PEM electrolyser technology
Flexible, efficient and scalable

New Energy Business
Early Engagements

HIGHLIGHT
Enable Hydrogen Economy
Decarbonization of steel production based on hydrogen
H2FUTURE® – A European Flagship project for the generation and use of hydrogen with the world’s largest and most advanced hydrogen pilot facility in Linz, Austria
Partner H2FUTURE®
Siemens | VERBUND | Voestalpine | Austrian Power Grid | K1 MET | TNO Project funded by EU

Our offerings

Hydrogen Systems
Industry grade and highest quality green electrolyzer-based Power-to-hydrogen systems and services

Power-to-X-Solutions
• Electrolyzer-based Power-to-Hydrogen and Power-to-Liquids solutions and services
• Electrolyzer-based turnkey solution package

Energy Consulting & Digital Services
• Electrolyzer-integrating Energy system design
• Specific Power-to-X related digital services and optimization solutions
“Sector Coupling” is the key lever for decarbonization of all end-user sectors

Shares in global CO\textsubscript{2} emissions by sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>CO\textsubscript{2} Emissions Share</th>
<th>Renewables Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Buildings</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>Transport</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>40%</td>
<td></td>
</tr>
</tbody>
</table>

Continuous emission reduction required
Share on CO\textsubscript{2} emissions: 40%
Share of Renewables: 22%

Source: World Energy Balances 2018

July 2021
## Why a Proton Exchange Membrane (PEM) electrolyzer system?

### PEM is the natural choice for our future renewable energy system

- Incredibly fast start-up and shut-down
- Highest operational flexibility
- Cold start capability

### PEM is clean by nature

- No CO₂ emissions, unlike SMR\(^1\), which emits 8 – 10 kg CO₂ for each kg of hydrogen
- There is nothing except water, hydrogen and oxygen in the system
- Highest hydrogen purity >99.9%
- Oxygen as the only “contaminant”
- No aggressive chemical electrolyte (e.g. KOH in alkaline systems)

### PEM is competitive

- Competitive hydrogen price per kg at green electricity prices below 3 ct/kWh
- Small footprint
- Significantly lower OPEX\(^2\) due to maintenance-free stack

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1 SMR: Steam Methane Reforming | 2 OPEX: Operational Expenses
Silyzer portfolio scales up by factor 10 every 4 – 5 years driven by market demand and co-developed with our customers.

Silyzer portfolio roadmap

- **2011**
  - Silyzer 100
    - Lab scale demo
    - ~4,500 OH¹
    - ~150k Nm³ of H₂

- **2015**
  - Silyzer 200
    - ~86,500 OH¹
    - ~7.3 m Nm³ of H₂
  - Silyzer 300
    - First investigations in cooperation with chemical industry

- **2018**
  - Silyzer 300
    - Biggest PEM cell in the world built by Siemens!

- **2023+**
  - Next generation
    - Under development

- **2028+**
  - 1,000 MW
    - First investigations in cooperation with chemical industry

1 Operating Hours; Data OH & Nm³ as of Dec 2019

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Silyzer 300
The next paradigm in PEM electrolysis

17.5 MW
Power demand per full Module Array (24 modules)

>76 %
System efficiency\(^1\) (higher heating value)

24 modules
to build a full Module Array

335 kg
Hydrogen per hour per full Module Array (24 modules)

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1 Ambient temperature 15\(^\circ\) C, air cooled

July 2021
# Silyzer 300 Fact Sheet

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen production</td>
<td>335 kg/h</td>
</tr>
<tr>
<td>Plant efficiency (HHV(^1))</td>
<td>&gt;75.5%</td>
</tr>
<tr>
<td>Power demand</td>
<td>17.5 MW</td>
</tr>
<tr>
<td>Start-up time</td>
<td>&lt;1 min, enabled for PFRS(^2)</td>
</tr>
<tr>
<td>Dynamics in range</td>
<td>10%/s in 0 – 100%</td>
</tr>
<tr>
<td>Minimal load</td>
<td>20% single module</td>
</tr>
<tr>
<td>Dimension full Mod. Array</td>
<td>15.0 x 7.5 x 3.5 m</td>
</tr>
<tr>
<td>Array lifetime</td>
<td>&gt;20 a (Module ≈10 a)</td>
</tr>
<tr>
<td>Plant availability</td>
<td>~95%</td>
</tr>
<tr>
<td>Demin water consumption</td>
<td>10 l/kg H(_2)</td>
</tr>
<tr>
<td>Dry gas quality(^3)</td>
<td>99,9999%</td>
</tr>
<tr>
<td>Delivery pressure</td>
<td>Customized</td>
</tr>
</tbody>
</table>

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1 Plant efficiency includes rectifier, transformer, transformer cooling and gas cooling | 2 Primary Frequency Response Service | 3 With DeOxo

July 2021
The modular design of Silyzer 300 can be easily scaled to your demands.

Between 12 and 24 modules

Scale up to the necessary demand

Modular concept to cover wide production rate
With the Silyzer 300 you get a highly efficient plant

View for 17.5 MW
24 modules:
Air cooled
ISO conditions¹

Power
PEM Module
Silyzer System
Auxiliaries
Plant w/o compression
Plant w. compression

Efficiency

Cooling system site specific optimized

>76.5%
>76%
>75.5%
>72.1%

¹ ISO conditions: 15°C, 1013 mbar, 0 m, 60% rel. humidity
² Atmospheric

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The Silyzer 300 enables grid support services with efficient hydrogen yield and maximum dynamics.

- **Start 0 – 100% \( \text{H}_2 \)**: <1 min, enabled grid support
- **Dynamics in range**: 10%/s in range 0 – 100%

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![Diagram showing start and grid support operations with time intervals and hydrogen delivery to TP (Terminal Point).](image-url)
Silyzer 300
Latest and most powerful product line in the double-digit megawatt class

High performance
High efficiency: System >76%
Modular: $H_2$ production range 100 – 2,000 kg/h

Maintenance friendly
Maintenance free module 80,000 OH¹
Easy exchange of modules
No cleaning effort
World wide service coverage

Digitally enabled
Data Driven Operation and Service
Secure Remote Support
Mindsphere

High availability
Advanced design for low degradation
Robust industrial design

Flexible operation
Fast start-up and shut-down
High dynamics
High Gas purity
No hazardous chemicals
Power factor compensation (optional)
No permanent operating personnel required
What can Siemens Energy offer to the P2X customers? Siemens Energy competence along the value chain

Siemens Energy covers important parts of the value chain to deliver Power-to-X projects on turnkey basis.

Solution provider for Power-to-liquids (i.e. Methanol)
- One face to the customer
- Overall system design
- Integration of Siemens products and technology & products from external partners

Wind Park
- Onshore wind
- Offshore wind

Siemens-Gamesa

Power Grid
- Transmission
- Distribution
- Substations
- Transformers
- Power cable systems

Electrolysis
- PEM technology
- Silyzer 300

Machinery
- Compressors
- Storage systems
- Water treatment
- Elec. equipment
- Mech. equipment
- Turbines/engines (back up power)

CO₂ Capture
- Capture from flue gas (PostCap)
- DAC: external

N₂ Supply
- Air separation: external

Synthesis
- Partnering
- CH₃OH
- CH₄
- NH₃
- Own concepts
- Novel, flexible methanol reactor concept in R&D stage

DAC: Direct air capture: Under development; no Siemens Energy activities | CCU: Carbon Capture and Utilization | typical share in value addition

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Energiepark Mainz
World’s largest PEM electrolysis facility in 2015

3.75 MW
Power demand/6.0 MW peak power (limited in time) based on three Silyzer 200

Project
- Customer: Energiepark Mainz (JV of Linde and Mainzer Stadtwerke)
- Country: Germany
- Installed: 2015
- Product: Silyzer 200

Use cases
- Green hydrogen is fed into the local natural gas grid
- Delivery to surrounding industrial companies
- Hydrogen for regional filling stations

Challenge
- Installation of world’s first PEM electrolysis plant in the multiple megawatt range
- Provision of balancing energy
- High degree of automation

Solutions
- Installation of three Silyzer 200 with a maximum power consumption of 6 MW
- Highly dynamic power consumption
- State-of-the-art process control technology based on SIMATIC PCS 7
- Hydrogen processing, condensing, and storage (provided by Linde)
H2FUTURE
A European Flagship project for generation and use of green hydrogen

<table>
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<tr>
<th>Project</th>
<th>Use cases</th>
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<tbody>
<tr>
<td><strong>Partner:</strong> VERBUND (coordination), voestalpine, Austrian Power Grid (APG), TNO, K1-MET</td>
<td><strong>Hydrogen for the steel making process</strong></td>
</tr>
<tr>
<td><strong>Country:</strong> Austria</td>
<td><strong>Supply grid services</strong></td>
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<tr>
<td><strong>Installed:</strong> 2019</td>
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<tr>
<td><strong>Product:</strong> Silyzer 300</td>
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**Challenge**
- Potential for “breakthrough” steelmaking technologies which replace carbon by green hydrogen as basis for further upscaling to industrial dimensions
- Installation and integration into an existing coke oven gas pipeline at the steel plant
- High electrolysis system efficiency of 80%

**Solutions**
- Operation of a 12-module array Silyzer 300
- Highly dynamic power consumption – enabling grid services
- State-of-the-art process control technology based on SIMATIC PCS 7

6 MW
Power demand based on Silyzer 300

1,200 Nm³ of green hydrogen per hour

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735503. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovative programme and Hydrogen Europe and NERGHY