Deutscher Verein des
Gas- und Wasserfaches e.V.

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Study on the Use of PtG Technology to Support the 110kv Electricity Distribution Network

G3-03-12-ERG

Bergische Universität Wuppertal

RWTH Aachen University

DBI Gastechnologisches Institut

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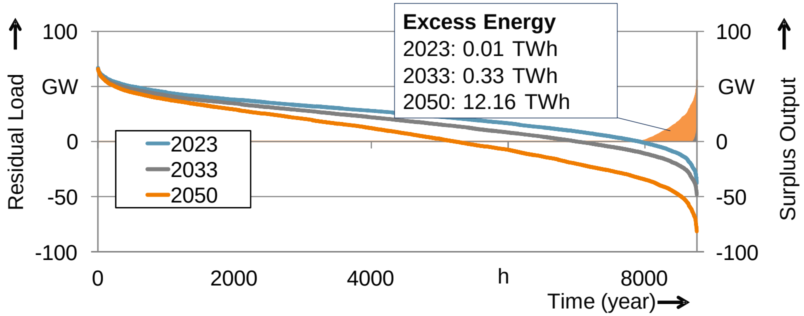
Structure

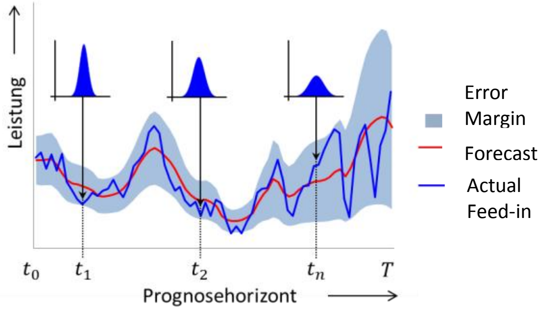
- Background and Objective of the Study
- PtG to Support the Distribution Network
  - Potential Analysis in the Gas Network
  - Combined Strategic Network Planning
- PtG as Offset of Forecast Errors
- Key Findings
- Conclusions and Prospects

Field of Application: System Benefits of Power-to-Gas

Storage Demands for Surplus Renewable Energy for Large Proportion of Renewable Energy in Germany and the EU
→ Long-Term Storage of Power-to-Gas (PtG)



Contribution to System Stability (Creation of Control Reserves, Offset Short-Term Forecast Insecurities)



Supply of „Green Energy“ for Mobility, Heating and Industry

Reduction in Expansion of the Electricity Grid through Utilization of the Existing

Long-Term Potential

Short- and Mid-Term Potential

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Project Consortium:

Bergische Universität Wuppertal
DBI Gastechnologisches Institut
DVGW
IAEW RWTH Aachen University
EWE netz
avacon
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Results of Previous Studies*

- Smart integration of the electricity and gas supply systems through PtG at medium- and low-voltage levels led to a significant reduction in the expansion of the existing grid.
- Integration of the low-voltage level saves further grid expansion in the upper medium-voltage level.

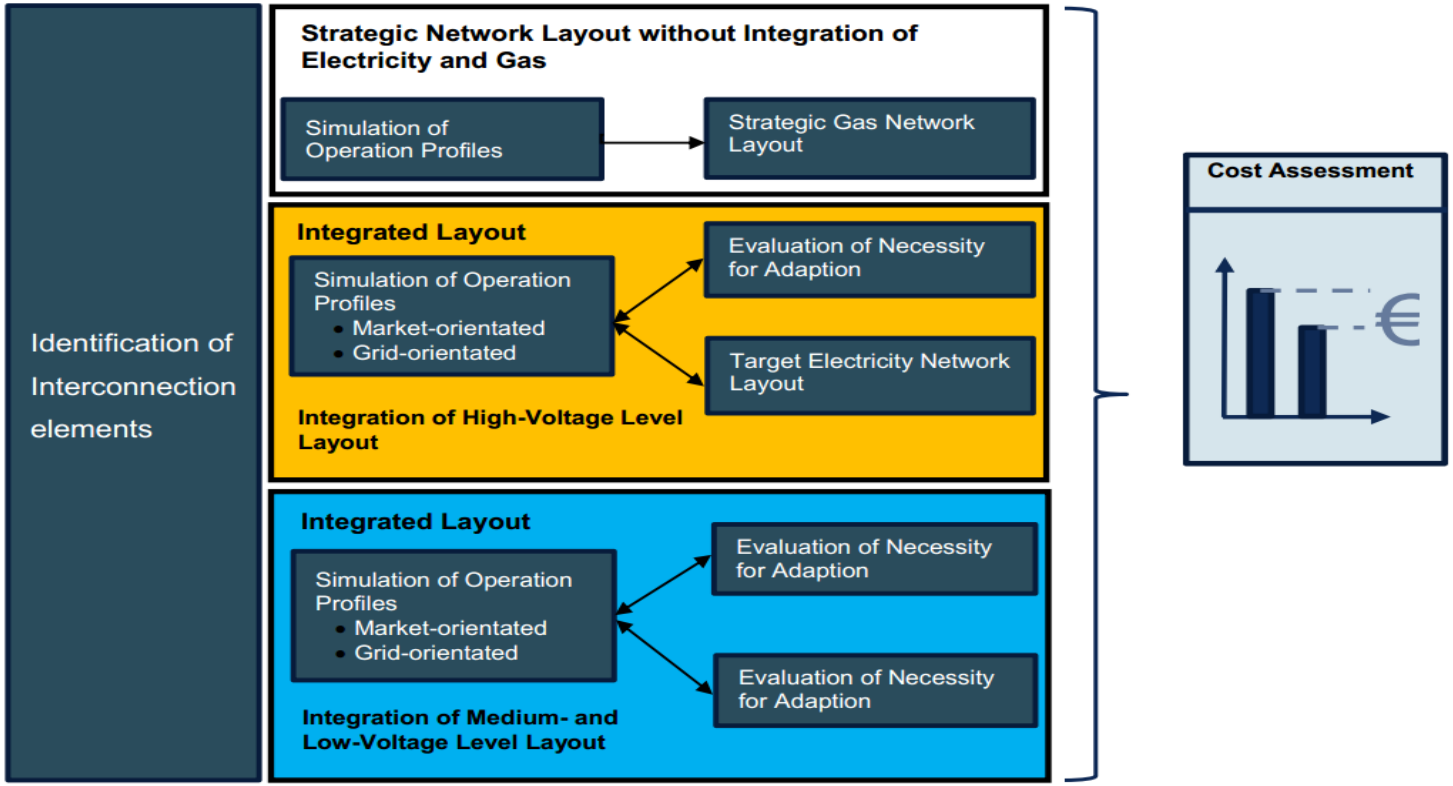
Goals of the Study: Expansion of the Field of Analysis

- **Integrated Supply Network Analysis**: Evaluation of network usage for PtG from low- through high-voltage levels.
- **Additional Fields of Application**: Evaluation of value-added from PtG to offset forecast errors in renewable energies, and also its application with mobility.

* Utility of Smart-Grid Concepts with regard to Power-to-Gas Technology

Methodology of Network Integration Electricity/Gas

- Establishment of an economic framework in the chosen network with goals measured for the base years 2023, 2033 and 2050.
- Simulation of facility usage in electricity and gas networks
- Target network planning for a real network area in Emsland (Germany)



➔ Evaluation of the separate and integrated planning of electricity and gas networks through cost comparison.

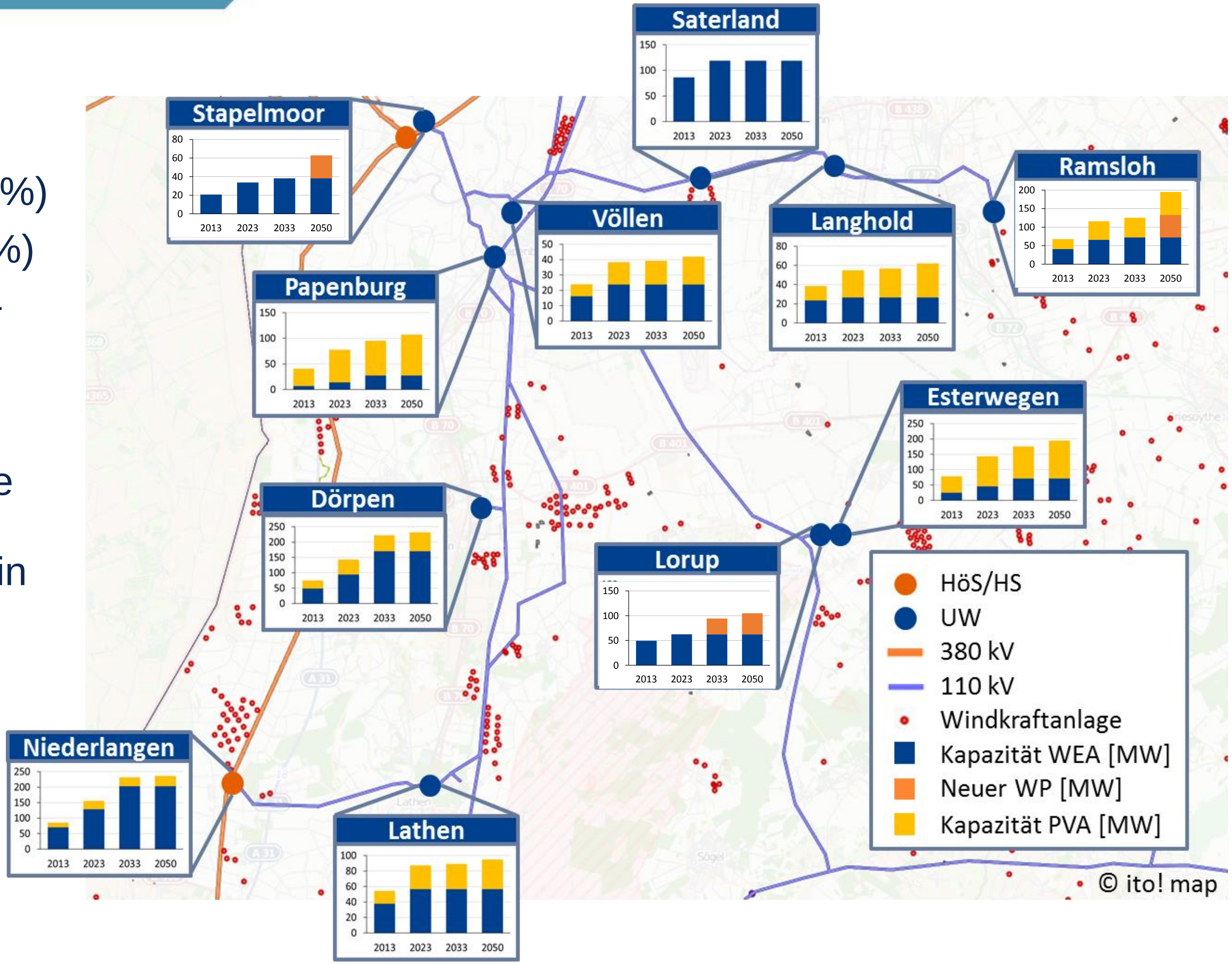
High-Voltage Network Emsland (Germany): Forecast on the Development of Decentralized Feed-In Facilities

Forecast 2050

- DFF: 1.7 GW (+250%)
  - PVP: 0.45 GW (+ 230%)
  - WEF: 1.0 GW (+ 230%)
- Peak Demand : 0.17 GW (+ 19%)

➔ High demand on the high-voltage network in case of feedback into upper voltage levels

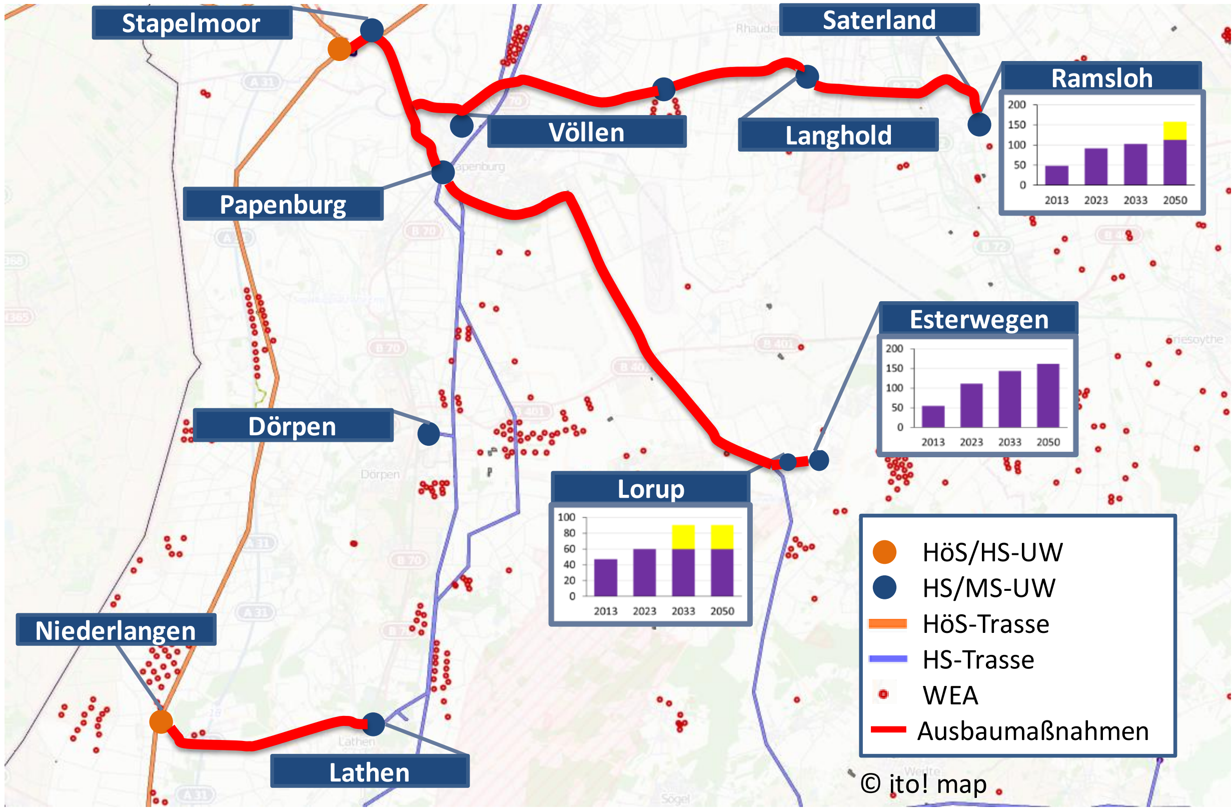
➔ Grid expansion necessary in several locations



<u>Abbreviations:</u>
DFF: Decentralized Feed-in Facility
WEF: Wind Energy Facility
WP: Windpark
PVP: Photovoltaic Power Plant
MaV: Maximum Voltage (380 kV)
HV: High Voltage (110 kV)
MeV: Medium Voltage (20 kV)

General Expansion Requirements (non-integrated)

- Overheat Line Monitoring: 95 km
- New Power Lines using TAL (heat-resistant aluminum): 45 km
- 2nd Overhead Line System: 9 km
- Replacement Overhead Line: 2 km
- New Control Panels: 2



Lines with Greatest Need of Extension

- Ramsloh to Langhold:
  2nd Overhead Line System (9 km)
- Papenburg to Esterwegen:
  New Power Lines (2 x 20 km)

➔ In many places the transmission capacity of the existing high-voltage network can be increased by using innovative technologies and systems such as TAL-lines and Power-Line Monitoring(FLM). Two lines require more extensive redevelopment.

➔ The Ramsloh and Esterwegen sites offer the greatest potential for a reduction of network expansion through PtG facilities.

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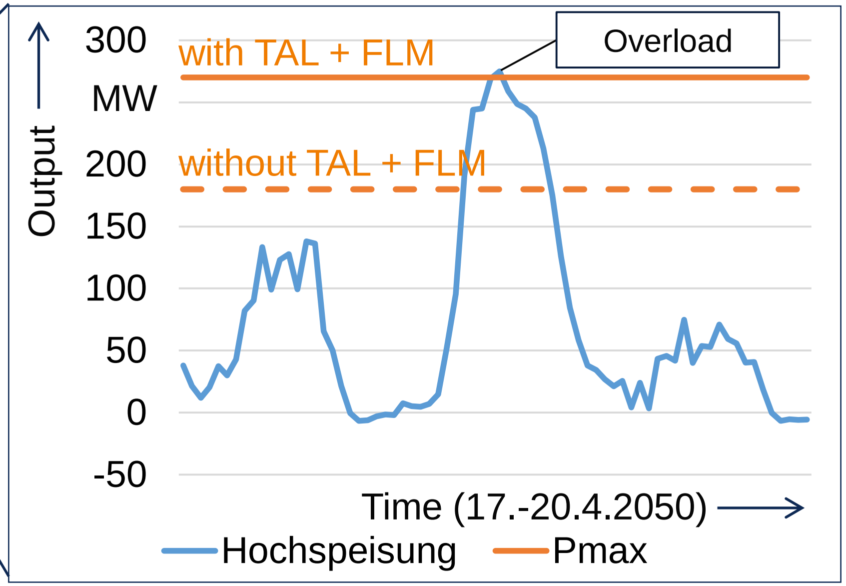
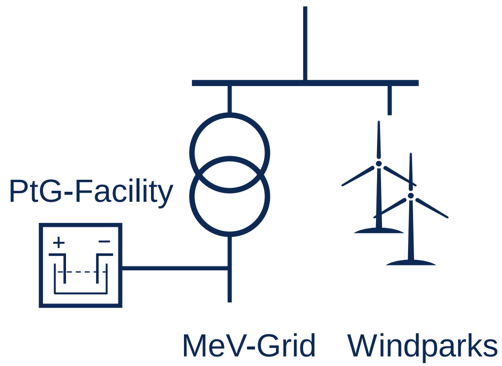
Operation Profile and Need for Peak-Shaving

Peak Demand High-Voltage Connections [MW]

	P^*_{max}	2023	2033	2050
Ramsloh	270	200	209	275
Esterwegen	317	243	303	330



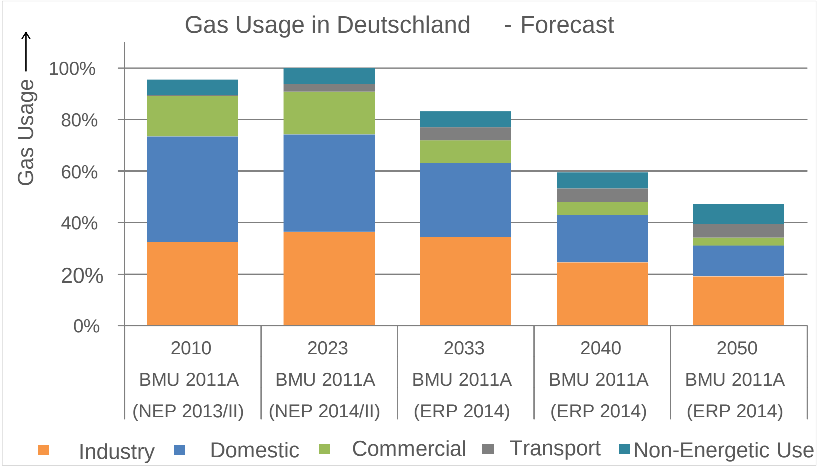
- Slight overload of High-Voltage Connections after base year 2033
- ➔ Peak-shaving potential through PtG at plants in Ramsloh (5 MW) and Esterwegen (13 MW)
- Connection to PtG plants at transformation levels (HV/MV)
- PtG-utilization during the market-orientated simulation led to the required unburdening of the grid.
- Acceptable correlation between local decentralized feed-in and spot market prices.



* incl. TAL and FLM

Methodology: Capacity Analysis - Gas Network

Analysis of the Capacity for PtG-produced Hydrogen and Methane

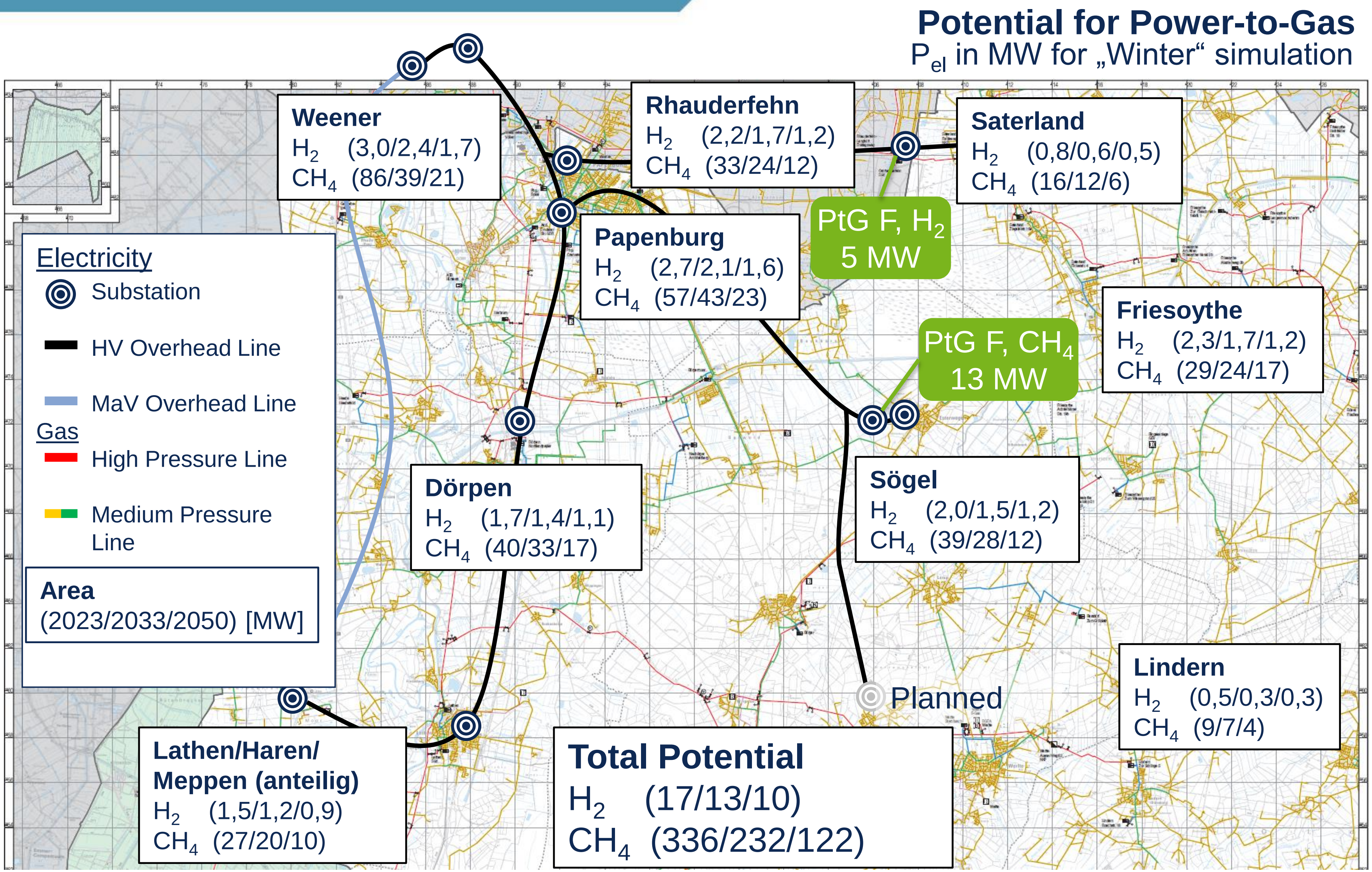


- Based on forecasts for acceptable load profiles at inter-connection points between different levels of the gas network
- Integration of Gas Regulator Stations
  - → Reduction in regulator stations and corresponding costs
  - → Increase in potential capacity for PtG feed-in
- Allowance for the expected (assumed) reduction in gas usage and the review of current regulation on hydrogen levels in the gas network

2023	2033	2050
10 Vol.-%	10 Vol.-%	15 Vol.-%

- Three options for the integration of PtG facilities:
  1. Year-round: Potential for PtG feed-in also guaranteed in summer months
  2. Winter: Potential primarily available in winter (October to April)
     → enables greater plant output, requires partial-load operation in summer months
  3. Daytime: Integration of medium-pressure gas network and low-voltage electricity network. Uptake of surplus energy from PV Plants. Guarantee energy potential between 7:00 – 19:00.
- The results show potential performance for PtG facilities to unburden the electricity network (upon feed-in to the gas network)
  - Constant feed-in to the gas network would be possible, where necessary, to ensure sufficient electricity capacity wherever and whenever required.

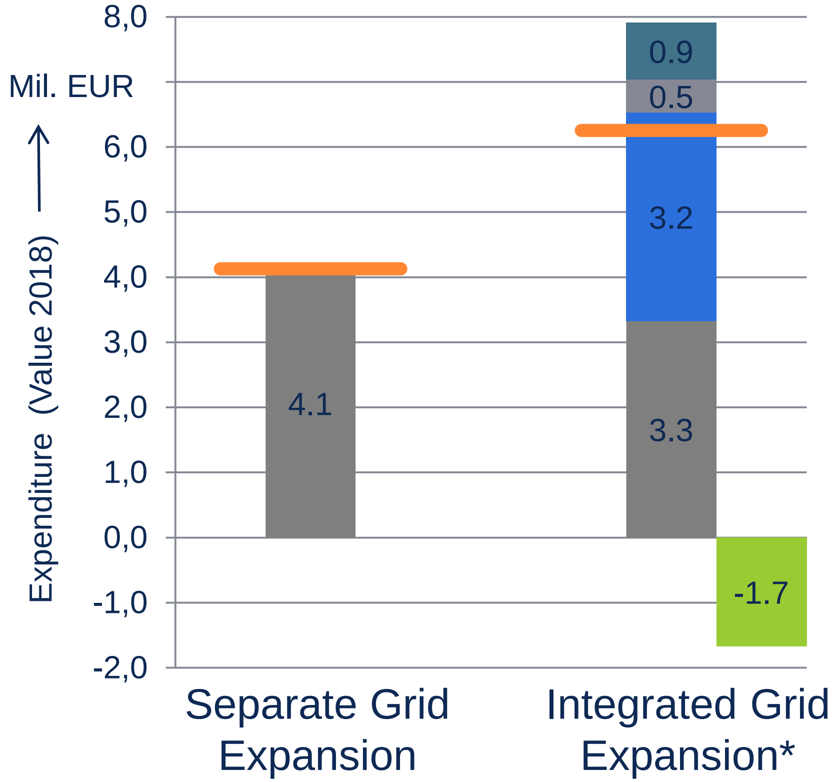
Results: Capacity Analysis - Gas Network



- The necessary electricity intake for the PtG facilities (5 MW H_2, 13 MW CH_4) could be achieved through redirection of gas in the gas network.

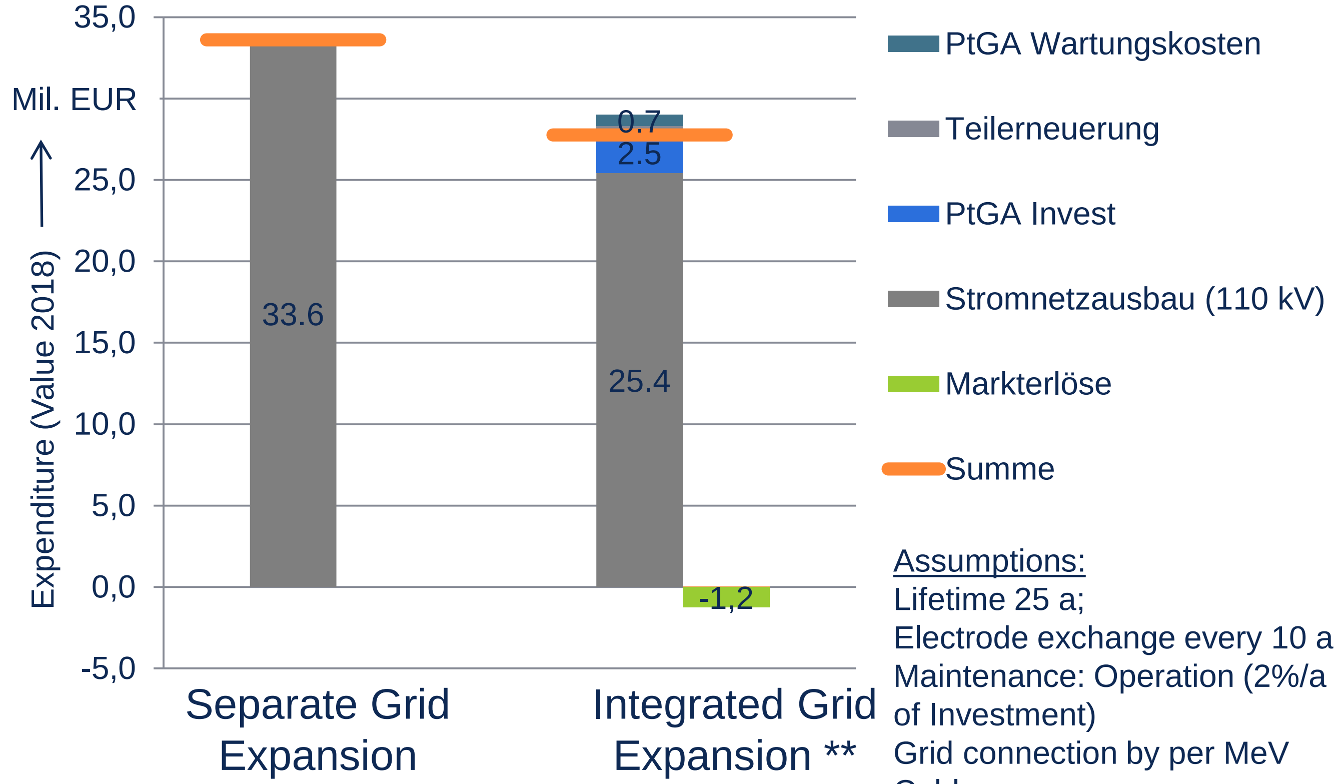
Results for the High-Voltage Network Emsland (Germany)

Grid Expansion Scenario „Innovative“



***) Network integration elements**
Ramsloh: PtGA (H_2) mit P_{el} = 5 MW
Esterwegen: PtGA (CH_4) mit P_{el} = 13 MW

Grid Expansion with buried cable (cost-intensive)



Assumptions:
Lifetime 25 a;
Electrode exchange every 10 a
Maintenance: Operation (2%/a of Investment)
Grid connection by per MeV Cable

****) Network integration element**
Esterwegen: PtGA (CH_4) mit P_{el} = 13 MW

- Where grid expansion using innovative technologies e.g. TAL (heat resistant aluminum) or overhead line monitoring is possible, there is no economic benefit to PtG facilities.
- Integrated expansion is more economical in comparison to the laying of buried cable.

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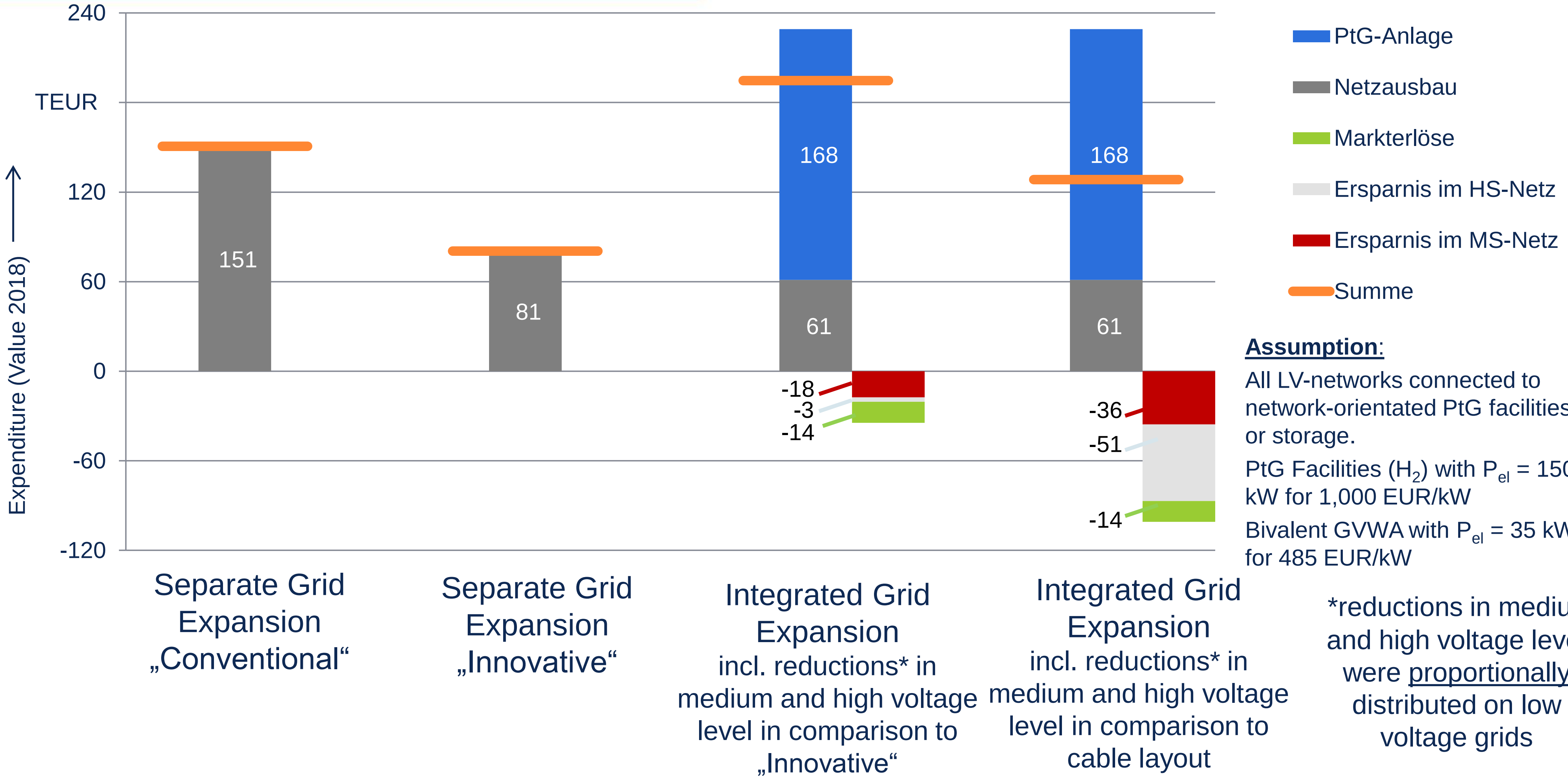
Results for the Low-Voltage Network considering the savings in the upper Medium- and High-Voltage Networks



<u>Assumption</u>:

All LV-networks connected to network-orientated PtG facilities or storage.

PtG Facilities (H_2) with P_{el} = 150 kW for 1,000 EUR/kW

Bivalent GVWA with P_{el} = 35 kW for 485 EUR/kW

*reductions in medium and high voltage level were <u>proportionally</u> distributed on low voltage grids

- Network orientated utilization scheme of the PtG facilities reduces the maximum of electricity fed into upper voltage levels

→ Reduced necessity for expansion, also in medium- and high-voltage levels

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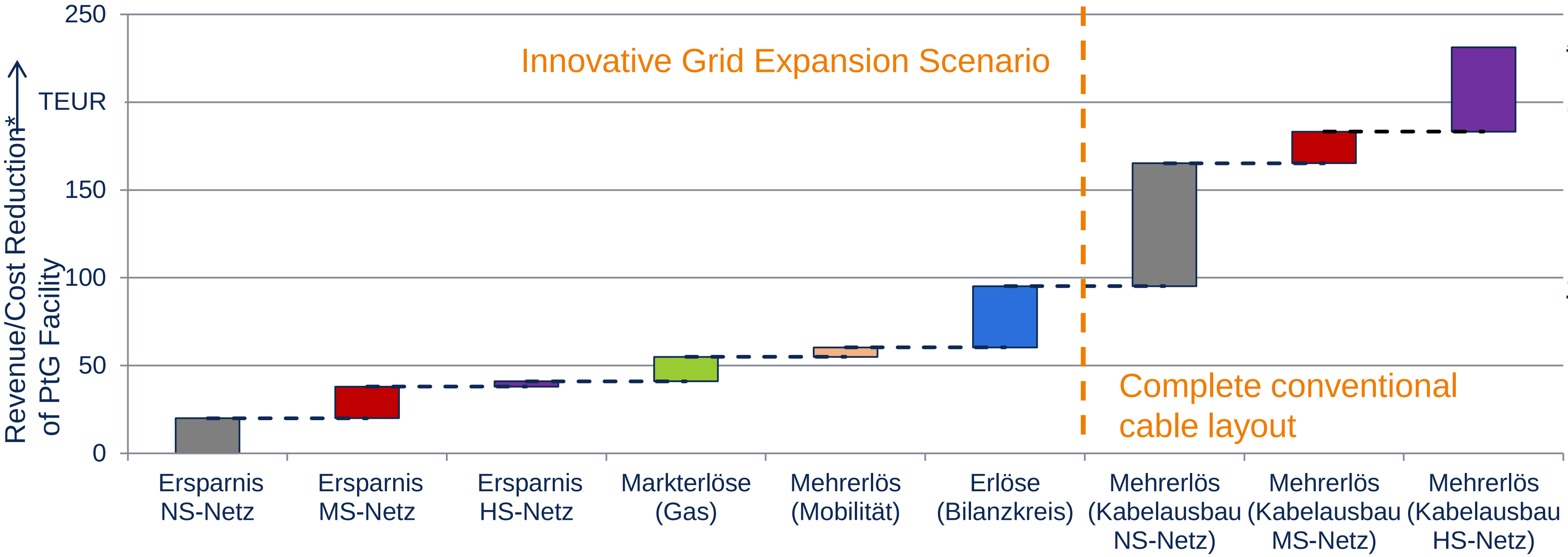
Economic Evaluation of PtG Technology: Network Relief, Mobility and optimized balance area



*)Value 2018

Assumption:

Integration in LV Level

Operation from 2018 to 2058

PtG Facility(H_2)with P_{el} = 150 kW

Bivalent pre-heating with P_{el} = 35 kW

Calculation Basis:

- Estimation of maximum potential through addition of all revenues in the business model (possible combinations of models to be considered individually)
- Network-orientated operation to relieve LV-, MeV- and HV levels
- Mobility: Additional revenue through delivery of H_2 per truck at fuel station(in 40 km), as soon as the profit margin exceeds that of feed-in to NG network.
- Utilizatrion of PtG in optimized balance area leads to a reduction in compensation energy payments (Updated simulation values for 2013/2014)

- PtG facilities generate income through avoidance of network expansion, fuel production (H_2) and optimized balance area
- Small-scale PtG facilities (H_2) (incl. feed-in) can become operationally economical from a unit price of 520 EUR/kW
- At unit prices of 1,400 EUR/kW, the utilization of small-scale PtG facilities is more economical than network expansion with buried cable on all three network levels (low-, medium-, and high-voltage)

➔ **The application of PtG requires a considerable reduction in unit prices and an increase in the lifetime of the facilities for dynamic operation.**

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Conclusions and Prospects

- **PtG technology will only become economically viable for high-voltage levels when it can substitute new overhead lines or buried cables, which are only required for peaks of electricity feed-in.**
- **Network integration elements (e.g. PtG facilities) in low voltage levels with grid-orientated operation scheme significantly reduces the necessity to expand upper voltage levels ➔ Integration at the lowest possible levels!**
- **PtG flexibility can avoid curtailment of electricity surpluses as a result of forecasting errors by direct marketing in renewables portfolios.**
- **Hydrogen can be utilized for mobility, in particular local public transport.**

Recommendations

- **Facility manufacturers**: Significantly reduce costs for PtG facilities through use of new technologies and modularization; Focus on„small“ facilities (P_{el}<0,5 MW)
- **Facility manufacturers:** Introduce „demonstration projects“ for PtG in the distribution network
- **Politicians / Regulators**: Establish framework that will enable the application of smart-grid technology and storage within the network operation
- **Research:** Quantify system-wide benefits to long-term storage

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Key Findings (I)

The utilization of PtG in the distribution network can have technical and economic benefits:

- High-voltage networks constantly require additional transmission capacity for feed-in from lower voltage levels
  - Conventional solutions are not easily scalable
  - ➔ Their additional transmission performance is only used on an occasional basis
- As long as innovative technologies (overhead line monitoring, heat-resistant aluminum) are sufficient, integrated development is generally not economical
- If costlier extensions(new high-voltage lines, new cabling) are required, the application of PtG plants can become more economical
- The utilization of PtG plants can allow the postponement of necessary network expansion, thus avoiding individual redevelopment projects, which would otherwise be inefficient.
- High correlation between regional feed-in performance and Germany-wide electricity prices in the high-voltage network is expected to lead to an unburdening of the electricity grid through market-driven utilization of PtG facilities.

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Key Findings (II)

Planning across multiple voltage levels can relieve several grid levels simultaneously

- Network integration elements (e.g. PtG facilities) in low-voltage levels, while grid-orientated used, significantly reduces the necessity of expansion at medium- and high-voltage levels
- A comprehensive application of unburdening „storage capacity“ is possible with the combination of different technologies (PtG, batteries, peak shaving)

PtG flexibility creates added-value in marketing portfolios for renewable energies

- Clear reduction in shutdowns due to positive forecast deviation
- Financial value through use of surplus energy in gas production portfolios and through a reduction in costs for balancing energy

PtG in regional mobility

- The utilization of hydrogen for local public transport and regional transport fleets can serve as the nucleus for inter-regional hydrogen-based mobility.
- The potential for regionalized energy production satisfies local public transport demands.

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