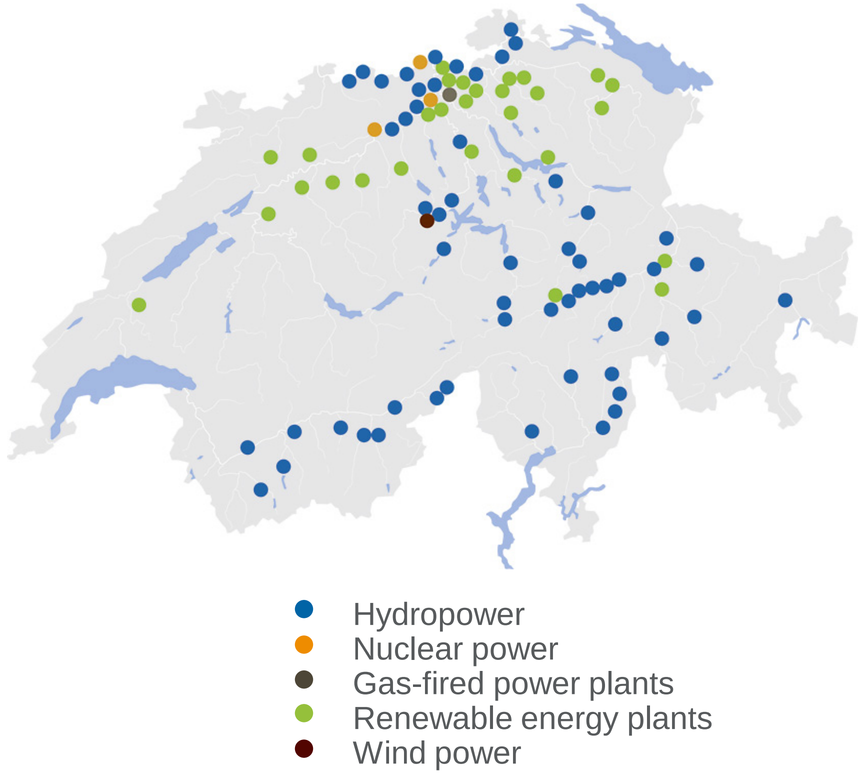
Experiences in optimal allocation of reserve obligations across a hydro power plant portfolio

Hydro Power Scheduling Workshop 2018

Hubert Abgottspon

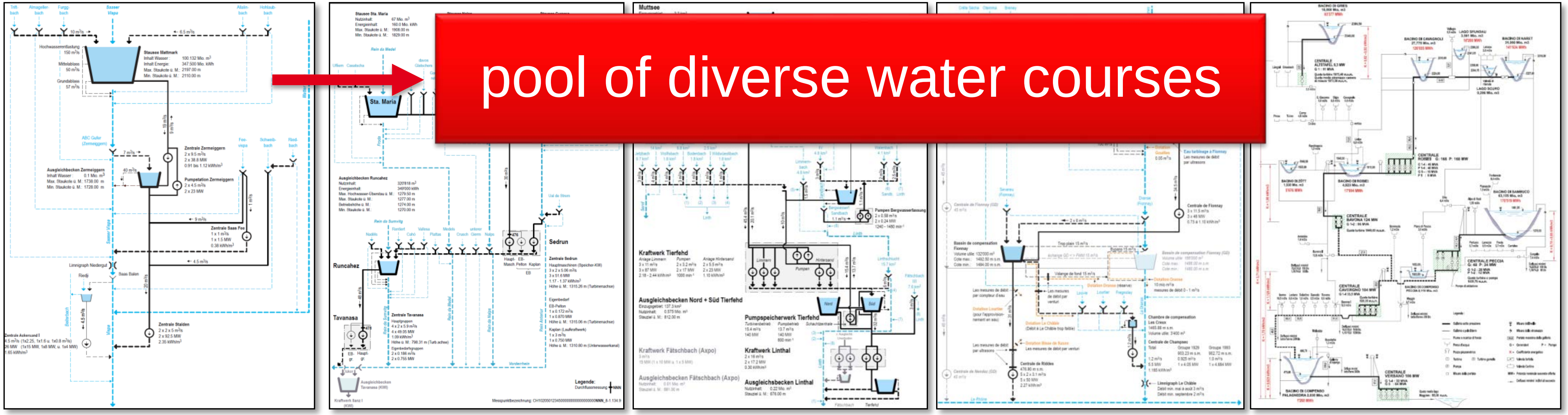
Introducing Axpo Trading AG

Activities all over Europe



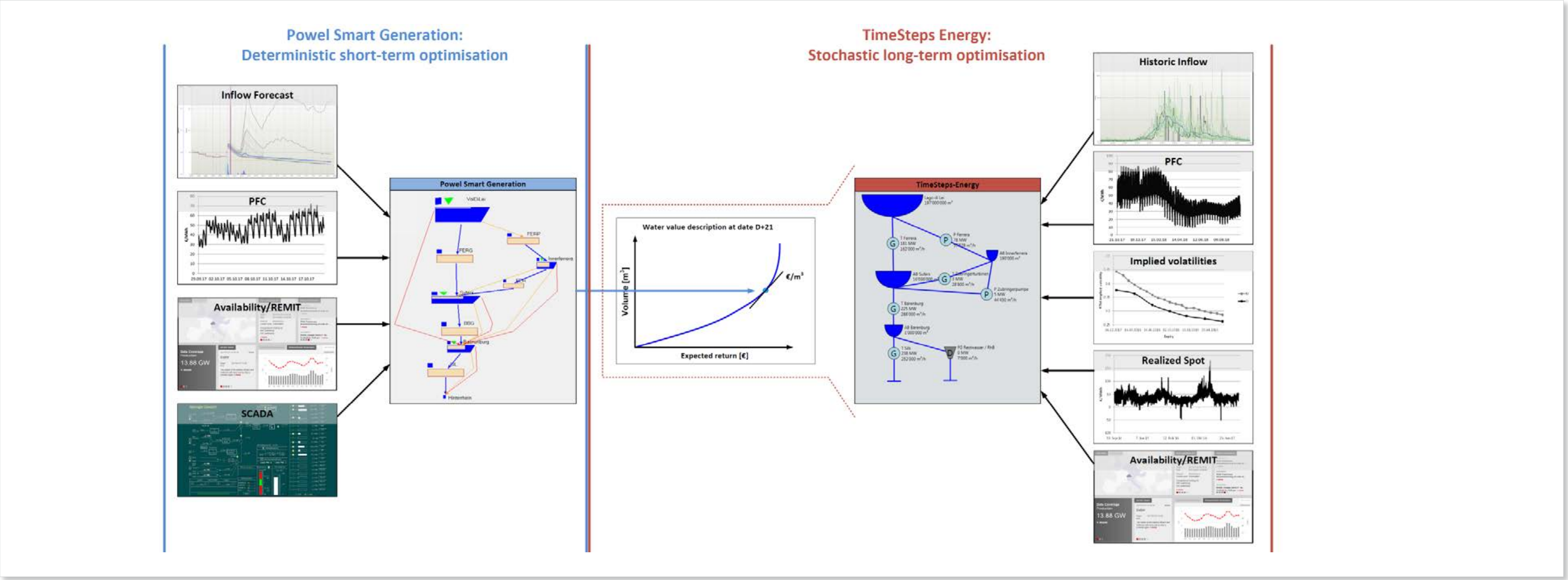
Introducing Axpo Trading AG

- 22 water courses: 25 Reservoirs & 32 balancing basins
- 54 stations: 130 turbines, 6 pumps, 17 pump-turbines & 4 var-speed pump-turbines



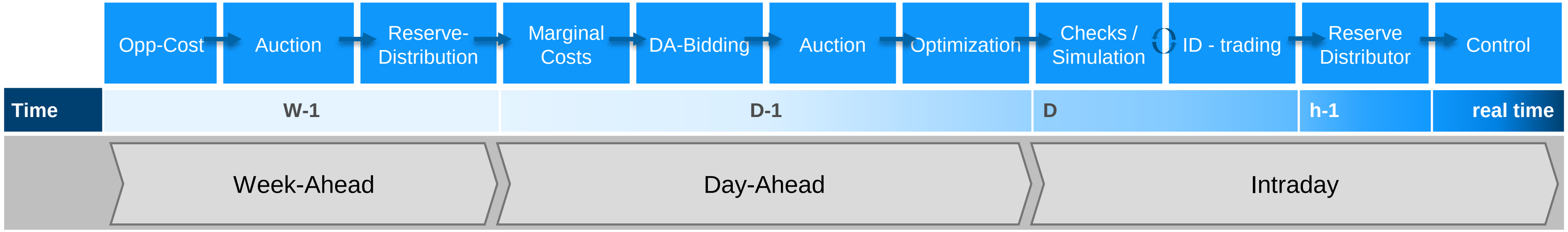
Basic system setup: model-based decision support

Combination of short-term deterministic and long-term stochastic tools



Basic system setup: model-based decision support

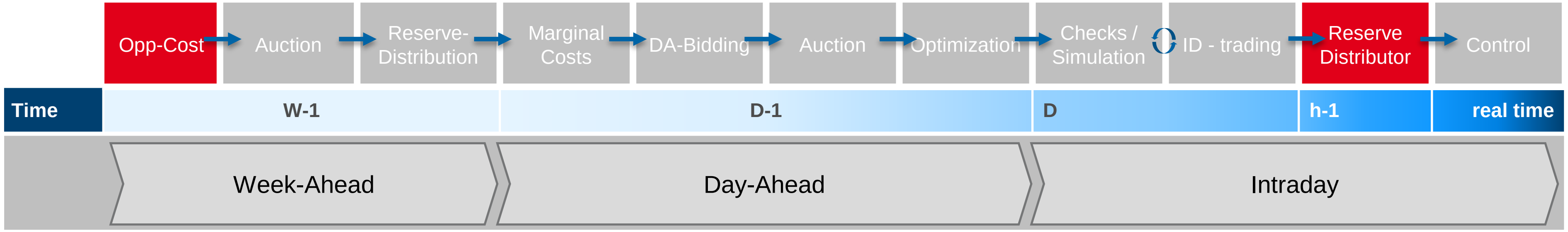
Chain of different optimizations



Basic system setup: model-based decision support

Chain of different optimizations

This talk: handling provision of spinning reserves:



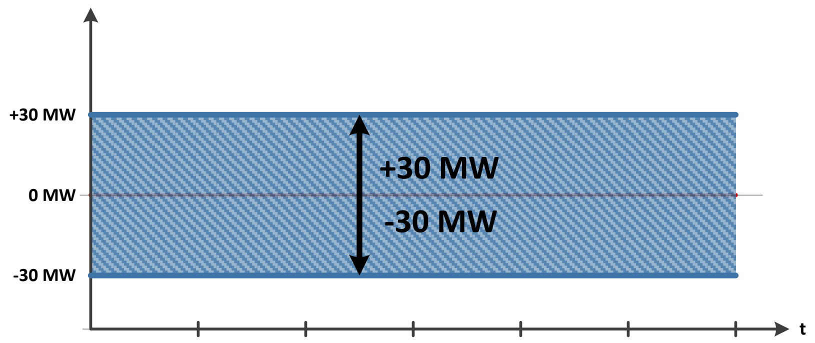
Basic system setup: model-based decision support

Reserve market in Switzerland

Spinning Reserves:

- Weekly auctions on Tuesday
  - pay-as-bid
  - FCR ± 74MW
  - aFRR +400MW, -400MW

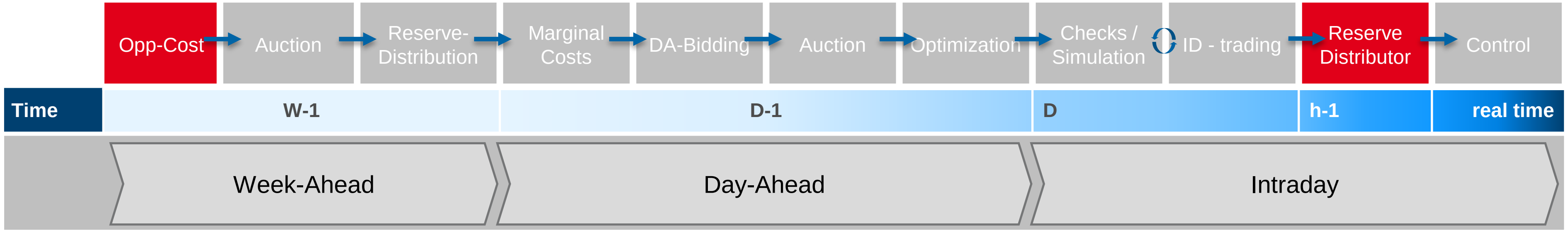
- Take decision on Tuesday with major impact on operation in the front week



Basic system setup: model-based decision support

Short-term perspective starts week-ahead

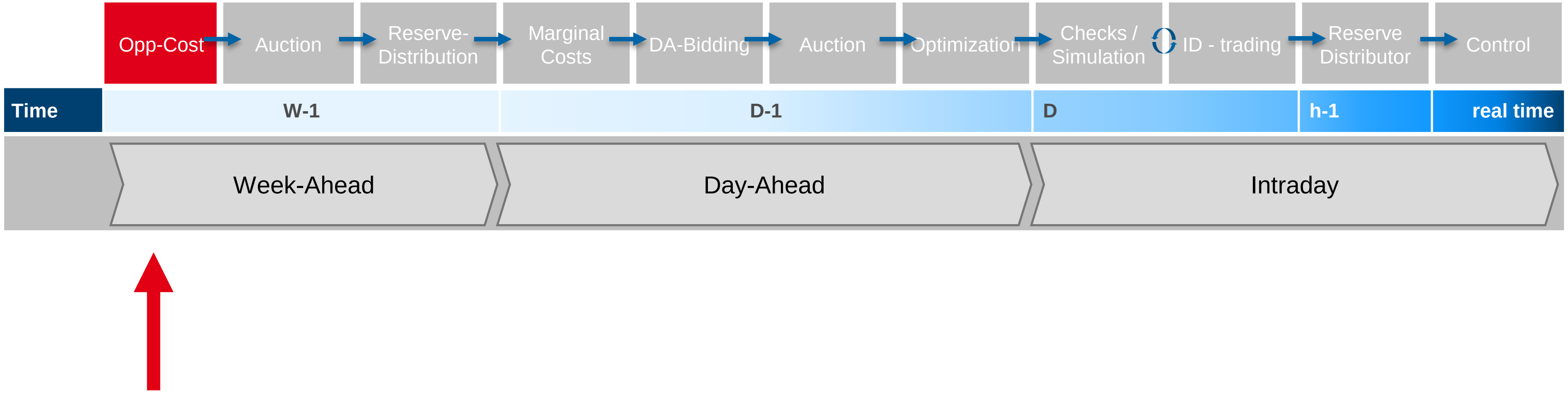
This talk: handling provision of spinning reserves



Two tasks:

1. Decision support for bidding of reserves: Reserve Opportunity Cost Calculation
2. Providing reserve obligations with least costs: Intraday Reserve Re-Distribution

1. Reserve Opportunity Cost Calculation



1. Reserve Opportunity Cost Calculation

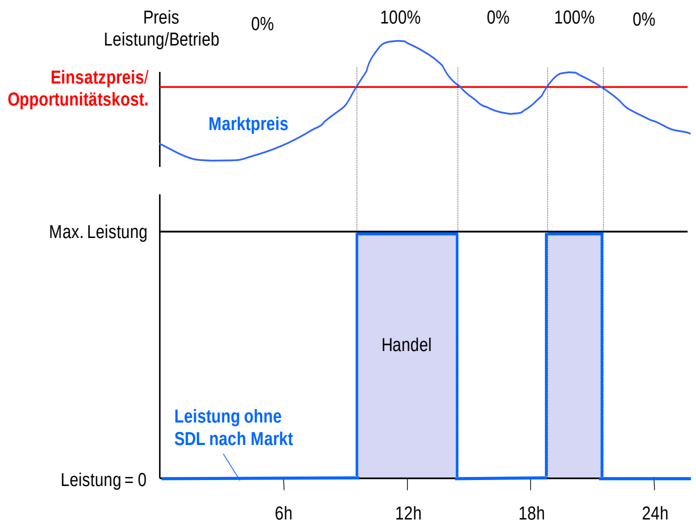
Opportunity Costs

Purpose:

Find financial impact when reserves are provided.

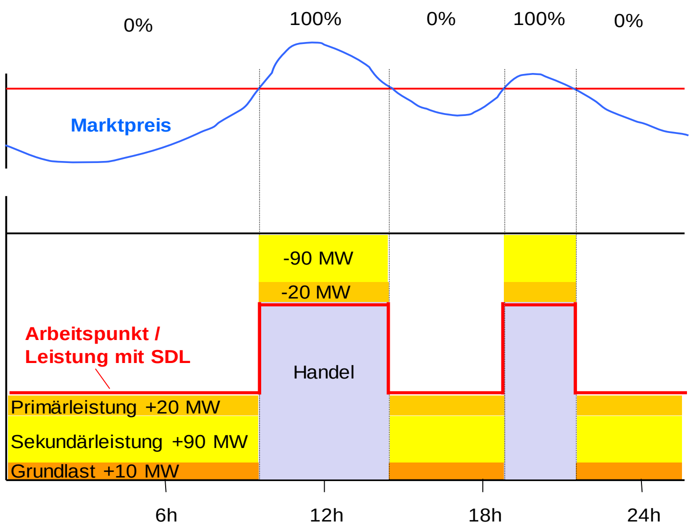
-> support for bidding

without reserves



→ revenue 1

with reserves



→ revenue 2

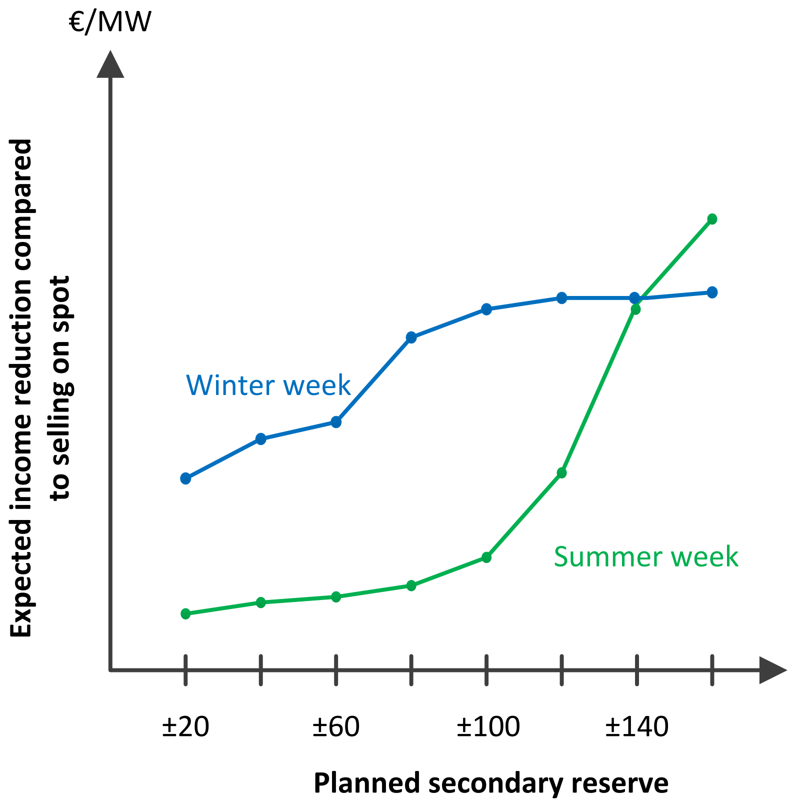
Opportunity Costs = revenue 1 - revenue 2

1. Reserve Opportunity Cost Calculation

Decision support

Optimization: Given amount of reserves: distribute it most optimally:

- Pool on unit level
- pay-as-bid –> average costs meaningful (?)
- Scenarios:
  - No aFRR
  - Different amounts of aFRR per water course
  - Different amounts of aFRR within the pool
- Curve shape and turning points support the bidding strategy



1. Reserve Opportunity Cost Calculation

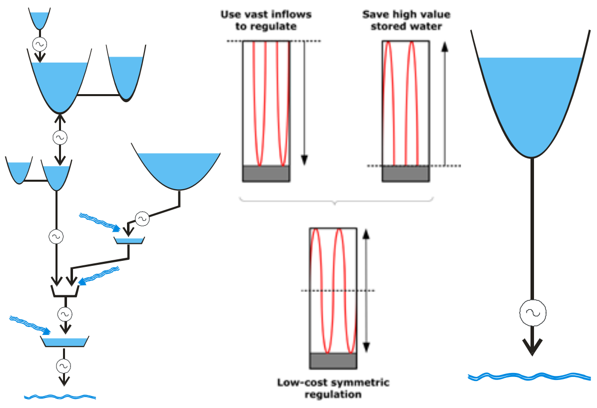
Challenges & Experiences: Pool optimization

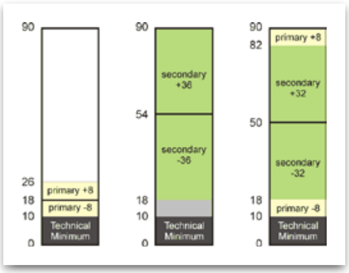
Importance of pool:

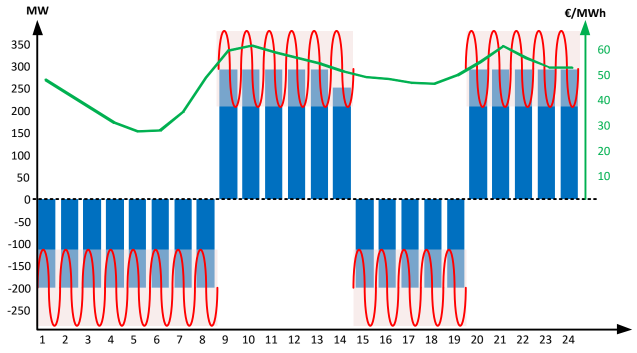
- asymmetric provision
- distribute simultaneously FCR, aFRR, mFRR
- provide reserves with pumps

Experience:

- pool in principle lower opportunity costs
- difference depends on many factors







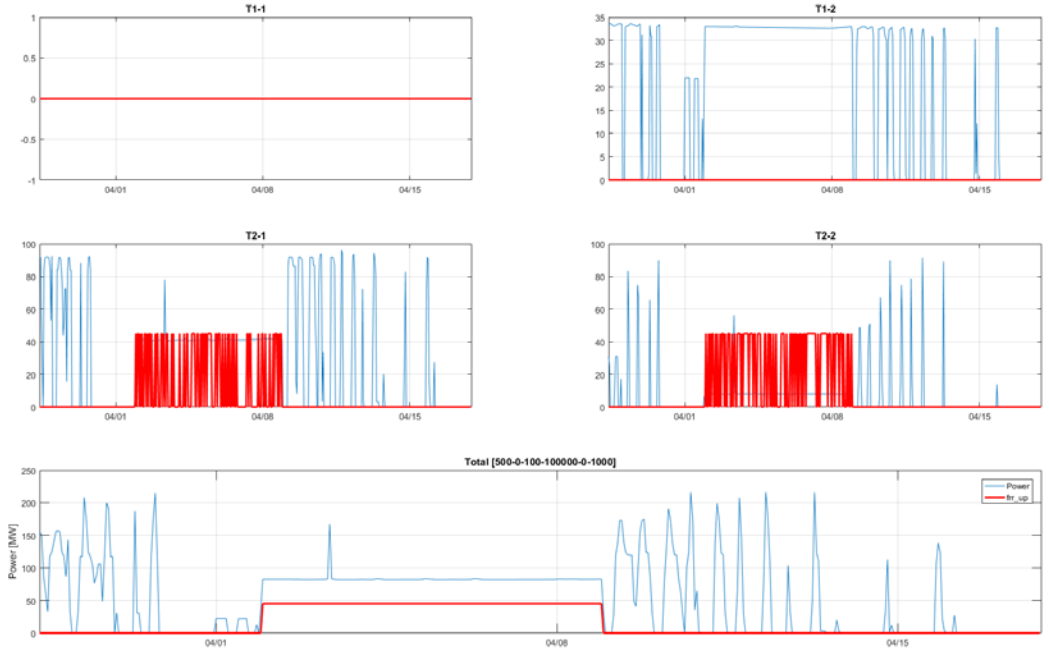
1. Reserve Opportunity Cost Calculation

Challenges & Experiences: Clustering

Clustering:

- “realistic” schedules
- -> de-optimization

“ramping costs” = 0



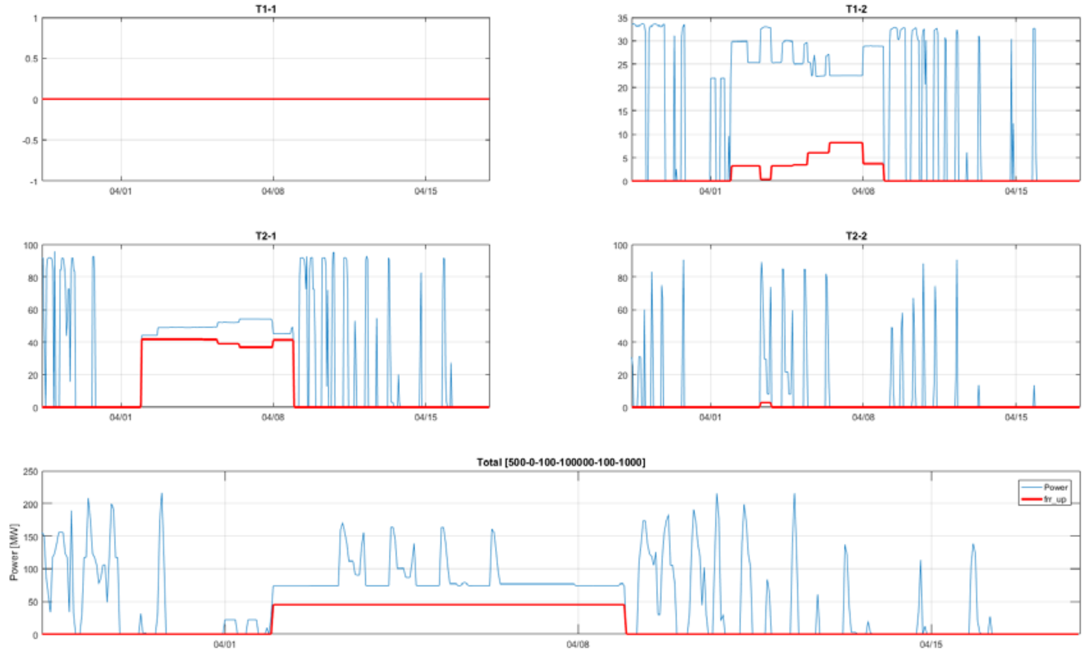
1. Reserve Opportunity Cost Calculation

Challenges & Experiences: Clustering

Clustering:

- “realistic” schedules
- -> de-optimization

“ramping costs” = 100



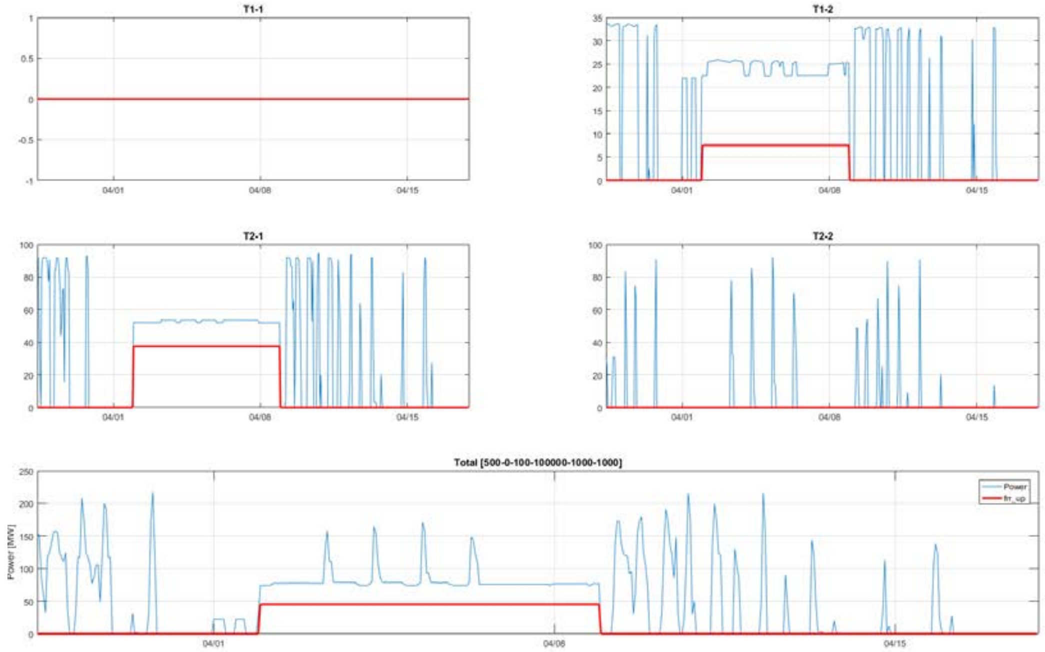
1. Reserve Opportunity Cost Calculation

Challenges & Experiences: Clustering

Clustering:

- “realistic” schedules
- -> de-optimization

“ramping costs” = 1000



1. Reserve Opportunity Cost Calculation

Challenges & Experiences: Clustering

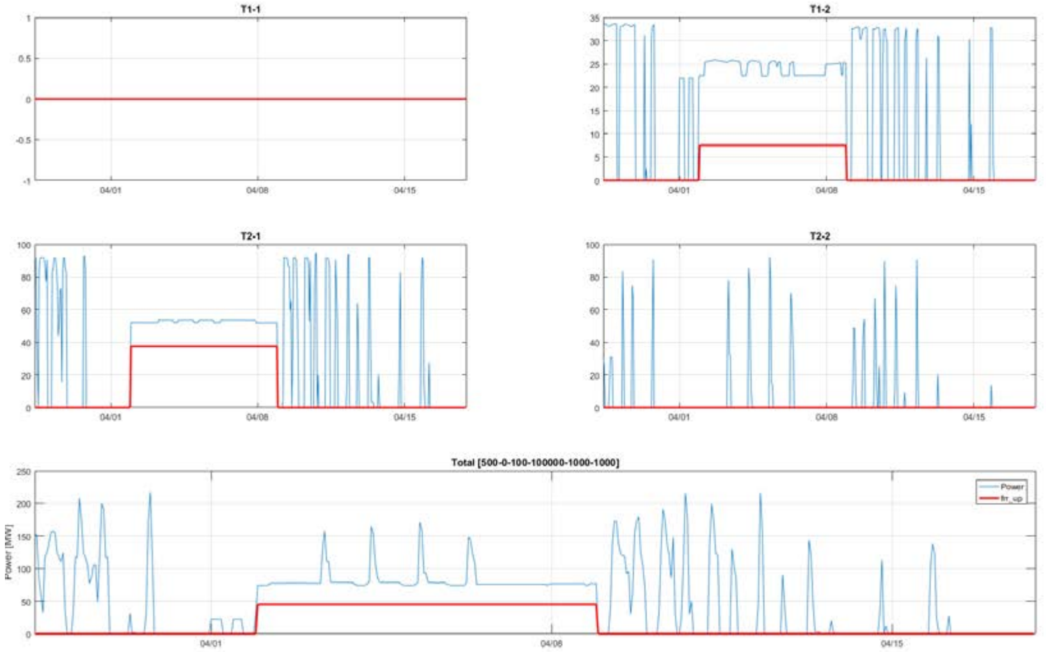
Clustering:

- “realistic” schedules
- -> de-optimization

Challenges:

- “tuning” of clustering costs
- dependence of clustering costs:
  - availability of units
  - interdependencies, e.g. cascades
  - current level of market price

“ramping costs” = 1000



1. Reserve Opportunity Cost Calculation

Challenges & Experiences: Penalties

When model not 100% clean:

- Cplex can have difficulties with solving mixed-integer problem:
  - numerical instabilities (coefficients 1e-5 to 1e7)
  - penalties -> relative MIP-gap not much use
  - -> useless opportunity costs (even negative possible!)

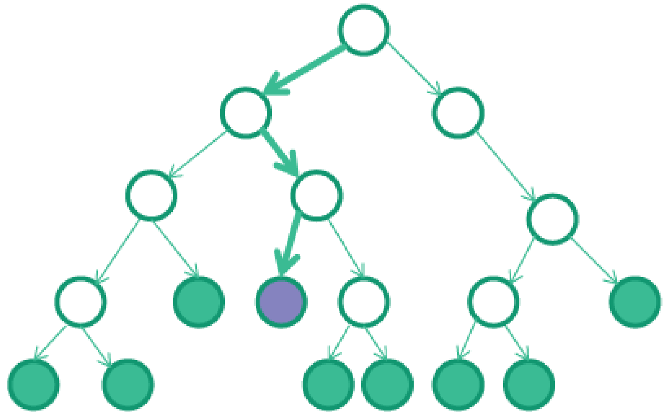
Interdependence of penalties:

- size of penalties often arbitrarily chosen
- however: as long as model is clean: not much influence

  (since penalties “not active”)

Unsolved issue:

- what to do when penalties are active? guidelines of size of penalties?



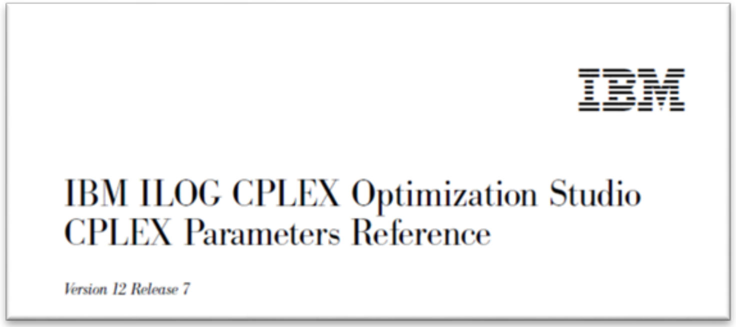
Picture from gurobi.com

1. Reserve Opportunity Cost Calculation

Challenges & Experiences: Computational Performance

Complexity:

- 250k variables, 150k constraints, 1.5k binaries
- Performance tuning:
  - hardware:
    - same solution: 3h – 6h
    - same calculation time available: 456 – 460 Mio Euro
  - parameters (SHOP and Cplex):
    - baseline: 30min -> 353.3Mio Euro
    - tuned for one instance: 4min -> 352.9Mio Euro
  - model:
    - time granularity
    - choice of water courses / type of reserves



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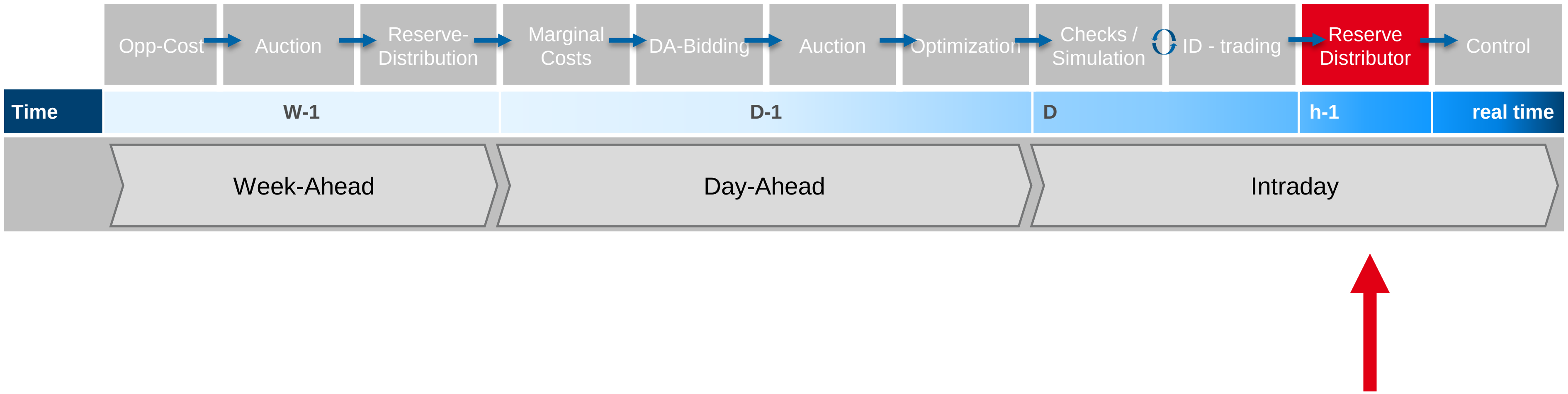
2. Intraday Reserve Re-Distribution



2. Intraday Reserve Re-Distribution

Purpose:

- intraday: decide where to fulfill reserve obligations: which units in the pool
- rerun if new information get available

In principle, not much difference to week-ahead reserve allocation. However:

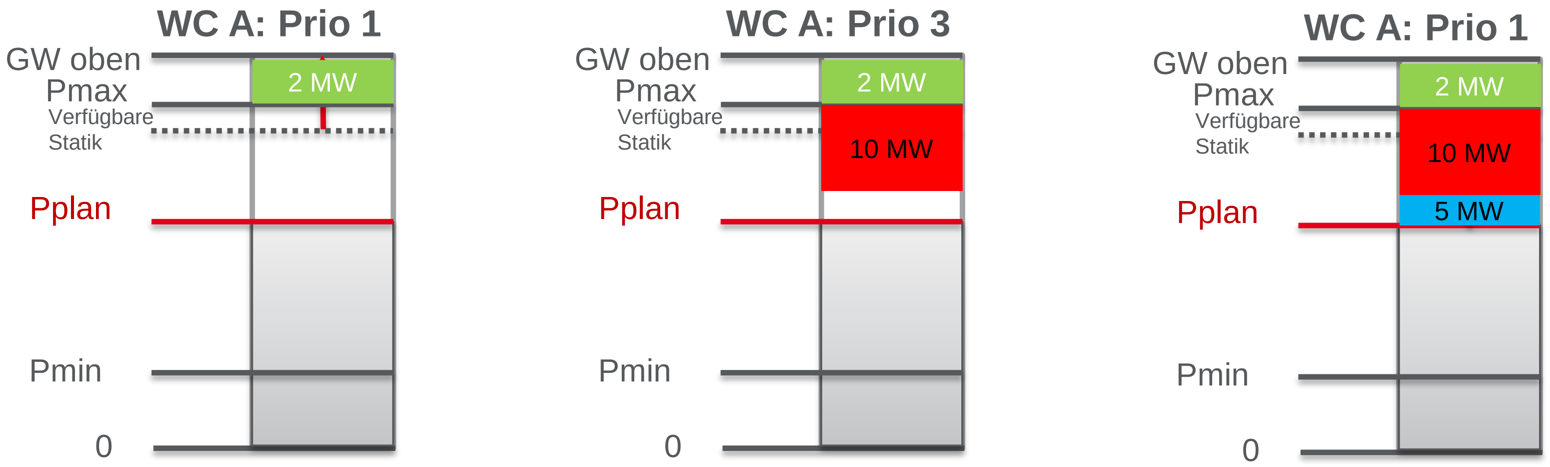
- known production profile for each unit
- time effort < 5min
- robustness

2. Intraday Reserve Re-Distribution

Heuristic approach

Since pool optimization not yet stable enough, heuristic:

- based on “merit order list” of water courses (based on marginal costs)
- six different lists: up/down FCR, aFRR, mFRR
- known operating points of all units
- very robust, whole process < 2min, rerun every 15min automatically



3. Outlook

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Goal: Bring reserve allocation optimization forward, in order to:

- Daily reserve bidding support
- Intraday re-distribution based on same optimization (meaningful?)
- Multi-market bidding support: DA, ID, reserves
- Bidding support for long-term reserve auctions


Many thanks for your attention
Axpo Trading AG | Baden | Switzerland