QualyGridS WP6

Opportunities identification
Definition of selected business cases and scenarios

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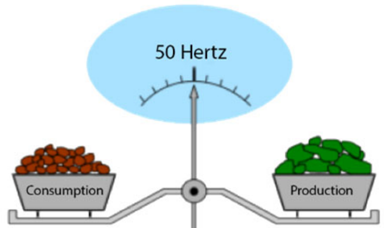
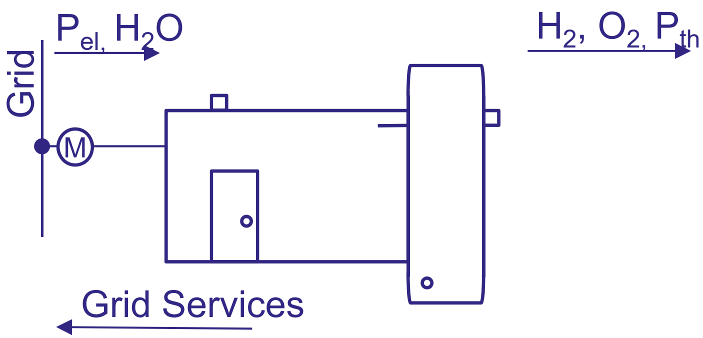
Goals





Grid services considered:

- TSO grid services (frequency containment and restoration, replacement reserve, congestion mgmt)
- DSO grid services (congestion mgmt, voltage control)
- BRP and P2P grid services (self-balancing, portfolio optimisation, P2P energy trading)

➢ Opportunity identification

➢ Consider future-scenarios

➢ Select the most promising 4 business cases for a water electrolyser (WE) in combination with grid services (GS)

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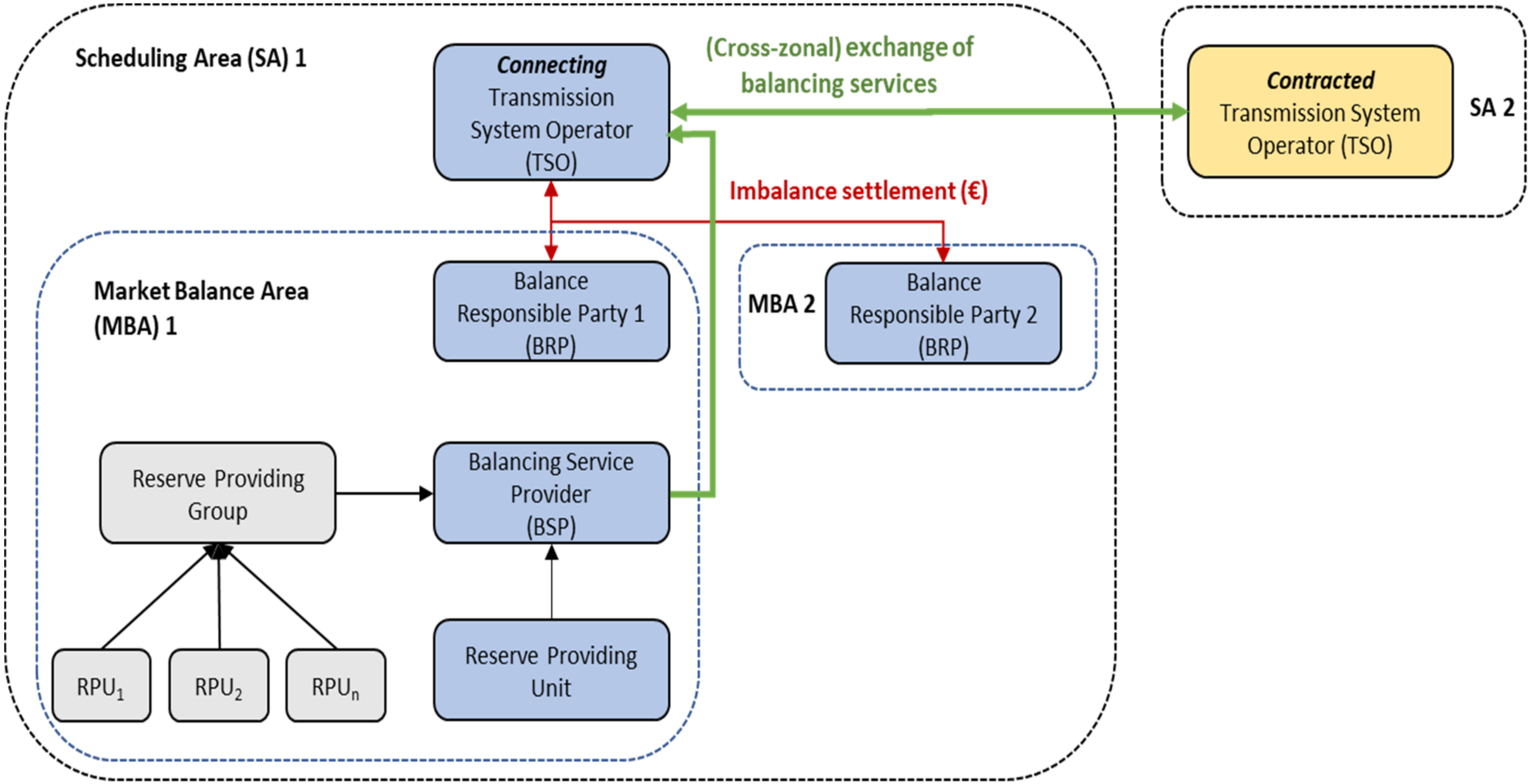
Business logic



Relations between relevant market participants for the TSO-TSO model according to GLEB

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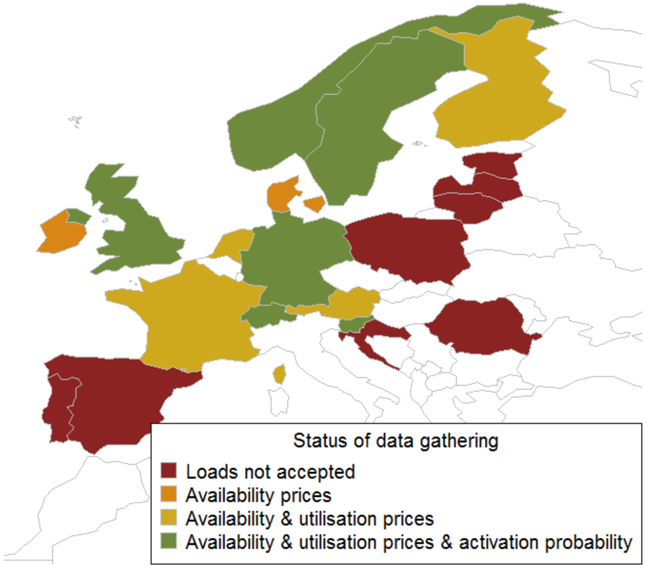
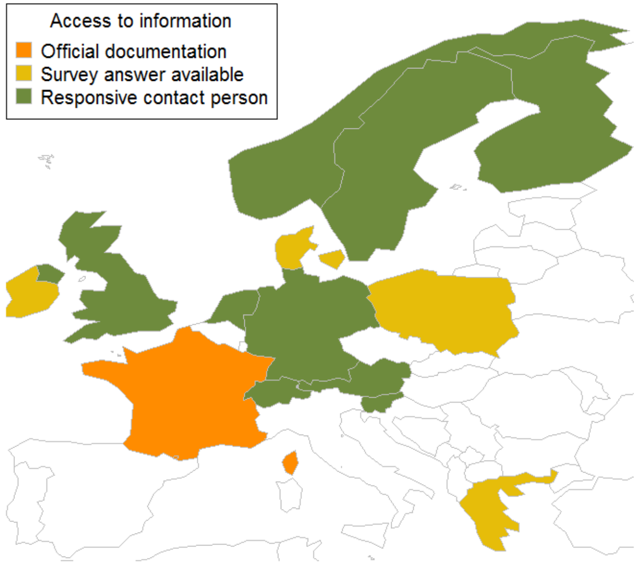
Select suitable grid-service products





- Survey and interviews in 30 countries (28 EU countries plus Switzerland and Norway) leading to 85 identified TSO GS.
- Based on GS & power prices and predicted H_2 demand, following GS were selected for further assessment:
  - TSO GS: Germany: **aFRR+, aFRR-, mFRR+, mFRR-, FCR;** Norway: **mFRR+, mFRR-**
  - DSO grid services: congestion management for wind farms.

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Future outlook - Short term (2025)

- ‘Flexibility’ understood as short term flexibility.
- Single flexibility products and technologies can be considered.
- FCR expected to remain constant at its current size of 3’000 MW till 2025, 10-20% covered by stationary batteries. (Kessels)
- aFRR expected to increase from 8’400 MW to 10’000 MW, 10-20% covered by stationary batteries. (Kessels)

→ Investments in batteries and DSM providing grid services are likely to increase in the short-term.

→ Costs (of batteries and opportunity costs for DSM) as well as the lack of consumer acceptance (for small load DSM) are likely to prevent these technologies from dominating the balancing markets.

Key source: Kessels et al. (2016). Support to R&D Strategy for battery based energy storage. EC Directorate General d’Energie.

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Future outlook - Long term (2050)

- Flexibility to be dealt with as a whole.
- Share of VRES expected to increase (40%), and flexibility sources double. (IEA, p. 76)
- Sustainable Development Scenario (SDS; IEA): Meet Paris Agreement targets for CO2; 41% VRES
- New Policy Scenario (NPS; IEA): Less ambitious, 38% VRES
- Roughly 60% of generation coming from dispatchable conventional power plants ➔ dispatchable conventional power plants remains major source of flexibility.
- For political reasons, market designs will avoid extreme price peaks. Flexibility investments will be incentivized with non-energy products.
- 4 classes of flexibility: power plant flexibility (approx. 60%), demand side management (DSM) incl. WEs (NPS: 3%), storage (batteries: 4% (NPS) - 10% (SPS)) and interconnections (NPS: 11%).

→ Electric flexibility demand is expected to grow dramatically as the demand profile changes and the share of VRES rises.

→ Despite the entry of new flexibility technologies, we cannot see any reason to believe there will be a dominating flexibility providing technology.

Key source: IEA (2018) World Energy Outlook 2018.

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Characterization of grid service products

Example: Germany

	Temporal Resolution	Availability	Utilization
aFRR	12 hour (peak/off-peak)	Pay As Bid	Pay As Bid
mFRR	4-hour	Pay As Bid	Pay As Bid
FCR	weekly	Pay As Bid	None (symmetrical)

- EEG surcharges are neglected: expert opinions give indication those will be changed in the future. The approach complies with the works of other authors (e.g. ELYntegration).
- For each case, evaluate a reasonable bidding strategy and calculate the expected impact on LCOH.
- First conclusion: operating the WE at lowest e-prices reduces the value of up regulation.

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Evaluation of selected business cases

General approach to TSO Grid Service evaluation:

1. Characterisation of typical WE applications:
    - Goal: derive constraints for water electrolyser operation

2. Formulate reasonable strategies for grid services operations
    - Goal: reduce electricity costs
    - Considering 7 power reserve TSO grid service products (2 Norwegian, 5 German)

3. Calculate the levelised cost of hydrogen (LCOH) for all grid service products
    - Goal: Make costs comparable to identify savings as a result of each grid service offering

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1. Characterization of WE applications

	A Industry with constant demand of process-hydrogen	B Industry with “unconstrained” demand of electrolyser-H2	C Distributed hydrogen fueling station	D Power to gas connected to the natural gas grid
Economical reasoning	On-site production economically advantageous over the supply of centrally produced H_2	No economic justification other than PR	On-site production economically advantageous over the supply of centrally produced H_2	Revenue: gas-price. Not regarded as being profitable in the mid-term!
Full load hours	CAPEX is predominant cost factor: dimensioning for +/- 8000 FLH		Due to the fluctuating character of H_2 demand: oversized electrolyser +/-4500 FLH	
Storage-assumptions	H2-storage due to fluctuations: 24h-storage		Due to the short-term H2 demand fluctuations: 24h-storage	

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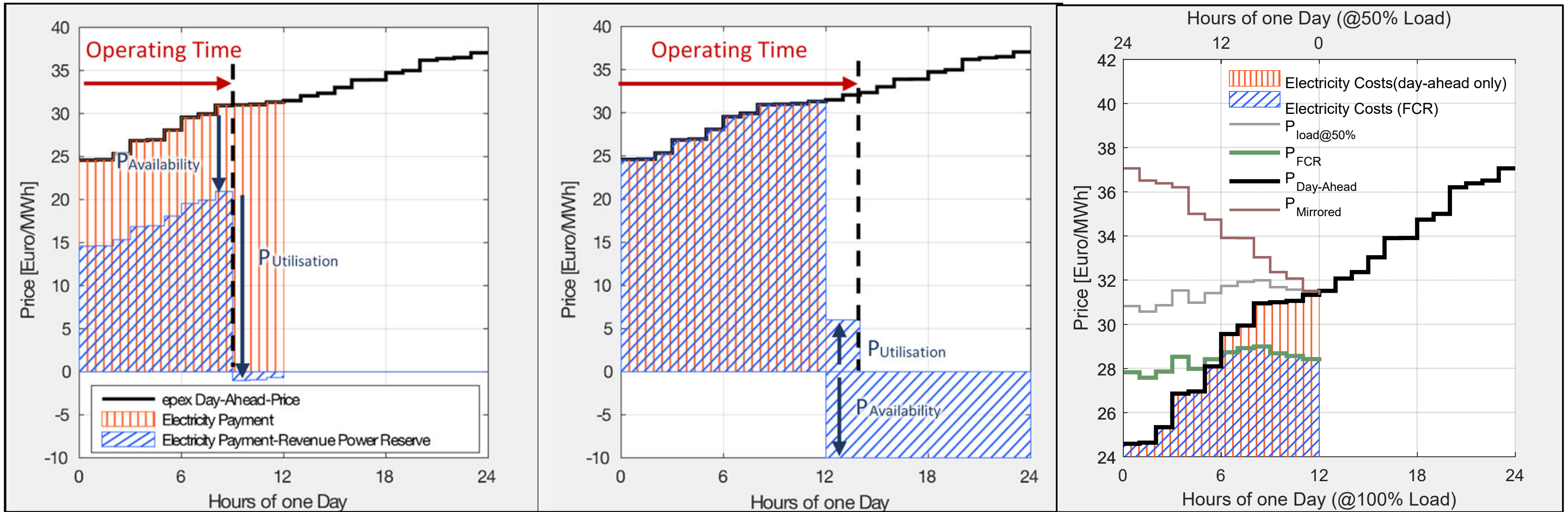
2. Strategies for grid service operations

Asymmetric positive (FRR+)	Asymmetric negative (FRR-)	Symmetric (FCR)



Example of one day and an electrolyzer operating 12h/day (4380 full load hours)

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3. LCOH calculation – WE parameters

	Alkaline (ALK)	PEM
Nominal Power	1 MW	
Maximal Power	1 MW	
Maximal Power (Positive Sensitivity)	1 MW	2 MW (1 MW)
Power Consumption	58 kWh_e/kg	63 kWh_e/kg
Lifetime - System	20 Years	
Stack - Lifetime	80'000 h	40'000 h
Degradation	not considered	
CAPEX - System	1'200 €/kW	1'500 €/kW
CAPEX - Stack replacement	420 €/kW	525 €/kW
OPEX	4 %/CAPEX	
Weighted average cost of capital (WACC)	8%	

Table 1: Assumptions [1]

[1] TRACTEBLE; engie; Hinicio. Study on early business cases for H2 in energy storage and more broadly power to H2 applications. FCH, 2017.

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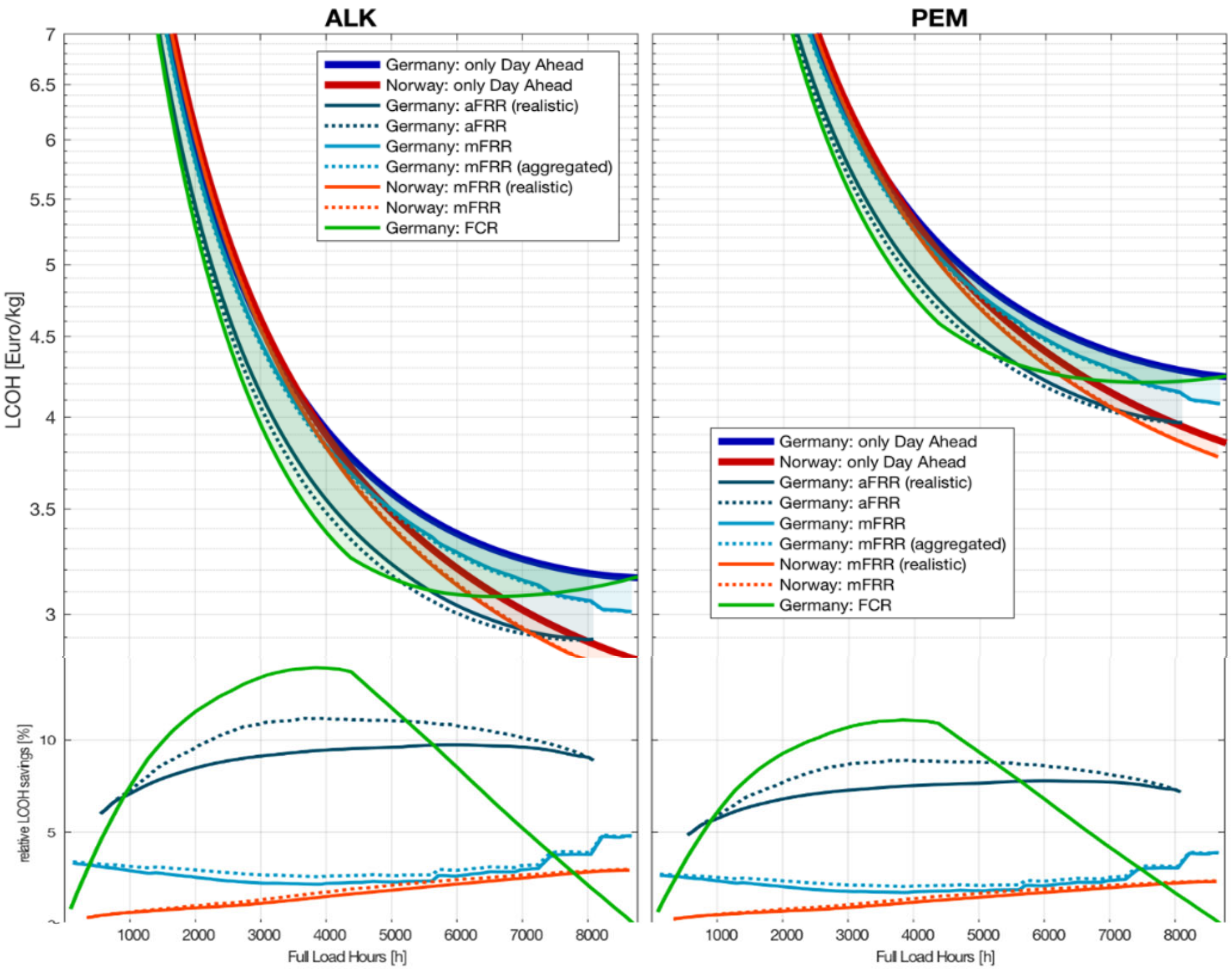
3. LCOH calculation - result



Conclusions

LCOH-savings up to:

- 11-13% due to FCR (Germany)
- 7-9% due to aFRR (Germany)

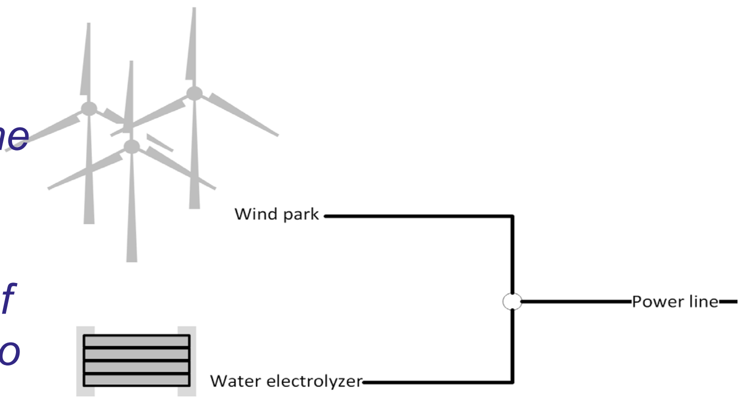
Limitations

Due to following reasons, the results might show an overly optimistic picture:

- Splitting of revenues between WE and aggregator
- Temporal splitting of contracts reduce the revenues further
- Reliability of WE-load
- Stand-by power consumption

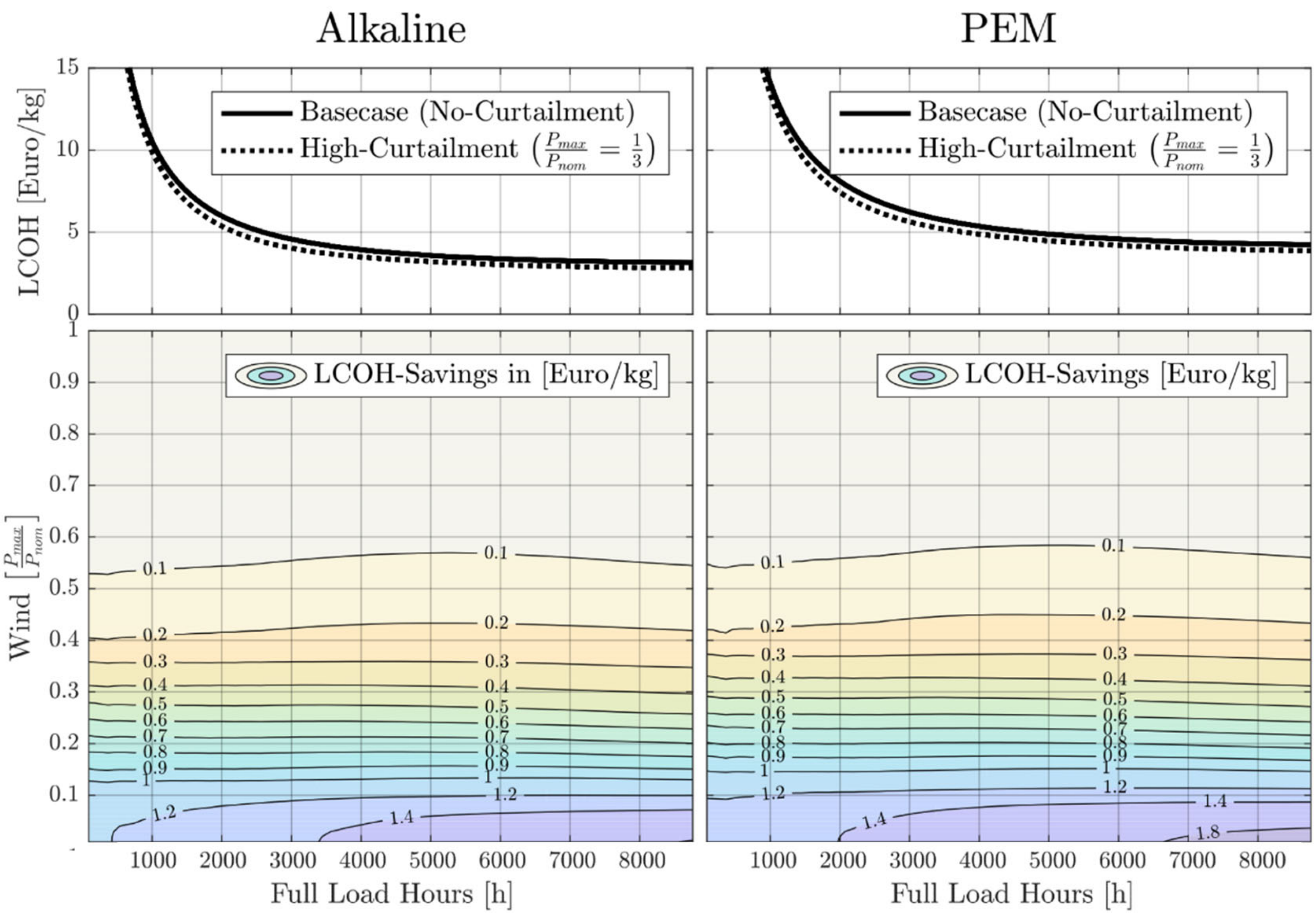
DSO Grid Services

Congestion management



- Base evaluation on a practical case.
  - *Much literature is focused on Germany as it has the highest concentration of demonstrations and pilot projects.*
  - *According to Prof. Nikos Hatziargyriou, the head of the Greek distribution network operators (DNO), no known cases exist in Greece and if so, it's on a high theoretical level.*
  - *Locations such as Spain and Italy, pointed out by an expert, have not resulted in any other such cases.*
- The result shows negative NPV → concentrate on an evaluation of sensitivities and target values for prices and cost factors.
  - *The case that has been analyzed in Germany (Haßfurt) shows a very negative business case which has been altered by adding congestion management remuneration at parity with redispatch costs and curtailment costs.*

DSO Grid Services
Congestion management



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Conclusions 1/2

- In most European countries, the TSO grid service markets develop towards similar structures, driven by the harmonization efforts of ENTSO-E. As such, many countries support an aggregator business model, where distributed WEs can become part of a virtual power plant.
- Long-term reliability, speed of electrical power control, level and stability of the electrical power consumption determine the value of the WE for the provision of GSs.
- 85 TSO grid services and one DSO grid service case were analysed and in a first step. The data available from literature was extended by a survey and an extensive verification round. German FCR, mFRR+, mFRR-, aFRR+ and aFRR-, Norwegian mFRR+ and mFRR- and one congestion management case are further analysed.

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Conclusions 2/2

- Current WE business cases were considered in order to formulate operational restrictions.
- A discounted cash flow method based on historical data (2016) is applied to calculate the impact of GS on LCOH.
- For the selected cases, FCR can reduce the LCOH up to 22 % for PEM WE with high overload capacity (more realistically: 10 %). For 5500 or more full-load hours, aFRR is more promising than FCR.
- No practical and profitable congestion management case could be identified. In extreme curtailment scenarios only (> 2000 curtailed hours) can LCOH savings reach up to 10%.
- The written report *Klemenz, V., Imboden, C., Mbavarira, T. & Harari, O. (2019). Definition of selected business cases and scenarios. D6.2b QualyGridS* will be published by the end of 2019 by the FCH JU.

Thank you

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