Energy Storage in a Grid with Fluctuating Sources : the German Perspective

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THE ROLE OF STORAGE IN ENERGY SYSTEM FLEXIBILITY
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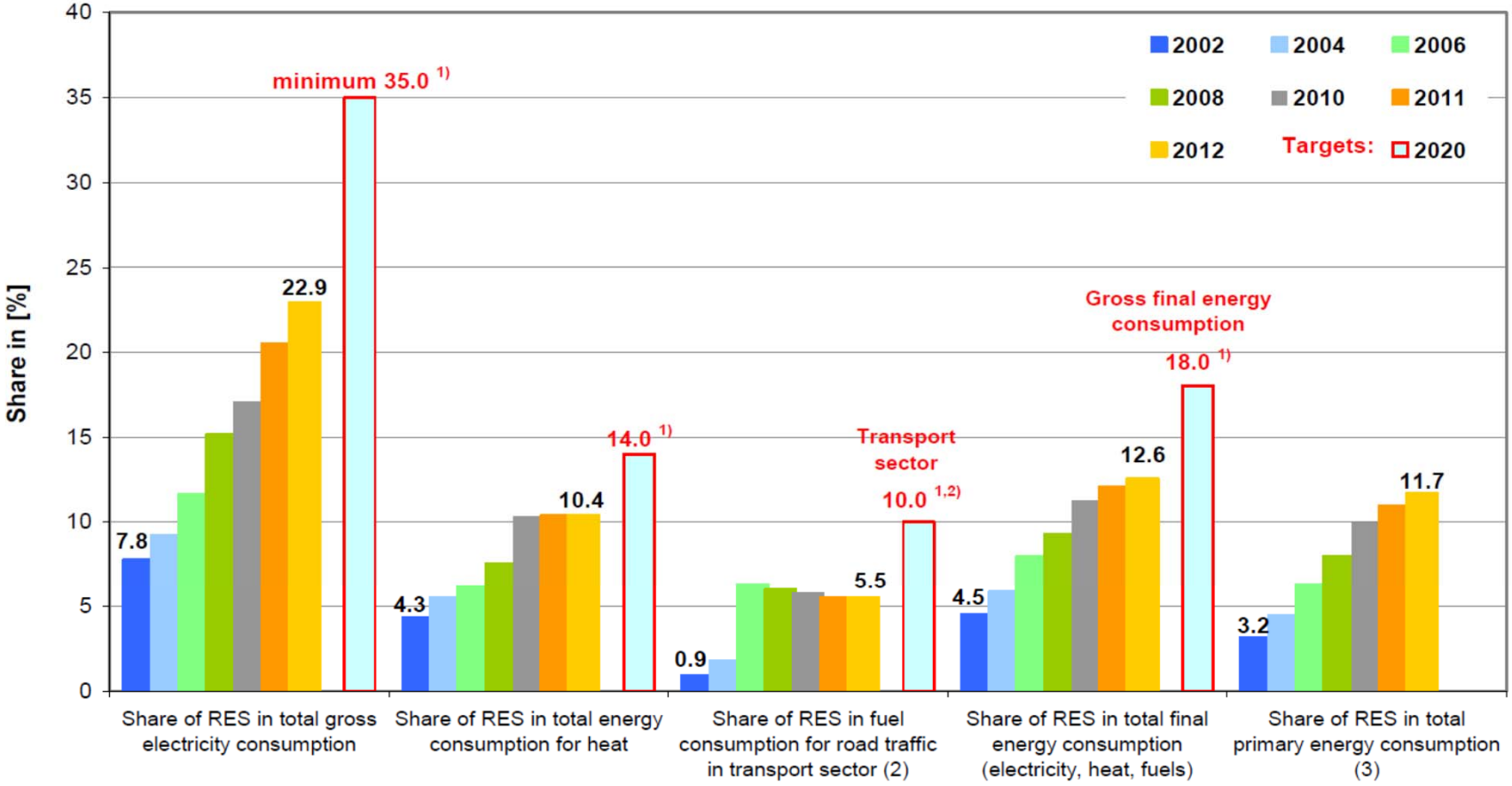
Outline

- Situation in Germany
- Future targets and challenges
- Flexibility options
- Modelling to analyse the options
- Preliminary results
- Summary

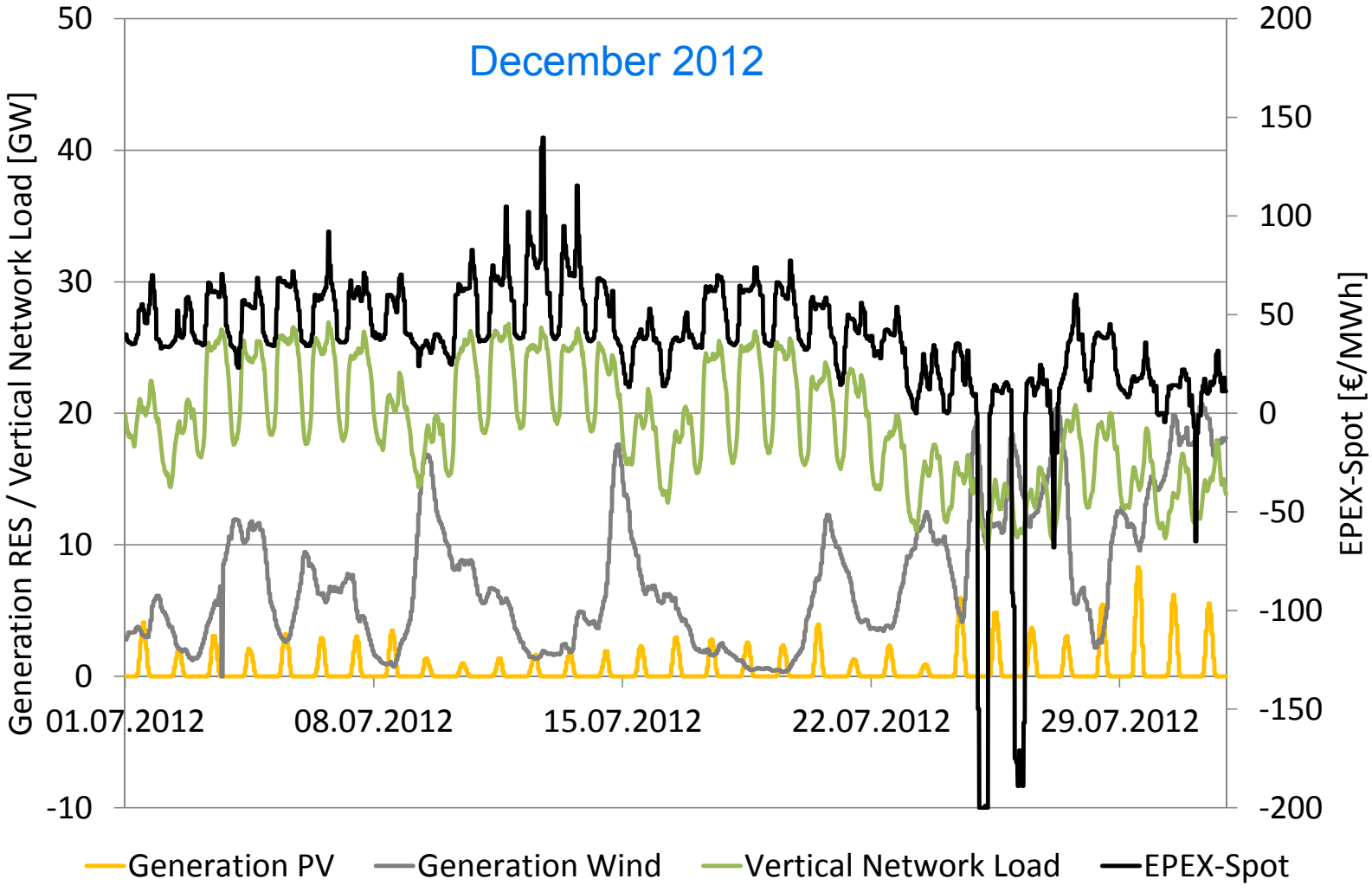
Situation in Germany

Targets for renewable energy sources in Germany and current level of achievement



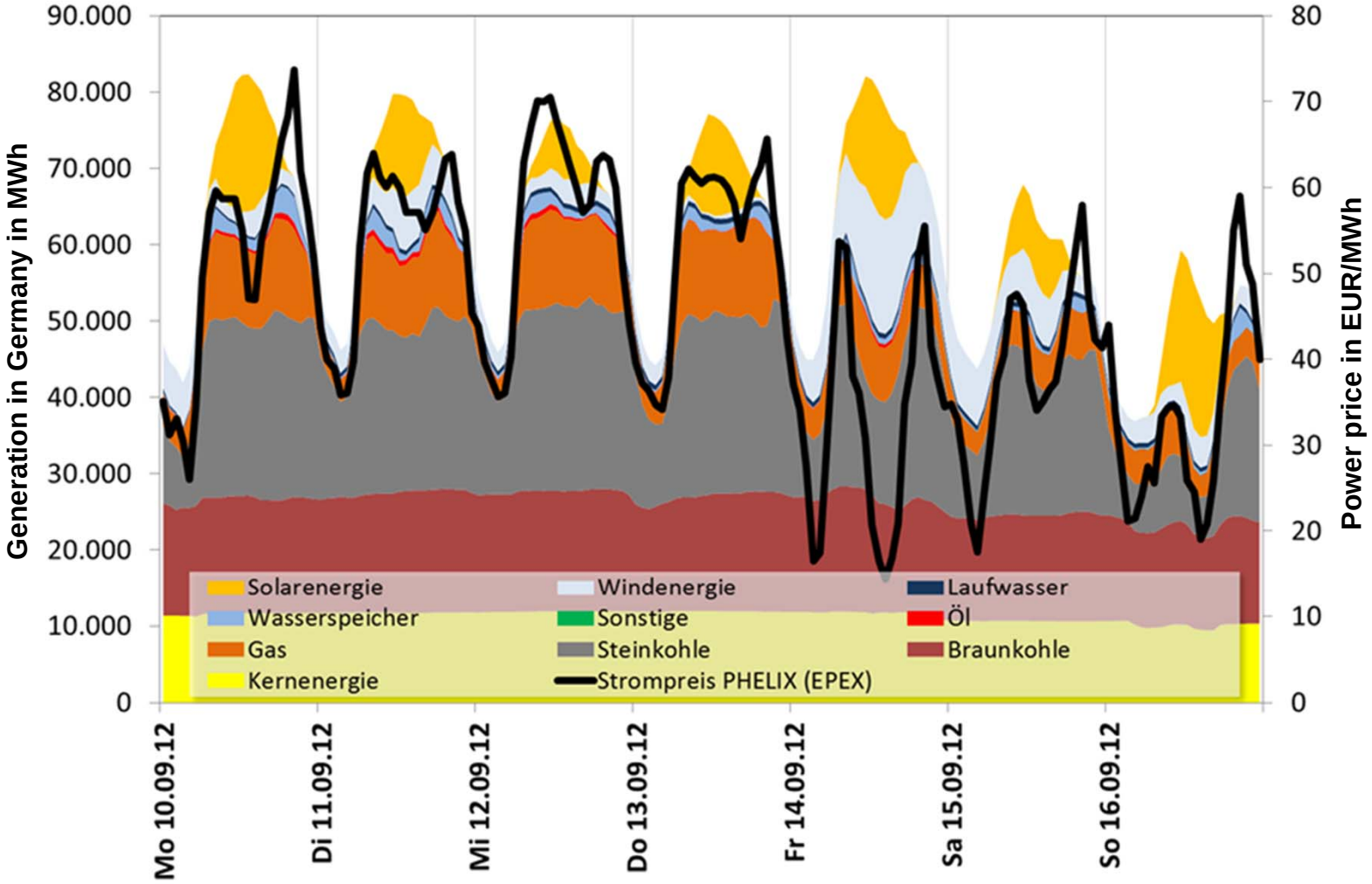
1) Sources: Targets of the German Government, Renewable Energy Sources Act (EEG); Renewable Energy Sources Heat Act (EEWärmeG), EU-Directive 2009/28/EC;
2) Total consumption of engine fuels, excluding fuel in air traffic; 3) Calculated using efficiency method; source: Working Group on Energy Balances e.V. (AGEB); RES: Renewable Energy Sources;
Source: BMU - E I 1 according to Working Group on Renewable Energy-Statistics (AGEE-Stat); as at: February 2013; all figures provisional

Vertical grid load, PV/wind power generation and power prices



Sources:
TSOs, EEX

Impacts on spot market prices today



Sources: EEX, ÜNBs, proprietary estimation

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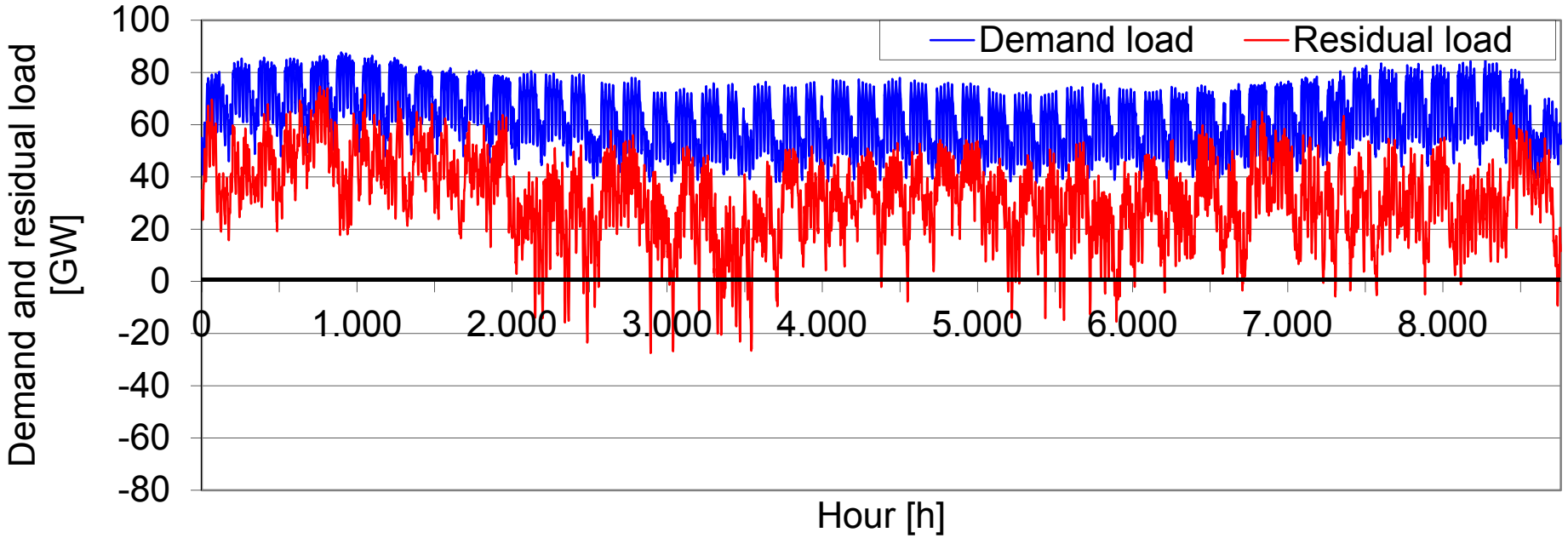
Political targets in Germany: “Energiewende”

- The long-term vision – the age of renewables to be achieved in 2050
- Expansion of the use of renewable energies:
  - Power production from renewables: 35% in 2020, 50% in 2030, 80% in 2050
  - Final energy by renewables: 60% in 2050
- Boosting energy efficiency to cut by:
  - Primary energy consumption: 20% in 2020 and 50% in 2050
  - Electricity consumption: 10% in 2020 and 25% in 2050
  - Climate neutral buildings in 2050
- Complete nuclear power shut down until 2022
- Stick to GHG reduction targets: -40% in 2020; 80 to 95% in 2050
- Electric cars – the vehicles of the future: 2020 one million, 2030 six million

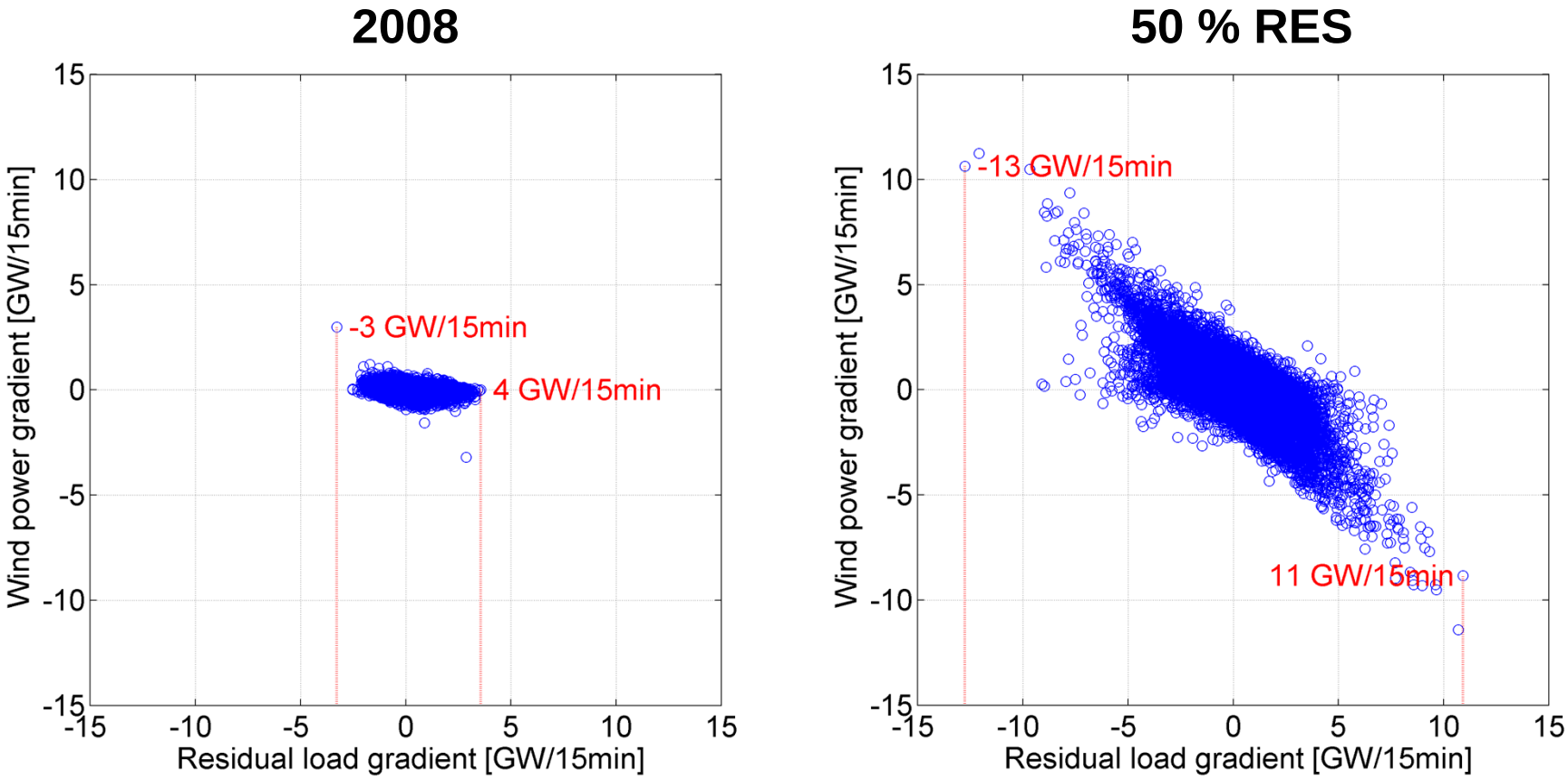
➡ *Role of storage taking into account all the other system developments?*

Demand load and residual load - 50 % share of RES



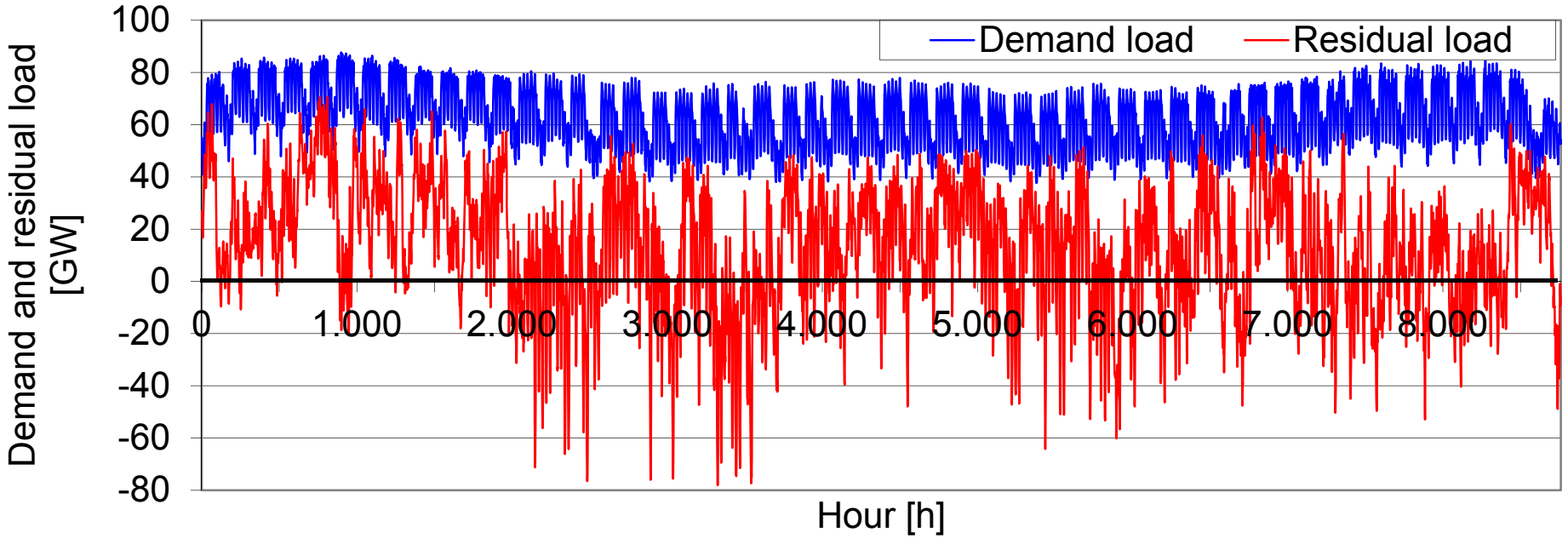
- Excess renewable power up to 27 GW
- Excess renewable production ~ 2 TWh, about 1 % of the electricity produced by wind and photovoltaics
- Storage capacity requirement ~ 250 GWh

Dynamics of residual load



- Strong increase of the residual load gradient with increased share of fluctuating production
- Range of residual load change ± 60 GW_{el} (50 % share of renewables)

Demand load and residual load - 80 % share of RES



- Excess renewable power up to 78 GW
- Renewable surplus production ~ 43 TWh, about 13 % of the electricity production by wind and photovoltaics
- Storage capacity requirement ~ 6,4 TWh

Required grid extension and reinforcement

Transmission grid

- Grid extension:
  i. AC-lines: 1,500 km
  ii. Additional AC-circuits: 3,400 km
  iii. Upgrading of AC-circuits: 1,200 km
  iv. DC-lines: 2,100 km
- Investment: 22 billion €
- Scenario B 2023:
  i. Wind offshore: 14.1 GW
  ii. Wind onshore: 49.3 GW
  iii. Photovoltaics: 61.3 GW
  iv. Share of renewable energies in electricity generation: 50 %

Source: TSOs, Netzentwicklungsplan , 2013

Distribution grid

- Grid extension based on wind and photovoltaics:
  i. Lines: 380,650 km
  ii. Transformers: 63,000 MVA
- Investment: up to 27 billion €

Source: BDEW, Ausbaubedarf in deutschen Verteilnetzen, 2011

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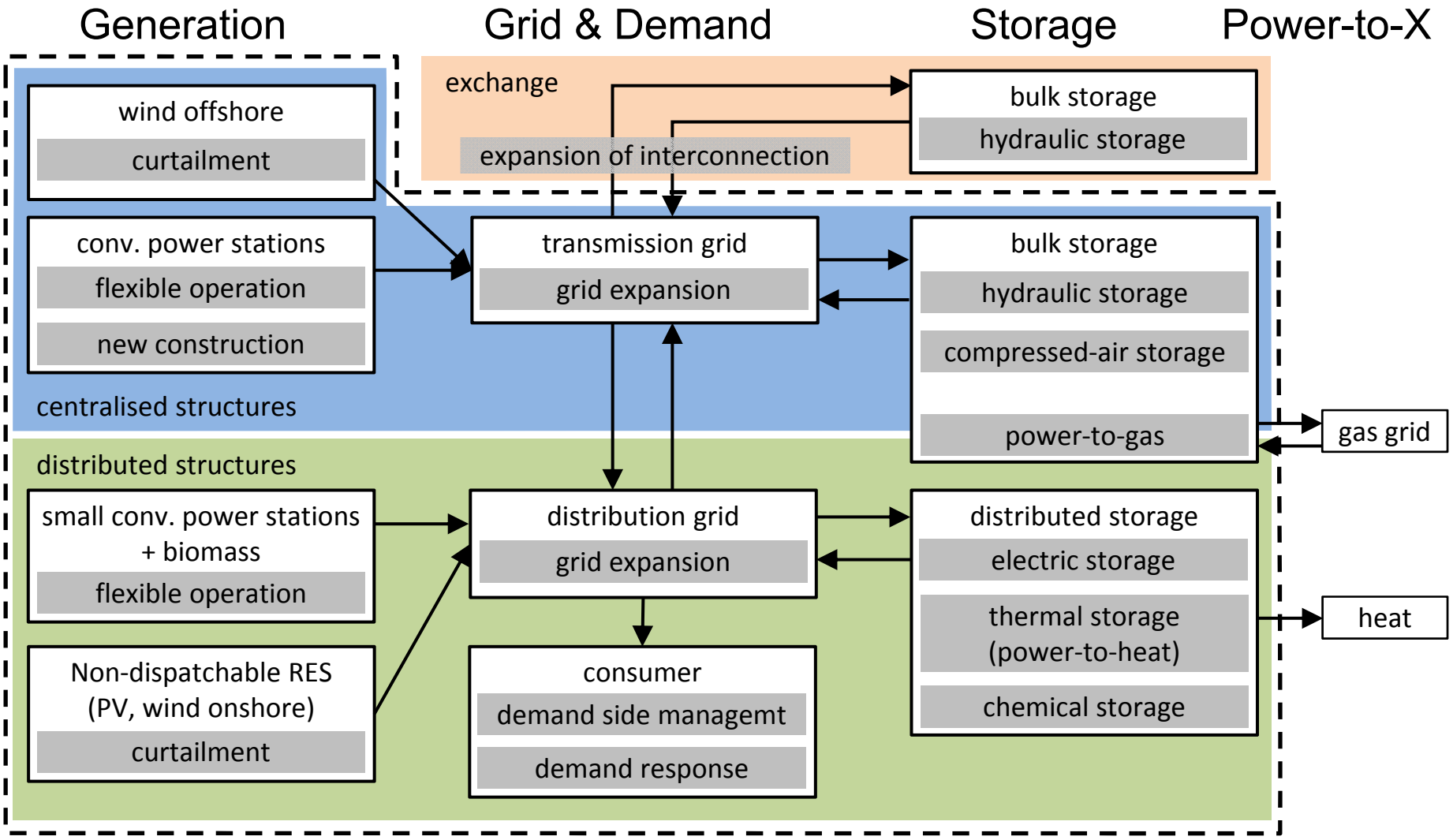
Flexibility options for the electricity system



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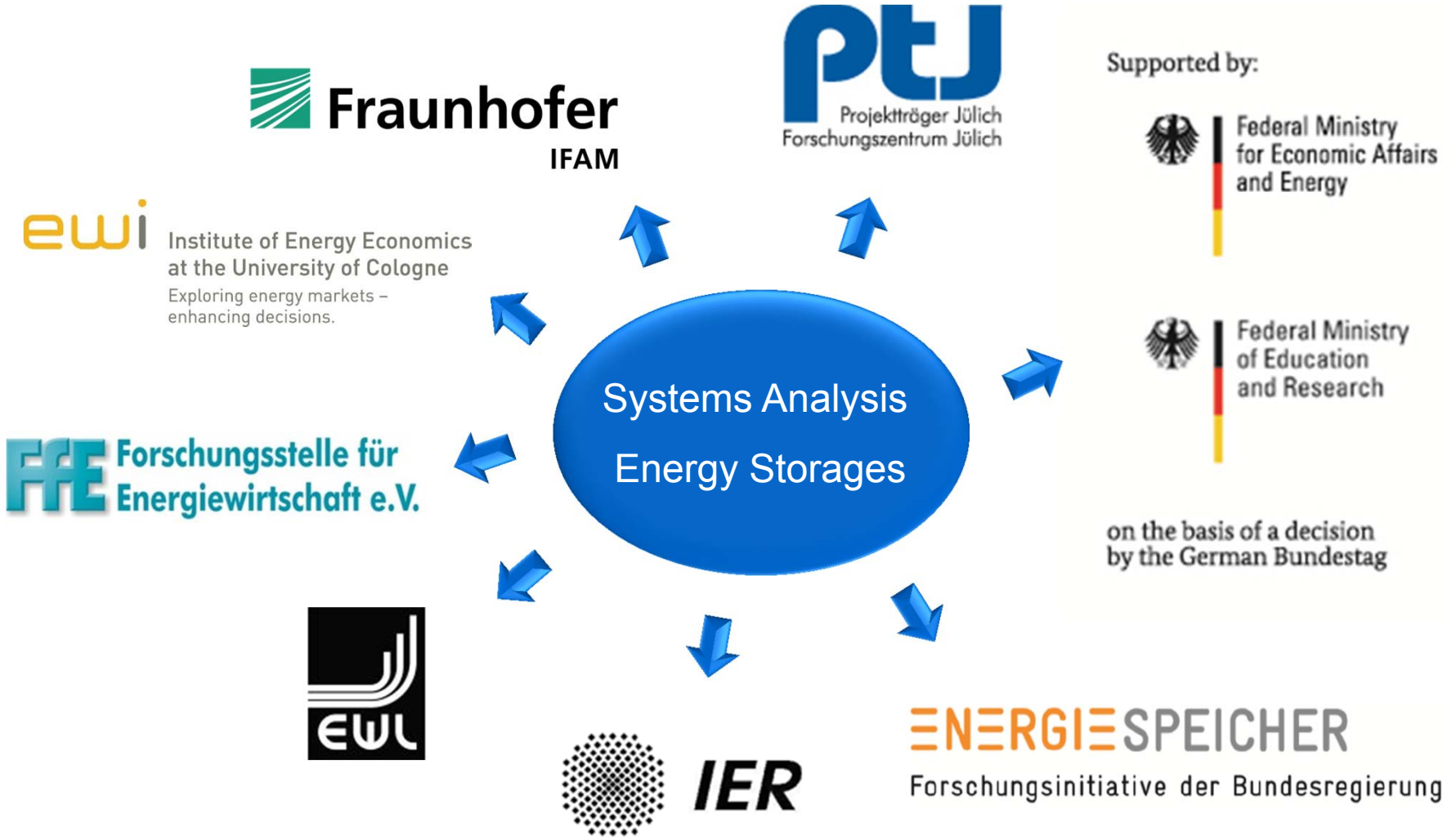
Research network „Systems Analysis of Energy Storages“



IER contribution to „Systems Analysis of Energy Storages“

- System analytics evaluation of energy storage technologies in Germany by an energy economic perspective in the European context
- How can energy storages and load flexibility support the integration of renewable energies in a future European energy supply system at the minimum cost?
- Integrated analysis of the contribution of storage technologies to future requirements in Germany by simultaneous consideration of all important fields of action (electricity, heat, transport – energy efficiency, renewable energies)

To conduct such analysis, further development of the optimisation models TIMES-PanEU and E2M2s existing at IER is required. Especially a differentiated representation of storage technologies, flexible loads and grid expansion has to be implemented.

Short model description

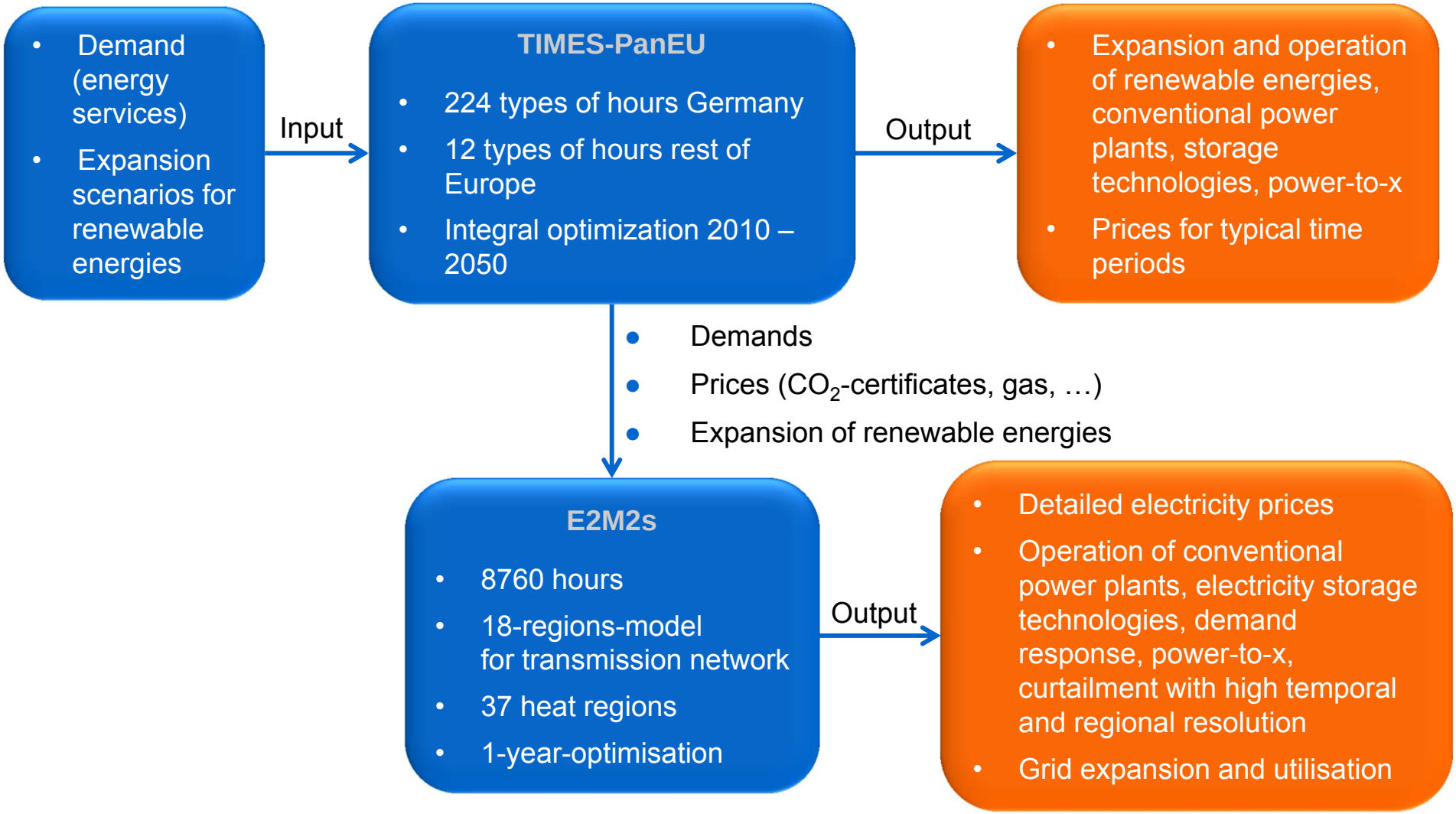
Energy System Model TIMES-PanEU

- **T**he **I**ntegrated **M**ARKAL EFOM **S**ystem, **Pan**-**Eu**ropean
- Linear optimisation model
- 30 regions (EU-28 + Norway, Switzerland)
- Time horizon: 2010 – 2050
- Representing the whole energy system and all energy carriers:
  i. Energy supply (electricity, heat, gas)
  ii. Energy demand, divided into sectors:
    1. Residential sector
    2. Commercial sector
    3. Agriculture
    4. Industry
    5. Transport

Electricity Market Model E2M2s

- **E**uropean **E**lectricity **M**arket **M**odel, **s**tochastic version
- Focus on the electricity system and its interaction with the heat sector (combined heat and power plants)
- Hourly time resolution
- 18 electricity and 27 heat regions in Germany + 29 European countries
- Integral optimisation of investments (power plants, storages and transmission lines) and unit commitment
- Provision of ancilliary services
- Flexibility options (storages, demand response, power-to-x, curtailment)

Model coupling TIMES-PanEU – E2M2s



E2M2s Scenario calculations

- Analysis of the German electricity system on a development path to a 80% share of renewable energies of electricity consumption (60% volatile feed-in)
- Renewable feed-in, electricity demand, fuel- and CO_2-prices are exogenously provided (by TIMES-PanEU model)
- Investment options: conventional power plants (coal, lignite, natural gas, oil) optionally including or excluding carbon capture and storage/CHP, generic electricity storage options with different capacity volume ratios
- Comparison of four scenarios:
  i. Base scenario excluding the options of demand response (flexible electricity demand) or curtailment (limitation of renewable output)
  ii. Demand response only
  iii. Curtailment only
  iv. Demand response and curtailment

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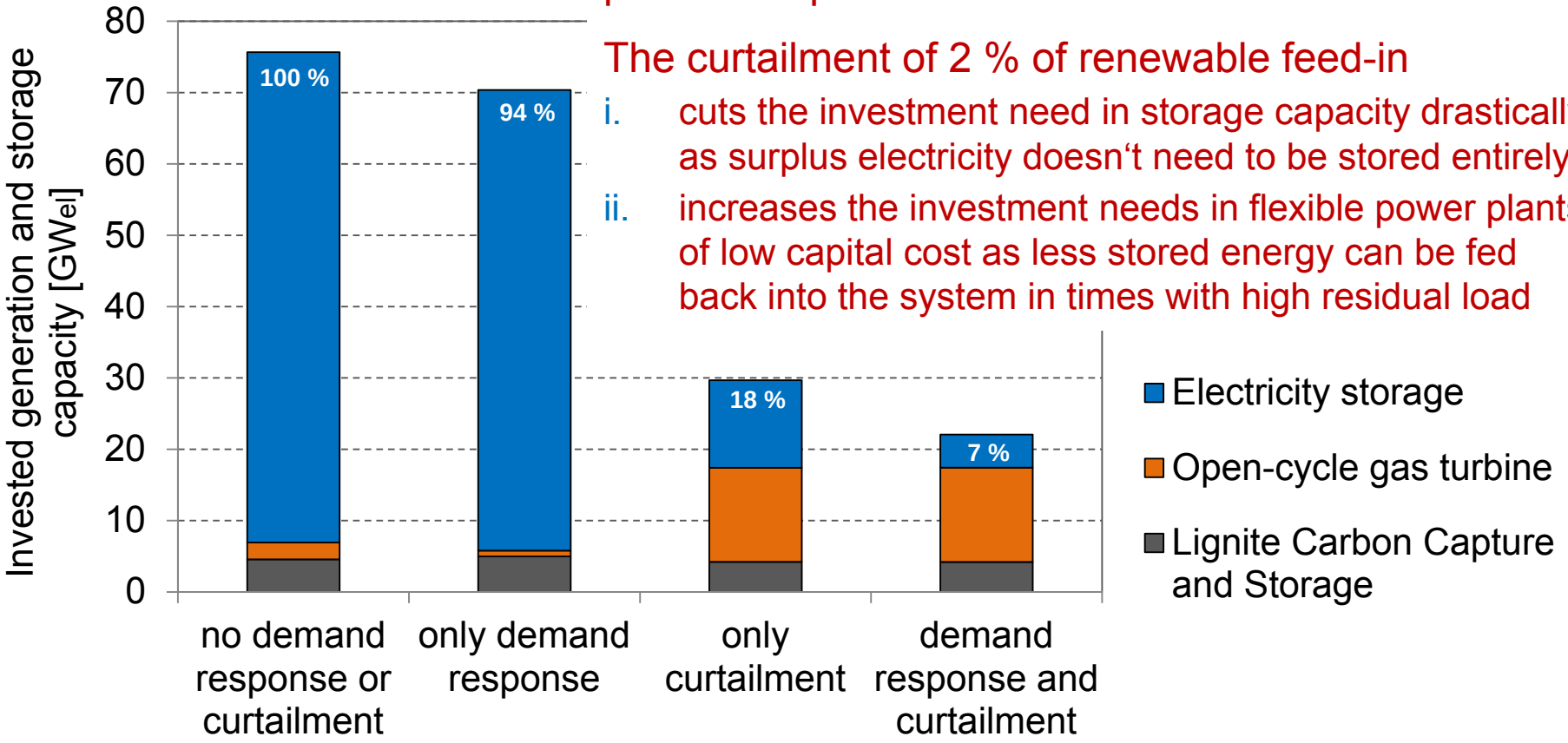
Preliminary results – investments in generation and storage capacity

The application of demand response cuts the investment need in generation capacity by a few percent as peak load is decreased

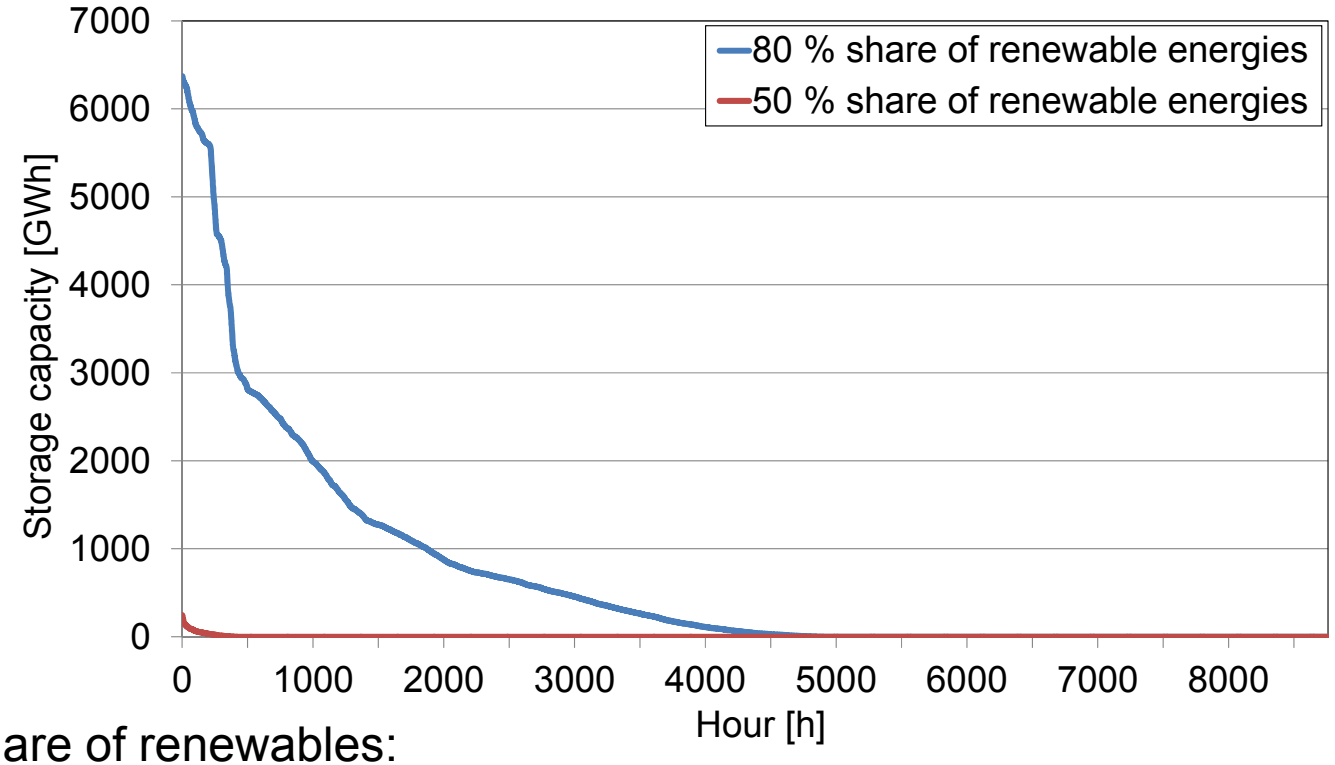
The curtailment of 2 % of renewable feed-in

i. cuts the investment need in storage capacity drastically as surplus electricity doesn‘t need to be stored entirely

ii. increases the investment needs in flexible power plants of low capital cost as less stored energy can be fed back into the system in times with high residual load



Storage capacity



- 50 % share of renewables:
  i. Present German pump storages, planned new pump storages and purchase rights from abroad offer sufficient storage capacities
- 80 % share of renewables:
  i. Cost optimum storage capacity of 4.2 TWh and charging power of 54.8 GW
  ii. Curtailment of fluctuating electricity generation from wind and PV power plants

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Summary

- The transformation of the energy system towards very high levels of fluctuating renewable energy sources requires the development of various flexibility options
- A management strategy has to be developed to ensure the present high level of security of supply in the future also.
- Electricity storages play an important role to the temporal balance between production and consumption. At the same time, it provides the option to include larger fractions of supply from renewable sources into the system.
- However, there are powerful alternative options to improve integration of fluctuating regenerative generation:
  - Improved demand side flexibility reduces the requirement for additional controllable capacity
  - Acceptance of curtailment of renewable feed achieves a strong reduction of requirement for additional controllable capacity
- Analysing the future role of storage in energy systems requires an integrated assessment. This can lead to new insights taking into account the interactions in the overall energy system and the integration in the European context

Thank you for your attention.