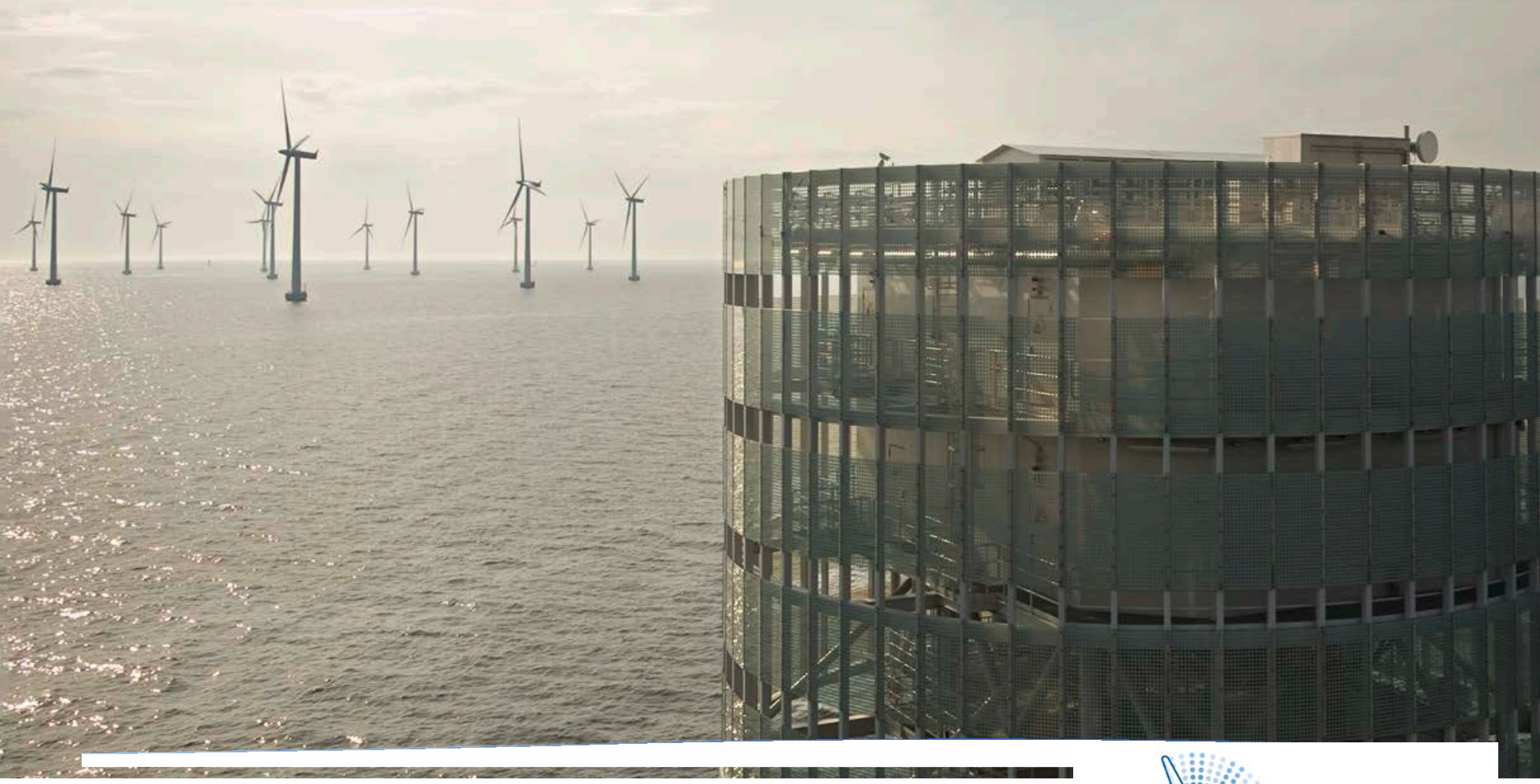


EERA-DTOC: DESIGN TOOLS FOR OFF-SHORE WIND FARM CLUSTERS

INCLUDING NEW RESULTS ON WAKE BENCH

G. Schepers, C. Bay Hasager, K. Hansen, P Hauge Madsen, P.E. Rèthorè, J. Badger, G. Giebel, D. Iuga, E. Cantero, M Faiella, Rebecca Barthelmie, T. Larsen, J. Prospathopoulos, J. L. Palma, V. C. Gomes, T. Young, P. Stuart

EERA DTOC

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

Support by

SEVENTH FRAMEWORK PROGRAMME

Contents

- *Introduction into project/objectives*
- EERA-DTOC concept
- Status of project
- WakeBench: Comparison between wake model calculations and measurements from Horns Rev off-shore wind farm

EERA-DTOC

Coordinated by DTU (Charlotte Bay Hasager)

EERA = European Energy Research Alliance
DTOC = Design Tool for Offshore Wind Farm Clusters

Project period: January 2012 to June 2015

Funding total ~4M Euro, hereof ~2.9M Euro from EU FP7

EERA-DTOC summary slide

EERA-DTOC

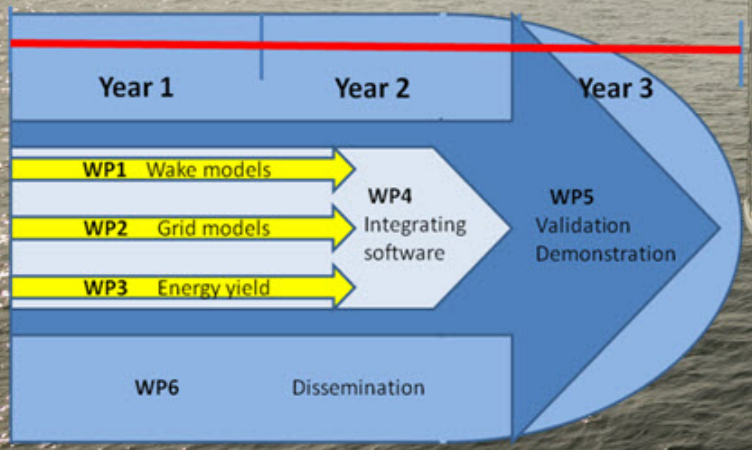
European Energy Research Alliance - Design Tools for Offshore Clusters

Charlotte Hasager, Gregor Giebel, Pierre-Elouan Rethore, EERA Wind members and industry

Contact: cbha@dtu.dk or grgi@dtu.dk, mob.+45 4056 5095

Start 1 January 2012, runs for 3.5 years

Total funding is ~4 M€, EU share is 2.9 M€.



Product Vision:

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

A keystone of this optimisation is the **precise prediction of** the future long term wind farm **energy yield and** its associated **uncertainty**.

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www.EERA-DTOC.eu

Contents

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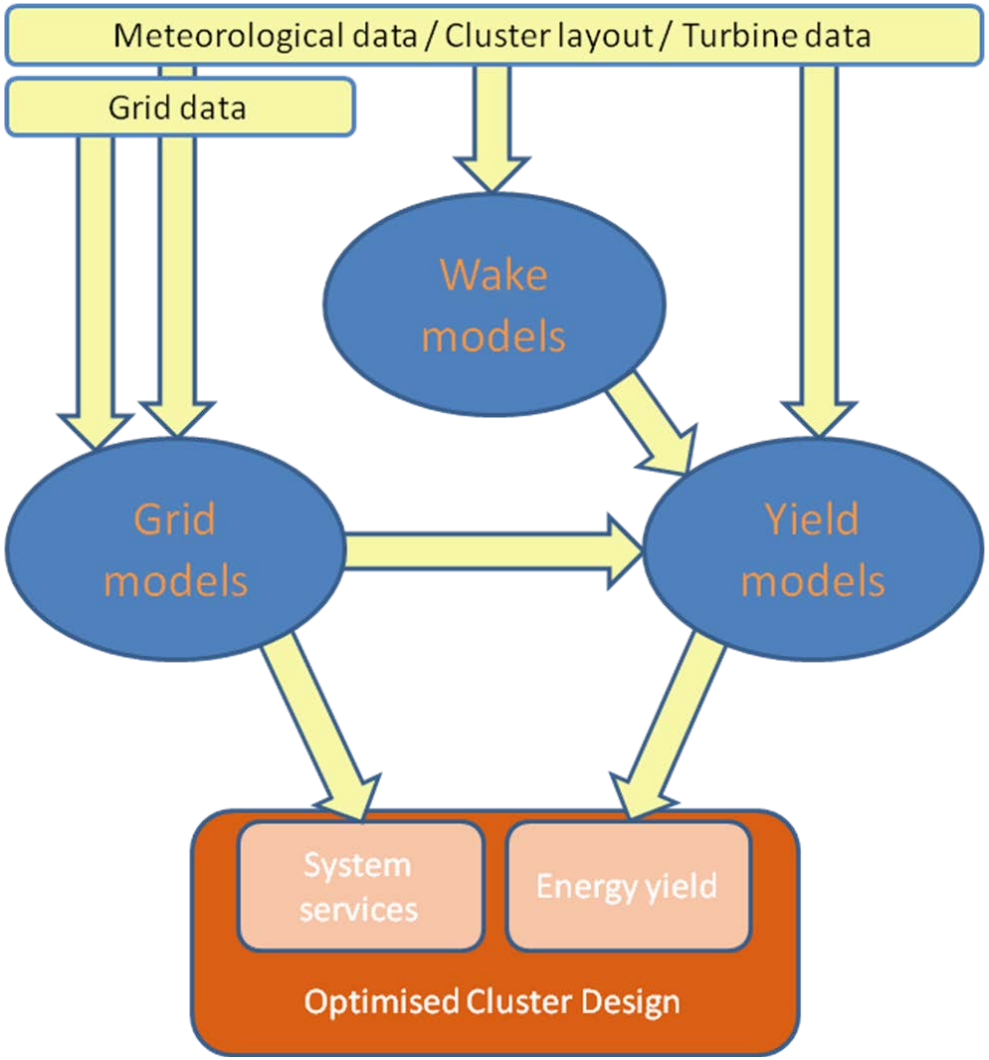
EERA-DTOC main idea

- 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 the final tool where possible and otherwise demonstrate its value through likely scenarios

EERA-DTOC concept



EERA-DTOC list of models

Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER		Fluent, C++, OpenFOAM	ASCII	script	Yes		
CorWind	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	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	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	DTU	Beta	Matlab/C/ Fortran	ASCII	script		+	
UAEP	DTU		Matlab, pc	ASCII/ binary	no	yes		
VENTOS	UPORTO	Beta	Unix/ Fortran	ASCII	no	yes	+	+
WAsP	DTU	Ope	Windows pc	ASCII	Script/ GUI	No	+	+
WCMS	Fraunhofer	Ope	Matlab/JAVA	OracleDB		yes	+	
WRF	DTU	Ope	Unix, Linux, Fortran90	netCDF	Shell script	yes		
WRF/ROMS	CIEMAT	Ope	Linux/ Fortran	netCDF	script	yes	+	

Contents

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Where are we now?

- User requirements have been defined
- The integrated design tool has conceptually been designed
  - A first ‘dry run’ with coupled meso/cluster/micro(wake) models is currently carried out.
  - Coupling with grid models in progress.
- First WakeBench is carried out based on Horns Rev off-shore wind farm measurements
  - Other WakeBenches (e.g. on cluster scale) are in progress
- More measurements for validation are underway (e.g. Lidar measurements on Bard Off-Shore)

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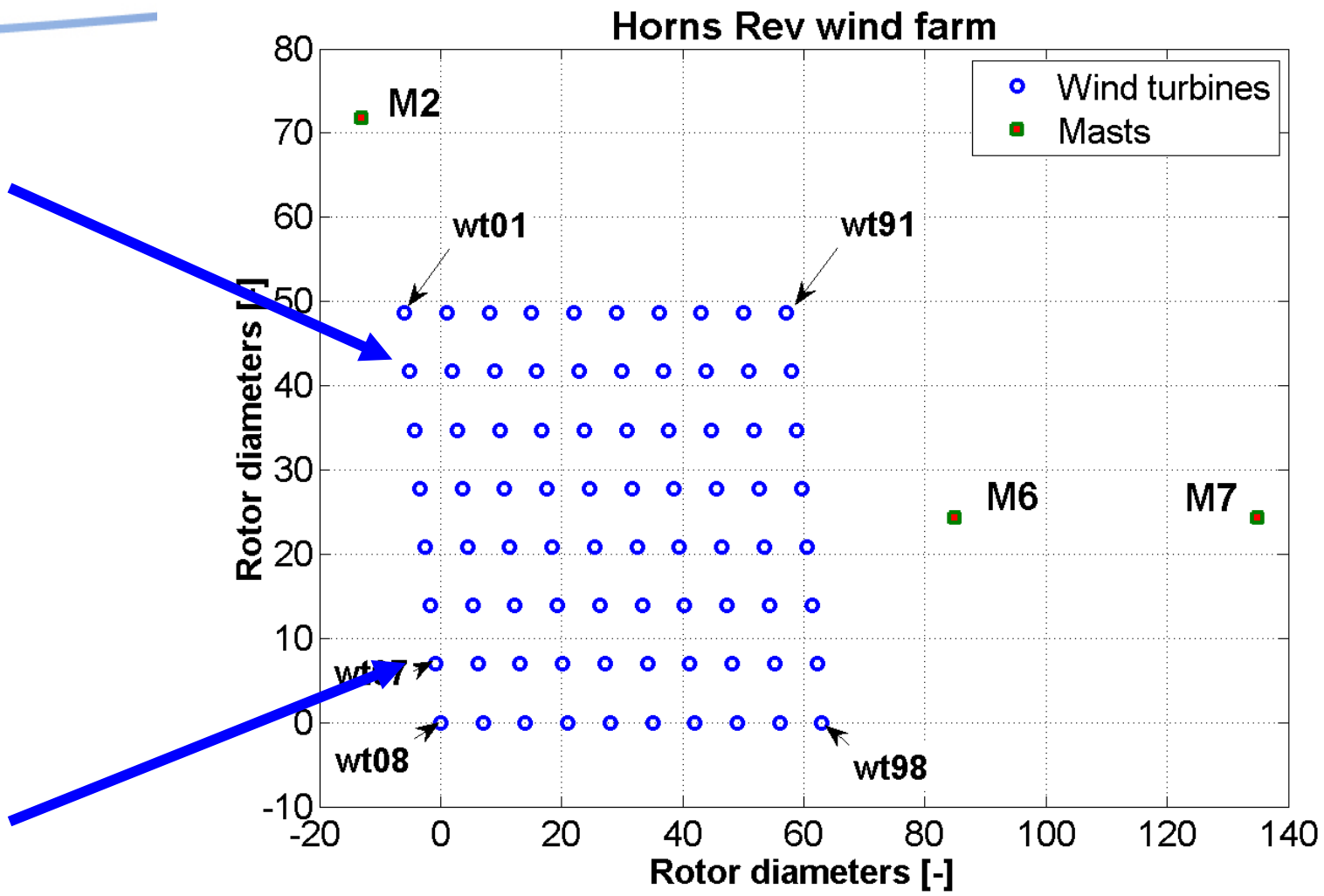
Horns Rev(DK) offshore wind farm



Horns Rev

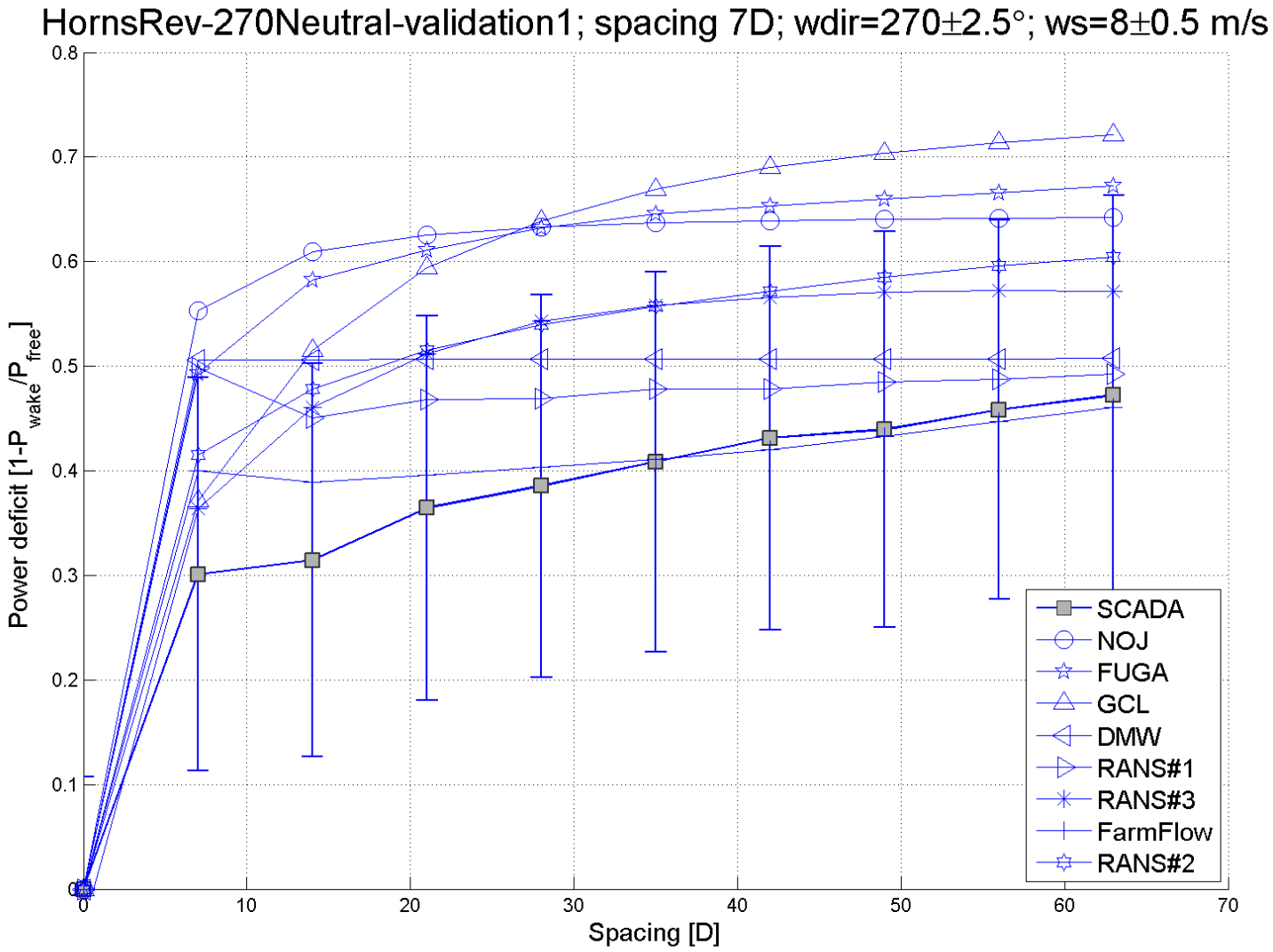
- SCADA data = 10 minute statistics;
  - Power, pitch, rotorspeed, yaw position (uncalibrated);
- Wind speed and direction from (wake) mast M6 & M7;
- Derived signals:
  - Wind speed determined from power value with reference to the official power curve;
  - Wind direction is based on M7 & calibrated for 8 wake sectors;
- Data qualification includes: 2005-2009;
- The following flow cases are simulated by several wake models:
  - Normal operation, 270°, 7D spacing;
  - Atmospheric stratification, 270°, 7D spacing;
  - Variable turbulence intensity;
  - Normal operation, variable spacing 7, 9.4 & 10.4D;

Benchmark matrix

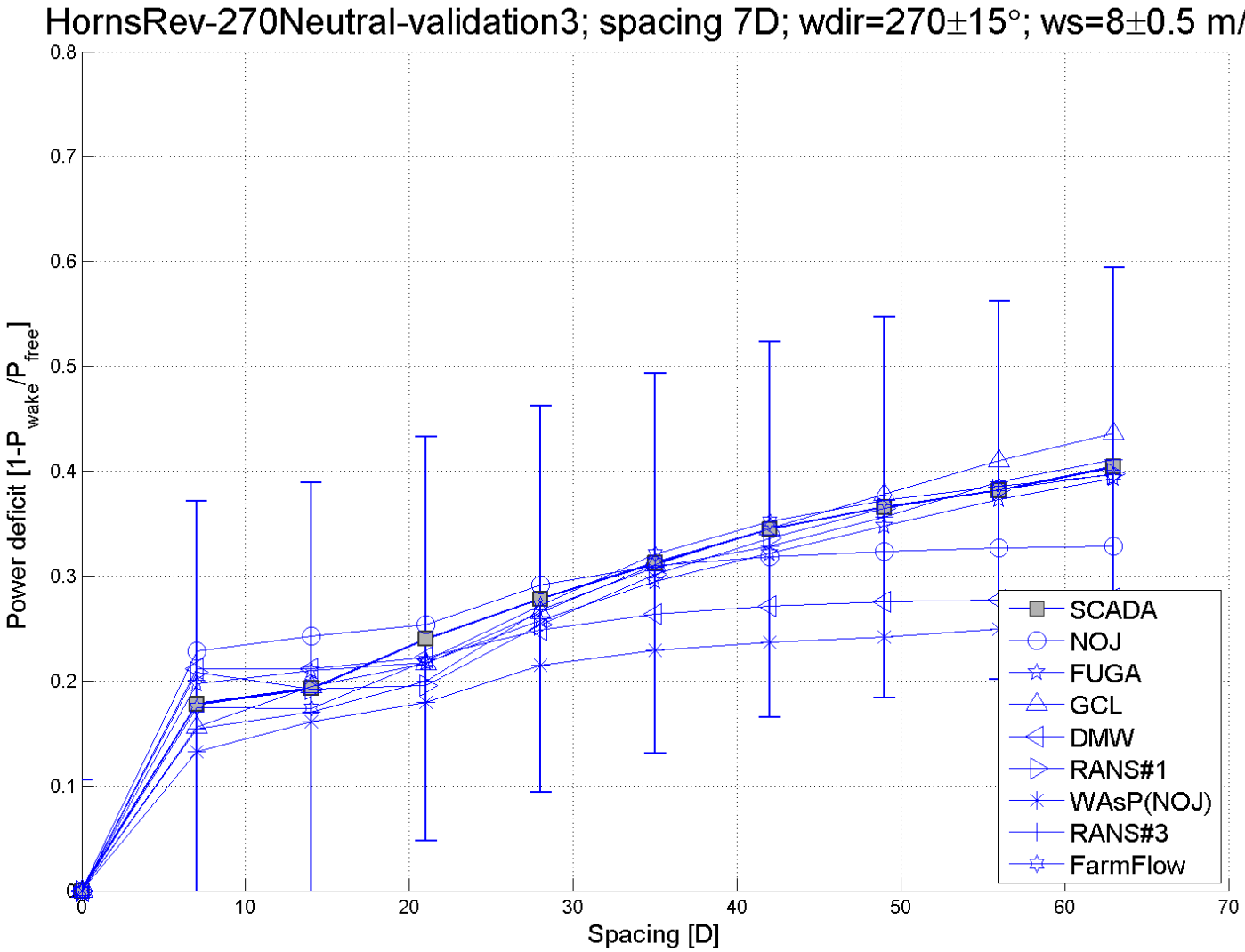
DTOC	Flow sector			Stratification			Turbulence			Spacing		
	1.1	*1.2*	*1.3*	*2.1*	*2.2*	*2.3*	*3.1*	*3.2*	*3.3*	*4.1*	*4.2*	*4.3*
WASP		1	1							1	1	1
NOJ	1	1	1				1			1		
FarmFlow	1	1	1	1	1	1	1	1	1	1	1	1
FUGA	1	1	1				1			1		
GCL	1	1	1				1	1	1	1		
DWM	1	1	1	1	1	1	1	1	1	1	1	1
CRESflowNS	1	1	1									
WindFarm	1	1	1					1	1			
RANS	1	1	1				1	1	1	1	1	1
sum	8	9	9	2	2	2	6	5	5	7	4	4

Note: Some of the shown results are still preliminary!

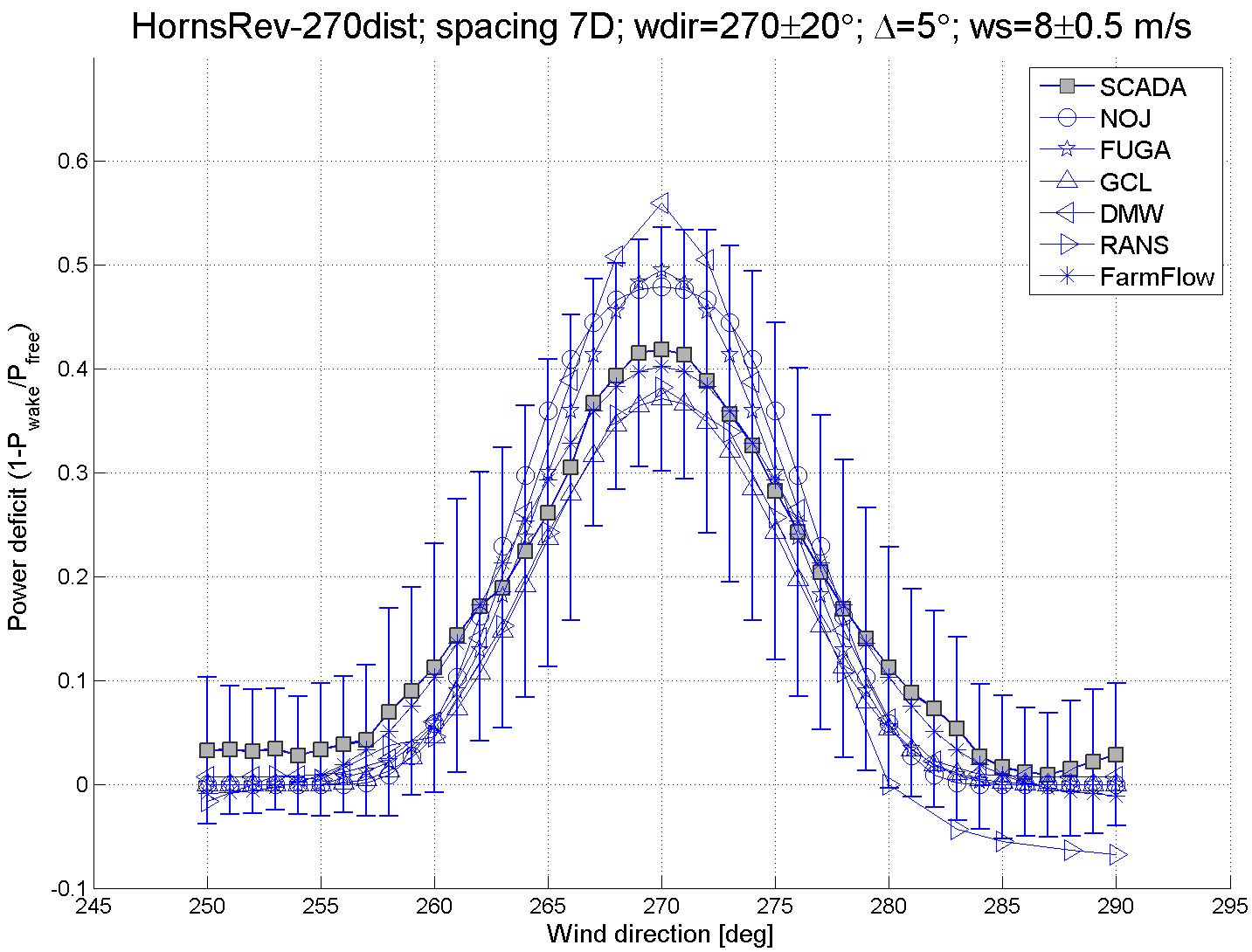
Wake Bench (Horns Rev), maximum power deficit at 270 degrees (narrow inflow sector)



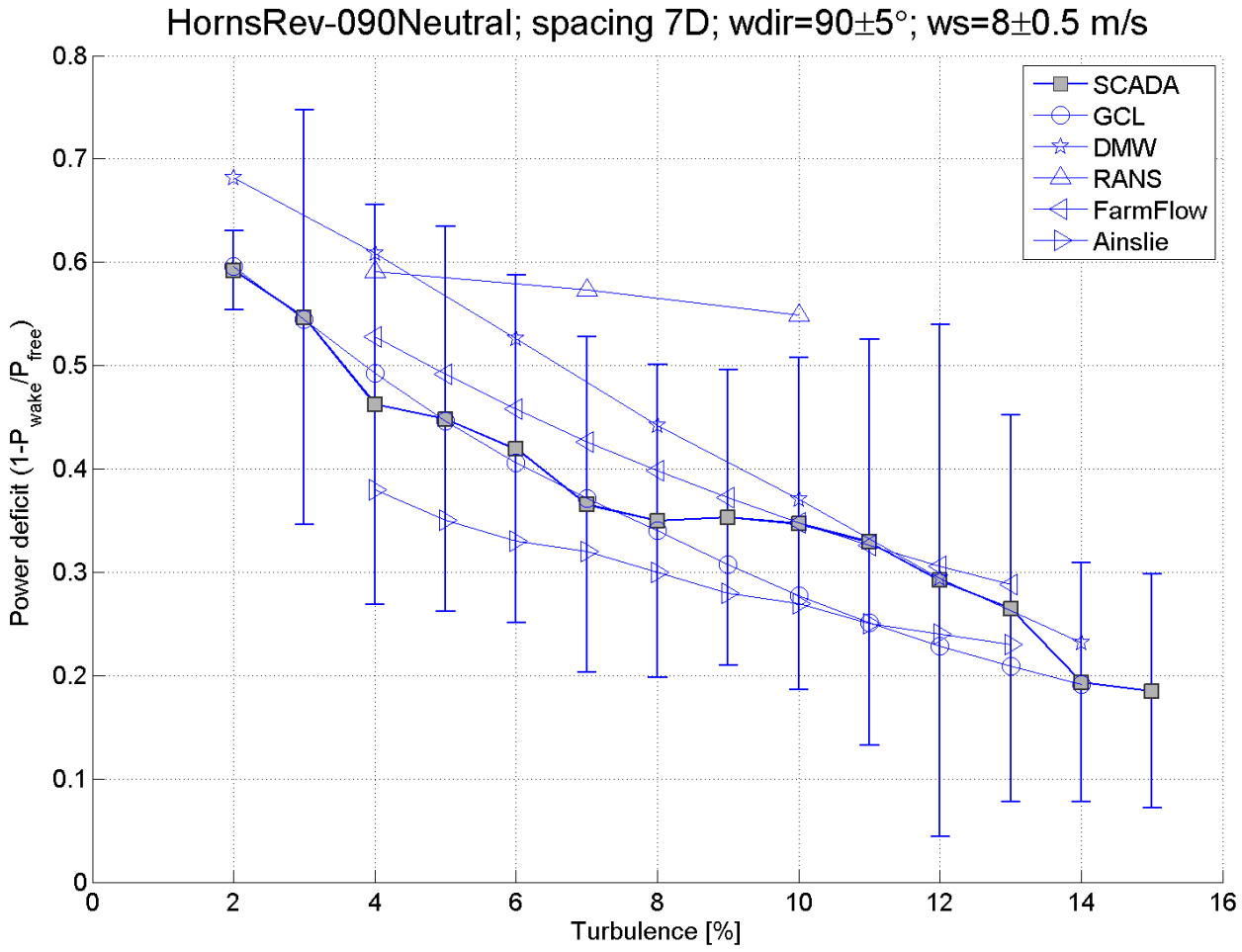
Wake Bench (Horns Rev), maximum power deficit at 270 degrees (wide inflow sector)



Wake Bench (Horns Rev), power deficit distribution



Wake Bench (Horns Rev), maximum power deficit at different turbulence levels



Conclusions

- Work is underway to deliver an integrated tool for the design of individual wind farms and clusters of wind farms
- The tool is composed of existing models as available throughout Europe
- The tool will be available in December 2014
- Generally speaking the results from the anticipated EERA-DTOC wake models fit well with the measured results from the Horns Rev wind farm

Invitation to workshop on
Offshore Wind Farm Clusters: Focus on Northern European Seas
London, UK, 6 June 2013 from 9.00 to 17.00

In line with the targets of the European Strategic Energy Technology Plan (SET Plan) of the European Commission, the offshore wind energy industry in Europe is to benefit by research and development by two large international projects co-funded by the European Union.

The projects are ***Cluster Design*** and ***EERA DTOC***.
The workshop is aimed at developers of offshore wind farm clusters, strategic planner and transmission system operators.

The workshop will include a series of presentations from the participants of Cluster Design and EERA DTOC. Keynote speakers: Peter Hauge Madsen (DTU Wind Energy), Rory Donnelly (3E), Mariano Faiella (IWES Fraunhofer), Elena Cantero (CENER), Gerard Schepers (ECN), Gregor Giebel (DTU Wind Energy), Pierre-Elouan Réthoré (DTU Wind Energy),

EERA DTOC is European Energy Research Alliance – Design Tools for Offshore Wind Farm Clusters
Venue: Renewable Energy Systesm (RES) in London

For further information, please visit our web-sites
FP7-ENERGY-2011-1/n°282797 EERA DTOC http://www.eera-dtoc.eu
FP7-ENERGY-2011-1/n°283145 Cluster Design http://www.cluster-design.eu/

Thank you very much for your attention