Electrolyzer technology – the Siemens view

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HFC Nordic, Sandviken, Sweden, Oct 26, 2016

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

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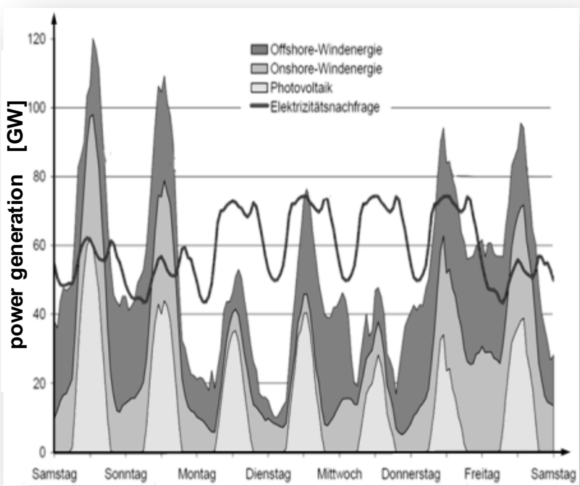
Nysted Offshore Wind Farm, 72 units 2.3 MW, 165.6 MW

RE power generation and load curves

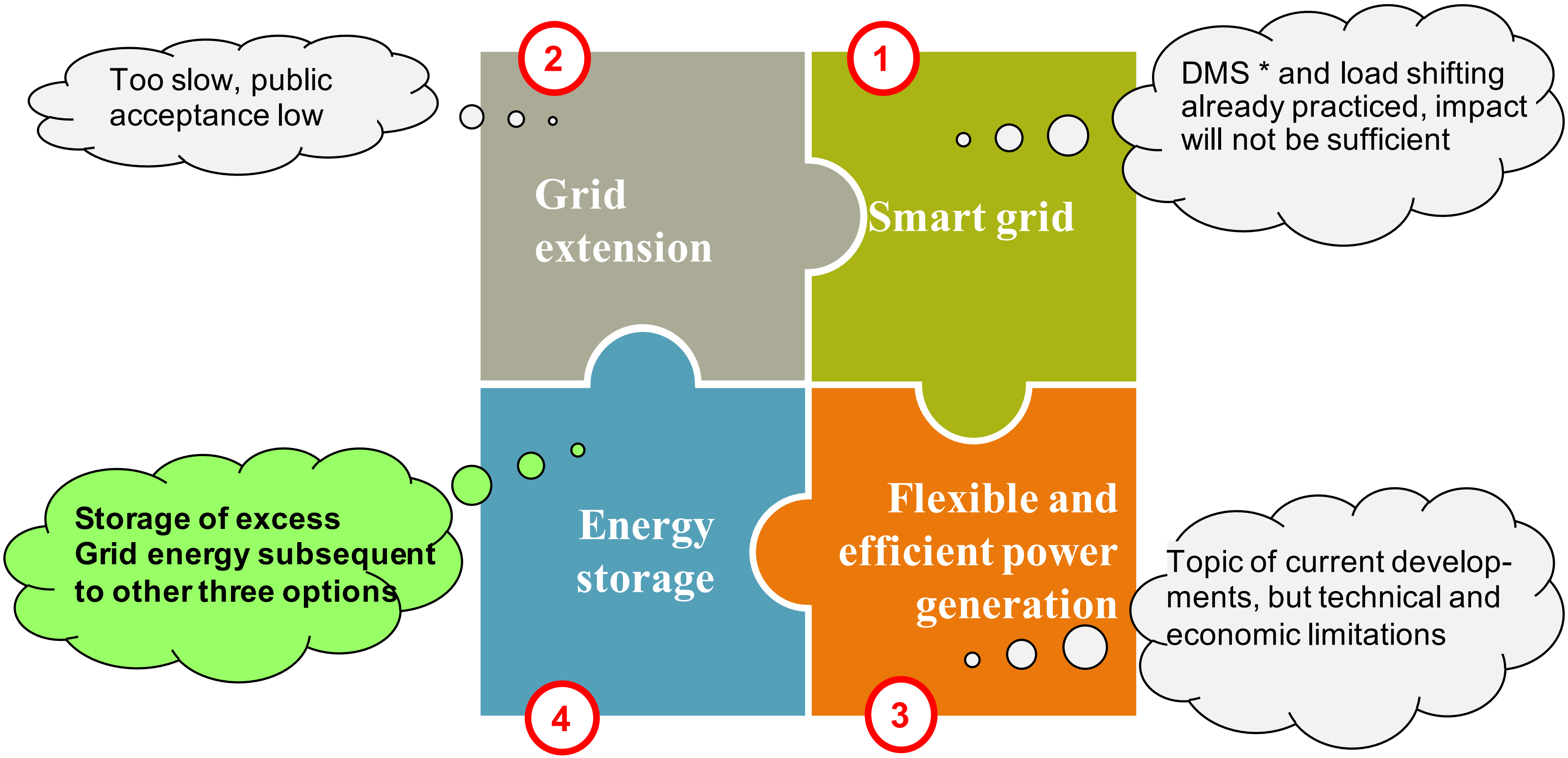


Source: TU Berlin, Prof. Erdmann, extrapolated for the year 2020

The mismatch between volatile RE power generation and local power demand may lead to notable curtailment.

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

Energy storage
will become essential in a Renewable Energy scenario



* DMS = demand side management

Electrical Energy Storage

Options to address large scale "Grid Storage" are limited

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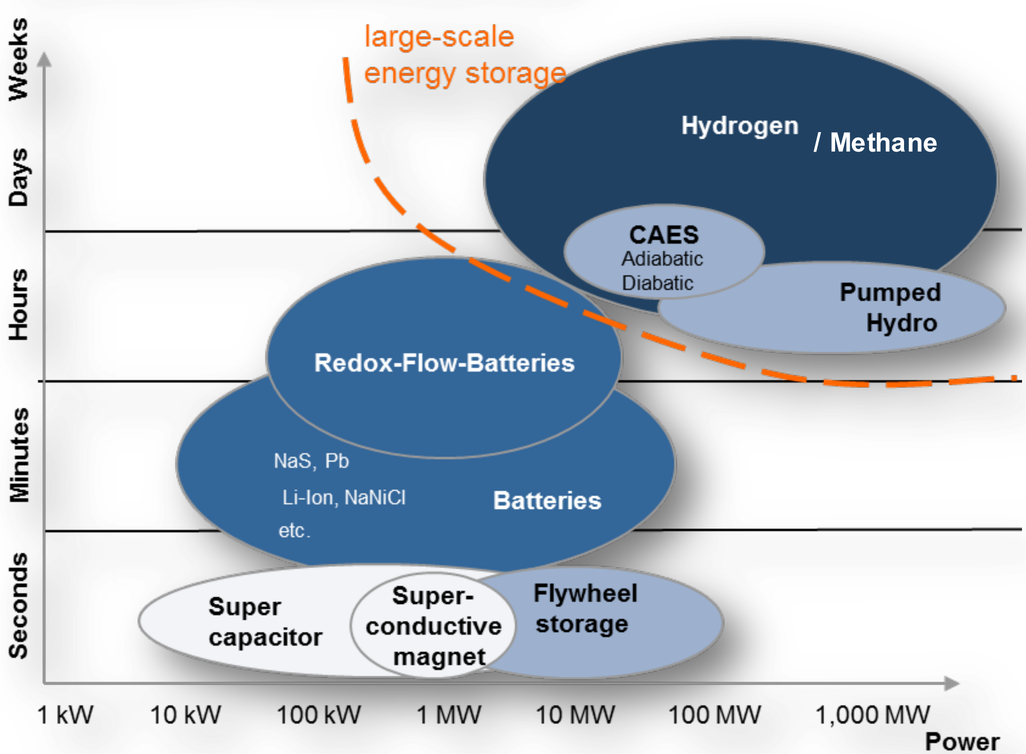
Segmentation of electrical energy storage



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

H_2 via P2G is the only viable approach to store electrical energy >10 GWh

Hydrogen is multi-functional: shifts CO_2-savings in power generation to mobility and industry

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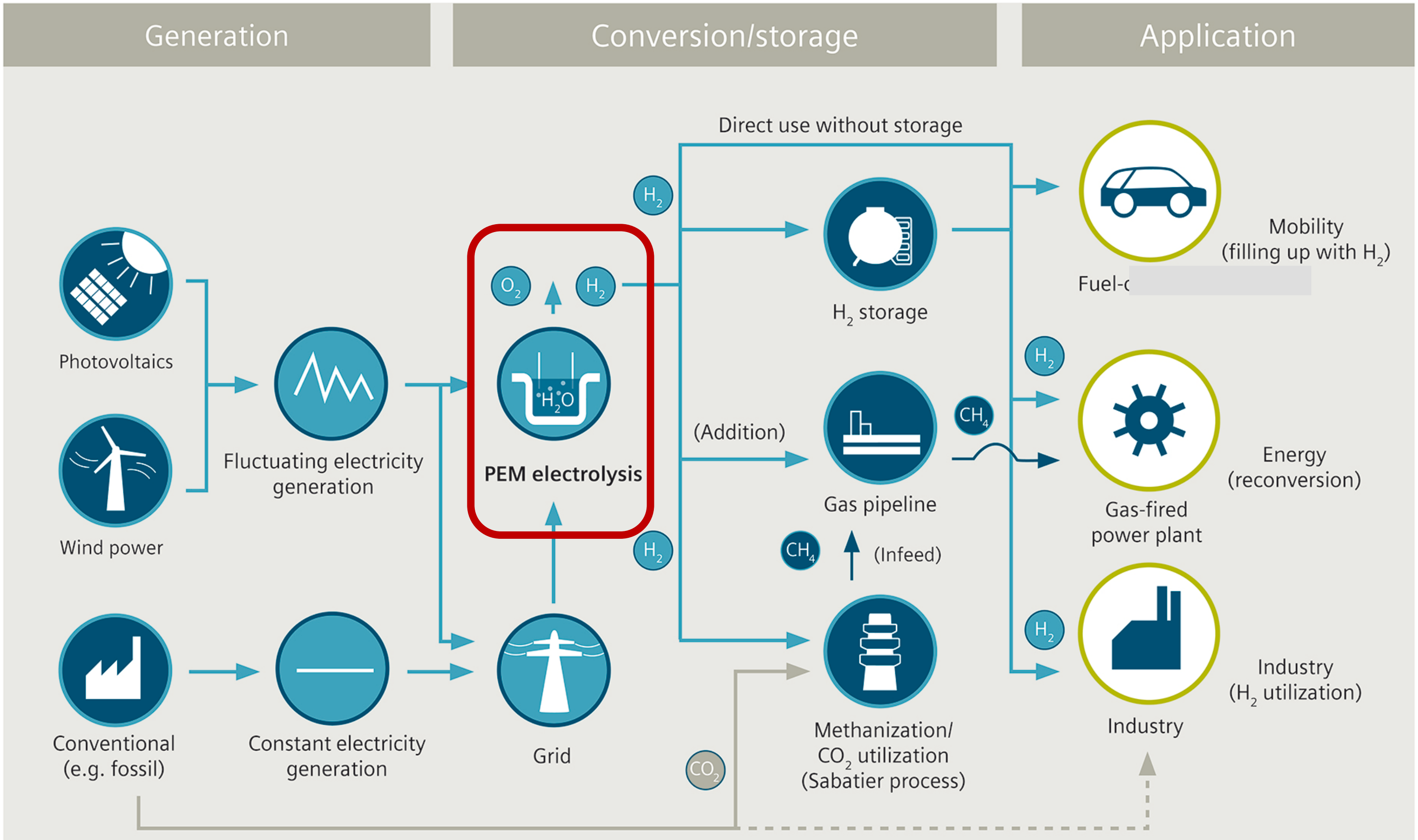

H_2 enables the coupling between energy, mobility & industry markets

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Hydrogen production via electrolysis
The enabler for large-scale energy storage/conversion

today

- There is a huge industrial demand of hydrogen (≈ 100 billion USD)
- Electrolyzers, splitting water into H_2 and O_2 are used in niches for hydrogen production.
- However, they will be the enabler to store (volatile) electricity.
  → New technical properties will be required

tomorrow

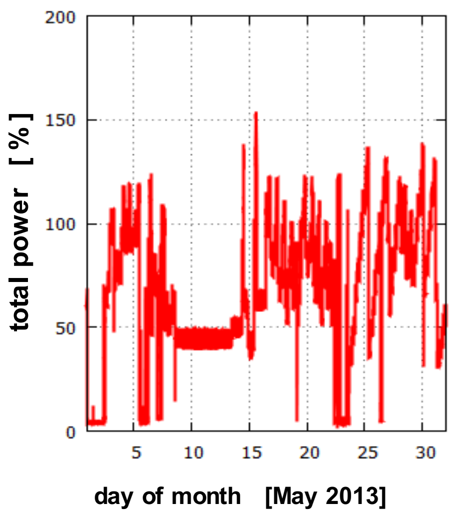
Fields of application	Technical requirements
Energy storage	Green generation
Power to chemicals	High dynamic
Hydrogen mobility	Intermittent operation
	Black start capability

Electrolyzers for renewable integration require specific properties

Electrolyzers for grid services

…. require specific properties

typical load profile of an electrolyzer
in a grid service project



source: Siemens

main technical requirements:

- quality of grid connection (harmonic distortions, power factor, flicker etc.)
- capable to be connected to grid control systems (hardware & software)
- low energy consumption in stand by mode; quick cold start
- low degradation in intermittent operation modes
- safety standards for customer friendly installations (not only restricted to chemical plants)
- high efficiency of the **overall system** in **intermittent** operation
- robustness and reliability have higher priority than performance (e.g. membrane thickness)
- service-friendly setup

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

Objective:

- Develop an energy storage plant for the decentralized use of grid bottlenecks in order to provide grid services (control power)
- 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

Milestones:

- Groundbreaking ceremony May 2014
- Commissioning July 2015

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

Project funded by BMWi

Energiepark Mainz

Elektrolyzer System

- 3 SILYZER 200 PEM-electrolyzer skids
- 1.25 MW rated power / 2.0 MW peak power (limited in time)
- High dynamic: load changes in seconds, capable for partial load in a wide range
- 35 bar outlet pressure

Ein Forschungsprojekt von STADTWERKE MAINZ AG, Hochschule RheinMain University of Applied Sciences Wiesbaden Rüsselsheim, THE LINDE GROUP Linde, SIEMENS

Gefördert durch Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

ENERGIESPEICHER Forschungsinitiative der Bundesregierung

SILYZER 200 / Electrolyser basic system
Solution for tomorrow

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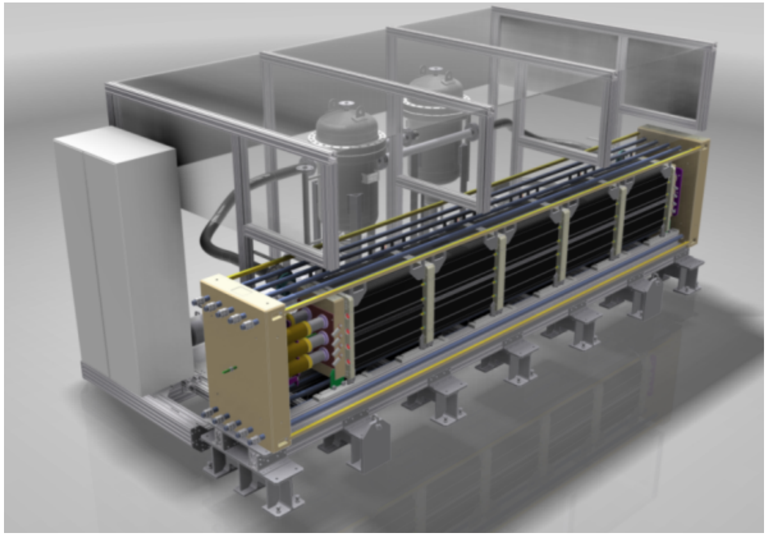
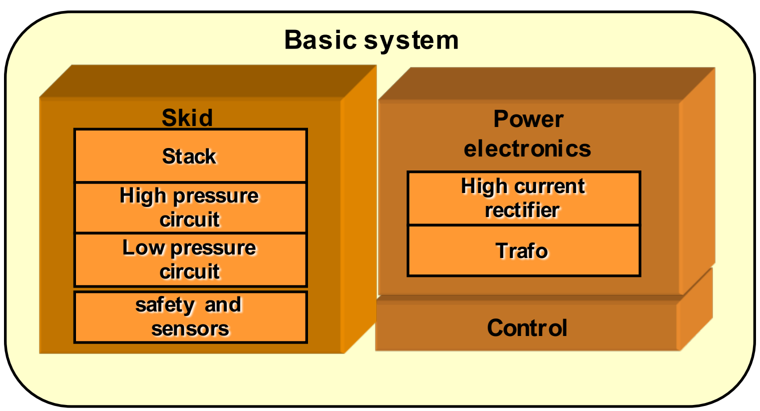




Main Technical Data - SILYZER 200	
Electrolysis type / principle	PEM
Rated Stack Power	**1.25 MW**
Dimension Skid	6,3 x 3,1 x 3,0 m
Start up time (from stand-by)	**< 10 sec**
Output pressure	**Up to 35 bar**
Purity H_2	99.5% - 99.9% *
H_2 Quality 5.0	DeOxo-Dryer option
Rated H_2 production	225 Nm³/h
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

* depends on operation

Energiepark Mainz

Silyzer System - Easy to transport and to install

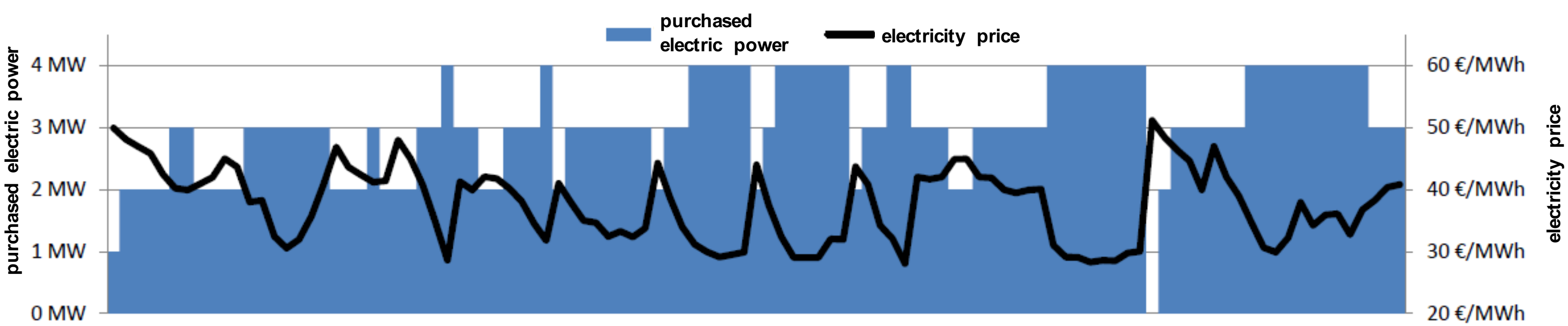
Energiepark Mainz – Status

First results

- Regular operation from Sep 01 to Oct 23, 2015
  - purchase of electricity following price development of EEX (workdays 8:00am to 06:00pm)
  - approx. 700 MWh electricity consumed
  - approx. 40 trailers filled

→ Expectations towards power, dynamic performance and efficiency fulfilled

→ No critical failures



Quelle: eigene Darstellung

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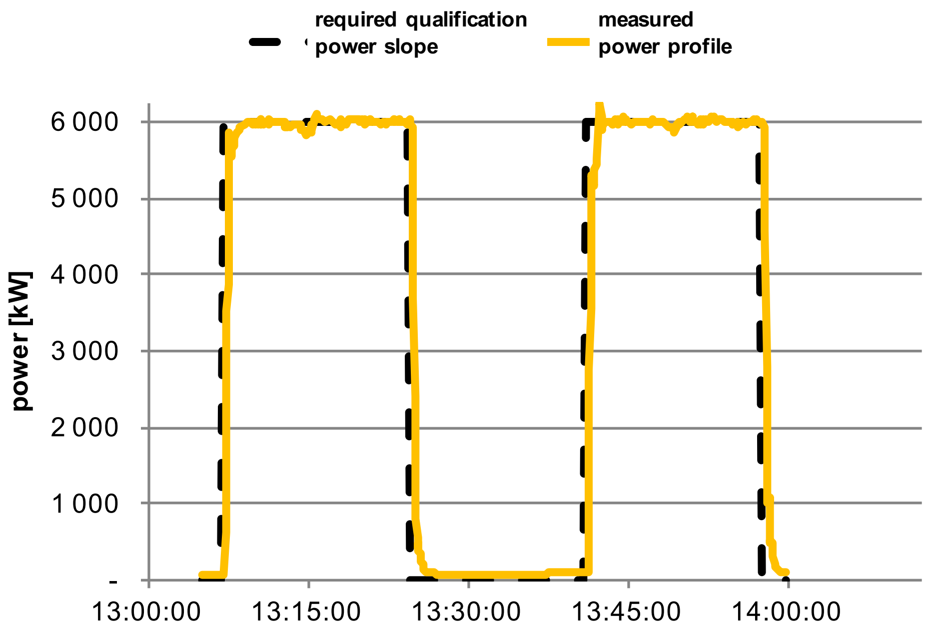
Energiepark Mainz

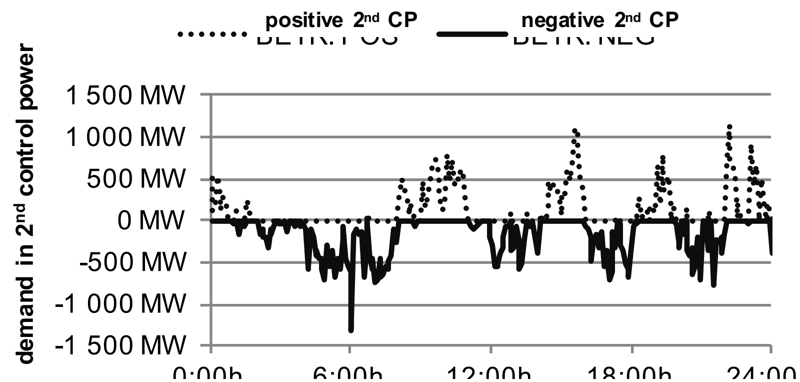
Qualification for grid services

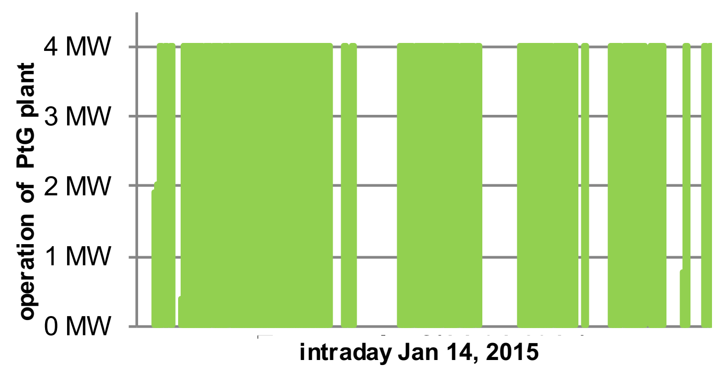
participation control power market starting in Q2 / 2016



source: own measurements

Demand in secondary control power (2nd CP) and conceivable use of a PtG plant

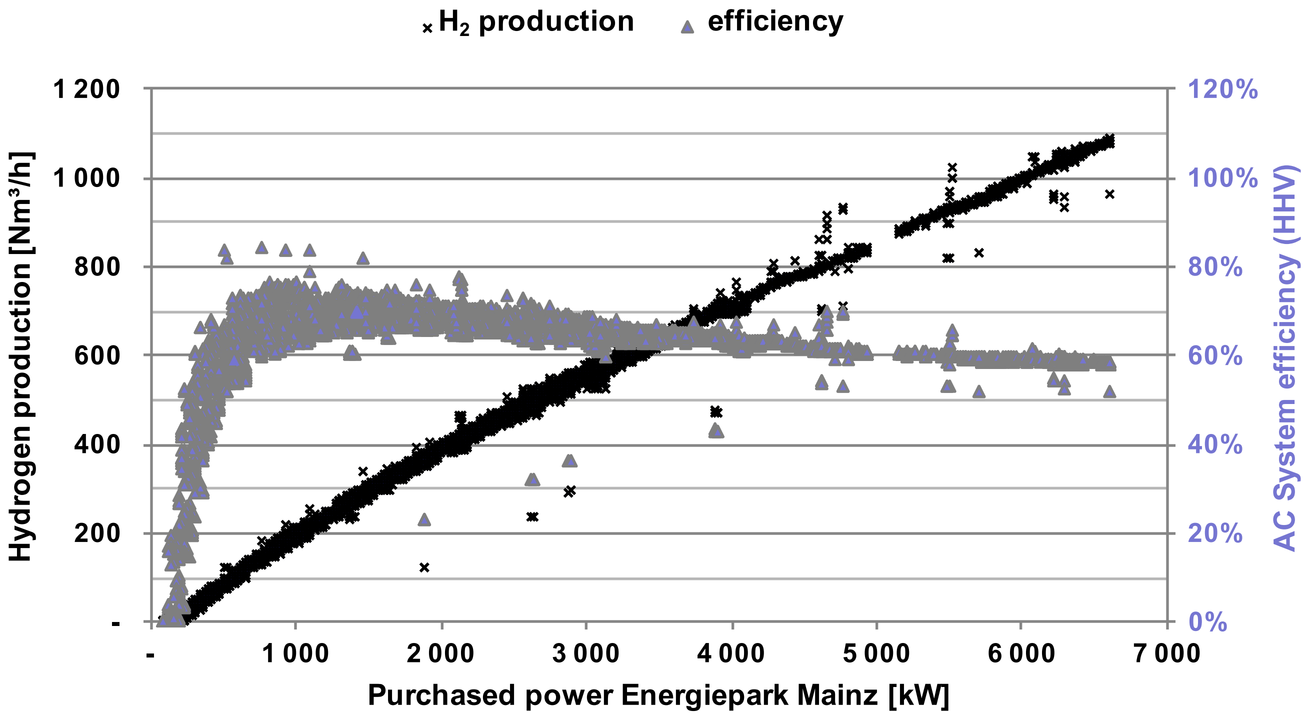




Energiepark Mainz – Status

First results

- Efficiency evaluations under consideration of **overall** purchased electricity and mea-sured H2 production (outlet electrolyzers)
- Data obtained by measurements in Oct 2015



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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.

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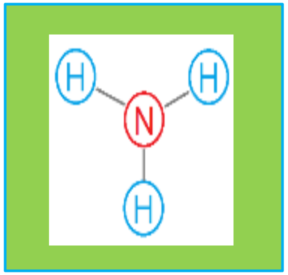
Green (CO_2-free) hydrogen:
a broad variety of potential applications

Industry *

- Refineries



- Ammonia plant

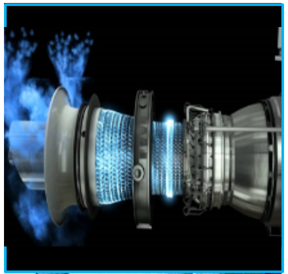
- Steel production

Mobility

- H_2 as fuel for public transport

- Substitute of bio-ethanol admixing

Energy



- Re-electrification in H2-turbines

- Admixing to conventional gas turbines

- Generator cooling

* Besides these: glass, semiconductor, food&beverage

Outlook

Siemens - Complete solutions from one hand

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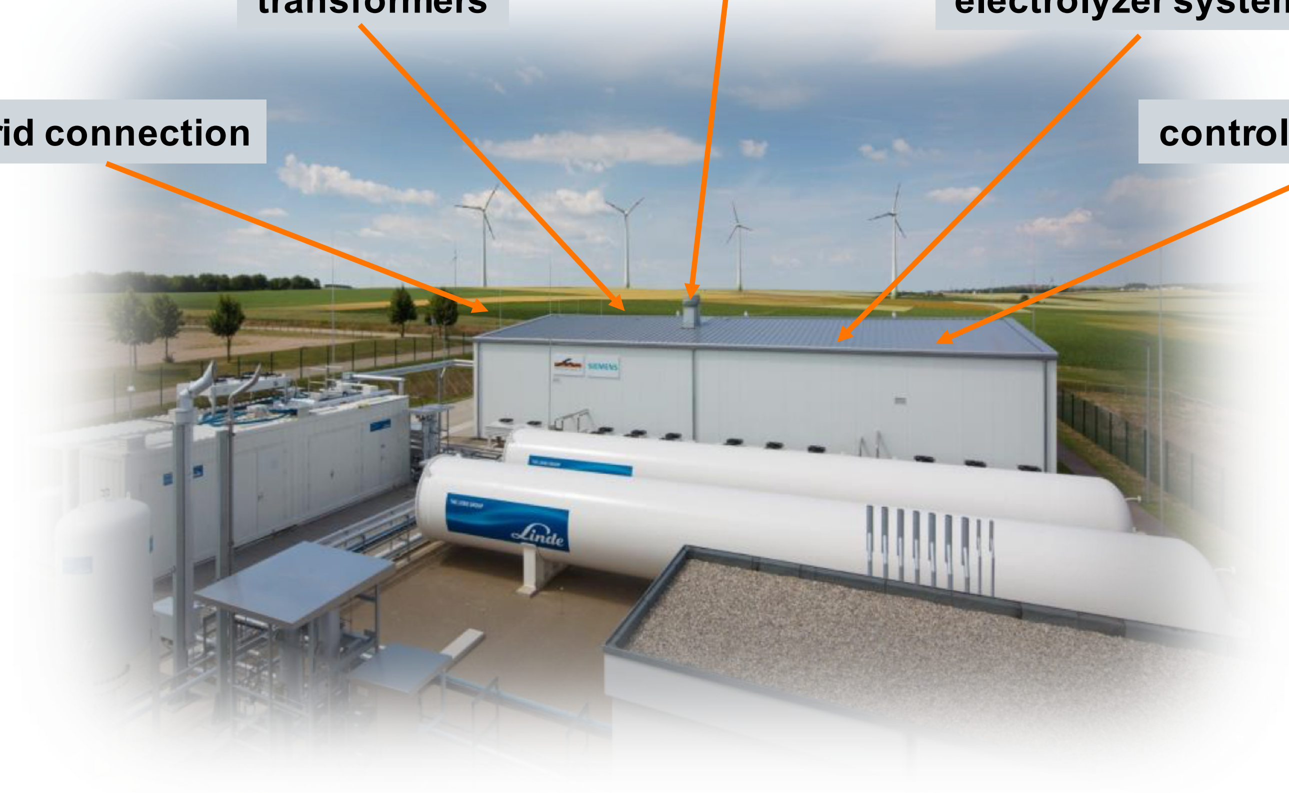
heavy duty rectifiers

transformers

electrolyzer systems

grid connection

control technologies



wind turbines

gas and steam turbine

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Summary

- CO_2-reduction targets are clearly linked with renewables. They will require storage capacities in the TWh-range
- Hydrogen via Power-to-Gas is the only viable approach to store electrical energy >10 GWh.
- Hydrogen is multifunctional: it can be re-electrified, but also shifted to the industry or mobility sector (“sector coupling“)
- Power to Gas - with electrolyzer as enabling component - is an economic option to increase the flexibility of the electric grid.
- Sector coupling will be essential to reach CO_2 reduction targets.
- Siemens is prepared to provide electrolyzer systems and related technologies in the required power range and volume.