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EERA –DTOC cost optimized farm design

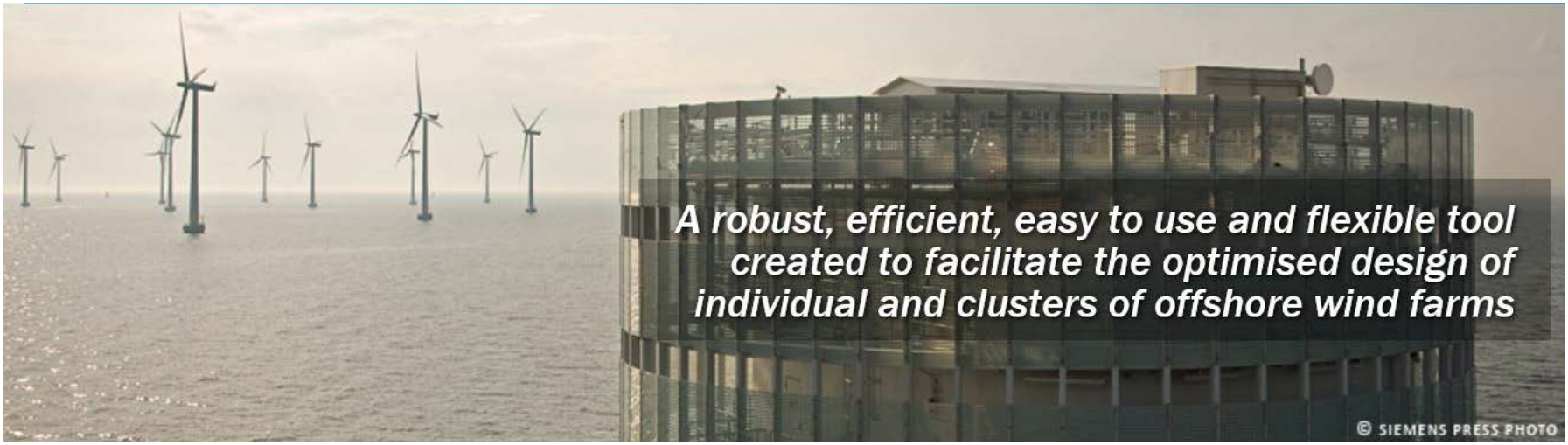
Charlotte Bay Hasager, Peter Hauge Madsen, Gregor Giebel

EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

Support by

Project partners

EERA DTOC project vision



Danish article

Streamlining project planning of offshore wind farms

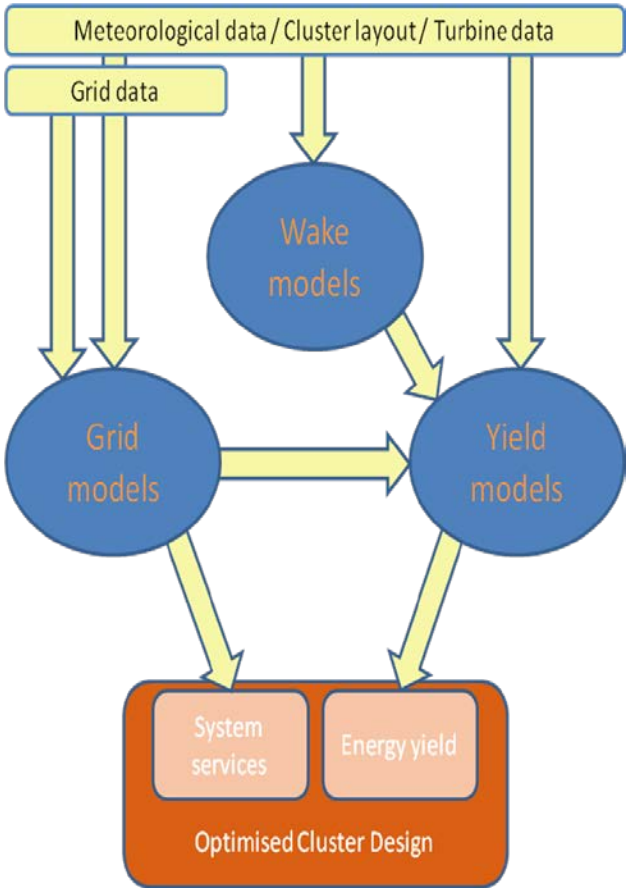
Even though offshore wind farms are incredibly expensive—and a great deal of time is devoted to planning them—communication between project developers leaves a lot to be desired. Simply put: one expert often has little idea what another is doing, and this costs a lot of time and money. However, this 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

- GIS
- LCOE
- uncertainty
- FUGA
- WAsP
- WRF
- WRF/ROMS
- CorWind

DTOC Services

- eefarm
- FarmFlow
- WCMS
- Net-op
- SKIRON
- VENTOS

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

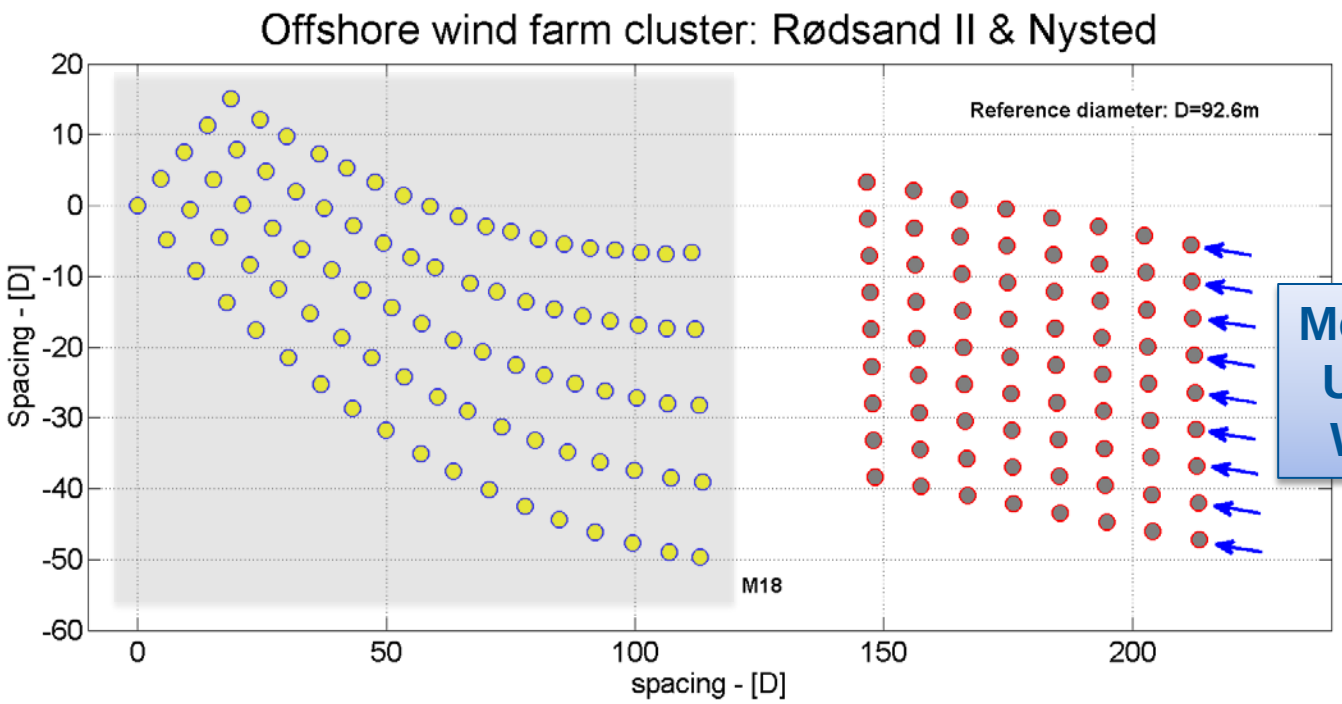
The benchmark concludes that several models were able to handle the clustering of wind farms

Participants and park models

Mo	Affiliation	Horns Rev WF	Lillgrund WF	Rødsand II WF	Rødsand II/Nysted WF
SCAD/	J 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_PC	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	

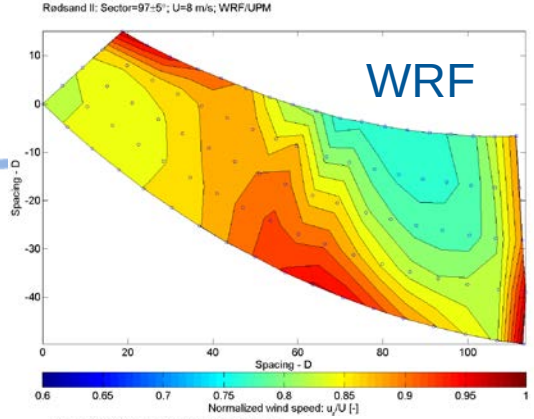
BA=Bin Averaged & GU=Gaussian Uncertainty

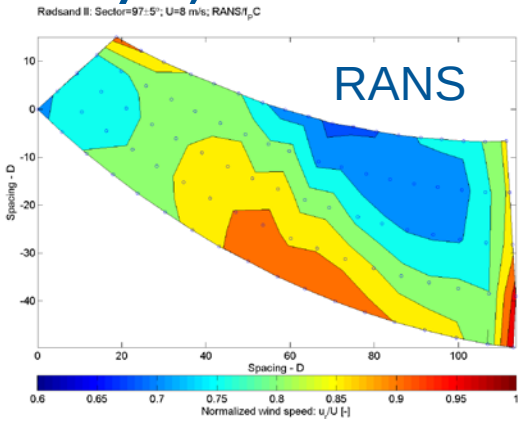
Rødsand-2 wind farm cluster effect

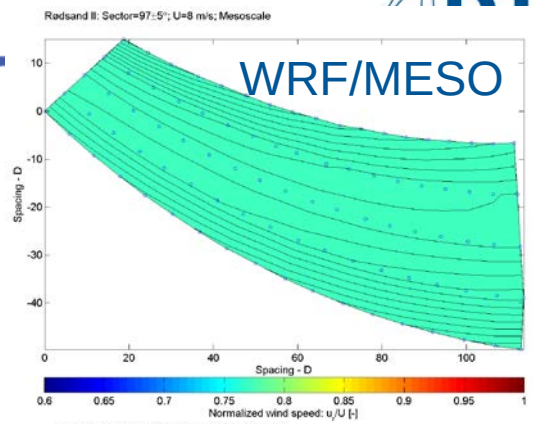


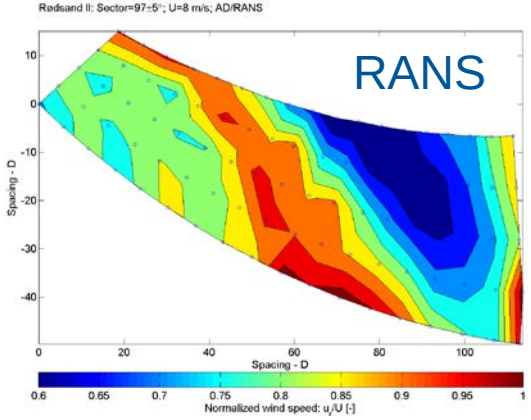
Model inflow
U_{hub}=8 m/s
WDIR=97°

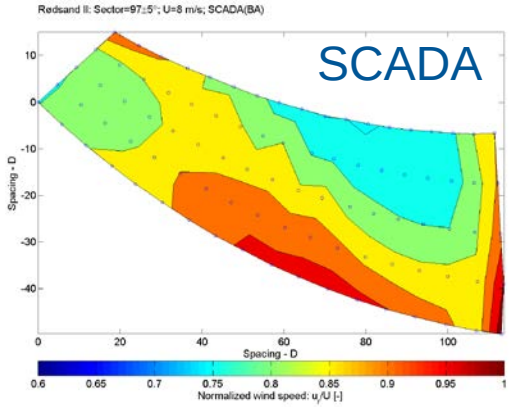
Cluster effect for U=8 m/s; WD=97°

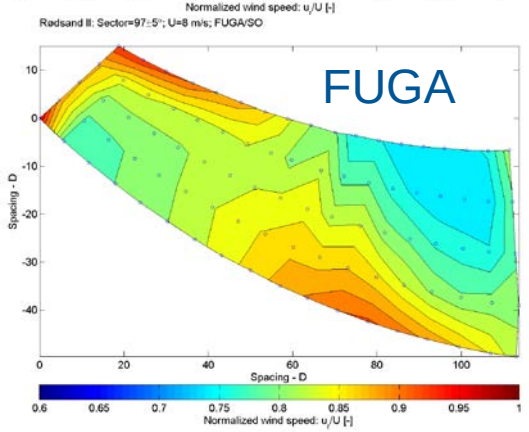


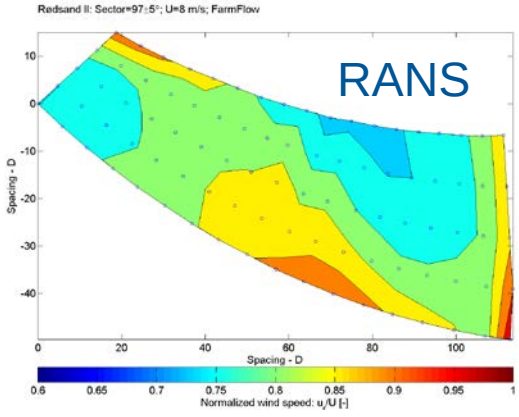


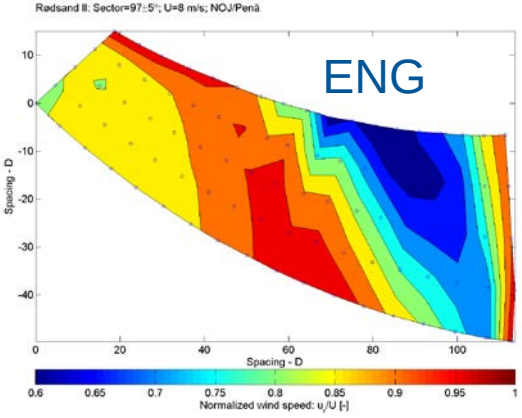


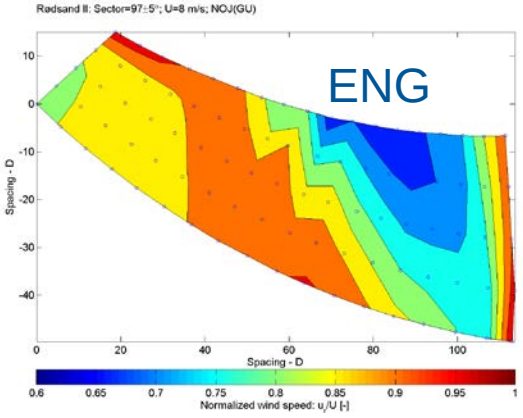




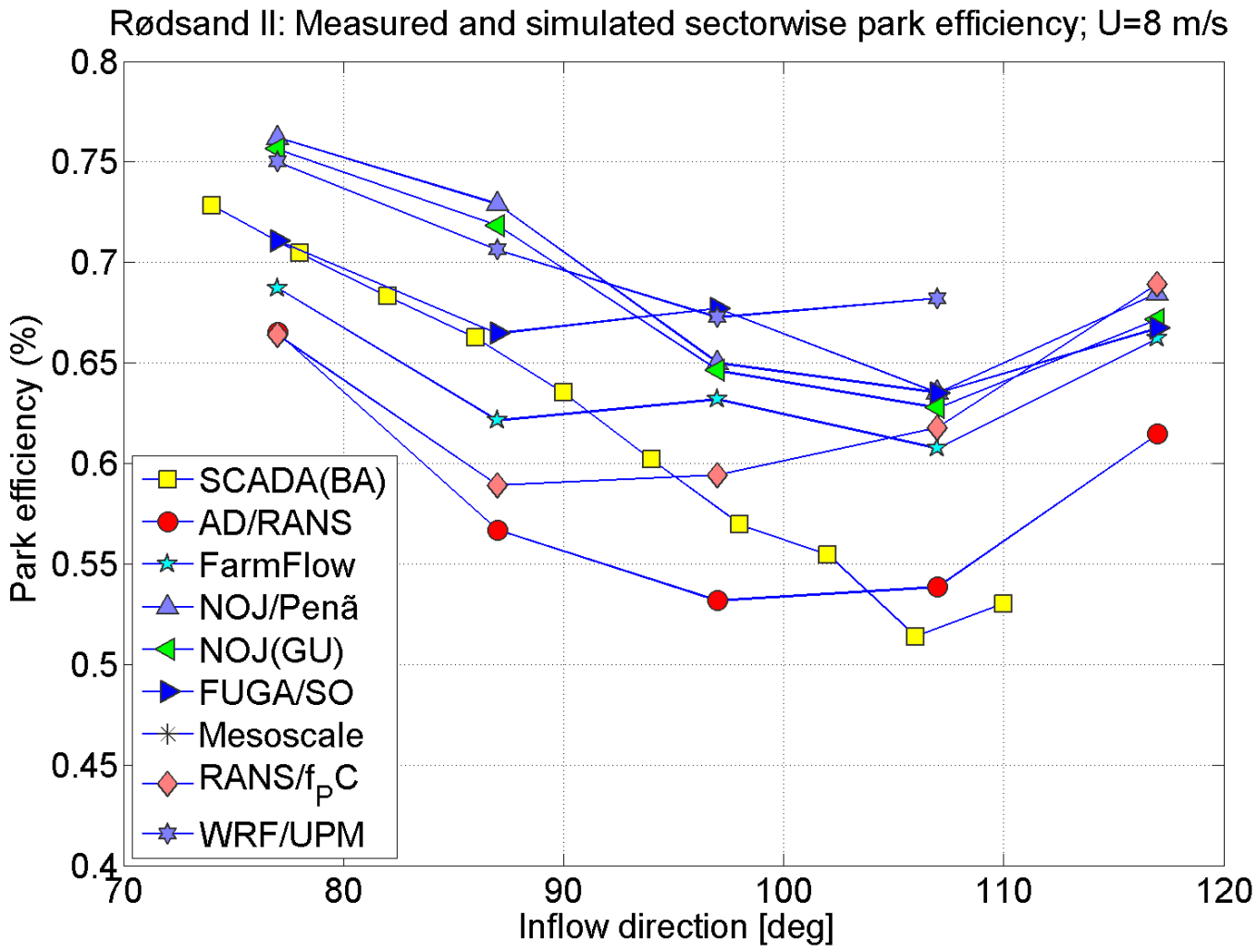








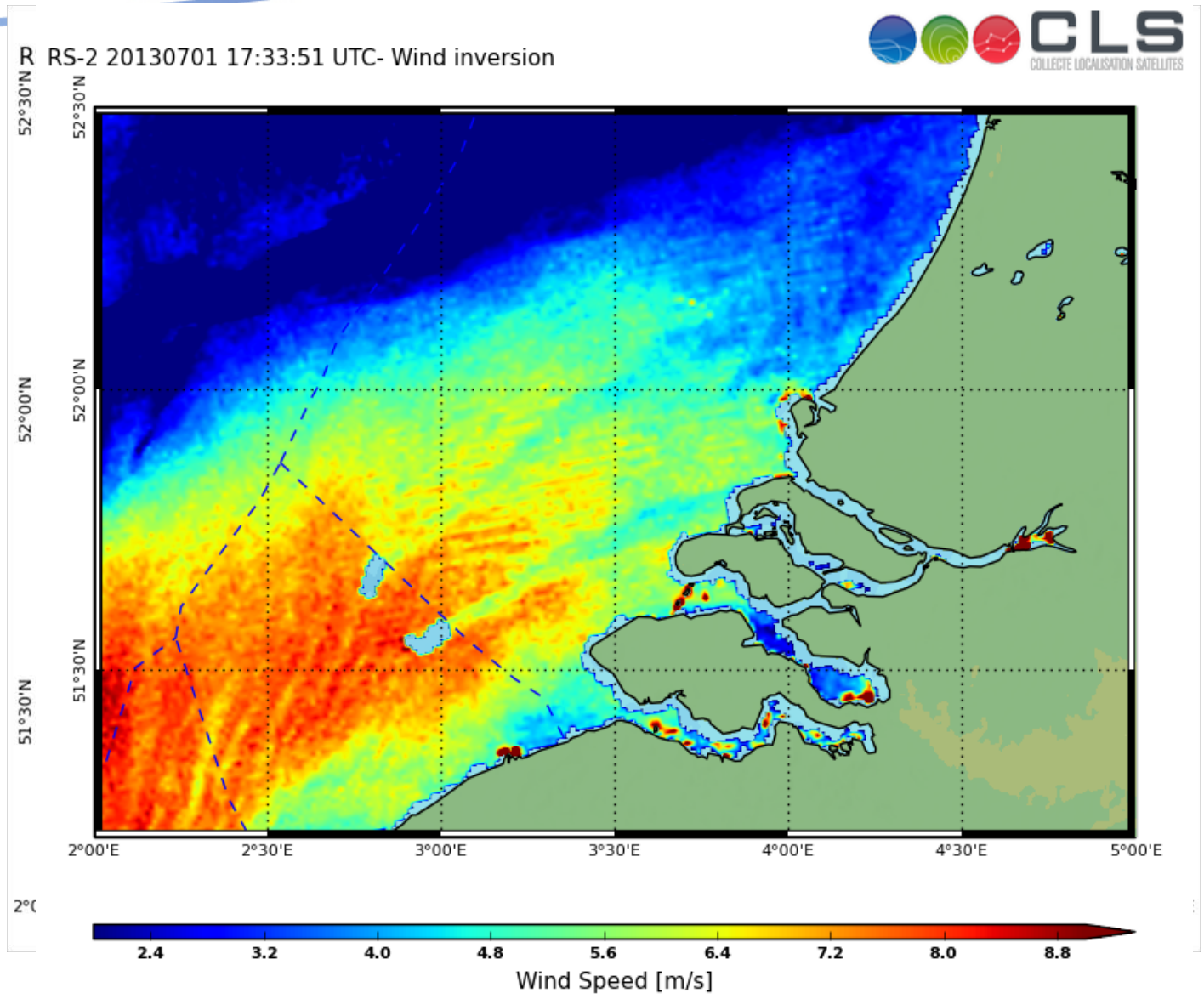
Rødsand-2 park efficiency @ 77-118°



Rødsand cluster effect - conclusion

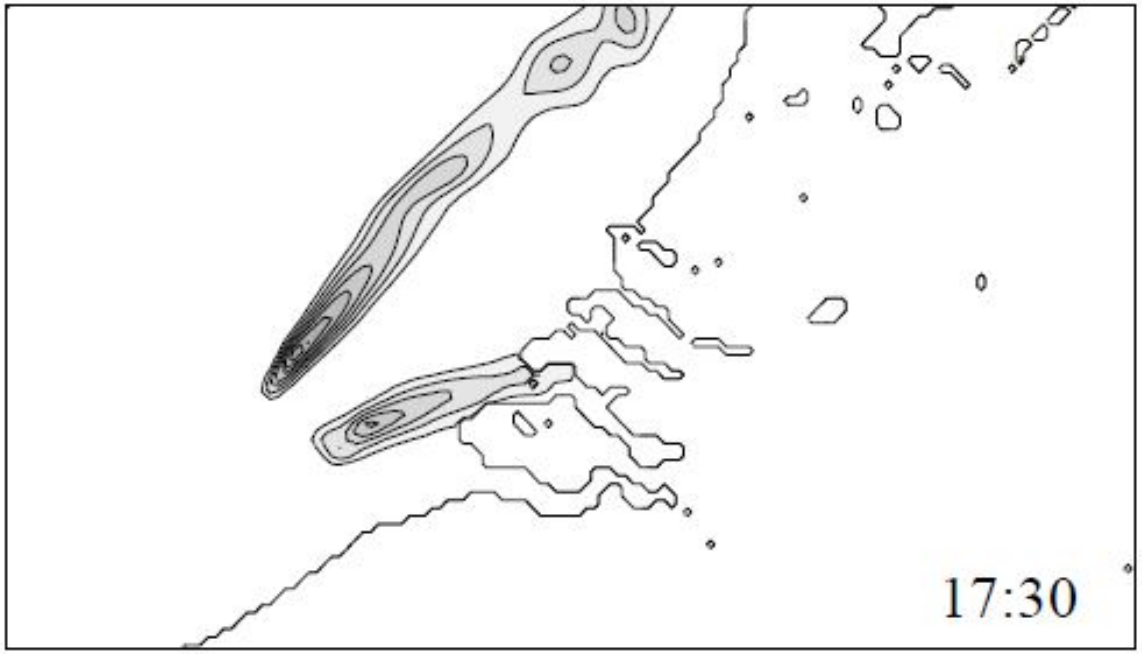
- Quantification of the cluster effect is not possible due to lack of measurements and park asymmetries.
- The benchmark has demonstrated that both size and location of the distinct deficit zone - caused by the Nysted wind farm has been predicted quite well by the models.
- The benchmark concludes that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

Satellite



Pauline Vincent

WRF



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

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

Patrick Volker

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

Optimisation process

- 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

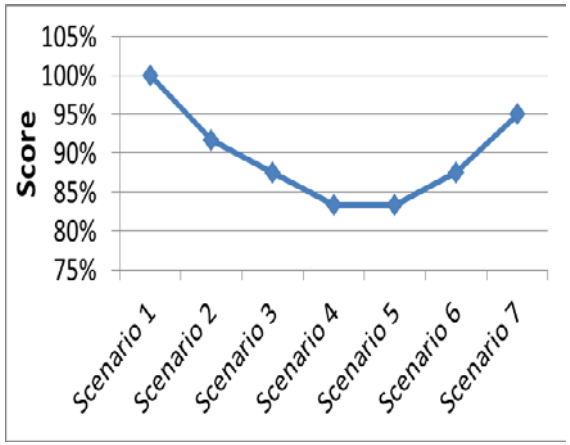
2. Evaluate Design Options

Wake Model

Electrical Model

Energy model

3. Compare Design Options



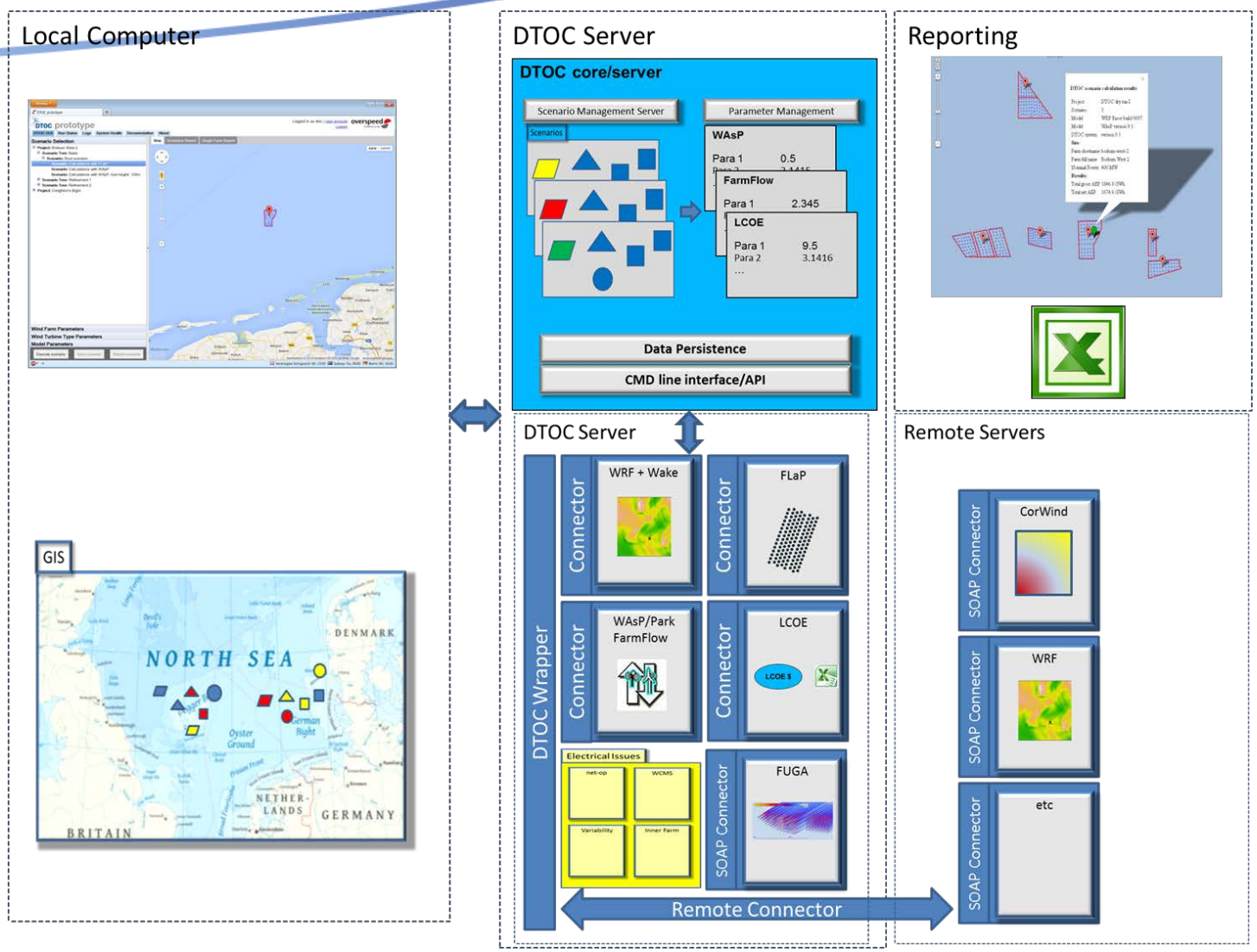
4. Iterate steps 1 to 3

Score: Levelized cost of energy

What decision parameter can we use to compare design options?

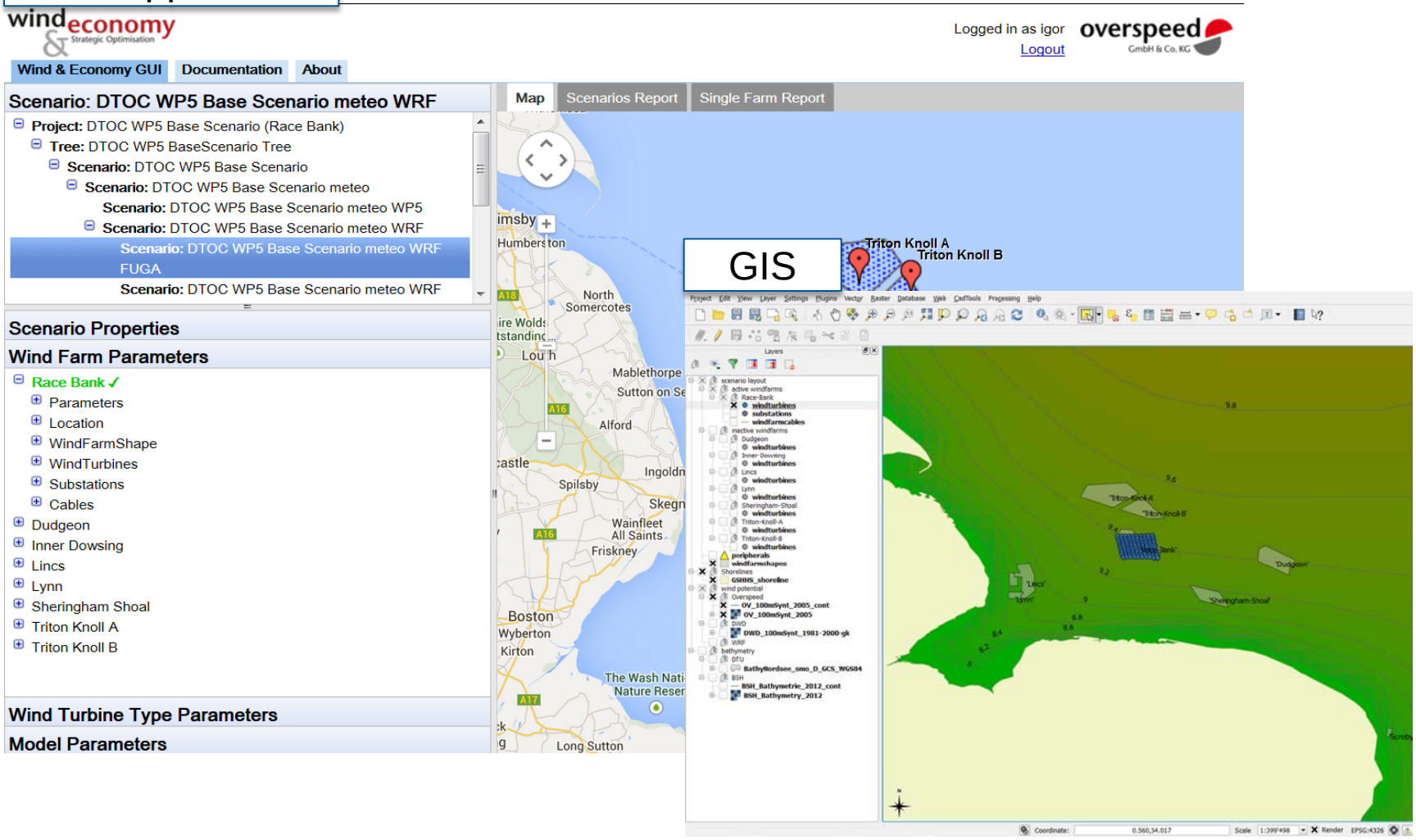
Commercial tool: Wind & Economy

System overview



Local computer: GIS and local web browser

Web application



Wind & economy

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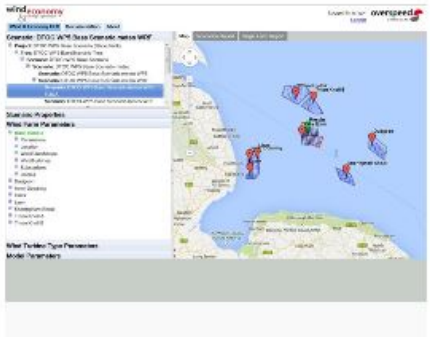
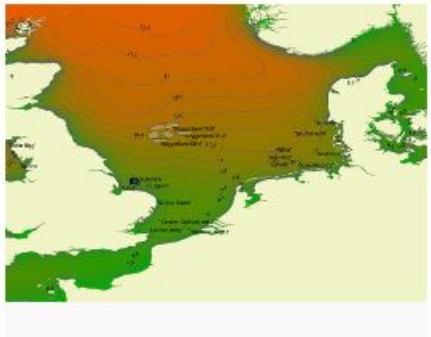
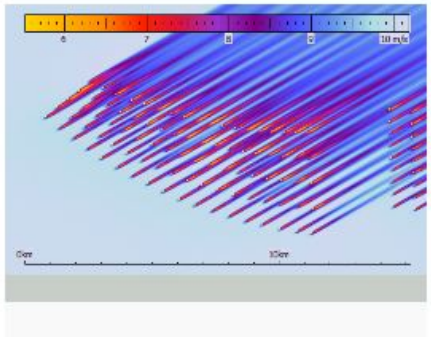
  - Wake Losses
  - GIS Integration
  - Uncertainty Modelling for Risk Management

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/

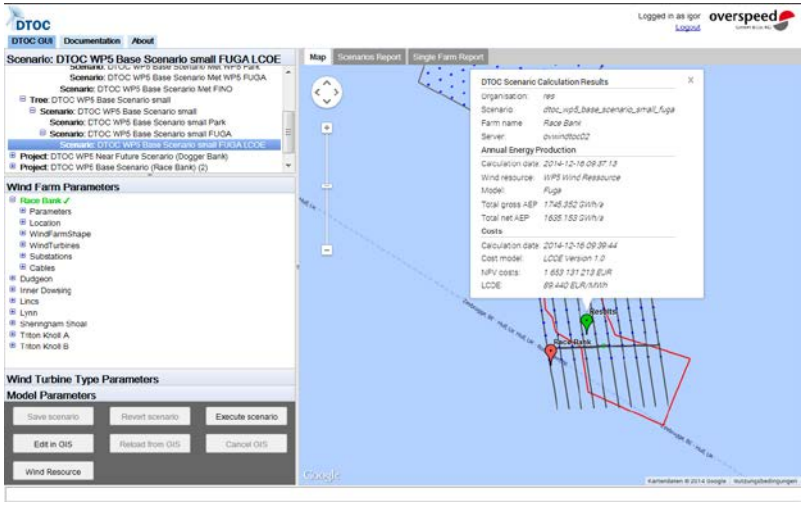
Wind & Economoy:
The tool for wind farm optimization

- 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.

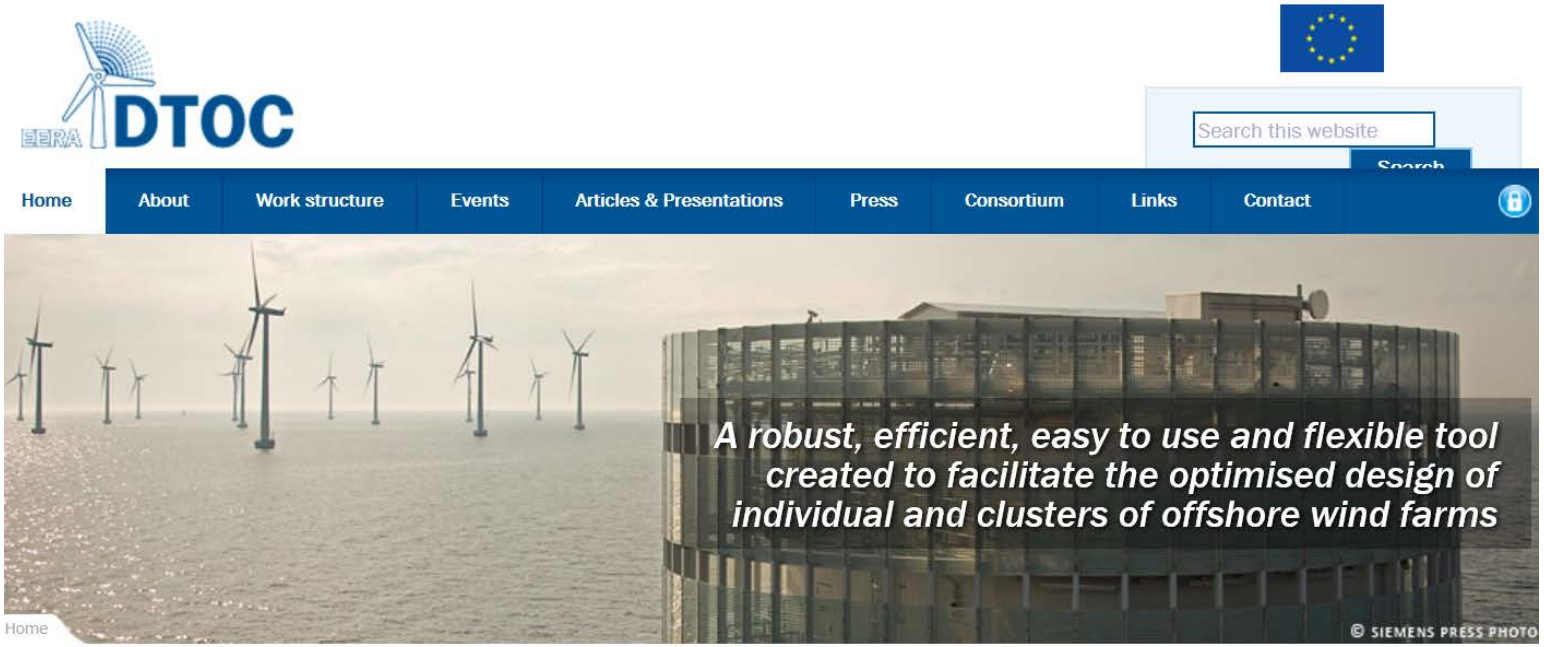
Strategic planning

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



Support by

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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