Power to Gas - an economic approach?

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

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

The future CO₂-optimized energy scenario will require smart solutions.
Components and tasks for a future energy system

- Cost-efficient use of conventional and renewable energy
- Flexible and efficient power generation
- Grid extension
- Cross-regional electricity transfer and integration of distributed generation
- Managing increasingly complex energy systems
- Grid stability and system efficiency
- Energy storage
- Smart grid digitization
- Flexible and efficient power generation

Cost-efficient use of conventional and renewable energy

Grid stability and system efficiency

Managing increasingly complex energy systems

Cross-regional electricity transfer and integration of distributed generation

Smart grid digitization

Energy storage

Grid extension
Options to address Large Scale "Grid Storage" are limited

The future CO₂-optimized energy scenario will require smart solutions
The role of efficiency
Often misleading information given

Efficiency as a function of electric load

Key statements
\[ \eta = \frac{E_{\text{in}}}{E_{\text{out}}} \]

- 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.

Costs of storage (per kWh\text{out})
“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 CO₂ 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

H₂ drives the convergence between energy & industry markets
The different use cases for green hydrogen follow a `merit order´ principle

Current H₂ 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 H₂ Costs

Key statements:

• The H₂ 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 H₂ 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 price: 3 ct/kWh

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Economy of operation
Threshold considerations

Key findings:

- electricity prizes of ≤ 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 H₂ 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

Further assumptions:
1) depreciation: 20y; interest rate: 5 %; maintenance: 3% of capex;
   efficiency electrolyzer system: 70 % vs HHV
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Power to Gas
The long-term perspective

Scenario 2035+:

• CO₂ 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
  • H₂ (multifunctional)

The role of Power to NG-grid and SNG

• incremental injection of (green) H₂ or SNG into the NG grid; CO₂ savings in:
  • residential heating
  • industrial processes
  • re-electrification in gas turbines
• This will happen, if / as soon as:
  • all opportunities to sell H₂ into mobility and industry market are fully used
  • the commitment to existing CO₂ reduction targets is still valid
Limitation: SNG in any case requires CO₂ -sources near-by
• If / as soon as the H₂-concentration will exceed the regulatory limits of the NG grid, the combustion of pure H₂ becomes likely.
• The co-existence with other storage options is on-going
Water Electrolysis – PEM* Electrolyzer Technology

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

The PEM Technology has numerous important advantageous system properties

Electrolyzer type

<table>
<thead>
<tr>
<th>Electrolyzer type</th>
<th>PEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 electrolyte</td>
<td>polymer membrane</td>
</tr>
<tr>
<td>2 separator</td>
<td>platinum + others</td>
</tr>
<tr>
<td>3 catalyst</td>
<td>metal sheet</td>
</tr>
<tr>
<td>4 frame + bipolar</td>
<td></td>
</tr>
</tbody>
</table>

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* Proton-Exchange-Membrane
Electrolyzer technology in a change

Yesterday
- demand driven, conventional electrical power generation; negligible share of renewables
- use of electrolyzers in continuous industrial processes with cheap electricity

Today
- Commitment to CO$_2$-reduction; increasing share of renewables;
- first demonstrations to use existing electrolyzer technology 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

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

Milestones:

- Groundbreaking ceremony May 15, 2014
- Commissioning 1st half 2015
### Main Technical Data - SÝLYZER 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 H₂ (depends on operation)**: 99.5% - 99.9%
- **H₂ Quality 5.0**: DeOxo-Dryer option
- **Rated H₂ 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 H₂
Hydrogen will be part of the future energy scenario
Summary

- CO₂ 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 is 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.