Steam Electrolysis as the Core Technology for Sector Coupling in the Energy Transition

Dr.-Ing. Oliver Borm / ICE2017
Basic Information
Solid Oxide Cells convert...

... electricity into hydrogen

... chemical energy into electricity and heat

Electrolysis Mode

Power & Heat Mode
Three Core USPs

+ **Highest efficiency** in hydrogen production (82%\textsubscript{LHV} or 3.7 kWh/Nm\textsuperscript{3}) and power & heat production (35-60\%\textsubscript{AC} and 90\%\textsubscript{total}) compared to legacy technologies such as PEM and Alkaline

+ **Tolerance to carbon** in electrolysis mode via co-electrolysis of CO\textsubscript{2} and H\textsubscript{2}O and in fuel cell mode via internal reforming of hydrocarbons (natural gas, LPG, diesel, etc.)

+ **Flexible** adjustment of output from part load to full load (30%-100%) in a short timeframe

Sunfire promises low costs, high reliability and readiness to scale.
Sunfire’s Mission 100 % “Energiewende” via sector coupling: To bring renewable energy everywhere by bridging the gap between the power, mobility, chemicals and heat sectors.
One Core - Multiple Products

+ Heat and Power for Households
+ Power and Heat for Commercial Buildings
+ Power for Remote Locations
+ Fuels and Gases for Mobility + Industry
Company facts

Knowhow
• 90 Employees
• Skills in Ceramics, Stack + System Production, Engineering, Synthesis Processes, etc.

Investors

Patents
• 43 patent families (i.e. »process patent sunfire« WO/2008/014854)

Recognition
• EcoSummit Silver Award 2014/2015
• Cleantech 100 Company 2014/2015/2016 (only fuel cell + electrolysis company)
• Fast Company Most Innovative Company of 2016 (with Tesla and Toyota)
• German gas industry’s 2016 Innovation & Climate Protection Award

Revenues
• Multi-million Euro Revenues in Global Markets since 2011
Sectoral Integration: The Hydrogen Opportunity

Why now?
We are lacking renewable solutions for oil and gas

Final Energy Consumption by Fuel (GER, 2015)

- Ambitious renewable energy consumption targets: 2030 = 30% and in 2050 = 60%
- Solar and wind power are competitive with fossils, but electrical sector only 25%
- 75% of energy is used in the oil & gas sector
Electrification requires large overcapacities

- 90 GW installed capacity of PV / wind
- 10 GW avg. electricity supply from PV / wind

Solar and wind power are fluctuating and seasonal
A full electrification would require significant overcapacities

Source: Agora-Energiewende
W/o solutions for the o&g sector CO₂ targets will be missed

Germany ranks amongst most CO₂-emitting countries in Europe, despite large investments in renewable energies (>25 bn€/a)

Source: Zukunft Erdgas and www.electricitymap.org
Hydrogen is the bridge between the sectors

Sectoral integration means the integration of the power sector with the oil and gas sectors via the use of hydrogen.

By purchasing renewable electricity directly from operators through Power Purchase Purchase Agreements (PPA) the share of renewable electricity production can be increased at no additional costs for the system.
Sectoral Integration in practice

Where does it make most sense?
Hydrogen for refineries - the first use-case

- Hydrogen required for the production of fuels in refineries (diesel, gasoline, etc.)
- Only in Germany, >100,000 t/a hydrogen demand currently produced from natural gas
Hydrogen from renewable electricity to fulfill quotas

- Fossil hydrogen can be replaced by hydrogen from renewable electricity
- Hydrogen can already achieve “biofuel parity” → no additional costs for system
- European market size estimated to be >10 GW of electrolysis
Technical Specification
Steam Electrolysis Module Performance and Interfaces

**Electrical Efficiency:**
Steam Electrolysis: AC $\rightarrow$ LHV 82 $\%_{LHV}$

Steam 40 kg/h @ 150°C, 3 bar(g)

H$_2$: 40 Nm$^3$/h (3.6 kg/h; 120 kW$_{LHV}$)
Selected Reference Projects

- 1x 150 kW SOEC power input and 40 Nm³/h hydrogen output
- SOEC efficiency of >80 %_{LHV}
- Installed at an industrial steel plant
- Meeting H₂ quality standards of steel industry

- 2x 100 kW SOEC power input and 50 Nm³/h hydrogen output
- Reversible mode with 2x 20 kW and roundtrip efficiency of ca. 45%
- Electricity storage for autonomous electricity supply during day and night (PV connected)
Sectorial Integration requires megawatt electrolysers
Next Generation Electrolysis

Modular Scaling Concept

SOEC Module:
- Hydrogen output: 50 Nm³/h
- Electricity input: 185 kW_{AC}

Standard 20’ container (TEU*):
- Up to 4 modules
- Hydrogen output: 200 Nm³/h
- Electricity input: 740 kW_{AC} power

Hydrogen drying unit
Gas cooling unit

* TEU = Twenty Foot Equivalent Unit = 20 ft. ISO container
Upscaling Concept

+ **SOEC Electrolysis Tower:**
  - Stack up to *five 20\textquotesingle container* over each other for a *Hydrogen* output of *1,000 Nm$^3$/h*
  - Electricity input: *3.7 MW$_{AC}$*
  - Central Hydrogen Processing Unit
  - Footprint: 1 TEU (6.1 m x 5.0 m)

+ **SOEC Electrolysis Bench:**
  - *Hydrogen* output: *20,000 Nm$^3$/h*
  - Electricity input: *74 MW$_{AC}$*
  - Footprint: 2 TEU (15 m) x 10 TEU (48 m)

+ No upscaling issues due to *serial production* of the same reliable SOEC module
+ ** Incremental** set-up of H$_2$ production capacity
Hydrogen Market & Competition
Hydrogen Demand and Applications

+ Today, fossil H2 markets in chemicals, metals and refineries

+ New market potential in H2 storage, H2 mobility and e-fuels

+ Green H2 for Refineries and Industry threatening traditional markets of established fossil H2 suppliers

Global Hydrogen demand (65 Mt/a = ~2,000 TWh/a)

Electrolysis hydrogen has a significant potential in chemical industries (1200 TWh/a) and refineries (600 TWh/a).
# Technologies for Renewable Hydrogen Production

<table>
<thead>
<tr>
<th>2020 scenario</th>
<th>Efficiency in $%_{\text{LHV}}$ (kWh/Nm³)</th>
<th>Costs in €/kW (€/kW divided by $\eta$)</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline</td>
<td>63 (4.8)</td>
<td>800 (1,270)</td>
<td>Reliable, Robust</td>
</tr>
<tr>
<td>PEM</td>
<td>65 (4.7)</td>
<td>1,000 (1,540)</td>
<td>Flexible</td>
</tr>
<tr>
<td>SOEC</td>
<td>82 (3.7)</td>
<td>1,500 (1,830)</td>
<td>Efficient, Reversible</td>
</tr>
</tbody>
</table>

+ Sunfire reaches **highest efficiencies** when using low-grade steam / heat
+ Efficiency reduces energy costs (**low OPEX**) and required electrolysis capacity to produce the same hydrogen output as less efficient products (**reduced CAPEX**)
+ This results in **cost-competitive and affordable renewable hydrogen**

+ Additionally, Sunfire’s SOEC has CO-electrolysis potential
H$_2$ Cost Comparison SOEC, Alkaline, PEM

Assumptions (2020 scenario):

- Electricity Costs: 80 €/MWh
- Capacity Factor: 60% (~5,000 full load hours)
- IRR 9%
- Sunfire electrolysis (SOEC) enables lowest costs compared to legacy technologies

Sunfire electrolysis (SOEC) enables lowest costs compared to legacy technologies.
THANK YOU FOR YOUR INTEREST!

ENERGY EVERYWHERE

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