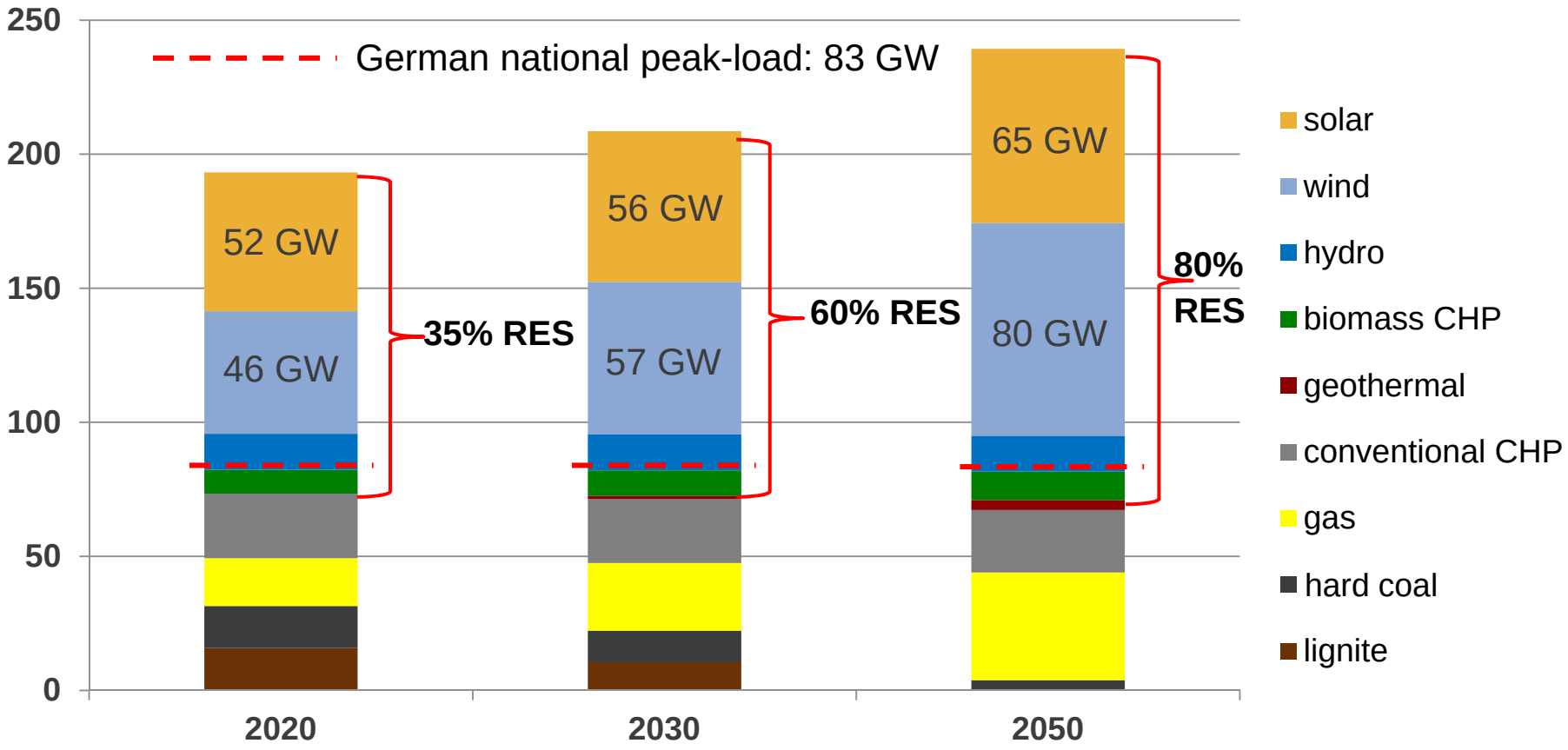
Hybrid Wind-Water Power Plant to facilitate Renewable Energy System Integration

Dr. Klaus Krüger, Voith Hydro Holding, Nov 2nd 2016, Philadelphia, USA

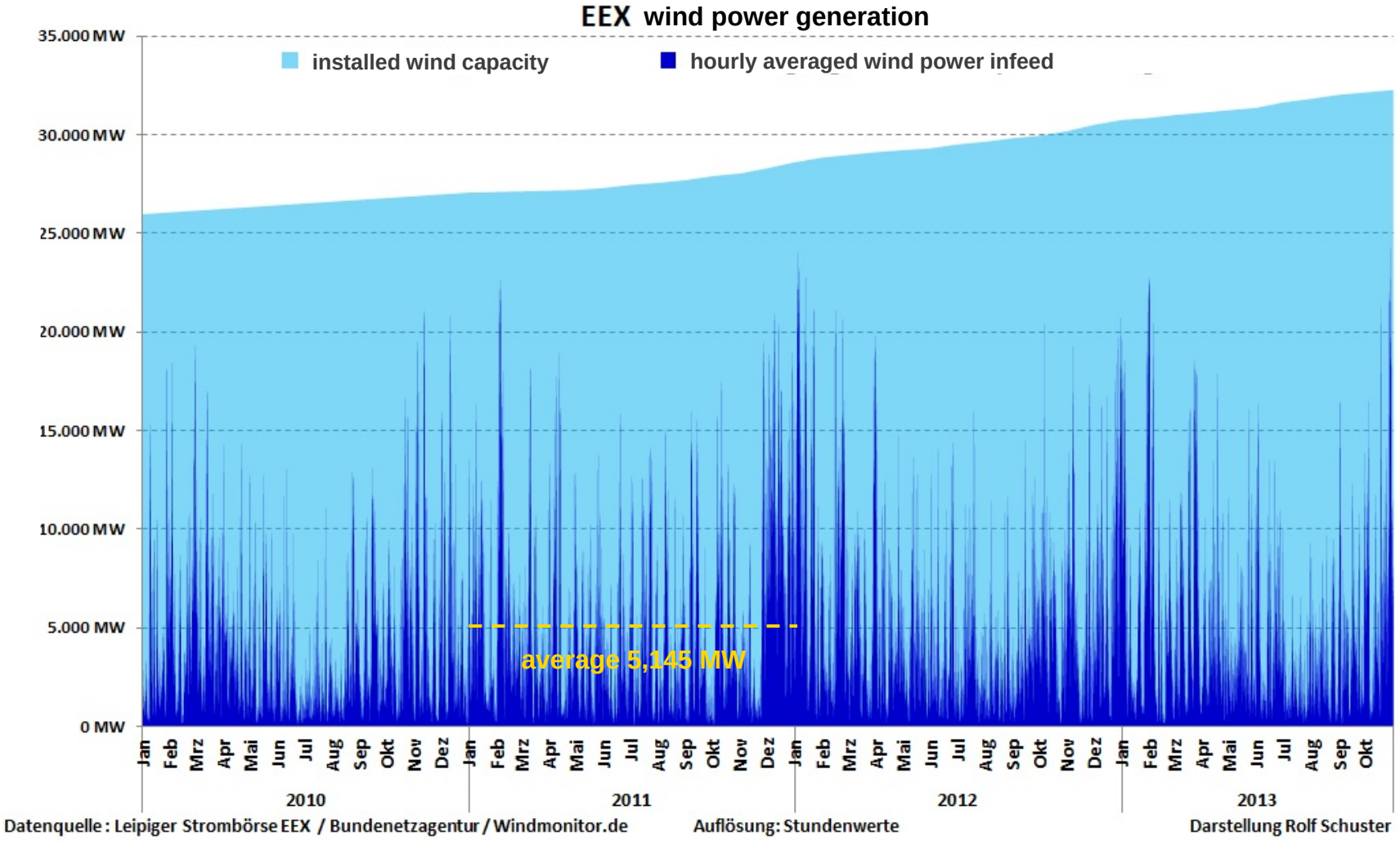
Forecasted break-down of installed power plant capacity 2020, 2030 and 2050 *) in Germany



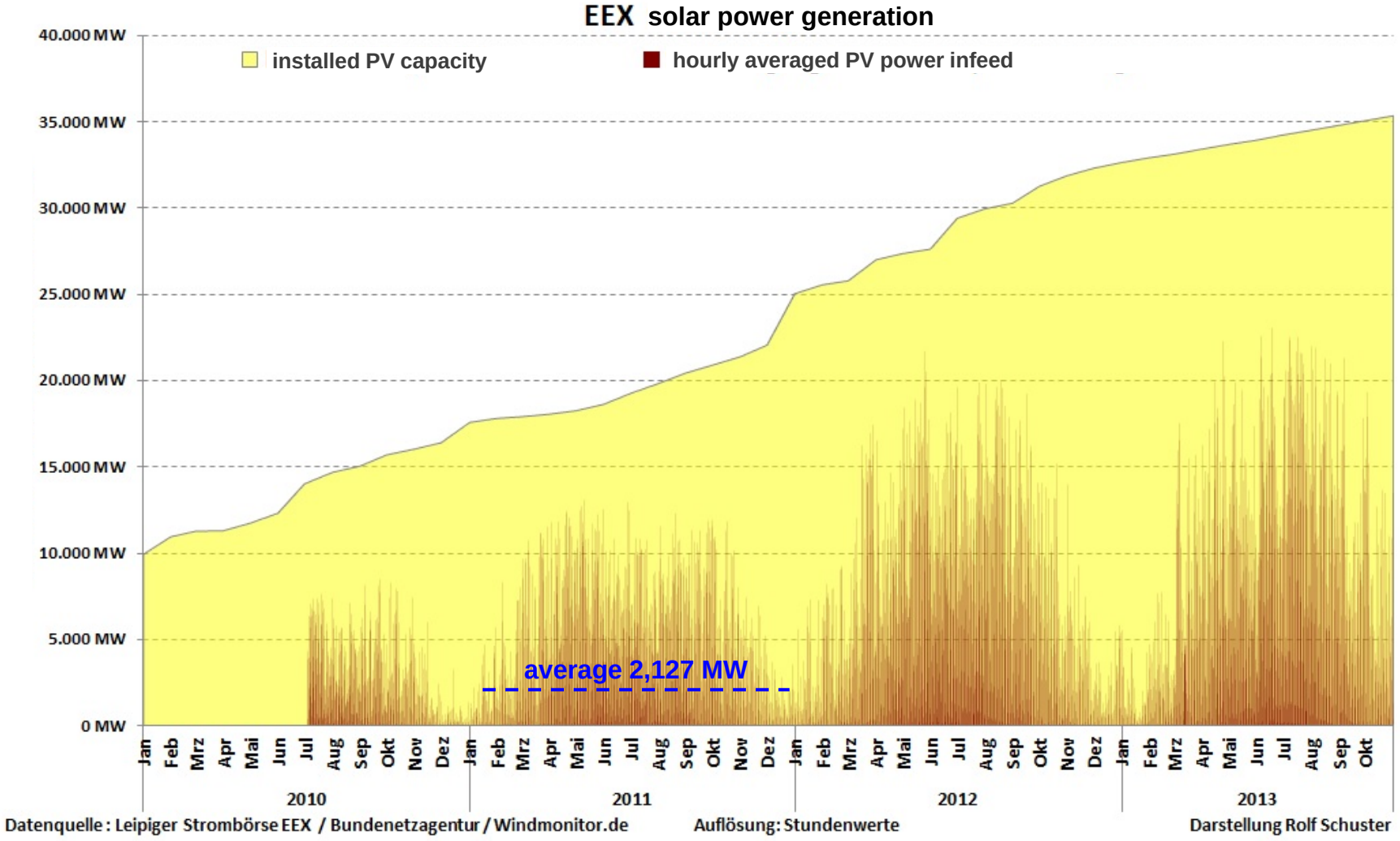
2014: wind 35,4 GW, solar 36 GW (peak), nuclear: 12,6 GW (will be shut down until 2022)

***) Nitsch, J., et al.: Pilot study of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), 2010**

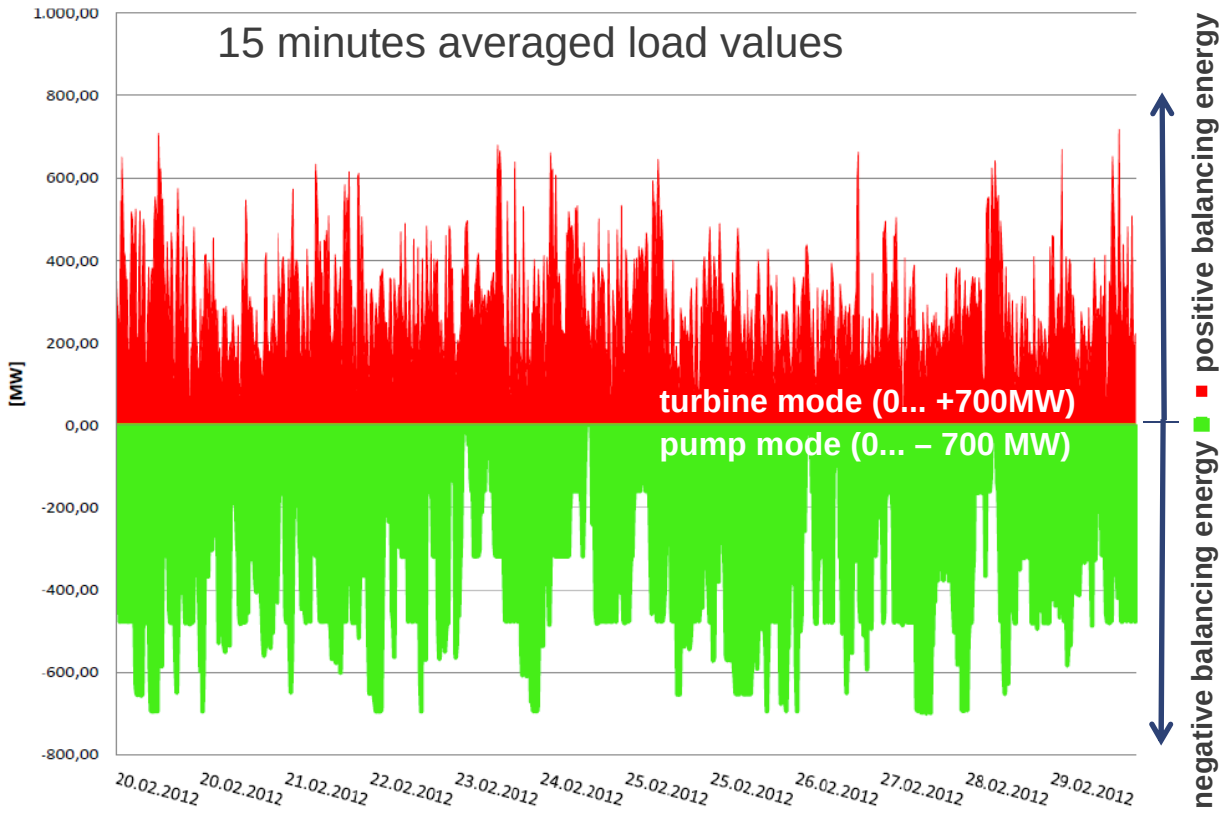
Wind: installed capacity vs. intermittent/ volatile generation in Germany



PV: installed capacity vs. intermittent/volatile generation in Germany



9 day load regime of a PSP complex compensating the volatility of wind & solar & their forecast errors



Source: Peter Matt, Vorarlberger Illwerke AG: Defining the Role of Hydropower in the European Energy Mix. Conference paper during the Hydropower Development, Porto, 17th-18th September 2014.

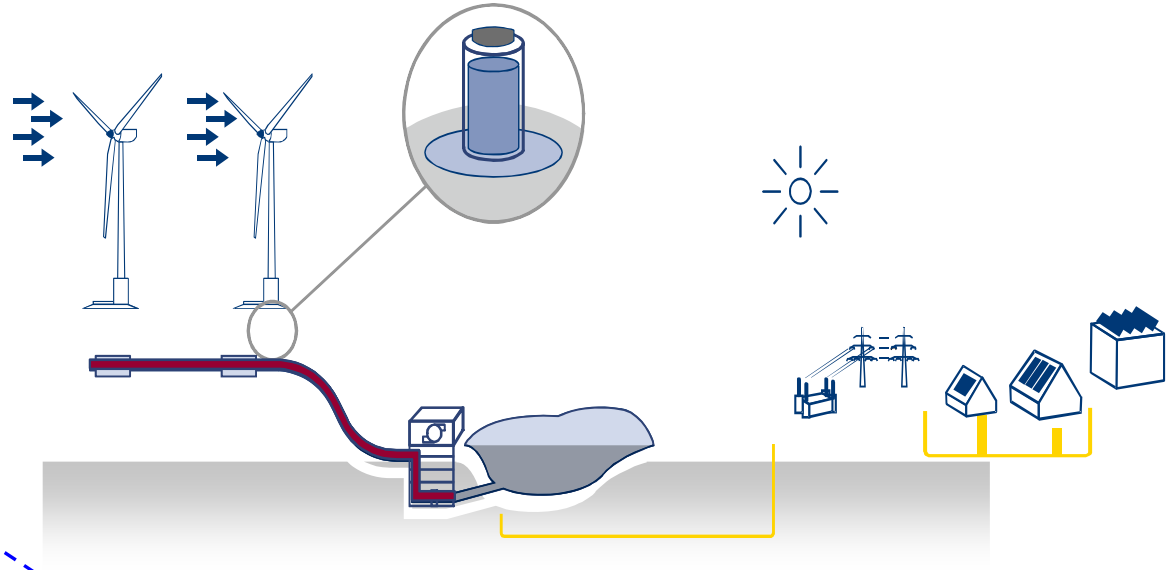
➔ Batteries or Demand Side Management cannot endure or comply with these frequent and short cycles

➔Pumped storage (PSP) is the only mature and feasible technology to provide such cycle-intensive services for the high voltage grid stability !

Owner: Vorarlbeger Illwerke EG in Austria.
Name of pumped storage complex:
Werksgruppe Obere Ill – Lünersee:

- Obervermutwerk (29 MW),
- Obervermutwerk II (360 MW) under commissioning
- Vermutwerk (156 MW)
- Kopswerk I (247 MW)
- Kopswerk II (525 MW)
- Lünerseewerk (232 MW),
- Rodundwerk I (198 MW) ,
- Rodundwerk II (276 MW)

Gaildorf: Hybrid pilot project wind energy generation & pumped-storage solution



Combination of

a) Wind power park (= el. energy generation)

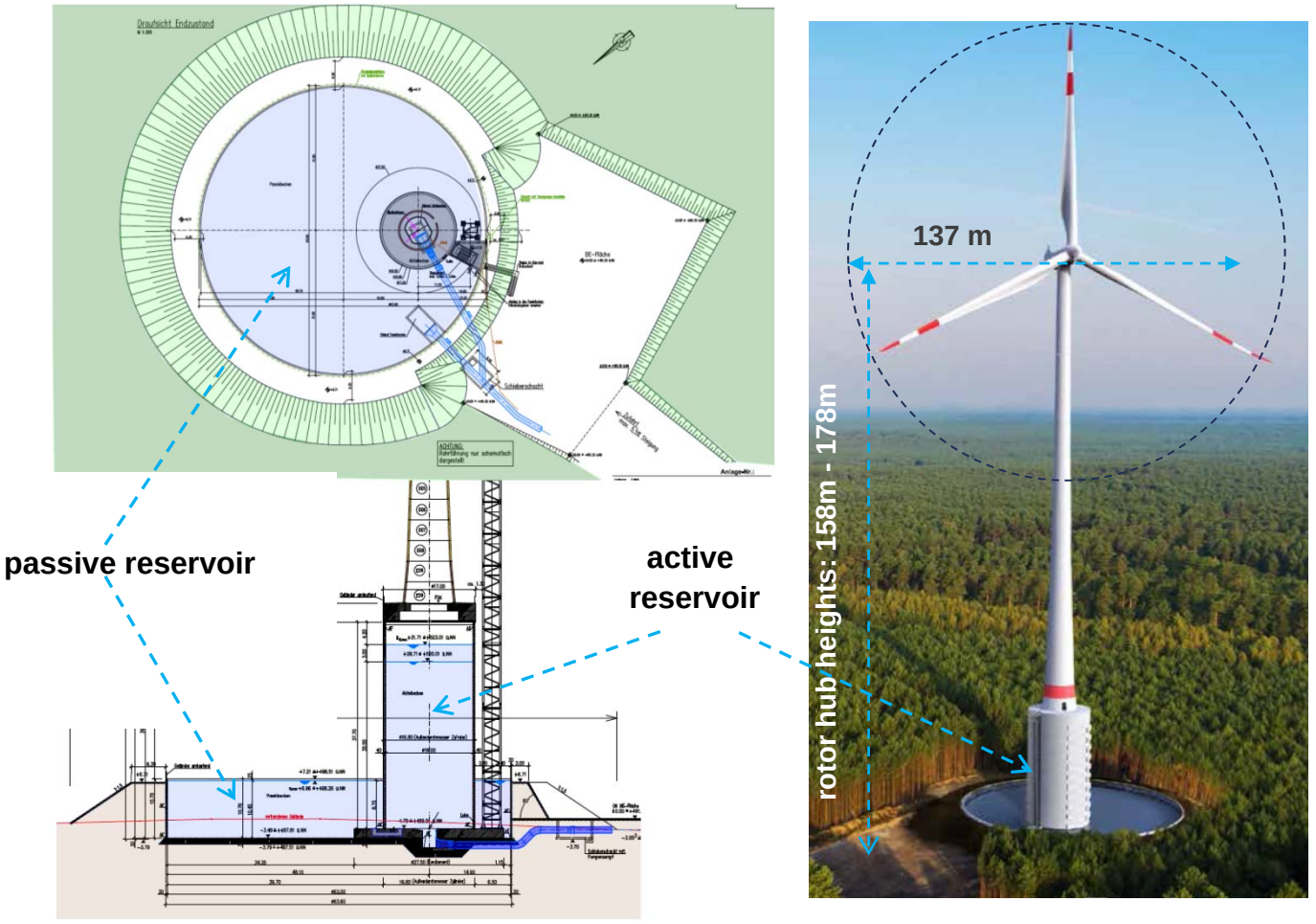
+

b) near-by pumped storage (= el. energy storage)

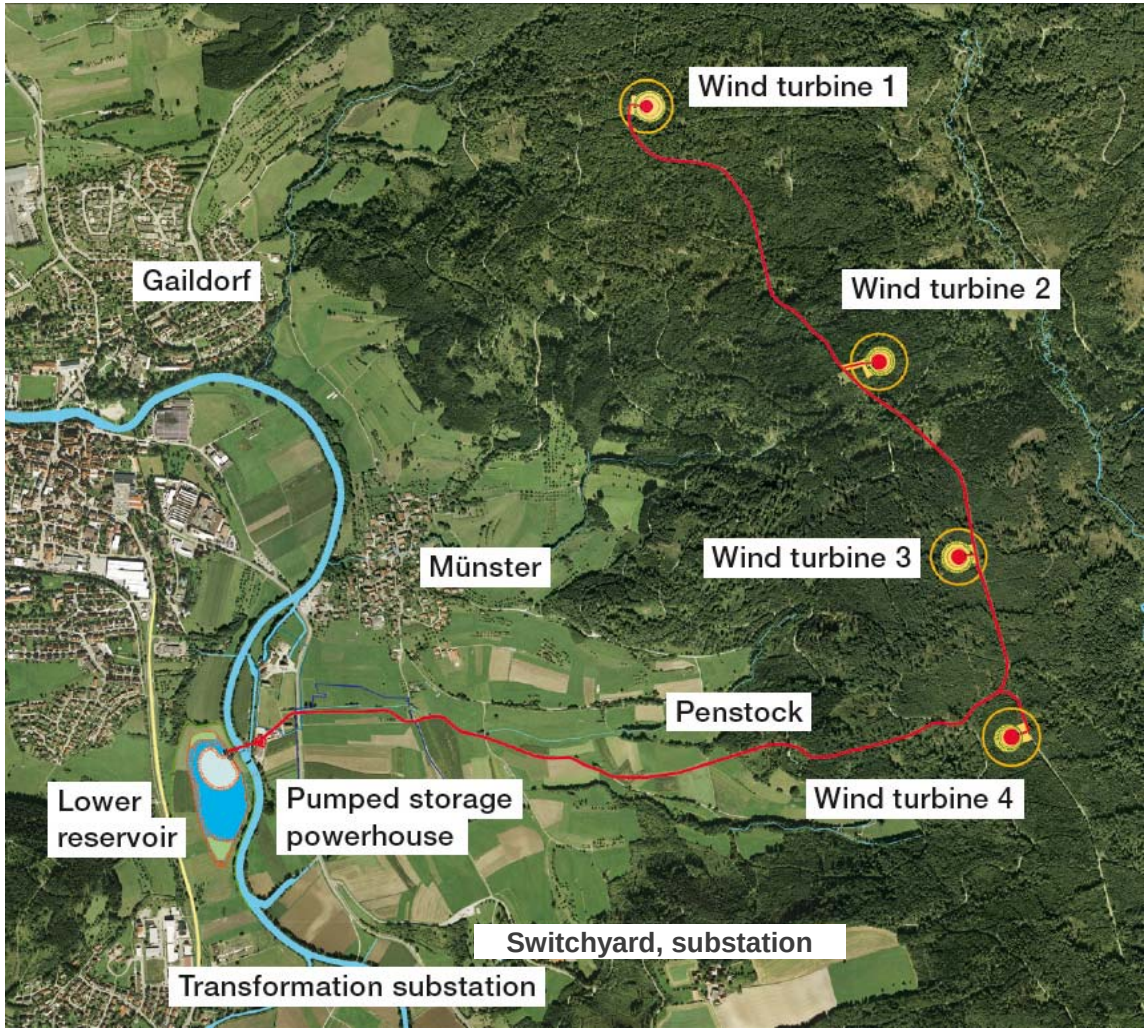
+

c) eco-friendly solutions (integrated upper reservoir, minimization of ecological impacts)

Details for the water storage in and around the wind tower (upper reservoir)



Plan of site & comments on lower reservoir

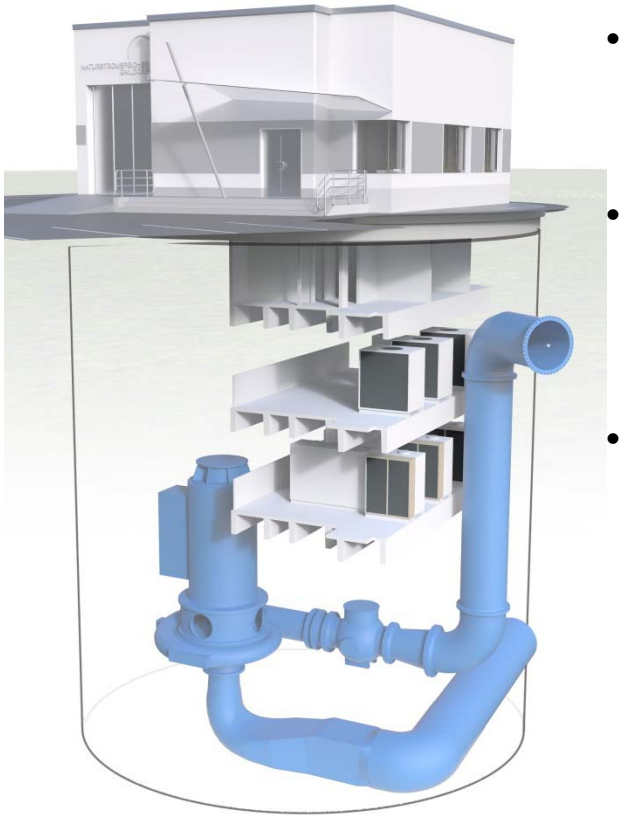


- total storage capacity of the lower reservoir: 210,000 m^3
- accommodation of 160,000 m^3 if the upper reservoirs are emptied
- plus additional 10,000 m^3 of evaporation reserves
- plus 10,000 m^3 for min. water storage for ecological reasons (e.g. fish population)
- plus accommodation of add. 30,000 m^3 during a 10 year flood condition, i.e. the lower reservoir can be used as a retention pond

Technical data I

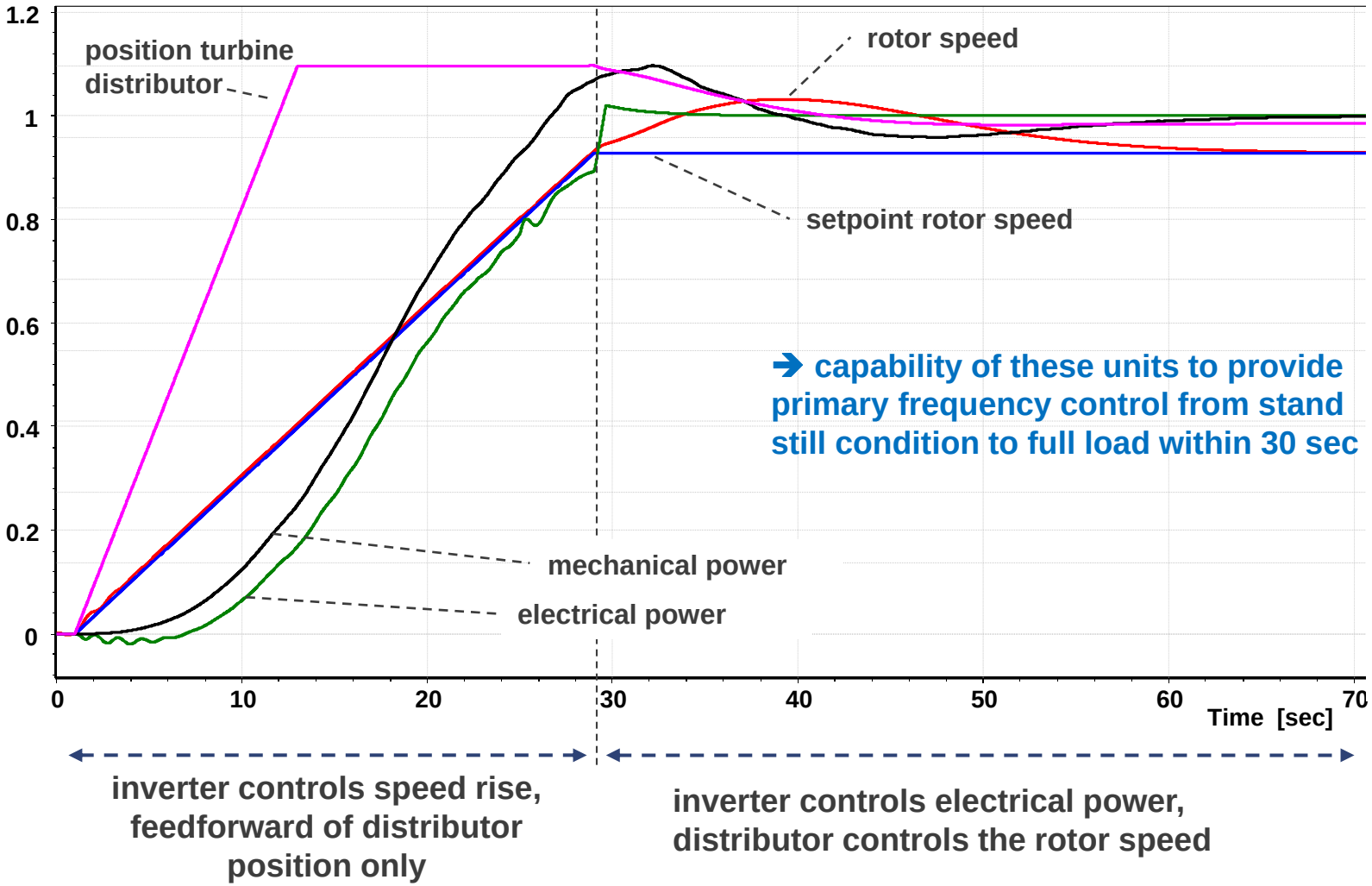
- Power wind turbines (4 x 3.6 MW) 14.4 MW
- Integrated water volume 160,000 m^3
- Power pumped storage power plant of 16 MW (3 x 5,3 MW vertical variable speed units)
- Net head: 200 m
- Electric storage capacity: 70 MWh
- CO_2 emissions are zero during operation since generation with wind & storage in pumped mode & generation in turbine mode are CO_2-free
- Complete coverage of the electrical energy consumption of the city of Gaildorf with 12,000 inhabitants
- Savings of approximately 10,000 tons of black coal or 25,000 tons of lignite coal & corresponding CO_2 emissions

Technical data II

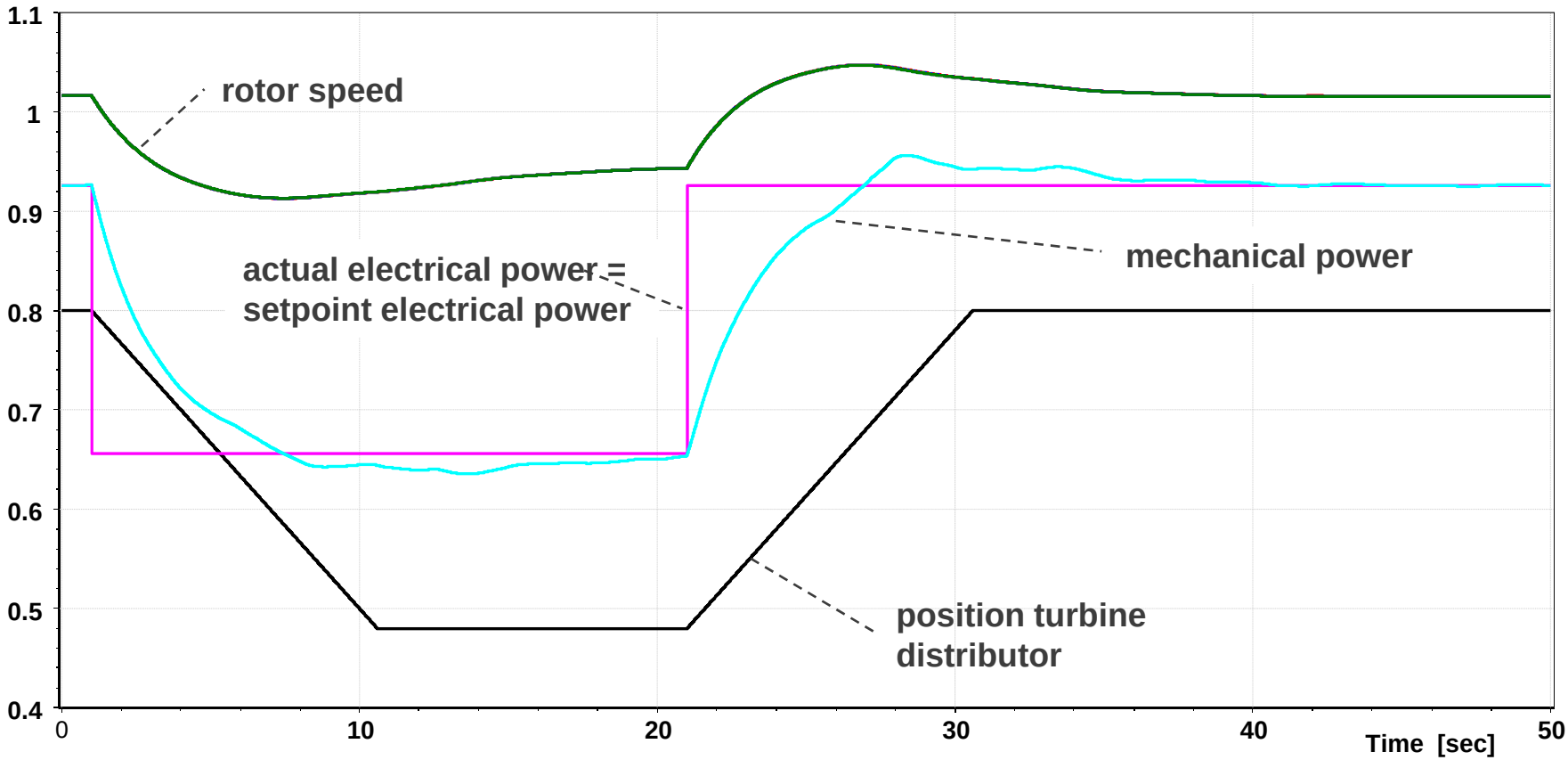


- Deep excavated power house type with 3 identical reversible and variable-speed pump-turbines.
- 3 squirrel cage type induction Motor-Generators (asynchronous MG).
- Each MG is connected to a four quadrant 3-level Voltage Source Inverter (VSI) using IGCT technology. These VSI are able to directly control the mechanical shaft torque (DTC technology).
- This solution allows a very high flexibility. The advantages of the chosen variable-speed solution allow for very fast load control in both pump and turbine mode, which is important to integrate volatile renewables.
- Further advantages of variable-speed solution are:
  - pump-turbines can be operated with higher water head variations,
  - part load limits in turbine mode may drop to lower values,
  - improvement of the dynamic responses of the pumped storage: all 3 units have the ability to supply positive primary frequency control, i.e. the start-up time in turbine mode from stand still to full load will be 30 seconds !

Simulation of the start-up of one unit in turbine mode

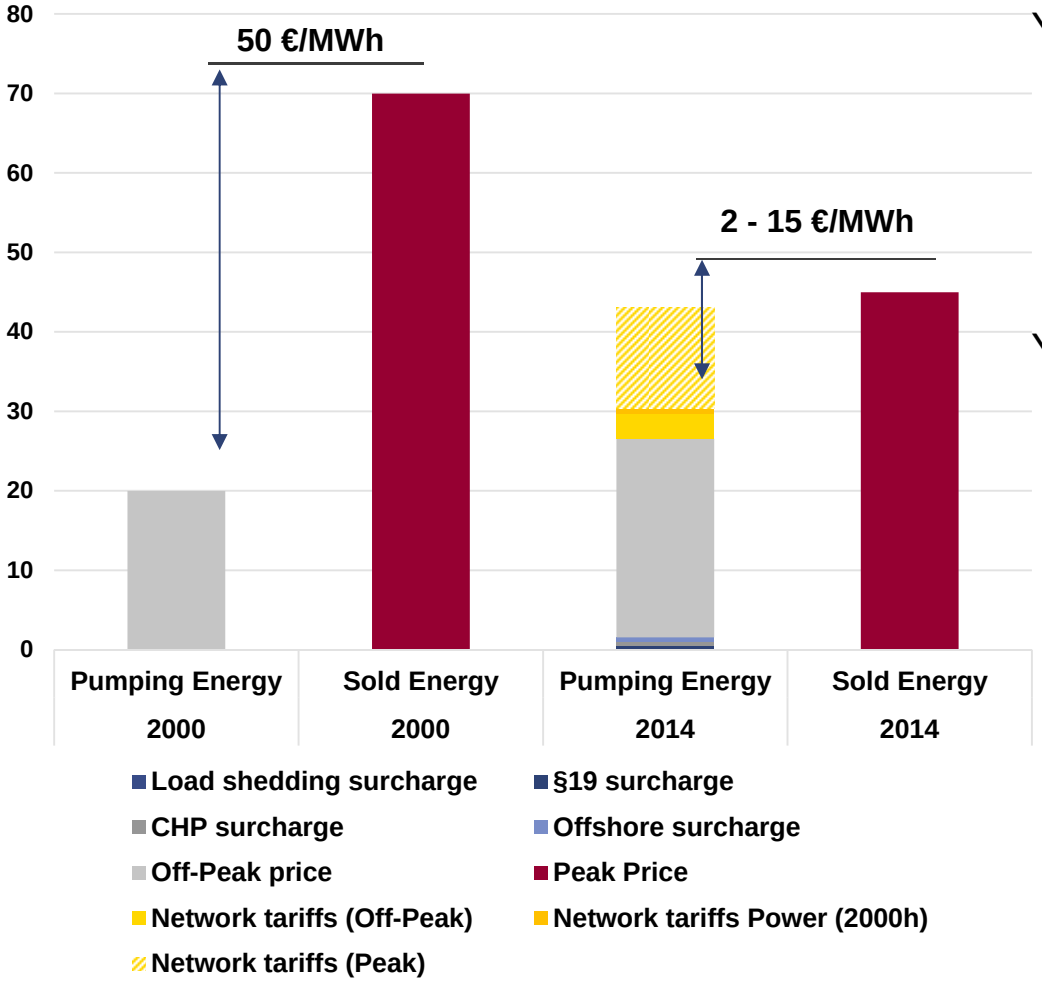


Simulation of load control in pump mode



The inverter is controlling the consumed power (dynamics equivalent to chemical batteries). The rotor speed is not controlled explicitly in the pump mode, i.e. the rotor speed adjusts itself as a function of power and head.

Development of price spread as seen by PSPs in Germany



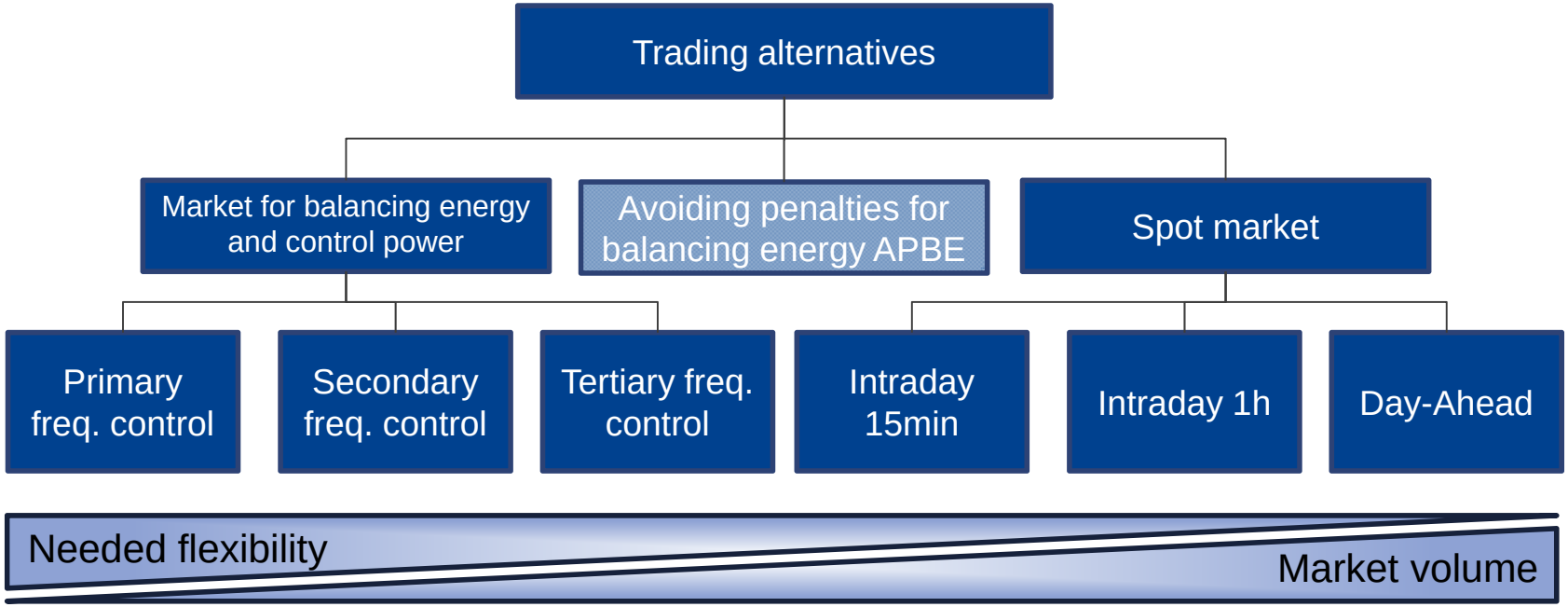
Year 2000:

- Sufficient spreads around 50 €/MWh
- Not networks tariffs for pumping electricity

Year 2014:

- Remaining price spread around 15 €/MWh (average prices)
- Decrease specially due to networks tariffs and decreasing peak price
- If full networks tariffs have to be paid (not solely atypical usage), no spread remains

Trading opportunities for the pumped storage In Germany

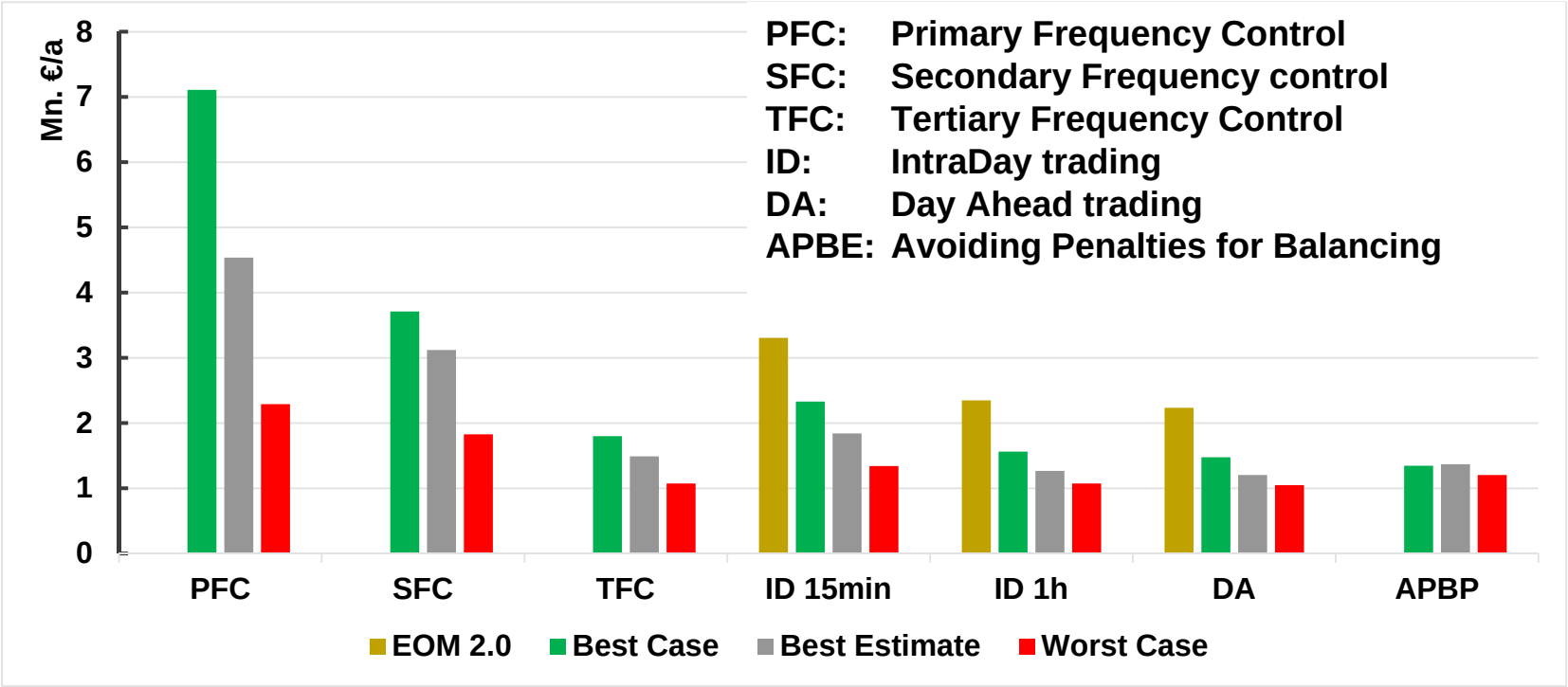


Markets have different flexibility requirements

Technical constraints are also restrictions for unit flexibility

➔The higher the required flexibility the lower the size of the market

Possible profit contributions for the pumped storage power plant



EOM 2.0: new release of the German Energy Only Market act

These different profit margins cannot be added together since they are alternatives; however, there is the possibility to jump from one alternative to another in order to maximize the profit

Advantages for on-site integration of PSP with the wind farm (under construction)

- Standardized pumped storage power plants (16 / 24 / 32 MW) for gross head ranges from 150m to 350m
- In Germany a fast & easy approval process for windfarms is in place, otherwise very massive public interventions due to the artificial upper reservoir
- Integration of the upper reservoir in the towers of the wind turbines reduces the interference in the natural areas significantly
- Short project implementation (3-5 years versus 10-15 years for large pumped storage power plants)
- Several project synergies PSP with a wind farm: substation, access roads, planning, land use, project & operation management, project volume, ...
- Easily bankable power plant solution
- Smoothening effects of the wind volatility regarding over-all power output

Dr. Klaus Krüger
Head of R&D Voith Hydro Holding
klaus.krueger@voith.com

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