HTE Status, Needs, and Meeting Hydrogen Shot Target

Olga Marina
Solid Oxide Electrolysis Cell (SOEC): Mature Technology with Low-Cost Materials

- **Electrolyte**: stabilized zirconium oxide
- **Hydrogen electrode**: Ni-zirconium oxide composite
- **Oxygen electrode**: ceramics La(Sr)CoO$_3$ or La(Sr)Fe(Co)O$_3$
- **Interconnect**: stainless steel with protective coatings against oxidation and Cr volatilization
- **Low cost (no Pt, Ir) materials**

**Stack of cells**

**Single Cell**

![Diagram of a single SOEC cell](https://doi.org/10.1016/j.nanoen.2017.11.074)

- H$_2$ + H$_2$O \rightarrow \text{Cathode}
- H$_2$O \rightarrow \text{Electrolyte}
- Anode
- Interconnector
- O$_2$ \rightarrow \text{Cathode}

**Electrolyte**
- Stabilized zirconium oxide

**Hydrogen electrode**
- Ni-zirconium oxide composite

**Oxygen electrode**
- Ceramics La(Sr)CoO$_3$ or La(Sr)Fe(Co)O$_3$

**Interconnect**
- Stainless steel with protective coatings against oxidation and Cr volatilization

**Low cost (no Pt, Ir) materials**

**Figure source**: https://doi.org/10.1016/j.nanoen.2017.11.074
HTE Achieve Very High Electrical Efficiencies; Energy is Provided by Heat

High temperatures provide thermodynamic and kinetic advantages

- > 95% stack electrical efficiency
- Thermal integration opportunities with process heat sources
- 90% system thermodynamic efficiency of making H₂
- Pressurization
- Low operating voltage, 1.28V

To enable large-scale commercialization, at least 5 years life is required
Scaleup and Demonstration Projects Started

Demo Projects

- 2.6 MW
- 250 kW HTE module successfully tested in May 2021 by Sunfire; 2.6 MW planned for 2022
- 120 kW DC reversible SOFC energy storage system demonstrated at Boeing Huntington Beach connected to the Southern California Edison grid.
- 50 kW, 120 kW, 320 kW, 720 kW, 1 MW
- Bloom Energy’s manufacturing facilities are capable of producing 500 MW of electrolysers; GW within a year

Haldor Topsoe to build large-scale SOEC electrolyzer manufacturing facility to meet customer needs for green hydrogen production

Production capacity of 500 MW/year, expandable to 5 GW; operational by 2023

• Demonstrate hydrogen production using direct electrical power offtake from a nuclear power plant (NPP)

• Develop monitoring and controls procedures for scaleup to large commercial-scale hydrogen plants

• Evaluate power offtake dynamics on NPP power transmission stations to avoid NPP flexible operations

• Produce hydrogen for captive use by NPPs and first movers of clean hydrogen

Figures source: INL (R. Boardman), 2021
H2NEW Consortium: H2 from the Next-generation of Electrolyzers of Water

H2NEW for HTE focuses on higher TRL electrolyzer technologies, based on oxide ion conductors. The emphasis is not on new materials but addressing components, materials integration, and manufacturing R&D.

Clear, well-defined stack metrics to guide efforts

<table>
<thead>
<tr>
<th>Electrolyzer Stack Goals by 2025</th>
<th>LTE PEM</th>
<th>HTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>$100/kW</td>
<td>$100/kW</td>
</tr>
<tr>
<td>Elect. Efficiency (LHV)</td>
<td>70% at 3 A/cm²</td>
<td>98% at 1.5 A/cm²</td>
</tr>
<tr>
<td>Lifetime</td>
<td>80,000 hr</td>
<td>60,000 hr</td>
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Makes use of a combination of world-class experimental, analytical, and modeling tools

Durability/lifetime is most critical, initial, primary focus of H2NEW

- Limited fundamental knowledge of degradation mechanisms including under future operating modes
- Lack of understanding on how to effectively accelerate degradation processes.
- Develop and validate methods to accelerate identified degradation processes to evaluate durability in weeks or months instead of years.
- National labs are ideal for this critical work due to existing capabilities and expertise combined with the ability to freely share research findings.
Hydrogen Energy Earthshot

“Hydrogen Shot”

“1 1 1”
$1 for 1 kg clean hydrogen in 1 decade

Launched June 7, 2021
Is Hydrogen Shot Achievable? How can we get there?

• R&D needs and technical gaps (panel session)
• Materials and components
• Key cost drivers:
  – Overall efficiency
  – Low electricity price
  – Thermal integration
  – Operating strategy/dynamic response
  – Low CAPEX
Identifying Pathways to Reduce Hydrogen Cost to $1/kg H₂

Key enablers for lower cost electrolytic H₂

- Electricity price
- High electrical efficiency
- Thermal integration
- Low-cost CAPEX
- Manufacturing at scale
- Low-cost manufacturing methods

Baseline: $50/MWh, $1500/kW system, 5 y. stack life, 70% eff.

Figures source: INL (R. Boardman), 2021

Figure source: PNNL (J. Holladay), 2021