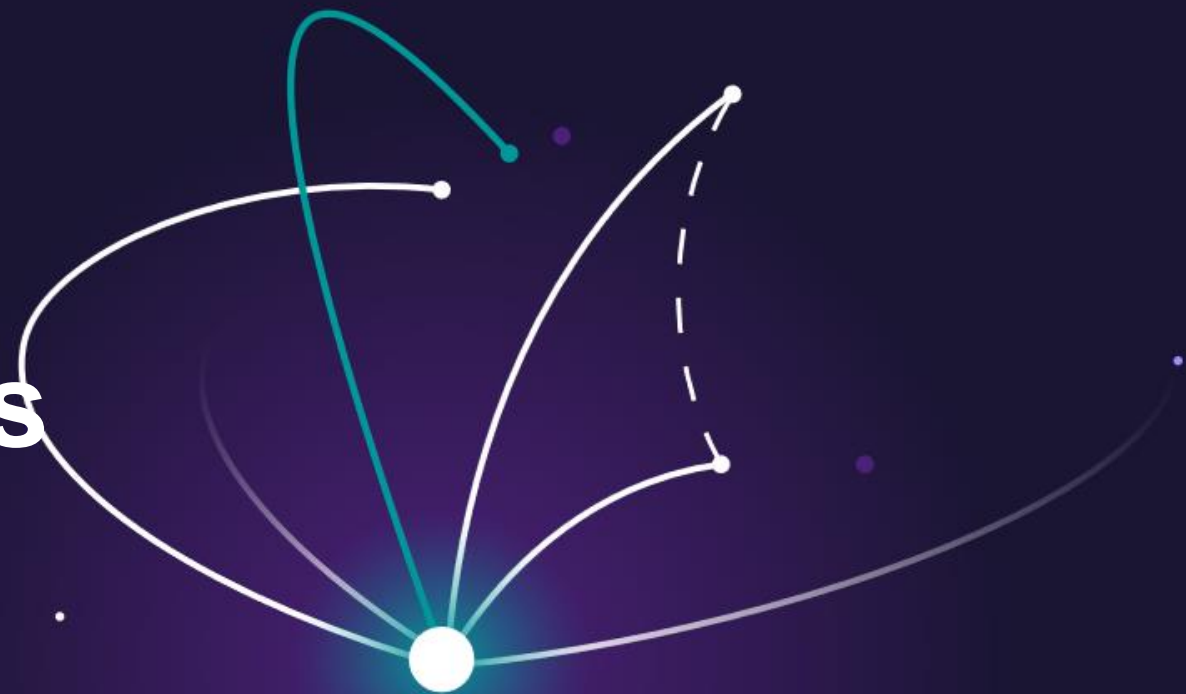


New Energy Business

Large-scale PEM Electrolysis for Industrial Applications

Prof. Dr. Armin Schnettler
March 19, 2021



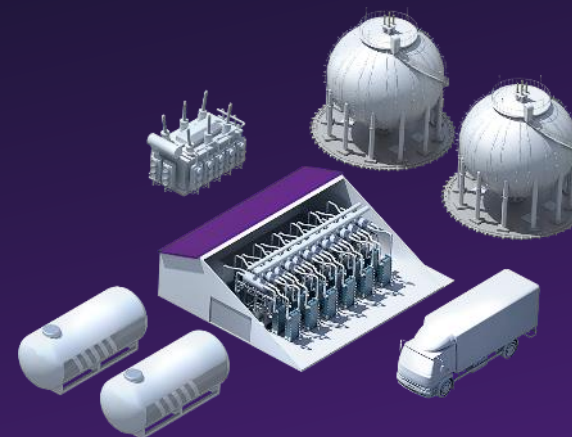
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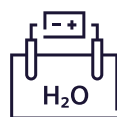
New Energy Business

By enabling the green hydrogen economy, we lead the transition towards a decarbonized world together with our customers and partners



Hydrogen Systems

Industry grade Power-to-hydrogen systems and services



Power-to-X-Solutions

- Power-to-Hydrogen and Power-to-Liquids solutions and services
- Turnkey solution package



Energy Consulting & Digital Services

- Electrolyzer-integrating Energy system design
- Power-to-X digital services and optimization solutions

Focus on Proton Exchange Membrane (PEM) electrolyzer system technology

Operational performance



- **Fast start-up** and shut-down
- Highest **operational flexibility**
- **Cold start capability**

Clean by nature



- Highest **hydrogen purity >99.9%**
- **No aggressive chemical electrolyte**
- **No contaminants** – only water, hydrogen and oxygen in the system

Competitiveness



- **Small footprint** compared to alkaline systems
- **Lower OPEX** compared to alkaline systems due to maintenance-free stack
- **Competitive hydrogen price** per kg at green electricity prices below 3 ct/kWh

We are front runner in industrial scale PEM technology innovation based on our in-house expertise

In-house expertise

- **Membrane Electrode Assembly (MEA):** Highly efficient and unique electrode design, perfectly matching the membrane properties and the Gas Diffusion Layer (GDL)
- **Electrode coating, cell and system design, testing and production**

Industry Scale design

- **Vertical cell design:** Optimization of water and gas transport dynamics through the stack
- **Specific cell frame material:** Enables safe and long-lasting operation of modules

Intellectual Property

- **Broad set of Patents:** ~200 patents about hydrogen generation by electrolysis and electrolyzer technology
- **Patented GDL design:** Cost efficient, fluid-dynamically optimized for water and gas transport, avoiding gas pockets and ensuring best cooling

Siemens Energy Electrolyzer portfolio scales up by factor 10 every 4 – 5 years

Silyzer portfolio roadmap

0.1 MW

1 MW

10 MW

100 MW

1,000 MW

2011

Silyzer 100

Lab scale demo

~20 kOH¹

~30 t of H₂

2015

Silyzer 200

~130 kOH¹

~1700 t of H₂



World's largest Power-to-Gas plants with PEM electrolyzers in 2015 and 2017 built by Siemens

2018

Silyzer 300



Biggest PEM cell in the world built by Siemens

2023+

Silyzer 300 plant



Pre-engineered and pre-fabricated electrolyzer systems enhanced with optimized operational concepts (digital twin)

2028+

Large scale, modular design electrolyzer plants



Silyzer 300 – Full Module Array

The next paradigm in PEM electrolysis

Silyzer 300

Full module array
(24 modules) ...



... and close-up of 6
modules (Linz plant)



17.5 MW
plant power demand

>75.5%
plant efficiency

24 modules
to build a full module array

335 kg
hydrogen per hour

German government funding drives innovation and development of electrolyzer production and technology



H₂Giga project draft accepted by Ministry of Education and Research

Initiator



German Federal
Ministry of Education and
Research

Duration



5/2021 to 4/2025

Status



H₂Giga project draft
accepted by BMBF –
full application ongoing



We leverage
funding in
innovation on
production and
innovation



01 SEGIWA

Development of **GW scale serial production** of PEM type water electrolyzers

SEGIWA – SEries production GIgaWAtt
DERIVA – DERIsking of VALue chain

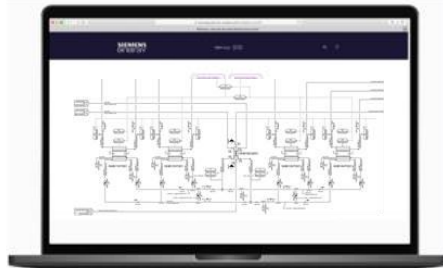


02 DERIVA

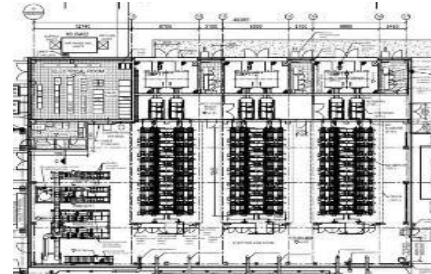
Green H₂ based biogenic kerosene production

Prepared for delivery at Gigawatt scale

Standardization, Modularization and Manufacturing



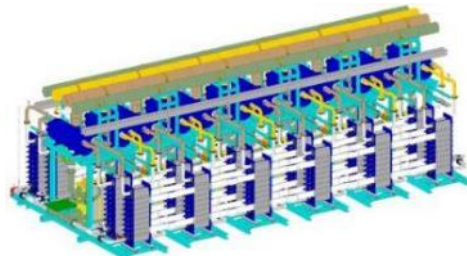
Digital engineering



50 MW plant design based on Silyzer 300



Prefabricated group of 4 modules



Silyzer 300 array system design



- **Standardized plant design** based on **modular** building-blocks
- **Pre-fabricated groups** with pre-defined interfaces
- Integrated **digital engineering** tools

- Ramp-up of manufacturing towards a lean **Gigafactory**
- Flexible **expansion to Multi-GW**
- **Automated**, highest-quality Silyzer production

Strong partnerships facilitate NEB business success



Project-specific/technology partners

Development of dedicated projects and coverage of complementary technologies in the PtH₂/PtL value chain



Partnerships with regional focus

Strengthened regional market access and localized parts of the value creation



Long-term, strategic alliance

Joint projects, manufacturing, innovation and eco system



Siemens ecosystem

SGRE and Siemens Mobility

Siemens Mobility

SIEMENS Gamesa
RENEWABLE ENERGY



6 MW

Power demand based on Silyzer 300

1,200 Nm³

of green hydrogen per hour



H₂FUTURE

A European Flagship project for generation and use of green hydrogen





Project

- Partner: VERBUND (coordination), voestalpine, Austrian Power Grid (APG), TNO, K1-MET
- Country: Austria
- Installed: 2019
- Product: Silyzer 300

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%

Use cases

-  Hydrogen for the steel making process
-  Supply grid services

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



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



750,000 liters

of e-methanol per year from 2022
(130,000 liters of e-gasoline)

>55m liters

e-fuel per year
planned from 2024

>550m liters

e-fuel per year
planned from 2026



Haru Oni Pilot Project

First integrated plant for climate-neutral e-fuel production from wind and water



Project

- Customer: HIF (Highly Innovative Fuels)
- Off-taker: Porsche AG
- Country: Chile, Patagonia
- Installation: 2021
- Product: Power-to-methanol solution based on SE Electrolyzer

Opportunity

- Huge wind energy potential in Magallanes
 - Existing industry and port infrastructure
- Perfect conditions to export green energy from Chile to the world

Use cases



E-Fuel for Porsche cars

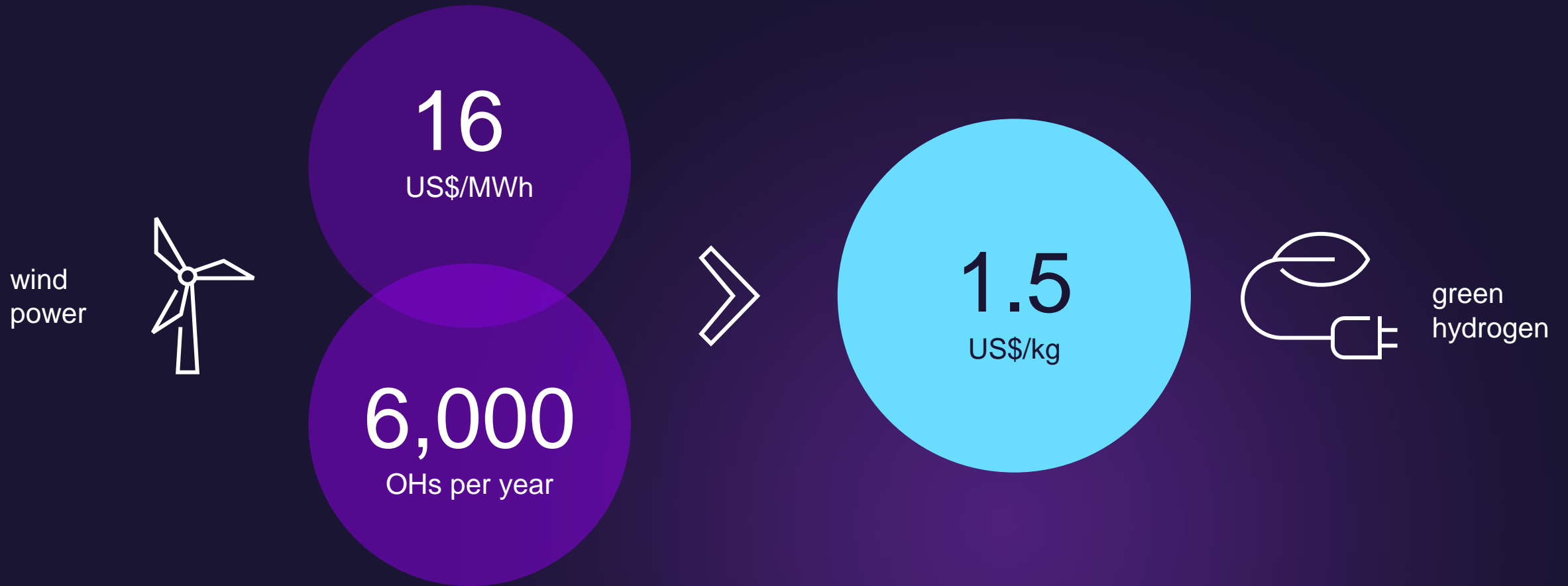
Potential for adding Kerosene or Diesel production in future phases

Methanol for ship motors

Solutions

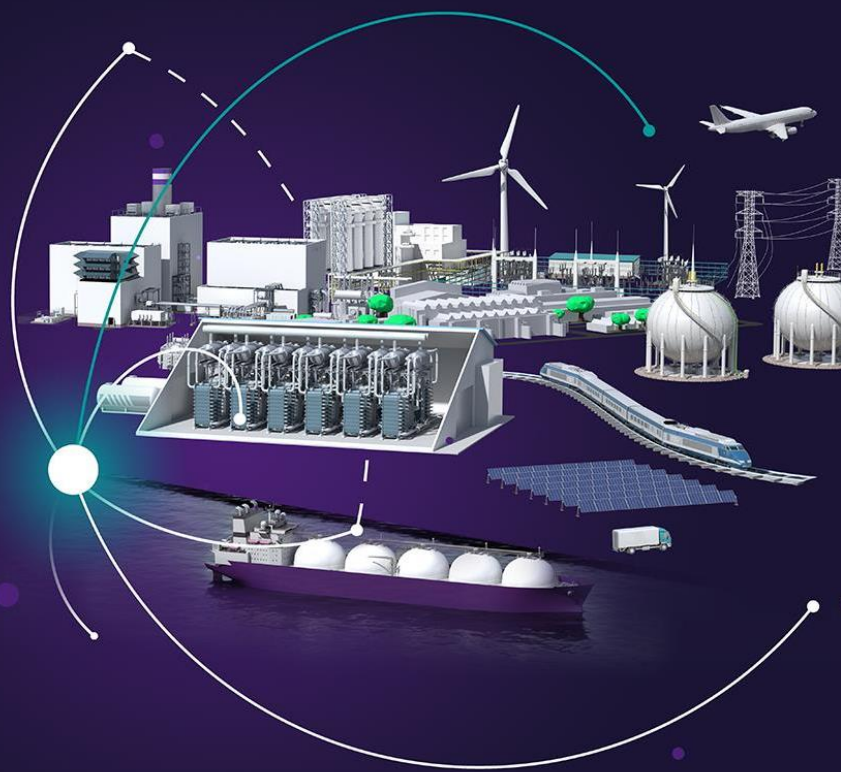
- Production of e-gasoline and e-methanol at one of the best spots worldwide for wind energy
- Co-developer Siemens Energy realizing the system integration from wind energy to e-fuel production
- International Partners like Porsche and AME

Competitiveness to grey hydrogen expected by 2025 based on large scale commercial projects in operation



OHs: Operating hours | **Assumptions:** GW manufacturing, 100 MW electrolyzer capacity, scope w/o gas treatment/compression systems

Conclusions



WHY

- Green hydrogen is the second stage of the energy transition
- Indispensable for decarbonization

WHAT

- In-house PEM electrolysis technology
- Large Power-to-X solutions enabled by the full Siemens Energy competence
- Digital twin and service concepts

HOW

- Secure technology and cost leadership
- Implement Giga factory
- Strong international partner ecosystem

We know how to industrialize technologies!