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Copernicus Climate Change Service (C3S)

Energy Seminar

C3S Enhanced Operational European Service in Support to ENTSO-E

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European Wind Power Indicators for the PECD

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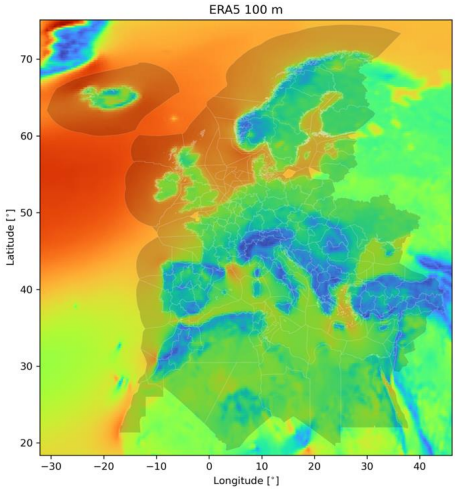
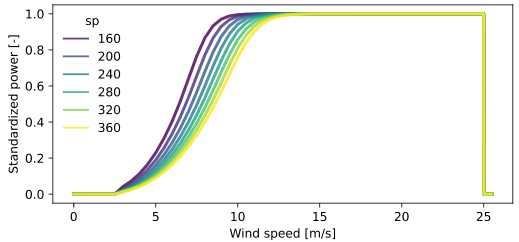
Agenda

- Overview of the wind runs for ENTSO-E for the Pan-European Climate Database (PECD)
- Overview of the methodology
- Results (as available in the project in Spring 2023)



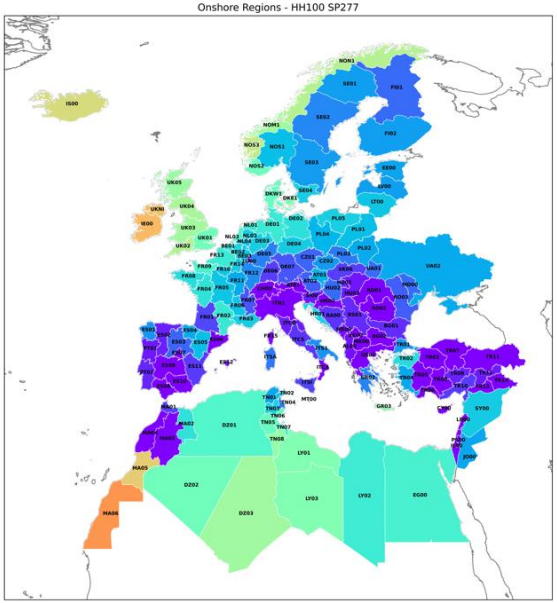


Overview of wind runs for PECD 4.0

- PECD version 4 is developed in the project
  - **Historical period** (1980 until present)
  - **Climate projections** (multiple models and scenarios)

- PECD regions specified by ENTSO-E

- **Onshore wind**
  - Existing installations
  - 9 future technologies
- **Offshore wind**
  - Existing installations
  - 2 future technologies



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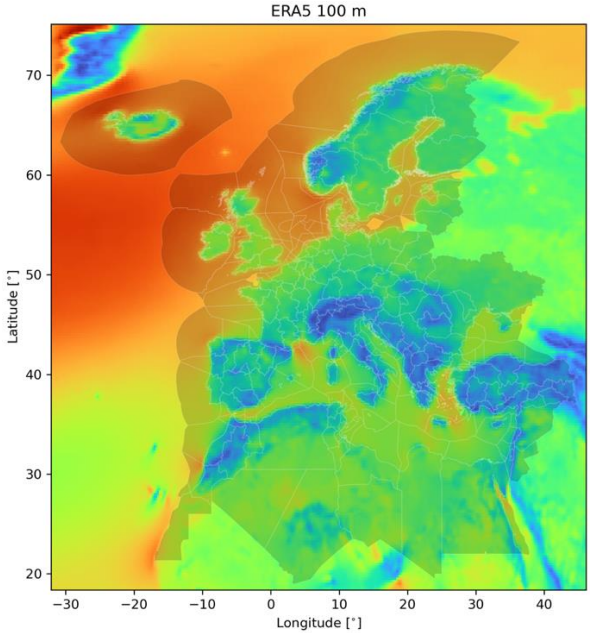
Methodology: Weather and climate data

- **ERA5 reanalysis for the historical period**
- **Climate projections**
  - EURO-CORDEX based on CMIP5
    - Presented in this presentation
  - CMIP6 based
    - Ongoing work
- **Wind speed bias correction needed**
  - Both the historical period[1] and the climate projection[2] wind speeds need to be bias-adjusted (scaled) to get coherent result



[1]J. P. Murcia, et al., "Validation of European-scale simulated wind speed and wind generation time series", *Applied Energy*, 2022 (https://doi.org/10.1016/j.apenergy.2021.117794)
[2]G. Luzia, et al., "Validating Euro-Cordex Climate Simulations For Modelling European Wind Power Generation". Pre-print, 2023 (available at SSRN: http://dx.doi.org/10.2139/ssrn.4401025)

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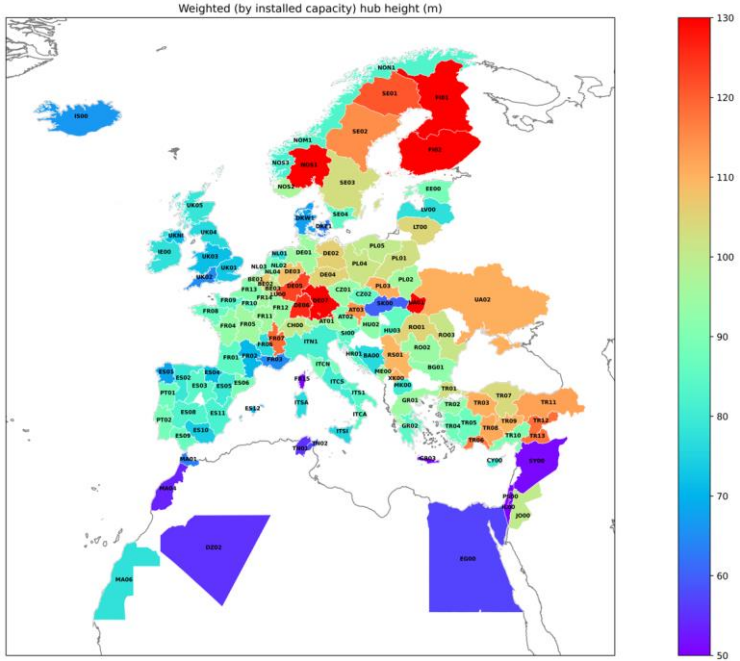
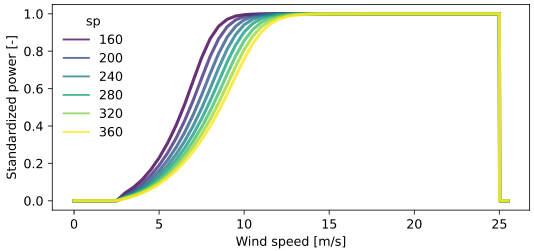
Methodology:
Conversion to power generation

- **Existing installations**
  - Onshore and offshore wind
  - 2020 fleets

- Information about the existing installations from:
  - https://www.thewindpower.net
  - Wind power plant locations
  - Hub heights, specifics powers, installed capacities…





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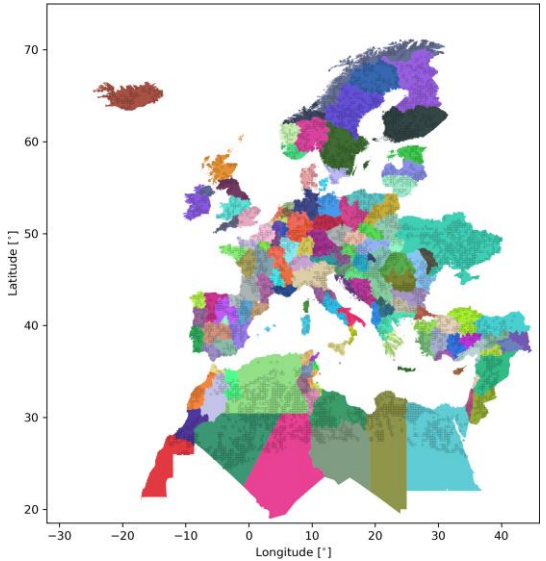
Methodology: Conversion to power generation

- **Future technologies, onshore wind**

Specific Power [W/m2]	Hub Height [m]
199	100, 150, 200
277	100, 150, 200
335	100, 150, 200

- **Why consider multiple technologies?**
  - Significant impact on capacity factors[1]
  - Different technologies found optimal in different regions[1]

- **10-50 % best locations considered for each region**
  - Considering limitations, e.g., due to nature protected areas
  - To model average future installations



Simulation locations for the future technology runs (onshore)

[1]P. Swisher, et al., "Competitiveness of a low specific power, low cut-out wind speed wind turbine in North and Central Europe towards 2050", *Applied Energy*, 2022 (https://doi.org/10.1016/j.apenergy.2021.118043)

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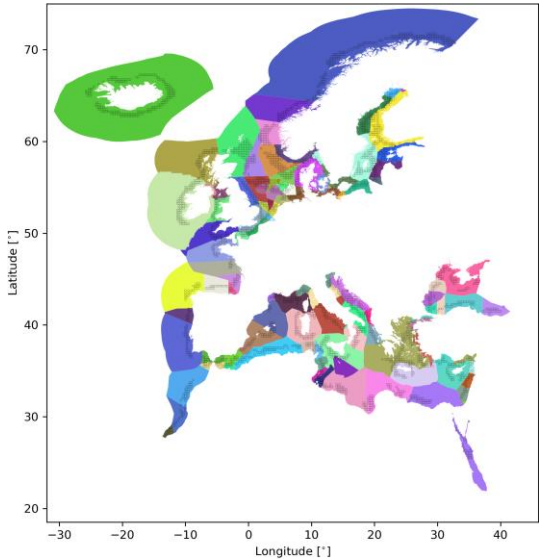
Methodology: Conversion to power generation

- **Future technologies, offshore wind**

Specific Power [W/m2]	Hub Height [m]
316	155
370	155

- **10-50 % best locations considered for each region**
  - Max 100 km from shore (except for the North Sea)
  - Considering limitations, e.g., due to nature protected areas
  - To model average future installations



Simulation locations for the future technology runs (offshore)

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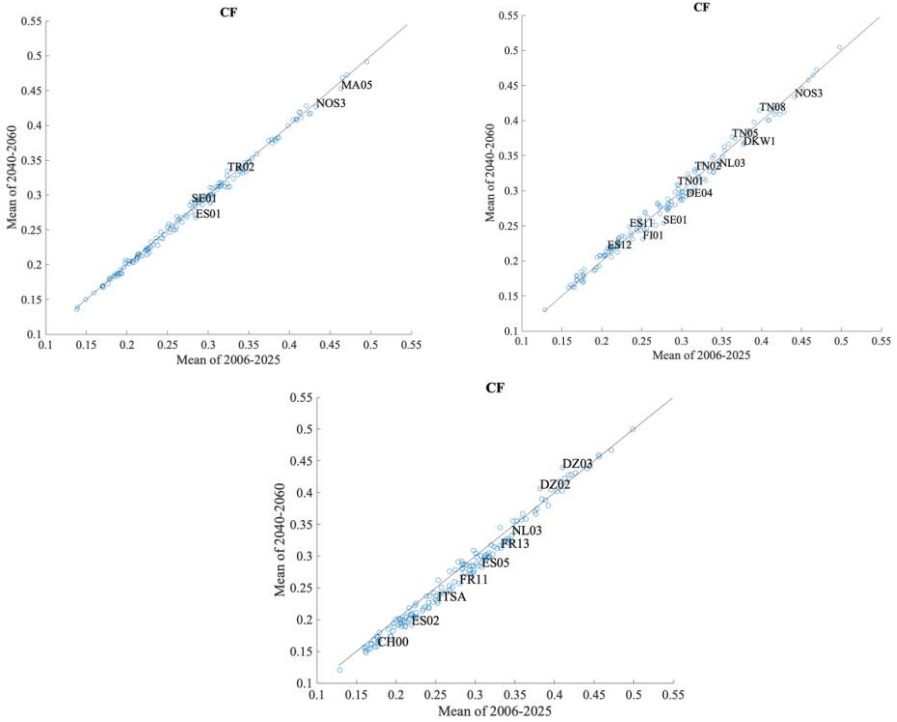
Results:
Climate change impacts on wind power capacity factors

- **Climate change expected to have limited impact on wind capacity factors on pan-European level**
  - Based on the 3 climate projections studied in the project thus far
  - Uncertainty about the impact on regional level
  - Uncertainty between the climate models
- Diurnal, seasonal and ramp rate impacts will be studied in more detail later in the project



Onshore wind capacity factors for an example technology for the current period and for around 2050 for the three analysed climate projections

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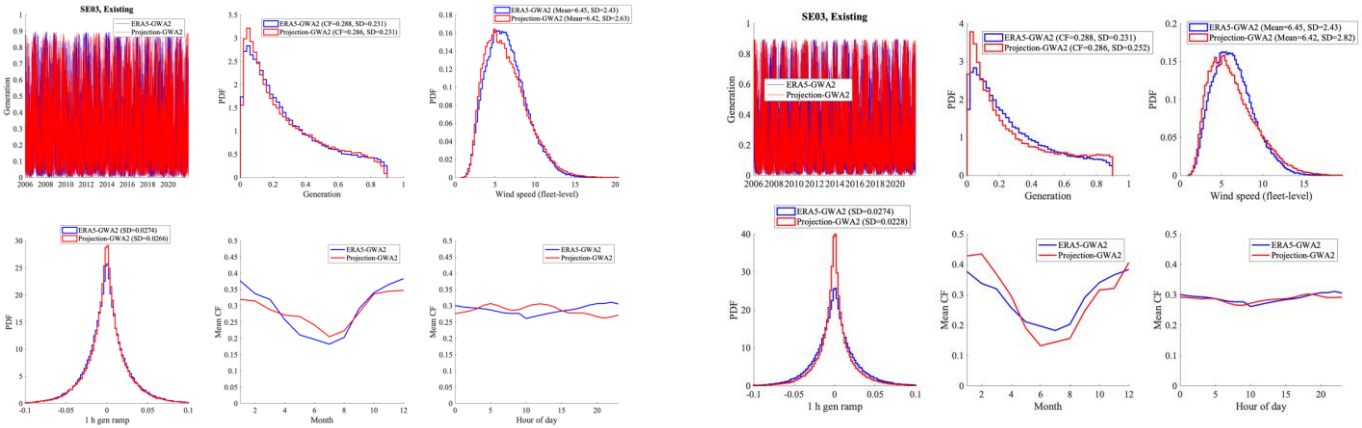
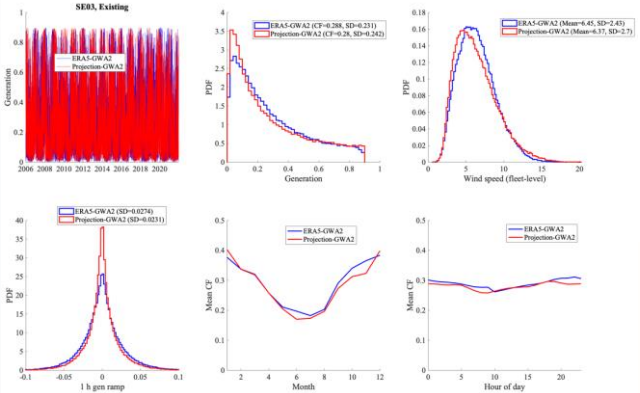
Results:
Consistency between the historical period and climate projections



Comparison of the historical period and the climate projections (1 figure per studied projection) for the overlap period (2006-2021).
For the existing installations for an example region (SE03)



- The consistency is ok for most regions
- But some regions show inconsistencies
  - This is being studied

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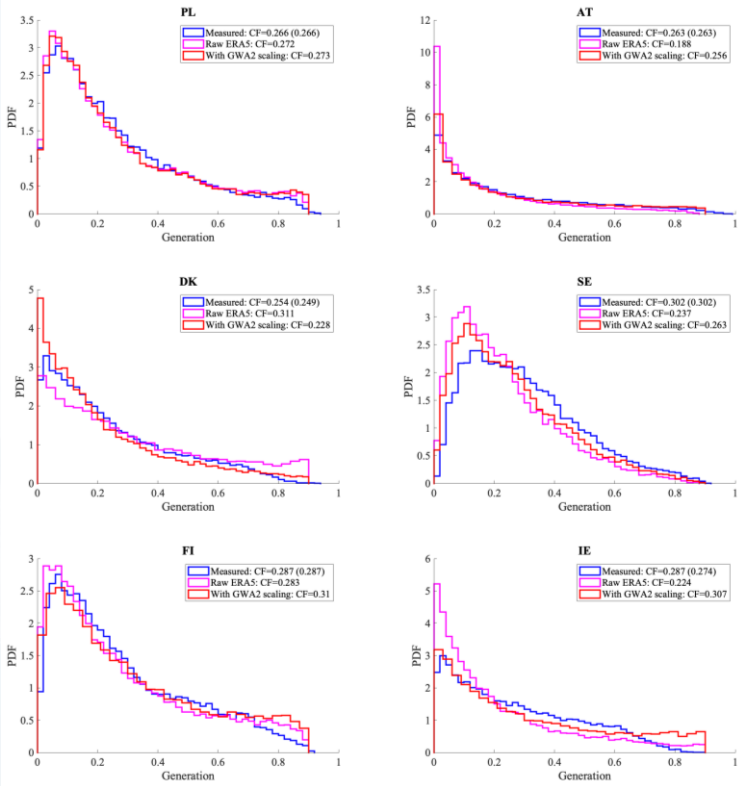
Results:
Validation of the historical period



- Validation to measured data
  - Mainly from ENTSO-E
- A separate Validation run was simulated
  - Installation information (fleet) updated for each year

- **Validation generally ok**
  - Assumptions related to losses may be incorrect for some countries
  - The Iberian peninsula (ES and PT) shows poorer validation compared to other areas
  - The methodology is being refined based on the results

Example countries with simulated onshore wind generation (2016-2019) compared to measured data for ERA5 directly and with bias correction (scaling). The measured average annual capacity factor (CF) in the legend is after considering curtailment (raw CF in brackets).

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Next steps

- **Analyse more climate models and scenarios**
  - CMIP6 based

- **Refine the methodology**
  - Bias correction (scaling)
  - Wind speed to power conversion
  - Focus on ensuring consistency between the historical period and climate projections

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