Climate change and extreme event influence on wind and solar power generation

What renewable supply shortages in Europe can be expected in the course of the 21st century?
Will the intensity of Dunkelflaute events be influenced by climate change?

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Data

EURO-CORDEX climate projections[1]

- Coupled Model Intercomparison Project (CMIP) 5
- Representative Concentration Pathway: RCP 8.5
- Global Climate Model: MPI-ESM-LR
- Regional Climate Model: REMO2009
  - "Minimal ensemble": realisations r1 and r2

European supply scenario based on TYNDP *Distributed Energy*[2]

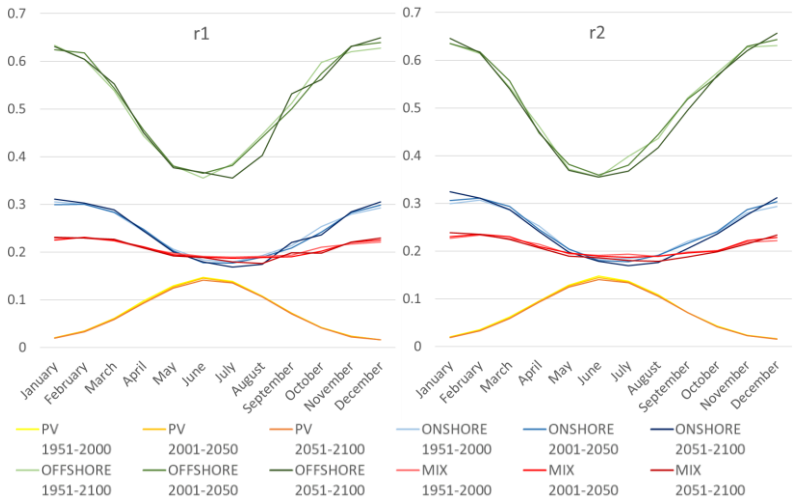
- Interpolated year 2035
- Capacity: 648 GW PV
  687 GW Wind onshore
  206 GW Wind offshore
- Power demand: 4365 TWh/a

Methods

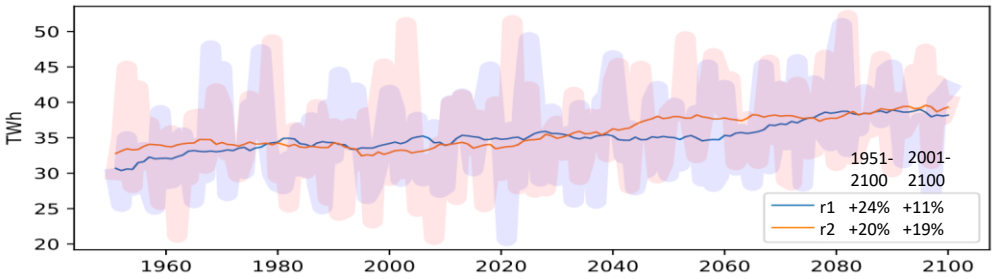
- Power generation time series with EnDAT[3] (Energy Data Analysis Tool)
- Monthly capacity factors (cf) for three time periods: 1951-2000, 2001-2050, 2051-2100
- Dunkelflaute: 14-day power generation compared to long term mean power generation
- Flexibility demand: 1) Residual load (RL) = Load - Wind onshore - Wind offshore - PV
  2) Fluctuation = RL – RL(mean) = annual flexibility demand
  3) Cumulation → inter-annual flexibility demand

Results

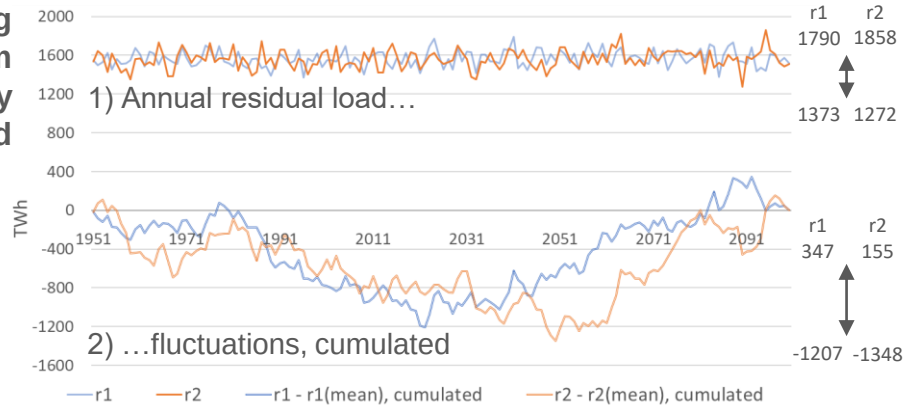
Monthly capacity factors



Dunkelflaute: annual maximum of 14-day supply shortage



Long term flexibility demand



Conclusions

- Change of the max. monthly mix cf in the 21st century: -6% to +4%
- Dunkelflaute intensity increase in the 21st century: 11-19%
- Flexibility demand in the TYNDP Distributed Energy scenario (2035)
  - Annual residual load fluctuations: 27-38% of mean value = 10-13% of annual power demand
  - Max. inter-annual flexibility demand: ~35% of annual power demand

Lessons learned

- Always use an ensemble of climate projections[4]
  - How many elements at least?
- High data storage requirements: up to 700 GB per parameter

[1] Subset of climate projection data as described in Jacob, D. et al., *EURO-CORDEX: new high-resolution climate change projections for European impact research*, Regional Environmental Change, 2014, 14, 563-578
[2] *TYNDP (Ten Year Network Development Plan) 2022 Scenarios*, ENTSO-E, 2022, https://2022.entsos-tyndp-scenarios.eu/download/
[3] Scholz, Y: *Renewable energy based electricity supply at low costs : development of the REMix model and application for Europe*, Dissertation, University of Stuttgart, 2012, http://dx.doi.org/10.18419/opus-2015
[4] EURO-CORDEX: *Guidance for EURO-CORDEX climate projections data use*, 2021, https://www.euro-cordex.net/imperia/md/content/csc/cordex/guidance_for_euro-cordex_climate_projections_data_use__2021-02_1_.pdf