Large Wind-Hydrogen Plants in Germany: The Potential for Success

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Contents

1. Introduction

- **Work carried out by:**

PLANET GbR | fachhochschule lübeck PROJEKT-GMBH | Fraunhofer ISI | IFEU Institut für Energie und Umwelt e.V. | KBB UNDERGROUND TECHNOLOGIES

- **Commissioned by:** NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

- **Advisory committee of eight companies (power suppliers, grid operators, wind farm operator, gases supplier, car manufacturer)**
  - ➢ **Discussion of assumptions, scenarios, results & conclusions**
  - ➢ **Supply of time series of renewable feed-in and system load, for calibrating the simulation model**

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Hydrogen-related projects include:

- **Demonstration of hydrogen-powered vehicles and refuelling infrastructures**
  - **Buses: CUTE, HyFLEET:CUTE, CHIC and HyTransit**
  - **Cars: SWARM (Birmingham, Brussels and Bremen)**
- **Wind-hydrogen systems:**
  - **Concept development**
  - **“Hardware projects”, such as RES2H2 and HyWindBalance**

2. Objective of the Study

Establish the conditions that facilitate an economically viable operation of wind-hydrogen plants in 2030:

- **Concentrating on surplus electricity in the transportation grid and on longer-term energy storage**
- **Focussing on two markets for selling hydrogen**
  - **Hydrogen as a fuel for road vehicles**
  - **Re-electrification / Provision of balancing power**

2. Key Aspects

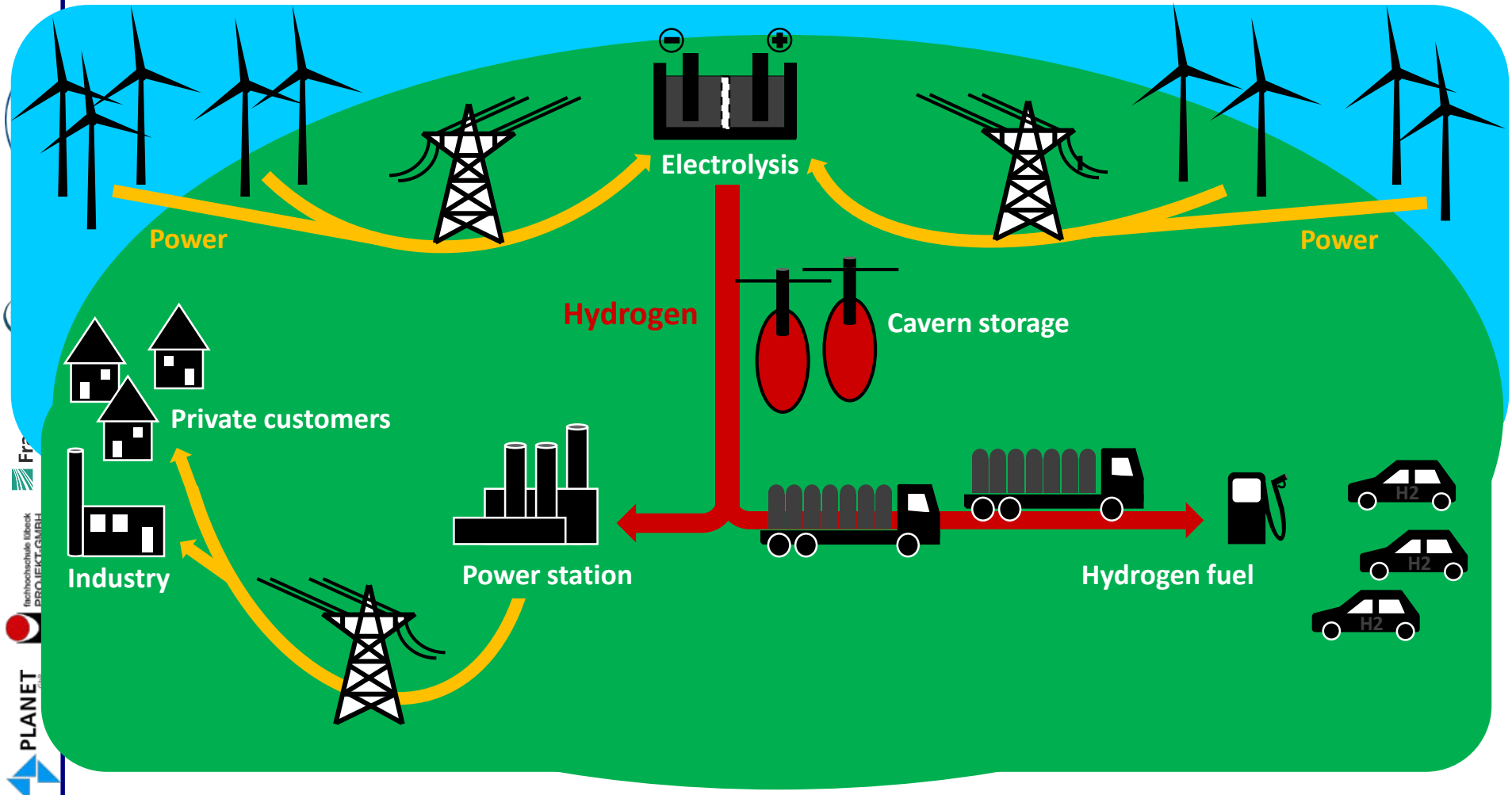
- **Amount and duration of surplus power in two grid zones (from renewable energy respectively wind, and must-run CHP)**
- **Shares of surplus that can be converted into hydrogen**
- **Components and techno-economic parameters of large-scale wind-hydrogen systems in 2030**

<u>Assumptions</u>

are numerous, usually made in a conservative and simple manner, and - where useful -

- ➢ **Relying on existing studies**
- ➢ **Supposing that there will be no change rather than speculating**

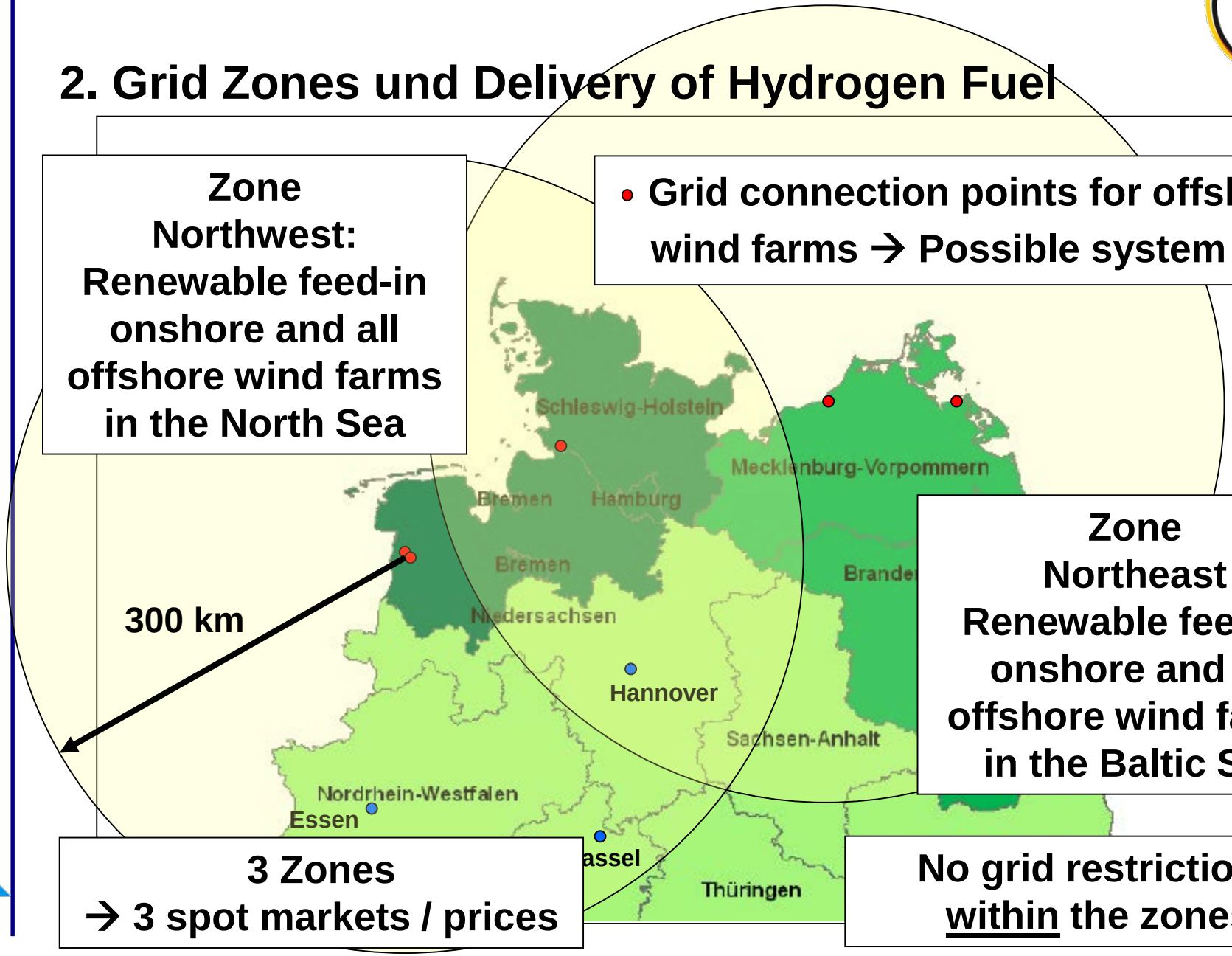
1. Utilise Surplus Wind Energy via Hydrogen



2. Grid Zones und Delivery of Hydrogen Fuel

Zone Northwest: Renewable feed-in onshore and all offshore wind farms in the North Sea

- **Grid connection points for offshore wind farms → Possible system sites**

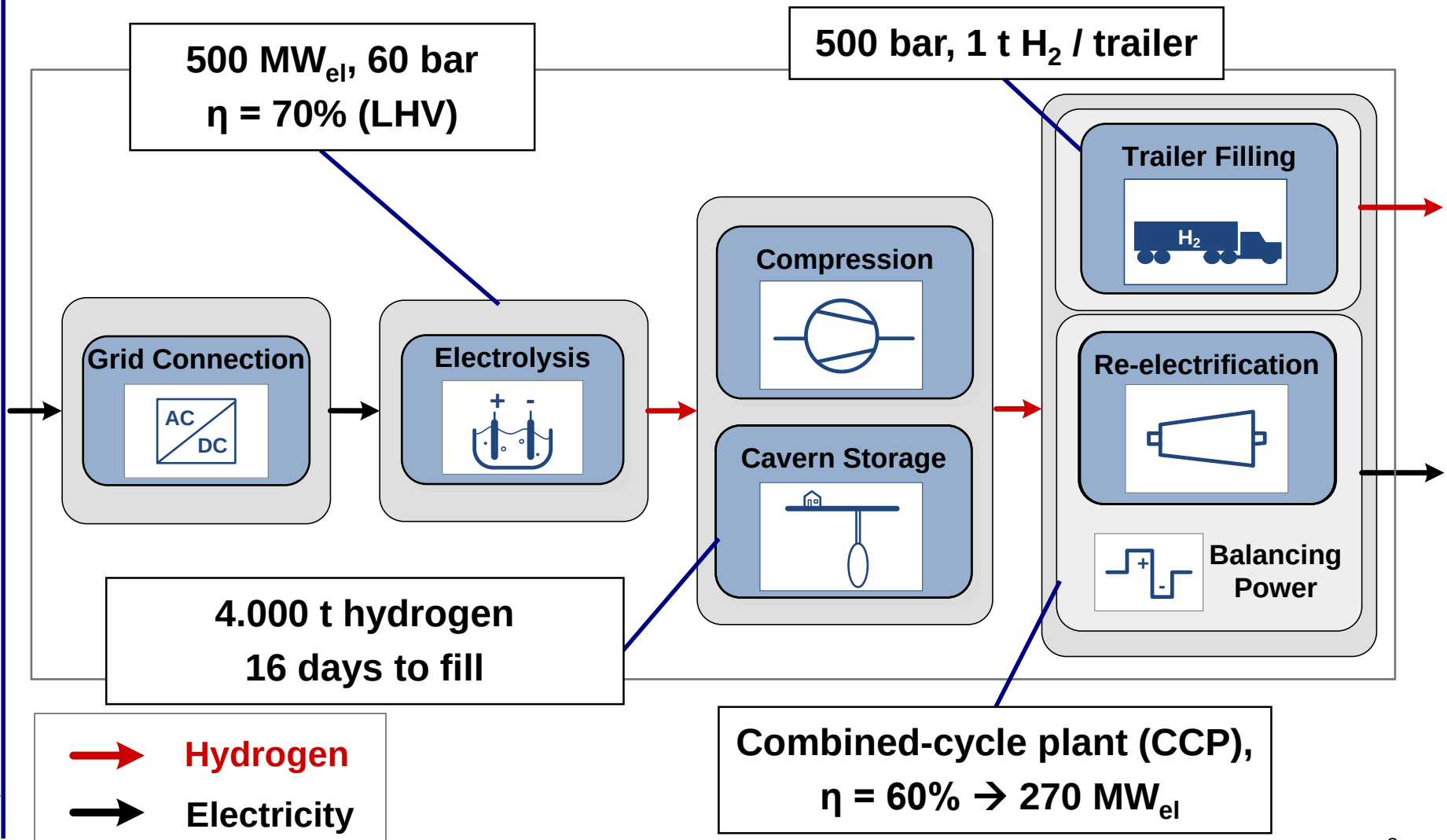


Zone Northeast Renewable feed-in onshore and all offshore wind farms in the Baltic Sea

3 Zones → 3 spot markets / prices

No grid restrictions <u>within</u> the zones

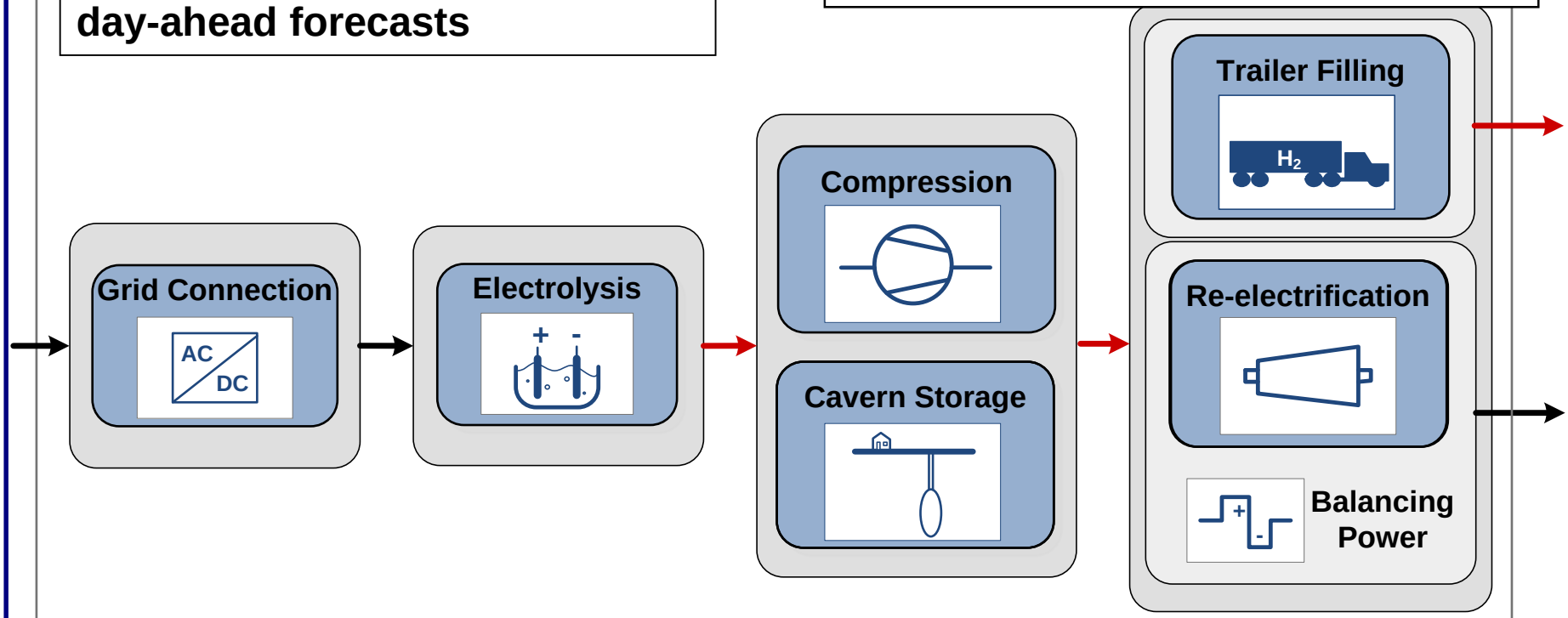
3. Wind-Hydrogen System on Power Plant Scale / 1



3. Wind-Hydrogen Plant on Power Plant Scale / 2

Purchase and sale of electricity on the spot market based on day-ahead forecasts

What can be accomplished with this plant?

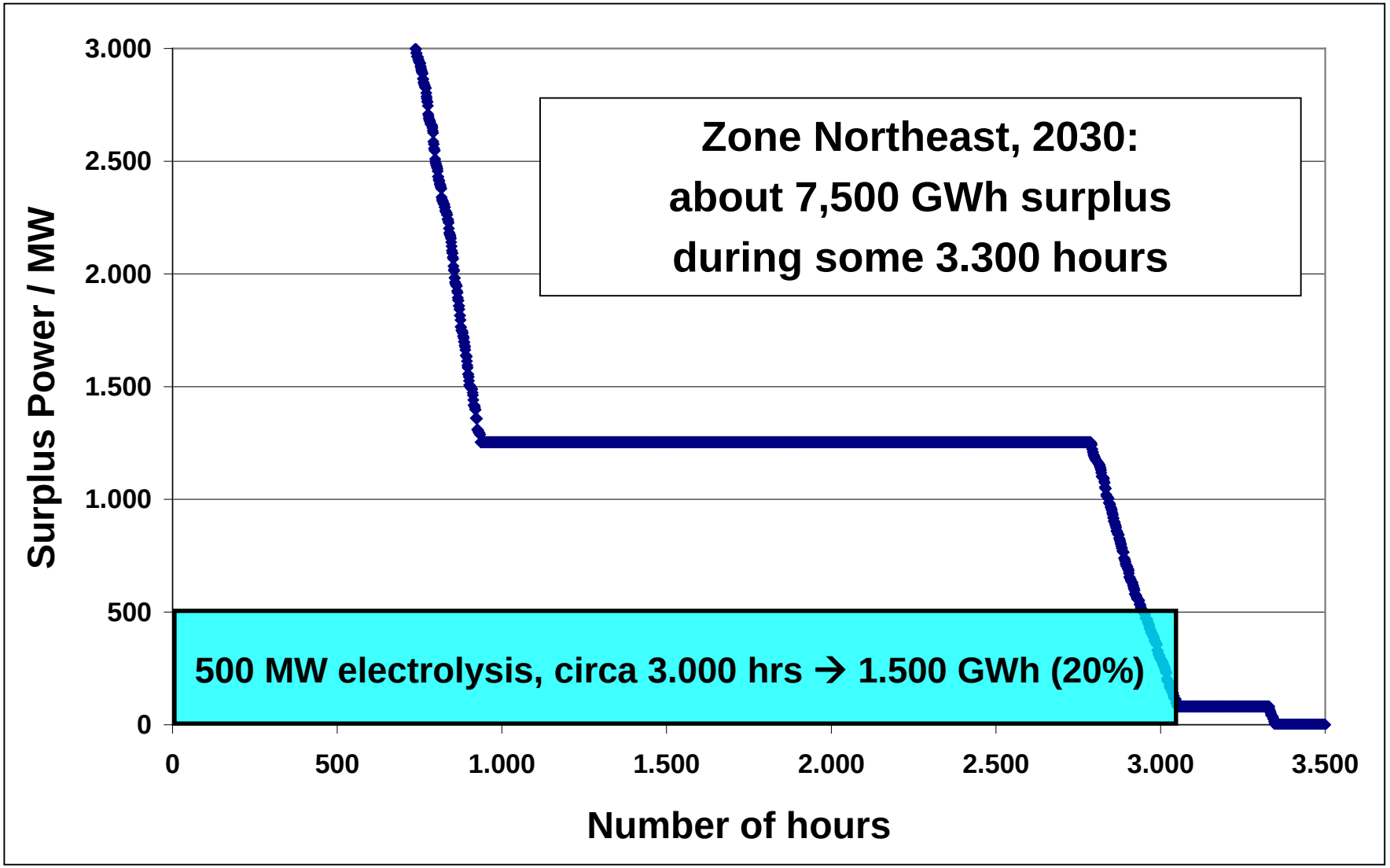


Hydrogen

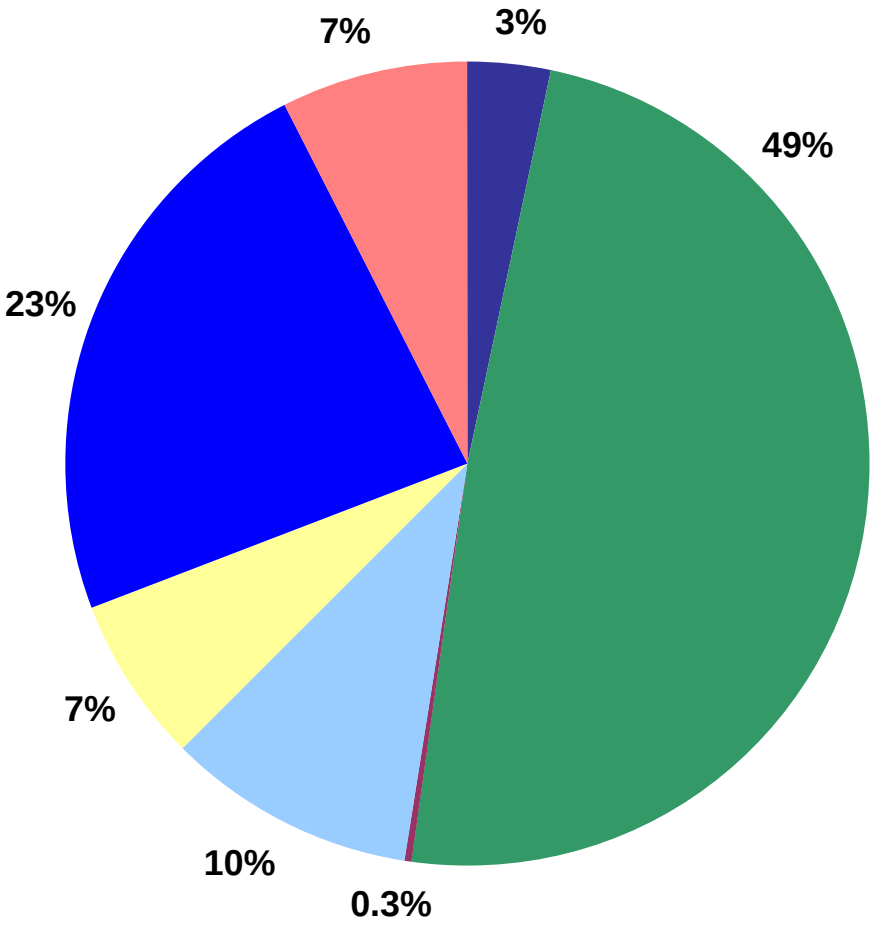
Electricity

Electrolysis without balancing power option, to separate generation and utilisation of hydrogen
→ Easier interpretation of results

3. Annual Duration Curve of Surplus Power



4. Investment: 923 million €



- Grid connection
- Electrolysis (900 €/kW)
- Buffer storage overground
- Cavern incl. overground components
- Trailer filling station
- Combined-cycle plant (800 €/kW)
- Indirect costs and reserve up to buffer storage

- Deprecation at 8% over 30 years (combined cycle plant 20 years)

  → 110 million €/year for annuity and fixed operating & maintenance costs

4. Variable Costs and Attainable Revenue

- **Purchase surplus power on the day-ahead spot market; market mechanisms as in place today → 0 €/MWh$_{el}$ (Assumption: Exemption from grid fees and levies)**

- **Sell power on the day-ahead spot and the reserve market**

- **Sell hydrogen as a vehicle fuel: Attainable revenue?**

  Target: Parity of fuel costs per km for FC and conventional cars

  → 10 €/kg H_2 price at the pump;
  subtract about 4 €/kg: VAT, costs for station & transportation

  → <u>Max. 6 €/kg revenue attainable</u>

  (Assumption: No energy tax on green hydrogen)

4. Decisive Point Regarding Revenue

Does the Specific Revenue that is required for cost recovery remain below 6 €/kg hydrogen fuel?

4. Selected Results for Zone Northeast

Case			"Standard Northeast"
Number of electrolysis full load hours			3.052
Amount of hydrogen generated (tonnes per year)			32.044
Hydrogen share used for re-electrification / balancing power			7%
		Specific Revenue required to break even [€/kg H_2 fuel]	
Electricity price for electrolysis €/MWh	Spot market price (0 €/MWh during surplus)		2,92
	40 €/MWh		5,00
	80 €/MWh		7,08

4. Selected Results for Zone Northeast

Case		"Less fuel"	"Standard Northeast"
Number of electrolysis full load hours		3.052	3.052
Amount of hydrogen generated (tonnes per year)		32.044	32.044
Hydrogen share used for re-electrification / balancing power		38% ←	7%
		Specific Revenue requi to break even [€/kg H_2 fu	
Electricity price for electrolysis €/MWh	Spot market price (0 €/MWh during surplus)	3,71	2,92
	40 €/MWh	6,80	5,00
	80 €/MWh	9,90	7,08

System economically feasible with power prices up to about 60 €/MWh$_{el}$ in the „Standard“ case and 30 €/MWh$_{el}$ with „Less fuel“

4. Selected Results for Zone Northeast

Case	"Less fuel"	"Standard Northeast"
Electrolysis full load hrs	3.052	3.052
Tonnes H_2 per year	32.044	32.044
Share for power plant	38%	7%
	Specifc Revenue to break even [€/kg H_2 fuel]	
Spot market price	3,71	2,92
40 €/MWh	6,80	5,00
80 €/MWh	9,90	7,08

gold = wind-hydrogen cheaper than hydrogen from natural gas

green = wind-hydrogen competitive at fuel market

red = wind-hydrogen not competitive

4. Selected Results for Zone Northeast

Case	"Less fuel"	"Standard Northeast"	Investment electrolysis 700 €/kW	Investment electrolysis 500 €/kW	Price driven electrolysis operation
Electrolysis full load hrs	3.052	3.052	3.052	3.052	5.600
Tonnes H_2 per year	32.044	32.044	32.044	32.044	59.100
Share for power plant	38%	7%	7%	7%	39%
	Specifc Revenue to break even [€/kg H_2 fuel]				
Spot market price	3,71	2,92	2,50	2,08	2,06
40 €/MWh	6,80	5,00	4,58	4,16	
80 €/MWh	9,90	7,08	6,66	6,24	

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Tonnes H_2 per year	32.044	32.044	32.044	32.044	59.100
Share for power plant	38%	7%	7%	7%	39%
	Specifc Revenue to break even [€/kg H_2 fuel]				
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40 €/MWh	6,80	5,00	4,58	4,16	
80 €/MWh	9,90	7,08	6,66	6,24	

Mind:
Exemption from grid fees assumed also for non-surplus periods

5. Conclusion: Economic Feasibility

- **<u>There are cases (sets of boundary conditions) that facilitate cost-covering operation of wind-hydrogen systems in 2030.</u>**
- **In particular: Power for electrolysis is required at favourable conditions but does not have to come "for free".**
- **0 €/MWh$_{el}$ power costs over long periods of time are unlikely to occur in reality.**

  → Important that with up to 60 €/MWh$_{el}$ cost recovery / profitable operation is feasible while keeping the target of fuel cost parity.
- **There is potential for reducing the investment.**
- **The system studied can be further optimised and additional options are worth exploring.**

5. Overall Summary and Conclusions

- **For 2030, substantial amounts of surplus wind power in the German transportation grid must be expected over long periods.**

  → Opportunities for hydrogen energy storage will emerge.

- **The type of wind-hydrogen system studied facilitates long-term storage at reasonable costs.**

  → Wind-hydrogen for mobility will be affordable and will most of the time be more profitable than stationary use.

- **Operating in very different market segments, fuel and power, supports acting flexibly (over 30+ years) and facilitates synergies.**

Thank you for your attention!

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