New Grid System Method

EERA-DTOC – Results and Model Integration

Amsterdam. Sept., 24th 2014

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

Support by

SEVENTH FRAMEWORK PROGRAMME

Content

1. Motivation
2. Potential users / use cases
3. Required models
4. Available models
5. Integration of the models
6. Results/ conclusions

Motivation

- To integrate, host and exchange data in a single platform
- Use different tools in an integrated environment
- Investigate complex interactions between wake effects and grid design decisions
- Integrate meteorological and synthetic data
- Analyze cost-effectiveness of grid designs based on scenarios
- Integrate different potential markets
- Investigate possible ancillary services provision
- Consider variability and forecastability in the process
- Open interfaces

Potential users / use cases

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STRATEGIC PLANNERS

- Identify strategic investments
- Optimum strategic infrastructure
- Design constraints for the developer
- Optimize infrastructure considering different markets
- Variability analysis for better clustering

Strategic Infrastructure

DEVELOPERS

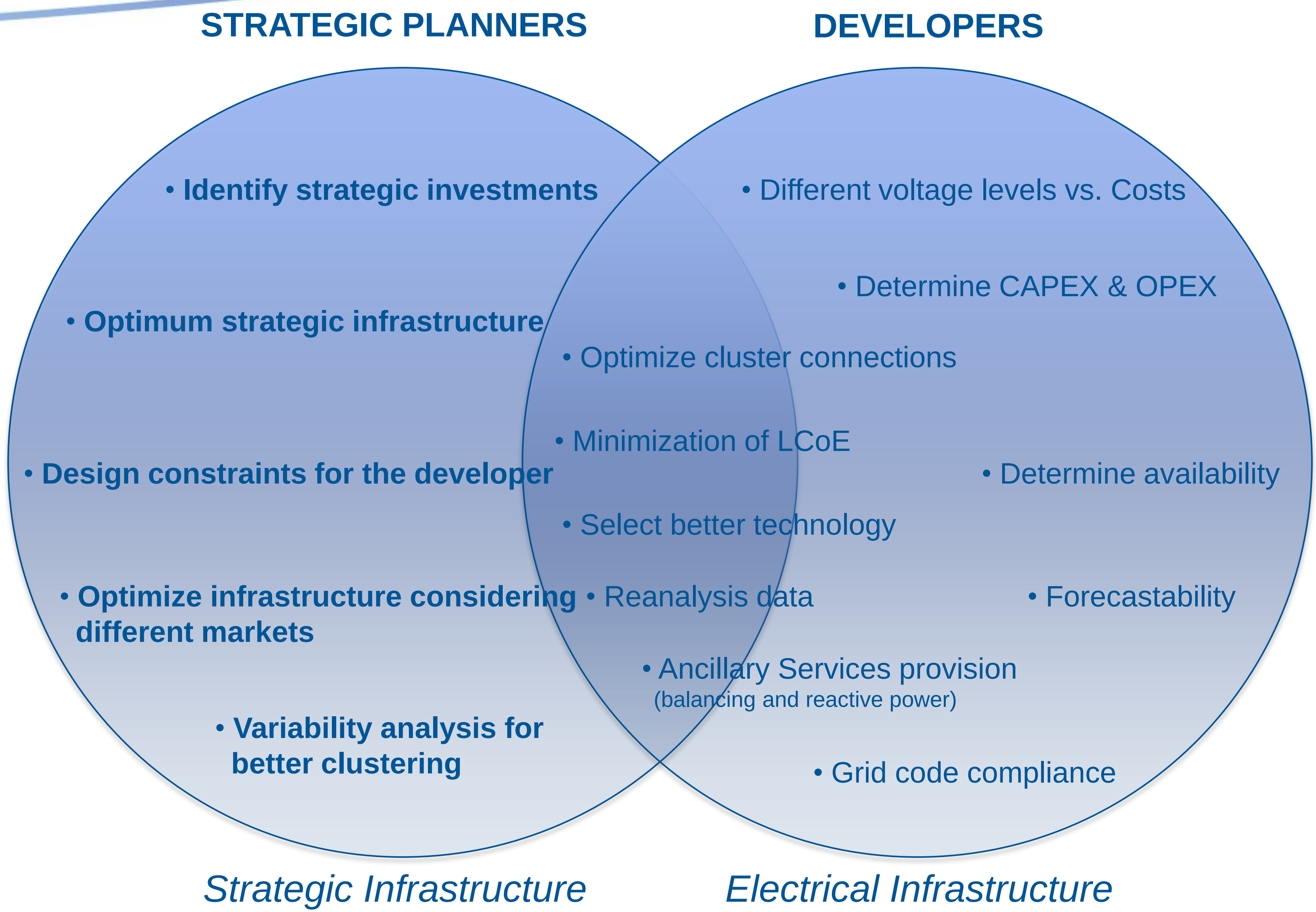
- Different voltage levels vs. Costs
- Determine CAPEX & OPEX
- Determine availability
- Forecastability
- Grid code compliance

Electrical Infrastructure

Shared (both)

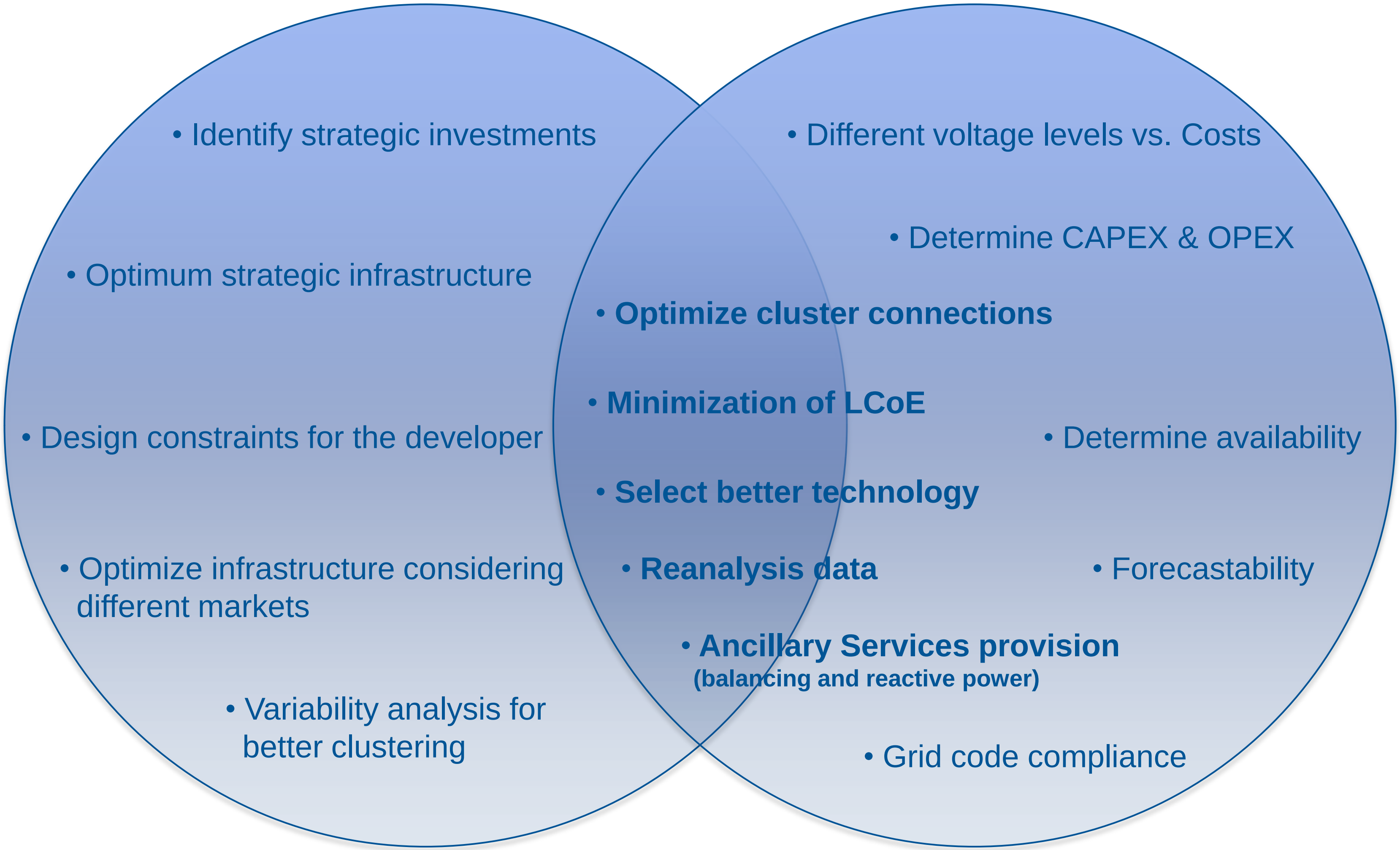
- Optimize cluster connections
- Minimization of LCoE
- Select better technology
- Reanalysis data
- Ancillary Services provision (balancing and reactive power)

Potential users / use cases



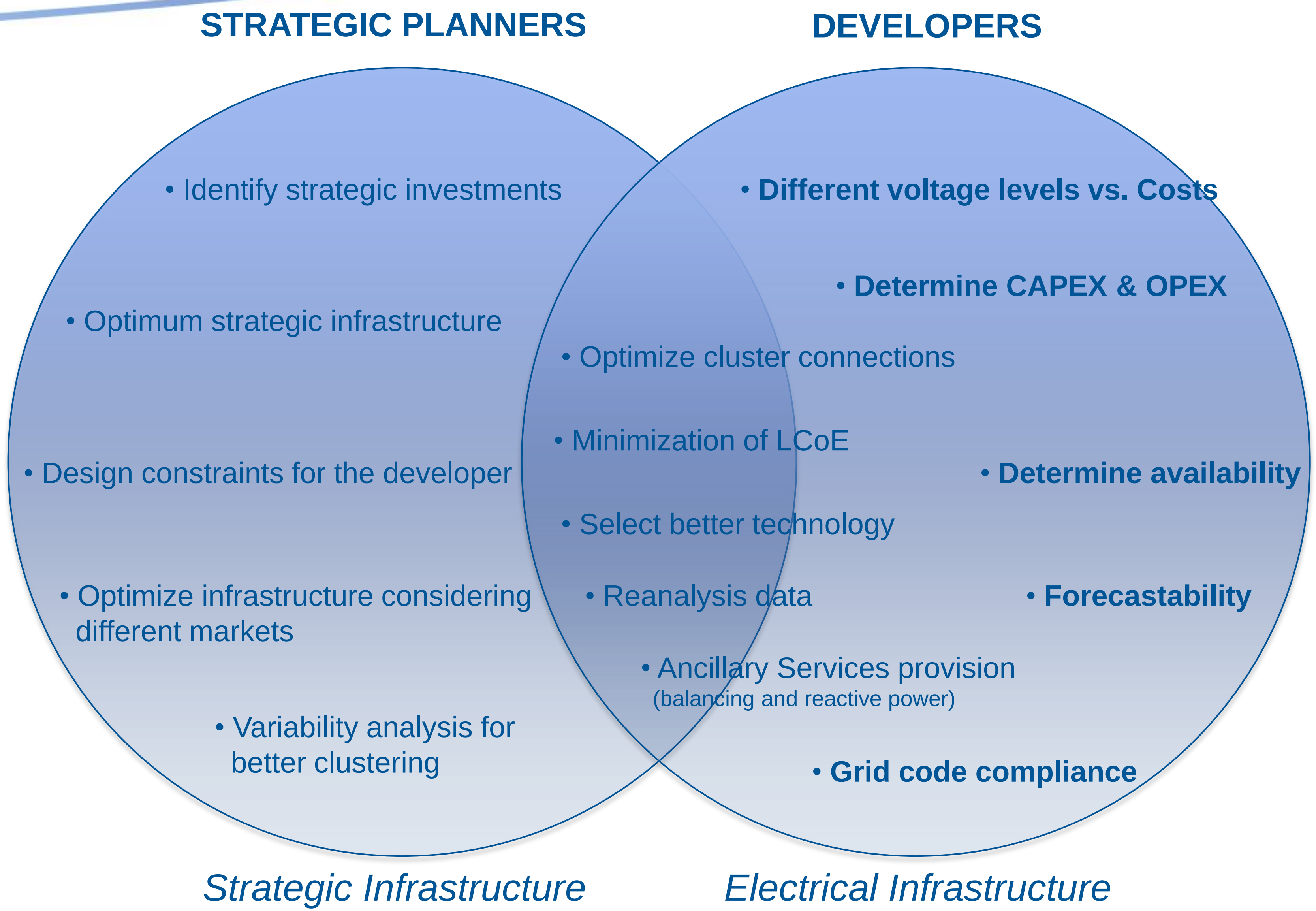
Potential users / use cases

STRATEGIC PLANNERS | **DEVELOPERS**



Strategic Infrastructure | *Electrical Infrastructure*

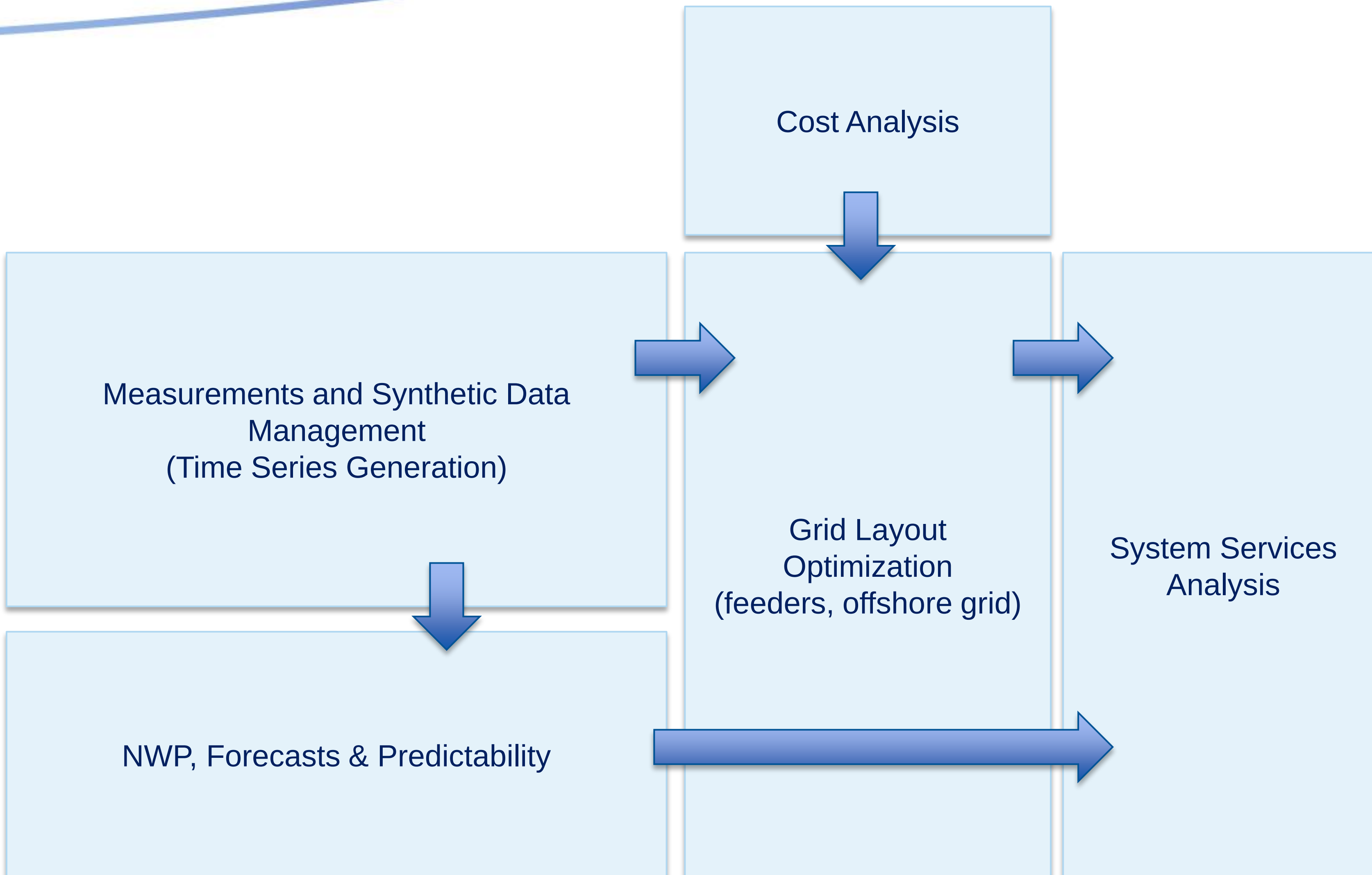
Potential users / use cases



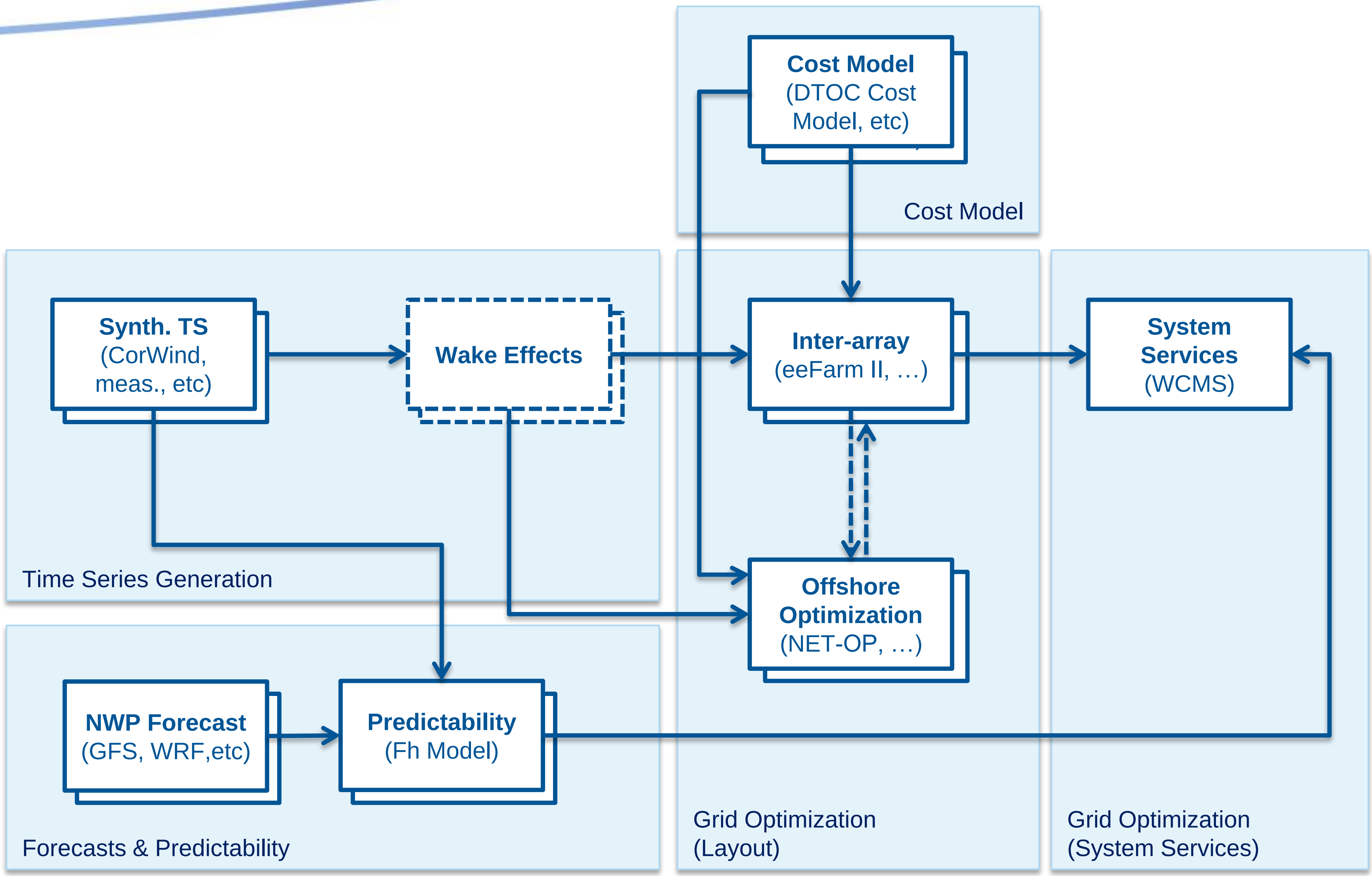
Required models

Grid Layout Optimization (feeders, offshore grid)	• NET-OP (SINTEF) → Optimization of grid infrastructure based on market prices and costs. • eeFarm (ECN) → Electrical and cost calculation
Measurements and Synthetic Data Management (Time Series Generation)	• CorWind (DTU) → Correlated time series
Cost Analysis	• Basic Cost Model (DTOC) → interchangeable
System Services Analysis	• WCMS (Fh IWES) → grid electrical calculation and ancillary services analysis
NWP, Forecasts & Predictability	• Global Forecast System/ GFS (NOAA) → NWP • ANN based Forecaster (Fh IWES) → Forecasts

Required models



Integration of the models



Integration of the models

Optimisation Process

1. Generate Design Options

- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7

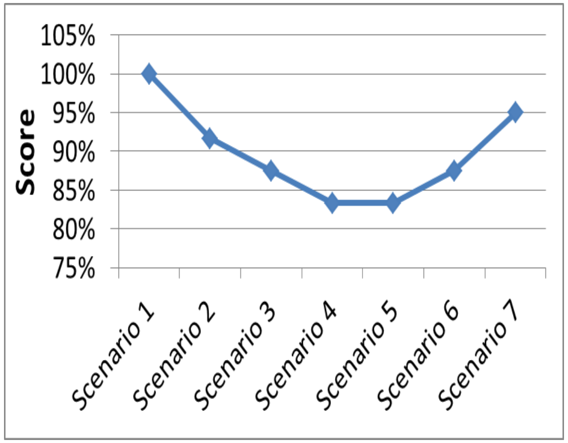
2. Evaluate Design Options

Wake Model (WP1)

Electrical Model (WP2)

Energy model (WP3)

3. Compare Design Options



4. Iterate steps 1 to 3

Decision parameters are used to compare design options

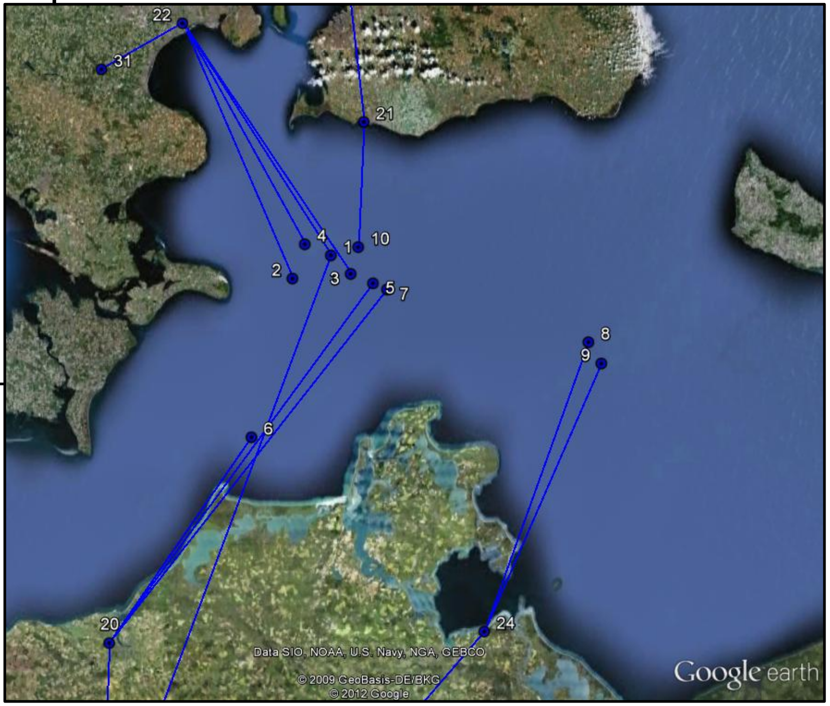
Integration of the models: case study

- Name: Kriegers Flak case study
- Location: Baltic Sea
- Complexity: medium
- Target user: interesting for strategic planners
- Connected wind farms: 10
- Interconnected countries: 3 (Germany, Denmark, Sweden)
- Different markets are investigated:
  - Nordpool
  - EPEX
- Applied technology: mixed HVAC and HVDC

Integration of the models: case study

#	Country	Wind farm	Capacity	Latitude	Longitude	Connection point
1	DK	Kriegers Flak A K2	200	55.05	12.98	DK Ishøj
2	DK	Kriegers Flak A K3	200	54.99	12.82	DK Ishøj
3	DK	Kriegers Flak A K4	200	55.01	13.07	DK Ishøj
4	DK	Kriegers Flak B K1	200	55.08	12.87	DK Ishøj
5	DE	EnBW Baltic 2	288	54.98	13.16	DE Bentwisch
6	DE	EnBW Baltic 1	48	54.61	12.65	DE Bentwisch
7	DE	Baltic Power	500	54.97	13.22	DE Bentwisch
8	DE	Wikinger	400	54.83	14.07	DE Lubmin
9	DE	Arkona Becken Südost	480	54.78	14.12	DE Lubmin
10	SE	Kriegers Flak	640	55.07	13.10	SE Trelleborg

Location of wind farms and default, radial connection points



- Wind farms: 10
- Total installed capacity: 3.156 GW
- Countries connected: 3

Models used for this case study:

CorWind
(Synthetic power time series)

NET-OP
(Offshore optimization)

WCMS
(Ancillary services investigation)

Integration of the models: case study (NET-OP)

1. Electrical and cost data

Offshore substation costs (from the Windpseed project)

Component	Cost	Comment
HVAC cable	2.49 M€/km	600 MW unit, includes installation
HVDC cable	0.76 M€/km	600 MW unit, includes installation
cable mobilisation	5 M€	Mobilisation of e.g. vessel
HVDC converter	126 M€	600 MW unit
AC switchgear	7.1 M€	600 MW unit
Other substation equipment	6.5 M€	Ignored in Net-Op
Offshore HVDC platform	27.6 M€	for converter, transformer, etc
Offshore HVAC platform	18.7 M€	for transformer, etc.

Net-Op cost parameters (linear with respect to MW)

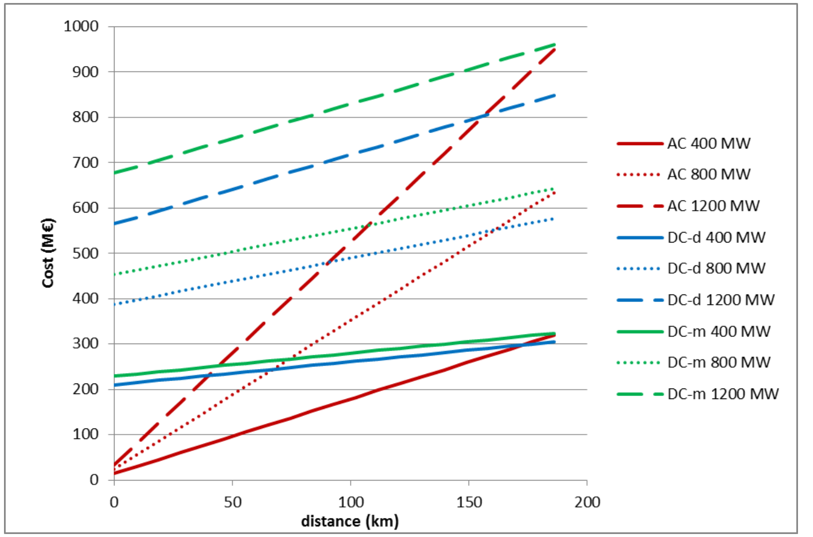
Type	Cost per branch			Cost per branch endpoint			
	B_d k€/km	B_{dp} k€/kmMW	B k€	C^L_p k€/MW	C^L k€	C^S_p k€/MW	C^S k€
AC	0	4.1	5,000	11.8	0	11.8	0
DC-mesh	0	1.27	5,000	70.0	0	70.0	0
DC-direct	0	1.27	5,000	221.8	0	221.8	27,600
converter	0	0	0	105.0	0	105.0	0

Branch specific parameters

Branch type	max distance	max power	power loss constant	slope
AC	65 km	700 MW	0	0.005 %
DC-direct		1000 MW	3.2 %	0.003 %
DC-mesh		1000 MW	0	0.003 %
converter		1000 MW	1.6 %	0

Parameters for capitalised operational costs

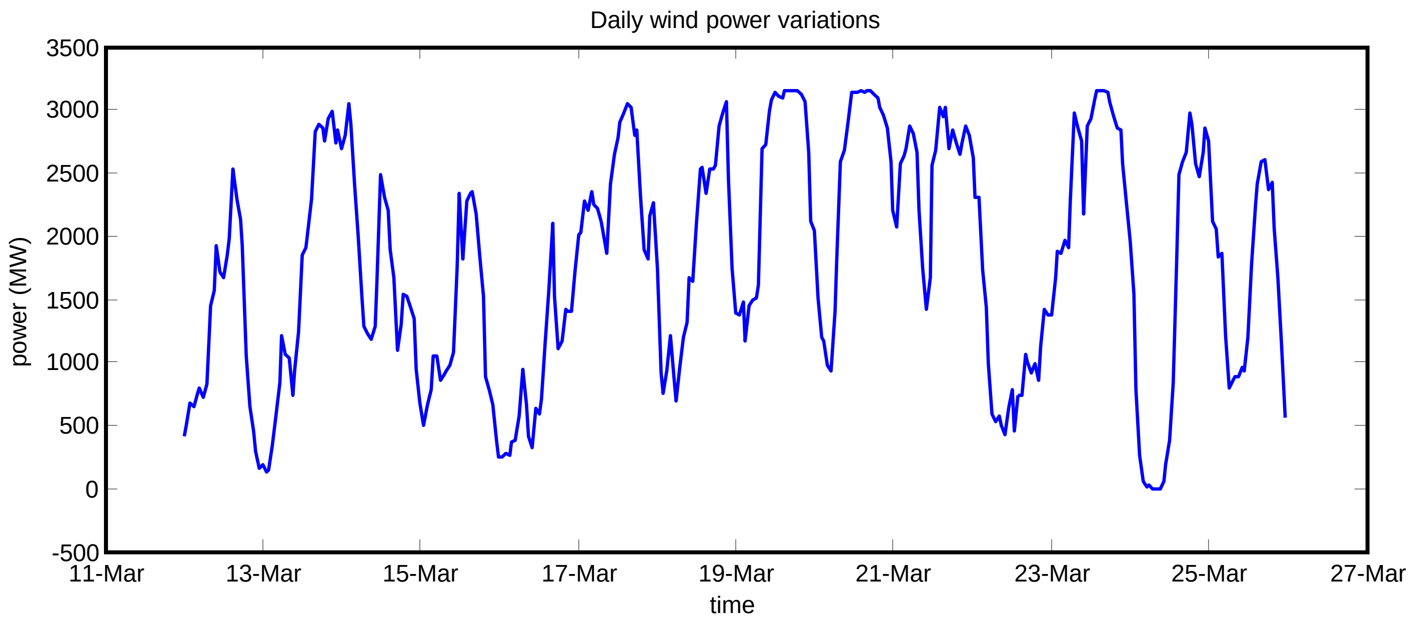
Parameter	Value	Comment
O&M rate	2 %	Operation and maintenance cost fraction relative to investment costs
Discount rate	8 %	For computing net present value of future costs
Lifetime	30 years	Duration over which to consider operational costs



Cost of different cable types as a function of distance and power rating. DC cables include the cost of converters at both ends.

Integration of the models: case study (CorWind)

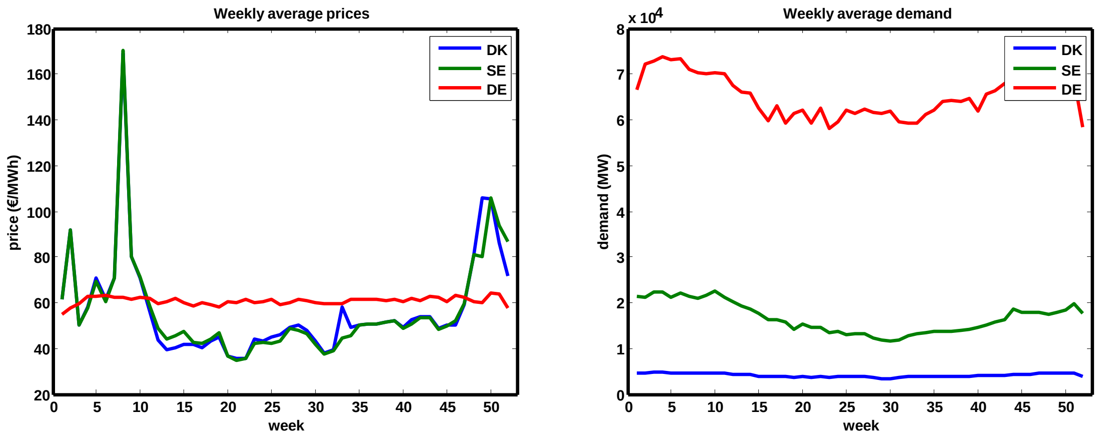
2. Power production data



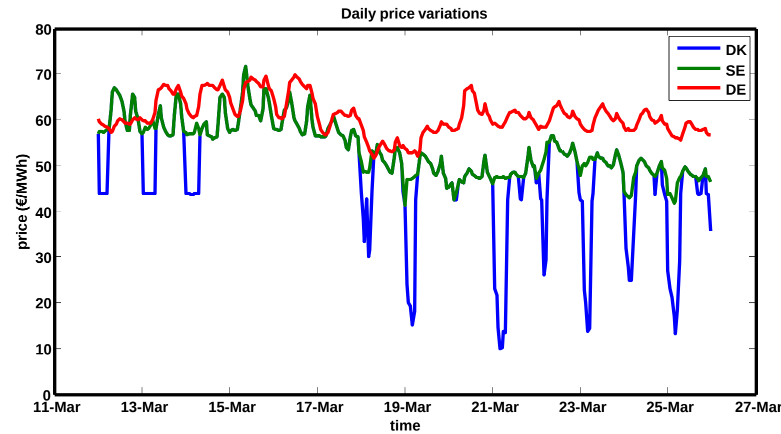
- Wind power time series for 2010 for the wind farms.
- Provided by **CorWind** model.
- Extract with aggregated power output of all wind farms during weeks 10 and 11

Integration of the models: case study

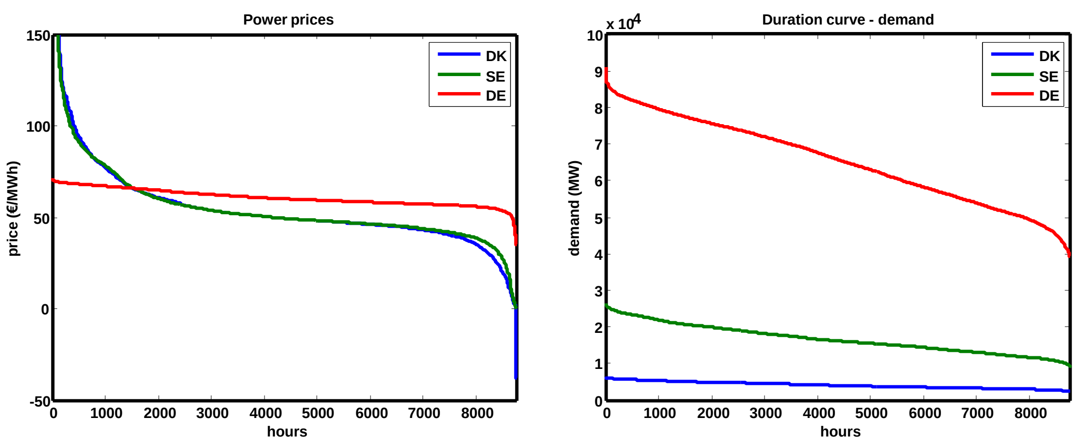
2. Power prices data (Nordpool/ EPEX)



Weekly average prices (left) and demand (right) in the three price areas



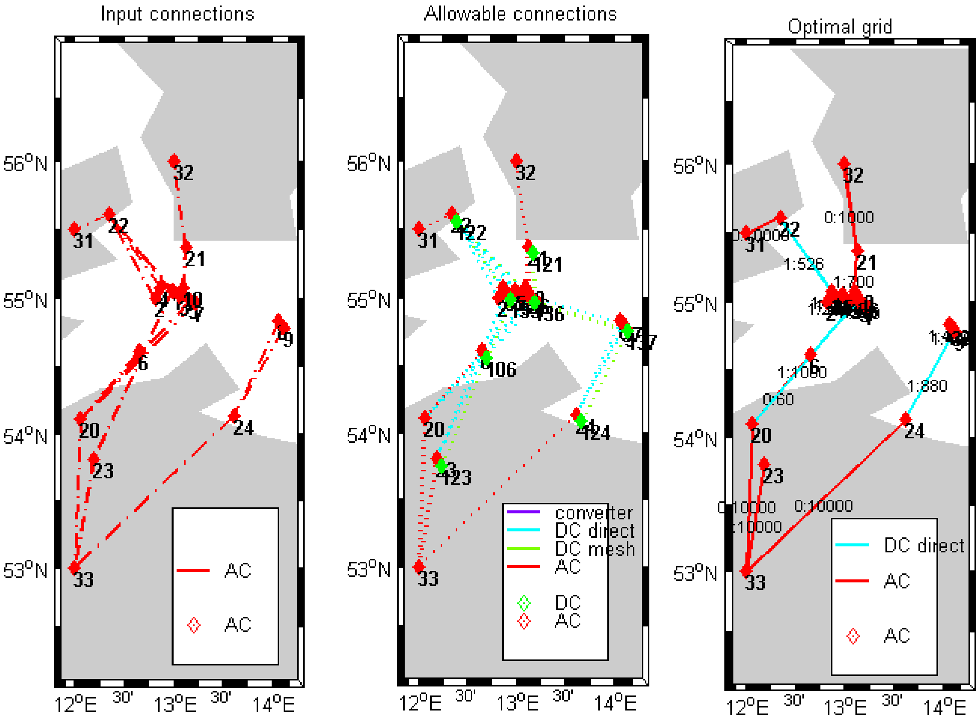
- Power price time series for Denmark, Sweden and Germany (Nordpool & EPEX)
- Scaled power demand time series as used in TradeWind and OffshoreGrid projects.

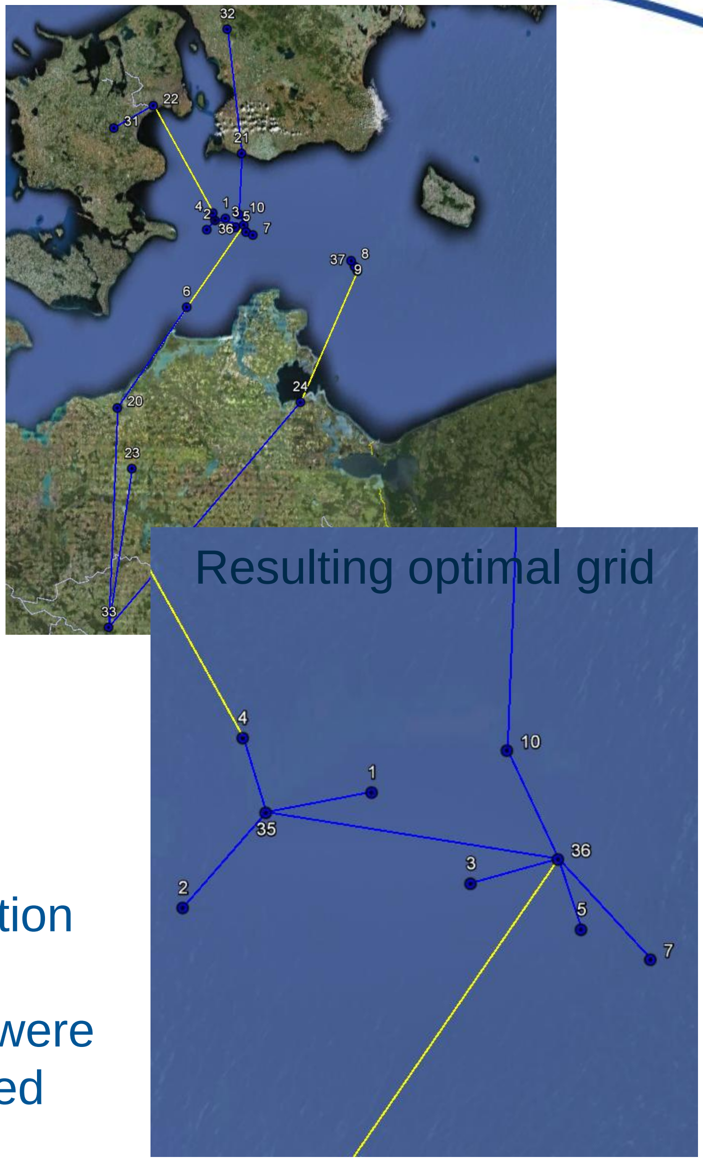


Duration curve for power prices (left) and demand (right) for the three relevant countries

Integration of the models: case study (NET-OP)

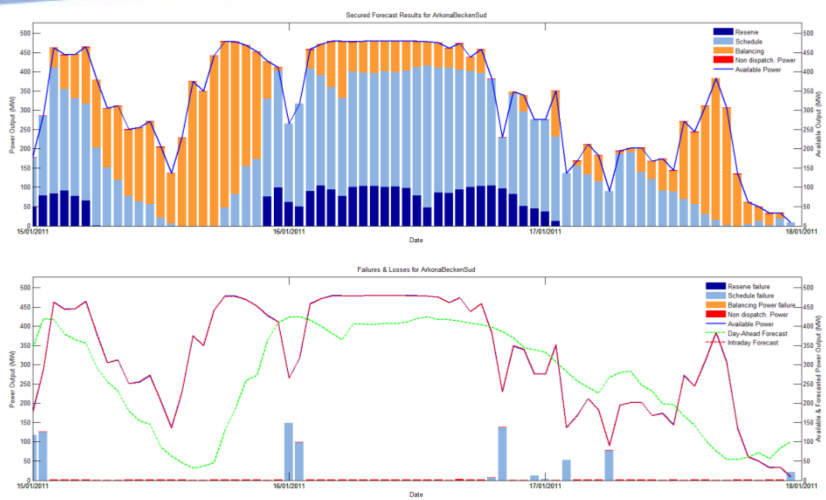
INPUT **RESULT**



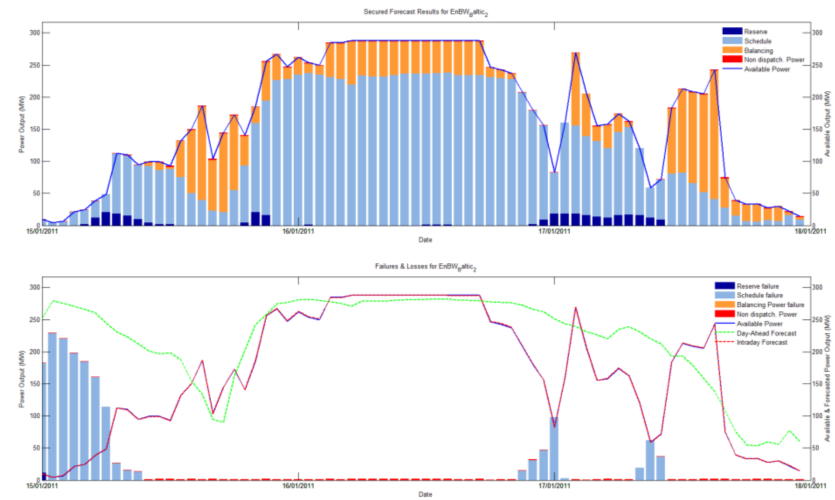


- Input and results from the Net-Op case study simulation
- The middle plot shows all connection options which were included in the optimalisation (automatically generated from the input)

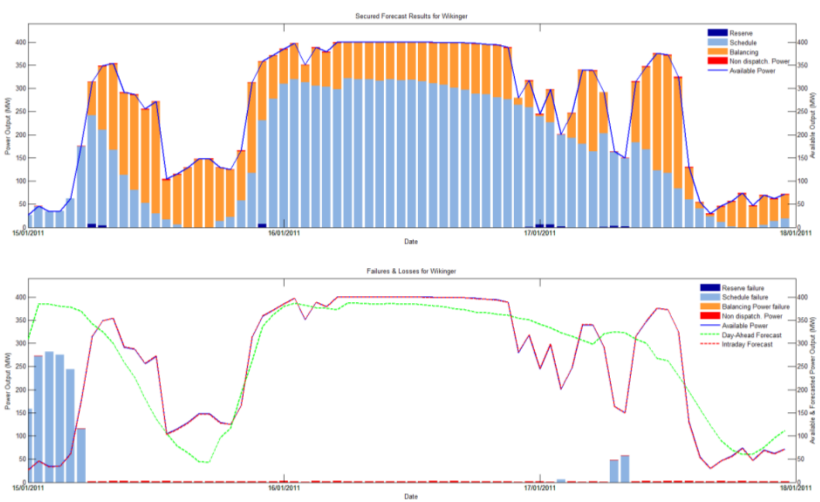
Integration of the models: case study (WCMS)



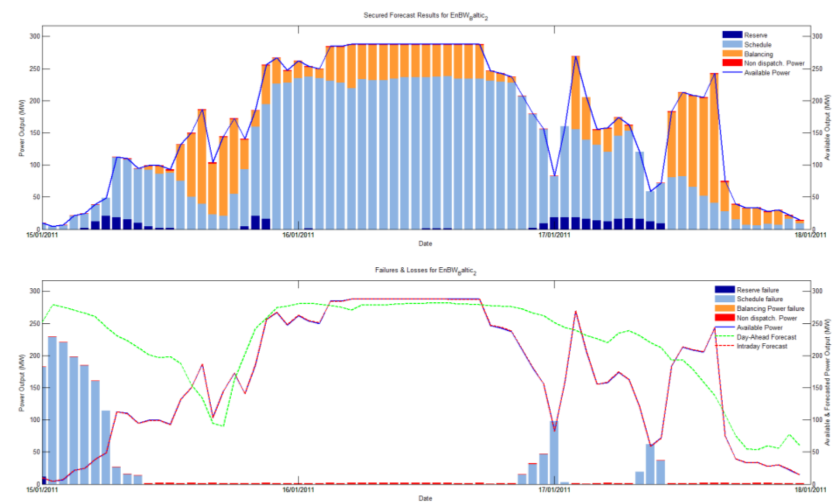
ARKONA BECKEN SUD (480 MW)



BALTIC POWER (500 MW)

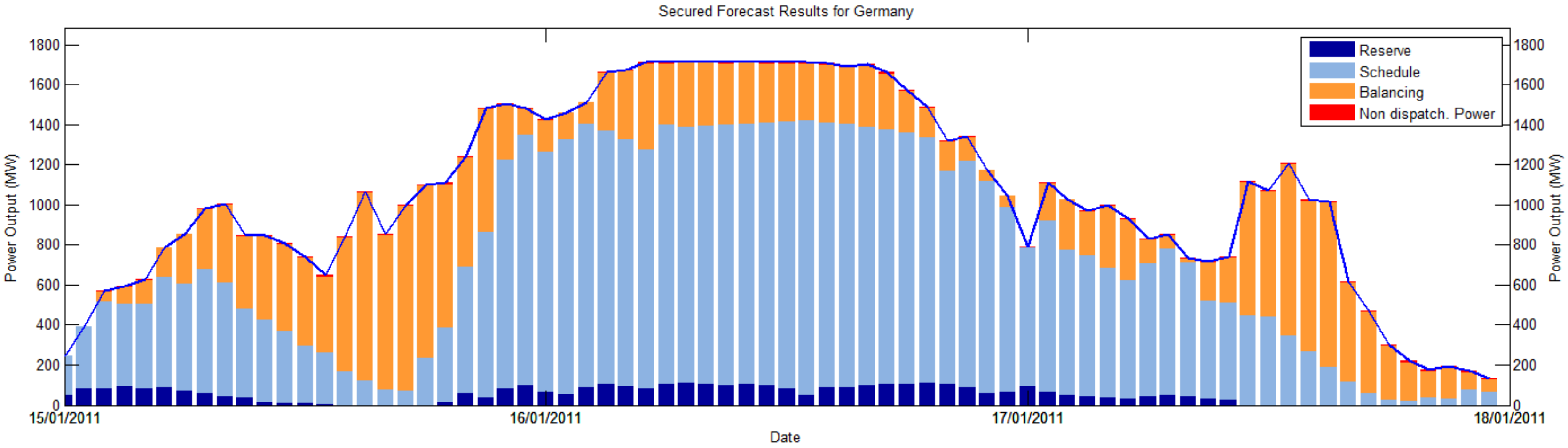


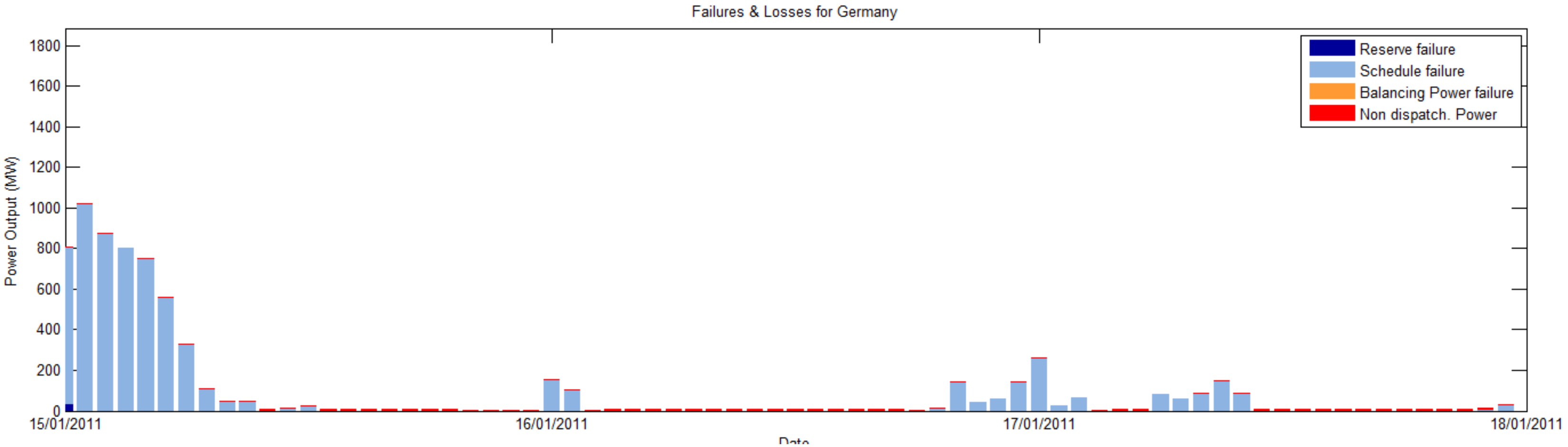
WIKINGER (400 MW)



BALTIC 2 (288 MW)

Integration of the models: case study (WCMS)





Extract for the forecasted power for the German cluster

Results/ conclusions

- Correlated time series of power output (based on reanalysis data) provided by CorWind has been used to test the study case
- The right combination of HVAC and HVDC technology was investigated reducing implementation costs and reducing losses
- Dimensioning the right capacity of the branches and the number of parallel systems was possible
- Different cluster configurations were tested in order to provide wind power and ancillary services
- Three new scenarios will be tested (base, near- and far-future) implementing another modules (i.e. eeFarm II)

Thank you very much for your attention

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