Risø, 14 September 2017

EERA Design Tool for Offshore wind farm Cluster (DTOC)

EERA DTOC

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

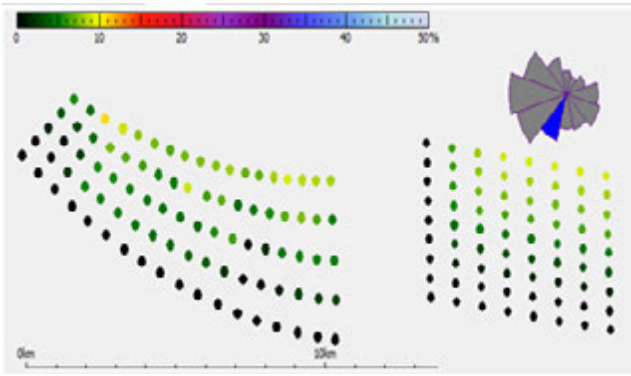
Gregor Giebel, *Senior scientist*
DTU Wind Energy

Support by

EERA-DTOC: Project Goals

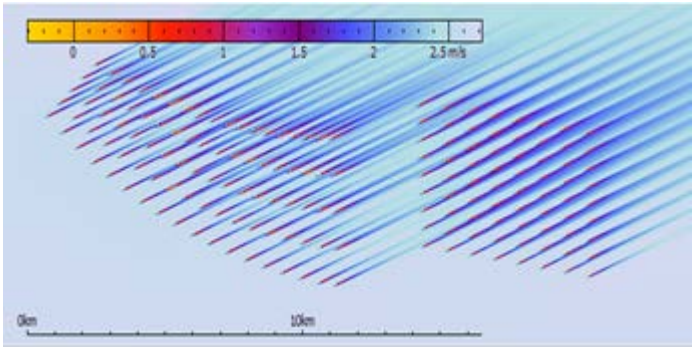
- Addressing wind farm developers and strategic planners

- Supporting the user in his/her goals
  - efficient planning of large offshore areas
  - efficient optimization of the layout of offshore wind farms



© DTU

Support of wind farm optimisation



© DTU

- … with respect to

- wind climate
- turbine selection
- turbine spacing and placing

- interaction between wind farms in clusters with respect to energy production

- wind resource, limitations of usage, grid connection
- electrical infrastructure

Development goals

- **Clear workflow** for layout, variation and comparison of variations in wind farm layout, called scenarios
- Integrated **comparative reporting**
- **Multi-user** mode
- Includes **economic calculations** for benchmarking different layout scenarios via the LCOE

Integration task

Project partners

EERA-DTOC portfolio of models

Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER							
CorWind	Risoe DTU	Ope						
CRES-farm	CRES	Ope						
CRES--flowNS	CRES	Ope						
DWM	Risoe DTU	Ope						
ECNS	ECN	Beta						
EeFarm	ECN	Alpha						
Farm-farm interaction	ECN	Ope						
FarmFlow	ECN	Ope						
FlowARSM	CRES	Alpha						
FUGA	Risoe DTU	Ope						
NET-OP	SINTEF	Proto type						
Skiron/WAM	CENER	Ope						
TOPFARM	Risoe DTU	Beta						
UAEP	Risoe DTU							
VENTOS	UPorto	Beta						
WAsP	Risoe DTU	Ope						
WCMS	Fraunhofer	Ope						
WRF	Risoe DTU	Ope						
WRF/ROMS	CIEMAT	Ope						

EERA-DTOC portfolio of models

Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER							
CorWind	Risoe DTU	Ope						
CRES-farm	CRES	Ope						
CRES--flowNS	CRES	Ope						
DWM	Risoe DTU	Ope						
ECNS	ECN	Beta						
EeFarm	ECN	Alpha						
Farm-farm interaction	ECN	Ope						
FarmFlow	ECN	Ope						
FI-WASP	CRES	Alpha						
FUGA	Risoe DTU	Ope						
NET-CP	SINTEF	Proto type						
Skiron/WAM	CENER	Ope						
TOPFARM	Risoe DTU	Beta						
UAEP	Risoe DTU							
VENTOS	UPorto	Beta						
WAsP	Risoe DTU	Ope						
WCMS	Fraunhofer	Ope						
WRF	Risoe DTU	Ope						
WRF/ROMS	CIEMAT	Ope						

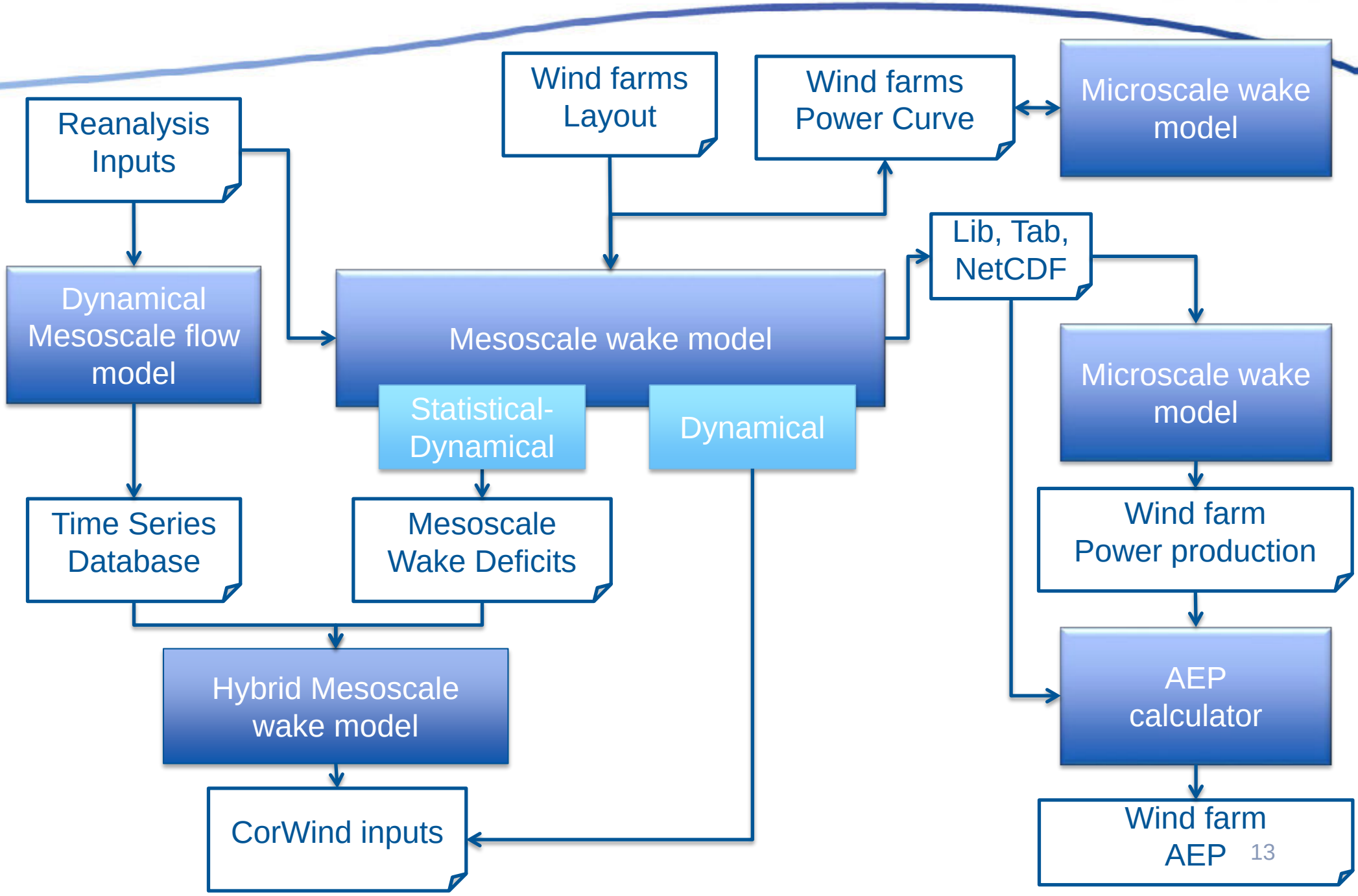
Wake models

EERA-DTOC portfolio of models

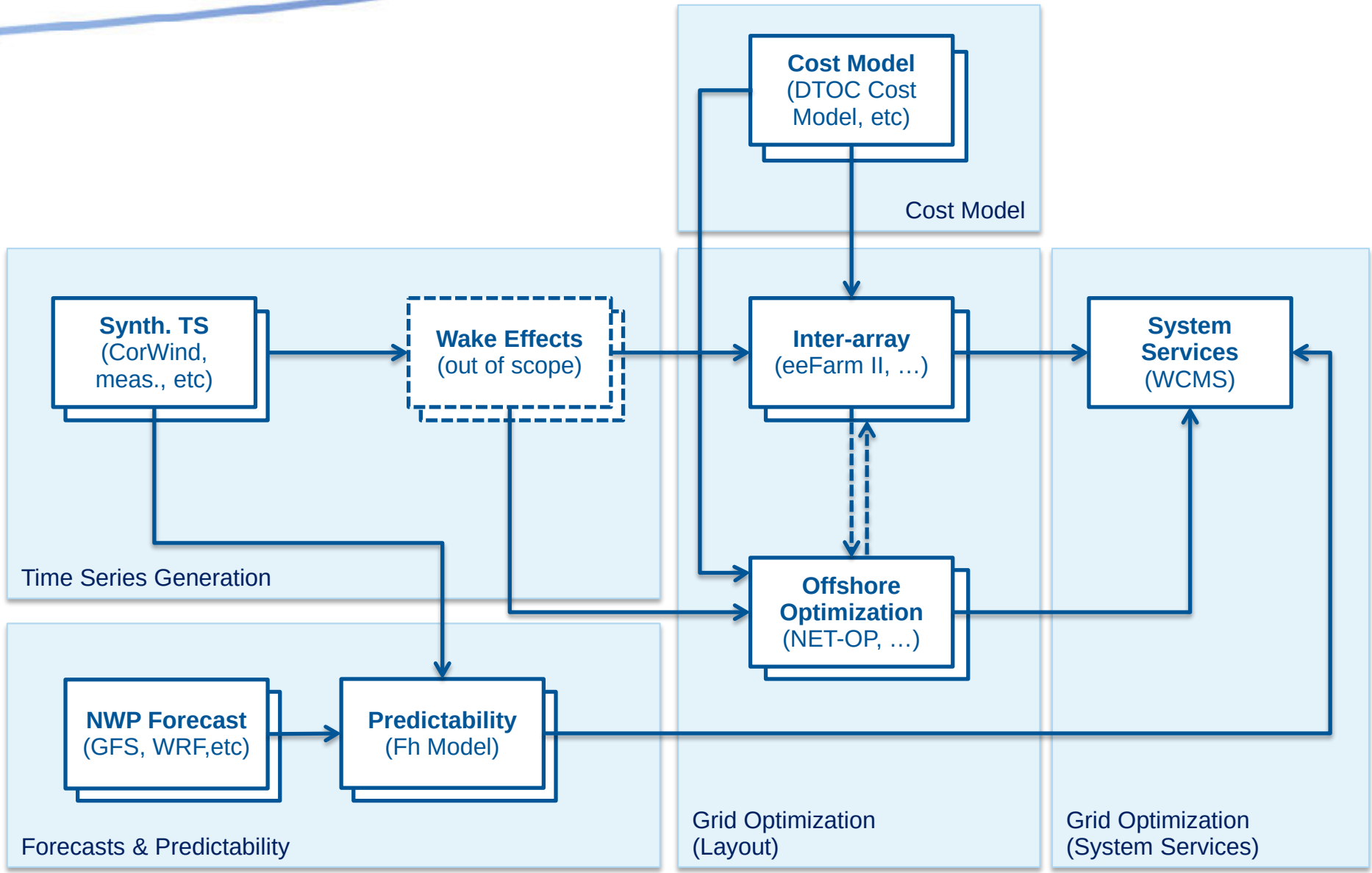
Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER							
CorWind	Risoe DTU	Ope						
CRES-farm	CRES	Ope						
CRES--flowNS	CRES	Ope						
DWM	Risoe DTU	Ope						
ECNS	ECN	Beta						
EeFarm	ECN	Alpha						
Farm-farm interaction	ECN	Ope						
FarmFlow	ECN	Ope						
FlowARSM	CRES	Alpha						
FUGA	Risoe DTU	Ope						
NET-OP	SINTEF	Proto type						
Skiron/WAM	CENER	Ope						
TOPFARM	Risoe DTU	Beta						
UAEP	Risoe DTU							
VENTOS	UPorto	Beta						
WASP	Risoe DTU	Ope						
WCMS	Fraunhofer	Ope						
WRF	Risoe DTU	Ope						
WRF/ROMS	CIEMAT	Ope						

Electrical models

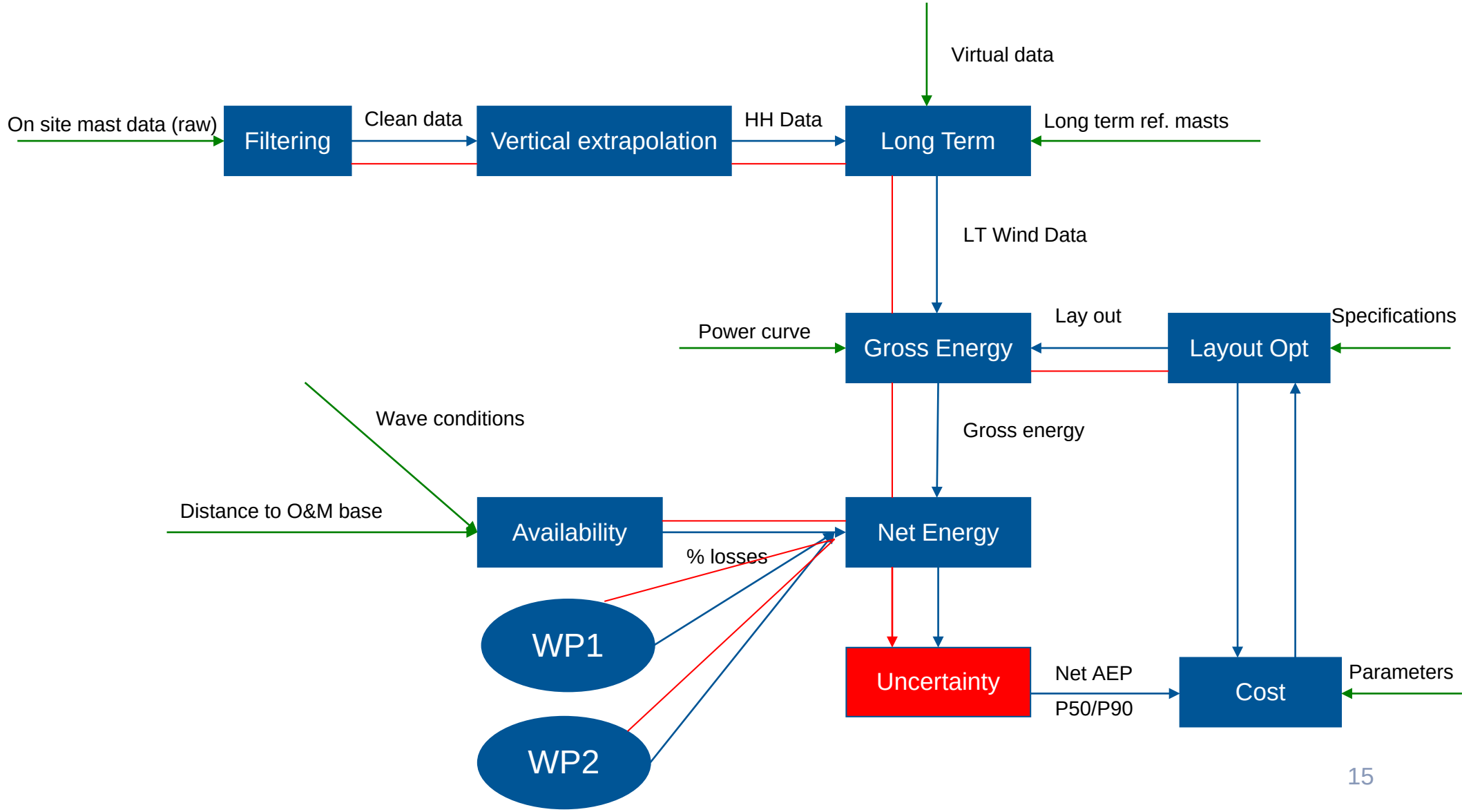
Model Workflow Wind Climate



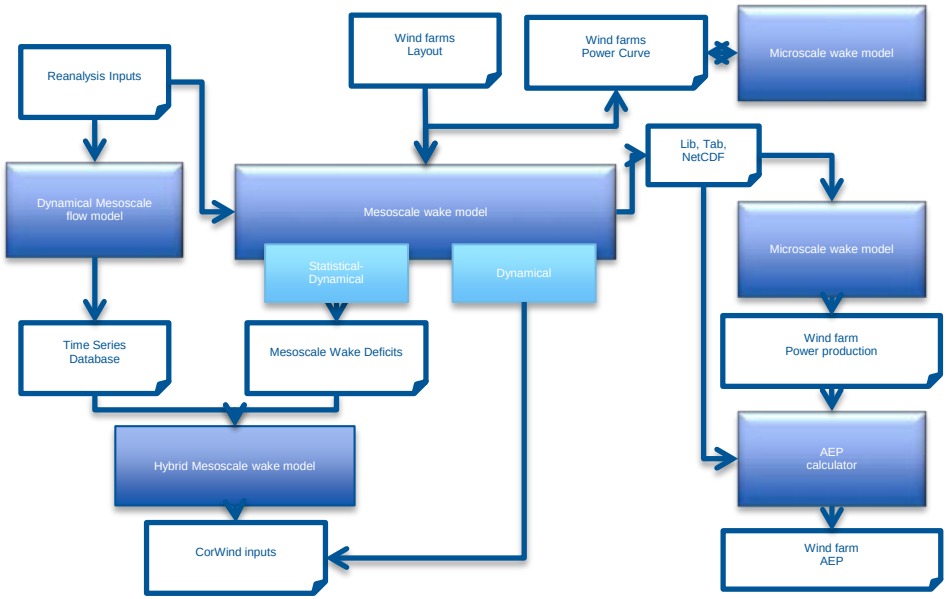
Model Workflow “Electrical”

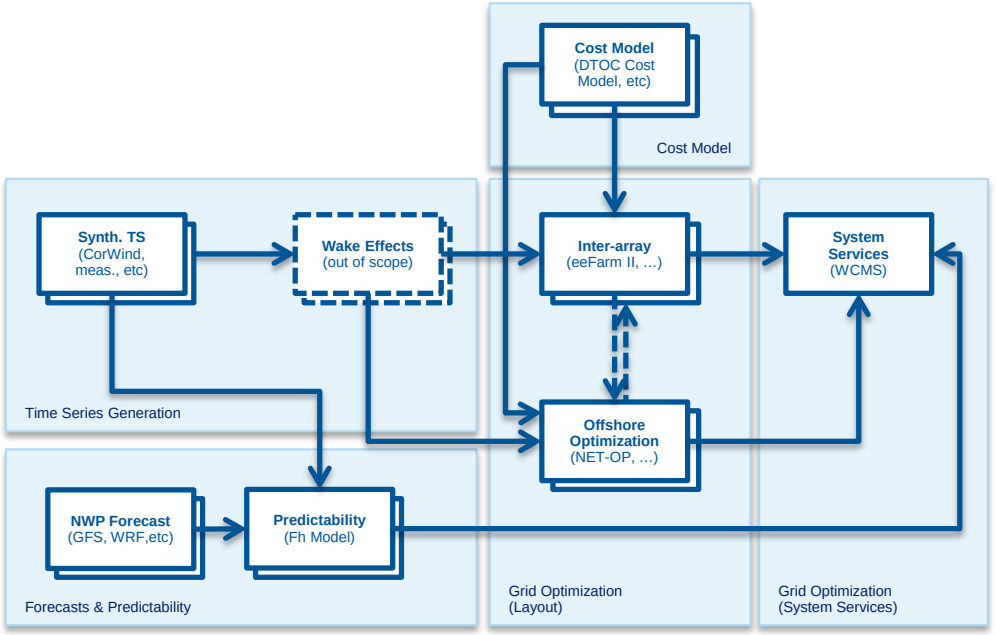


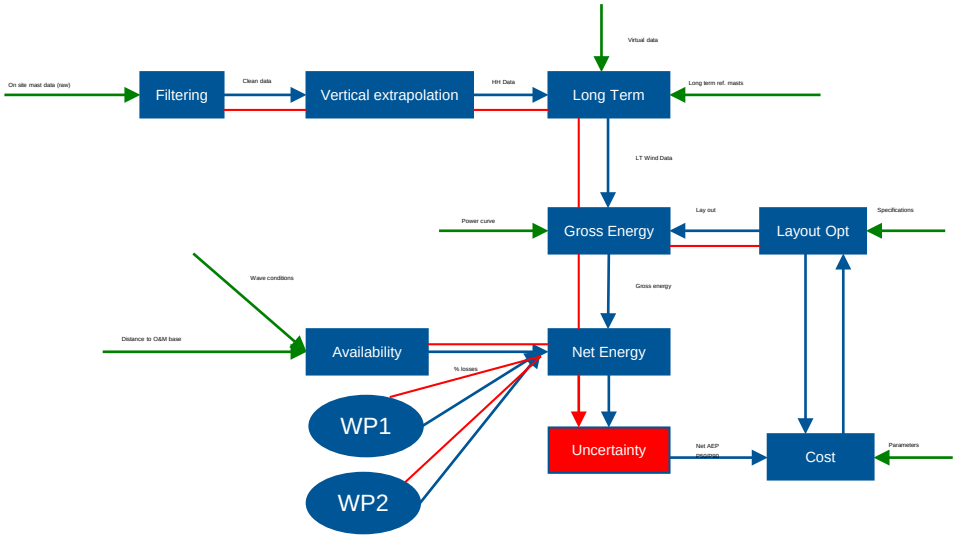
Yield modelling



Total tool overview







Total tool overview – very complex!

User Requirements

Vision and Work Flow

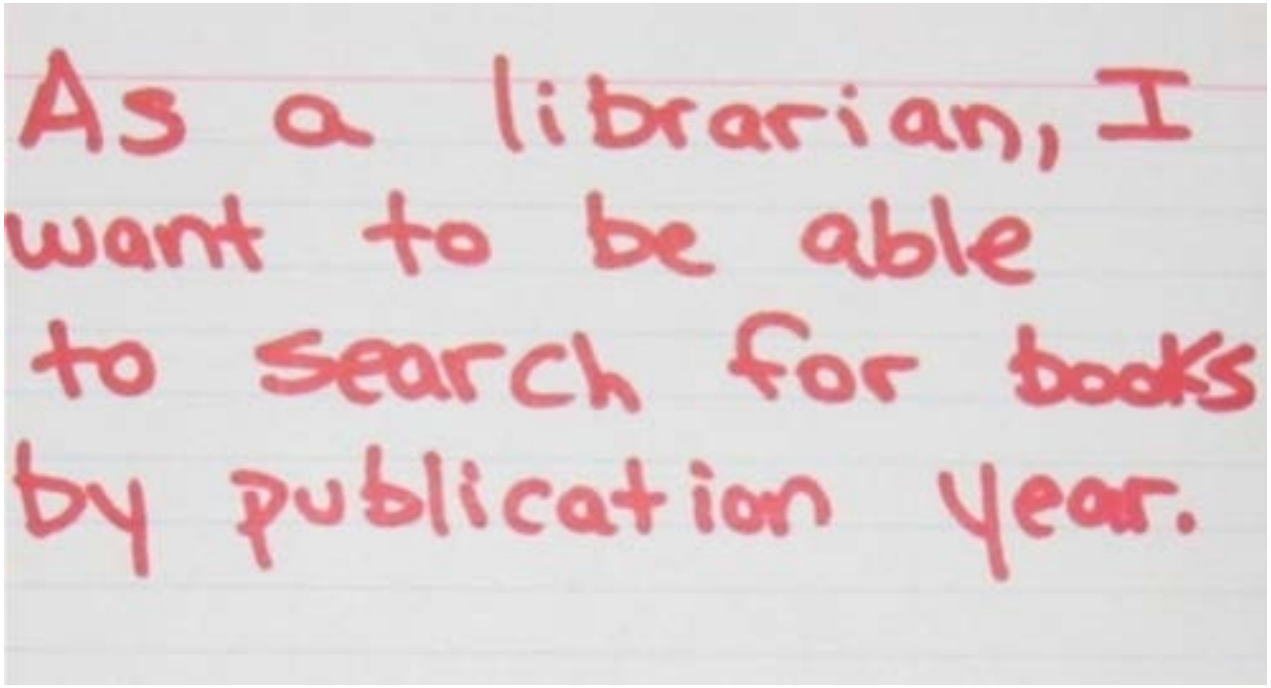
EERA-DTOC vision

- 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.

User Story

As a <user> I want to be able to <goal>



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

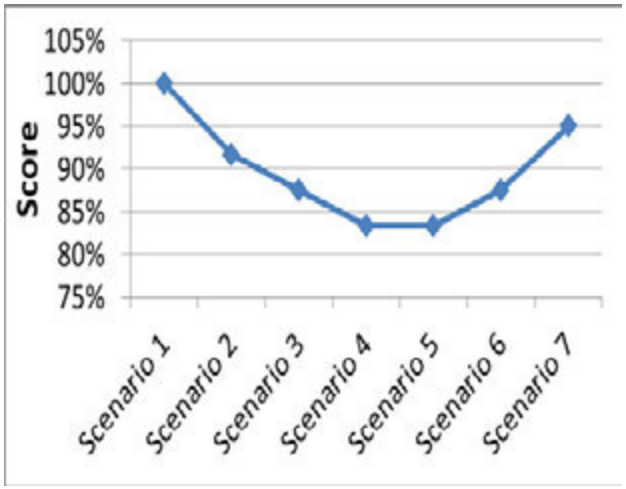
2. Evaluate Design Options

Wake Model

Electrical Model

Energy model

3. Compare Design Options



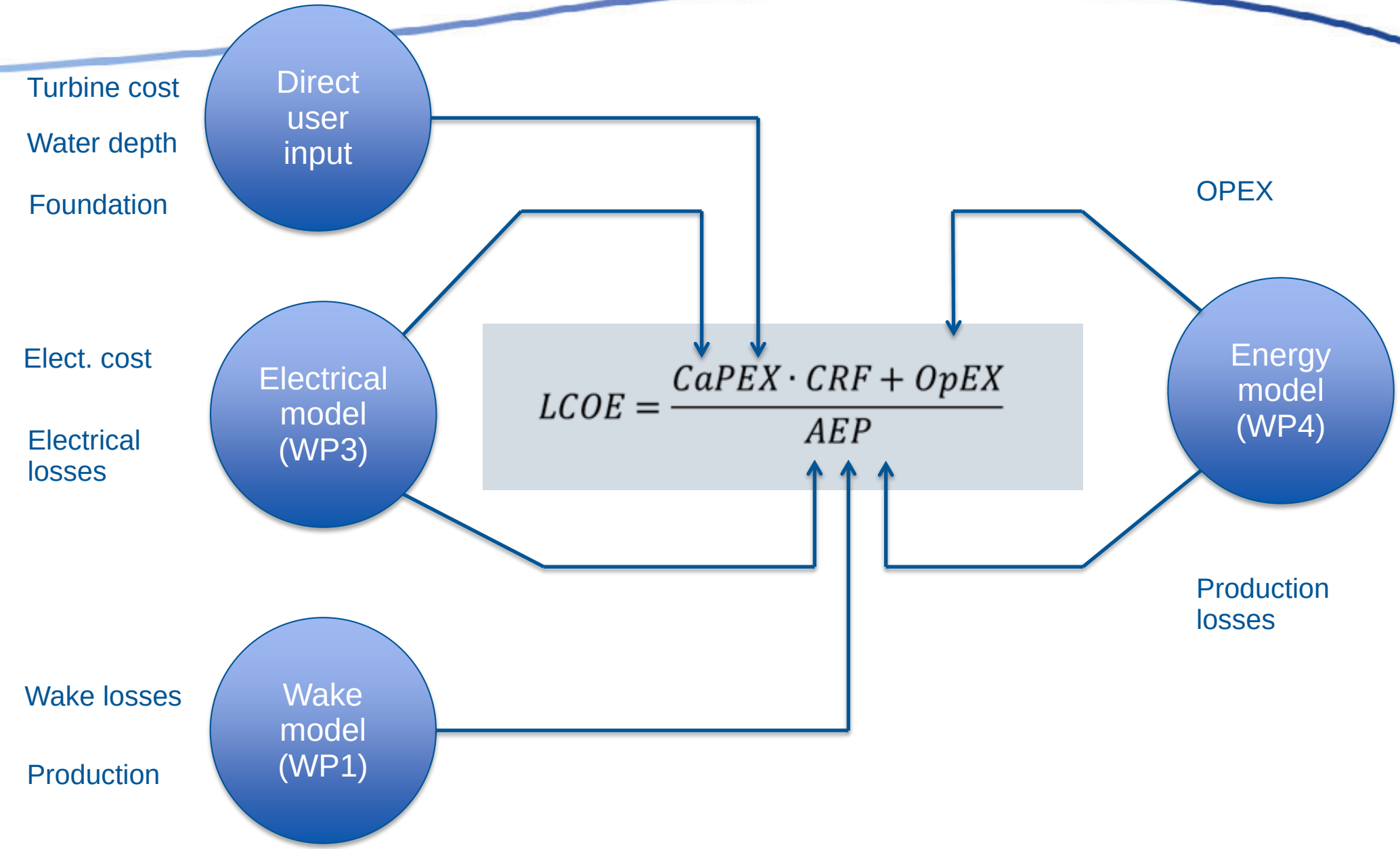
4. Iterate steps 1 to 3

Score: Levelized cost of energy

What decision parameter can we use to compare design options?

LCoE Model

Interfaces


Turbine cost
Water depth
Foundation
Direct user input
OPEX
Elect. cost
Electrical losses
Electrical model (WP3)
$LCOE = \frac{CaPEX \cdot CRF + OpEX}{AEP}$
Energy model (WP4)
Production losses
Wake losses
Production
Wake model (WP1)

Software Implementation

EERA-DTOC portfolio of models

Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER							
CorWind	Risoe DTU	Ope						
CRES-farm	CRES	Ope						
CRES--flowNS	CRES	Ope						
DWM	Risoe DTU	Ope						
ECNS	ECN	Beta						
EeFarm	ECN	Alpha						
Farm-farm interaction	ECN	Ope						
FarmFlow	ECN	Ope						
FlowARSM	CRES	Alpha						
FUGA	Risoe DTU	Ope						
NET-OP	SINTEF	Proto type						
Skiron/WAM	CENER	Ope						
TOPFARM	Risoe DTU	Beta						
UAEP	Risoe DTU							
VENTOS	UPorto	Beta						
WAsP	Risoe DTU	Ope						
WCMS	Fraunhofer	Ope						
WRF	Risoe DTU	Ope						
WRF/ROMS	CIEMAT	Ope						

EERA-DTOC portfolio of models

Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER							
CorWind	Risoe DTU	Ope						
CRES-farm	CRES	Ope						
CRES--flowNS	CRES	Ope						
DWM	Risoe DTU	Ope						
ECNS	ECN	Beta						
EeFarm	ECN	Alpha						
Farm-farm interaction	ECN	Ope						
FarmFlow	ECN	Ope						
FlowARSM	CRES	Alpha						
FUGA	Risoe DTU	Ope						
NET-OP	SINTEF	Proto type						
Skiron/WAM	CENER	Ope						
TOPFARM	Risoe DTU	Beta						
UAEP	Risoe DTU							
VENTOS	UPorto	Beta						
WAsP	Risoe DTU	Ope						
WCMS	Fraunhofer	Ope						
WRF	Risoe DTU	Ope						
WRF/ROMS	CIEMAT	Ope						

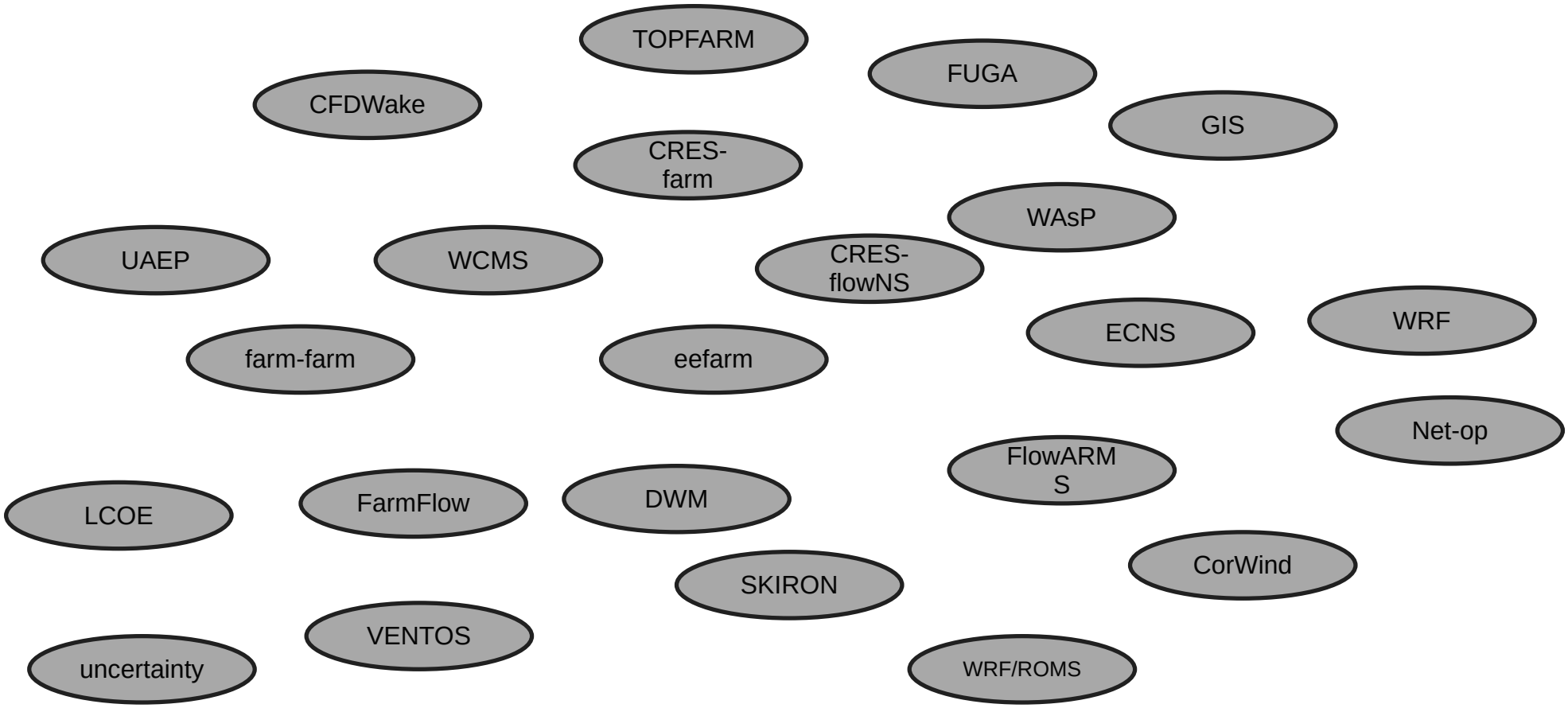
Run on Windows, on a single PC

EERA-DTOC portfolio of models

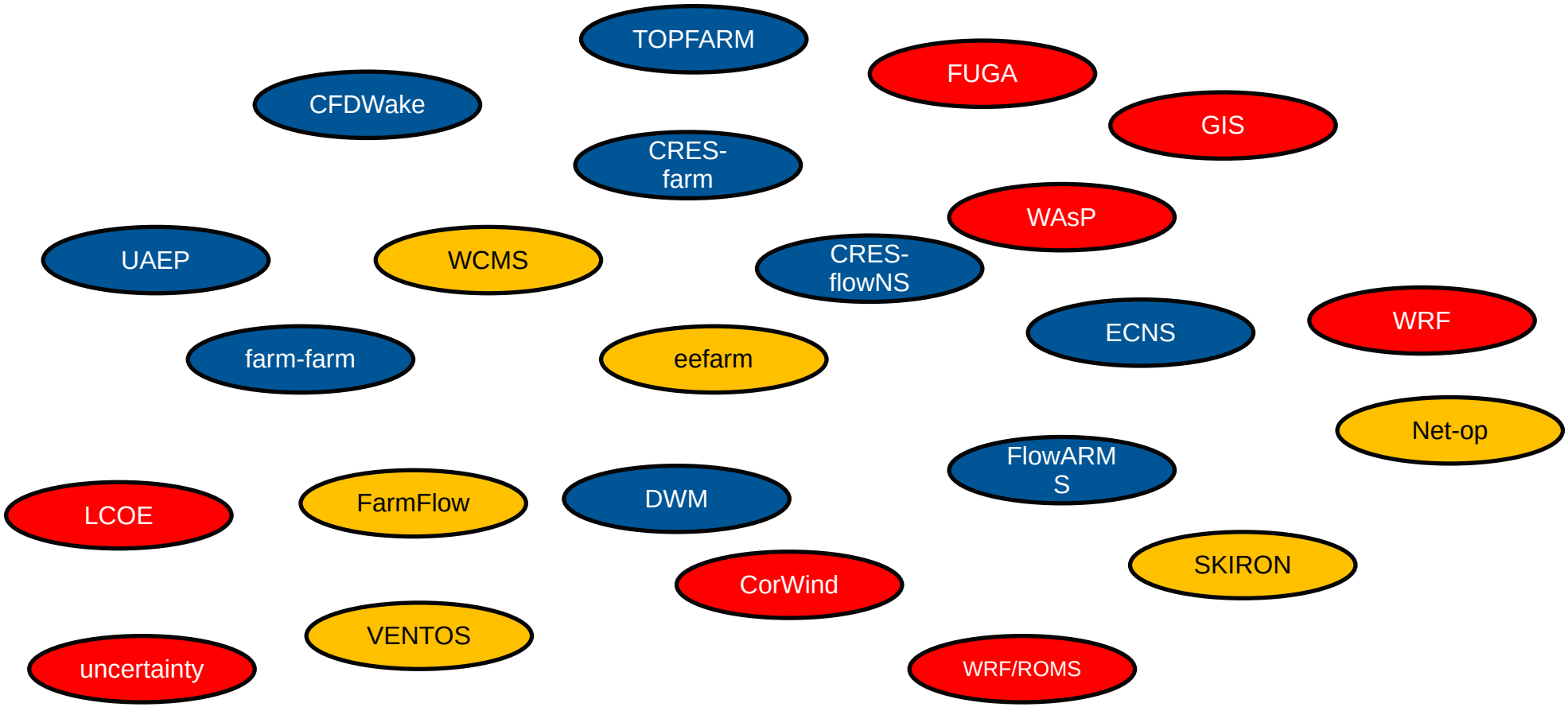
Name	Partner	Status	Programs	Input/ output	Script/ GUI	Database interface	IPR	Com
CFDWake	CENER							
CorWind	Risø DTU	Ope						
CRES-farm	CRES	Ope						
CRES--flowNS	CRES	Ope						
DWM	Risø DTU	Ope						
ECNS	ECN	Beta						
EeFarm	ECN	Alpha						
Farm-farm interaction	ECN	Ope						
FarmFlow	ECN	Ope						
FlowARSM	CRES	Alpha						
FUGA	Risø DTU	Ope						
NET-OP	SINTEF	Proto type						
Skiron/WAM	CENER	Ope						
TOPFARM	Risø DTU	Beta						
UAEP	Risø DTU							
VENTOS	UPorto	Beta						
WAsP	Risø DTU	Ope						
WCMS	Fraunhofer	Ope						
WRF	Risø DTU	Ope						
WRF/ROMS	CIEMAT	Ope						

Runs on Cluster under UNIX/Linux

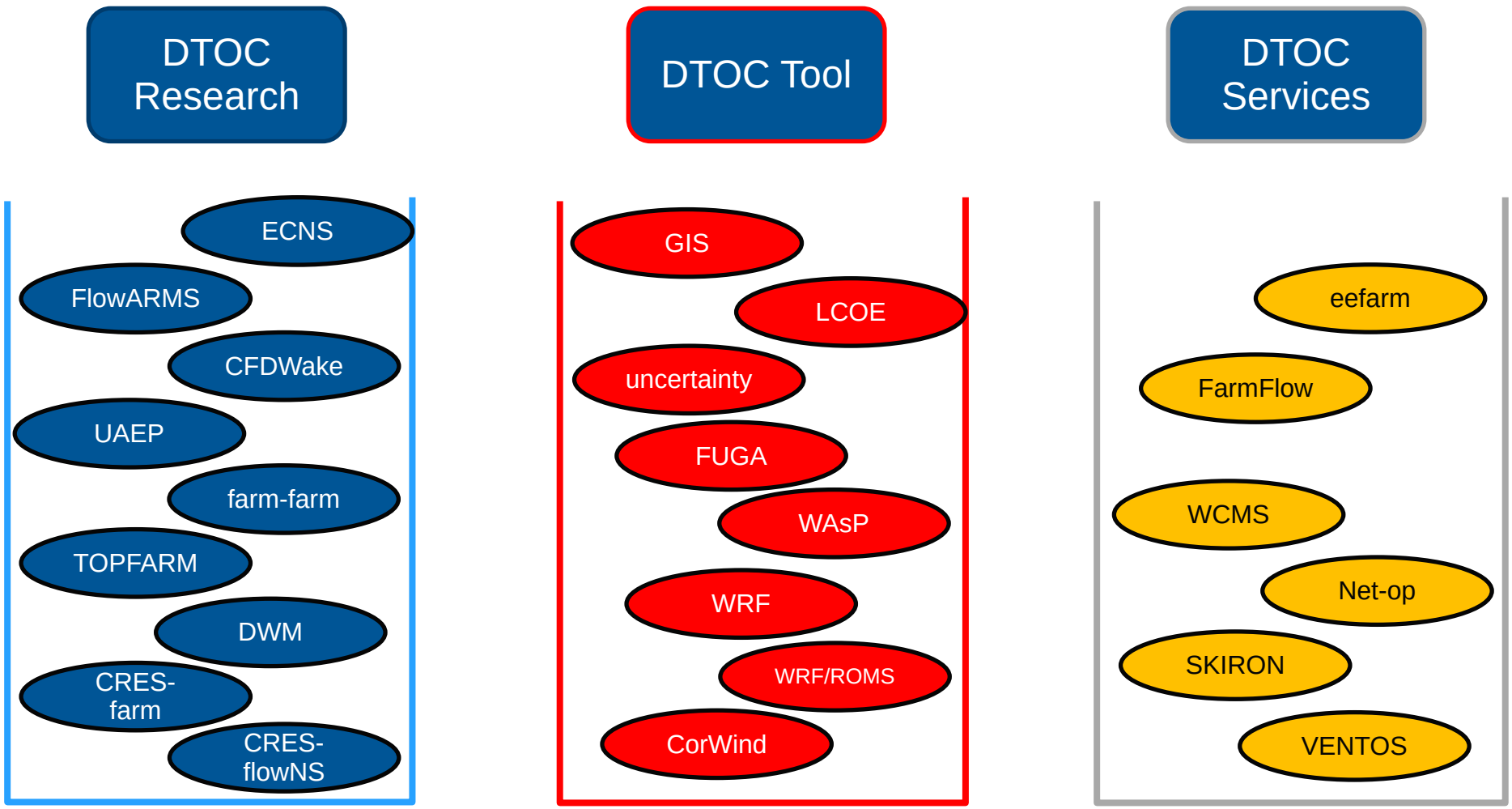
Model candidates



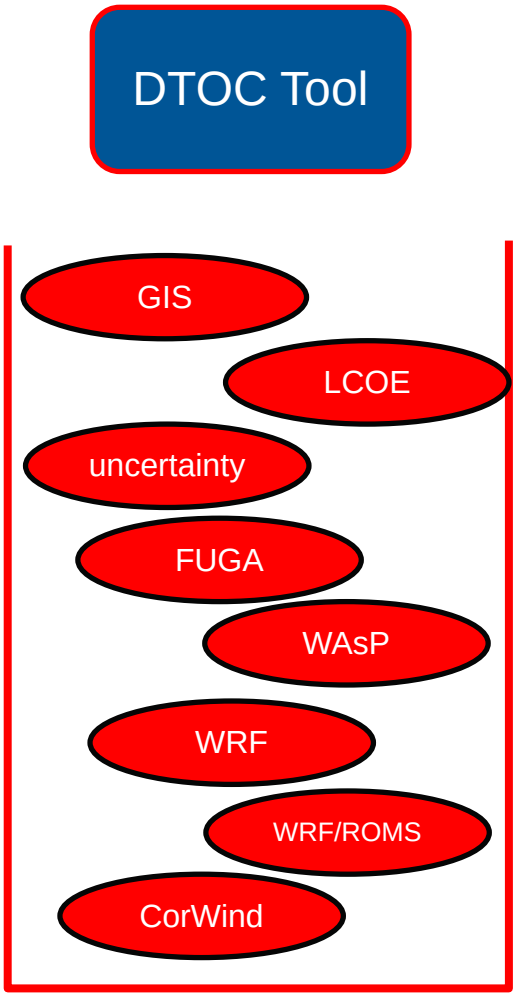
Model candidates: Categorization



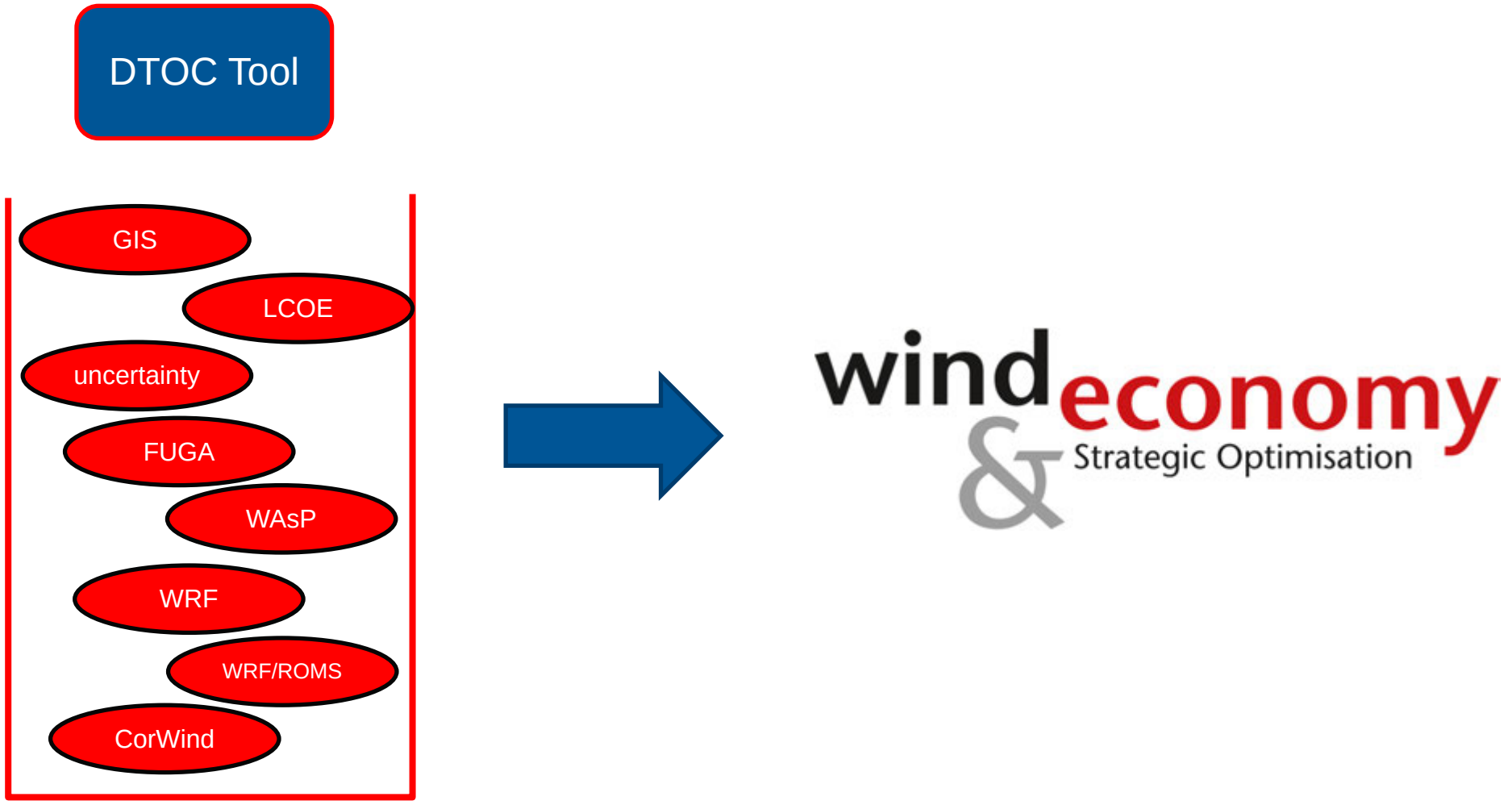
Selection and Implementation



Selection and Implementation



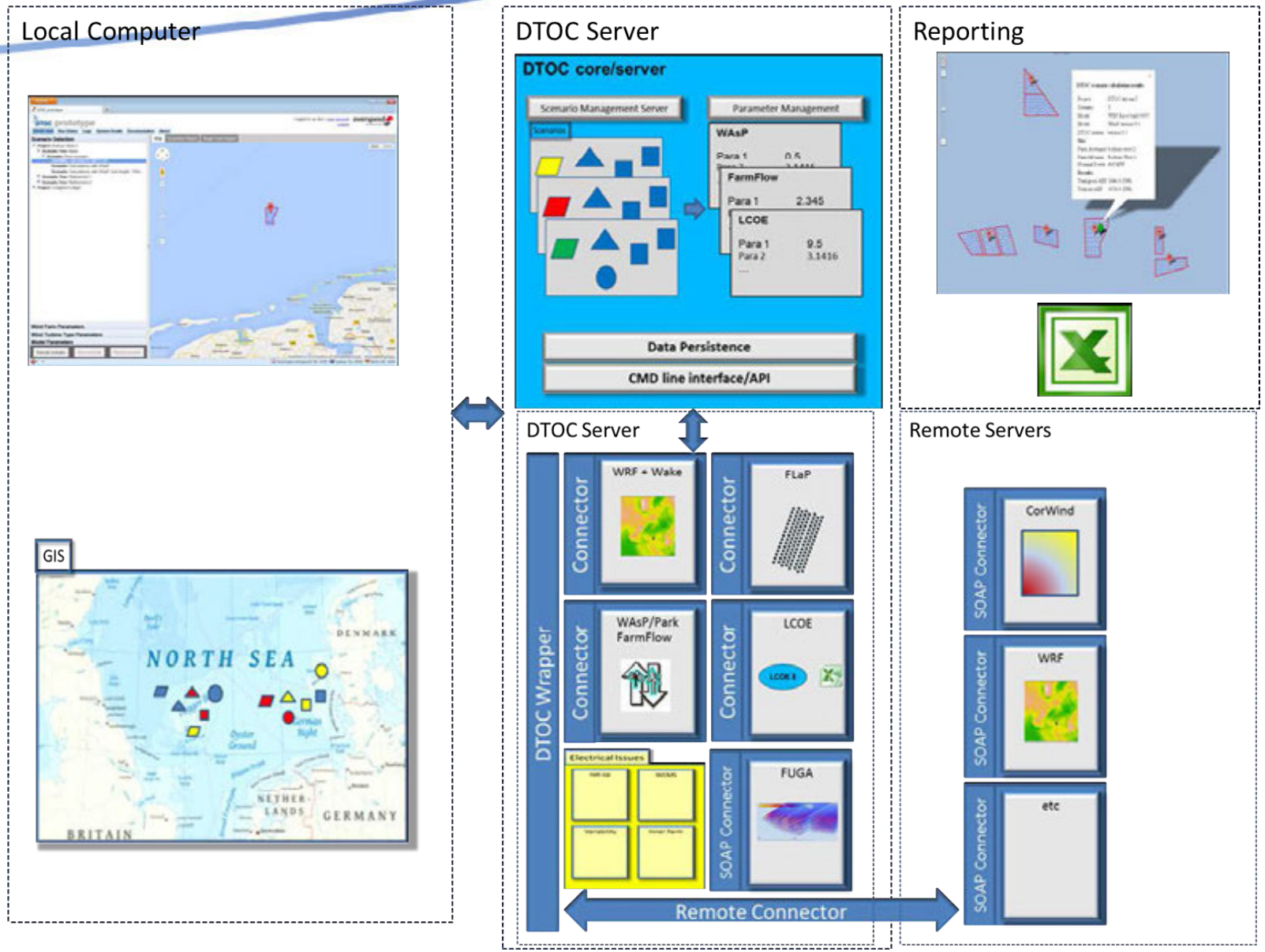
Selection and Implementation



DTOC tool and commercialisation

Commercial tool: Wind & Economy

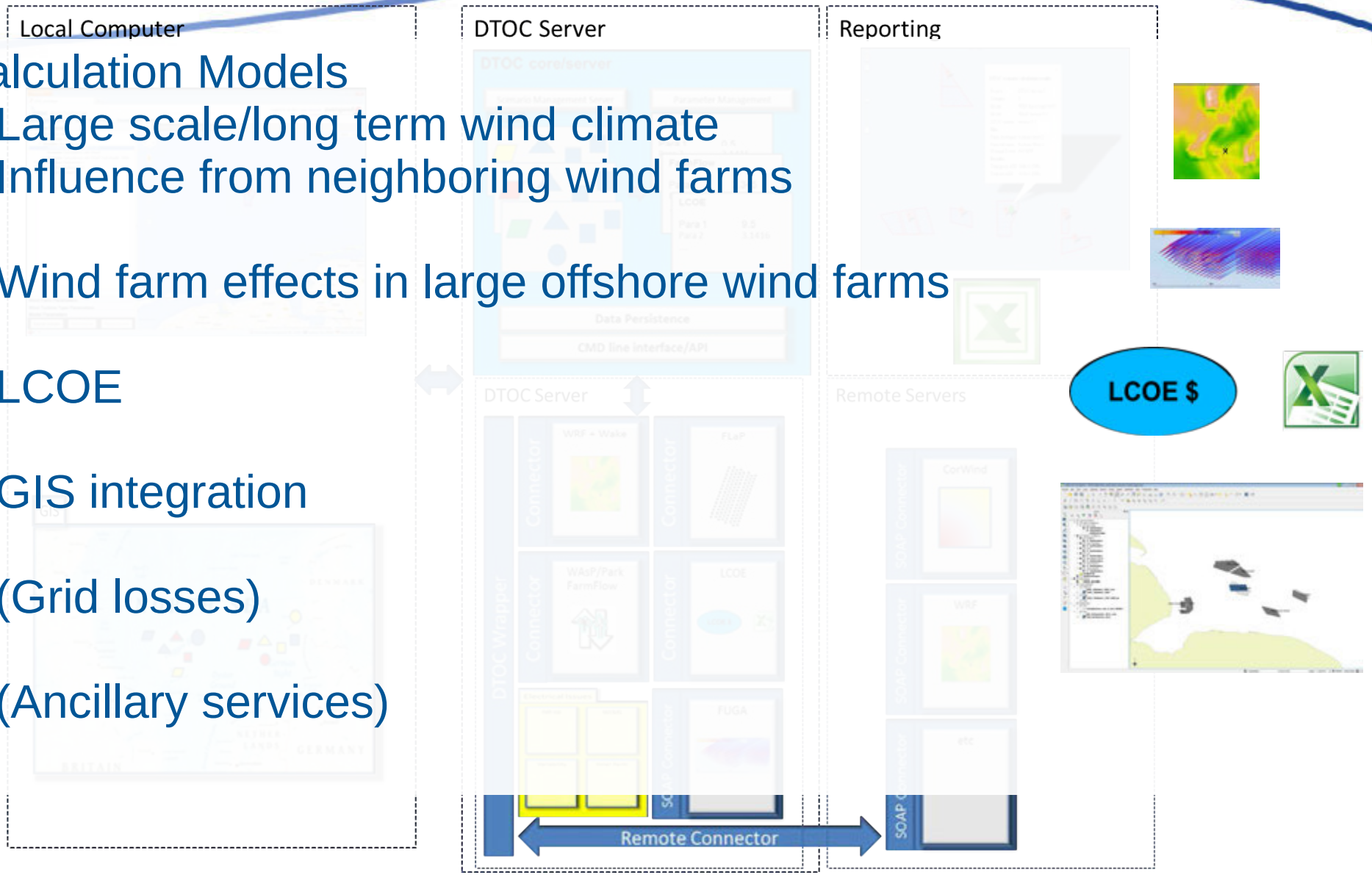
System overview



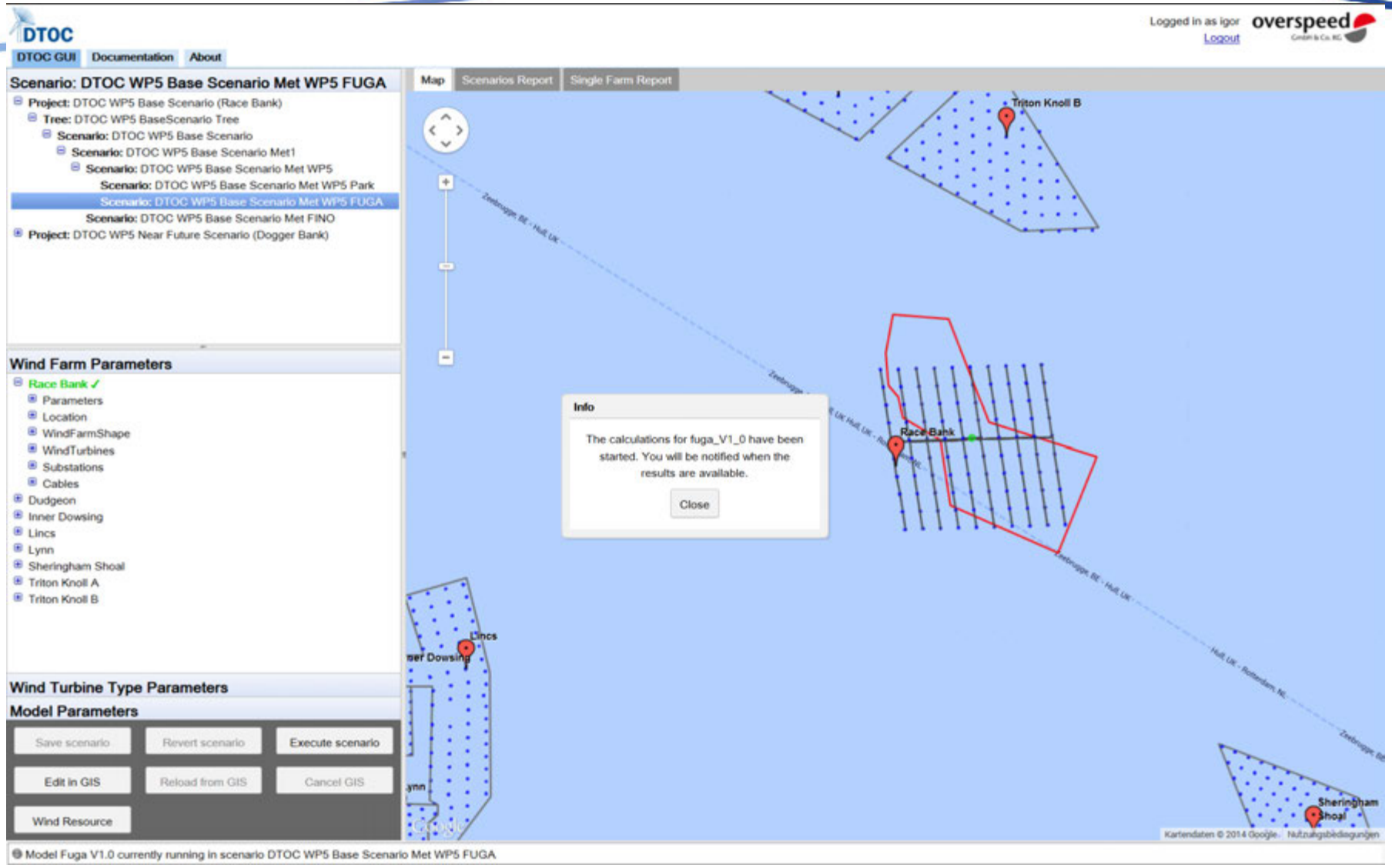
System overview

Calculation Models

- Large scale/long term wind climate
- Influence from neighboring wind farms
- Wind farm effects in large offshore wind farms
- LCOE
- GIS integration
- (Grid losses)
- (Ancillary services)

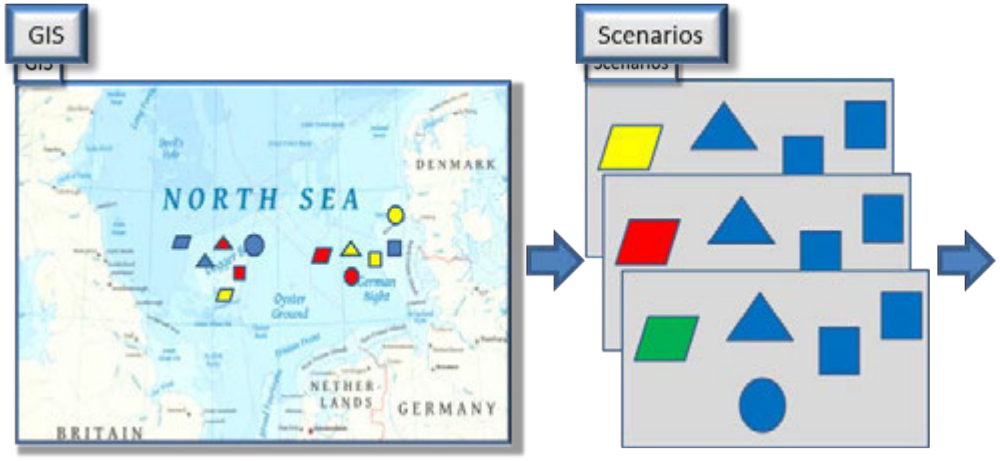


DTOC GUI


DTOC
DTOC GUI
Documentation
About
Logged in as igor
Logout
overspeed
Scenario: DTOC WP5 Base Scenario Met WP5 FUGA
Project: DTOC WP5 Base Scenario (Race Bank)
Tree: DTOC WP5 BaseScenario Tree
Scenario: DTOC WP5 Base Scenario
Scenario: DTOC WP5 Base Scenario Met1
Scenario: DTOC WP5 Base Scenario Met WP5
Scenario: DTOC WP5 Base Scenario Met WP5 Park
Scenario: DTOC WP5 Base Scenario Met WP5 FUGA
Scenario: DTOC WP5 Base Scenario Met FINO
Project: DTOC WP5 Near Future Scenario (Dogger Bank)
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
Save scenario
Revert scenario
Execute scenario
Edit in GIS
Reload from GIS
Cancel GIS
Wind Resource
Map
Scenarios Report
Single Farm Report
Triton Knoll B
Race Bank
Info
The calculations for fuga_V1_0 have been started. You will be notified when the results are available.
Close
Lincs
Sheringham Shoal
Model Fuga V1.0 currently running in scenario DTOC WP5 Base Scenario Met WP5 FUGA

Scenario approach

- Organizing wind farm variants as scenarios
- Scenario tree: hierarchy
- Inheritance between branches and trees



DTOC

DTOC GUI | Documentation | About

Scenario: DTOC WP5 Base Scenario Met WP5 FUGA

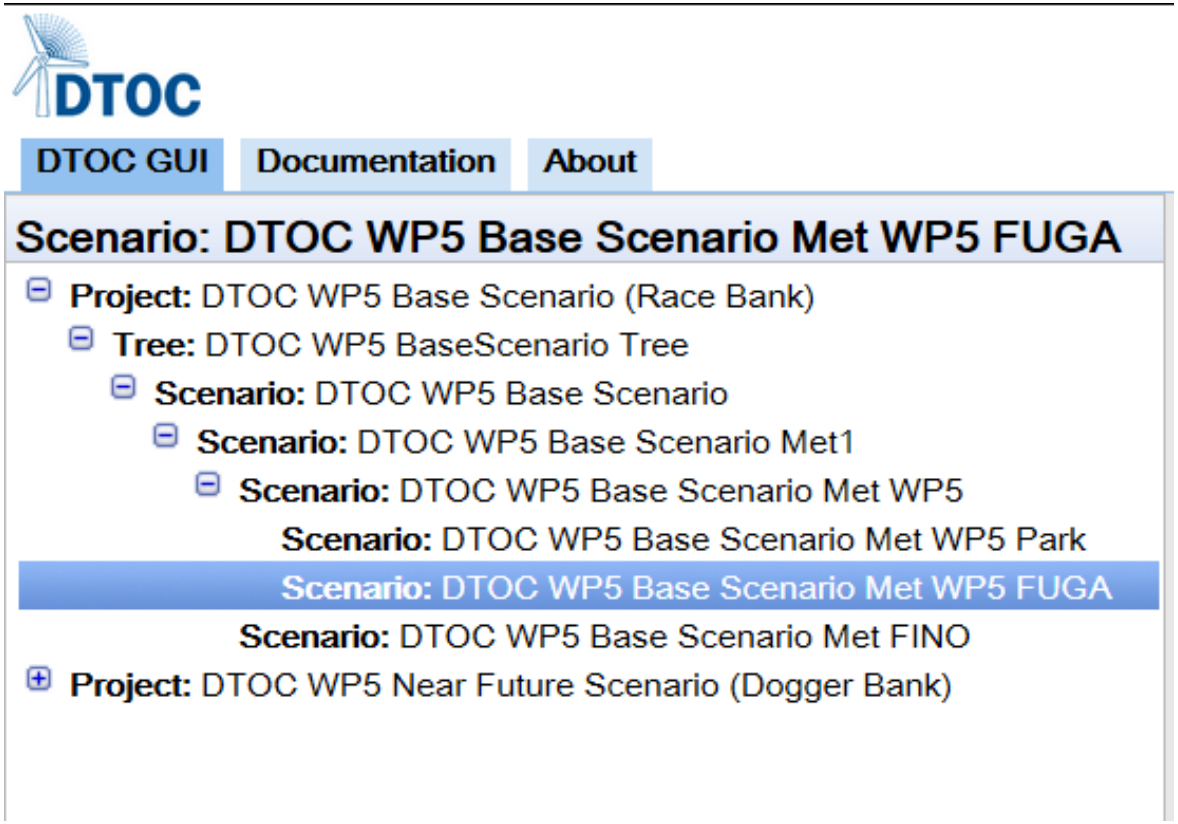
- **Project:** DTOC WP5 Base Scenario (Race Bank)
  - **Tree:** DTOC WP5 BaseScenario Tree
    - **Scenario:** DTOC WP5 Base Scenario
      - **Scenario:** DTOC WP5 Base Scenario Met1
        - **Scenario:** DTOC WP5 Base Scenario Met WP5
          - **Scenario:** DTOC WP5 Base Scenario Met WP5 Park
          - **Scenario:** DTOC WP5 Base Scenario Met WP5 FUGA
          - **Scenario:** DTOC WP5 Base Scenario Met FINO
- **Project:** DTOC WP5 Near Future Scenario (Dogger Bank)

What is a scenario?

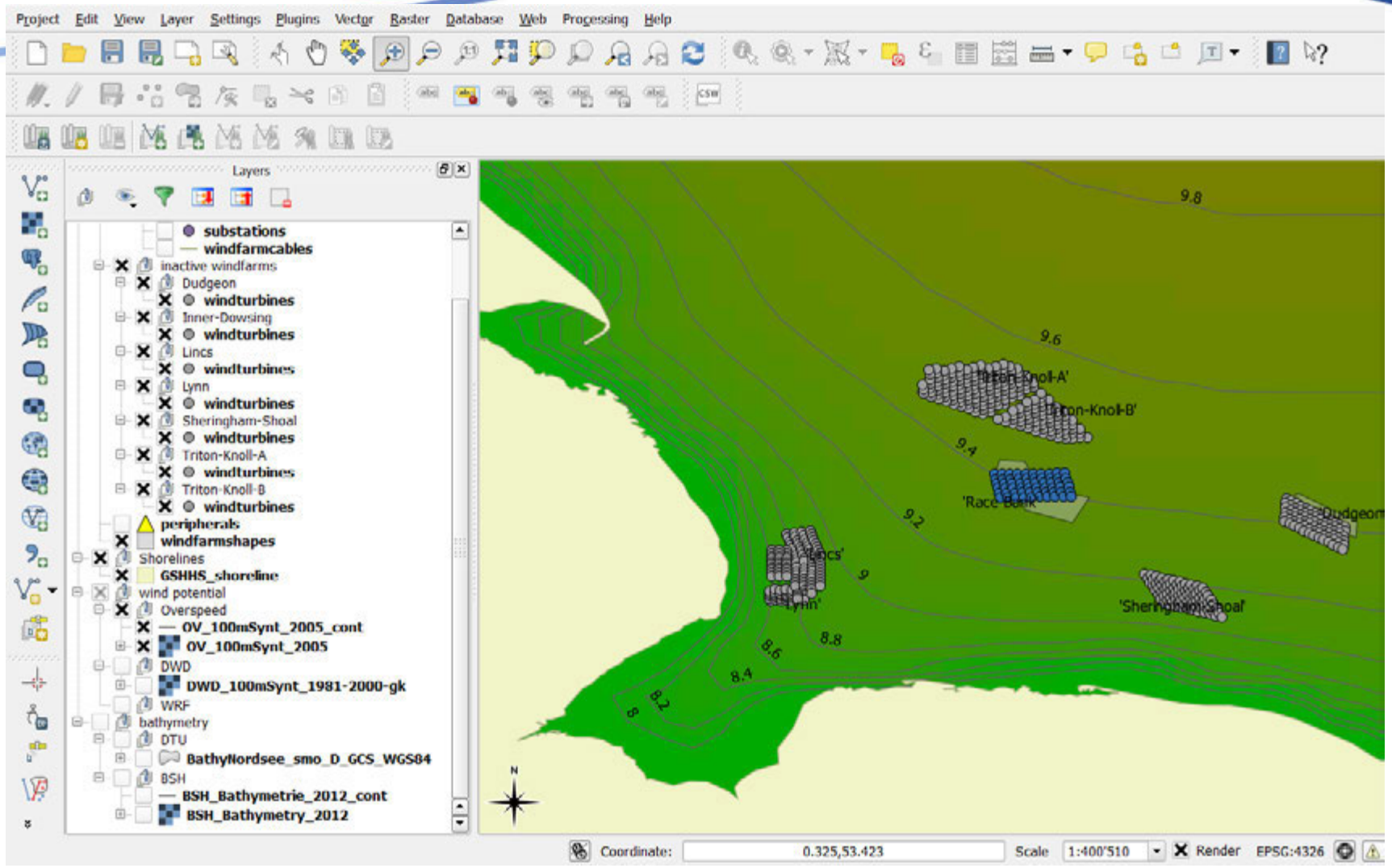
- Wind climate

- Turbinepositions
- Turbinetypes

- Model combinations
- Model runs
- Model parameters



DTOC GIS



Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help
Layers
substations
windfarmcables
inactive windfarms
Dudgeon
windturbines
Inner-Dowsing
windturbines
Lincs
windturbines
Lynn
windturbines
Sheringham-Shoal
windturbines
Triton-Knoll-A
windturbines
Triton-Knoll-B
windturbines
peripherals
windfarmshapes
Shorelines
GSHHS_shoreline
wind potential
Overspeed
OV_100mSynt_2005_cont
OV_100mSynt_2005
DWD
DWD_100mSynt_1981-2000-gk
WRF
bathymetry
DTU
BathyNordsee_smo_D_GCS_WGS84
BSH
BSH_Bathymetrie_2012_cont
BSH_Bathymetry_2012
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
8
'Triton-Knoll-A'
'Triton-Knoll-B'
'Race Bank'
'Dudgeon'
'Lincs'
'Lynn'
'Sheringham-Shoal'
N
Coordinate:
0.325,53.423
Scale
1:400'510
Render
EPSG:4326

Comparative reporting

DTOC Energy Production Report

23.04.2014

EON, 2014 Reference LCOE: 13.5 ct/kWh

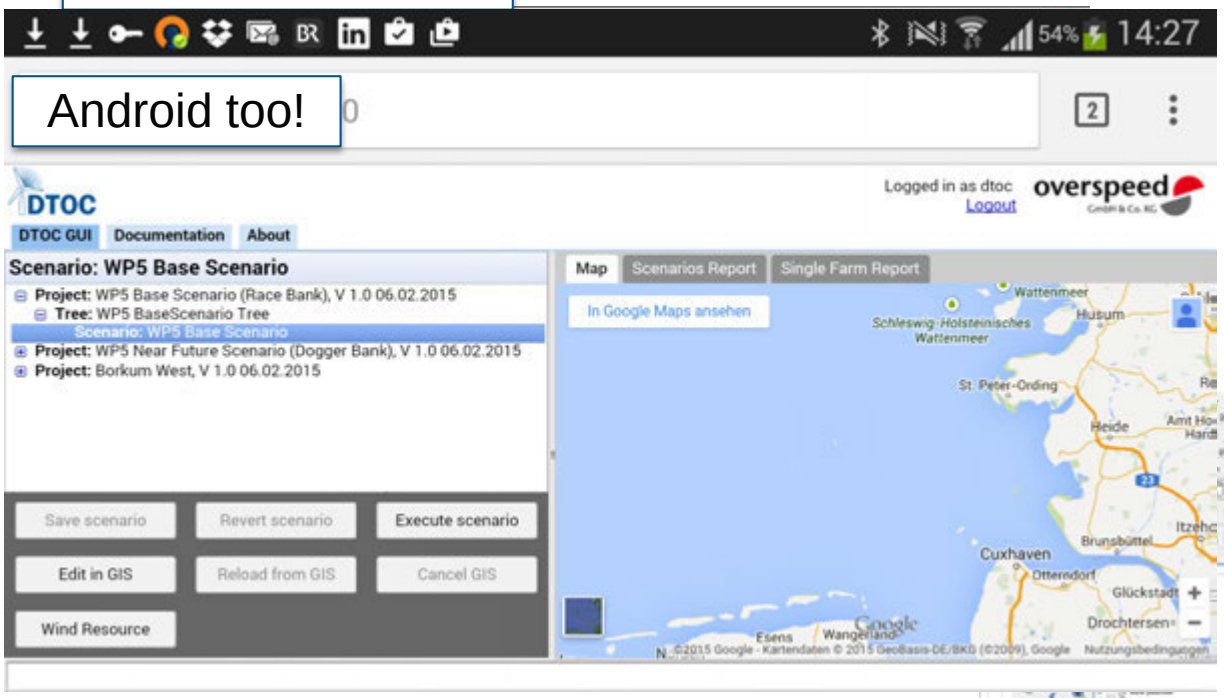
Reference Scenario: BWII - WAsP

	Scenario Shortname	BWII - WAsP *	BWII - FLaP	BWII - WAsP 100m
Comment		Calculations with WAsP	Calculations with FLaP	Calculations with WAsP, hub height: 100m
	Last Update	2014.04.22 14:30	2014.04.22 16:30	2014.04.23 11:05
Turbines				
	Turbine Manufacturer	Areva	Areva	Areva
	Turbine Type	M5000	M5000	M5000
	Nominal Power [kW]	5000	5000	5000
	Rotor Diameter [m]	116	116	116
	Hub Height [m]	90	90	100
Farm				
	Number of Turbines	80	80	80
	Nominal Power Wind Farm [MW]	400	400	400
Results				
	AEP Gross [GWh/a]	1'758.2	1'747.6	1'846.1
	AEP Farm [GWh/a]	1'613.8	1'600.9	1'702.6
	AEP Net [GWh/a]	1'495.0	1'483.1	1'577.1
	Capacity Factor [%]	46.1%	45.7%	48.6%
	Wind Farm Efficiency	91.8%	91.6%	92.2%
	Availability	96.0%	96.0%	96.0%
	Electrical Losses	3.50%	3.50%	3.51%
	LCOE [Cent/kWh]	13.5	13.4	14.2
	LCOE [%]	**+100.00%**	**+99.20%**	**+105.50%**
	delta LCOE [%]	**+0.00%**	**-0.80%**	**+5.50%**

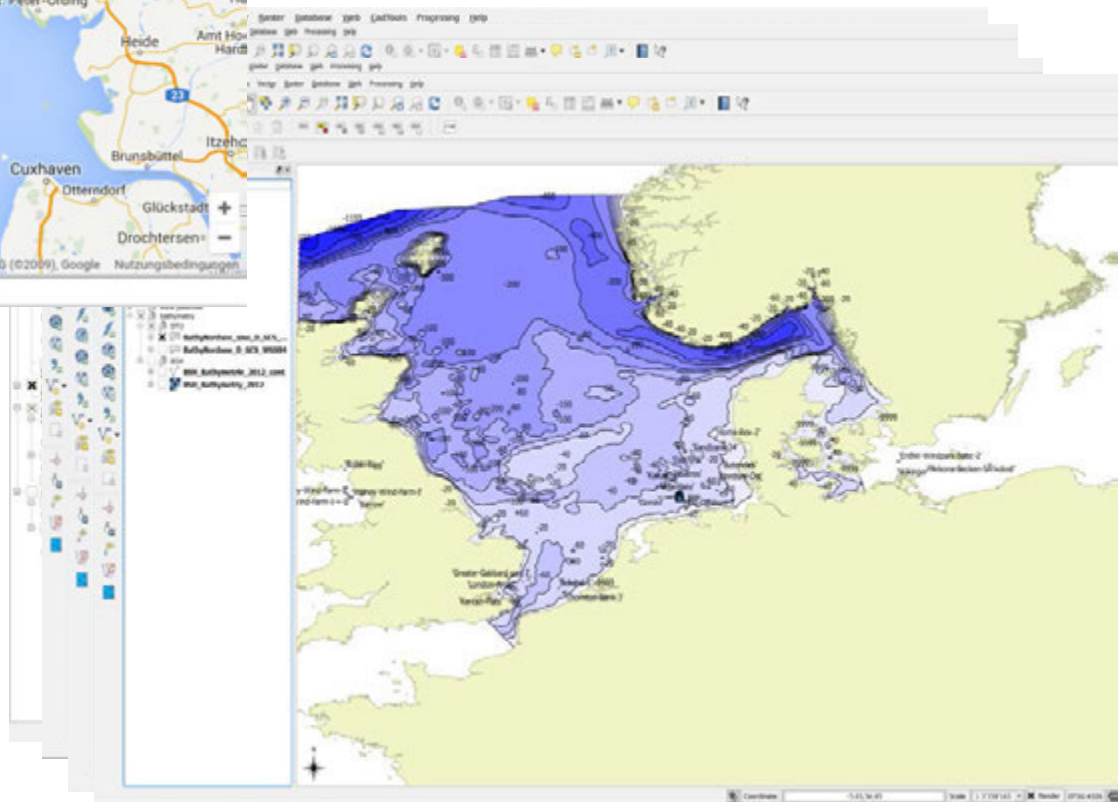
Local computer: GIS and local web browser

Web application

Android too!



Data



Conclusions

- Combined many existing models
- From meso-scale model input to farm model
- In a multi-user framework
- Supports optimisation

EERA DTOC project vision