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Technische Universität
Cottbus - Senftenberg

Energy systems modelling

Tutorial 6

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Intertemporal dynamics

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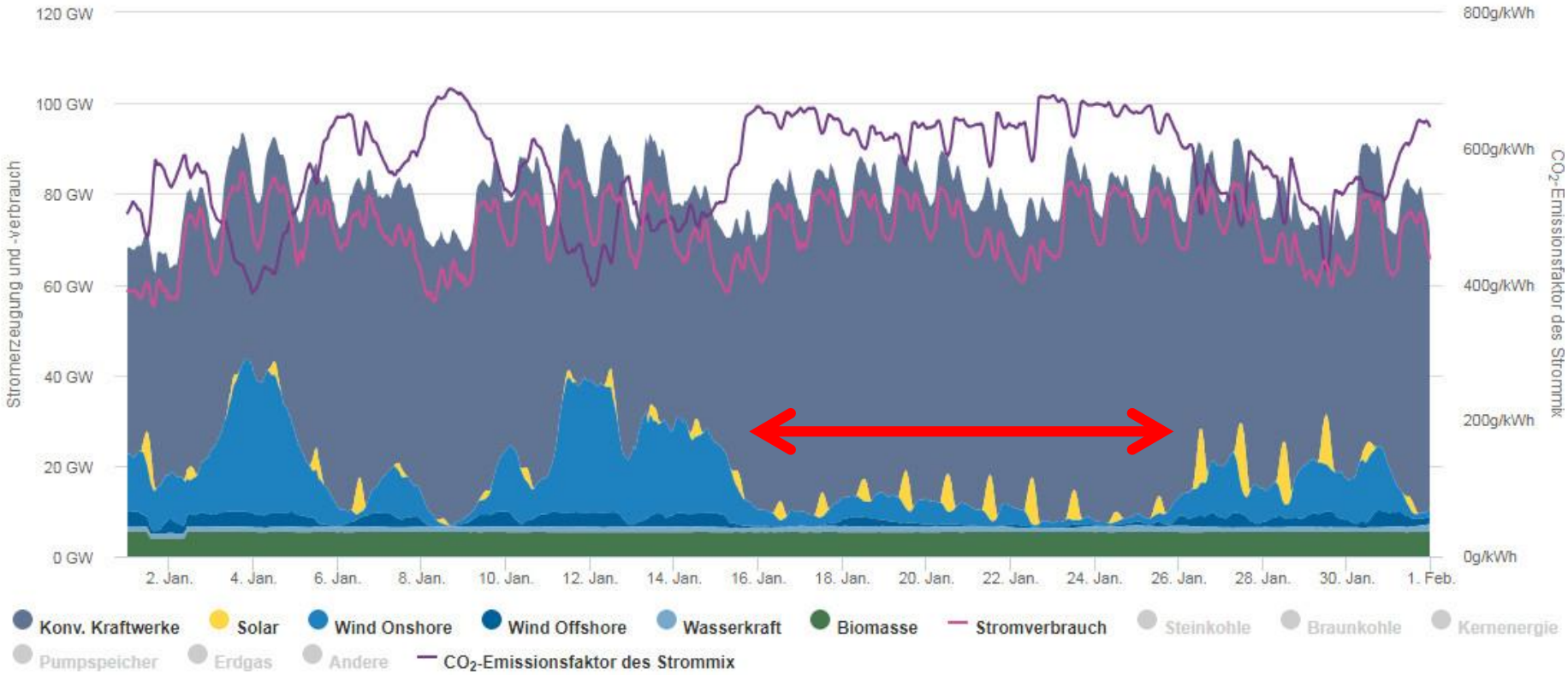
Intertemporal dynamics - a decision made at one time step has an effect on the optimal decisions in other time steps

- Q: What are the causes of intertemporal dynamics in electricity markets?
  - **Energy storages**
  - Investment decisions
  - Start-up constraints
    - Partial-load costs
    - Start-up costs

“Dunkelflaute”: German term for the co-occurrence of ‘Dunkelheit’ (darkness) and ‘Windflaute’ (windlessness)



January 2017, 10 days of “Dunkelflaute”

source: Agora Energiewende

https://www.agora-energiewende.de/service/agorameter/chart/power_generation/01.01.2017/31.01.2017/

Illustration of storage activity

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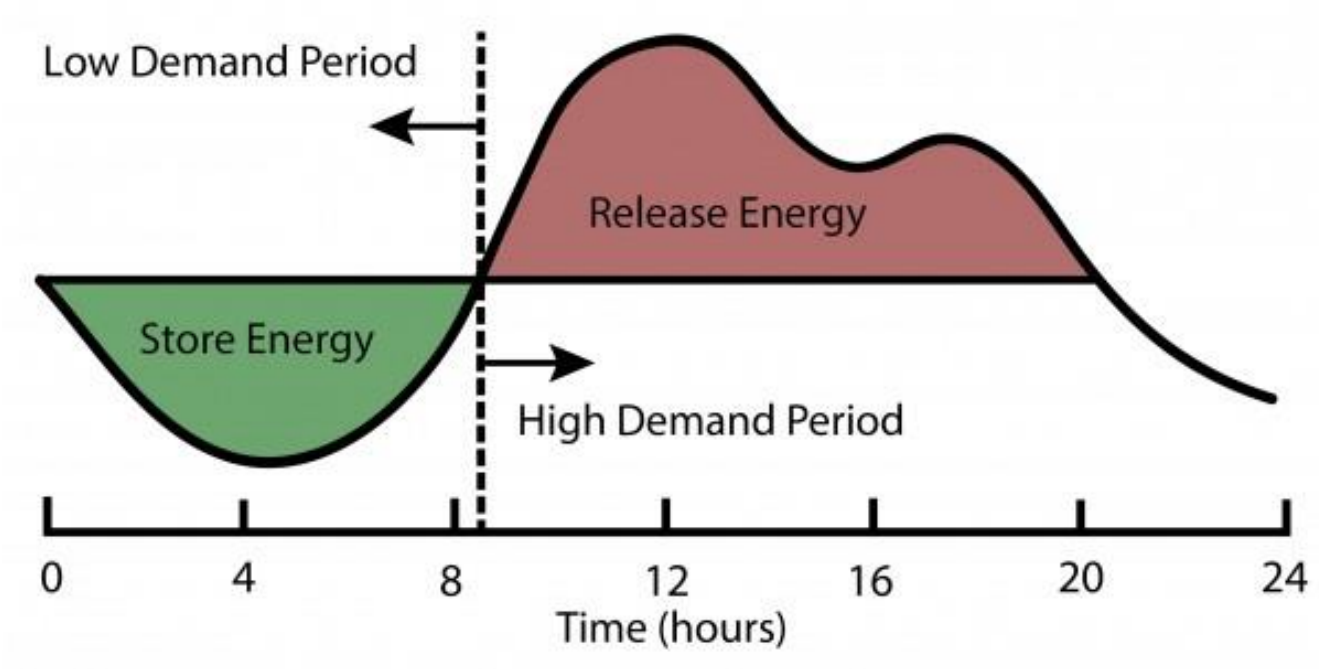
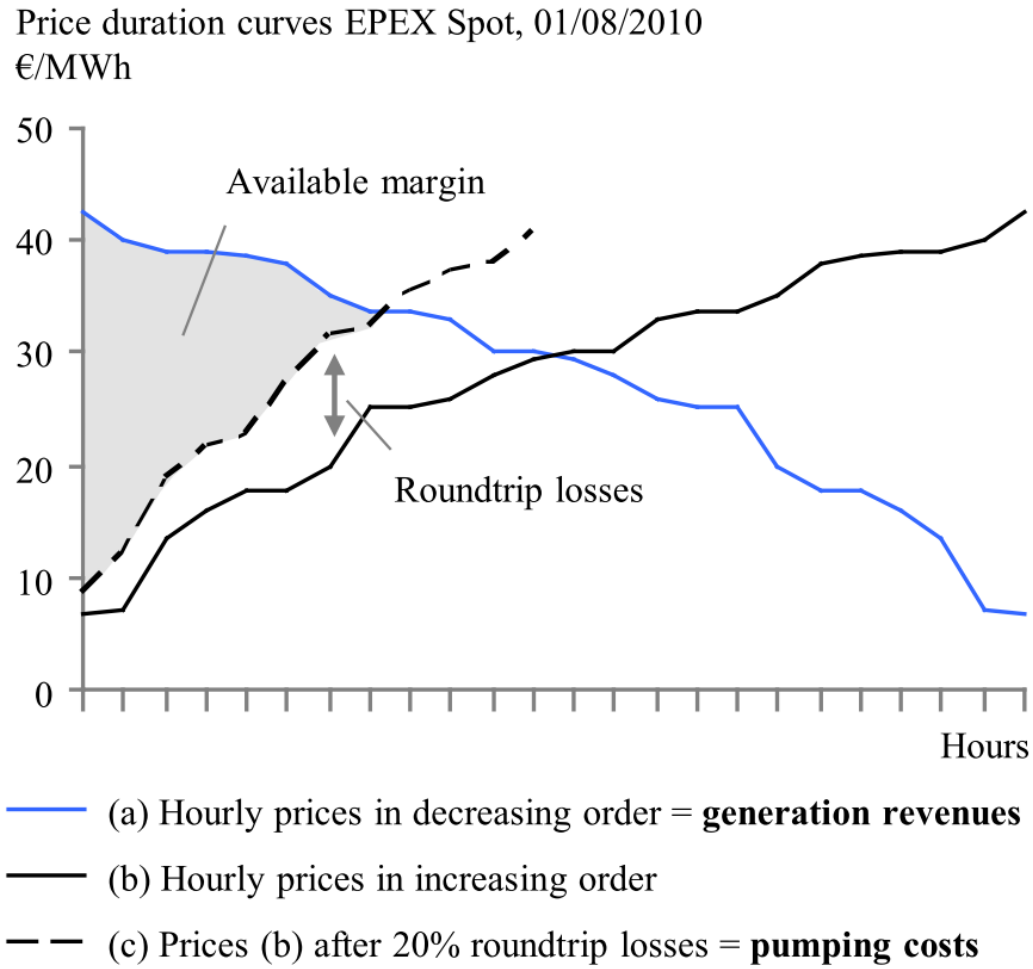
- Storing energy during low demand (off-peak periods) and using that energy during high demand (on-peak periods)



Source: U.S. Grid energy storage factsheet
http://css.umich.edu/factsheets/us-grid-energy-storage-factsheet

Illustration of time spread margin



Discussion: What are the other revenue sources (in addition to energy arbitrage at a spot market) for energy storage?

Source: Steffen, Bjarne, Prospects for Pumped-Hydro Storage in Germany (December 8, 2011). EWL Working Paper No. 07/2011. http://dx.doi.org/10.2139/ssrn.1969767

Implementing energy storage

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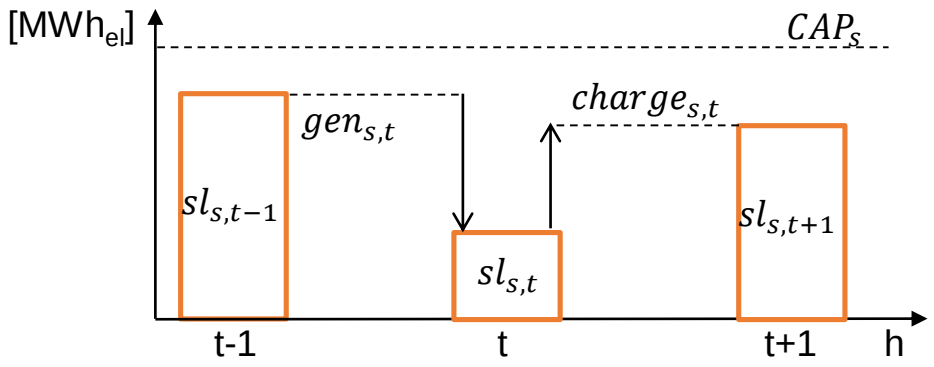
Storages – mathematical description on the electricity market

Defining a storage level of a storage s at time t:

$$sl_{s,t} = sl_{s,t-1} + charge_{s,t} - gen_{s,t} \quad \forall s,t$$

Defining maximum storage capacity:

$$sl_{s,t} \leq CAP_s \quad \forall s,t$$



New index:

s	index for storage technologies

New parameters:

CAP_s	storage capacity [MWh]
$POWER\_X_s$	generation/charging power [MW]

New variables:

$sl_{s,t}$	storage level [MWh]
$charge_{s,t}$	charging storage [MW]
$gen_{s,t}$	generation by storage [MW]

Implementing energy storage

Storages – mathematical description on the electricity market

Constraint for the charging/generation power:

$$charge_{s,t} \leq POWER\_PUMP_s \qquad \forall s,t$$

$$gen_{s,t} \leq POWER\_TURB_s \qquad \forall s,t$$

Constraint for the generation quantity:

$$gen_{s,t} \leq sl_{s,t-1} \qquad \forall s,t$$

Non-negativity constraints:

$$0 \leq sl_{s,t}, gen_{s,t}, charge_{s,t} \qquad \forall t$$

New index:

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New parameters:

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Implementing energy storage

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Storages – mathematical description on the electricity market

2) Effects on the energy balance

$$\sum_{c} g_{c,t} + \sum_{r} g_{r,t} = DEMAND_t + \sum_{s} (\boldsymbol{charge_{s,t}} - \boldsymbol{gen_{s,t}} * (\mathbf{1} - \boldsymbol{LOSS_s})) \qquad \forall t$$

Charging the storage increases demand for electricity

Losses in storage cycle
(here: LOSS parameter represents the losses of the entire storage cycle)

See you next class!