PEM Electrolysis: Enabling a Decarbonized Energy Future
Stephen Szymanski, Proton OnSite
May 8, 2017
Company Overview….for today

- World leader in PEM water electrolysis
- 2,700 Systems delivered in 75 countries for:
  - Industrial applications
  - Laboratory markets
  - Military customers
  - Fueling and energy storage
- ISO 9001:2008 certified
- ~ 100 employees
Contemplated acquisition of Proton OnSite

27 February 2017

“Acquiring the world's largest manufacturer of PEM hydrogen electrolysers”

PRESS RELEASE / OSE FILING
27 February 2017 – Oslo, Norway
Nel ASA: Acquires Proton OnSite to create the world’s largest electrolyser company and launches private placement
Commercial Electrolysis Technologies

- Liquid KOH
  - Corrosive electrolyte
  - Enables non-noble metals
- PEM = solid electrolyte

Liquid KOH

Proton Exchange Membrane (PEM)
Where our electrolyzers are used

**Power Plants**
- Cooling electric generators

**Laboratories**
- Carrier gas for analytical instrumentation

**Other Industrial**
- Process gas for semiconductors, heat treatment, and meteorology

**Grid Energy Storage**
- Storing stranded excess renewable energy

**Biogas**
- Turning waste CO₂ into methane

**Transportation**
- Fueling fuel-cell vehicles

**Military**
- Oxygen production and specialty vehicle fueling
How much H$_2$ can we make?

- **7 kW**: 1 day: 2.3 kg
- **40 kW**: 1 day: 13 kg
- **175 kW**: 1 week: 455 kg
- **1,000 kW**: 1 day: 451 kg
Announcing the largest PEM electrolyzer sale in the world!

Proton OnSite Awarded 13 Megawatt Electrolyzers for the Deployment of Fuel Cell Buses in China

- World’s largest megawatt PEM electrolyzer deal
- Electrolyzers to provide green hydrogen for fuel cell bus fueling in China
- 3 systems released for shipment; balance to ship over next 18 months
M Series Building Blocks

- Process Skid – Stacks, Cooling & O₂ Mgt
- H₂ Gas Mgt Skid – Water Removal
- Power Supplies, Power Distribution & Controls
- PLC-based HMI Interface
“P2G”: storing electricity as a gas
P2G enables bulk/seasonal energy storage:
“P2G Hydrogen”: hydrogen is the end-use fuel
“P2G Methane”: hydrogen is converted to syngas
P2G Demo Project Site: UCI Central Plant
Sponsor: SoCalGas

Proton’s electrolyzer injecting hydrogen into the CNG piping at the UCI Central Plant, feeding their combined-cycle turbine generator. A first in the U.S.!
P2G with microbial methanization:
Viessmann (MicrobEnergy), Schwandorf, Germany

- 30Nm³/h Proton PEM electrolyser combined with a methanization process.
- H₂ produced from surplus electricity & combined with CO₂ from a biogas plant to produce bio-methane (4H₂ + CO₂ → CH₄ + H₂O).
- Bio-methane is injected into the gas grid, leading to a carbon neutral process.
“Levelized Cost of Returned Energy”: analysis of P2G use-cases shows P2G can compete with batteries on cost

**LCORE Results**

**CURRENT COSTS & EFFICIENCES**

- 45% Capacity Factor for Batteries;
- 90% Capacity Factor for All Other Equipment

---

![Diagram showing energy storage and conversion processes](image)

- Battery Energy Storage: $31.56/GJ ~ $67.06/GJ
  - $113.36/MWh ~ $240.85/MWh
- Electric Grid: $58.30/GJ ~ $158.71/GJ
  - $209.40/MWh ~ $570.02/MWh
- Power to Grid: $19.50/GJ ~ $63.12/GJ
  - $70.03/MWh ~ $226.72/MWh

- Power from Wind and Solar

- Electrolyzer: $5.24/GJ ~ $11.47/GJ
  - $0.74/kg H₂ ~ $1.62/kg H₂
- Methanation: $10.02/GJ ~ $20.77/GJ
  - $5.52/MMBtu ~ $12.07/MMBtu
- Natural Gas Pipelines and Storage Facilities

---

*SoCalGas, A Sempra Energy Utility*
**Key Takeaway:**
Even with a dedicated fuel cell for converting the stored energy back to electricity, P2G is cost effective at longer discharge times.
Improving the economics of renewable H2:

Cost of Hydrogen Production ($/kg)

- **4.20**
- **3.46**
- **2.24**
- **1.95**

**Capacity Factor**
- 97% 66%
- 40% 66%
- 40% 60%
- 90%

**Cost of Electricity**
- $6.6/kWh
- $1/kWh
- $1/kWh
- Steam Methane Reforming (SMR)

**Capital Cost**
- $400/kW
- $400/kW
- $100/kW

**Efficiency (LHV)**
- 66%
- 66%
- 60%

**DOE H2@Scale webinar, 7/28/16**
Where do we need to go from here?

• Regulatory and systemic barriers need to be removed: all energy storage is not like a battery!
• Use cases that support a business case need to be developed and proven.
• Some technology work remains:
  – Electrolysis efficiency improvements and cost reduction.
  – Power conversion and controls for renewable electrolysis.
  – Gas blending and end-use conversion devices.
  – Biomethanation, ammonia synthesis, other process development.
• A relevant grid scale demonstration, showing multiple value streams from a P2G system.
Renewable Electrolysis
Enabling the Future of an Integrated Energy System