

Development of an open access O&M tool for availability and cost estimation of offshore wind farms

Prof Athanasios Kolios

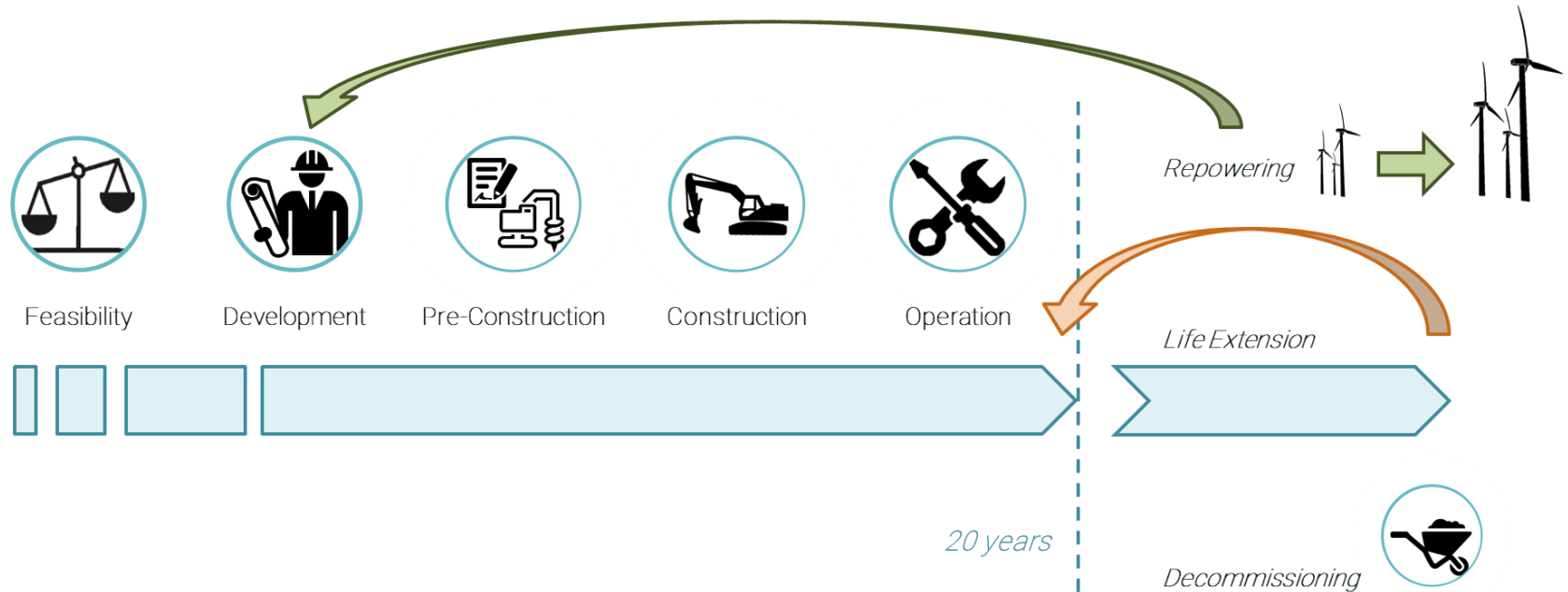
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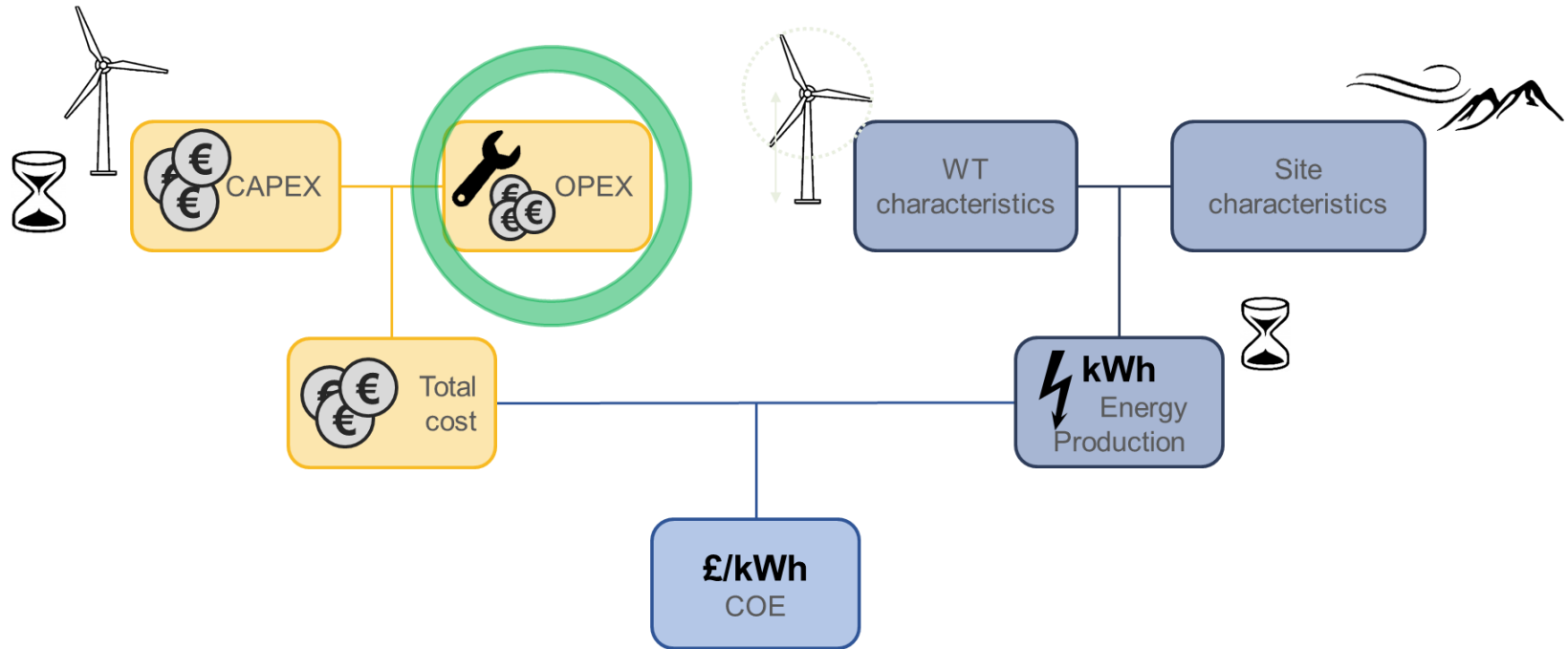
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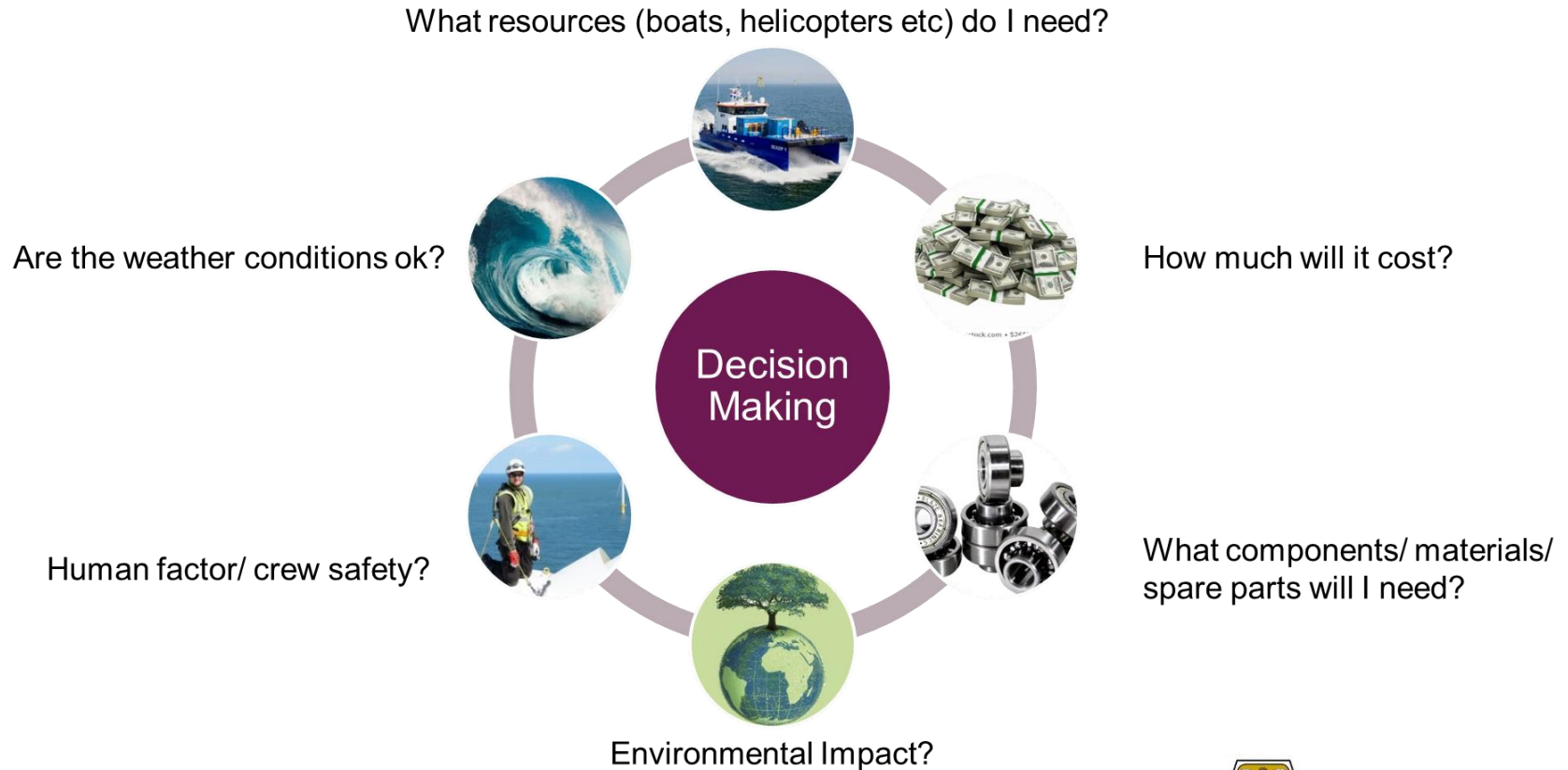
Wind Project Lifecycle



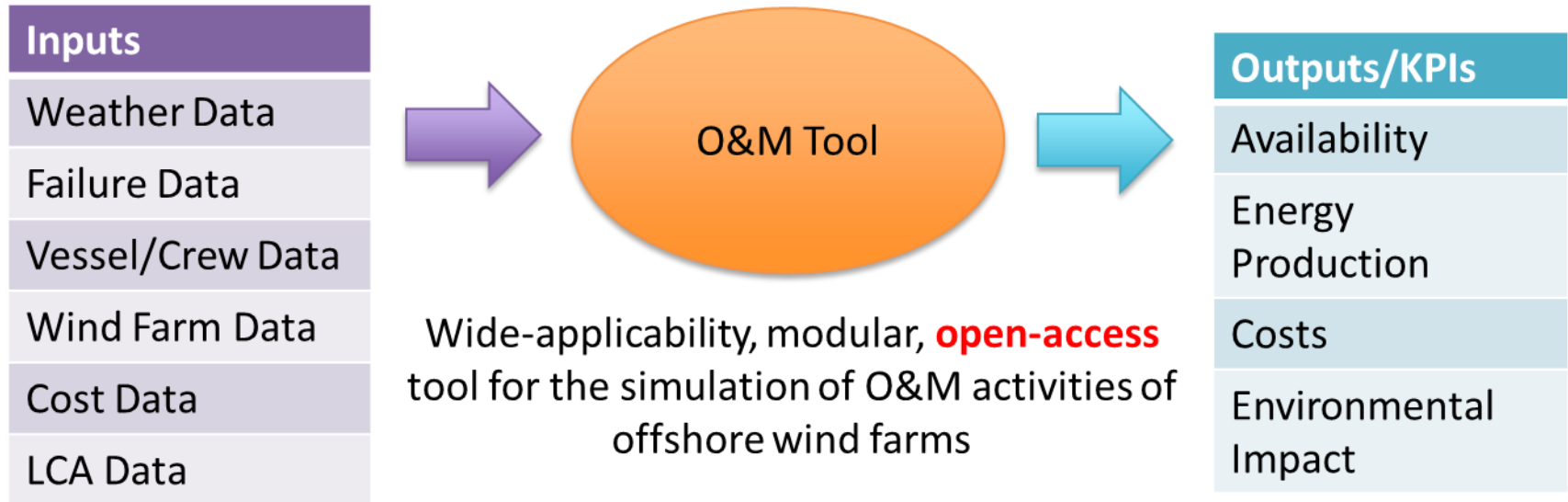
Wind Project Economics



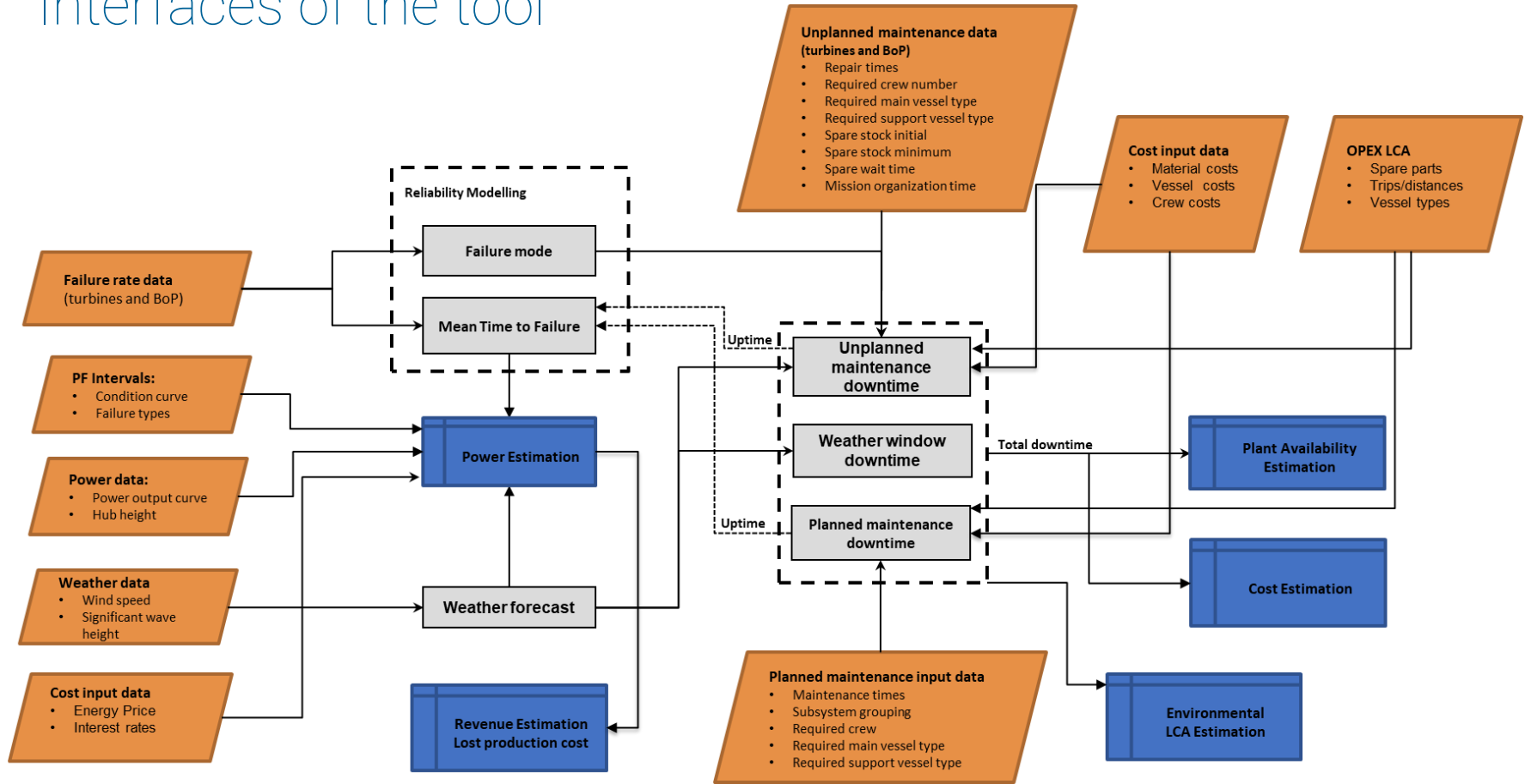
The Complexity of Decision Making



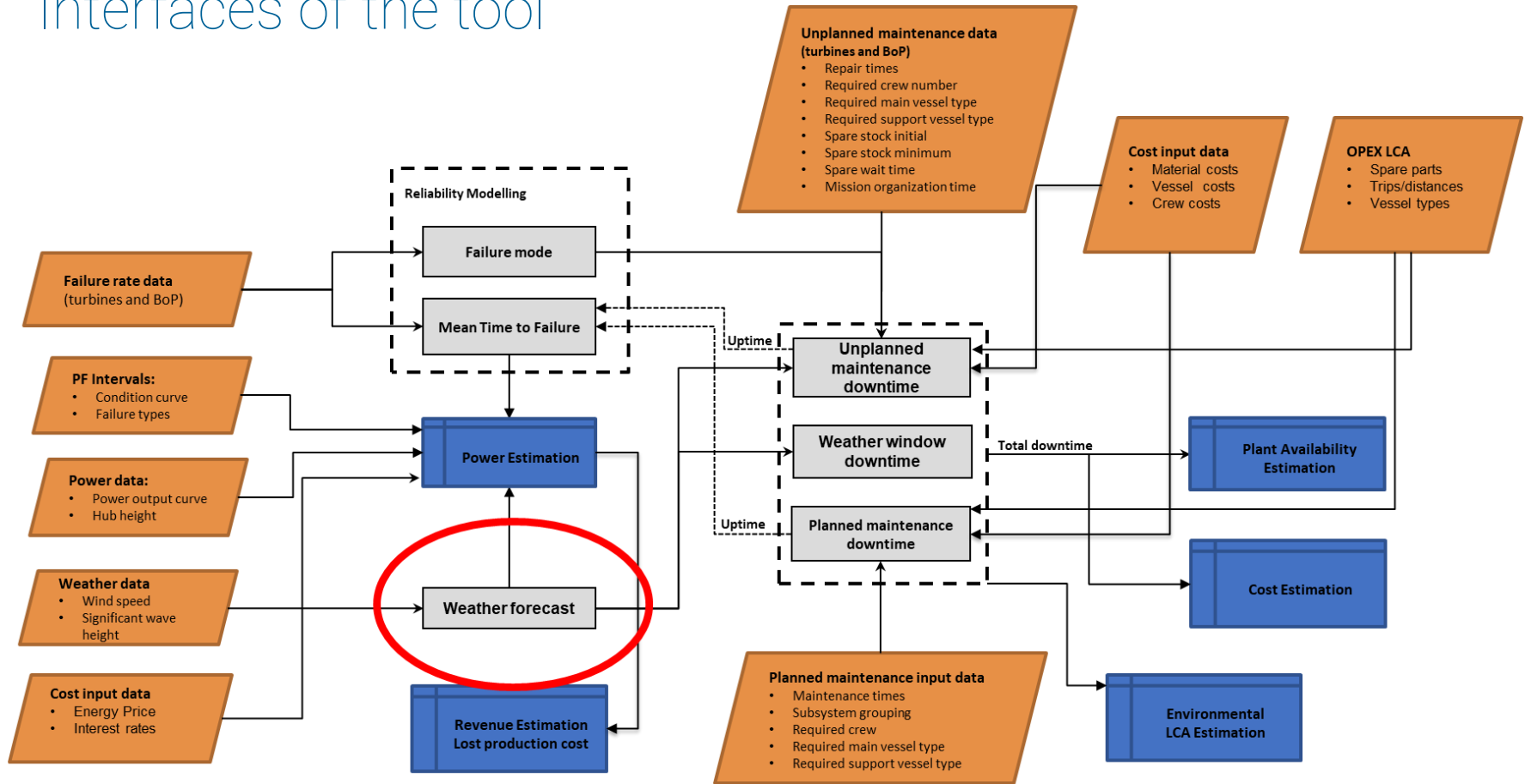
Purpose of the O&M Tool



Interfaces of the tool

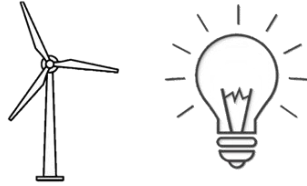


Interfaces of the tool



Weather Forecasting

1. Power Production



2. Accessibility

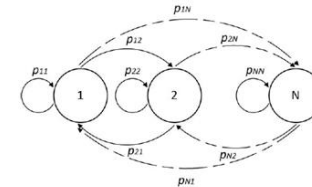
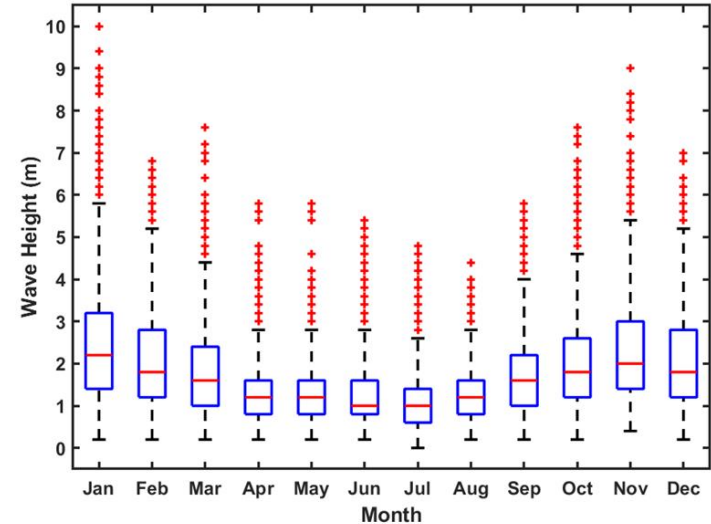


Forecasted variables:

1. Wind Speed
2. Wave height

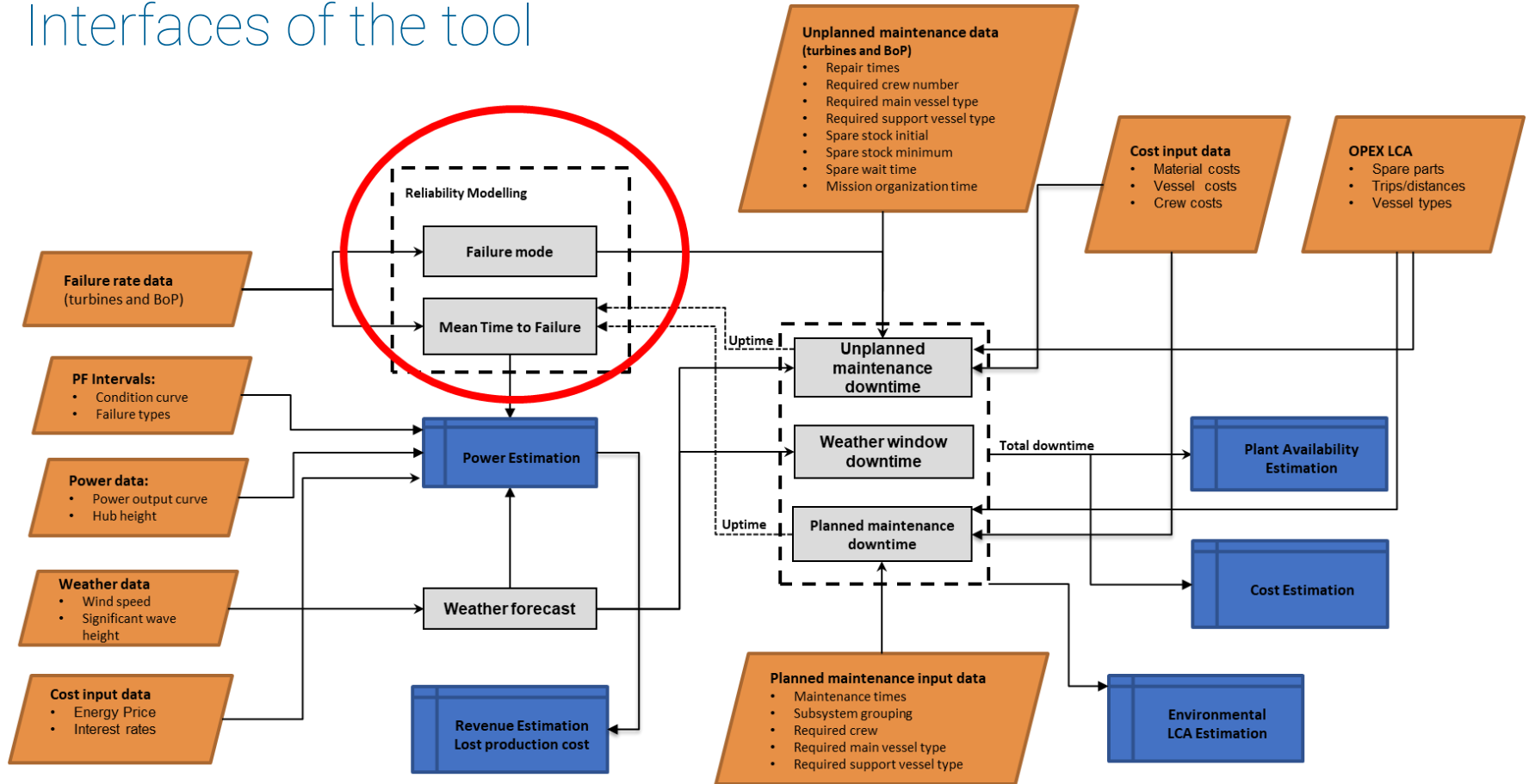
Forecasting Methods (modularity of code):

1. Markov Chains
2. Neural Networks
3. ...



Source :Alsaif et al., 2017

Interfaces of the tool

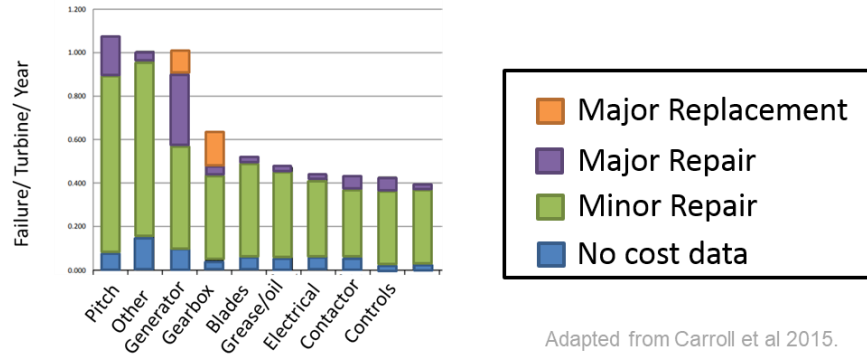


Reliability Module

Simulates the **occurrence** and **severity** of the different failure types corresponding to the **subsystems** of the turbine, along with the overall mean time to failure (MTTF) of the turbine

1. Minor failure
2. Major failure
3. Replacement

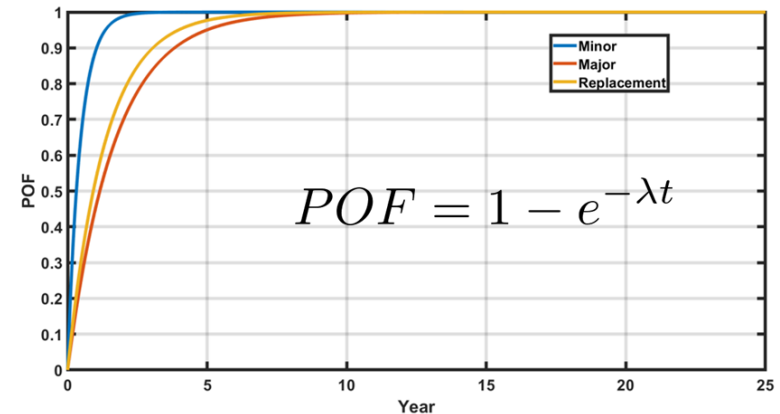
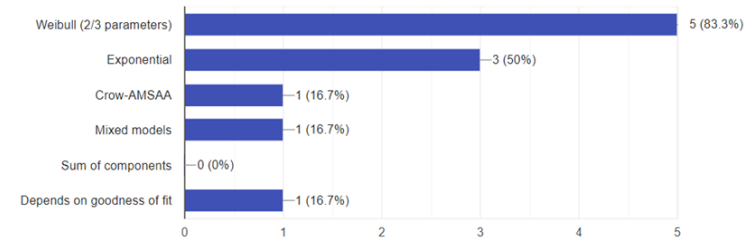
The TTF associated with each failure mode for a particular subsystem is assumed to be distributed by an exponential probability density function. The faulty subsystem will be the one with the lowest time to failure



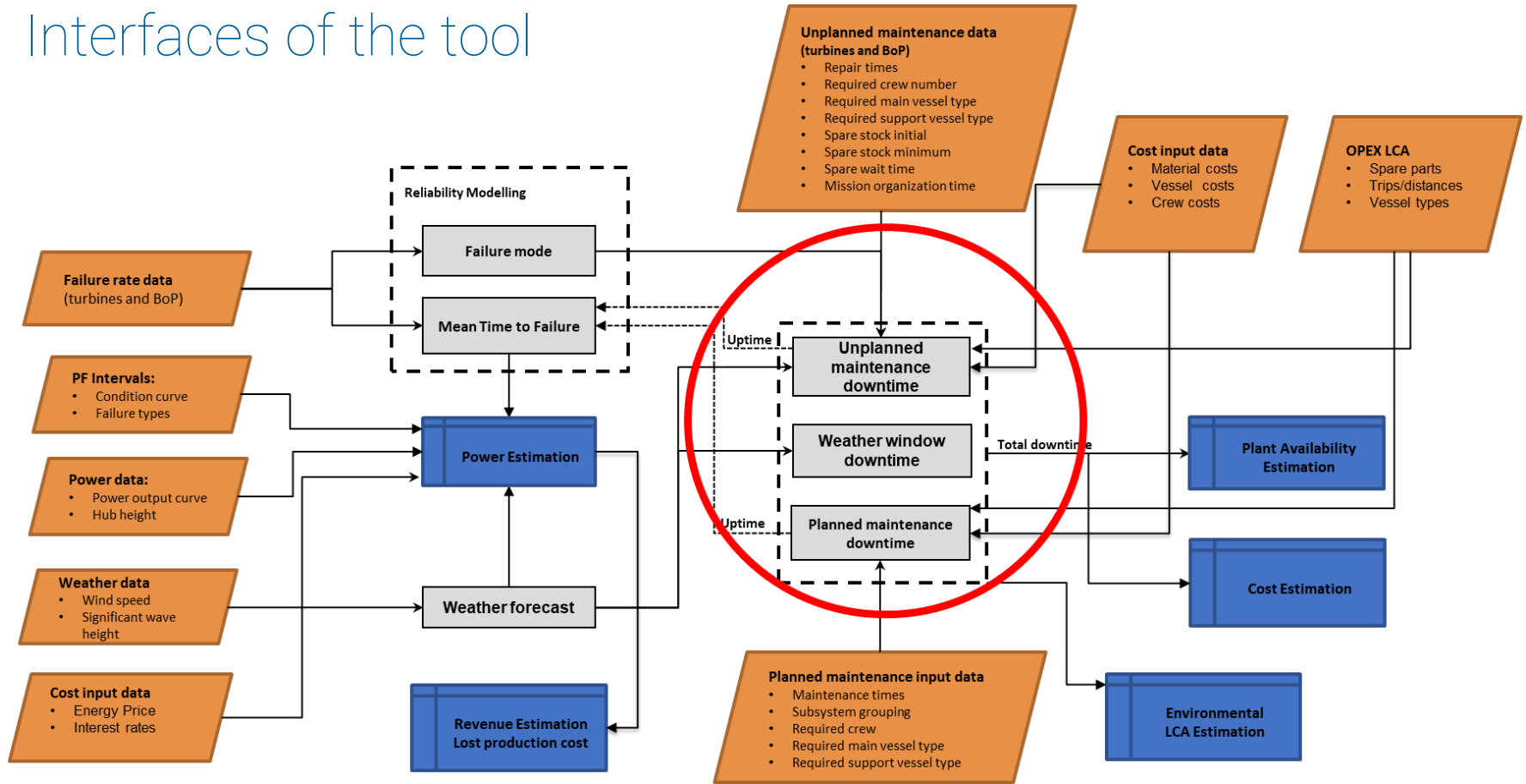
Adapted from Carroll et al 2015.

Which distribution do you use to model probability of failure?

6 responses

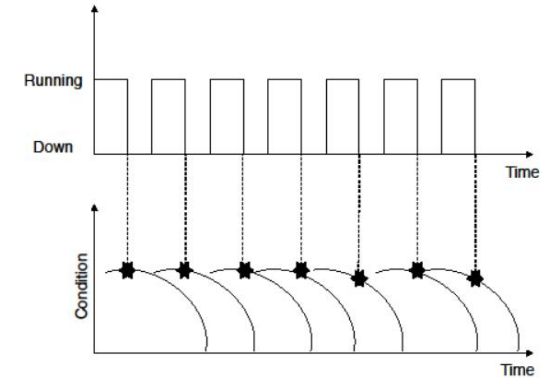
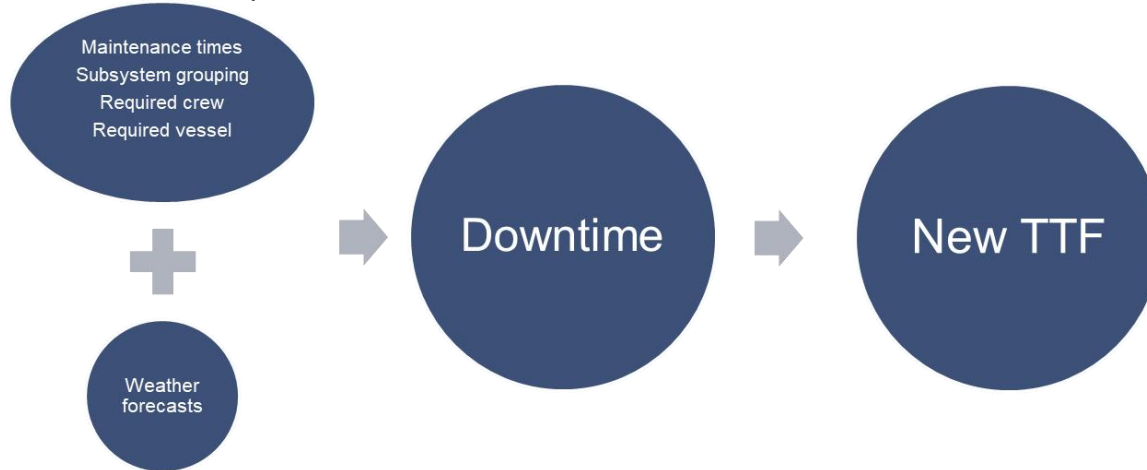


Interfaces of the tool

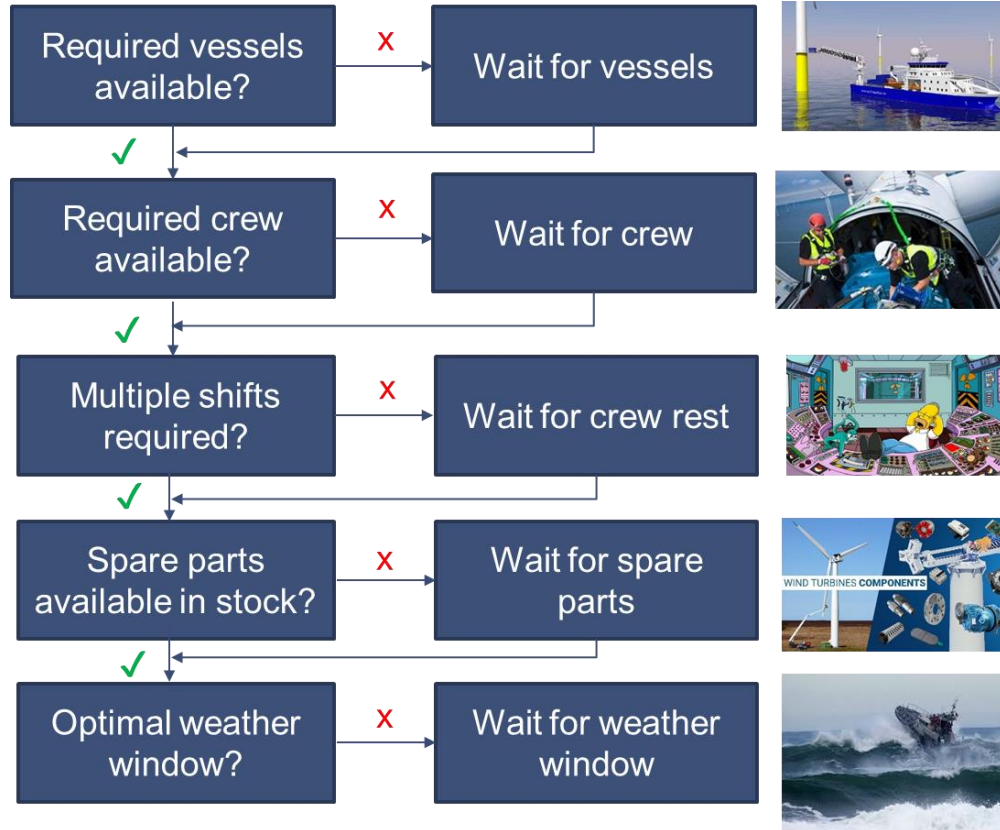


Planned Maintenance

- Planned maintenance takes place at fixed intervals (e.g. yearly)
- Only workboats are considered
- Maintenance is performed in all subsystems of the turbine to ensure normal operation and avoid unscheduled breakdowns.
- Downtimes are calculated based on the maintenance activity duration (assumed to be fixed)

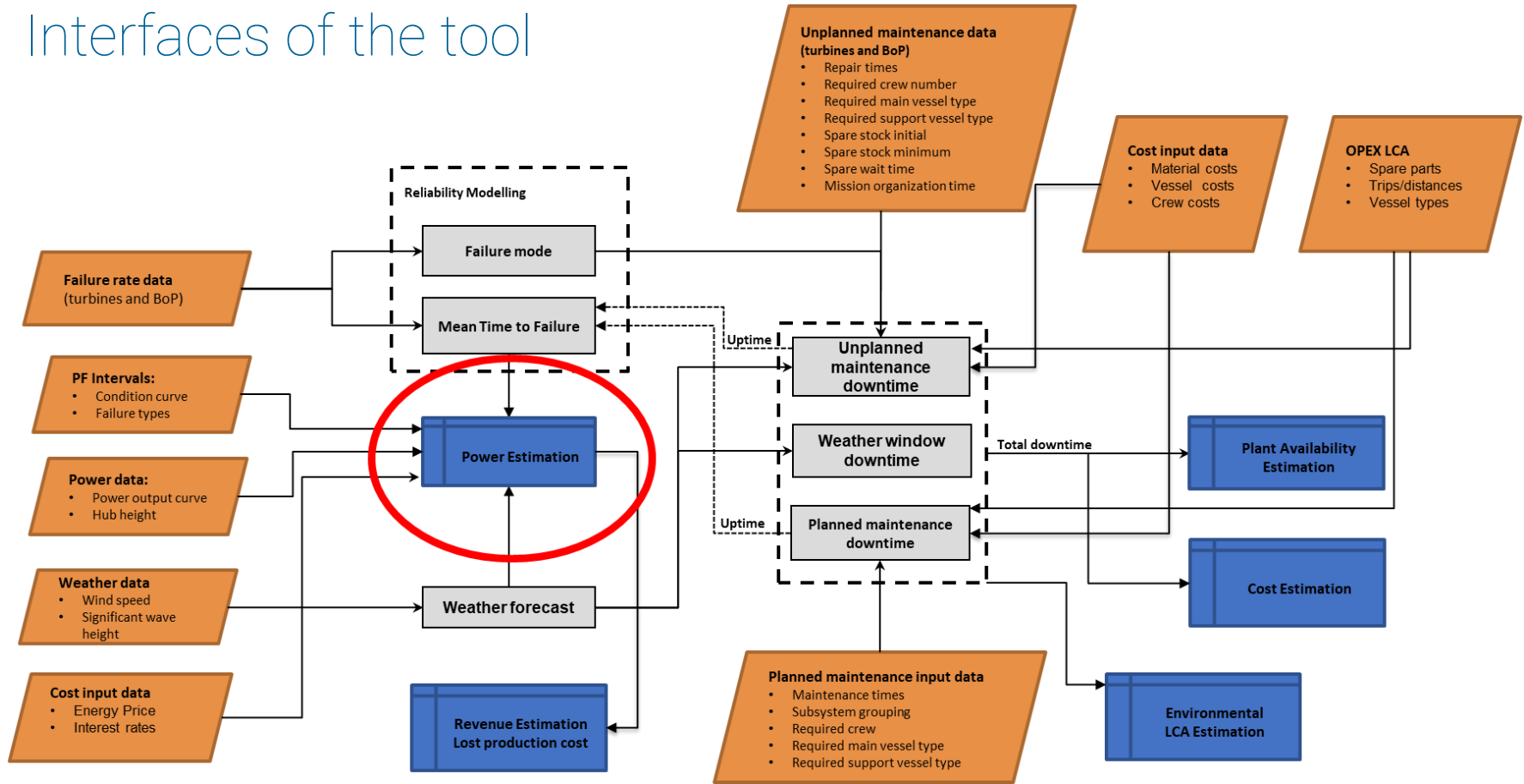


Unplanned Maintenance



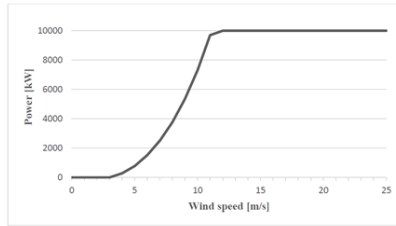
- e Depending on component for each failure type, the respective vessel can be defined
- e Maintenance campaigns in order to decrease downtime:
 - Maintenance for all failures occurring during lead time of ordering JUV
 - Maintenance for failures that occur overnight for CTV
- e In the event of infrastructure failure, all turbines connected to it are considered to be in non-operational mode at that time.

Interfaces of the tool



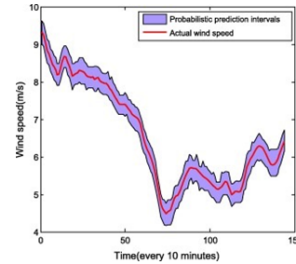
Power Module

1. Power Curve



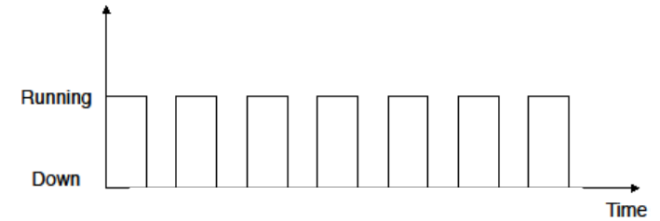
DTU 10MW Reference Power Curve

2. Wind Speed Forecast



Wind speed forecast. (Peng et al 2017)

3. Uptime



$$P = \frac{1}{2} \rho C_p A V^3$$



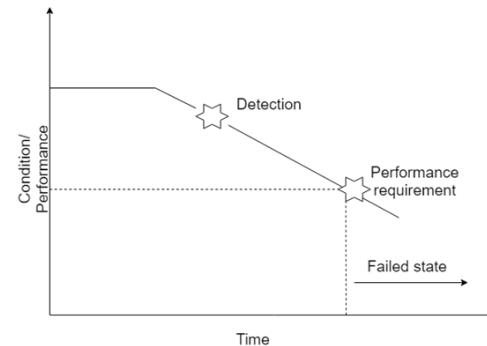
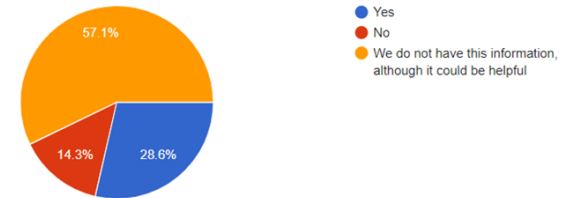
PF Intervals

The interval between the point in time a developing failure can be detected until the failure occurrence

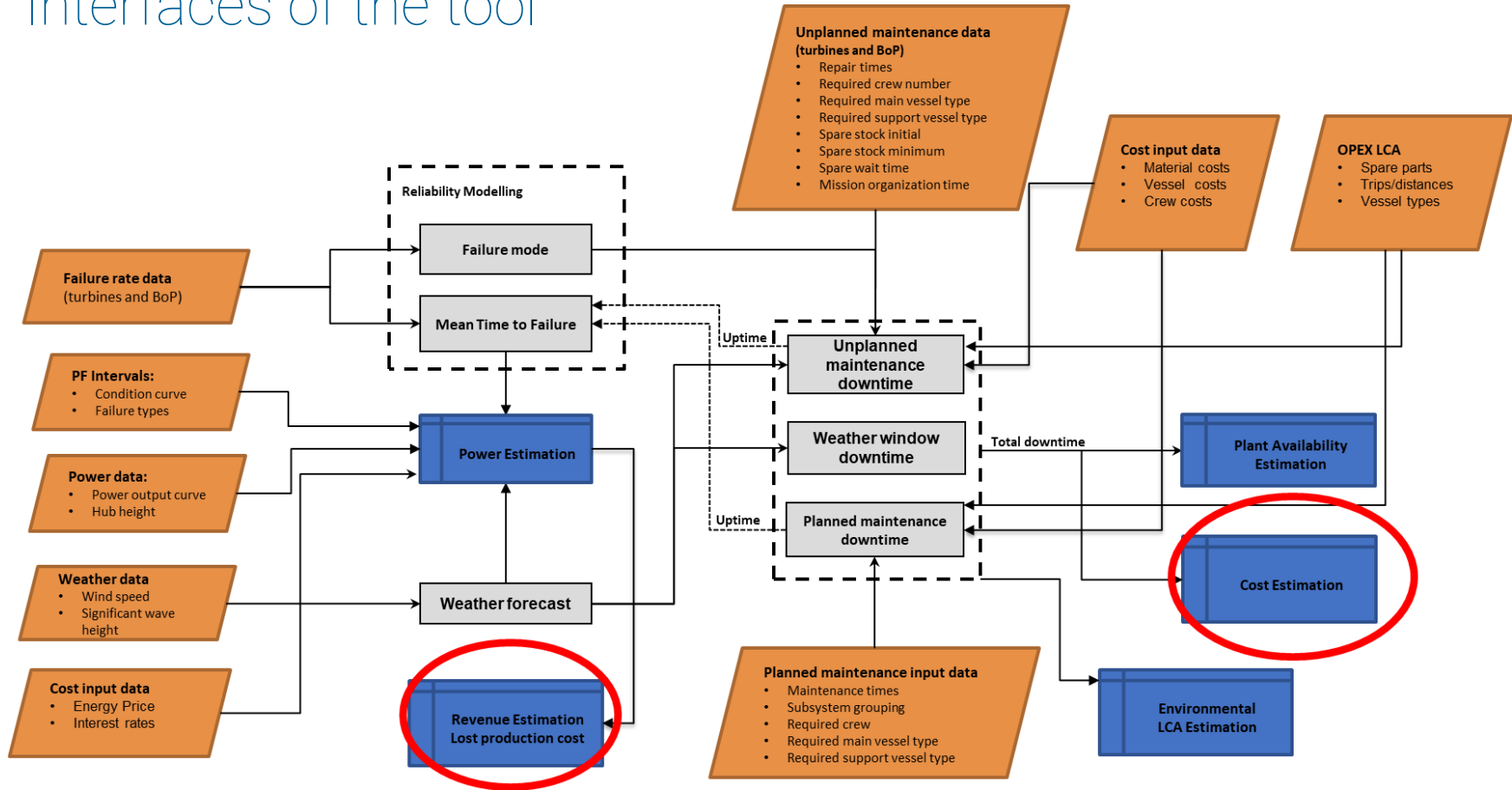
- Major failures were initially assumed to cause immediate downtime to the WT
- Now a gradual drop in performance is taken into account
- This causes an increase in energy production and a decrease in downtime, allowing more realistic simulations
- Linear degradation is assumed, but other models can be simulated

When a damage has been detected and an intervention is required, do you account for expected time to failure (PF intervals) in the planning?

7 responses

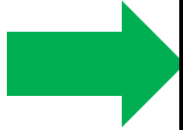


Interfaces of the tool

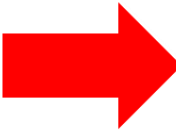


Cost Module

Revenue
from energy
production



Cash Flow



Cost inputs:

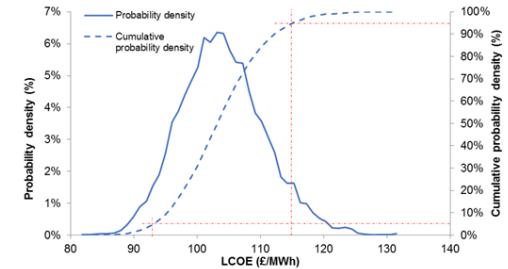
- Material Costs
- Vessel costs
- Crew costs
- Energy Price
- Interest rates

- Maintenance costs
- Lost production costs

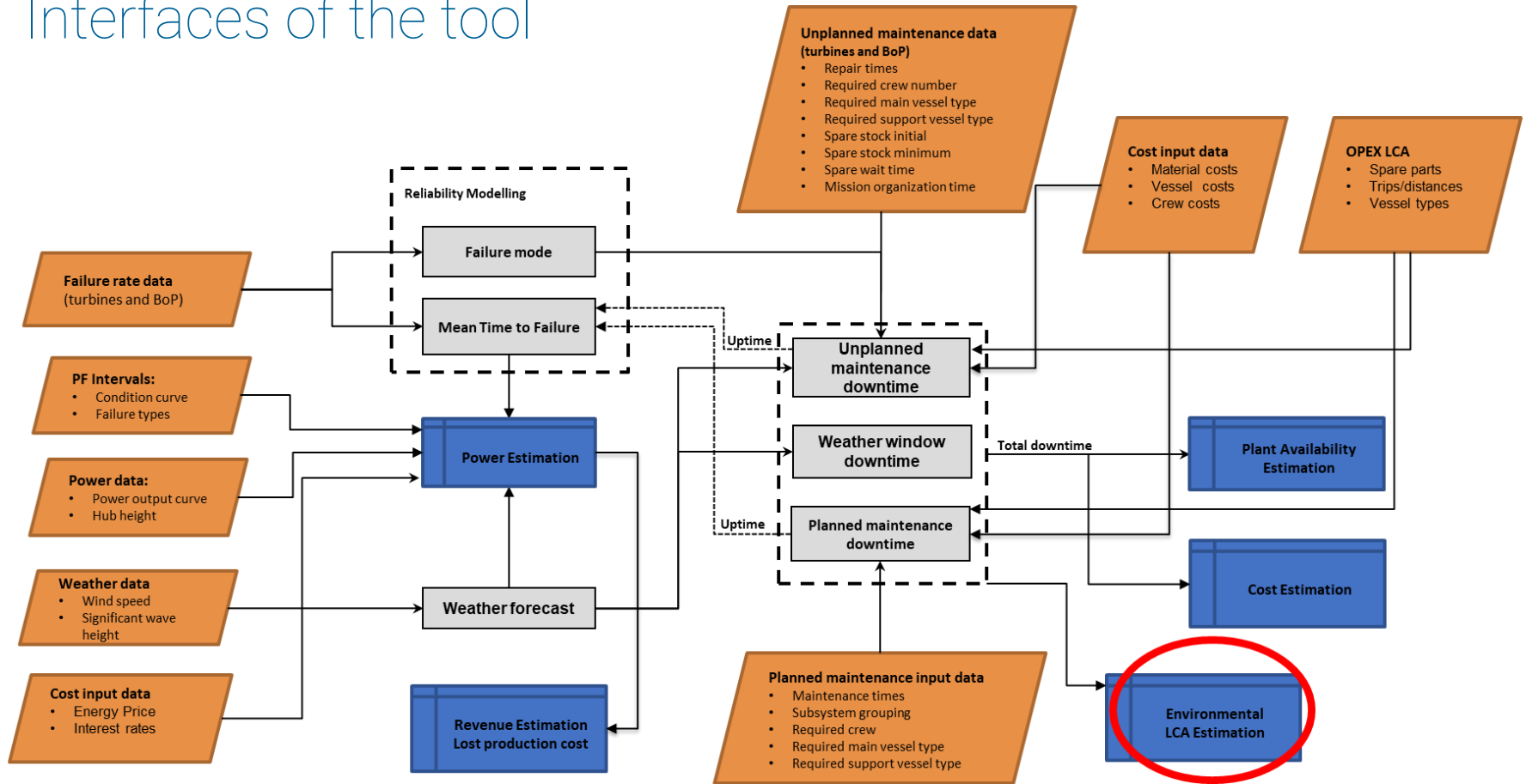


Net Present Value
Formula

$$\text{Net Present Value Formula} = \frac{\text{NPV}_{t=1 \text{ to } T} = \sum X_t}{(1 + R)^t - X_0}$$



Interfaces of the tool

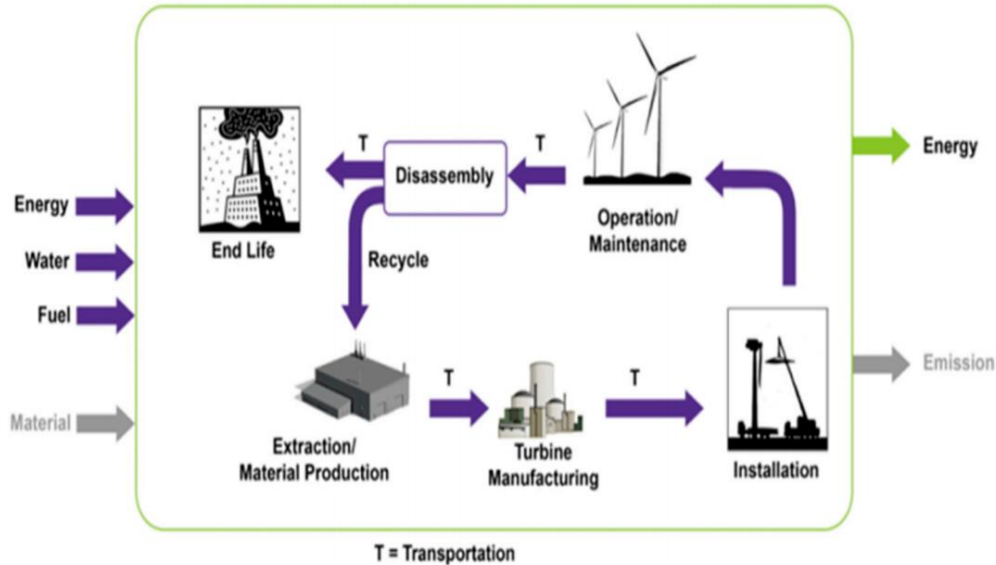


Environmental Lifecycle Assessment Module

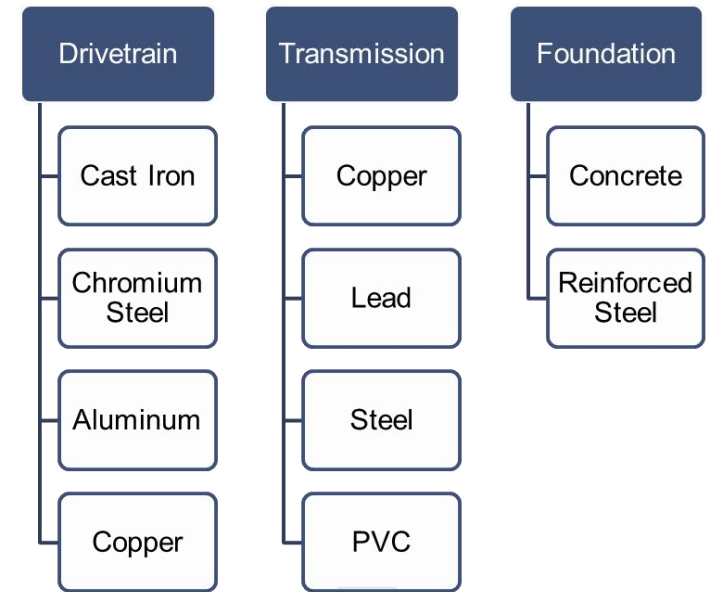
Life Cycle Thinking – ‘from cradle to grave’

production & acquisition (raw materials, energy in manufacturing, transportation) → **installation**
→ **OPEX** (spare parts, trips) → **decommissioning & disposal** (energy for dismantling, materials etc)

LCA databases (e.g. Ecoinvent used). Functional unit is kg-CO₂e/kWh



Source: Chipindula et al 2018

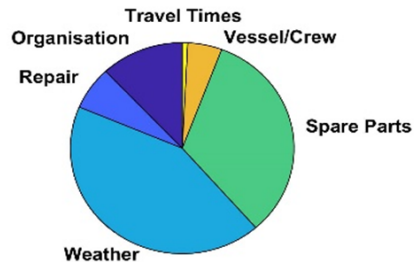


Outputs

What are my KPIs?

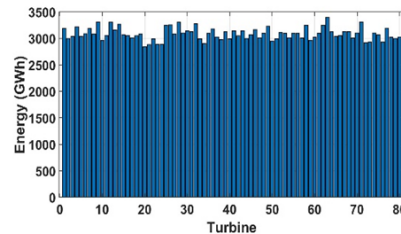
Availability

%



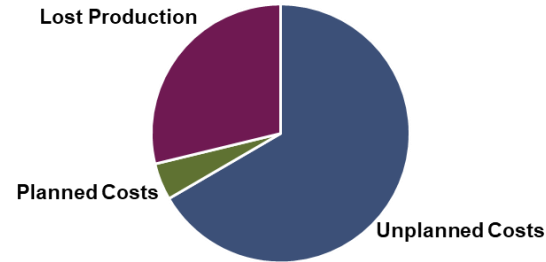
Energy

kWh



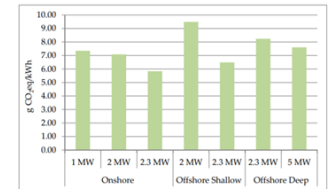
Costs

£/kWh



LCA

kg-CO2e/kWh

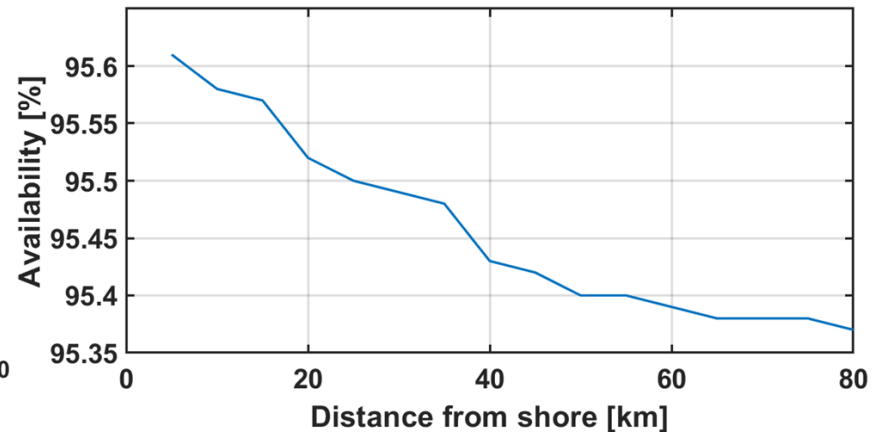
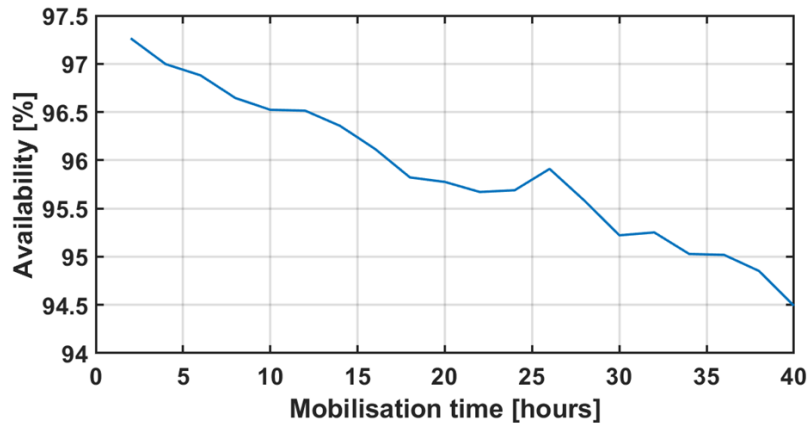


Source: Chipindula et al 2018

Sensitivity Analysis Scenarios

How does the mobilisation time affect my availability?
Does it make sense to have an own JUV?

Which impact has the distance from shore on the
availability of the WF? (distance tends to increase over
years)



Conclusions & Future Work

- A **flexible and modular** O&M evaluation model is incorporated for a fully integrated, robust analysis
- Calculation of various **KPIs**, such as availability is calculated
- **Costs** and the **revenues** throughout the life cycle of the assets are calculated, while the real value of cash-flows is taken into account
- **Stochasticity** of certain inputs are taken into account through Monte-Carlo sampling to assign confidence levels in the assessment

Next Steps:

- Predictive maintenance
- Travel time optimisation
- Release of tool



...Give us your feedback!



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