EERA DeepWind'2014
11'th Deep Sea Offshore Wind R&D Conference

Trondheim, 22 - 24 January 2014

EERA Design Tool for Offshore wind farm Cluster (DTOC)

PETER HAUGE MADSEN. Director

Charlotte Hasager. Senior scientist

DTU Wind Energy

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

Support by

SEVENTH FRAMEWORK PROGRAMME

Project partners

- DTU Wind Energy (former Risø)
- Fraunhofer IWES
- CENER
- ECN
- EWEA
- SINTEF
- ForWind
- CRES
- CIEMAT
- University of Porto
- University of Strathclyde
- Indiana University
- CLS
- Statkraft
- Iberdrola Renovables
- Statoil
- Overspeed
- BARD
- Hexicon
- Carbon Trust
- E.On
- RES

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"Design Tool for Offshore wind farm Clusters" is the first EERA project.
EERA is based on national science activities.

EERA – European Energy Research Alliance

Background: The EERA JP Wind Energy was officially launched at the SET-Plan conference in Madrid in June 2010. The strategy and main activities of the JP is described in the "Strategic Action Plan" (yearly updated).

The programme vision is:

- to provide strategic leadership for the scientific–technical medium to long term research
- to support the European Wind Initiative and the Technology Roadmap's activities on wind energy, and on basis of this
- to initiate, coordinate and perform the necessary scientific research.

Joint Programme and Sub-programmes
Wind Conditions. Coordinated by Prof. Erik Lundtang Petersen, DTU Wind Energy (DK)
Aerodynamics. Coordinated by Dr. Peter Eecen, ECN (NL)
Offshore Wind Energy. Coordinated by Dr. John O. Tande, SINTEF (NO)
Grid Integration. Coordinated by Dr. Kurt Rohrig, FhG IWES (DE)
Research Facilities. Coordinated by Dr. Pablo Ayesa Pascual, CENER (ES)
Structural design and materials. Coordinated by Dr. Denja Lekou, CRES (GR)

EERA DTOC funding from EC FP7

Topic ENERGY.2011.2.3-2:
Development of design tools for Offshore Wind farm clusters

Open in call*: *FP7-ENERGY-2011-1
Funding scheme: Collaborative project

- EERA DTOC is 3.5 years: January 2012 to June 2015
- Budget is 4 m€ hereof 2,9 m€ from EC

- Parallel project is ClusterDesign coordinated by 3E

FP7: Expected impact

- To contribute to the SET-Plan on the development of offshore wind power.

- To demonstrate the capability of designing virtual wind power plants composed of wind farms and wind farm clusters while minimizing the negative spatial interactions, improving the overall power quality output and providing confidence in energy yield predictions.

ENERGY.2011.2.3-2: Call objective

The objective of this topic is to develop new **design tools** to optimise the exploitation of individual wind farms as well as wind farm clusters, in view of transforming them into virtual power plants.

Such design tools should integrate:

- Spatial modelling: medium (within wind farms) to long distance (between wind farms) **wake effects**
- **Interconnection optimisation**: to satisfy grid connection requirements and provide power plant system service.
- **Precise energy yield** prediction: to ease investment decisions based on accurate simulations

The project should focus on offshore wind power systems and **make optimal use of previously developed models**.

ENERGY.2011.2.3-2: Call objective

EERA DTOC Work Packages (WP)

DTOC

The objective of this topic is to develop new **design tools** to optimise the exploitation of individual wind farms as well as wind farm clusters, in view of transforming them into virtual power plants.

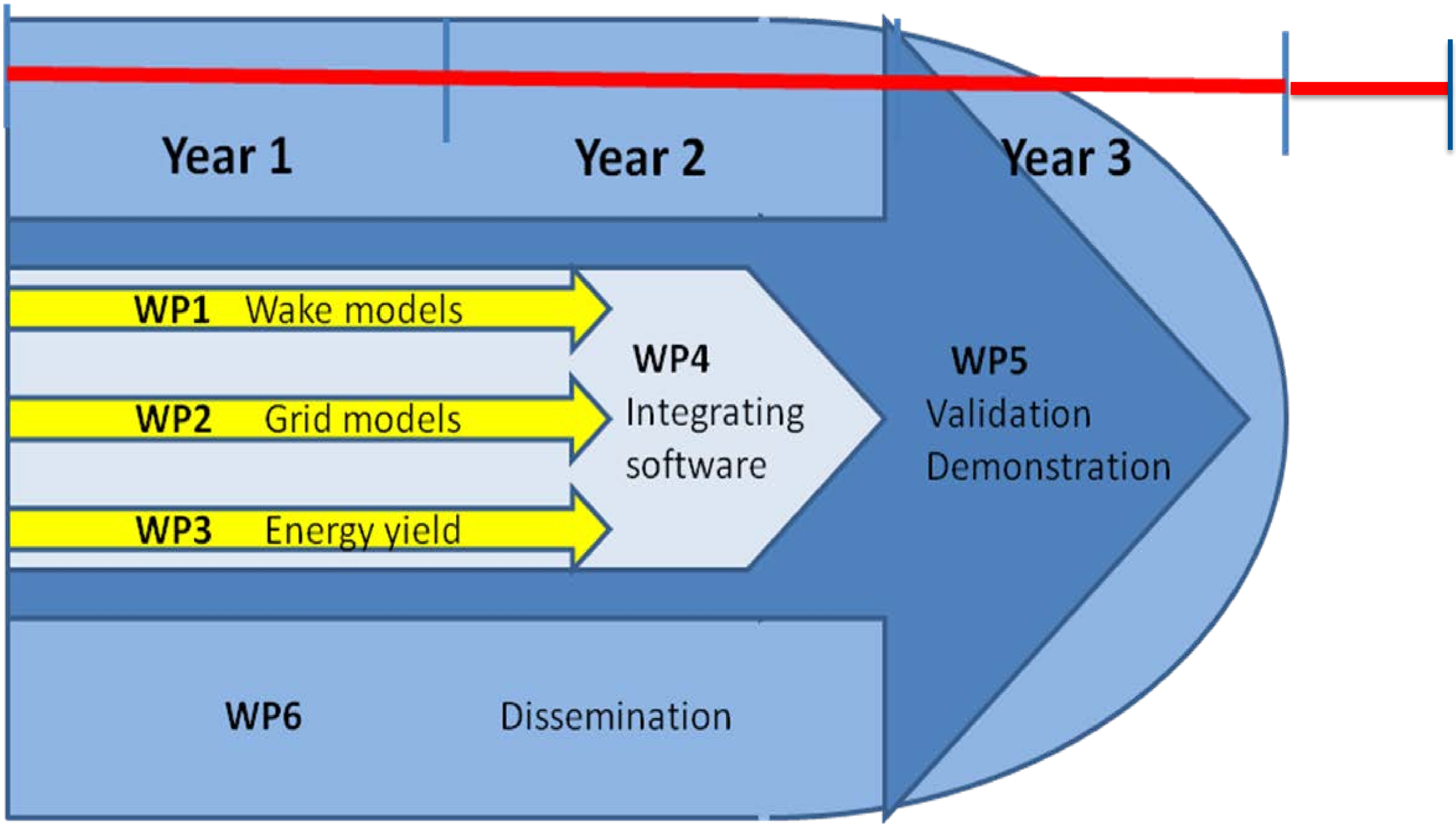
Such design tools should integrate:

- Spatial modelling: medium (within wind farms) to long distance (between wind farms) **wake effects** **WP1 wake**
- **Interconnection optimisation**: to satisfy grid connection requirements and provide power plant system service **WP2 grid**
- **Precise energy yield** prediction: to ease investment decisions based on accurate simulations **WP3 yield**

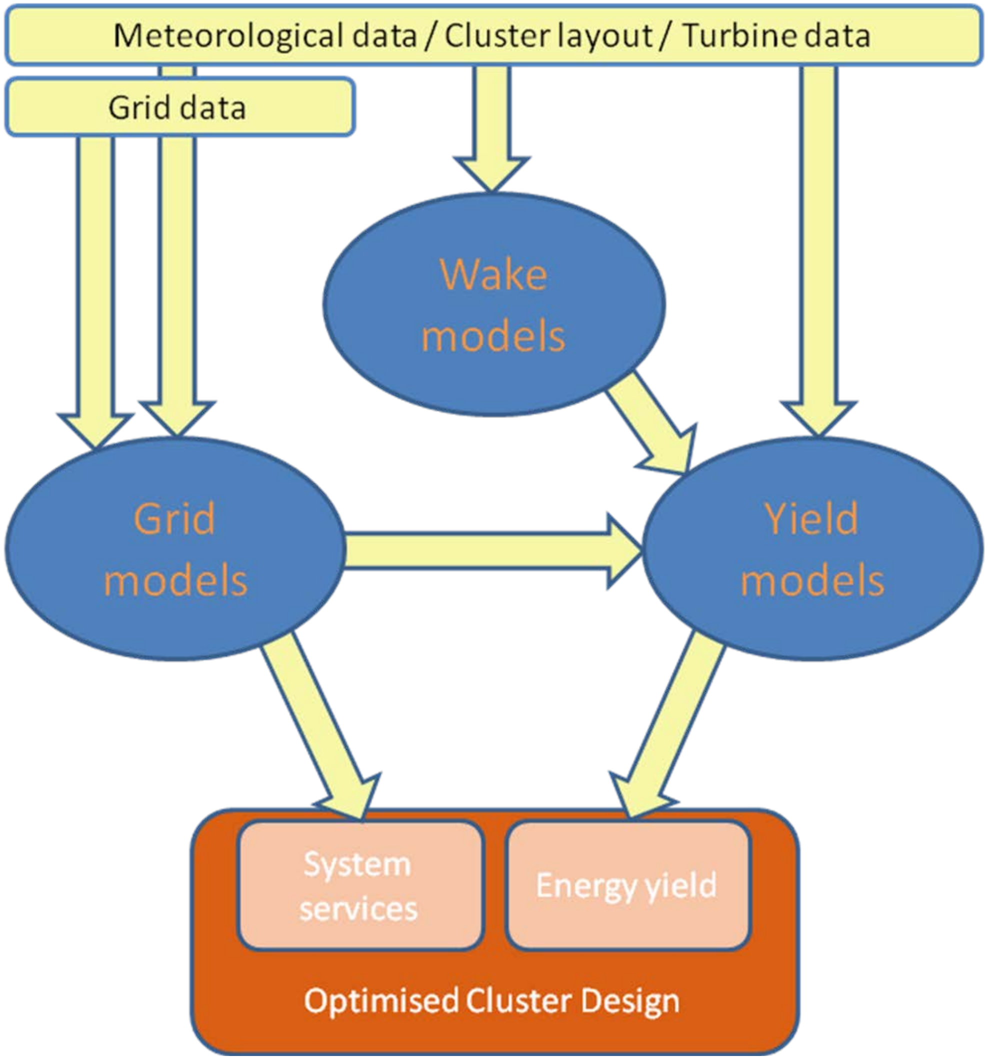
The project should focus on offshore wind power systems and **make optimal use of previously developed models**.

WP4 tool and WP5 demo

WP structure



EERA DTOC concept



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

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	+	

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Run on Windows, on a single PC

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Runs on Cluster under UNIX/Linux

User Requirements

Users

Design and model selection guided by end-users

Two **main user groups** were identified:

- Strategic planners
- Developers of offshore wind farms

Associated users could be:

- Consultants
- Research institutions
- Manufacturers
- System Operators

Selected user stories

- As a developer I can determine the wake effects of neighbouring wind farm clusters on a single wind farm.
- As a developer I can determine the optimum spacing, position, turbine model and hub height of turbines within an offshore wind farm.
- As a strategic planner I can determine the optimum strategic infrastructure to accommodate offshore wind farm clusters.
- *14 relevant user stories in total*

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

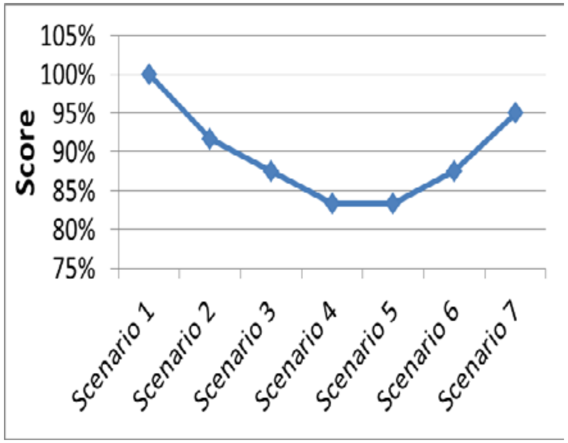
1. Generate Design Options

- 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

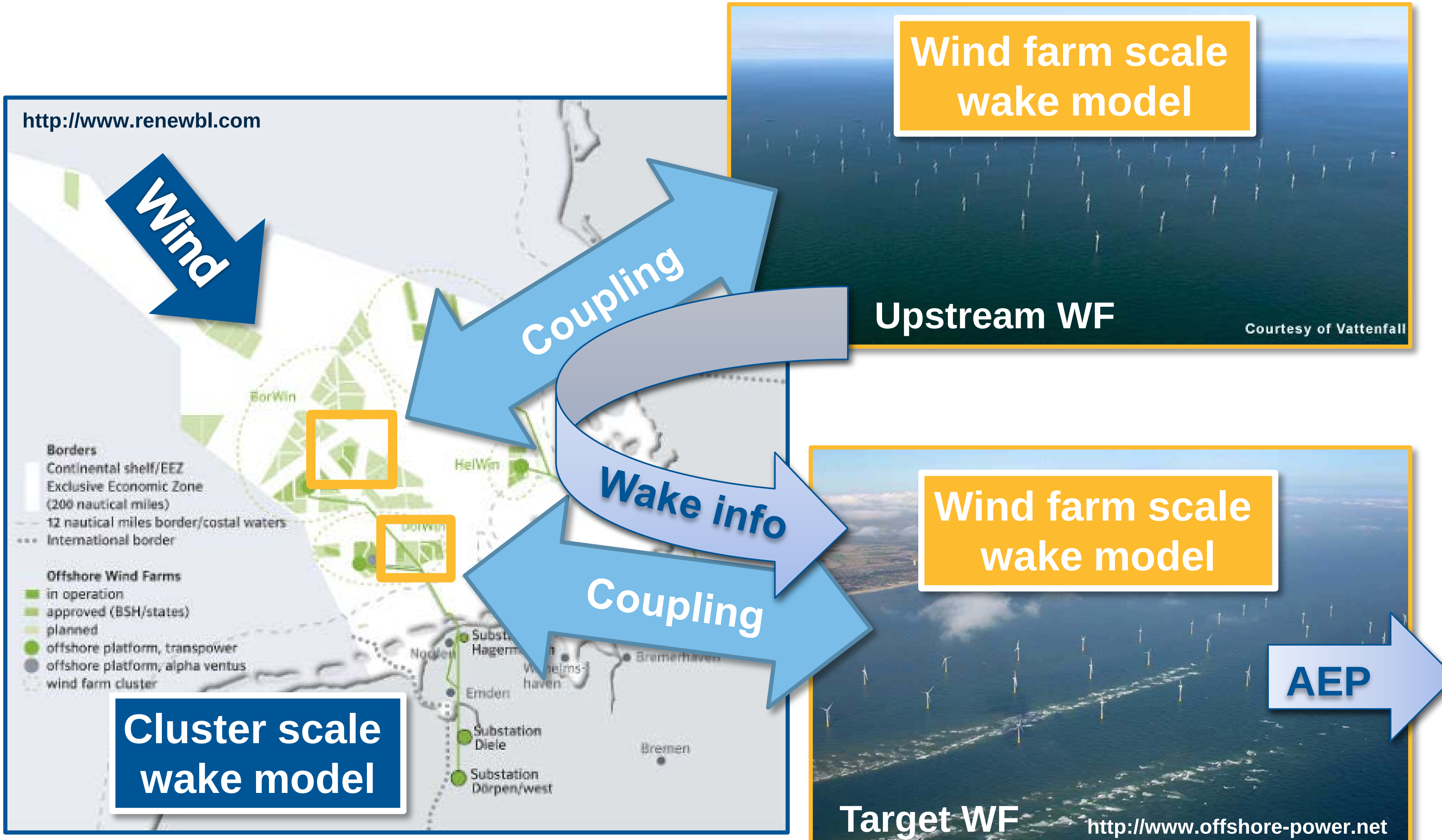
Score: Levelized cost of energy

What decision parameter can we use to compare design options?

EERA DTOC 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.

Introduction
The “big wake” picture



Wind farm scale wake models

DTU
- DWM
- FUGA
- GCL
- NOJ

INDIANA UNIVERSITY
- WASP / NOJ

U.PORTO
- RANS

CRES
- CRES flowNS

res power for good
- Ainslie

ECN
- FarmFlow

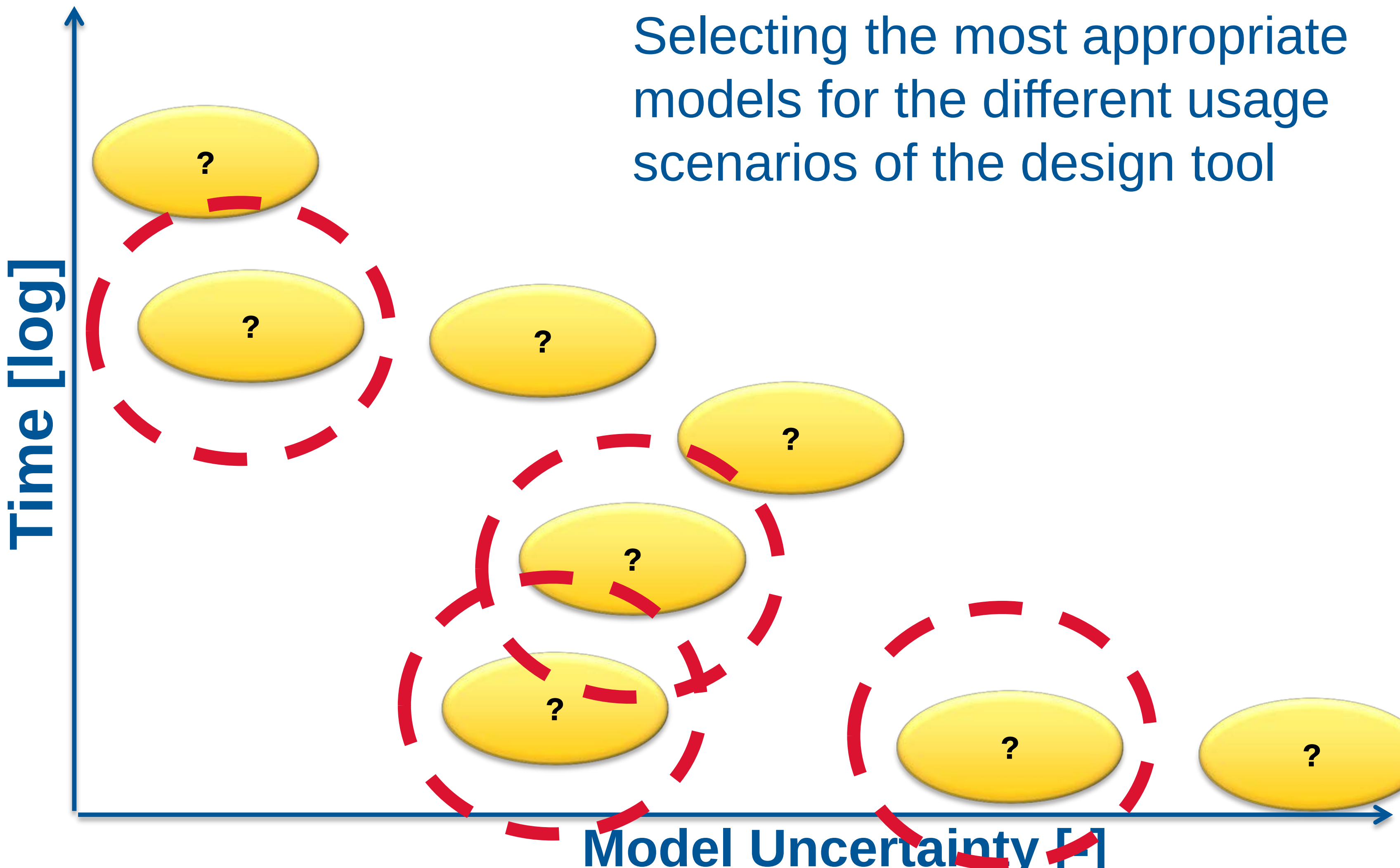
Enginneering

Simplified CFD

Full CFD

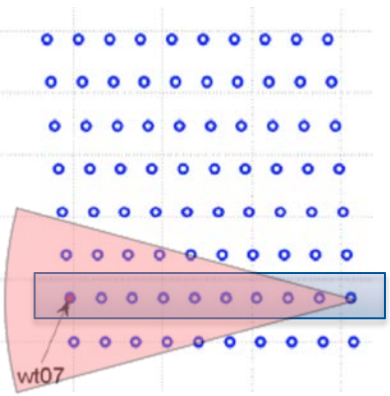
Benchmarking purpose

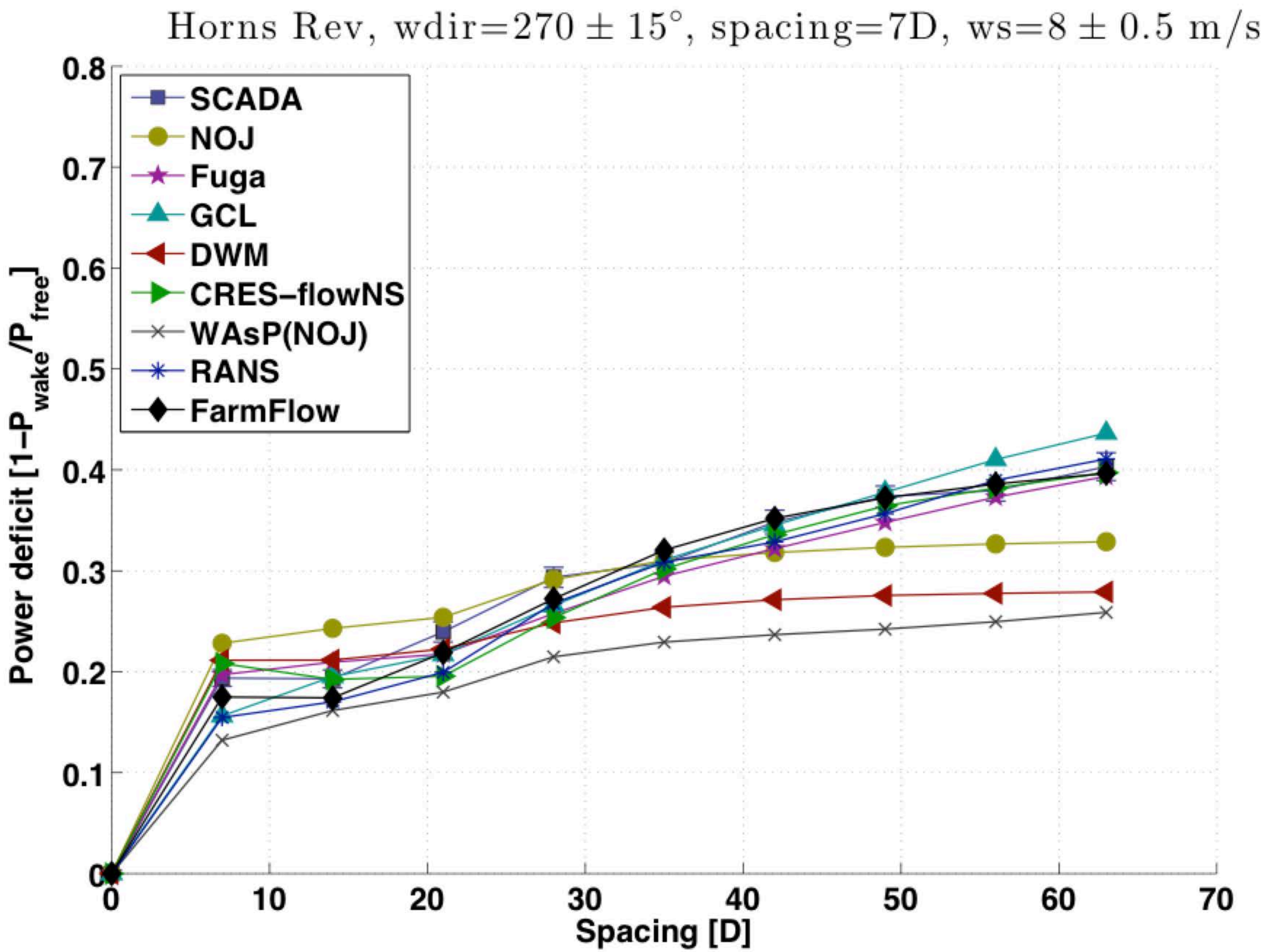
Selecting the most appropriate models for the different usage scenarios of the design tool



Horns Rev 1 benchmark (DONG energy & Vattenfall)
Lillgrund benchmark (Vattenfall)

Example:
Power deficit
along one row



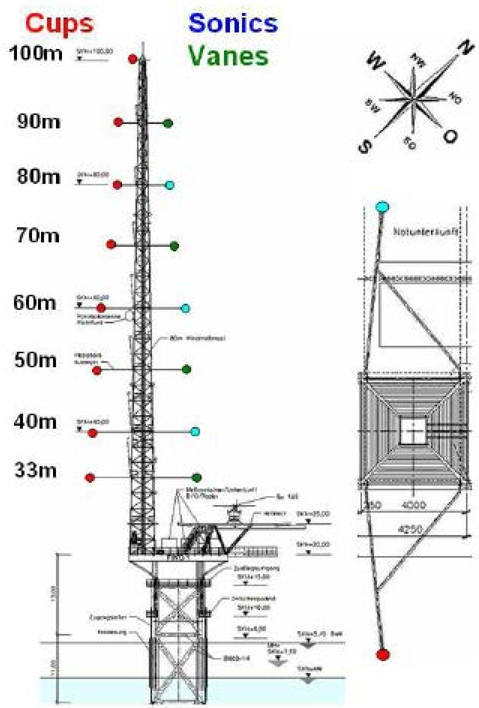


Gross energy : FINO-1 test case (BMU)

- Wind speed and direction data (10 minutes)

  From 13/01/2005 to 30/06/2012 (total of 7.5 years data)

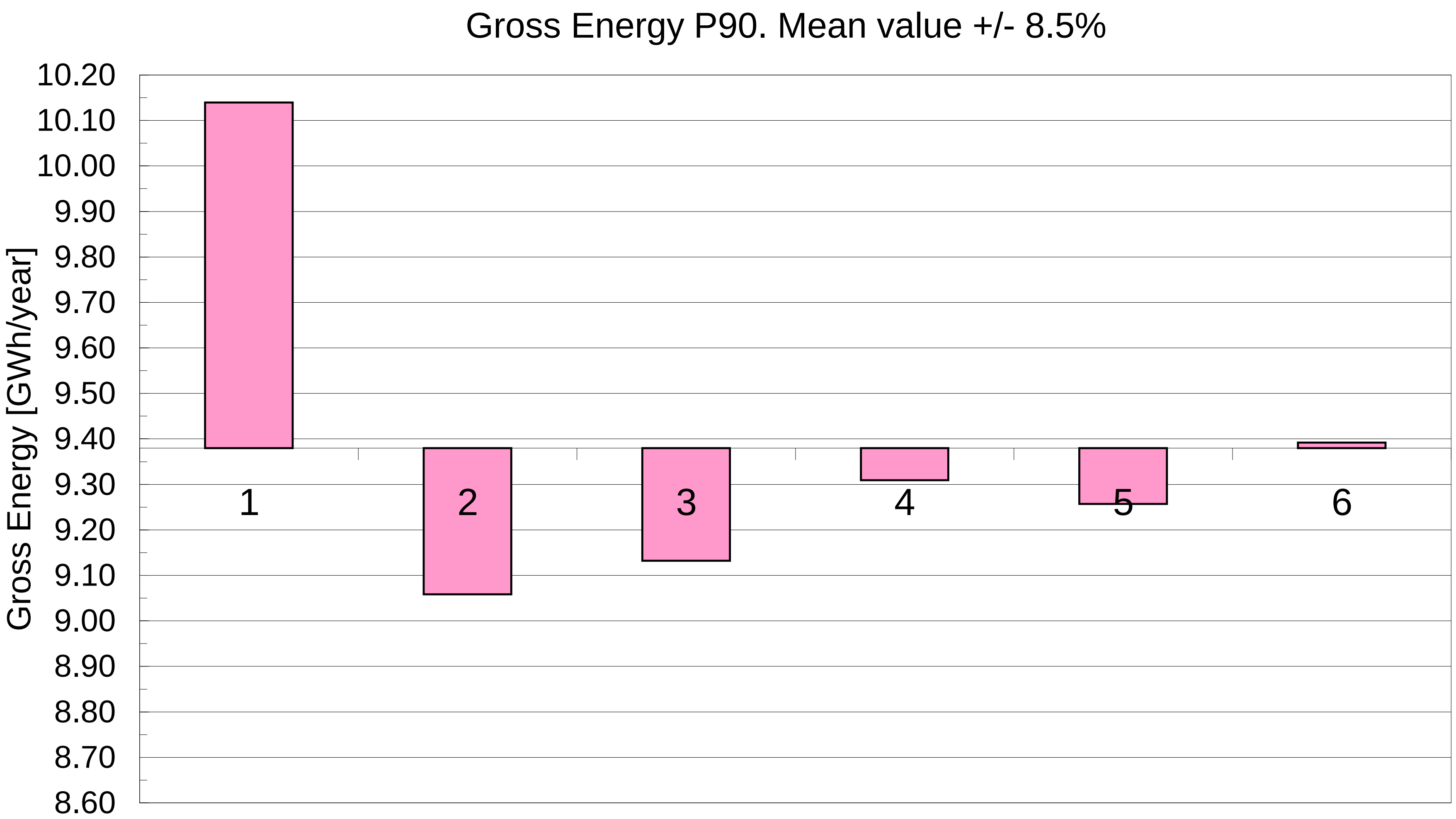
  (Generic power curve (1.225 kg/m^3))



Gross energy – output parameter checks

- Mean wind sped (before filtering)
- Mean wind speed (after filtering)
- Long term mean wind speed, free decision
- Vertical extrapolation between 100m and 120m
- Gross energy P50
- Gross energy P90

Gross energy P90



O&M losses

- Offshore Wind Farm
  - o Inputs
    - o Turbine layout and turbine model
    - o Site wave climate
    - o Location of O&M base (from 10 to 150 km)
    - o O&M strategy
  - o SWARM software

Wave Climate Scenario	Description	Mean Wind Speed at 100m [m/s]	% of Time Above Hs Limit	
			1.5 meters	2.0 meters
1	Benign Climate	9.0	16.5%	6.3%
2	Moderate Climate	9.4	21.0%	7.4%
3	Severe Climate	9.5	28.3%	12.6%

Scenario	Number of Workboats	Number of Helicopters	Wave Hs Limit for Boats [m]
1	5	0	1.5
2	5	0	2.0
3	5	2	2.0

EERA DTOC

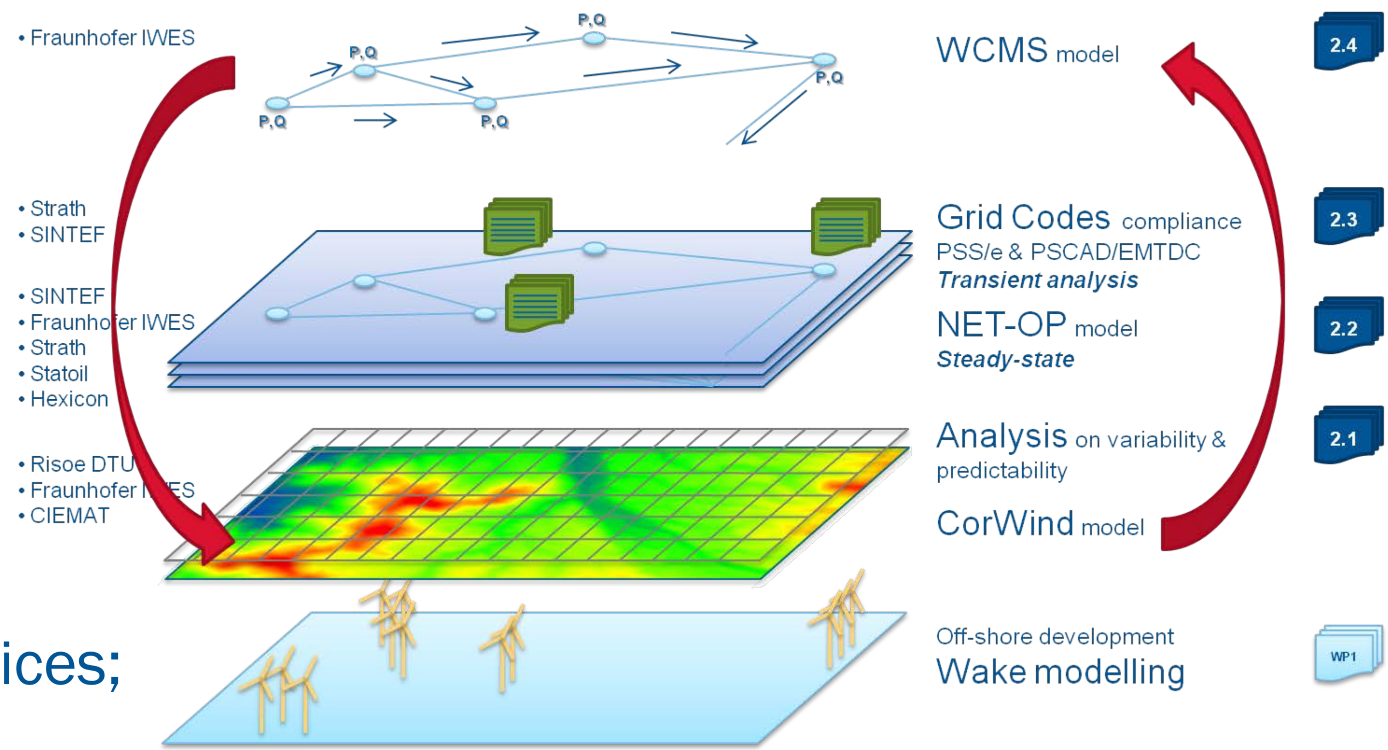
Aims of grid layout optimization

- Design tool and procedure assisting the optimization of the electrical design;

- Clustering;

- Grid code compliance;

- Power plant ancillary services;

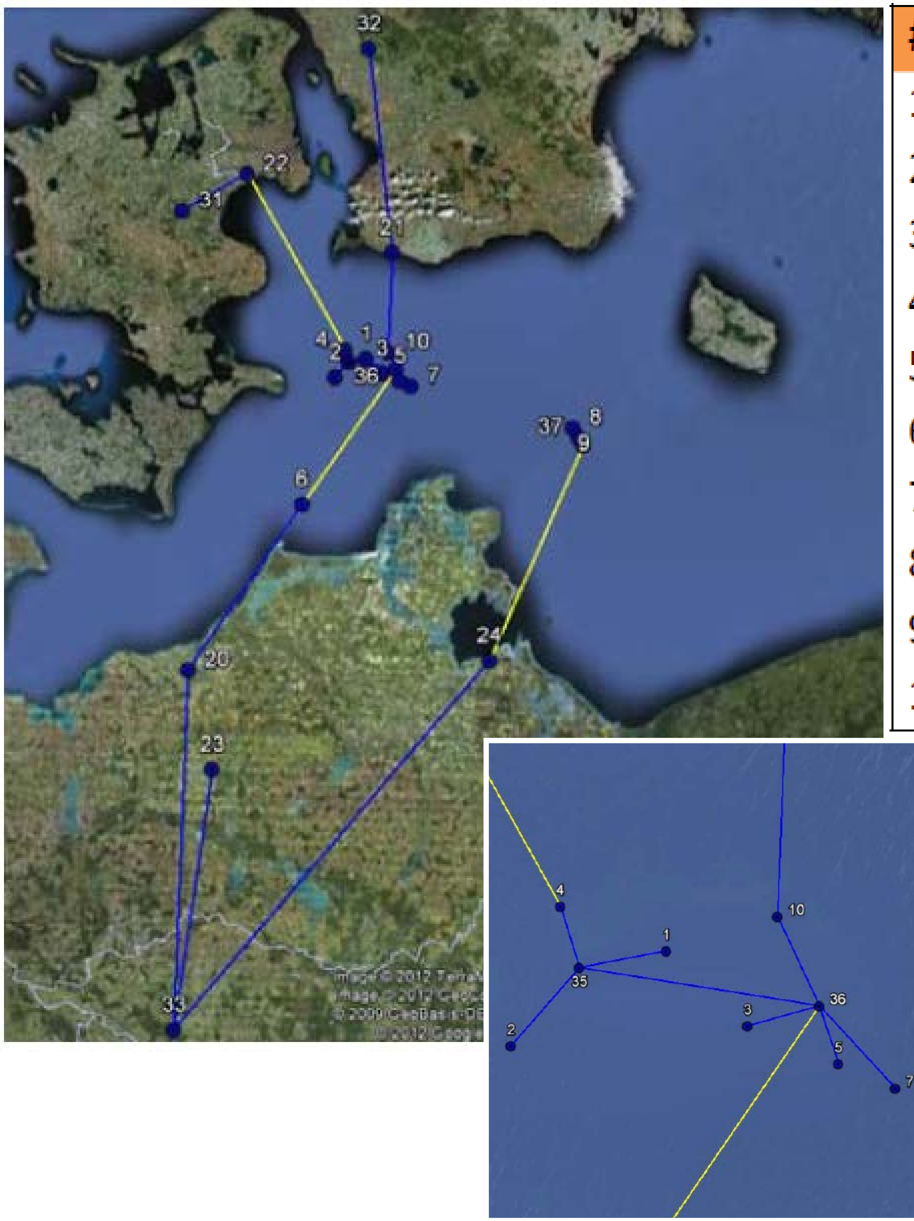


- Evaluate impact of the variability and the predictability.

Methodology

1. Determine the models chain, interactions, I/O;
2. Establish the data flow/ data gaps according to the user cases;
3. Procedure to fill overcome gaps was investigated:
   1. Automatic electrical data generation
   2. User intervention providing accurate data.
   3. Implementation of a new module
4. Dry runs (based on scenarios)
5. Assessment/ convenience evaluation

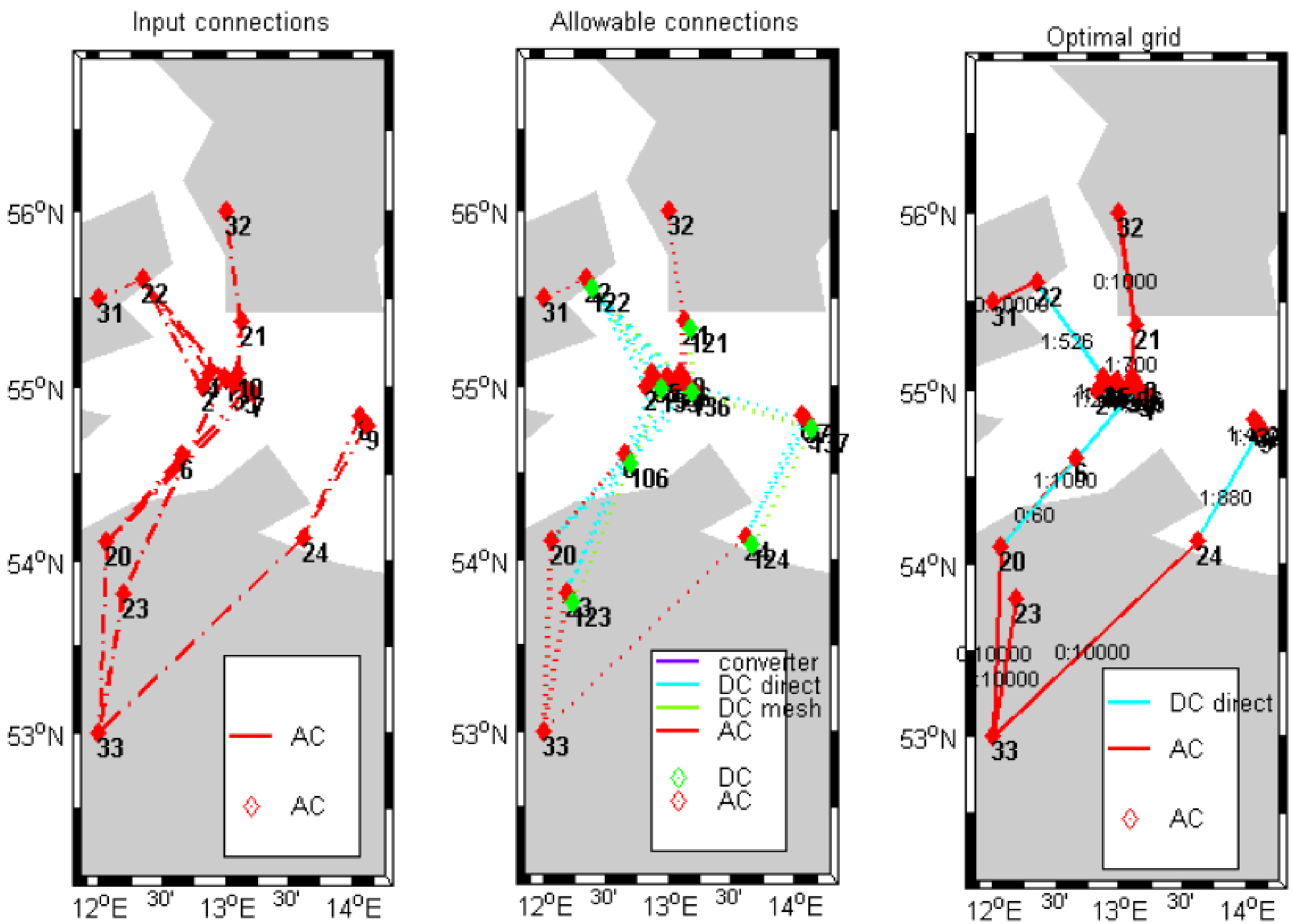
Kriegers Flak case study



#	Country	Wind farm	Capacity
1	DK	Kriegers Flak A K2	200
2	DK	Kriegers Flak A K3	200
3	DK	Kriegers Flak A K4	200
4	DK	Kriegers Flak B K1	200
5	DE	EnBW Baltic 2	288
6	DE	EnBW Baltic 1	48
7	DE	Baltic Power	500
8	DE	Wikinger	400
9	DE	Arkona Becken Südost	480
10	SE	Kriegers Flak	640

Branch type	max distance	max power
AC	65 km	700 MW
DC-direct		1000 MW
DC-mesh		1000 MW
converter		1000 MW

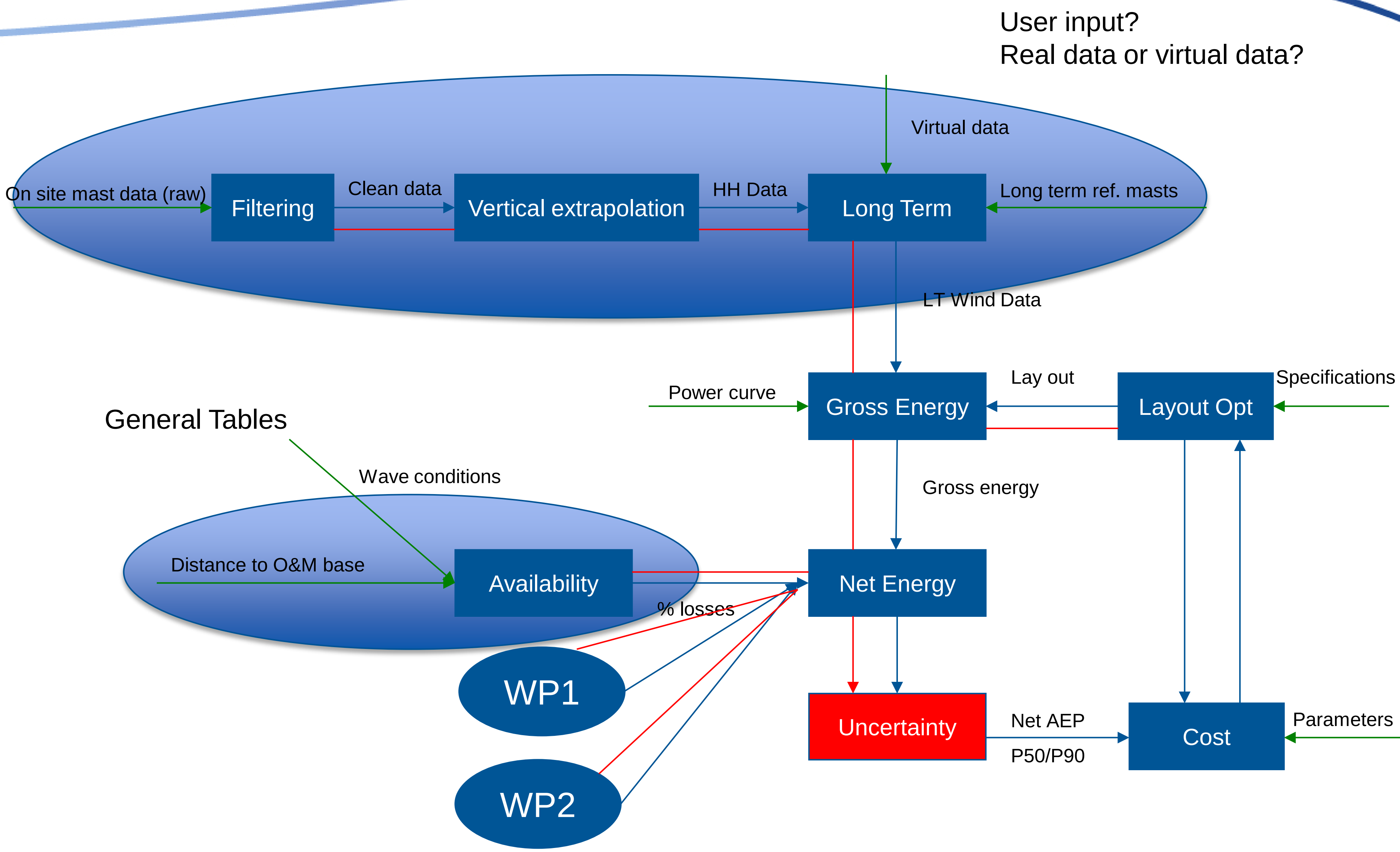
Kriegers Flak case study results



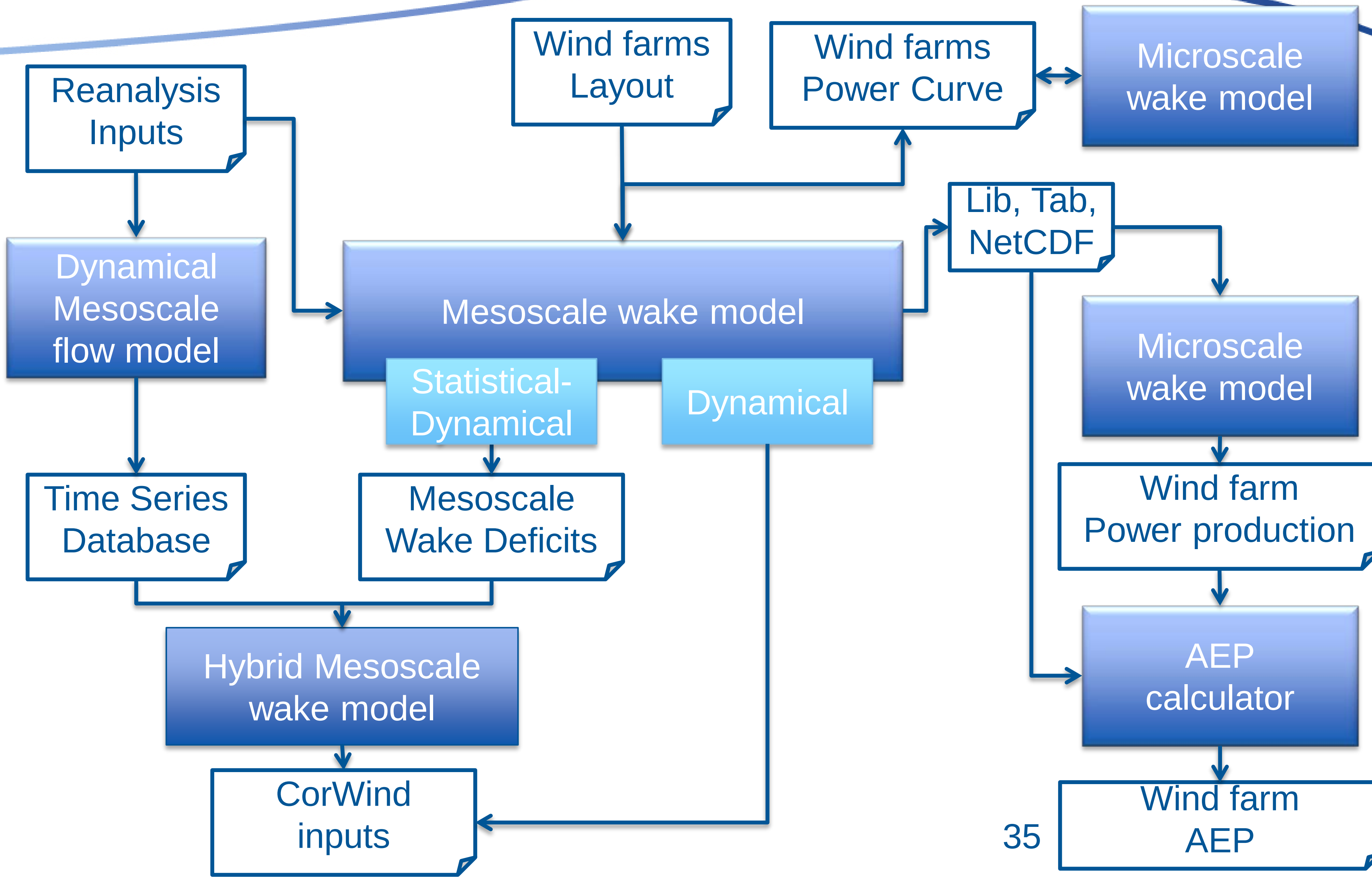
Expected achievements

- Checking planned grid:
  - Fulfillment of full load flows → calculate component utilization factors.
  - Fulfillment of certain average load flows situations.
  - Checking congestions and voltages.
  - Control power:
    - Power reserve
    - Balancing power
  - Voltage control
  - Enabling market/ transport

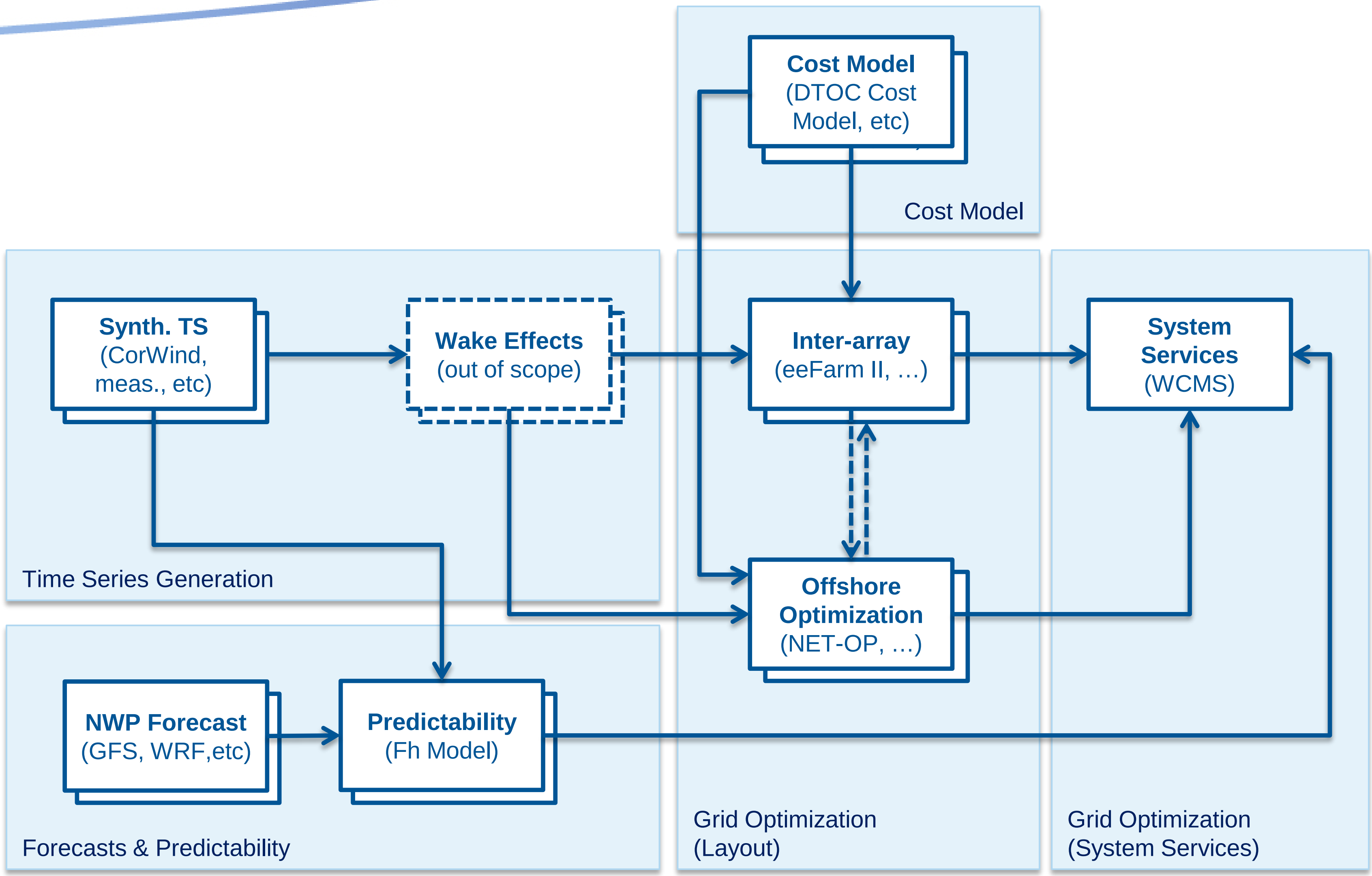
Model workflow energy yield (WP3)



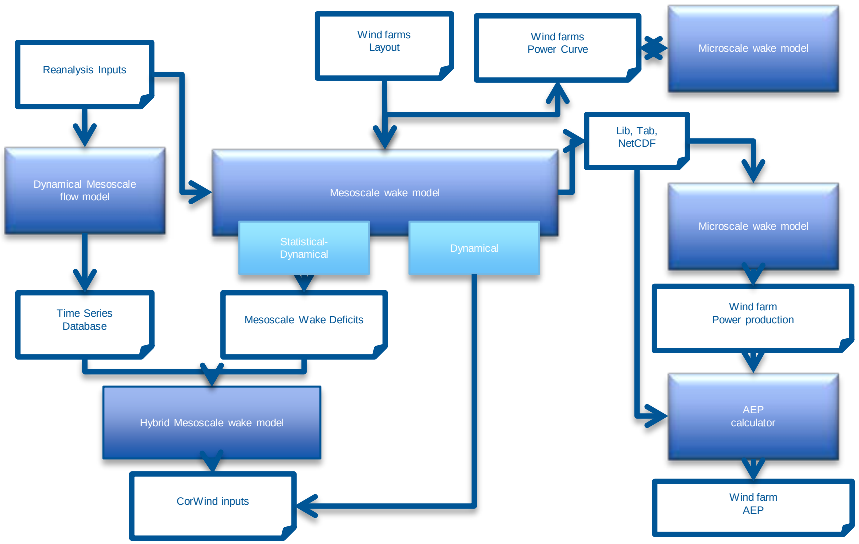
Model workflow wake (WP1)

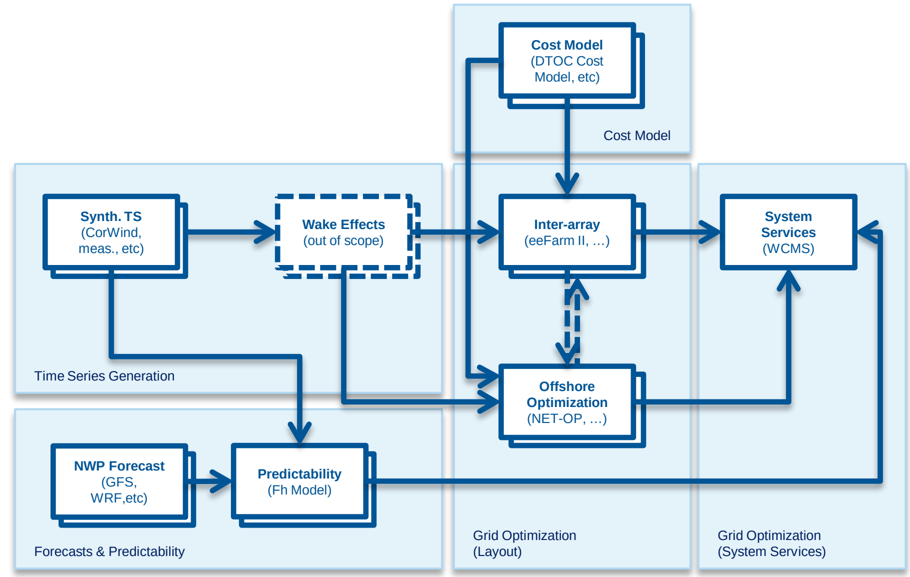


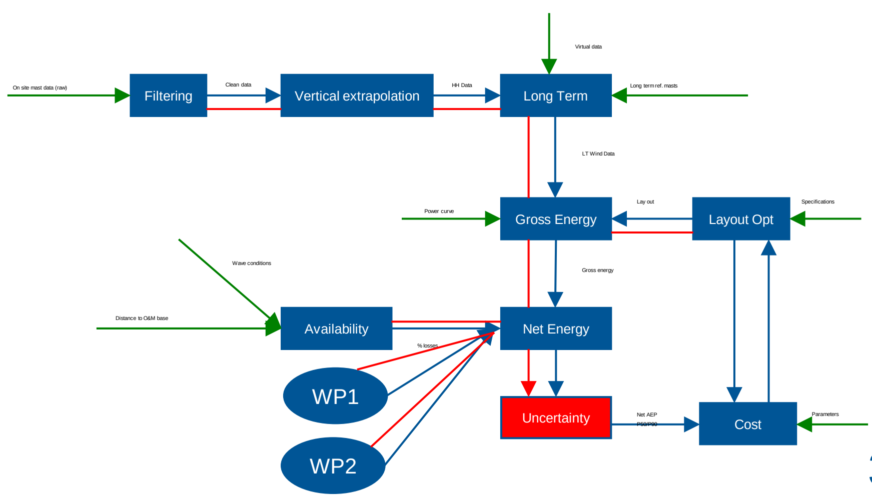
Model workflow "Electrical" (WP2)



Total tool overview – very complex!





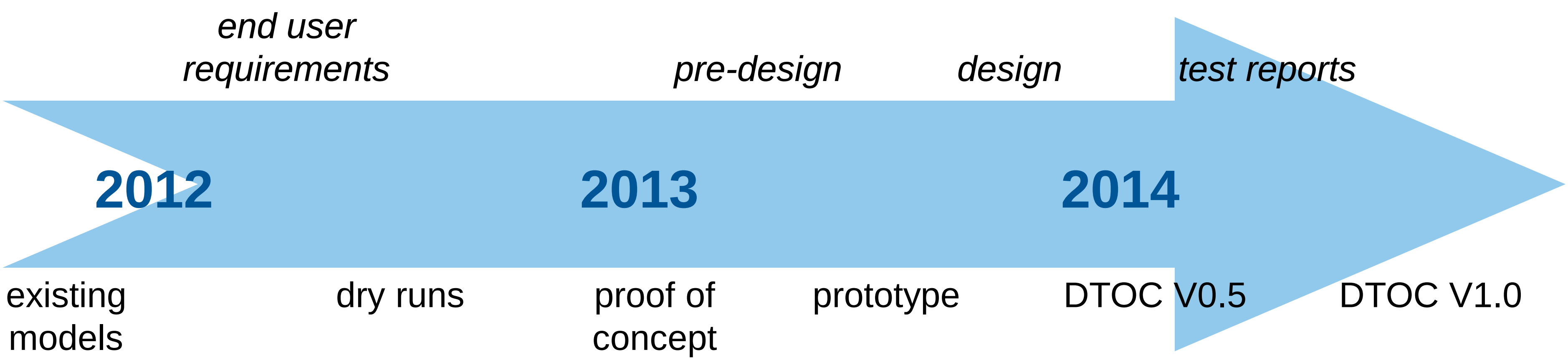


Open interfaces

- The sub-models are protected by IPR…
- …but the interfaces in the model chain are going to be open

- File formats for data exchange are based on existing industry standard formats, e.g. the WAsP types based on XML and ESRI shape file standard

DTOC software development timeline

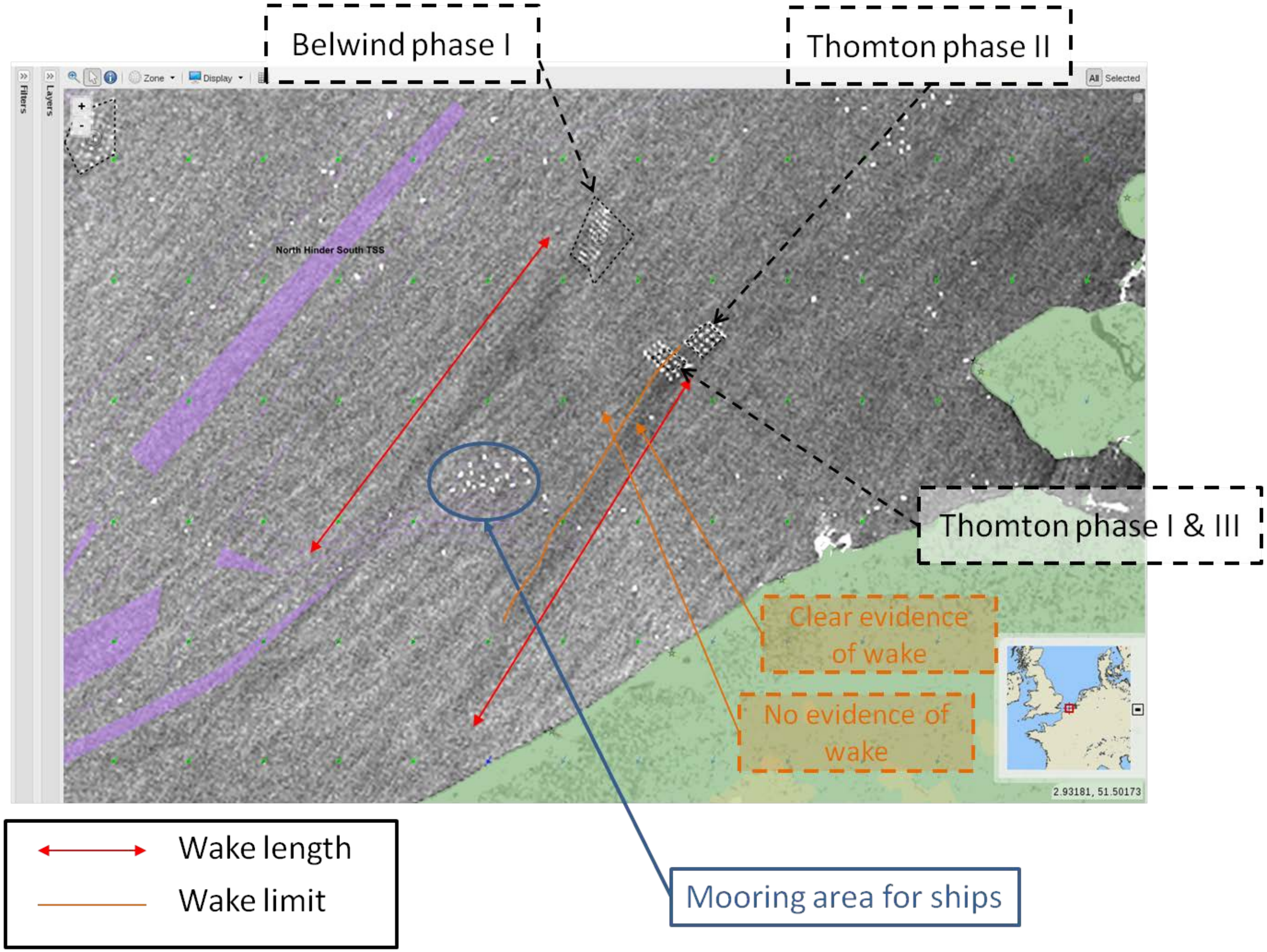


Validation and demonstration

Rødsand 2 data (E.On)

10 minute statistical data from meteorological mast and Rødsand 2 turbines
(No data from neighbouring Nysted farm)

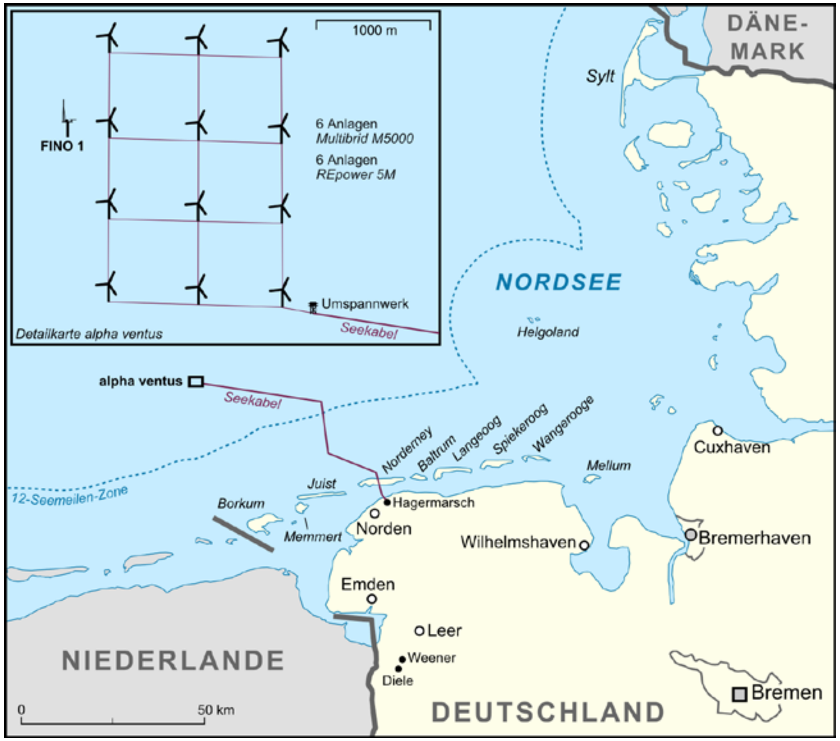
SAR satellite images (CLS, DTU)



Lidar measurements (ForWind & Fraunhofer IWES)

- Long range wind scanner measurements from fixed positions
- Ship based LIDAR measurements

- EERA DTOC partners requested
- Alpha Ventus SCADA data



Scenarios

Industry partners are very important!

Iberdrola, Statoil, Carbon Trust, Hexicon, Statkraft, E.On, RES

Purpose of the scenarios

- The tool should fullfill the previously defined user requirements:
  - The tool should be useful, easy to use, complete and robust
- Functionality of all modules in EERA DTOC should be proven → All parts of the tool should be activated during the scenarios
- Inventory of user experiences:
  - How steep is the learning curve?
  - Which tutorials should be added ?
- The results should LOOK realistic from an expert point of view

EERA DTOC web www.eera-dtoc.eu

EERA DTOC

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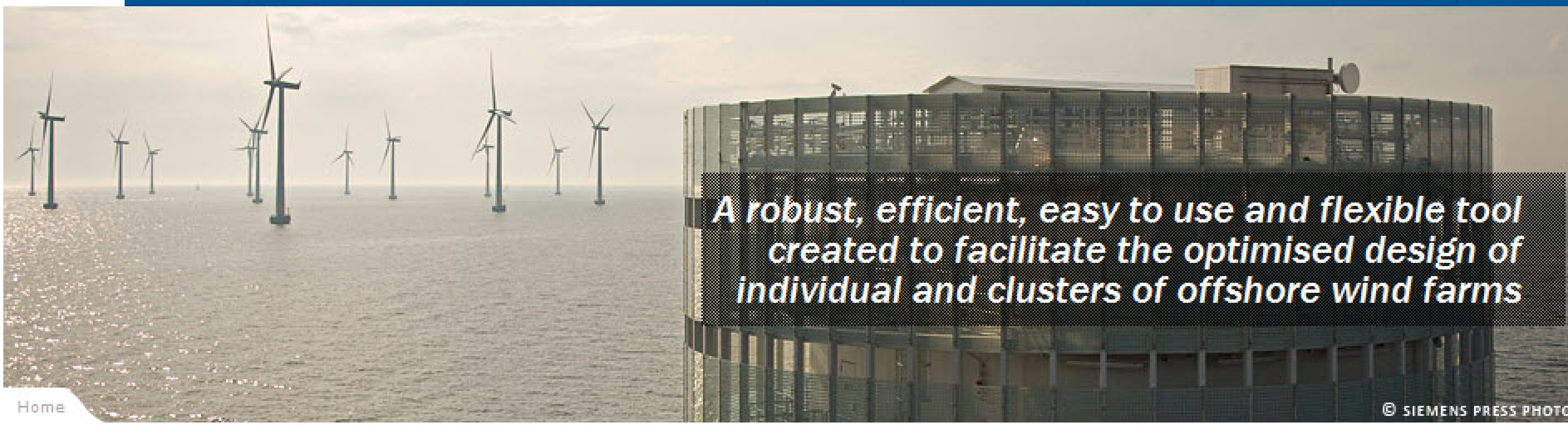

What is EERA-DTOC?

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 – and runs from January 2012 to June 2015. It is coordinated by the Technical University of Denmark - DTU Wind Energy. The concept of the **EERA-DTOC** project is to combine this expertise in a common integrated software tool for the optimized design of offshore wind farms and wind farm clusters acting as wind power plants.

Deliverables

- 7th Framework

Thank you very much for your attention

EERA DTOC

Support by

EERA DTOC project
FP7-ENERGY-2011-1/ n°282797