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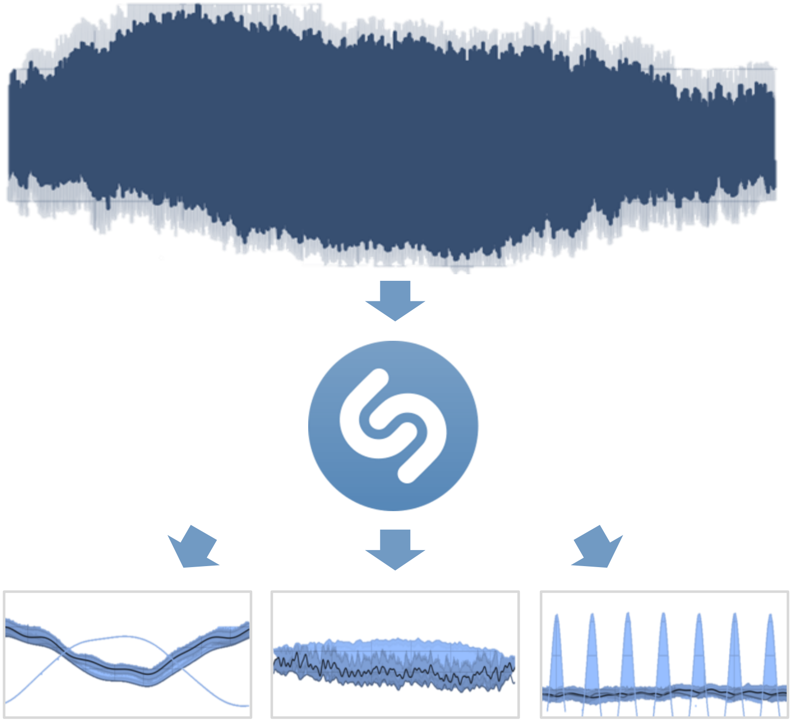
Shazam for the power sector

Application of Fourier transformation to unravel energy portfolio intermittency in the European power system



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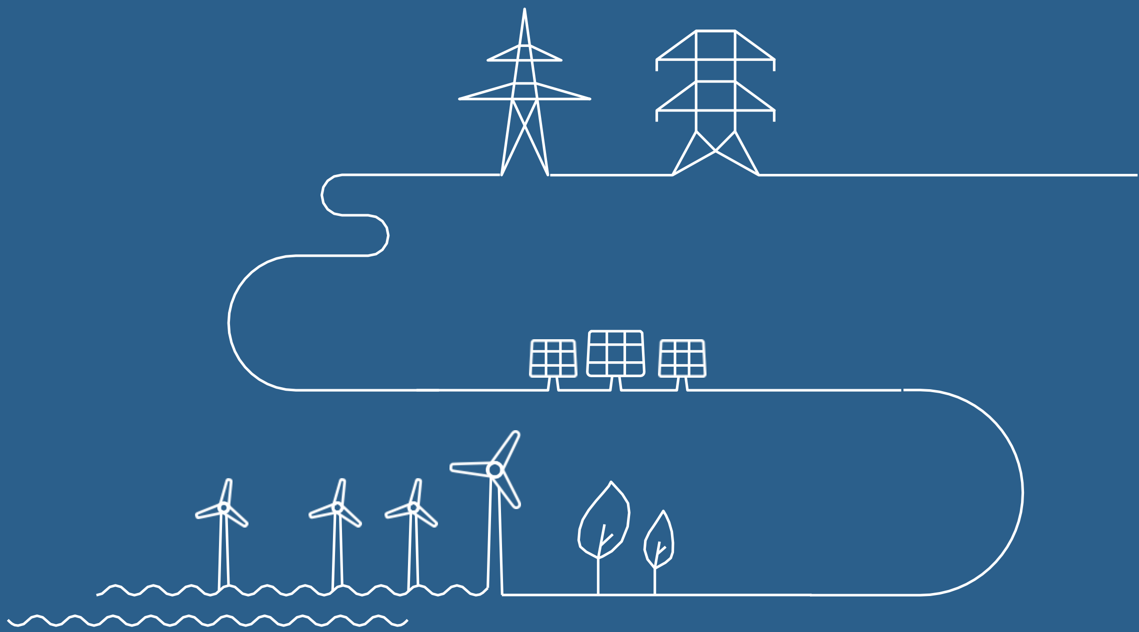
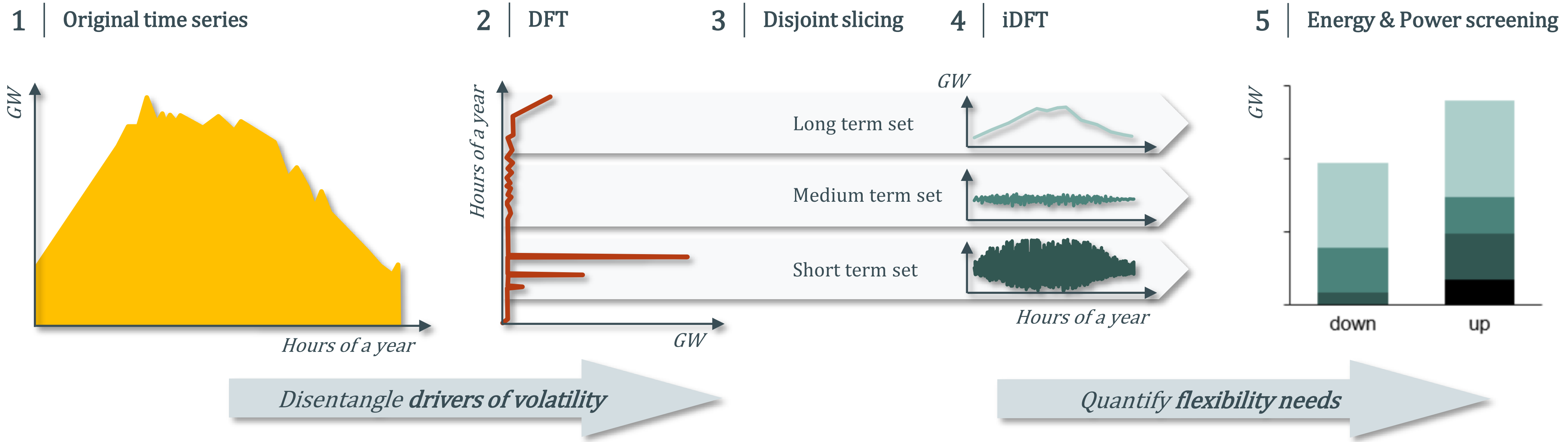
2. **Methodology** – Fourier in context of energy systems analysis
3. **Results** – Portfolio intermittency & Correlation & Pooling
4. **Conclusion** – Future applications

Setting the scene

Fingerprints of volatility



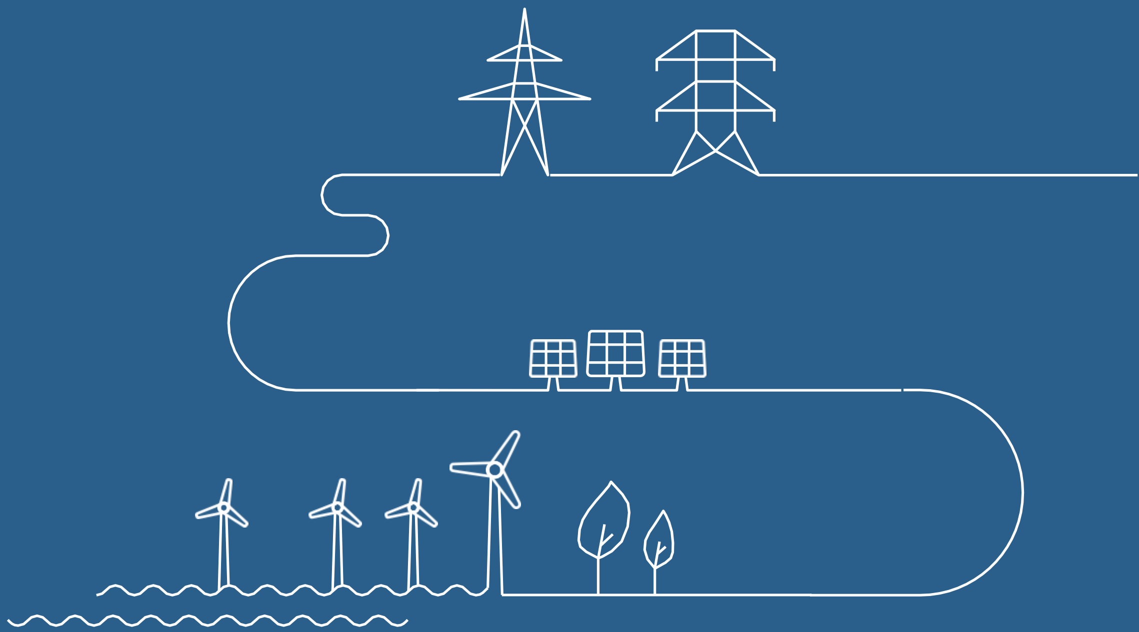
Fourier transformation allows reverse engineering of volatile mixed time series data into reoccurring patters of volatility



Data: Example analysis based on PV generation in DE

Methodology

Fourier in context of energy systems analysis



Analysis is applied to a high RES powered European system

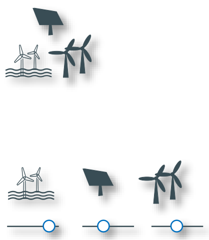
1 | RE availability

- EU + UK, CH, NO in 165 zones aggregated into country levels
- 35 climate years
- Hourly resolution

2 | RE portfolio

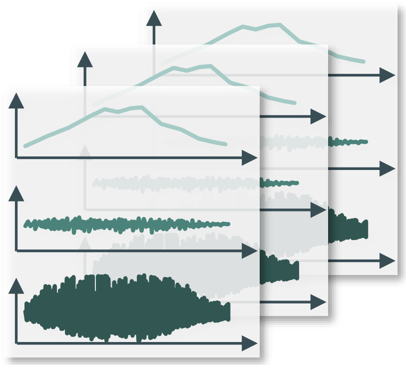
Base Case

Sensitivity



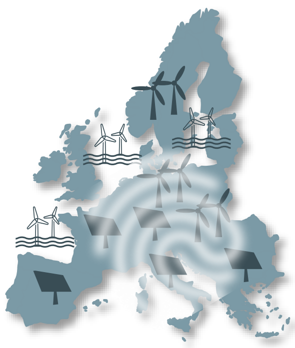
- TYNDP, GA 2050
- MAF + EU 1.5TECH
- Sensitivity for high offshore and high PV capacities

3 | Fourier analysis



- Four time horizons
- Results per climate year, region and technology

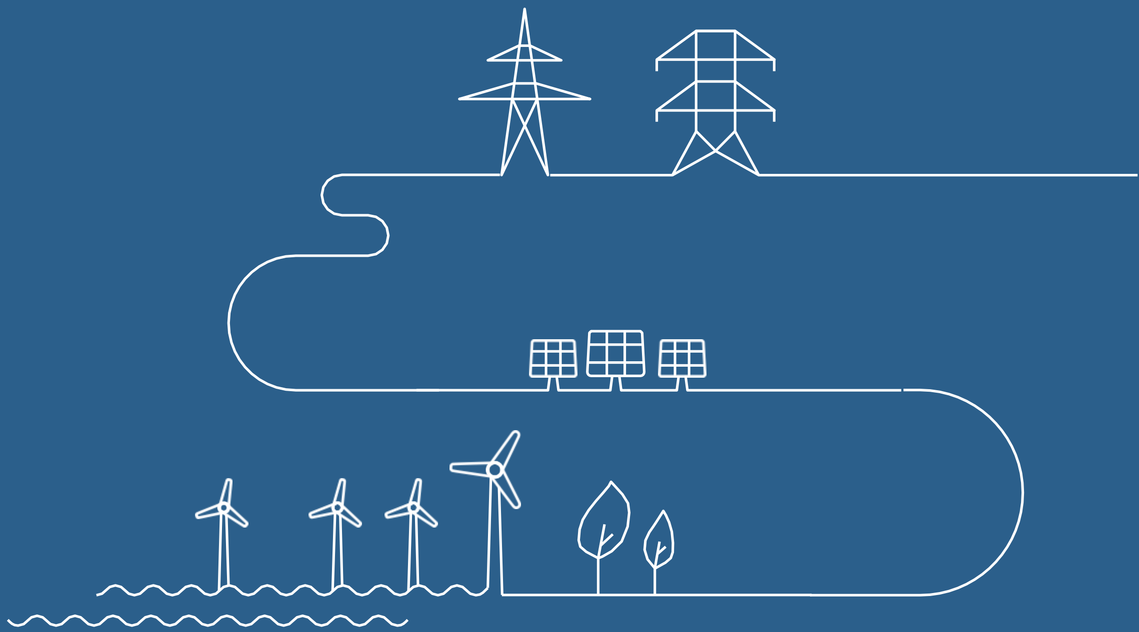
4 | Flexibility requirements



- Quantification of upward flexibility needs

Data: RE time series: PECD | RE capacities: TYNDP draft scenario report 2022 GA 2050 | demand: MAF 2030 calibrated to EU 1.5TECH

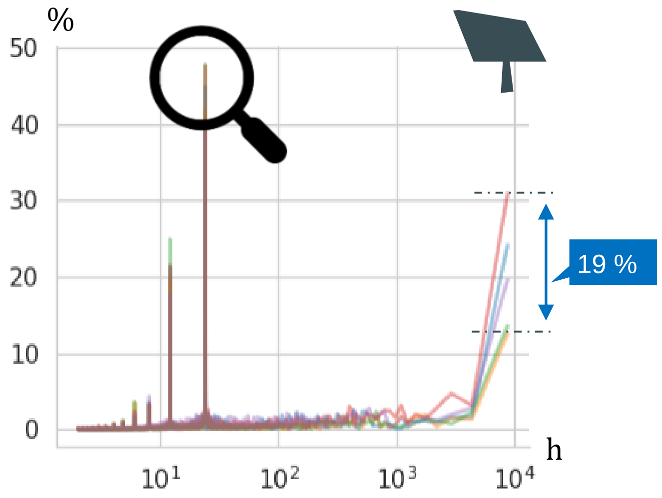
Results

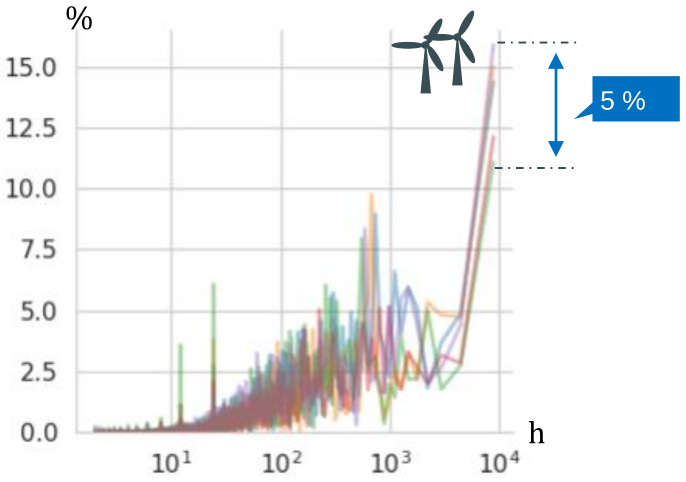


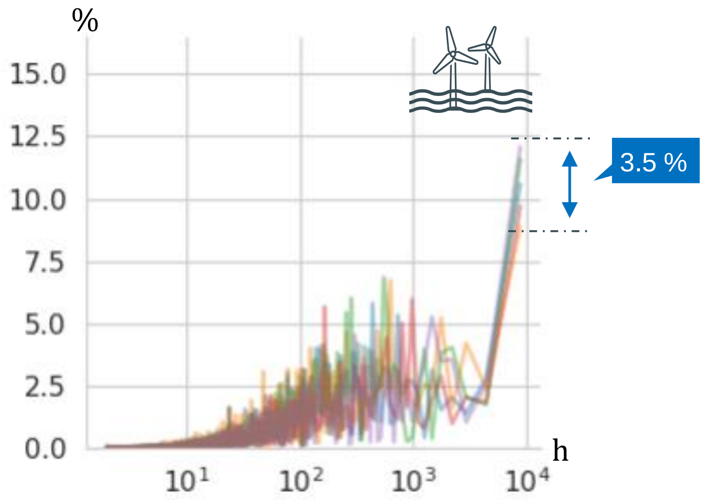
Frequency spectra of RE infeed reveal distinct patters of volatility

Normalised frequency spectra for RE in five countries

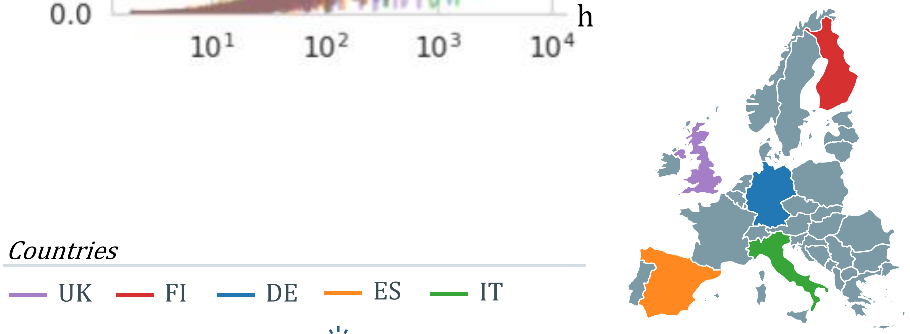
Average deviations from mean capacity factor in % for 8760 hours over 35 climate years







Based on the spectra, frequency cuts for the disentanglement analysis can be derived

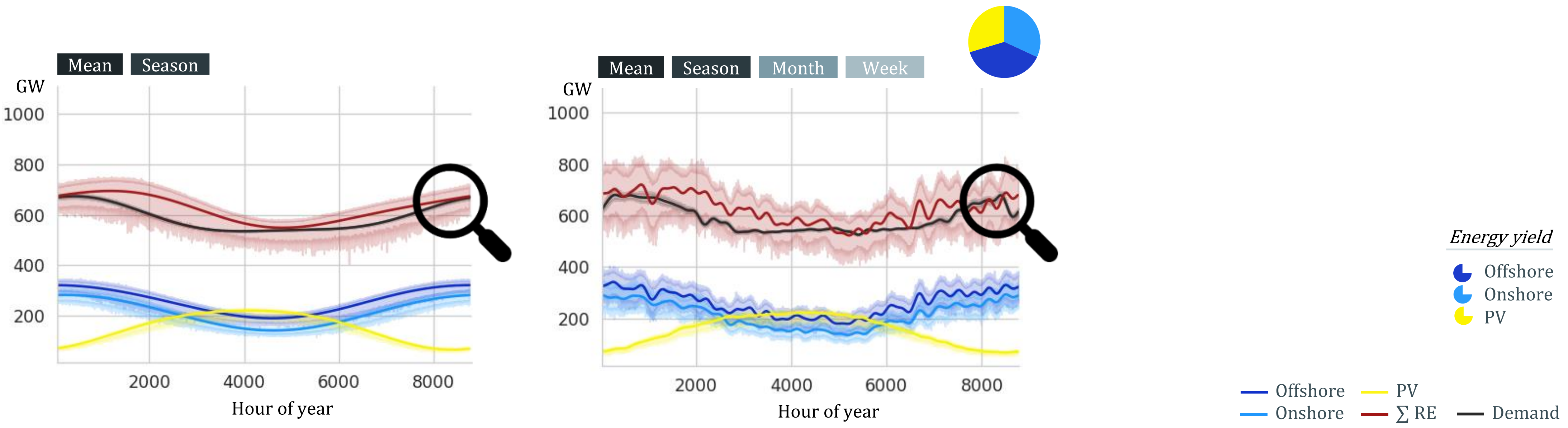


Data: PECD hourly data per country for 35 climate years, normalised to capacity factors

Seasonality of RE mix matches well with demand on European average

Decomposed oscillations for RE infeed and demand in Europe 2050 – Seasonal & Weekly

Average hourly values in solid lines, climate year range in shades



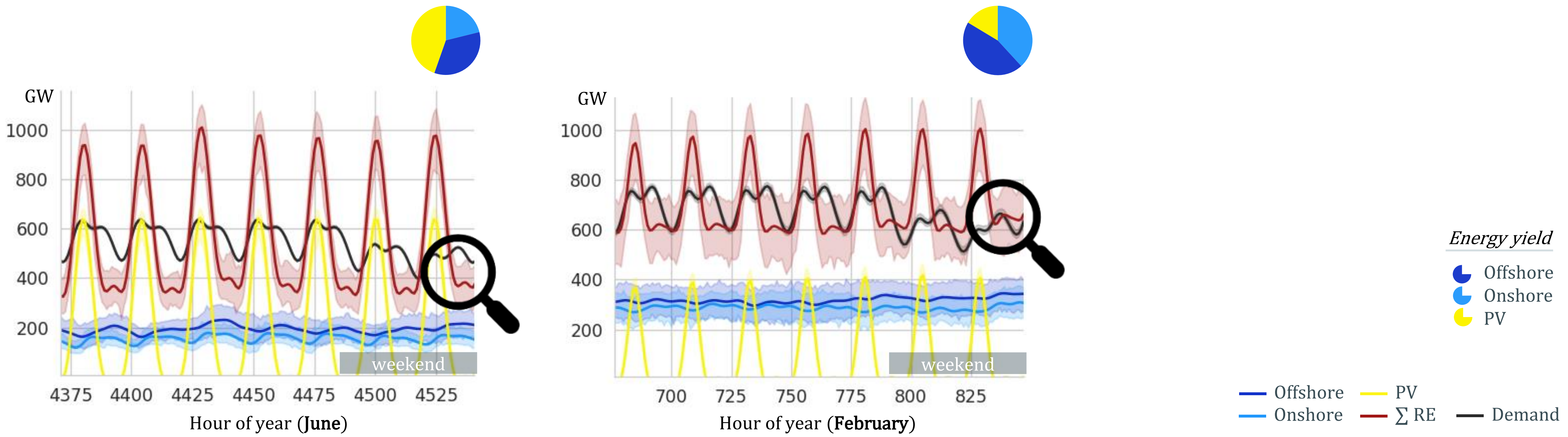
Data: RE time series: PECD | RE capacities: TYNDP draft scenario report 2022 GA 2050 | demand: MAF 2030 calibrated to EU 1.5TECH

PV drives daily volatility the most, RE surplus generation also substantial in winter time

Decomposed oscillations for RE infeed and demand in Europe 2050 – Daily

Average hourly values in solid lines, climate year range in shades

Mean | Season | Month | Week | Day

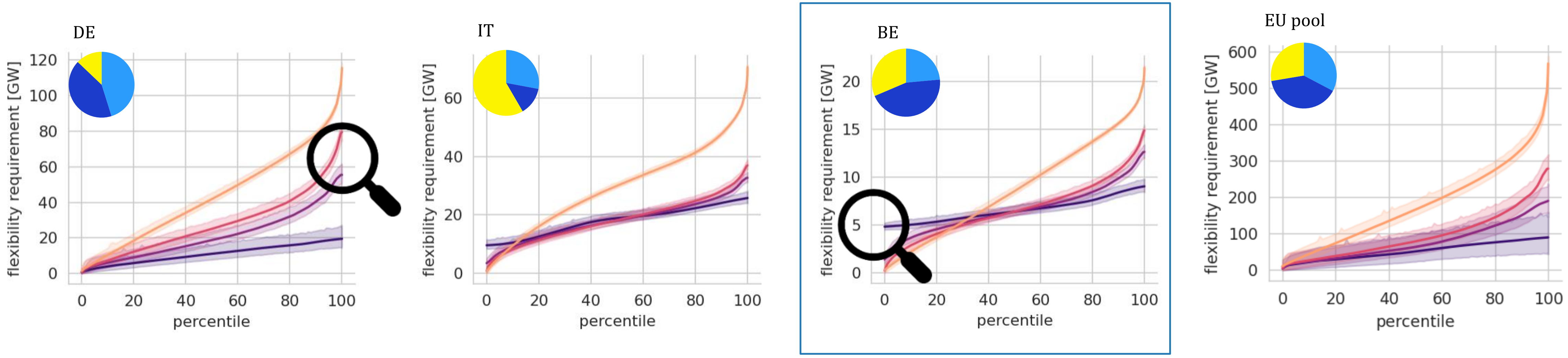


Data: RE time series: PECD | RE capacities: TYNDP draft scenario report 2022 GA 2050 | demand: MAF 2030 calibrated to EU 1.5TECH

Relative share of PV versus wind shapes flexibility needs

Upward flexibility requirements in GW in Europe 2050

Selected regions, solid line is mean, shade is climate variability



Sensitivity Analysis:
Fill up adequacy gap

Time horizons

- Sn + Mn + Wk + Id
- Sn + Mn + Wk
- Sn + Mn
- Sn

Where
Sn…Season,
Mn…Month,
Wk…Week,
Id…Intradaily

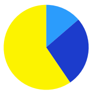
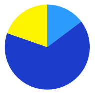
Energy yield

- Offshore
- Onshore
- PV

Data: RE time series: PECD | RE capacities: TYNDP draft scenario report 2022 GA 2050 | demand: MAF 2030 calibrated to EU 1.5TECH

Sensitivity analysis on adequate Belgian power mix

RE portfolio for BE sensitivity analysis

Base case	High PV	High Offshore Belgium	High Offshore North Sea
			
25 GW	85 (+60) GW	25 GW	25 GW
8 GW	8 GW	8 GW	8 GW
9.8 GW	9.8 GW	23.8 (+14) GW	23.8 (+14) GW

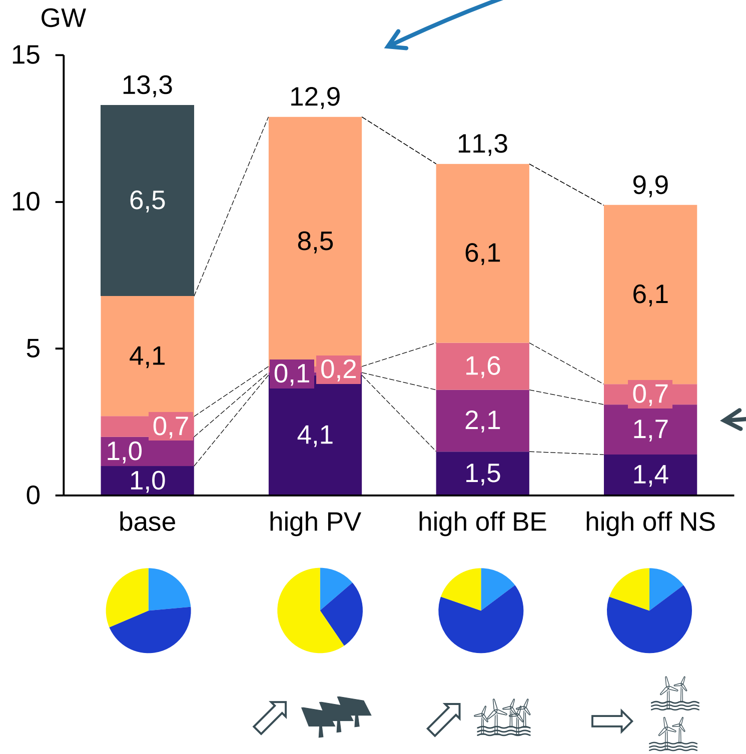
energy yield

- Offshore
- Onshore
- PV

Adding more PV to a power system is not a “wild card”

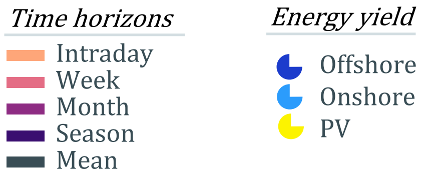
Upward flexibility needs in Belgium

80th percentile of 35 climate years



PV closes the RE supply gap, but offsets the gains with high flexibility needs on seasonal and daily level

Geographical smoothening of offshore wind volatility reduces medium term flexibility substantially



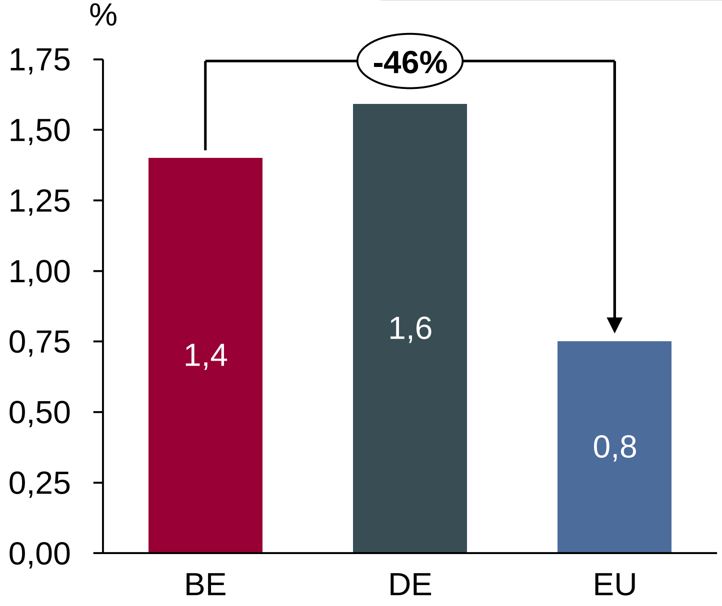
Data: RE time series: PECD | RE capacities: TYNDP draft scenario report 2022 GA 2050 and own assumptions

Weekly offshore wind volatility is not correlated across Europe

Weekly volatility of **offshore** wind in % of mean infeed

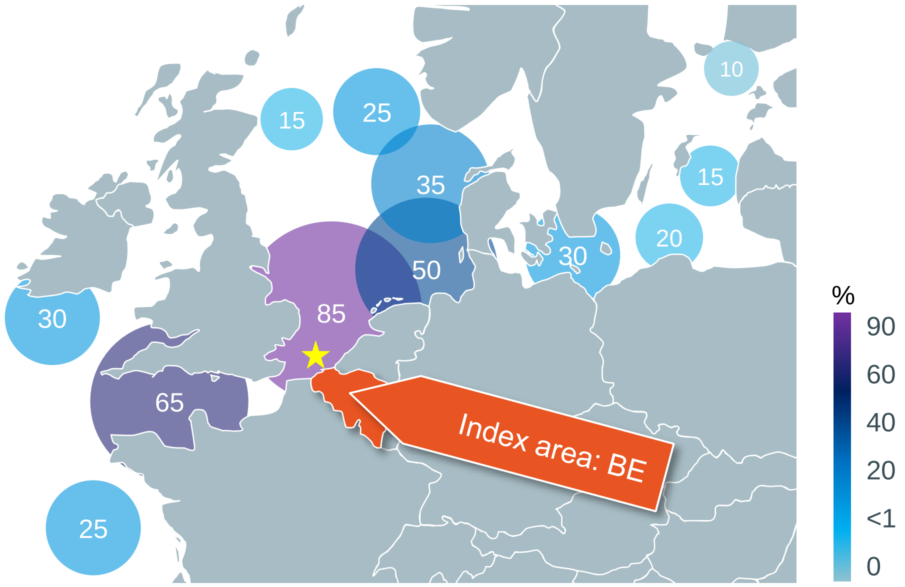
80th percentile of 35 climate years

$$\frac{Weekly\ deviations\ from\ mean\ infeed\ [GW]}{mean\ infeed\ [GW]}$$



Correlation of BE offshore wind infeed with Europe in %

Statistics on fluctuations that occur simultaneously from one day up to a week



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Summary

- Fourier Transformation is applied to RE time series data across Europe to disentangle drivers of volatility in a high RES powered power system
- Portfolios of RE mixes across countries reveal different fingerprints of volatility
  - Seasonality in the mix is best mitigated in a mix of 1/3 power generation from PV, onshore and offshore wind respectively
  - Daily volatility is driven by PV and best mitigated by short term flexibility means such as batteries
  - Medium term volatility is driven by wind onshore and offshore and efficiently mitigated by geographical spreading
- Future offshore grid development can leverage de-correlated infeed patterns
- An open-access python tool is made available to explore findings beyond this presentation

Access to the python tool: https://github.com/helgestefan/FUTURE