Power-to-Gas demonstration plant Ibbenbüren

Project description and background information

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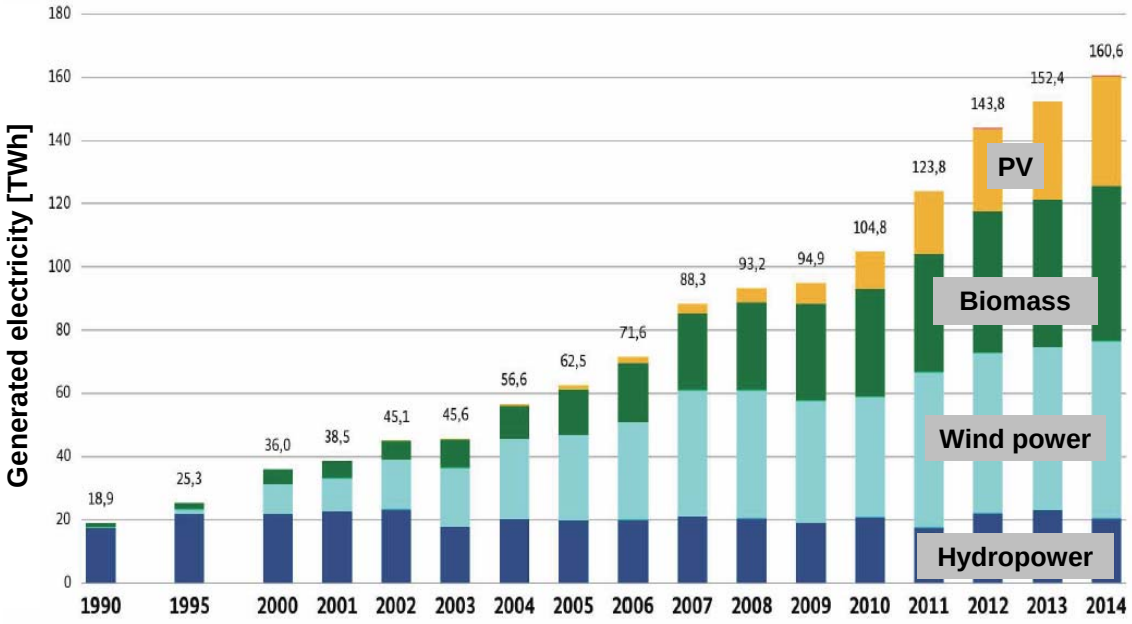
RWE Deutschland AG

Renewable power generation grew significantly during the last years

Development of power generation from renewable energy since 1990



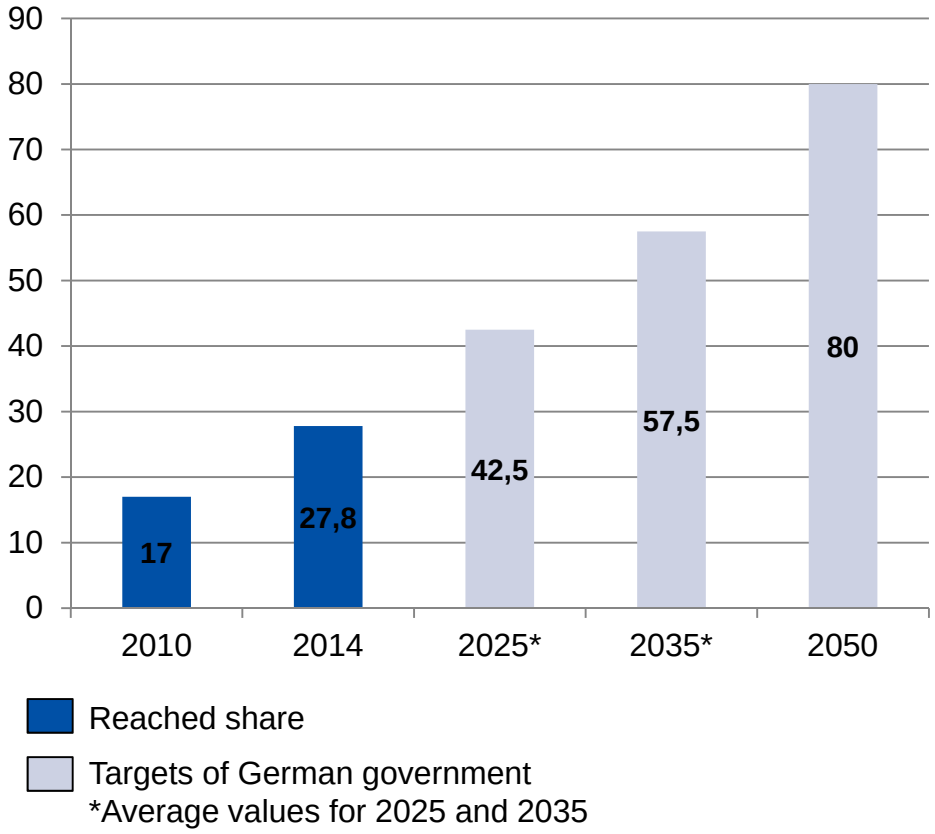
Source: German ministry of economics (2015)

Remark: Wind power nearly exclusively wind onshore

- The „Renewable Energy Law“ (originated in april 2000) led to intense development of power generation on renewable basis
- Main increase in the last years in the sectors „wind power“, „photovoltaics“ and „biomass“
- Current status:
  - Hydropower: Nearly completely utilised
  - Biomass: No significant extension expected due to reduced subsidies

With a renewable generation target of 80% in 2050, the key challenges are still to come

Regenerative generated share (%) of electricity demand

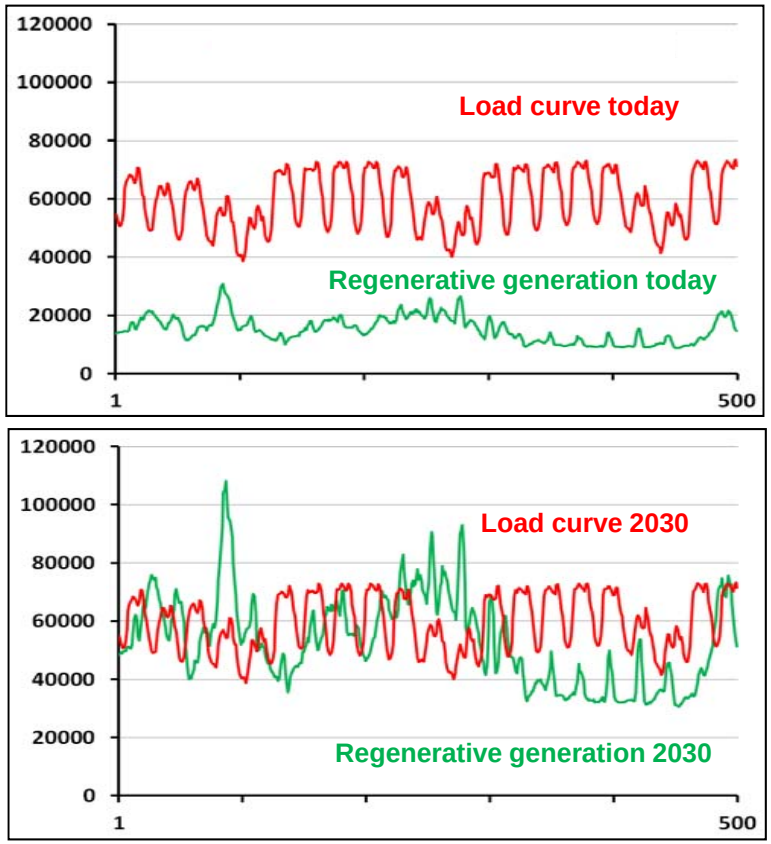


- Further increase only possible by extension of strongly fluctuating sources (wind power and photovoltaics)
- Planned development of installed power (2014 to 2035)*
  - **Photovoltaics** (factor 1,6) from 38 GW to **60** GW
  - **Wind** onshore (factor 2,3) from 38 GW to **89** GW
  - **Both** (factor 2,0) from 76 GW to **149** GW
  - In comparision: Load bandwidth in entire Germany approximately between **30 – 80** GW (also in the future)

* According to the German network development plan 2015 scenario „B“

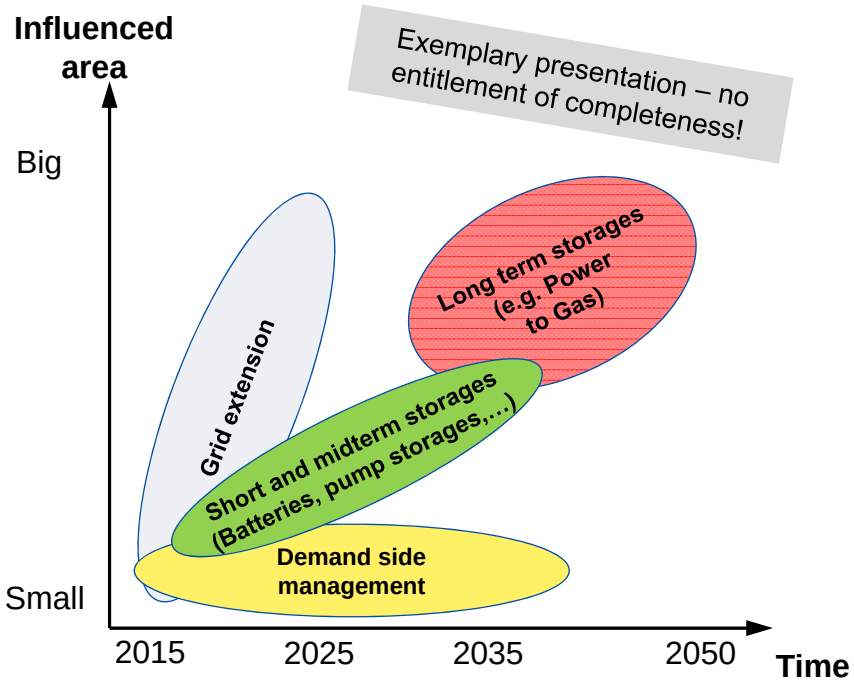
Level and bandwidth of power generation from renewable sources will increase extremely

German demand versus generation from renewables – exemplary presentation over 500 hours



- Today:
  - Demand always above generation from renewables (at regional level partly already inverted!)
  - Gap between „green generation“ and demand filled by existing power plants
- Future (2030):
  - Generation from renewables nearly always higher or lower than demand => necessary balance not existing
  - Frequent and expensive shut-downs of plants for renewable generation expected
  - Future availabilty of conventional power plants unclear due to questionable economic situation

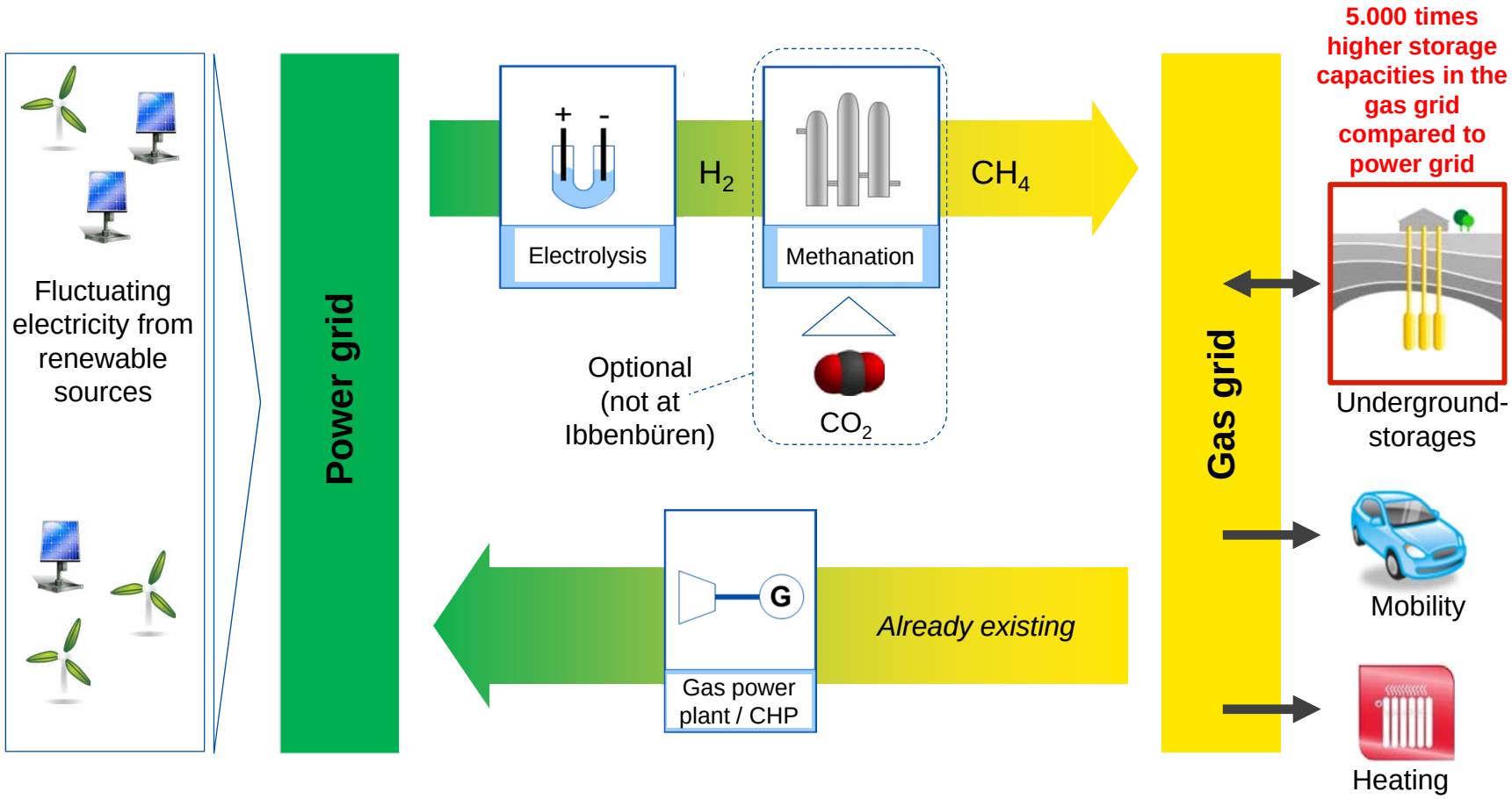
Power-to-Gas is a long-term option for balancing supply and demand of electricity



Electricity market Germany	Gas market Germany
Consumption ~ 550 TWh Storage ~ 0,04 TWh	Consumption ~ 870 TWh Storage ~ 240 TWh

- There is not one option that fits all scenarios
- Instead, a combination of different methods is getting more and more likely
- Single methods do not have to compete with each other – a reasonable amendment is probable
- Specific application and point in time depend on the achieved status of „green generation“ and grid extension
- In this context usage of „Power-to-Gas“ for electricity storing only expected in the long term

Power-to-Gas creates flexibility by connecting the gas and the electricity grid

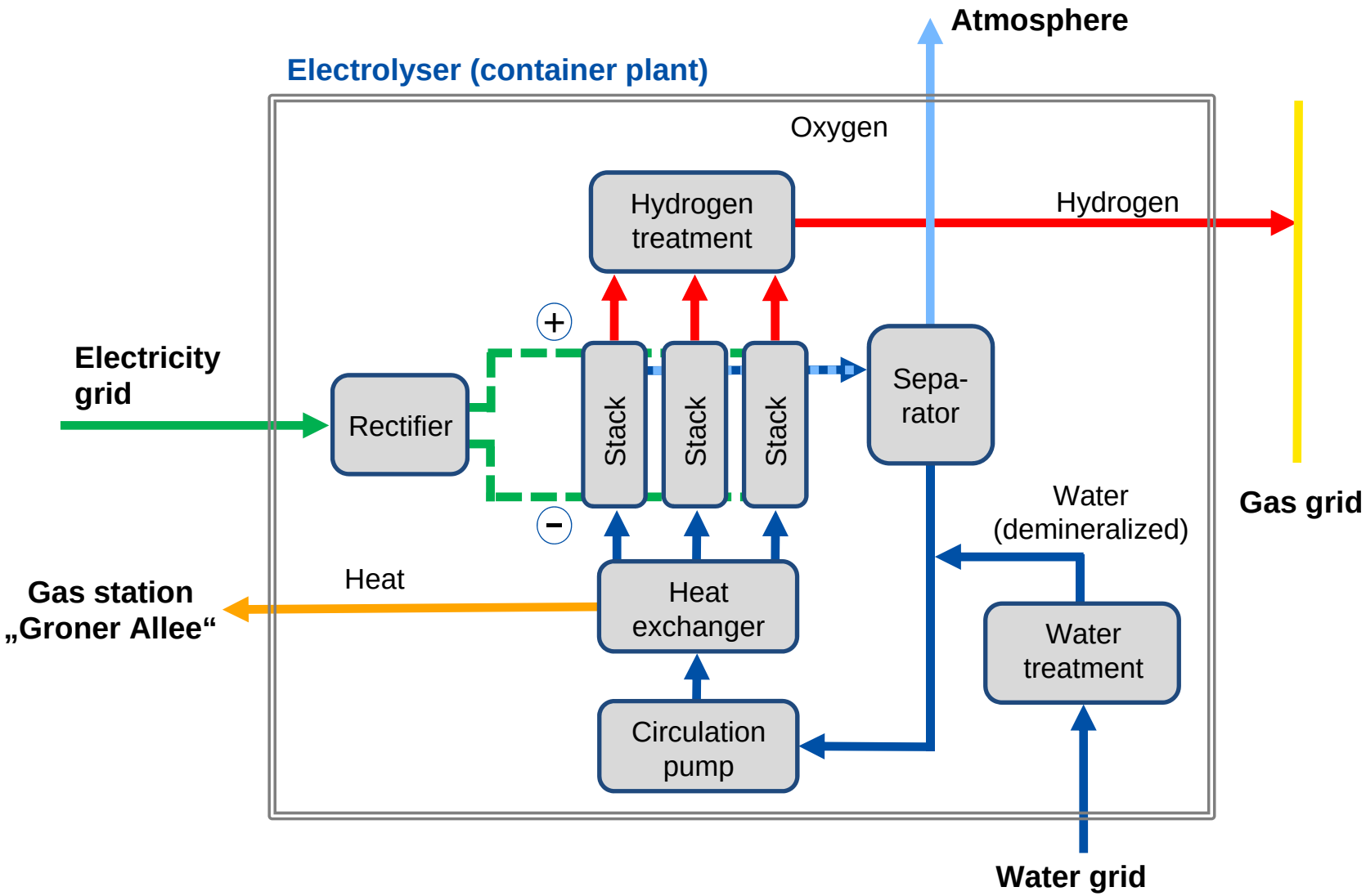


In Ibbenbüren RWE is piloting a plant to produce hydrogen via electrolysis

Compartment of the electrolysis (length 6 m)

- Electrolysis with innovative PEM (Proton Exchange Membrane)-Technology
- Standard operating point 150 kW (el. consumption)
- Production of approx. 30 m^3_N/h hydrogen at 14 bar(g) – Feed-in into the regional gas grid of RWE Deutschland AG
- Production of approx. 15 m^3_N/h oxygen – vented to surrounding
- Electrolysis operated with excl. „green“ electricity

Simplified process of the plant

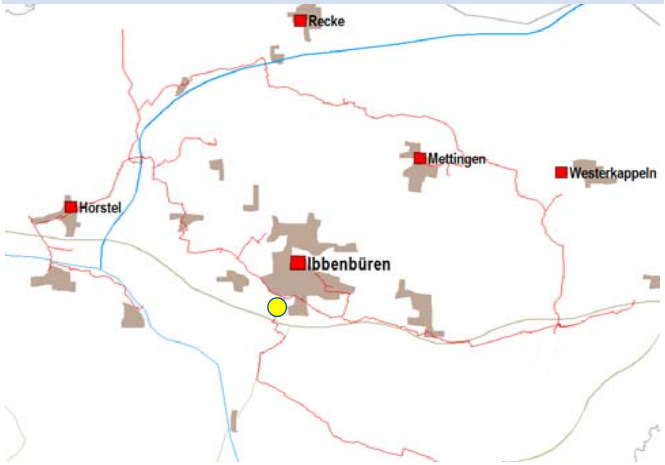


Further details of the plant

- Electrolysis built into a 20-ft-Container (length: 6 meter), weight approx. 12 to
- Max. overload: ca. 130% based on normal operating point (40 m^3_N/h hydrogen)
- Purity of hydrogen: 99,9% (requirement for H2-mobility met)
- Waste heat of electrolysis used in gas station at a temperature level of 55° C
- Total efficiency (electricity and heat): approx. 86% (71% power to H2)
- Flexibility:
  - Cold start up within 300 seconds
  - Warm start up immediately
  - Response time within 2 seconds
- SIEMENS safety and automation techniques applied (SIEMENS-PLC)
- Automated operation via remote control from dispatch centre at WESTNETZ GmbH
- TÜV Nord: Certification of plant and safety concept

The hydrogen is fed into the local gas station

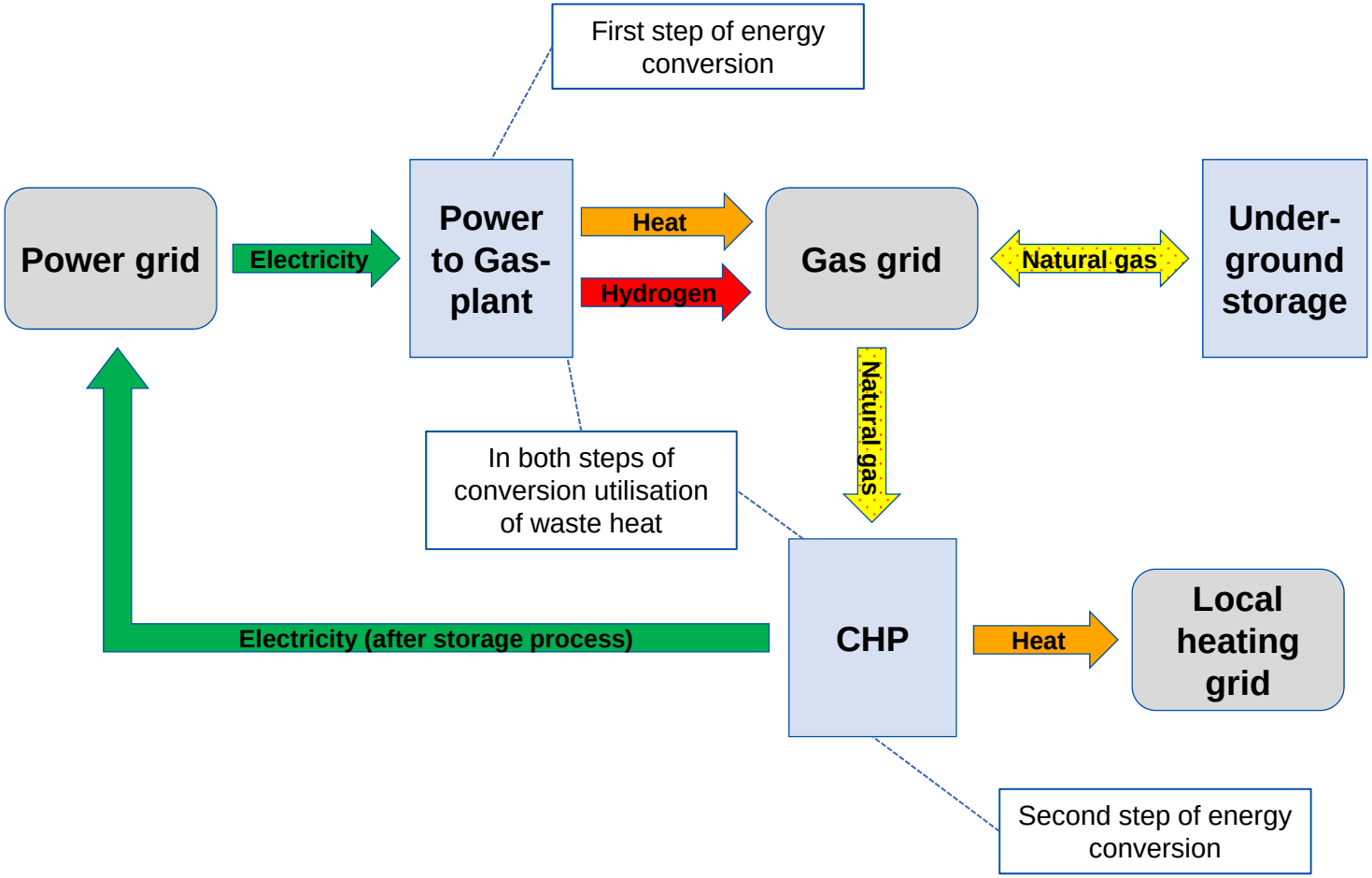
Regional RWE high pressure pipelines



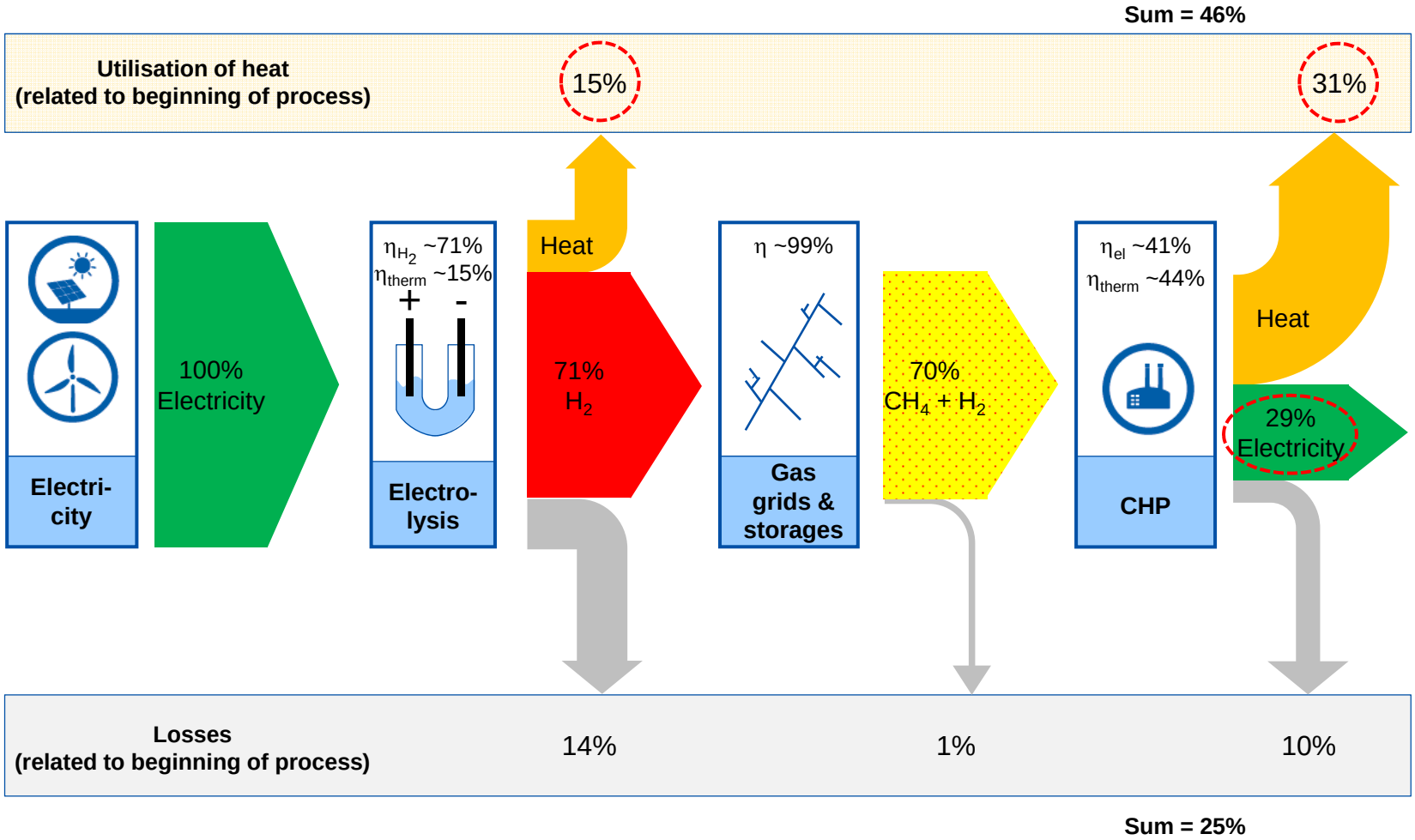
Gas station „Groner Allee“

- Hydrogen is fed-in at the outlet side of the gas station – no further compression needed
- Hydrogen together with natural gas is distributed in Ibbenbüren and surrounding
- Ideal condition for hydrogen feed in in Ibbenbüren as also in summer high gas volumes are distributed
- No differences in calorific value within the downstream-grid due to one feed in only
- Hydrogen is used in CHP in Ibbenbüren connected to the local heating grid
  - CHPs raise overall efficiency
  - Swap into a mixture of natural gas and hydrogen

The system solution in Ibbenbüren reduces energy losses by a high degree of cross-linking



Multiple utilisation of waste heat increases total efficiency substantially up to 75%



The project contributes to the development and deployment of the Power-to-Gas technology

- Gain operational experience for electrolysis in the context of renewable energy
  - First PtG plant in Germany with
    - Waste heat concept
    - Direct feed-in into a 16 bar regional gas transportation system without additional hydrogen compression
  - Second electrolysis with innovative PEM-Technology in Germany; Technology advancement with regard to:
    - Efficiency of stacks and power electronics
    - Stack size (reduced costs) and purity of hydrogen
    - Plant engineering (simplified)
- The project will contribute to further cost reduction and increase in efficiency etc.
- Commercially: Check and validation of business models in the field of power to gas

Thank you for your attention

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