

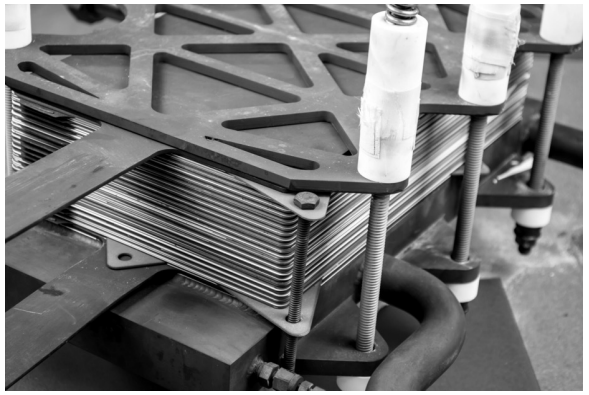



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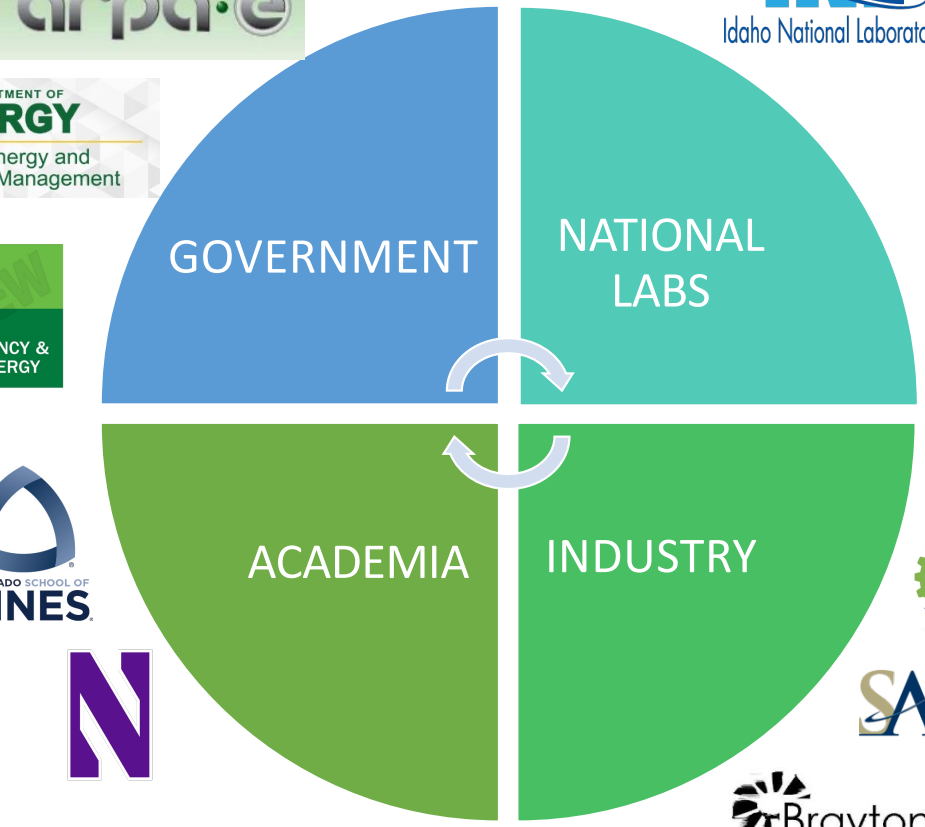
Cost Analysis of Syngas Production with Nexceris' Co-Electrolysis Technology

Kiran Adepalli, Ph.D.
Senior Program Manager, Solid Oxide Business Unit

Acknowledgements

Our Partners, Collaborators & Sponsors



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INL Idaho National Laboratory

U.S. DEPARTMENT OF ENERGY Fossil Energy and Carbon Management

Pacific Northwest NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

RTI INTERNATIONAL

Pradeep Sharma,
Lisa Tarr
Sameer Parvthikar

COLORADO SCHOOL OF MINES

Czero ENGINEERING TOMORROW

STRATEGIC ANALYSIS INC

Brayton Energy LLC

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Nexceris Business Portfolio

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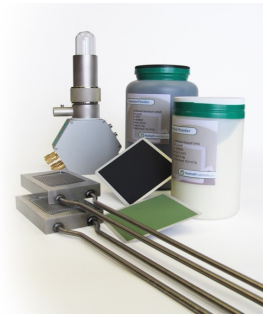
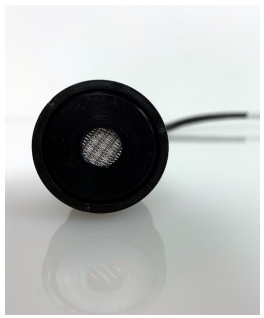
Materials	Solid Oxide Stacks	Sensors	Catalysts	Protective Coatings
Solid oxide cells and energy storage	Stationary and military	Transportation and energy markets	H_2 and chemicals production	Solid oxide and high temperature





FCM LI-ION TAMER® HeatPath SOLUTIONS

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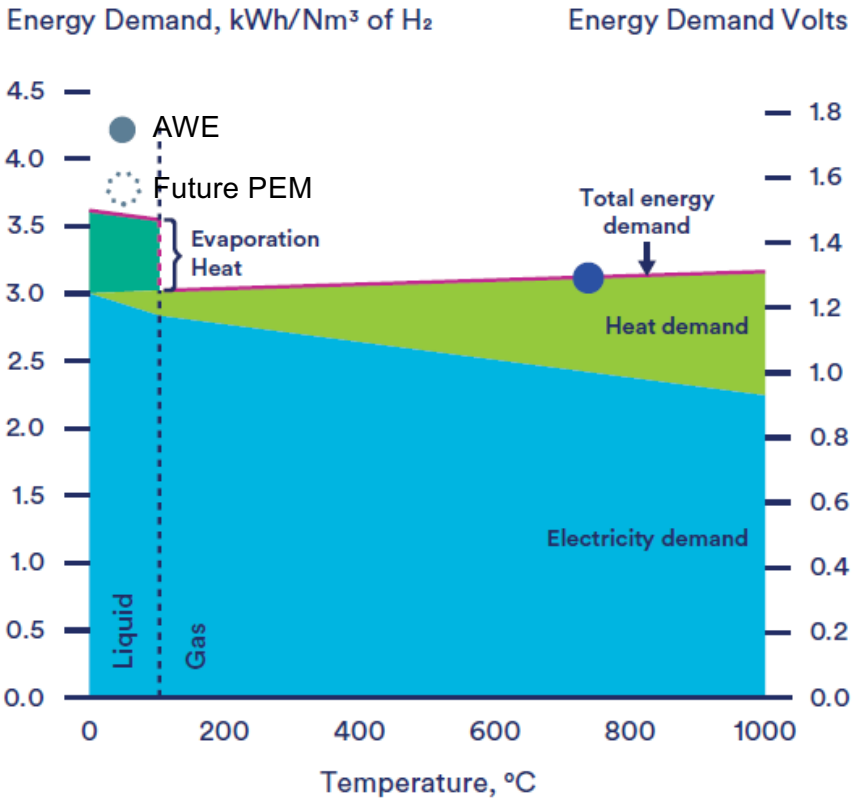
SOC vs. PEM vs AWE

Thermodynamic favorability



	SOEC	PEM	AWE
electrolyte	ceramic	polymer	KOH
System efficiency (KWh/Kg. H_2)	38-48	50-83	50-78
Degradation (%/1000h)	0.5	0.25	0.13
Stack life (hours)	50k	50-90k	60-100k
Operating temp (°C)	600-800	50-80	70-90
Co-electrolysis (syngas)	yes	no	no

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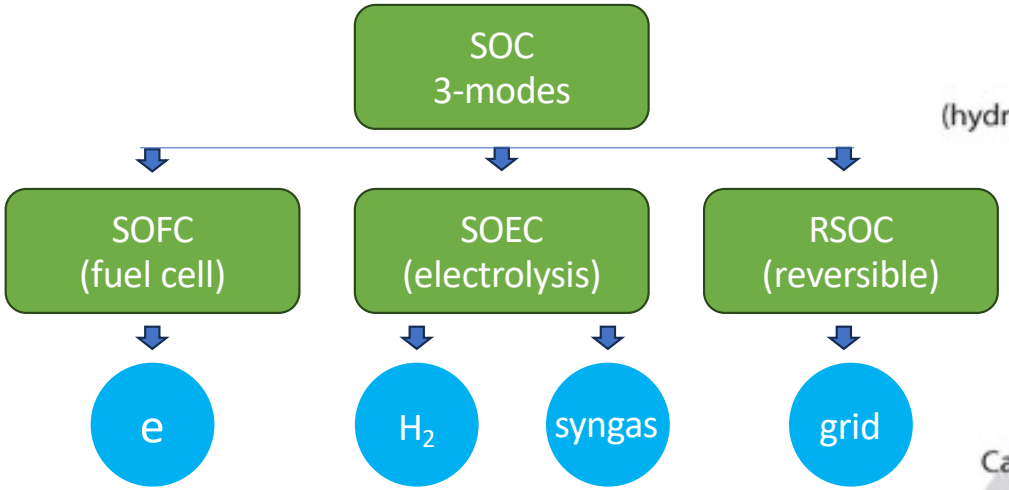
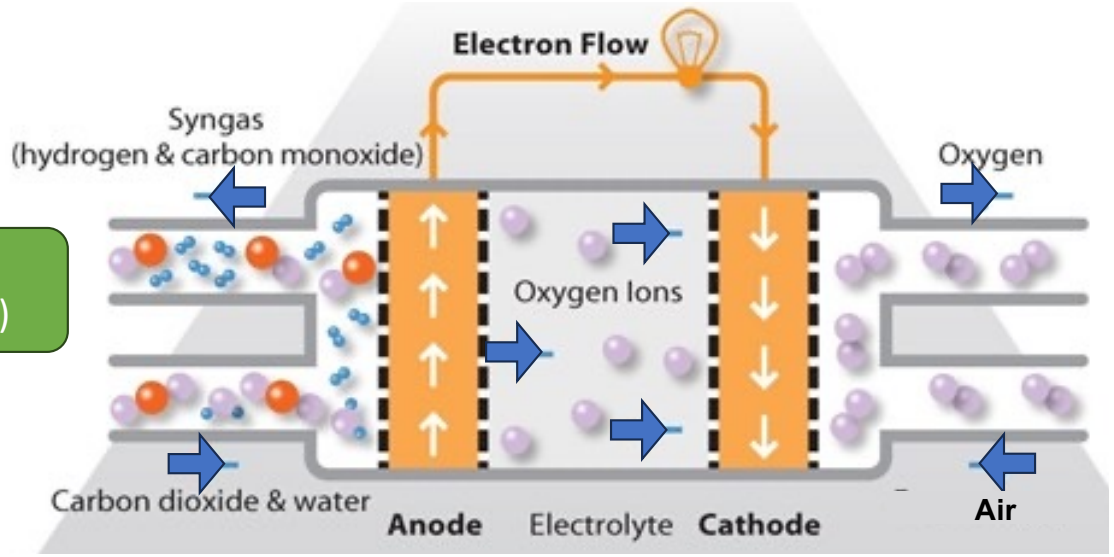
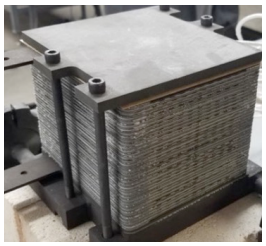
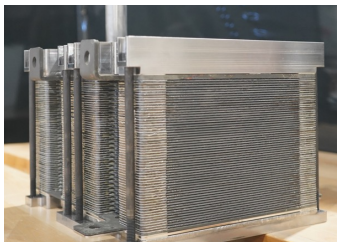
Solid oxide electrolysis: A technology status assessment by G. Flis

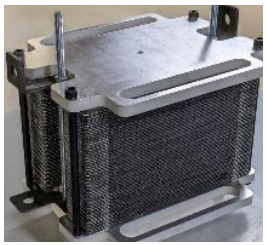
Nexceris Solid Oxide Cell (SOC) Technologies

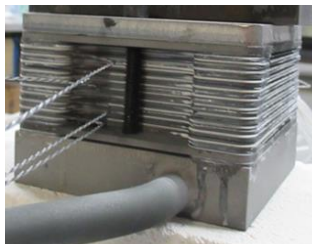


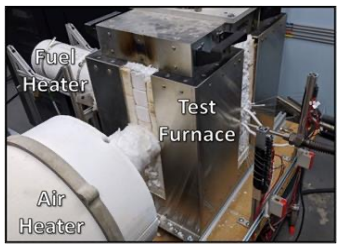


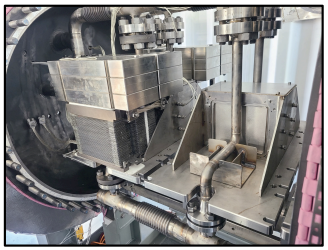












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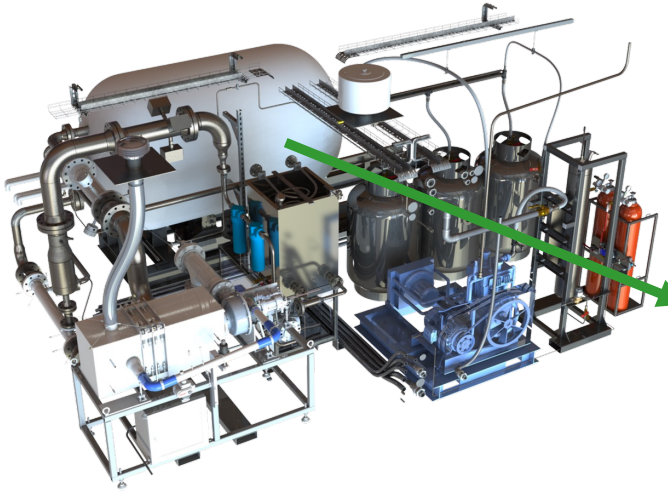
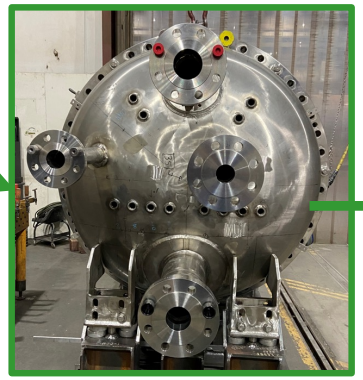
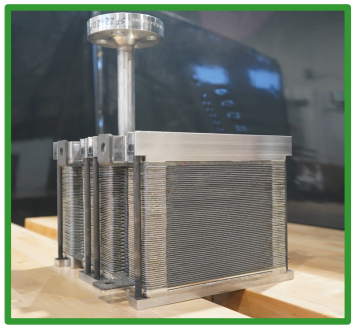
SOFC – Turbine Integration Project

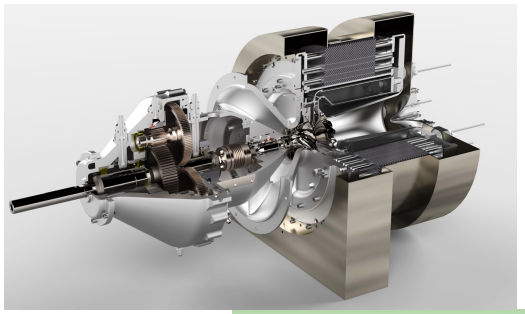
High Efficiency SOFC/Turbine Hybrid Power System

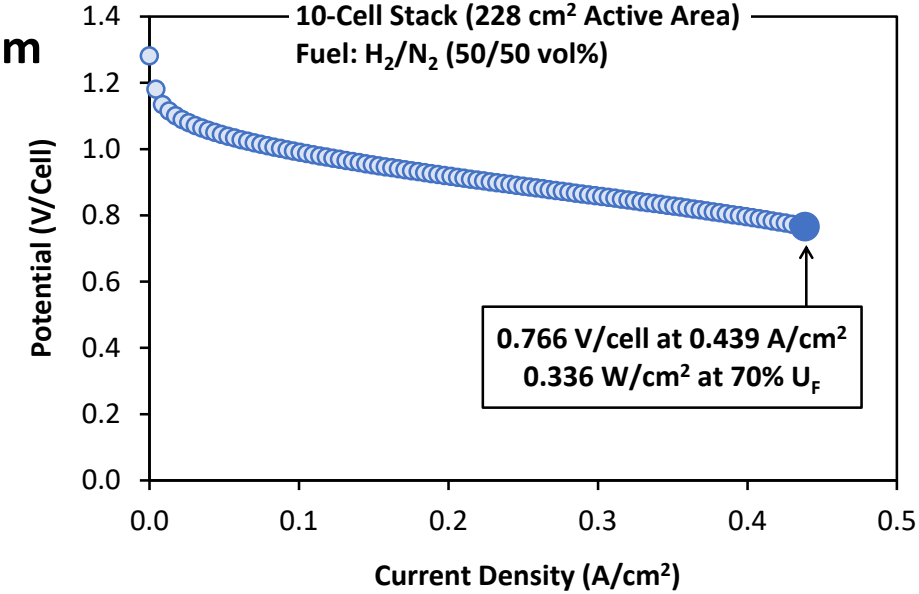
- 50 kWe power to operate on natural gas
- Unutilized fuel expands in gas turbine
- Target LHV efficiency is 70%
- High pressure stack operation at 2-3 bar
- System under construction, demo next month.











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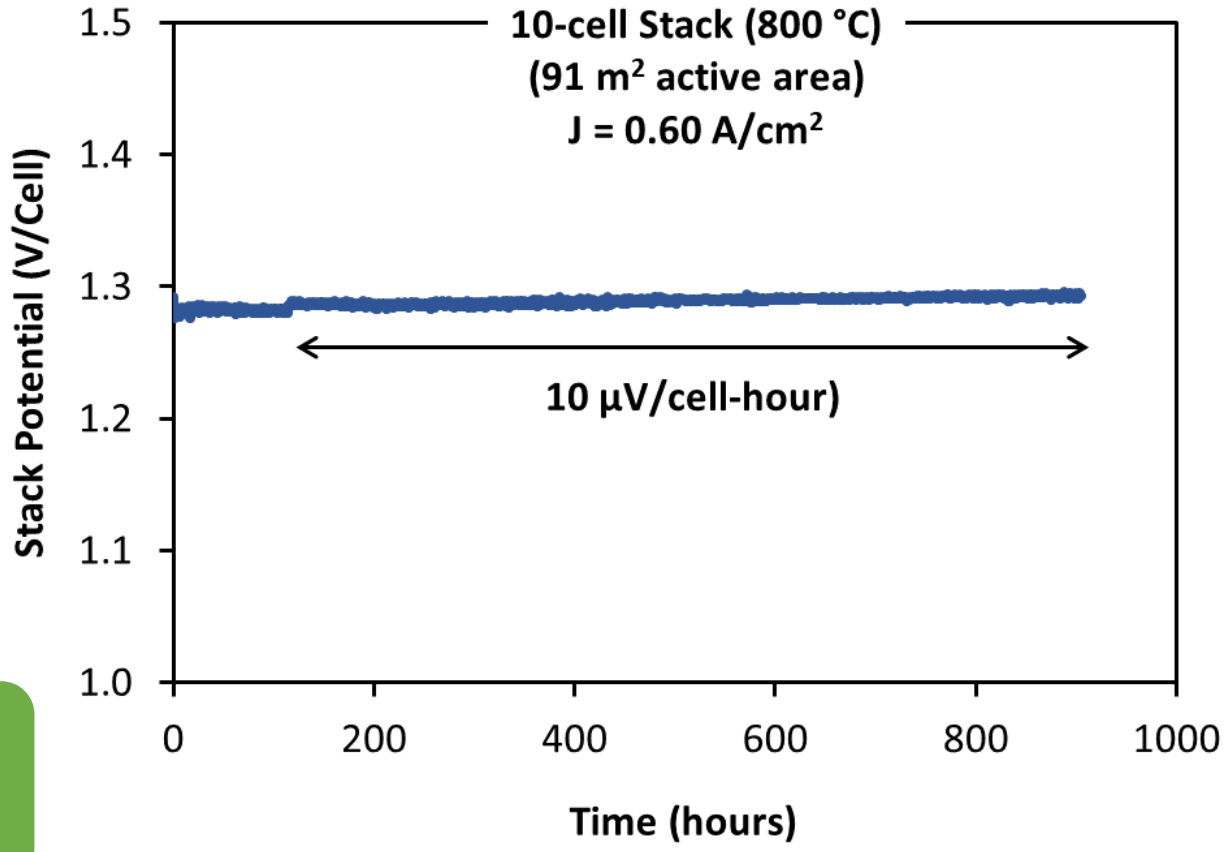
SOEC Technology

Long term durability is key

- Our current long term stack degradation target is 10 µV/hour (achieved).
- Even better durability expected as technology matures.
- Long duration testing is required (and is ongoing).

Nexceris won $60 million cooperative agreement grant from DOE to scale up SOEC production.



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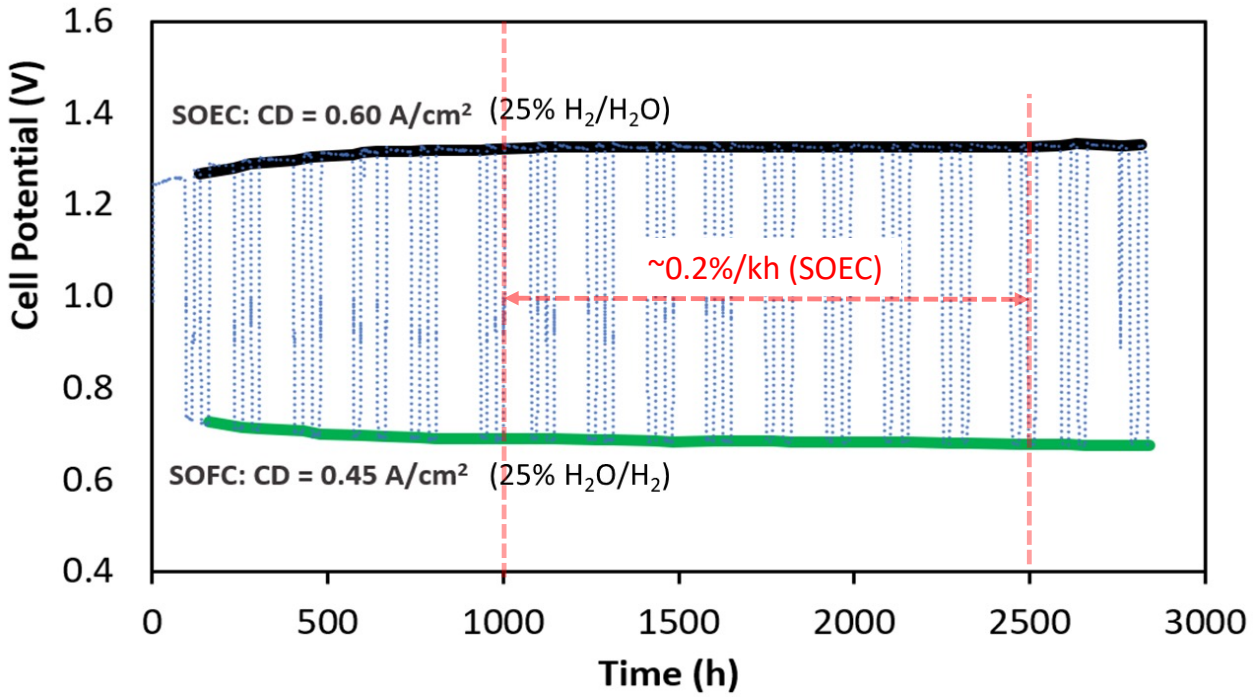
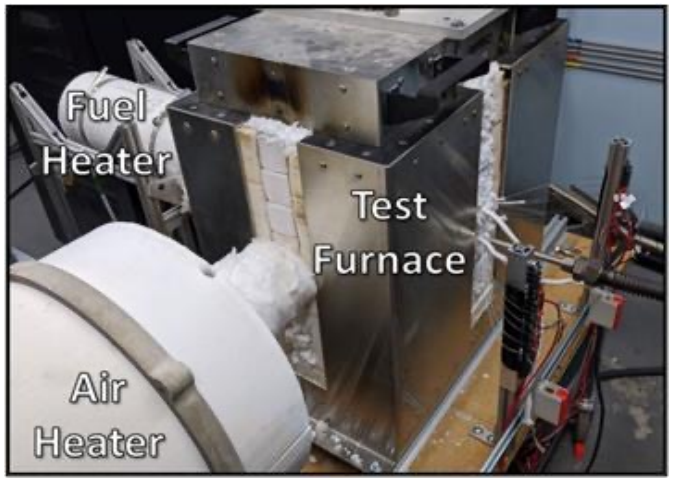
Stack level performance and durability





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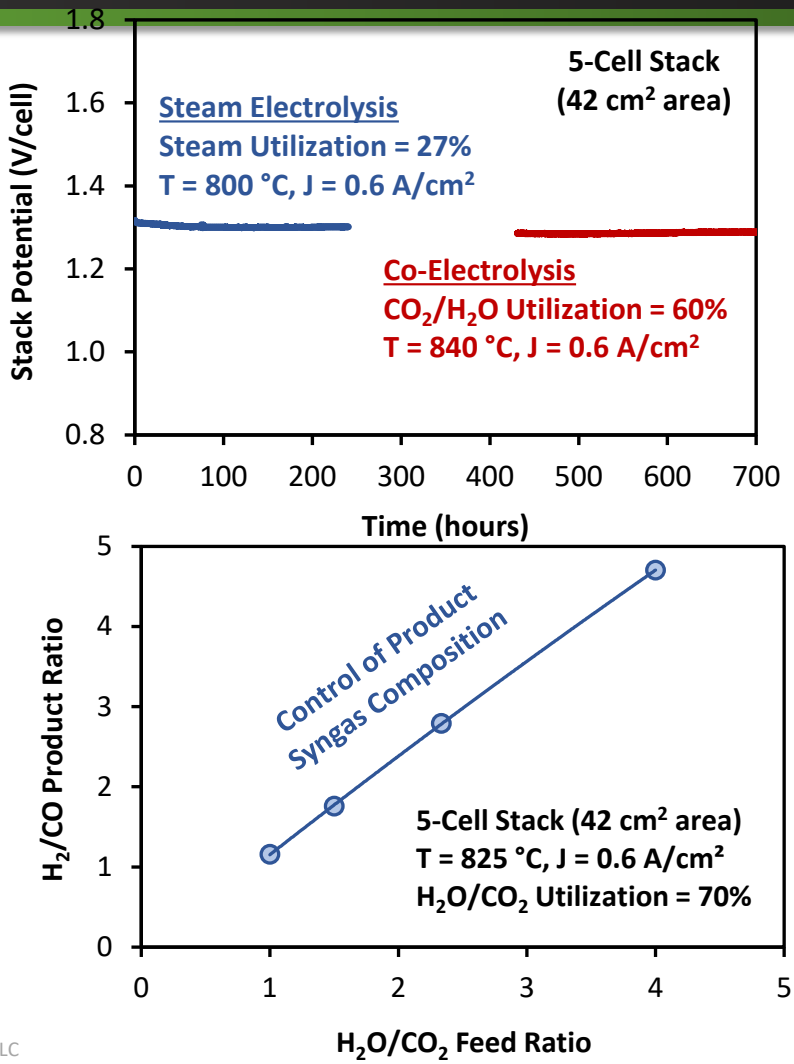
Power-to-X by Co-electrolysis

Path to Carbon-neutral production of fuels

- Co-electrolysis of steam and CO_2 into syngas, further converted into value added chemicals / fuels
- Nexceris looking into this technology to potentially combine it with our Fischer-Tropsch catalyst technology that we have been developing
- Our stacks can operate stably in the co-electrolysis and it is possible modulate the syngas composition by controlling the feed input.



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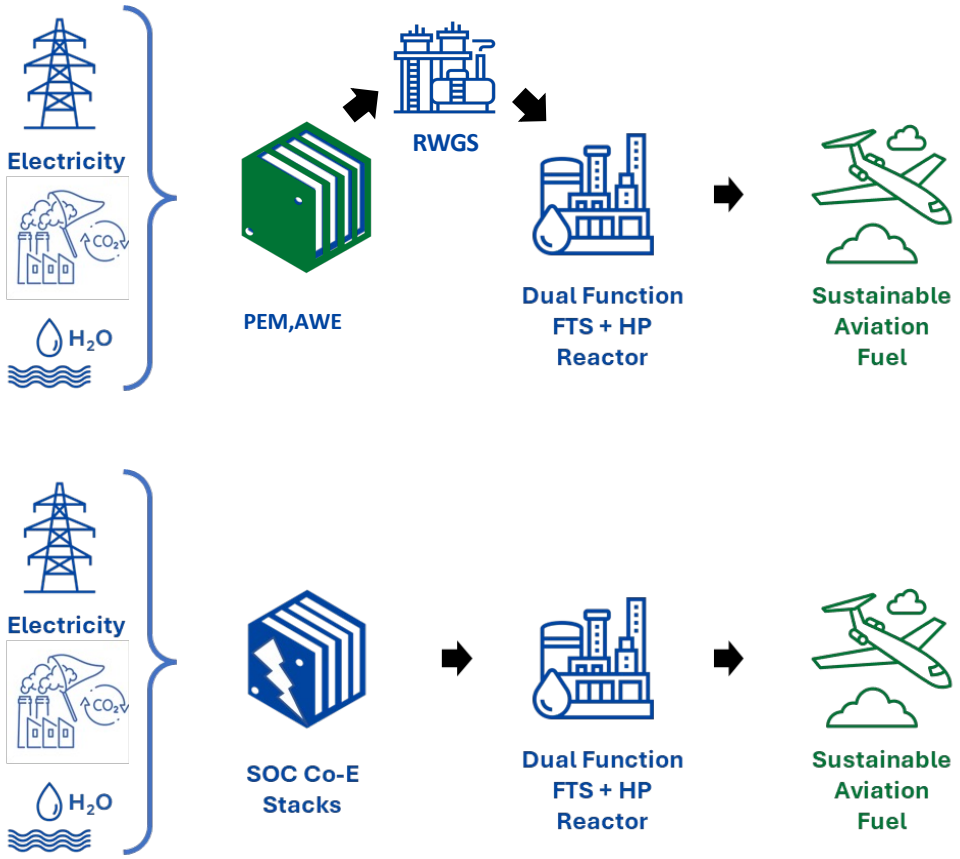
Techno-Economic Analysis (TEA) for HT Co-electrolysis Syngas Production

Conventional vs green technologies

- Scenario -1
  - SMR to produce syngas followed by F-T synthesis
- Scenario-2
  - Low temperature electrolysis followed by RWGS reactor and F-T synthesis
- Scenario-3
  - High temperature co-electrolysis to produce syngas followed by F-T synthesis
- Assumptions
  - Plant capacity 1kg/s (sensitivity 0.1-5kg/s)
  - Electricity cost $30/MWh (sensitivity $25-90/MWh)
  - Cost of stack is $1000/kW (sensitivity $250-2000/KW)
  - Stack life is 10 years (sensitivity 5-20 years)
  - Costs for CO2 ($40/ton), water ($1.67/1000gallon)



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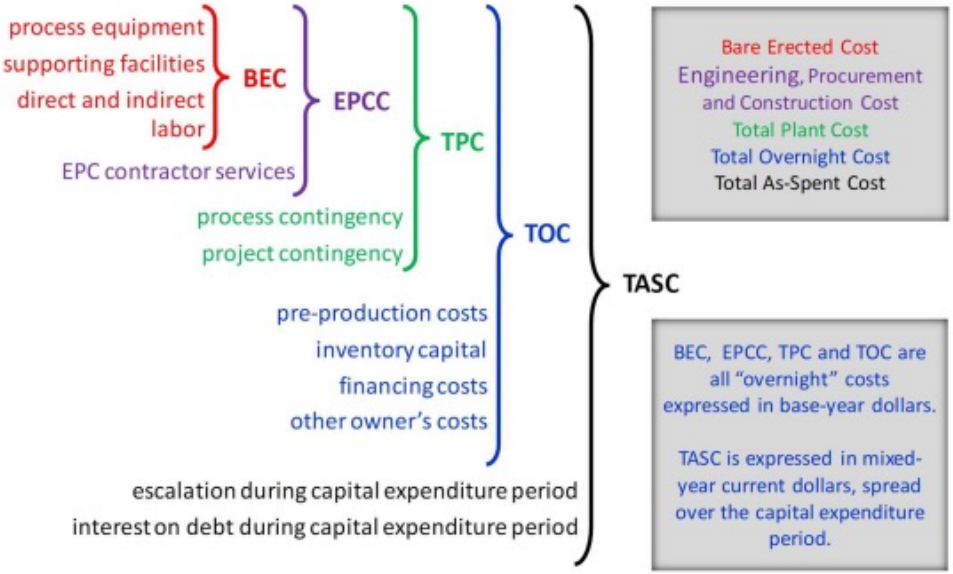
TEA Methodology and KPI's



Key Performance Indicators	Values
Syngas Production Capacity (kg/s)	1.0
Electrolyzer Operating Conditions	750°C, 4 barg
Feed H_2O Flow to SOEC (kg/s)	1.1
Feed CO_2 Flow to SOEC (kg/s)	1.5
Sweep Air Flow to SOEC (kg/s)	7.1
Single Pass Stack Conversion (%)	75%
Overall Conversion (%)	85%
Number of Cells per Stack	80
Number of Cells	160,000
SOEC Sweep/O_2 Outlet O_2 Content	≤ 35%
Syngas Quality for SAF Production	~ 20 barg, H_2:CO = 2:1
F-T Liquid Production Capacity (bbl./day)	~ 180
SAF Production Capacity (bbl./day)	~ 60

$$LCOS = \frac{(\mathrm{FCR})(\mathrm{TASC}) + OC_{FIX} + (\mathrm{CF})(OC_{VAR}) + \mathrm{CF}(\mathrm{FC})}{(\mathrm{CF})(F_{SG})}$$

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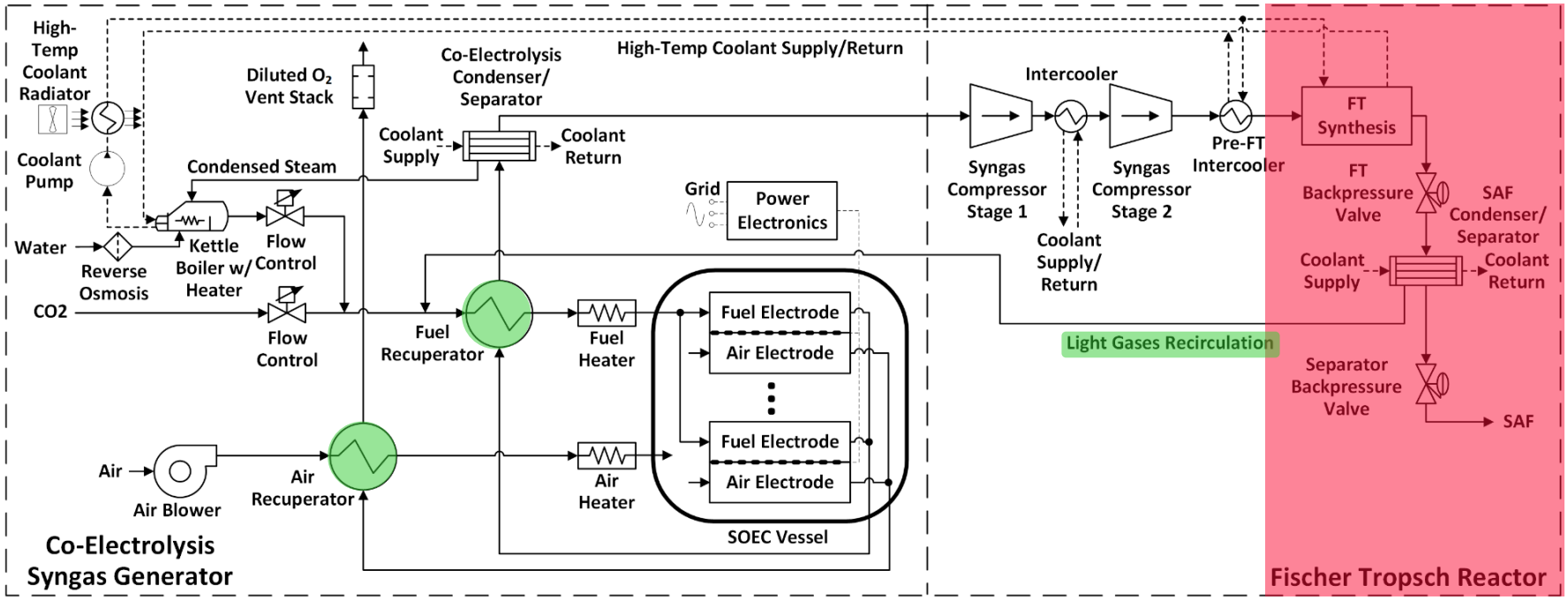
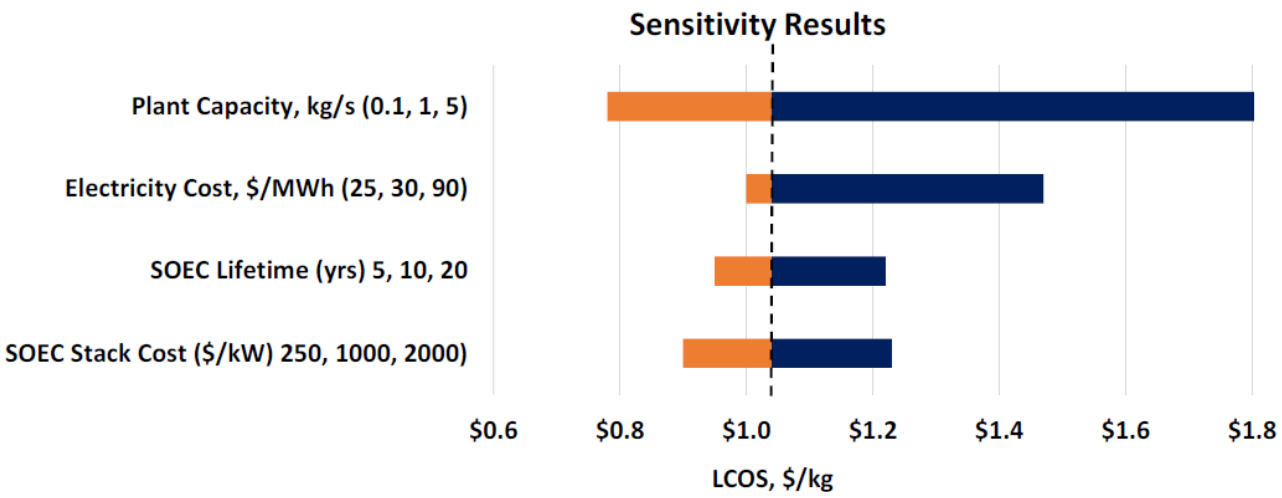
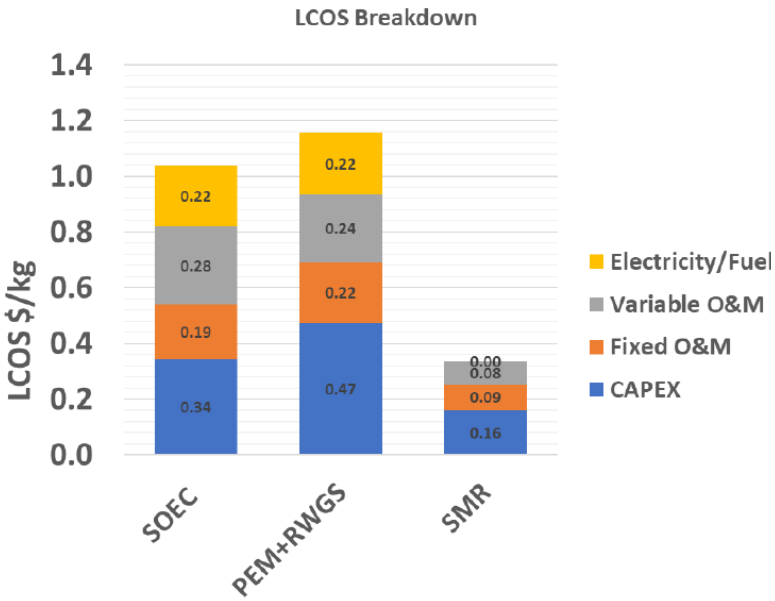
TEA focus on syngas generation (not on conversion to SAF)



LCOS Cost Sensitivity Analysis

Conventional vs Green technologies





- Economies of scale is important for cost reduction
- Capex cost is the key differentiator for LT vs HT electrolysis (waste heat availability would advantage SOEC)

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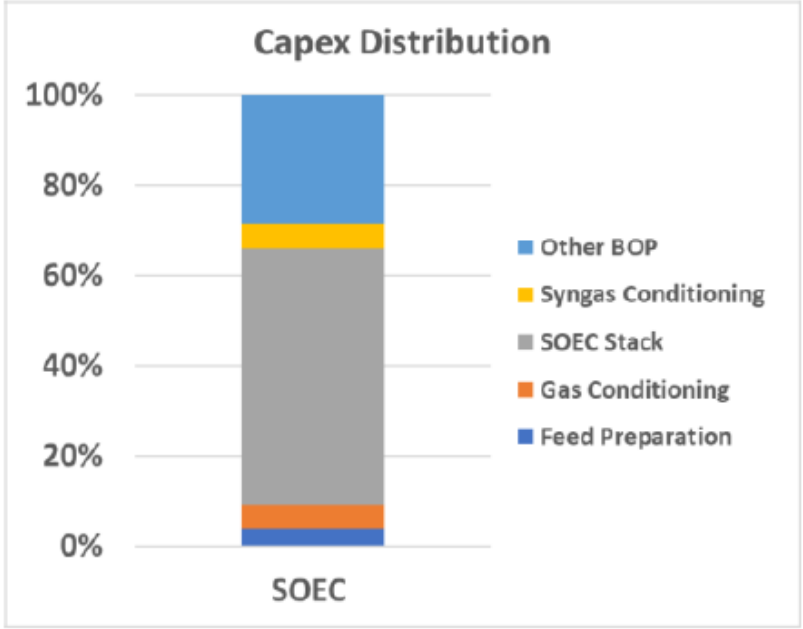
SOC Technology CAPEX distribution

Path for improvement by scale-up?

- Stack cost dominates the capex distribution
- Nexceris worked with a third party to identify pathway for cost reduction



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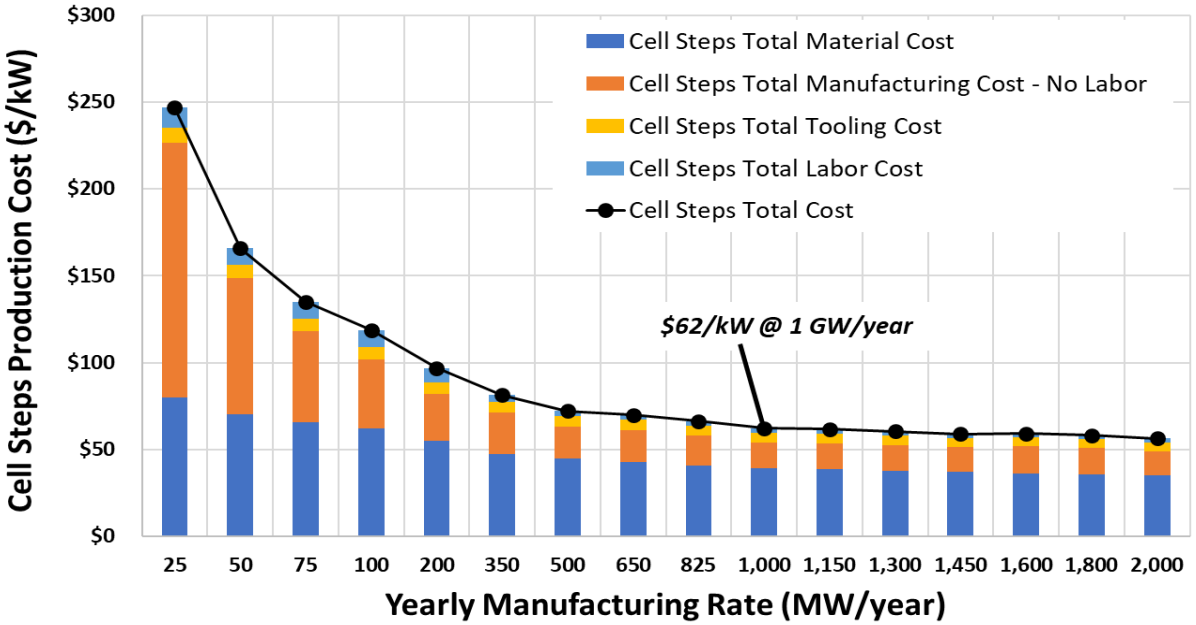
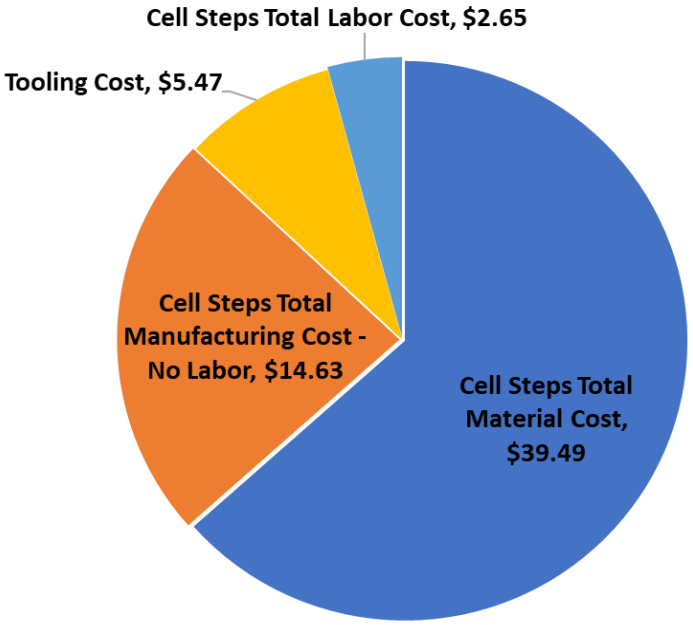
Cost analysis for SOEC Cell Manufacturing





- Cost reduction opportunities around cell and stack materials as well as equipment utilization
- Bigger opportunities are volume, materials and process steps

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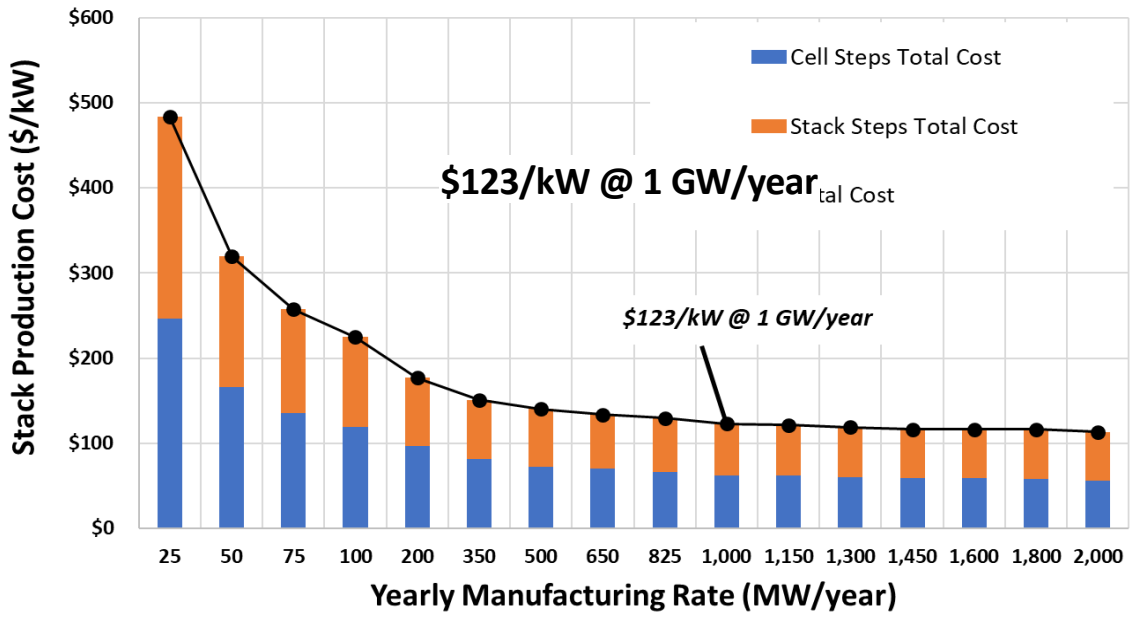
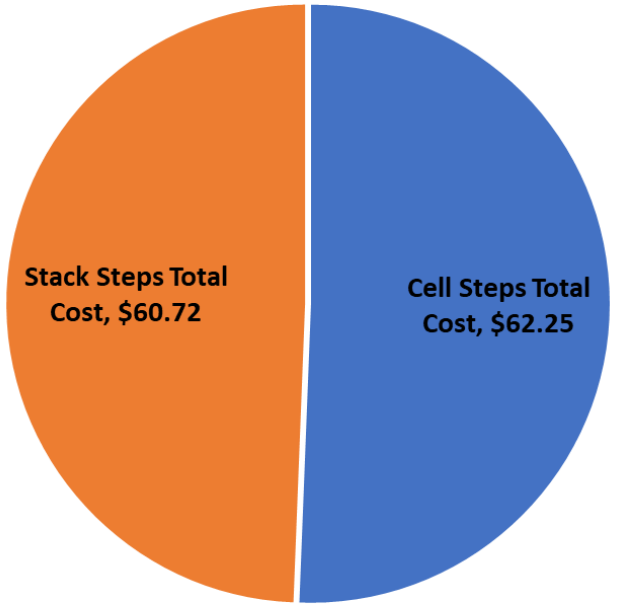
STRATEGIC ANALYSIS INC

DOE Project Award No. DE-EE0009621

Stack cost at scale

- Total stack cost is $122 per kW. Cell and stacking costs are essentially the same. The largest cost contributor to stacking is materials (53 percent).





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Future of Nexceris Solid Oxide Technologies

- Economies of scale is key to make it cost competitive compared to conventional technology
  - LCOS for Nexceris SOC is 10-15% better compared to LT technologies (room for further improvement)

What's next?

- Recently signed $60 million cost shared DOE cooperative agreement to scale up electrolysis stack technology to 20MW/year
- Long term durability and performance data on syngas production for accurate lifetime estimates
- Third-party evaluations of HTE stacks at INL and other partner sites.
- We look for strategic partners to scale up, demonstrate and commercialize our SOC technology.

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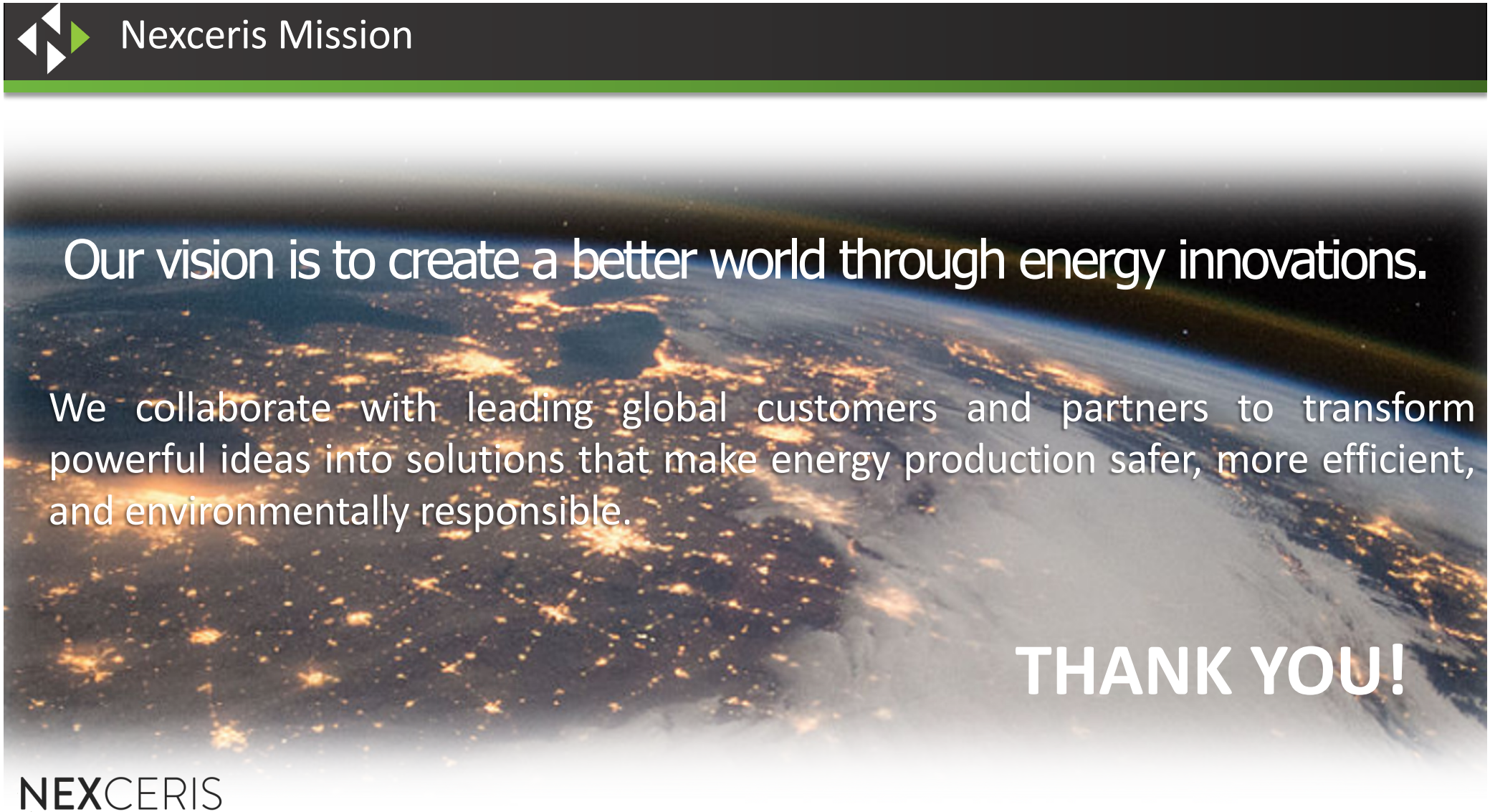
Nexceris Mission



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