corewind

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

# Floating offshore wind farm layout optimisation

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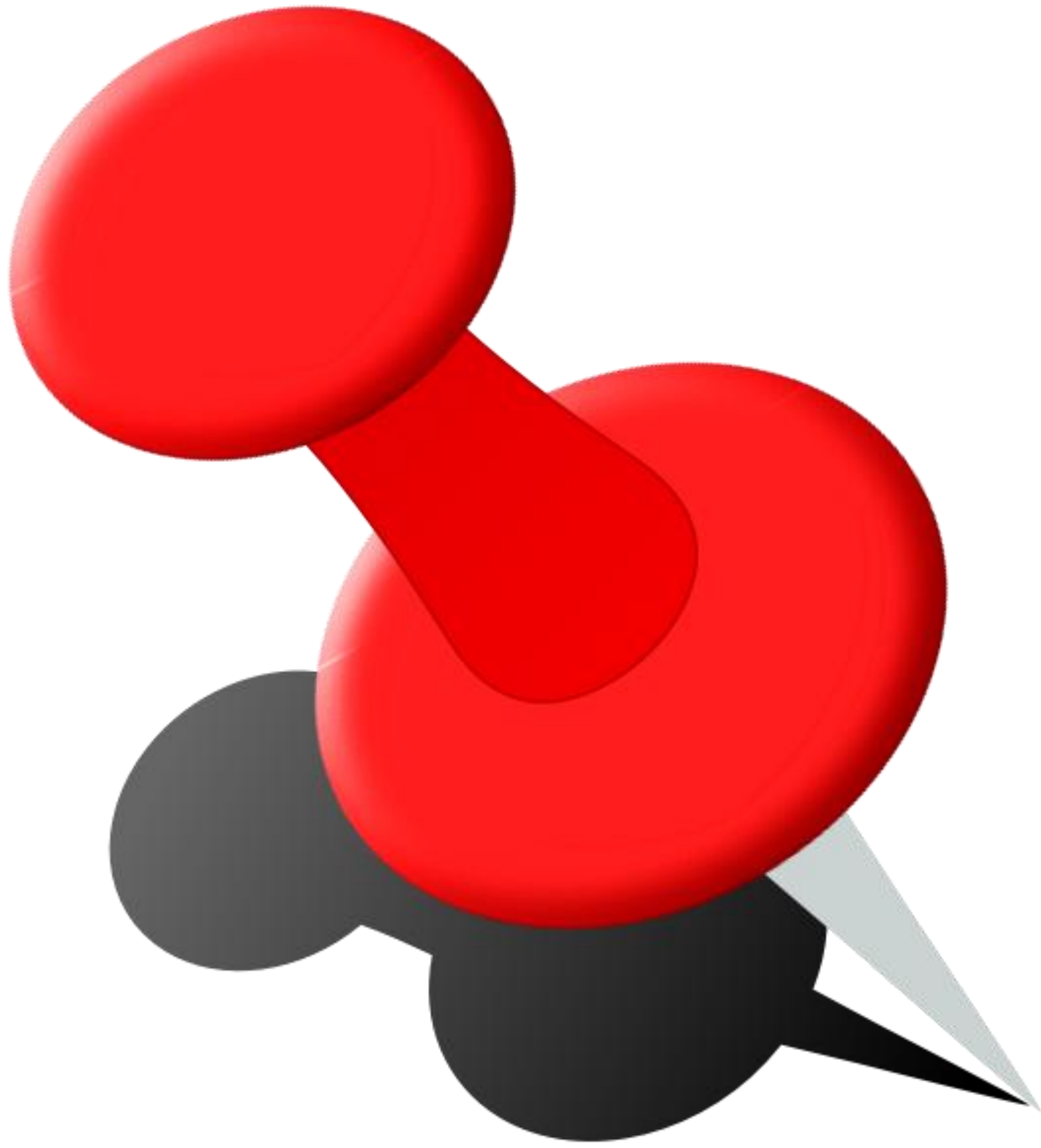


# Problem description

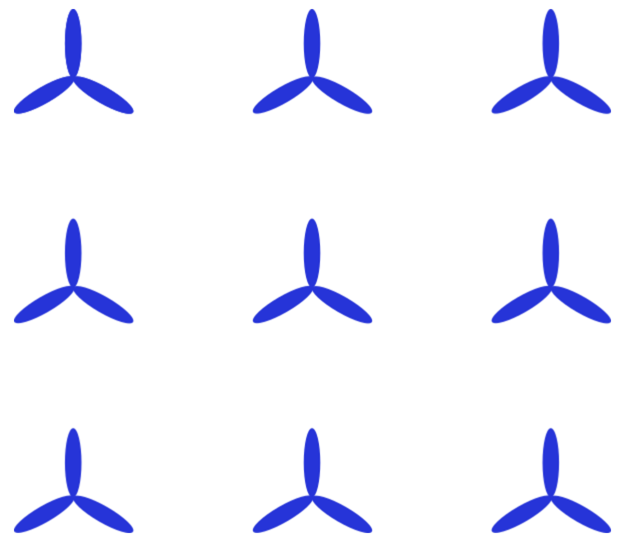
- Wind farm micro-siting

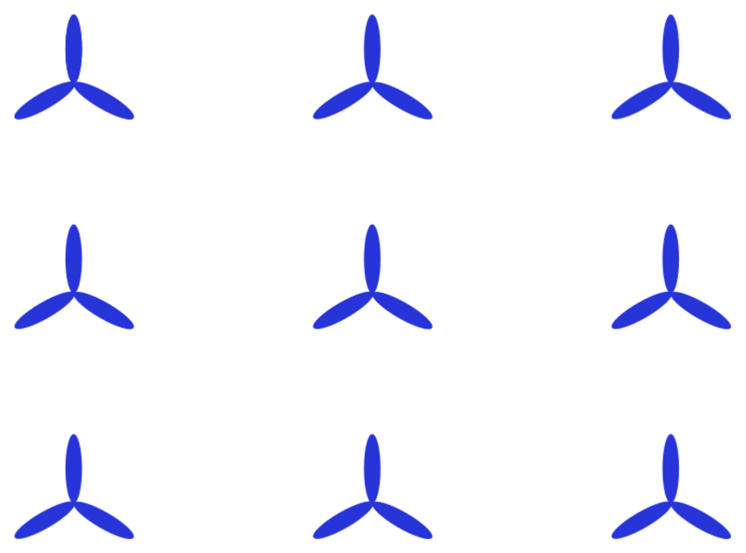
  It is the process of establishing the exact location of each turbine in the farm and the offshore substation(s), if applicable.

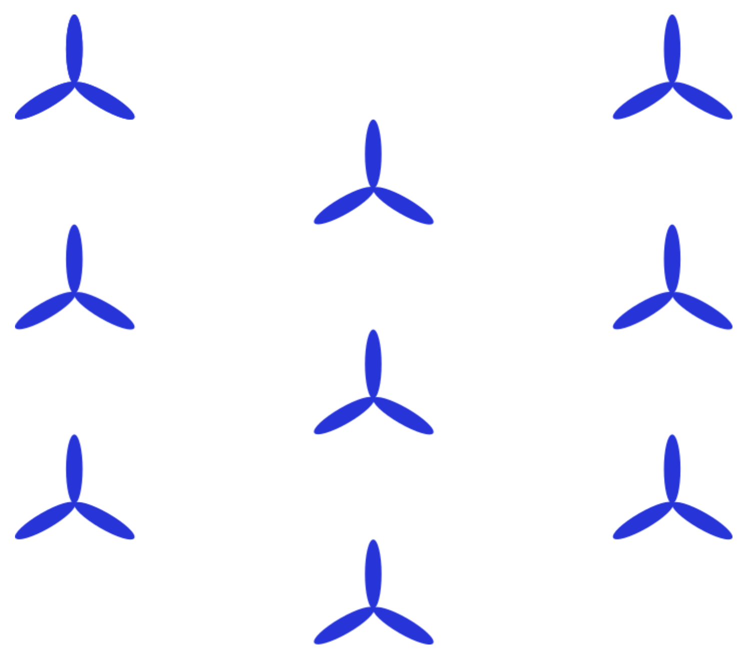
- Typical layouts

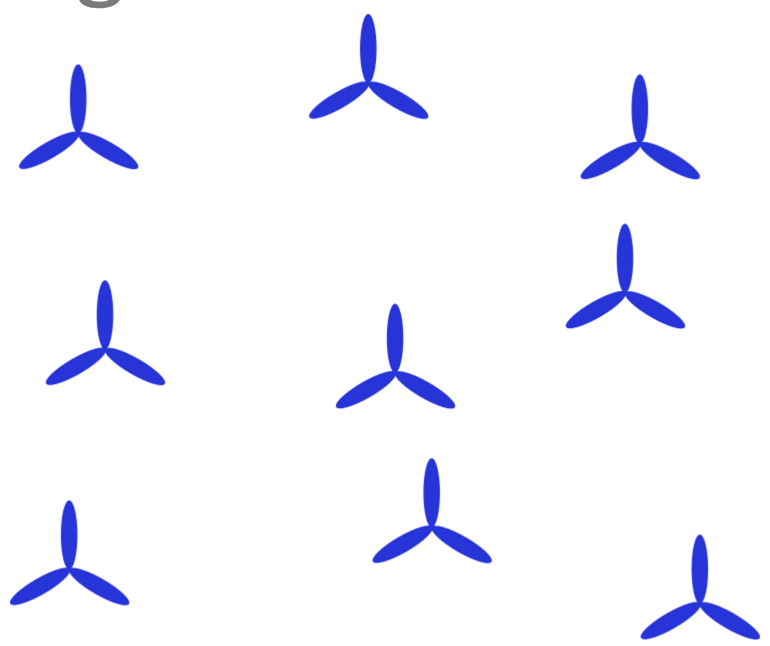
  Sorted by increasing complexity:

  - Rectangular matrix with equidistant turbines in both directions
  - Rectangular matrix with direction-dependent spacing
  - Staggered matrix
  - Irregular positioning









# Problem description

- Key drivers

A number of parameters influence the layout definition. The most relevant are:

- Wakes
- Local wind speeds
- Bathymetry
- Soil conditions
- Lease fee
- Mooring design
- Electrical layout
- Minimum distance from shore
- Distance to port
- Distance to onshore substation

# Approach

- Options

  Depending on the year and country:

  - Simplicity: first offshore wind farms with regular layouts
  - Energy yield: maximal AEP (annual energy production)
  - Low LCOE (levelised cost of energy): minimal cost of energy
  - High energy density: maximal energy yield per $km^2$

- Selected approach

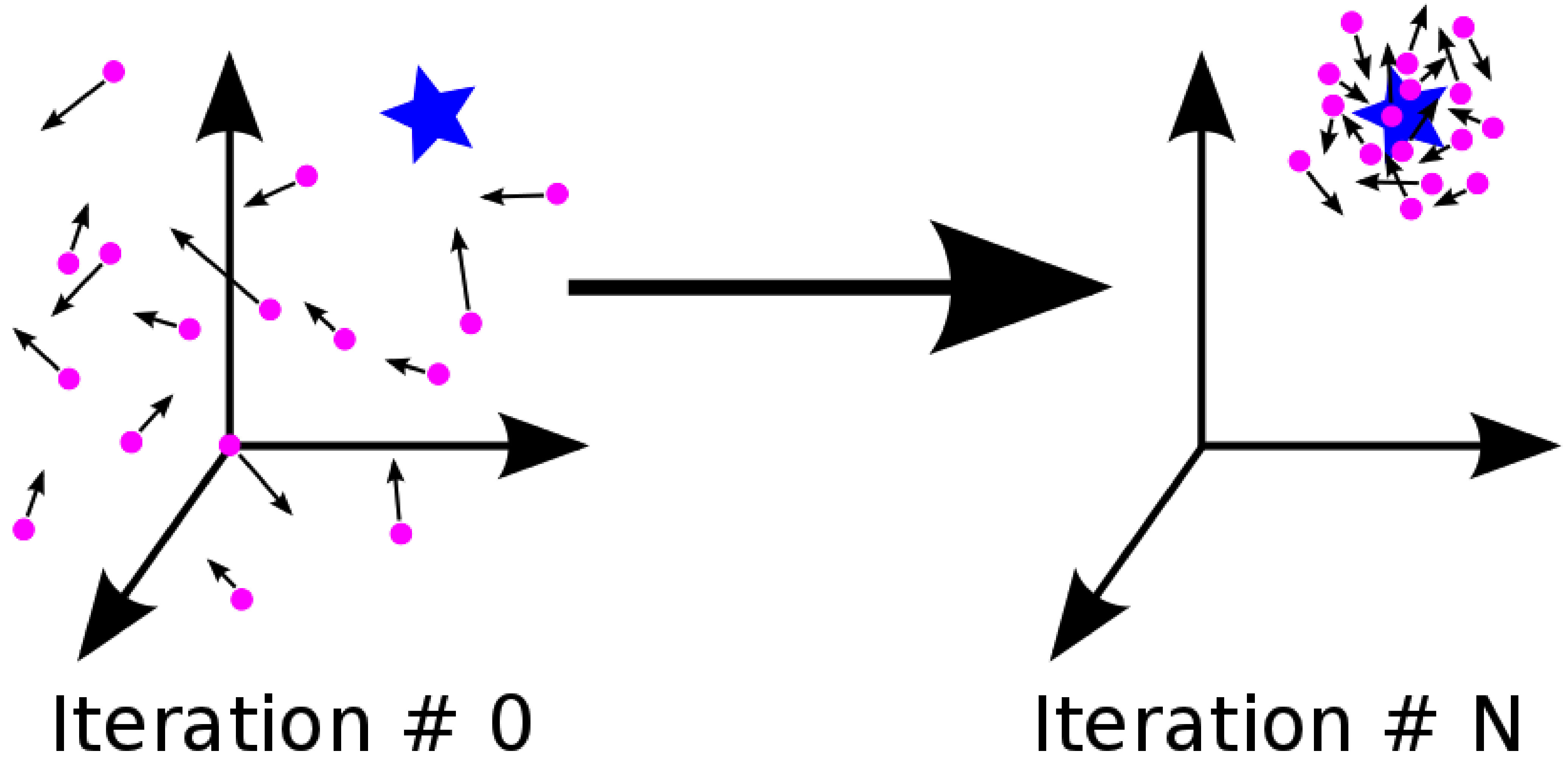
  Low LCOE

# Approach

- Selected algorithm

  The PSO (particle swarm optimisation)

  - It is a population-based heuristic optimisation algorithm
  - It replicates the behaviour of some collective animals
  - It was presented in 1995
  - Generally, it leads to good results and converges quickly
  - It allows parallel computation



# Approach

- Key drivers treatment

Methodology:

- To allow a fast wake calculation, the Jensen model is used
- Electrical grid losses are calculated using power flows
- The initial solution is a regularly spaced matrix

Assumptions:

- The free-stream wind speed is constant along the site
- Mooring and suspended cable lengths vary linearly with water depth
- Cables and mooring lines crossing is not allowed
- The mooring footprint is constant
- The same anchor is used for all turbines
- A one-time lease fee of 0.2 €/$m^2$ is considered
- The electrical layout is predefined, therefore only the cable lengths change
- The O&M cost is constant

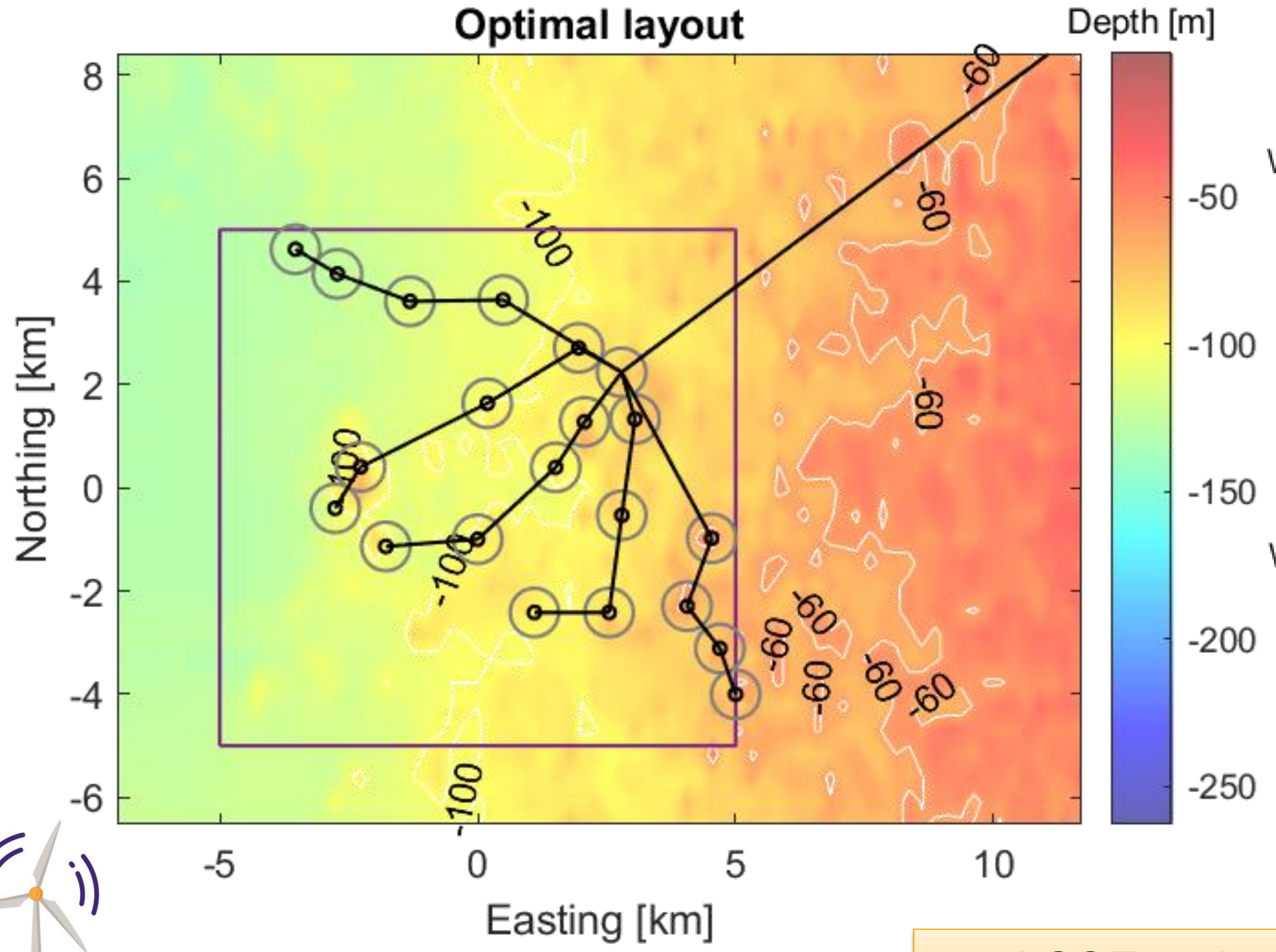
# Studied cases

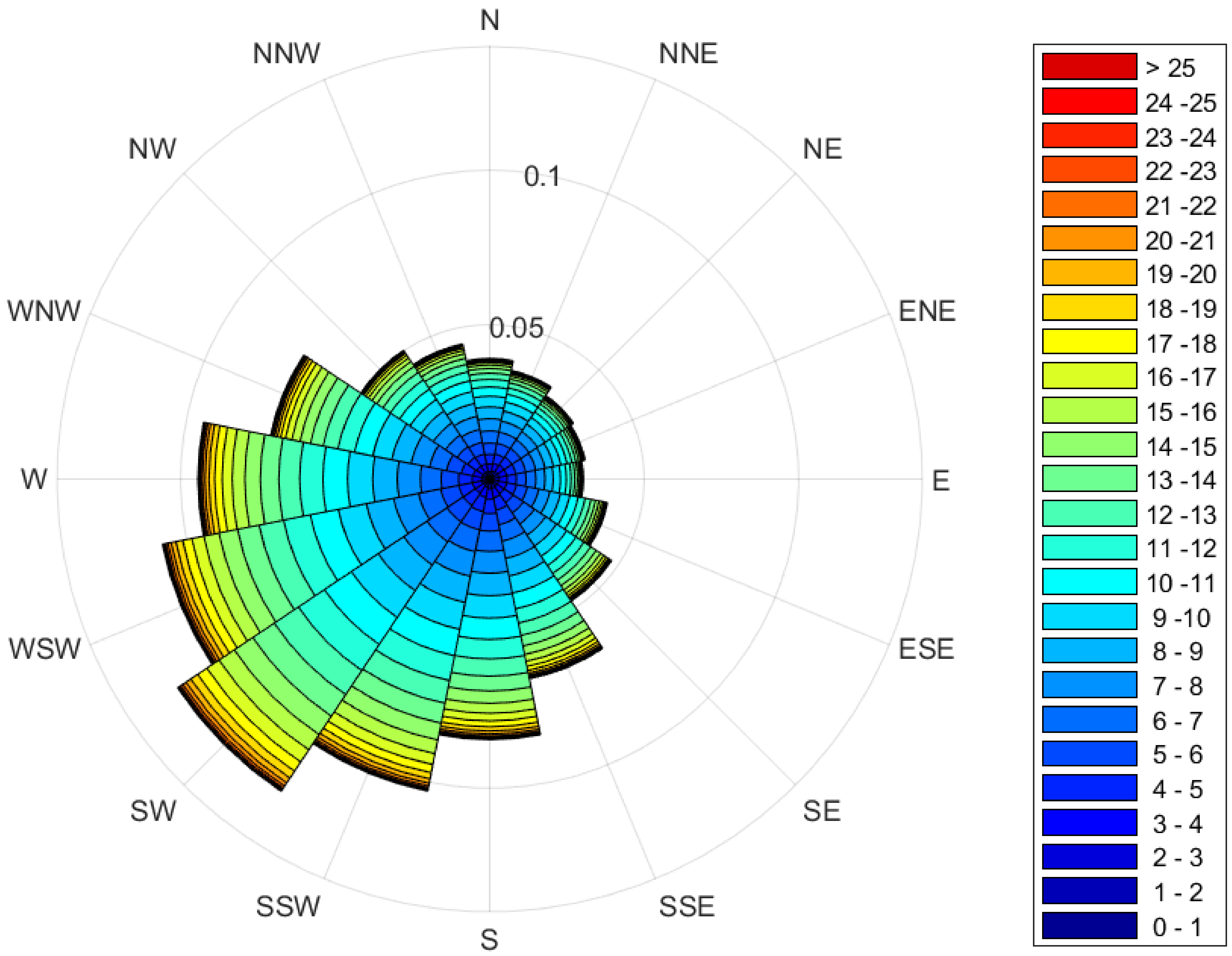
| Scenario | Location | Capacity (turbines) | Grid connection | Default spacing |
|---|---|---|---|---|
| 1A | W of Barra | 60 MW (4 WT) | Single string to onshore substation | 7D x 7D |
| 2A | | 300 MW (20 WT) | 5 strings to offshore substation, plus export cable to onshore substation | |
| 3A | | 1200 MW (80 WT) | 16 total strings to 2 offshore substations, plus export cables to onshore substation | |
| 4A & 4W | SE of Gran Canaria | 60 MW (4 WT) | Single string to onshore substation | |
| 5A & 5W | | 300 MW (20 WT) | 5 strings to onshore substation | |
| 7A & 7W | Morro Bay | 60 MW (4 WT) | Single string to onshore substation | 10D x 10D |
| 8A & 8W | | 300 MW (20 WT) | 5 strings to offshore substation, plus export cable to onshore substation | |
| 9A & 9W | | 1200 MW (80 WT) | 16 total strings to 2 offshore substations, plus export cables to onshore substation | |

A: ActiveFloat
W: WindCrete
WT: wind turbine
D: rotor diameter

# Results

- Scenario 2A: 20 turbines in shallow waters and bumpy seabed
  - Initial LCOE: 93.5 €/MWh
  - Achieved LCOE: 92.0 €/MWh

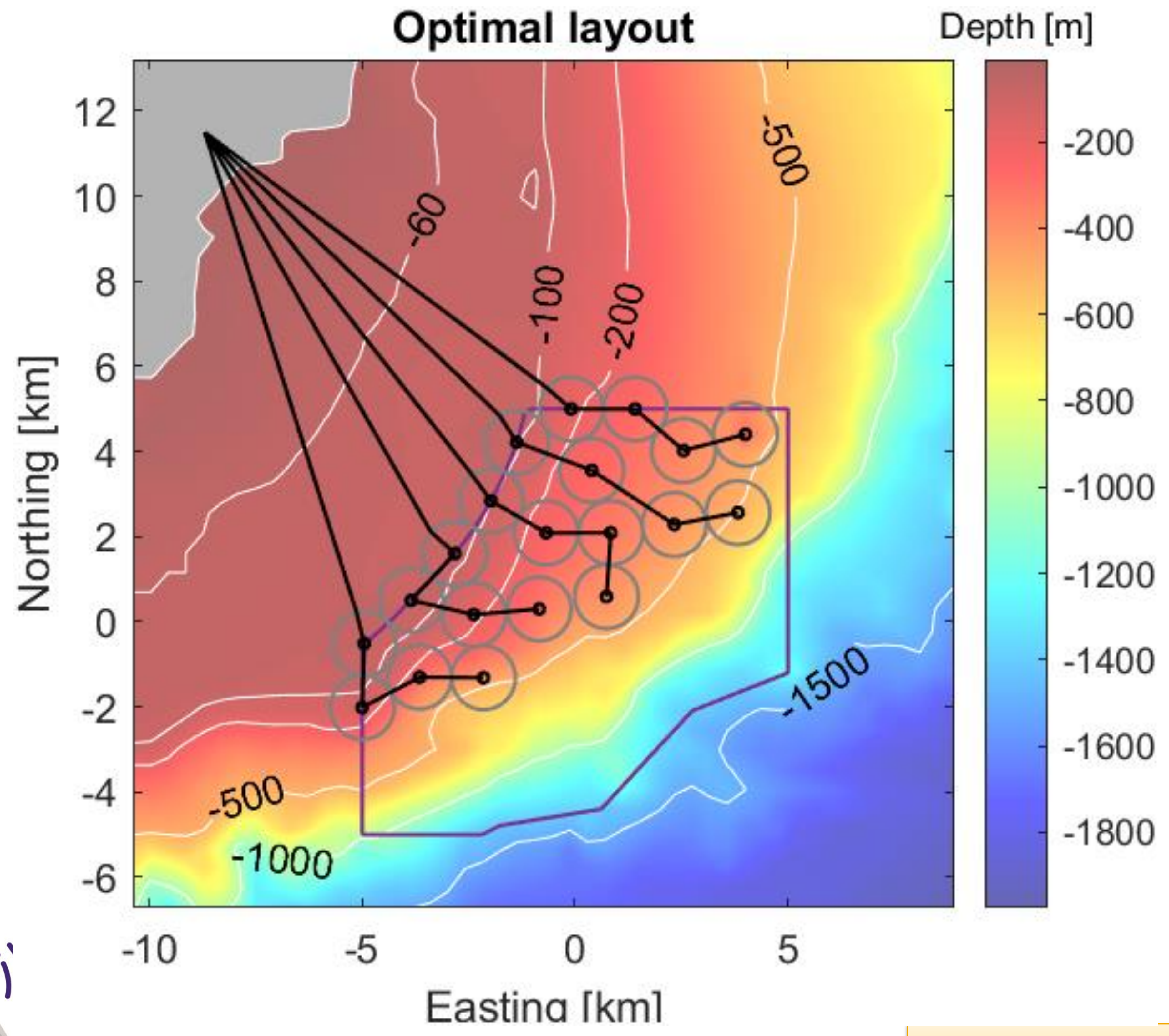


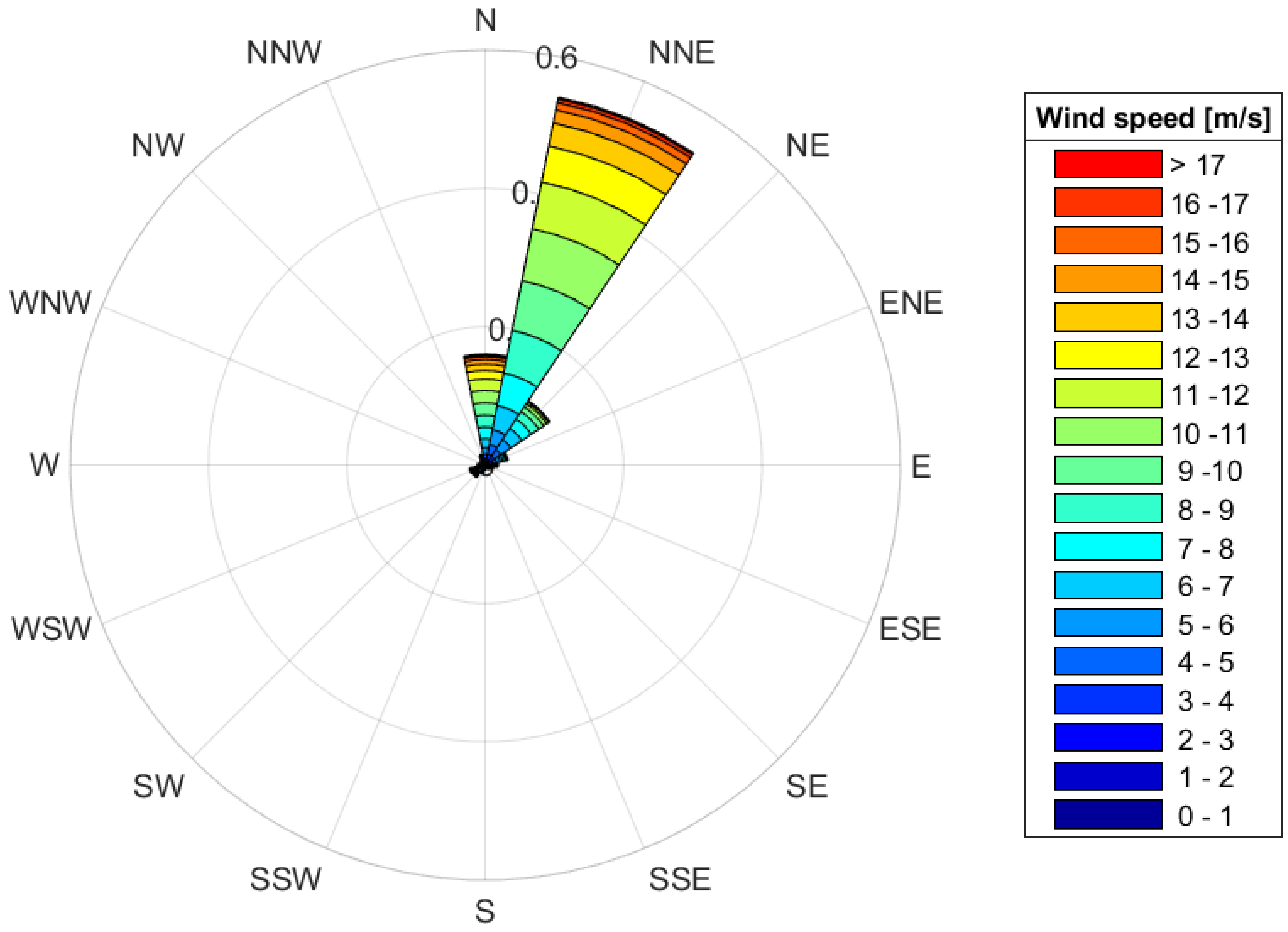




LCOE reduction: 1.6%

# Results

- Scenario 5W: 20 turbines in steep area without offshore substation
  - Initial LCOE: 60.8 €/MWh
  - Achieved LCOE: 57.9 €/MWh

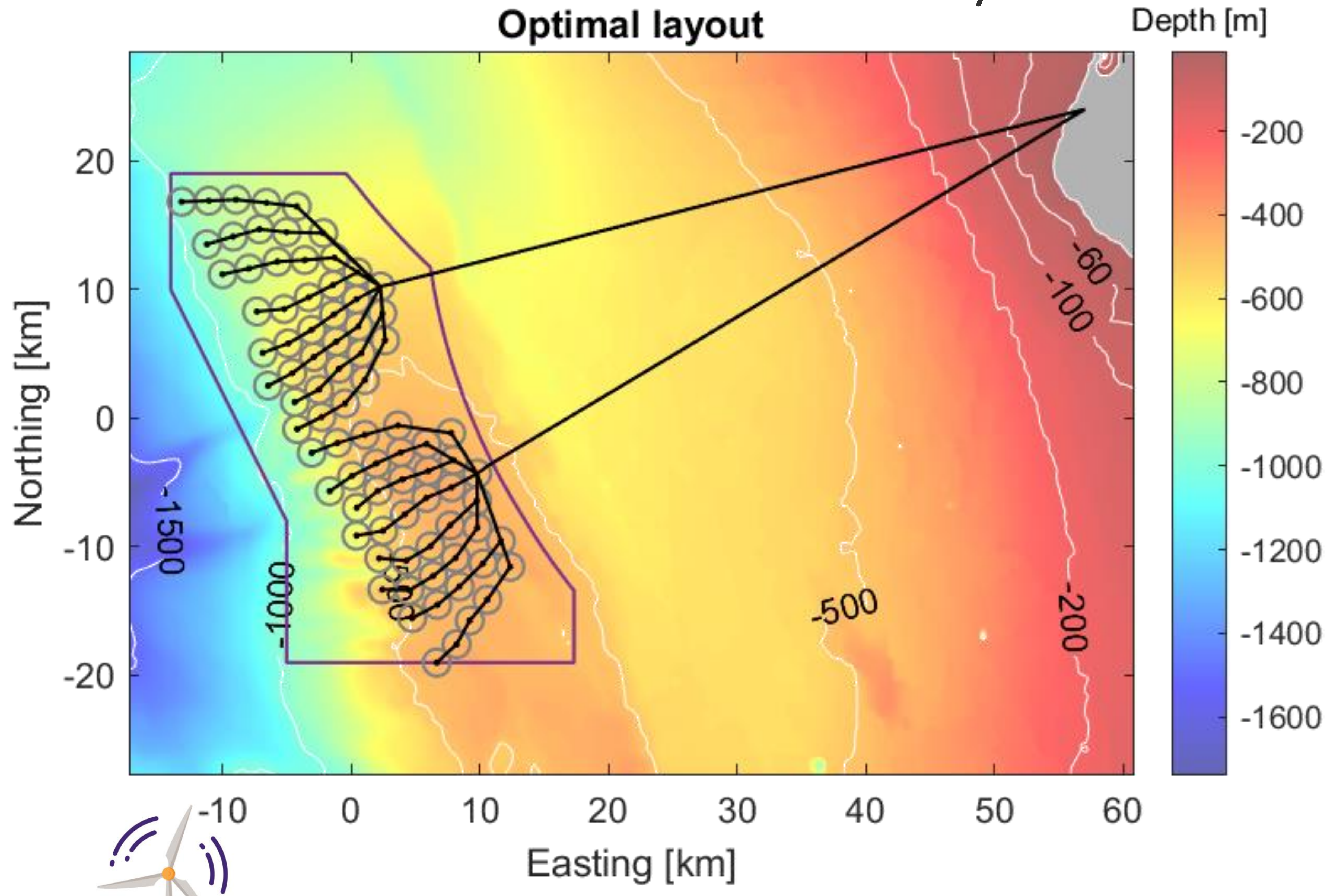


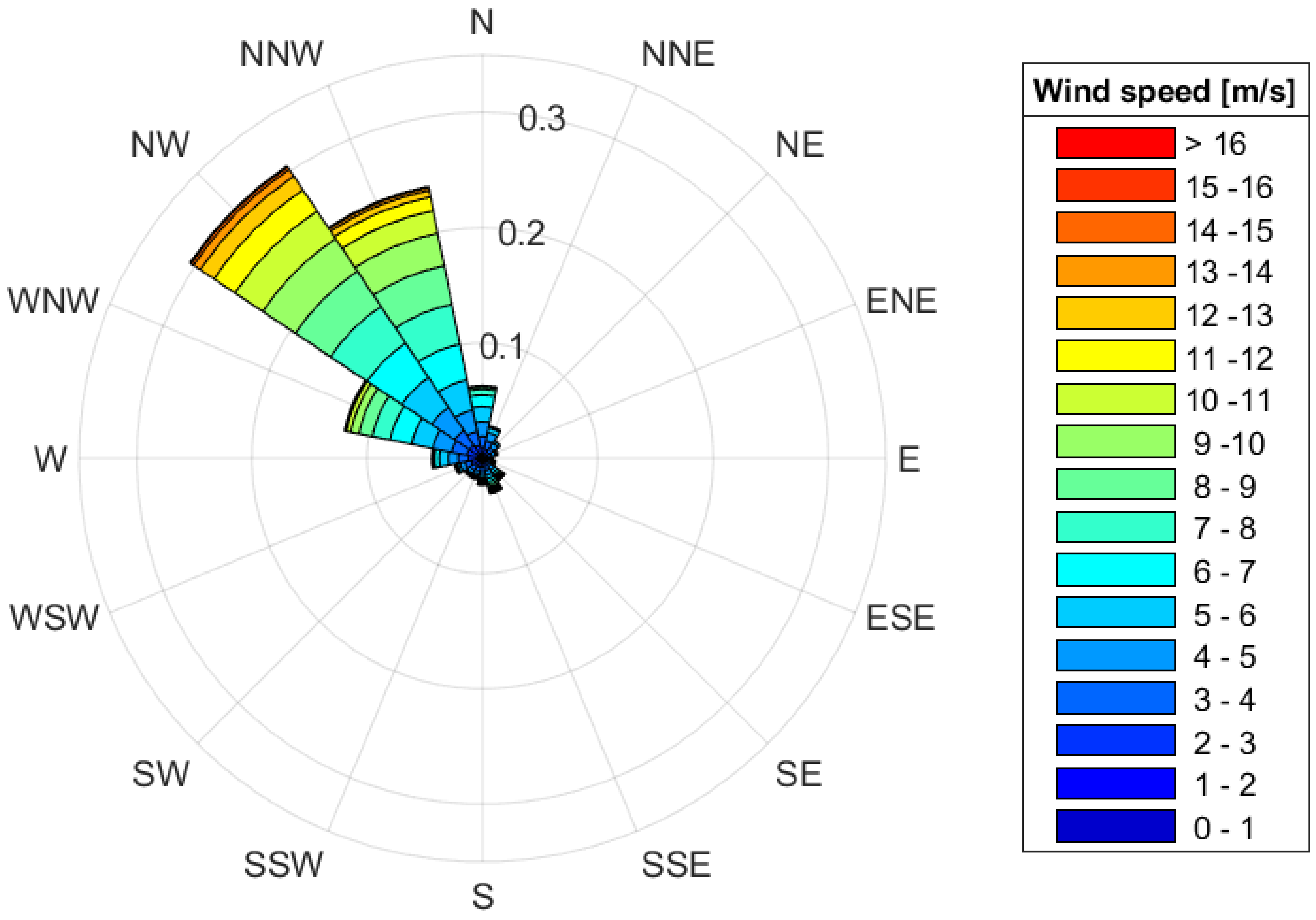




LCOE reduction: 4.8%

# Results

- Scenario 9W: 80 turbines in deep waters
  - Initial LCOE: 115.1 €/MWh
  - Achieved LCOE: 112.0 €/MWh




LCOE reduction: 2.7%

# Results

- Summary

| Reference scenario | Initial LCOE [€/MWh] | Optimised LCOE [€/MWh] | LCOE reduction [%] |
|---|---|---|---|
| 1A | 99.5 | 97.5 | 1.9 |
| 2A | 93.5 | 92.0 | 1.6 |
| 3A | 95.3 | 94.4 | 1.0 |
| 4A | 79.6 | 69.1 | 13.2 |
| 4W | 61.1 | 58.6 | 4.2 |
| 5A | 80.2 | 68.6 | 14.5 |
| 5W | 60.8 | 57.9 | 4.8 |
| 7A | 133.0 | 130.1 | 2.2 |
| 7W | 124.8 | 121.5 | 2.7 |
| 8A | 119.0 | 116.5 | 2.1 |
| 8W | 112.2 | 109.8 | 2.1 |
| 9A | 122.1 | 119.2 | 2.3 |
| 9W | 115.1 | 112.0 | 2.7 |

# Conclusions

- Floating offshore wind farms micro-siting depends on multiple factors, which increases its complexity and requires a multi-disciplinary work
- The proposed PSO behaves correctly when optimising the layout, converging to optimal solutions in 1 hour for 4 turbines, 4 hours for 20 turbines and 12 hours for 80 turbines; near-optimal solutions may be found in minutes.
- When the LCOE is minimised during the micro-siting, a reduction between a 1% and a 15% can be achieved (typically 2-3%), compared to a regular 7Dx7D/10Dx10D spacing
- The results show that the bathymetry, wind climate, anchor radius and cable lengths are relevant, but with varying weights depending on the site

# Further work

Many aspects may be improved to achieve more realistic results. The ones expected to have a greater impact on the micro-siting are:

- Improve the performance of the algorithm with bumpy seabed
- Consider free-stream wind speed variations in large wind farms
- Consider the soil conditions for anchor selection
- Perform de optimisation with variable windfarm capacity
- Simultaneously optimise the cable routing

# Thanks for your attention

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