Optimisation of offshore grid considering step-wise investments and uncertainty

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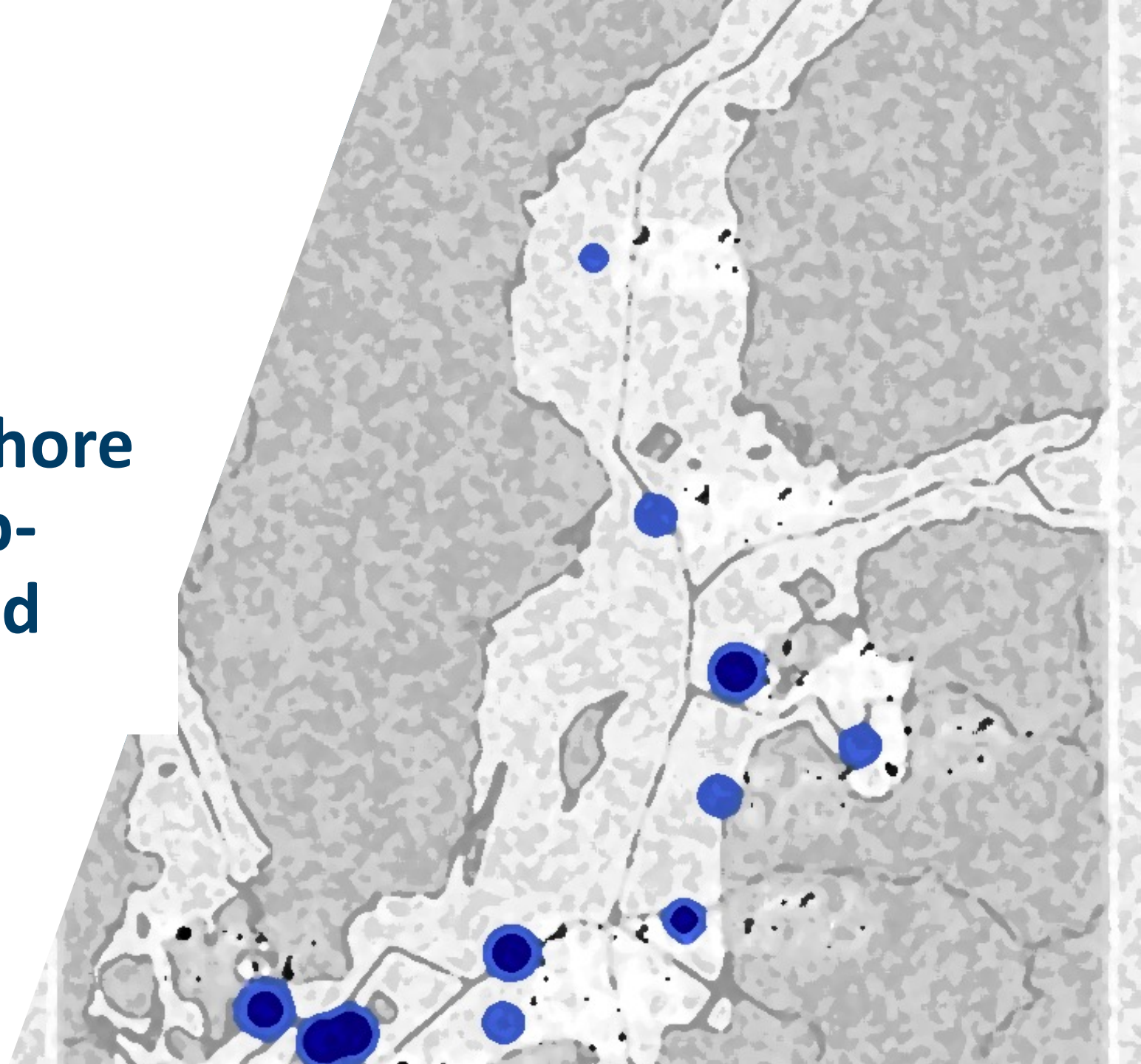
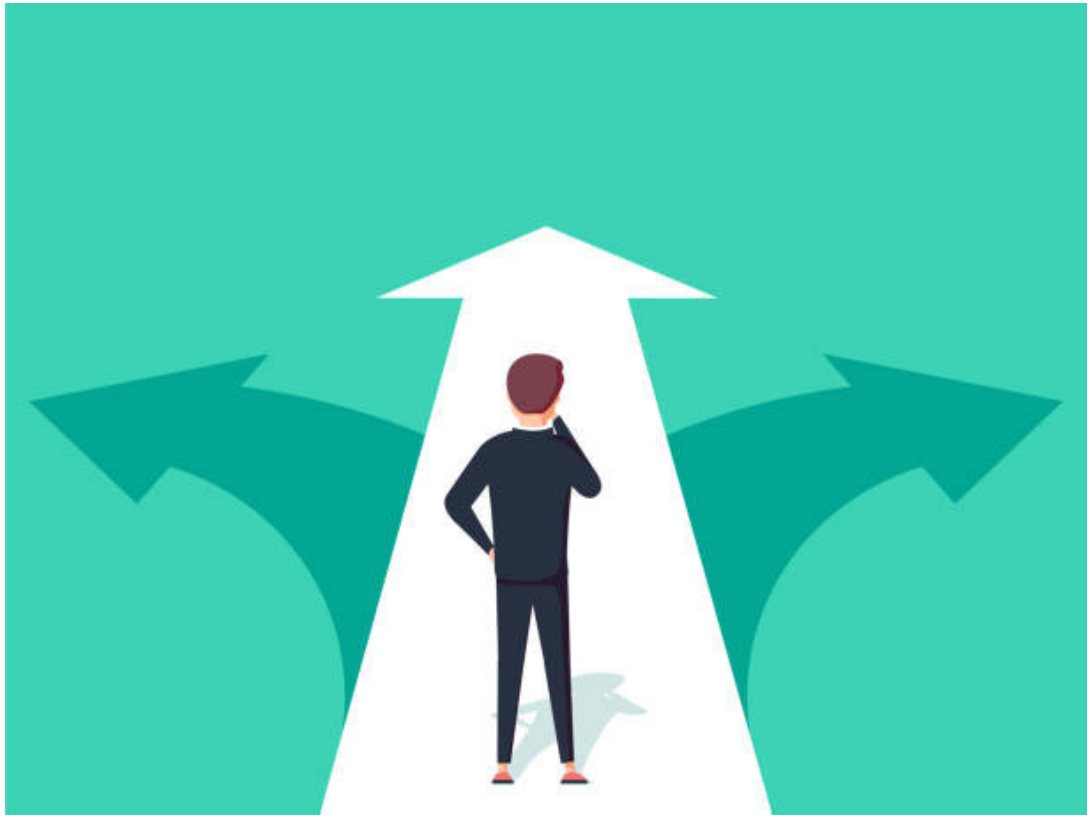
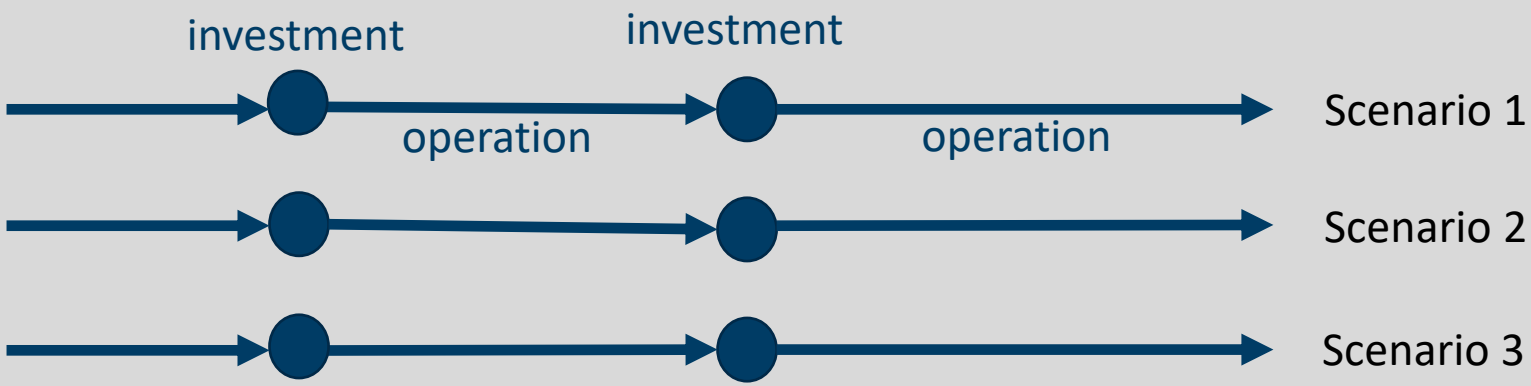


Optimisation under uncertainty
Research Question and Goal

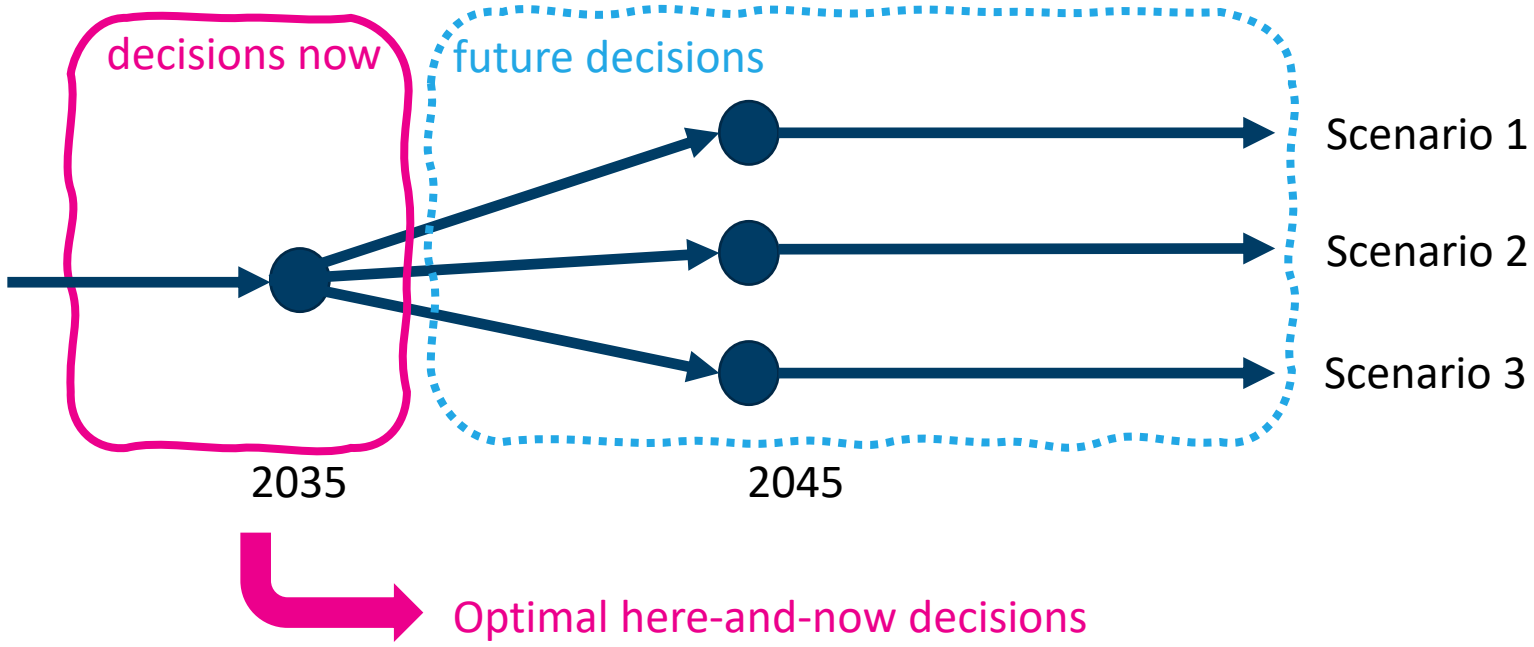
- **Research Question**: How can optimal offshore infrastructure investment decisions here-and-now be made when the development towards 2050 is uncertain?
- **Goal**: Identify optimal Baltic Sea grid investment decisions considering step-wise development and uncertainties
  - Using the PowerGIM optimisation model
  - Using results from Balmorel study



Balmorel study
3 development scenarios



PowerGIM study
3 future scenarios



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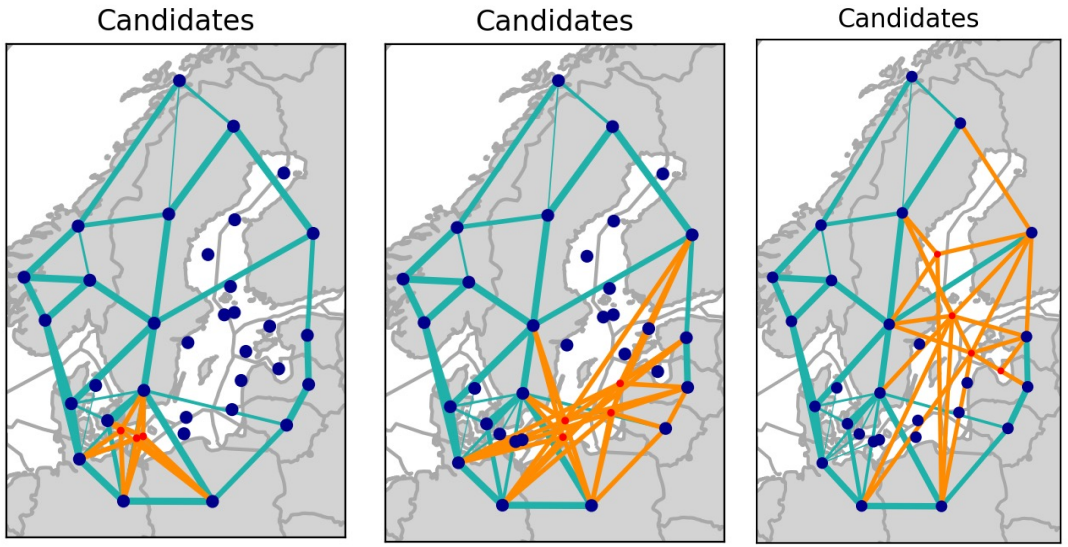
Assumptions



Baltic Sea divided into 3 regions of interest, analysed separately

3 regions of interest analysed independently

- Outside region of interest: Assumptions based on Balmorel results (grid, prices, wind)

Uncertainty: Scenario 1, 2, 3 from Balmorel

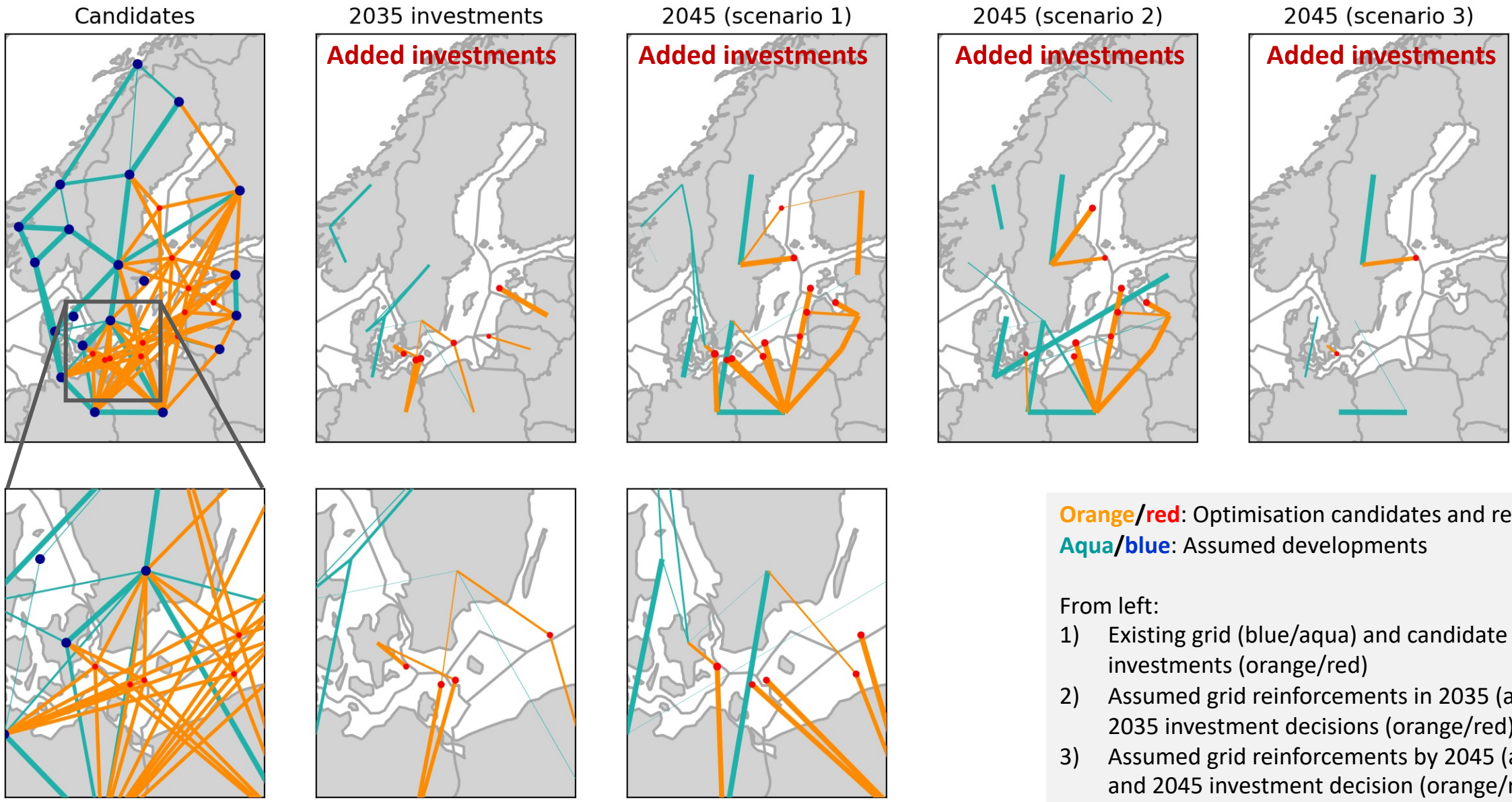
2035 is considered “here and now”

Investment decisions in hubs and transmission for 2035 is done without knowing wind power capacities.

- Corresponds to a situation where grid developer decides grid build-out before knowing what generation capacities will be installed

Variables: Baltic sea hub and HVDC connection capacities

RESULTS: Combined into the same map:

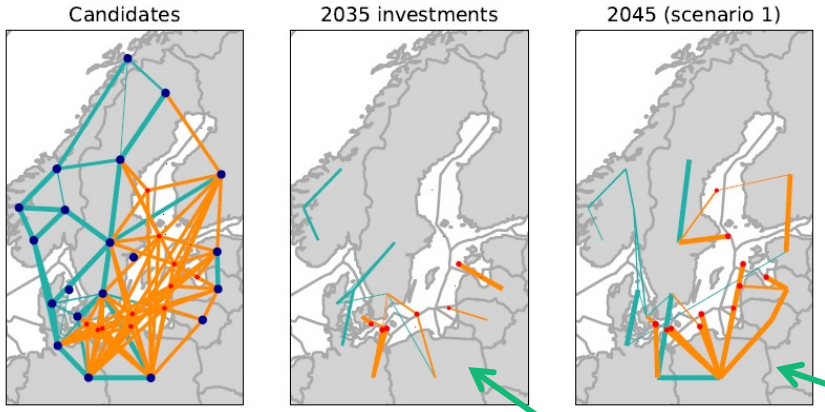


Orange/red: Optimisation candidates and results
Aqua/blue: Assumed developments

From left:

1) Existing grid (blue/aqua) and candidate investments (orange/red)
2) Assumed grid reinforcements in 2035 (aqua) and 2035 investment decisions (orange/red)
3) Assumed grid reinforcements by 2045 (aqua) and 2045 investment decision (orange/red), depending on scenario

Comparison with Balmorel results

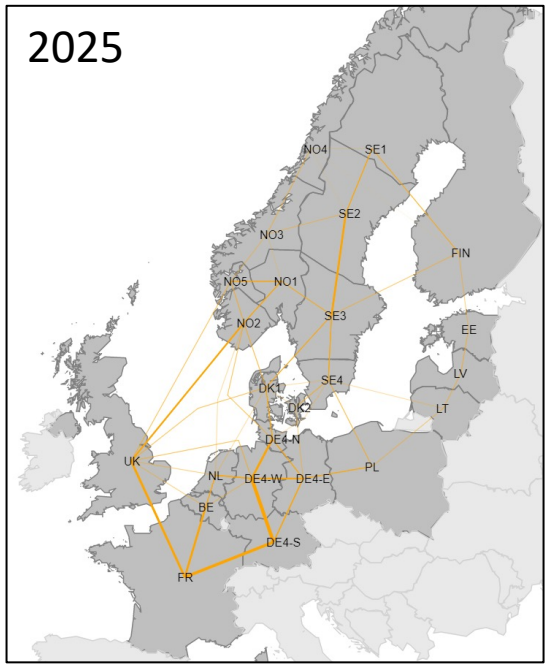


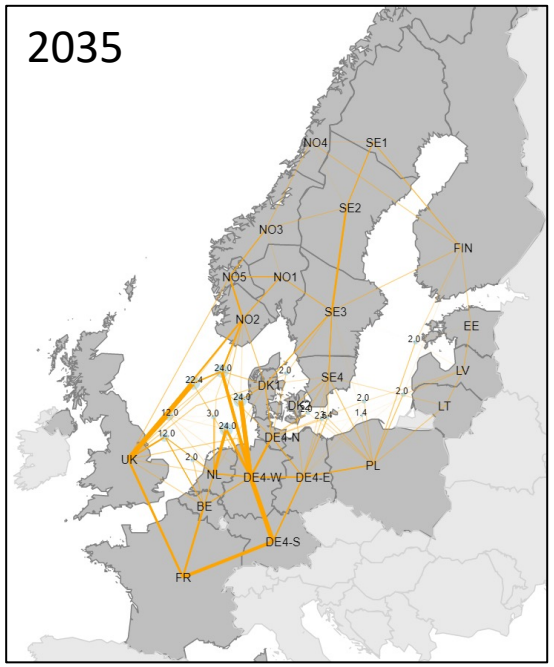
Fewer offshore connections than found in the Balmorel study

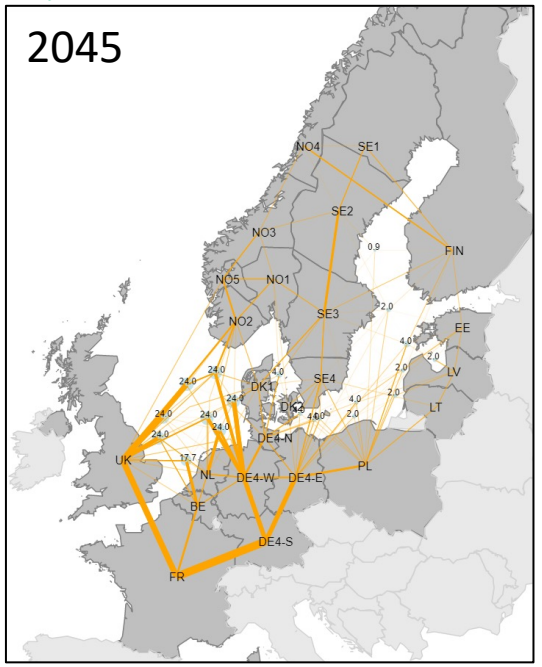
As expected

- **Balmorel**: LP model without fixed costs
- **PowerGIM**: MILP model with fixed costs (discourages investments with small capacity)

Balmorel (scenario 1)





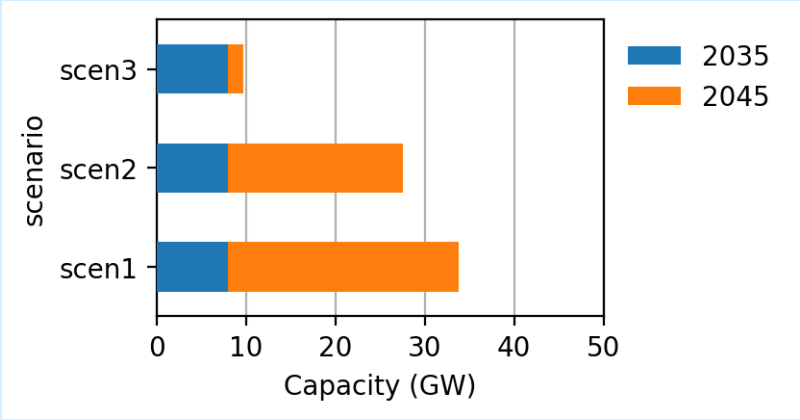


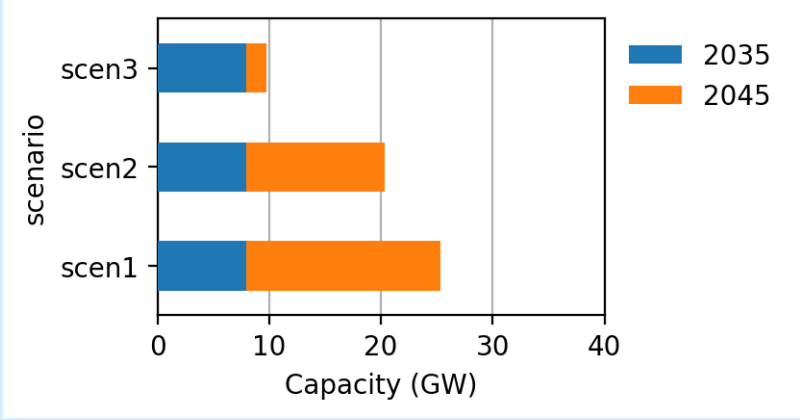
RESULTS: Baltic Sea grid capacity

HVDC connections

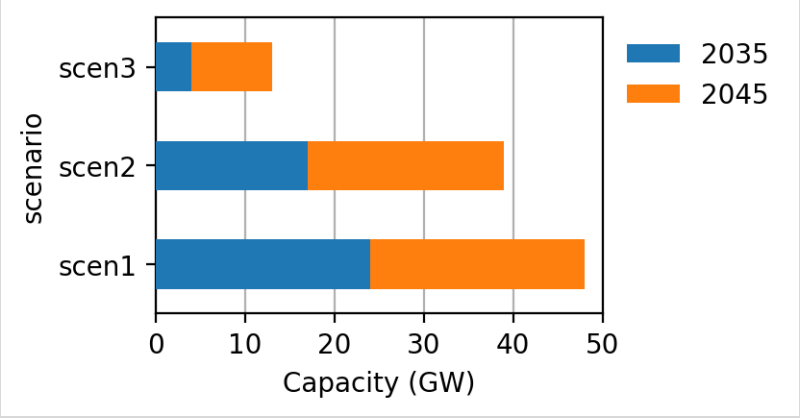
Offshore hubs

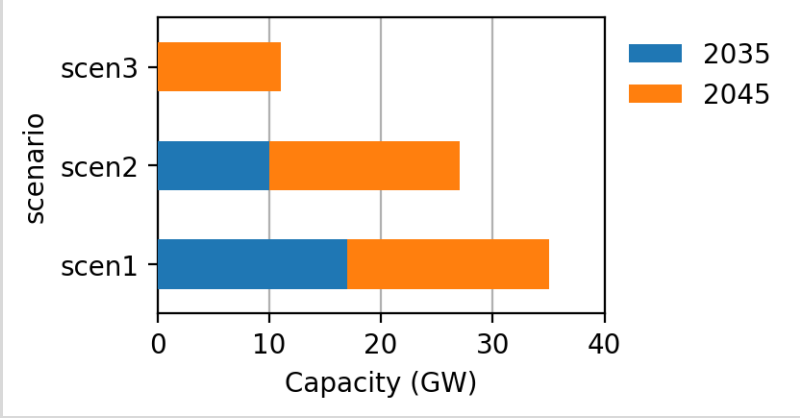
PowerGIM

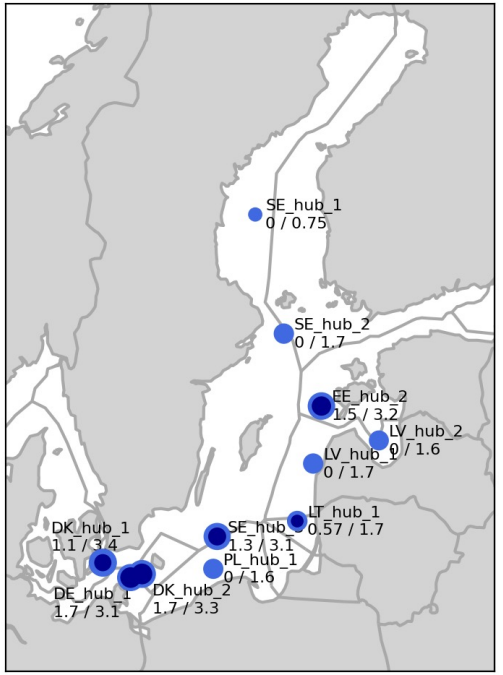




Balmorel



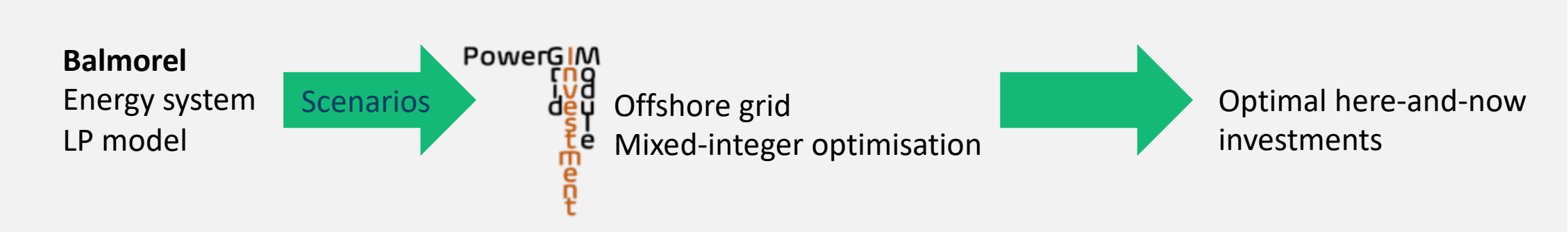




PowerGIM results show less installed offshore infrastructure (MW) than Balmorel (but same order of magnitude)

Summary

- Successfully completed a study combining Balmorel and PowerGIM models

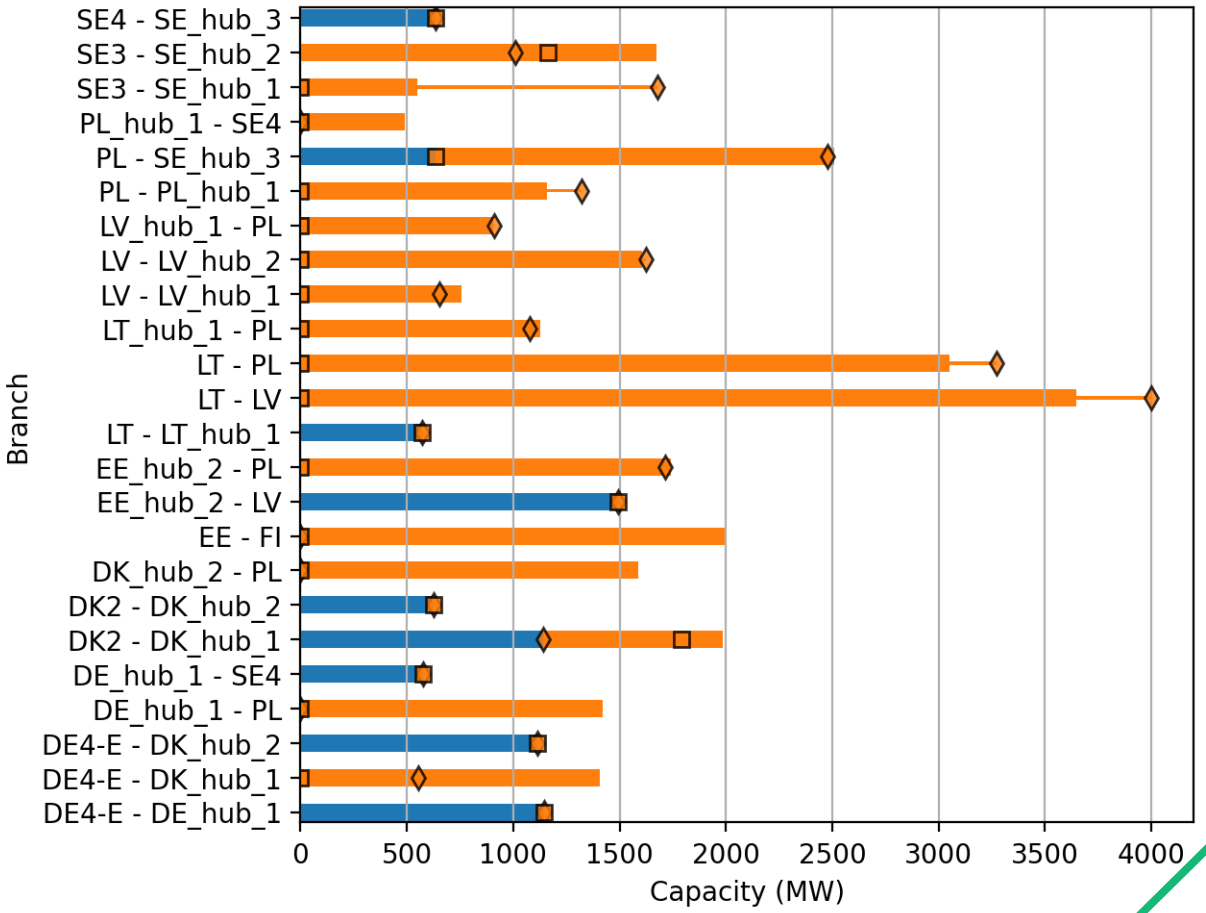


  - Demonstrates a work flow relevant for here-and-now decision making

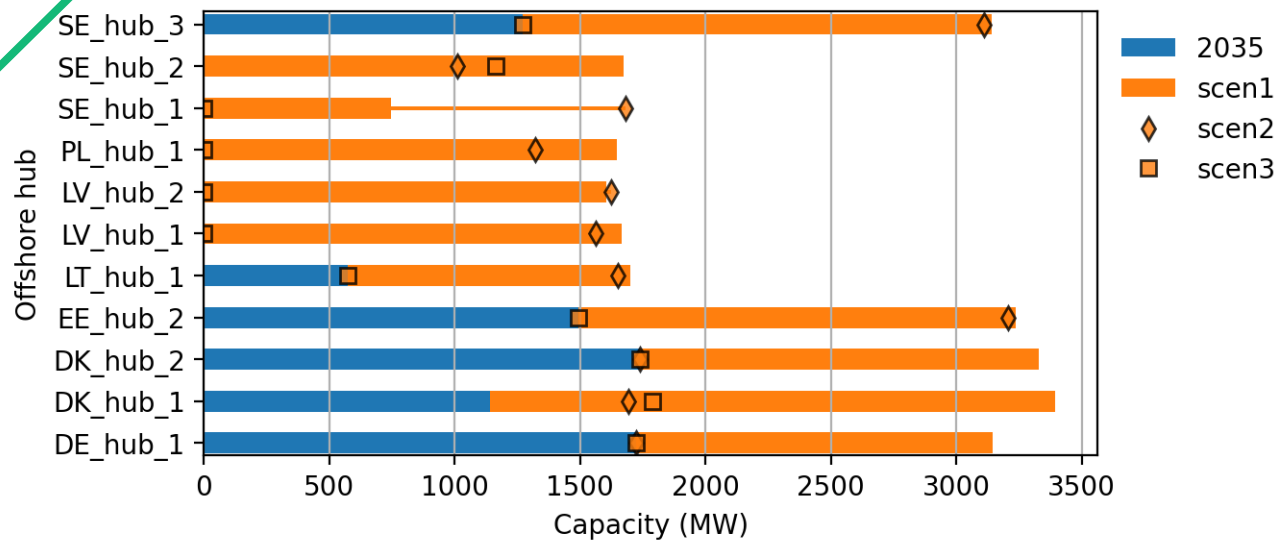
- PowerGIM results are different, but consistent with Balmorel findings

Thank you for the attention

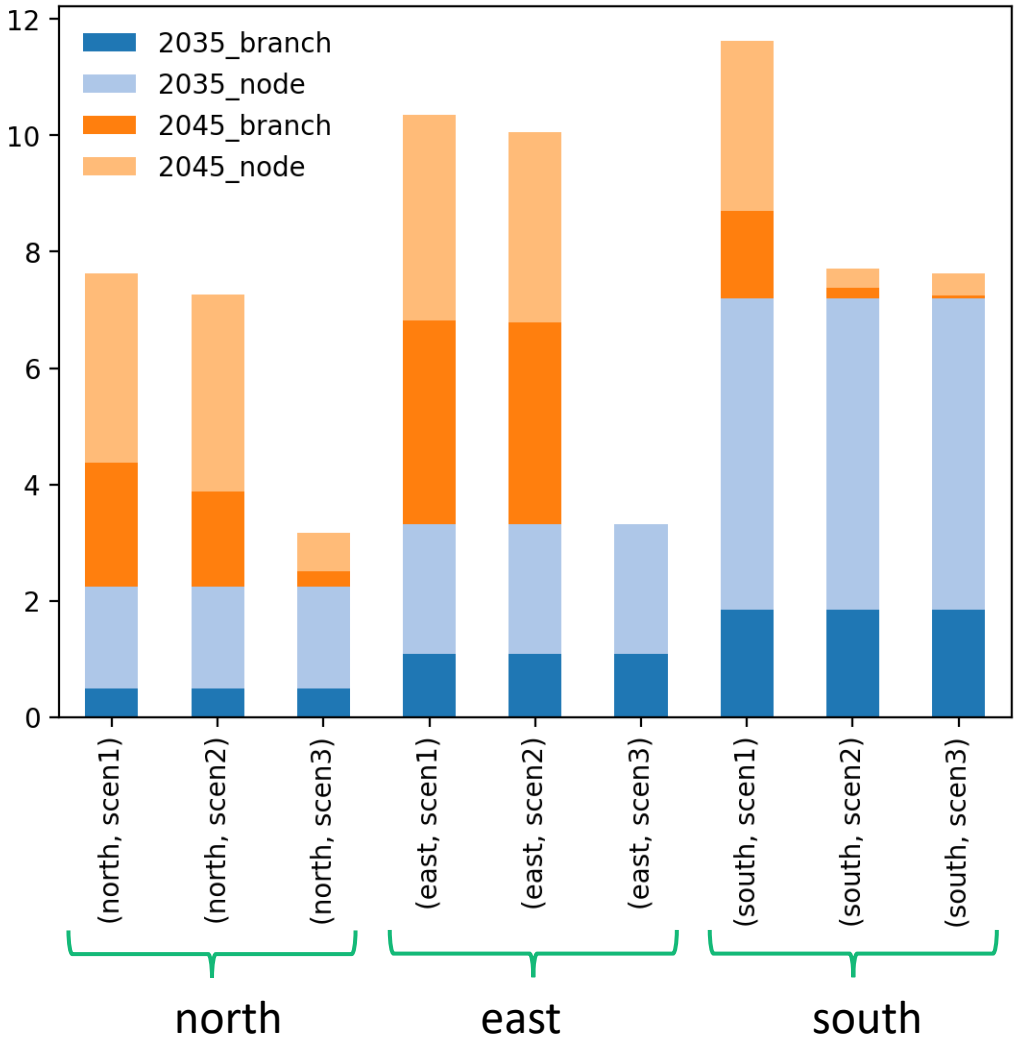
Baltic Sea HVDC connections



Baltic Sea hubs



PowerIGM RESULTS –Investments (bn EUR)



Investment costs
Split per region and per scenario

(2035 investments are independent of scenario)

The BaltHub project

2021-2022
Funding: Nordic Energy Research

- BaltHub analyses the cost-effectiveness of Baltic Sea energy hubs using integrated energy system analysis of the Baltic-Nordic region and beyond
- Partners:
  - DTU (DK)
  - SINTEF (NO)
  - Tallinn University of Technology (EE)
  - Kaunas University of Technology (LT)
- Models:
  - CorRES
  - Balmorel (LP)
  - PowerGIM (MILP)

Results from Balmorel study

Baltic Sea energy hubs (blue circles, in GW) and transmission lines in different scenarios by 2050

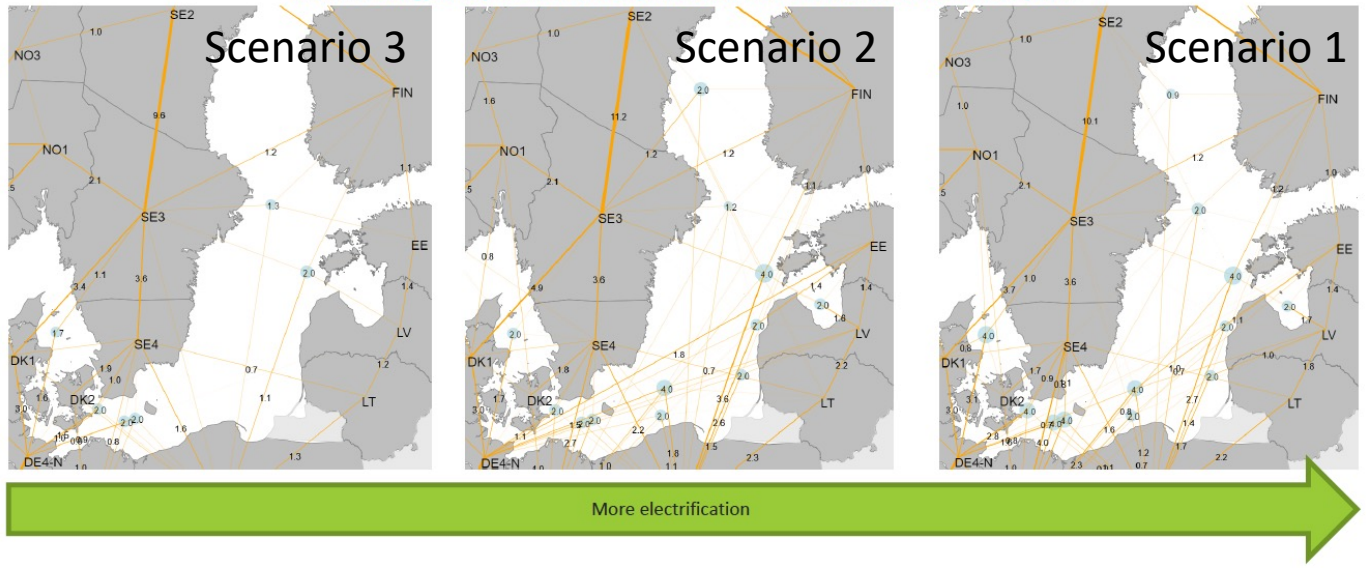


TABLE I. STUDIED SCENARIOS IN TERMS OF ELECTRIFICATION.

	Scenario	Electric heating (household & industry)	Electric mobility	Hydrogen demand (industry & transport fuels)
3	**Heat only**	Optimized	-	-
2	**Heat and Elec. Mobility**	Optimized	Operation optimized	-
1	**All Electrified**	Optimized	Operation optimized	Operation optimized