Solid Oxide Electrolysis for Hydrogen and Fuels Production

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Founder and CTO

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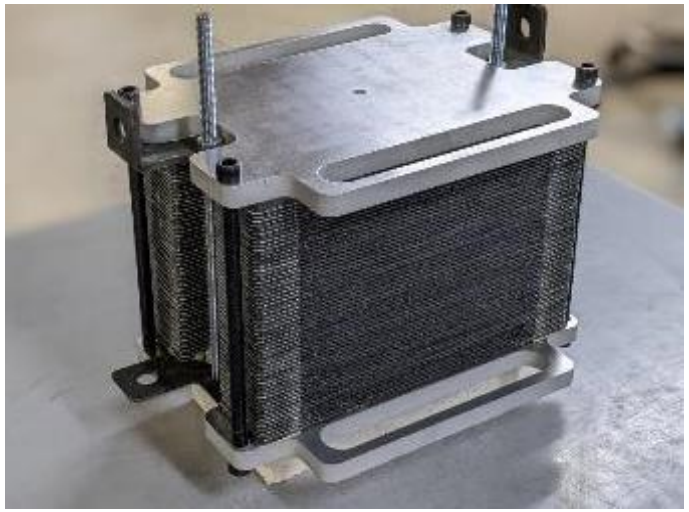

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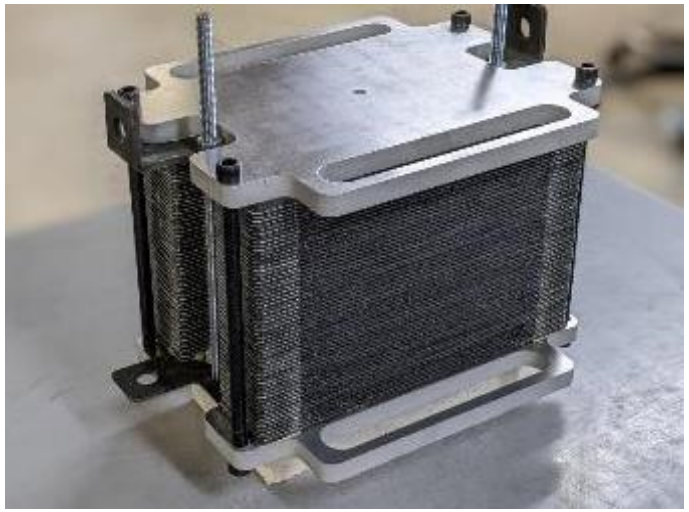
Solid Oxide Electrolysis for Hydrogen and Fuels Production

Presentation Outline:

- About Nexceris
- Nexceris SOEC Cell and Stack Technology
- Recent SOEC Stack Testing Results
- Co-Electrolysis for Syngas and SAF Production
- Q&A



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Premier Solution Provider to the Climate Tech Industry

Vertically Integrated Material Science and Engineering Firm

- Over 30 years of continuous business operations.
- Servicing the industry with products and services since 2000.
- Electrochemical products through Fuel Cell Materials (FCM).
- Catalyst services through HeatPath Solutions.
- Battery safety through Li-ion Tamer.

FCM

HeatPath SOLUTIONS

LI-ION TAMER®

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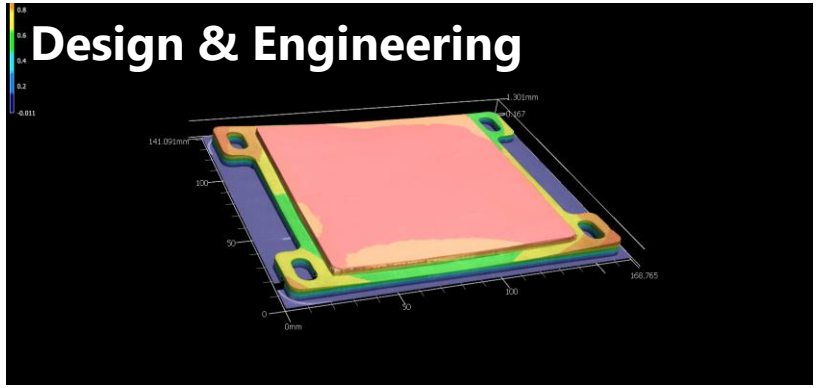
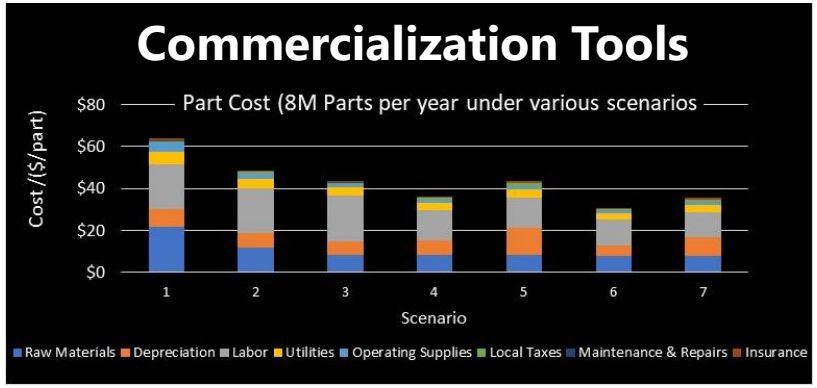
Nexceris Capabilities

Connecting Technology Interfaces with Nexceris Capabilities to Provide Value





- The best solutions come from the use of multiple capabilities.

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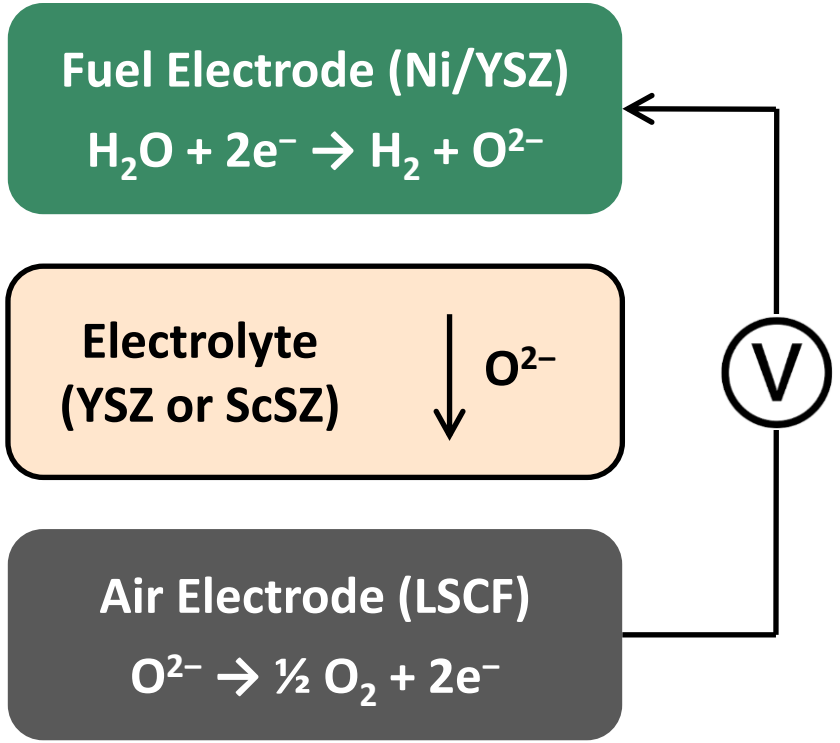
Alternative Electrolysis Technologies

Attribute	SOEC	PEM	Alkaline
Electrolyte	Ceramic	Polymer	KOH
System Efficiency (KWh/kgH_2)	**37-43**	**50-60**	**50-60**
Stack Life (hours)	50k	50-90k	60-100k
Operating T (°C)	600-800	50-80	70-90
Co-Electrolysis (syngas)	**Yes**	**No**	**No**



SOEC provides the highest possible efficiency, especially when integrated with a heat source.

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Key Applications of Solid Oxide Electrolysis

Steel Manufacturing

Ammonia Manufacturing

Nuclear Power Plants

SOEC provides the highest possible efficiency, especially when integrated with a heat source.

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Nexceris – a vertically integrated SOC technology provider

Nexceris is vertically integrated – from materials and cells to stacks and breadboard systems.

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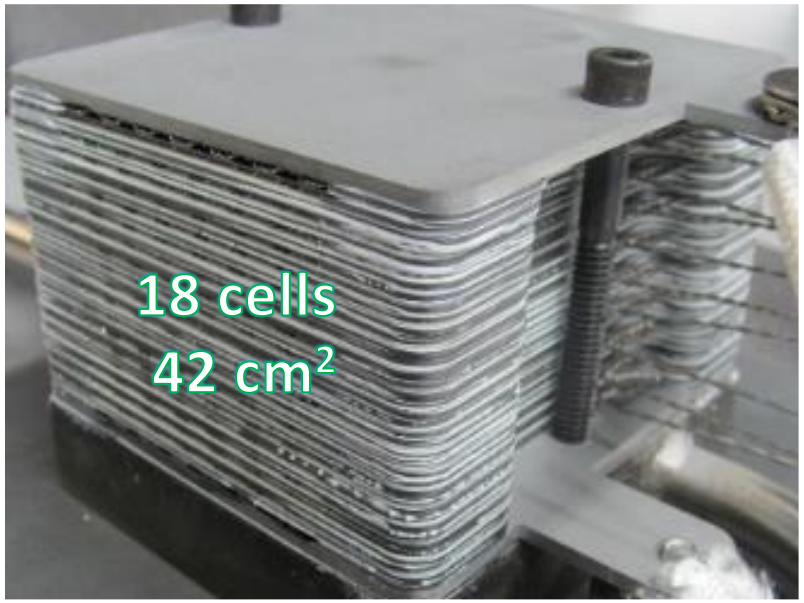
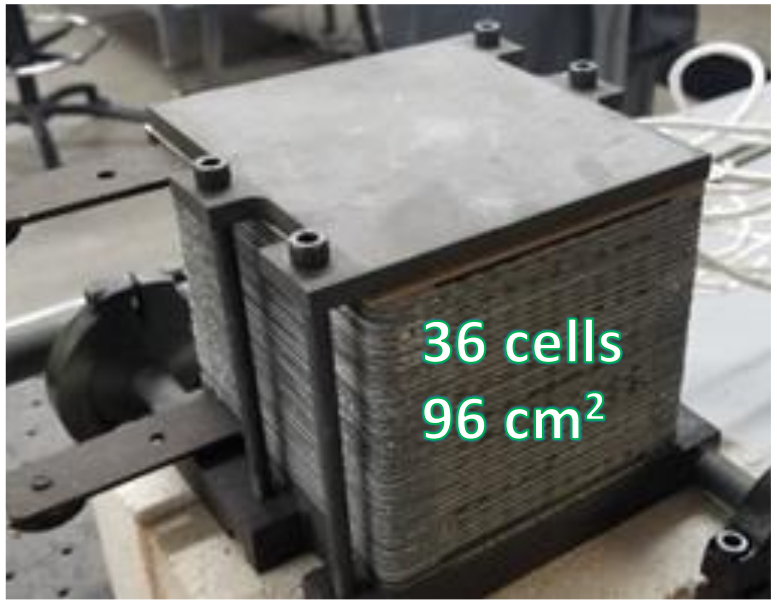
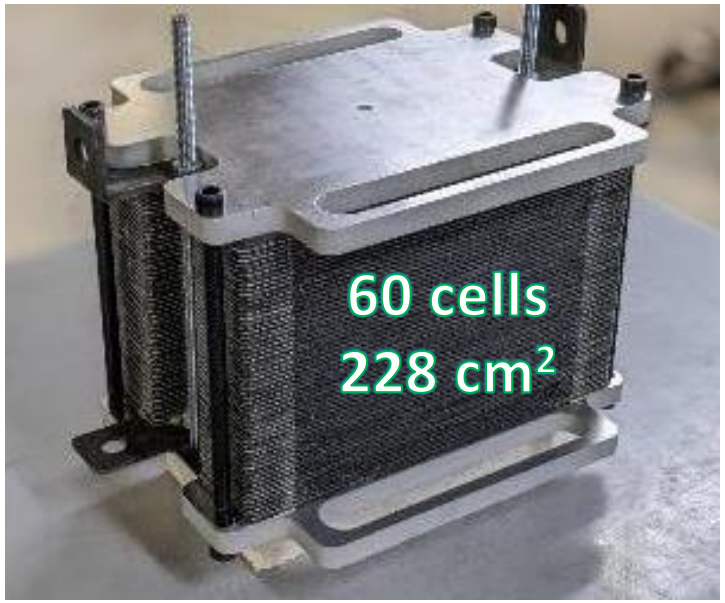
Multiple Nexceris Cell and Stack Platforms







Nexceris SOEC Stack Platforms

- **Multiple stack platforms with active cell areas ranging from 42 to 228 cm².**
- **Different stack platforms used, depending on application requirements or test plans.**

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Cell Design Options for Planar SOEC Stacks

Electrolyte Supported Cells

- Membrane thickness: 100-200 microns.
- High conductivity (ScSz) electrolyte membrane.
- Operating Temperature: 750 to 850 °C.
- Dense cell periphery makes stack sealing easier.
- Manufacturers: **Nexceris**, Bloom, Oxeon, Sunfire.

Fuel Electrode Supported Cells

- Membrane thickness: 3-10 microns.
- High intrinsic performance (thin electrolyte membrane).
- Operating Temperature: 600 to 700 °C.
- Stack sealing can be challenging (porous support layer).
- Manufacturers: FCE, Topsoe, Elcogen, SolydEra.

Nexceris Progress on Reducing Membrane Thickness

Thickness = 54 µm
Flatness = 91 µm

Thickness = 87 µm
Flatness = 124 µm

Thickness = 105 µm
Flatness = 75 µm

Thickness = 120 µm
Flatness = 103 µm

Nexceris established tape casting and sintering methods for thin and flat electrolyte membranes. Reducing electrolyte thickness will be key to improving performance and reducing cost.

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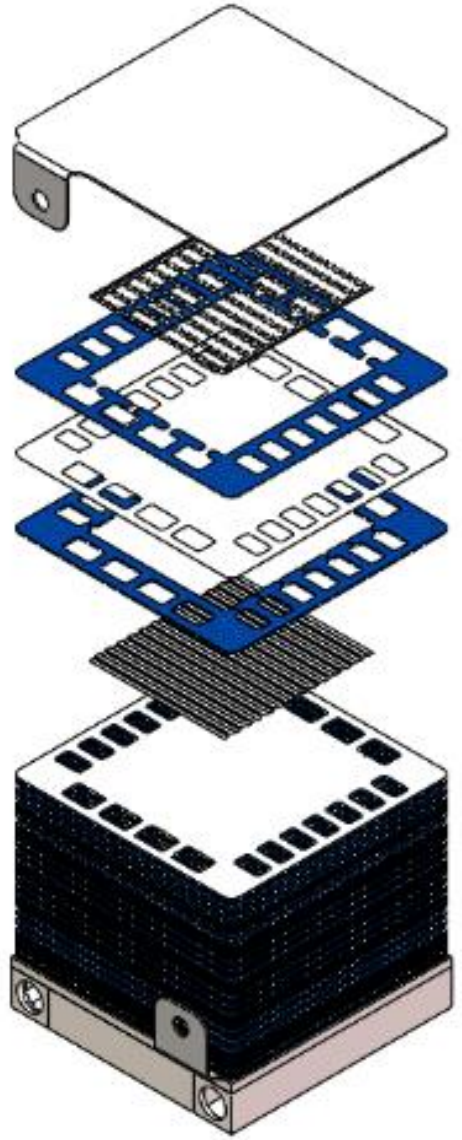
SOEC Stack Design Considerations

Requirements, Challenges and Design Decisions

- ❑ Cell platform: planar or tubular, electrolyte or fuel electrode supported?
- ❑ Cell area and cell count.
- ❑ Co-flow, cross-flow or counter-flow reactant manifolding?
- ❑ Interconnect design – flat plates or built-in flow paths?
- ❑ Internal or external manifolding?
- ❑ Sealing materials and approaches: glass-based or gaskets?
- ❑ Managing thermal expansion mismatches.
- ❑ Fuel flow uniformity: vertical (cell-to-cell) and over the cell area.
- ❑ Maintaining low pressure drops to minimize parasitic losses.



U.S. Patent No. 8,968,956

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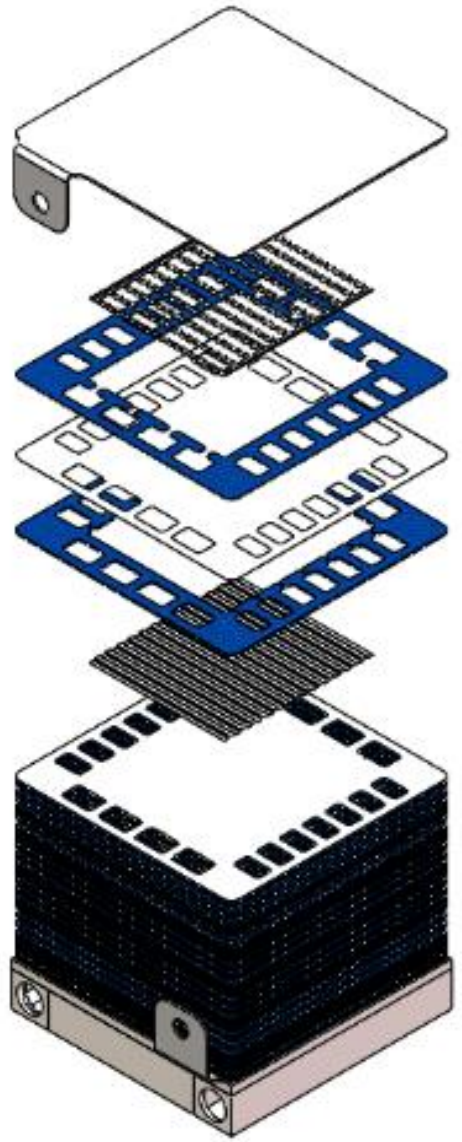
Electrolysis Specific SOEC Stack Design

Stack Design Approach

- ***It's not as simple as running a fuel cell stack in reverse!***
- Nexceris established the following hierarchy of stack design goals: ***Durability > Performance > Cost.***
- **Clean-Slate.** All historical stack design decisions were questioned: ***Were they legacy to fuel cell operation? Are they still valid for electrolysis?***

Stack Design and Validation Progress

- Core stack design established.
- SOEC-specific electrode materials sets established.
- CFD modeling to optimize reactant flow distribution uniformity.
- Components fabricated and several test iterations completed.



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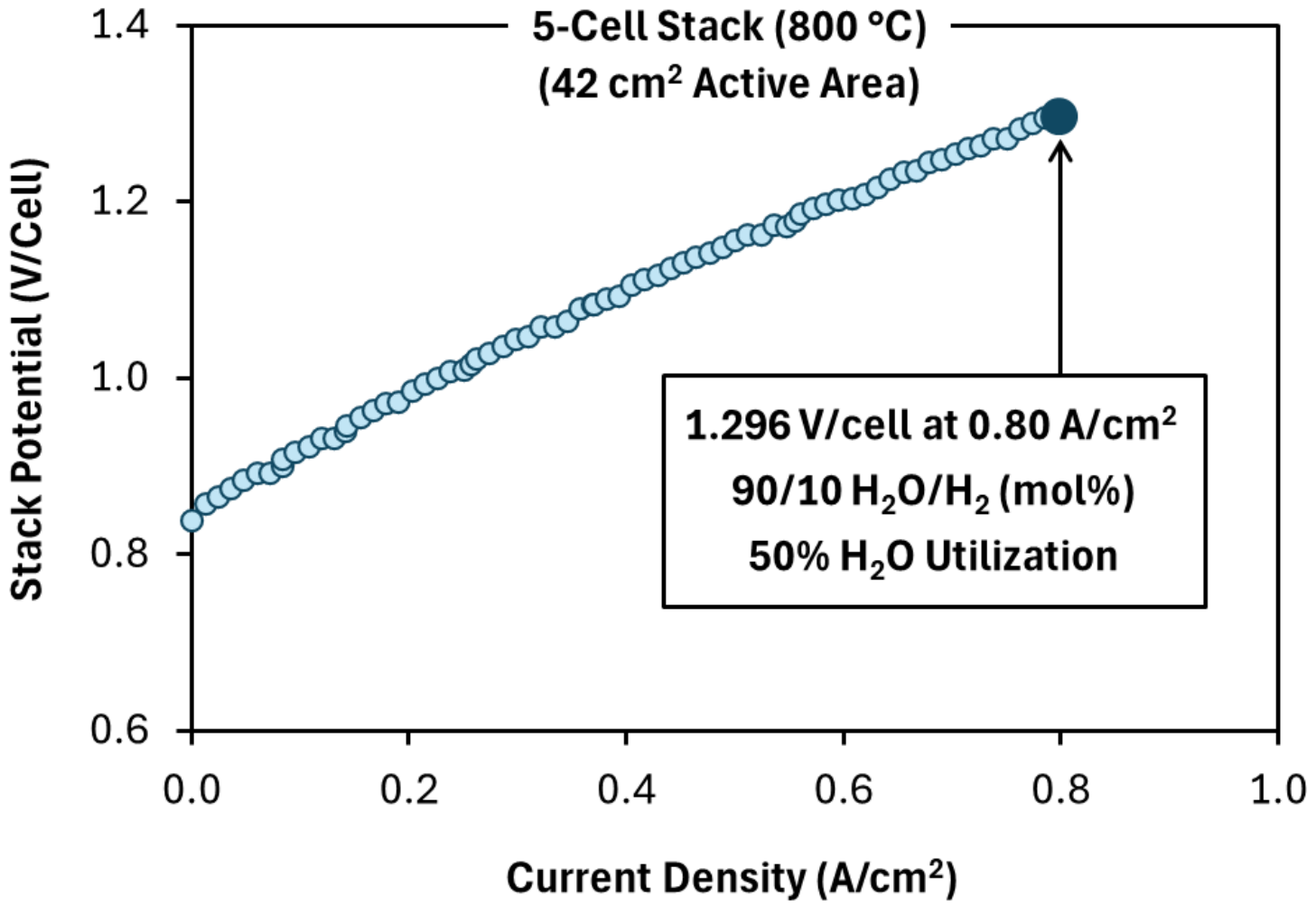
Nexceris Progress on Improving SOEC Stack Performance

Optimizing air electrodes and reducing membrane thickness enabled a current density of 0.8 A/cm² at 1.3 V/cell.



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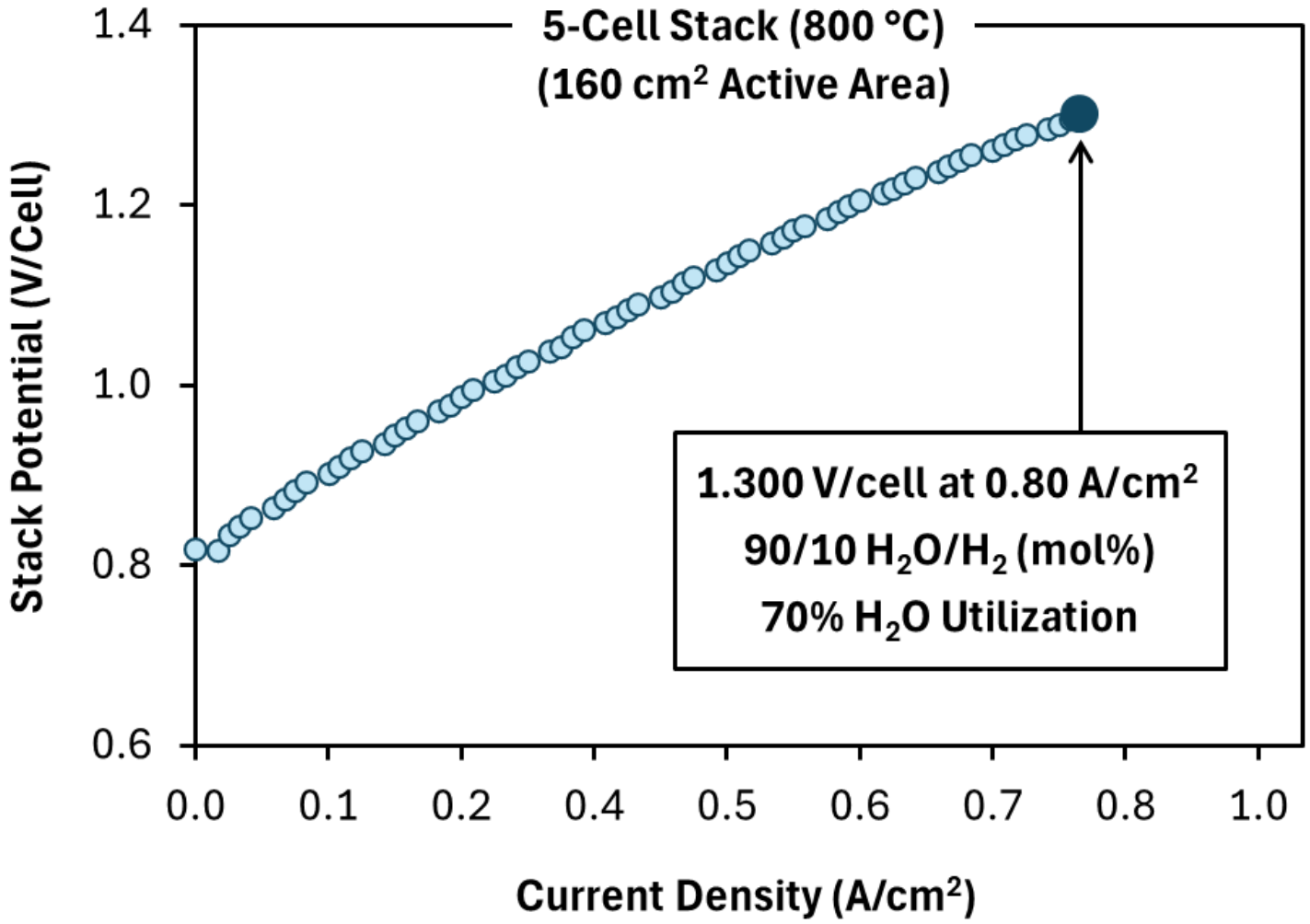
Nexceris Progress on Electrolysis Specific Stack Design

Nexceris electrolysis-specific stack design achieved high steam utilization (improved reactant flow uniformity).



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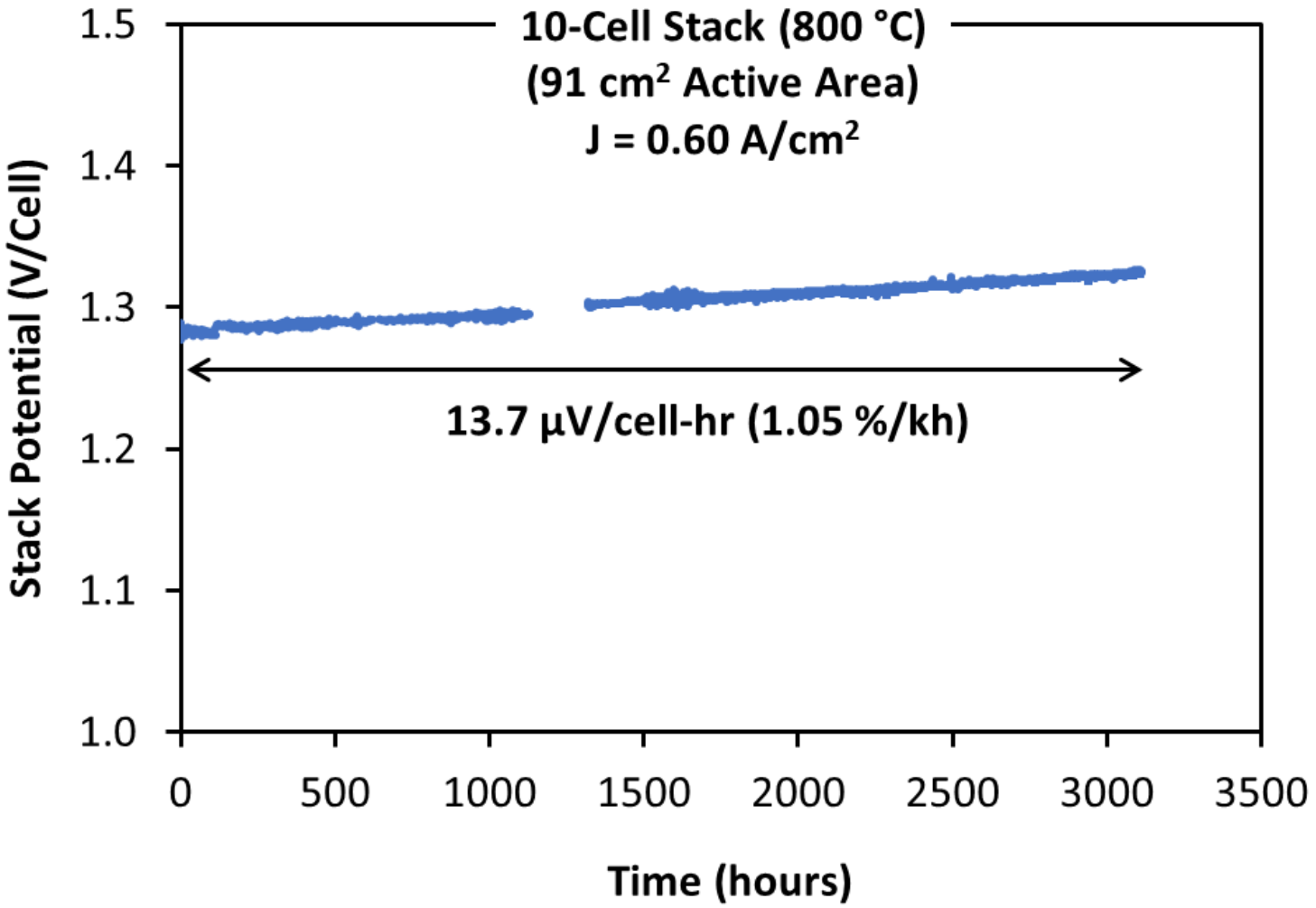
Nexceris Progress on Improving SOEC Stack Durability

Nexceris has demonstrated low degradation rates in stacks operating at relatively high current density.



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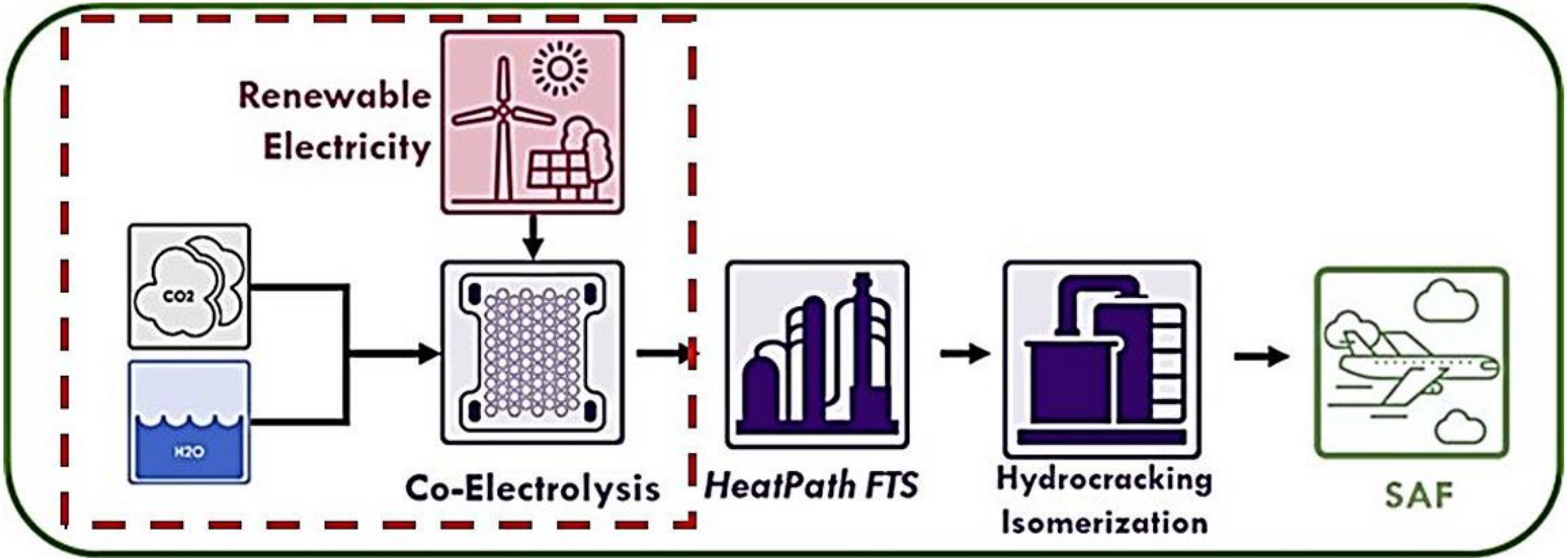
Co-Electrolysis for Syngas and SAF Production



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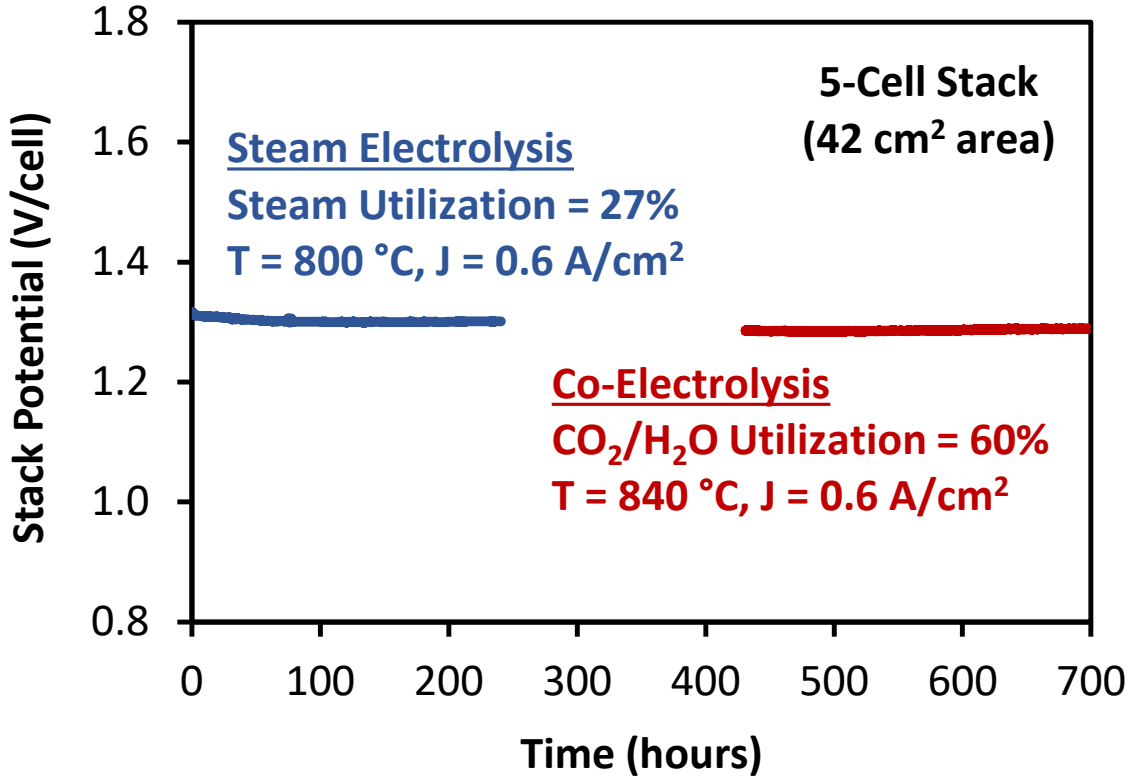
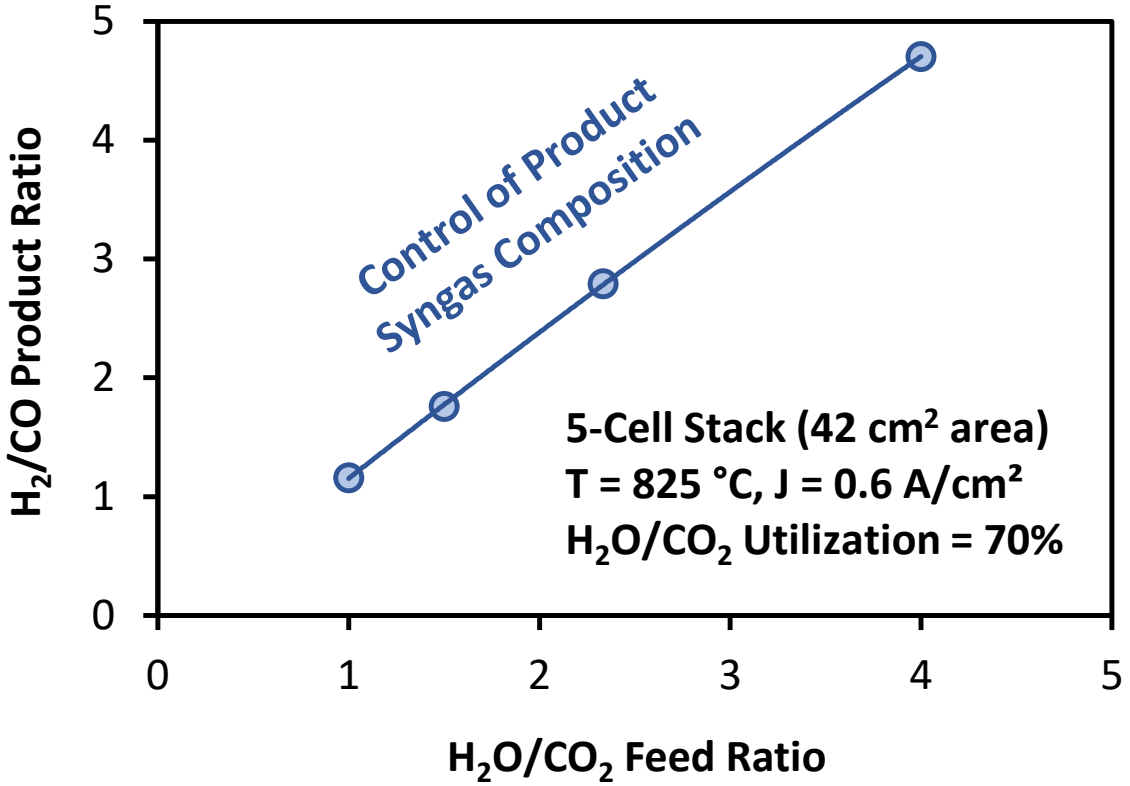
Power-to-X via Co-Electrolysis





Conversion of steam and captured CO_2 to syngas offers a path to carbon neutral production of liquid fuels and chemicals.

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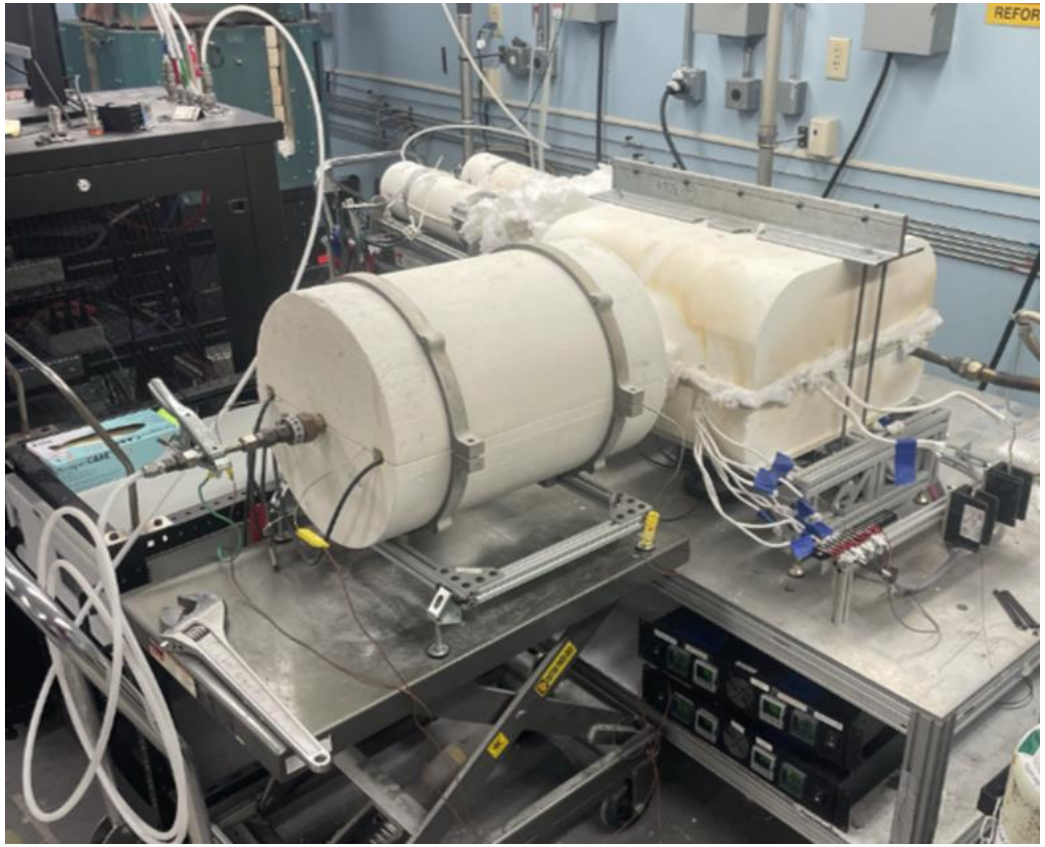
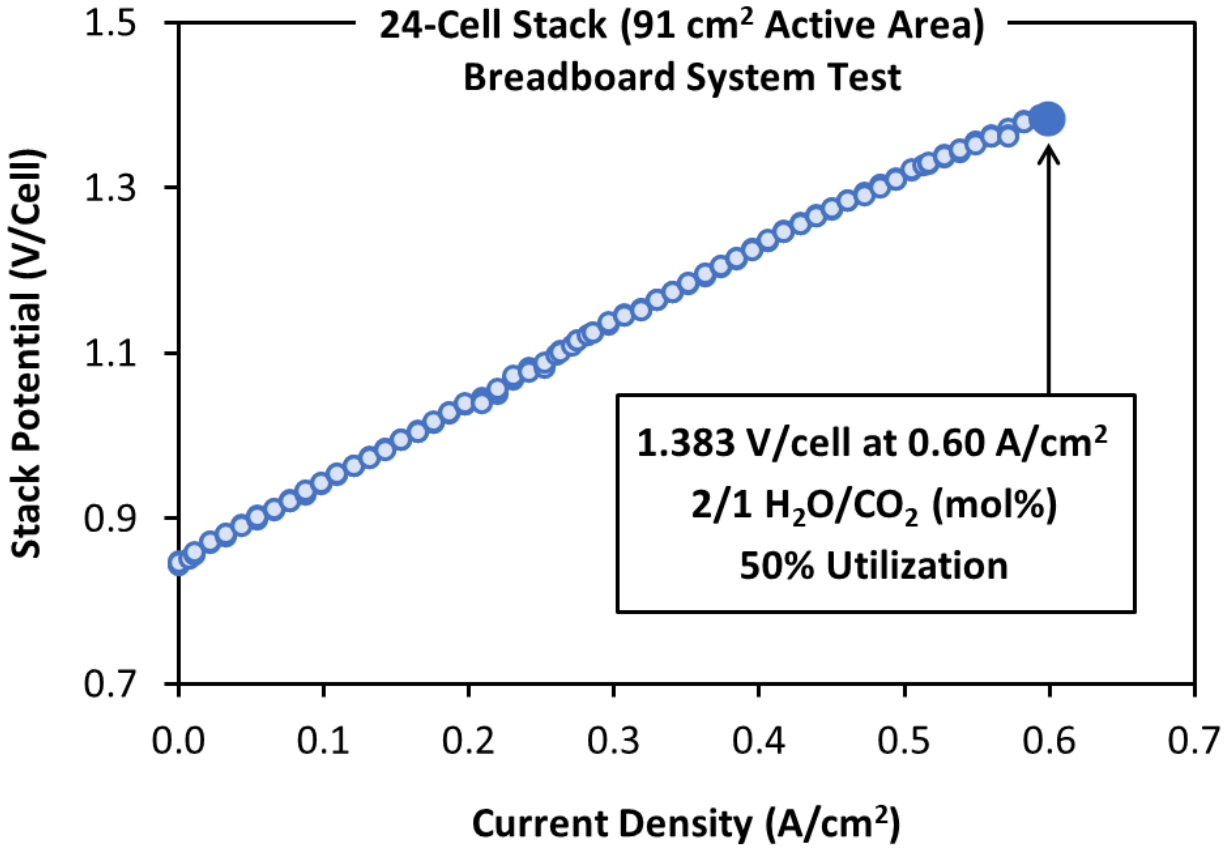
Co-Electrolysis Stack Testing in Breadboard System





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- Lura Armbruster
- Geoff Merchant
- And many others

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Our vision is to create a better world through energy innovations.

We collaborate with leading global customers and partners to transform powerful ideas into solutions that make energy production safer, more efficient, and environmentally responsible.

Questions?

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