Simulation of long term solar power feed-in and solar balancing potential in European countries

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14th EMS and 10th ECAC, Prague, Czech Repulic

7 October, 2014

GEFÖRDERT VOM

ENERGIESPEICHER
Forschungsinitiative der Bundesregierung

Outline

- Brief overview on the project
- Description of data sources & methodology
- Evaluation of regional power timeseries
- Analysis of fluctuations of intermittent renewables
- Impact of module configurations on fluctuations
- Summary & outlook

Project RESTORE 2050

- Investigates European energy system in 2050 with $\sim 100\%$ renewables
- Analysis of fluctuations of intermittent renewables
- Estimation of storage needs[1]

Here focus will be on solar energy & its fluctuations

[1] *Kies* et al, *Investigation of balancing effects in long term renewable energy feed-in with respect to the transmission grid* , EMS2014-331

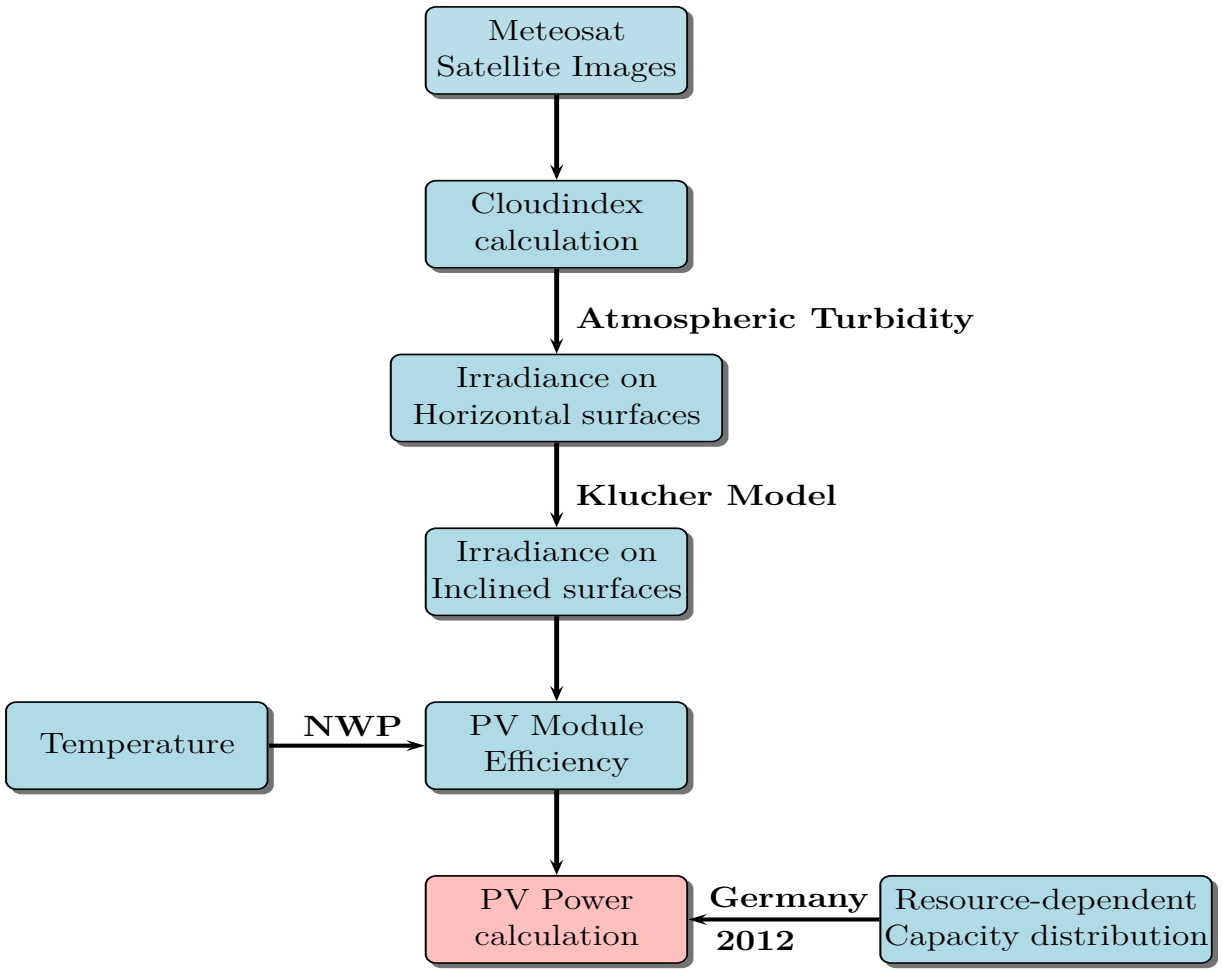
Data sources & models

- Irradiance calculated using *Heliosat*[1] method
- Meteosat 1^{st} & 2^{nd} generation satellites
  - regridded to $7km \times 7km$
  - temporal resolution: 1 hour
- projected country-level installed power from Energy scenario of Fraunhofer ISI
- Ambient temperature and Wind: downscaled from Merra Reanalysis
- Load: estimated from Entso-E data

Model domain: EU-28, Norway, Switzerland and Balkan countries
Simulation performed for 10 years (2003-2012)

[1] *Hammer* et al, *Solar Energy Assessment Using Remote Sensing Technologies*, 'Remote Sensing of Environment', 86, 423-432 (2003)

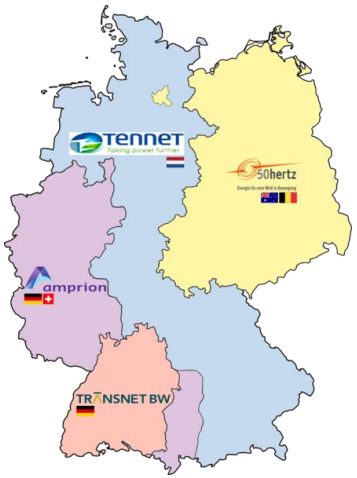
Methodology



Evaluation of regional power timeseries

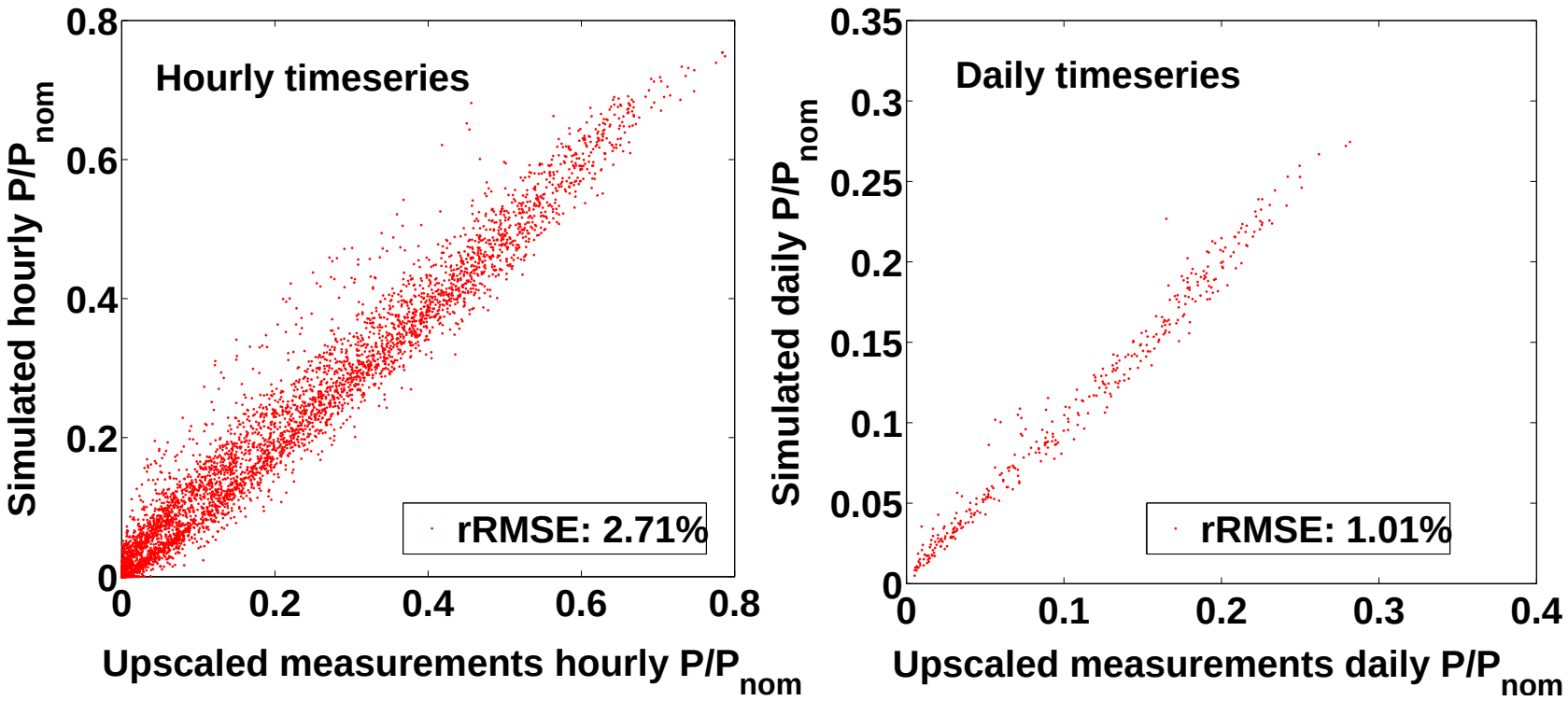
Timeseries of PV power feed-in in Germany are provided by the 4 transmission system operators:

- 50 Hertz
- amprion
- tennet
- transnet-bw



The data is upscaled from a number of measurement sites

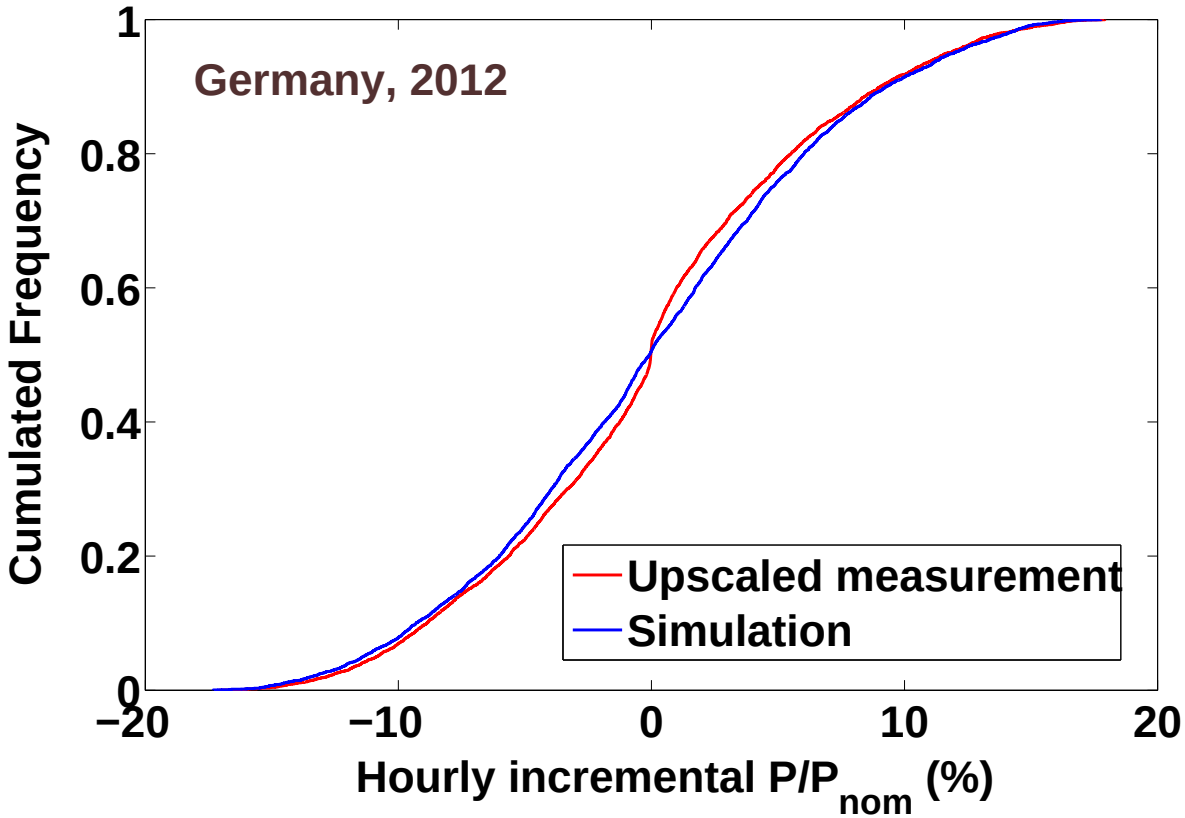
Comparison with upscaled measurements, Germany,2012



Average of normalised power P/P_{nom}, P_{nom}: installed nominal power
Estimated $= 0.1112$ & *Simulated* $= 0.1130$

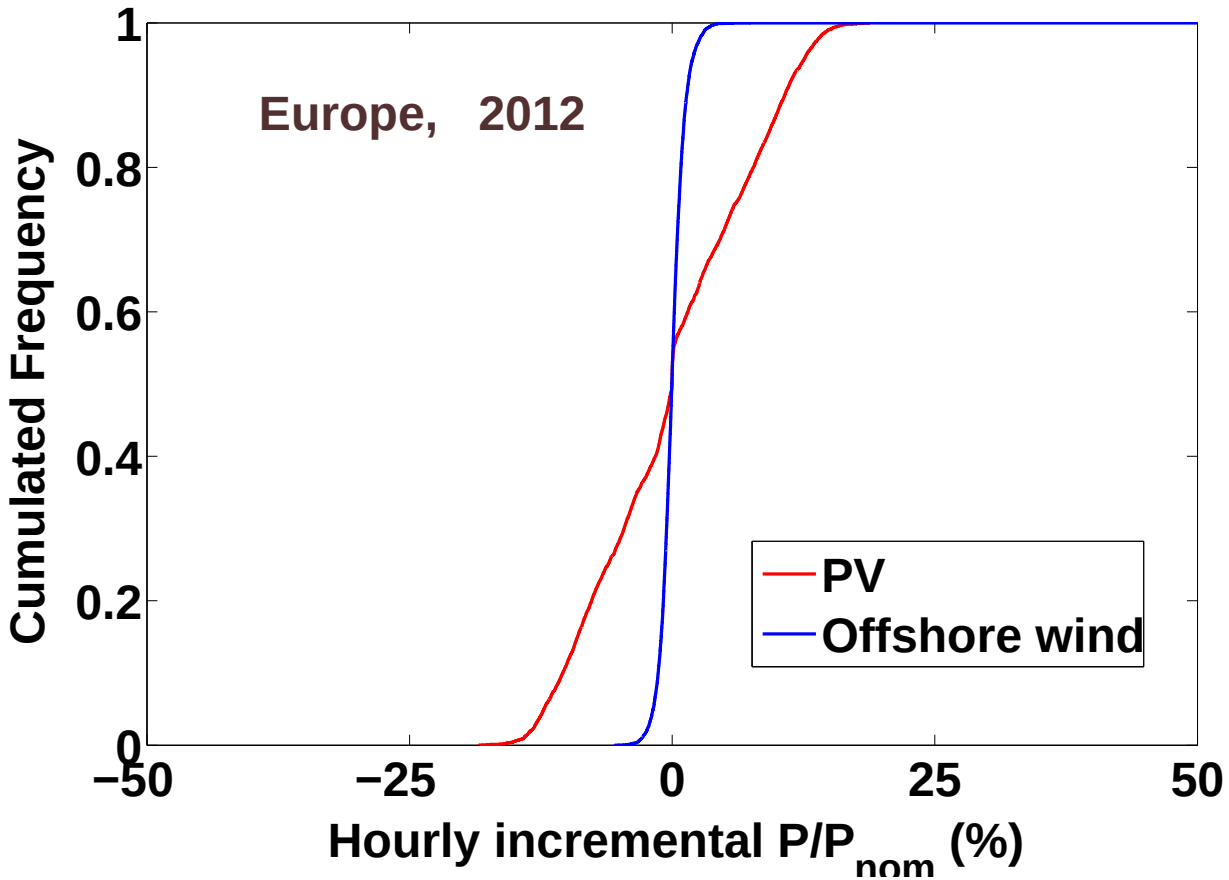
Comparison of incremental timeseries

Analysis of fluctuations: cummulated frequency distribution of increment timeseries



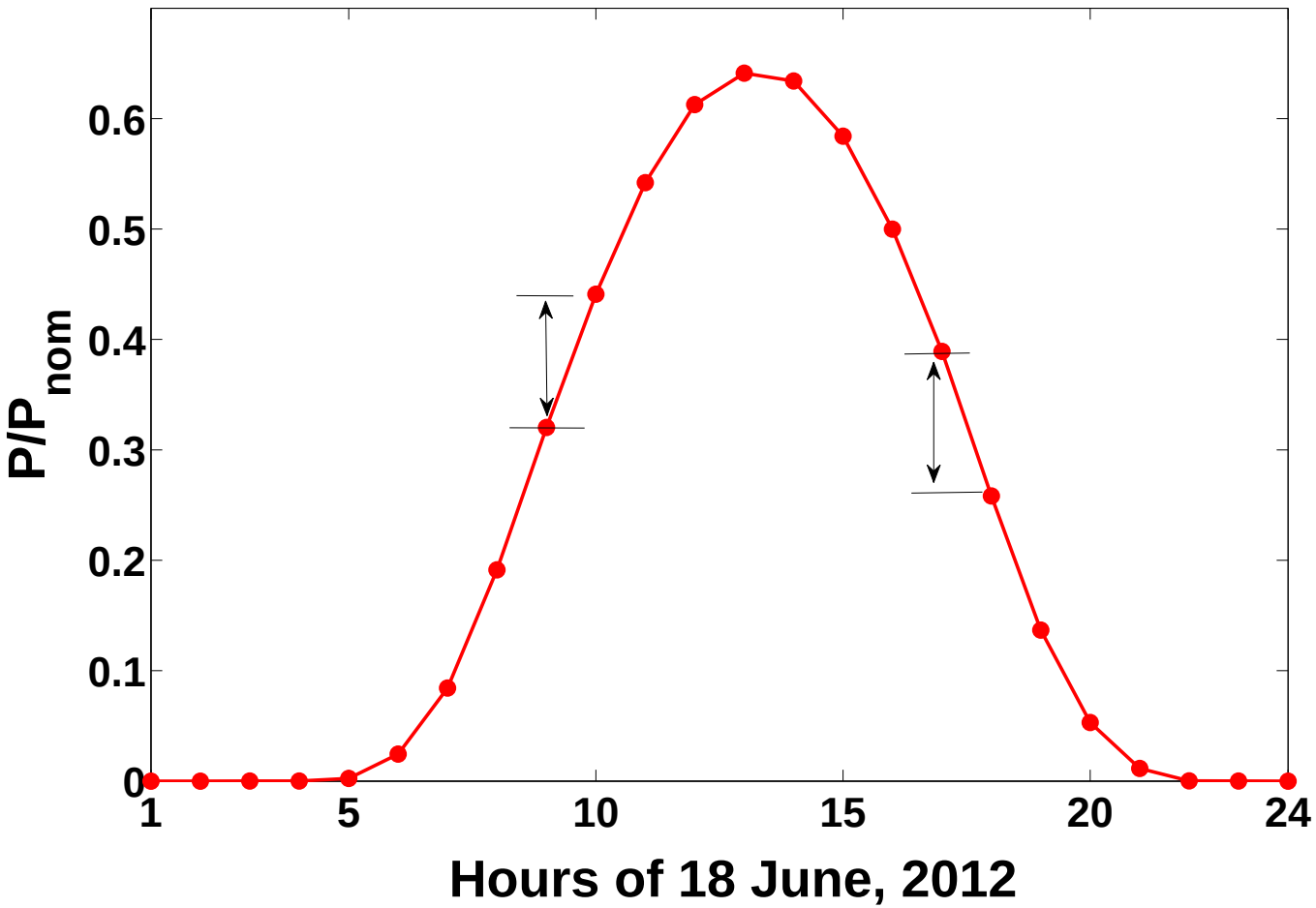
good agreement of simulation with upscaled measurements

Incremental timeseries of PV & offshore wind

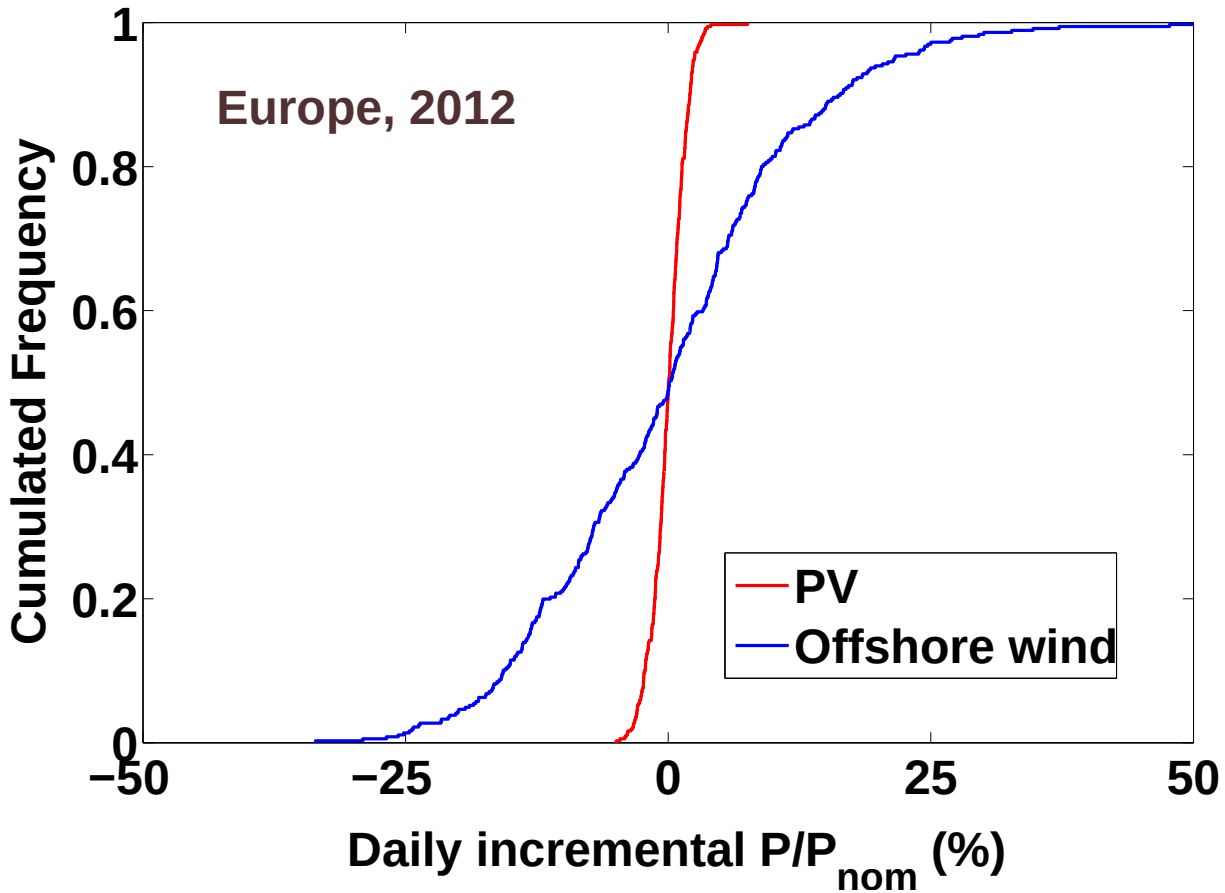


Due to its diurnal pattern, PV shows higher fluctuations than Wind

Solar fluctuations on hourly scale

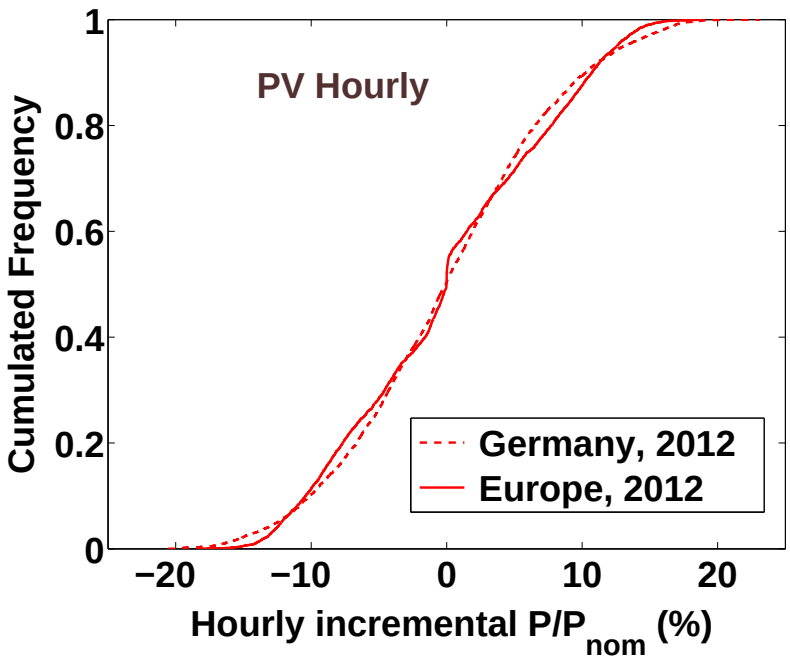


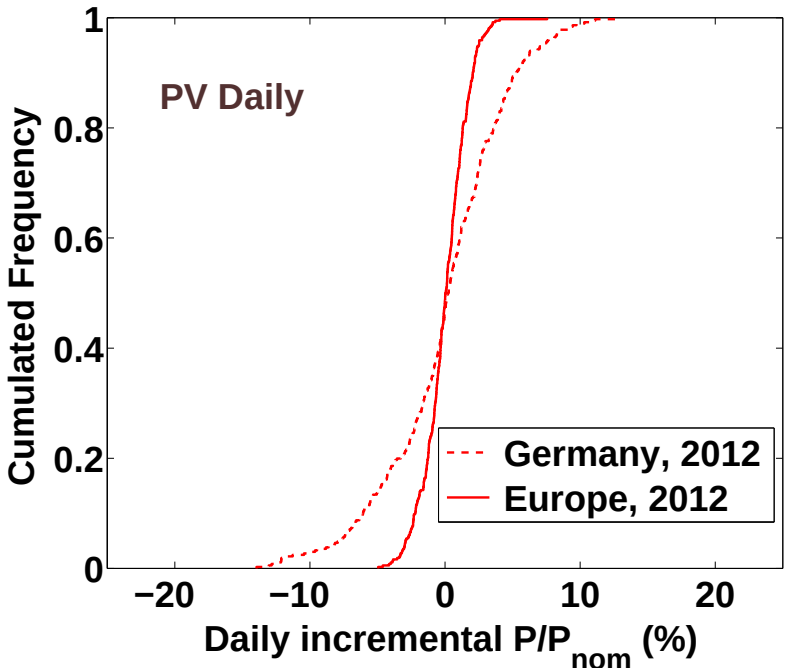
Incremental timeseries of PV & offshore Wind



Daily incremental timeseries for both technologies mainly determined by meteorological factors, wind shows higher fluctuations than PV

Effects of regional averaging on fluctuations

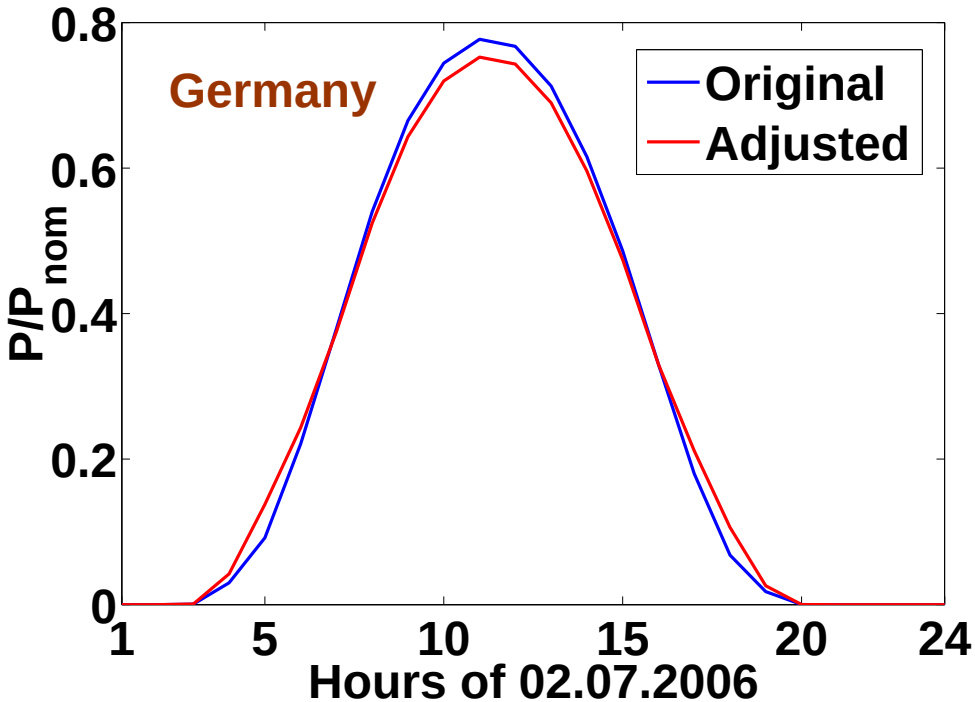




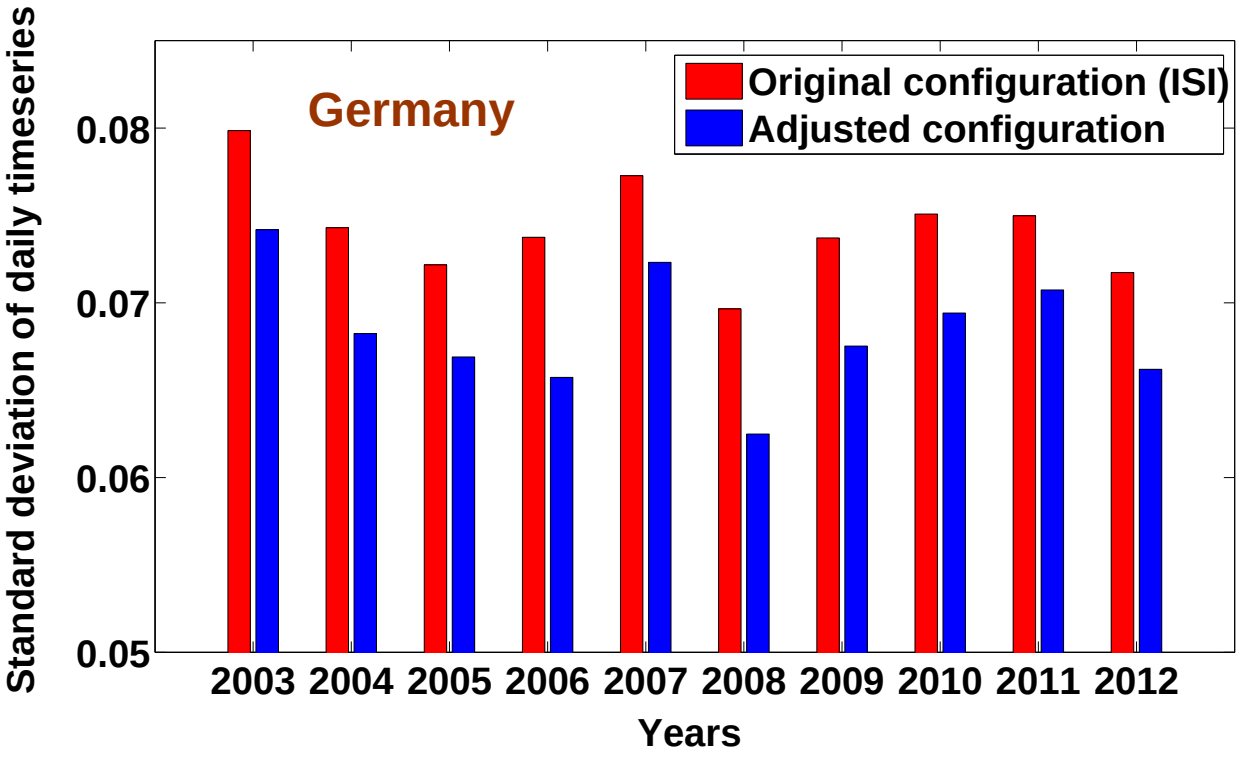
Hourly timeseries remains almost unaffected to regional averaging
On daily scale, PV fluctuations decrease on regional averaging

Analysis of fluctuations for changed module configurations

- Reference configuration from Energy scenario, Fraunhofer ISI
- Compared with South-East & South-West oriented modules
- Steeper inclination applied to increase annual production

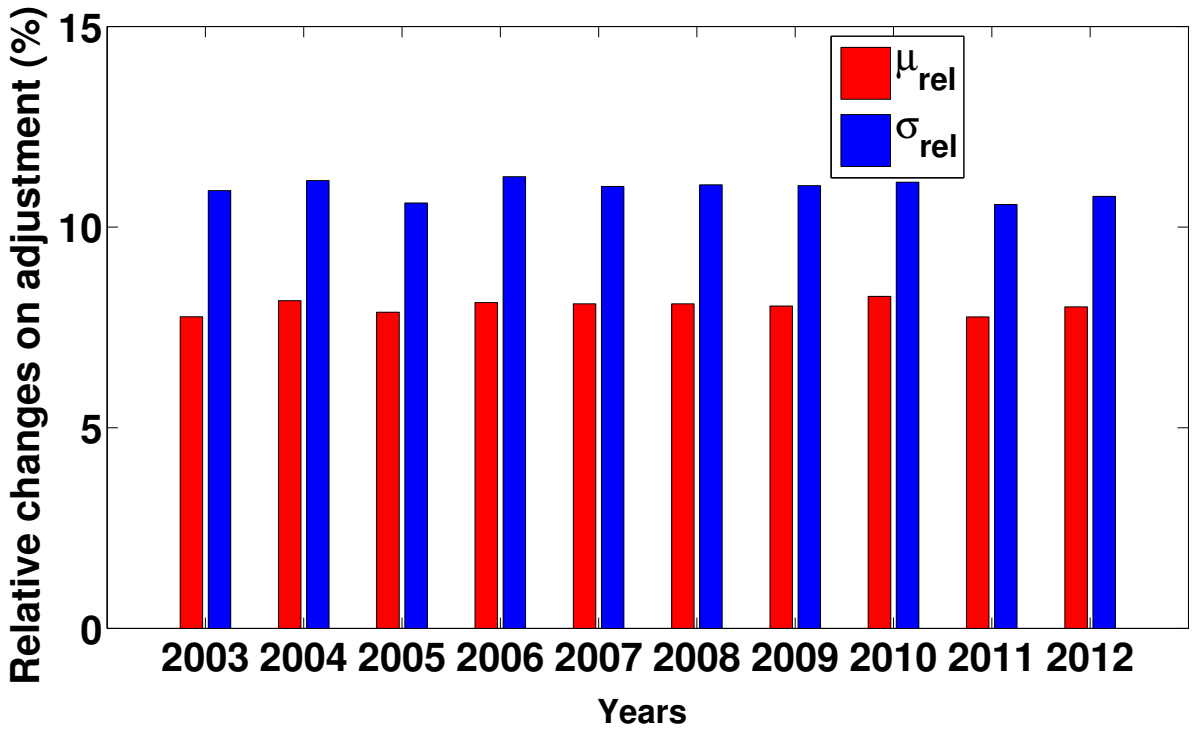


Results: fluctuations for changed PV module configuration



Standard deviation of daily P/P_{nom} is decreased by $\sim 11\%$

Results: fluctuations for changed PV module configuration



$$\mu_{rel} = \left| \frac{\left\langle P_{adj} \right\rangle - \left\langle P_{orig} \right\rangle}{\left\langle P_{orig} \right\rangle} \right| \times 100$$

$$\sigma_{rel} = \left| \frac{\sigma_{adj} - \sigma_{orig}}{\sigma_{orig}} \right| \times 100$$

Summary

- Feed-in timeseries for fluctuating renewables produced
- Solar PV shows good agreement with upscaled measurements
- PV power shows higher fluctuations than wind on hourly scale and less fluctuations on the daily scale
- Module configurations adjusted to reduce fluctuations to $\sim 11\%$ with a compromise to $\sim 8\%$ decrease in power production & can be mitigated by adequate storage, proper DSM etc

Outlook

- Incorporate adequate storage for different technologies
- System behavior under extreme events
- For CSP, power import from Sahara

Thank you for your attention!!!

Questions & Comments are welcome

Many thanks to our project partmers from:

- Wuppertal Institut für Klima, Umwelt, Energie GmbH, Germany
- NEXT ENERGY, Oldenburg, Germany

Special thanks to BMBF, Förderinitiative Energiespeicher for funding the project

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Thank You for your Attention!!!