Universität zu Köln

ewi Energiewirtschaftliches Institut an der Universität zu Köln

Adjusting or shifting? - The economic differences between demand response and energy storages in a long-run equilibrium model

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Motivation

Shifting energy through time promotes the integration of variable RES

- The integration of large shares of variable RES requires system flexibility
- Shifting energy through time can ease fluctuating generation patterns
- Most often associated with either storages or demand side management
- Both feature a downward- and an upward-shifting potential
- Storages typically have symmetric charging and discharging capacity
- DSM processes may rely on asymmetric production schedules and hence, show asymmetric shifting capacities

Literature and research question

Literature

Detailed analyses dealing primarily with storage technologies, e.g. summarized in Newbery, 2018

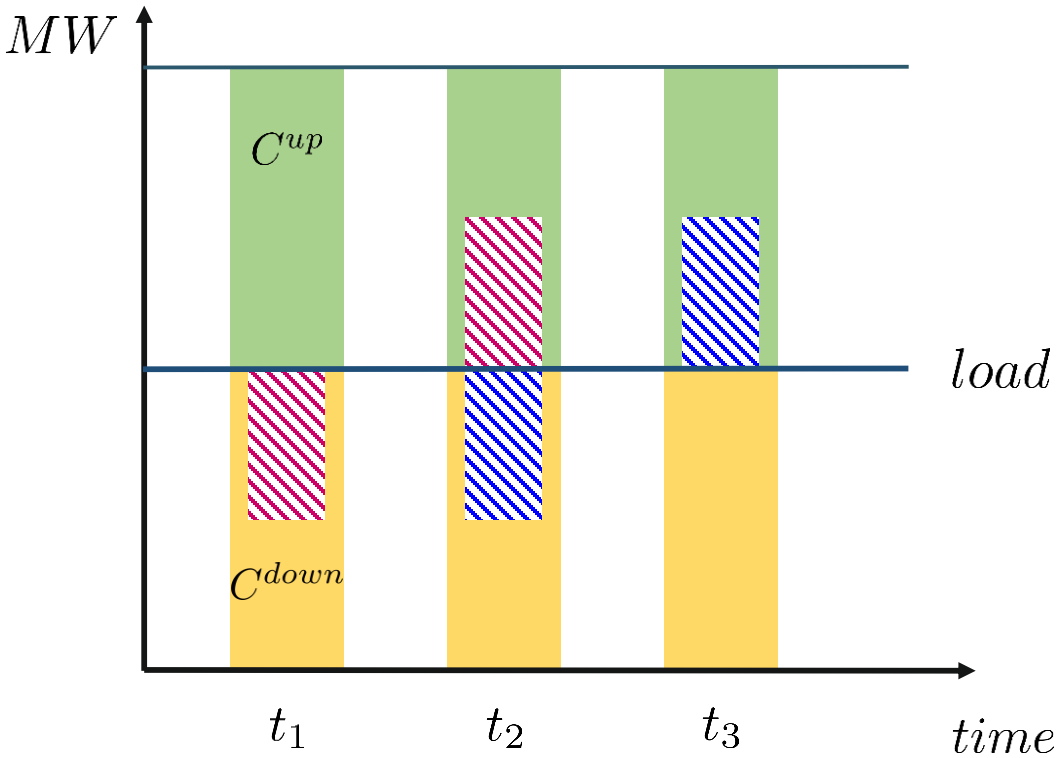
Comprehensive energy system models comparing shifting technologies, e.g. Bertsch et al., 2016; Zerrahn & Schill, 2018

Analyses focusing on demand side management characteristics and their economic effects, e.g. Geske et al., 2017; Zerrahn & Schill, 2015

Research questions

- How can asymmetry be included in an aggregated DSM formulation?
- How do asymmetric shifting capacities affect market outcomes in a long-run equilibrium?

Model
Integrating DSM on an aggregated level in an Energy-Only market



Capacity restrictions:

$$DSM_t^{up} \leq C^{up}$$

$$\sum_{t=\tilde{t}-L}^{\tilde{t}+L} DSM_{t,\tilde{t}}^{down} \leq C^{down}$$

Balancing over time:

$$DSM_t^{up} = \sum_{\tilde{t}=t-L}^{t+L} DSM_{t,\tilde{t}}^{down}$$

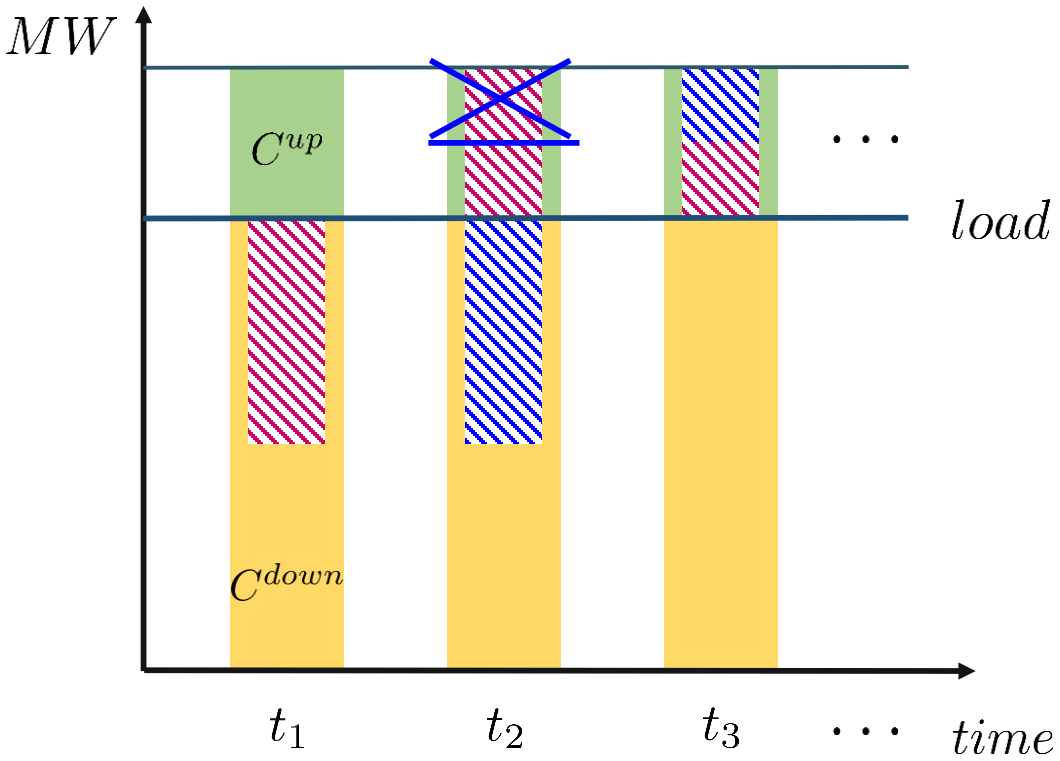
Prevent the DSM processes from cycling, i.e. simultaneous up- and downshifting is limited

$$DSM_t^{up} + \sum_{t=\tilde{t}-L}^{\tilde{t}+L} DSM_{t,\tilde{t}}^{down} \leq \max(C^{down}, C^{up})$$

DSM_t^{up}	upward shifting in t	C^{up}	maximal upward capacity
$DSM_{t,\tilde{t}}^{down}$	downward shifting in $\tilde{t}$ for t	C^{down}	maximal downward capacity

Formulation based on Zerrahn & Schill, 2015

Model
Cycling is not limited in the case of asymmetric shifting capacities



In case of a mean load ≠ 50% the up- and down-capacities are asymmetric

The former condition

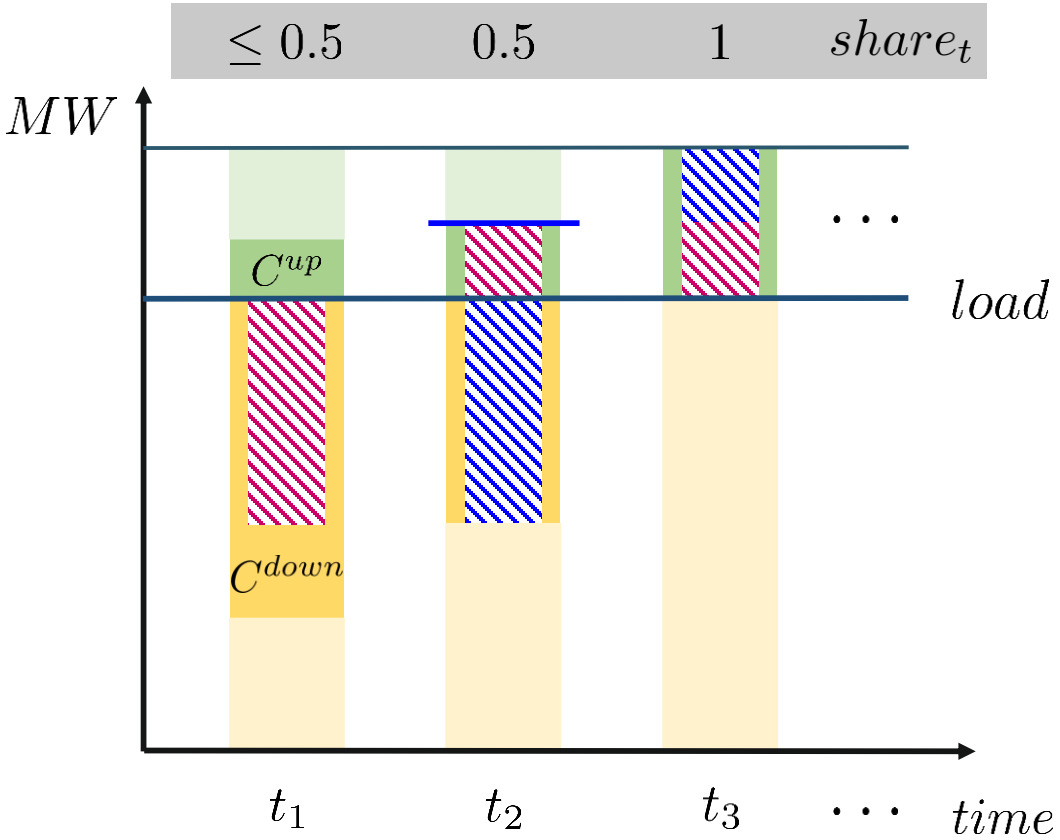
$$DSM_t^{up} + \sum_{t=\tilde{t}-L}^{\tilde{t}+L} DSM_{t,\tilde{t}}^{down} \leq \max(C^{down}, C^{up})$$

does not prevent from cycling

DSM_t^{up}	upward shifting in t	C^{up}	maximal upward capacity
$DSM_{t,\tilde{t}}^{down}$	downward shifting in $\tilde{t}$ for t	C^{down}	maximal downward capacity

Model

Asymmetric capacities lead to varying availability of shifting capacities



Including a variable to define the share of DSM process capacity which is shifting upwards in t

$$0 \leq share_t \leq 1$$

$$DSM_t^{up} \leq share_t \cdot C^{up}$$

The remaining capacitiy share can be used for downward shifting

$$DSM_t^{down} \leq (1 - share_t) \cdot C^{down}$$

DSM_t^{up}	upward shifting in t	C^{up}	maximal upward capacity
$DSM_{t,\tilde{t}}^{down}$	downward shifting in $\tilde{t}$ for t	C^{down}	maximal downward capacity

Model
Long-run equilibrium model of an Energy-Only market

- Greenfield model with 8760h resolution
- Loosely calibrated to the German power sector in 2030
- 65% RES, fuel prices from WEO 2018 New policies scenario
- Base scenario: 10 GW installed DSM capacity with 75 % mean load and balancing interval of 2*48h
- Inelastic demand and RES productivity factors follow historic patterns
- In off-peak hours: power price=MC
- Annuities of capacities are paid by peak prices

$$\min \quad TotalCosts := \sum_i fc^i \cdot CAP^i + \sum_t \sum_i vc^i \cdot GEN_t^i + \sum_t vc^{dsm} \cdot DSM_t^{up}$$

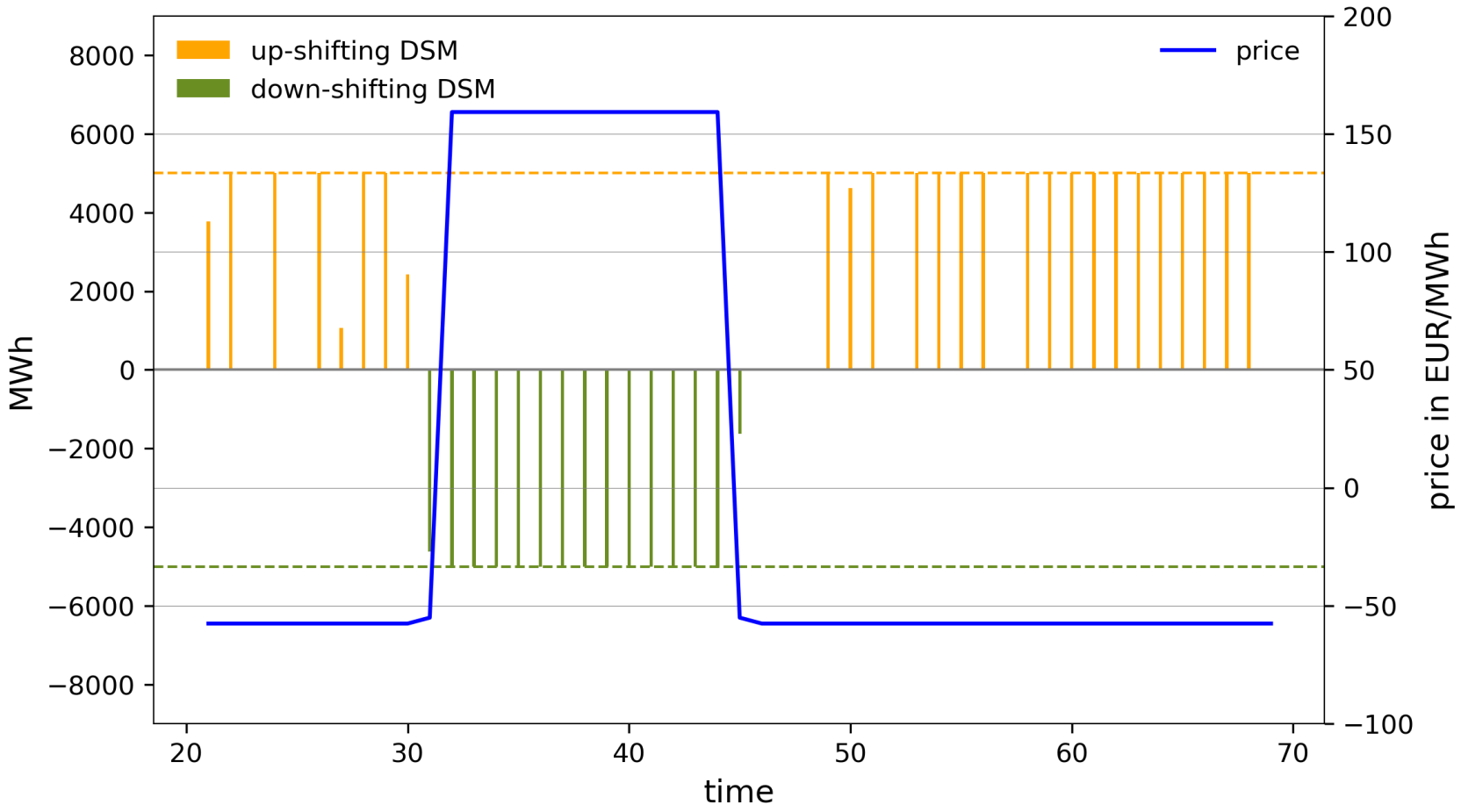
$$\text{s.t.} \quad demand_t = \sum_i GEN_t^i + \sum_{\tilde{t}=t-L}^{t+L} DSM_{\tilde{t},t}^{down} - DSM_t^{up}$$

$$GEN_t^i \leq pf_t^i \cdot CAP^i$$

$$DSM \text{ equations}$$

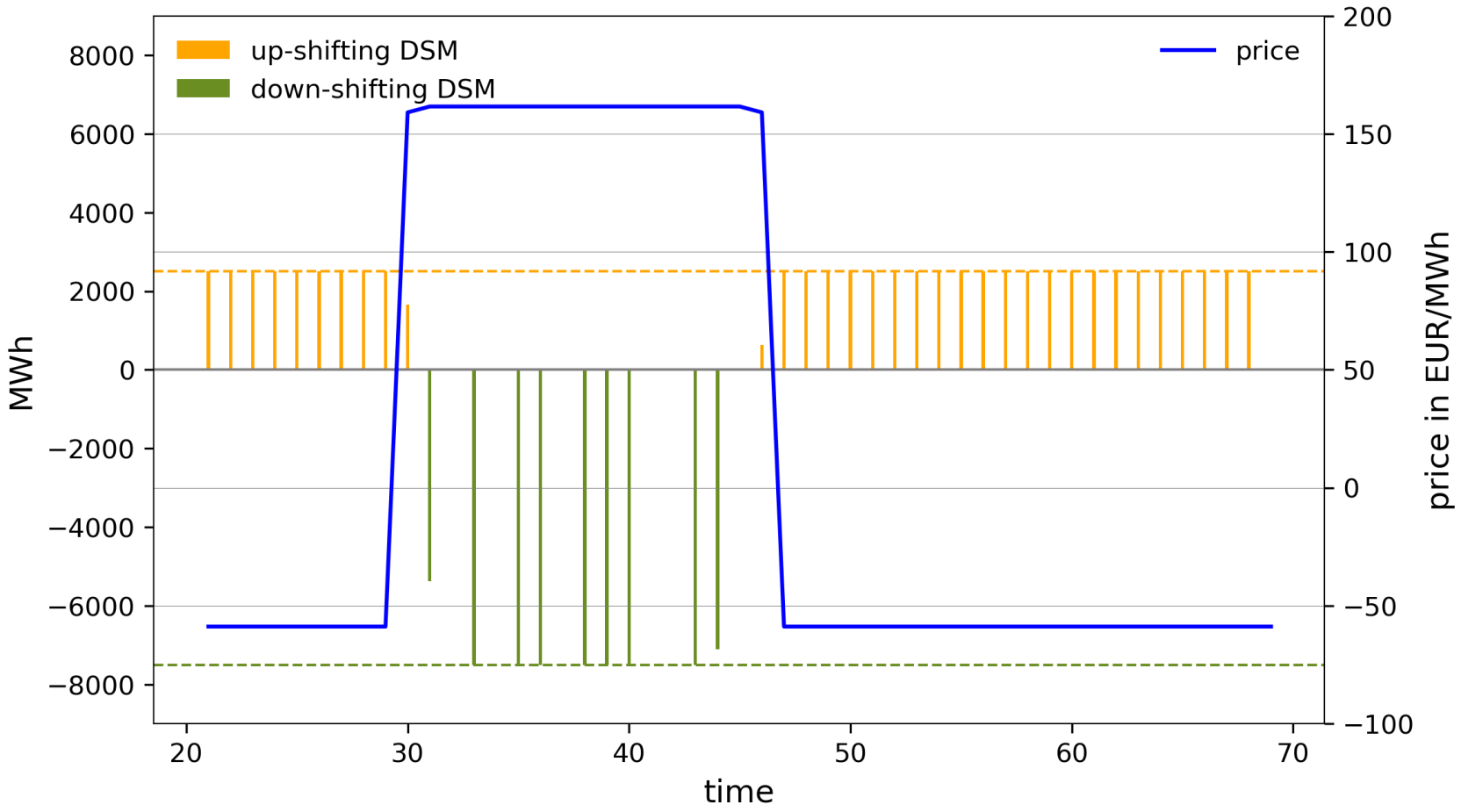
Results shifting and cycling

Exemplary hourly profile with symmetric 50% load factor



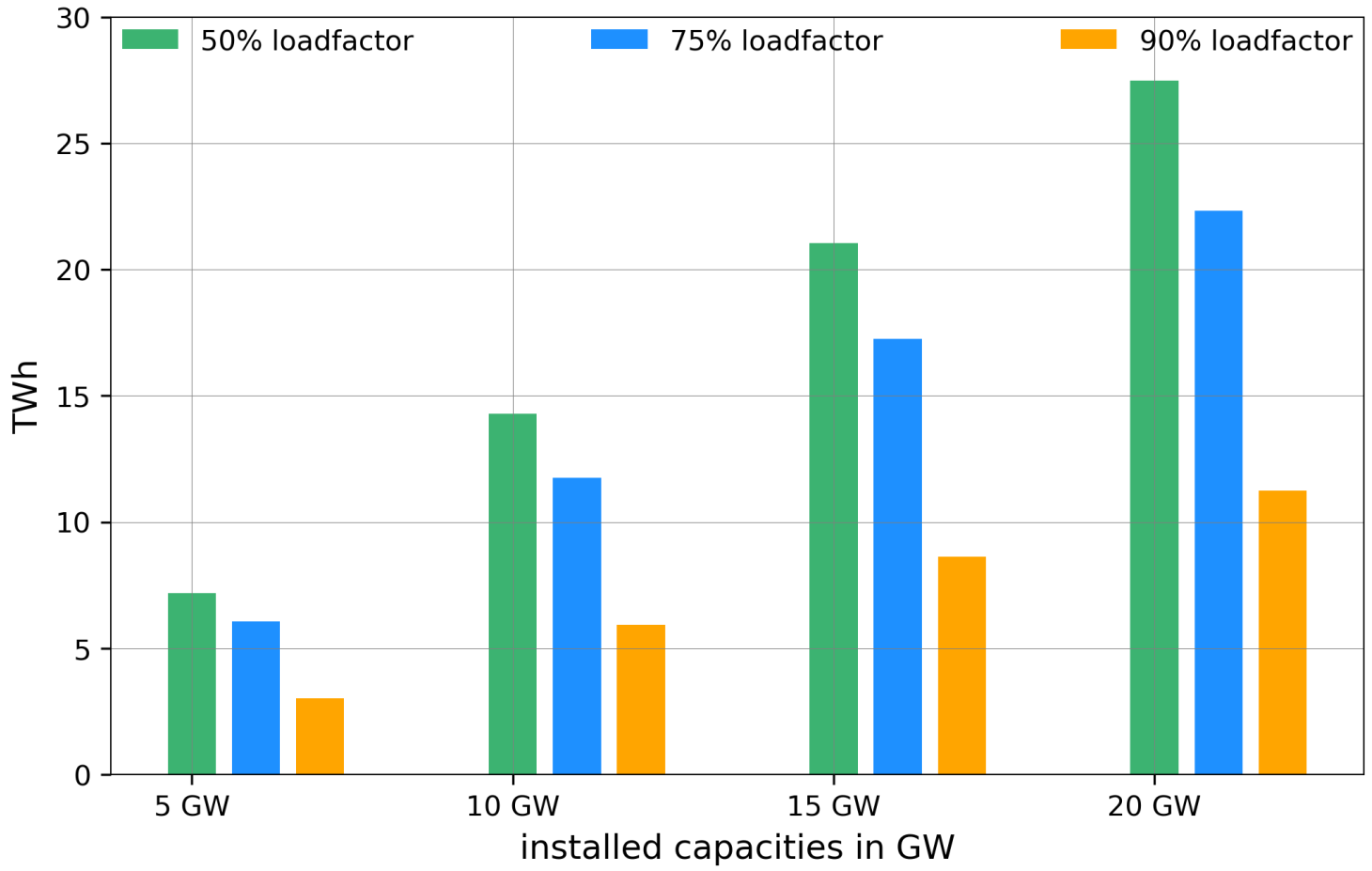
Results shifting and cycling

Exemplary hourly profile with asymmetric 75% load factor



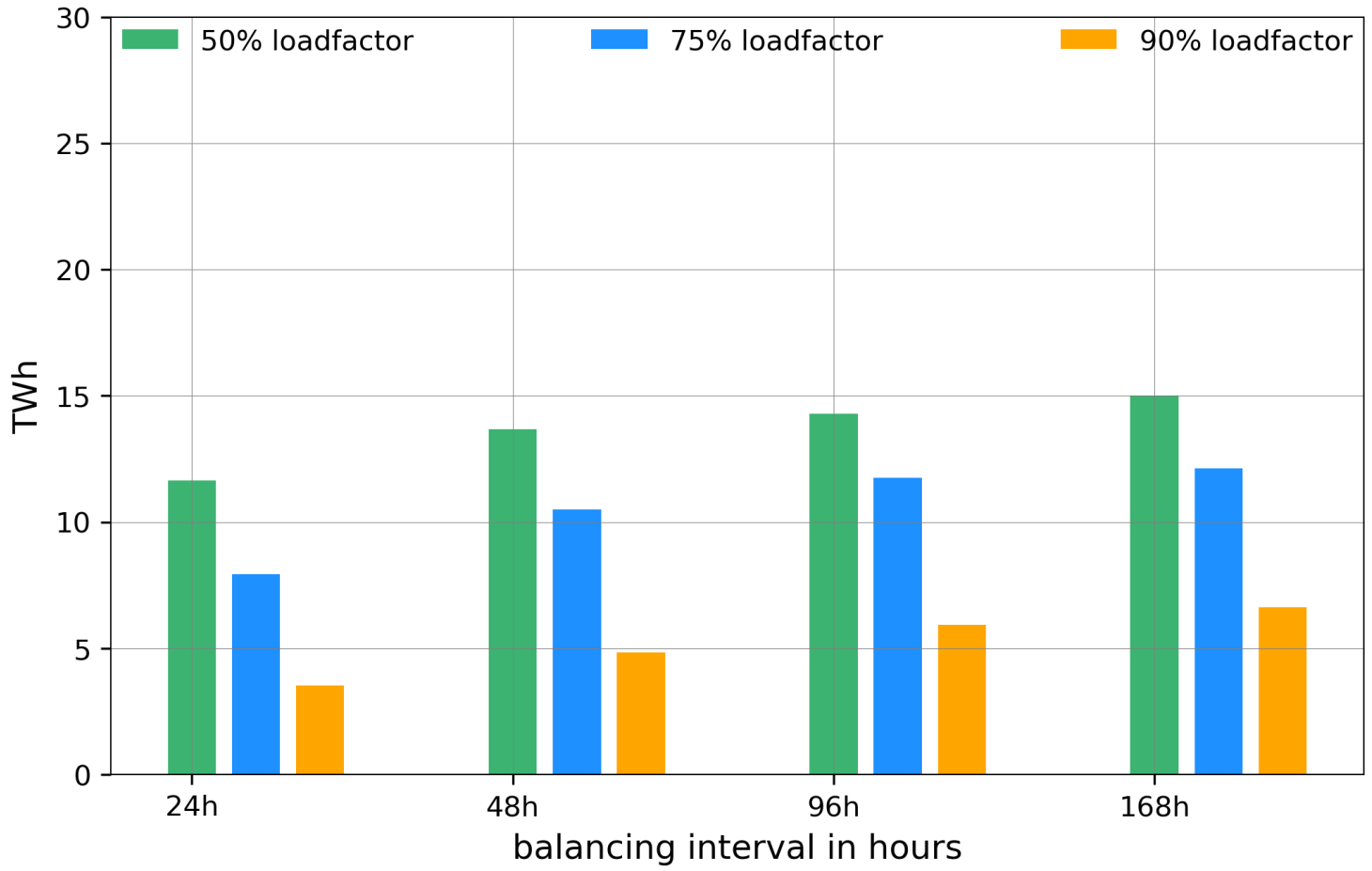
Results

Shifted energy per year with varying DSM capacities



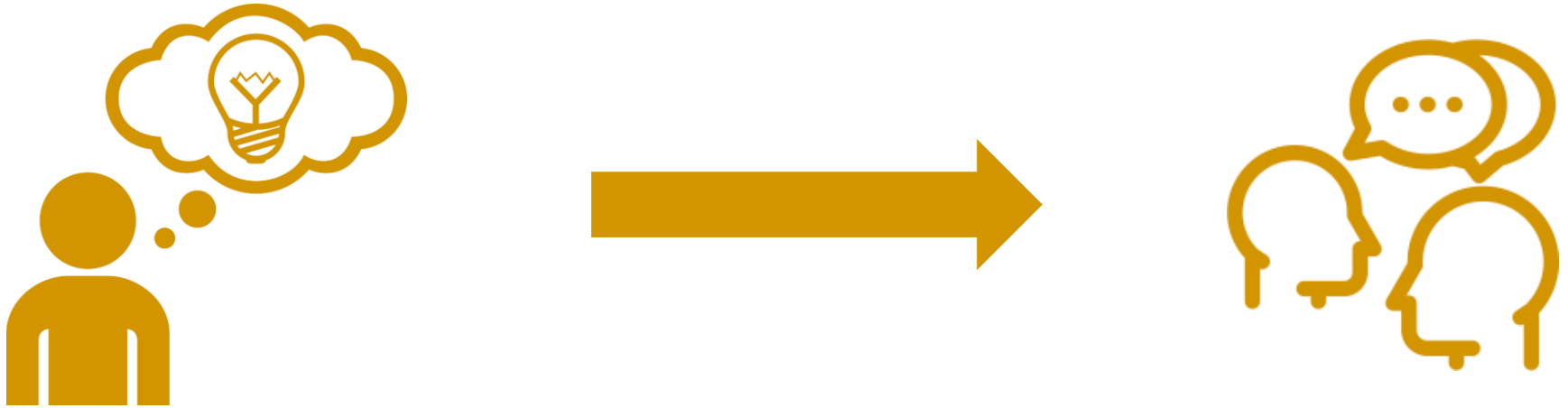
Results

Shifted energy per year with varying balancing intervals



Conclusion

- In order to integrate asymmetric DSM processes in energy system models the formulation of DSM is extended
- An additional $share_t$, accounting for time-varying availability of DSM capacities, prevents DSM from cycling while allowing to analyze the impact of asymmetry on system effects
- It is important to account for asymmetries – even in aggregated formulations - because it has a significant impact on market outcomes
- With smaller shifting potentials other balancing options are necessary in order to balance residual demand and supply



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Thank you for your attention!

Questions? Recommendations? Ideas?

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