Chemical Energy Storage

– with focus on Hydrogen

ENERGY STORAGE SEMINAR

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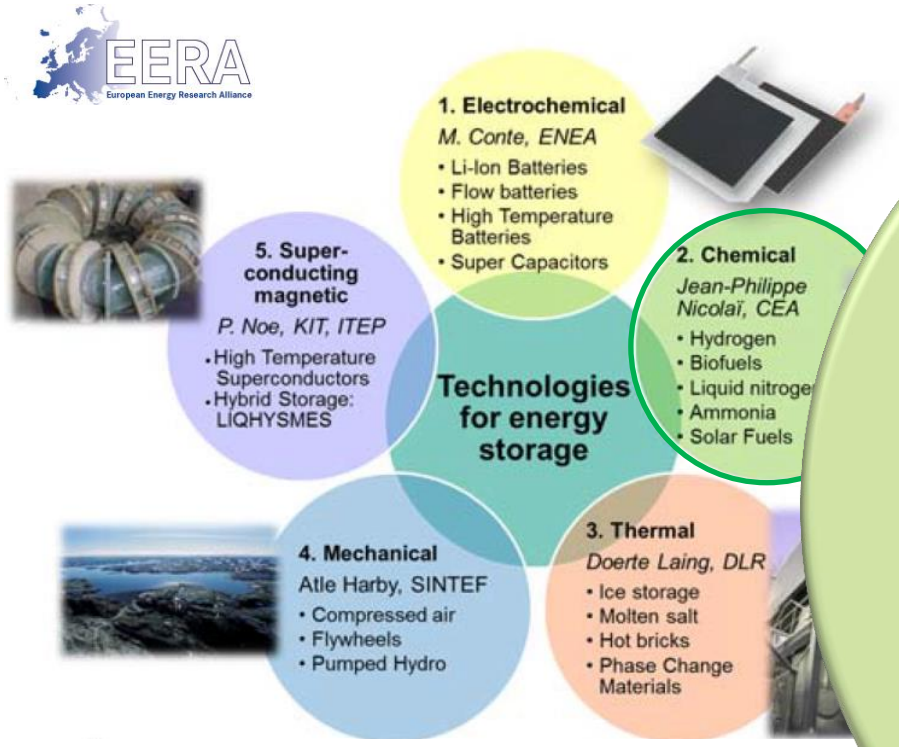
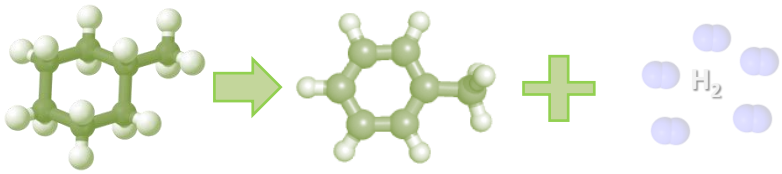
Outline

- Chemical Energy Storage alternatives
- Large scale energy storage options in Germany
- Synthetic natural gas from Renewables, PtG
- Hydrogen as energy carrier, a global view
  - *Supplement to electricity*
  - *Intercontinental transport of energy*
  - *Utilization of Stranded wind resources*
- Conclusions

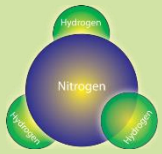
Chemical Energy Storage - alternatives





2. Chemical

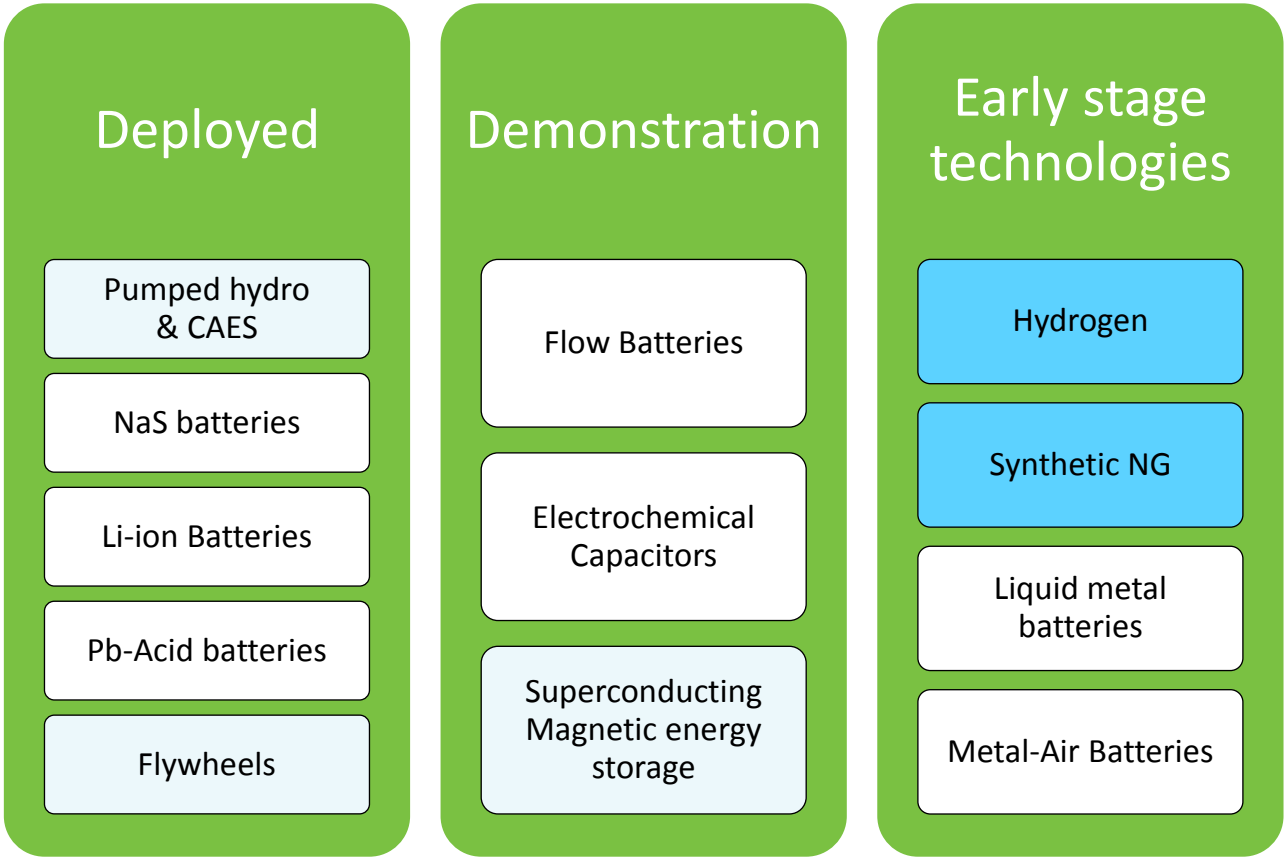
- Hydrogen
- Hydrogen derivatives
  - –Ammonia
  - –Methylcyclohexane-Toluene[1]



- Synthetic fuels (NG, etc.)
- Solar energy derivatives
  - Bioenergy
  - Fossil hydrocarbons
    - Coal, Oil, NG etc.

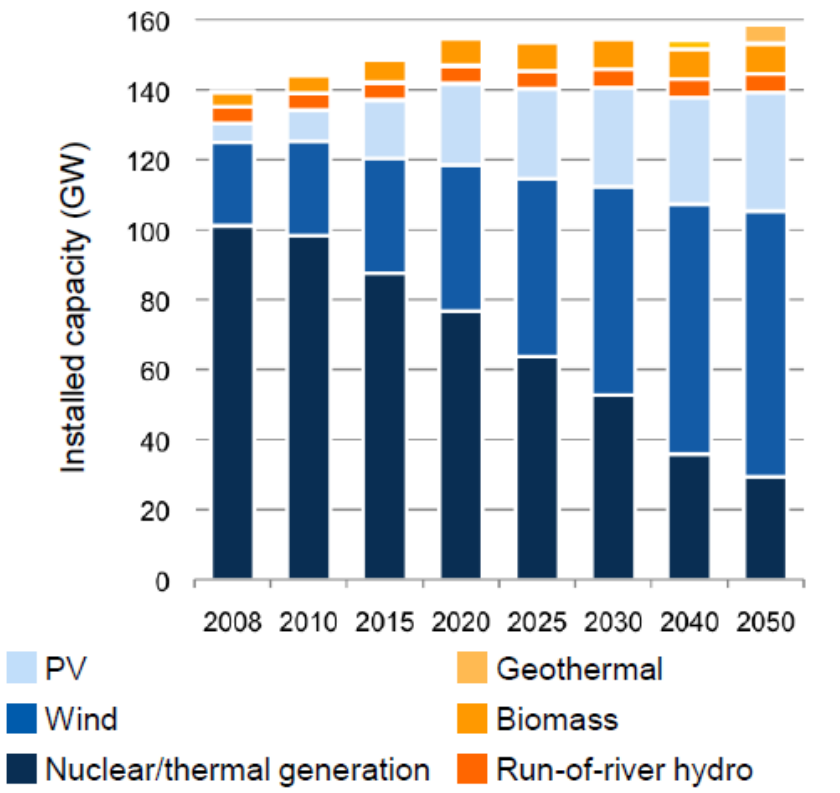
1) Chiyoda Corporation, Japan

Overview, this talk

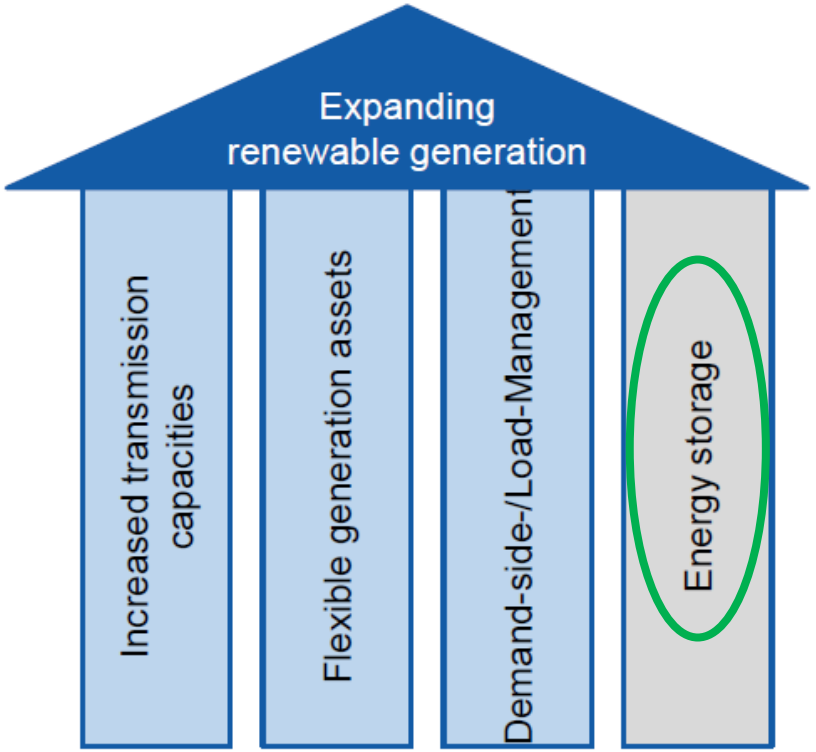


Market projections show strong renewable growth - requiring various countermeasures in the energy system

Projection of installed capacity[1)] in Germany according to BMU 2009 Scenario[2)]



Countermeasures for energy system change

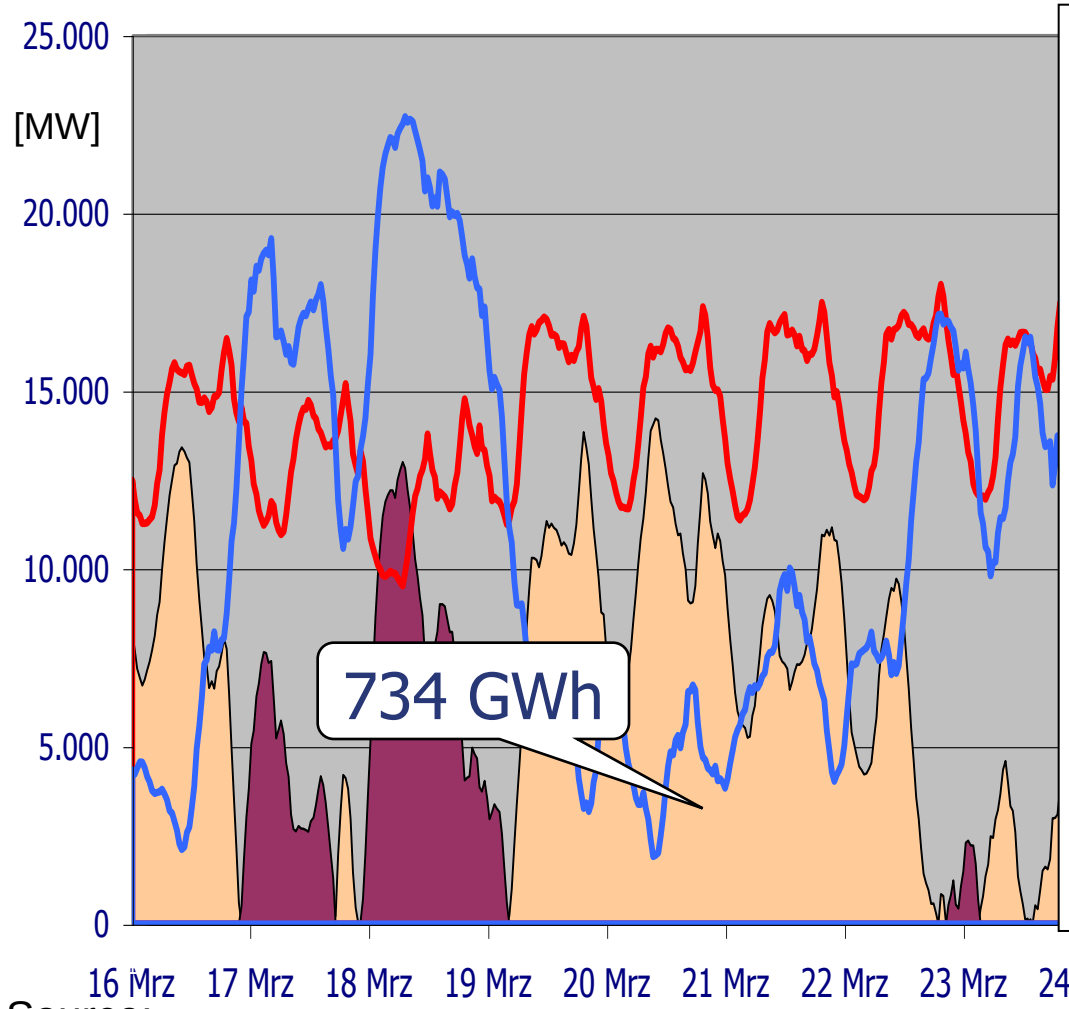


1) Without pumped-storage

2) BMU: German Ministry for Environmant

Storing intermittent REN electricity

Energy storage tasks and comparison of possible technical solutions

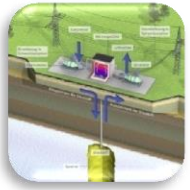


734 GWh storage capacity requires

- Pumped hydro
  86 x Goldisthal
  or

- Compressed air
  1 112 x Huntorf

  or



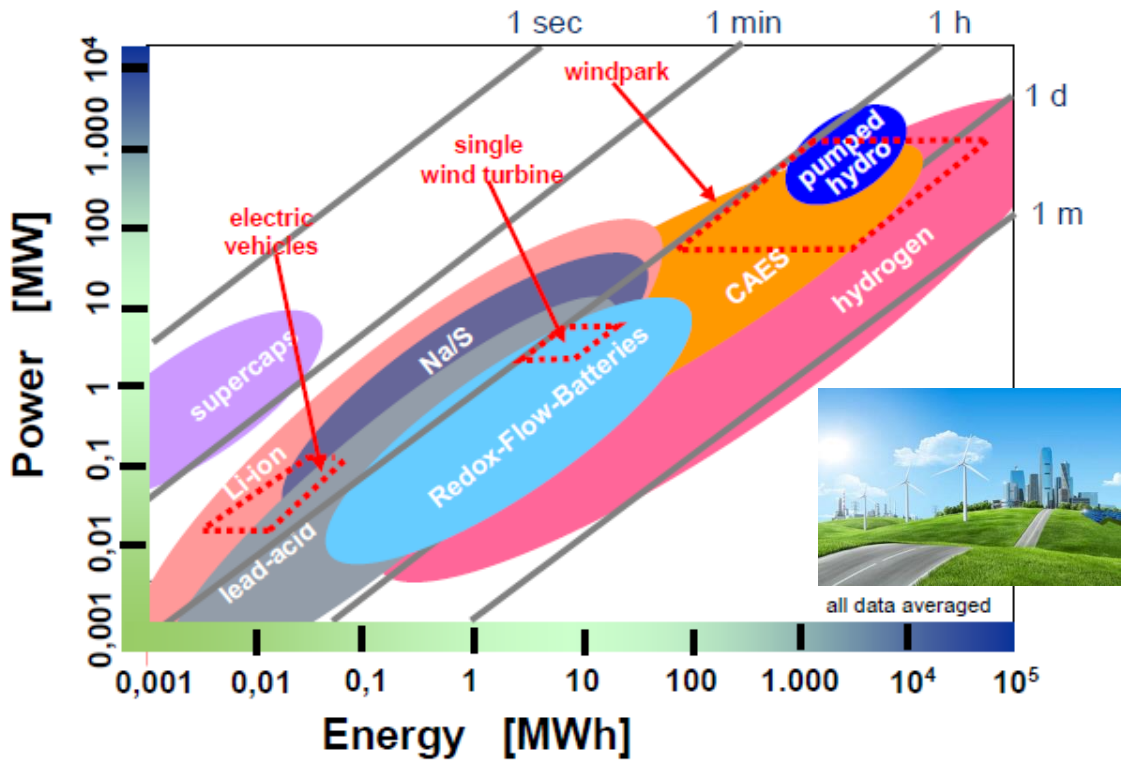
- Salt cavern (hydrogen)
  ~1,2 x cavern field Etzel
  ~0,5 x cavern field Nüttermoor
  (both used for NG)

Source:
U.Bünger, NTNU

Large Scale Energy Storage
Options to address `grid storage´ are limited

SIEMENS

segmentation of large-scale (electrical) energy storage



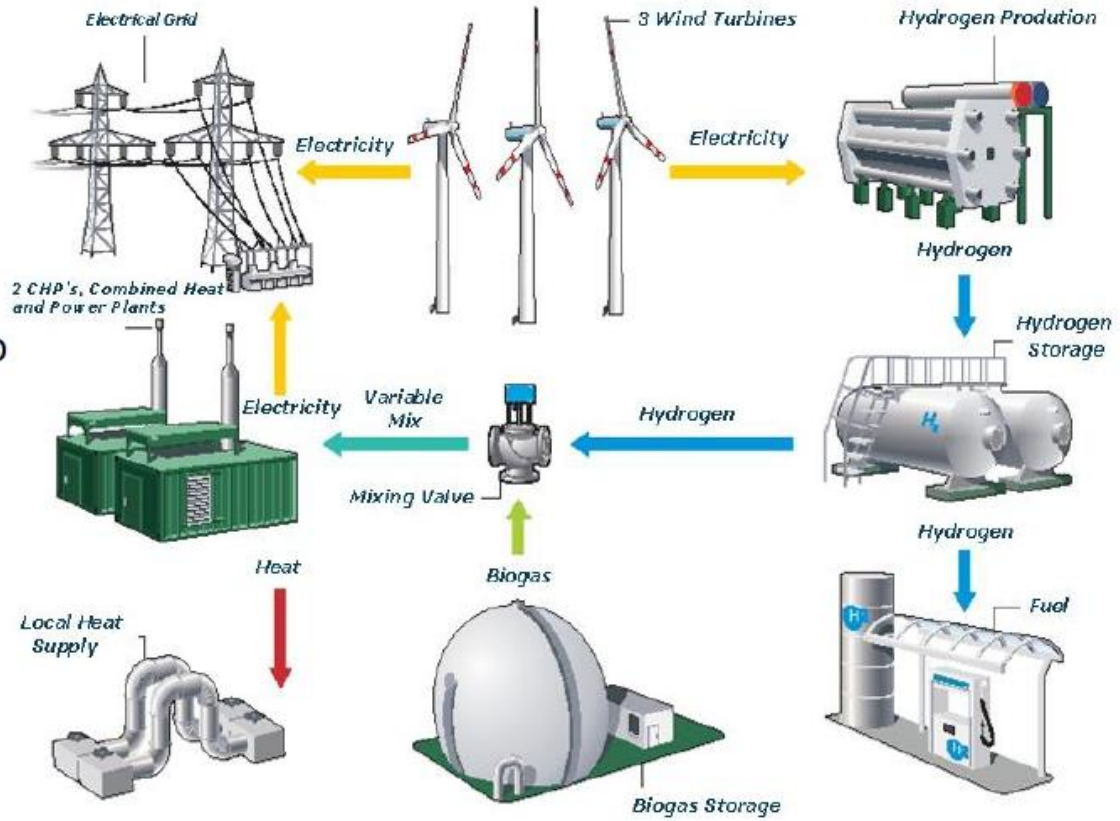
key statements:

- Battery storage applications are limited in the hour range
- Energy storage >100 MW can only be addressed by Pumped Hydro, Compressed Air (CAES) and Hydrogen
- The potential to extend pumped hydro capacities is very limited
- CAES has limitations in operational flexibility and capacity

Hydrogen is the only option to cover energy capacities > 10 GWh

Hydrogen Storage – Hybrid Power Plant

- Enertrag, Vattenfall, Total are developing a wind-hydrogen hybrid power plant
- Wind farm with direct coupling to electrolyzer
- Hydrogen storage
- Utilization of hydrogen in small scale CHP and for external use



Opened in October 2011, the world wide first hybrid power plant which utilizes a mix of wind power and biomass energy to supply an independent, integrated and self-stabilized sustainable power network.

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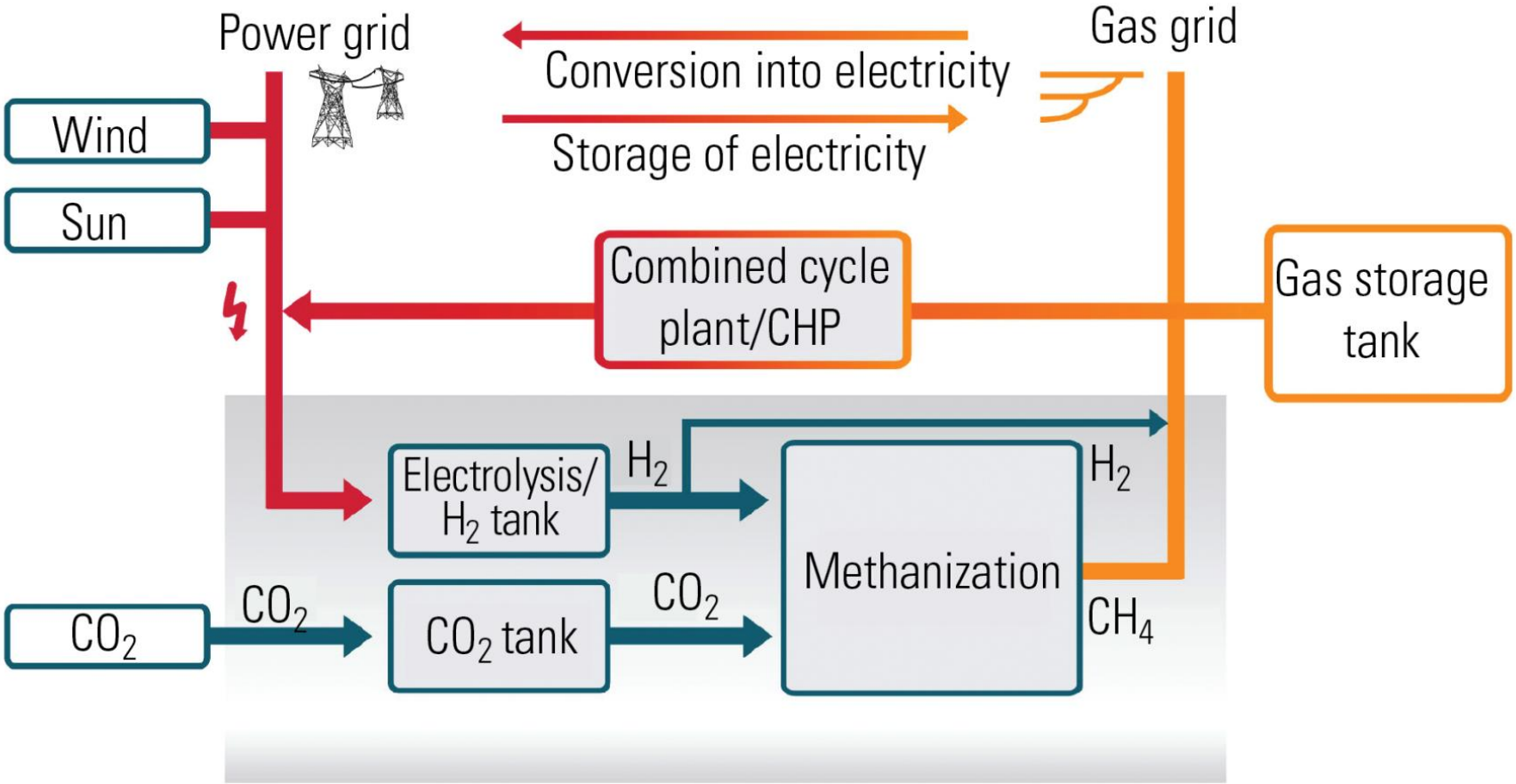
Synthetic Natural Gas



Possible scenario 2050

Week during summertime

Multiple solutions for energy storage are needed

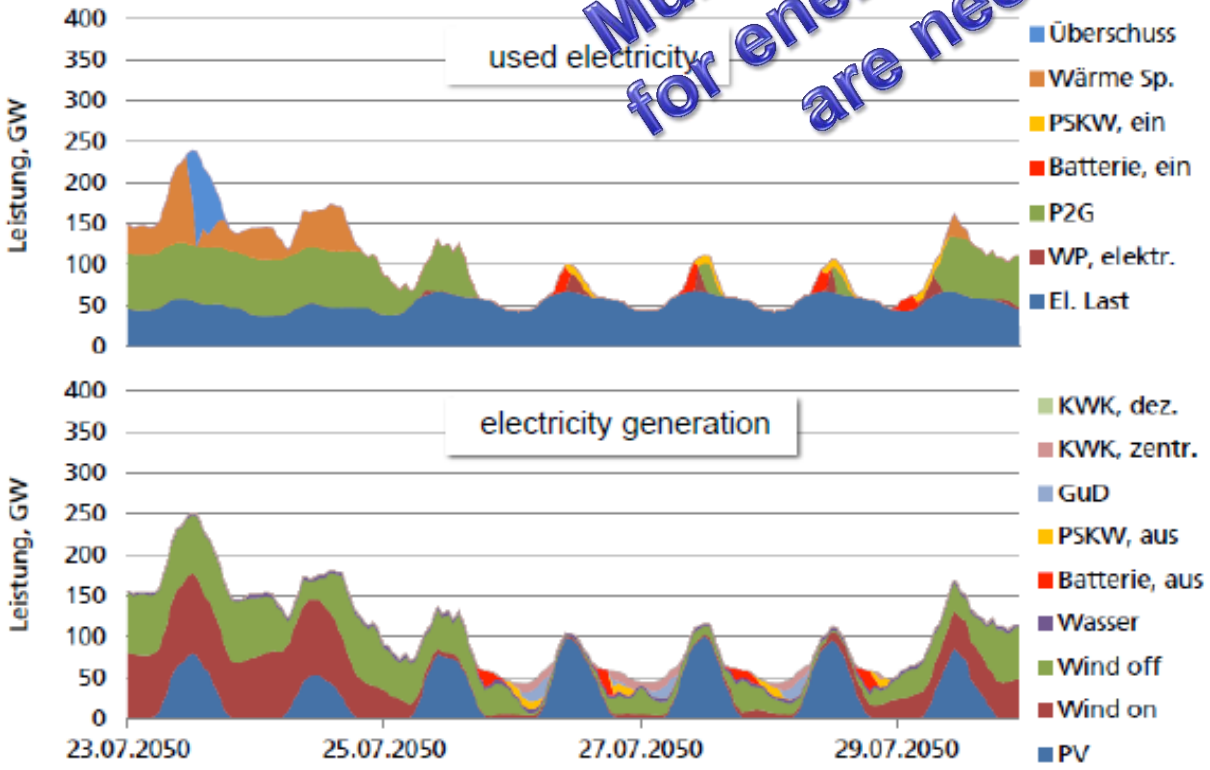
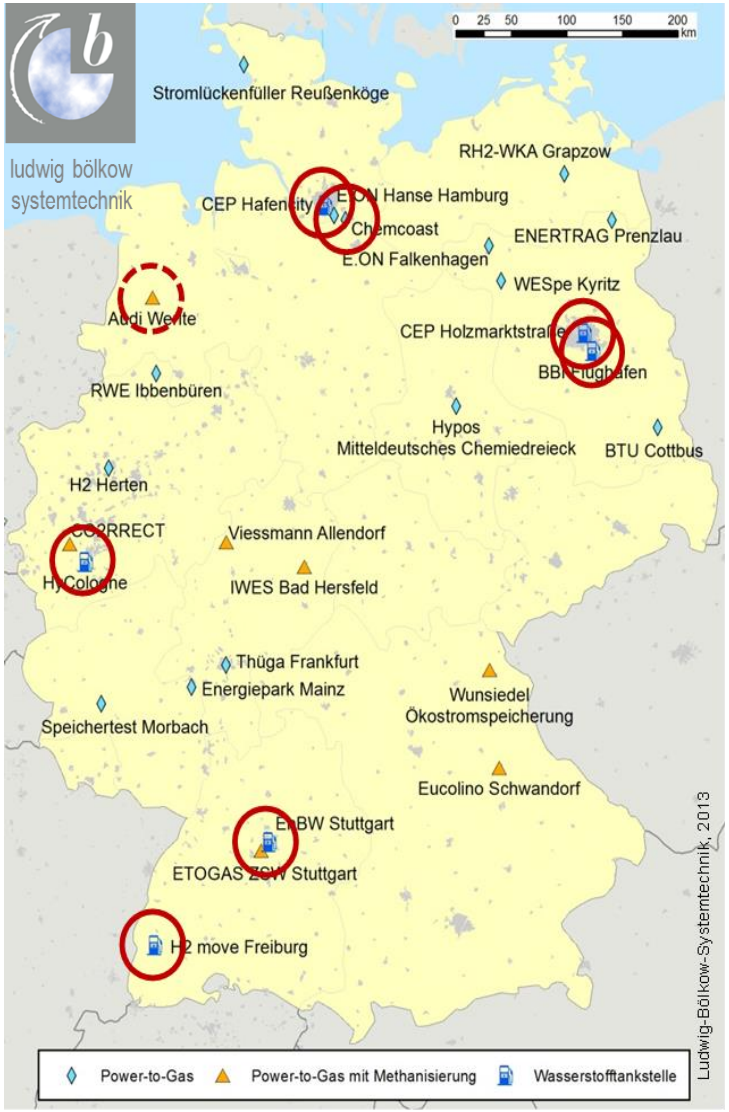


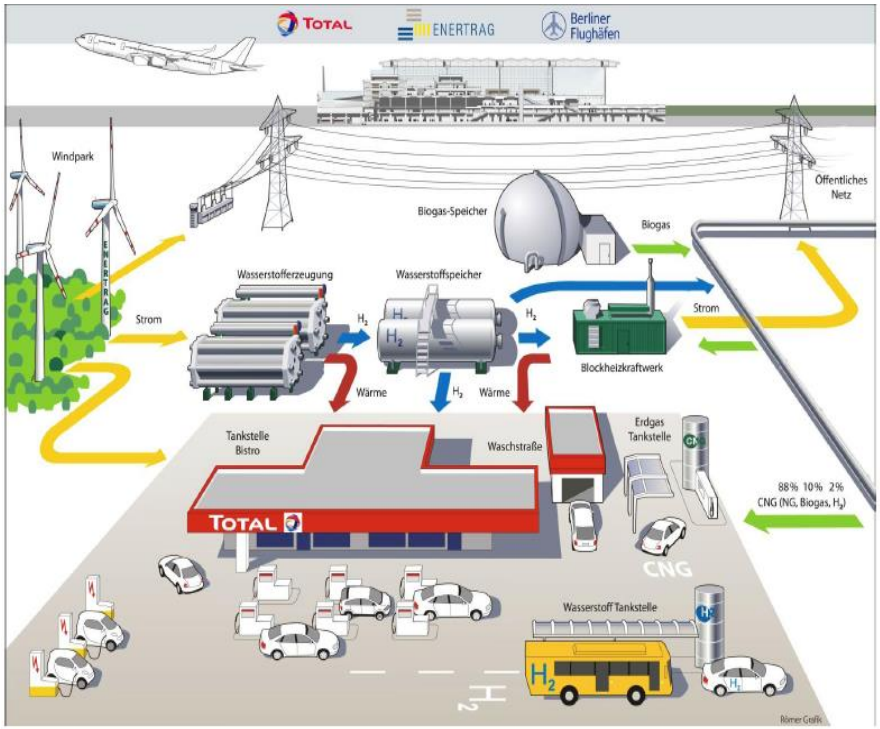
Abb. 13 Stromverbrauch und Stromerzeugung des Szenarios „Medium" in einer Sommerwoche (PSKW=Pumpspeicherkraftwerk; P2G=Power-to-Gas; WP=Wärmepumpe; KWK=Kraft-Wärme-Kopplung).

Quelle: Fraunhofer ISE, Hans Martin Henning 2012

Power to Gas

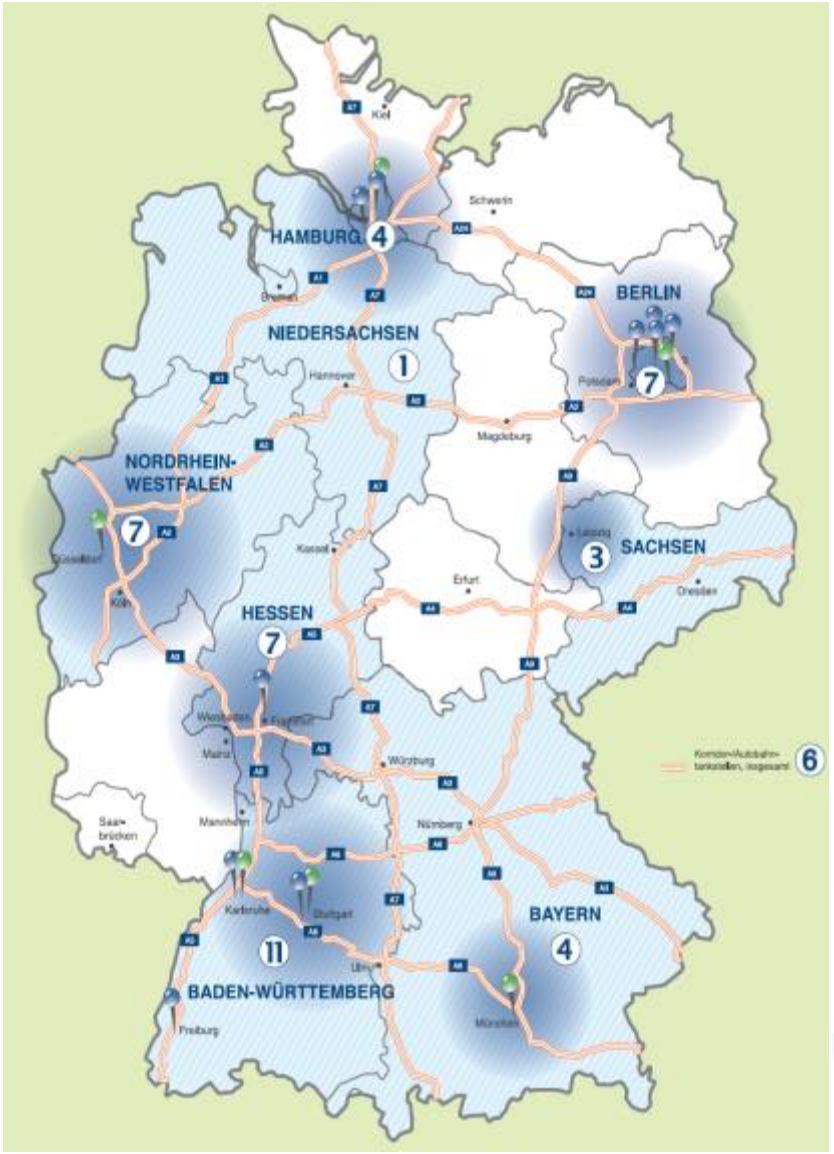


Use of
<u>Hydrogen as energy storage medium</u>
links stationary sector to transportation



50 HRSs in Germany by 2015

ludwig bölkow systemtechnik



Existing HRSs

HRS under construction/ decided locations

0 Locations per Federal State by end of 2015

Metropolitan regions

Source: CEP map, June 2012

Planning:

H_2 Mobility

CEP

2015:
- 50 HRS‘s

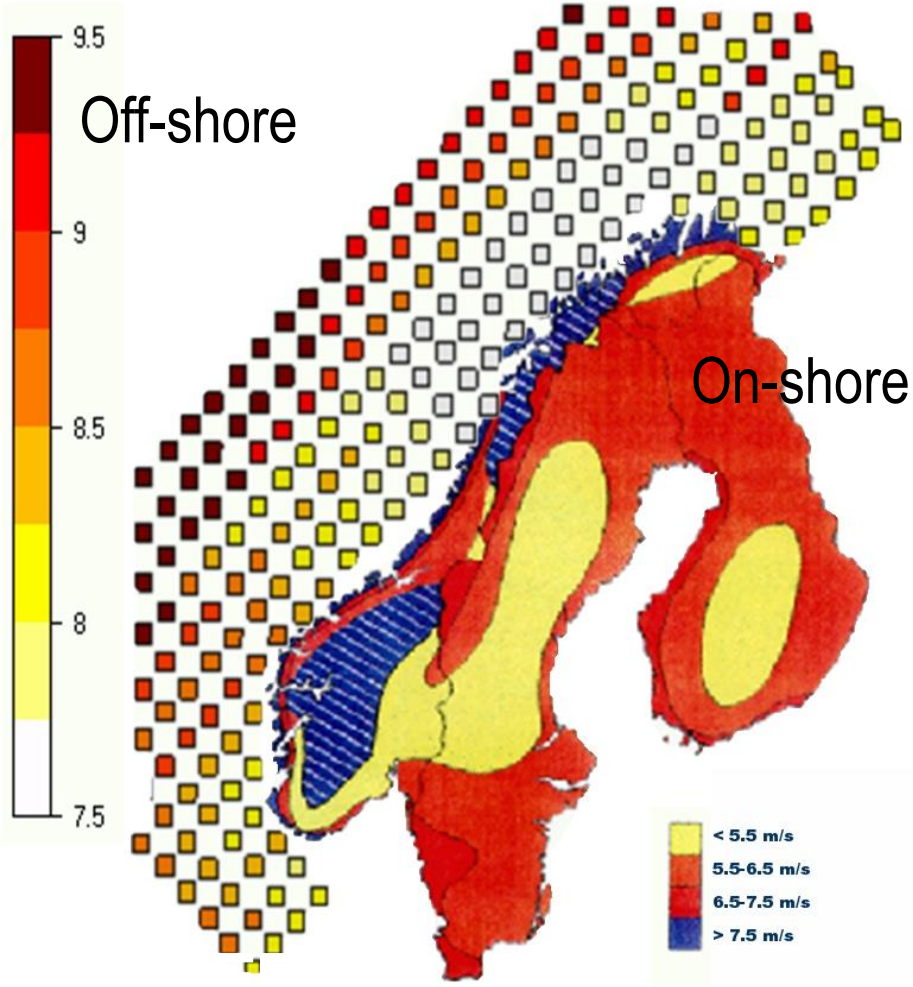
2017
- 100 HRS‘s

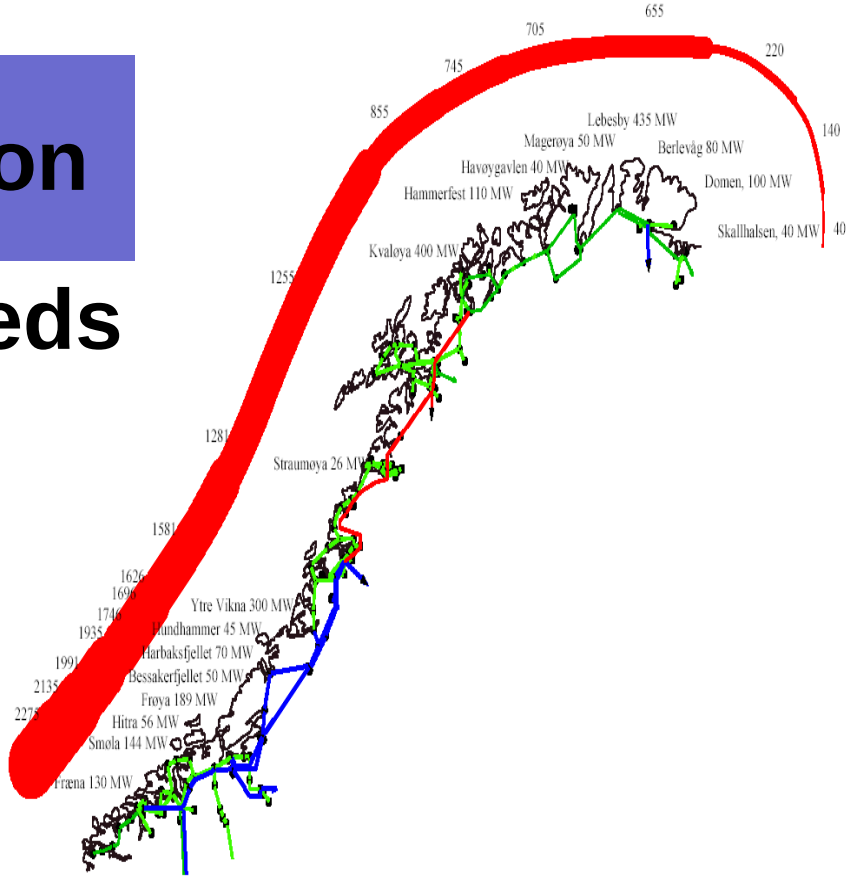
2023
- 400 HRS‘s

2025
- > 500 HRS‘s

Norway – an energy nation

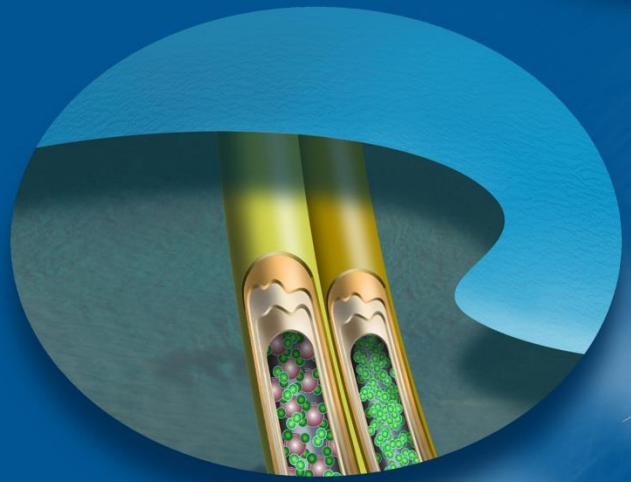
High average wind speeds





Kilde: www.windsim.com

*"**Norway** – pioneering sustainable hydrogen"*



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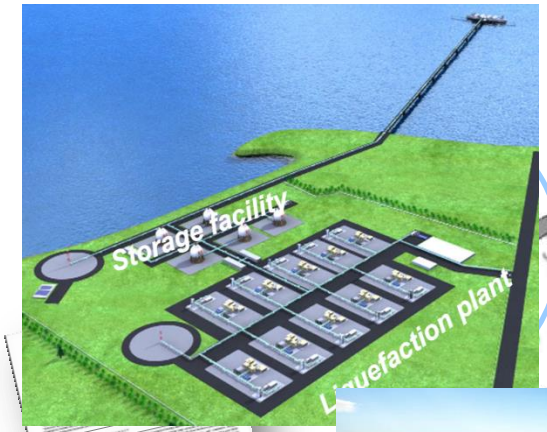
Hydrogen Potential from Overseas

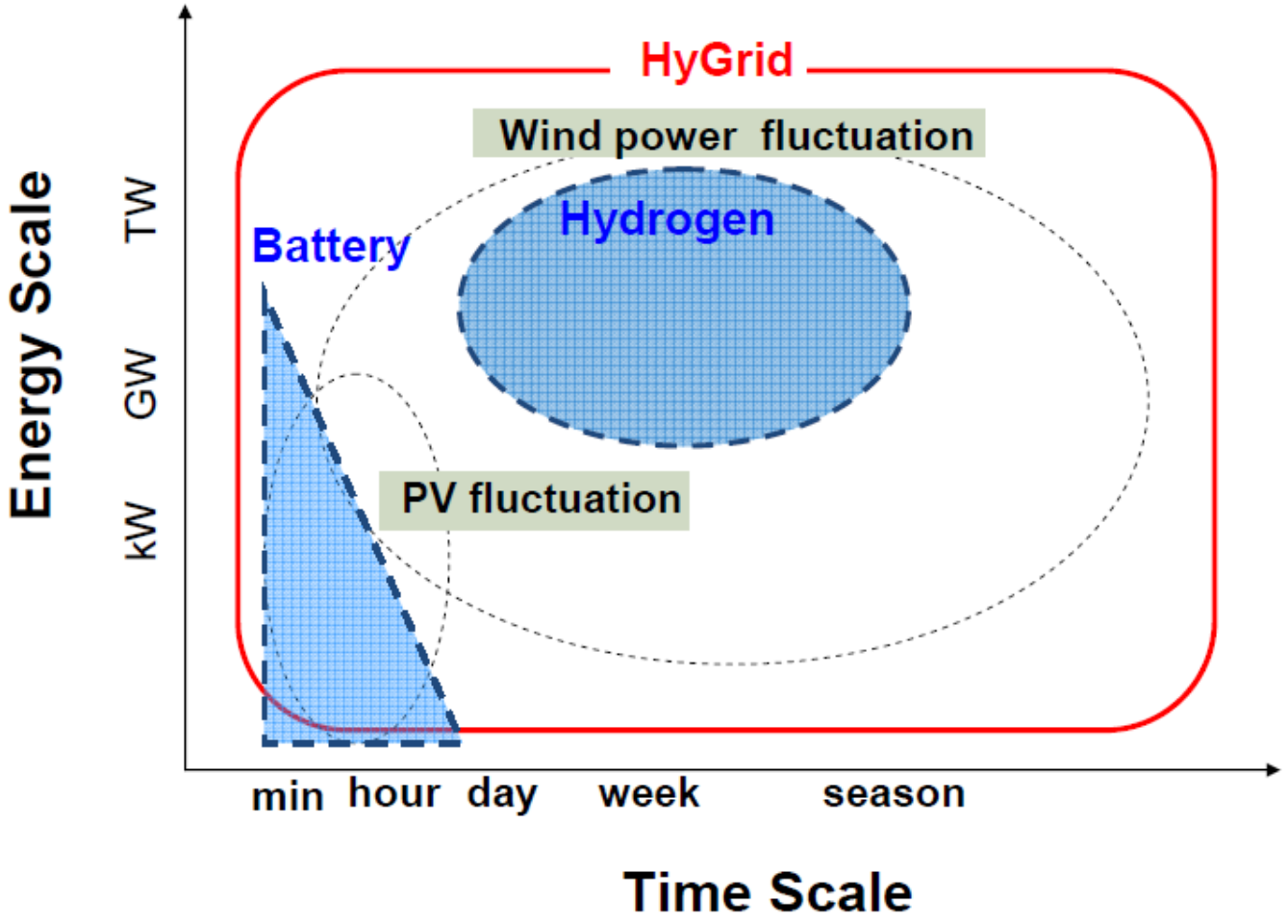


Kawasaki

HyGrid basic concept

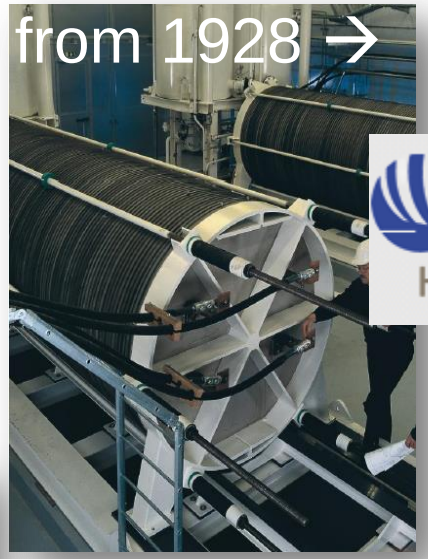
Kawasaki

HyGrid is absorbing larger energy scale and longer fluctuation



Norwegian industry may provide technology

- Large scale H_2-production as reactant for fertilizer production (Norsk Hydro, NEL Hydrogen)
- "Low cost" hydrogen
  ➔ based on *"stranded wind*" resources
- Hexagon Raufoss, composite tanks for efficient transport, 1 tonnes H_2/unit



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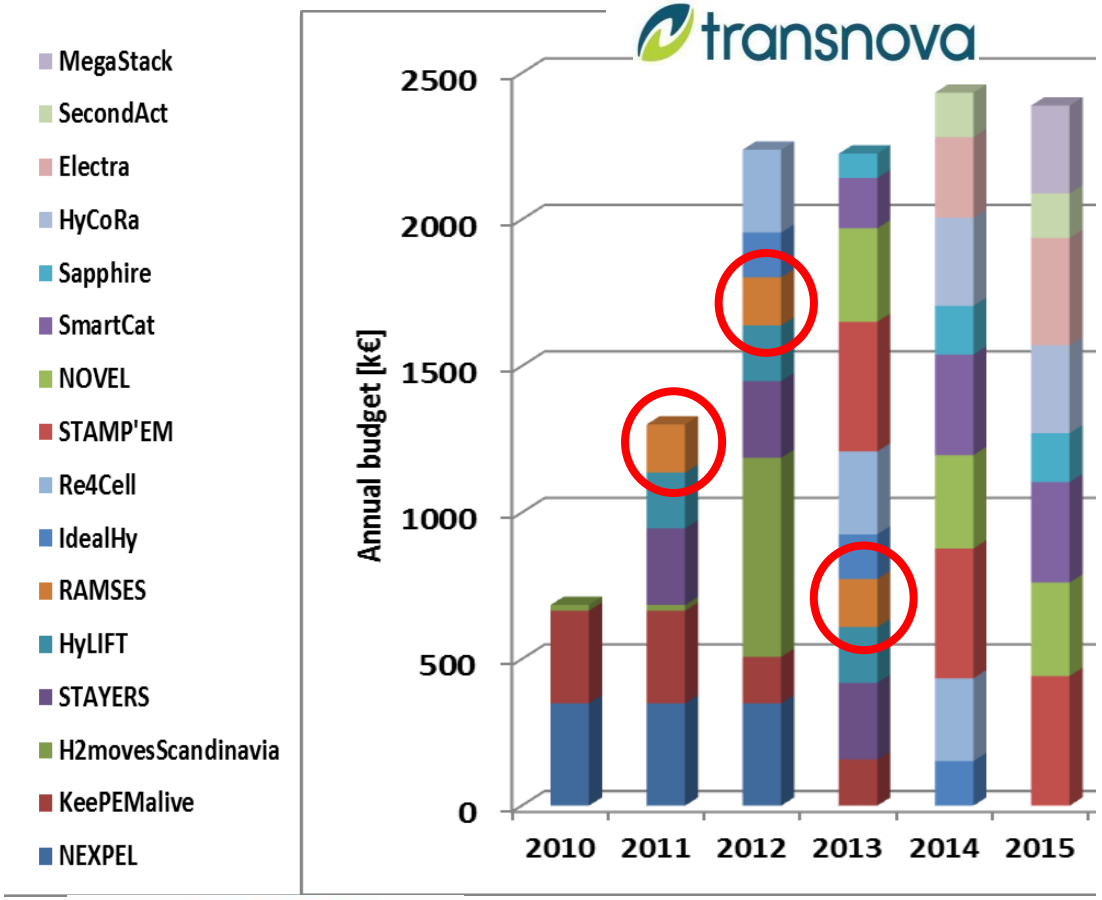
Sources: *1) NEL Hydrogen*
2) Hexagon, Raufoss

SINTEF's FCH JU-projects & partners

National top-financing: Norges forskningsråd — *The Research Council of Norway*



transnova

HELION HYDROGEN POWER

fumatech

Shell

IRD Fuel Cell Technology

seasonve

Linde

Solvay Solexis

SOLVAY

Höganäs

Nedstack PEM FUEL CELLS

STILL

SolviCore Fuel Cell Technologies

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Conclusions

Thank you for your attention!

- Many chemical energy storage options
- Leading international industrial companies point at H_2 as a key energy carrier (storage and fuel)
- Multiple use lowers the total investment costs
- Japan is planning to fully integrate H_2 in all sectors of society, transport & stationary
- Norway will naturally pursue pumped hydro, but possesses vast *"stranded wind"* resources suitable for being harvested as H_2 and exported
- The technology is here ➔ Business opportunities