Power to Gas - an economic approach ?

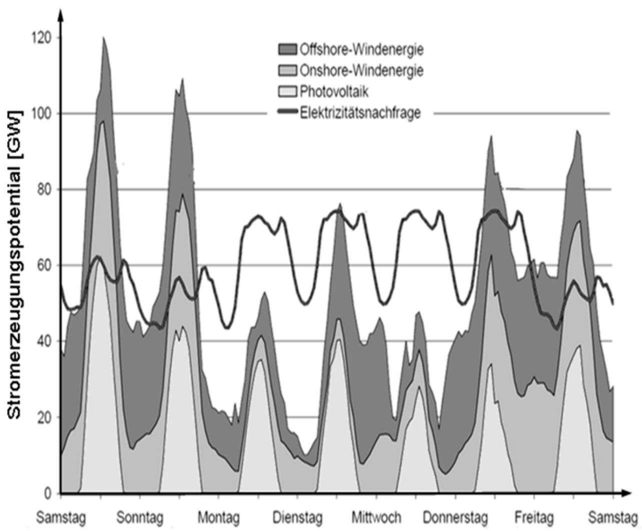
Manfred Waidhas, Siemens AG, PD LD HY, 91058 Erlangen

DPG Conference, Berlin, March 17, 2015.

Integration of renewable energy
...will challenge the energy industry

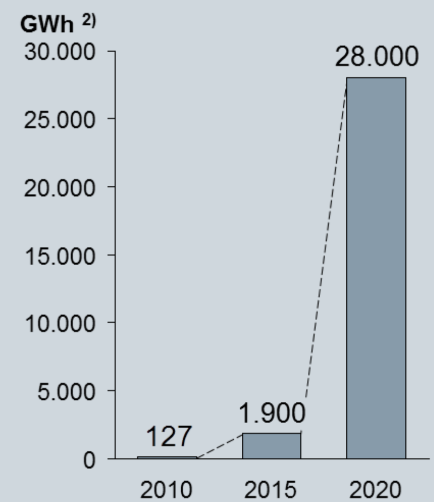

Nysted Offshore Wind Farm, 72 units 2.3 MW, 165.6 MW

Power generation and load curves



Source: TU Berlin, Prof. Erdmann, extrapolated for the year 2020

Curtailment 1)



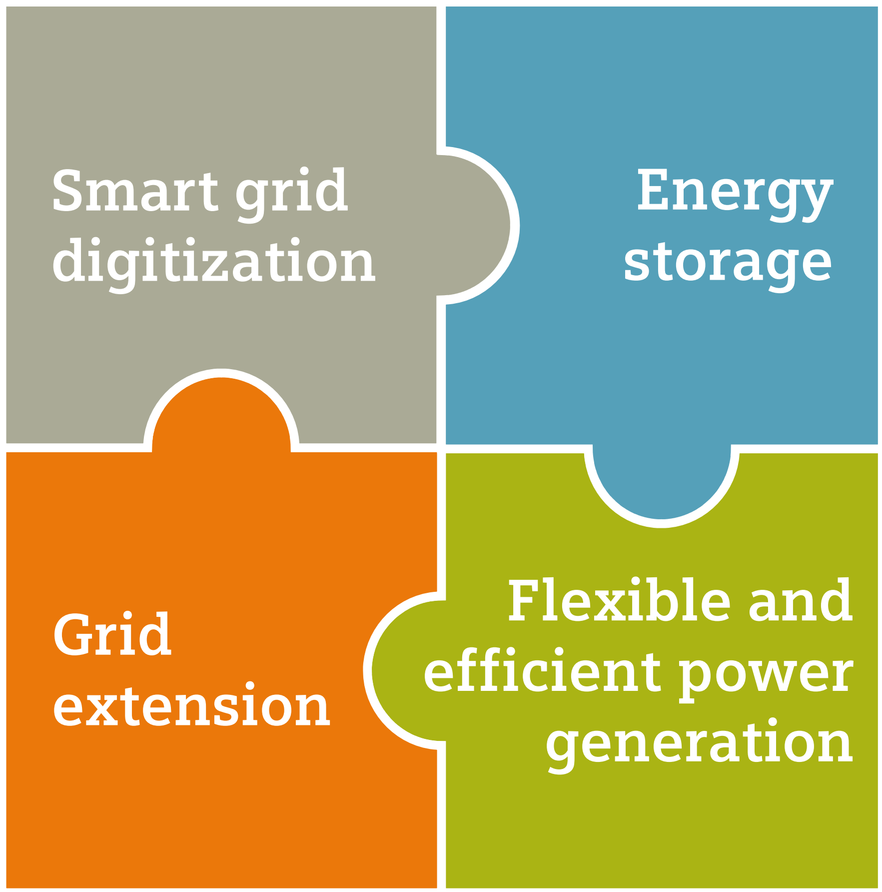
1) EnBW (Münch) at BMU Strategy Meeting, 05.09.12
2) total demand Germany 2011: 615.000 GWh

The future CO_2-optimized energy scenario will require smart solutions.

Components and tasks for a future energy system

Managing increasingly complex energy systems

Grid stability and system efficiency



Cross-regional electricity transfer and integration of distributed generation

Cost-efficient use of conventional and renewable energy

Options to address Large Scale "Grid Storage" are limited

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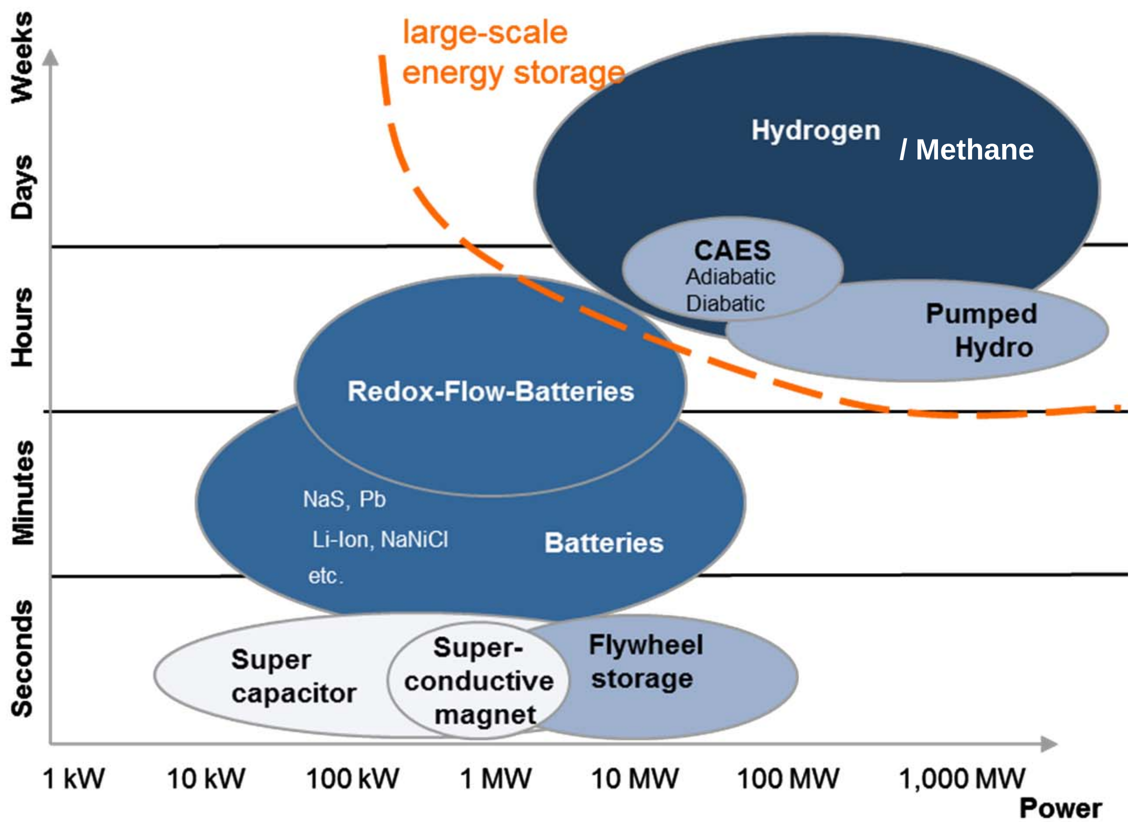
Segmentation of electrical energy storage



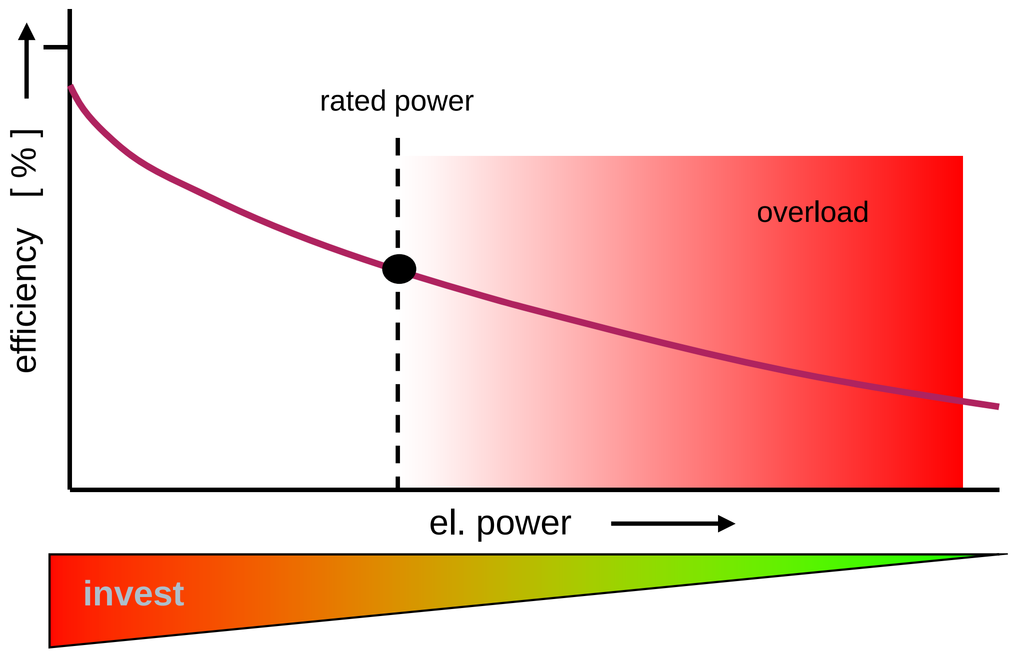
Key statements

- There is no universal solution for electrical storage
- Large scale storage can only be addressed by Pumped Hydro, Compressed Air (CAES) and chemical storage media like Hydrogen and Methane
- The potential to extend pumped hydro capacities is very limited
- CAES has limitations in operational flexibility and capacity

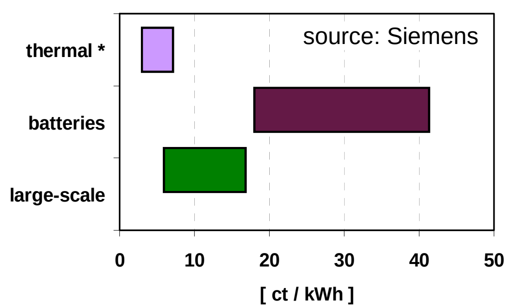
The future CO_2-optimized energy scenario will require smart solutions

The role of efficiency
Often misleading information given

Efficiency as a function of electric load



Costs of storage
(per kWh_{out})



Key statements

$$\eta = E_{in} / E_{out}$$

- efficiency is related to a specific point of operation or a specified cycle
- efficiency data without the above mentioned information do not say anything !!!
- life cycle costs is a key indication to find the most reasonable storage technology
- “efficiency” is implemented part of the equation.

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“Power to Gas” needs a common understanding

Power to Gas (P2G)

Power to Hydrogen (P2H)

use of hydrogen as a valuable material
- directly as fuel
- chemical syntheses
- process gas

Power to NG-grid (P2NG)

injection of hydrogen into the natural gas grid

Power to SNG (P2SNG)

reaction of hydrogen with CO_2 to methane and subsequent
- use as fuel
- injection into the NG grid

The business cases of the individual P2G approaches differ notably.

The big picture “Hydrogen”:
Hydrogen is a multifunctional energy vector

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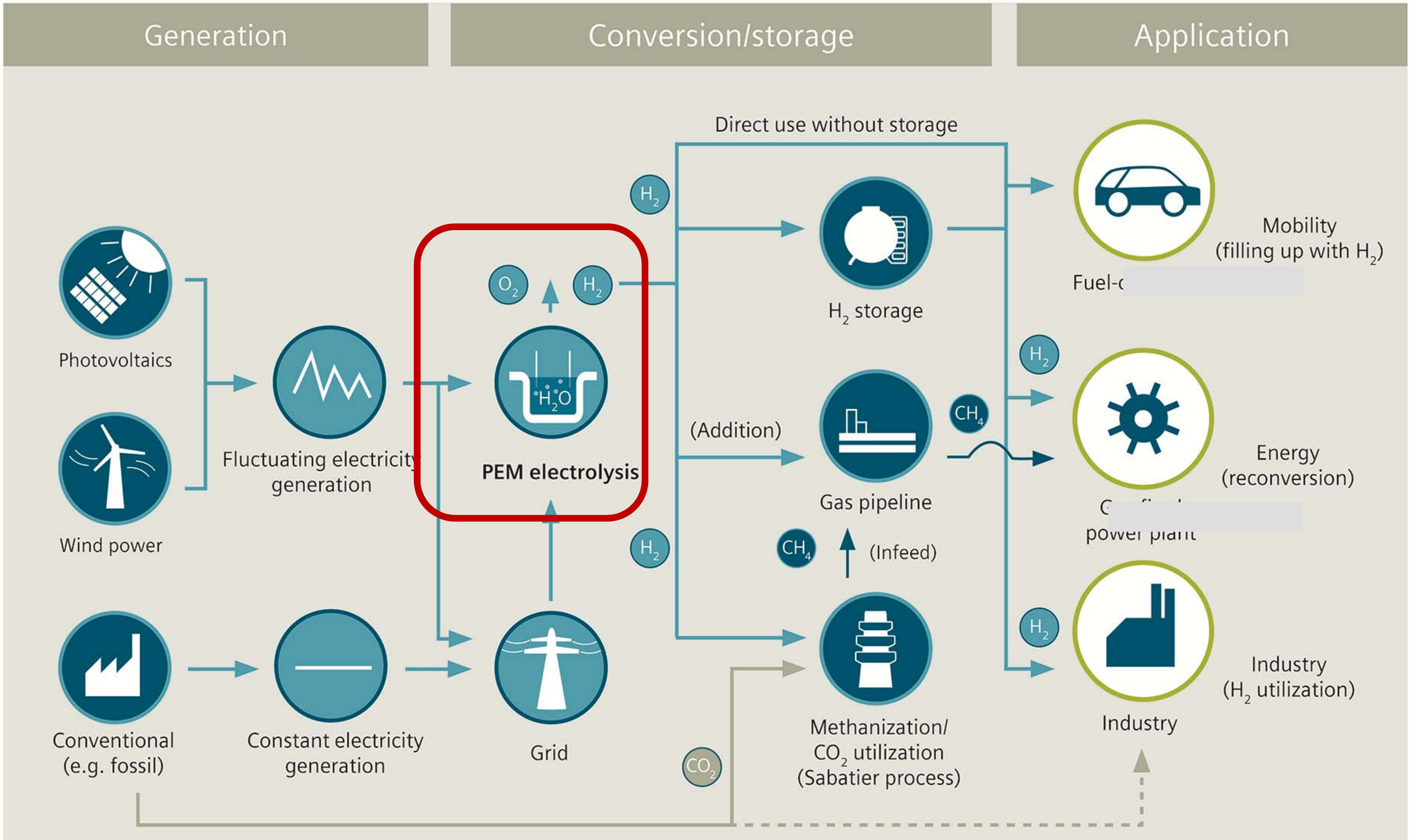
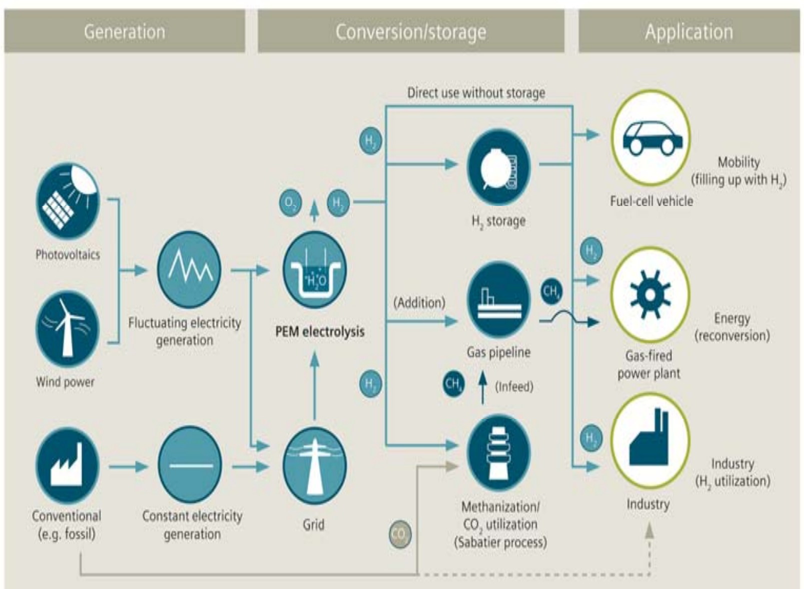


H_2 drives the convergence between energy & industry markets

The different use cases for green hydrogen follow a `merit order´ principle



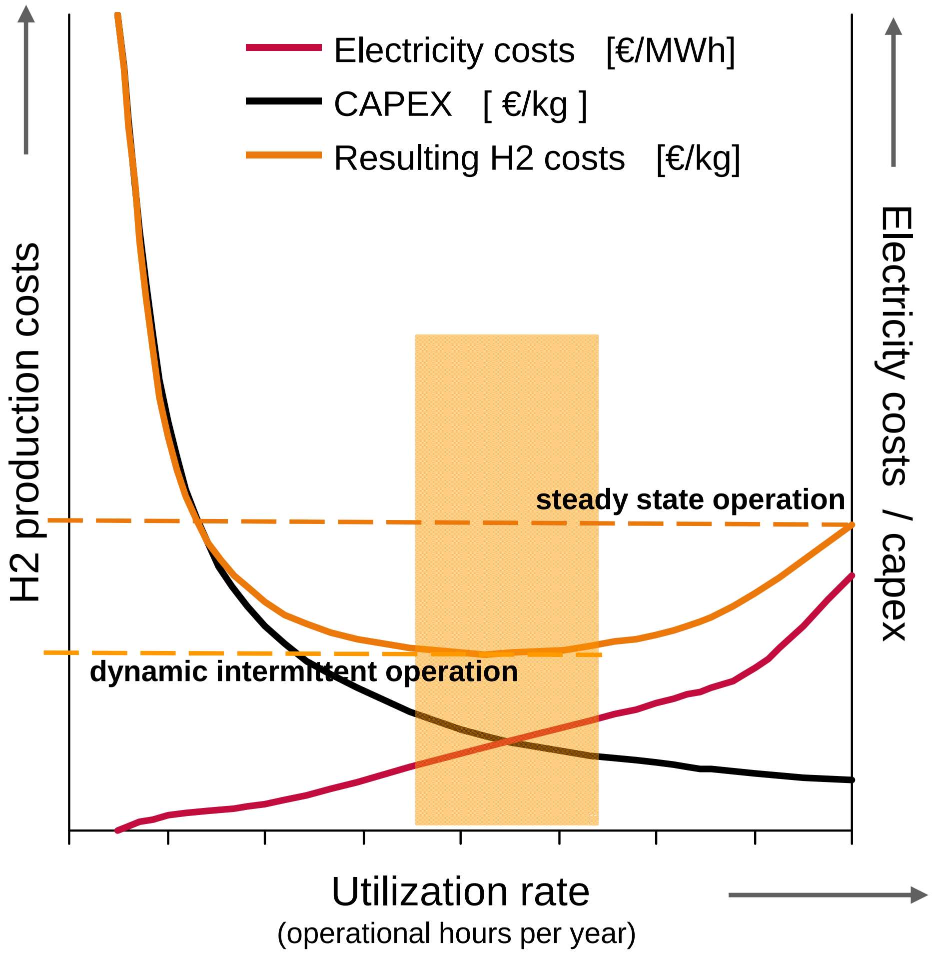
Applications and examples of use of hydrogen electrolysis

current H_2 market prices

mobility	**~ 4 – 10 €/kg**
industry	**~ 1,4 – 5 €/kg**
energy	**~ 0,7 – 1 €/kg**

- Compared to re-electrification ("power to power") the use of hydrogen in industry or mobility leads more easily to a positive business case.
- The three use cases have different maturity, market potential and market starting points.

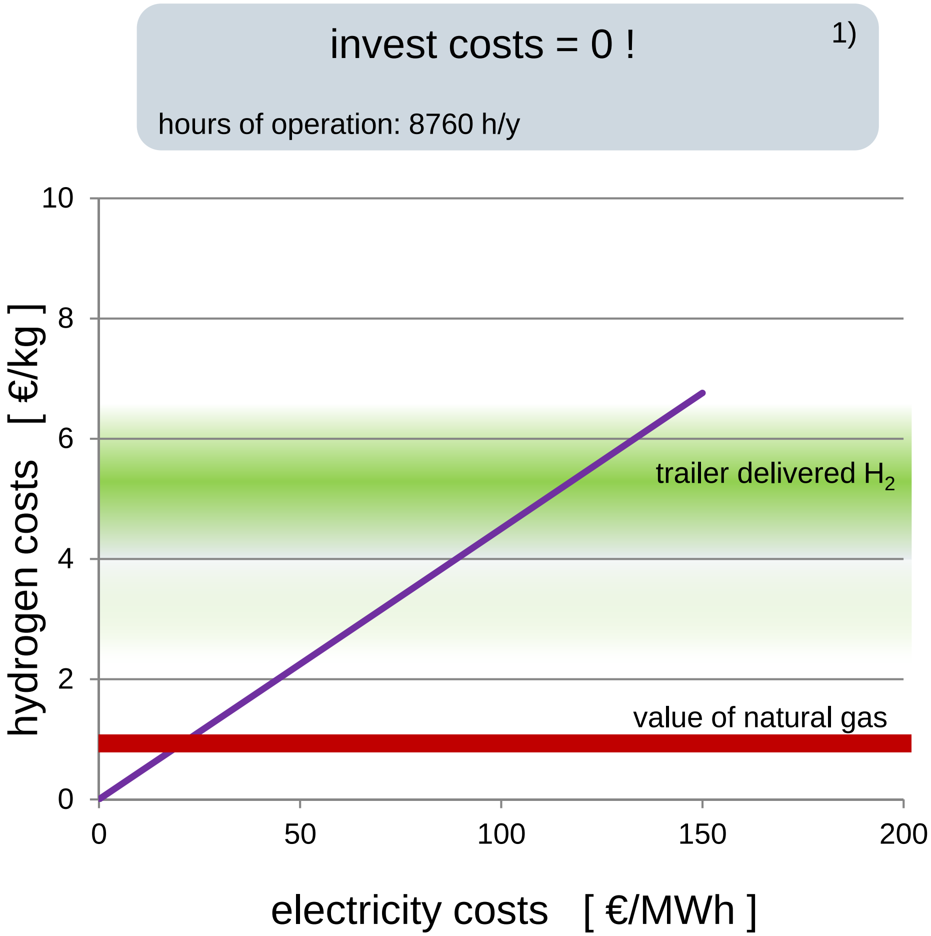
Utilization rate, CAPEX and Electricity Costs Impact on the H_2 Costs

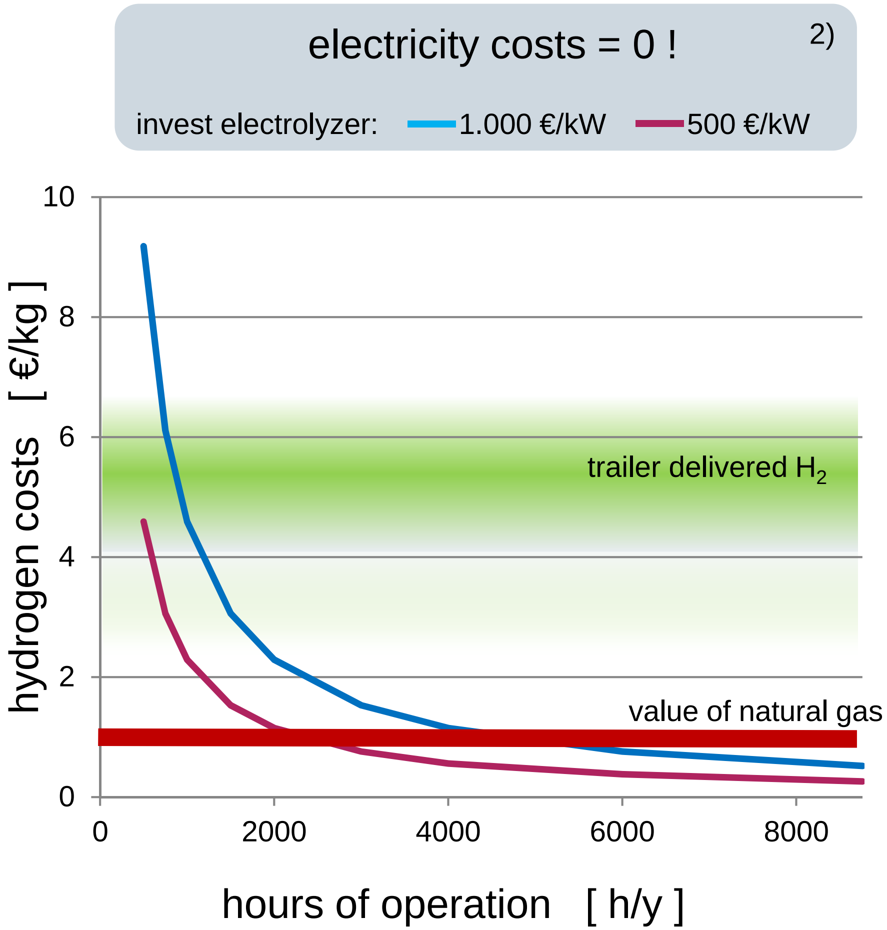


Key statements

- The H_2 production costs are mainly dependent from electricity costs, operational hours and capex.
- dynamic operation can yield incentives from "Regelenergie" and further select attractive low price periods for intermittent operation. This leads to lower H_2 production costs
- Benchmarking different technologies a comparison of capex costs only is misleading.

Economy of operation
Threshold considerations





further assumptions:

1) maintenance costs = 0; efficiency electrolyzer system = 70 % vs HHV;
2) depreciation: 20y; interest rate: 5 %; maintenance: 3% of capex; efficiency electrolyzer system: 70 % vs HHV
3) natural gas prize: 3 ct/kWh

Economy of operation
Threshold considerations

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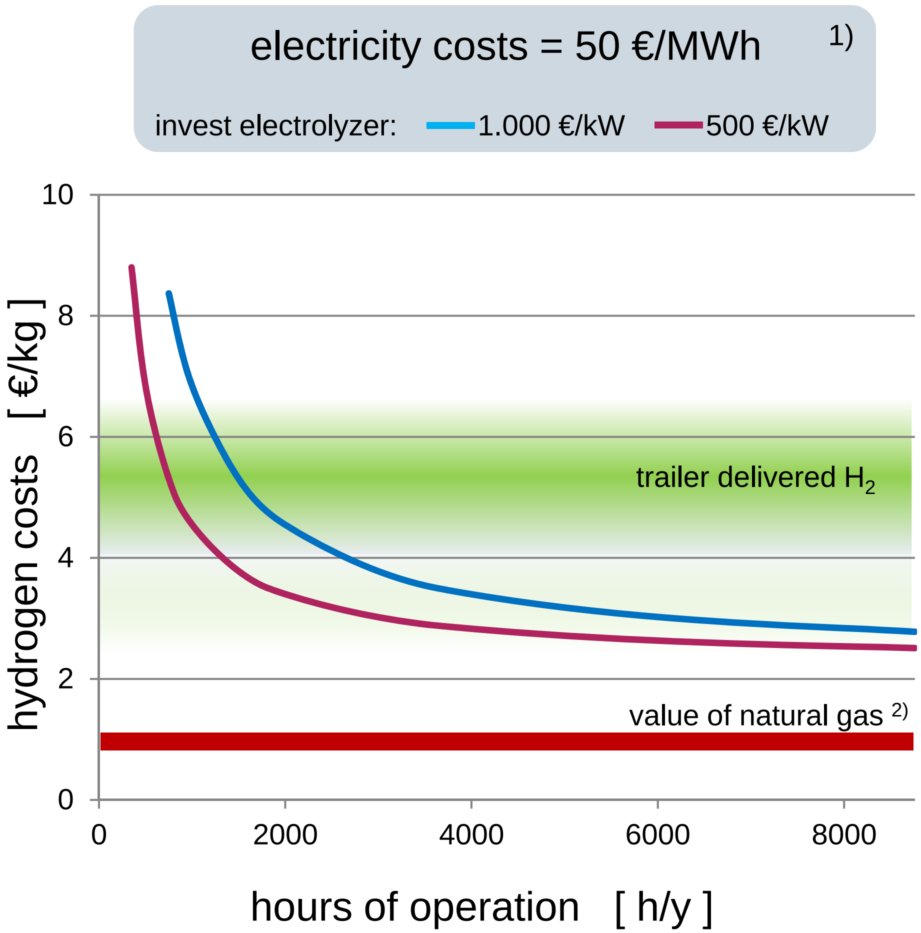

further assumptions:

1) depreciation: 20y; interest rate: 5 %; maintenance: 3% of capex; efficiency electrolyzer system: 70 % vs HHV

2) natural gas prize: 3 ct/kWh

Key findings:

- electricity prizes of $\leq$ 50 €/MWh can be found at the EEX for more than 4000 h per year.
- Injection into the NG grid does not reveal a positive business case (even with capex=0) under given assumptions,
- On-site electrolysis may be an attractive alternative to trailer delivered H_2 if the electrolyzer has access to “cheap” electricity
- the business case will be supported by supplying grid services (like secondary control power)

but:

- grid fees in many cases ruin individual business cases

➡ regulatory framework necessary

Power to Gas
The long-term perspective

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Scenario 2035+:

- CO_2 reduction targets require stringent measures in mobility, industry and power generation.
- High share of renewables
- Gas turbines as fast response and flexible (backup) power generation *
- Installations of different storage options
  - thermal
  - pumped hydro
  - batteries
  - H_2 (multifunctional)

The role of Power to NG-grid and SNG

- incremental injection of (green) H_2 or SNG into the NG grid; CO_2 savings in:
  - residential heating
  - industrial processes
  - re-electrification in gas turbines
- This will happen, if / as soon as:
  - all opportunities to sell H_2 into mobility and industry market are fully used
  - the commitment to existing CO_2 reduction targets is still valid

Limitation: SNG in any case requires CO_2 -sources near-by

- If / as soon as the H_2-concentration will exceed the regulatory limits of the NG grid, the combustion of pure H_2 becomes likely.
- The co-existence with other storage options is on-going

Water Electrolysis –
PEM* Electrolyzer Technology

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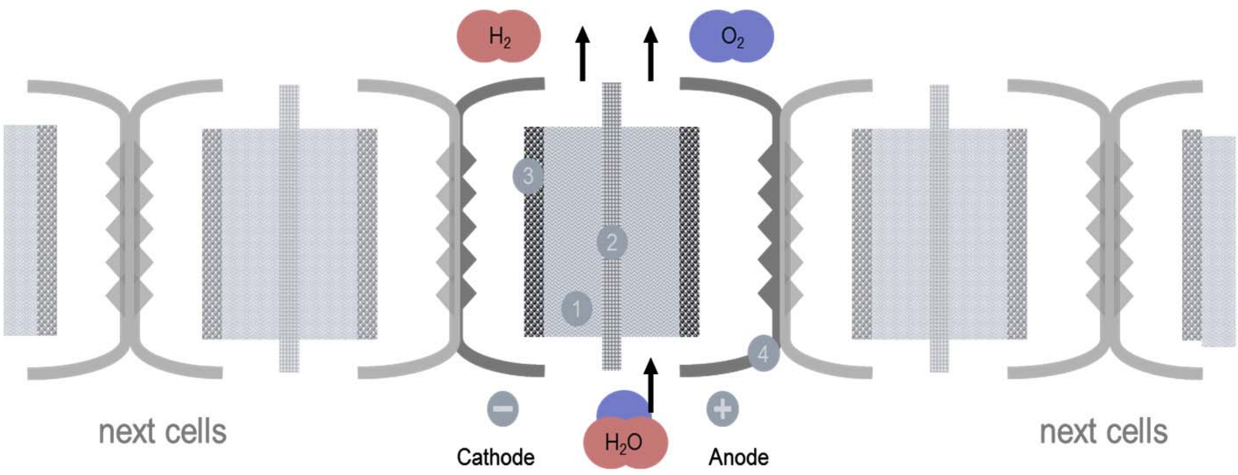
Key Statements

- DC current splits water into H2 and O2
- production rate is related to current
- 9 liters of water yield 1 kg of hydrogen
- approx. 50 kWh electrical energy generate 1 kg hydrogen
- 1 kg of hydrogen contain 33,3 kWh energy
- high dynamic operation
- compact design, small footprint
- simple cold-start capability
- high pressure operation (less compression costs)
- rapid load changes
- high stability / low degradation



Electrolyzer type	PEM
1 electrolyte	polymer membrane
2 separator	polymer membrane
3 catalyst	platinum + others
4 frame + bipolar plate)	metal sheet

The PEM Technology has numerous important advantageous system properties

* Proton-Exchange-Membrane

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Electrolyzer technology in a change

Yesterday

- demand driven, conventional electrical power generation; negligible share of renew-ables
- use of electrolyzers in con-tinuous industrial processes with cheap electricity

Today

- Commitment to CO_2-reduction; increasing share of renewables;
- first demonstrations to use existing electrolyzer techno-logy for intermittent grid services

Solution

- intelligent integration of renewables and storage in a smart grid
- highly dynamic electrolyzers provide grid services; shift of excess electricity to fuels and chemicals

Project "Energiepark Mainz": Delivery of the first Siemens Electrolyzer in the MW-range

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Objective:

- Develop an energy storage plant for the decentralized use of grid bottlenecks in order to provide grid services ("Regelenergie")
- High efficiency, dynamic load changes
- Injection in local gas grid and multi-use trailer-filling
- 6 MW Electrolyzer (3 Stack à 2 MW)
- Timeline: 03/2013 – 12/2016

Project Scope

Milestones:

• Groundbreaking ceremony	May 15, 2014
• Commissioning	1st half 2015

Partners: THE LINDE GROUP; STADTWERKE MAINZ AG; Hochschule RheinMain University of Applied Sciences Wiesbaden Rüsselsheim Geisenheim; SIEMENS

Outstanding performance paired with technical options allows integration in any project scope

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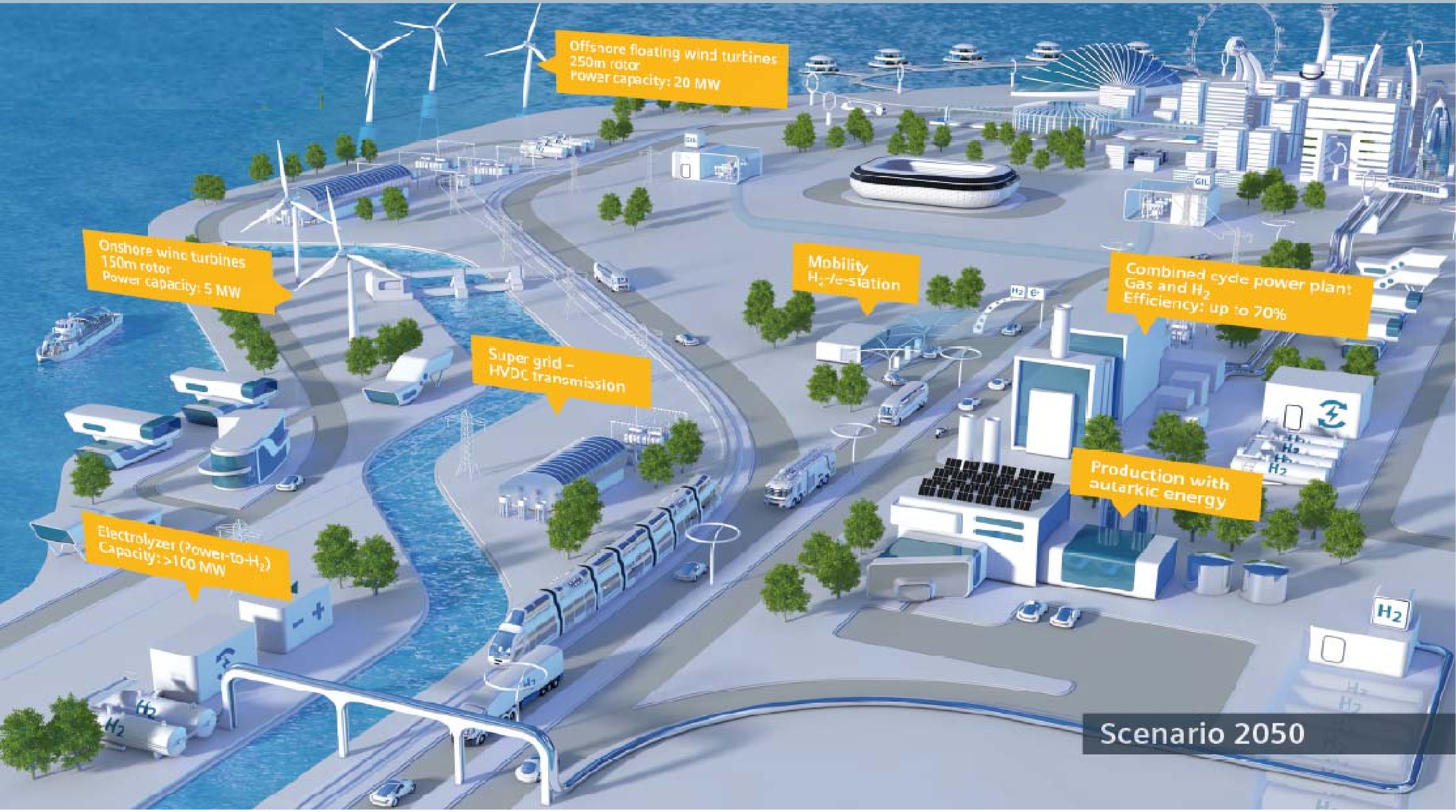
Main Technical Data - SILYZER 200	
Electrolysis type / principle	PEM
Rated Stack Power	1.25 MW
Dimension Skid	6,3 x 3,1 x 3,0 m
Start up time (from stand-by)	< 10 sec
Output pressure	Up to 35 bar
Purity H_2 (depends on operation)	99.5% - 99.9%
H_2 Quality 5.0	DeOxo-Dryer option
Rated H_2 production	225 Nm³/h
Overall Efficiency (system)	65 – 70 %
Design Life Time	> 80.000 h
Weight per Skid	17 t
CE-Conformity	yes
Tap Water Requirement	1,5 l / Nm³ H_2

Hydrogen will be part of the future energy scenario



Summary

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- CO_2 reduction targets are clearly linked with renewables. They will require storage capacities in the TWh range.
- Hydrogen is the only viable approach to store energy quantities > 10 GWh.
- In future there will be an increasing convergence between industry and energy markets.
- Power to Gas in an option to increase the flexibility of the electric grid.
- P2G is multifunctional: it provides three main business cases with individual maturity and market entry scenarios.
- P2G will start in economic niche applications and enable further extension of renewable power generation.