Local Incentives and Sector Coupling: Friends or foes?

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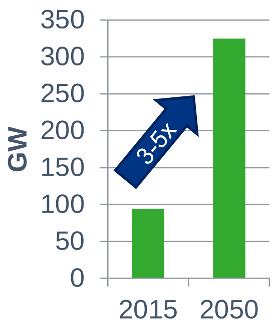
A renewable system comes with challenges…

Renewable capacity

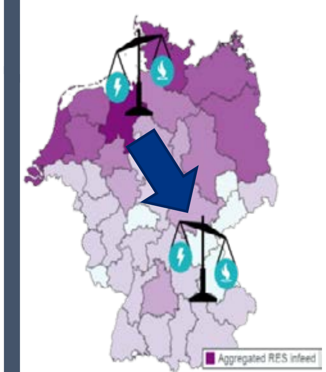
RES capacity in DE



Source: dena Leitstudie, Technology mix 95 scenario

A ***substantial increase of renewable capacities*** *in acceptable and accepted regions is required.*

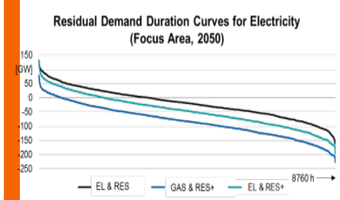
Transporting energies



Source: Phase II

Effective ***transport and distribution of energies*** *across regions are key for a secure and reliable energy system.*

Storage and balancing

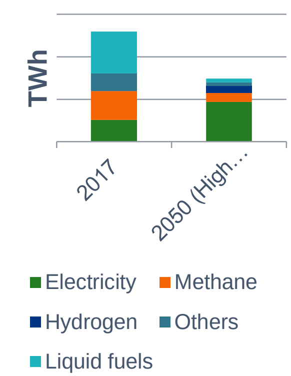


Source: Phase II

Renewable energies depend on fluctuating weather conditions. ***Energy storages*** *are required for daily and saisonal balancing.*

Demand

Load development



Source: Phase II

Substantial change in ***demand structure*** *across energy carriers with respect to volumes, time and location of consumption.*

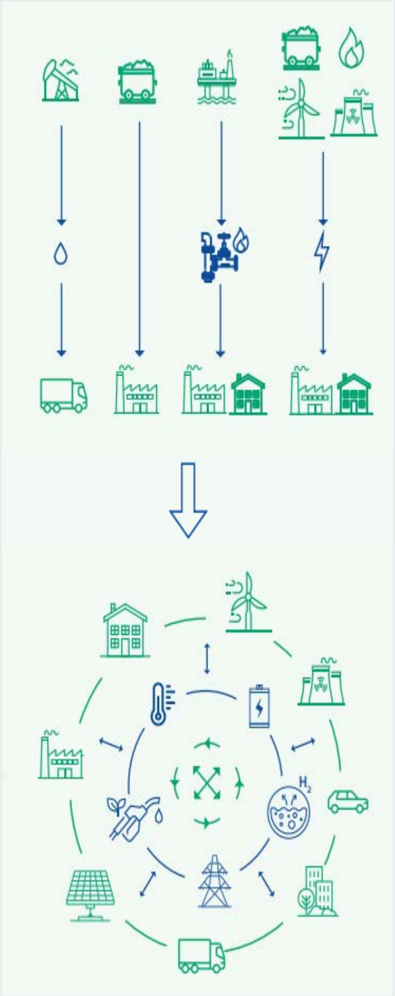
Energy system integration is the key!

The energy system needs to be more **operated and planned „as a whole“** to deliver

- low-carbon,
- reliable and
- resource-efficient energy services,
- at the least possible cost for society.

Efficiency and **greater direct electrification** of end-use sectors are at the core.

Hydrogen is an option for hard-to-decarbonize and existing applications.



Source: EC. Energy system integration strategy..

Qualitative Research Method

Focus on **locational marginal pricing (as one option among many)**

→ What are the **effects on sector coupling** in the form of P2G?

SWOT analysis:

- Characteristic strenghts and weaknesses of LMP that can **help** achieve the goals of **sector coupling** (Decarbonization, flexibility of energy consumption and production, cost-efficient integration of gas and power sector)
- External Threats and Opportunities that may improve or hinder the **introduction of LMP**

Literature Review to filter most aspects of LMPs regarding their influence on those goals (selected aspects)

- **strengths :** Signal of regional and timely electricity surplus; Potential for higher cost-efficiency and transparency of market power;
- **weaknesses:** Credibility / predictability issues and higher transactional costs
- **opportunities :** RES increase leads to energy trading closer to real-time – spatial granularity needed
- **threats:** incomplete information about LMP and their effects

Quantitative Research Method

Analysis on dispatch hours of a P2G plant in simulated uniform prices and LMPs and the grid-friendliness of the dispatch for German north – south congestion

- Nodal price = energy component + congestion component
- Congestion component as proxy to evaluate grid-friendliness of dispatch

$$electricity\ WTP = \frac{(revenue\ H_2 - cost\ H_2O)}{power\ consumption\ of\ electrolyzer} \quad (1)$$

$$power\ consumption\ electrolyzer = \frac{HHV_{H_2}}{efficiency * 1000 * \rho} \quad (2)$$

Input variable	Value
Electrolyzer efficiency in %	78
Price of hydrogen in EUR / kg (H_2)	1.5
water needed in kg (water) / kg (H_2)	9
water price in EUR / kg (water)	0.00069
WTP in EUR / MWh	**29.59**

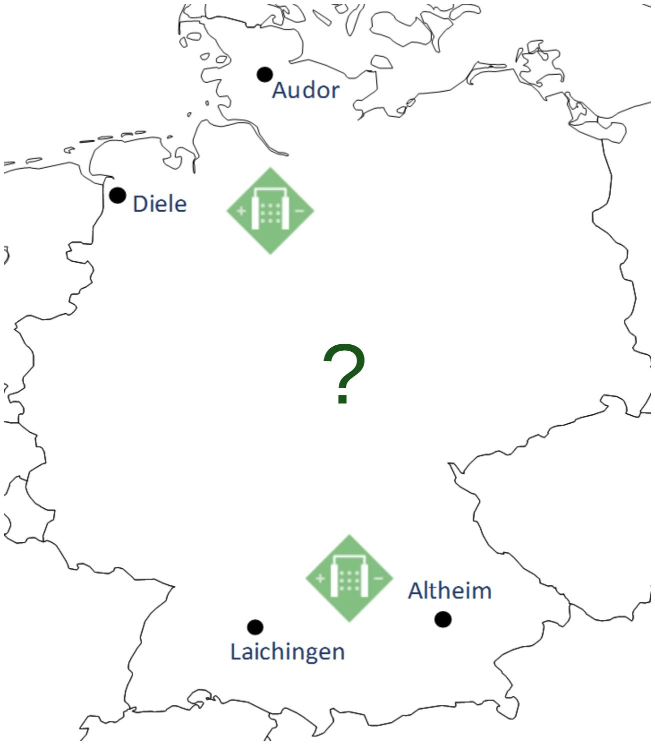
Assumptions:

- P2G plant is dispatched at full load
- Taxes, levies and grid tariffs not considered
- Dispatch of the P2G plant does not influence the price at the node
- Grid losses not considered

Methodology Based on C. van Leeuwen and M. Mulder, “Power-to-gas in electricity markets dominated by renewables”, Applied Energy, vol. 232, pp.258-272, 2018
Siimulated Prices as presented in D. vom Stein, H. Chang, A. Moser, C. Pflanz, B. Bartosch, C. Neumann and F. Kunz, “Analyse von Gebotszonenzuschnitten und nodalen Preisindikatoren. Einfluss deutscher HGÜ-Leitungen im europäischen Strommarkt”, Magazin für die Energiewirtschaft, vol.1 (2020), 2020

Depending on the market design, dispatch behavior differs significantly

	Number of operating hours (of which grid friendly)			
Placing the P2G plant in…	Uniform system		Benchmark LMP system	
Altheim_SE	1,215	(620)	4,340	(4,212)
Laichingen_ SW	1,215	(811)	4,973	(4,826)
Diele_NW	1,215	(997)	5,605	(5,587)
Audorf_N	1,215	(1,165)	6,726	(6,717)



Depending on the market design, dispatch behavior differs significantly

Grid expansion scenario

Scenario: 4 HVDC lines in operation based on vom Stein et al. (2020)

→ spatially more homogeneous price pattern and lower average prices at nearly all nodes - except for the Audorf node

Results:

- Strong increase in number of dispatch hours in Altheim_SE and Laichingen_SW
- Similar values in Diele_NW
- Decrease in dispatch hours at Audorf_N

- LMPs case: almost always grid-friendly dispatch in northern locations

Sector Coupling and LMPs: Friends!

By promoting flexibility and efficiency in the electricity sector, nodal pricing contributes to the goals of sector coupling (beware of credibility risks and transactional costs, though)

01 While in a zonal case the number of operating hours of a P2G plant is the same at all locations, its positive contribution to easing congestion situations differs widely between the nodes.

02 Nodal prices lead to significantly higher number of dispatch hours at all locations compared to the zonal system.

03 As theoretically expected, a market-oriented dispatch of a P2G plant in a nodal market is better aligned with the needs of the transmission network than in a zonal system

04 The scenario with higher grid expansion shows the robustness of the results at three of the four nodes - however, the often-cited point that the effectiveness of nodal pricing as a local coordination mechanism is dependent on grid expansion can also be seen in the analysis.

Thank you!

Sources

Input variable	Value	Source
Electrolyzer efficiency in %	78	T. Bossmann, L. Fournié, L. Humberset and P. Kallouf: "METIS Studies. Study S8. The role and potential of Power-to-X in 2050", Study prepared for the European Commission, Directorate-General for Energy, 2018
Price of hydrogen in EUR / kg (H_2)	1.5	Based on current cost of large-scale hydrogen supply as presented in [21] G. Glenk, "Economics of renewable hydrogen", PhD Dissertation, Department of Business and Economics, TU Munich, 2019
water needed in kg (water) / kg (H_2)	9	S. Drünert, U. Neuling, S. Timmerberg and M. Kaltschmitt, "Power-to-X (PtX) aus Überschussstrom in Deutschland - Ökonomische Analyse", Zeitschrift für Energiewirtschaft vol 43, pp. 173-191
water price in EUR / kg (water)	0.00069	C. van Leeuwen and M. Mulder, "Power-to-gas in electricity markets dominated by renewables", Applied Energy, vol. 232, pp.258-272, 2018
WTP in EUR / MWh	**29.59**	**Own calculation**

Backup

Scenario with increased grid expansion

Placing the P2G plant in…	Number of operating hours (of which grid friendly)			
	Uniform system		Benchmark (Nodal system)	
Altheim_SE	1,215	**(871)**	5,593	(5,457)
Laichingen_ SW	1,215	(809)	5,504	(5,388)
Diele_NW	1,215	(**1,122**)	5,957	(5,935)
Audorf_N	1,215	(1,110)	5,773	**(5,741)**

09 April 2021
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