Renewable Energy Storage ♦ Present Status of Development and Outlook

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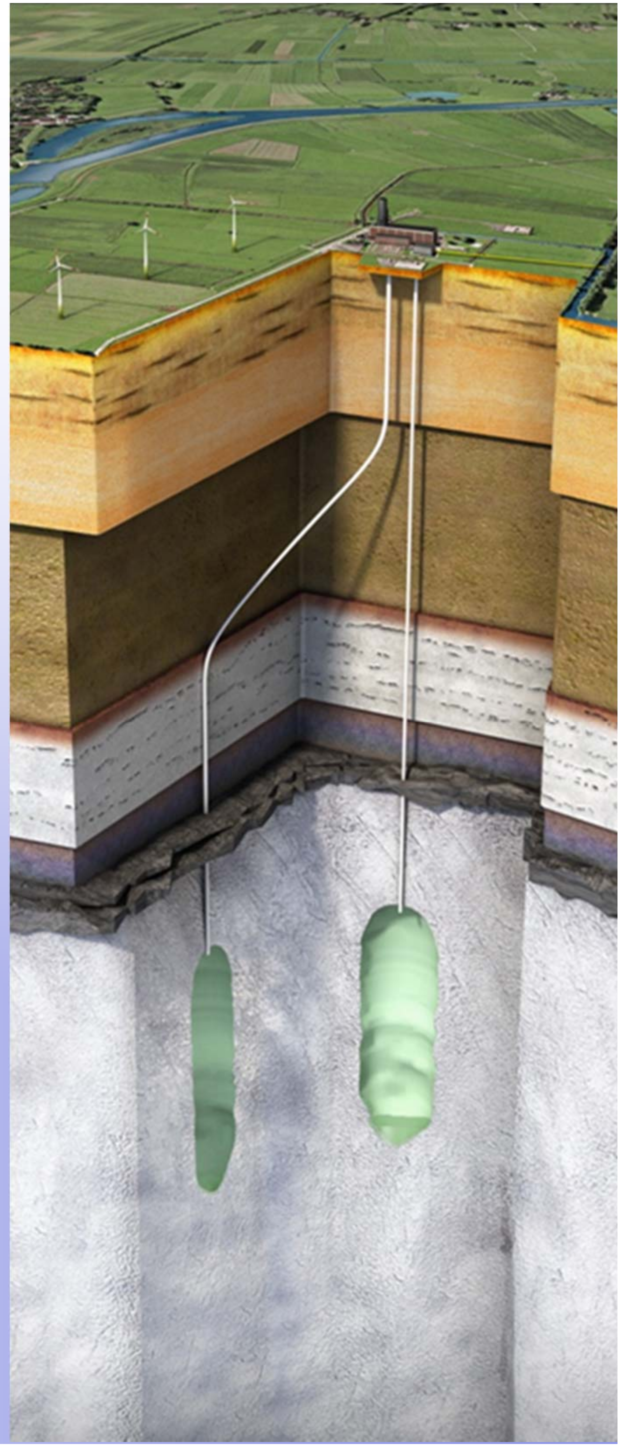
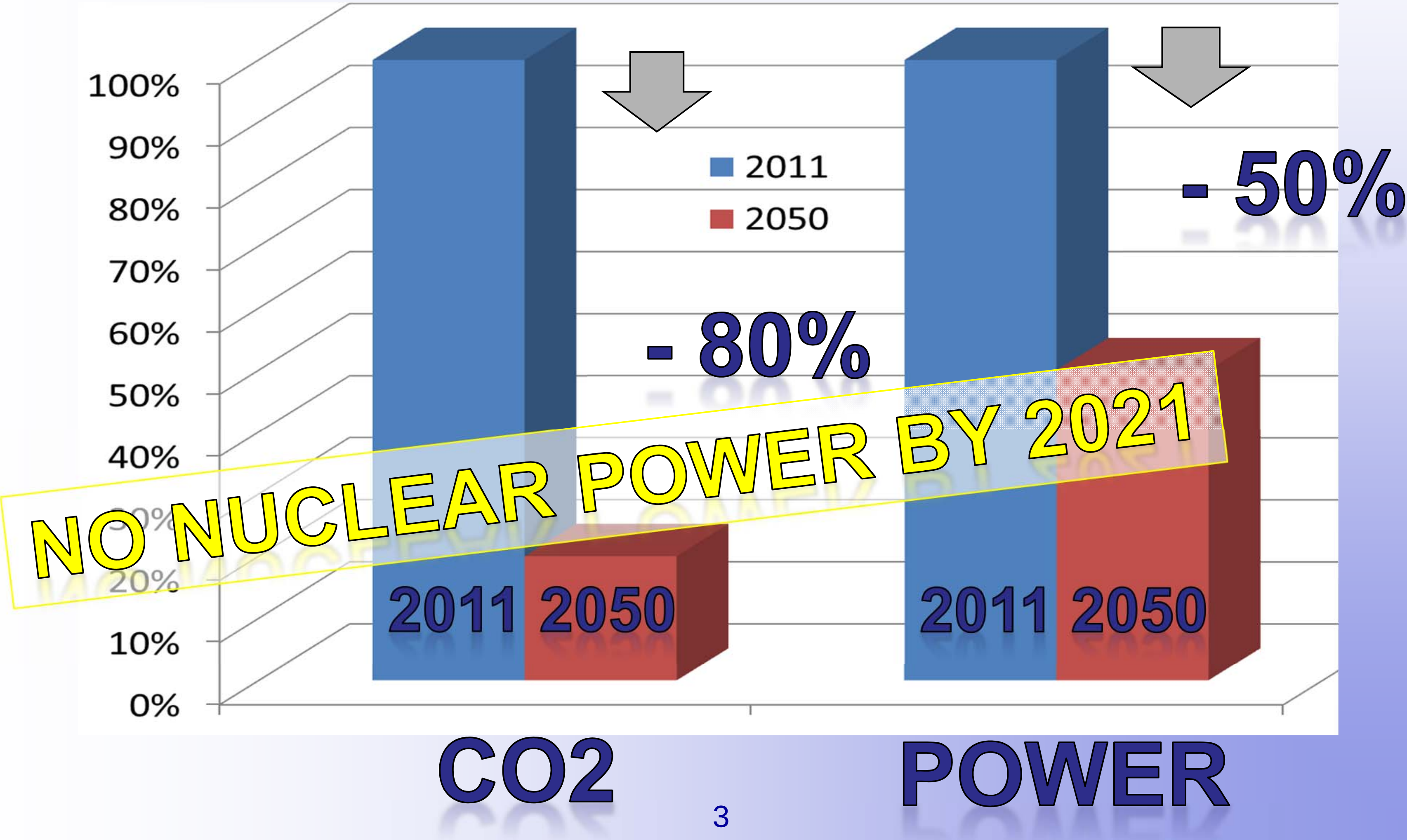
06. Dec. 2012 X



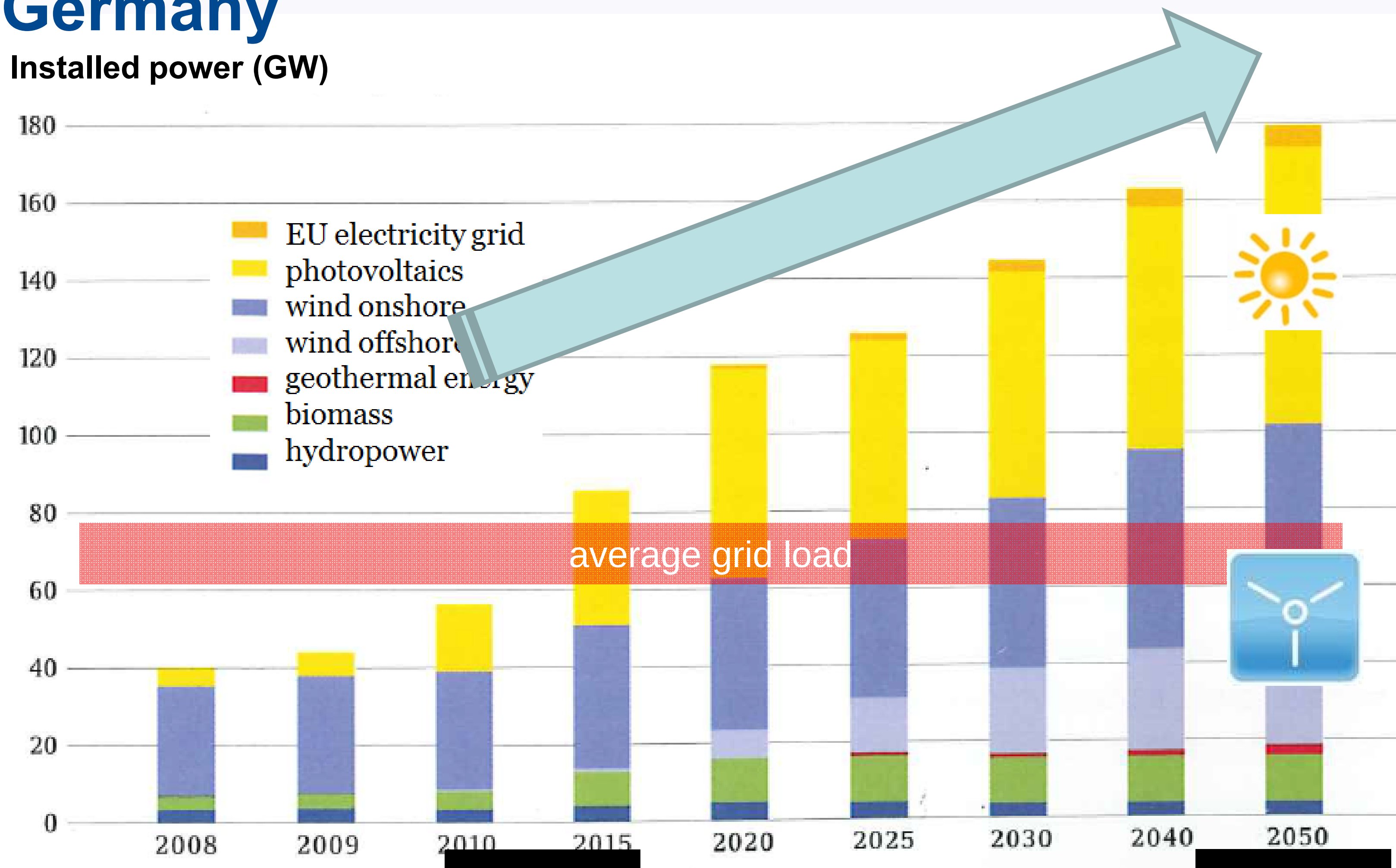
1. Transition to renewable energies – need for large scale storage
2. Grid scale storage options
3. Power-2-Gas
4. Summary

Goals of German government

CO2 + electric power reductions until 2050



Prognosis for installed Renewable Energy production in Germany



Expansion scenario for renewable energies in G… GW (FME-reference scenario, scenario A).

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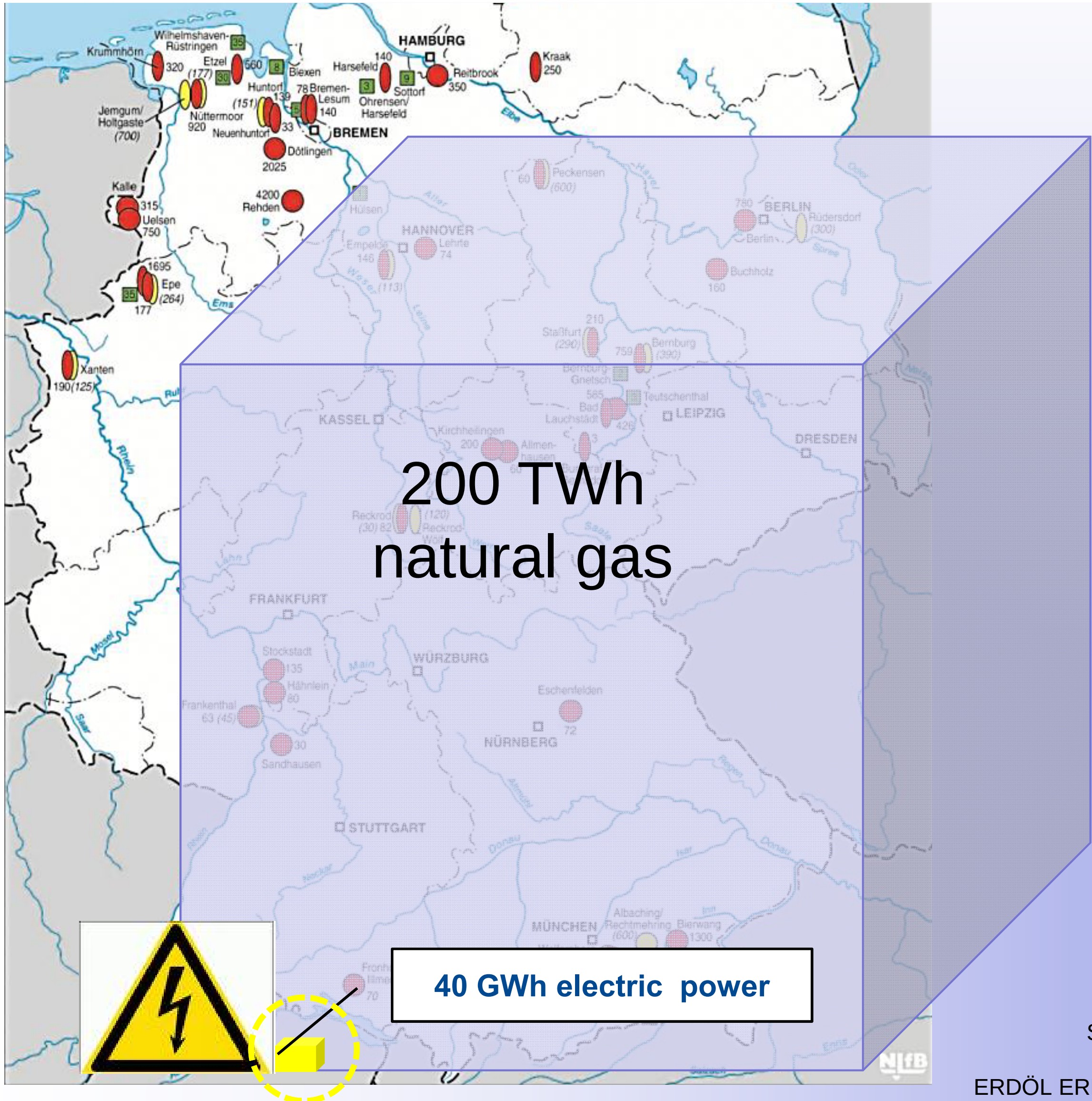
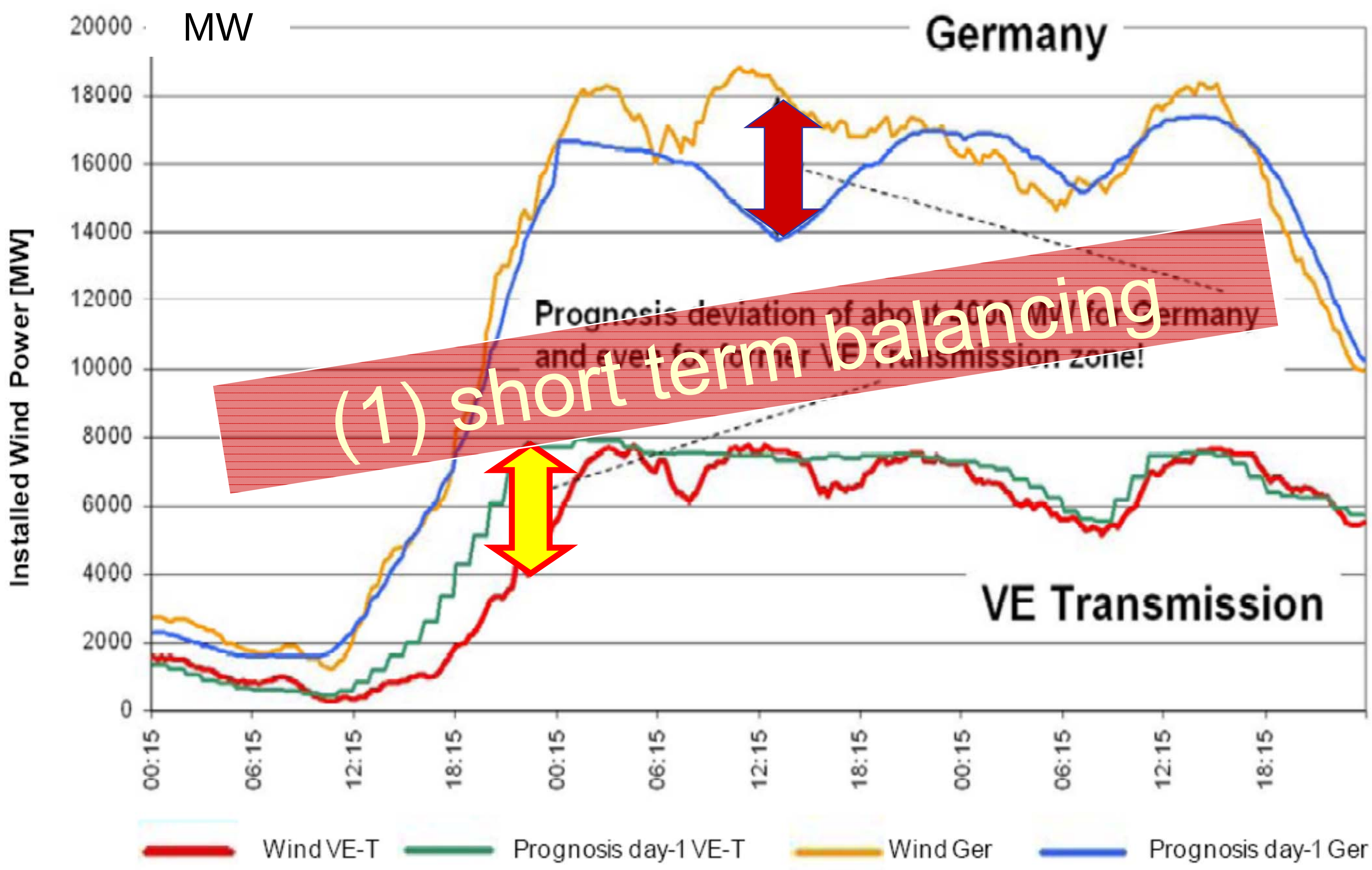
Capacity of existing underground gas storages in Germany



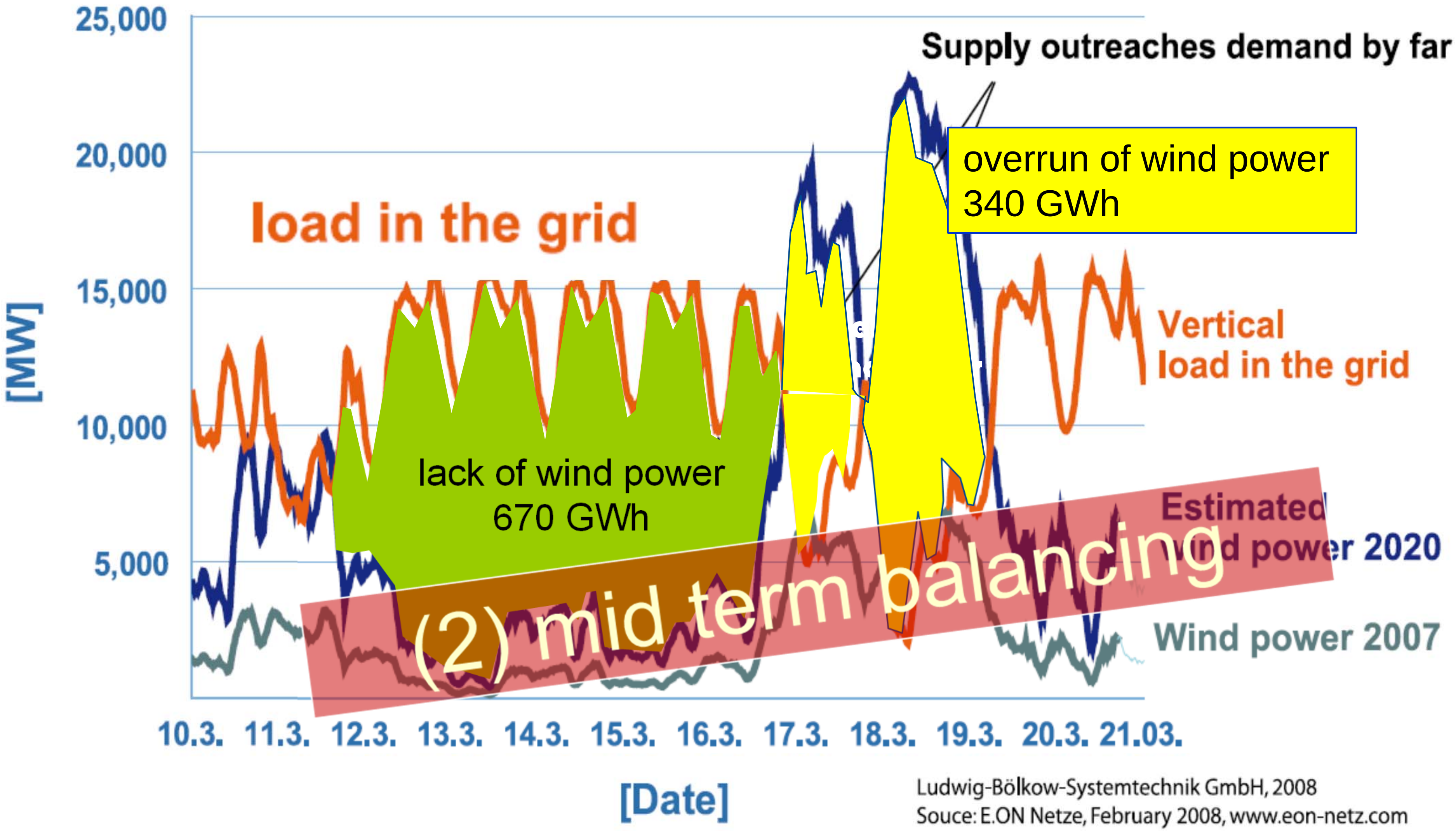
- for natural gas
- theoretical value for hydrogen

Source: Untertage-Gasspeicherung in Deutschland
ERDÖL ERDGAS KOHLE 127, Jg. 2011, Heft 11

Wind forecast deviations during storm EMMA

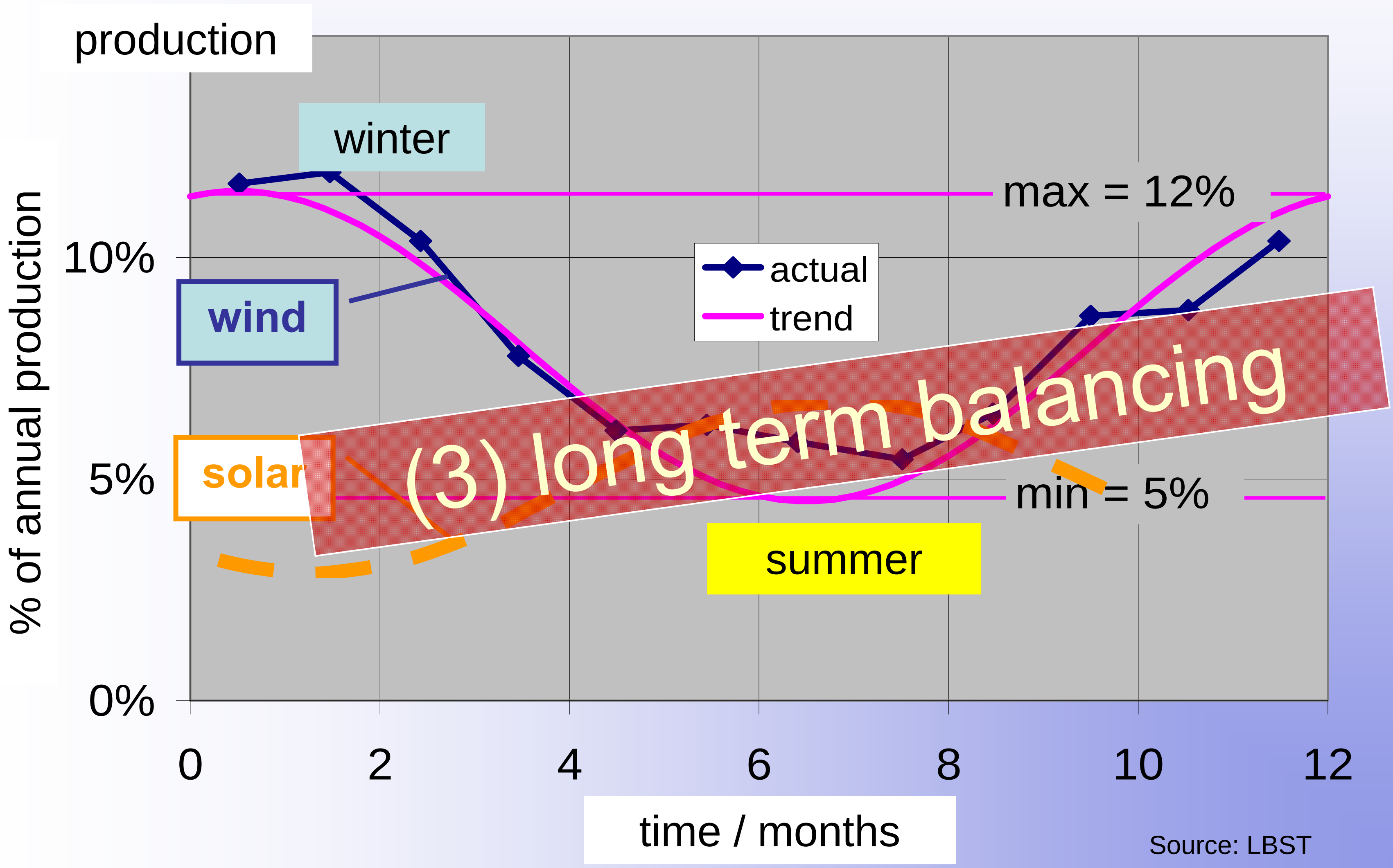


In future large amounts of *excess wind* power and *flaws*



Ludwig-Bölkow-Systemtechnik GmbH, 2008
Souce: E.ON Netze, February 2008, www.eon-netz.com

Seasonal swing of wind & solar power



Source: LBST

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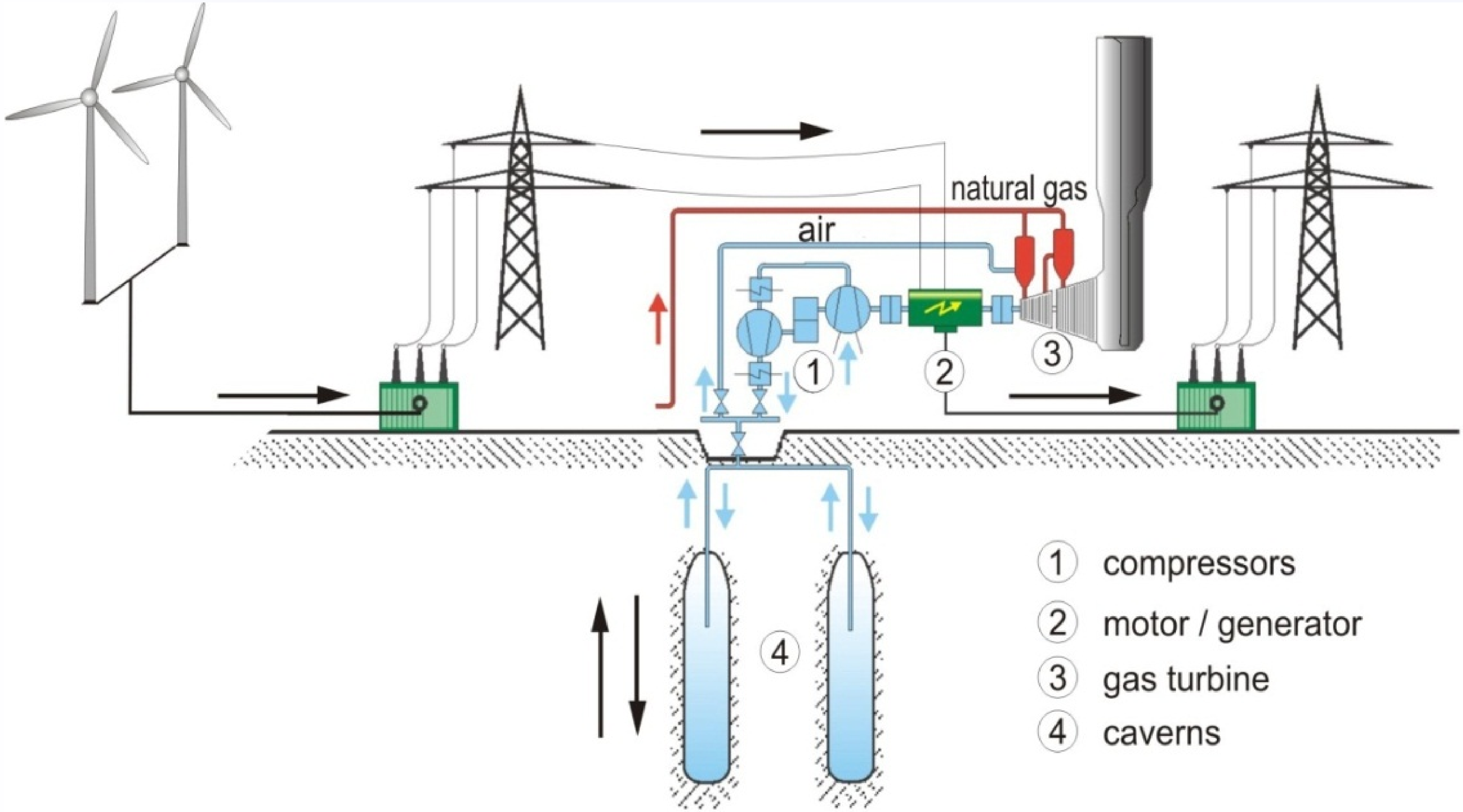
Pumped hydro plant ($\eta \leq 80\%$)

Compressed air energy storage (CAES)

η = 42% (55% w/ waste heat recovery)



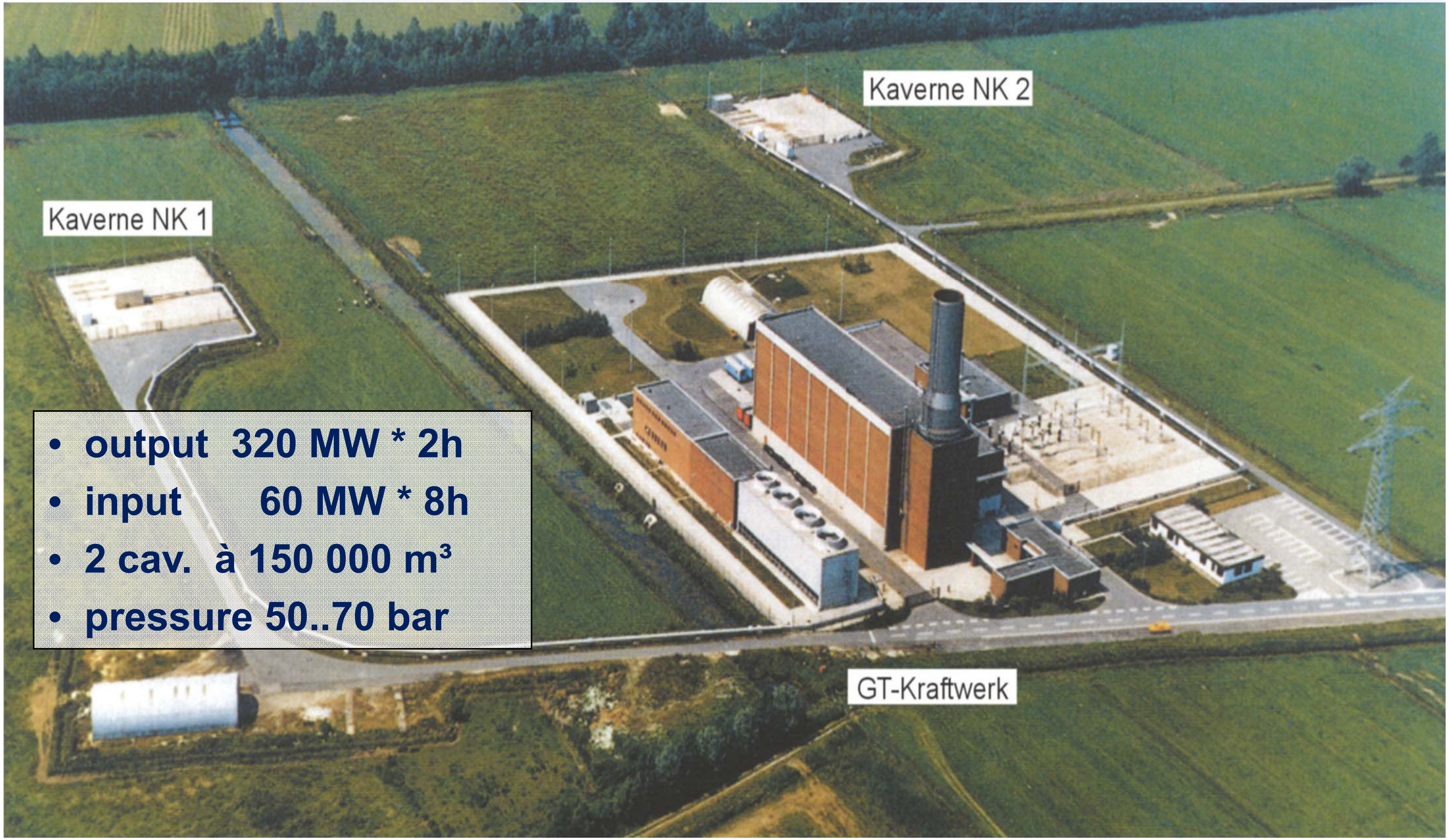
EON 330 MW Huntorf CAES plant

Compressed Air Energy Storage Plant

Renewable Wind Energy

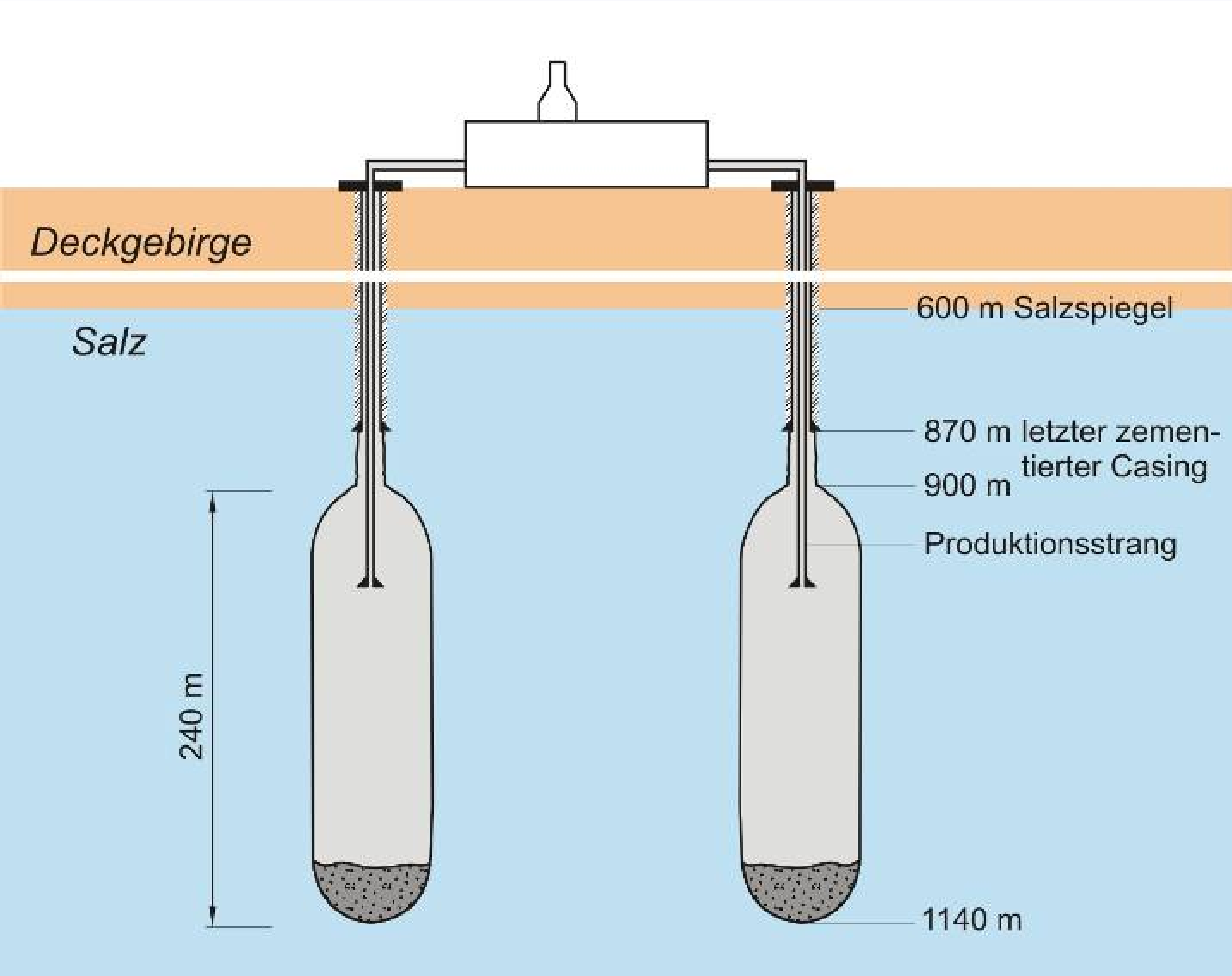
Methan

EON 320 MW CAES-power plant Huntorf

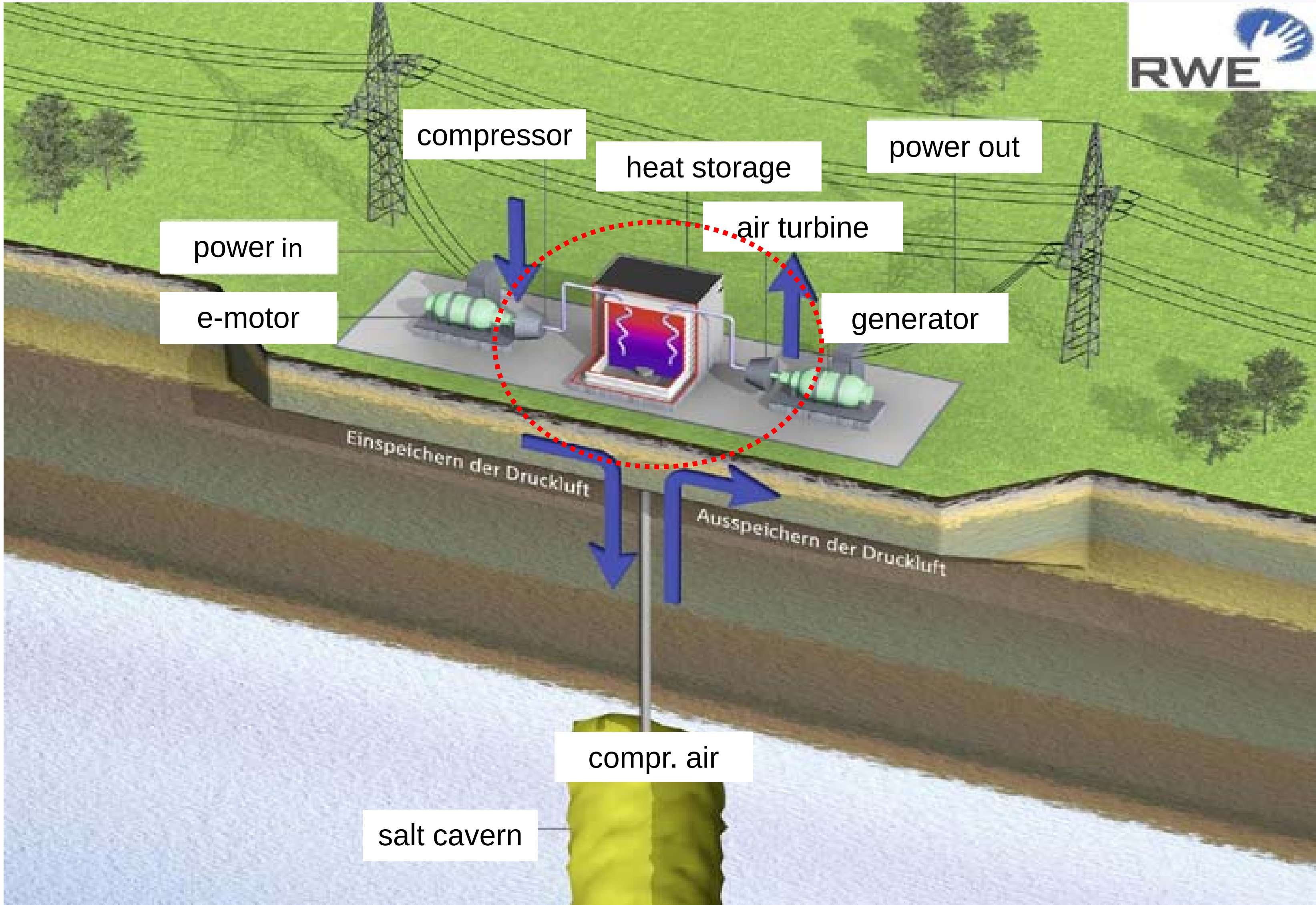


- output 320 MW * 2h
- input   60 MW * 8h
- 2 cav. à 150 000 m³
- pressure 50..70 bar

2 caverns of Huntorf EON CAES plant

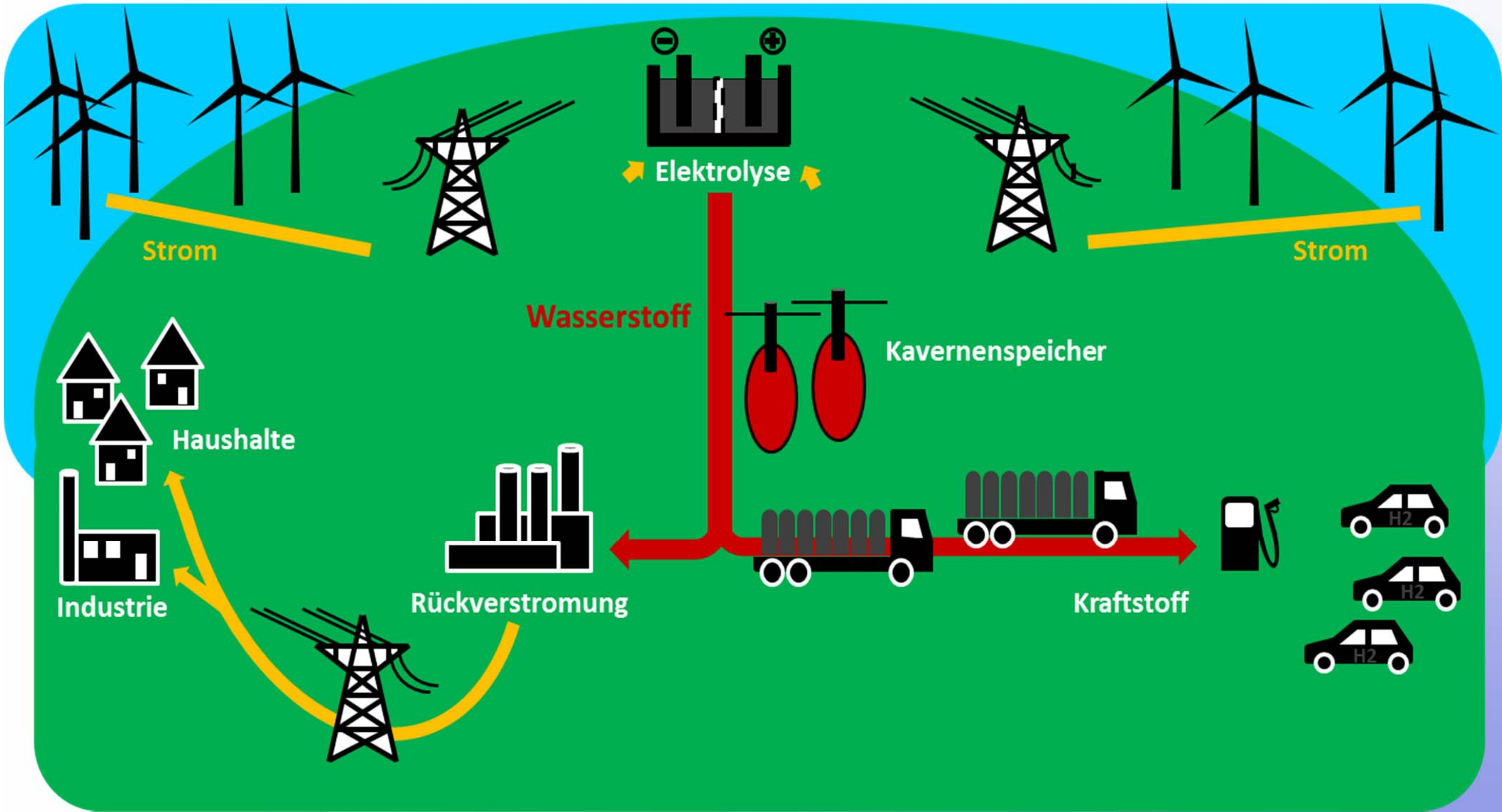


Adiabatic CAES project ADELE (η < 70%)

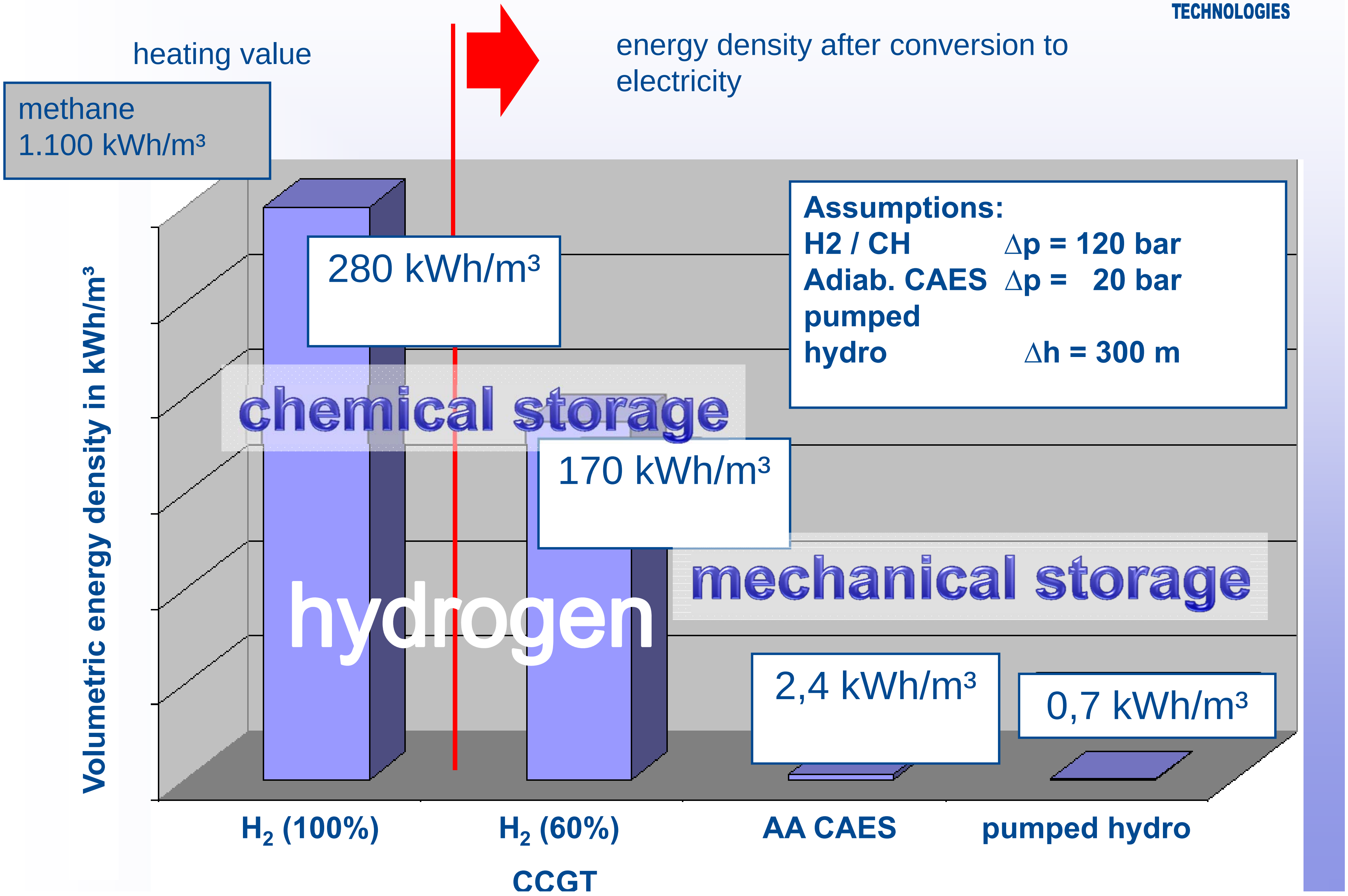


Hydrogen-storage-scheme (η > 40%)

wind power > hydrogen > storage > power



Volumetric Energy Densities



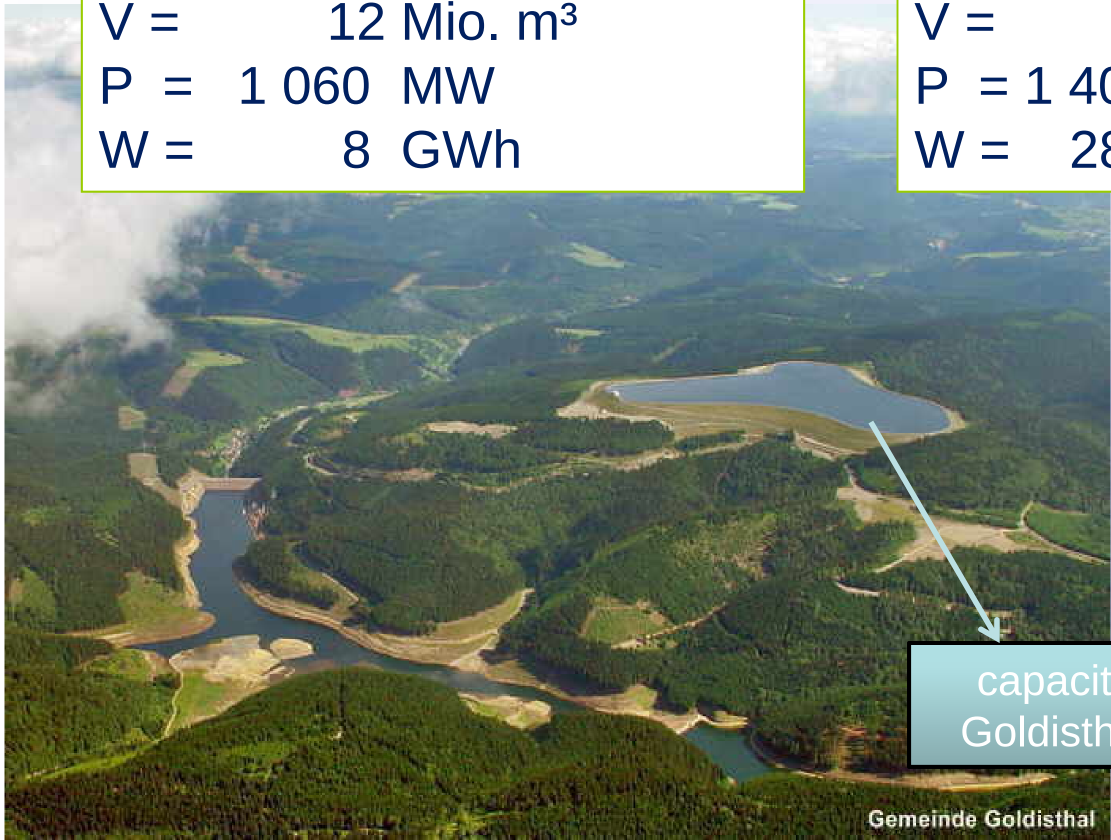
Pumped hydro vs. hydrogen storage

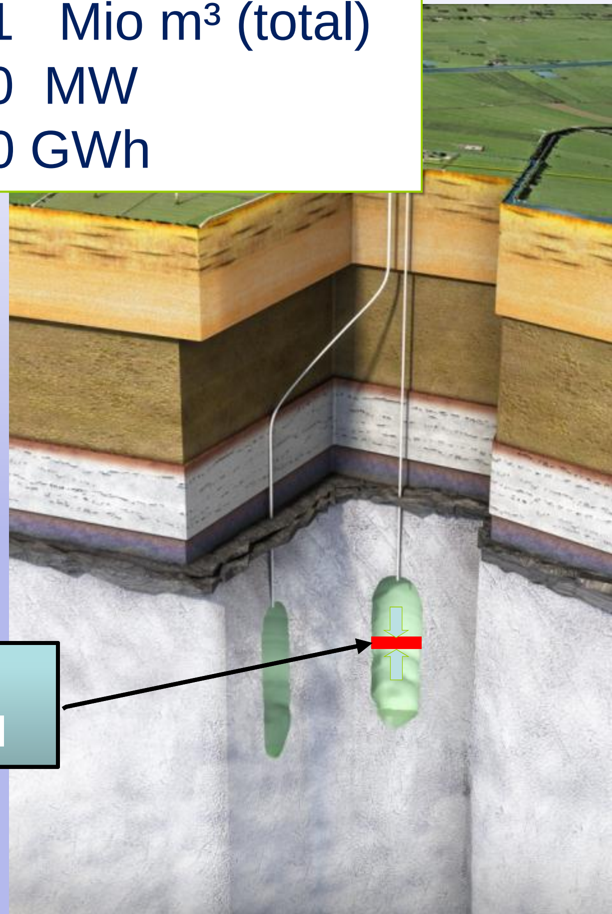
pumped hydro plant Goldisthal

V = 12 Mio. m³
P = 1 060 MW
W = 8 GWh

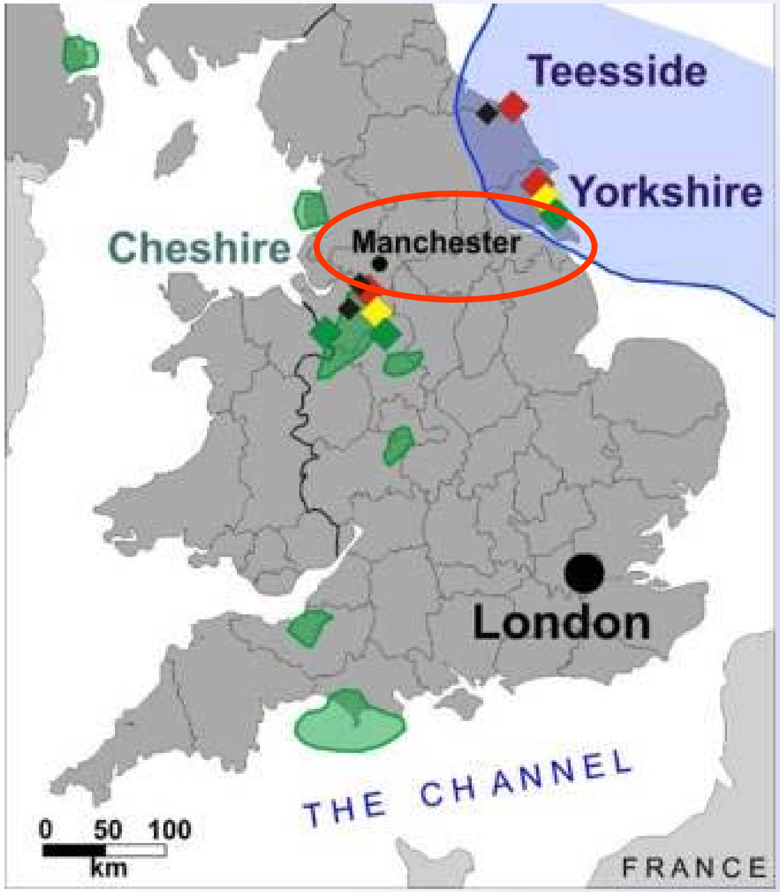
2 caverns H2 plant

V = 1 Mio m³ (total)
P = 1 400 MW
W = 280 GWh

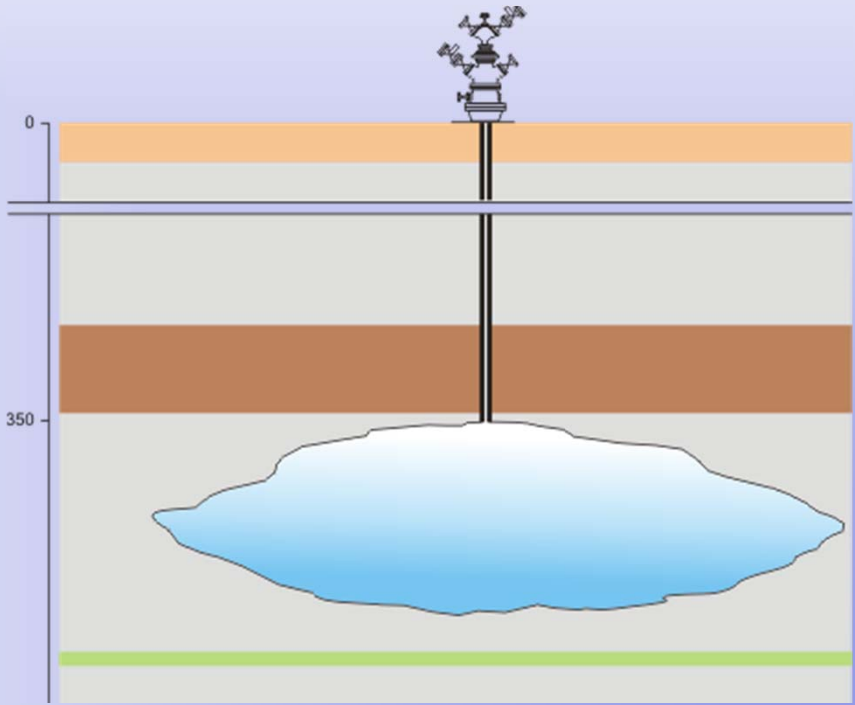




Existing hydrogen caverns in the UK. Sabic Petrochemicals H2 caverns at Teesside, UK

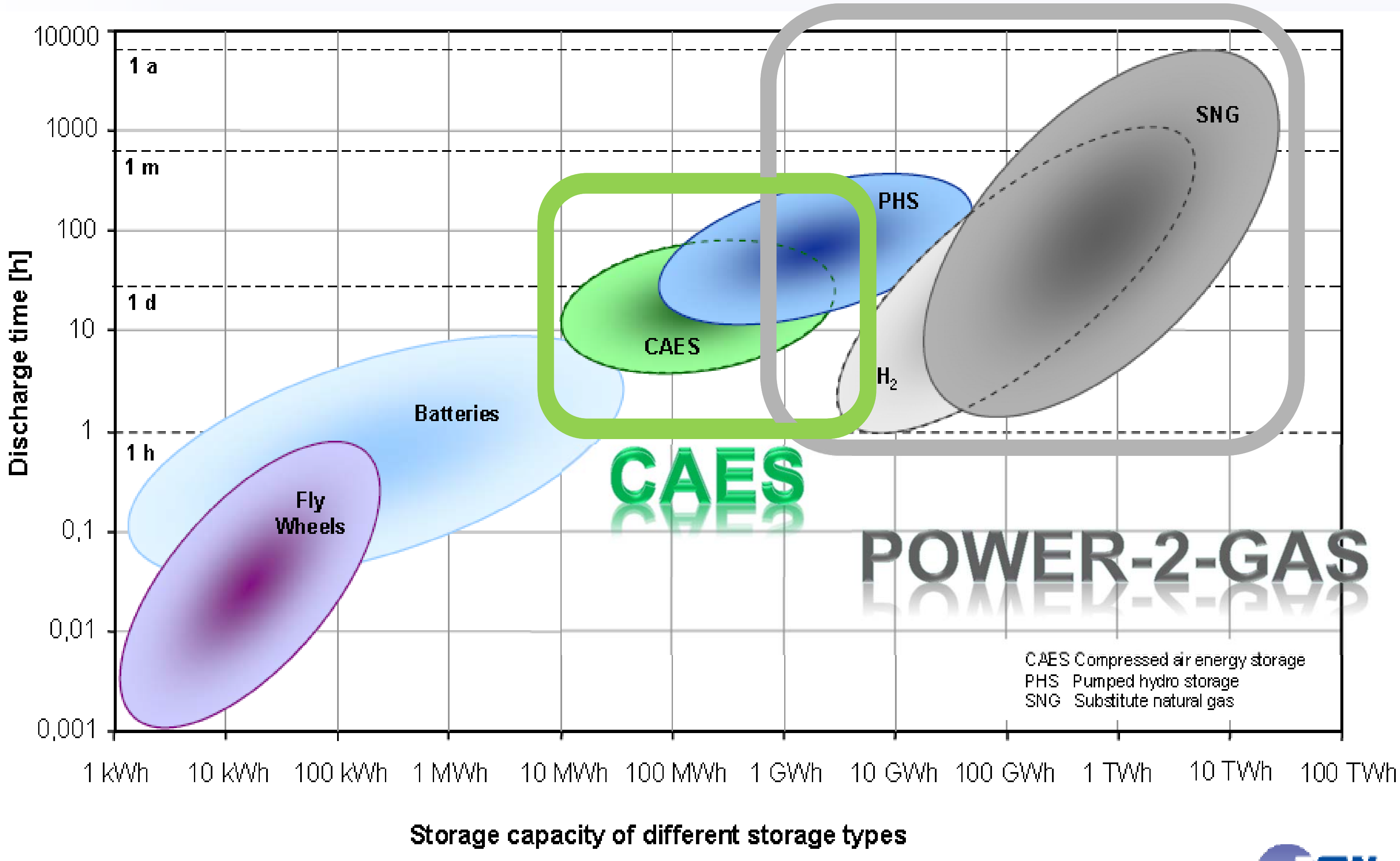


3 caverns a 70,000 m³
p = 45 bar constant
depth ca. 370 m



Existing hydrogen caverns in Texas / USA

Storage capacity of different options

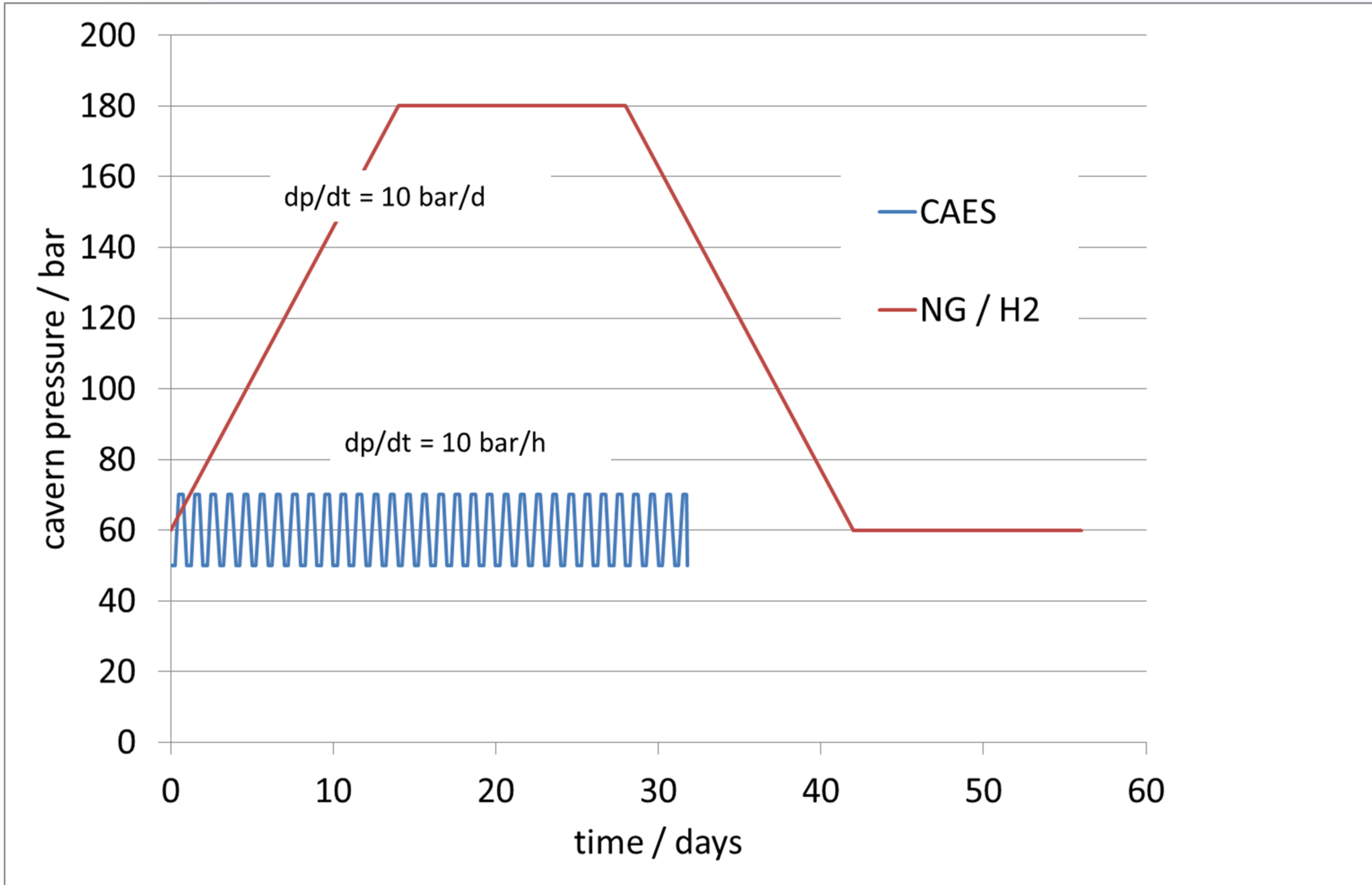


Fraunhofer IWES

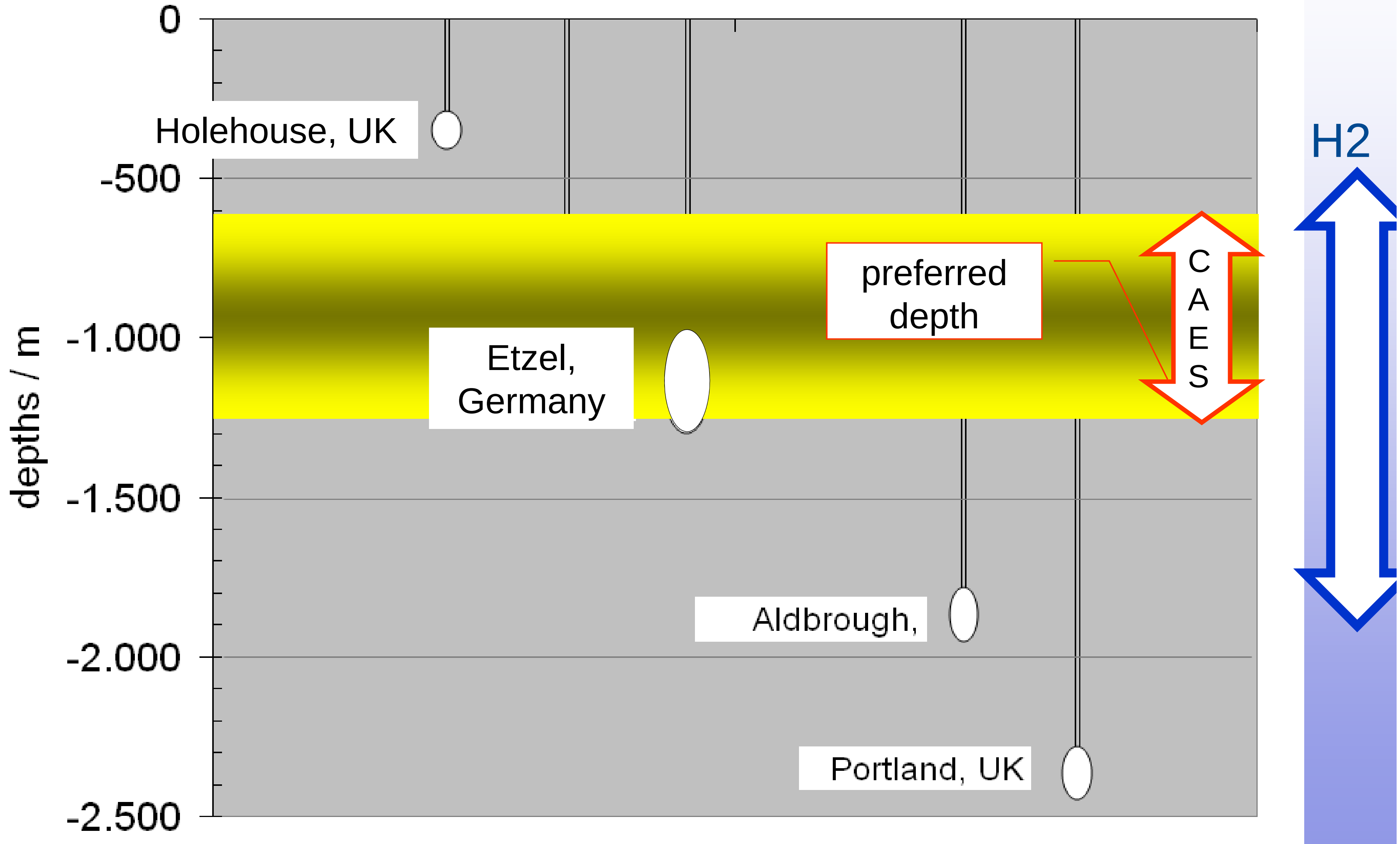
SOLARFUEL

ZSW

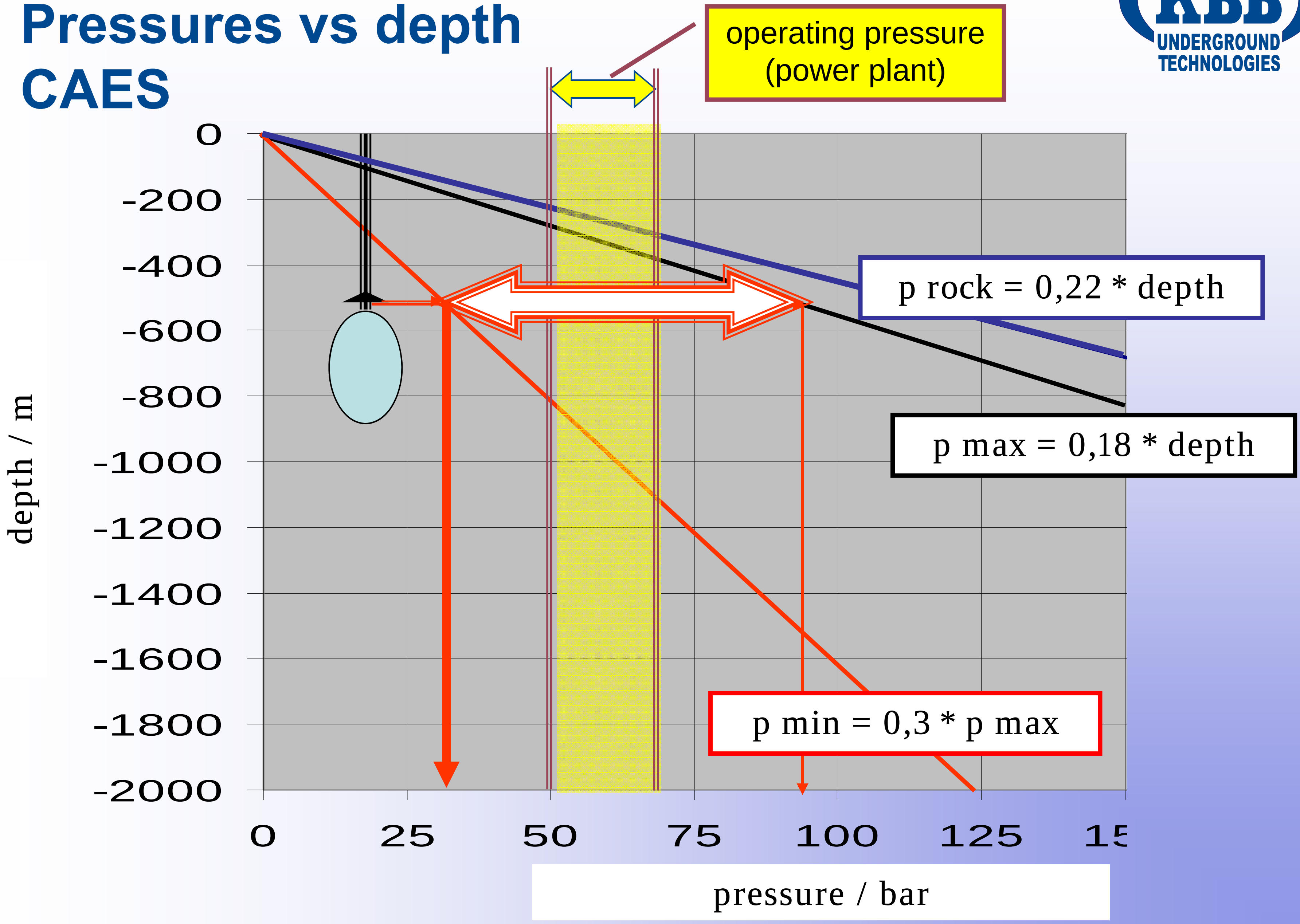
Pressure (filling & emptying) vs time in CAES + in H2 caverns



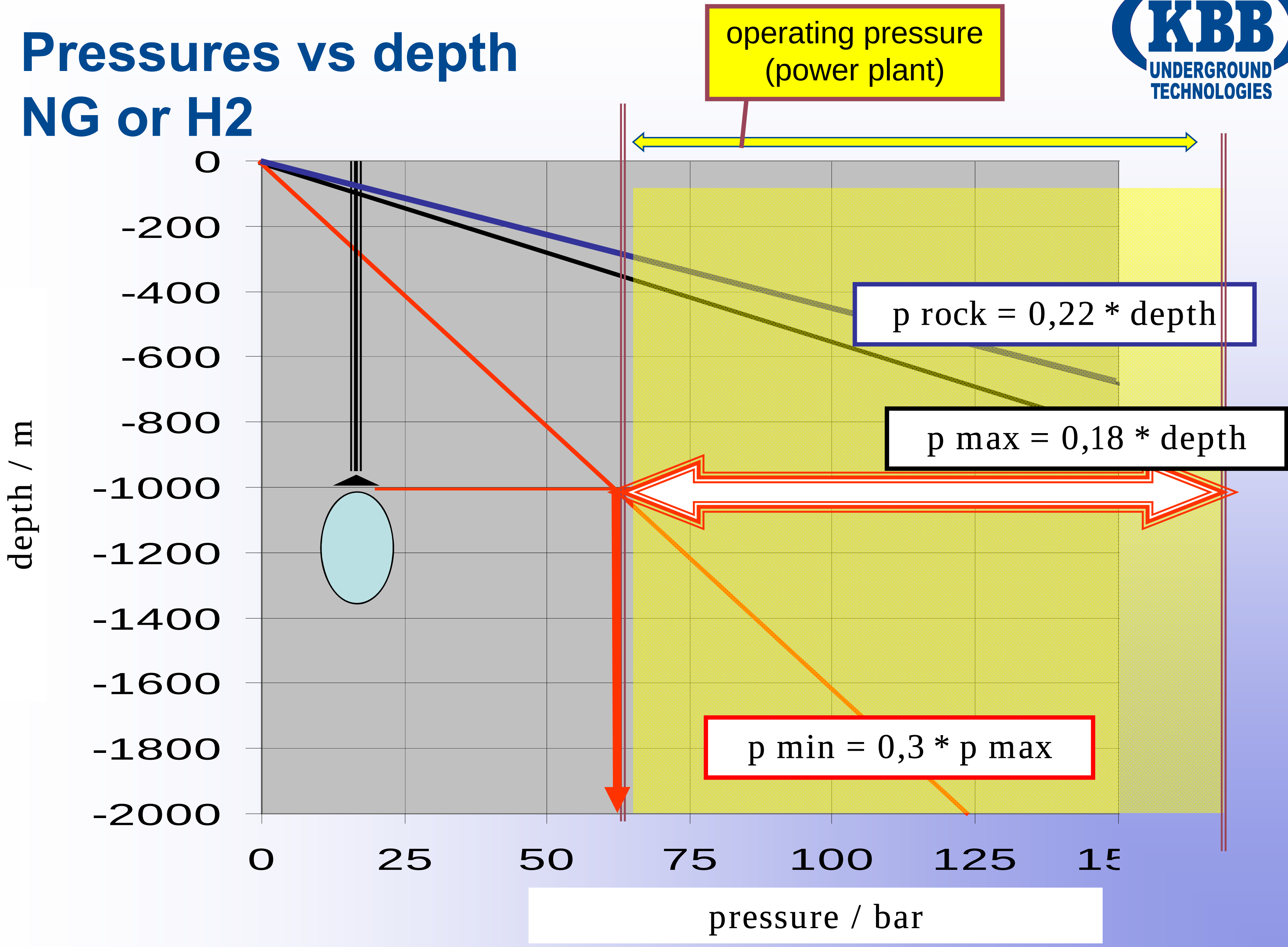
Optimum depth of salt formation for CAES caverns



Pressures vs depth CAES



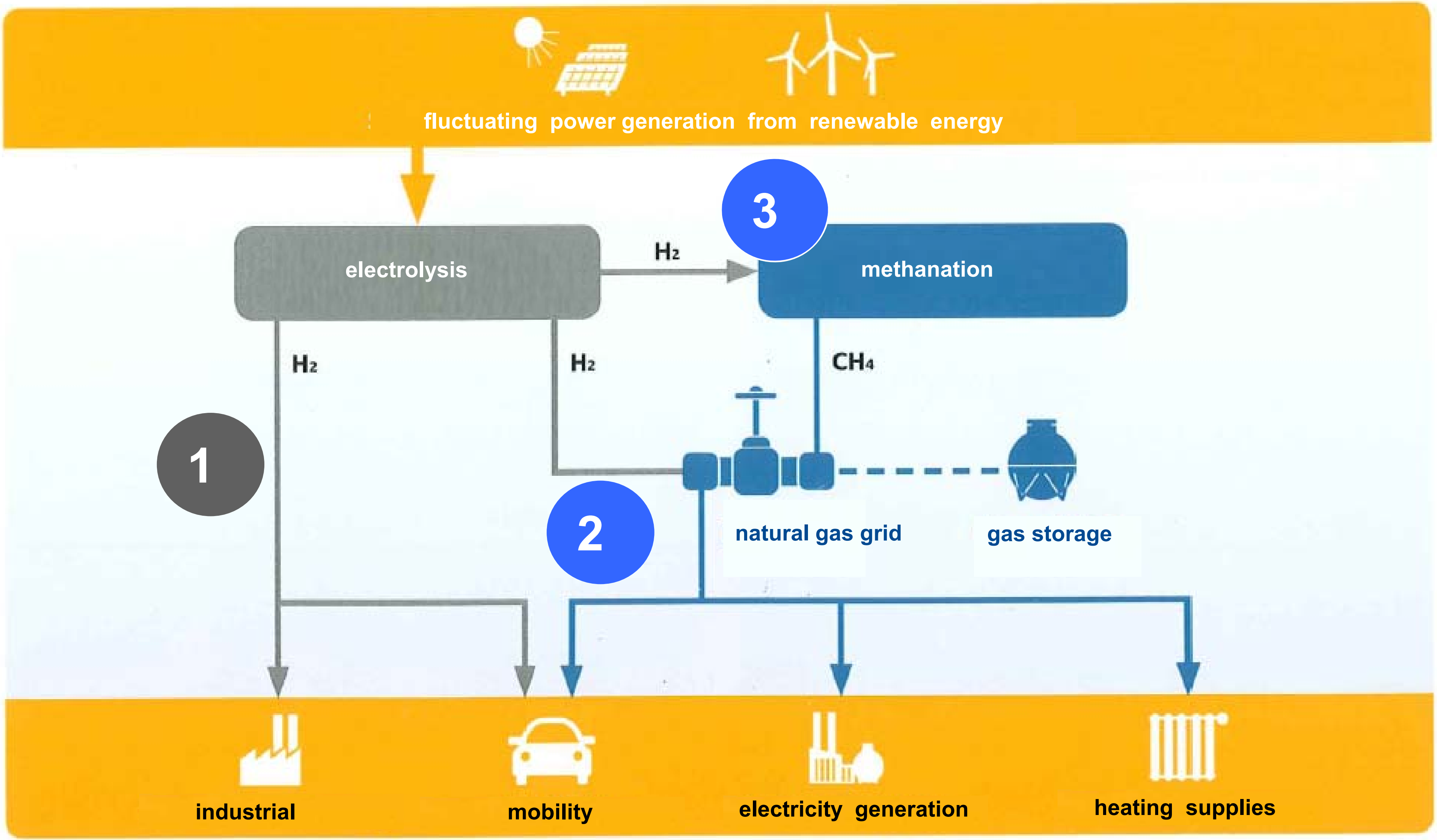
Pressures vs depth
NG or H2



1. Transition from fossil to renewable energy
2. Grid scale storage options
3. Power-2-Gas
4. Summary

Basic applications of Power-2-Gas

The Power-2-Gas process: ares of application



1. Transition to renewable energies
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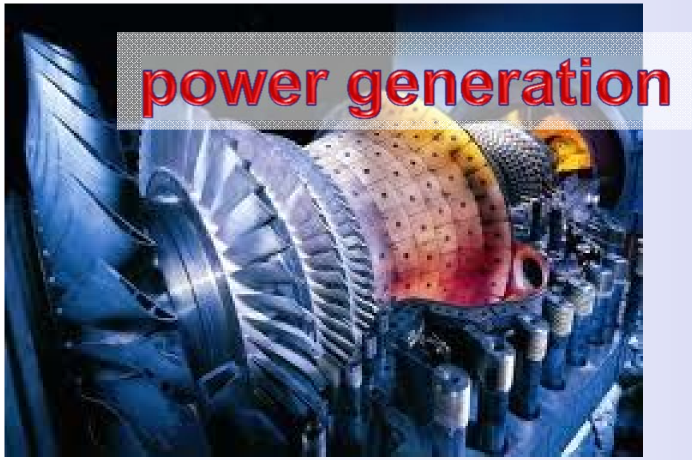
3. Power-2-Gas

   Direct use of hydrogen

   Blending of H2 to natural gas grid

   Methanation
4. Summary

Direct use of green hydrogen



1. Transition to renewable energies
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   - Direct use of hydrogen
   - Blending of H2 to natural gas grid
   - Methanation
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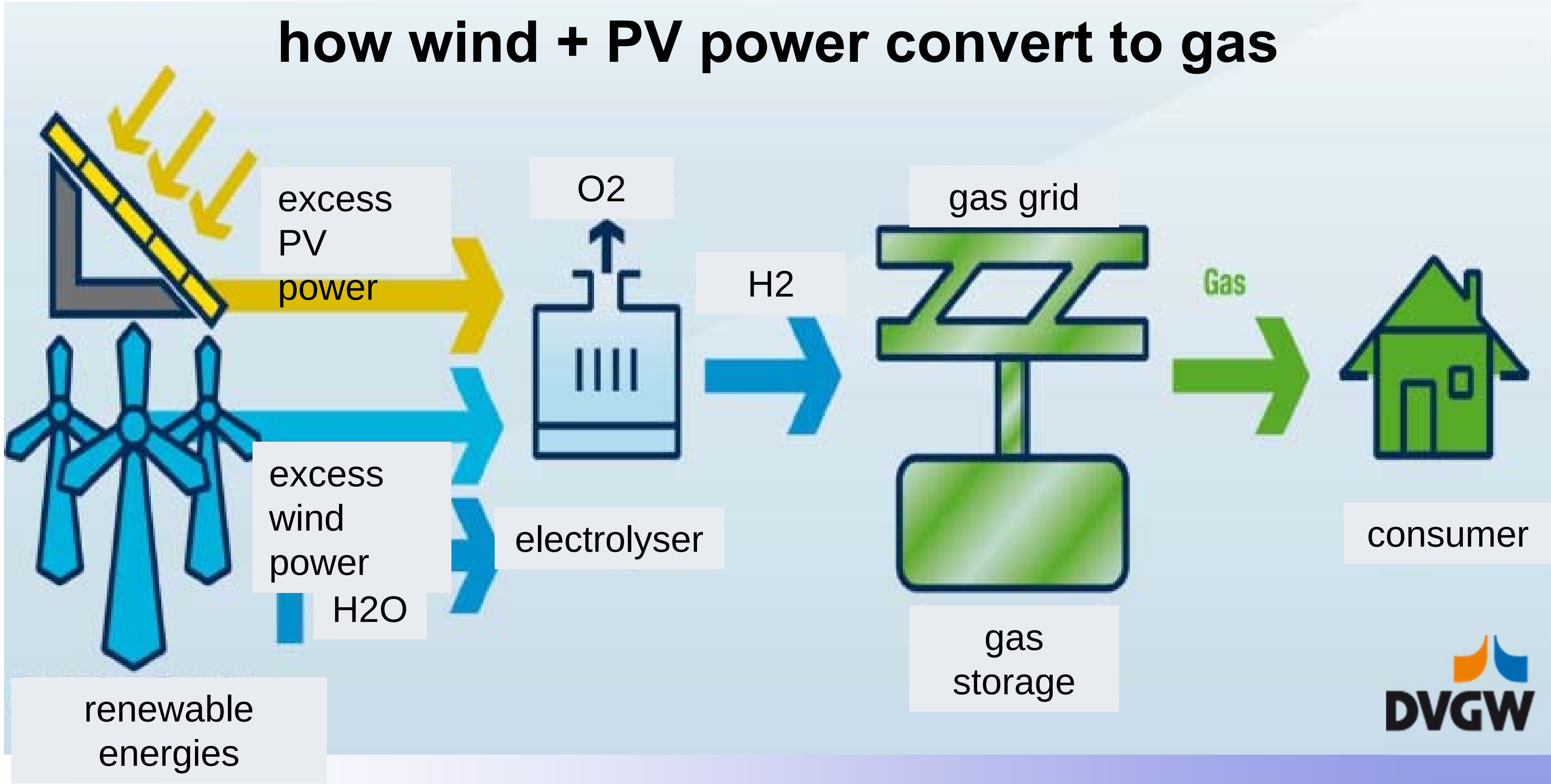
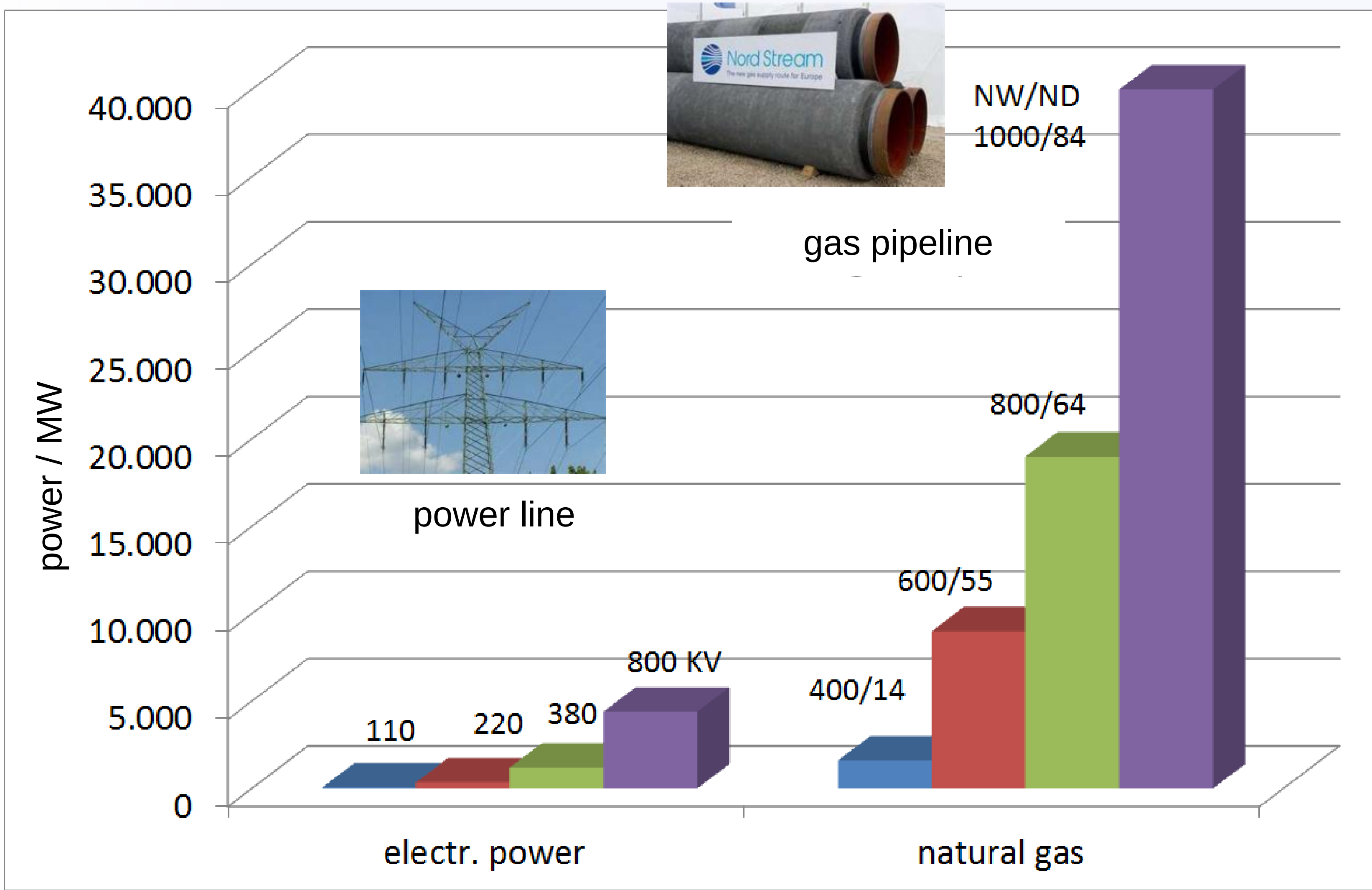
Blend hydrogen to natural gas system

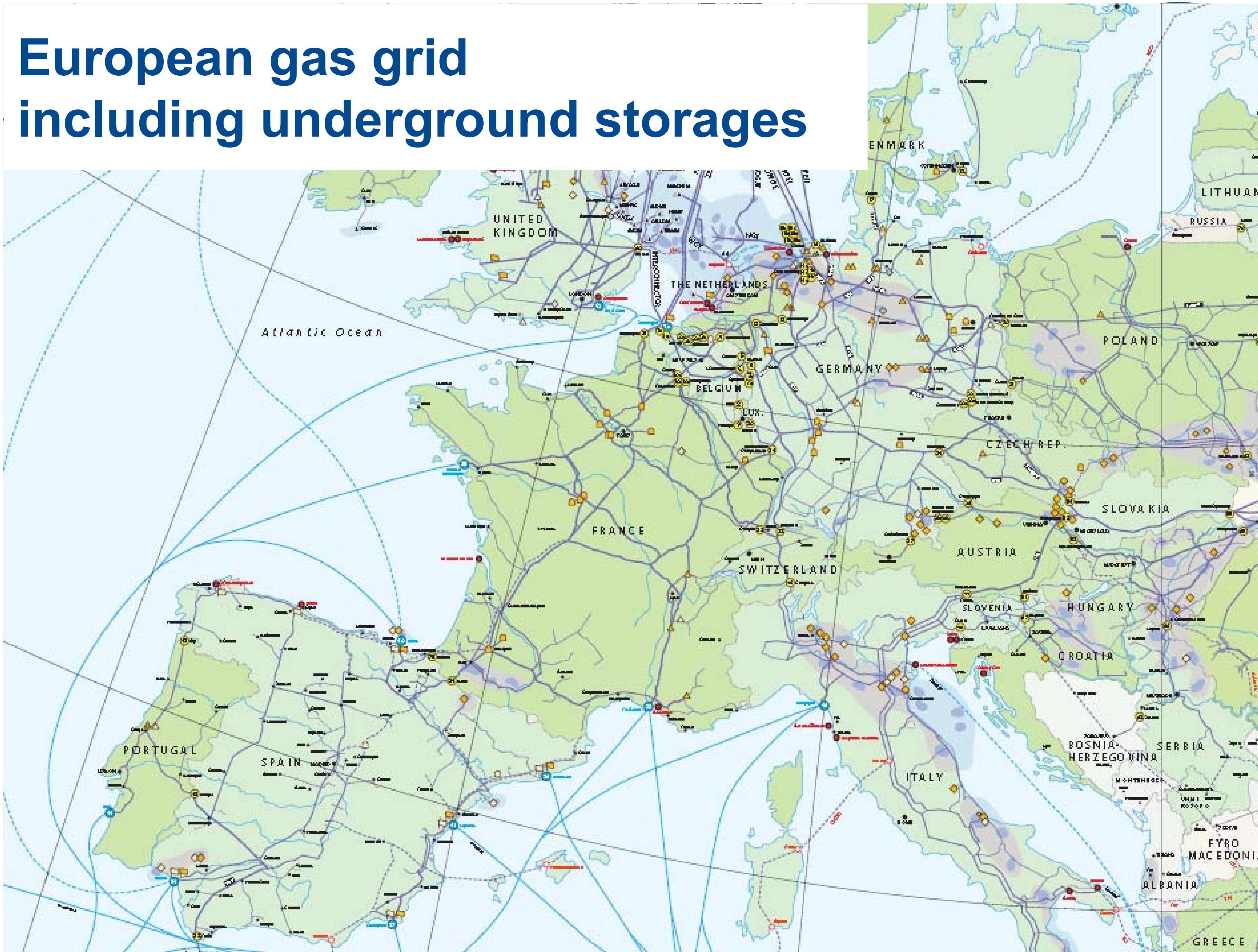


Source: DVGW (German Technical and Scientific Association for Gas and Water)

Transmission power for power line vs. natural gas pipeline

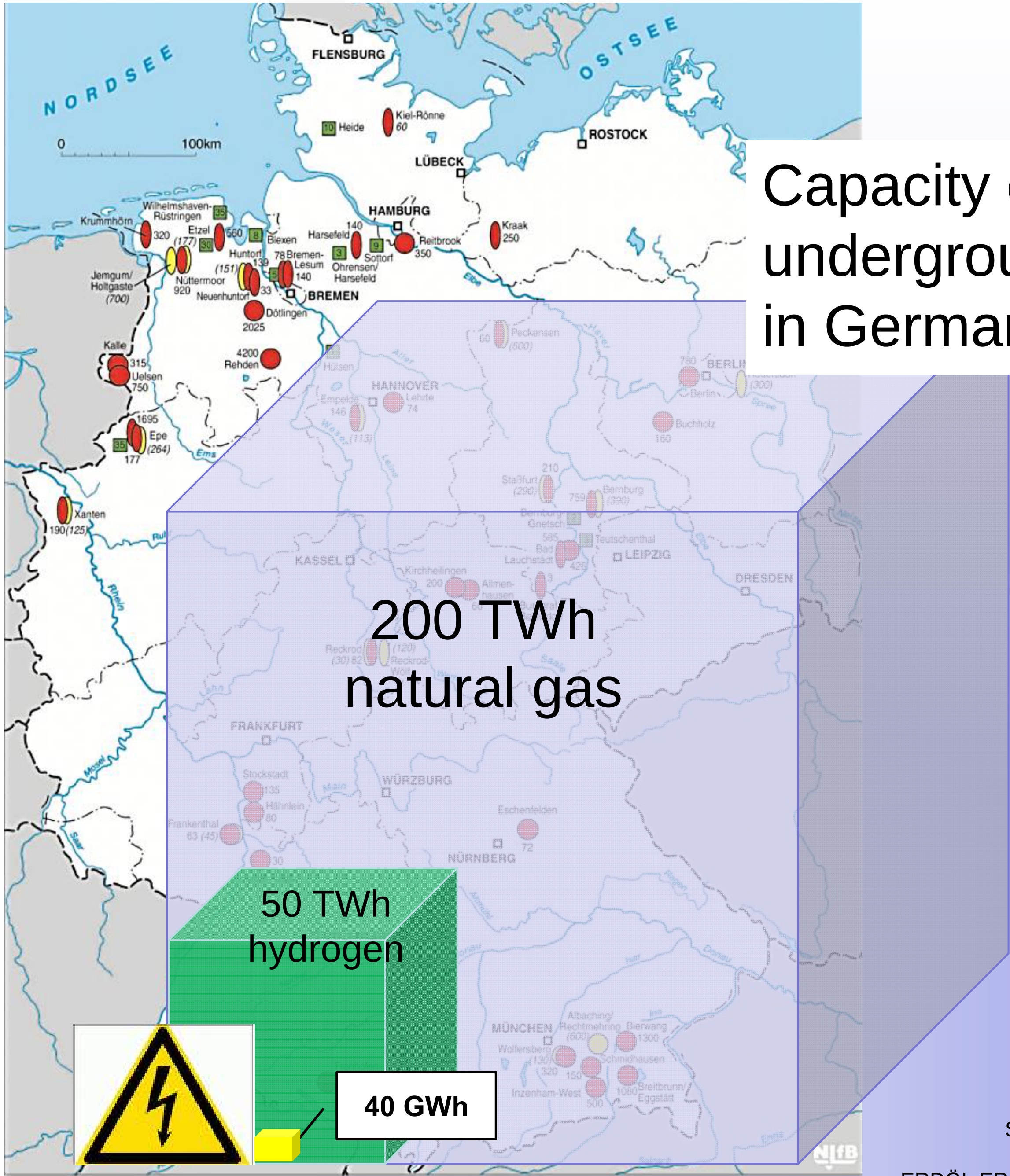


European gas grid including underground storages



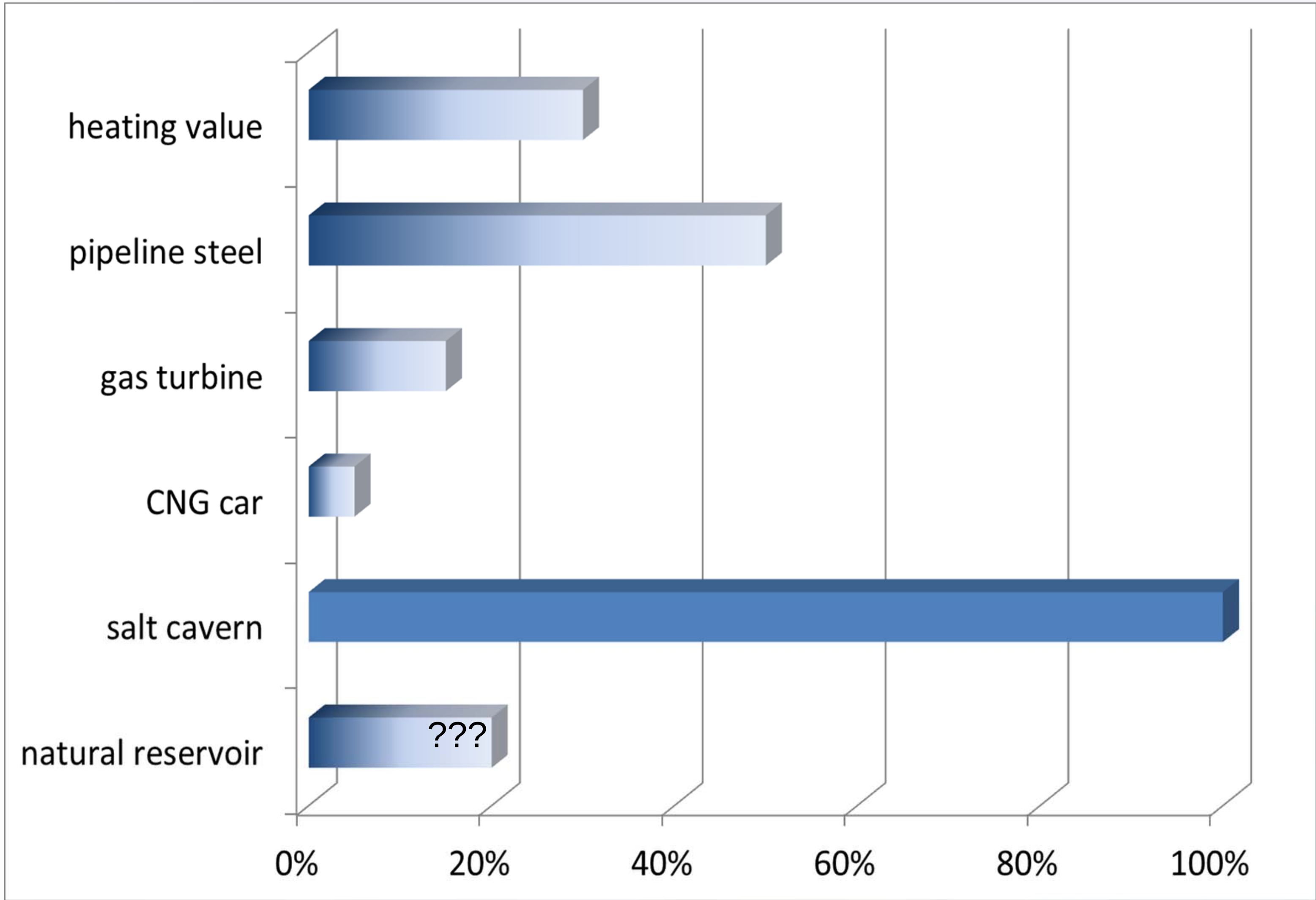
KBB UNDERGROUND TECHNOLOGIES

Capacity of existing underground gas storages in Germany

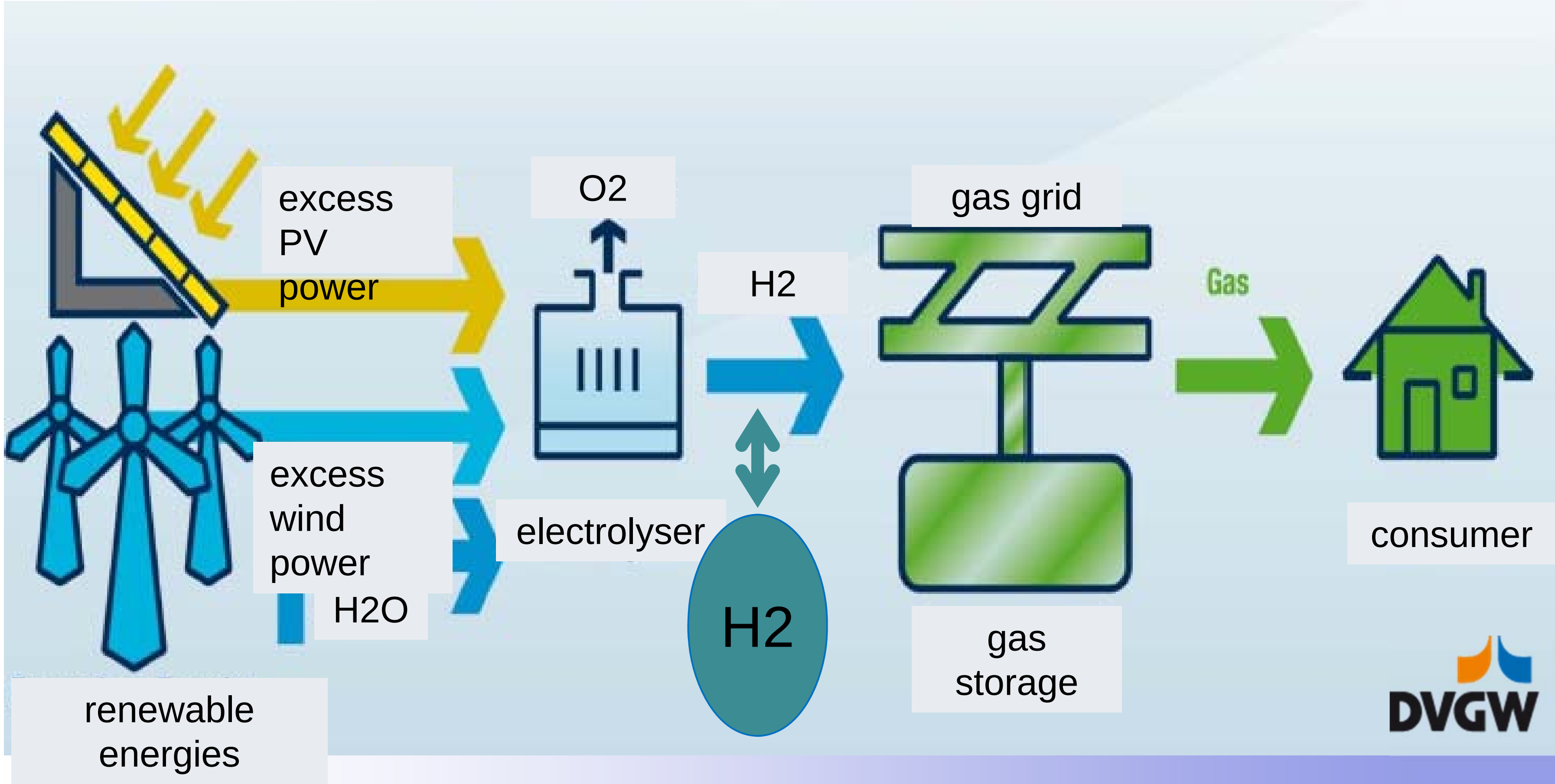


Source: Untertage-Gasspeicherung in Deutschland
ERDÖL ERDGAS KOHLE 127, Jg. 2011, Heft 11

Limiting values for hydrogen within natural gas (rough estimates only)



DVGW: Blend hydrogen to natural gas system



Source: DVGW

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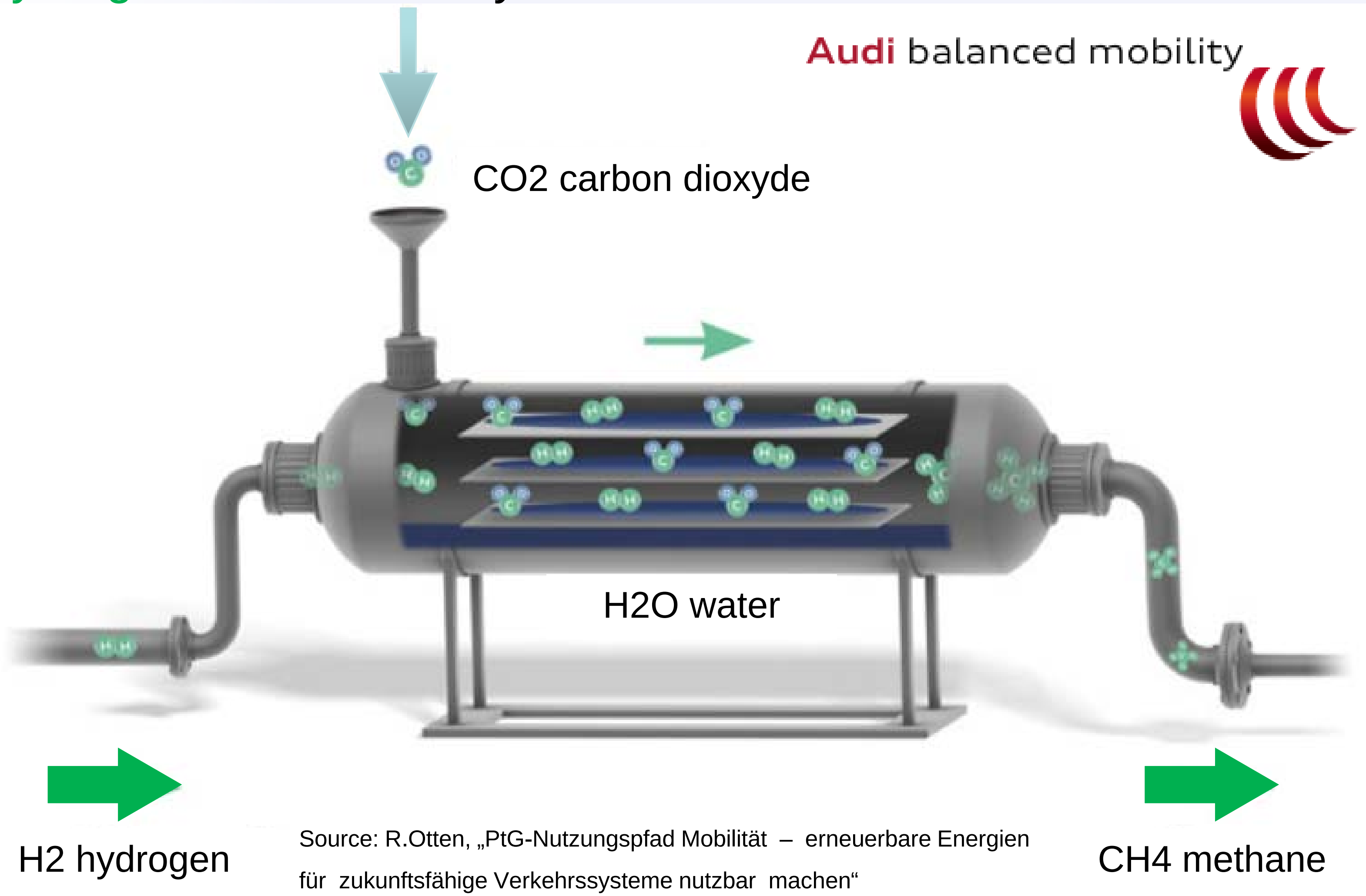
Methanation

$4 H_2 + CO_2 > CH_4 + 2 H_2O$

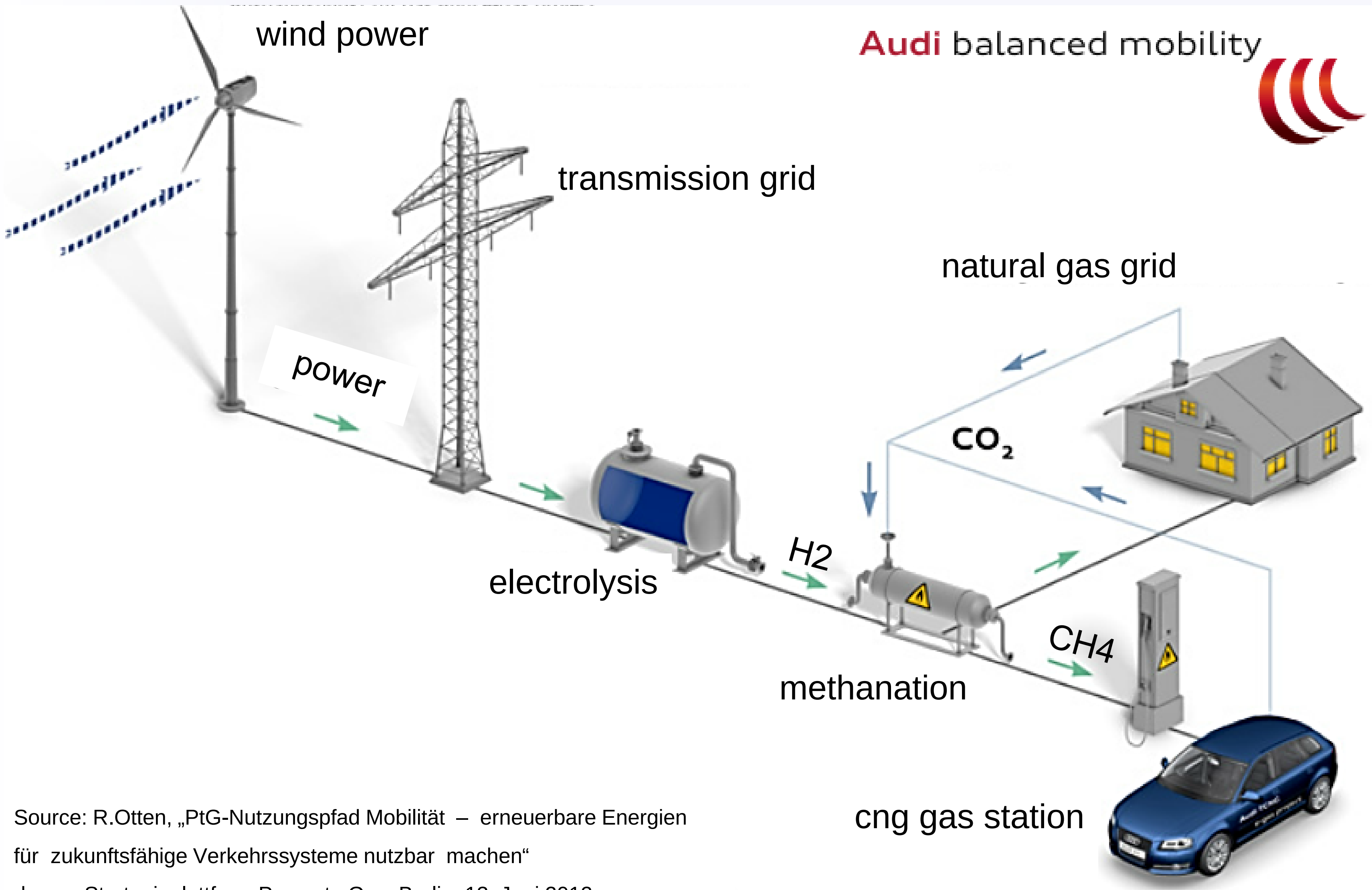
hydrogen + carbon dioxyde > methane



Source: R.Otten, „PtG-Nutzungspfad Mobilität – erneuerbare Energien für zukunftsfähige Verkehrssysteme nutzbar machen“

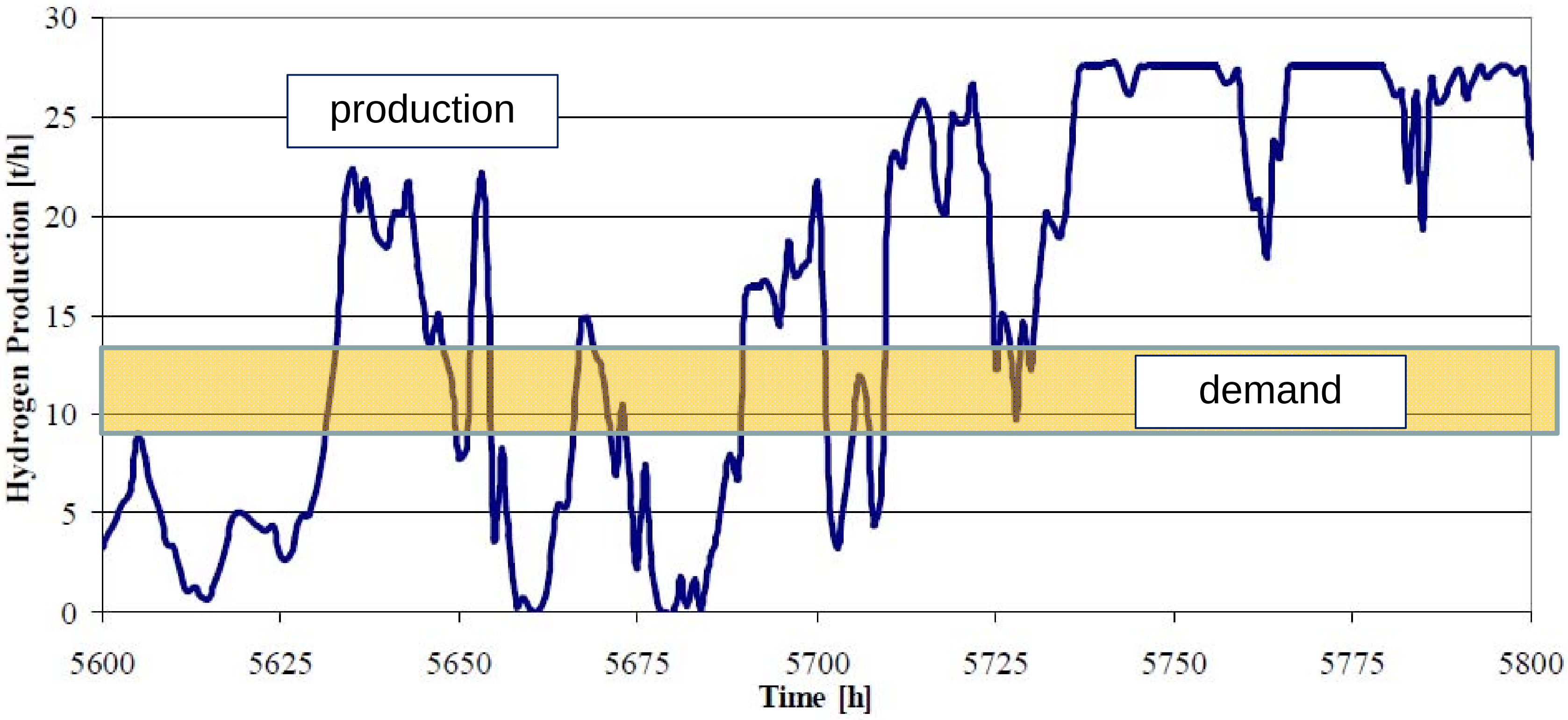
dena – Strategieplattform Power to Gas. Berlin, 13. Juni 2012

Audi *balanced mobility* project / CNG production from green energy

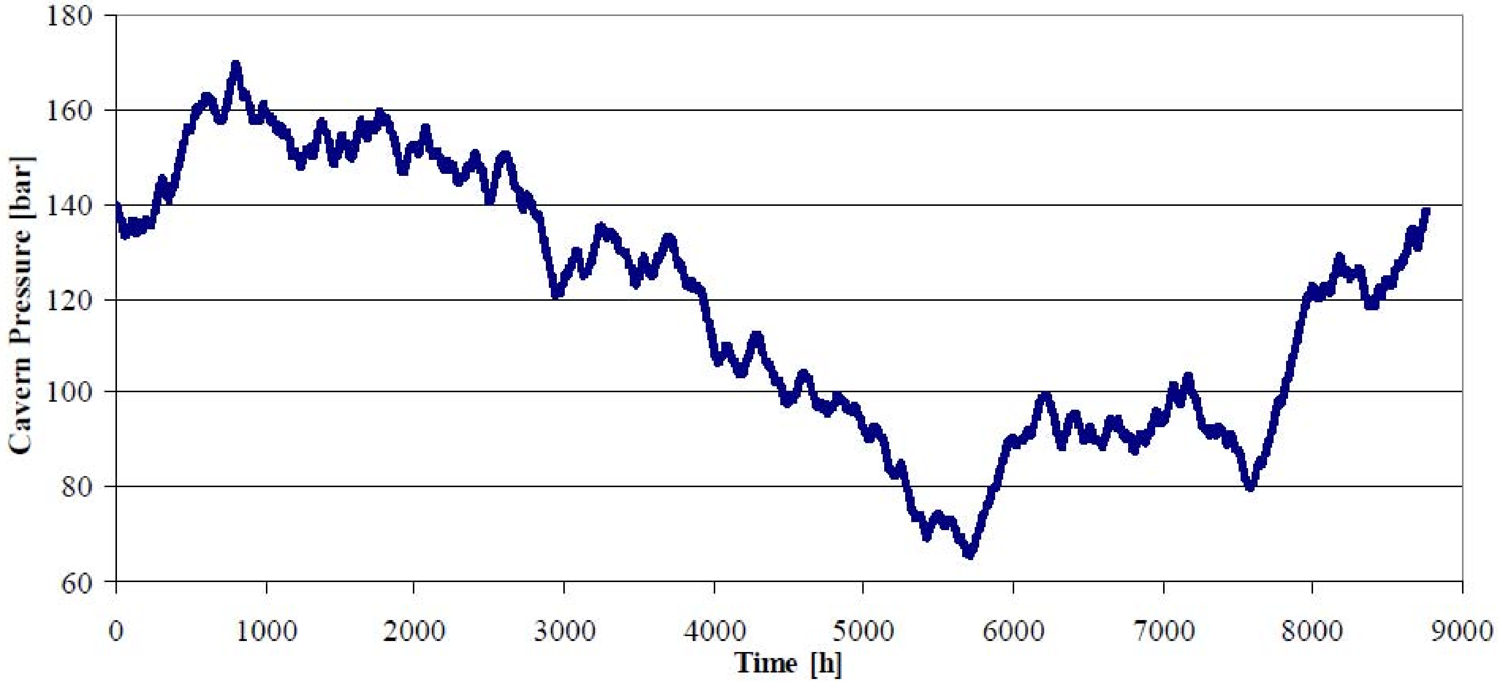


Source: R.Otten, „PtG-Nutzungspfad Mobilität – erneuerbare Energien für zukunftsfähige Verkehrssysteme nutzbar machen“
dena – Strategieplattform Power to Gas. Berlin, 13. Juni 2012

Green hydrogen production during 1 year



Fill level of hydrogen storage during 1 year



4 Summary

- Transition to Renewable Energies will require electric power storage
- CAES & pumped hydro > short term applications
- hydrogen > mid to long term applications
- Power-2-Gas strategy:

 - excess power: convert to H2 and store
 - lack of power: compensate by flexible GT power plants