TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Business and Economics, Chair of Energy Economics, Prof. Dr. Möst

Interaction of sector coupling technologies with further flexibility options in energy systems with different PV-Wind shares

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DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

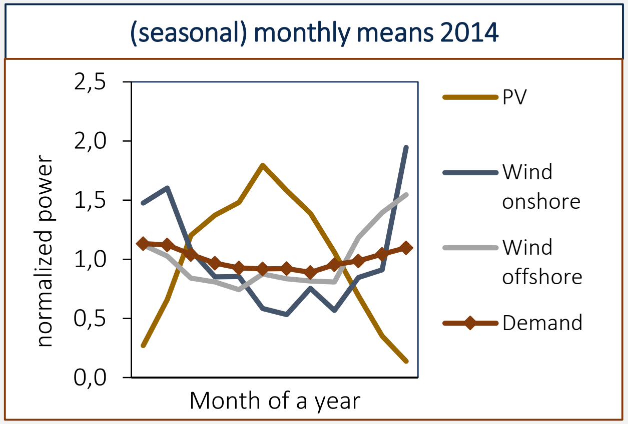
Agenda

1. Motivation
2. Development of high RES scenarios with different wind-PV share in central western Europe
3. Model approach including different flexibility options and sector coupling technologies
4. Results without further restrictions for sector coupling technologies
5. Influence of enforced sector coupling with varying flexibility
6. Summary

Future European renewable energy expansion mainly based on fluctuating renewable energy

Differences in the electricity generation characteristics for wind and PV

- **Availability**
- **Temporal**
  - PV is correlating daily with demand
  - Wind is correlating seasonally with demand
- **Spatial**
  - Day-night dependency of PV generation results in high spatial correlation
  - Stronger local variability of wind generation leads to spatial balancing effects



	Mean hourly correlation	Mean seasonal correlation
PV	0,78	0,98
Wind Onshore	0,25	0,72
Wind offshore	0,29	0,75

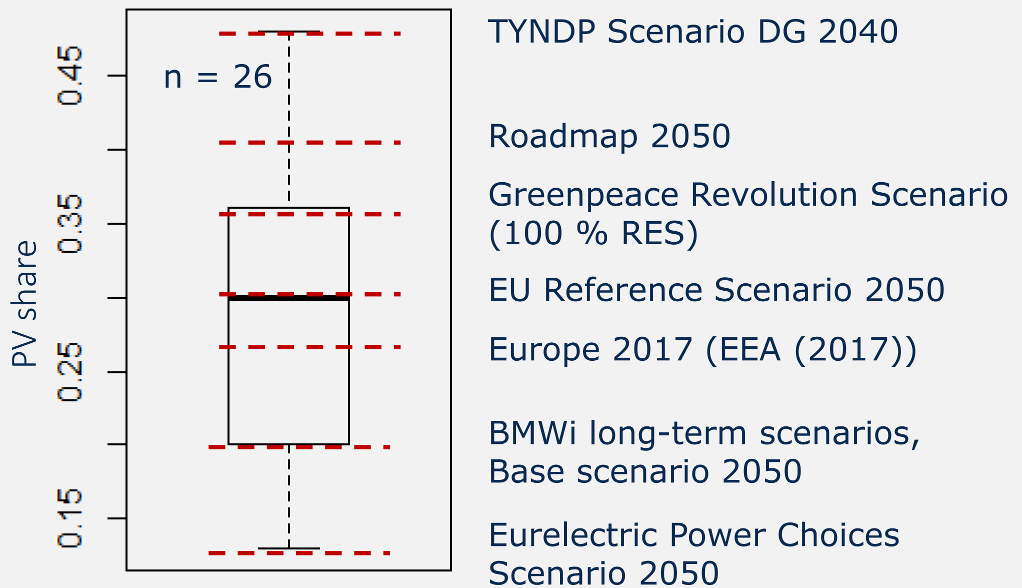
Additionally, future RES expansion not only driven by techno-economical factors, but also by challenges regarding land use and acceptance

Varying future PV shares in Literature as basis for scenario development

Studies included with

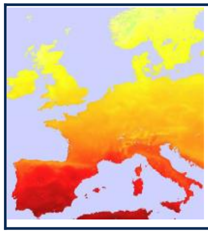
- Europe as observed region
- Scenarios for the years beyond 2030
- Data for installed capacities or generation

PV share in RES generation mix



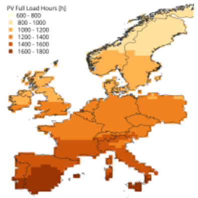
Scenario	PV-Wind share
High PV	50:50
	40:60
REF	30:70
	20:80
High Wind	10:90

Weather- and GIS-Data based optimal wind and PV expansion up to share of 80% of today's electricity demand in CWE



MERRA 2 weather data for
- Solar radiation & temperature
- Wind speed and roughness

GIS based restriction of raster areas
- Nature reserve
- Height and slope
+ urban areas and meadows



Transformation in PV and wind electricity generation time series

Land use potentials for wind and PV

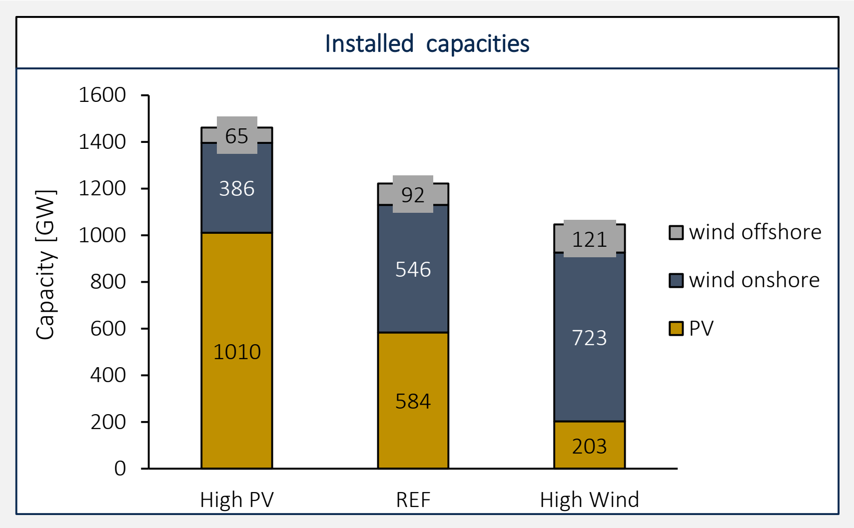
RES potentials for 17 countries (1481 raster à 0,5 ° x 0,625 ° / 68 x 68 km)

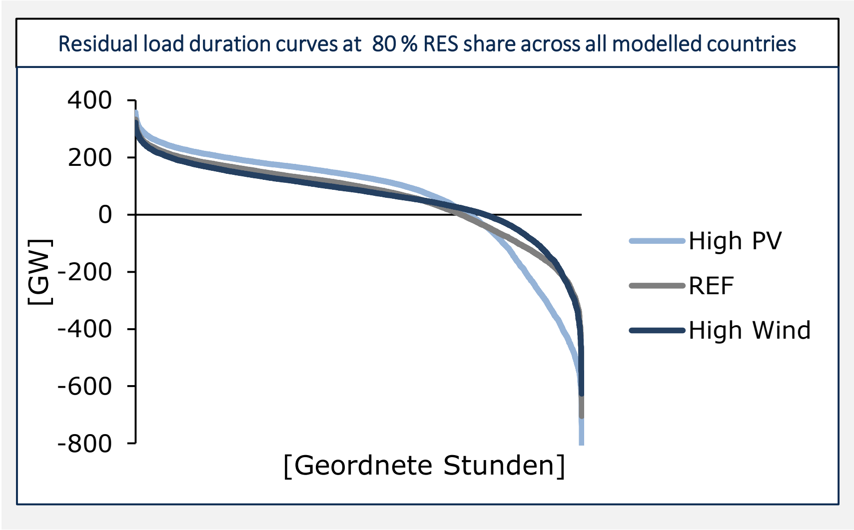
Optimal wind and PV expansion for each of the scenarios and countries

Objective: Minimizing specific investment costs

Restriction:
- Wind and PV share of 80% of today's CWE electricity demand (~ 2,700 TWh)
- Restriction of land use
- Country specific minimal and maximal RES expansion

Resulting flexibility need in the scenarios





- More than 1000 GW fluctuating RES in each scenario
- Lower availability of PV results in higher capacity requirements
- Small differences in positive residual load peak
- Increasing amount surplus energy and negative peak with increasing PV share due to feed in characteristics

Model based analysis of optimal combinations of flexibility options

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Input

Infrastructure

- 17 countries
- Technology specific power plant characteristic
- 3 storages, 6 DSM processes
- Heat pumps, E-vehicles, electrolyser
- European transmission capacity (NTC)

Supply Side

- RES capacity and generation profiles per country
- Prices for fuel und emission
- Costs of flexibility options

Demand Side

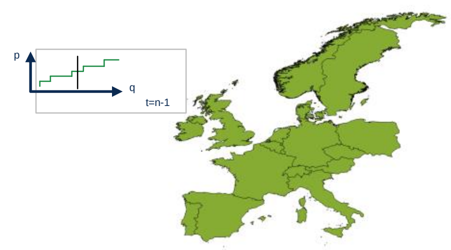
- Hourly electricity demand per country (ENTSO-E 2018)
- Hourly district heat demand profiles per country
- Hourly charging and parking profile for e-vehicles per country

Modelling

Electricity market model (ELTRAMOD)

Endogenous Investment
(Greenfield)

Objective:
Cost minimization of investments
Temporal resolution:
Cluster based selection of 10 representative weeks



Dispatch

Objective:
Cost minimal dispatch of fixed flexible capacities

Hourly resolution
for an entire year

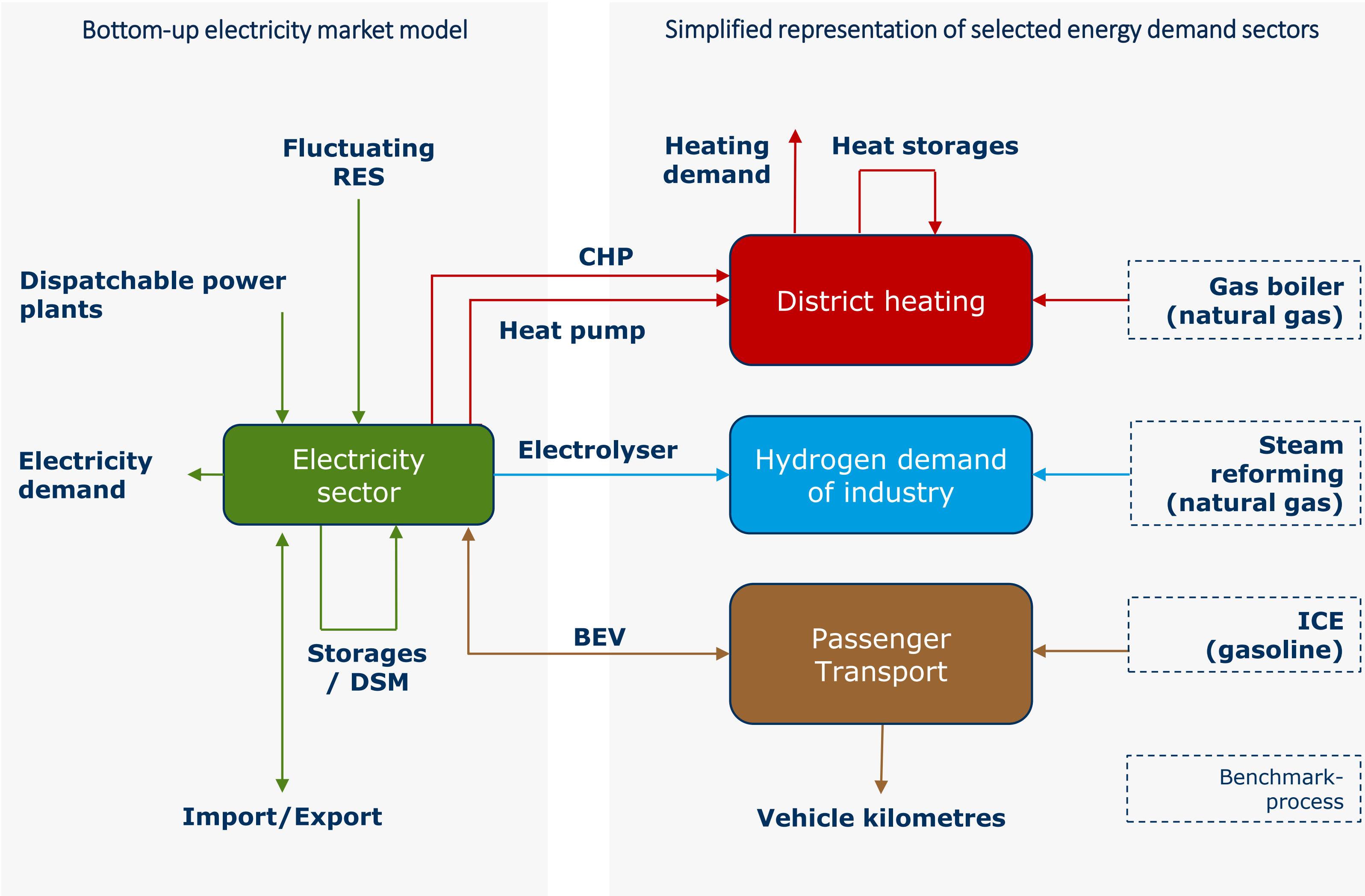
Output

- Installed conventional and renewable capacities
- Installed storage and DSM capacities
- NTC-expansion
- Investment in Power-to-X technologies
- Investment costs

Optimal flexibility mix in an electricity market perspective

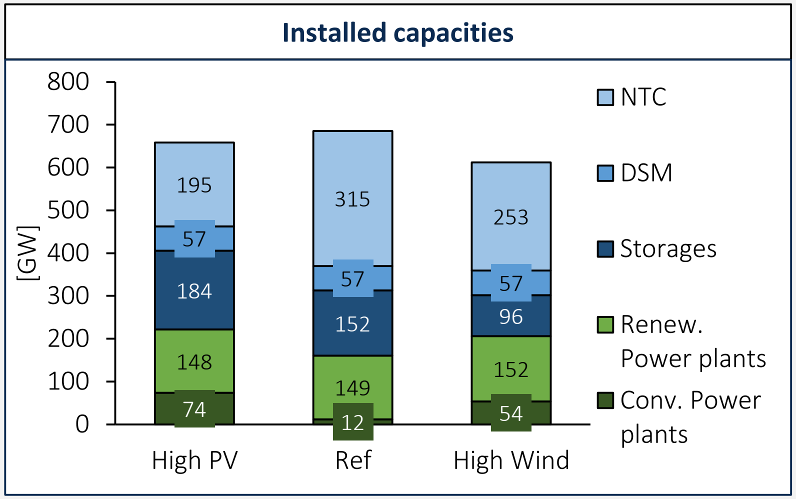
- Technology specific dispatch energy
- Export-Import flows
- Integrated/curtailed RES
- CO_2-emissions
- Dispatch costs

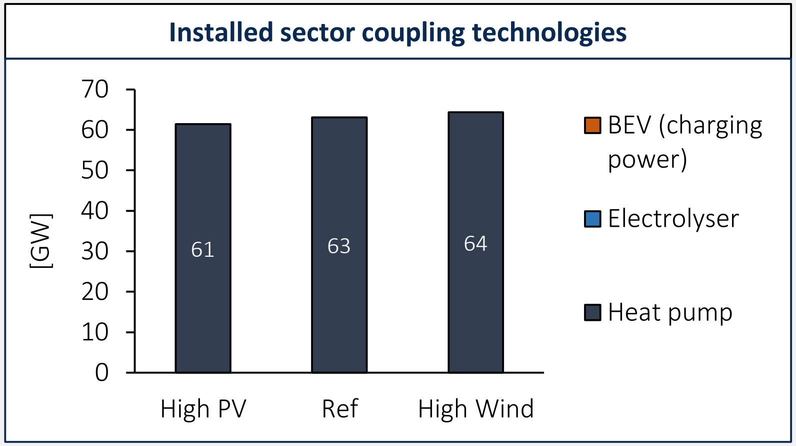
System boundaries and selected sectors coupling technologies



Trade-off between storages and NTC in case of unrestricted endogenous investment in flexibility options

Base scenarios





- High correlation of RES generation results in lowest NTC expansion and highest installed storage capacity in High PV scenarios
- Lowest installed conventional capacities in REF scenario due to storage and NTC mix
- Investment in full DSM potential to balance shorter term fluctuations
- Only endogenous investments in heat pumps due to high opportunity costs of benchmark process

Goal to decarbonise energy system might enforce electrification of parts of other sector

Basic scenarios
No restrictions for energy supply by PtX

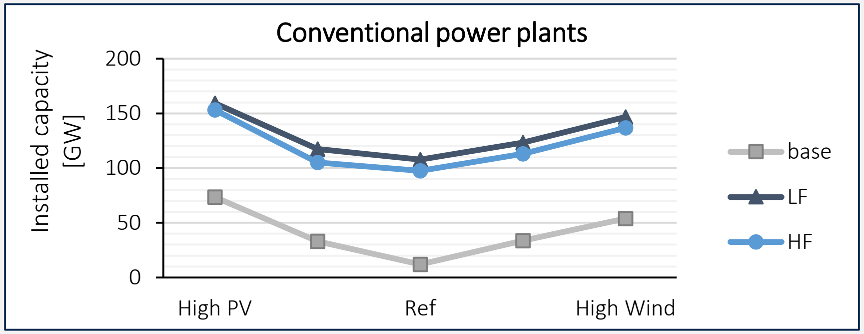
Besides heat pumps no further endogenous investments in Power-to-X (PtX) technologies
→ No electricity market based incentives for sector coupling within scenario framework

↓

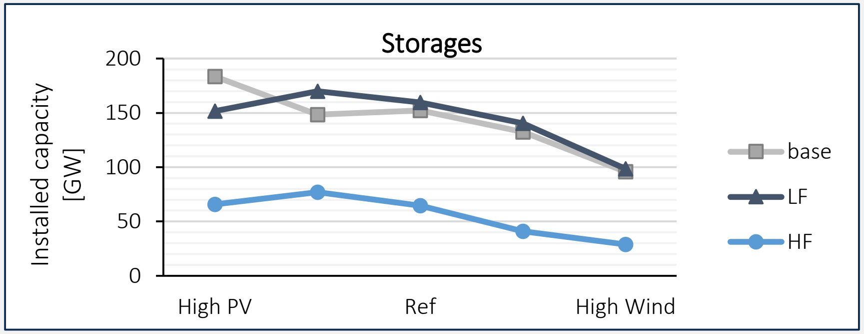
Enforced sector coupling
Exogenous restrictions for energy supply by PtX with low and high flexibility

	Power-to-Heat	Power-to-Vehicle	Power-to-Gas
	• Heat supply by heat pumps to cover 50% of district heat demand • Additional electricity demand: 242 TWh	• 50 % BEV for passenger transport • Charging power: 11 kW • Additional electricity demand: 260 TWh	• 50 % of industries hydrogen demand by electrolysers • Additional electricity demand: 195 TWh
Low flexibility (LF)	• Without thermal energy storages	• Uncontrolled charging	• Maximal full load hours of electrolysers
High flexibility (HF)	• With thermal energy storages	• Bi-directional charging	• With hydrogen storages

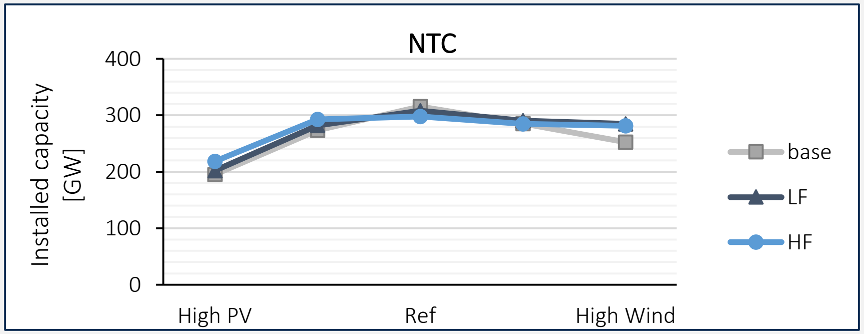
Enforced sector coupling influences investment in flexibility options differently



- Increase in electricity demand requires additional power plant capacities
- Higher flexibility of PtX decreases need for additional power plants



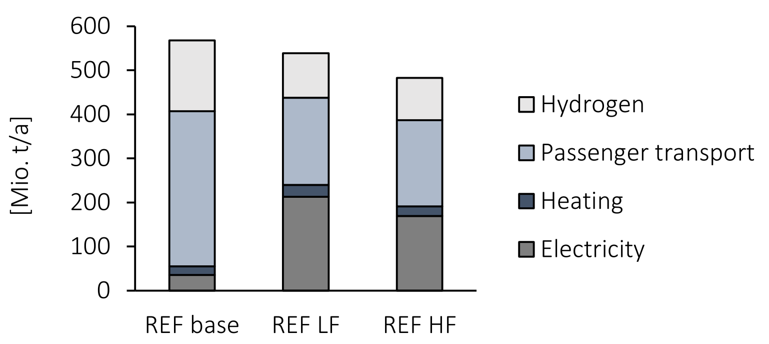
- Low flexibility of PtX technologies slightly increases storage capacities in most of the scenarios
- Significant reduction of storage requirements with highly flexible sector coupling



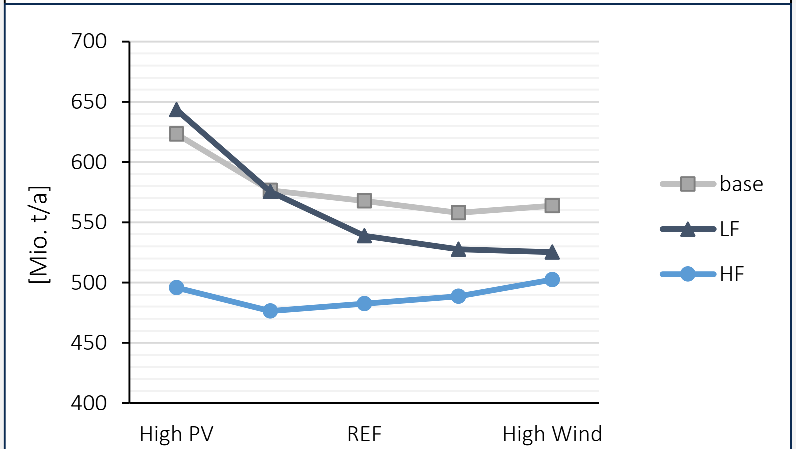
- Small impact of sector coupling technologies on NTC expansion

Wind-PV share and level of flexibility influences the achievable emission reduction by sector coupling

Composition of emissions with different sector coupling approaches (REF as example)



Total emissions* within system boundaries



- Electrification of other sectors decreases emissions in these sectors and compensates increase in emissions in electricity sector in most scenarios
- In base case, highest CO_2 emissions in the High PV scenario, due to highest amount of conv. electricity generation
- For inflexible sector coupling, CO_2 emissions increase with higher PV shares due to discontinuous PV generation and higher conv. electricity generation
- Flexible sector coupling allows for better use of RES surplus phases, resulting in emission reductions by 11 % (High Wind) and 20 % (High PV) compared to base case

*CO2 Emissions include benchmark processes as well as hourly emission factors for direct electricity demand and electricity for sector coupling

Summary

- Lower availability and higher correlation of PV generation lead to higher flexibility requirements in energy systems with higher PV shares
- Wind-PV share in total RES generation influences strongly composition of optimal flexibility provision
- An enforced sector coupling requires additional conventional capacities (if there is no further RES expansion) and less storages capacities
- Nevertheless, further emission reductions can be achieved when electrification substitutes carbon intensive benchmark processes in respective sectors
- Only with flexible sector coupling RES surplus phases can be used optimally and CO_2 Emissions can be reduced significantly

»Wissen schafft Brücken.«