

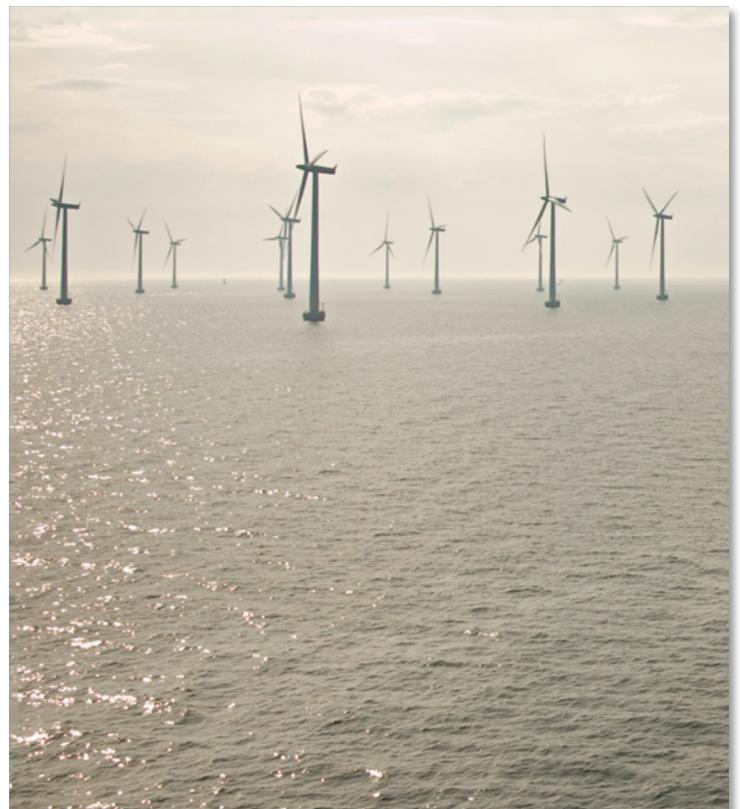
Wind Farms Design and Optimization

Presentation of **TOPFARM** and **EERA-DTOC**

Dr. Pierre-Elouan Réthoré
Senior Researcher

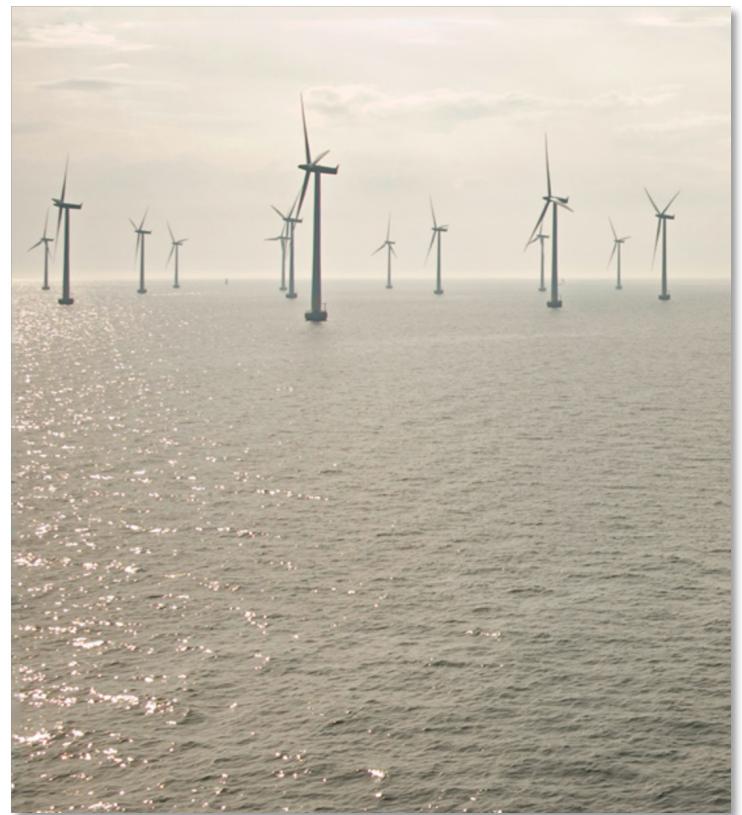
Aero-Elastic Design Section
DTU – Wind Energy, Risø

DTU Wind Energy
Department of Wind Energy



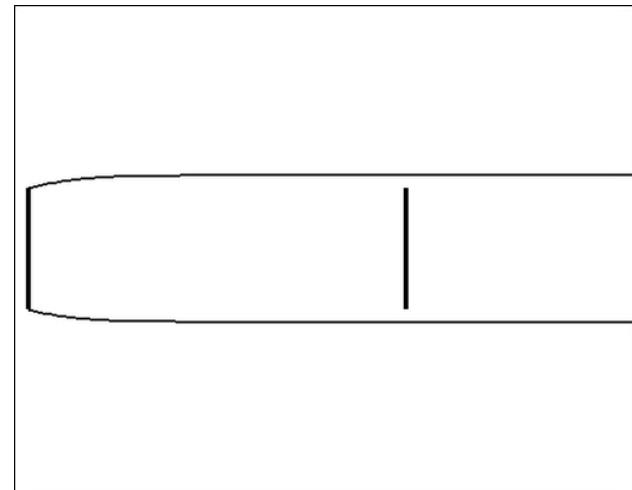
Outline

- Background
- TOPFARM
 - Main Ideas
 - System Overview
 - Some Results
 - Feedbacks from the industry
- Unified Framework
- TOPFARM II
 - Main Ideas
 - System Overview
- EERA-DTOC
 - Main Idea
 - System Overview
- Conclusions



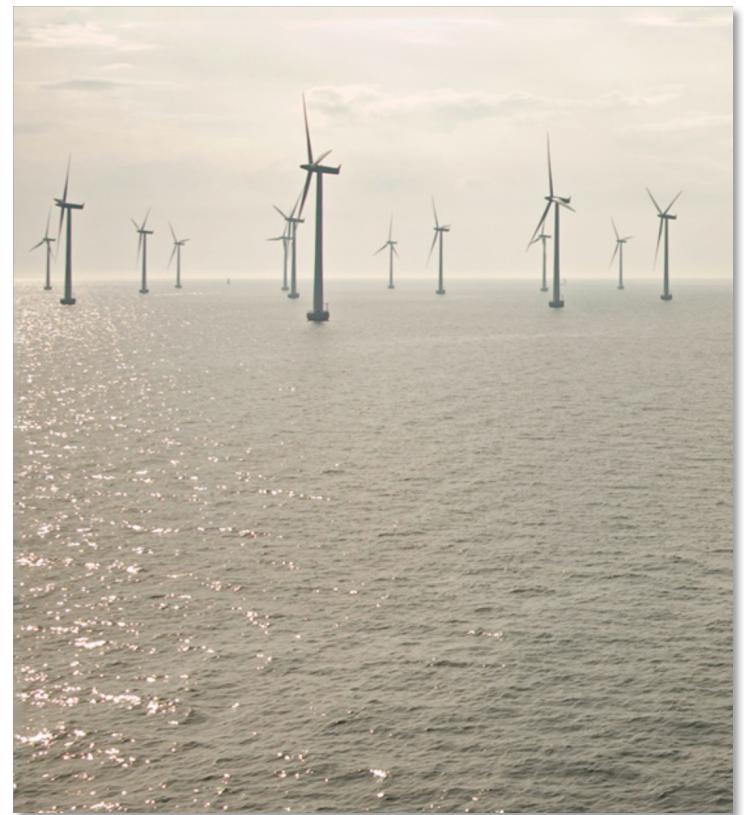
Background

- Aero-Elastic Design Section is principally interested in wind turbine design
- Wind turbines design depends of inflow inputs (upstream wakes)
- Dynamic Wake Meandering (DWM) can calculate wake induced loads
- Other wake models can calculate power production (e.g. FUGA)
- How can we introduce these tools together into wind farm design?



Outline

- Background
- TOPFARM
 - Main Ideas
 - System Overview
 - Some Results
 - Feedbacks from the industry
- Unified Framework
- TOPFARM II
 - Main Ideas
 - System Overview
- EERA-DTOC
 - Main Idea
 - System Overview
- Conclusions



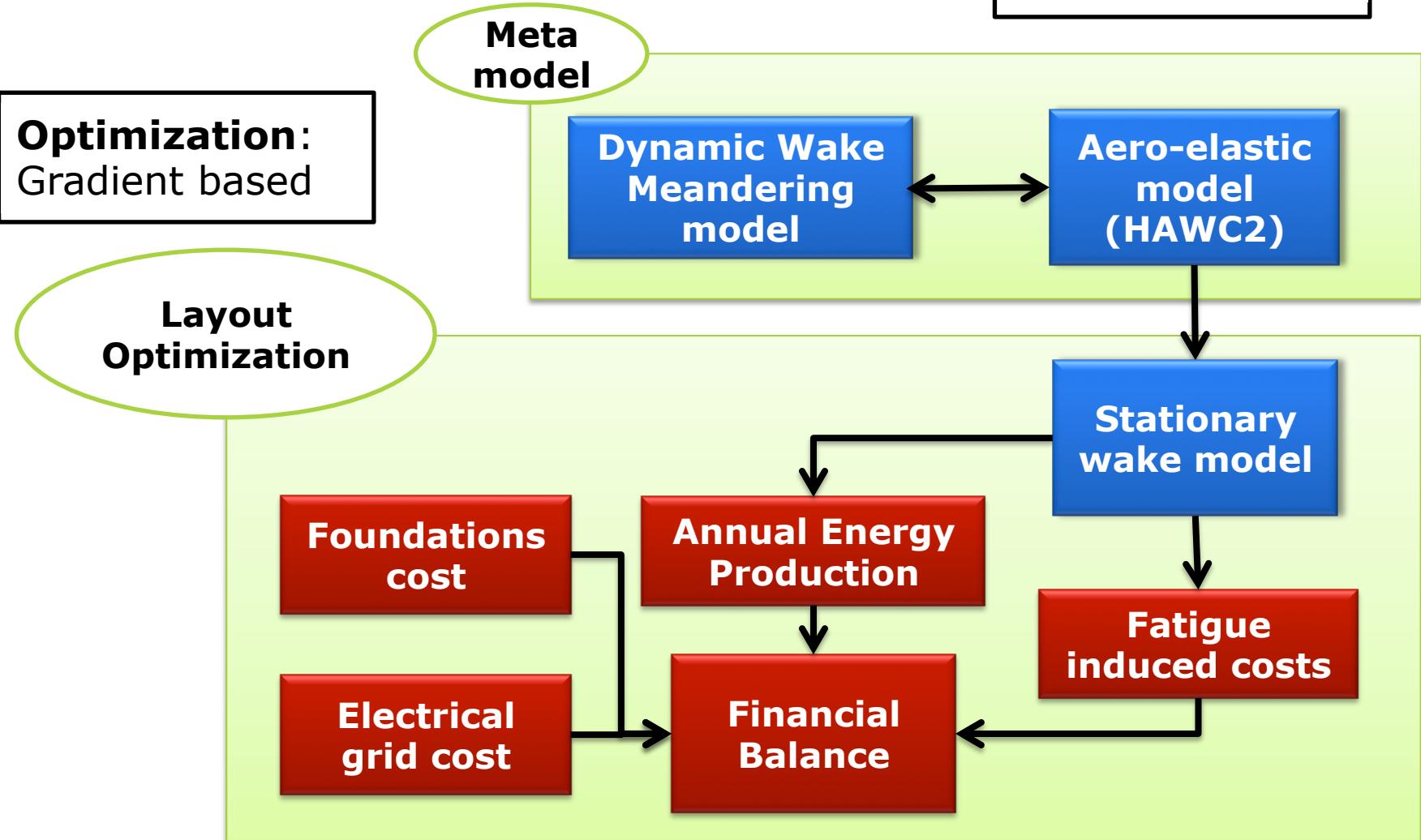
TOPFARM

Main Idea

- **TOPFARM** = Topology **O**Ptimization of wind **FARM**
- **EU-FP6** Funded project 2006-2010
- **Multi-fidelity** framework for wind farm layout optimization
- Optimization from the **wind farm developer** perspective
- Objective function is the wind farm lifetime **financial balance**
- The cost models take into account:
 - Wake effects on power production
 - Wake effects on wind turbines components fatigue
 - Offshore foundation costs
 - Electrical grid cabling
 - Financial parameters

TOPFARM System Overview

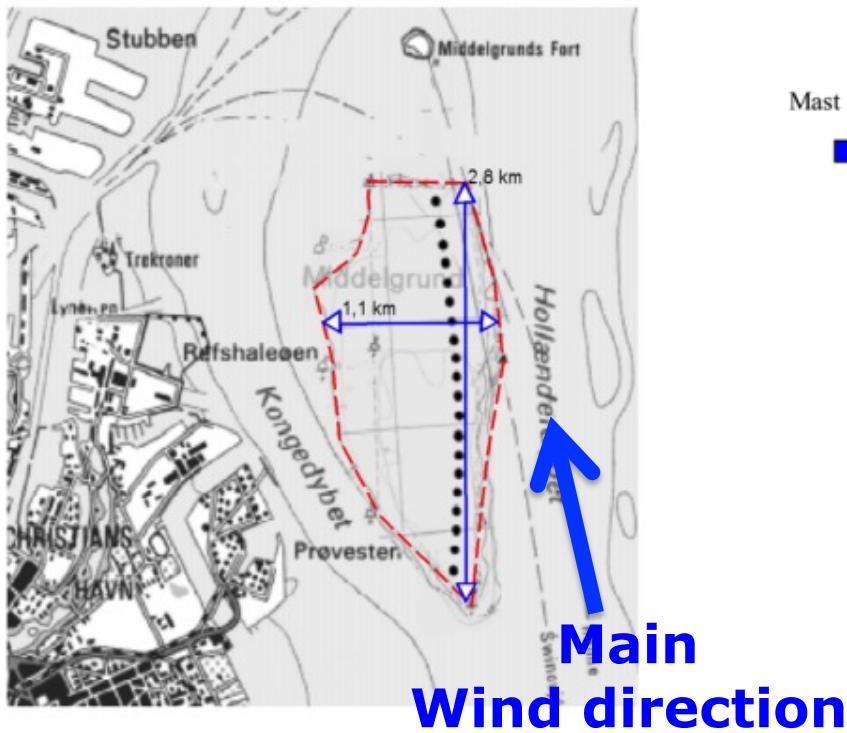
Multi-fidelity:
2nd Level



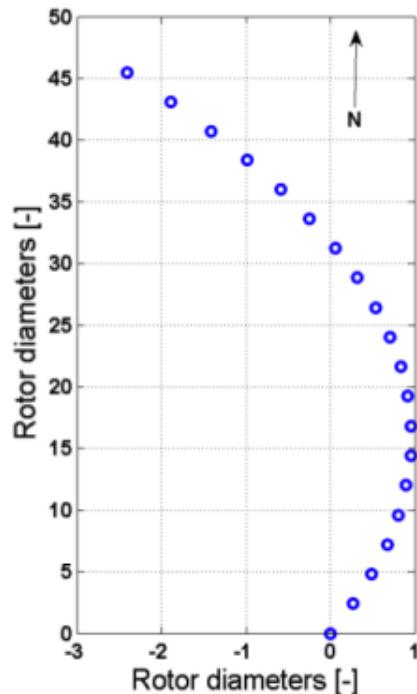
TOPFARM

Demonstration example

- Middelgrunden



Allowed wind turbine region

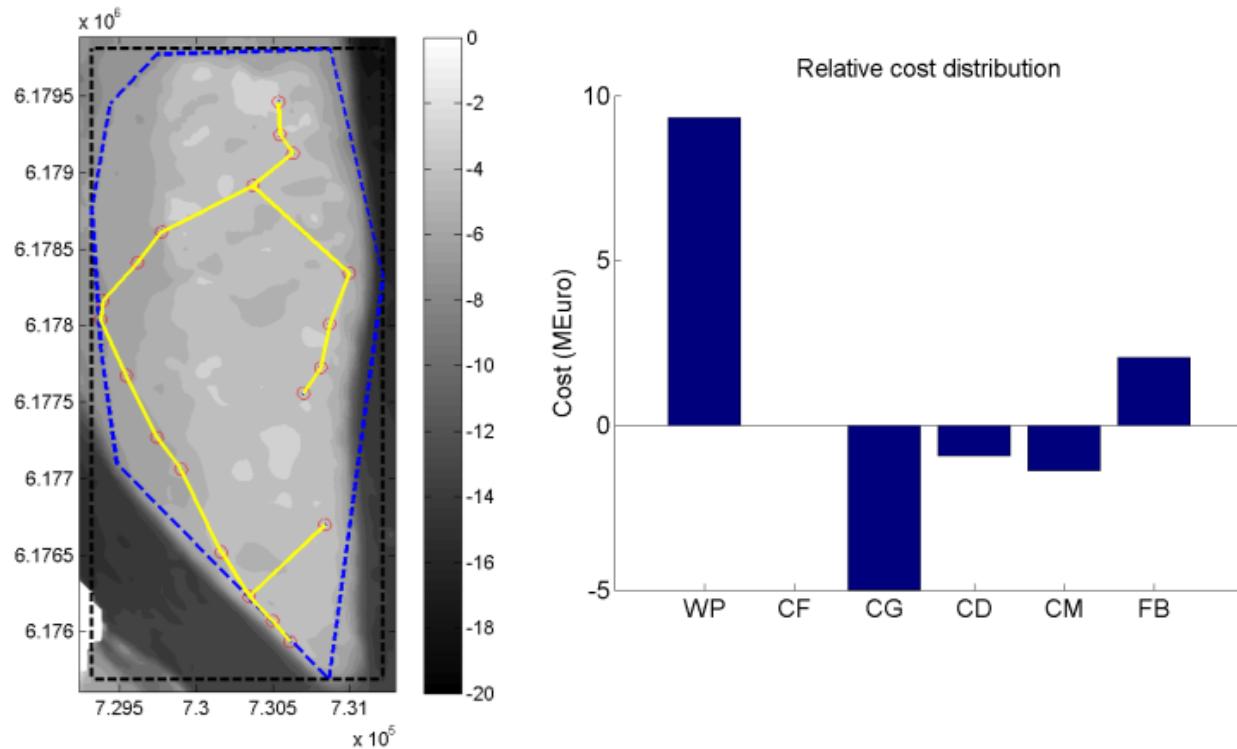


Middelgrunden layout

TOPFARM

Demonstration example

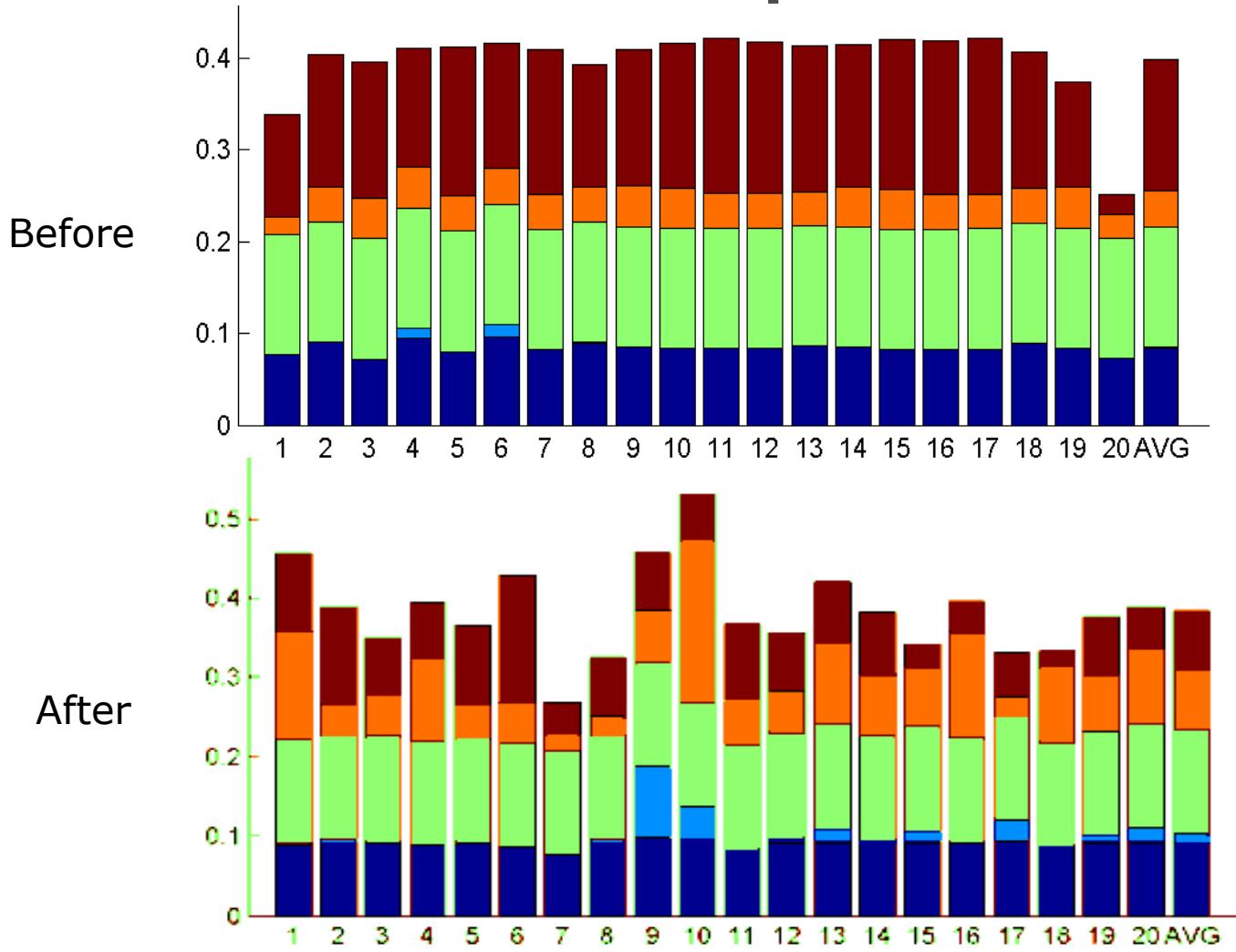
- Middelgrunden iterations: 1000 SGA + 20 SLP



Optimum wind farm layout (left) and financial balance cost distribution relative to baseline design (right).

TOPFARM

Demonstration example



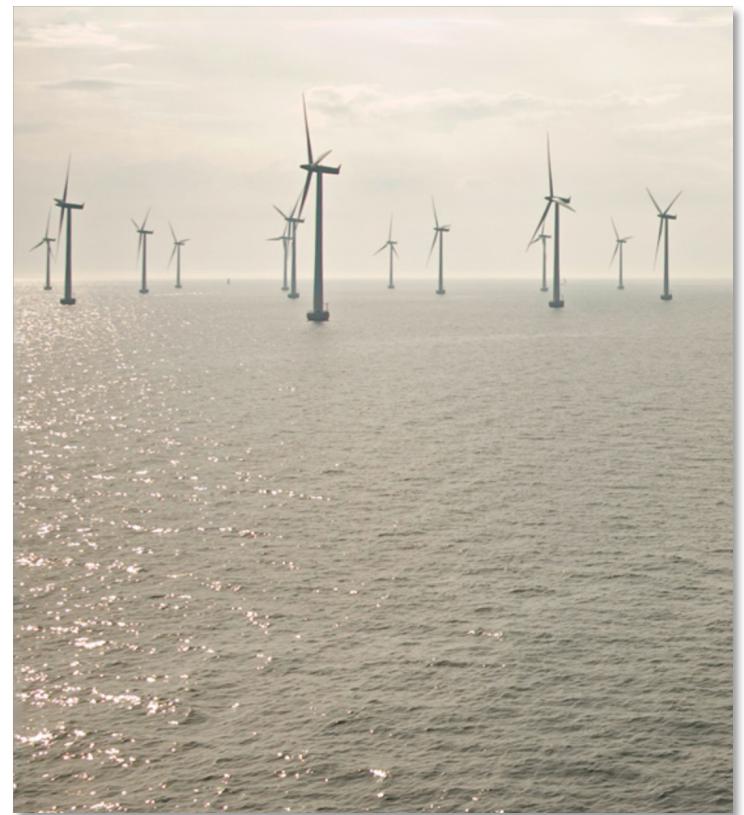
TOPFARM

Feedbacks from the wind industry

- Nice to be able to estimate the wake induced fatigue
- Workflow not ready for a *push-of-a-button* holistic solution
- Multi-disciplinary design tools are difficult to be used in large “bureaucratic” organizations.
- Expert(s) opinion(s) within optimization loop, *somewhat*
- Wish for an open framework, to use their own cost & physical models they already have experience with.

Outline

- Background
- TOPFARM
 - Main Ideas
 - System Overview
 - Some Results
 - Feedbacks from the industry
- Unified Framework
- TOPFARM II
 - Main Ideas
 - System Overview
- EERA-DTOC
 - Main Idea
 - System Overview
- Conclusions

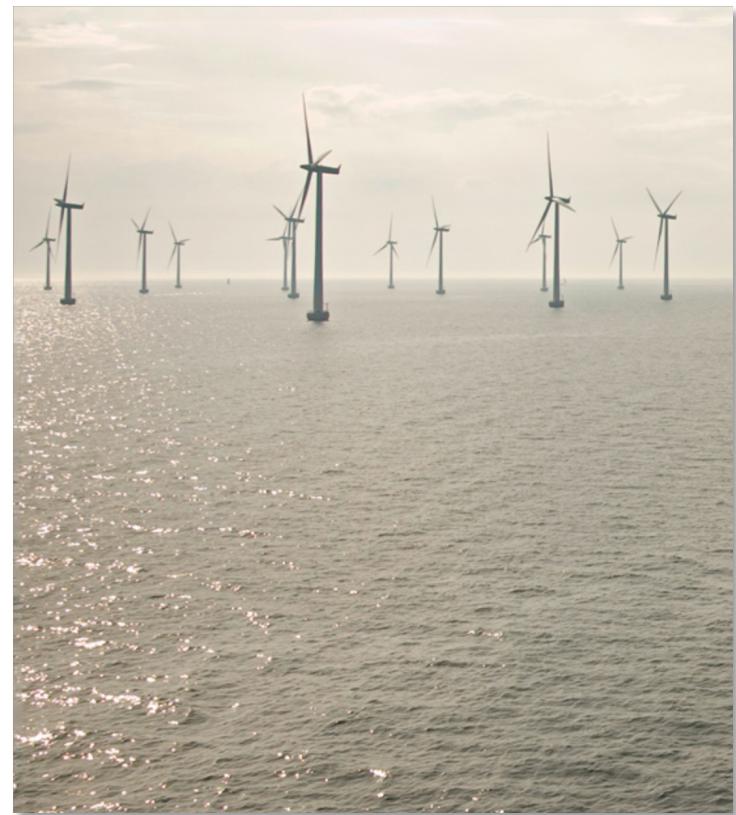


Unified Framework

- In Python
- Based on OpenMDAO (supported by NASA)
- Based on a common wind energy library between DTU & NREL to connect models
- Open source Framework & open/closed modules
- Possibility to easily define and connect your own cost and physical models

Outline

- Background
- TOPFARM
 - Main Ideas
 - System Overview
 - Some Results
 - Feedbacks from the industry
- Unified Framework
- TOPFARM II
 - Main Ideas
 - System Overview
- EERA-DTOC
 - Main Idea
 - System Overview
- Conclusions



TOPFARM II

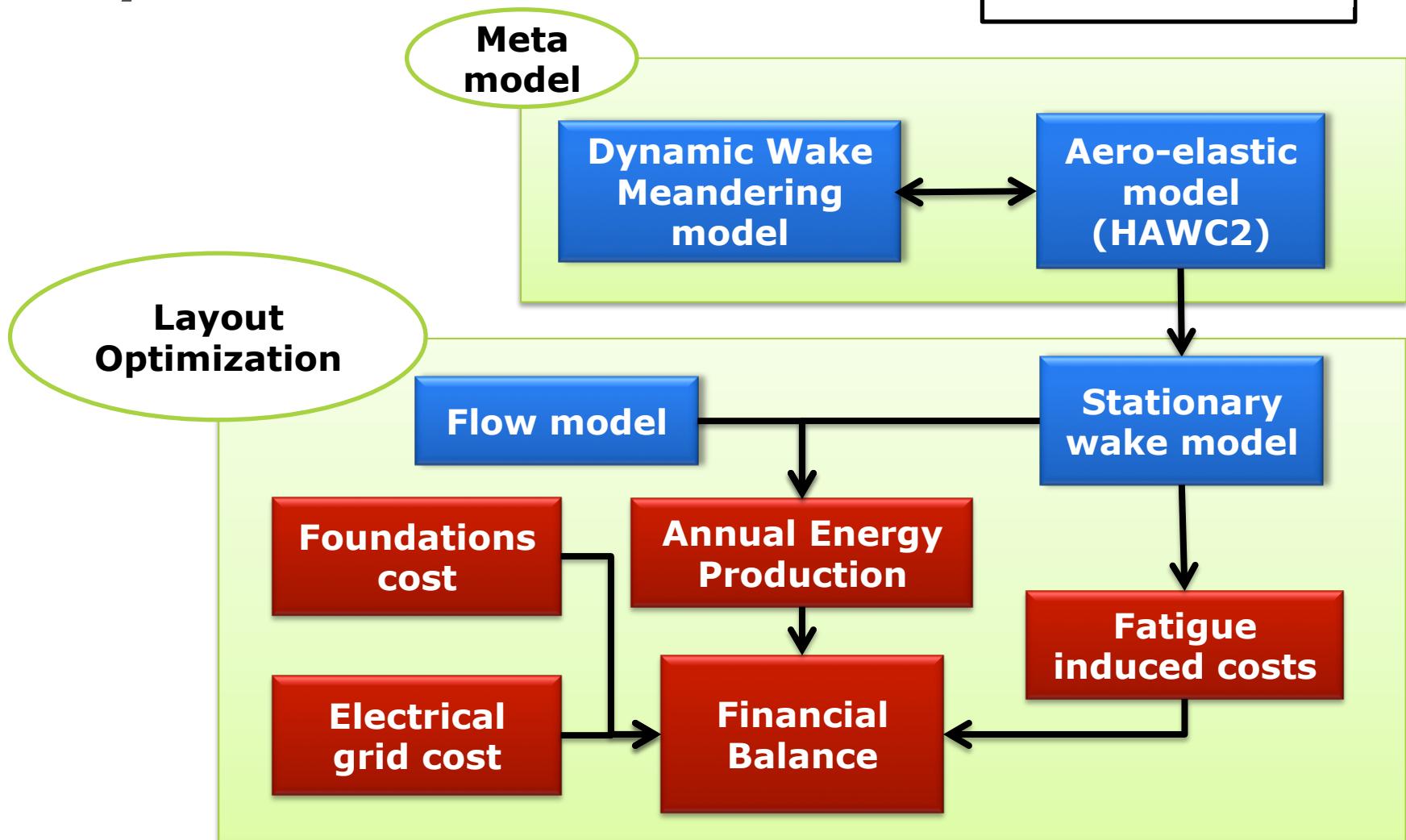
Main Ideas

- Use **FUGA** as the main stationary wake model
- Use **WAsP** & **WRF** engine to calculate accurate local wind resources
- 3rd level of fidelity: running the whole wind farm with **DWM**
- More advanced multi-fidelity optimization strategy
- Higher degree of parallelization
- Expert driven iterative design process
- GUI connected to **WAsP**

TOPFARM II

System Overview

Multi-fidelity:
2nd Level

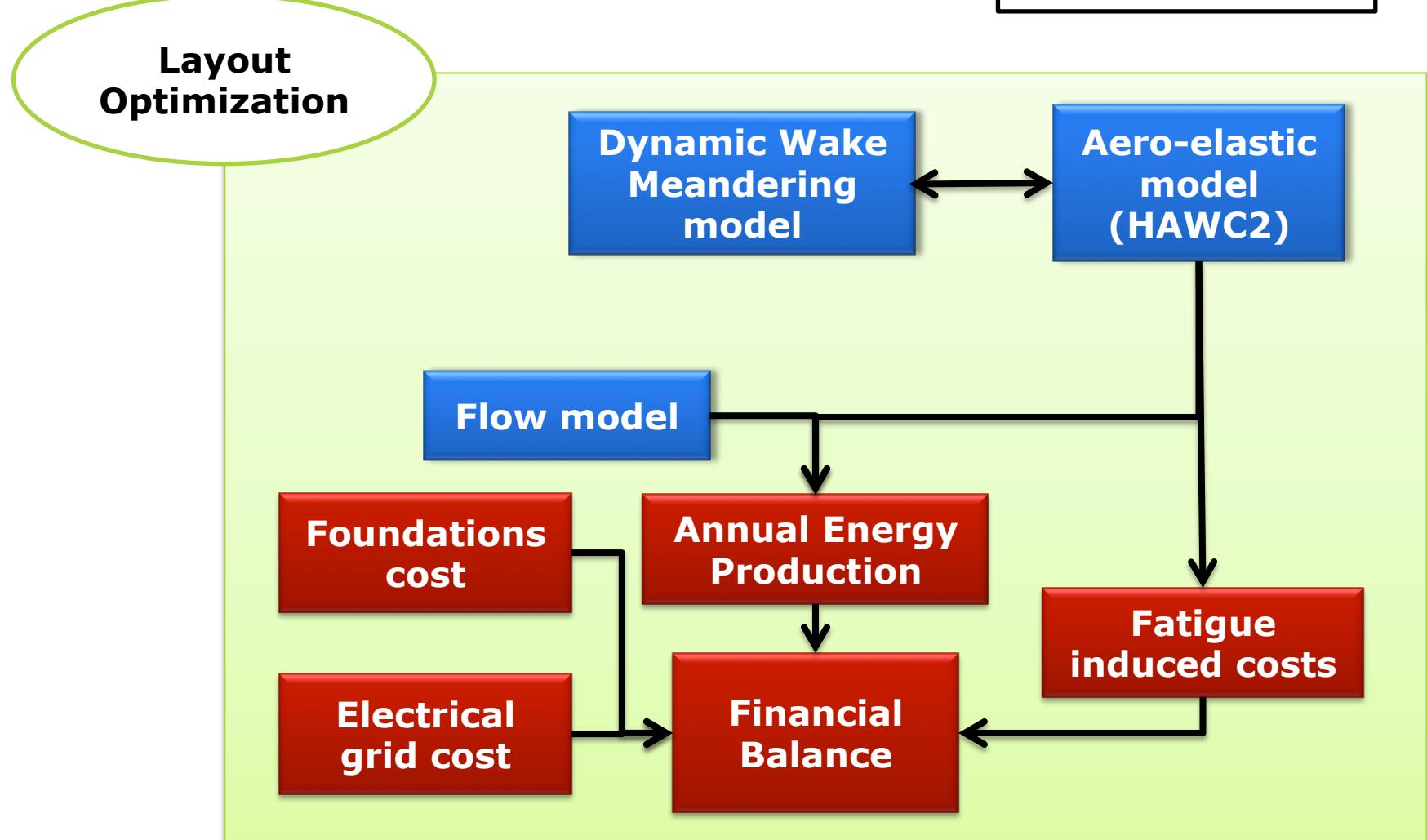


TOPFARM II

System Overview

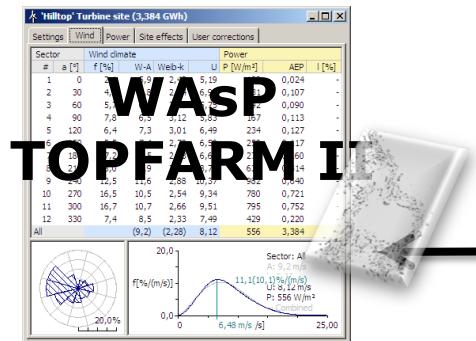
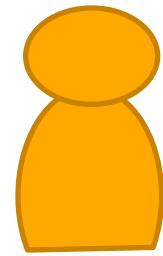
Multi-fidelity:
3rd Level

**Layout
Optimization**



TOPFARM II

User Scenario

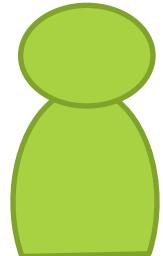


Automatic

Cloud Cluster



Indirect, with data control



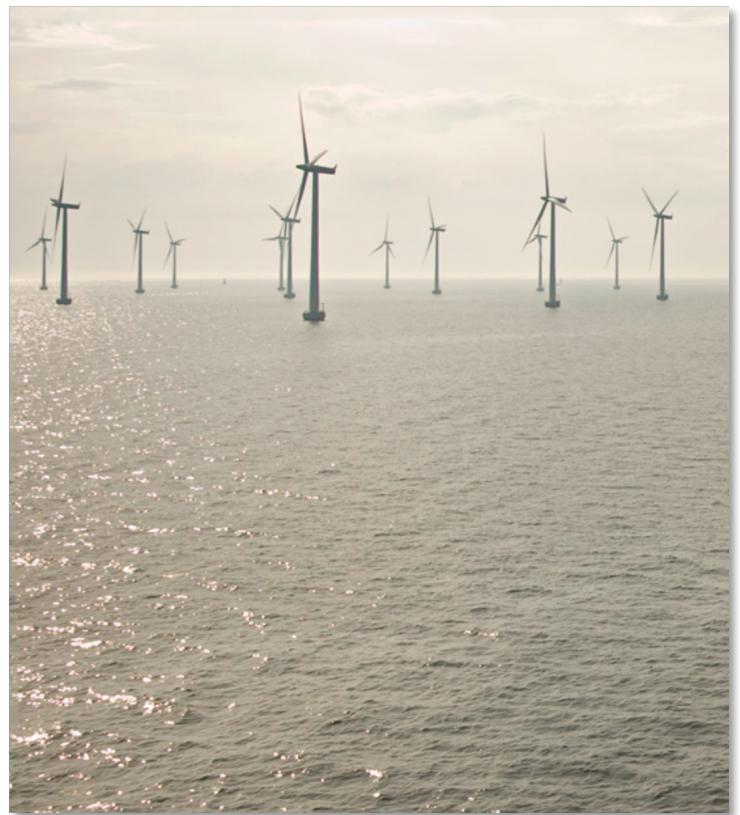
Automatic

Private Cluster



Outline

- Background
- TOPFARM
 - Main Idea
 - System Overview
 - Some Results
 - Feedbacks from the industry
- Unified Framework
- TOPFARM II
 - Main Ideas
 - System Overview
- EERA-DTOC
 - Main Idea
 - System Overview
- Conclusions



EERA-DTOC

Main Ideas

- **EERA:** European Energy Research Alliance
- **DTOC:** Design Tool for Offshore (wind farm) Clusters
- EU-FP7 funded project, 2012-2015
- Focus on designing wind farm **clusters** considering:
 - Inter wind farms **wake losses**
 - Inter wind farms **electrical cabling**
- 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

EERA-DTOC summary slide



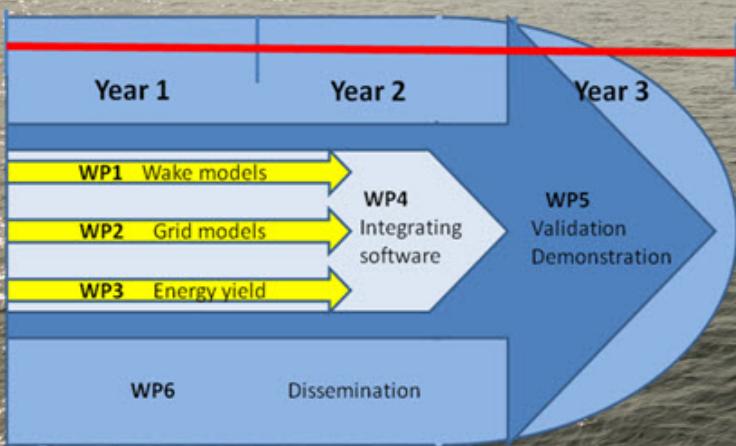
EERA-DTOC

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:

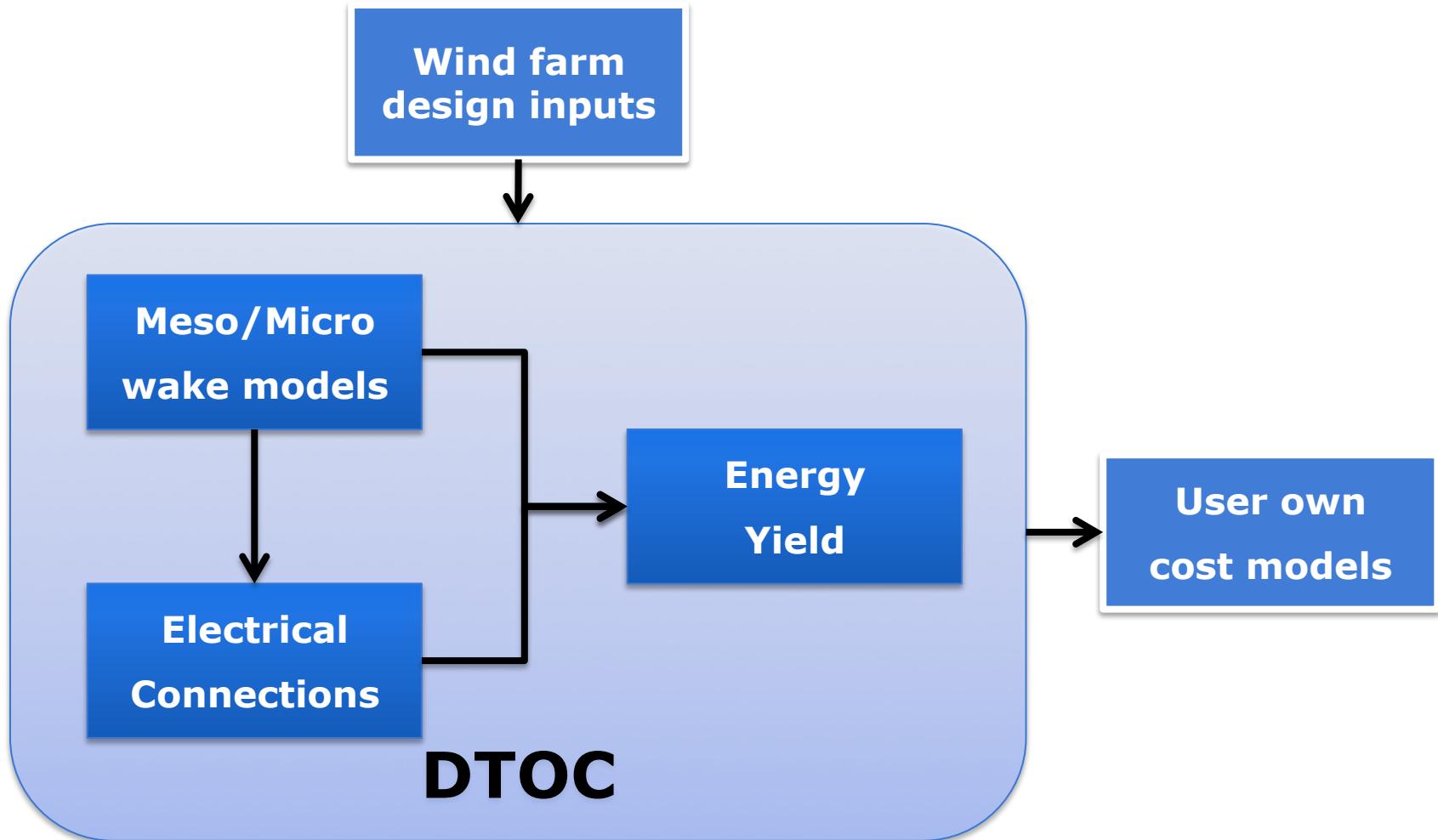
A robust, efficient, easy to use and flexible tool created to facilitate the **optimised design of individual and clusters of offshore wind farms**.

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



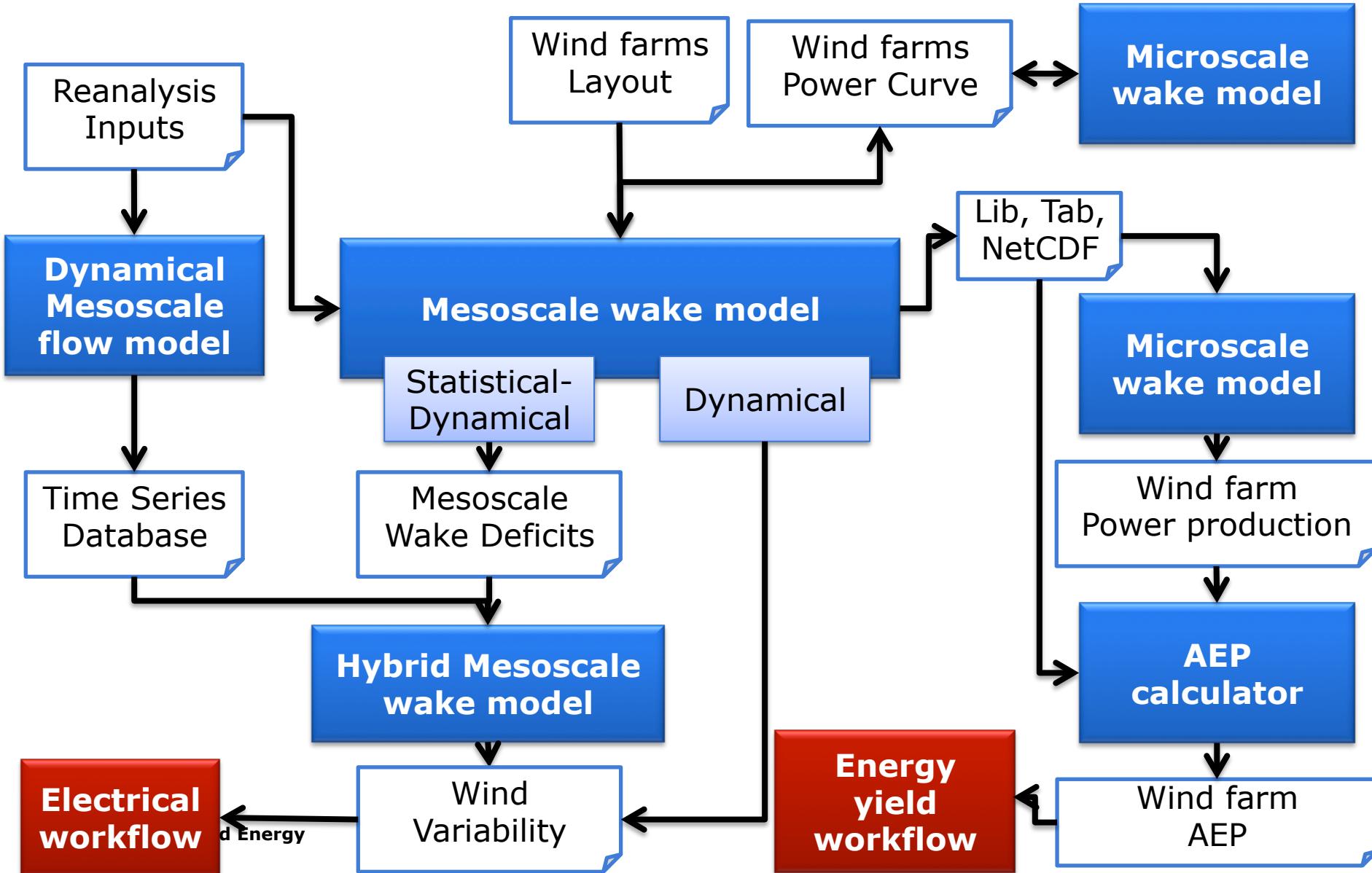
EERA-DTOC

System Global Overview



EERA-DTOC

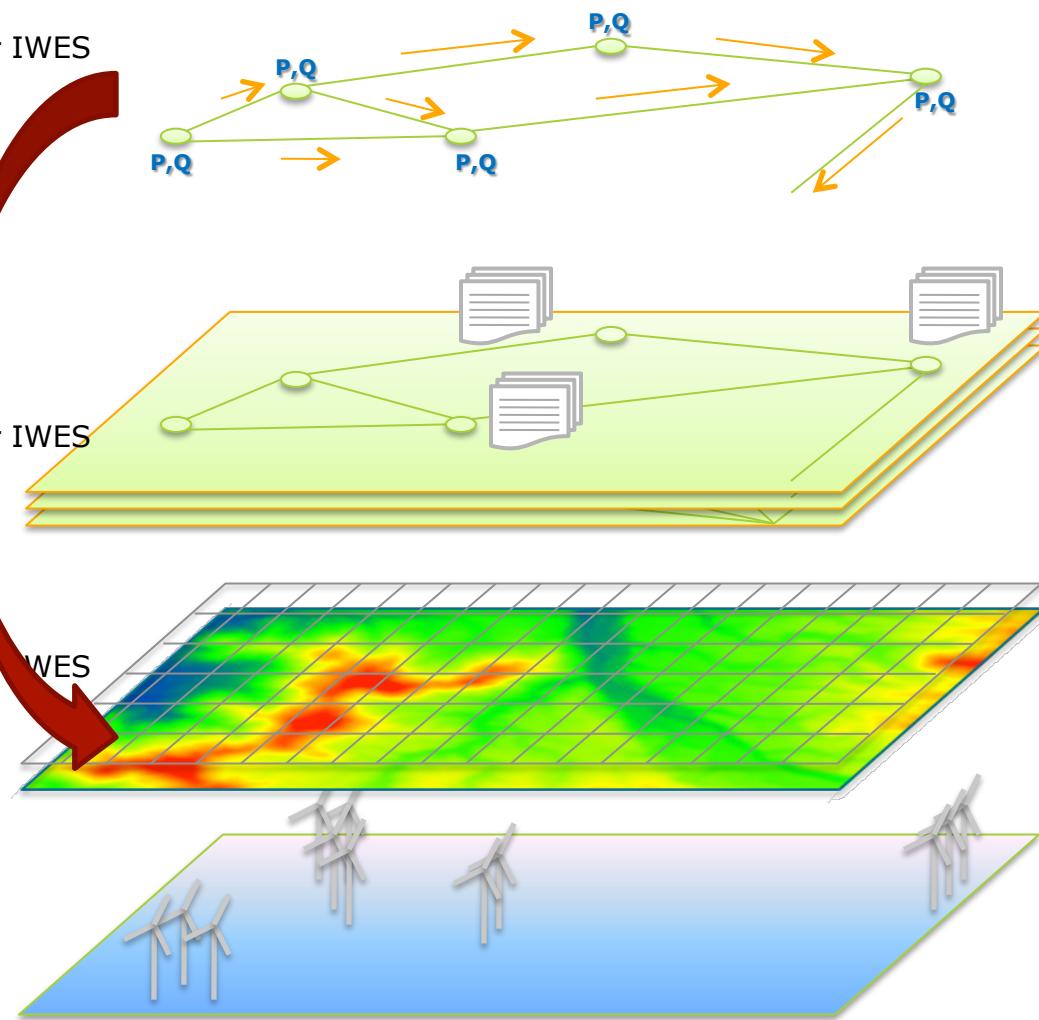
Wake Models Workflow



EERA-DTOC

Electrical Grid Models Workflow

- Fraunhofer IWES



- Strath
- SINTEF
- SINTEF
- Fraunhofer IWES
- Strath
- Statoil
- Hexicon
- Risoe DTU
- Fraunhofer IWES
- CIEMAT

WCMS model
Analysis of the availability of power plant system services

Grid Codes compliance
PSS/e & PSCAD/EMTDC
Transient analysis

NET-OP model
Grid optimization
Steady-state

Analysis on variability & predictability

CorWind model

Off-shore development
Wake modelling

2.
4

2.
3

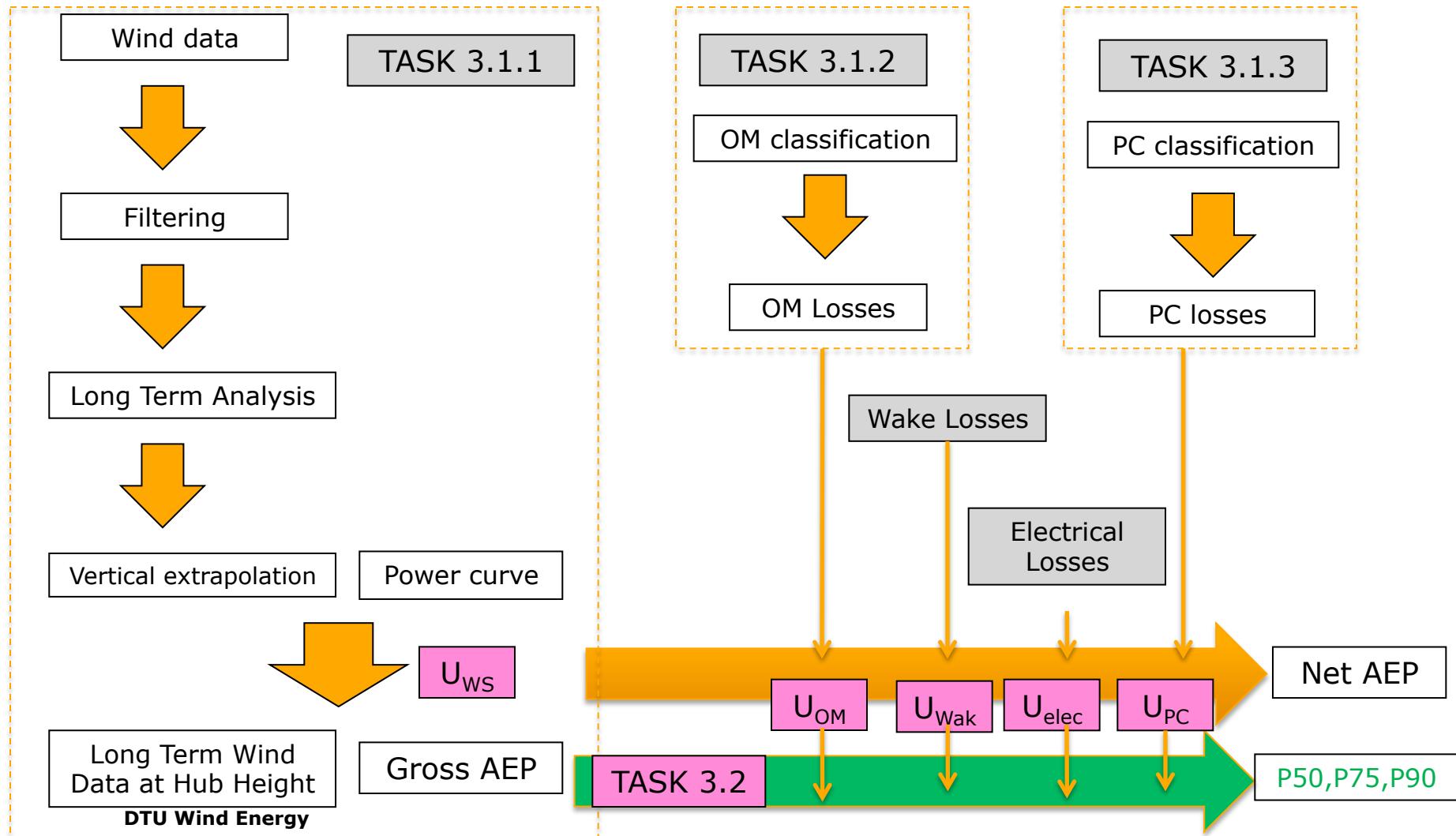
2.
2

2.
1

WP
1

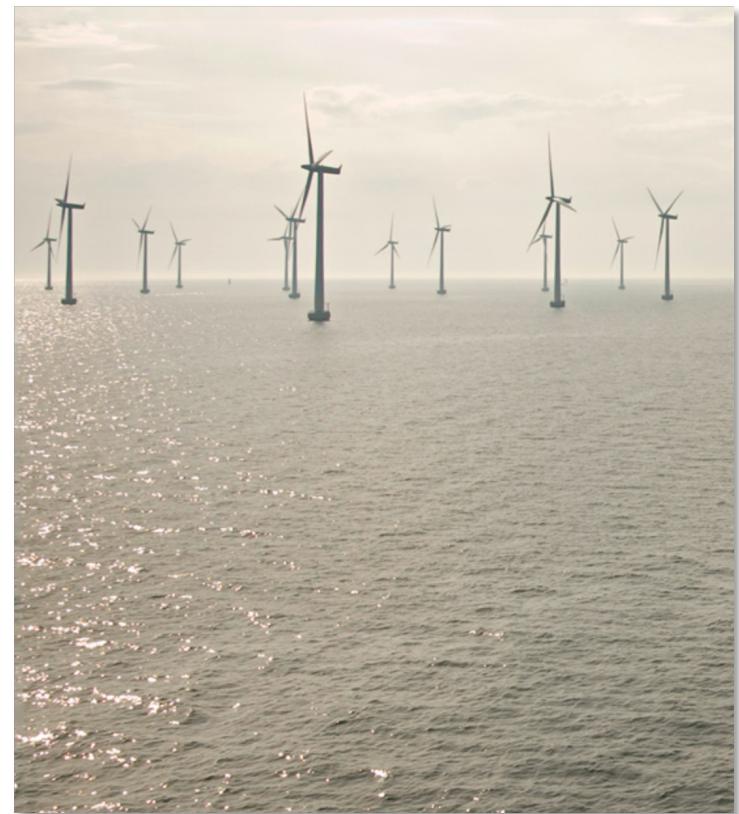
EERA-DTOC

Energy Yield Models Workflow



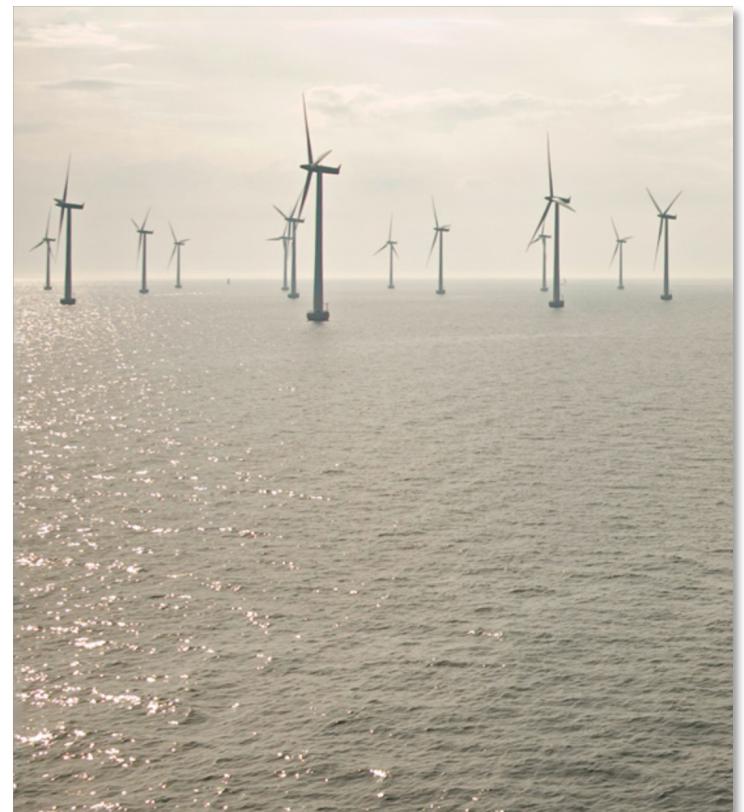
Outline

- Background
- TOPFARM
 - Main Idea
 - System Overview
 - Some Results
 - Feedbacks from the industry
- Unified Framework
- TOPFARM II
 - Main Ideas
 - System Overview
- EERA-DTOC
 - Main Idea
 - System Overview
- Conclusions



Conclusions

- “press-of-a-button” is not expert friendly
- Open framework is important
- Multi-disciplinary = Multi-user = Communication “challenges”
- Wake induced fatigue is relevant for wind farm design & optimization
- In the future we will have to take the potential wind farms into account in the risk analysis





ClusterDesign



**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 Systems (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/>
DTU Wind Energy

