Wind Farm Optimization and Multi-Fidelity Wake Modelling

Presentation of TOPFARM I & II, FUSED-Wake

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Presentation of **TOPFARM I & II, FUSED-Wake**

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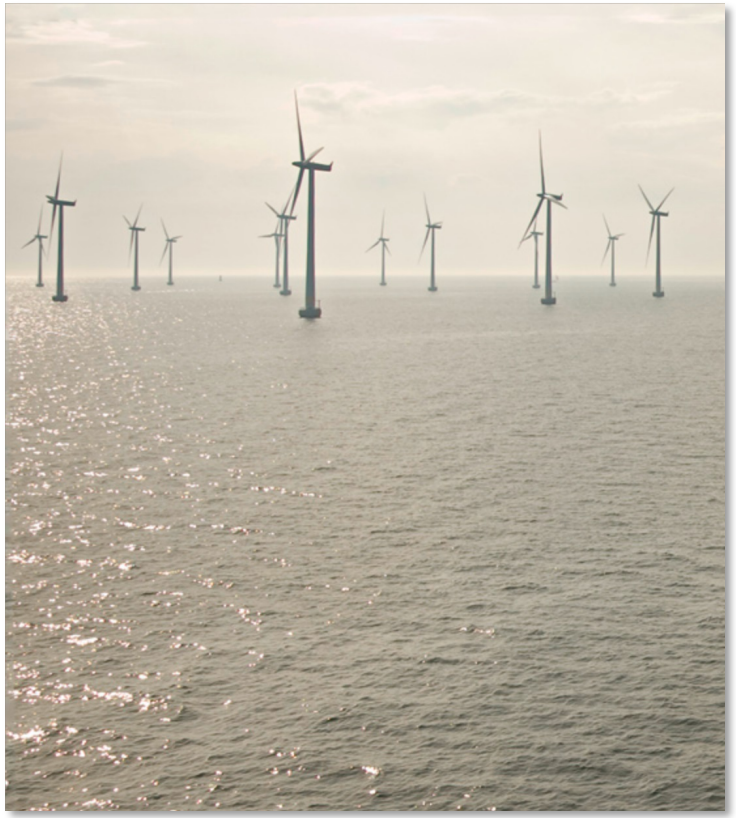
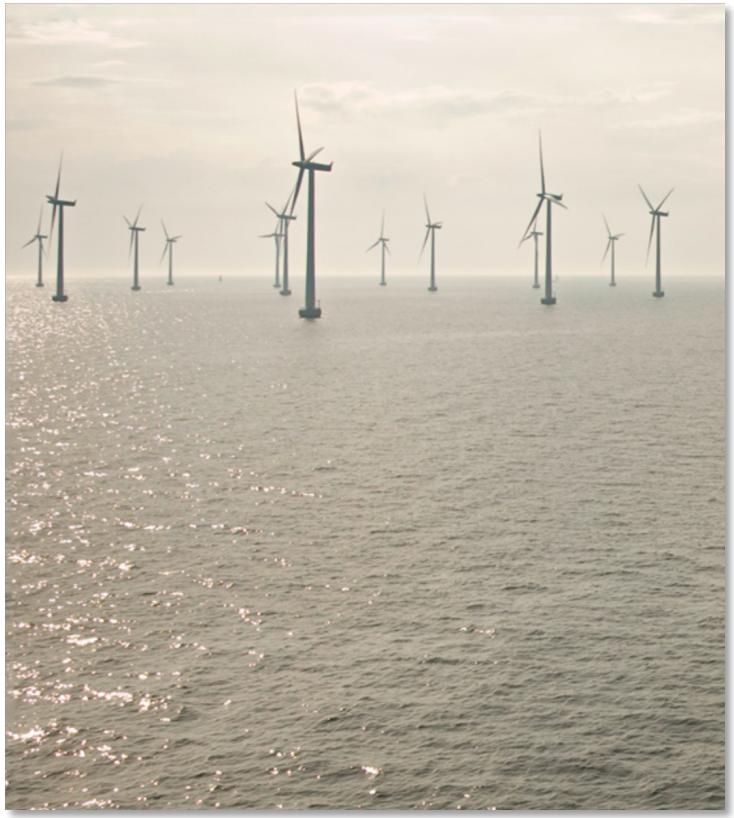


DTU Wind Energy

Department of Wind Energy

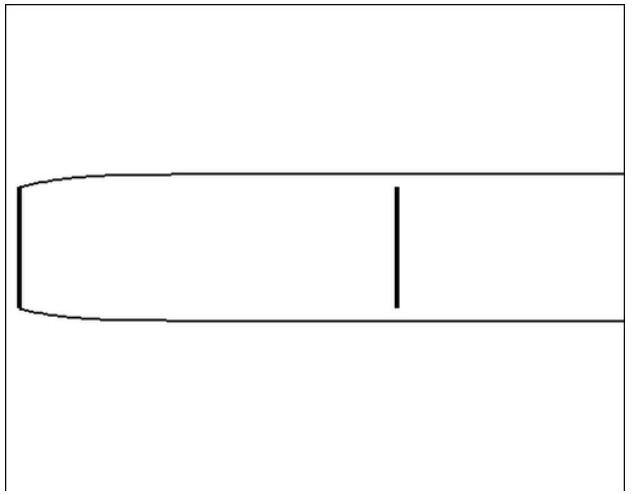
Outline

- Background
- TOPFARM
  - Main Idea
  - System Overview
  - Some Results
  - Feedbacks from the industry
- FUSED-Wake
- TOPFARM II
  - Main Ideas
  - 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?



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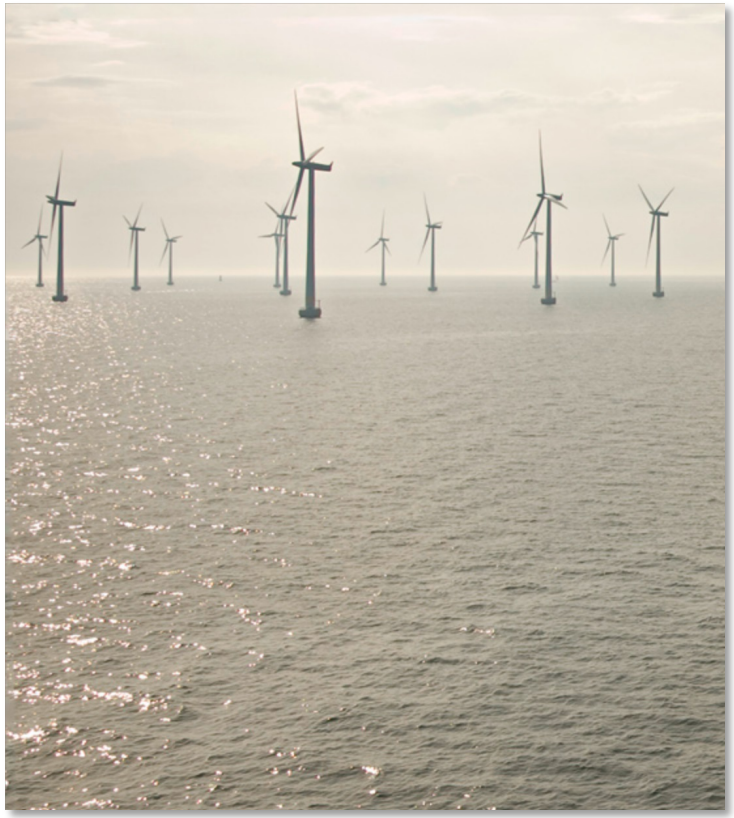


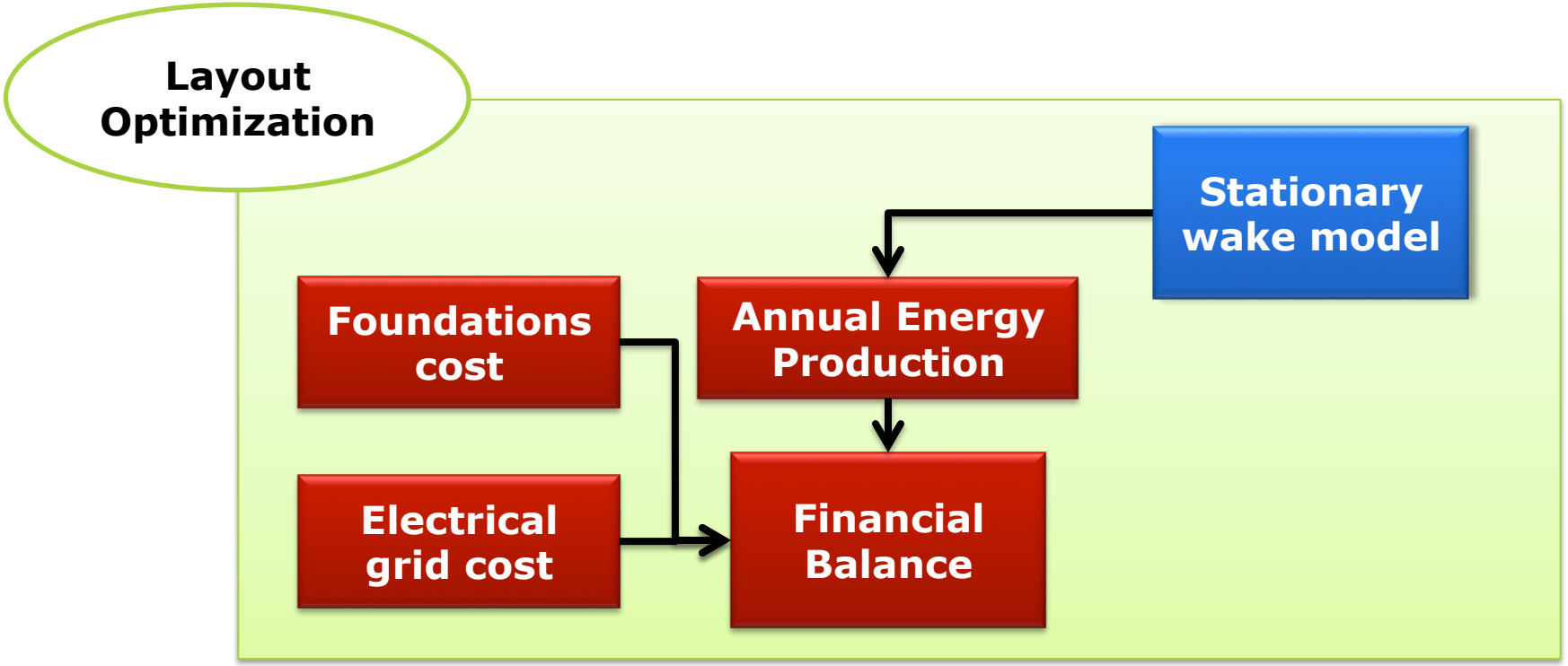
TOPFARM
Main Idea

- **TOPFARM** = **T**opology **OP**timization 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:
1st Level

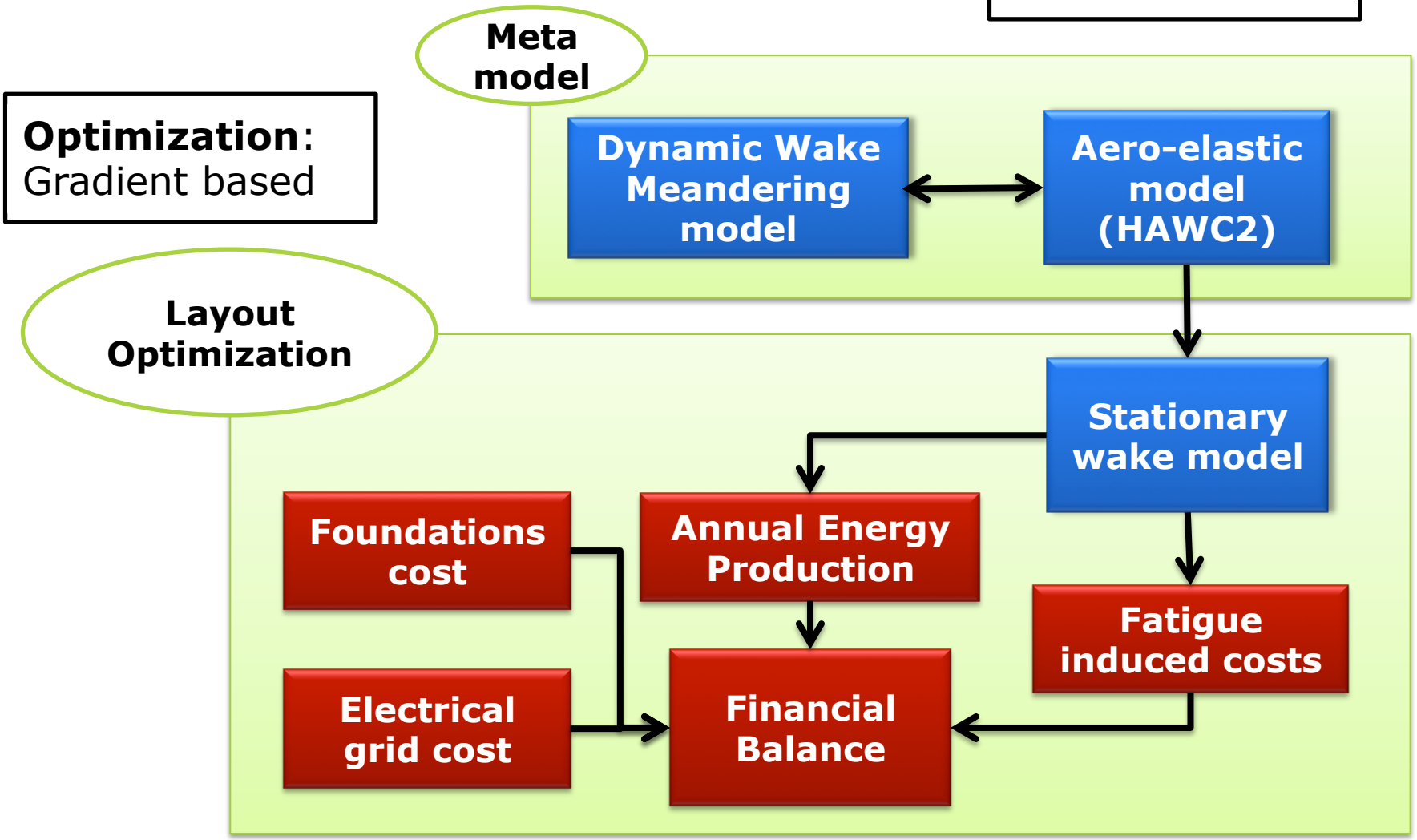
Optimization:
Gradient based



TOPFARM
System Overview

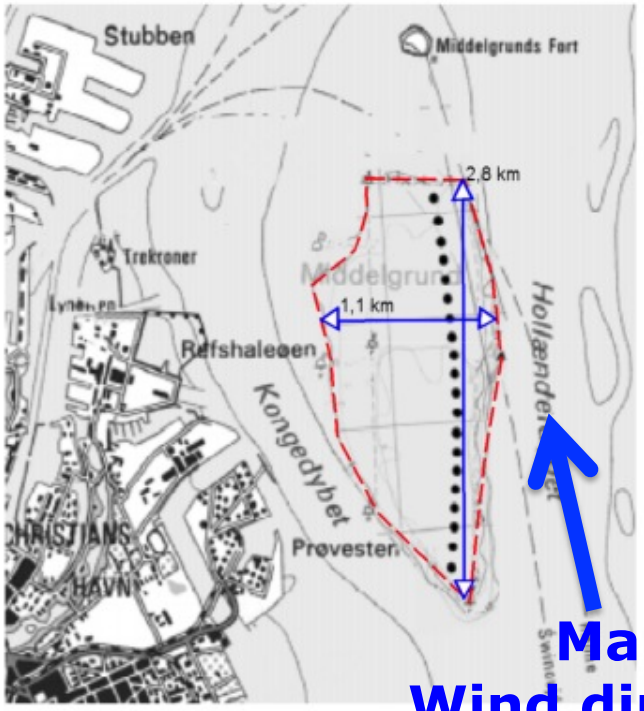
Multi-fidelity:
2nd Level

Optimization:
Gradient based

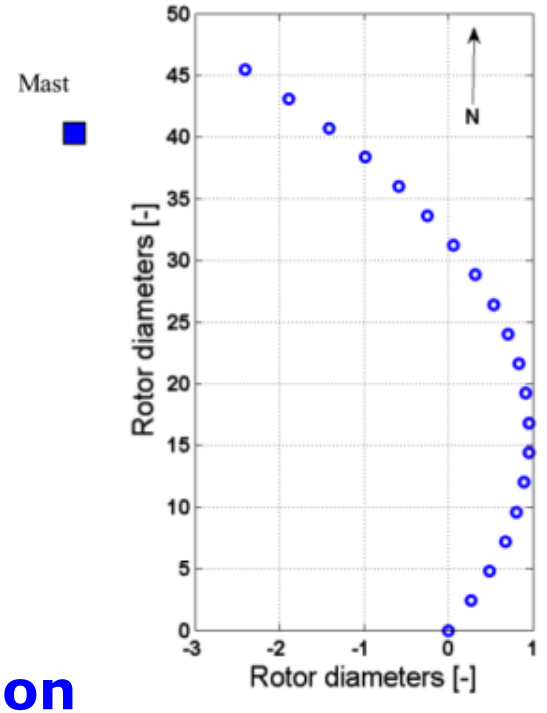


TOPFARM
Demonstration example

- Middelgrunden



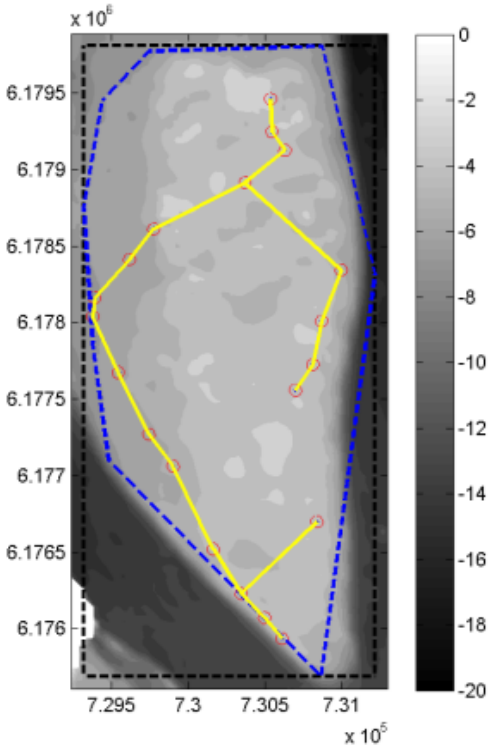
Allowed wind turbine region

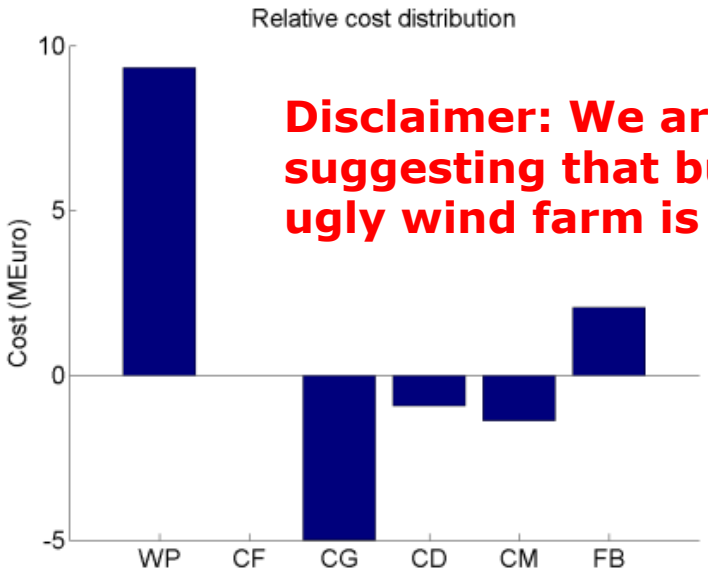


Middelgrunden layout

TOPFARM
Demonstration example

- Middelgrunden iterations: 1000 SGA + 20 SLP



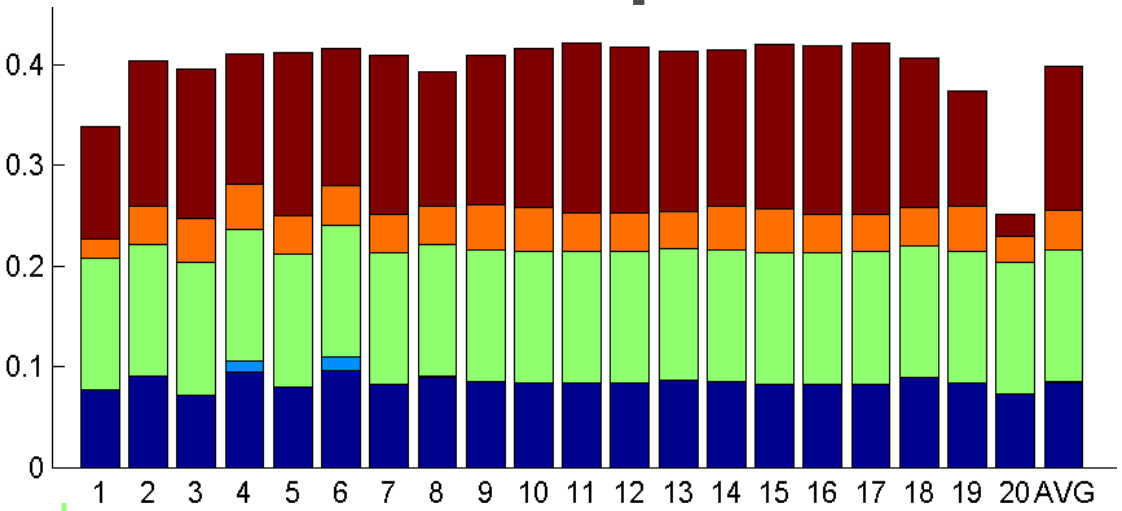


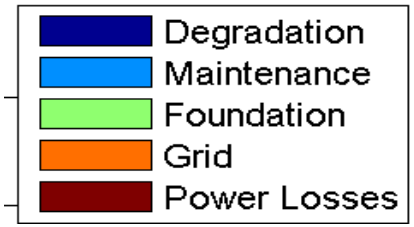
Disclaimer: We are not suggesting that building this ugly wind farm is a good idea

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

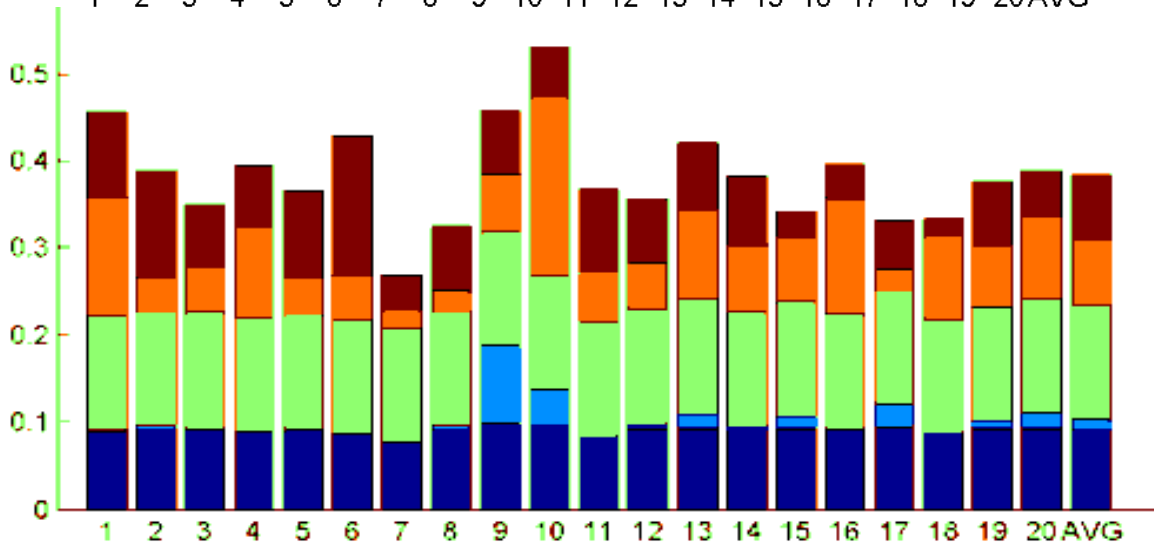
TOPFARM
Demonstration example

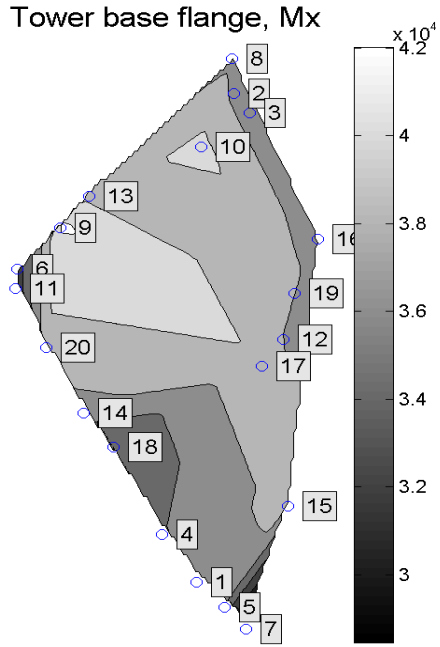
Before





After





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 use in large “bureaucratic” organizations.
- Integrate the expert(s) opinion(s) within optimization loop, *somehow*
- Wish for an open framework, to use their own cost & physical models they already have experience with.

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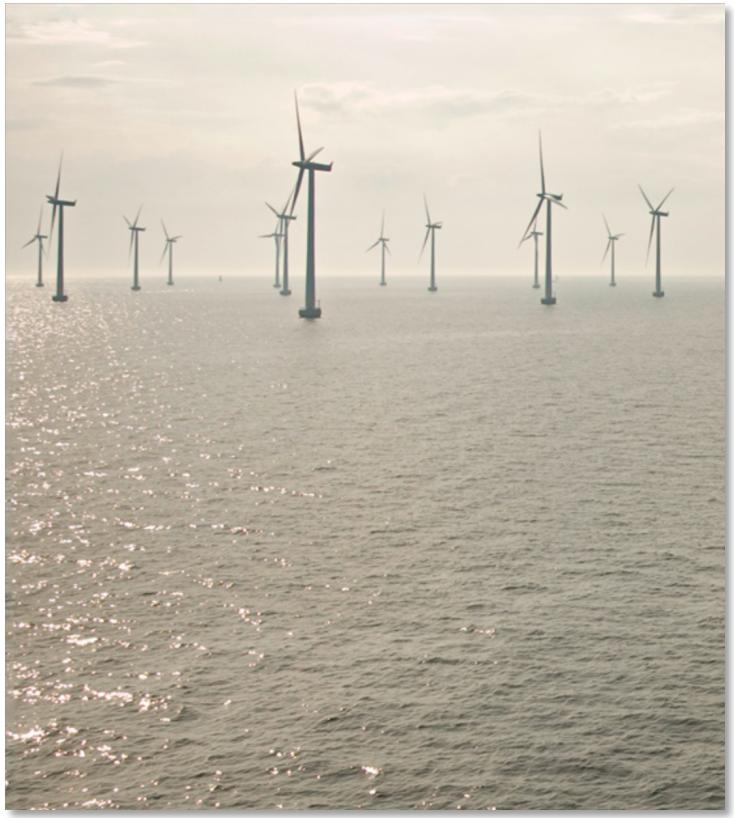
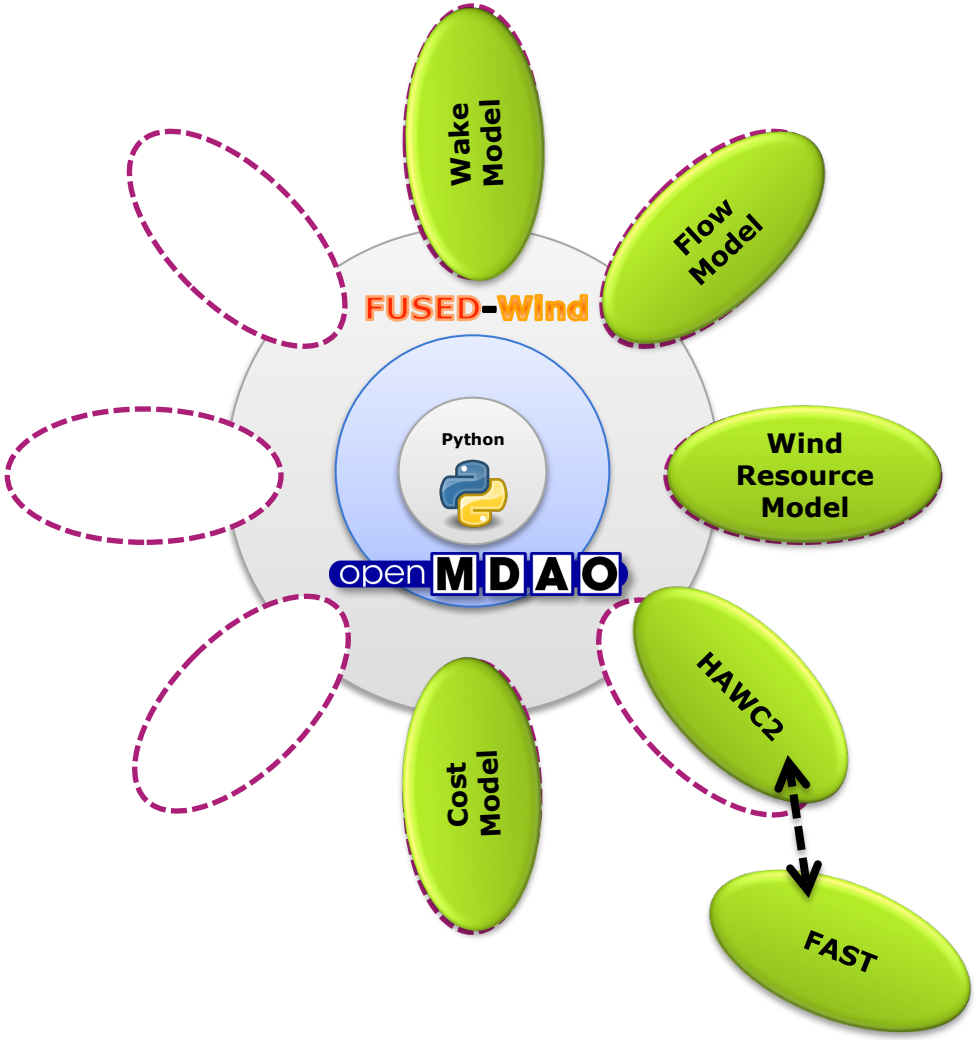


FUSED-Wind

- Collaborative effort between **DTU** and **NREL** to create a **F**ramework for **U**nified **S**ystem **E**ngineering and **D**esigned of **Wind** energy plants.

- Based on OpenMDAO, a python based **Open** source framework for **M**ulti-**D**isciplinary **A**nalysis and **O**ptimization.

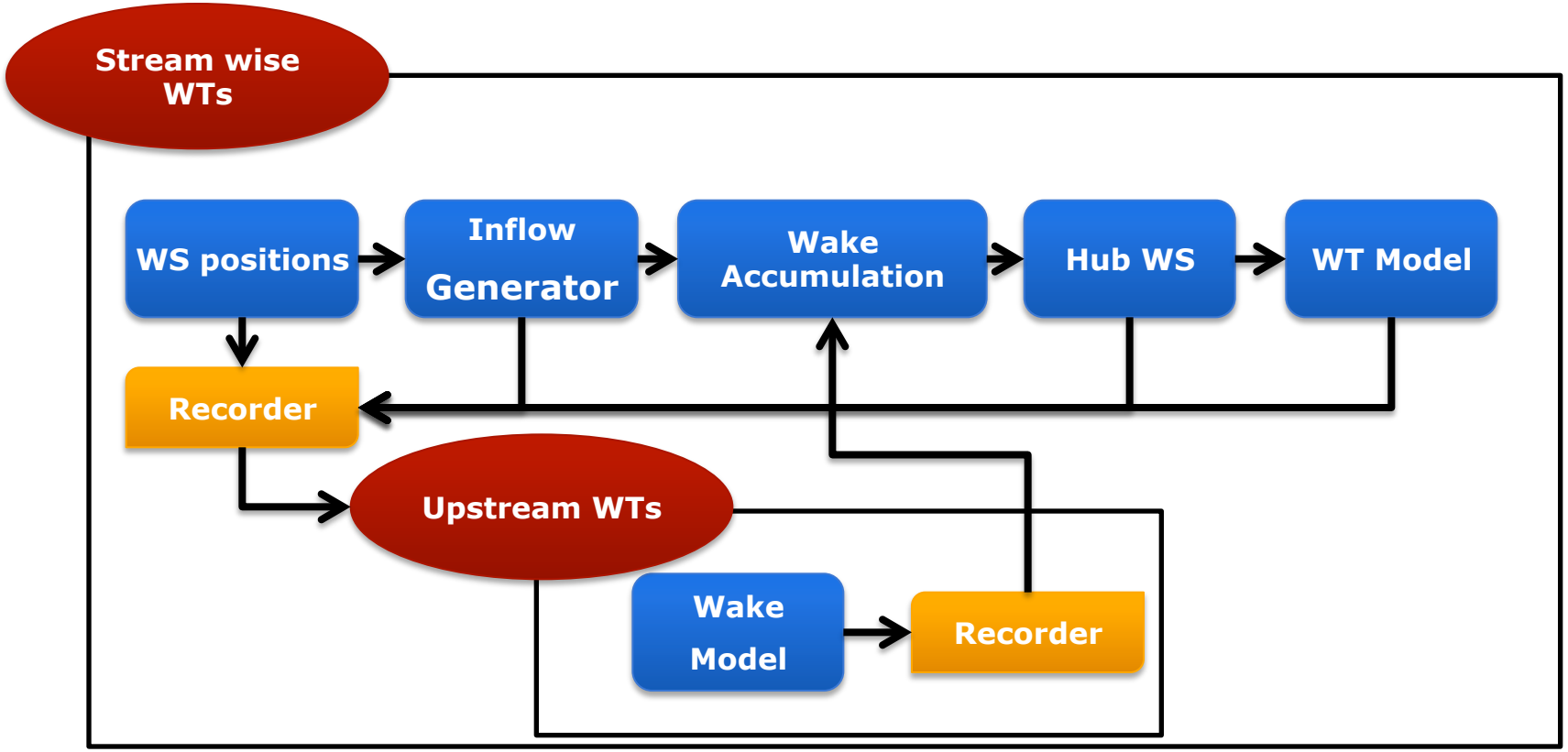


FUSED-Wake

- Collaborative open source tool developed by DTU
- General purpose (AEP, Loads, Optimization, steady/ unsteady)
- Modular (workflow divided in sub components)
- Each component is “swappable”
- Each component have multiple fidelity levels
- Derivatives friendly (faster Uncertainty Quantification & Optimization)
- **Open Source** framework + Closed source subcomponents
- Alpha version is ready for testing

Research tool: Modularized concept

- The wind farm wake models are split into a generalized workflow



Potential applications of the framework

- Model automatic selection
- Model Averaging (combining the information of several models)
- Machine learning (systematic model recalibration)
- Uncertainty quantification
- Multi-fidelity optimization
- Robust optimization
- Standard way to run wind farm models
- Bridging the gap between researchers and industry

FUSED-Wake: Status

- Framework in alpha version is ready for testing
  - N.O. Jensen
  - G.C. Larsen
  - FUGA
  - EllipSys
  - DWM

Next steps

- Gathering interest group
- Alpha release to interest group
- Public release of beta version
- Forming a project portfolio to coordinate the efforts

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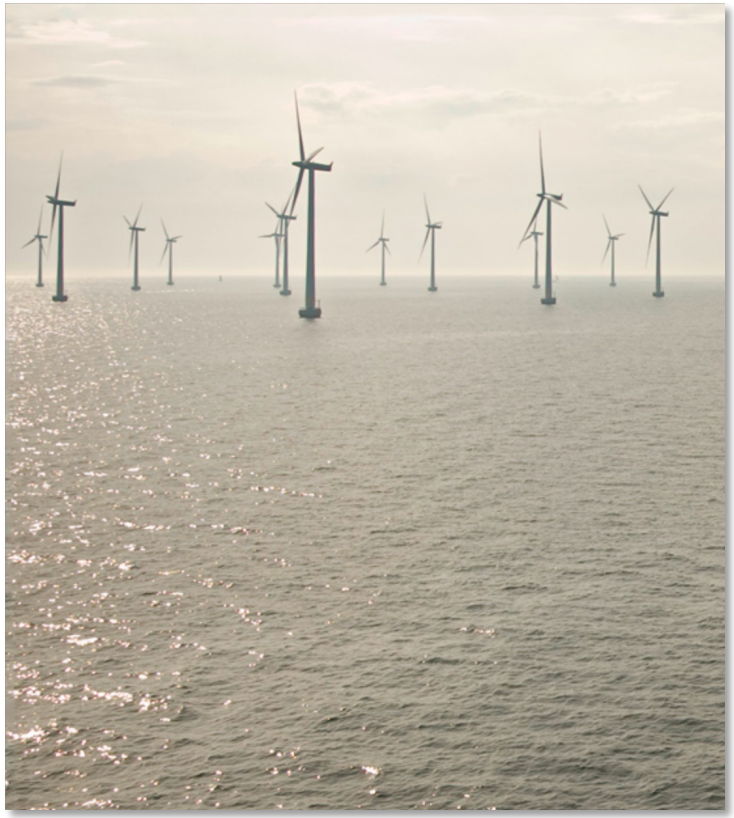
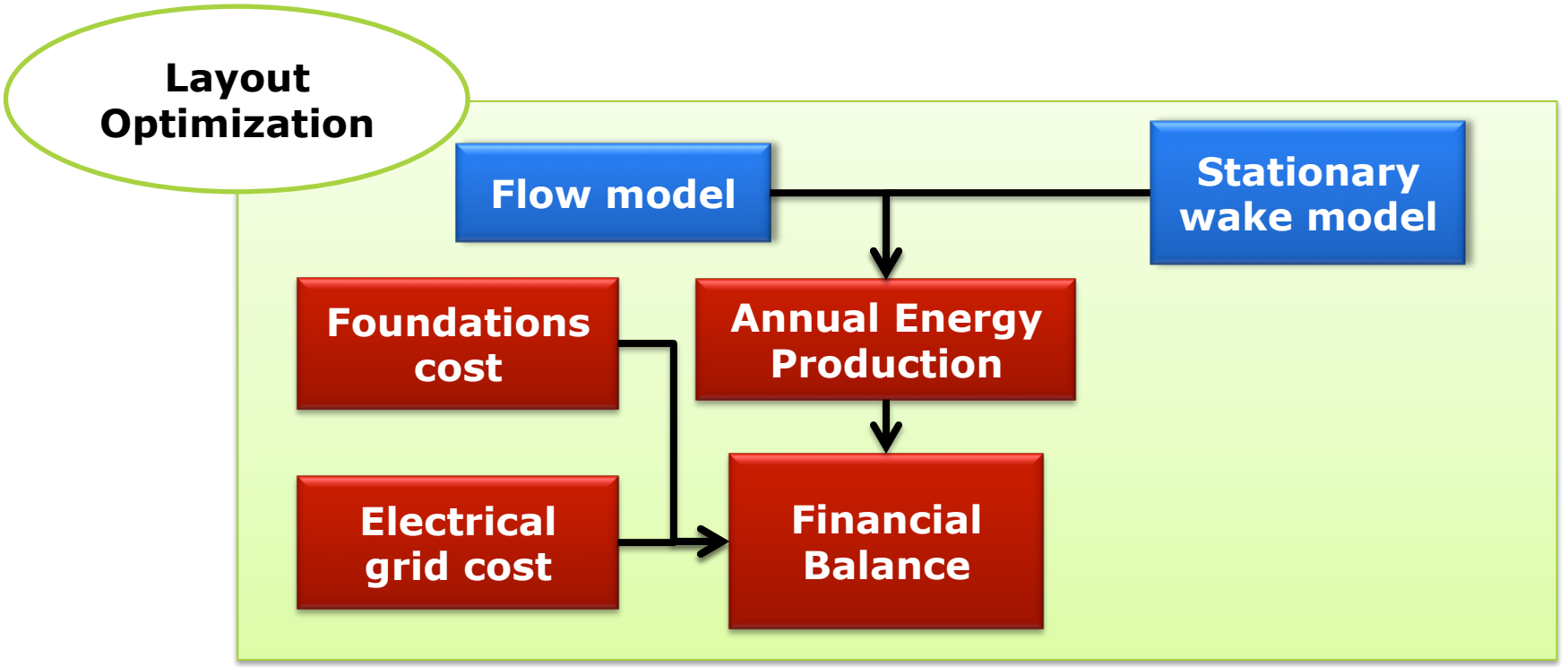


TOPFARM II
Main Ideas

- Framework based on **FUSED-Wind**
- Use **WAsP** & **WRF** engine to calculate accurate local wind resources
- Multi-fidelity wake model based on **FUSED-Wake**
- 3rd level of fidelity: running the whole wind farm with dynamic wake models (**DWM & AL/LES**)
- More advanced multi-fidelity optimization strategy
- Higher degree of parallelization
- Expert driven iterative design process
- GUI connected to **WAsP**

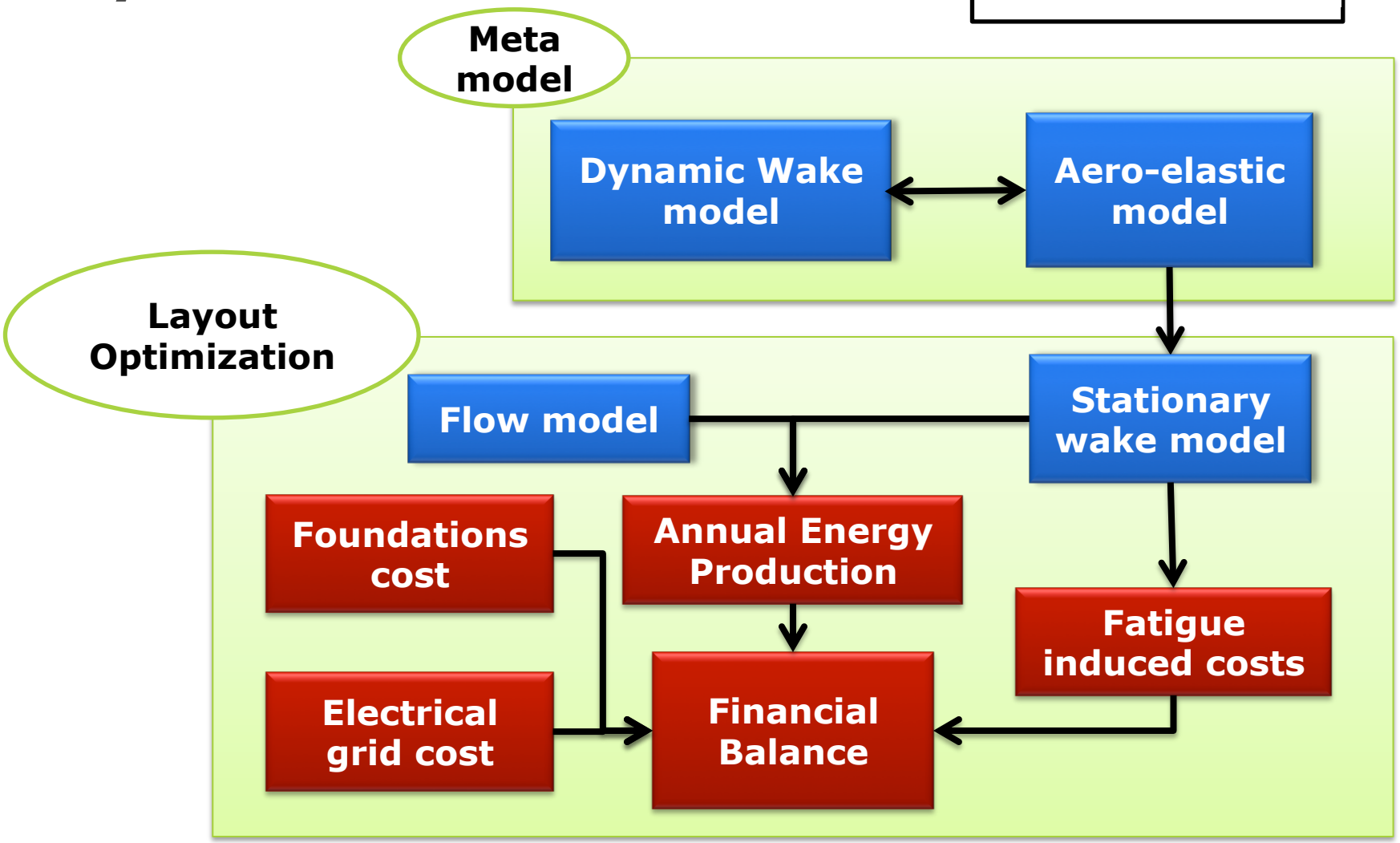
TOPFARM II
System Overview

Multi-fidelity:
1st Level



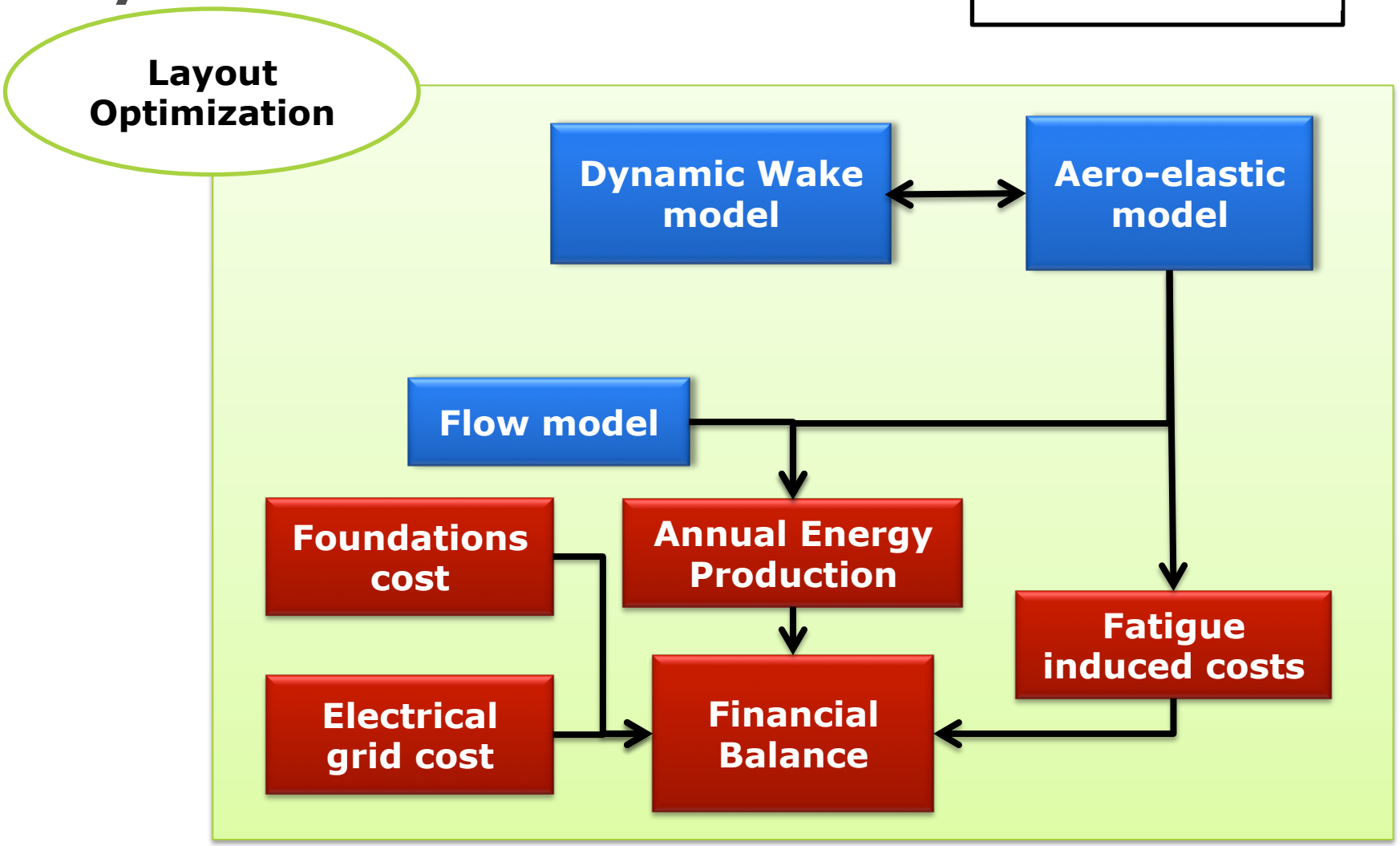
TOPFARM II
System Overview

Multi-fidelity:
2nd Level



TOPFARM II
System Overview

Multi-fidelity:
3rd Level



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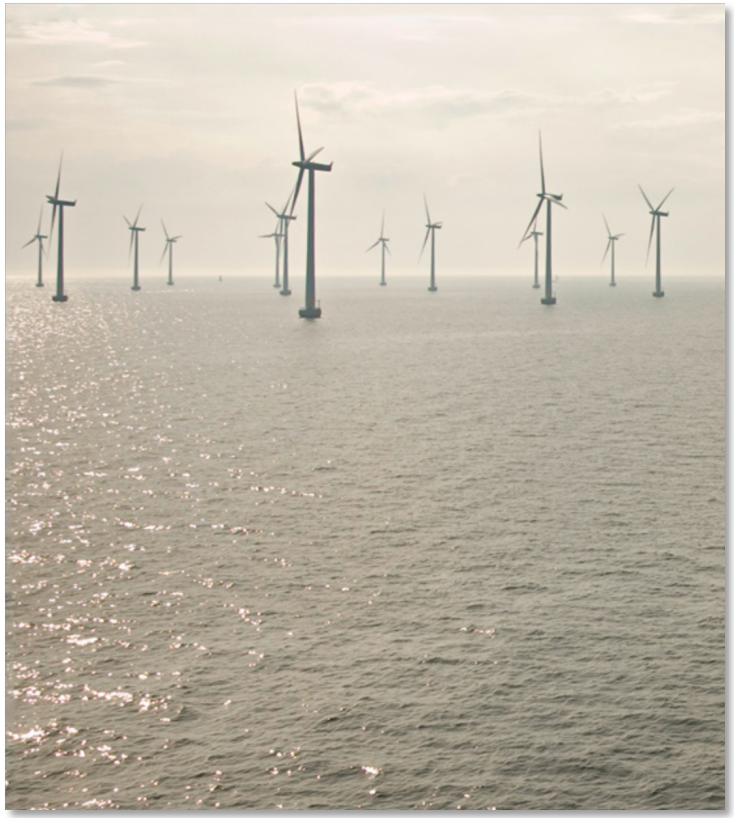

Conclusions

- When we design a system, you have to take the user into account
- "press-of-a-button" is not expert friendly
- Multi-disciplinary = Multi-user = Communication "challenges"
- Open framework is important
- Wake induced fatigue is relevant for wind farm design & optimization