Electricity storage demand in European long-term energy scenarios

A sensitivity analysis

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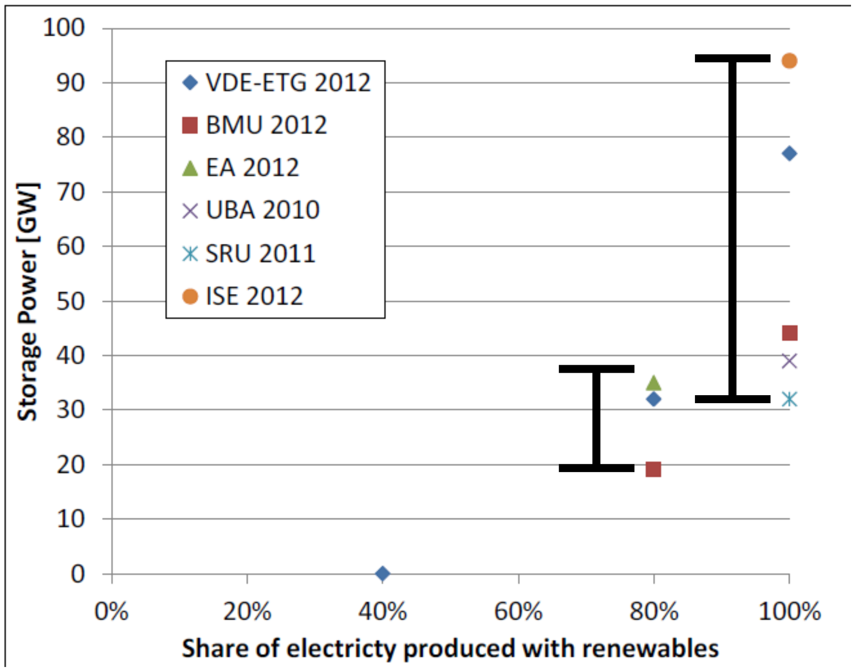
Agenda

1. Motivation & Aim
2. Methodology
   - Model
   - Scenario
   - Assumptions
3. Results
4. Conclusion & Outlook

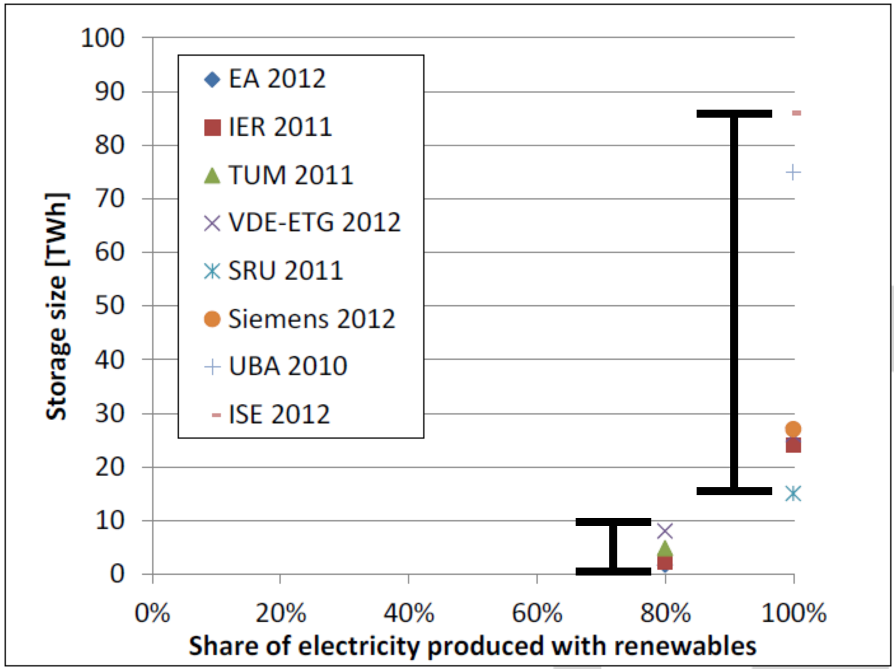
Motivation & Aim

- Research on future electricity storage demand result in broad ranges regarding the capacities and the power

Discharge power [GW]



Storage capacity [TWh]



Motivation & Aim

Different methodological as well as techno-economic assumptions

Methodological assumptions	Techno-economic assumptions
Different model types: optimization, simulation, top-down, bottom-up, agent-based modeling etc.	Total share of renewable generation
Normative scenarios, predefined capacity structures	Ratio of fluctuating to dispatchable generation
Open capacity expansion, greenfield approach	Structure of volatile generation (e.g. wind to pv ratio)
Combined approach: predefined capacity (scenario) and und capacity expansion	Costs and price paths (fuel, CO_2 and investment costs)
…	…

Motivation & Aim

In how far are model-based results of future storage demand robust with regard to uncertain energy economic, political and technical frameworks?

➔ Sensitivity analysis

Testing the influence of:

a) Fuel and emission costs

b) Grid expansion scenarios

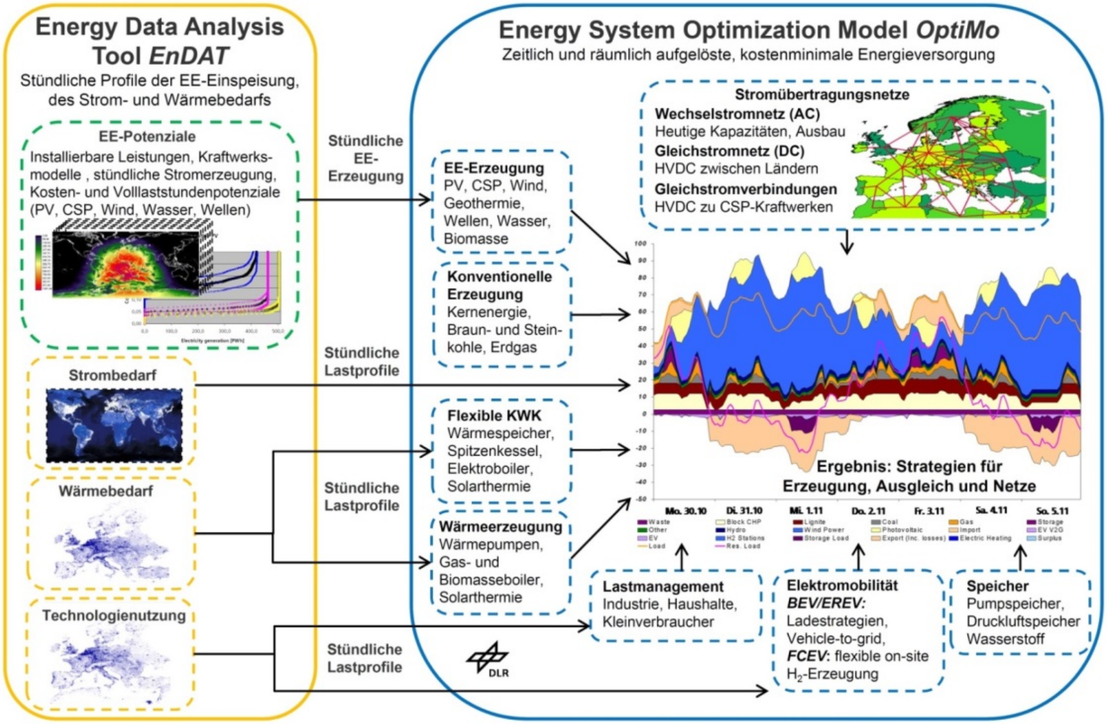
c) Constraints on curtailment of fluctuating renewable generation

d) Scenario vs. greenfield approach

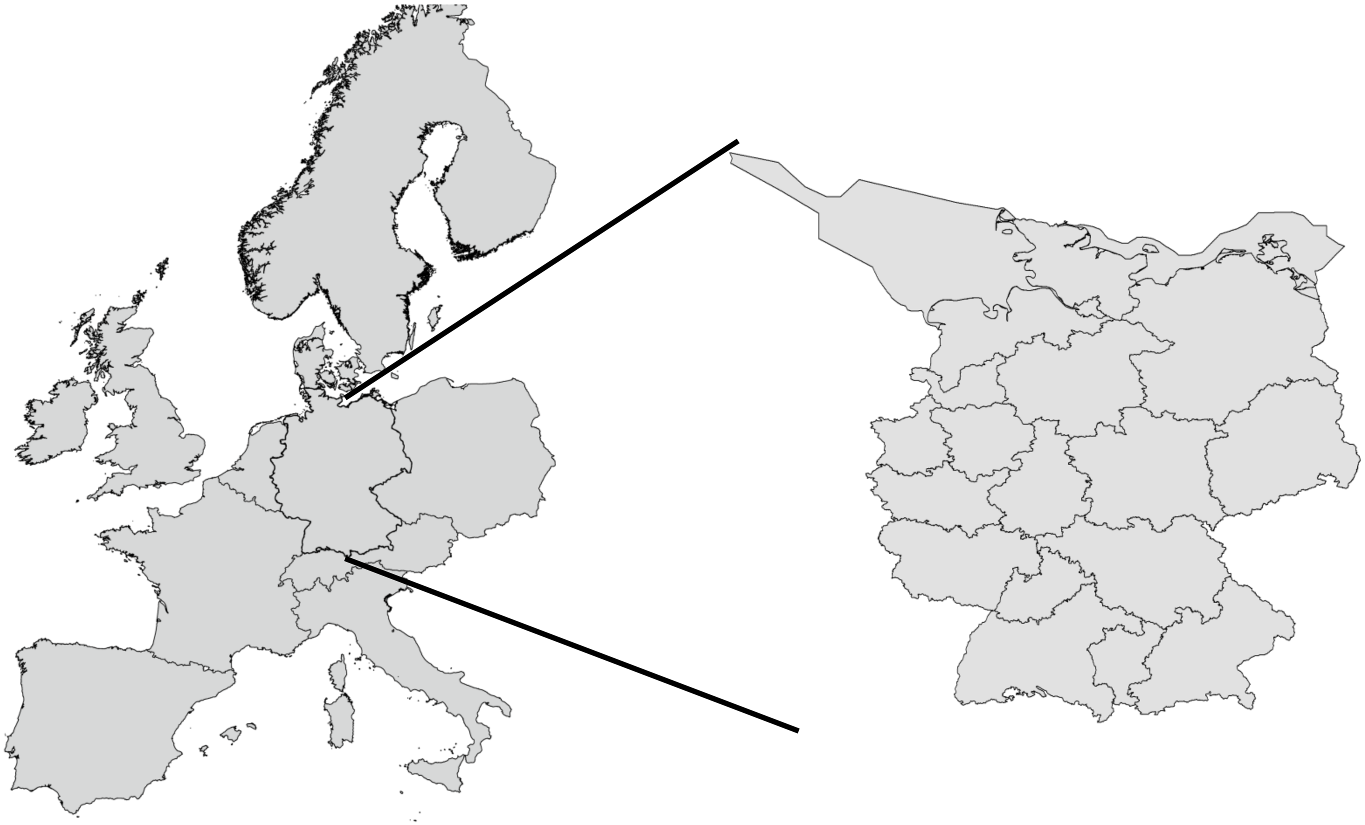
Methodology- model

- Linear bottom-up optimization model REMix
- Cost minimizing dispatch and expansion optimization
- Electricity, heat and transport sector; H_2-infrastructure
- High temporal (1h) and spatial resolution

- Around 20 technology modules which enable different applications:
  - Validation and construction of long-term energy scenarios
  - Validation of balancing options
  - Short-term capacity expansion



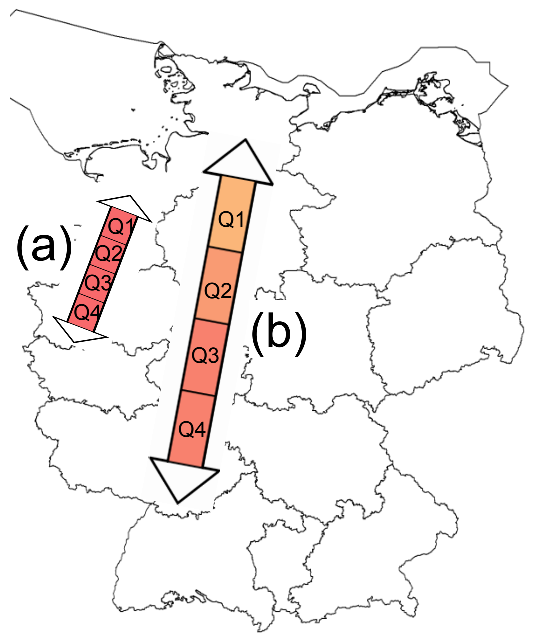
Methodology- scenario I
Model nodes/spatial resolution



- 9 European and 20 German model regions

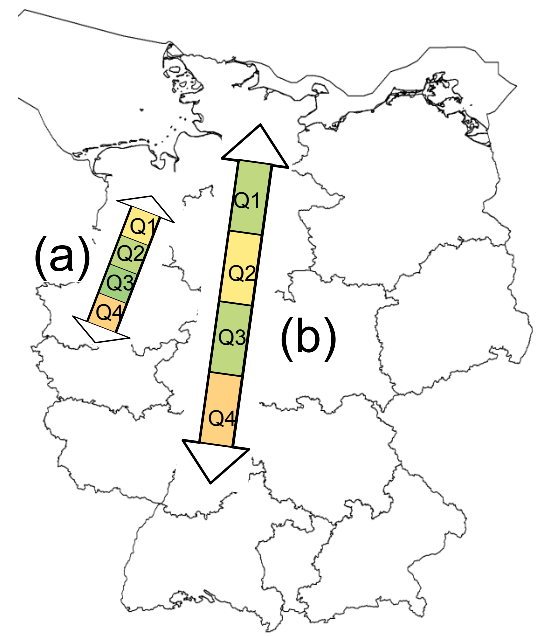
Methodology- Scenario II
Grid scenarios

Restricted grid (G-)



	(a)	(b)
Mean util. [%]	97	83
Numb. of util > 0.98	8,175	4,942

Expanded grid (G+)



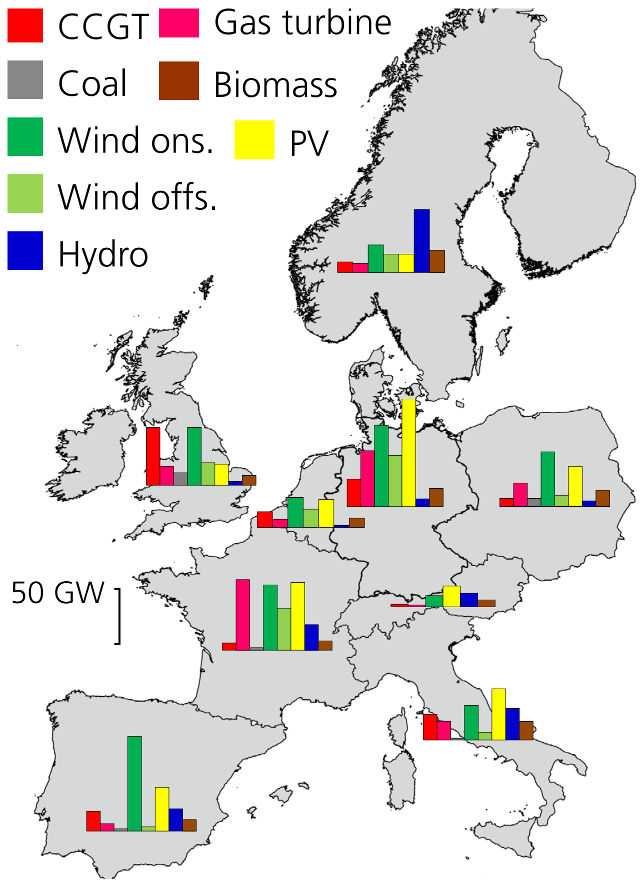
	(a)	(b)
Mean util. [%]	43	48
Numb. of util > 0.98	838	9

Expanded grid, all lines

- Bi-directional mean electricity line utilization over 3 months
- Example links: Tennet2 ⬄Amprion2, Tennet1 ⬄ EnBW1

Methodology- Scenario III
Scenario capacities

- Installed power for Germany based on lead study 2011 scenario A
- Installed power for Europe based on Trans-CSP study (modified)
- Normative target: 80% Renewable generation with regard to the annual gross electricity generation (year 2050)



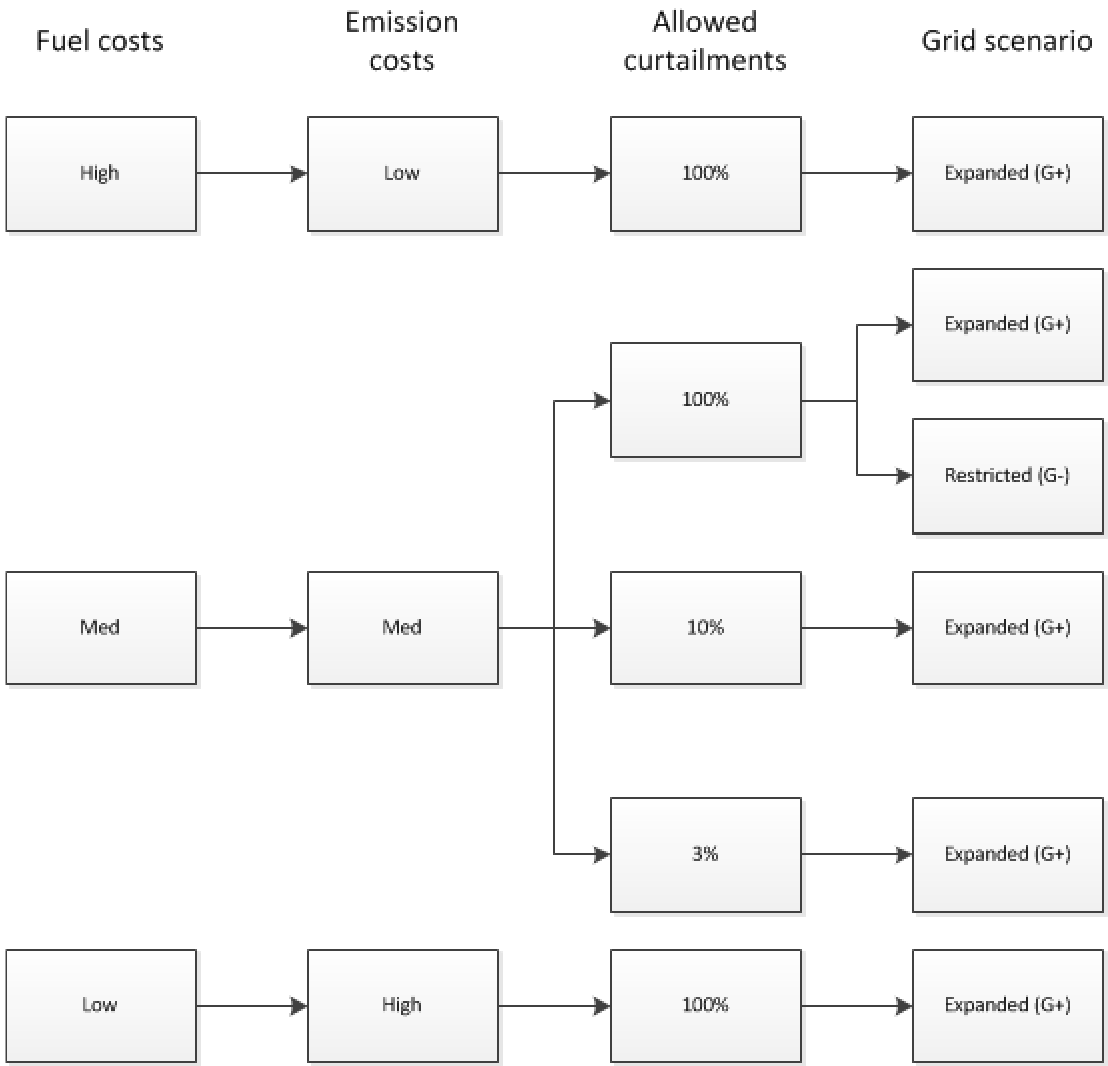
Methodology- Scenario IV

Other assumptions

- 3 curtailment scenarios: 100%, 10%, 3% shedding of annual electricity generation allowed (cur.100, cur.10, cur.3), technology specific
- 5 storages: adiabatic compressed air storage, hydrogen storage (electrification in CCGT), lithium-ion battery, pumped storage, redox-flow battery
- One weather year (2006) and the associated load time series from ENTSO-E
- Expansion options (endogenous): storages and gas turbines

Methodology- Scenario V

Scenario tree



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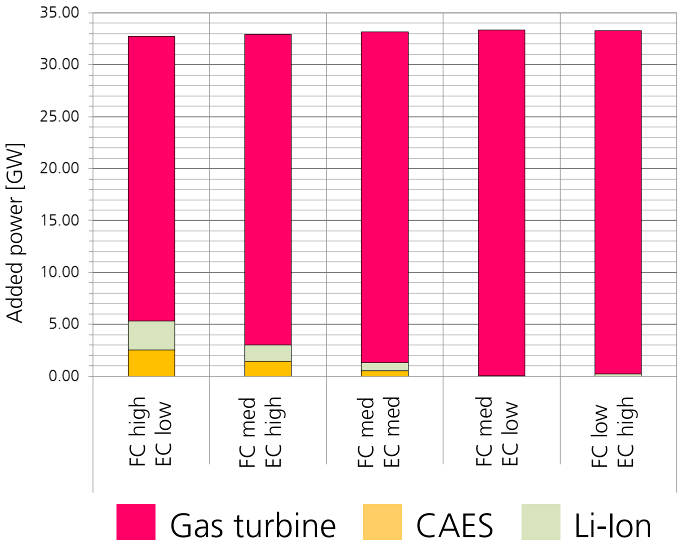
Results I

Total storage and gas turbine expansion

Influence of fuel and emissions costs

- Base scenario: expanded grid + unlimited curtailments
- High fuel costs can quadruple the added storage power, while high emission costs only increase the model endogenous expansion by factor 2
- With lower FC- and EC costs storages are substituted by gas turbines

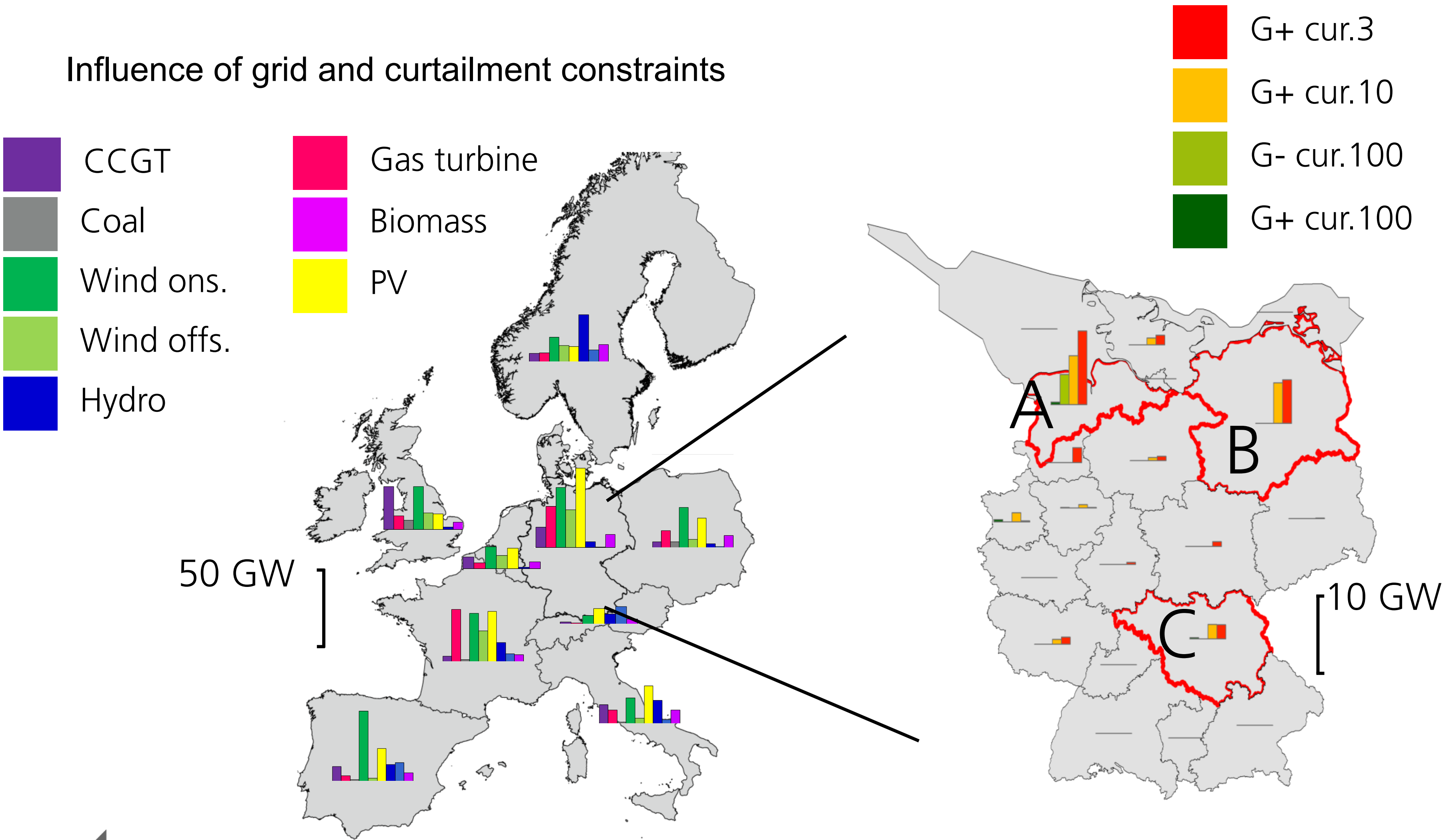


	Fuel costs (FC)	Emission costs (EC)
	low-med-high [€/MWh]	low-med-high [€/t CO_2]
Coal	14 - 21- 35	4 - 47 - 88
Lignite	8 - 9 - 10	4 - 47 - 88
Nat. Gas	33 - 48 - 73	4 - 47 - 88

Results II

Regional storage and gas turbine expansion

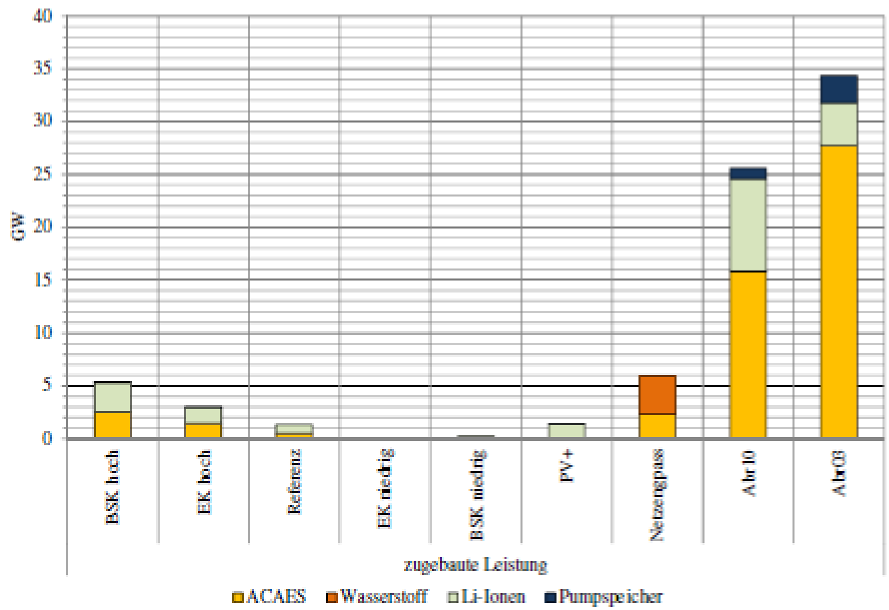
Influence of grid and curtailment constraints



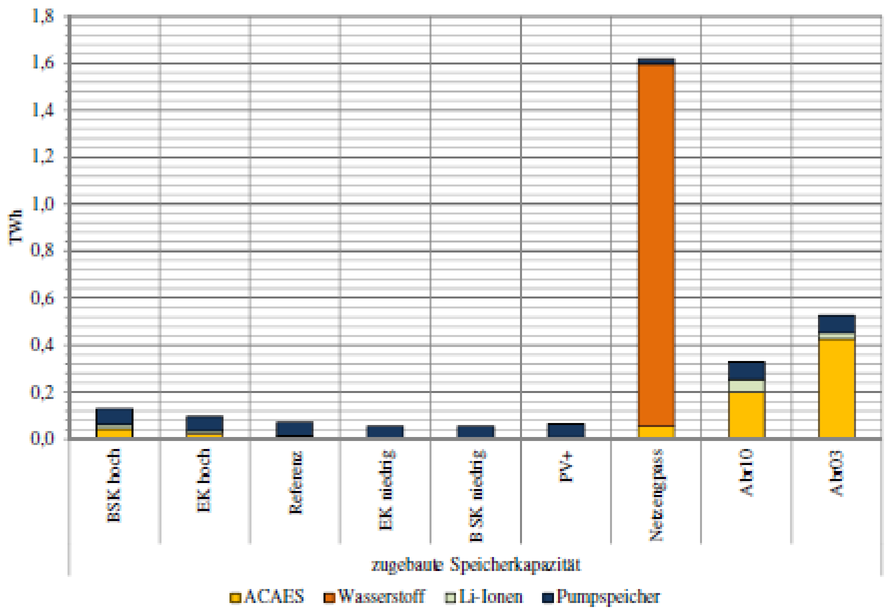
Results III

Scenario specific storage expansion

Discharge power [GW]



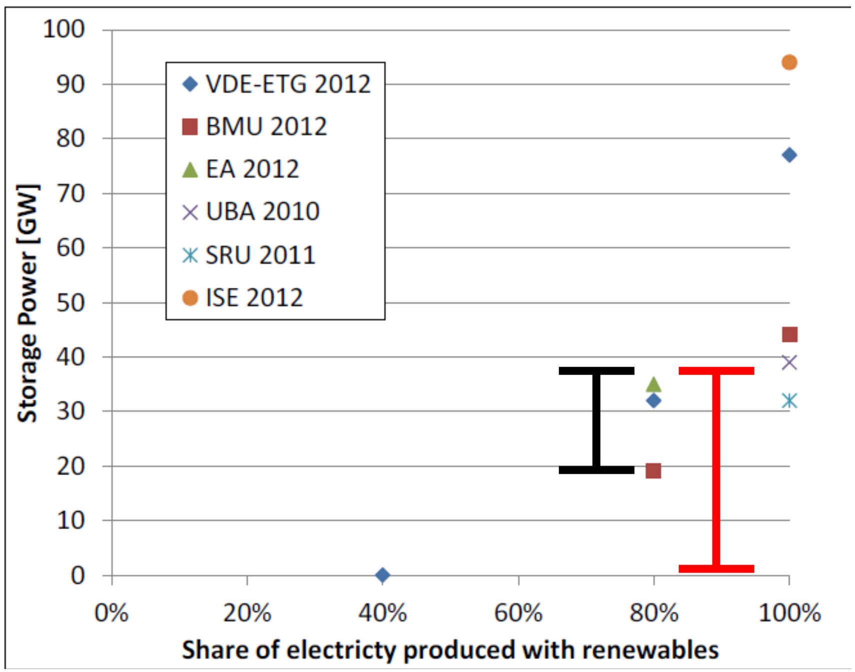
Storage capacity [TWh]



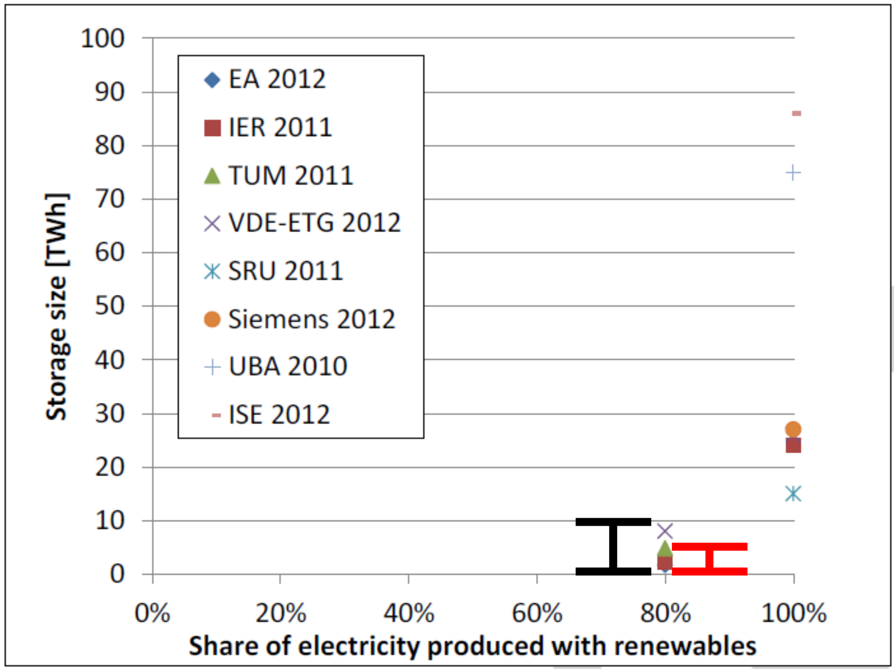
Results IV

Comparison of model results with exiting research

Discharge power [GW]



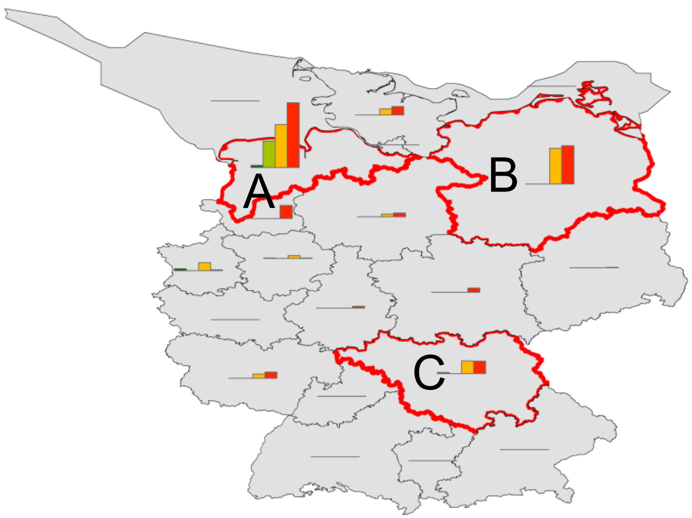
Storage capacitiy [TWh]



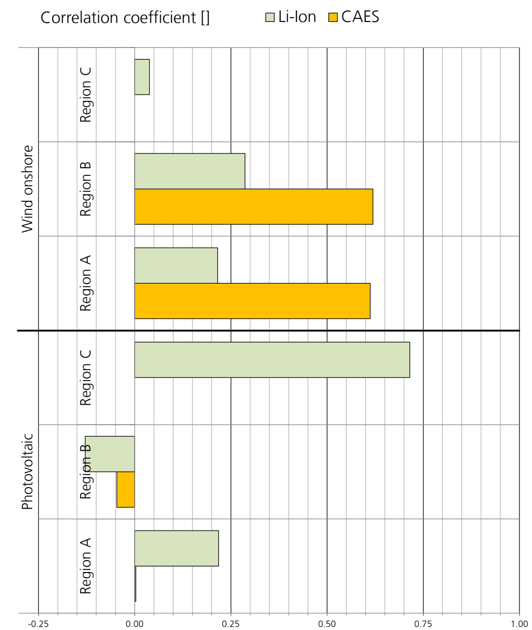
Results V

Region specific storage utilization

Regional storage expansion



Node specific correlation coefficient between discharge power and wind/pv generation

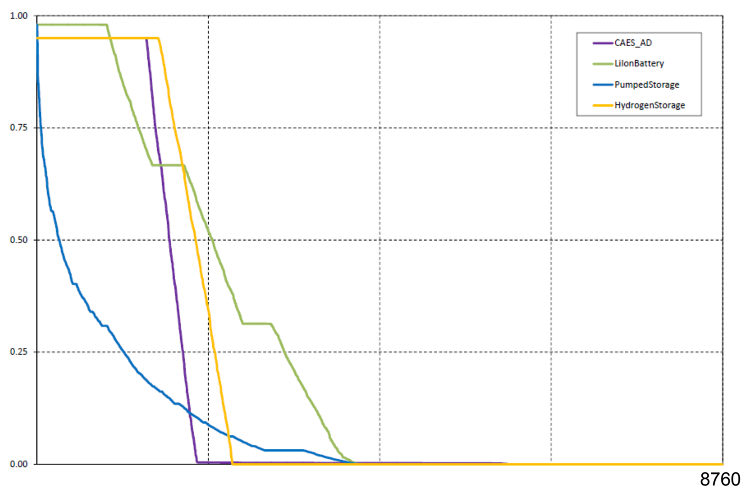


- Storage operation is mainly used for balancing wind power (region A, B), apart from model region C where high PV potentials foster the storage capacity expansion

Results VII

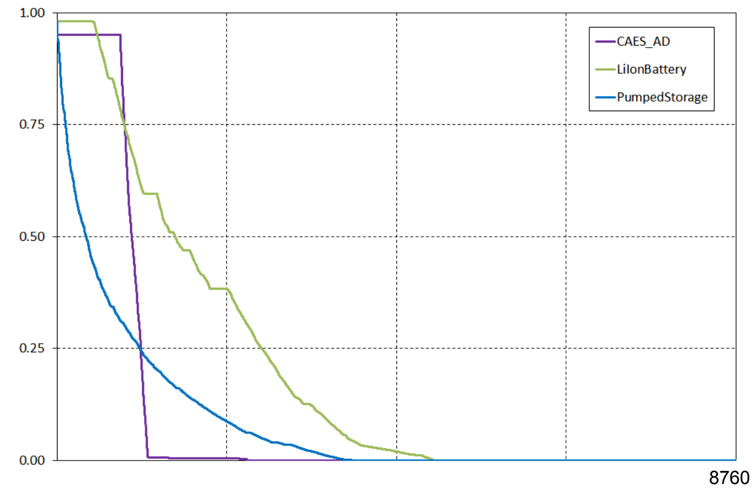
Yearly storage utilization

Restricted grid (G-)



	CAES	Li-Ion	Hydro	Hydrogen
Mean util. [%]	27	55	17	78
Numb. of util > 0.9	1,430	1,017	10	1,615
E2P ratio [h]	22	6	13	446

Expanded grid (G+)



	CAES	Li-Ion	Hydro	Hydrogen
Mean util. [%]	38	37	19	-
Numb. of util > 0.9	829	596	33	-
E2P ratio [h]	14	6	15	-

- Grid expansion substitutes long term storages, such as hydrogen
- Storage utilization decreases significantly within the G+ scenarios (mean util., numb. Of util. > 0.9)

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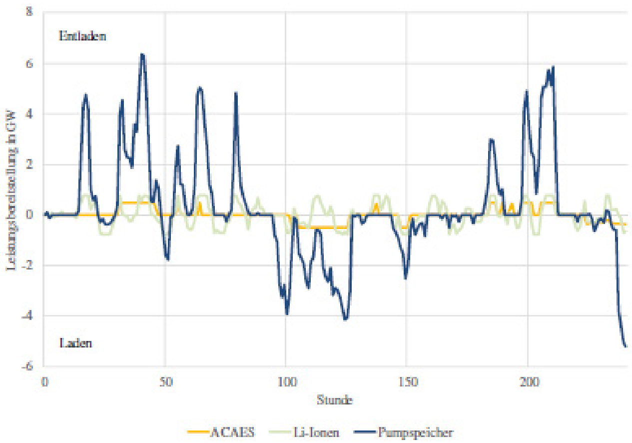
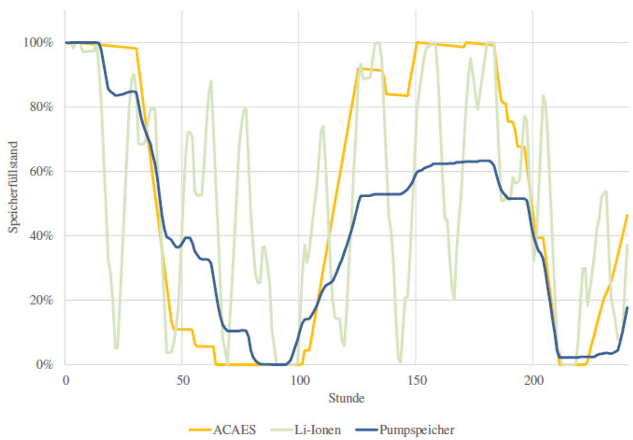
Results VI

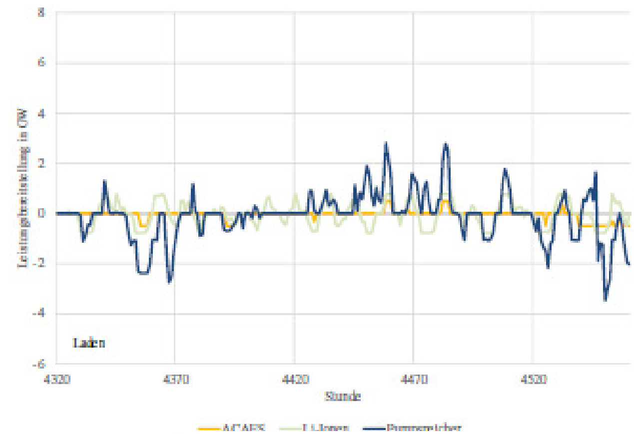
Seasonal storage utilization

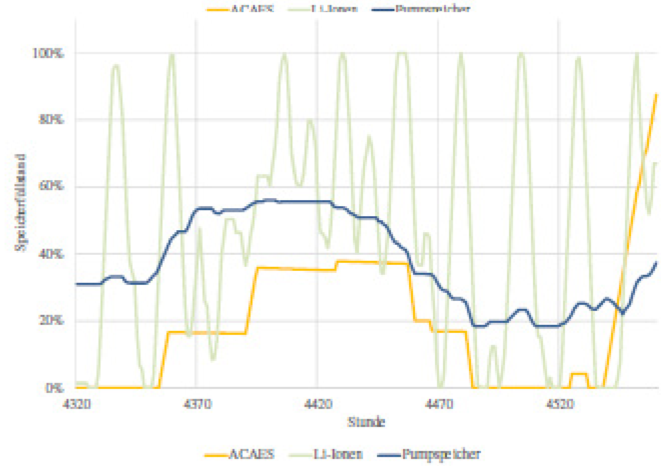
Winter (h 0-240)





Summer (h 4320-4560)





Conclusion & Outlook

- Both storage power as well as storage capacity are robust with regard to changes of fuel and CO_2 certificate costs
- Storage demand is more sensitive to the chosen grid scenario and the allowed curtailments
- These results have to be tested for an open capacity expansion (greenfield)

- Further analysis could include cost related and node specific curtailments
- A review of the robustness of the storage demand is essential with regard to the following sensitivities:
    - Different weather year
    - Load times series
    - Further flexibility options
    - Power plant modeling approach (MILP vs. LP)

energy scenarios school

Thanks for your attention!

Questions?

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