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F&U som støtte for innovation og konkurrencedygtighed

Madsen, Peter Hauge; Buhl, Thomas

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F&U som støtte for innovation og konkurrencedygtighed

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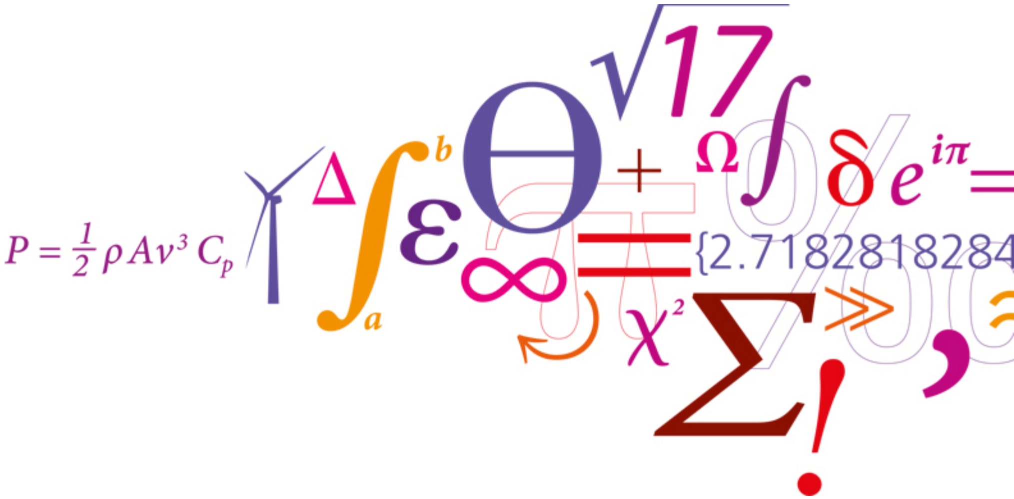
Institut for Vindenergi, DTU

Offshoreenergy.dk's årsmøde
23. og 24. oktober 2014 i Odense



DTU's Mission

DTU skal udvikle og nyttiggøre naturvidenskab og teknisk videnskab til gavn for samfundet.

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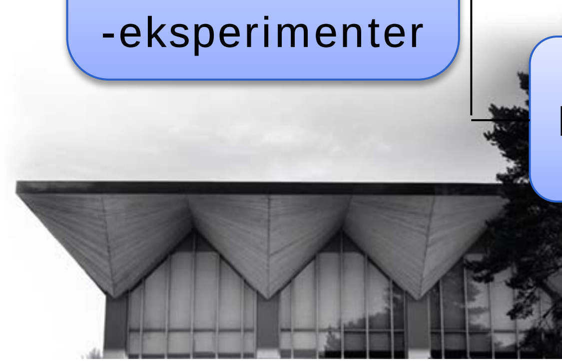


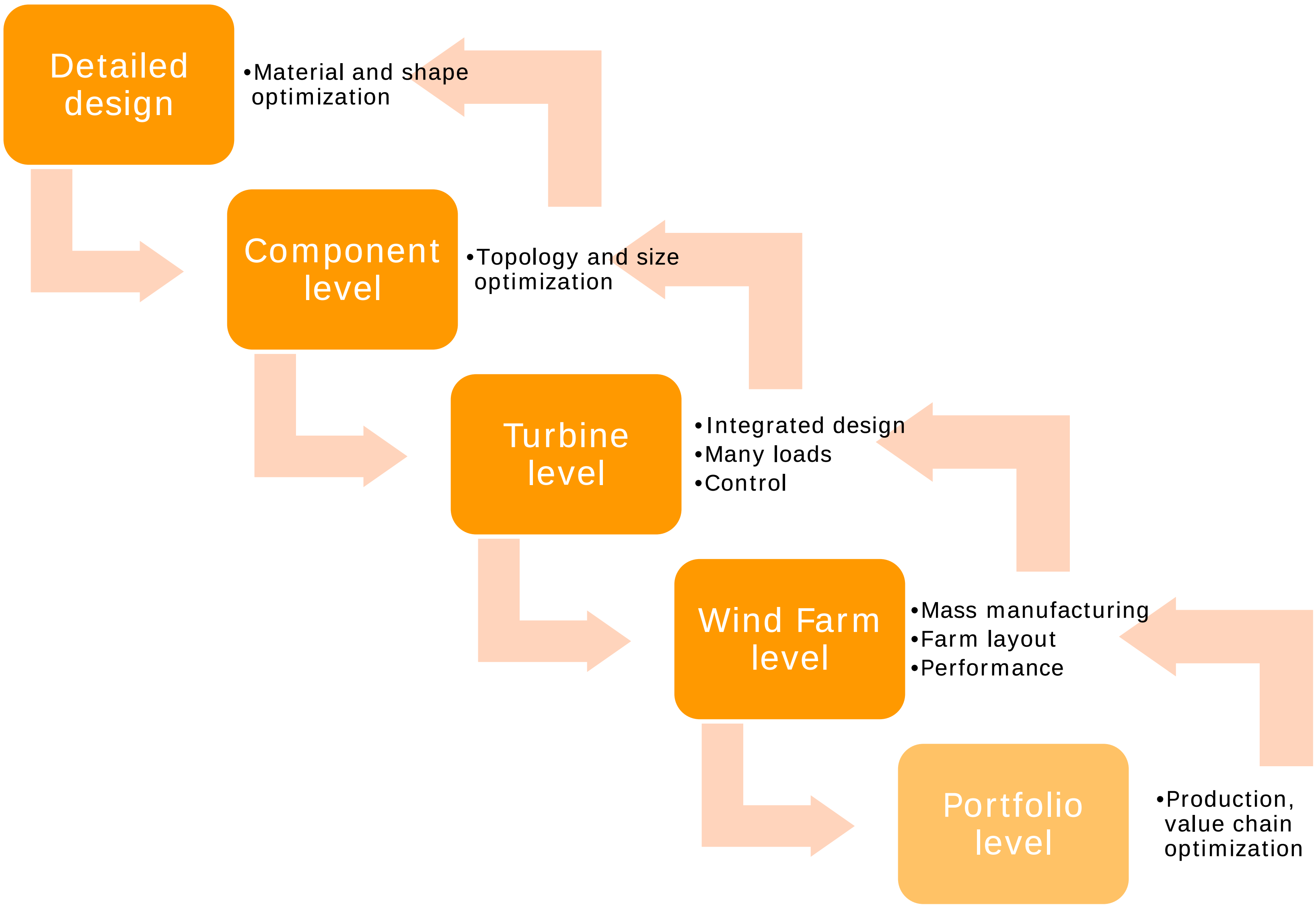
F&U
- -teori
- -eksperimenter

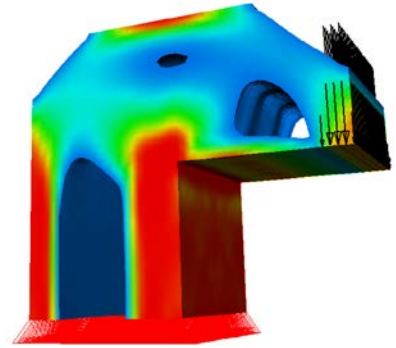
Viden
Forståelse

Modeller

- Uddannelse
- Standarder
- Koncept ideer
- Beregningsværktøjer
- Validering & test
- Rådgivning & analyse

Innovation


Detailed design
•Material and shape optimization
Component level
•Topology and size optimization
Turbine level
•Integrated design
•Many loads
•Control
Wind Farm level
•Mass manufacturing
•Farm layout
•Performance
Portfolio level
•Production, value chain optimization



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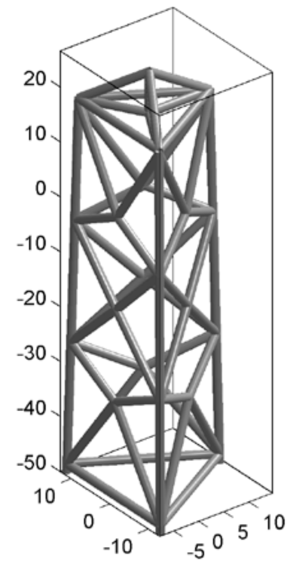

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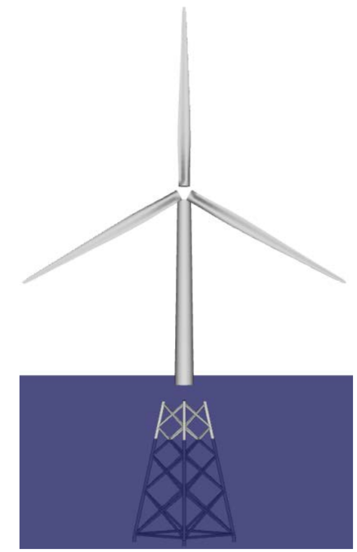

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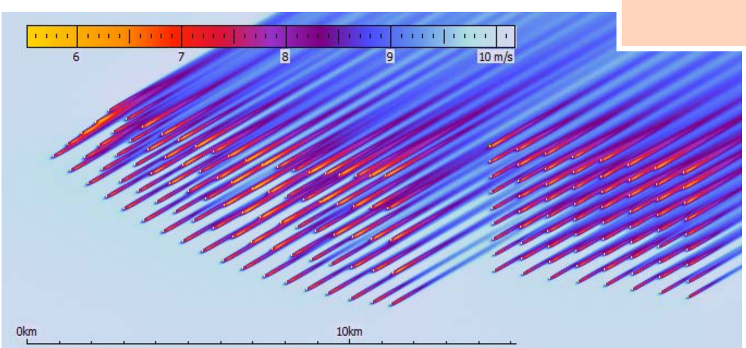

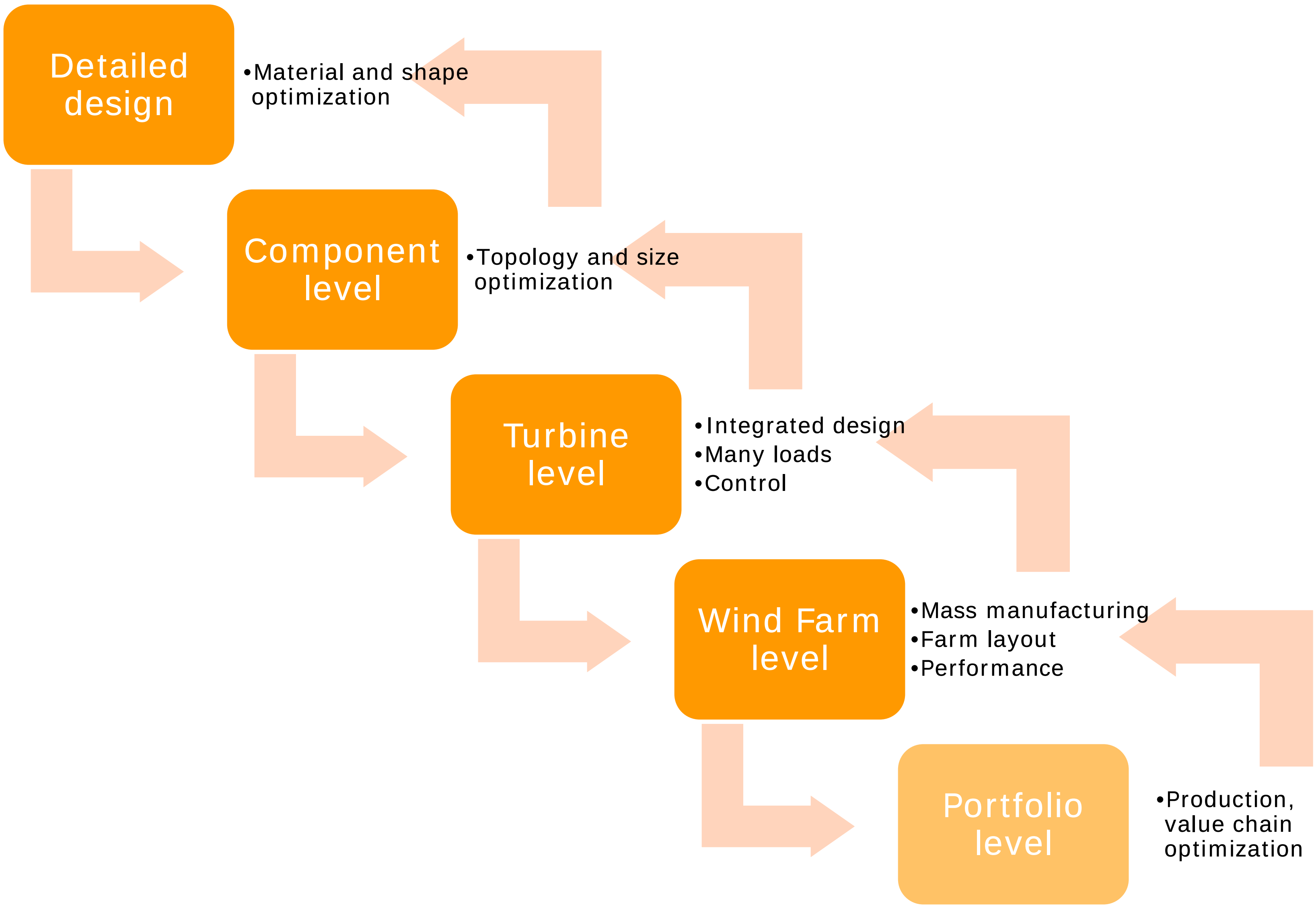
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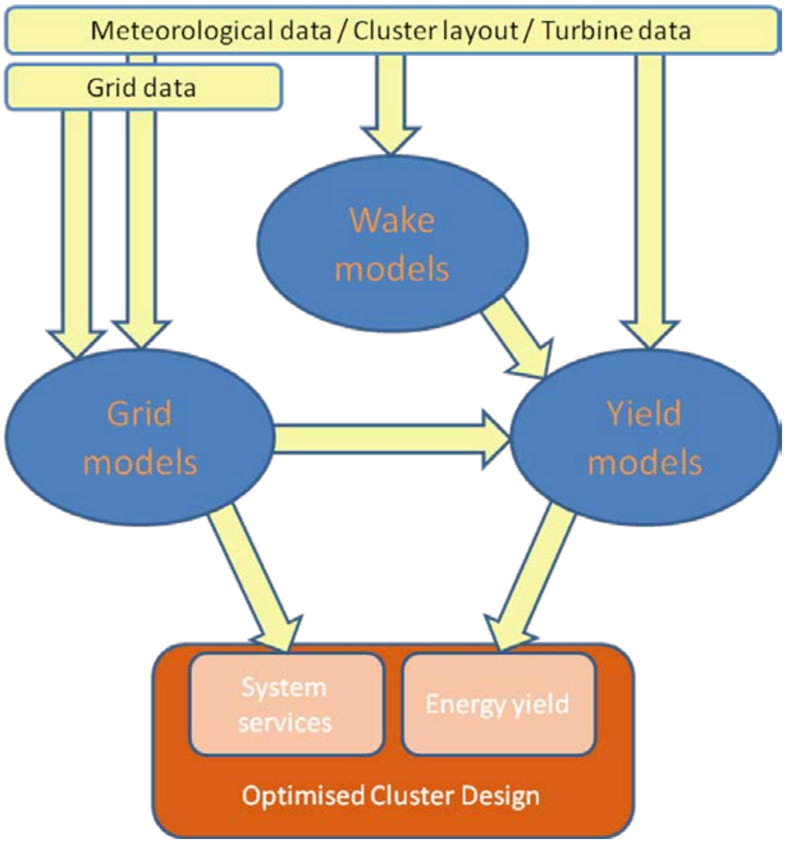
FP7 project – Design Tool for Offshore Wind Farm Clusters

Progress is to achieve a robust design tool for planning of offshore wind farms. The progress include benchmark analysis of several wake models using production data, investigation on some uncertainties on annual energy production and study of inter- and intra-array grid possibilities for the offshore.

EERA DTOC concept

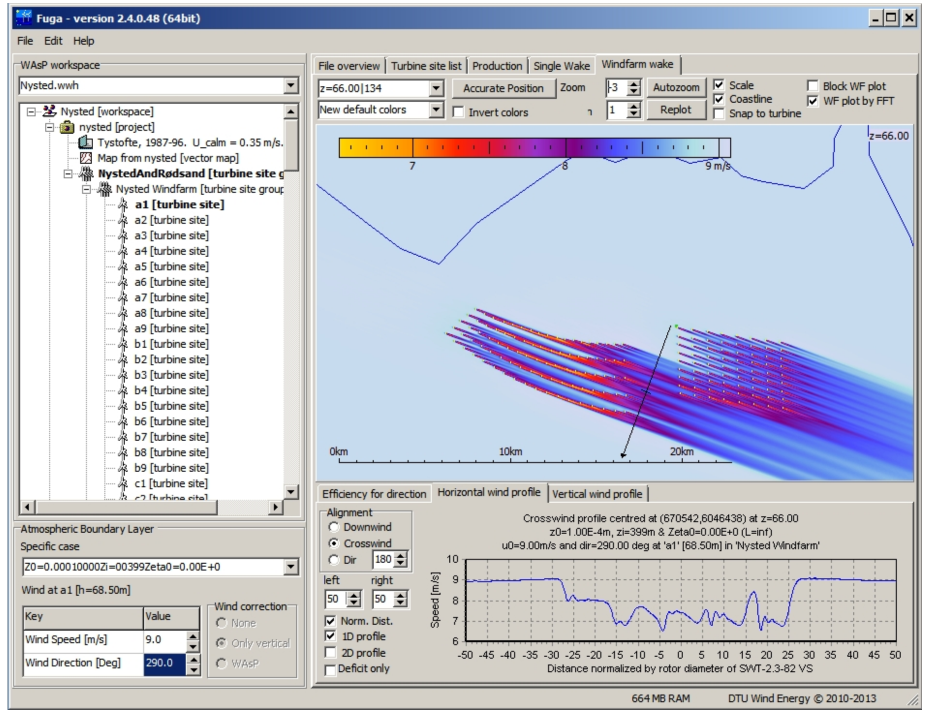


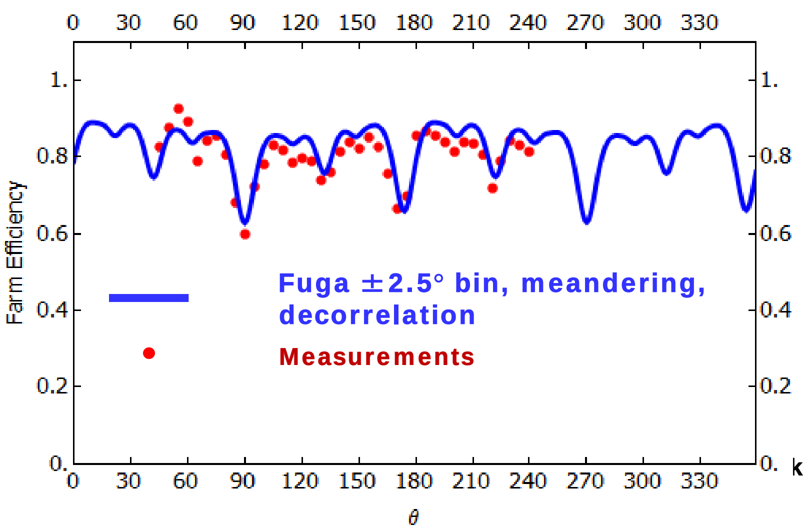
Main Components

- Use and bring together existing models from the partners
- Develop open interfaces between them
- Implement a shell to integrate
- Fine-tune the wake models using dedicated measurements
- Validate final tool

Fuga – wake model for large offshore windfarms

- Solves linearized RANS equations
- Latest version incorporates: atmospheric stability, meandering, effects of non-stationarity and spatial de-correlation of the flow field.
- No computational grid, no numerical diffusion, no spurious pressure gradients
- Integration with WAsP: import of wind climate and turbine data.
- Fast, mixed-spectral solver:
  – 10^6 times faster than conventional RANS!
  – 10^8 to 10^{10} times faster than LES!





Hornsrev validation

* Søren Ott, Jacob Berg and Morten Nielsen: 'Linearised CFD Models for Wakes', Risoe-R-1772(EN), 2011

EERA DTOC portfolio of models

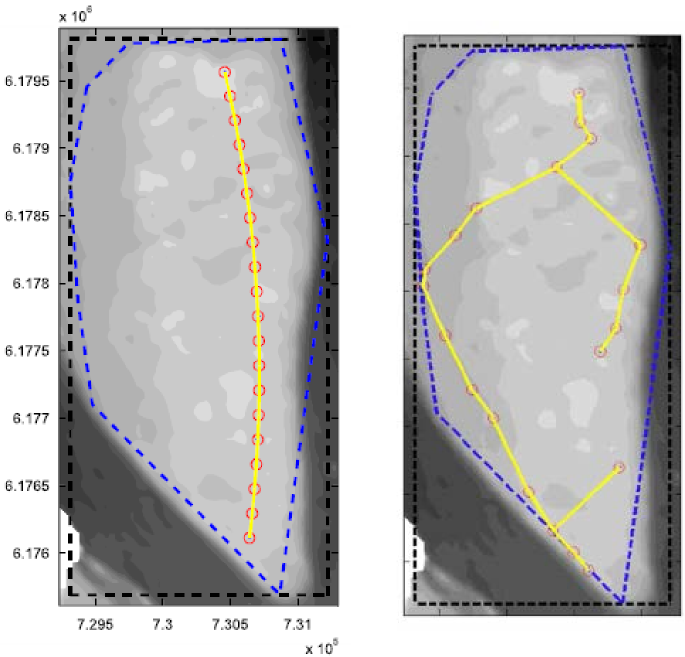
Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER		Fluent, C++, OpenFOAM	ASCII	script	Yes		
CorWind	Risoe DTU	Ope	DOS exe Delphi	CSV files	no	no	+	+
CRES-farm	CRES	Ope	Linux/ Fortran77	ASCII	no	no	+	
CRES--flowNS	CRES	Ope	Linux/ Fortran77	ASCII	no	no		
DWM	Risoe DTU	Ope	Fortran, pc, pc-cluster	ASCII	script		+	
ECNS	ECN	Beta	Linux/ Fortran90	ASCII	No	No	+	
EeFarm	ECN	Alpha	Matlab	Matlab scripts	Script/ GUI	yes	+	+
Farm-farm interaction	ECN	Ope	Fortran	ASCII	No	no	+	
FarmFlow	ECN	Ope	Delphi	ASCII/ binary	GUI	Yes	+	+
FlowARSM	CRES	Alpha	Linux/ Fortran77	ASCII	no	no		
FUGA	Risoe DTU	Ope	Fortran, C, Delphi, pc	ASCII	Script/ GUI	No	+	
NET-OP	SINTEF	Proto type	Matlab	ASCII	script	No	+	
Skiron/WAM	CENER	Ope	Unix/ Fortran	GRIB	script	yes		
TOPFARM	Risoe DTU	Beta	Matlab/C/ Fortran	ASCII	script		+	
UAEP	Risoe DTU		Matlab, pc	ASCII/ binary	no	yes		
VENTOS	UPorto	Beta	Unix/ Fortran	ASCII	no	yes	+	+
WAsP	Risoe DTU	Ope	Windows pc	ASCII	Script/ GUI	No	+	+
WCMS	Fraunhofer	Ope	Matlab/JAVA	OracleDB		yes	+	
WRF	Risoe DTU	Ope	Unix, Linux, Fortran90	netCDF	Shell script	yes		
WRF/ROMS	CIEMAT	Ope	Linux/ Fortran	netCDF	script	yes	+	

TOPFARM

TOPFARM is a fundamentally new approach to layout optimization of wind farms. From the investor's perspective the TOPFARM platform answers the fundamental question:

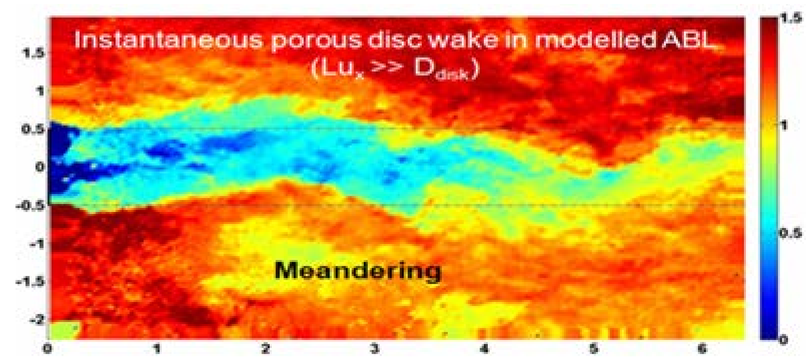
"What kind of layout results in the optimal economical performance of the wind farm throughout its lifetime".

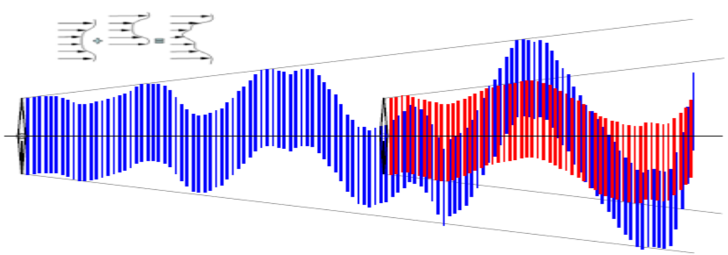
The balance between power, loads and costs



Middelgrunden layout as of now and as results of the TOPFARM optimization.

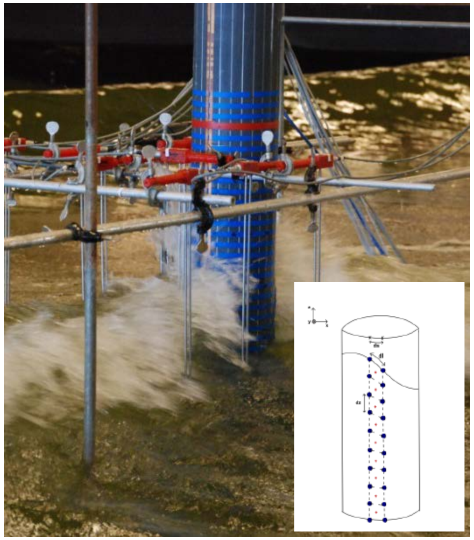
Measurement of deficit in atm. boundary layer wind tunnel



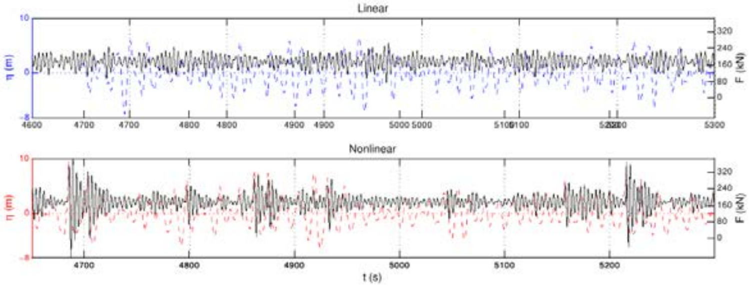


Wake meandering assumption in DWM

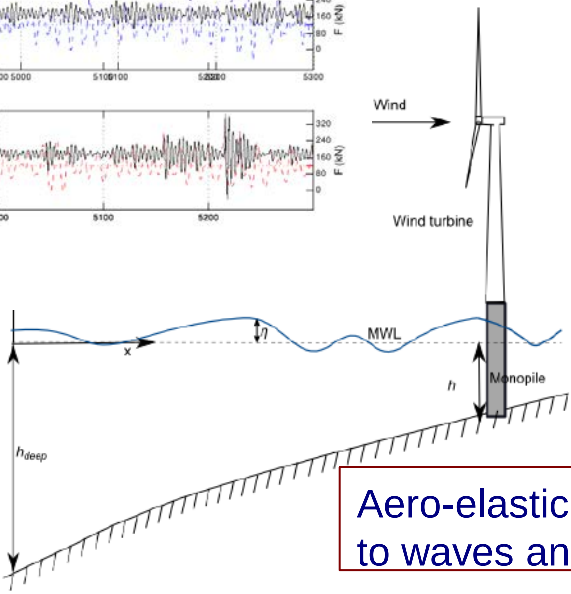
Wind-wave loads and response for offshore wind turbines



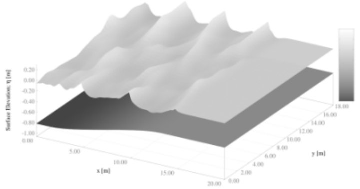
Load models for highly nonlinear waves

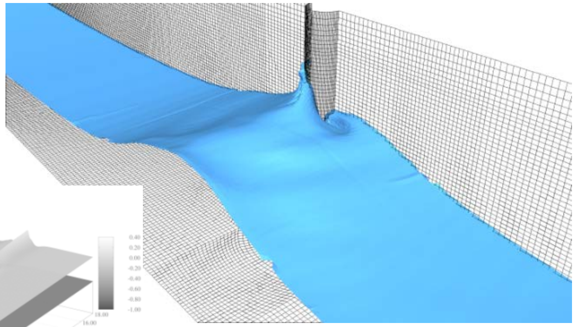


Dynamics of floating wind turbines



Aero-elastic response to waves and wind

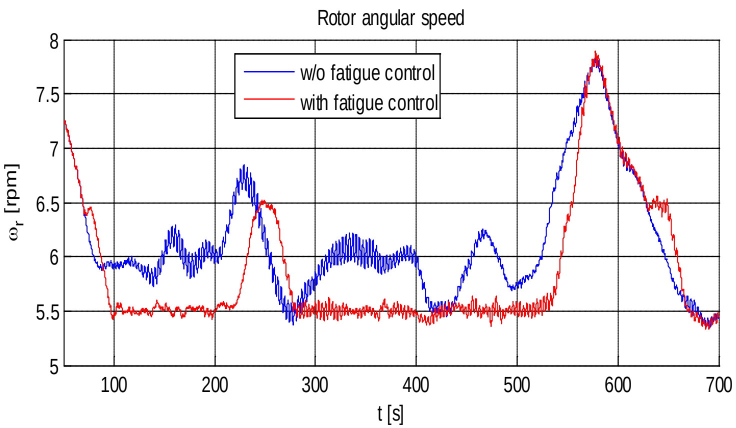


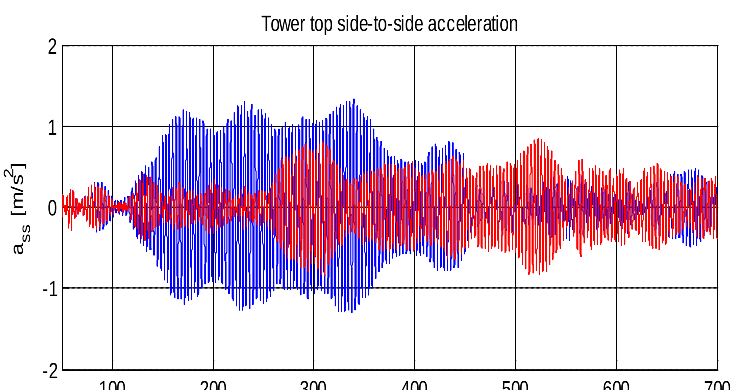


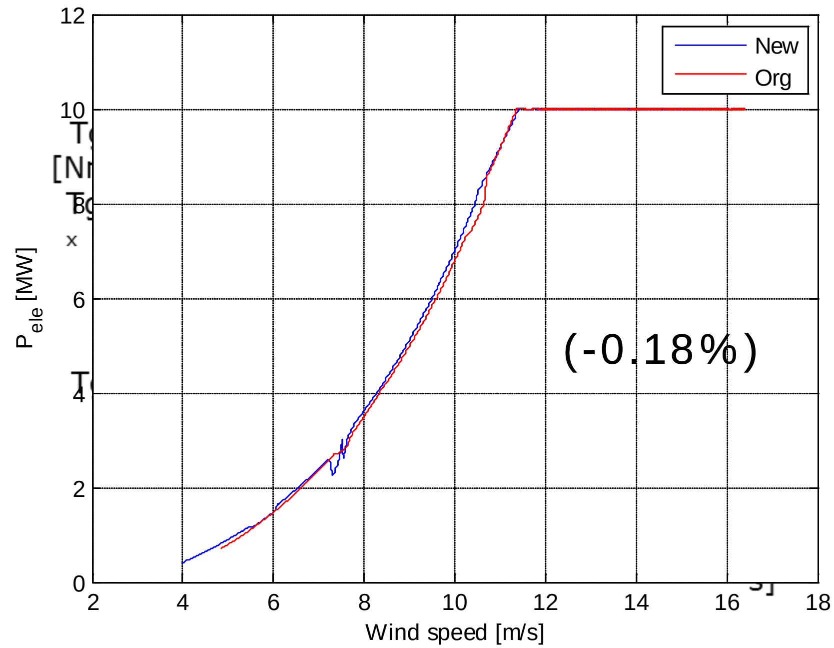
CFD for detailed loads

Offshore wind turbine control system

- **Power production**
  - o Generator torque control
  - o Collective pitch control



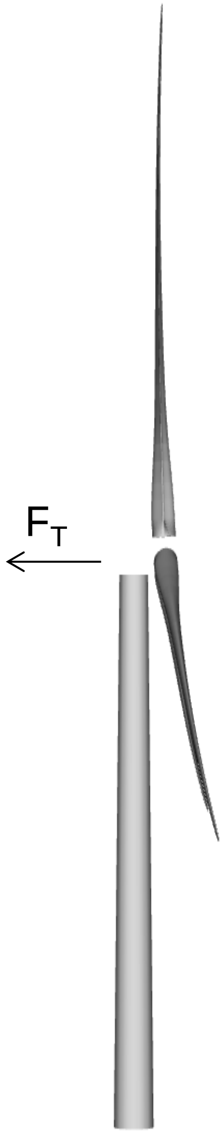


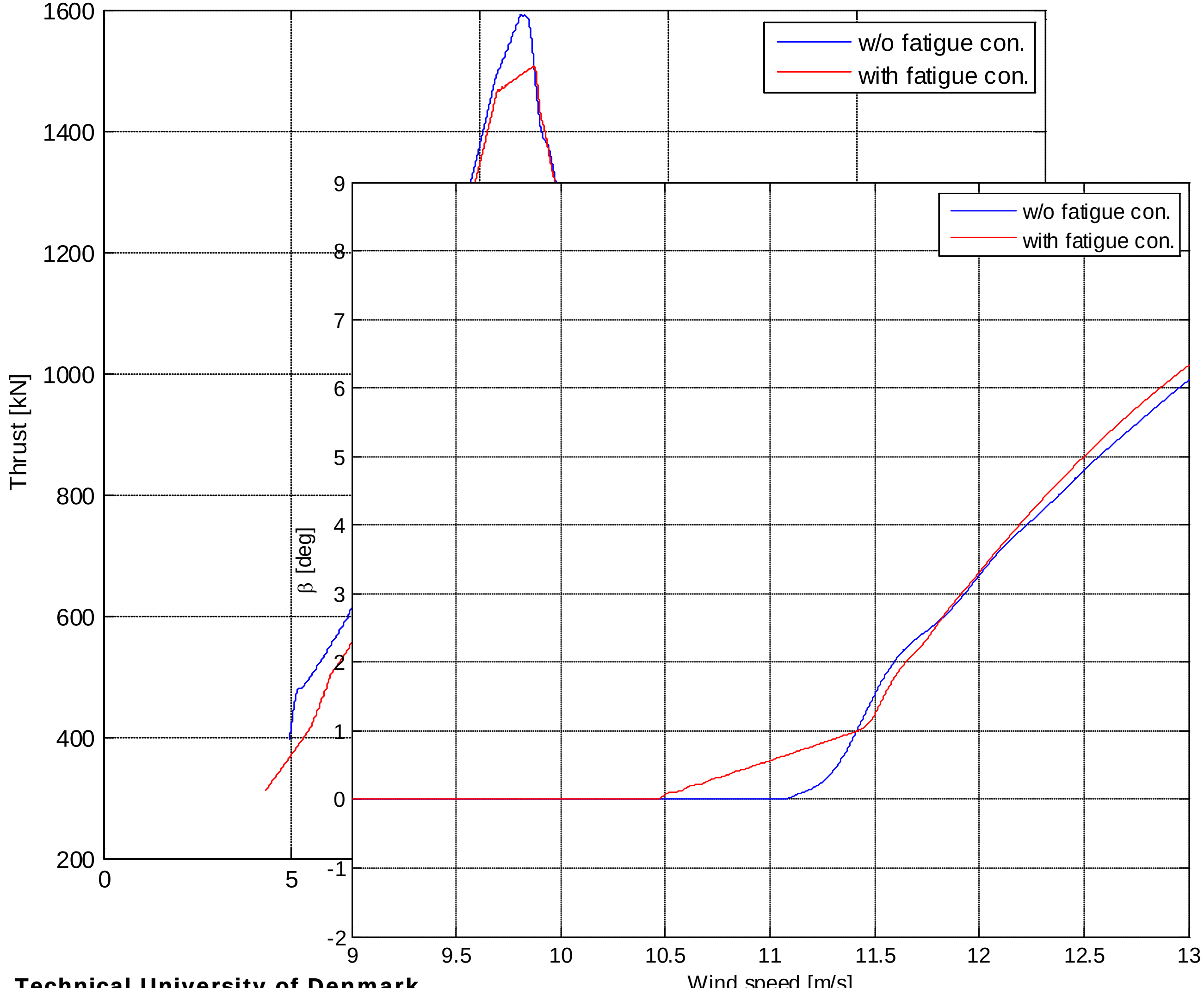


- **Extreme and fatigue load reduction**
  - o Drive train damper (T_G)
  - o Exclusion zone (T_G)
  - o Tower for-aft mode damper (CPC)
  - o Thrust peak shaver (CPC)

Collective pitch control

- Thrust peak shaving

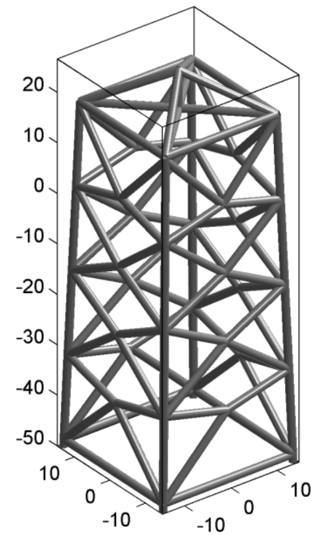


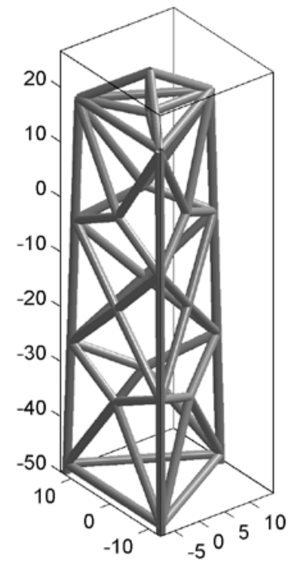


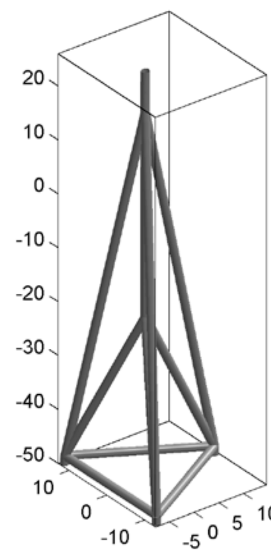
JacketOpt

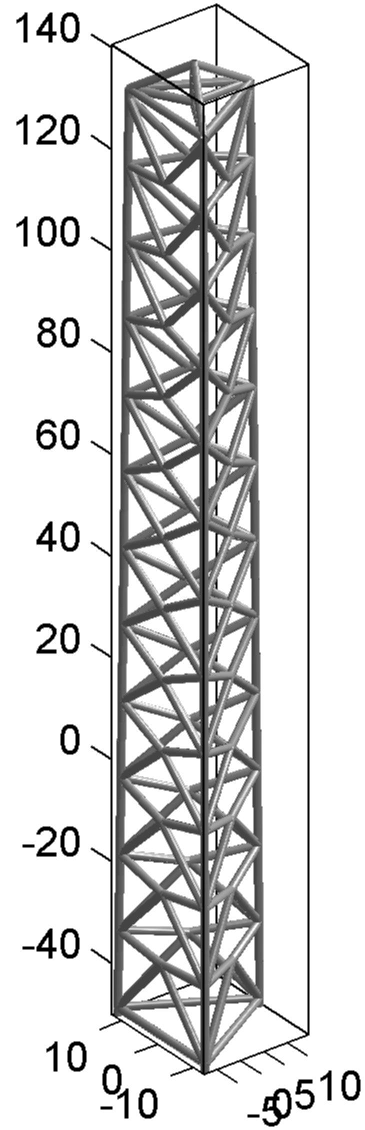
Topologies

- Classical four legged jackets
- Classical three legged jackets
- Pod-like structures (three or four legs)
- Full-lattice towers (three or four legs)
- Monopiles
- User defined structures









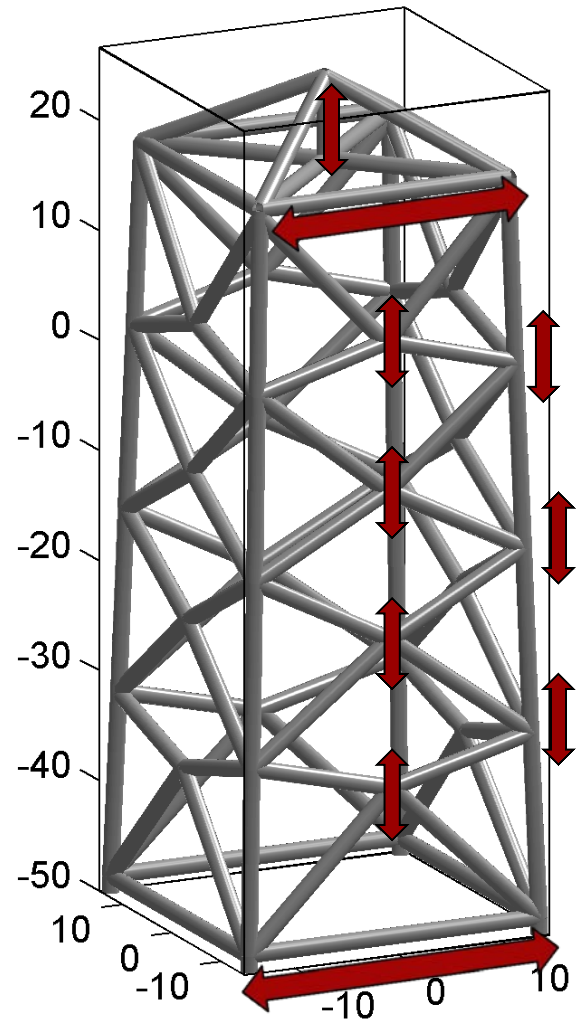
JacketOpt

Design variables (outer)

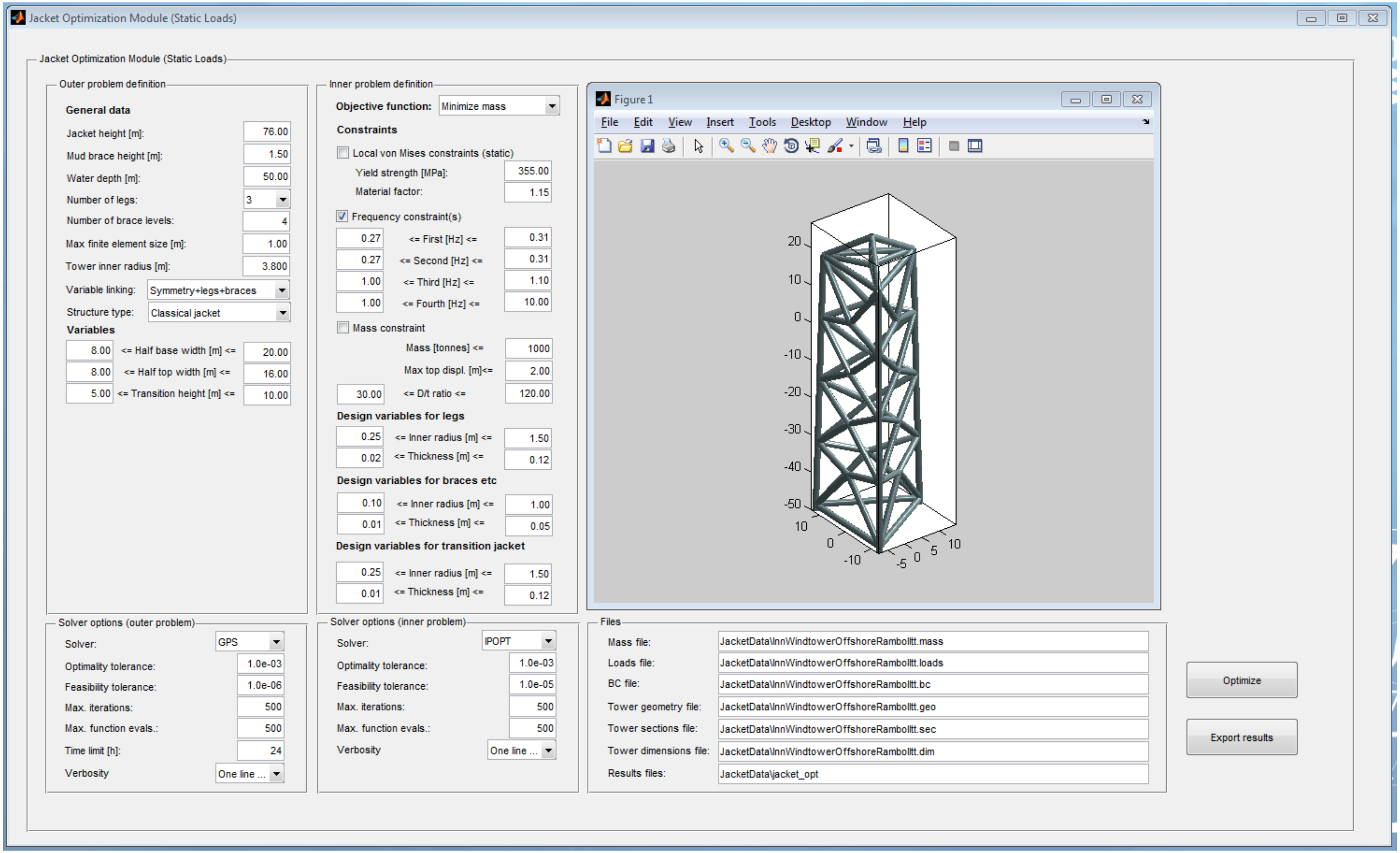
- Overall dimensions within bounds
- Placement of X-braces within bounds

Design variables (inner)

- Member diameters within bounds
- Member thickness within bounds



JacketOpt GUI



A preliminary example for INNWIND.EU

DTU 10 MW reference turbine

- Hub height 119 m
- Rotor mass 229 tons
- Nacelle mass 446 tons
- Tower mass 505 tons

Four legs and four levels of X-braces

Minimum mass design

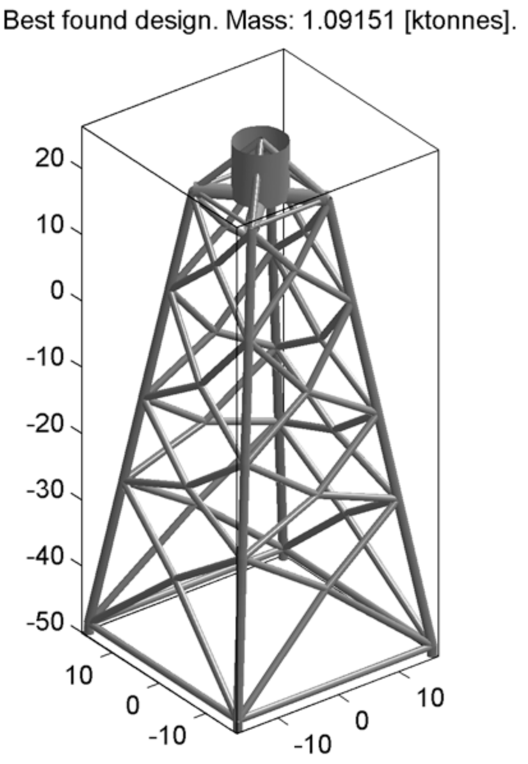
Max tower top displacement 2.25 m

First and second frequency between 1P and 3P

Third and fourth frequency above 6P

Static loads only!

No fatigue constraints!



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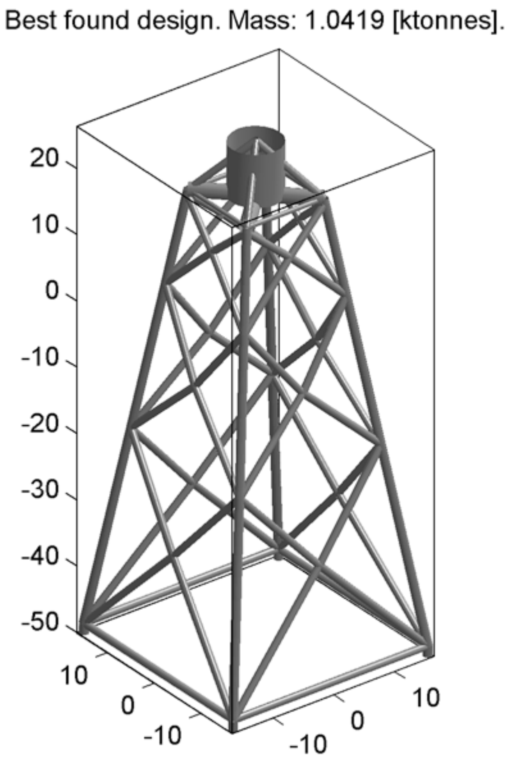
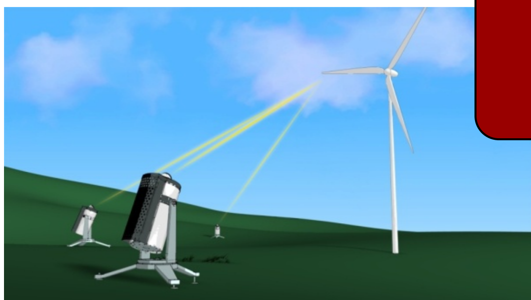
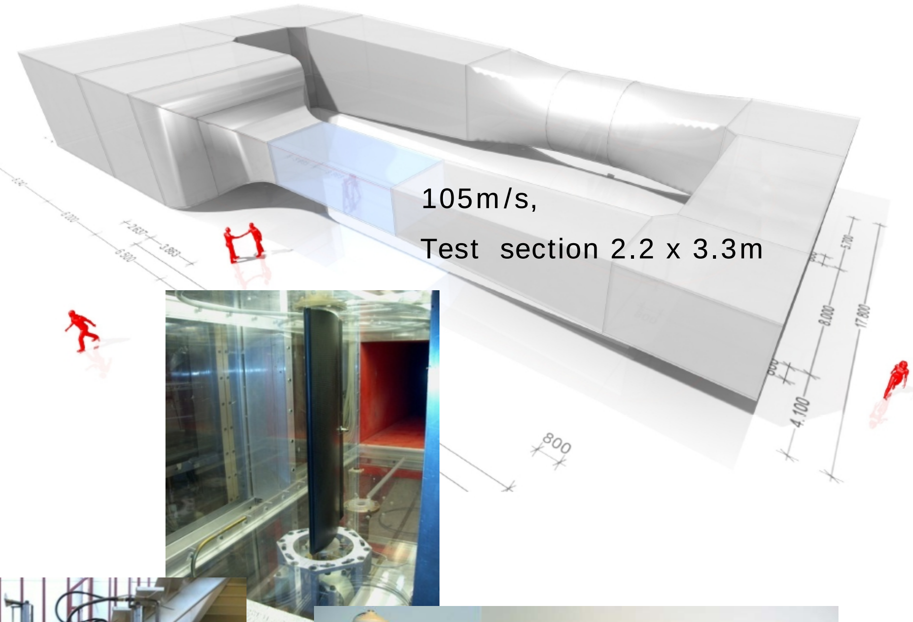


Validering og Test

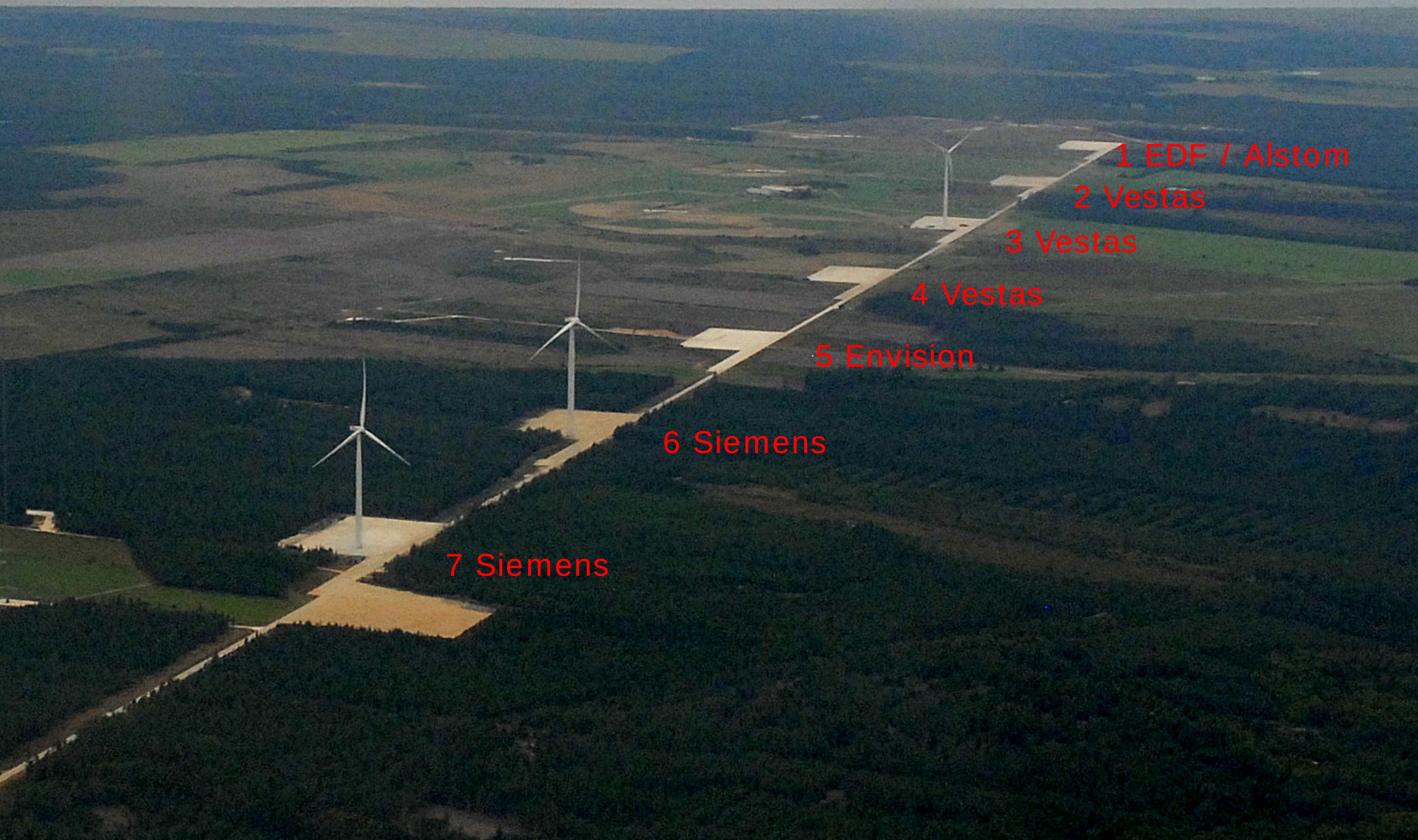
F&U og test faciliteter



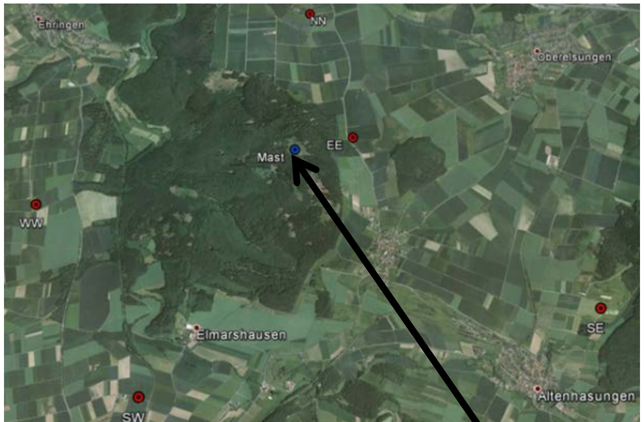


Østerild Test Centre – Prototype Wind Turbines

7 Wind Turbines – Max. 16 MW each – Max. height 250 m

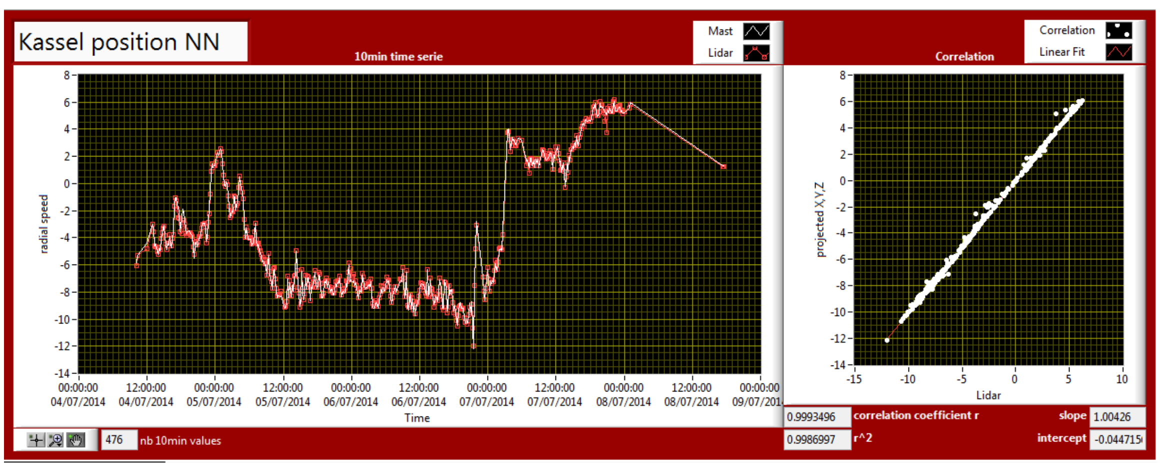


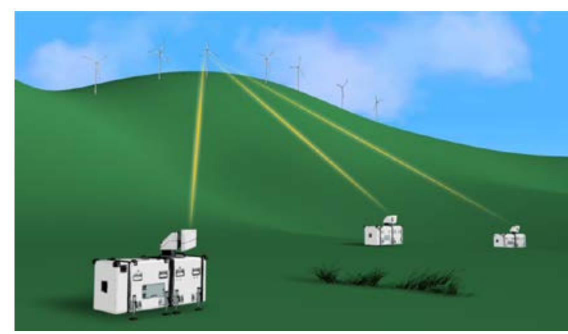
Long range windscanner – Kassel campaign



Metmast

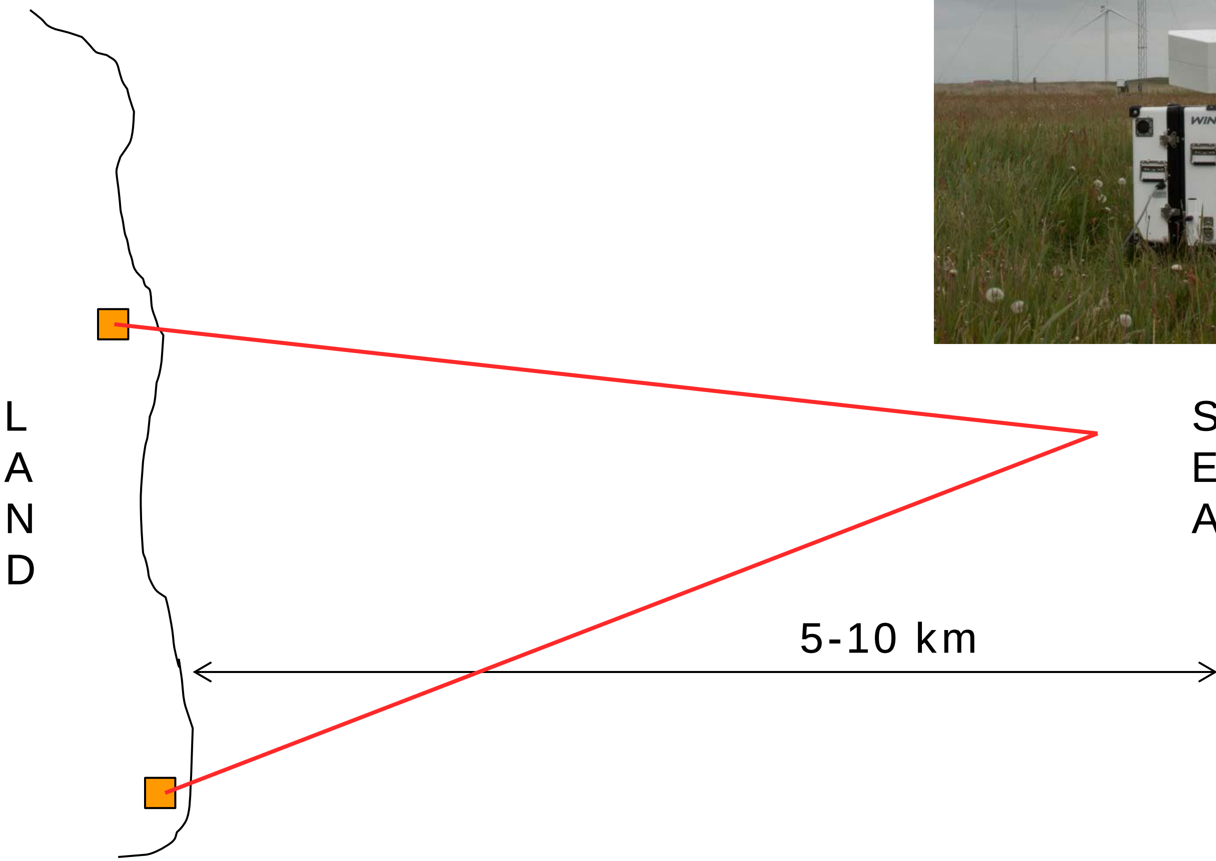
- Measured for 6 weeks with 6 windscanners, full synchronisation over a 3G network
- Alignment accuracy of about 0.05° (1m over 1km)
- Excellent measurement results in scanning mode – within 1% accuracy at > 3km





Lidar ways of measuring the offshore resource

2. Windscanner(s) on the coast



Colourbox