Christoph Zöphel

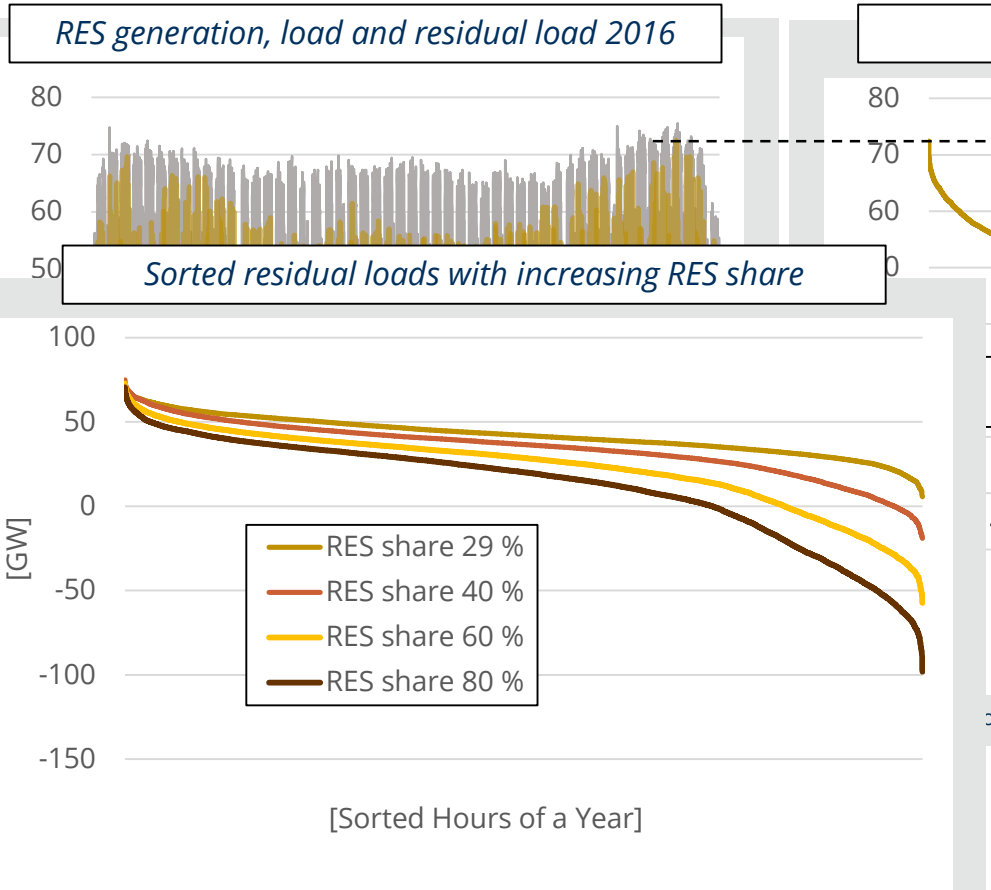
# Optimal Investments in Flexibility Options – An Analysis of Interactions and Sensitivities

Chair of Energy Economics, TU Dresden

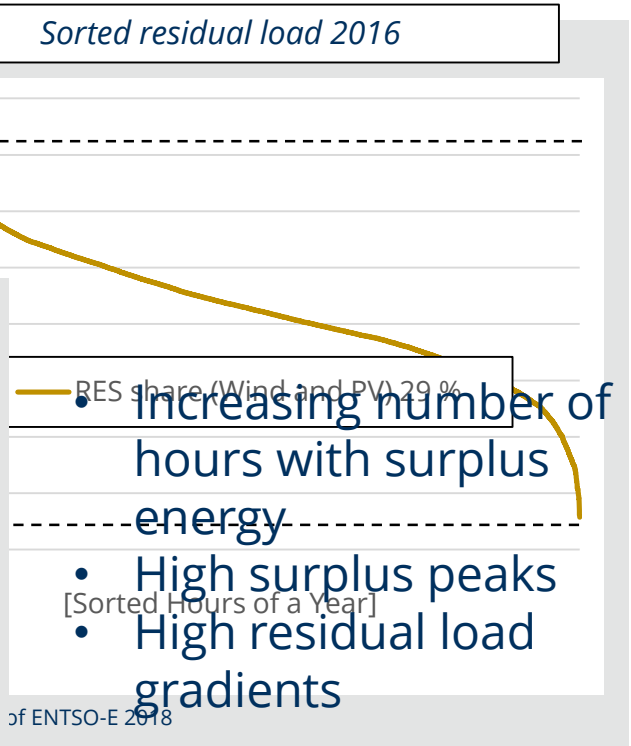
Enerday - Dresden, 27th of April 2018

# Effects of Renwable Energy Sources (RES) Extension

Example: Germany




Own assumptions based on Data of ENTSO-E 2018

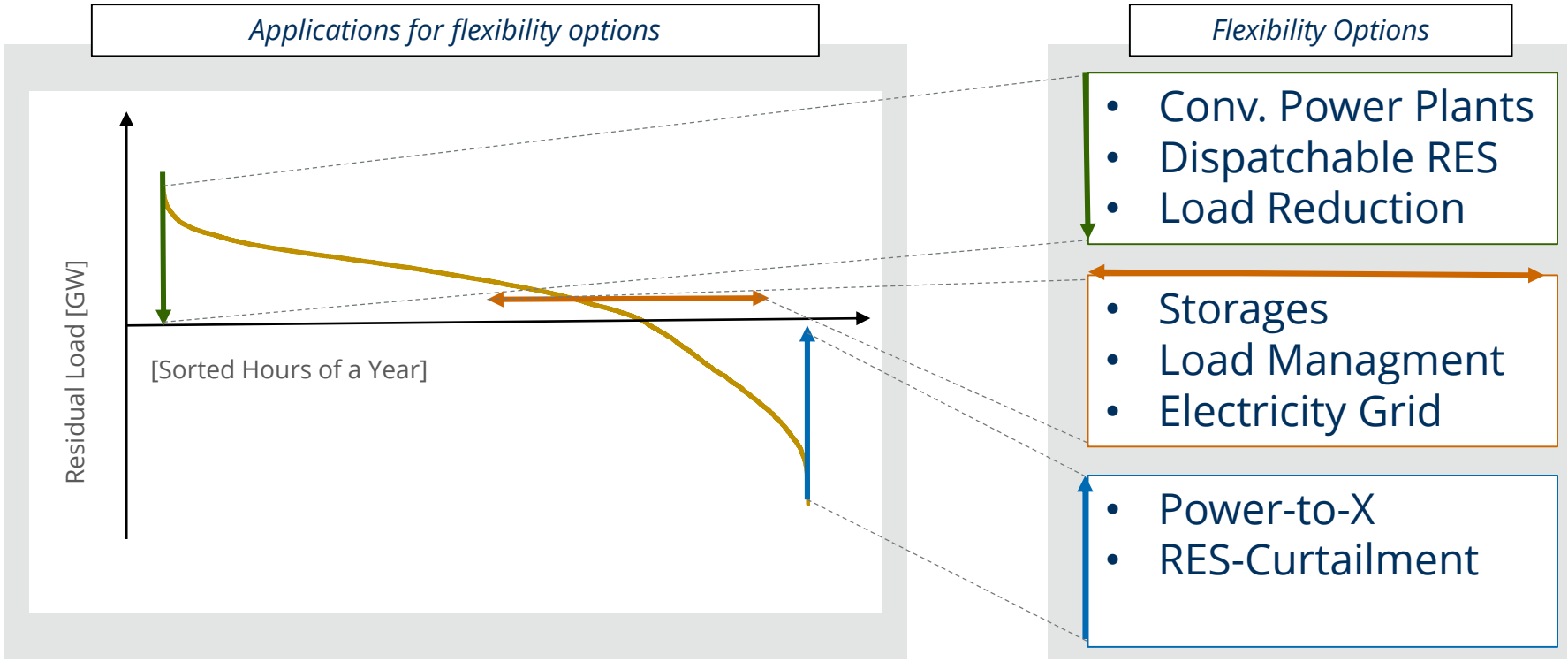



of ENTSO-E 2018

- Increasing number of hours with surplus energy
- High surplus peaks
- High residual load gradients

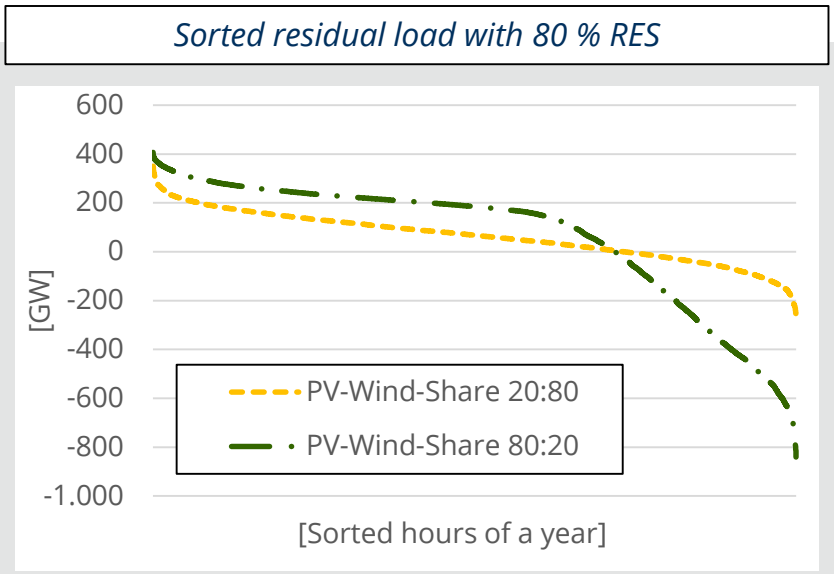
# Theoretical Applications for Flexibility Options

## Smoothing of the residual load



# Influence of the PV-Wind-Mix on the Need for Flexibility

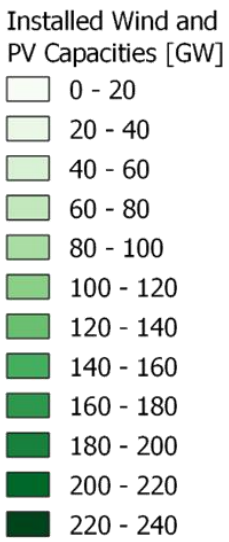
- Development of RES-extension scenarios based on RES-potentials in 17 countries
- In total 80% share of PV- and Wind generation on electricity demand



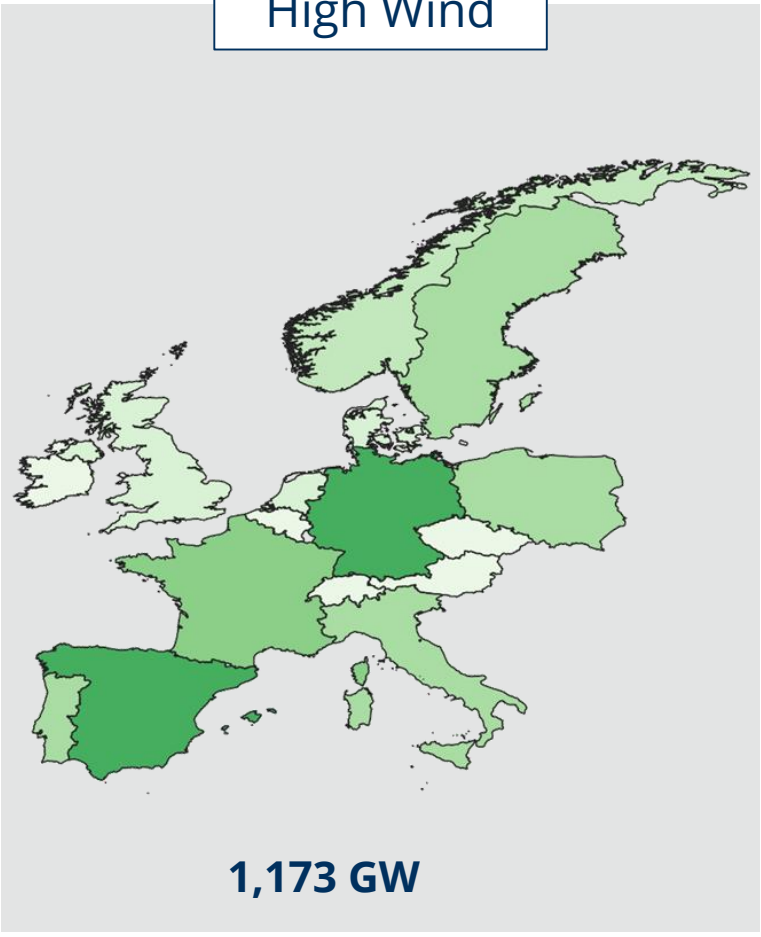

(own calculations based on ENTSO-E 2018)

| | High WIND | High PV |
|---|---|---|
| PV-Wind-Share | 20:80 | 80:20 |
| Ø full load hours of PV and wind | 1.847 h | 1.191 h |
| Average correlation of RES generation between countries | 0,40 | 0,79 |

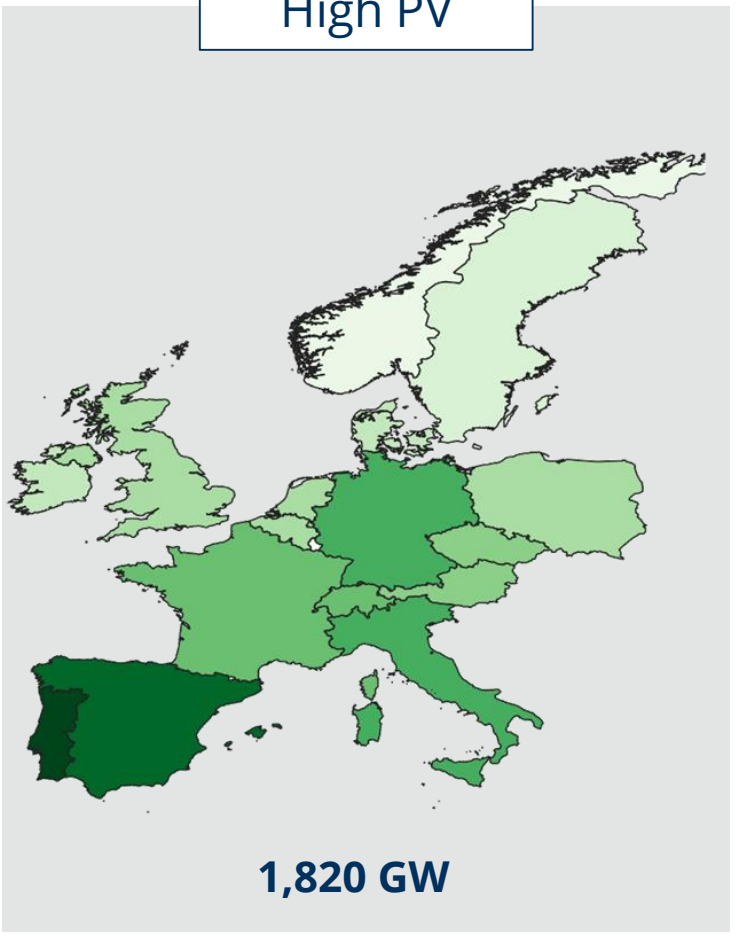
# Installed Capacities in the Countries




High Wind



High PV



**Total Capacities**

**1,173 GW**

**1,820 GW**

# Research Questions

## Forschungsfragen

**Which influence has the need for flexibility at a high share of RES on the optimal combination of flexibility options?**

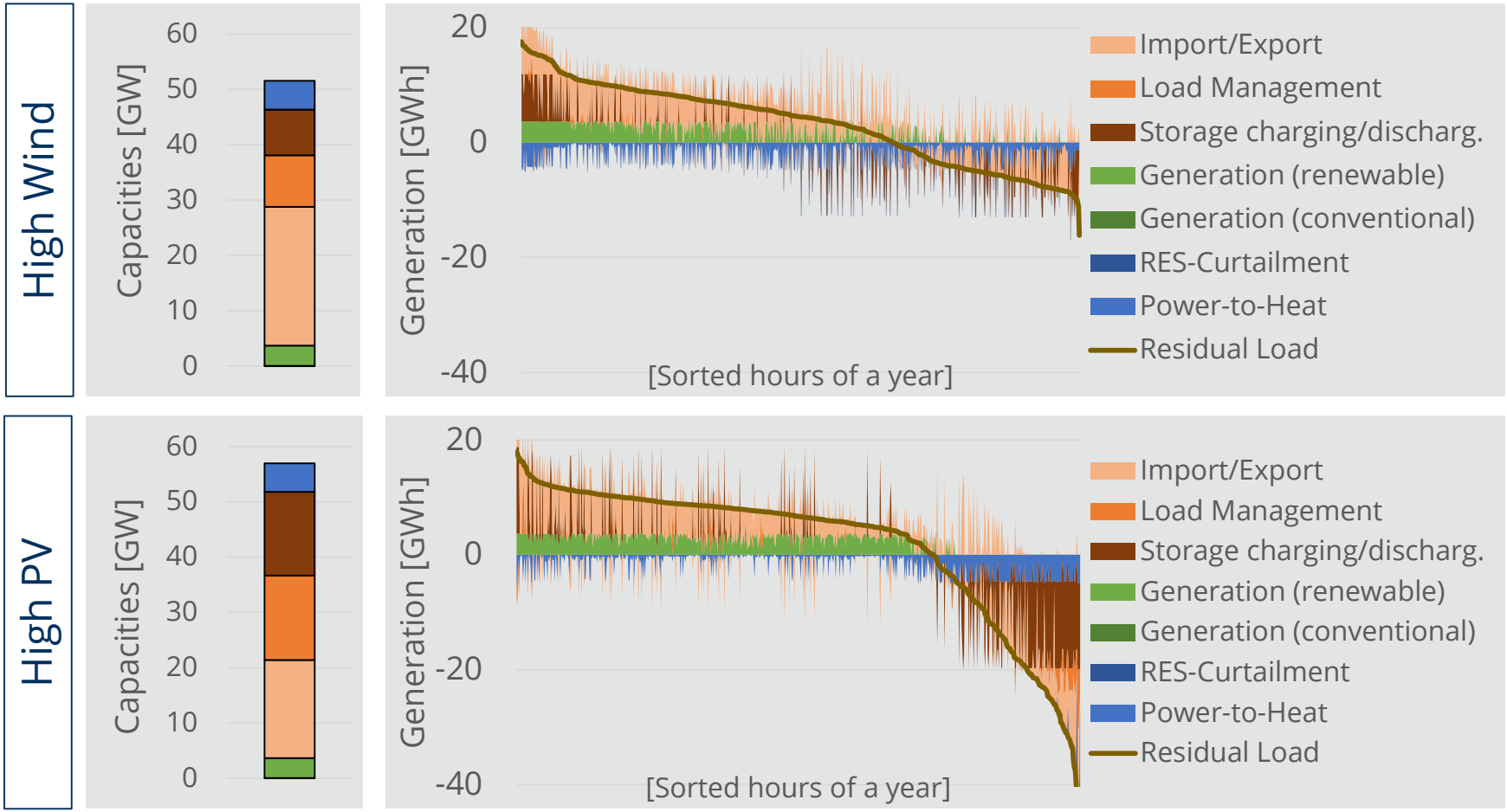
**Which effect does the PV-Wind- Mix have?**

# Using and extending ELTRAMOD

| Input | Linear Optimization | Output |
| --- | --- | --- |
| • Hourly profiles for load and RES generation for 17 countries<br>• Conventional power plants<br>• Export/import capacities (NTC) for transnational exchange | Objective: cost-minimizing investment and dispatch of flexibility options | • Installed capacities<br>• Generation and use of electricity<br>• System costs<br>• Emissions<br>• … |
| **Model Extensions** | | |
| • In total 21 flexibility options including storages, RES power plants, DSM processes, Power –to-Heat<br>• Technical and economical characteristics: efficiencies, number of activations, shifting durations, fuel costs, investment costs, ramp-up and –down costs, … | • Additional restrictions for observed flexibility options<br>• Endogenous investment decision<br>• Greenfield approach | • Optimal combinations of flexibility options<br>• Synergies and competition of technologies<br>• Interaction between need for flexibility and flexibility provision |

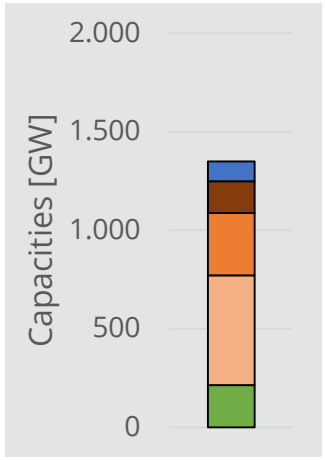
# Installed capacities and Meeting of the Residual Load

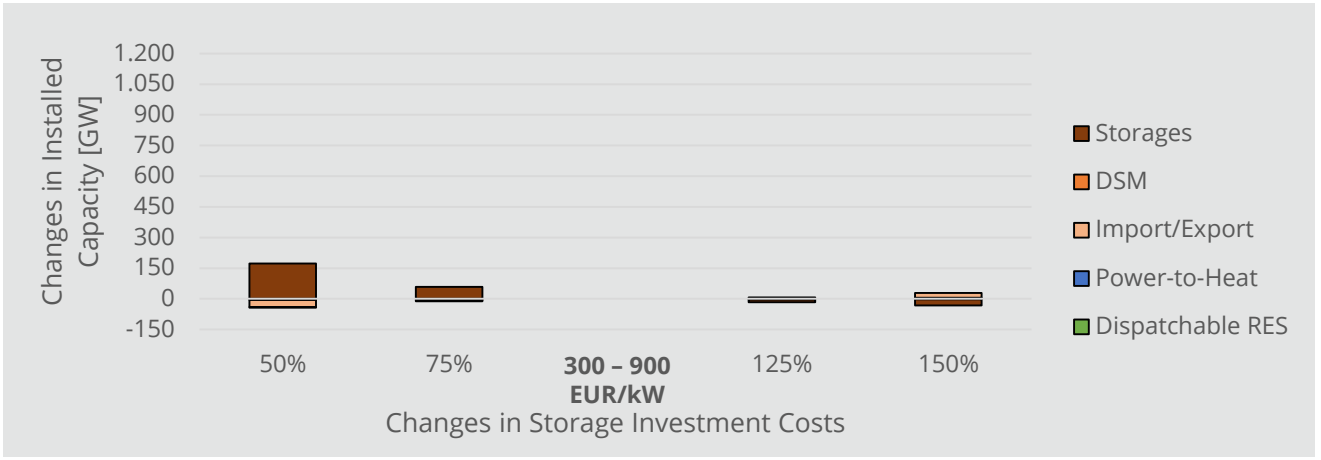
## Example: Netherlands



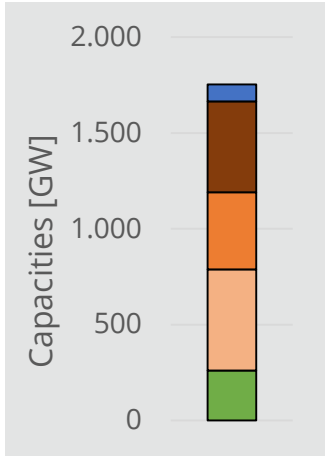
# Sensitivities of Investment Costs on Total Installed Capacities – Example: Storage

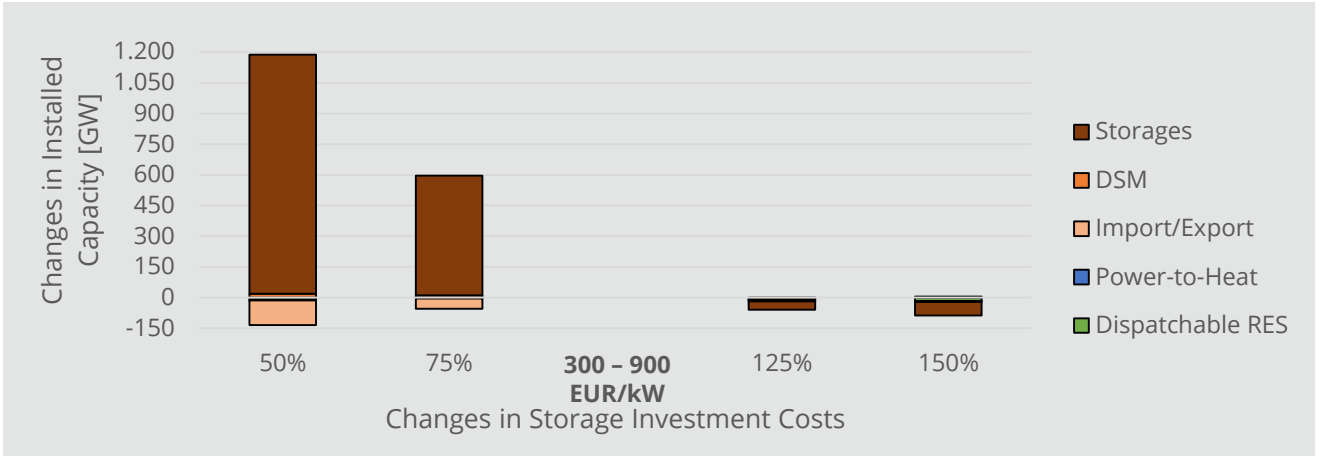
High Wind




High PV



# Summary

- PV-Wind-Mix effects optimal combinations of flexibility options regarding the optimal investments and dispatch
- Availability and Simultaneity of RES generation have high influence on flexibility mix
- Technologies to shift energy regionally and temporarily play a major role in the flexibility provision
- When investment costs are increased/decreased these effects increase/decrease optimal investments in flexibility options

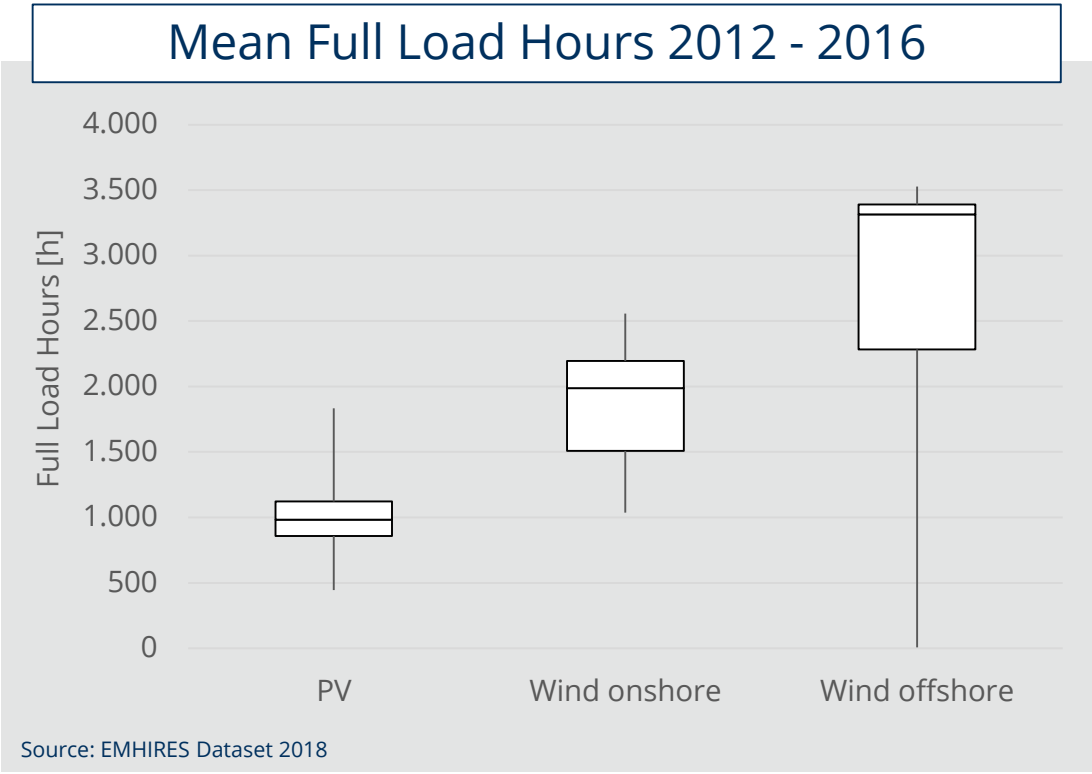
# Thank You for Your Attention

**Christoph Zöphel**
**Christoph.zoephel@tu-dresden.de**

# Some Interactions between need for flexibility and flexibility provision

| | Application | Factors influencing the flexibility need | Value of flexibility option |
|---|---|---|---|
| **Power Plants** | • Dispatchable electricity generation | • Availability of fluctuating RES | • Increasing with higher PV share |
| **NTC** | • Regional Shifting of Energy | • Simultaneity of RES generation | • Increasing with higher PV share |
| **Storages** | • Temporal Shifting of Energy | • Simultaneity of RES generation | • Decreasing with higher PV share |
| **Power-to-x** | • Increase Load | • RES surplus peaks | • Increasing with higher PV share |

# Full Load Hours in the Observed Region




Source: EMHIRES Dataset 2018

# Cost Assumptions

| | Flexibility Option | Specific investments [kEUR/MW] [1] [2] [3] | Fuel Costs [EUR/MWh] [4] [5] [6] |
|---|---|---|---|
| **REF** | OCGT | 400 | 33,7 |
| | CCGT | 800 | 33,7 |
| | Coal | 1.300 | 10,4 |
| | Lignite | 1.500 | 1,5 |
| | CCGT_chp | 1.000 | 33,7 |
| | Coal_chp | 2.030 | 10,4 |
| | Lignite_chp | 2.350 | 1,5 |
| | Reservoir | --- | |
| | RoR | --- | |
| | PSP | --- | |
| **DRES** | Biomasse | 1.951 | 35,0 |
| | Geo | 2.740 | |
| | Geo_chp | 2.740 | |
| | CSP | 1.520 | |
| **PTX** | Boiler | 140 | |
| | Wärmepumpe | 1.100 | |
| | PtG | 530 | |
| **SHIFT** | DSM | 0 - 250 | |
| | NTC | 400 [EUR/MW/km] | |
| | HOU | 300 | |
| | DAY | 640 | |
| | SEA | 900 | |