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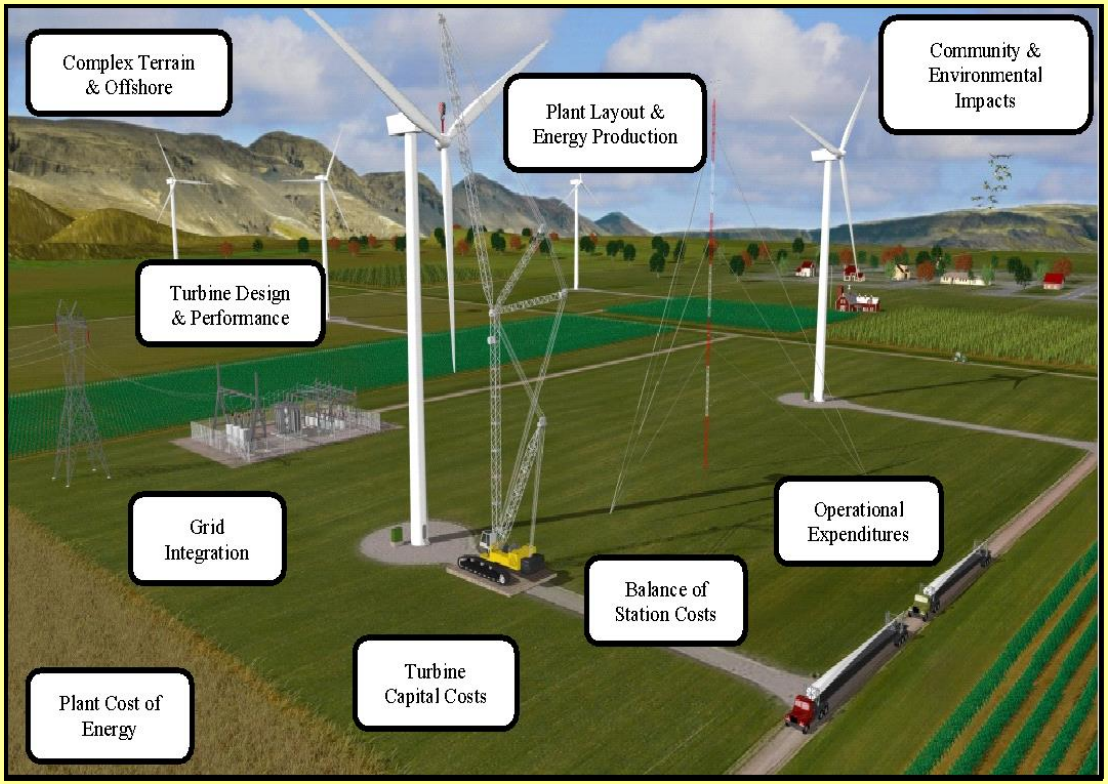
NORCOWE reference wind farm: An international perspective

Angus Graham, Uni Research

Schedule:

1. Background
2. Baseline approach to design of a reference wind turbine: NREL 5MW and DTU 10 MW turbines
3. Baseline approach to design of a reference wind farm: NORCOWE vs NOWITECH farms
4. Conclusions



NORCOWE reference wind farm: An international perspective

1. Background

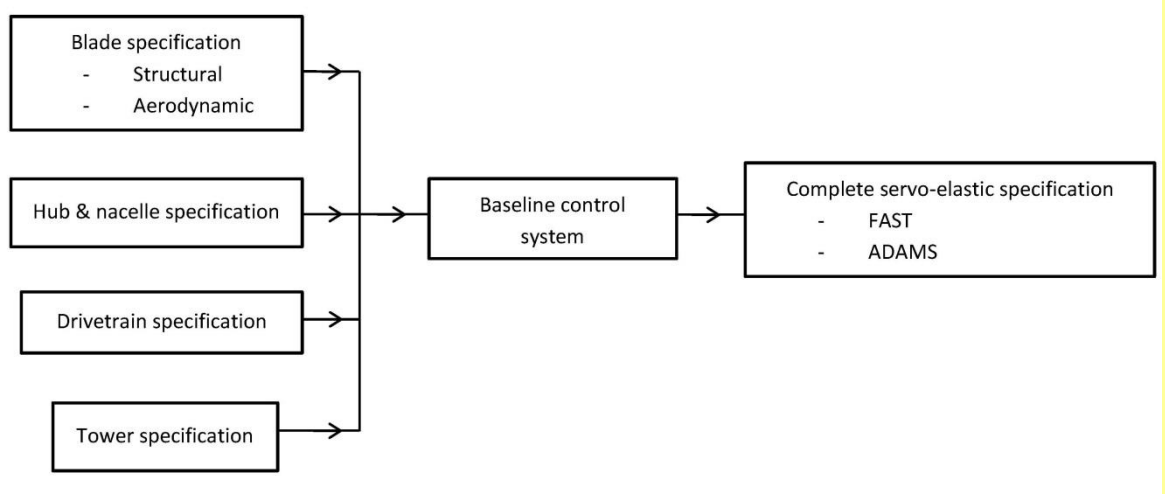
NORCOWE is participating in IEA Task 37 Wind Energy Systems Engineering, which addresses reference wind turbines and farms.

- These reference design systems are specified fully and openly, with current industrial practices and standards in mind.
- An aim is to establish baseline specifications that facilitate and stimulate subsequent optimisation studies.
- Design of reference wind turbines naturally proceeds in liaison with turbine manufacturers and energy utilities: it paves the way for upscaling to the next generation of turbines, and optimisation of turbines either as standalone units or with regard to aerodynamic interactions and requirements placed on the electrical collection system.
- Design of reference wind farms naturally proceeds in liaison with energy utilities and grid planners: it paves the way for upscaling to farms with more turbines of higher rating, farther offshore and in deeper water.

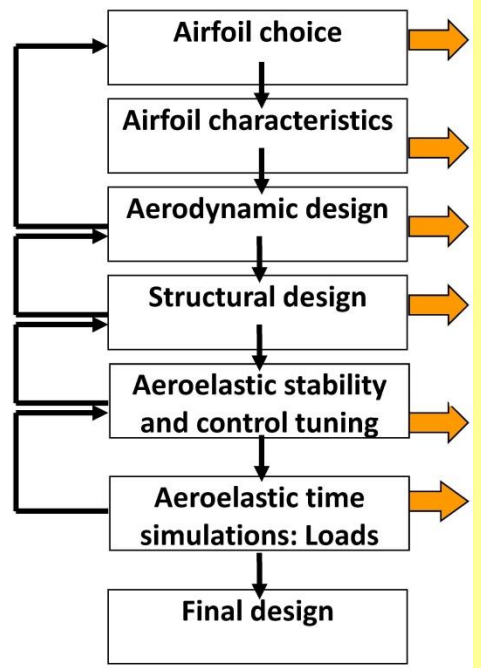
NORCOWE reference wind farm: An international perspective

2. Baseline approaches to design of a RWT: NREL 5 MW and DTU 10 MW turbines

Work flows for the NREL 5MW and DTU 10MW reference wind turbines:



NREL 5 MW



DTU 10 MW

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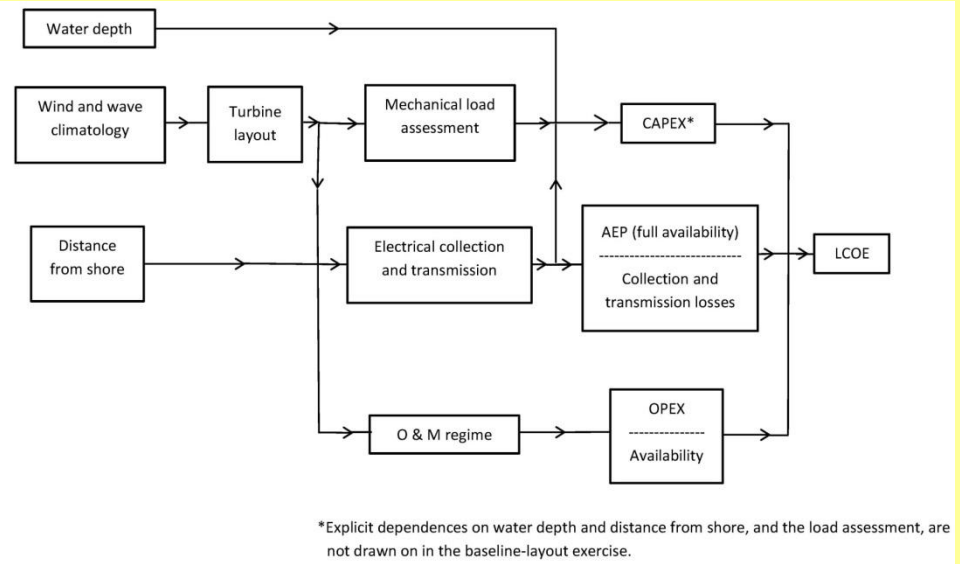
3. Baseline approach to design of a RWF: NORCOWE vs NOWITECH farms

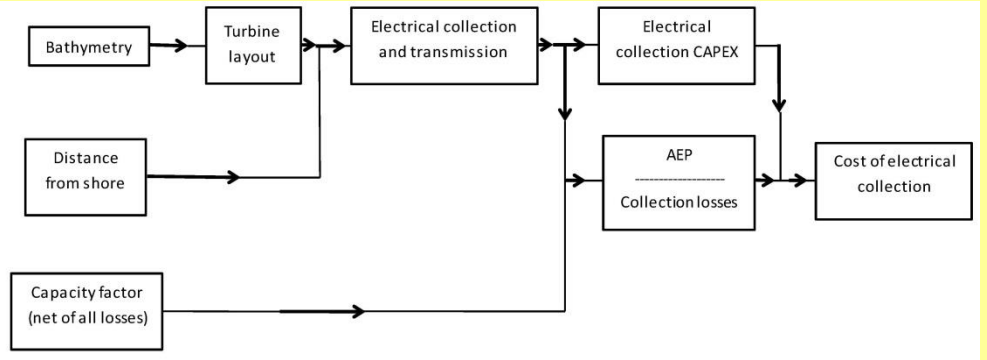
Specifications:

	NORCOWE	NOWITECH
Location of origin of farm reference frame	FINO 3 met mast, North Sea: 55° 11.7' N, 7° 9.5' E	Creyke Bank A, Dogger Bank, North Sea: 54° 50.1' N, 1° 38.0' E
Installed capacity (GW)	0.8	1.2
Number of turbines	80	120
Turbine type	DTU 10 MW reference wind turbine	DTU 10 MW reference wind turbine
Water depth (m)	23	20-35
Foundation	monopile	monopile
Geodesic transmission distance (km)	80	172

Work flows followed:



NORCOWE



NOWITECH

norcowe
Norwegian Centre for Offshore Wind Energy

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3. Baseline approach to design of a RWF: NORCOWE vs NOWITECH farms / ctd

Turbine layout

NORCOWE:

- Variations in water depth and soil substrate over the farm are ignored.
- Turbines are laid out according to the directional distribution of available wind energy, and spacing rules defined with respect to this.
- Two layout variants are defined, occupying the same area of seabed - a perimeter-weighted curvilinear layout and a regular rectilinear one.

NOWITECH:

- Turbines are grouped within three stands in relatively shallow water within the overall zone, to minimise capital expenditure.
- In each stand, turbines are laid out in curvilinear rows, according to an indicative wind-velocity climatology and some spacing rules.

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3. Baseline approach to design of a RWF: NORCOWE vs NOWITECH farms / ctd

Load assessment

NORCOWE:

- An effective turbulence intensity experienced by rotor blades is derived from the directional wind distribution, a Wohler exponent for the blade material and the wake model adopted in IEC 61400-1.

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3. Baseline approach to design of a RWF: NORCOWE vs NOWITECH farms / ctd

Electrical collection and transmission

NORCOWE:

- Collection is at 66 kV via two substations and thence two 220 kV AC transmission lines to a grid substation onshore.
- A method for approximately minimising the total cost of cables in collection is used.

NOWITECH:

- Transmission to shore involves a single line at 420 kV DC.
- Three collection configurations are considered, involving a substation and voltages of 33 kV and 66 kV, the latter with and without the substation (there are transformers on the DC converter platform).

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3. Baseline approach to design of a RWF: NORCOWE vs NOWITECH farms / ctd

Operations and maintenance regime

NORCOWE:

- Vessels are assumed berthed 50 km south of the farm, on permanent hire for crew transport and charter for heavy lifts.

Capital expenditure

NORCOWE:

- For simplicity, a flat-rate cost per turbine is assumed, without explicit consideration of water depth or distance from shore, or possible variation of design load with location in the layout, according to fatigue loads identified in the load assessment.

NOWITECH:

- Calculated on the acquisition and installation of cables, substations and switch gear on turbines and the converter platform.

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3. Baseline approach to design of a RWF: NORCOWE vs NOWITECH farms / ctd

Annual energy production and collection and transmission losses

NORCOWE:

- Calculated at 100% availability using WAsP.

NOWITECH:

- Production is calculated via an assumed overall capacity factor (48%), net of losses through wakes and turbine unavailability.
- Electrical losses in collector cables and at the substation through to the converter platform are calculated.

Operational expenditure

NORCOWE:

- Calculated assuming an annually-scheduled summertime service and responses to exponentially-distributed random failures, without allowing for wake-enhanced fatigue loads.

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3. Baseline approach to design of a RWF: NORCOWE vs NOWITECH farms / ctd

Costs

NORCOWE:

- Levelised cost of energy calculated given capital and operational expenditures, net annual energy production and design lifetime, using different discount rates for the energy production and operational expenditure.

NOWITECH:

- Costs of electrical collection in the three collection scenarios are compared, using a simplified energy-pricing regime to identify costs of collection losses over the design lifetime.

NORCOWE reference wind farm: An international perspective

4. Conclusions

- There is considerable interest in the wind-energy research community in developing families of reference wind turbines and farms, according to site conditions, bathymetry/topography etc.
- To do this, research groups from a wide range of disciplines must commit to work together to the point at which the turbine or farm is well specified.
- Internationally, to date, only the two Norwegian FMEs in offshore wind energy have been involved in developing reference wind farms.
- The NORCOWE RWF:
  - A fairly complete specification is provided, including wind and wave climatologies and the operations and maintenance regime, and worked through up to and including calculation of the levelised cost of energy.
  - There is no methodological provision for a variation in mean water depth or soil type over the farm, or the effect of this on the capital expenditure.
- The NOWITECH RWF:
  - The turbine layout accommodates farm bathymetry.
  - The focus is on the electrical collection system, rather than generation: losses associated with wakes and turbine downtime are dealt with only through a prescribed net capacity factor.