



THE FUTURE of wind farm design

DATE
18th of November 2015

TIME
10.30 – 13.00

LOCATION
EWEA 2015, Paris, France

An open session organised by
European Energy Research Alliance
Joint Programme Wind

EERA –DTOC cost optimized farm design

Charlotte Bay Hasager, Peter Hauge Madsen, Gregor Giebel

DTU Wind Energy



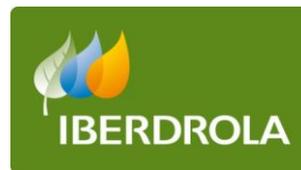
Support by



Project partners



INDIANA UNIVERSITY



EERA DTOC project vision



*A robust, efficient, easy to use and flexible tool
created to facilitate the optimised design of
individual and clusters of offshore wind farms*

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Streamlining project planning of offshore wind farms

Even though offshore wind farms are incredibly expensive—and a great deal of time is devoted to planning them—communication between project developers leaves a lot to be desired. Simply put: one expert often has little idea what another is doing, and this costs a lot of time and money. However, this situation may soon be history thanks to a new tool developed by DTU Wind Energy in Roskilde.



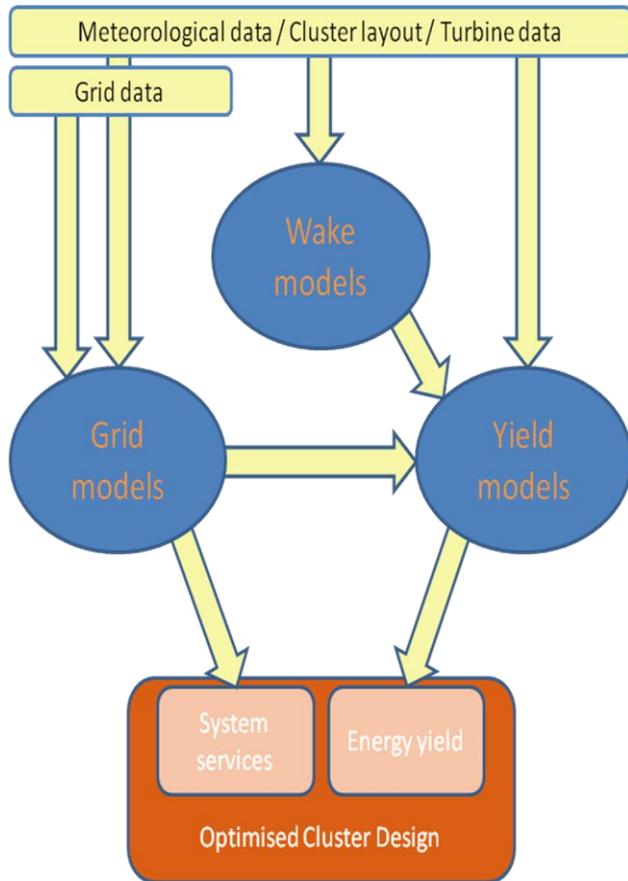
<http://www.dtu.dk/english/News/2015/04/Offshore-wind-farms-to-be-developed-with-a-single-model?id=c3435bfd-ef12-42cf-8f39-fd5fa8e948c8>

EERA DTOC main components

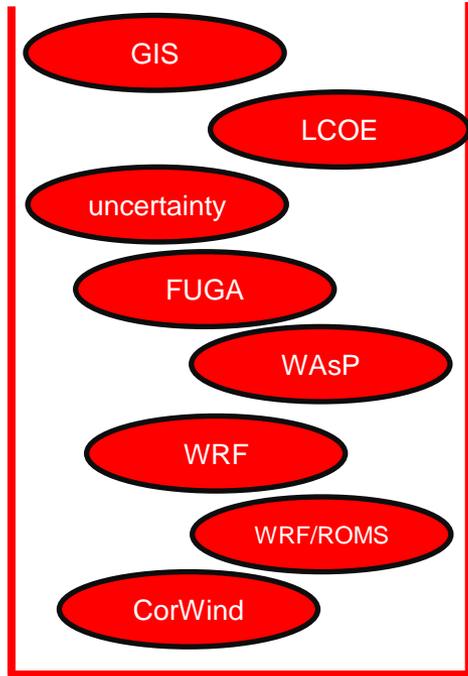


- Use and bring together existing models from the partners
- Develop open interfaces between them
- Implement a shell to integrate
- Fine-tune the wake models using dedicated measurements
- Validate final tool

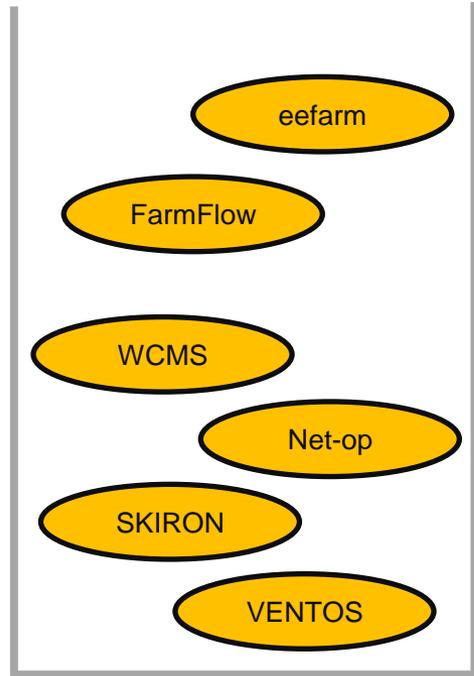
Concept and implementation



DTOC Tool



DTOC Services



Validation of wake models



SCADA data at Horns Rev 1, Lillgrund and Rødsand 2 offshore wind farms have been compared to more than 10 wake models

SCADA data and lidar data at Alpha ventus have been compared to three wake models

Satellite data have been compared to four wake models

Main conclusion

The benchmark concludes that several models were able to handle the clustering of wind farms

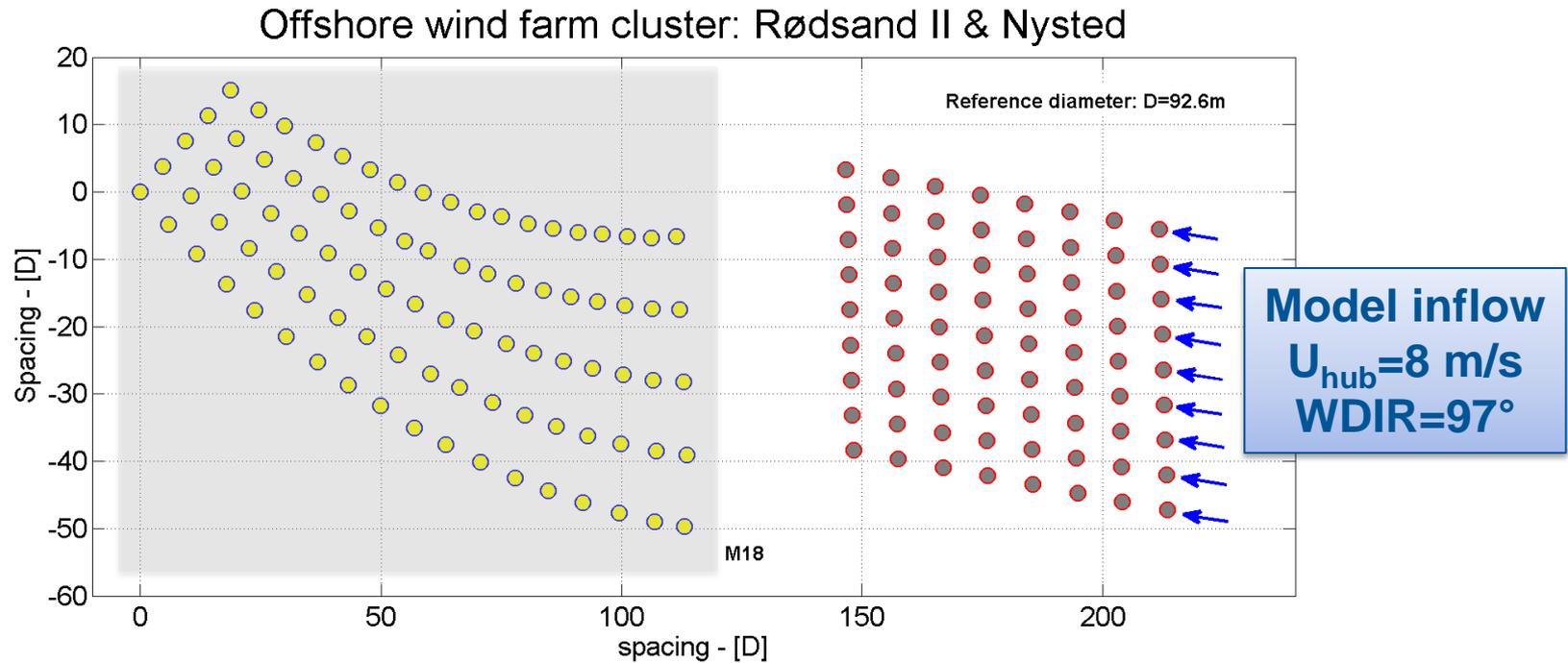
Participants and park models



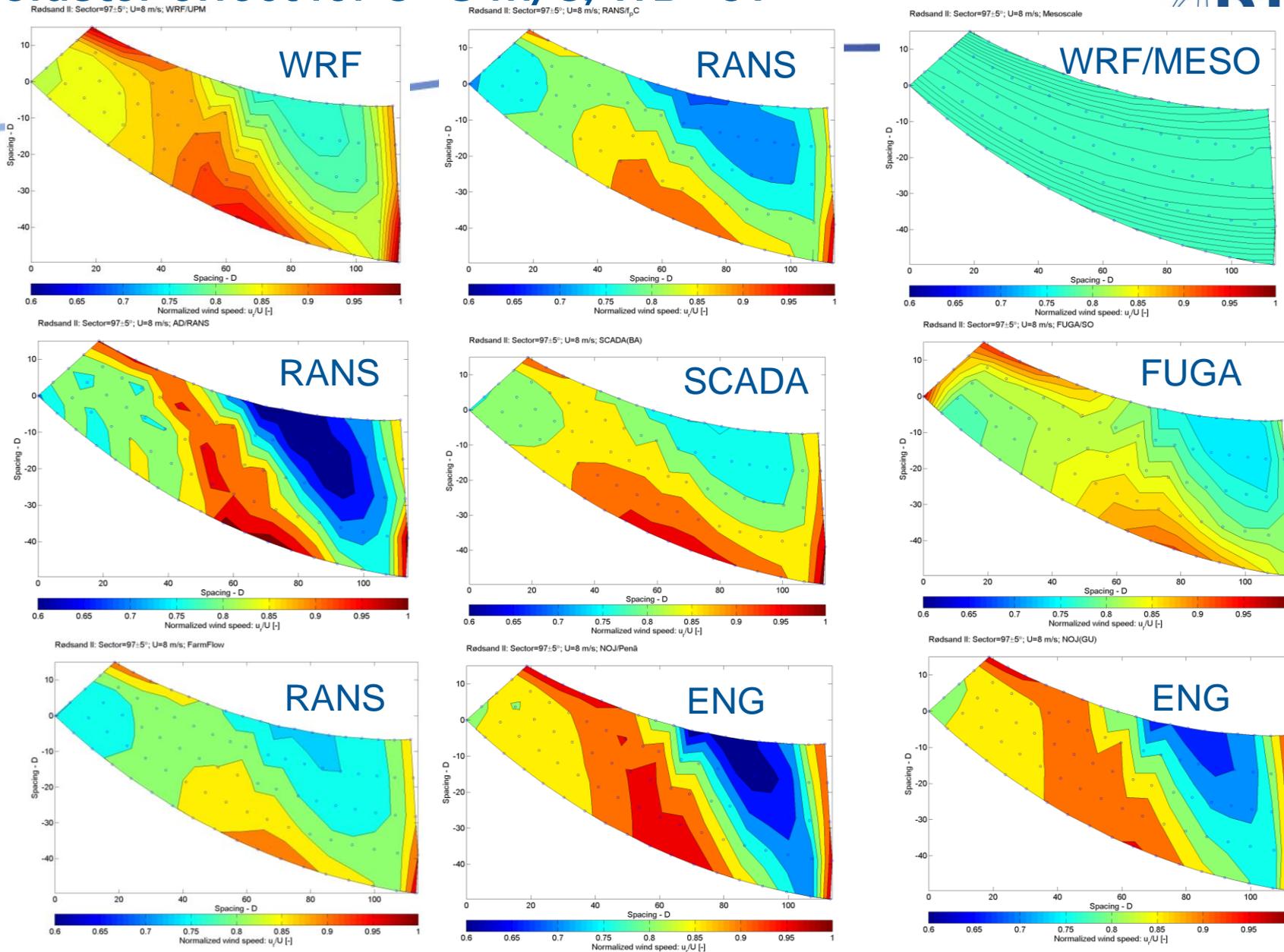
Mo	Affiliation	Horns Rev WF	Lillgrund WF	Rødsand II WF	Rødsand II/Nysted WF
SCAD/RAVE <small>RESEARCH AT ALPHA VENTUS</small>	Wind Energy/K.S.Hansen	x	x	x	(x)
NOJ/BA	DTU Wind Energy/misc		x		
NOJ/GU	DTU Wind Energy/misc		x	x	
NOJ/BA	DTU Wind Energy/A. Pena	x	x	x	
WASP/NOJ	Indiana Uni/RB	x			
GCL/BA	DTU Wind Energy/misc		x		
GCL/GU	DTU Wind Energy/misc	x	x		
GCL(GU)	CENER/JS.Rodrigo	x	x		
FUGA/SO	DTU Wind Energy/S. Ott	x	x	x	
DMW	DTU Wind Energy/TJ.Larsen	x			
AD/RANS	UPORTO/J.L. Palma	x		x	x
CRESflowNS	CRES/ J. Prospathopoulos	x	x	x	
FarmFlow	ECN Wind Energy/J.G Scheepers	x	x	x	x
CFDWake	CENER/B.G. Hevia	x		x	
RANS/f _p C	DTU Wind Energy/P.vd Laan			x	x
Ainslie	RES-LTD/T.Young	x	x		
WRF/UPM	Ciemat/A.Palomares			x	
Mesoscale	DTU Wind Energy/P.Volker			x	

BA=Bin Averaged & GU=Gaussian Uncertainty

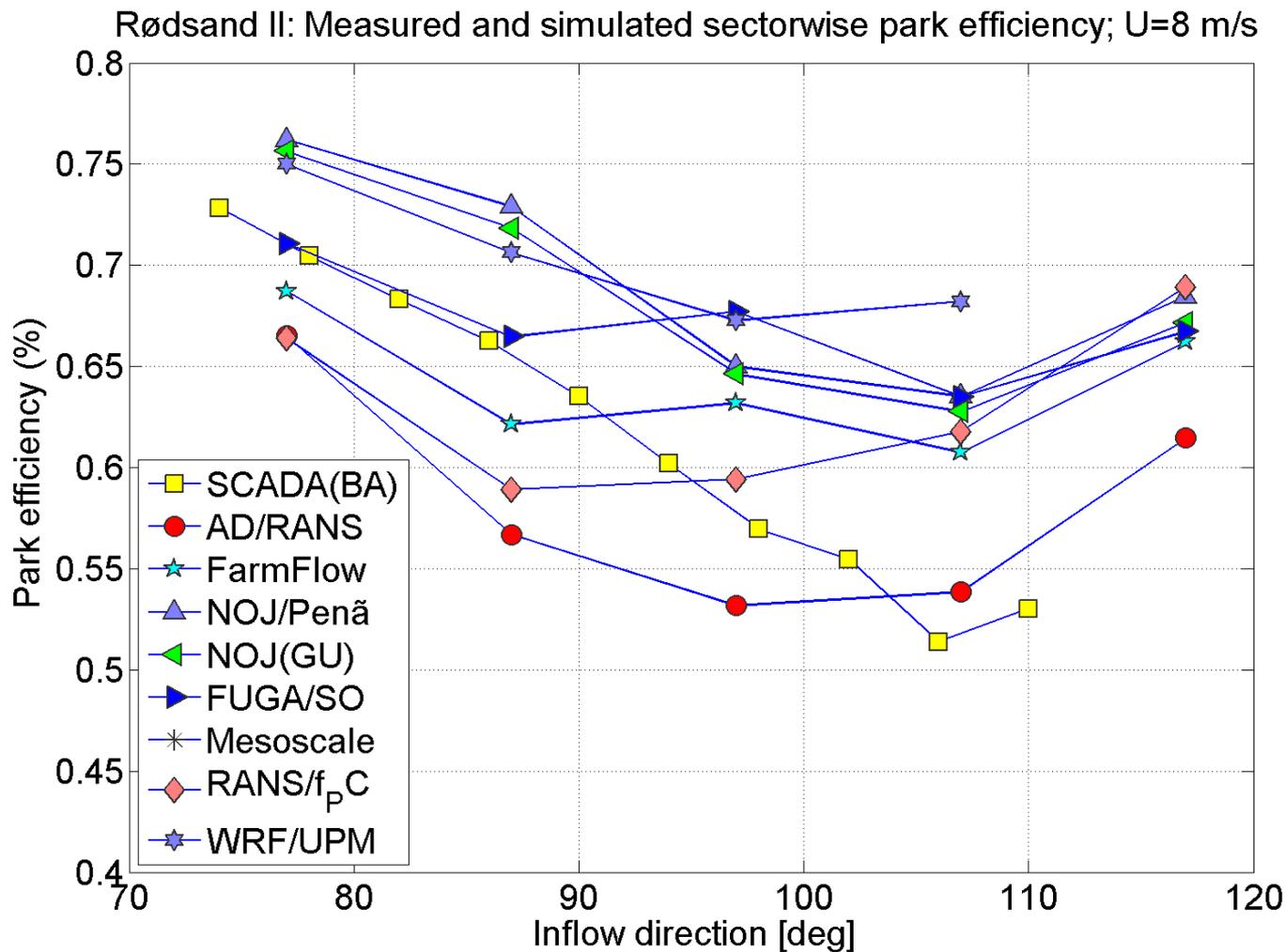
Rødsand-2 wind farm cluster effect



Cluster effect for $U=8$ m/s; $WD=97^\circ$



Rødsand-2 park efficiency @ 77-118°

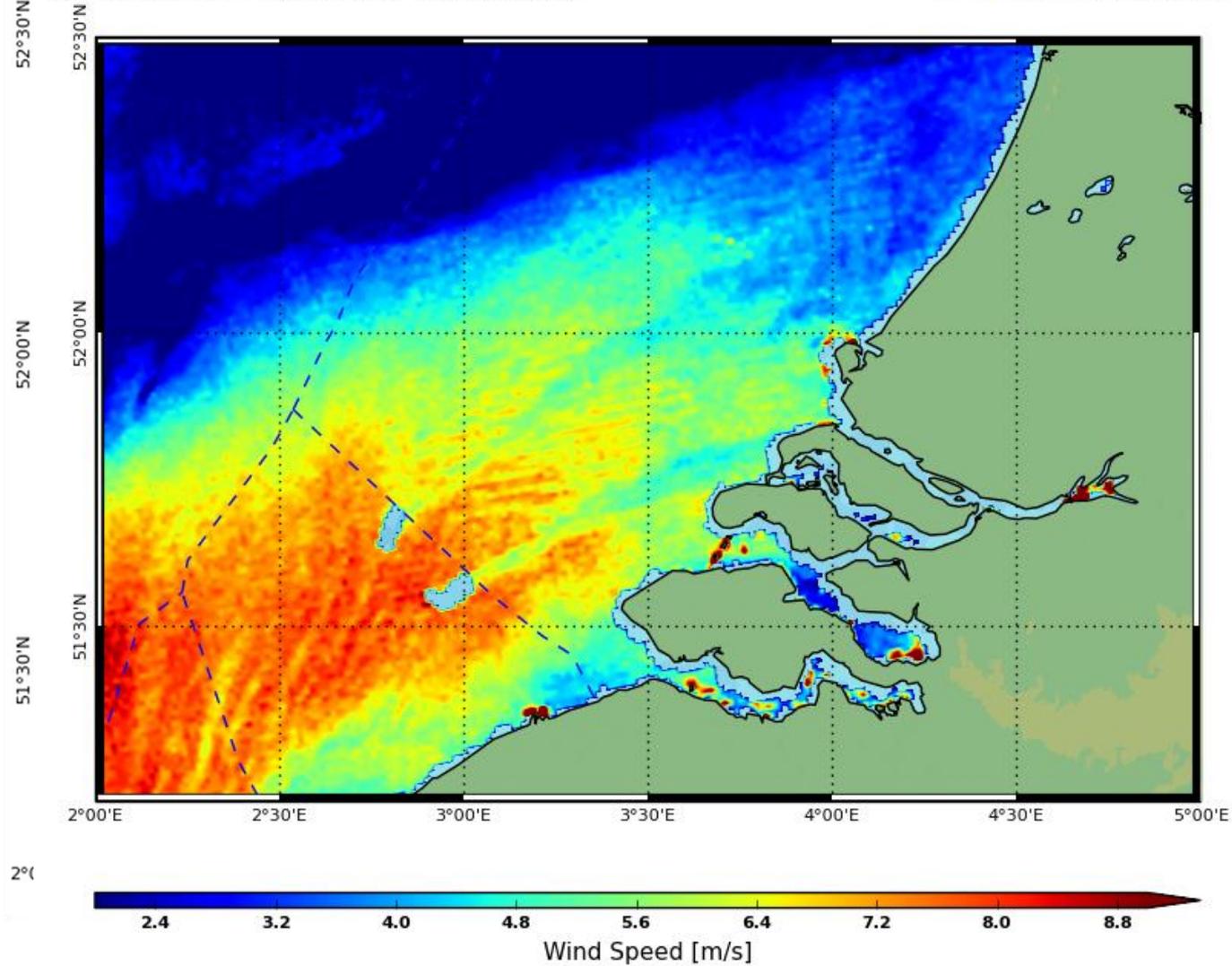


Rødsand cluster effect - conclusion

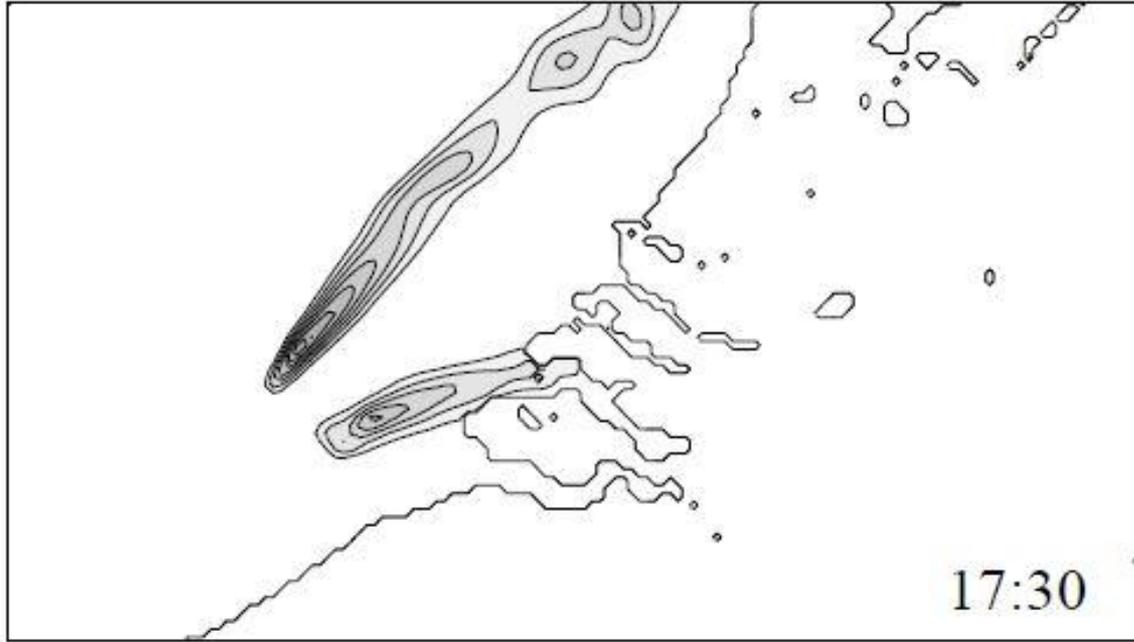


- Quantification of the cluster effect is not possible due to lack of measurements and park asymmetries.
- The benchmark has demonstrated that both size and location of the distinct deficit zone - caused by the Nysted wind farm has been predicted quite well by the models.
- The benchmark concludes that several models were able to handle the clustering of wind farms.

R RS-2 20130701 17:33:51 UTC- Wind inversion



Pauline
Vincent



Velocity deficit with contours in ranges from -1.25 to -0.1 ms⁻¹ over the sea surface only

Patrick Volker

WRF V3.4
ERA Interrim
Nests 18 km, 6 km, 2 km
12 m amsl
MYNN
EWP scheme applies a grid-cell averaged deceleration to the model's flow equation and additional turbulence is produced by the PBL scheme from the changed vertical shear in horizontal velocity.

Volker, P.J.H., Badger, J., Hahmann, A.N., Ott, S.
Geosci. Model Dev. DOI: 10.5194/gmdd-8-3481-2015

DTOC tool and commercialisation

Avoid re-inventing the wheel...

- Coupling to GIS software for editing of locations and properties
- Consideration of limitations and other exploitation by GIS approach
- Integrate existing models seamlessly:
 - WRF (meteorology, wind climate)
 - WAsP
 - FUGA (wind farm effects)
 - FarmFlow (wind farm effects)
 - LCOE

- As a developer I can **determine the optimum** spacing, position, turbine model and hub height of turbines within an offshore wind farm.

*Software supports the **comparison** of many design scenarios.*

***Comparative** reporting enables selection of optimised configurations.*

Score for comparison: Levelised Cost of Energy

Optimisation Process

1. Generate Design Options

- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7

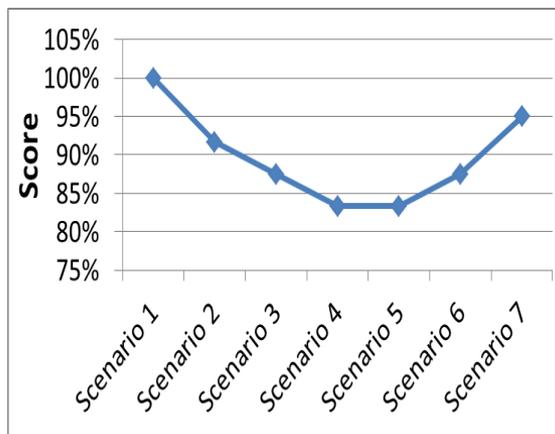
2. Evaluate Design Options

Wake Model

Electrical Model

Energy model

3. Compare Design Options



4. Iterate steps 1 to 3



Score: Levelized cost of energy

What decision parameter can we use to compare design options?

Commercial tool: Wind & Economy



wind economy & Strategic Optimisation

Scenario: DTOC WP5 Base Scenario meteo WRF

- Project: DTOC WP5 Base Scenario (Race Bank)
- Tree: DTOC WP5 BaseScenario Tree
 - Scenario: DTOC WP5 Base Scenario
 - Scenario: DTOC WP5 Base Scenario meteo
 - Scenario: DTOC WP5 Base Scenario meteo WP5
 - Scenario: DTOC WP5 Base Scenario meteo WRF

Scenario Prop

Wind Farm Pa

- Race Bank ✓
 - Parameters
 - Location
 - WindFarmSI
 - WindTurbine
 - Substations
 - Cables
 - Dudgeon
 - Inner Dowsing
 - Lincs
 - Lynn
 - Sheringham Shoal
 - Triton Knoll A
 - Triton Knoll B

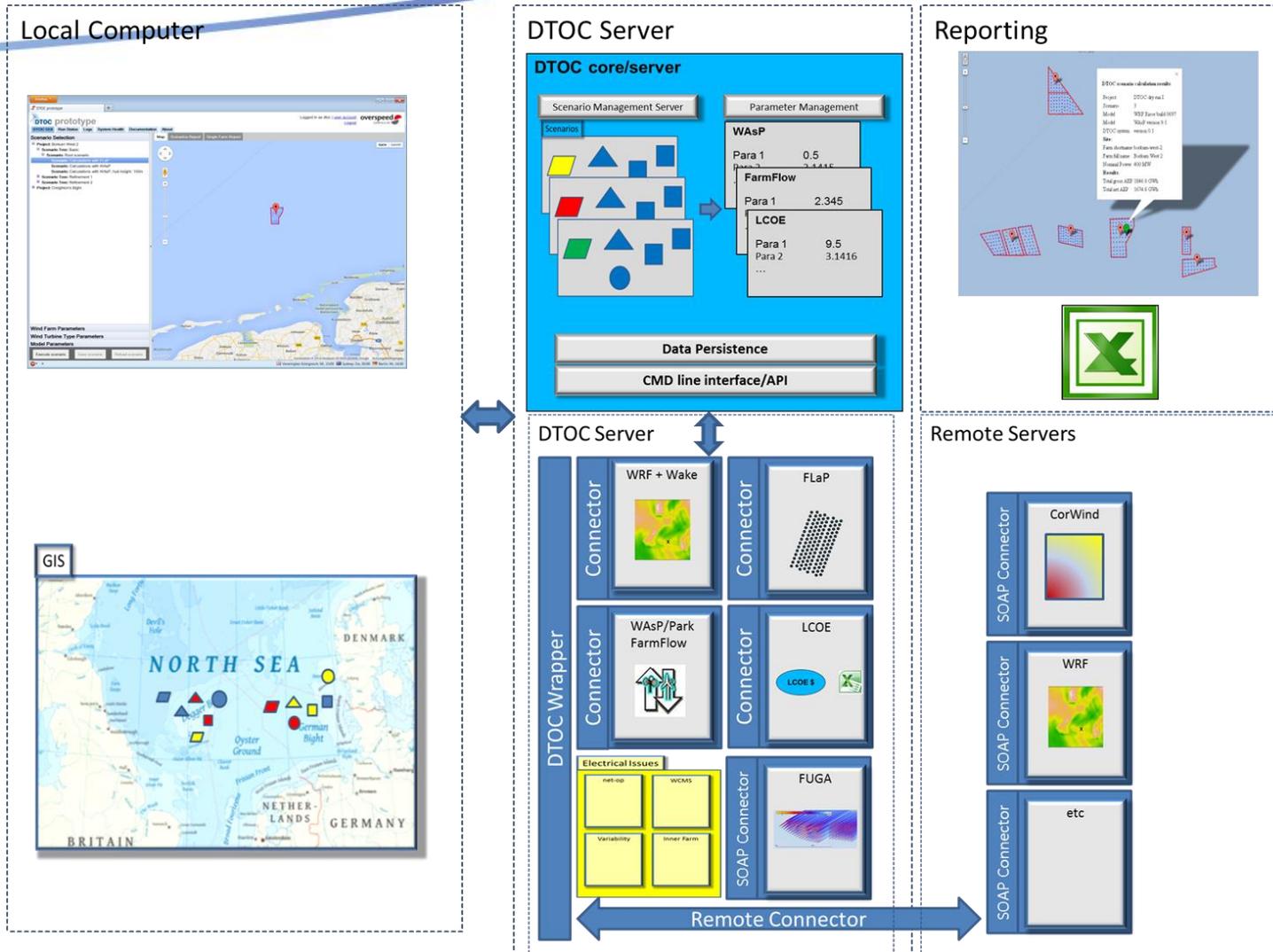
Wind Turbine Type Parameters

Model Parameters

Map Scenarios Report Single Farm Report

Logged in as igor [Logout](#) **overspeed** GmbH & Co. KG

System overview



Local computer: GIS and local web browser



Web application



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GmbH & Co. KG

[Wind & Economy GUI](#) | [Documentation](#) | [About](#)

Scenario: DTOC WP5 Base Scenario meteo WRF

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 - Scenario: DTOC WP5 Base Scenario meteo WP5
 - Scenario: DTOC WP5 Base Scenario meteo WRF
 - Scenario: DTOC WP5 Base Scenario meteo WRF FUGA
 - Scenario: DTOC WP5 Base Scenario meteo WRF

Scenario Properties

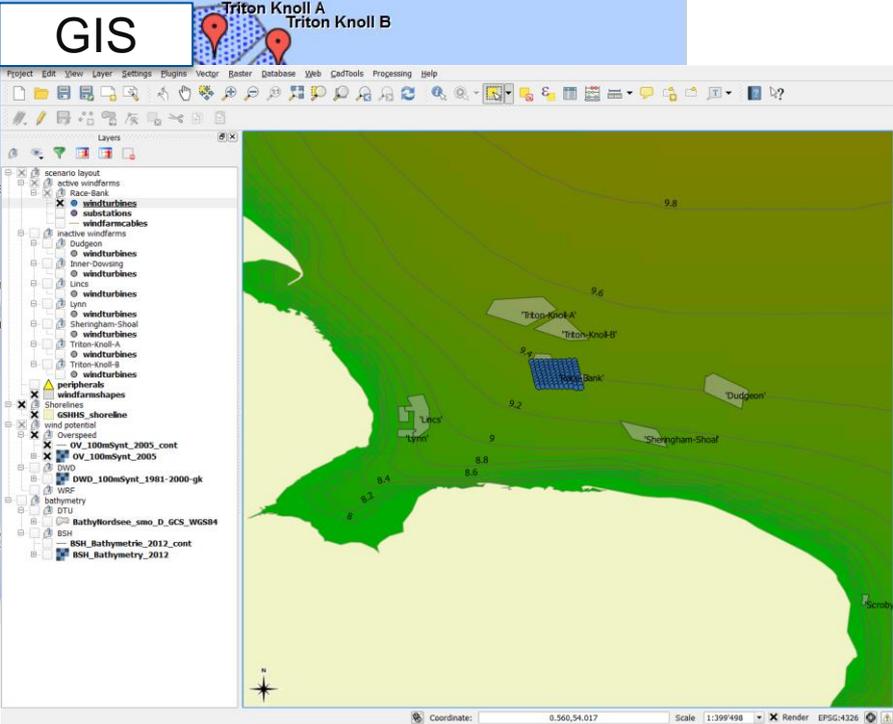
Wind Farm Parameters

- Race Bank ✓
 - Parameters
 - Location
 - WindFarmShape
 - WindTurbines
 - Substations
 - Cables
 - Dudgeon
 - Inner Dowsing
 - Lincs
 - Lynn
 - Sheringham Shoal
 - Triton Knoll A
 - Triton Knoll B

Wind Turbine Type Parameters

Model Parameters

Map | Scenarios Report | Single Farm Report



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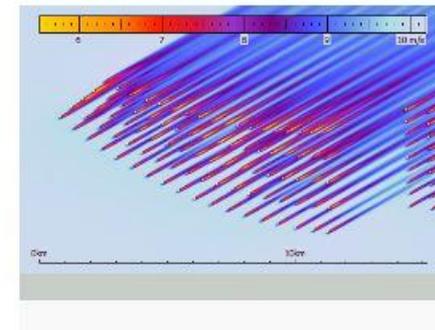
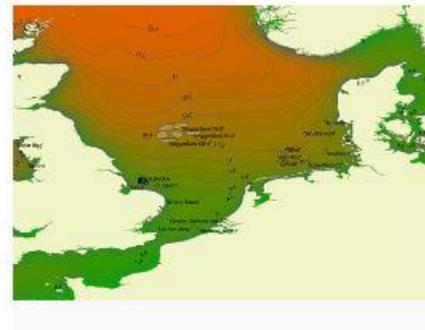
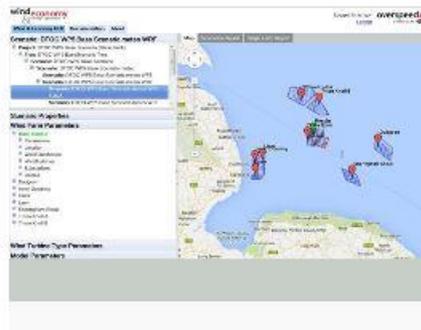
Wake Losses

GIS Integration

Uncertainty Modelling
for Risk Management

Welcome to Wind & Economy

One of the most challenging tasks for wind farm developers is the optimisation of offshore wind power plants. Our new software tool, Wind & Economy, supports your challenging work with the seamlessly integrated modelling of wind climate, large scale and localized wind farm effects, electrical loss calculations and derivation of economic key figures.

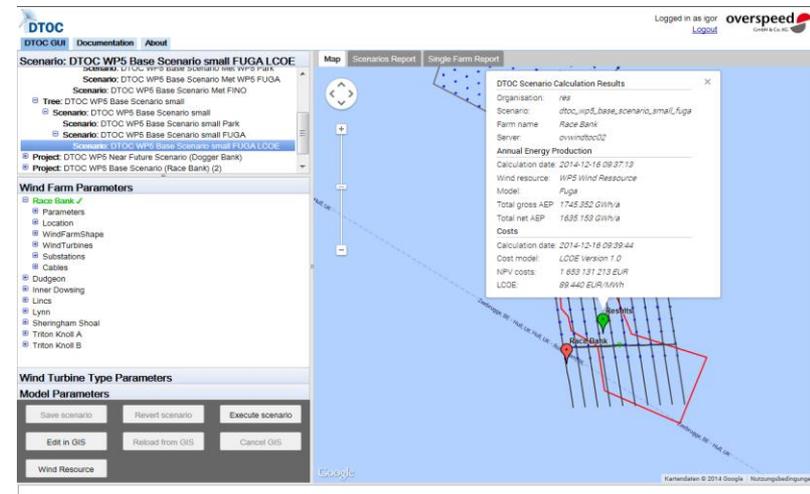


<http://wind-and-economy.com/home/>

Wind & Economy: The tool for wind farm optimization



- wind climate
- turbine type selection
- turbine spacing and placing
- interaction between wind farms in clusters with respect to energy production
- LCOE and economic uncertainty
- Scenario approach
- GIS integration



Bringing leading edge modelling to your desktop

Wind&Economy Demo

Conclusion



The main project output, the 'Wind & Economy' software, provides a new frame for planning offshore wind farm clusters.

By seamless integration of state- of-the-art models from the scientific development by the EERA members, which have been compared and validated by the research community and end-users, provides a significant potential for cost reductions.

The rapid development of offshore wind farms in the Northern European Seas with major clusters planned in many countries makes the release of this novel tool available with due diligence.

We aim at developing the tool for strategic planners

- 1) Add environmental aspects and restricted zones
- 2) Add sea bed and estimate foundation costs
- 3) Improved cost of energy and O&M module
- 4) Further detail wind farm cluster effects
- 5) Include social acceptance

DTU has submitted EUDP2015 proposal (Danish national activity).

Visit www.eera-dtoc.eu



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What is EERA-DTOC?

EERA-DTOC stands for the European Energy Research Alliance - Design Tool for Offshore Wind Farm Cluster.

The project is funded by the EU – [Seventh Framework Programme \(FP7\)](#) – and runs from January 2012 to June 2015. It is coordinated by the [Technical University of Denmark - DTU Wind Energy](#).

- New: Final Summary Report available now!
- New: software tool (Wind & Economy) available now!
- Consult the presentations with results from EERA-DTOC

Support by



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No FP7-ENERGY-2011-1/ n° 282797

Acknowledgements:

Funding: EERA DTOC FP7 and partners

SCADA data: DONG energy, Vattenfall, E.On, RAVE

Radarsat image: MacDonald, Dettwiler and Associates Ltd.

Wake modelling more than 20 participants at many partner institutes