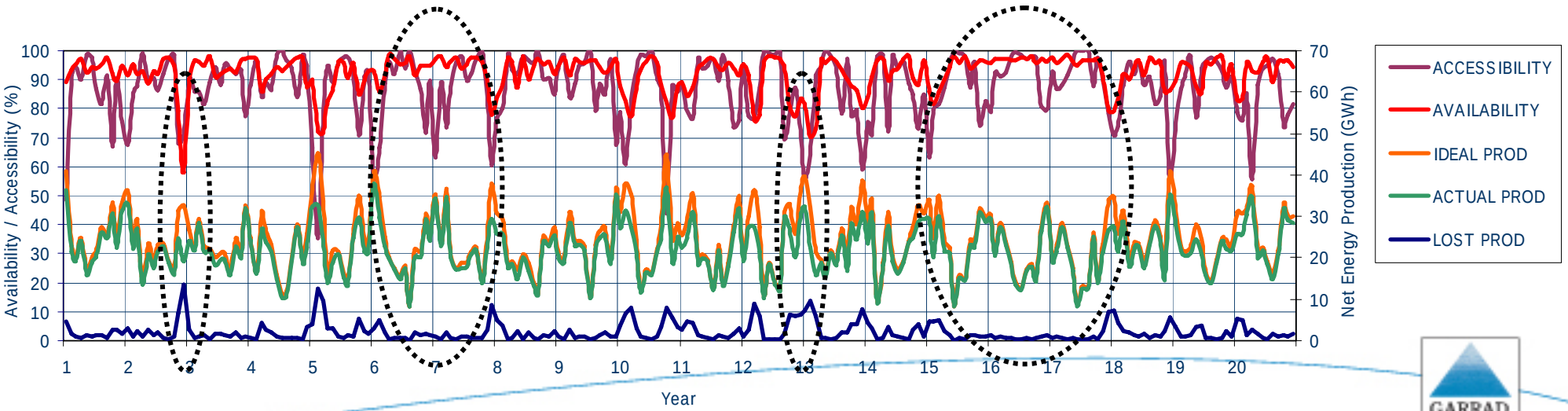
- Hourly time step, run for N years
- At each time step:
  - Failures (Monte Carlo)
  - Actions
  - Status updated
    - Turbines
    - Crews
    - Parts
  - Results recorded



Outputs

- Availability
- Production and Lost Production
- Costs, resource and spares usage
- Example output plot
    - Access double-whammy
    - “Lucky” periods

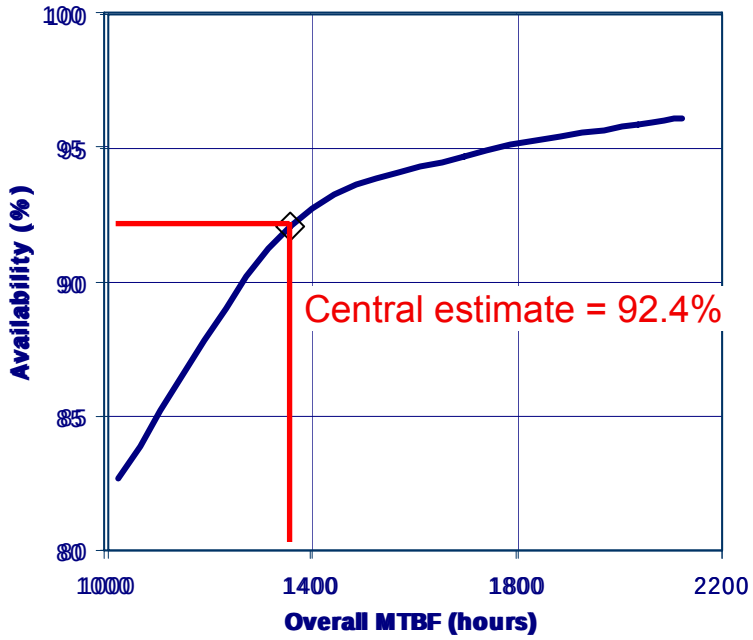




Example Applications (1)

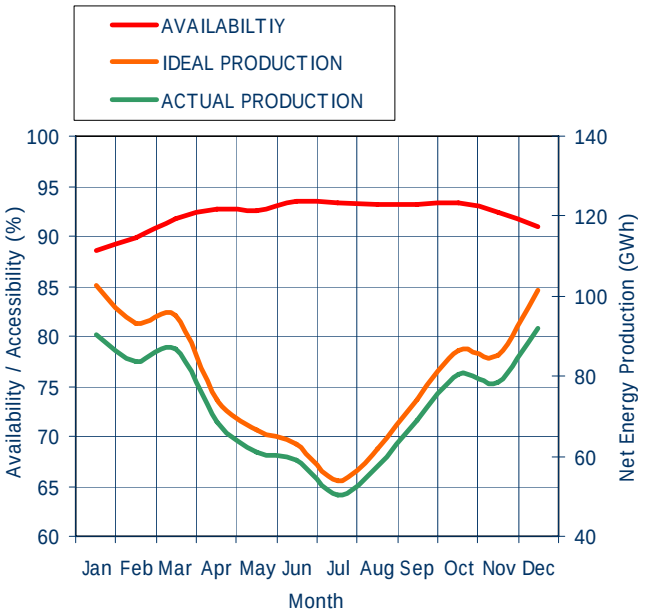
- LT Availability Estimation + Sensitivity Study
- Input Assumptions
  - *100 turbines x 3MW @ 36% cap factor (~9m/s)*
  - *6 crews, 8 hour shift, 5 days/week*
  - *mobilisation + transit time = 2 hours*
  - *Access capability: Hs < 2.0m, wind speed < 15 m/s*
  - *Moderate wave climate (accessibility = 81 %)*
  - *Central overall MTBF = 1357 hours*

	DESCRIPTION	MTBF (HRS)	MTTR (HRS)
1	Manual restart	4000	2
2	Small component change-out	2500	8
3	Major component repair	15000	30
4	Major component change-out	50000	45

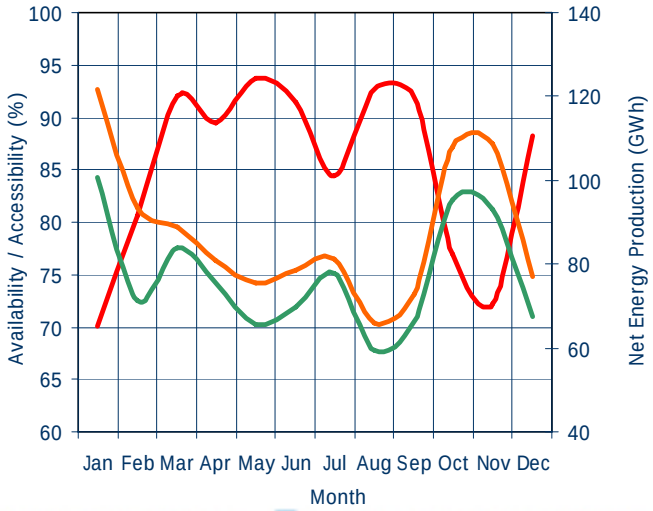


Example Applications (2)

- Seasonal Analysis
  - Mean seasonal trend
  - “Worst” expected year



- Scenario Modelling
  - Serial defects in years 1-5
  - Wear-related failures in years 10-20



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Example Applications (3)

- Cost Benefit Analysis
  - Example: Access Method Capability

	Capex M €	Access Limit (Hs)	Accessibility (%)	Availability (%)
Method 1	0.4	< 1.5 m	68.8	86.7
Method 2	0.6	< 2.0 m	80.6	92.4
Method 3	1.2	< 2.5 m	88.3	94.8

- Economic Measures: NPV, ROI etc

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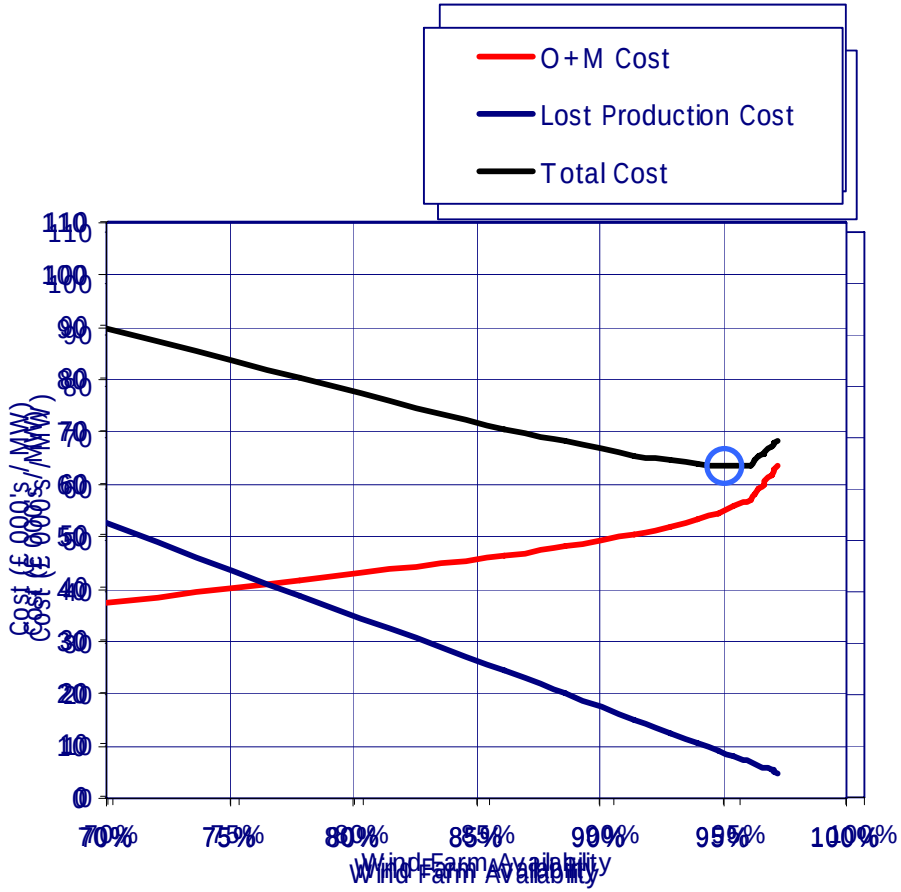
Example Applications (4)

- O&M Optimisation
  - O&M Direct Costs
  - + Lost Production Cost
  - = Total Cost



Summary

- Offshore O&M Risks: Access + Costs
- O2M Structure: Time domain, Monte Carlo, etc
- Example Applications
    - LT Availability
    - Sensitivity Studies
    - Seasonal Analyses
    - Scenario Modelling
    - Cost Benefit Analyses / O&M Optimisation

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