EERA-DTOC – The Software

Offshore Clusters Workshop, London, 6 June 2013

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Peter Stuart, *RES, London, UK*

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

Support by

SEVENTH FRAMEWORK PROGRAMME

EERA-DTOC partners

- DTU Wind Energy
- Fraunhofer IWES
- CENER
- ECN
- EWEA
- SINTEF
- ForWind
- CRES
- CIEMAT
- University of Porto
- University of Strathclyde
- Indiana University
- Collecte Localisation Satellites
- Statkraft
- Iberdrola Renovables
- Statoil
- Overspeed
- BARD
- Hexicon
- Carbon Trust
- E.On
- RES

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- ~~BARD~~
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- ~~Carbon Trust~~
- ~~E.On~~
- RES

User Requirements + User Stories

User requirements process

Activities:

- Internal workshop at kick-off
- Online survey
- External workshop at EWEA 2012 Copenhagen
- Internal workshop at 6-month meeting

Outcome:

- **Product Vision**
- **User Stories**

Run by RES and industrial partners

Users

Two main users were identified:

- Strategic planners
- Developers of offshore wind farms

Associated users could be:

- Consultants
- Research institutions
- Manufacturers
- System Operators

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.

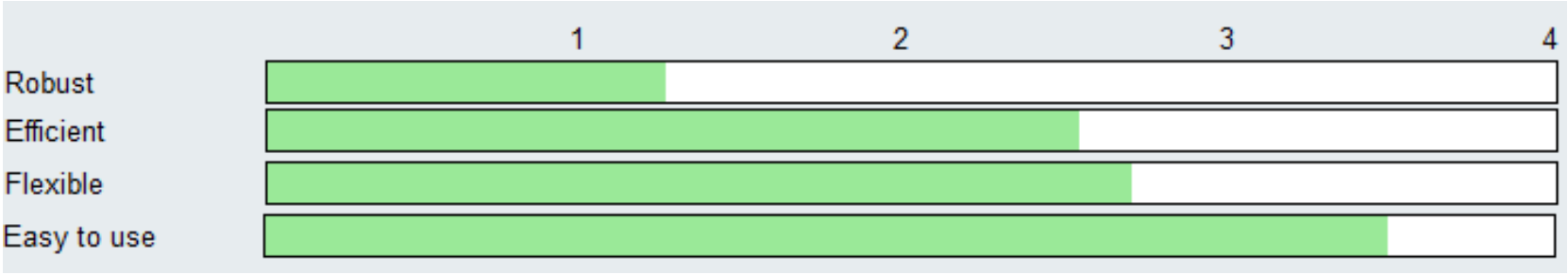
EERA-DTOC vision (continued)

- **Robust**, in the context of EERA-DTOC is understood to mean **validated, stable, reliable, reproducible and technically convincing** (e.g. would stand up to the scrutiny of an independent engineer during technical due diligence for project finance).
- EERA-DTOC is to be built by **integrating existing models (wake, grid, production etc.)**.
- The design in question is that of the **wind turbine layout** (and/or wind farm clusters) and their associated **electrical infrastructure**. Design optimisation is with regard to the total **cost of energy** (including cost of finance). The EERA-DTOC tool will facilitate the optimisation process by supporting decision making through the efficient processing of **many design scenarios** for consideration in conjunction with separate cost/financial modelling tools.
- At the **individual wind farm level** the anticipated users are primarily developers looking to optimise their specific wind farms subject to the influence of neighbouring wind farms.
- At the **cluster level** the anticipated users are strategic planners looking to optimise the location of many offshore wind farms (and their associated electrical infrastructure) within a particular region.
- In particular EERA-DTOC will focus on **precisely predicting the wake losses**, and associated uncertainty, due to both a specific offshore wind farm on itself (internal wake losses) and wake losses due to clusters of neighbouring offshore wind farms (external wake losses).

Online Survey

- The survey had 22 respondents (19 project participants and 3 external)
- 11 of the responses were from industry (primarily developers)
- 18 of the respondents considered themselves potential users of the tool.
- '**Robust**' and '**Validated**' were identified as key project values.
- The survey suggests that **existing tools do not allow efficient design**. Cluster design in particular has the weakest existing tools.
- The survey indicates that exploring many design options is fundamental to the design process.
- The survey indicates that the wind farm layout and electrical infrastructure cannot be optimised in isolation.
- The survey suggests that all the proposed requirements are important. This makes the prioritisation exercise of the workshop very important.

Online Survey Results: Project Values



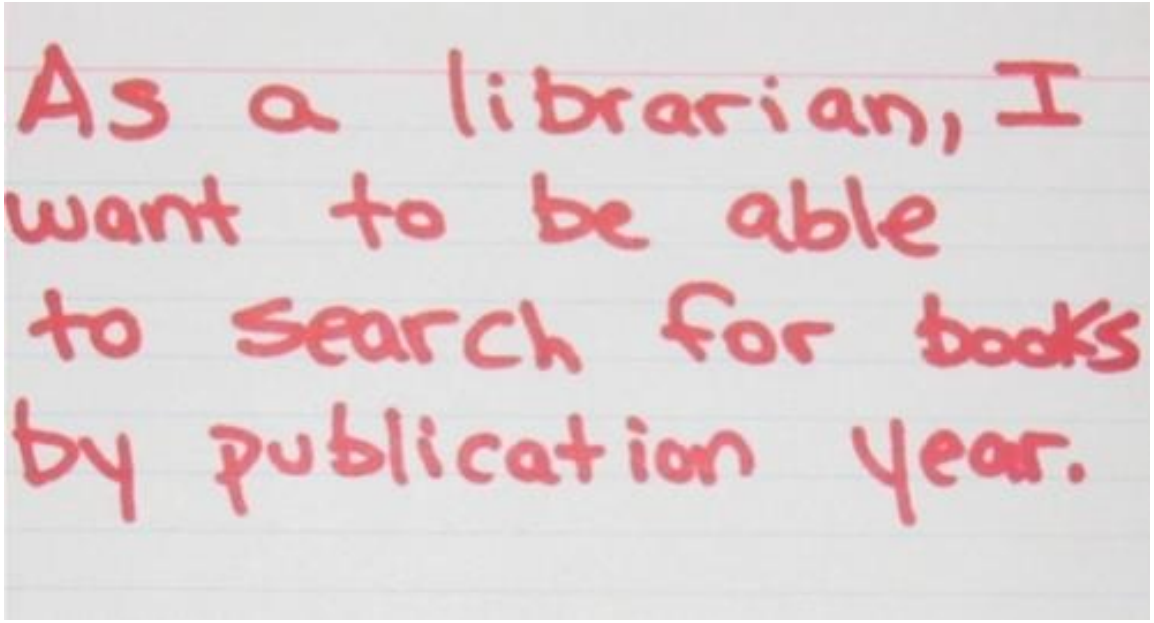
Robust and Validated are the key project values!

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

Robust, in the context of EERA-DTOC is understood to mean **validated, stable, reliable, reproducible and technically convincing*

Concept of User Stories

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



Example 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

Software Implementation

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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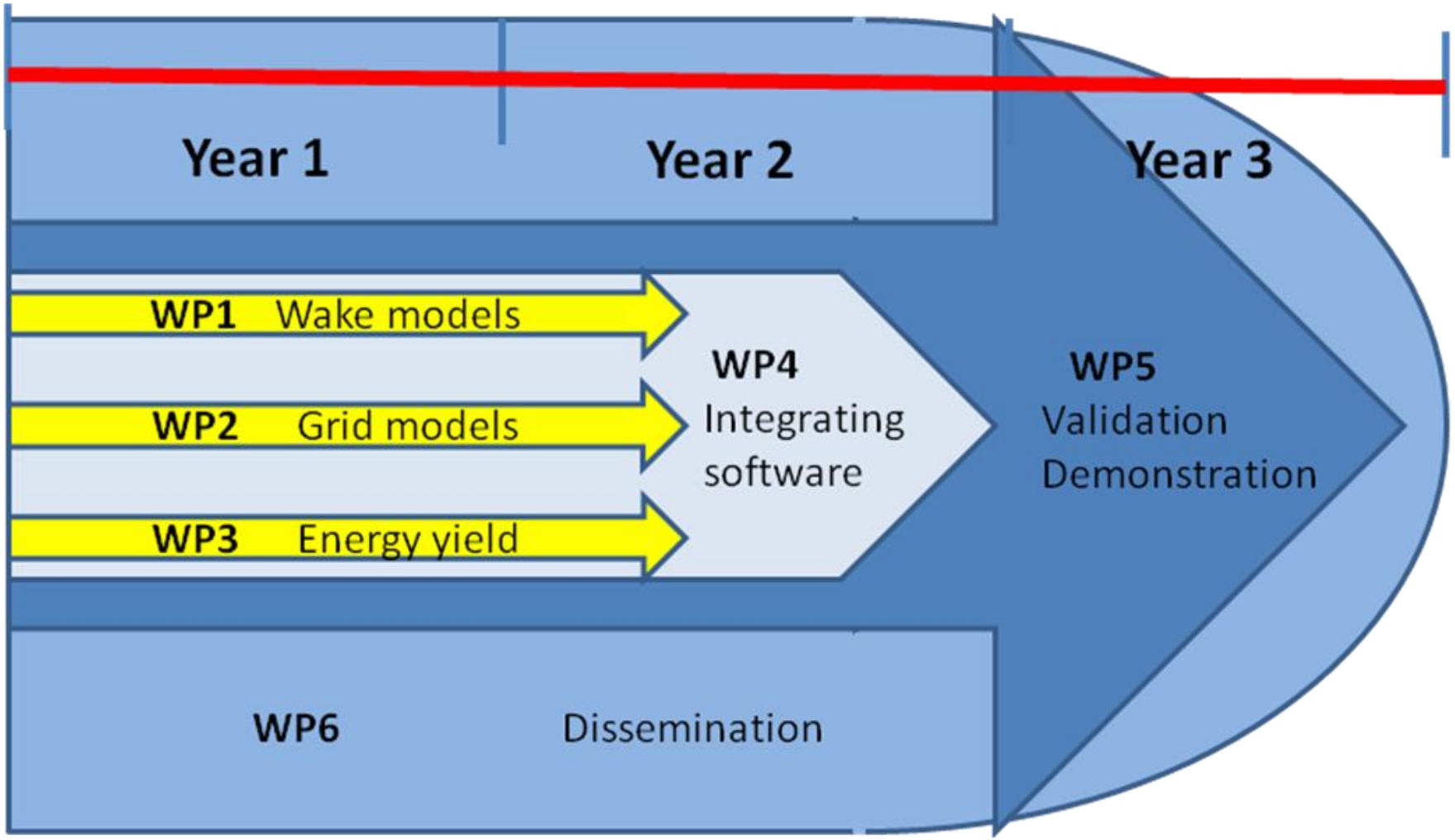
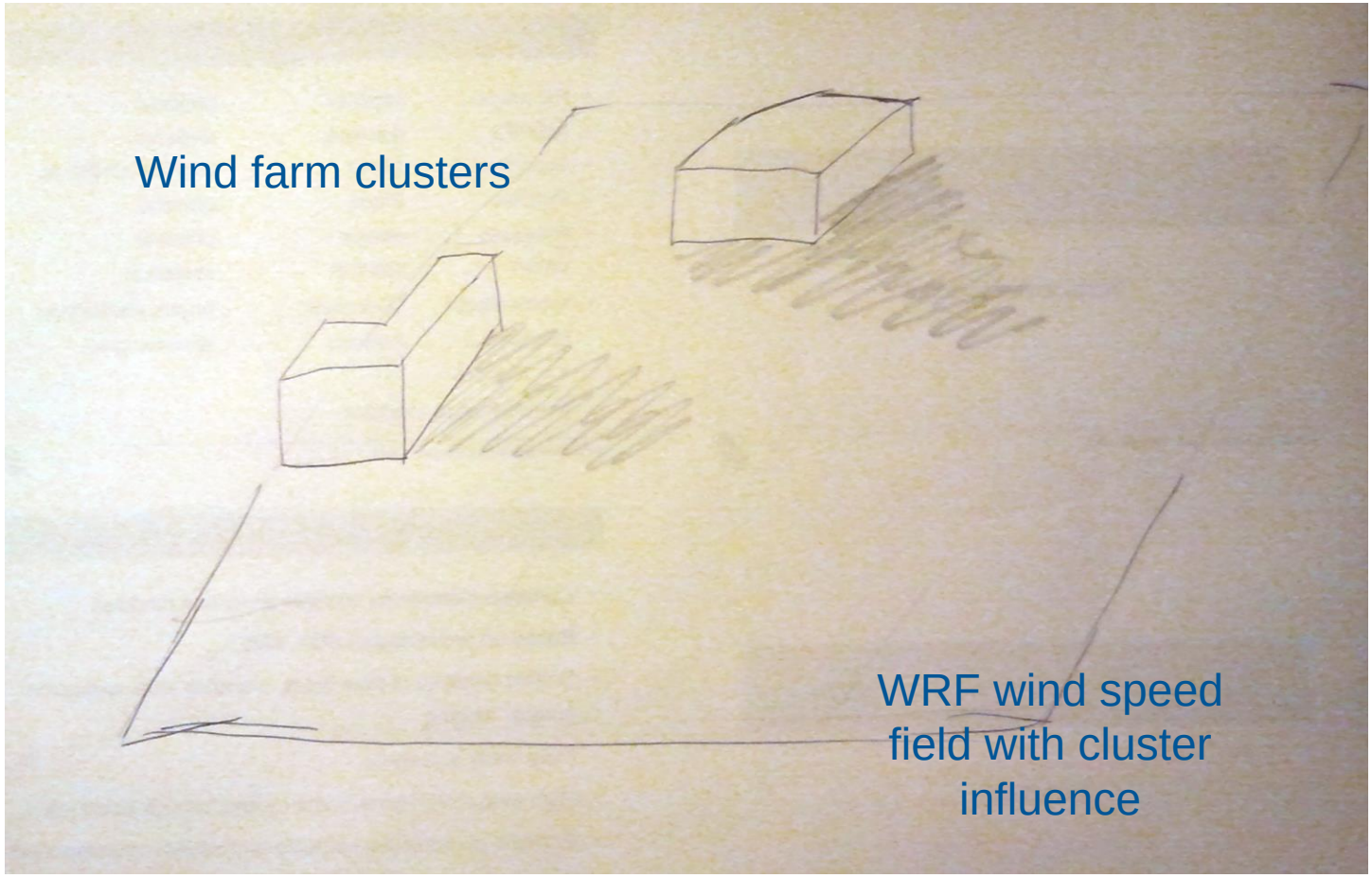
Runs on Cluster under UNIX/Linux

Model Chain

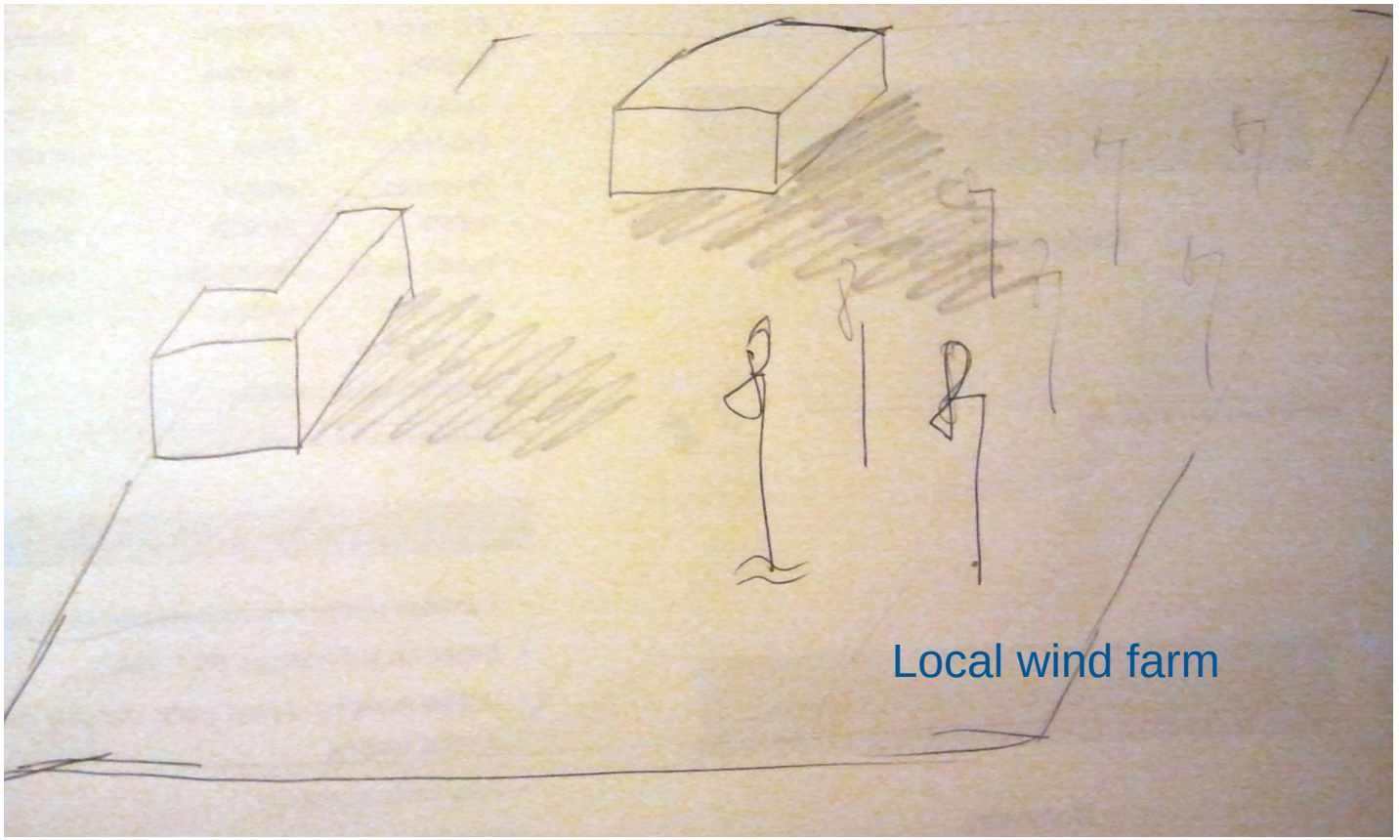
EERA-DTOC WP structure



WRF/Wind farm model coupling



WRF/Wind farm model coupling ctd.



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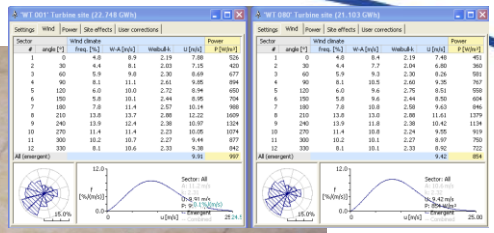
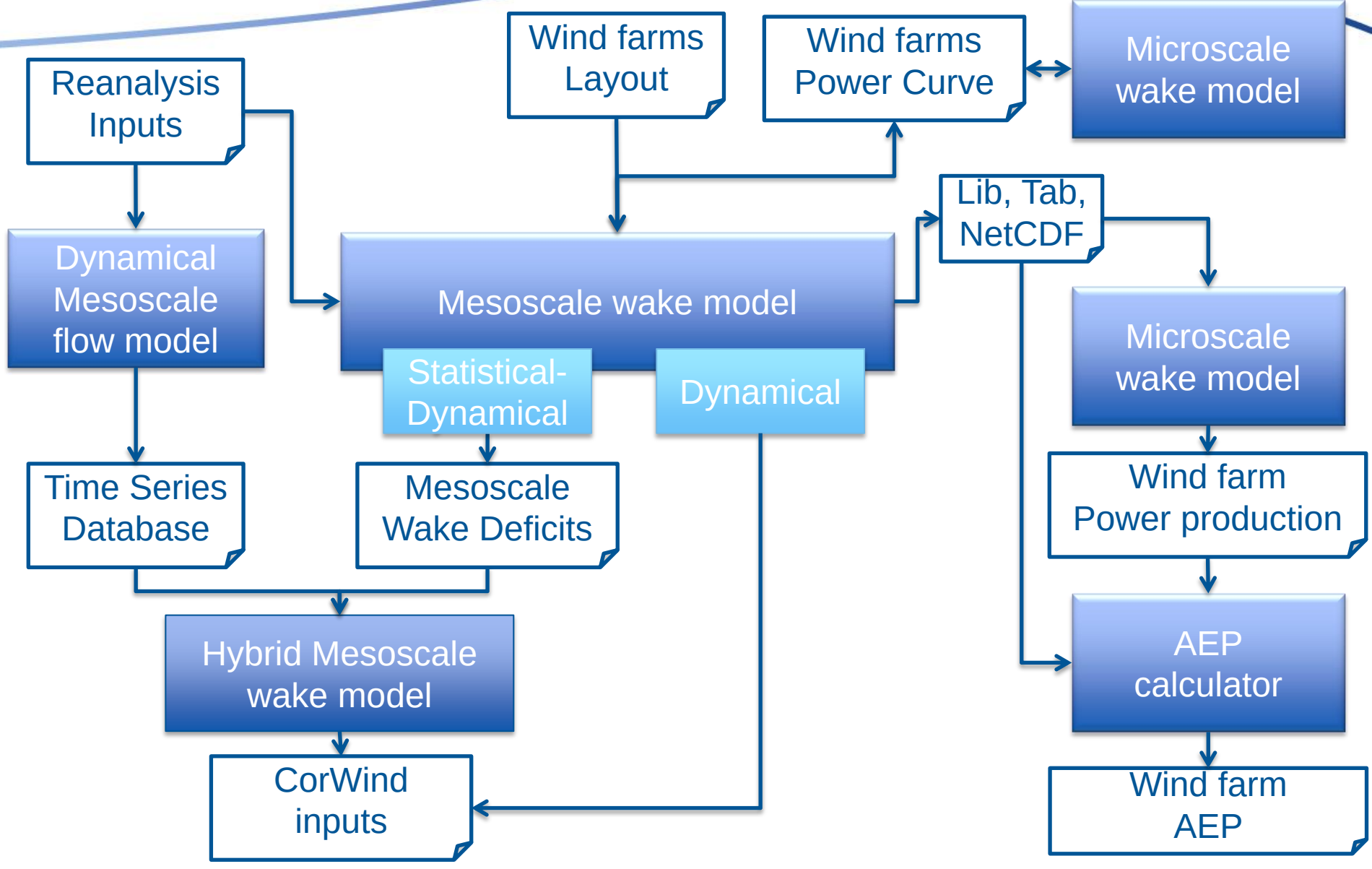
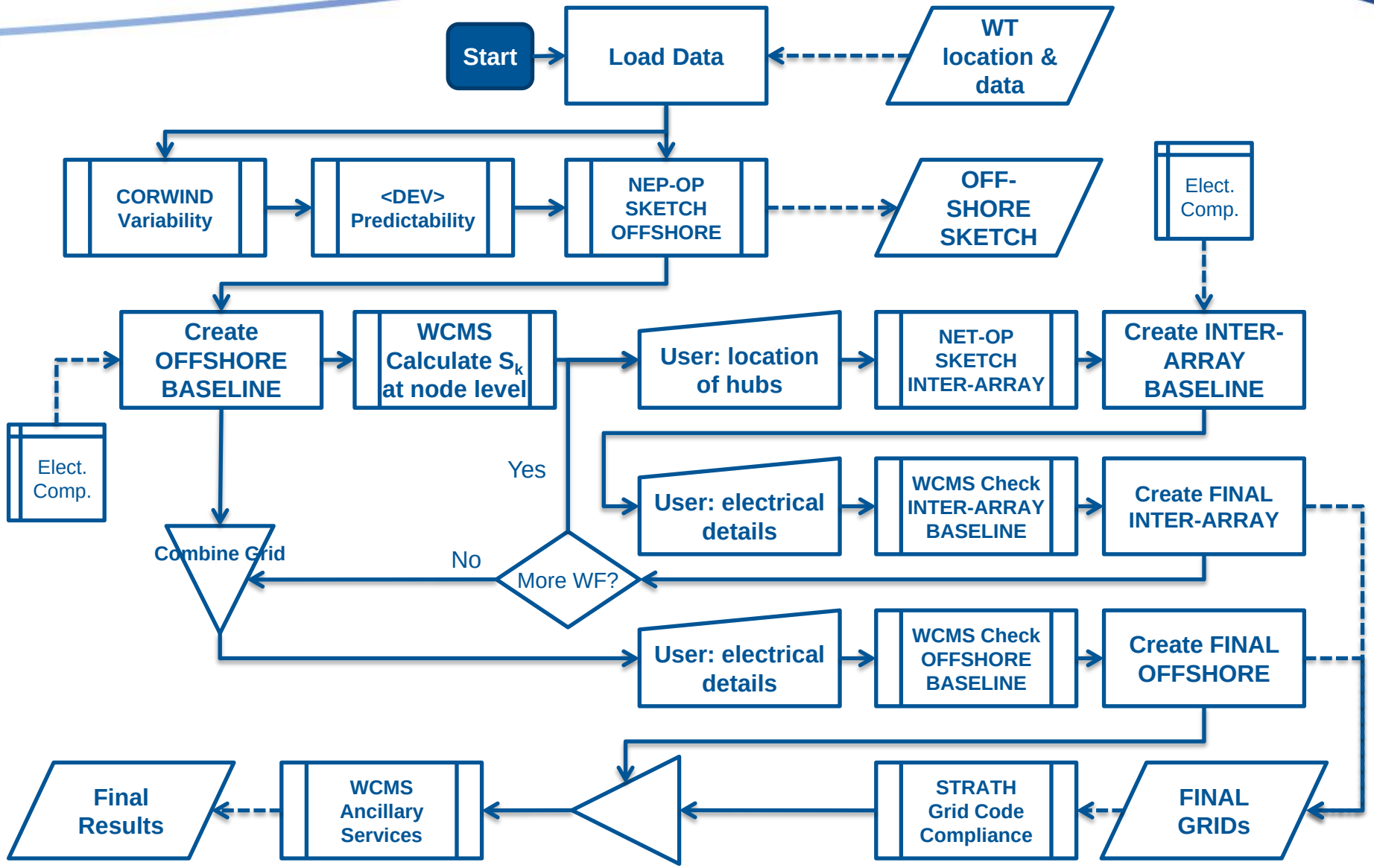


WRF level at hub height, wind climate for each turbine position

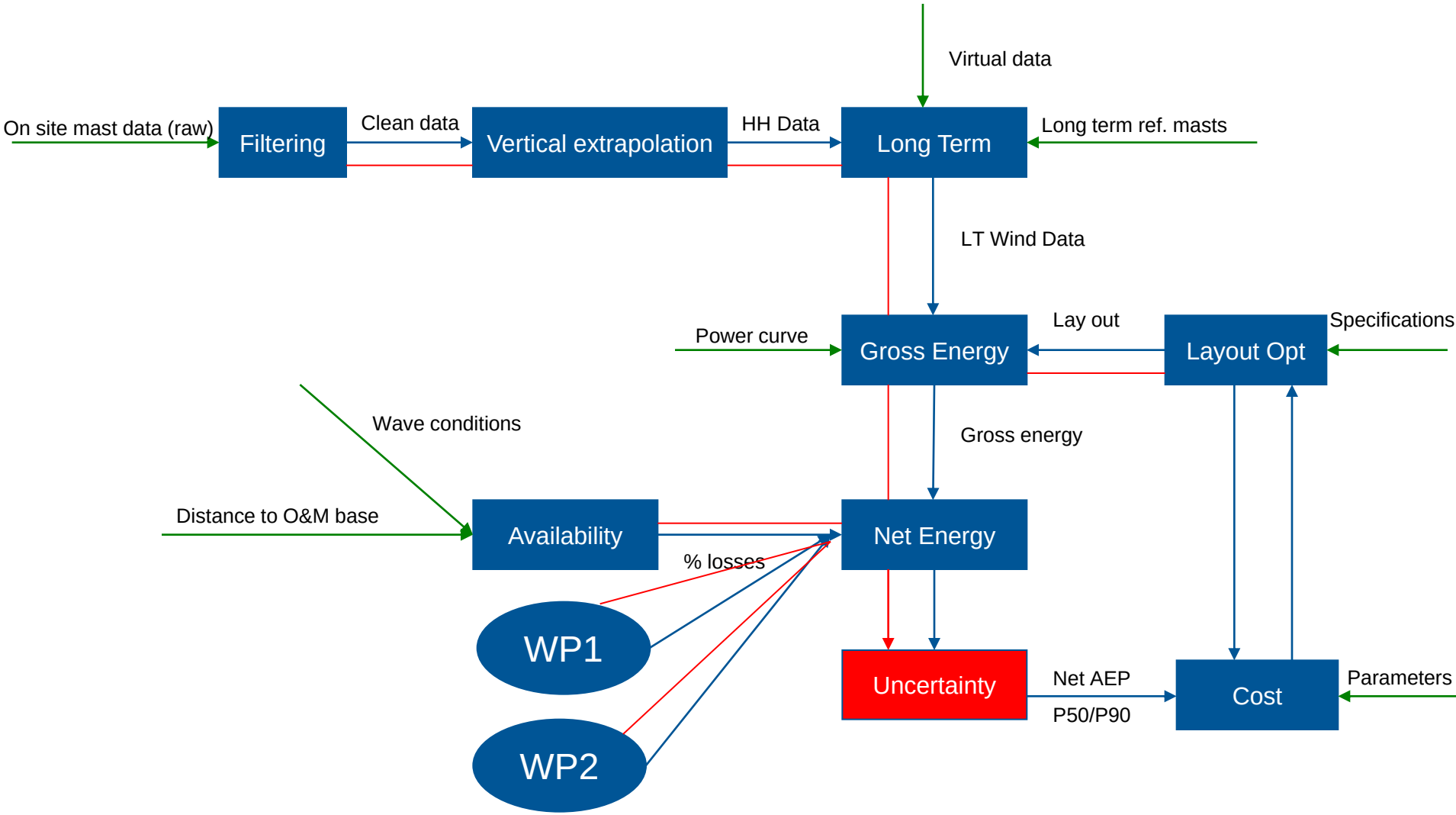
Model Workflow WP1



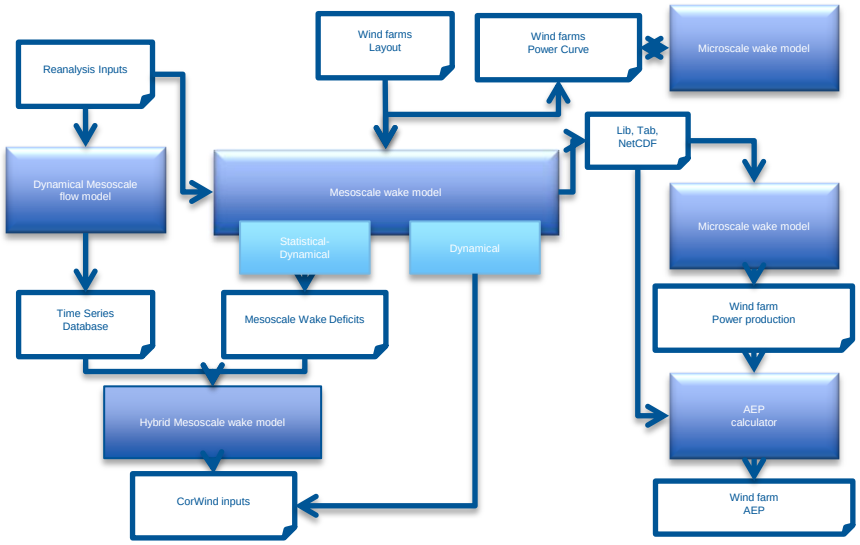
Model Workflow WP2

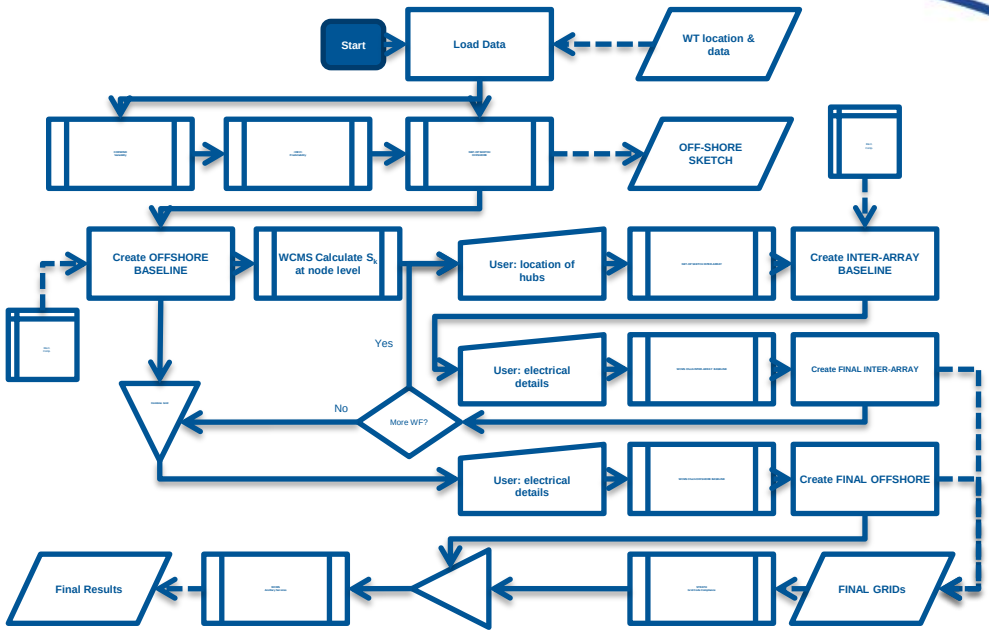


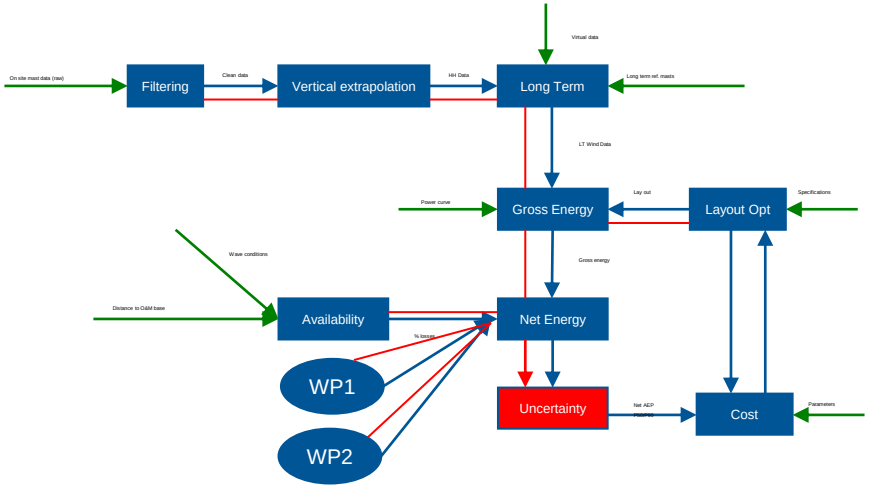
Model Workflow WP3



Total tool overview







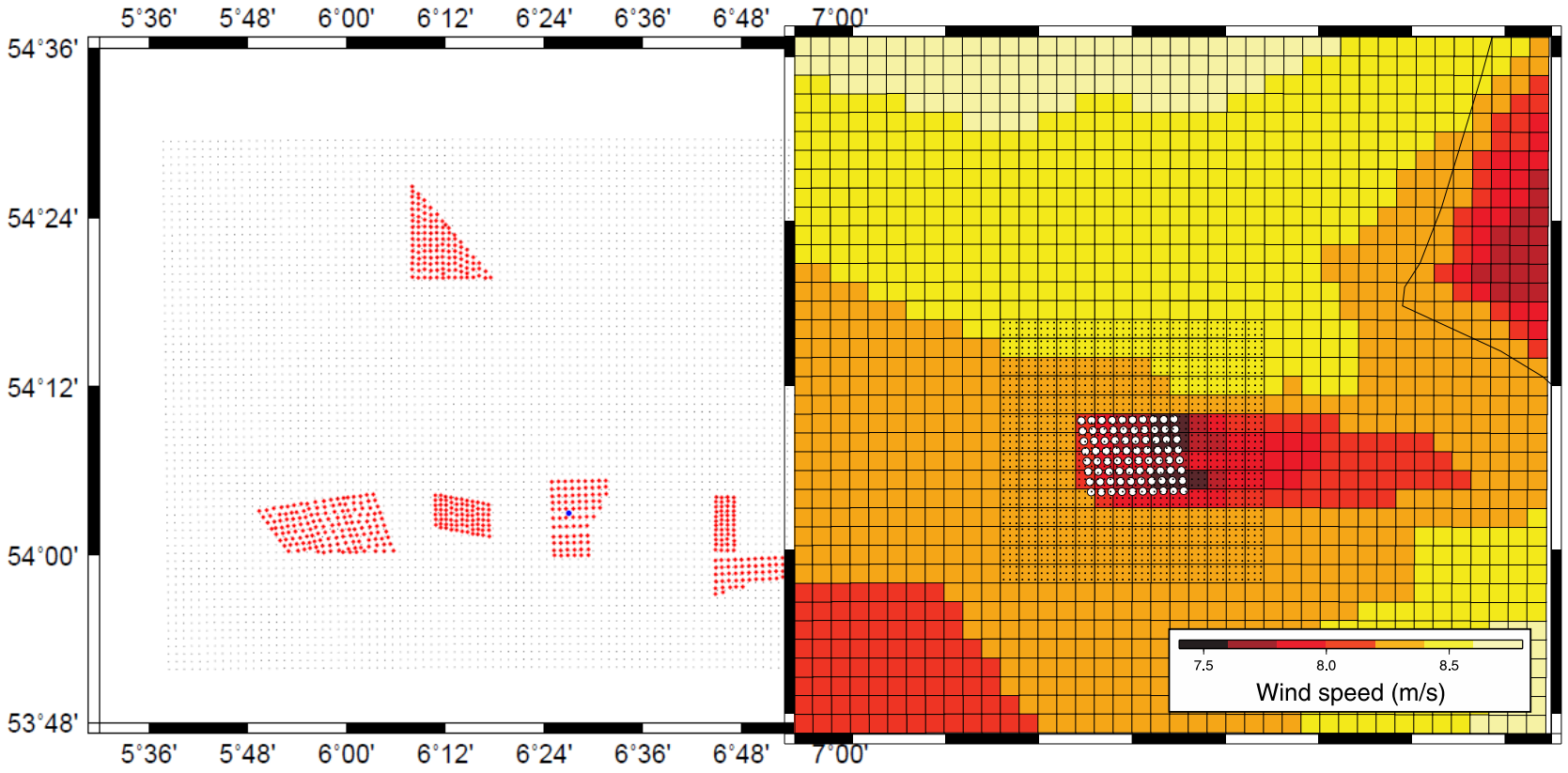
Total tool overview

Dry Run Approach

Understanding the Model Coupling

Example User Story:

As a developer, I can determine the wake effects of neighbouring wind farm clusters on a single wind farm.



DR I: Energy prod. of single farm in cluster

Wind farm clusters/meso-scale effects

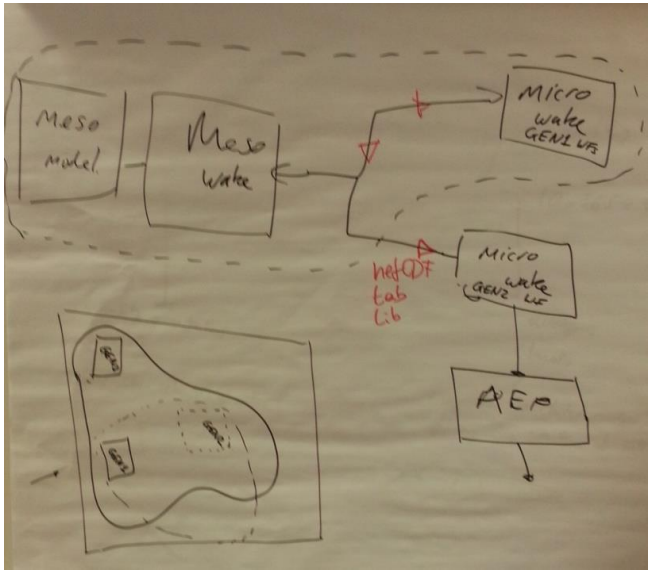
Wind speed field with wind farm cluster influence

Single wind farm model

Wind farm AEP with consideration of cluster influence

WRF with wind farm extension:
WRF @ Risoe DTU
WRF @ Ciemat

WAsP/Park
FarmFlow
Jensen model

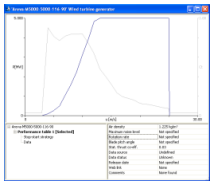


WRF/Farm model coupling

DTOC XML

Turbine clusters

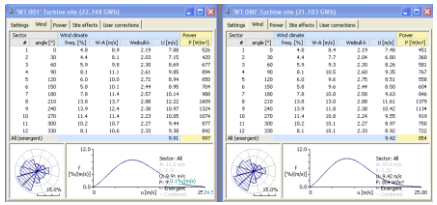
Turbine types



Turbine types

Turbine positions single farm

Representative meteo



Turbine positions

Turbine types

WRF

WRF netCDF

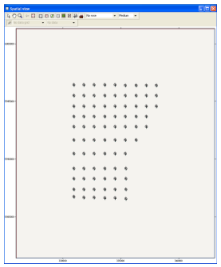
Tab for each wturbine site

WAsP

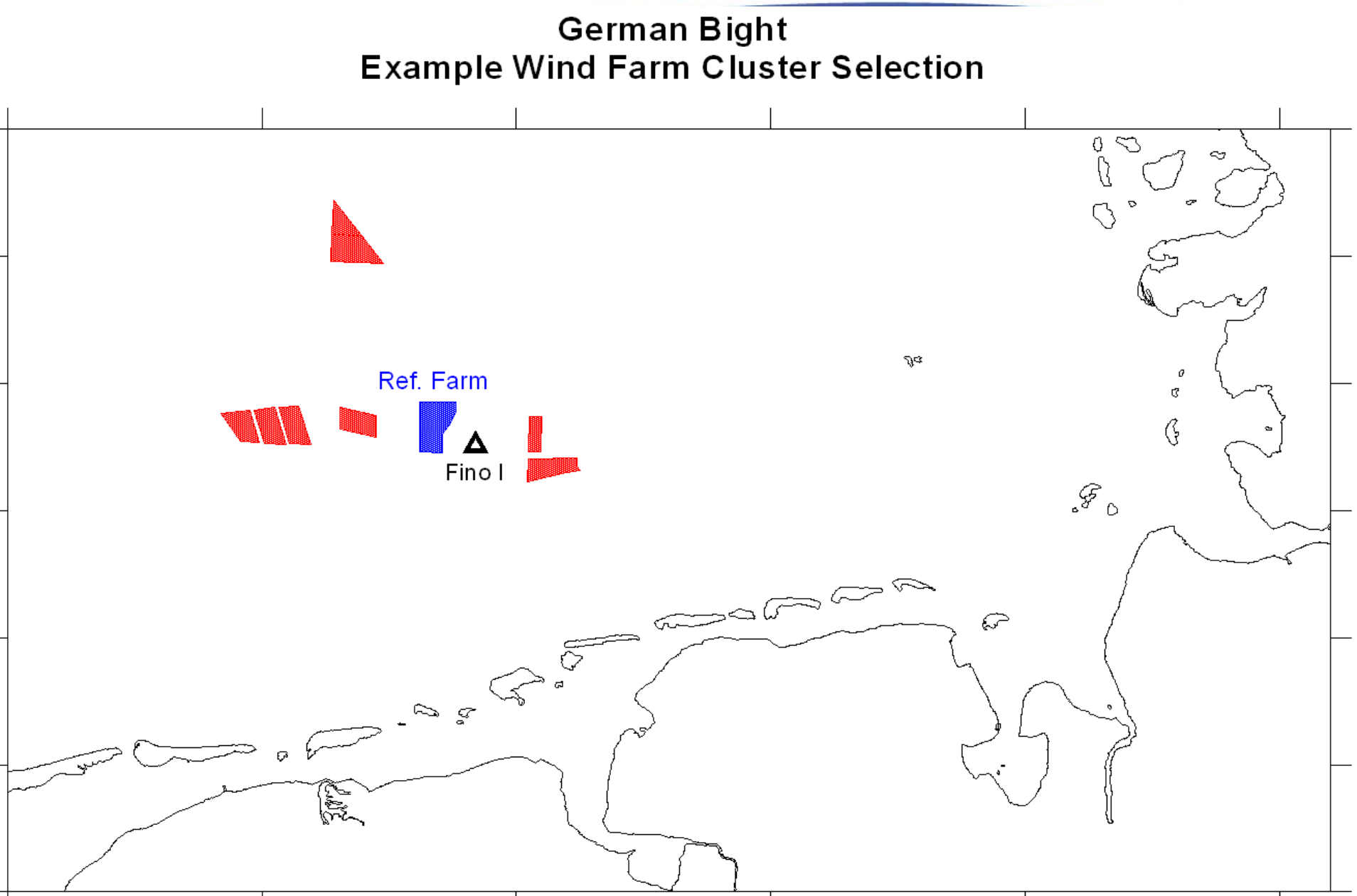
Park

AEP

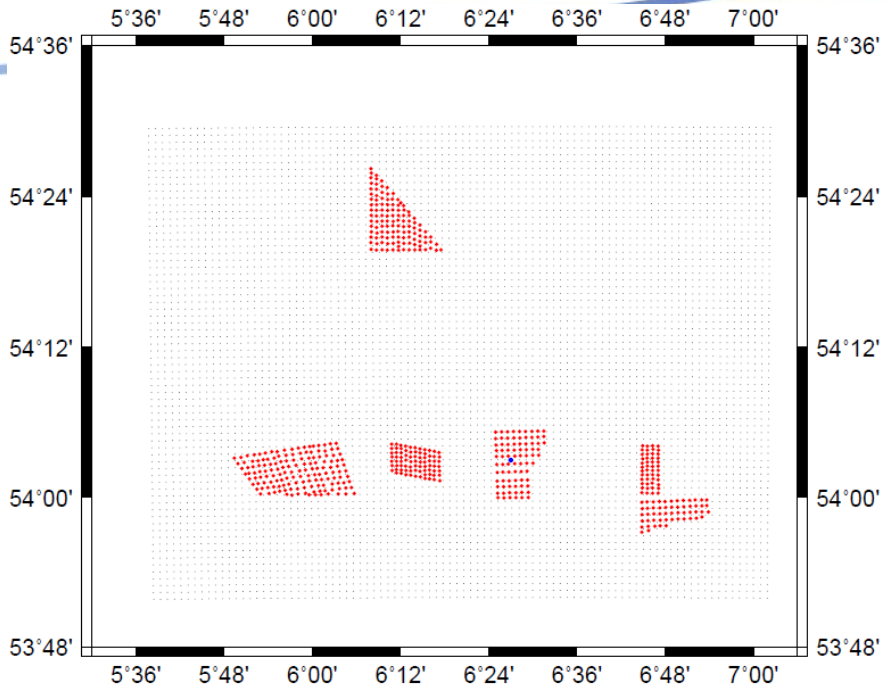
Google maps

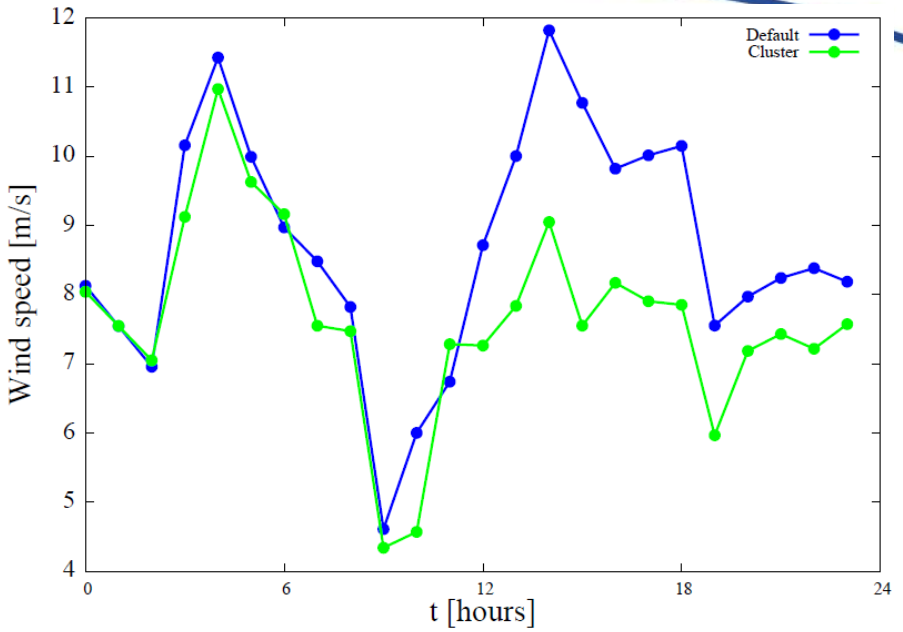


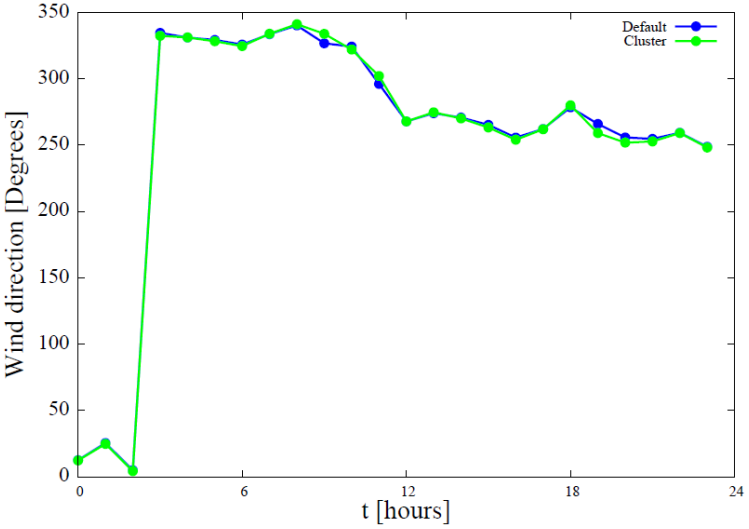
Dry run example:
calculate one farm in presence of Cluster



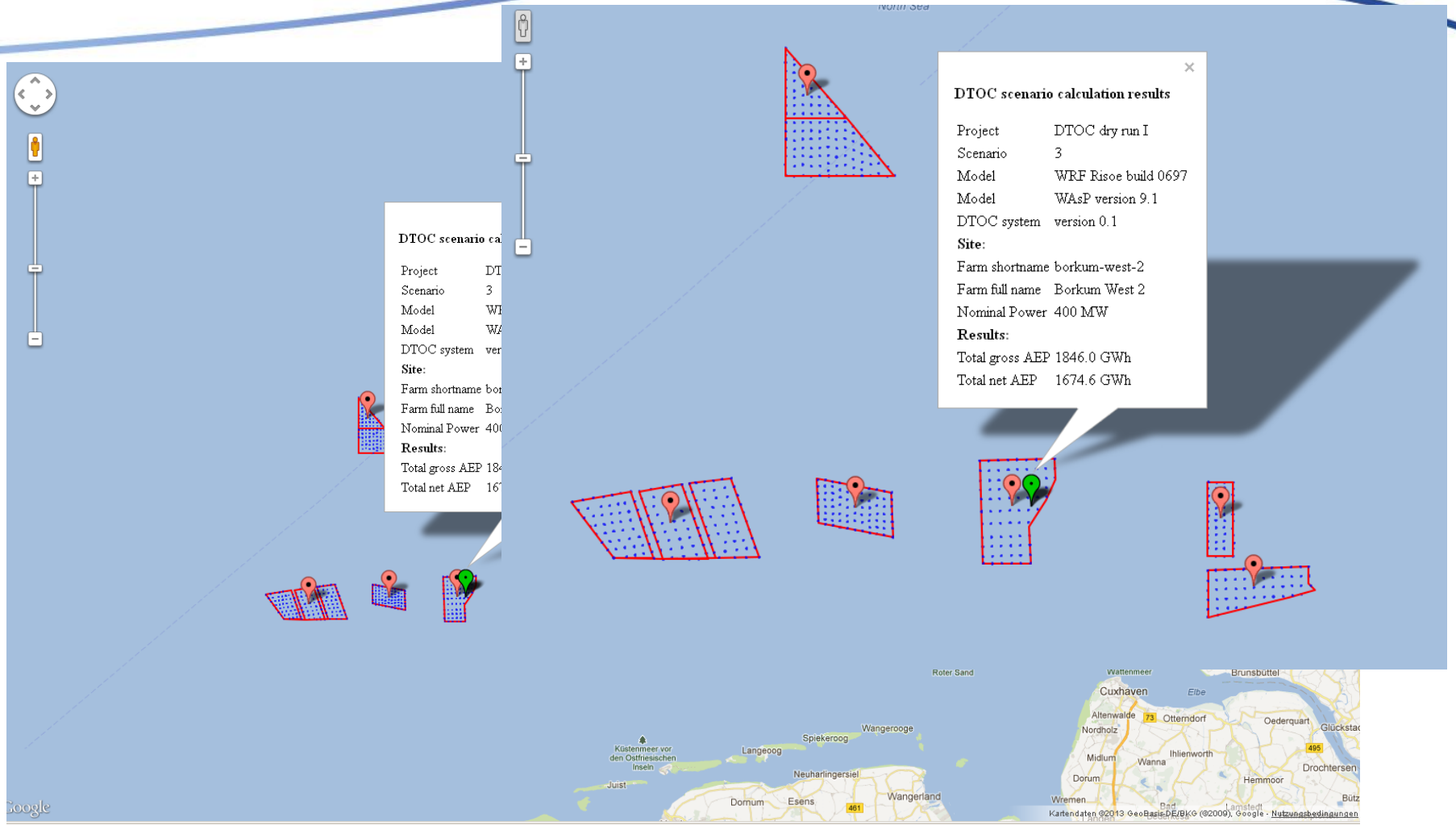
DR I: WRF@Ciemat







WRF/Farm model coupling Google maps



EERA DTOC

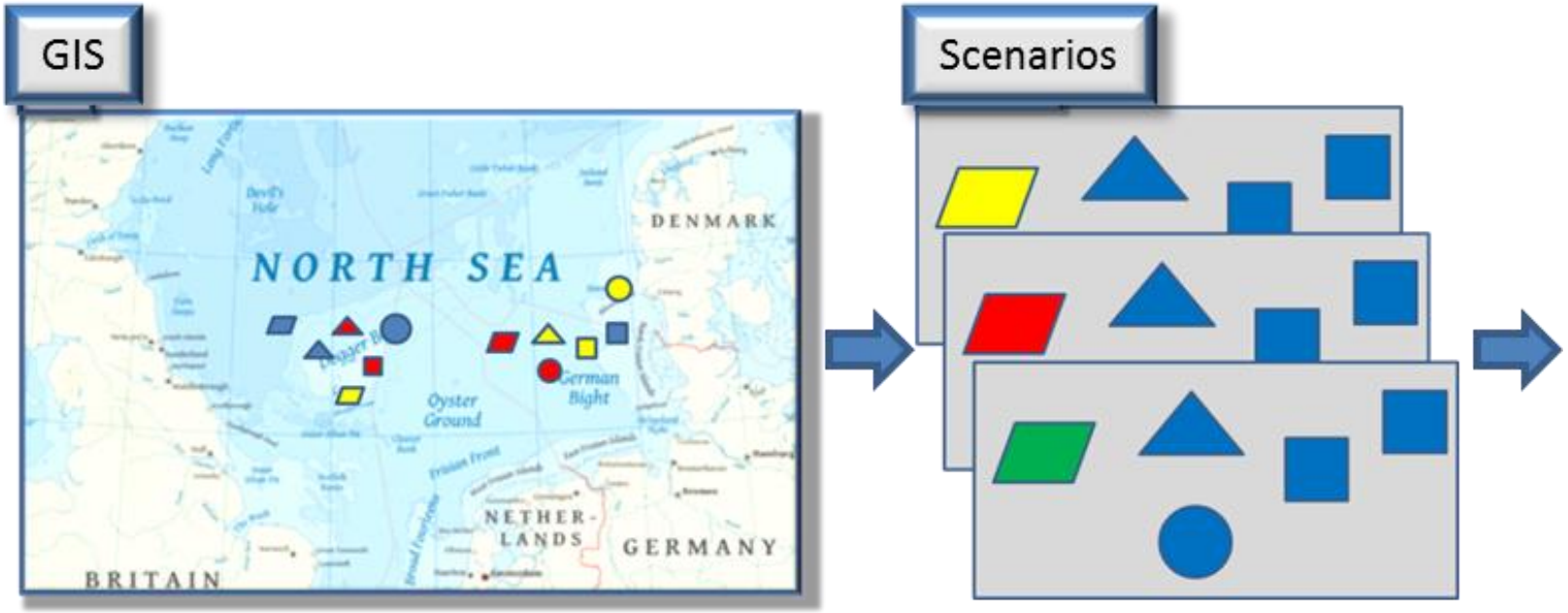
Software Design

Open interfaces

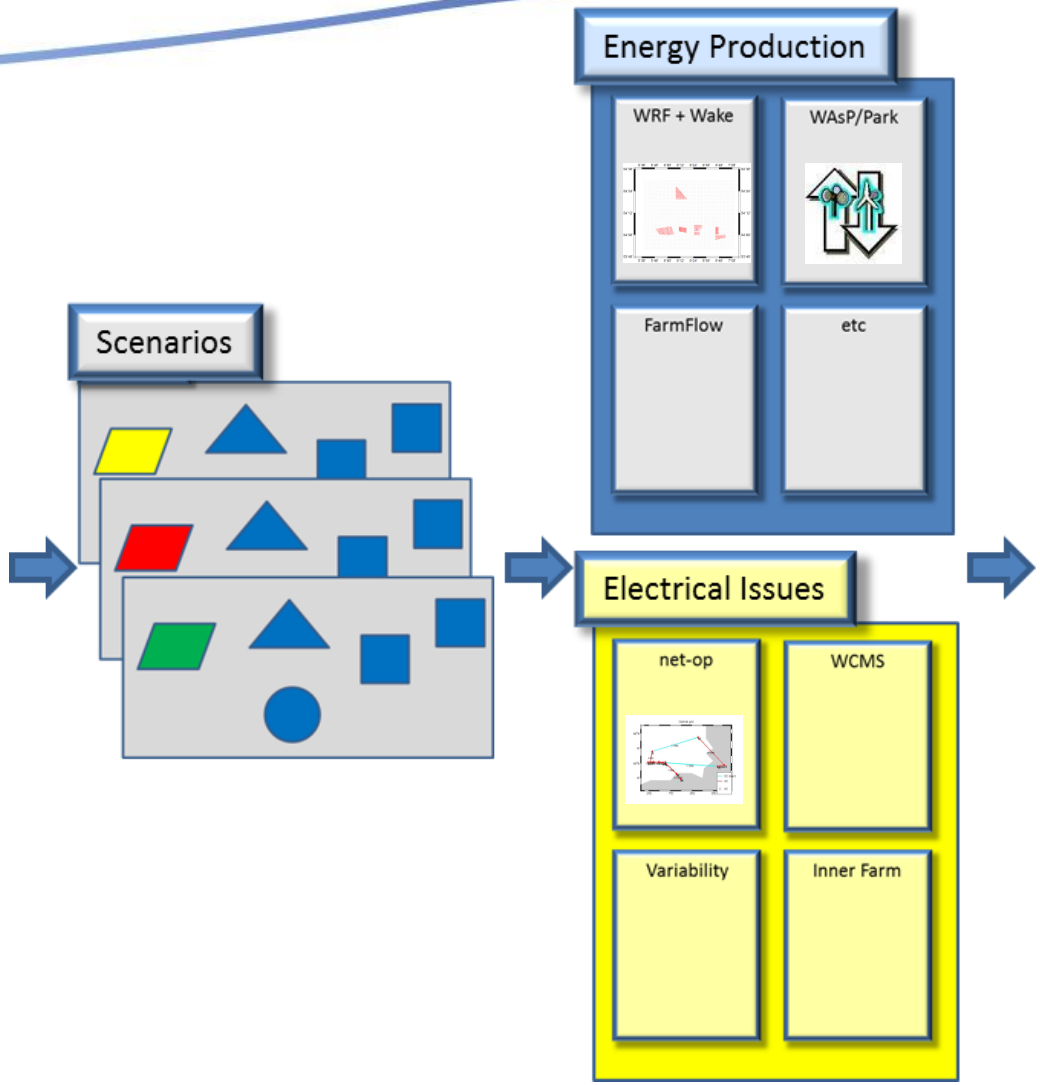
- The sub-models are protected by IPR…
- …but the interfaces in the model chain are going to be open
- File formats for data exchange are based on existing industry standard formats, e.g. the WAsP types based on XML

- This means that integrating a new model is possible with small effort. Commercialisation can begin quickly (*Fra forskning til faktura, or From Research to Revenue*).

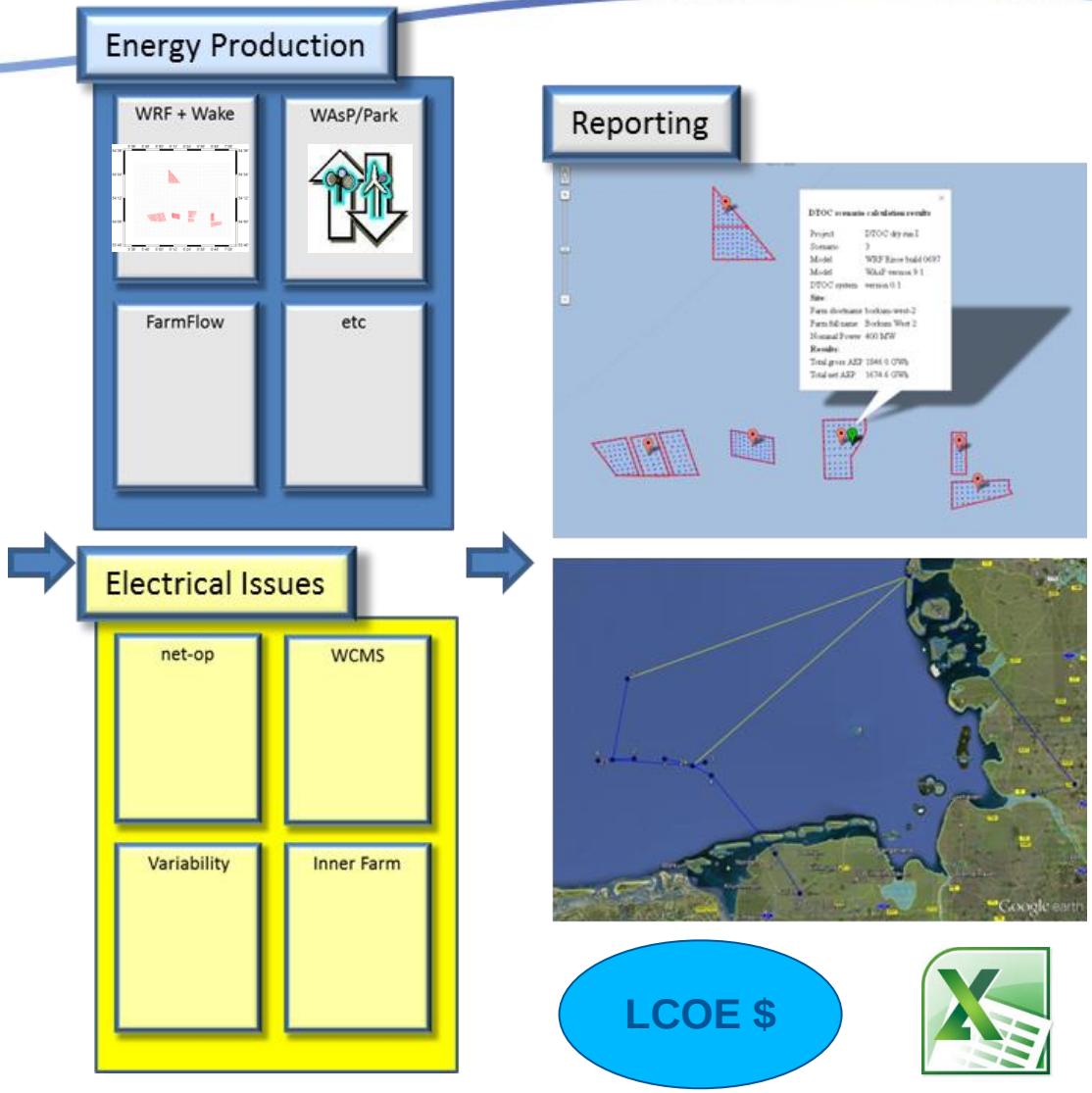
Generating Scenarios



Modelling: Energy and Electrical Part

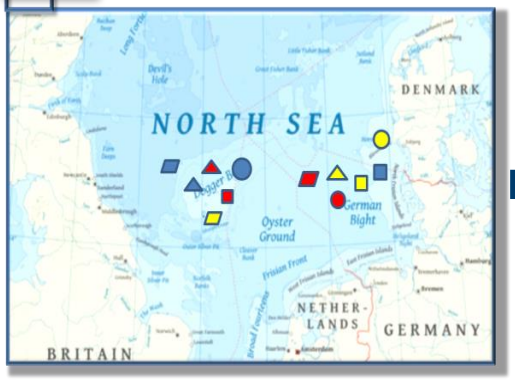


Model Results and Reporting

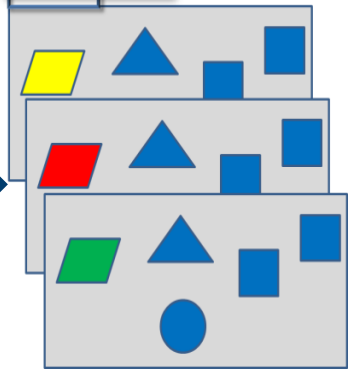


DTOC concept

GIS



Scenarios



Energy Production

WRF + Wake

WAsP/Park

FarmFlow

etc

Electrical Issues

net-op

WCMS

Variability

Inner Farm

Reporting

LCOE $

Conclusions

- Integration of many existing softwares
- Development driven by user requirements / needs
- Supports manual optimisation process through design scenarios
- Cost model: Levelised Cost Of Energy
- Open interfaces, also usable for third party models