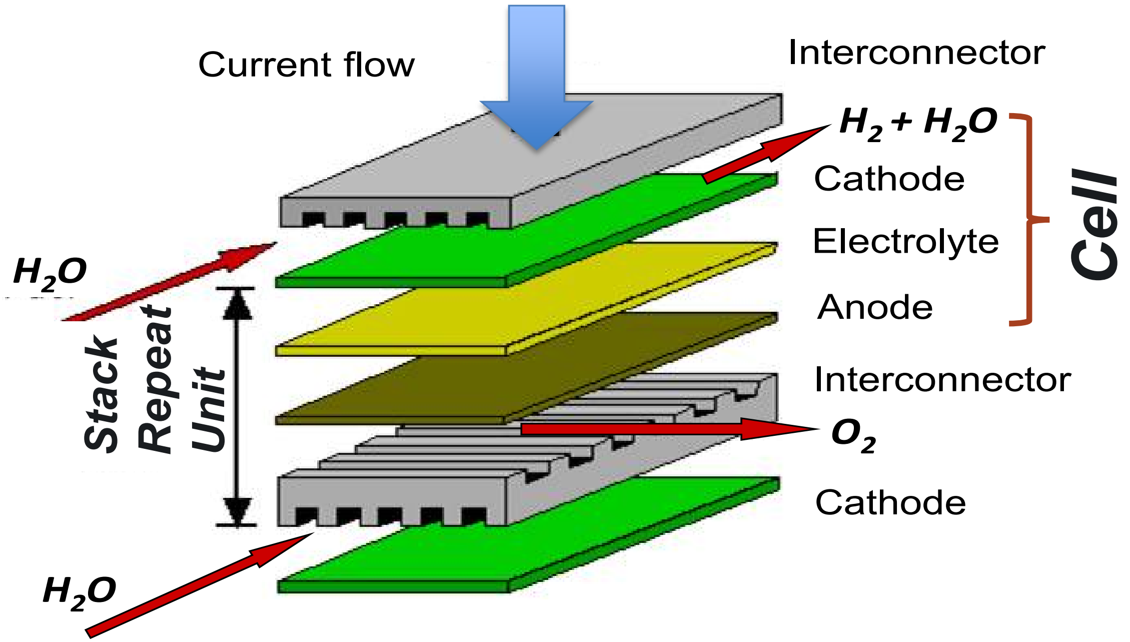
Hydrogen

HTE Status, Needs, and Meeting Hydrogen Shot Target

Olga Marina

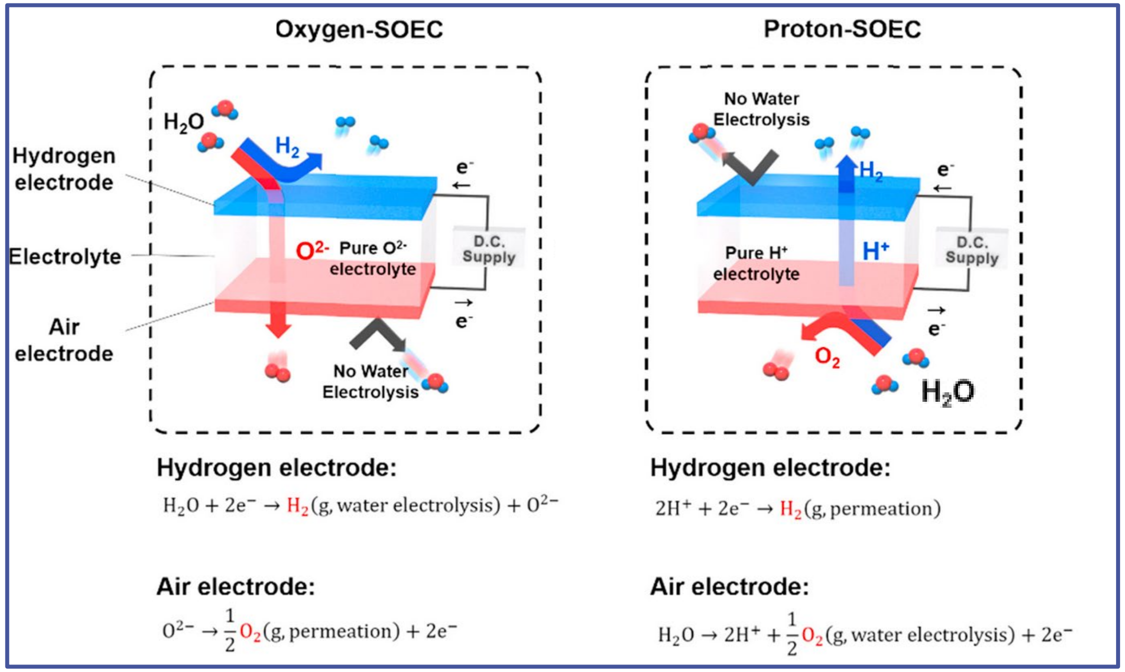
Hydrogen Shot Summit

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



Single Cell

Stack of cells



- 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

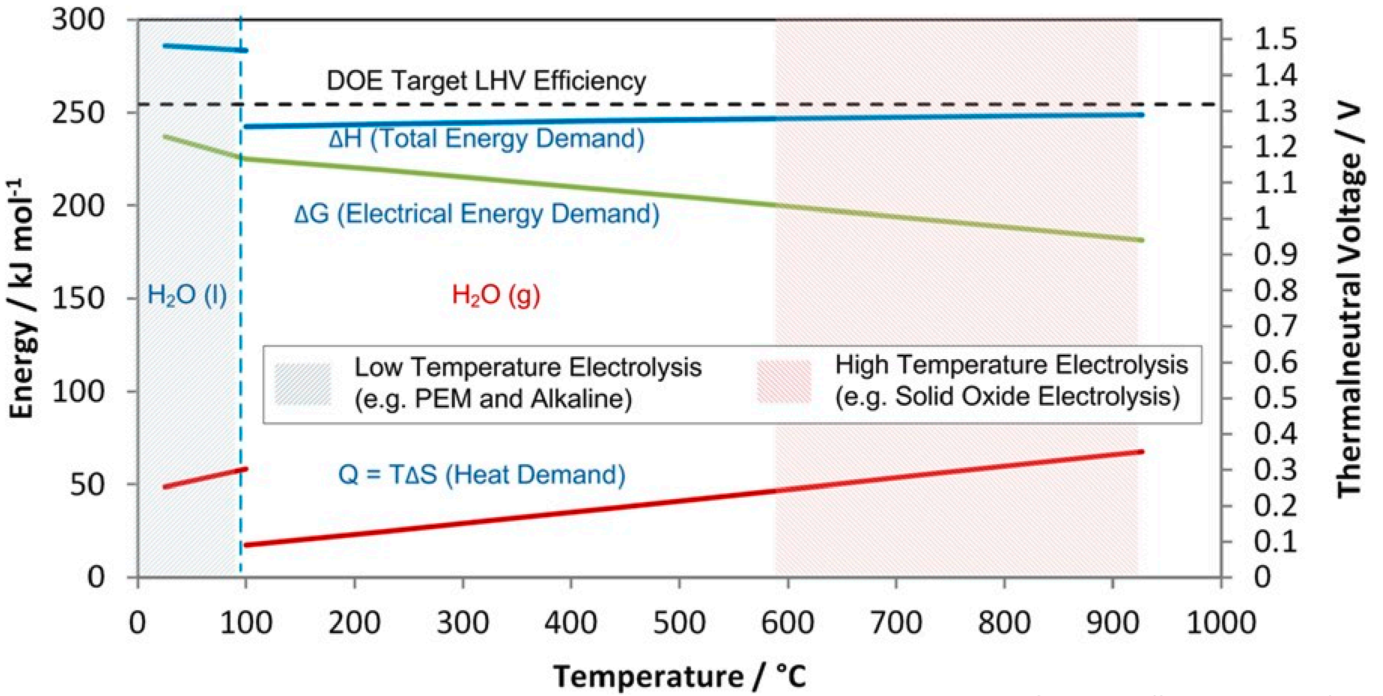


Figure source: DOI 10.1002/fuce.201600185)

FuelCell Energy (USA)

OxEon (USA)

Nexceris (USA)

BloomEnergy (USA)

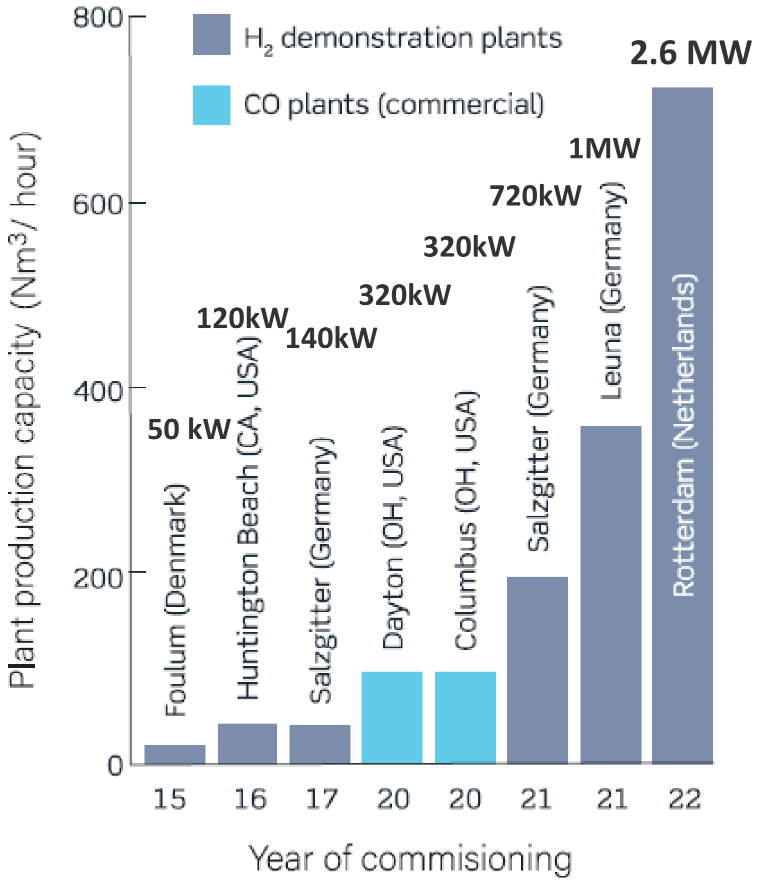
High temperatures provide thermodynamic and kinetic advantages

- **> 95% stack electrical efficiency**
- **Thermal integration opportunities with process heat sources**
- **90% system thermodynamic efficiency of making H_2**
- **Pressurization**
- **Low operating voltage, 1.28V**

To enable large-scale commercialization, at least 5 years life is required

Scaleup and Demonstration Projects Started

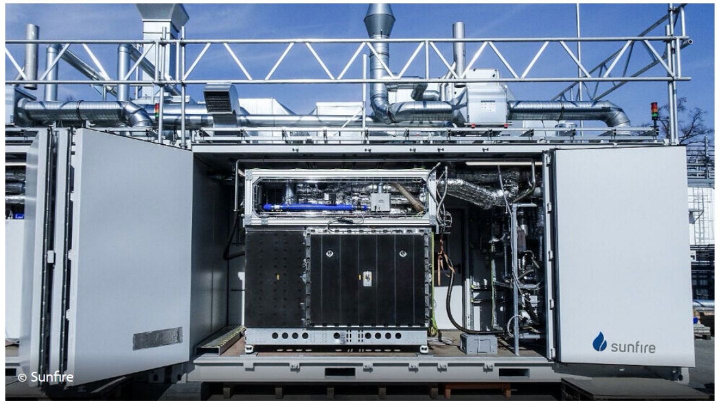
Demo Projects



Hauch *et al.*, *Science* **370**, eaba6118 (2020)

120 kW$_{DC}$ reversible SOFC energy storage system demonstrated at Boeing Huntington Beach connected to the Southern California Edison grid.

https://onlinelibrary.wiley.com/doi/full/10.1002/fuce.201600185



250 kW HTE module successfully tested in May 2021 by Sunfire; 2.6 MW planned for 2022

https://fuelcellsworks.com/news/sunfire-successfully-tests-the-worlds-largest-high-temperature-electrolysis-module/

Bloom Energy's manufacturing facilities are capable of producing 500 MW of electrolyzers; GW within a year

https://www.bloomenergy.com/news/bloom-energy-unveils-electrolyzer/

March 4, 2021

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

https://blog.topsoe.com/haldor-topsoe-to-build-large-scale-soec-electrolyzer-manufacturing-facility-to-meet-customer-needs-for-green-hydrogen-production

Joint EERE-NE Hydrogen Production Demonstration Projects at NPP

H2@Scale U.S. Department of Energy

LWRS LIGHT WATER REACTOR SUSTAINABILITY

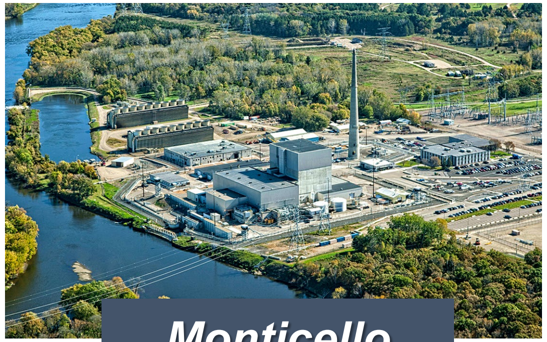
- Demonstrate hydrogen production using direct electrical power offtake from a nuclear power plant (NPP)
- Develop monitoring and controls procedures for scaleup to large commercial-scale hydrogen plants
- Evaluate power offtake dynamics on NPP power transmission stations to avoid NPP flexible operations
- Produce hydrogen for captive use by NPPs and first movers of clean hydrogen

Davis-Besse Nuclear Power Plant LTE-PEM Vendor 1

Nine Mile Point Nuclear Power Plant LTE/PEM Vendor 2

Thermal & Electrical Integration at an Xcel Energy Nuclear Plant HTE/Vendor 1

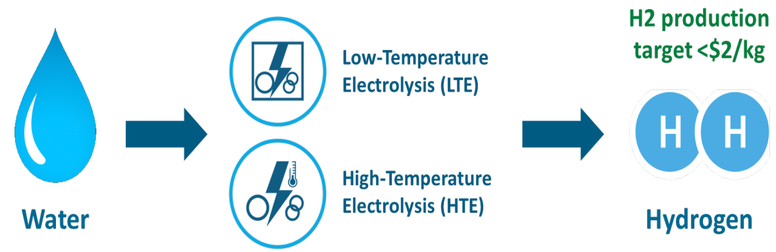
Prairie Island



Monticello

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

National Lab Consortium Team

NREL NATIONAL RENEWABLE ENERGY LABORATORY

INL Idaho National Laboratory

Argonne NATIONAL LABORATORY

BERKELEY LAB

Pacific Northwest NATIONAL LABORATORY

Los Alamos NATIONAL LABORATORY

Lawrence Livermore National Laboratory

OAK RIDGE National Laboratory

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

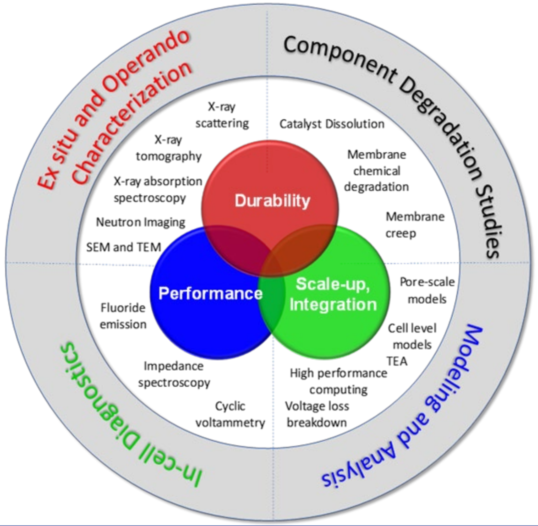
H2NEW U.S. DEPARTMENT OF ENERGY

Clear, well-defined stack metrics to guide efforts

Electrolyzer Stack Goals by 2025

	LTE PEM	HTE
Capital Cost	$100/kW	$100/kW
Elect. Efficiency (LHV)	70% at 3 A/cm²	98% at 1.5 A/cm²
Lifetime	80,000 hr	60,000 hr

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.


ENERGY earthshots U.S. DEPARTMENT OF ENERGY
Hydrogen
Hydrogen Energy Earthshot
“Hydrogen Shot”
“1 1 1”
$1 for 1 kg clean hydrogen
in 1 decade
Launched June 7, 2021
DEPARTMENT OF ENERGY UNITED STATES OF AMERICA

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 H_2

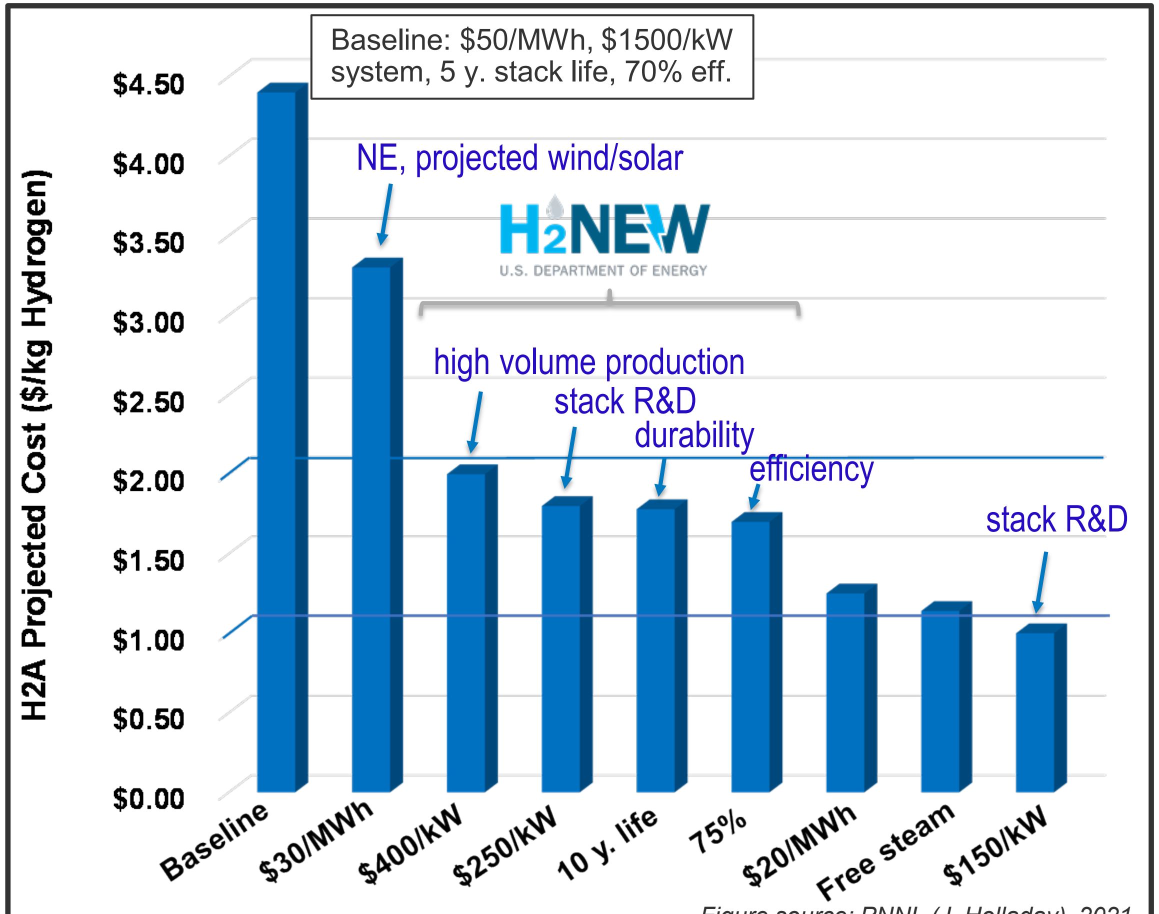
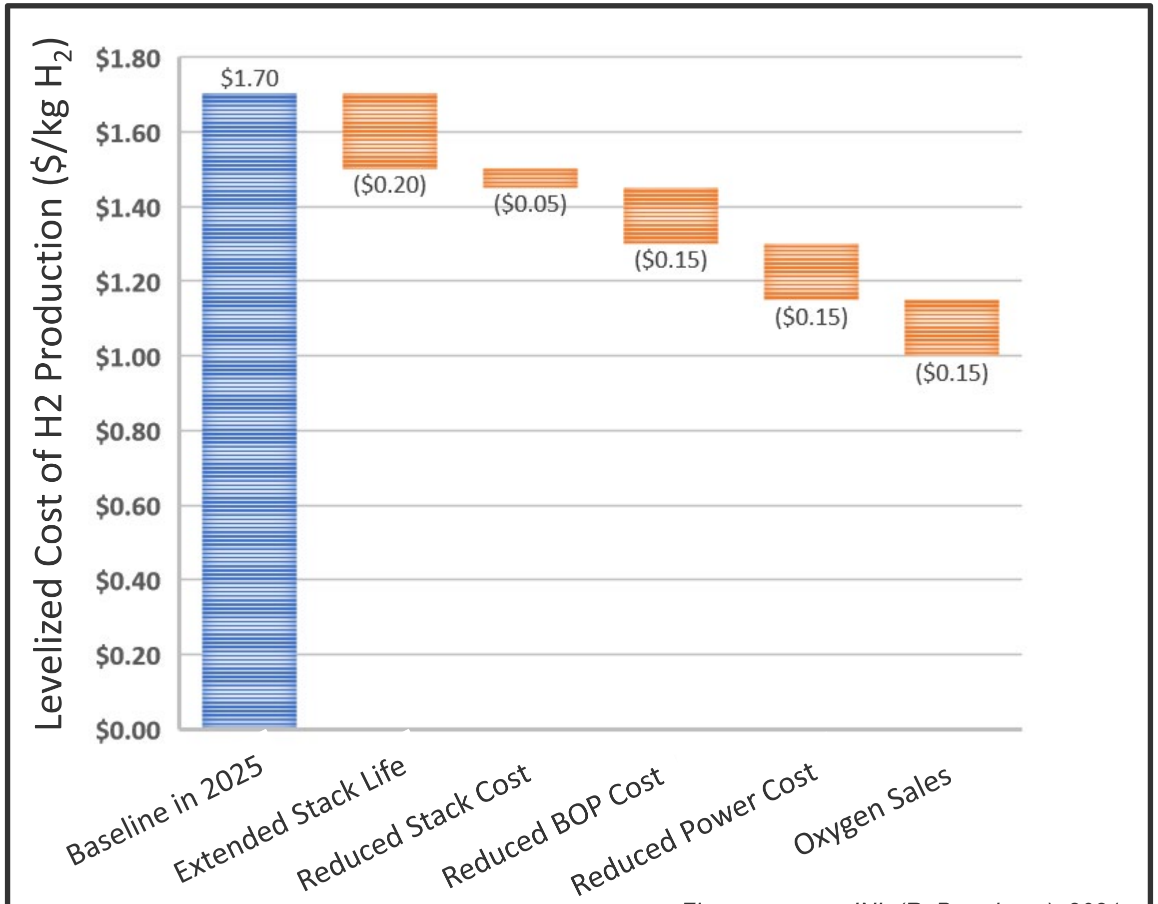


Figure source: PNNL (J. Holladay), 2021



Figures source: INL (R. Boardman), 2021

Key enablers for lower cost electrolytic H_2

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

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