Storage placing in Germany in mid-term context - Which site will be best?

Thomas Möbius, David Gunkel

Dresden, 11. April 2014

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

AGENDA

1 Motivation

2 Methodology

3 Model

4 Results and Conclusion

Motivation

Structural changes on the electricity market

- Integration of fluctuating and uncertain capacities by RES
- Geographical separation between generation and consumption
  - Extension of wind power in Northern Germany
  - Nuclear phase-out
  - Maintenance of demand hotspots in the South and West

More flexibility in generation and demand is needed

➢ **Energy storages can do both**

- To set incentives for locational planning a nodal pricing approach is applied and physical network restrictions are considered by using the DC-load flow model ELMOD

Methodology

- Integration of a site selection into an investment decision
  - Generation of an endogenous decision variable which is defined as a special ordered set of type 1, the so-called SOS1-Variable $d_{n,z}$

$$0 \leq d_{n,z} \leq 1 \qquad d_{n,z} \in \mathbb{R}$$

- Storage mechanism
  - Control of storage activities by SOS1-Variables

$\vec{s}_{r,n,z,t}$ charge of storage

$\overleftarrow{s}_{r,n,z,t}$ discharge of storage

  - charging and discharging process is limited to respectively one hour within the several reference days → one average full load hour is generated
  - Annual Investment costs are scaled to one full load hour

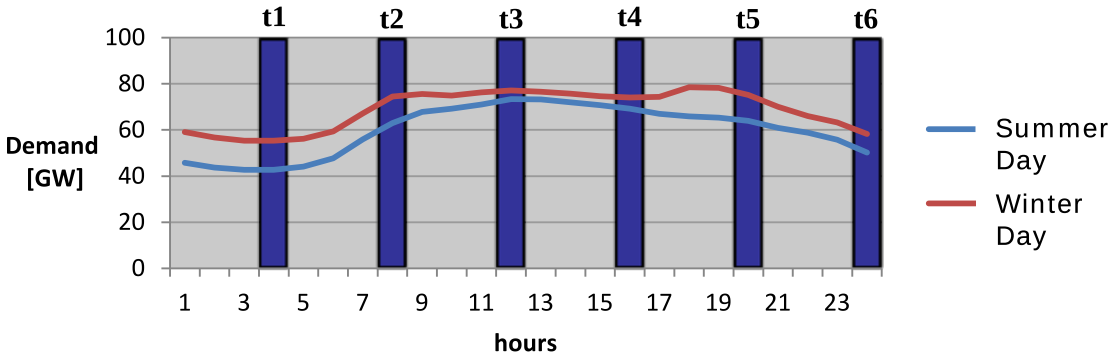
Methodology

Development of 6 reference days

- To represent a typical year they vary in solar and wind feed-in and in their demand load curves

Reduction of reference days

Considered hours:



- Development of 6 reference days á 6 real hours
- Time periods are allocated consistently within a day
- Maintenance of characteristic load curves and their time-related gradients

Model

- Objective function: Minimization of total system costs

$$\min_{g_{r,n,s,t}\, d_{n,z}} \left\{ TC = \sum_{r} \left(\underbrace{\sum_{n,s,t} OC_{r,n,s,t}}_{\text{Electricity generation}} + \underbrace{\sum_{n,s,t} su_{r,n,s,t}}_{\text{Start up costs}} + \underbrace{\sum_{n,t} x^{WI}_{r,n,t} * p^{VW}_{n}}_{\text{Wind curtailment}} \right) * WEIGHT_r + \underbrace{\sum_{n,z} A_{n,z} * P^{pot}_{n,z} * d_{n,z}}_{\text{Storage extension}} \right\}$$

  - No time interdependency between, but within reference days

- Energy balance: clearing the market

Storage activities

$$\underbrace{\sum_{s} g_{r,n,s,t} + WI_{r,n,t} + SI_{r,n,t}}_{\text{Electricity generation}} + \overbrace{\sum_{z} \overleftarrow{s}_{r,n,z,t}} = \underbrace{Q_{r,n,t}}_{\text{Consumption}} + \overbrace{\sum_{z} \vec{s}_{r,n,z,t} * {}^{1}/_{\eta_Z}} + \underbrace{ni_{r,n,t}}_{\text{Net input}} + \overbrace{x^{WI}_{r,n,t}}^{\text{Wind curtailment}} \qquad \forall\, r, n, t$$

Results and Conclusion

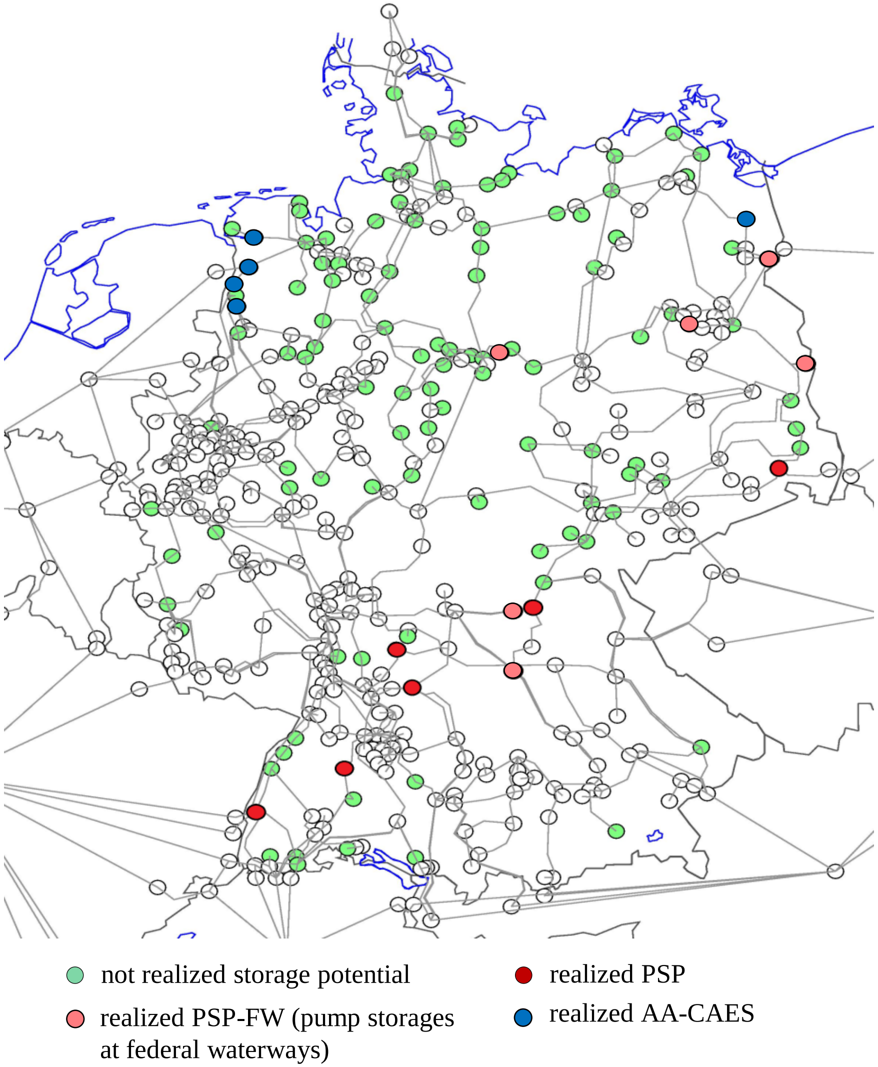
Storage extension

2020-BASE

- compulsory execution rate of 3 GW
- Realization of 1.2 GW AA-CAES in Northern Germany
- Reduction of wind curtailment is reduced about 73% after storage extension

2020-PLAN

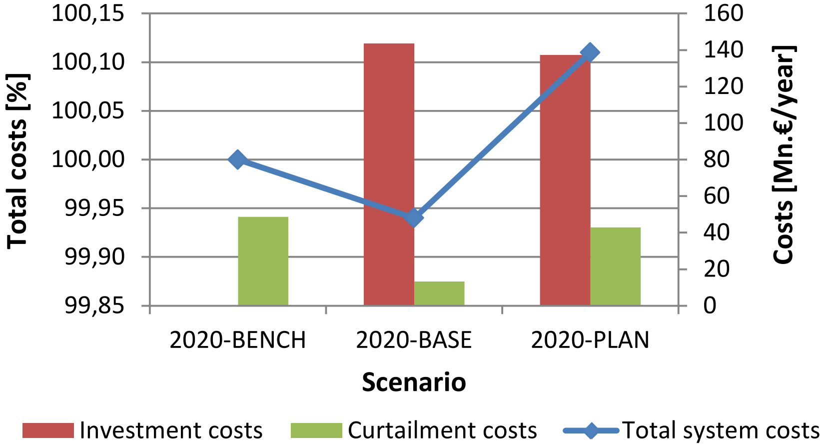
- Reduced storage potential to plants which are currently planned or in construction

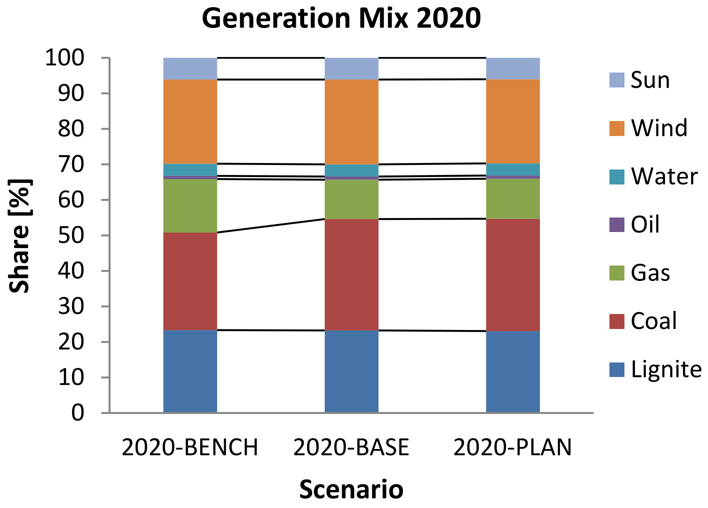


Results and Conclusion

Comparison of scenarios in 2020

- Limited storage potential in *2020-PLAN* leads to less efficient allocation and higher overall costs
- In both extension scenarios peak load capacity gets substituted by coal fueled power plants





- wind curtailment highly impacts the storage placing

Results and Conclusion

- A locational planning for storage investments has a significant economic effect with regard to minimize total system costs
  - Might compensate for more expensive storage technologies, e.g. AA-CAES

- In particular, the expansion of wind power capacities in Northern Germany highly impacts the site selection for additional storages

- Further research might address
  - Interactions between optimal located storage extension and
    - Grid expansion and Demand Side Management
    - removal of the feed-in priority of RES and the resulting curtailment payments to RES operators

Thank you very much!

Questions?

Contact:

Thomas Möbius

Chair of Energy Economics

BTU Cottbus-Senftenberg

thomas.moebius@tu-cottbus.de

Backup

- Subject is the optimal located extension of energy storages
  - Three different technology types
  - Potential is allocated within Germany

Technology	PSP	PSP-FW[1]	AA-CAES
Efficiency	0.8	0.8	0.7
Investment costs [€/kW]	750	570	800
Storage potential [GW]	40.3	0.4	47.4

[1] Pump storage plants at federal waterways

Backup

Some further restrictions

- Min-Max generation $\underline{G}_{n,s} * on_{r,n,s,t} \leq g_{r,n,s,t} \leq \bar{G}_{n,s} * on_{r,n,s,t} * Availability_{r,s}$
- Storage mechanism (1) $StorageLevel_{r,n,z,t+1} = StorageLevel_{r,n,z,t} + \overleftarrow{s}_{r,n,z,t} - \vec{s}_{r,n,z,t}$

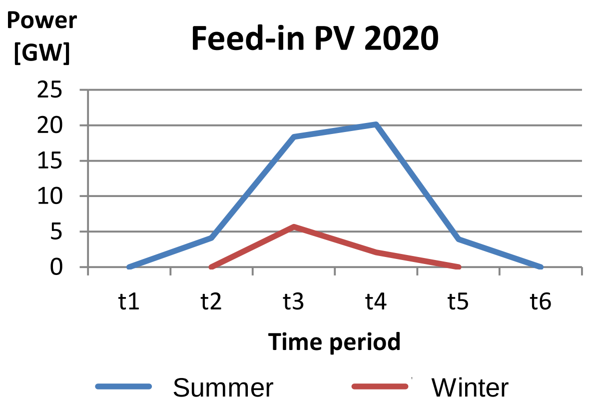
(2) $StorageLevel_{r,n,z,t=1} = 0$

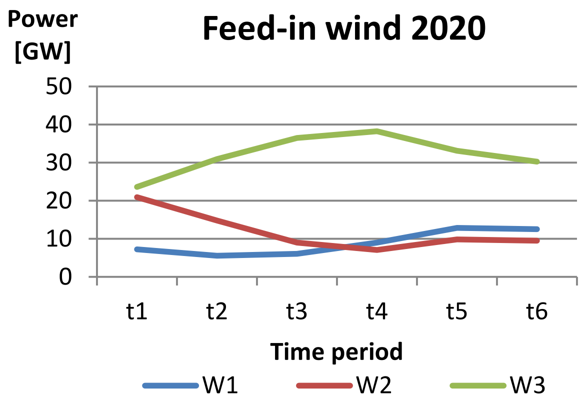
(3) $\overleftarrow{s}_{r,n,z,t} + \vec{s}_{r,n,z,t} \leq P_{n,z}^{\mathrm{pot}} * d_{n,\mathbf{z}} + P_{n,z}^{old}$

(4) $\vec{s}_{r,n,z,t} \leq StorageLevel_{r,n,z,t}$

Backup

Wind und solar load curves in a reduced reference day





- Two solar load curves (summer and winter) and three wind load curves allocated to two demand load curves (summer and winter)