Opportunities of water electrolysers in the European flexibility markets

A report from the FCH ELYntegration research project

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ELYntegation Project

- ELYntegration – Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications, H2020 Project
- Duration: September 2015 until August 2018
- Strategic goal
  - design of a robust, flexible and cost competitive multi megawatt alkaline water electrolyser (AWE) being able to be used under **highly dynamic power supplies** for **energy applications**
- Objectives
  - technical developments of AWE components (electrodes, membranes, stack)
  - testing of AWE prototype
  - **market and business preparation for energy applications**

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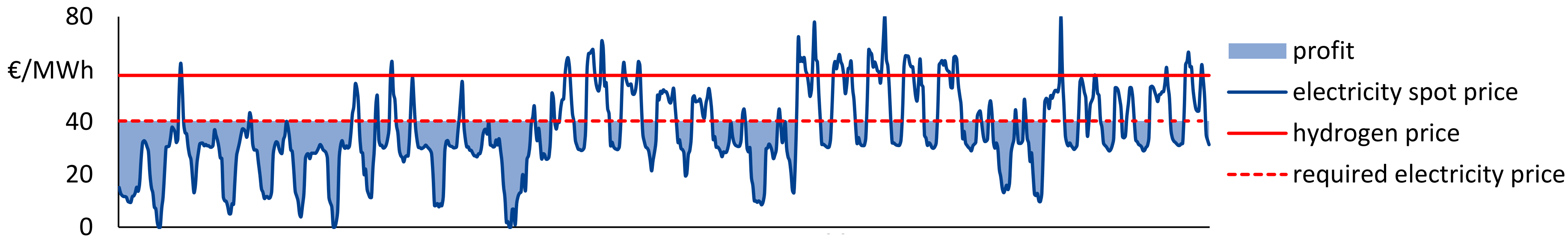
Chances for Water Electrolysis

- New market opportunities in markets with increasing RES shares for electrolyser with dynamic operation capabilities (fast start-up and ramping capabilities)
  - participation at **spot market for electricity**
  - provision of load flexibility within **control reserve markets**
- Both markets require highly flexible operation

➔ Which markets and operations are promising?

Exemplary electrolyser dispatch in cross-commodity arbitrage trading



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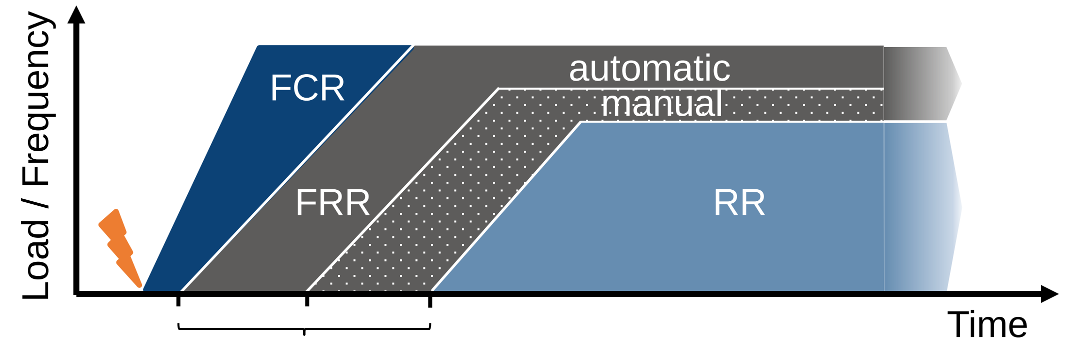
Grid Services

- Requirement: Consumers as market participants allowed
- Suitability of electrolysers determined by:

Control Reserve Qualities



technical restrictions { ramping abilities → ramping is not problematic
activation time → technically feasible when kept in hot condition

economic restriction { tender → higher chance of high electricity prices during long tenders

Control Reserve Requirements in Germany

	FCR	aFRR	mFRR
Activation time	< 30 s	~ 5 min	~ 15 min
Tender	one week	Currently:one week, Future: 6x4 hours	6x4 hours
Ramping Ability	high performance	at least 2 % of nominal power	no requirement

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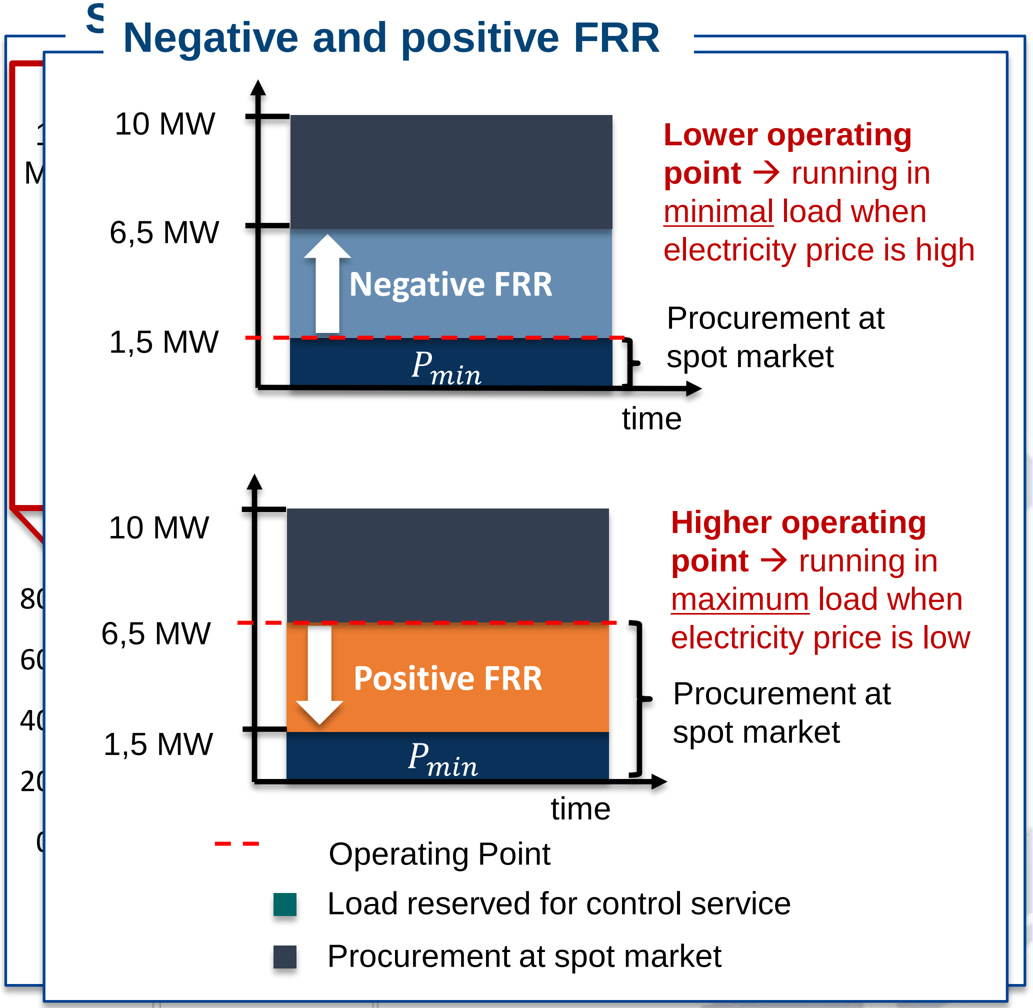
Operation schemes

Objectives of Operation

- 10 MW electrolyser
- Field of application depends on electrolyser use
  - Fixed generation volume when end user requires certain amount of hydrogen (e.g. hydrogen for plant)
  - Market optimized dispatch when end-use is flexible (e.g. hydrogen for mobility market)

→ Calculation of maximal revenues for market-optimal dispatch



Opportunities in future markets

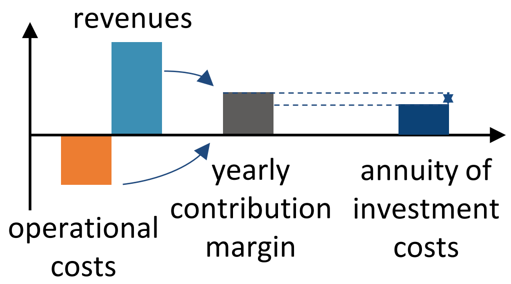
- What contribution margin may be possible in a future market surrounding?
- Consideration of **future prices of different markets** and **technical restrictions** for electrolyser dispatch for each business model

➔ Electrolyser dispatch based on market and transmission grid simulation results

➔ Assessment of full load hours and contribution margins

Calculation scheme of contribution margin

Contribution margin



Revenues

- Sales of hydrogen
- Provision of control reserve

Operational Costs

- Electricity purchase

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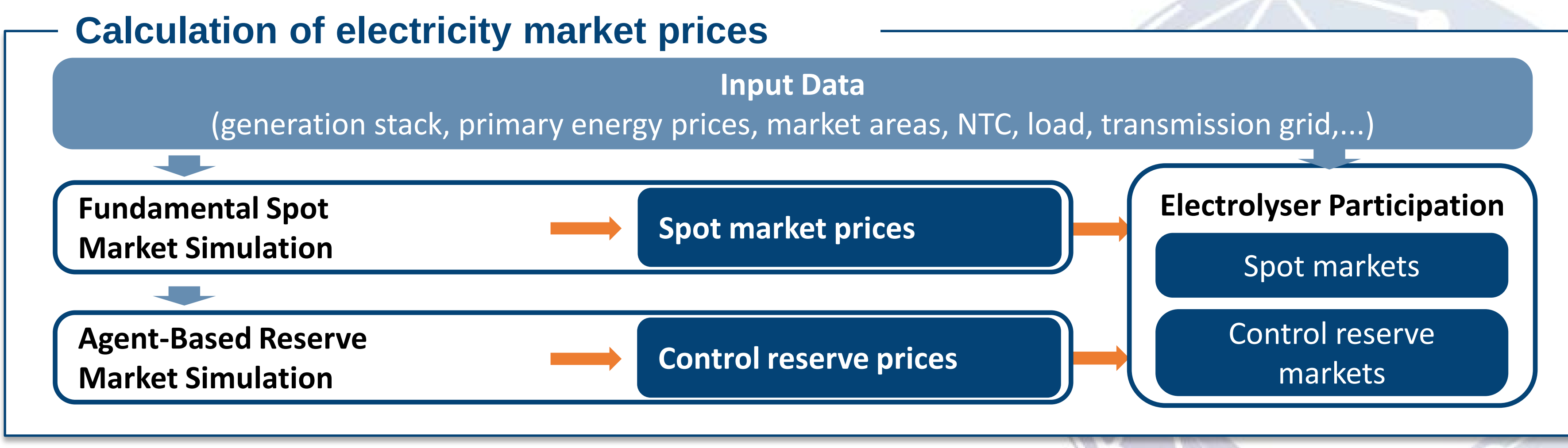
Calculation of electricity market prices

- Simuation of future spot and control reserve markets as well as transmission grid simulation
- Different market characteristics require different mathematical approaches

➔ Three different simulation tools used for calculation of future market situation



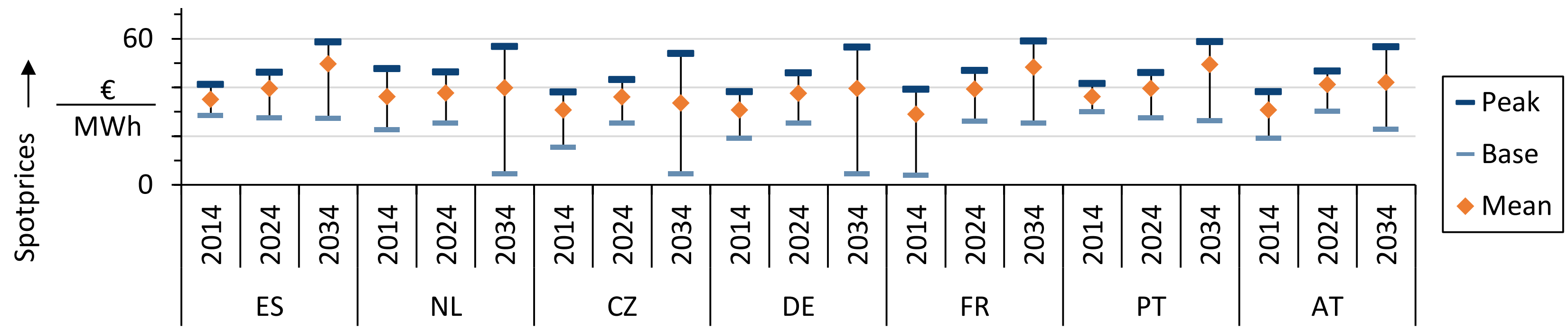
Simulation Set-Up

Scenario Definition

- Three time frames considered for assessment of future development
  - **2014** – Backtesting to assess current situation and validate model results
  - **2024** – Near future to assess transformation process
  - **2034** – Farther future to assess transition into “green” environment

➔ Rising average spot prices due to higher primary energy prices

Calculated average spot prices in different countries in Europe



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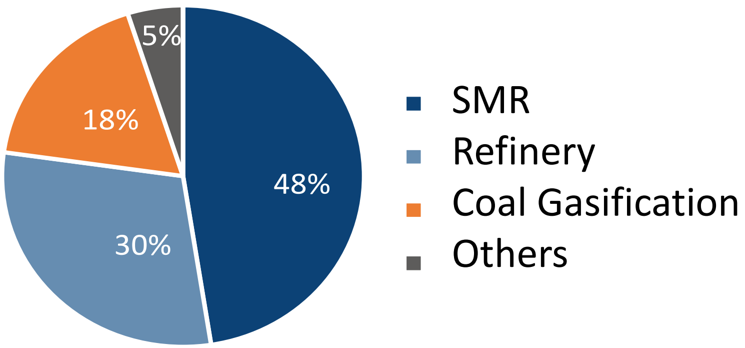
Calculation of hydrogen prices

Hydrogen production market and competitors

- Hydrogen demand exists in different sectors, e.g. industry, mobility or energy storage, but no central market exists
- Production market competitive, established conventional processes in place
- Assumed higher value of green hydrogen compared to conventional hydrogen

➔ Calculation of future prices based on competing prices plus “green premium”

Hydrogen market and assessment of hydrogen prices



Simulation year	2014	2024	2034
Natural gas price (€/MWh)	26.28	32.00	35.00
CO_2 emission permit price (€/tCO_2)	6.00	13.00	28.00
H_2 production costs by SMR (€/kg)	1.23	1.54	1.84
Asssumed green H_2 price (€/kg)	1.85	2.31	2.76

*1.5

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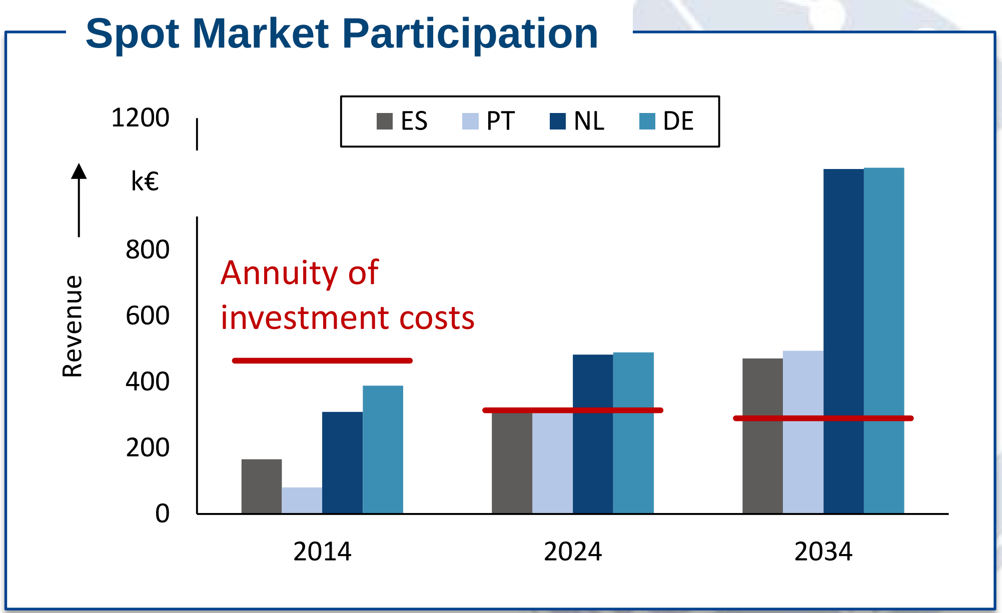
Results – Cross-Commodity Arbitrage Trading

- 2014 no cost coverage possible in either scenario
- **Higher full load hours** and **higher contribution margins** in future scenarios
  - Higher volatility due to higher share of RES in future markets
  - More hours with low electricity prices
- Effects **stronger in markets with high shares of wind turbines**
  - High wind feed-in leads to declined prices in many hours (DE, NL)
  - PV simultaneity and peak at noon lead to limited number of hours with very low spot market prices (ES, PT)



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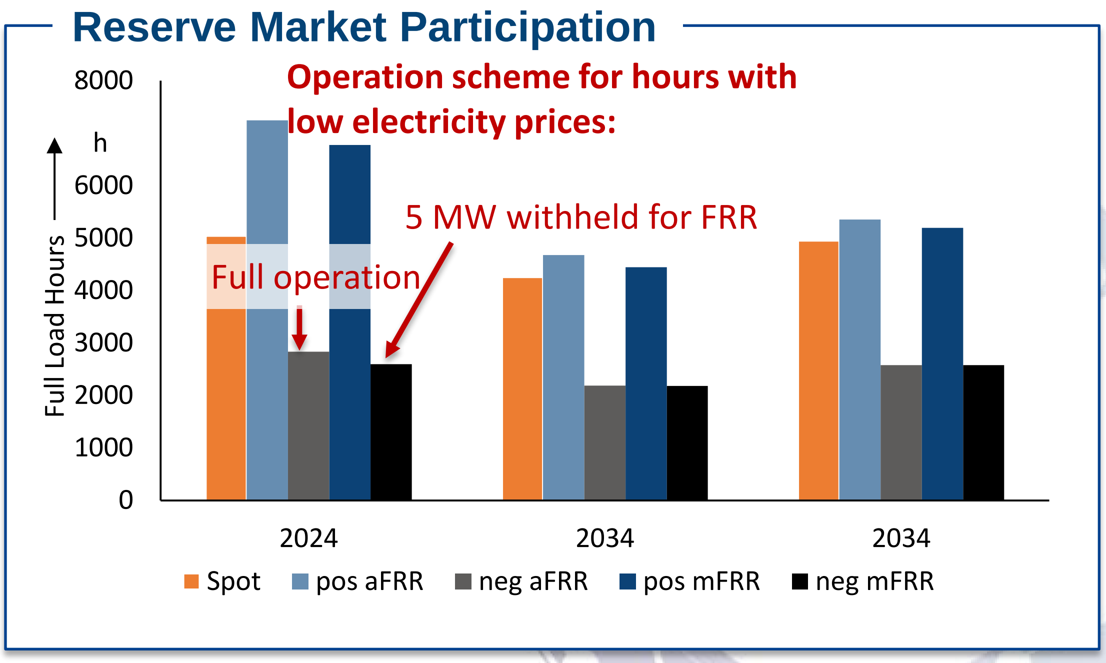
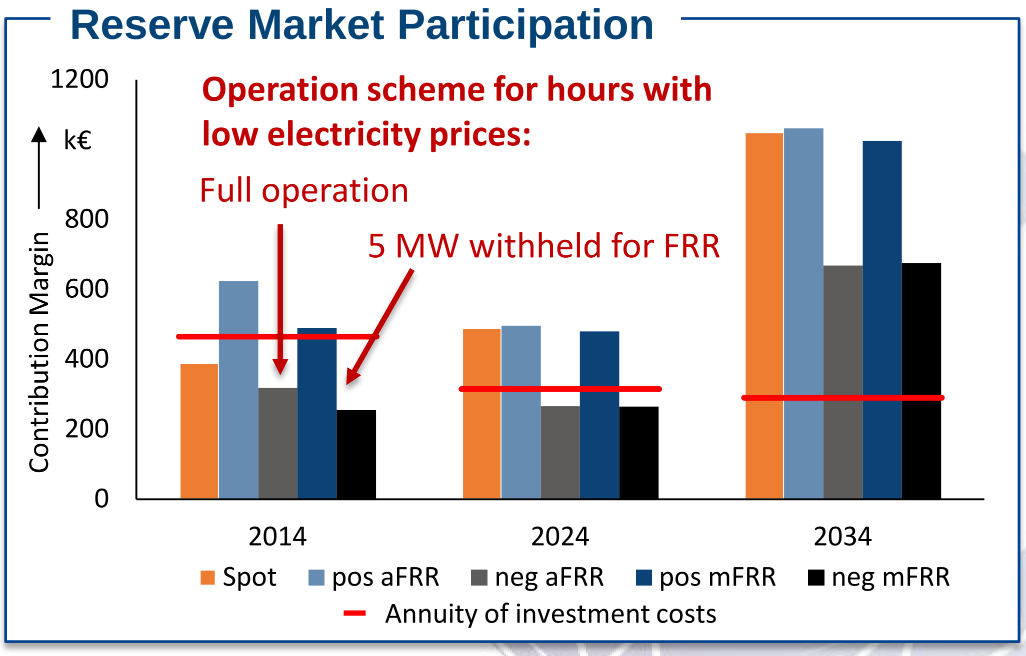
Results – Spot and Reserve Market Participation

- Full load hours decrease in future scenarios
  - Higher average spot prices leave fewer hours for market optimized dispatch
- Full load hours are **higher for positive reserve** than for negative reserve
  - Operation scheme for positive FRR requires higher operating point
- Full load hours are higher for aFRR than mFRR
  - Prices are higher for aFRR because technical requirements are higher



Results – Spot and Reserve Market Participation

- Even though full load hours decline, **contribution margins rise in future**
  - High RES feed-in entails hours with very low spot market prices
- Participation on markets for positive aFRR or mFRR increase revenues
  - Operation scheme allows to flexibly exhaust profitable spot market situations and reserve market
  - Negative FRR keeps electrolyser less flexible
- Decreasing advantage of reserve provision in future scenarios
  - Higher competition
  - Flexibility more important to exploit spot market volatility



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Conclusion

- **Economic efficiency** of new business models for grid integrated electrolysers **highly dependent on hydrogen price** – "green premium" assumed for electrolyser hydrogen
- Participation at **spot market for electricity**
  - contribution margins are rising for future scenarios with high RES shares
  - promising markets are especially those with high shares of wind power
- Participation at **control reserve markets**
  - Provision of positive FRR is profitable business model
  - Decreasing advantage of reserve provision in future scenarios due to competition and relevance of flexibility

➔ **Flexibility** becomes highly relevant in the future for exploitation of low spot market prices and control reserve opportunities

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