# Optimised grid for offshore wind connections

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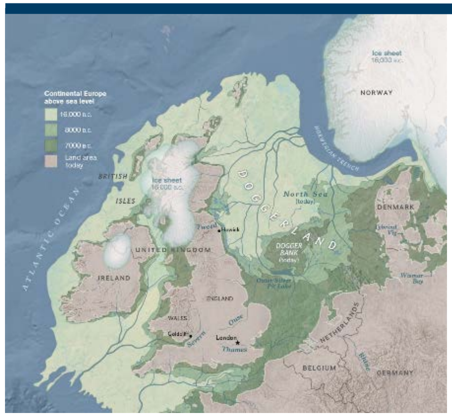
# Content

- The need to consider uncertainties
- Optimisation approach
- Examples
- Outlook

# North Sea electricity grid – not a new idea

-16000 2010 2020



Deep Sea Wind

NOWITECH
Research Centre for Offshore Wind Technology

OffshoreGrid

TradeWind

NSON

IRPWind

Twenties
Transmitting wind

DTOC

NORTH WIND

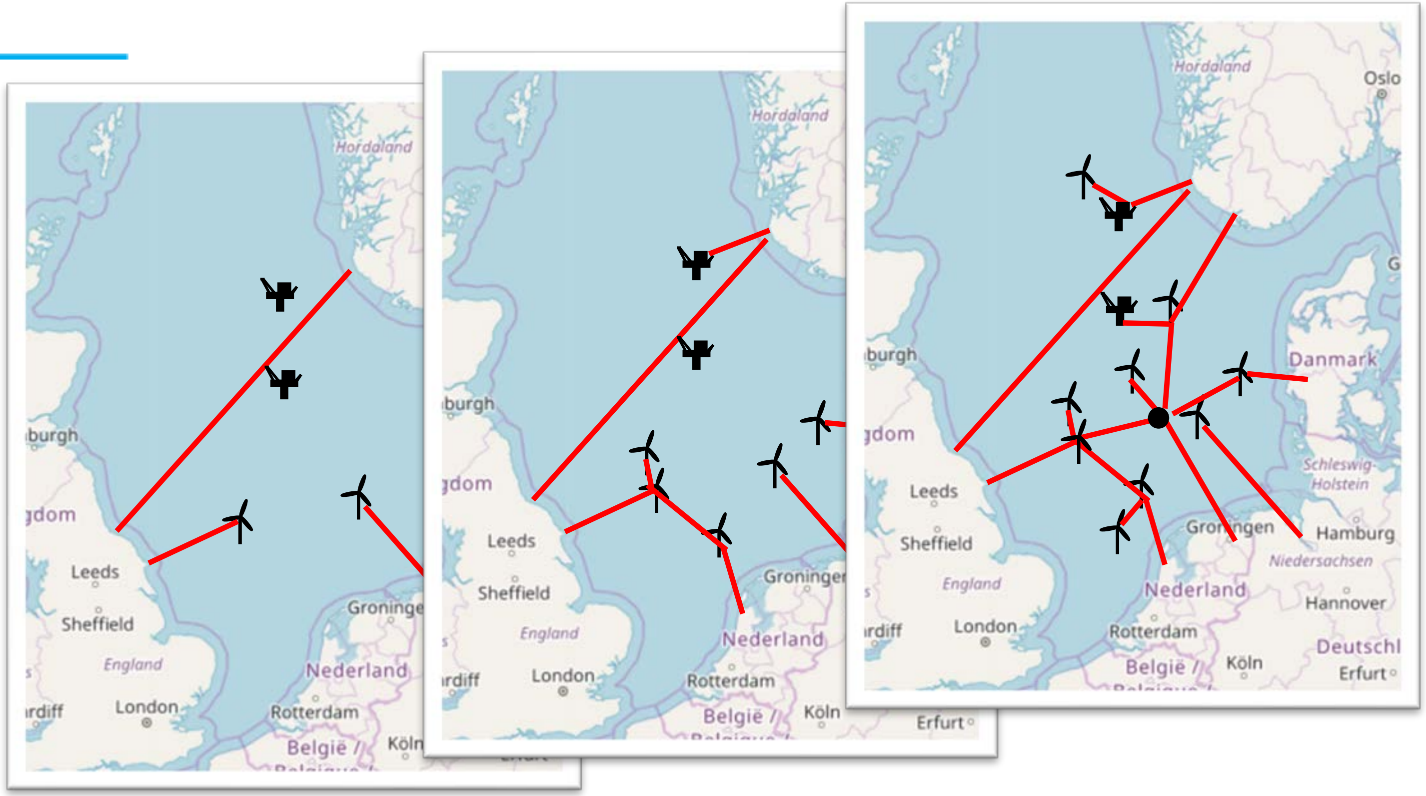
LOWEMISSION

BaltHub

Best Paths

*...and others*

# Offshore wind energy and grid will be built step by step




We seek grid solutions that are good both in the near and in the long-term

*– for developers and the society as a whole*



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# Need to consider uncertainties

## Step-wise development

- Wind farms built at different times.
- Always uncertainties about what happens in the future
- Some decisions are here-and-now, others can wait

## Some information is by nature uncertain

- Weather, climate, energy prices, world economy, ...

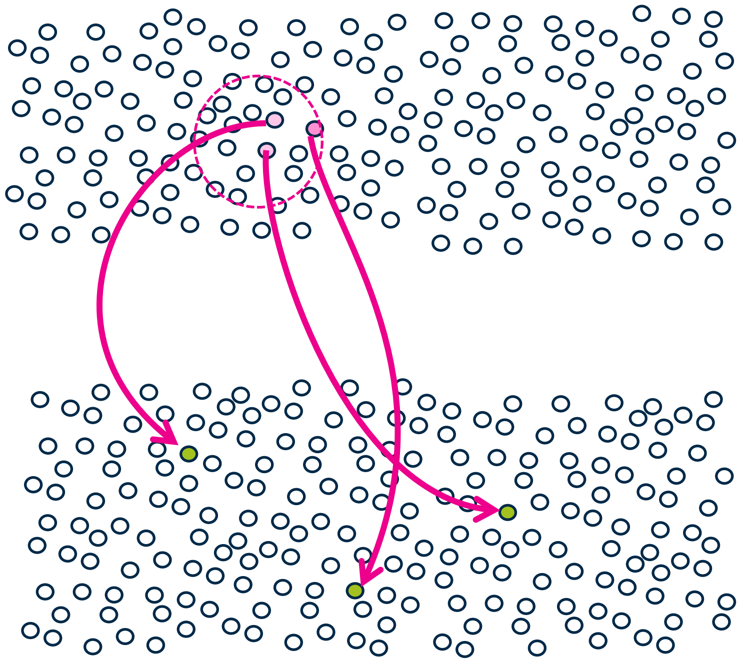
We are interested in solutions that are good for a range of likely future scenarios, not a solution that is optimal (only) for a single scenario

# Sensitivity analysis vs optimisation with uncertainty

Space of parameters

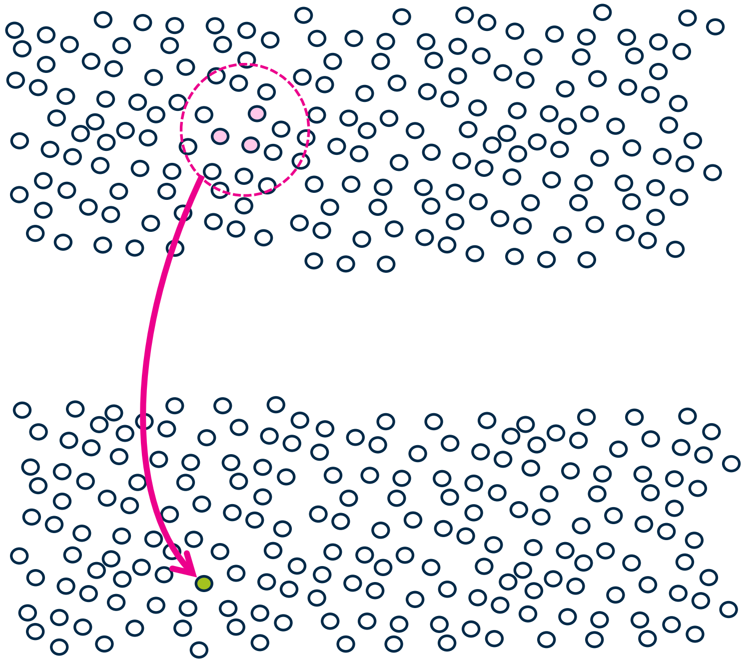
Space of solutions

sensitivity analysis:



Not clear how to "average" the results to find the best solution...

optimisation with uncertainty:





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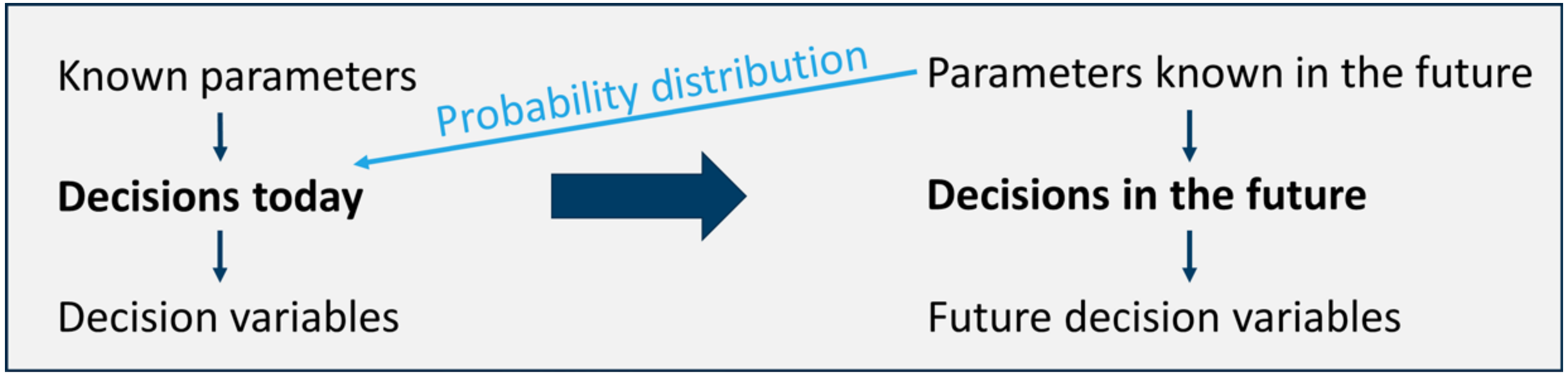
# Optimisation with uncertainty

Optimal solution is irrelevant if it is based on wrong assumptions, so we consider a range of parameter values

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# Optimisation problem

**Main variables**

- Which connections to build (grid layout) (integer)
- Cable capacities (continuous)

**Considering**

- A set of candidate investments
- Different operating conditions (variable generation and demand/power prices)
- Linear cost model (linear function of power rating)

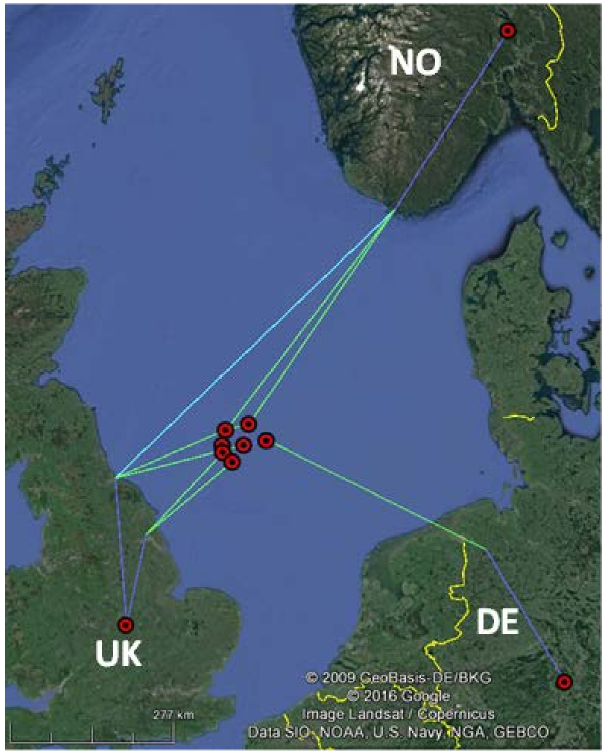
**Implementation**

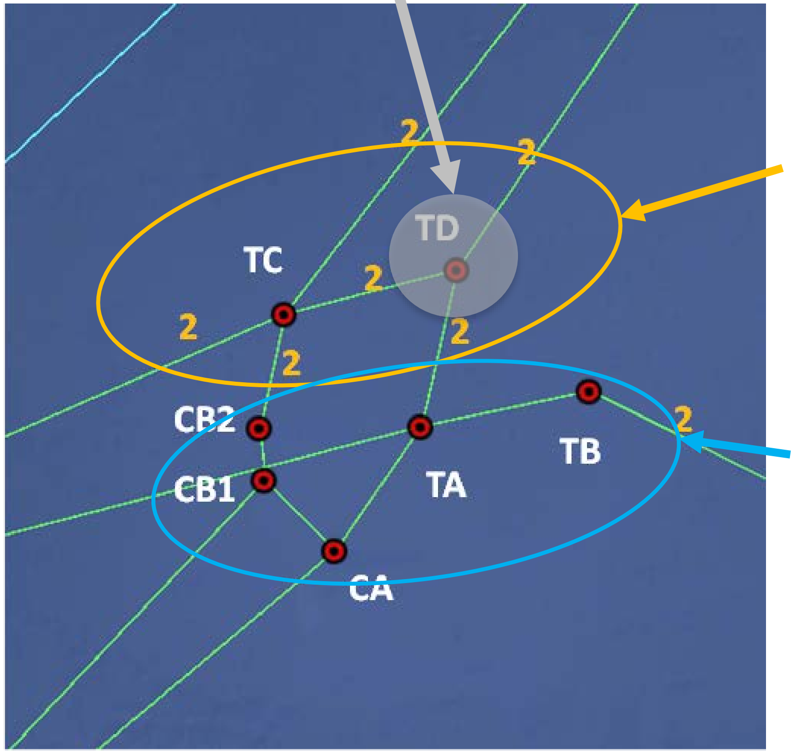
- Python package using Pyomo/PySP: PowerGAMA/PowerGIM

# Example 1: North Sea wind farm cluster

2-stage development

Uncertain development at TD



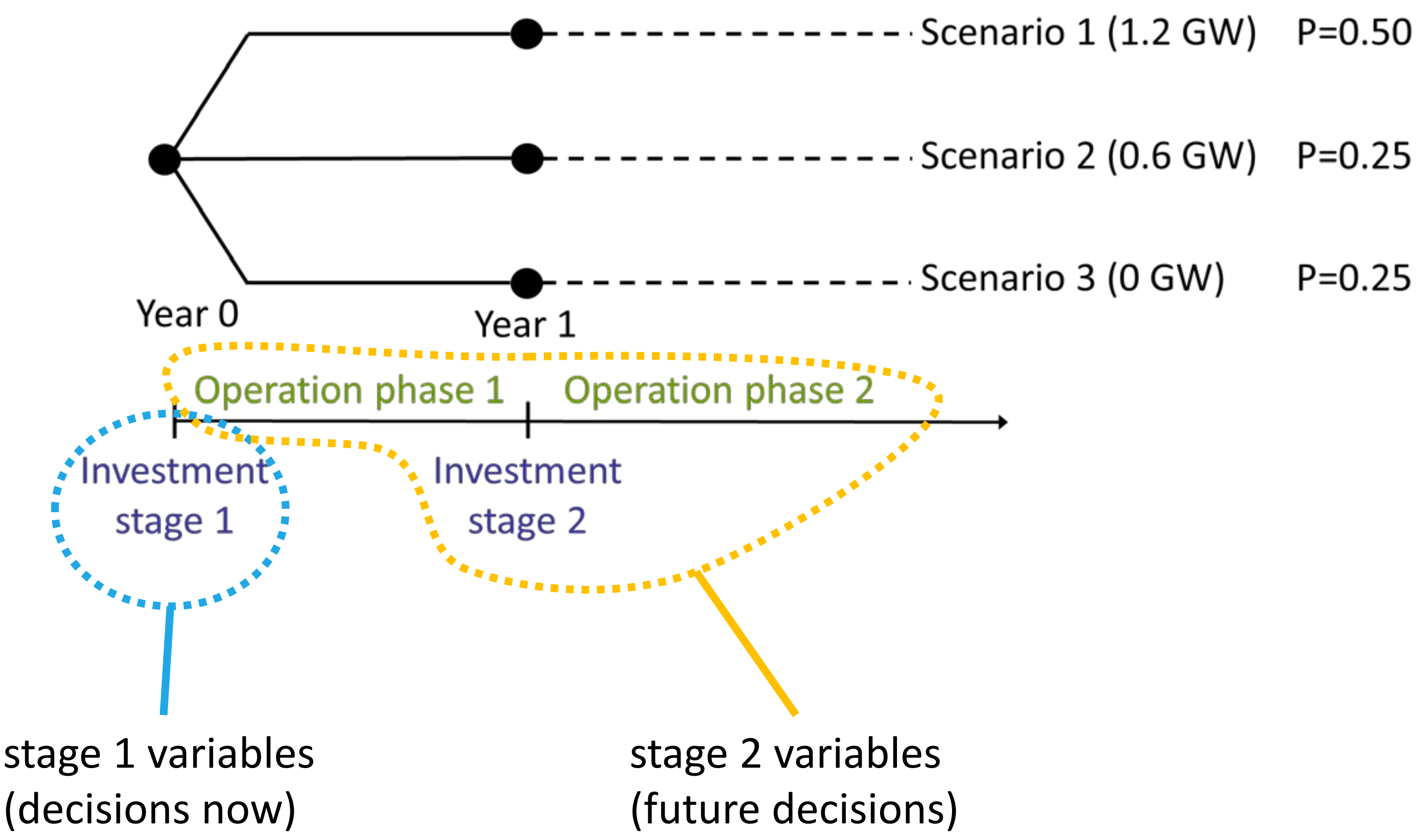




**Stage 2**
TC, TD
(2 × 1.2 GW, year 1)

**Stage 1**
CA, CB, TA, TB
(4 × 1.2 GW, year 0)

*wind farms and candidate connections*

# 2 stages – 3 scenarios



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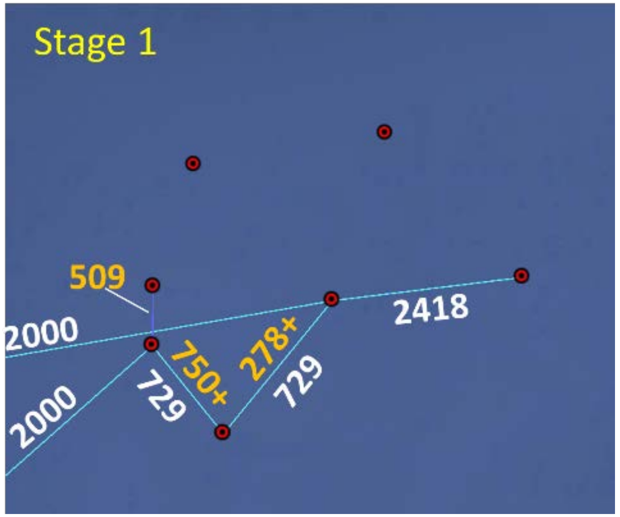
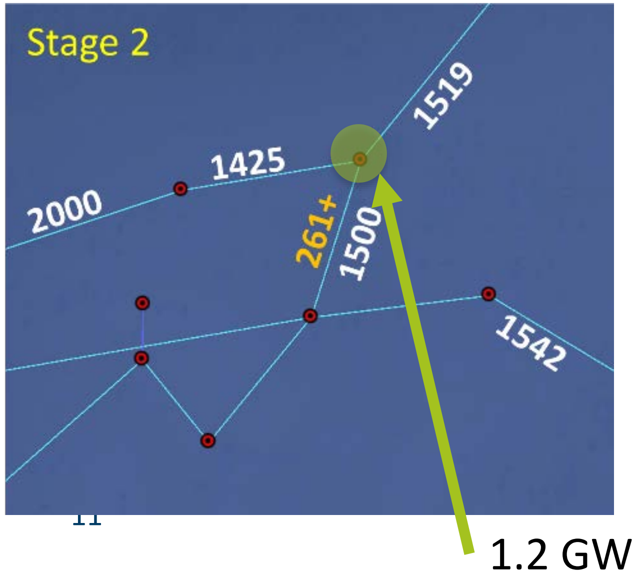
# Without uncertainty

Stage 1: Here-and-now:

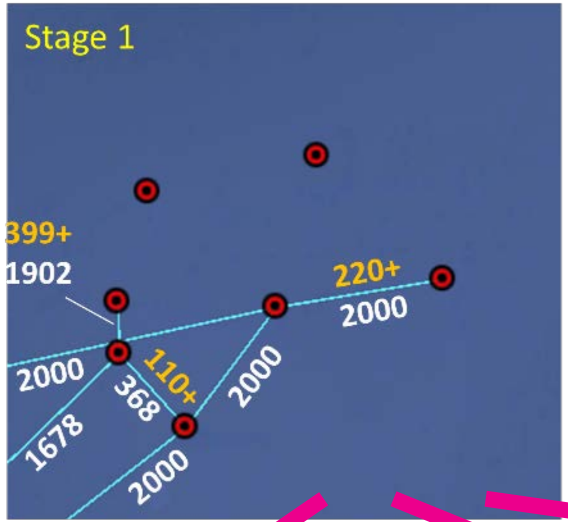


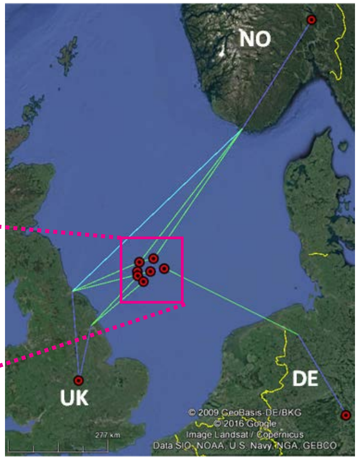

Stage 2: Future decisions:




1.2 GW

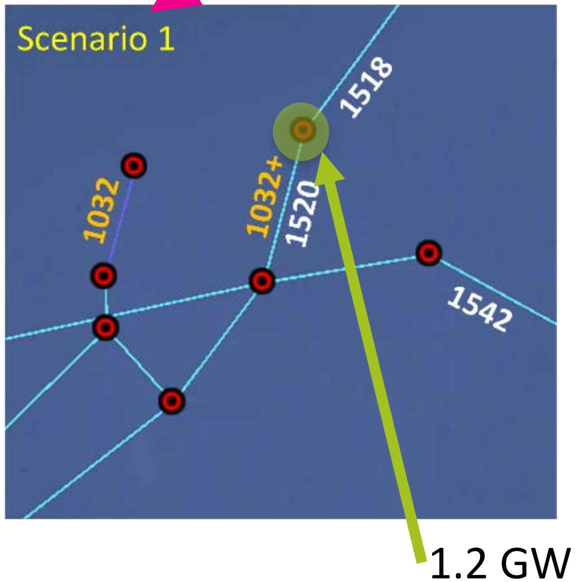
# With uncertainty



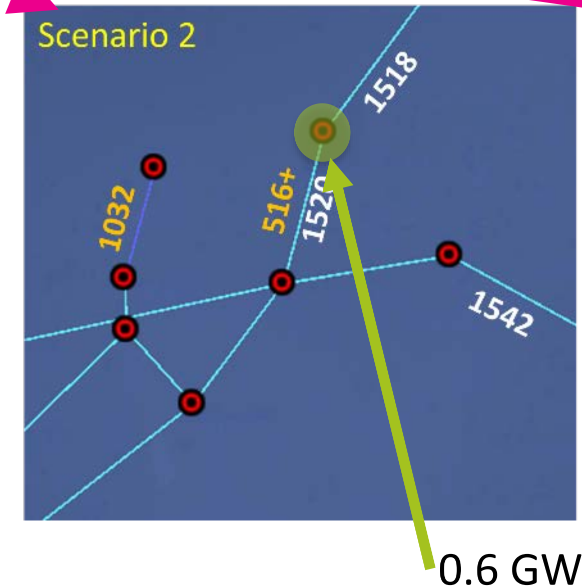




numbers show capacities in MW

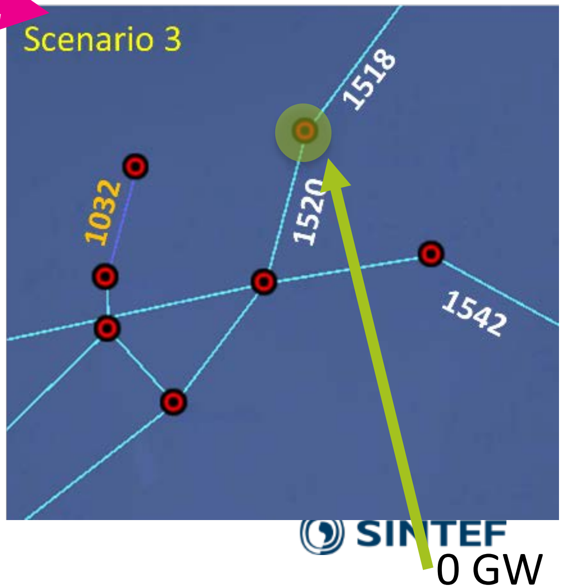
yellow = AC
white = DC




1.2 GW




0.6 GW




0 GW



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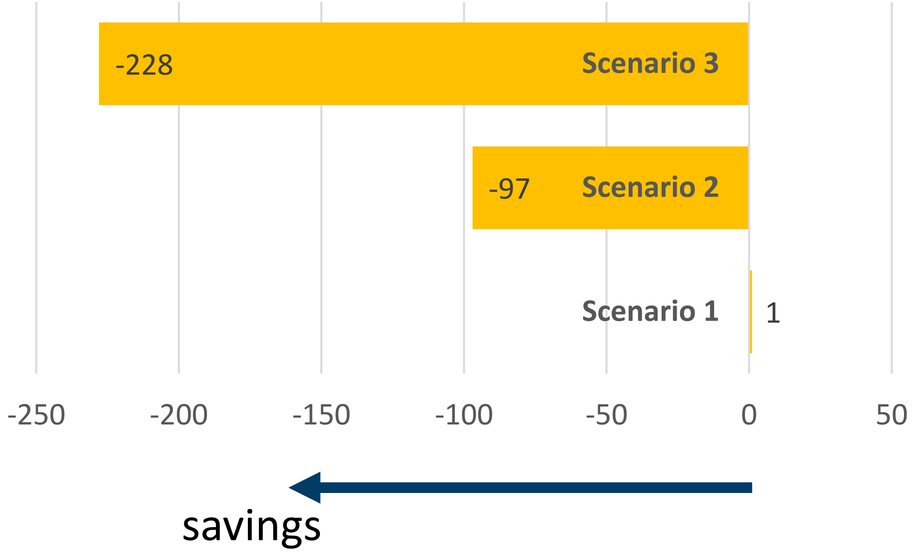
# Benefit of optimising with uncertainties

Total cost difference compared to case without uncertainty (which assumes scenario 1 is realised)



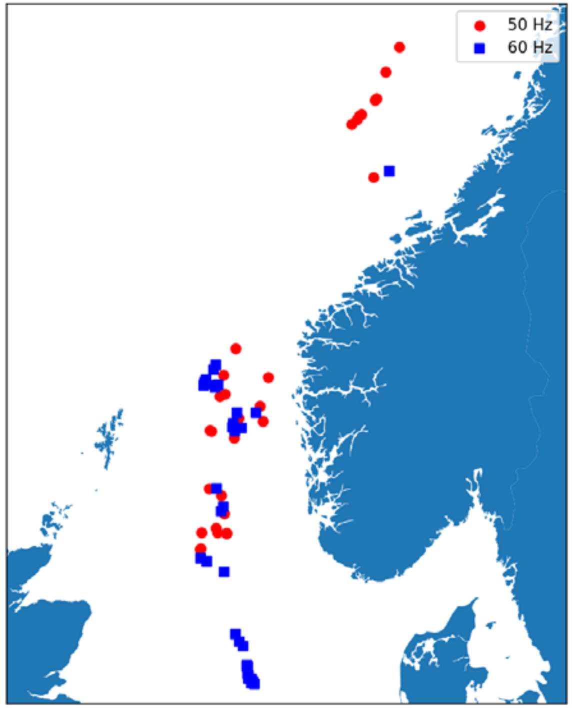

Large benefit if scenario 2 or 3 is realised

Slightly sub-optimal if scenario 1 is realised

Expectation value (average) = **–81**

# Example 2: Oil and gas field electrification

- Reducing emissions from oil and gas *extraction*
- Renewable power from shore
- Some 50Hz and some 60Hz systems, both AC and DC transmission relevant
- Short (remaining) lifetimes







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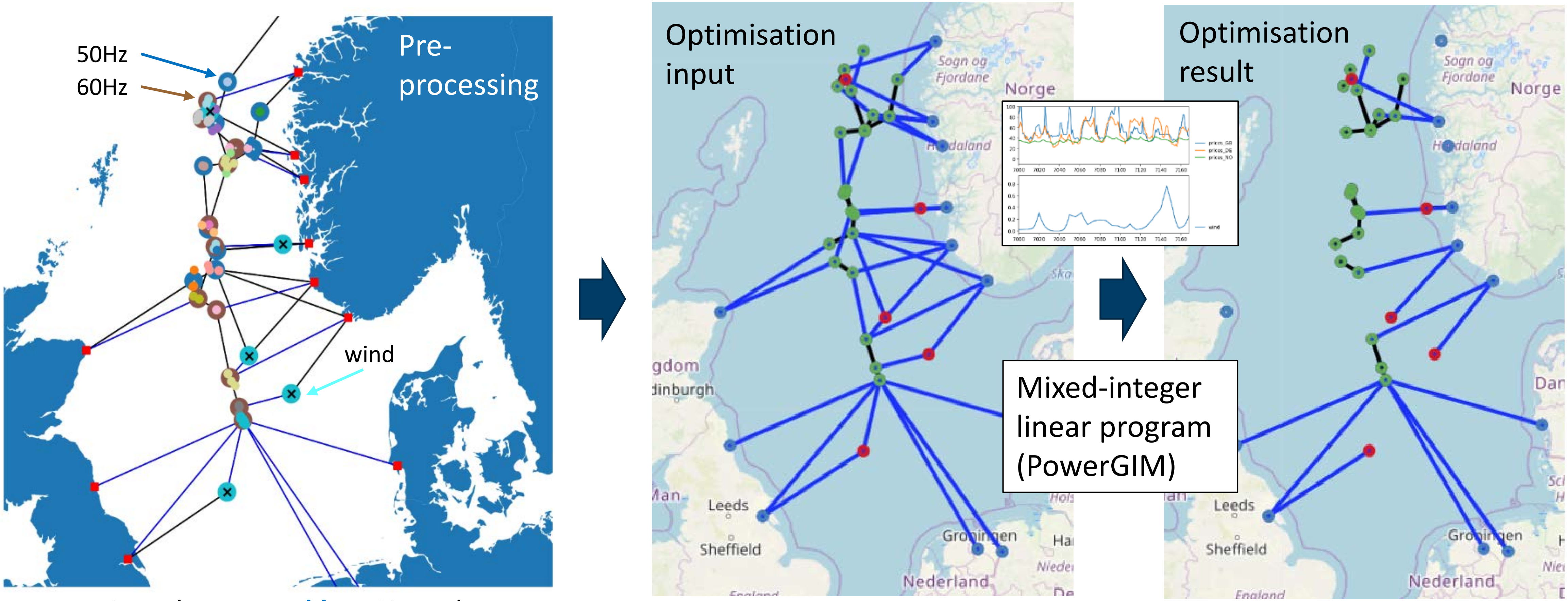
# Full electrification of Norwegian oil and gas

## (preliminary study)

Clustered oil and gas facilities, wind farms, candidate power cables

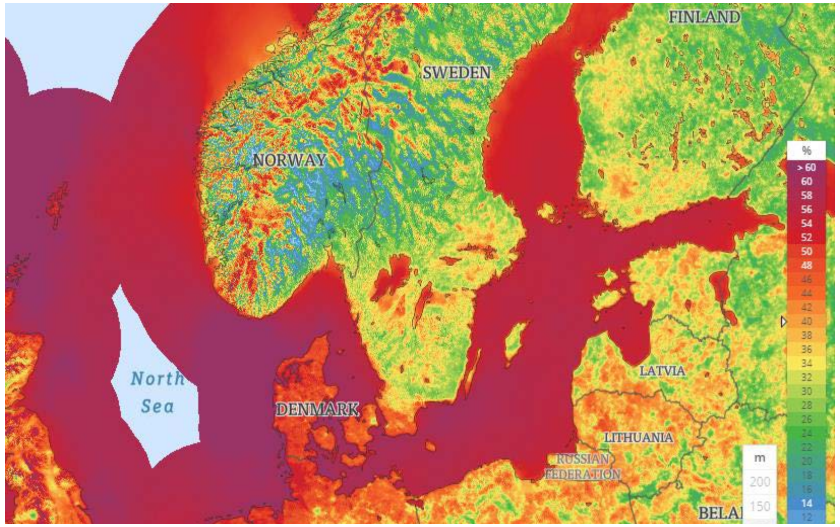
Candidate AC and DC connections

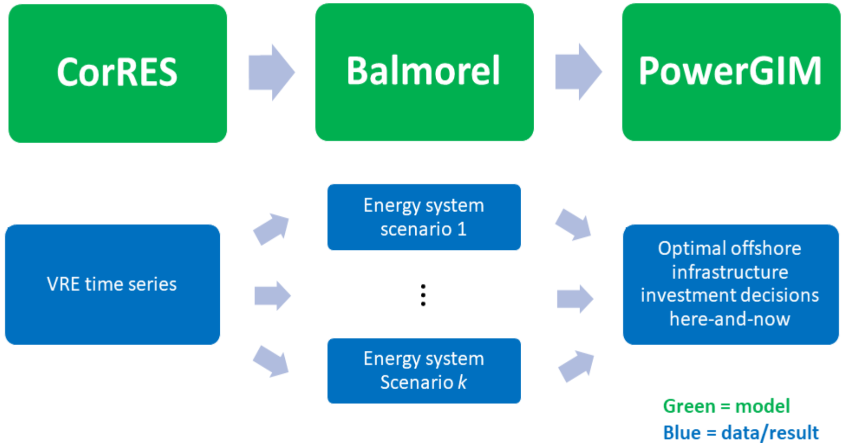
Optimal North Sea grid layout




*50 Hz clusters are **blue**, 60 Hz clusters are **brown**, Wind farms are turquoise with a cross*

# BaltHub project: Interconnecting the Baltic Sea countries via offshore energy hubs




## Project starting Jan 2021

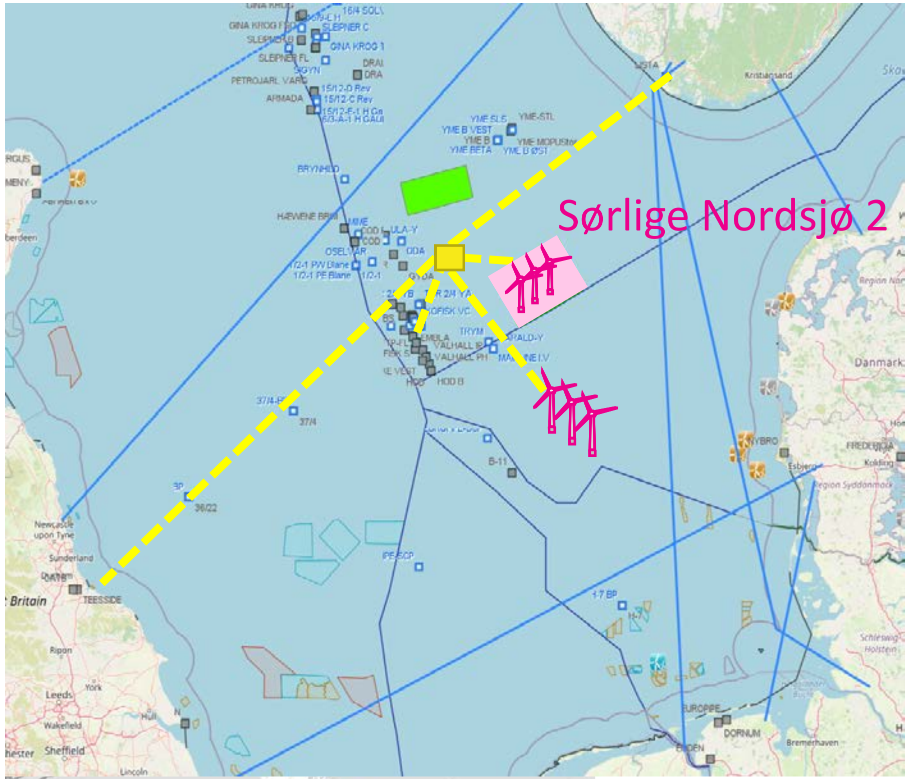
## Research questions:

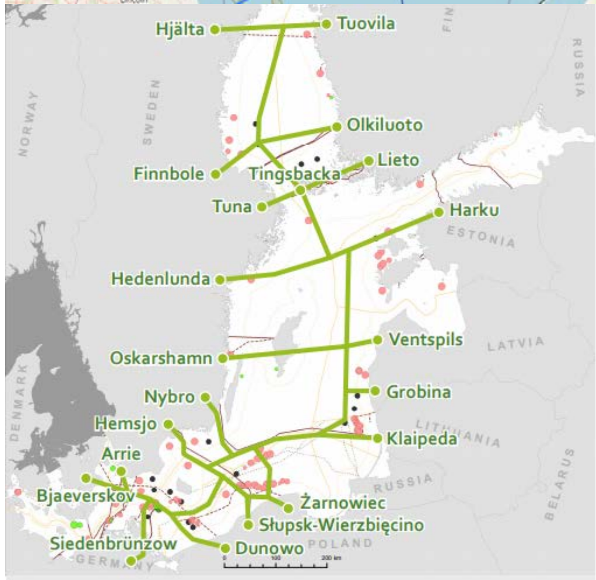
- Are Baltic Sea energy hubs a cost-effective solution for driving green transition in Baltic Sea countries? How is this impacted by key input parameters?
- Do large-scale wake losses jeopardize the cost-effective buildout of offshore energy hubs in the Baltic Sea?
- Are the offshore hubs beneficial in interconnecting the Baltic Sea region's countries?
- How can optimal offshore infrastructure investment decisions be made here-and-now when the development towards 2050 is uncertain?

DTU Technical University of Denmark *DK*
TALLINN UNIVERSITY OF TECHNOLOGY *EE*
ktu 1922 kaunas university of technology *LT*
SINTEF *NO*

# Outlook

- Thorough analysis of what are the most important parameter uncertainties
- Assess more complex scenario trees (using parallel computing)
- Interesting cases
  - North Sea hubs – Sørlige Nordsjø 2 wind farm area (Norway)
  - Baltic Sea Hubs – BaltHub project



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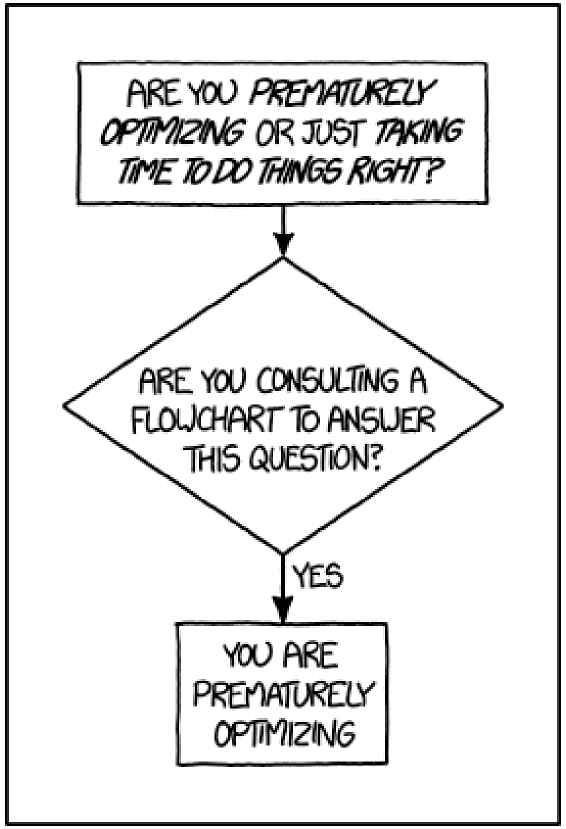
# Concluding remarks

- High costs, long planning times and long lifetime makes multistage optimisation with uncertainties **highly relevant**
  - More economically robust decisions
  - Increased computation times
- Caution: "Optimal solution" is only optimal if input data is accurate



https://xkcd.com/1691/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