Università degli Studi di Firenze
Wind Energy Section – REASE Group

EERA DeepWind CONFERENCE 2025

16/01/2025

Optimization strategy to quantify the potential of low-specific-power floating wind turbines in non-conventional sea basins

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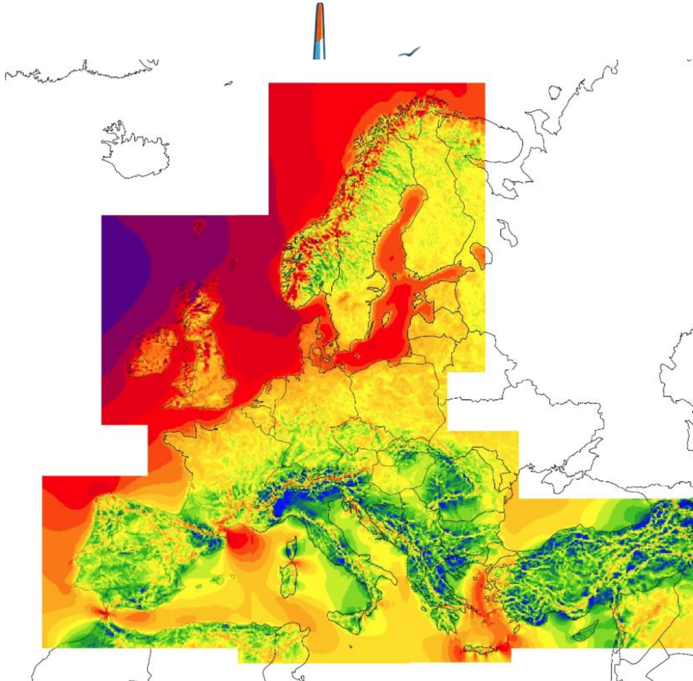
Background and motivation

Offshore wind energy is expected to become one the backbones of future energy EU mix

- ✓ expanding it beyond the North Sea to unconventional basins, such as the Mediterranean Sea, is essential

Many of these sea basins feature lower average wind speeds and deep waters even relatively close to shore, making **floating wind** a priority

While capital costs and supply shortages are slowing down the technology, R&D actions are needed to reduce LCOE



RESEARCH QUESTION

Does a WT with a lower specific power result in a lower LCOE in installation sites with lower average wind speed (e.g., the Med Sea)?

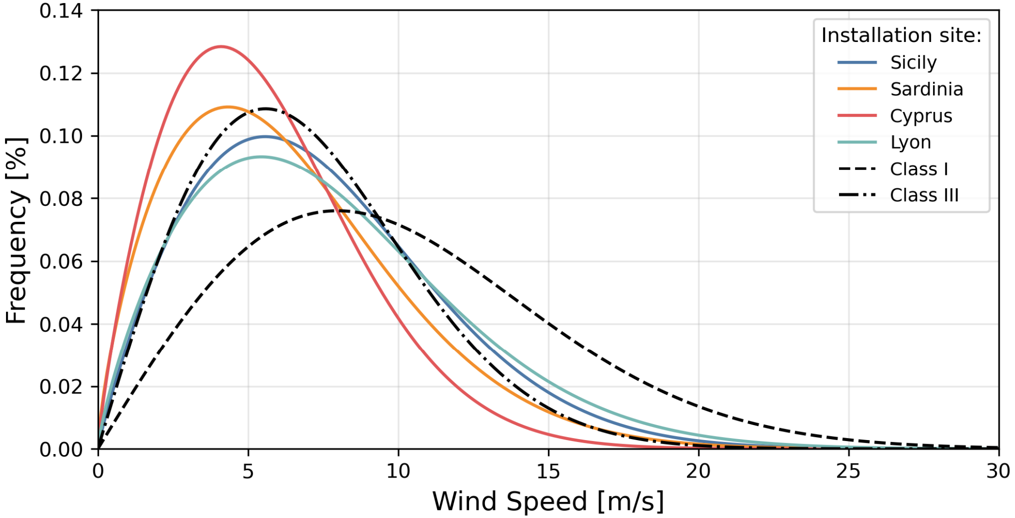
Case study: offshore wind in the Mediterranean Sea

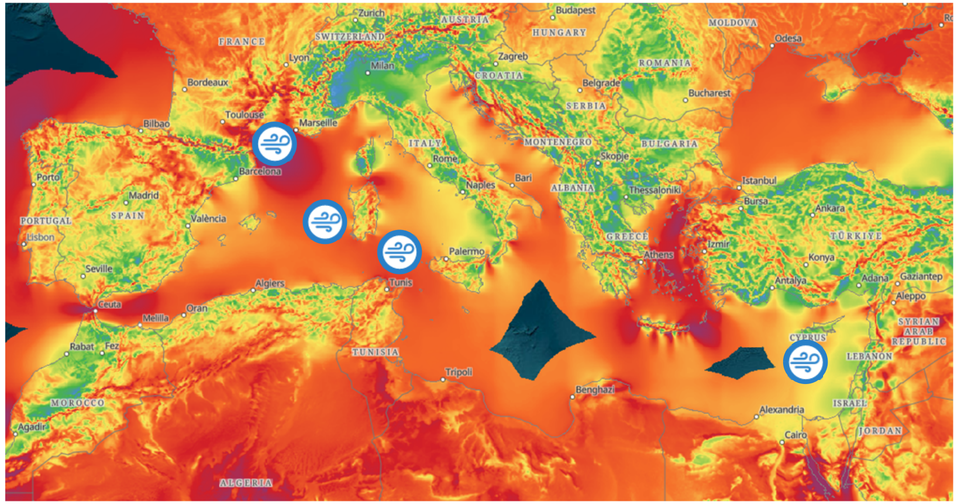
Several sites are promising, despite wind speeds much lower than those in the North Sea

✓ most of today’s WTs are designed for such conditions (Class I)

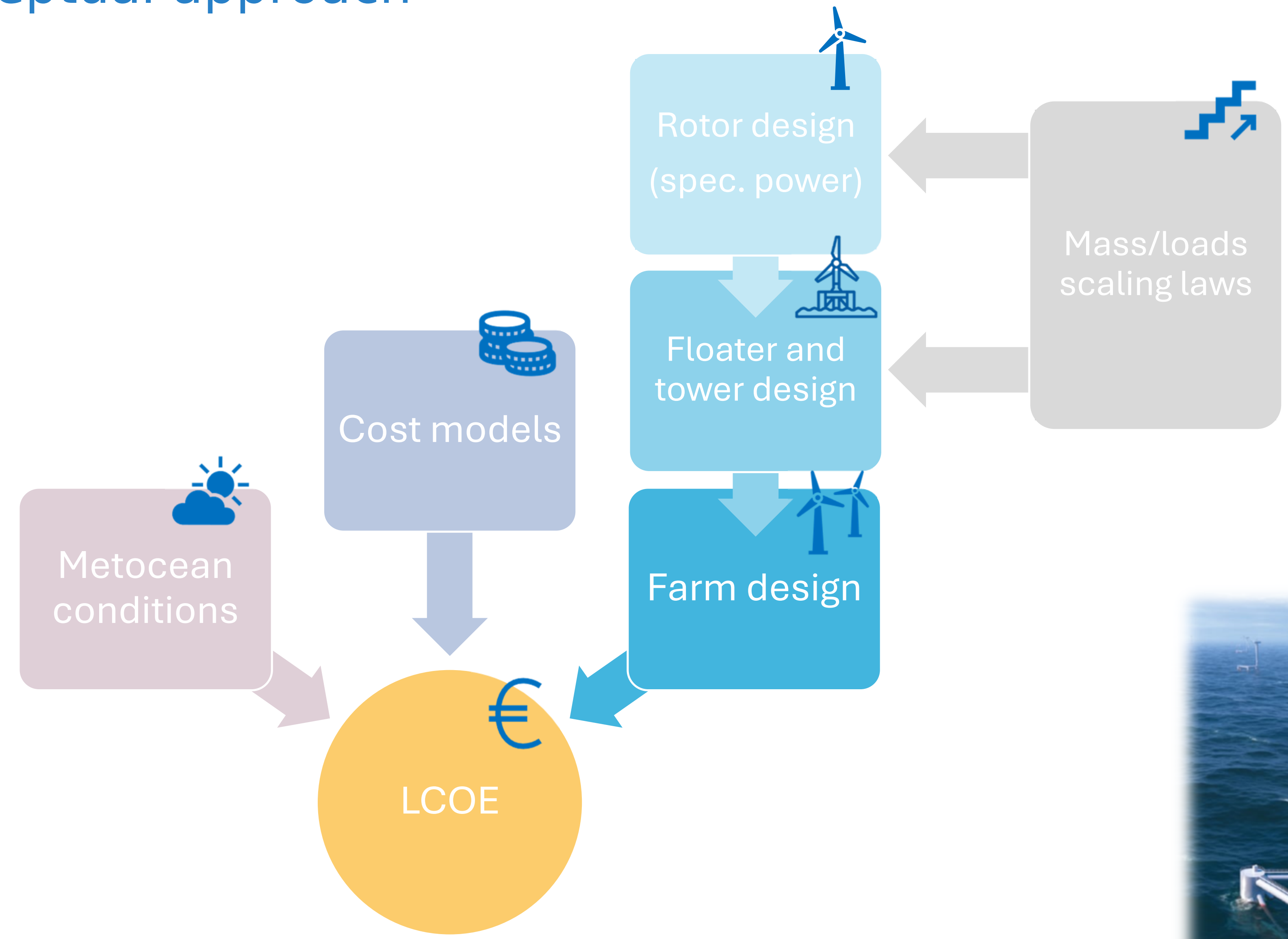
WT designs for the Med Sea should be tailored for Class III

According to a well-established trend, **lower specific power rotors** could be a viable option





Conceptual approach



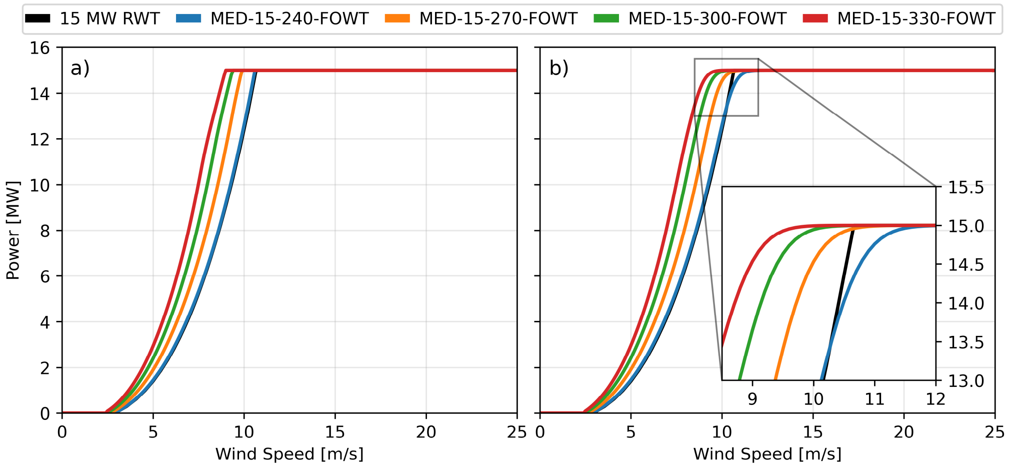
Methods - wind turbines

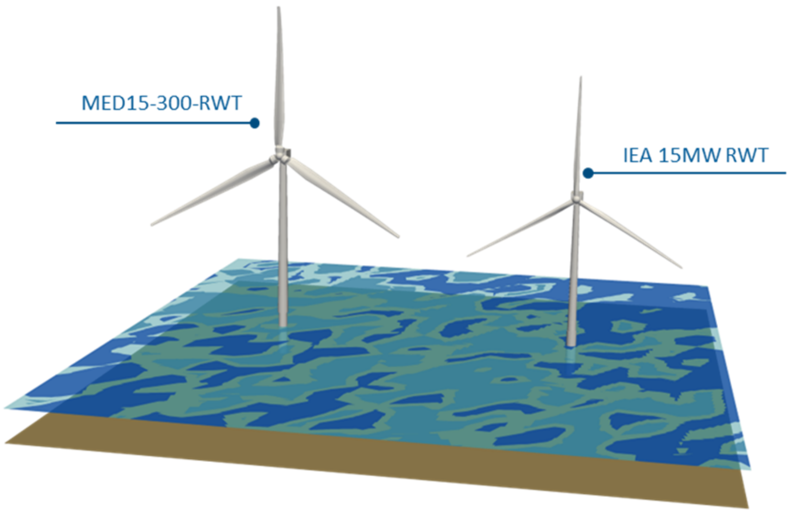
4 different rotors having the same rated power (15 MW) but different specific power

- ✓ MED15MW_d240_h150 — 331 W/m²
- ✓ MED15MW_d270_h165
- ✓ MED15MW_d300_h180
- ✓ MED15MW_d330_h195 — 175 W/m²

Rotors share the same performance map ($C_p = f(\lambda, \beta)$) of the IEA 15MW and operate at same TSR

- ✓ turbulence effects on power are accounted for using with the surrogate model of Saint-Drenan et al* (based on FINO1 data)





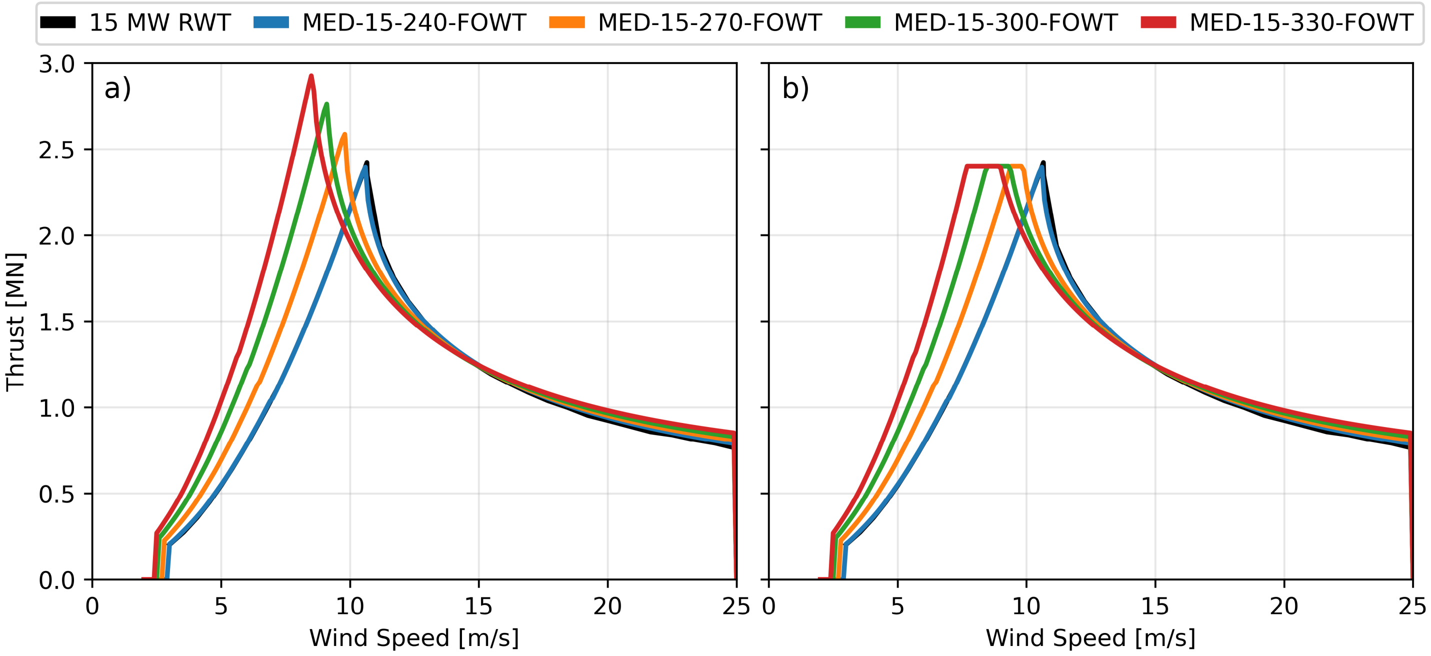
* DOI: 10.1016/j.renene.2020.04.123

Methods - operating curves

Peak shaving introduced through active pitch control

Maximum thrust is limited to the same value of the IEA 15MW

- ✓ overturning moment limited (from -5% to -11%) to contain the floater's dimensions
- ✓ negligible changes in power curves



Methods – rotor mass/cost extrapolation

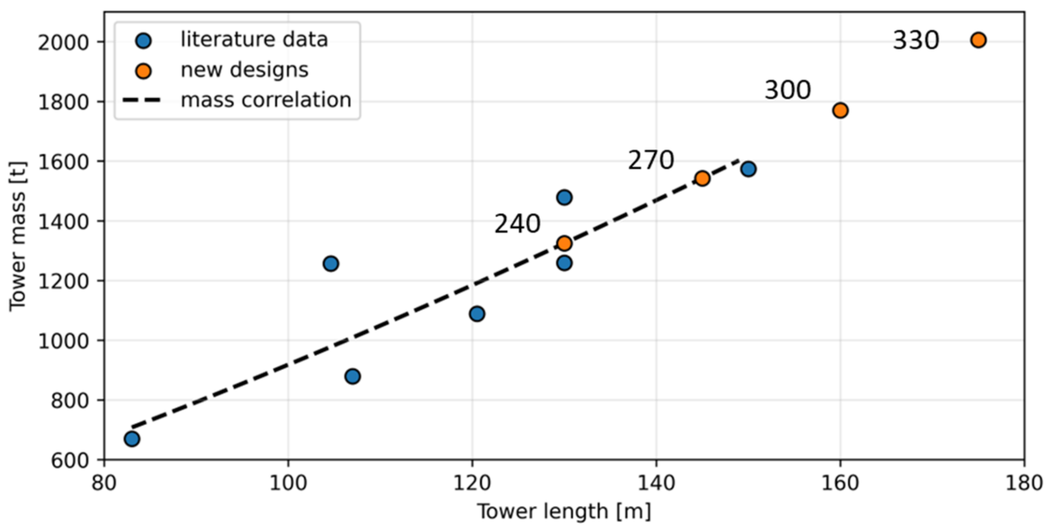
RNA

- ✓ effect of D on blade mass → NREL's correlation for osshore turbines (DOI: 10.2172/897434)
- ✓ all other RNA components → DTU's mass scaling model in TopFarm

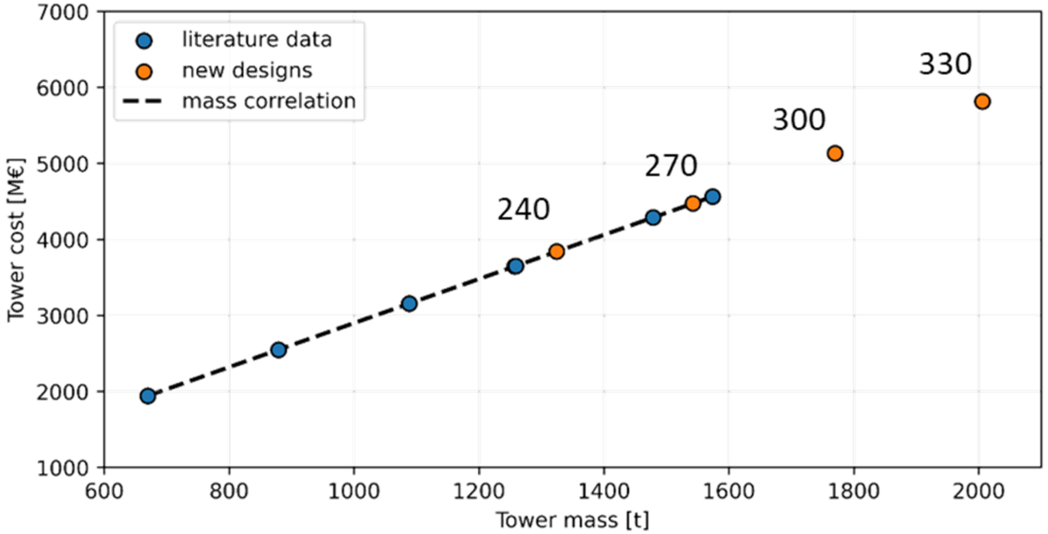
TOWER

- ✓ constant water tip clearance of 30m for all rotors
- ✓ scaling models not tuned for FOWTs (offshore or fixed-bottom) → use of literature data to extrapolate a dedicated correction

$$M_{Tower} = 1.479 * L_{Tower}^{1.39} \text{ [t]}$$



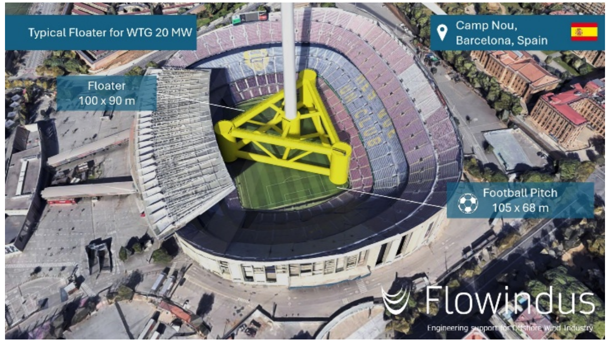
$$CAPEX_{Tower} = 2.9 * M_{Tower} * 1e03 \quad [€]$$



Methods - platform mass extrapolation

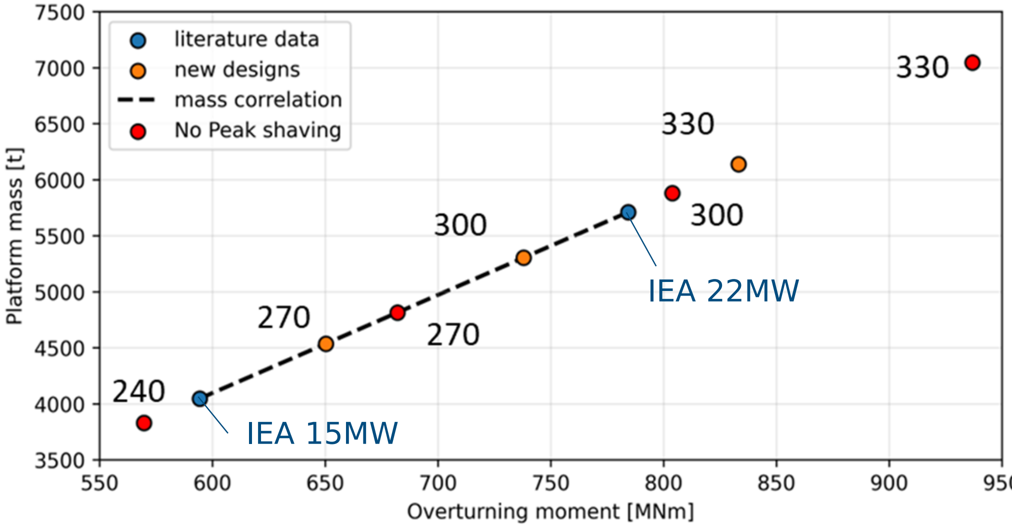
Floater scaled based on the overturning moment in pitch

- ✓ total restoring stiffness in pitch mainly depends on waterplane area
- ✓ thrust limited by peak shaving – weight scales with the rotor
  - savings in mass between 6% and 13%
  - relevant cost and mass decrease

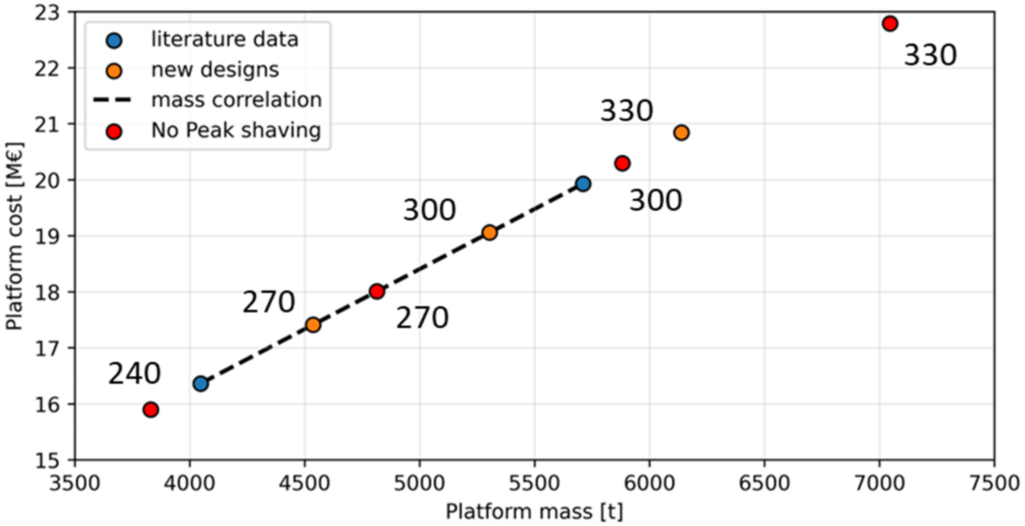


NREL’s WISDEM used to calculate platform cost from mass for IEA 15MW and IEA 22MW floaters

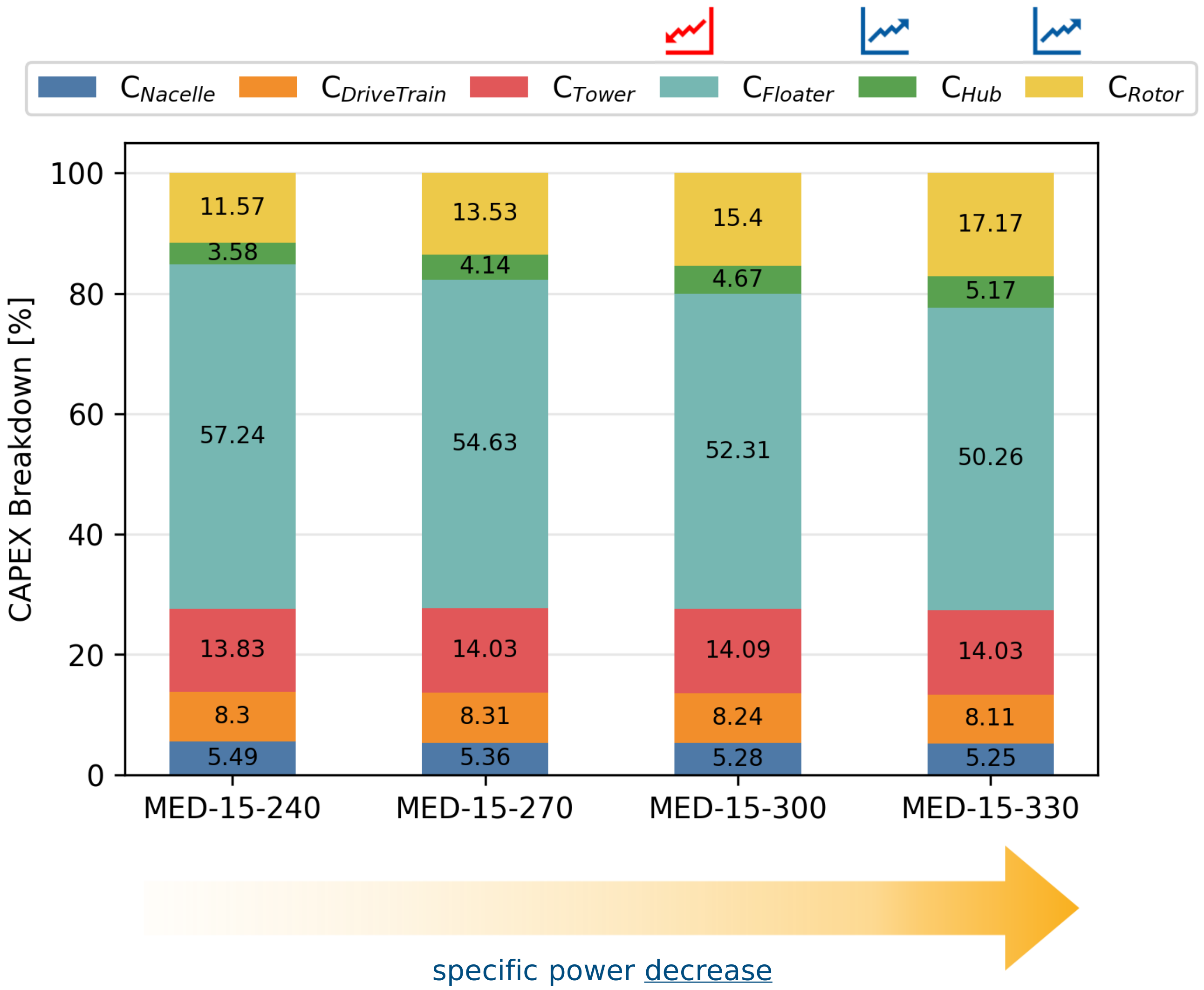
$$M_{Floater} = 0.004 * OM + 1.70\ e06\ [\text{t}]$$



$$CAPEX_{Floater} = 4.75 * M_{Floater} - 2.87e06\ [€]$$



WT CAPEX breakdown



Farm optimization

1 GW wind farm based on 67 FOWTs

Wind source
Wind turbines
Economic data
Constraints
Wake model
Optimization model

Bastakhah Gaussian model for wakes

PyWake (AEP)

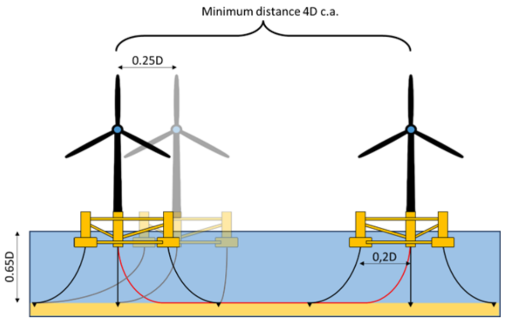
Economic model (LCOE)

DTU's TopFarm

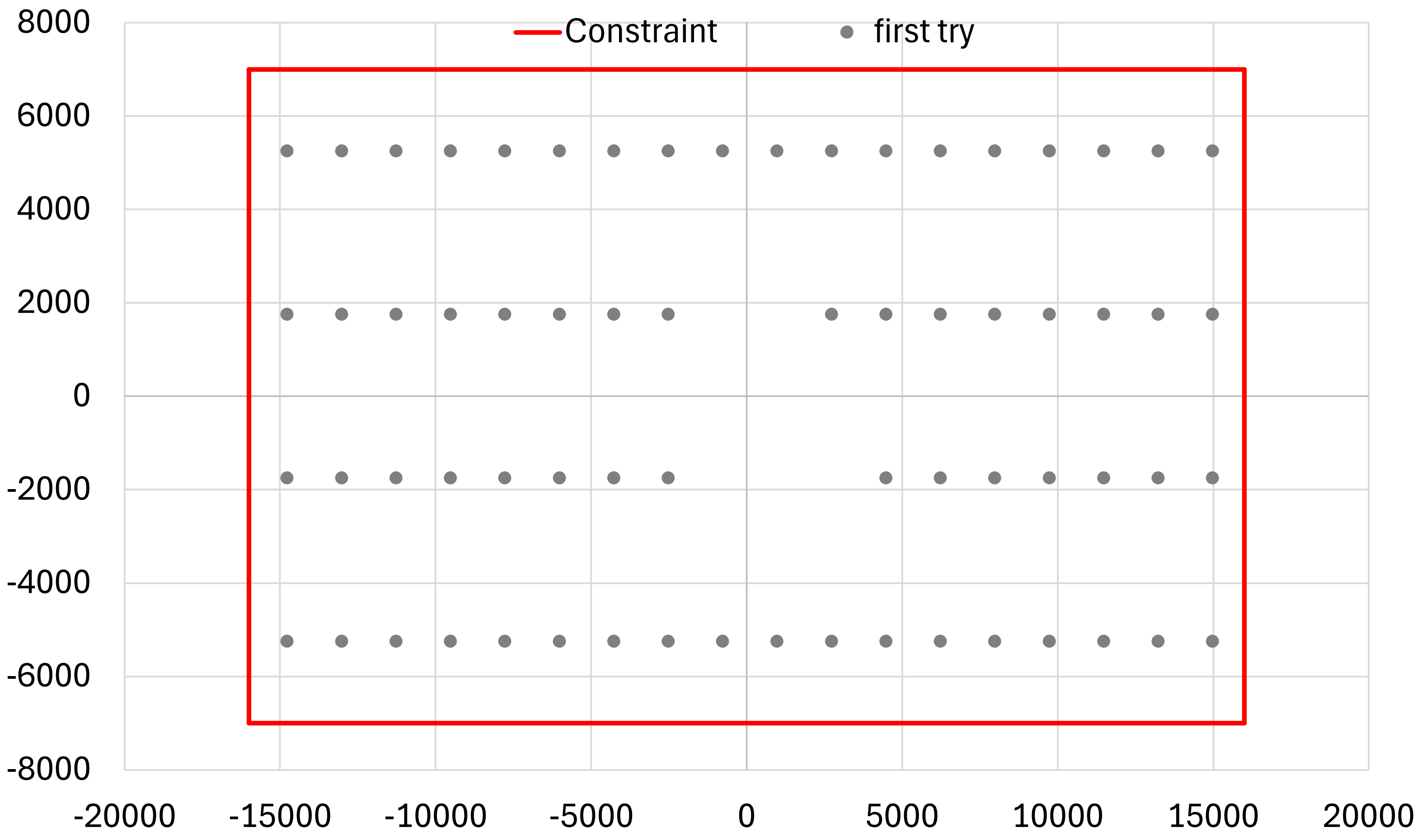
COBYLA optimization algorithm

Optimal LCOE
Optimal layout
WF parameters
Economic parameters

One central substation + HVAC export cables



Results – farm layout (Sicily test case)



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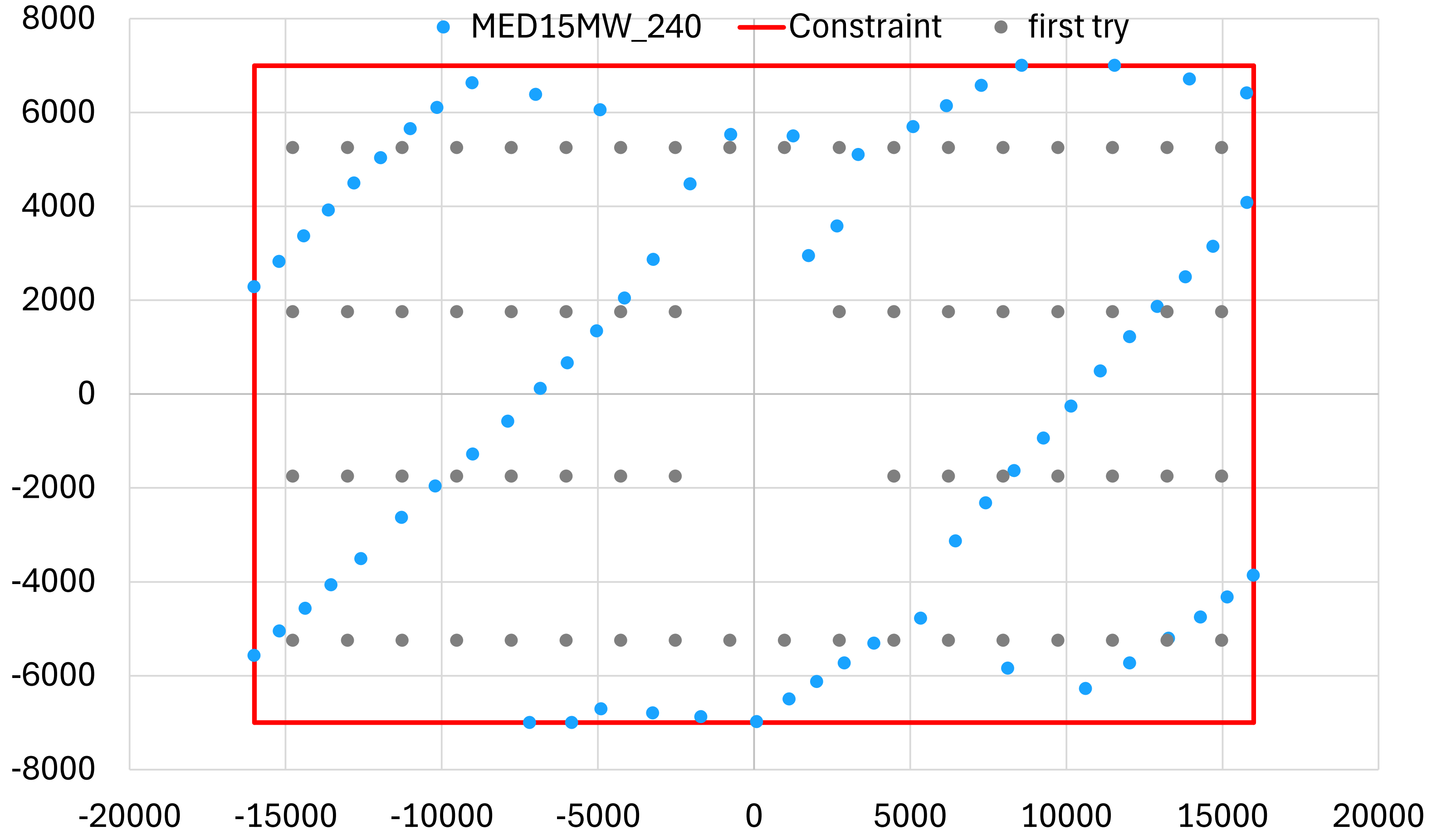

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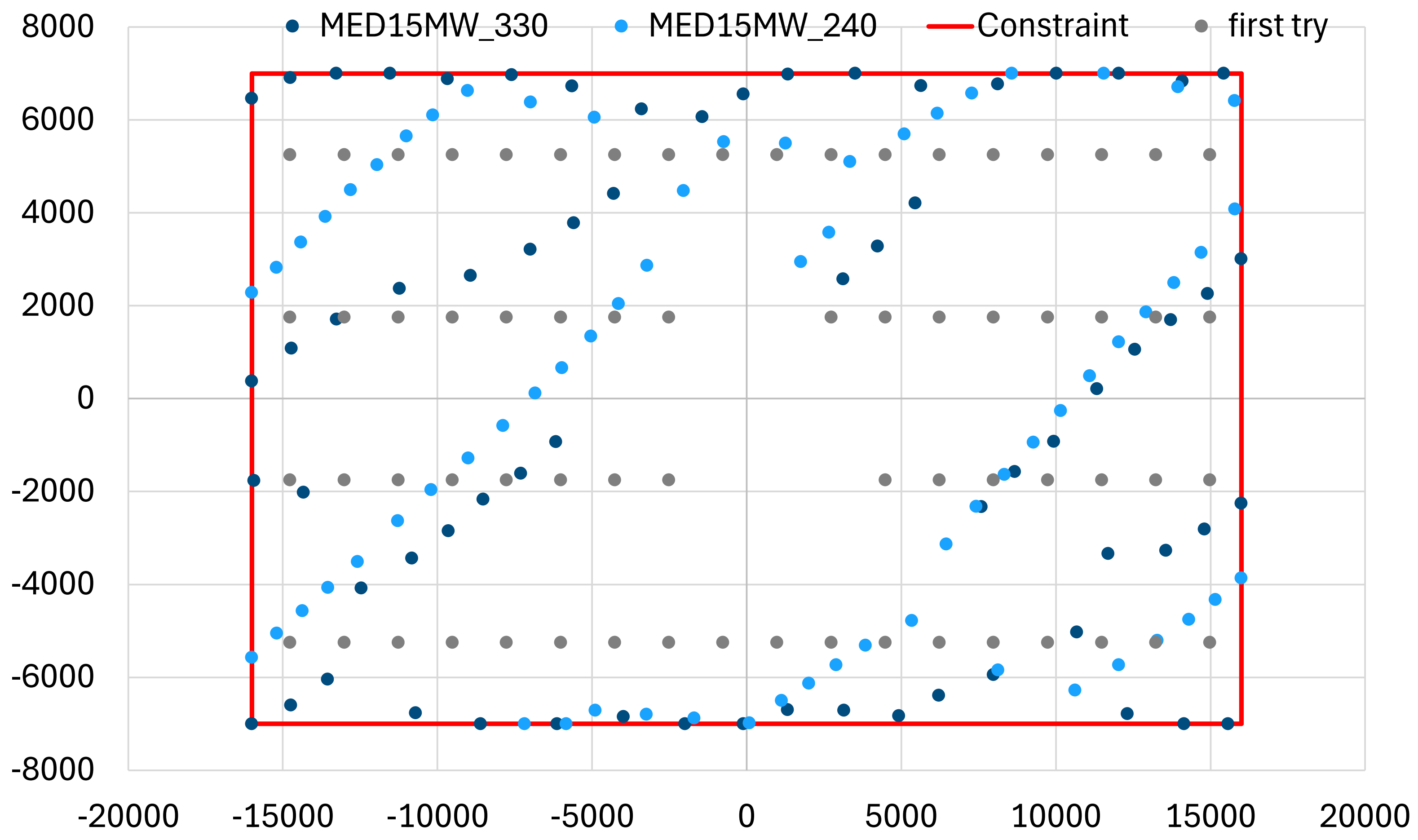
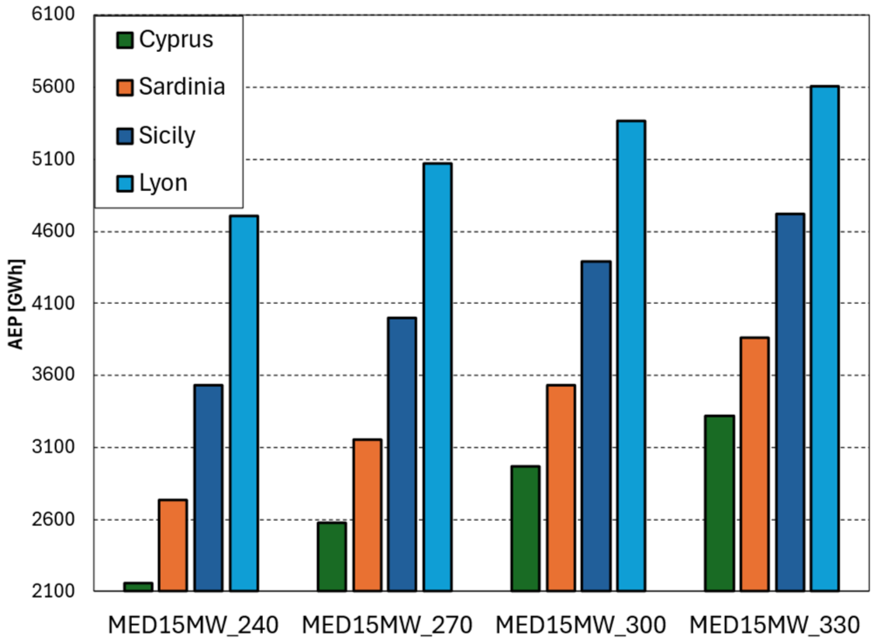
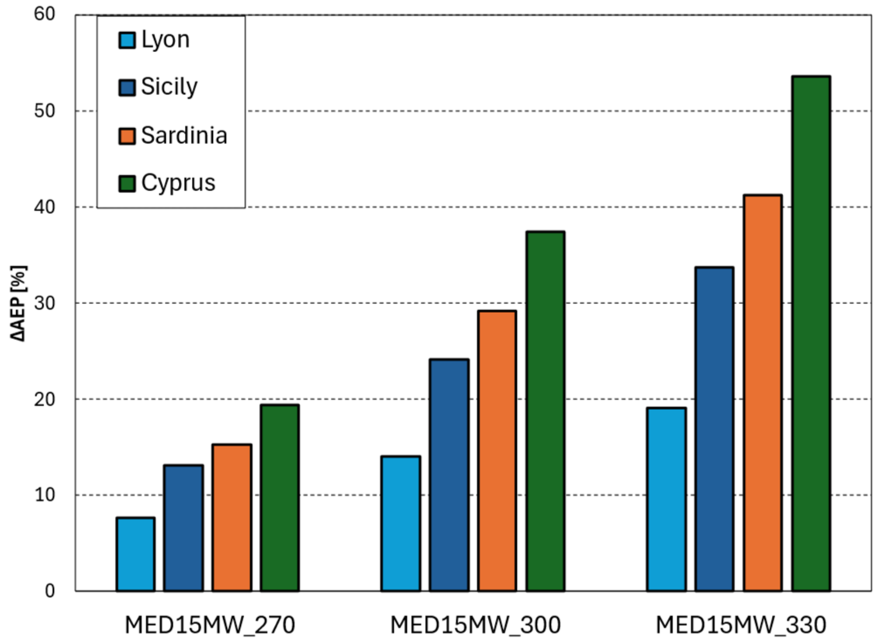


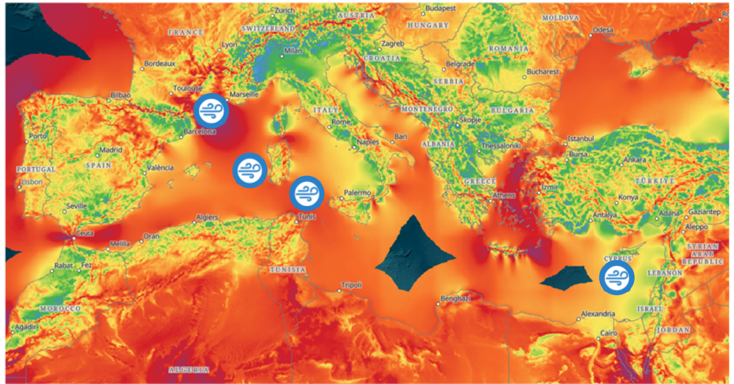
Results - AEP



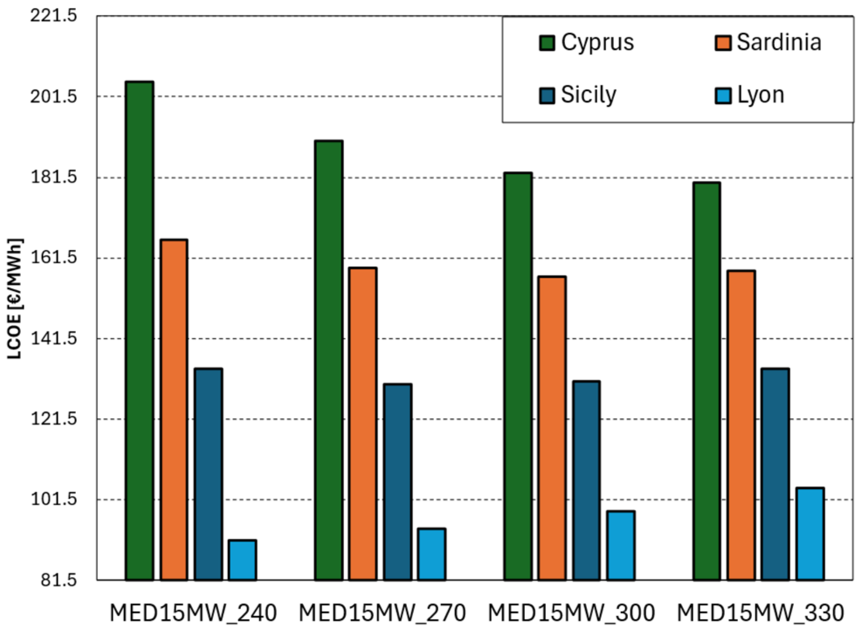
6100
5600
5100
4600
4100
3600
3100
2600
2100
AEP [GWh]
Cyprus
Sardinia
Sicily
Lyon
MED15MW_240
MED15MW_270
MED15MW_300
MED15MW_330

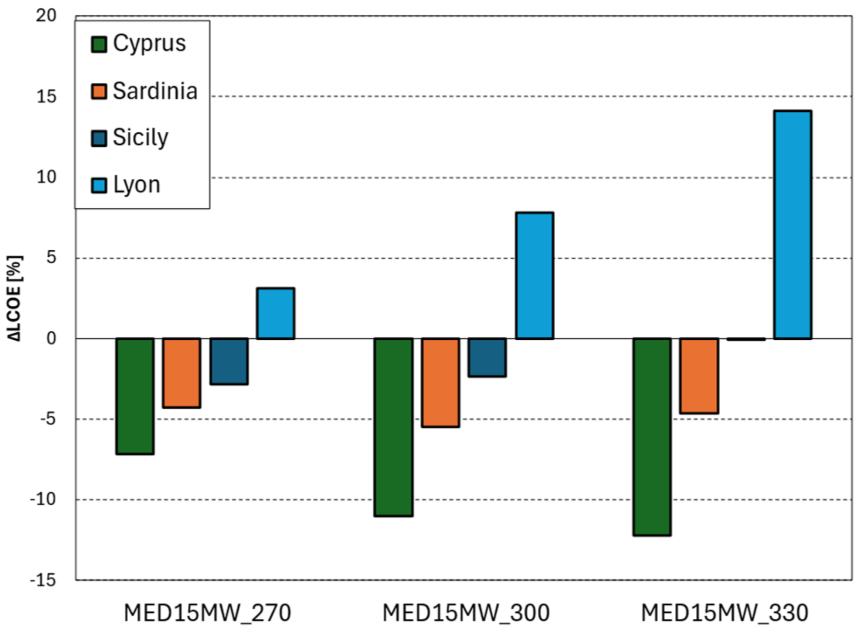


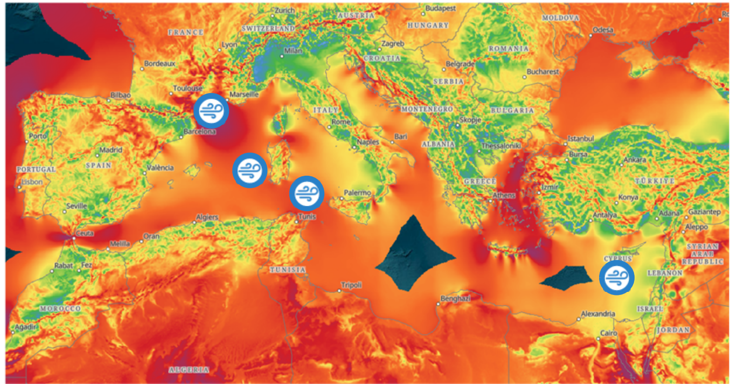
60
50
40
30
20
10
0
ΔAEP [%]
Lyon
Sicily
Sardinia
Cyprus
MED15MW_270
MED15MW_300
MED15MW_330



Results - LCOE







Conclusions

While it is acknowledged that lower specific rotors can be a solution for sea basins with lower wind speed, the study proves that a holistic approach is needed to guide the design

We developed an optimization framework able to optimize the farm layout and evaluate the LCOE of floating wind turbines in a specific location

By testing 4 FOWTs with specific power ranging from 331 W/m^2 to 175 W/m^2 in 4 different locations in the Mediterranean Sea, we found that:

- ✓ depending on the location, increases in AEP can range from 8% up to 53%
- ✓ in sites with moderate-to-low wind speeds (equivalent Class III or less), this leads to reduction in LCOE ranging from 7% to 12%
- ✓ in sites with higher winds (equivalent Class II) the moderate increase in AEP is not repaid by the increased cost for the turbine, leading to increases in LCOE wrt state-of-the-art turbines

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FLOATFARM
NEXT GENERATION FLOATING WIND FARMS

Funded by the European Union