COMMERCIALLY AVAILABLE SOFC PERFORMANCE AND DURABILITY USING COAL-DERIVED SYNGAS

EERC | UND UNIVERSITY OF NORTH DAKOTA

GOAL

1) **DESIGN, CONFIGURE, OPTIMIZE, AND DEMONSTRATE SYNGAS CLEANUP TECHNOLOGY (SCT)** capable of supplying sufficiently cleaned/decontaminated coal syngas to yield solid oxide fuel cell (SOFC) performance (defined as % performance degradation per 1000 hours) equivalent to baseline performance on deodorized natural gas.
2) **CONDUCT A TECHNO-ECONOMIC ANALYSIS** of the integrated syngas production–syngas cleanup–SOFC power generation pathway.

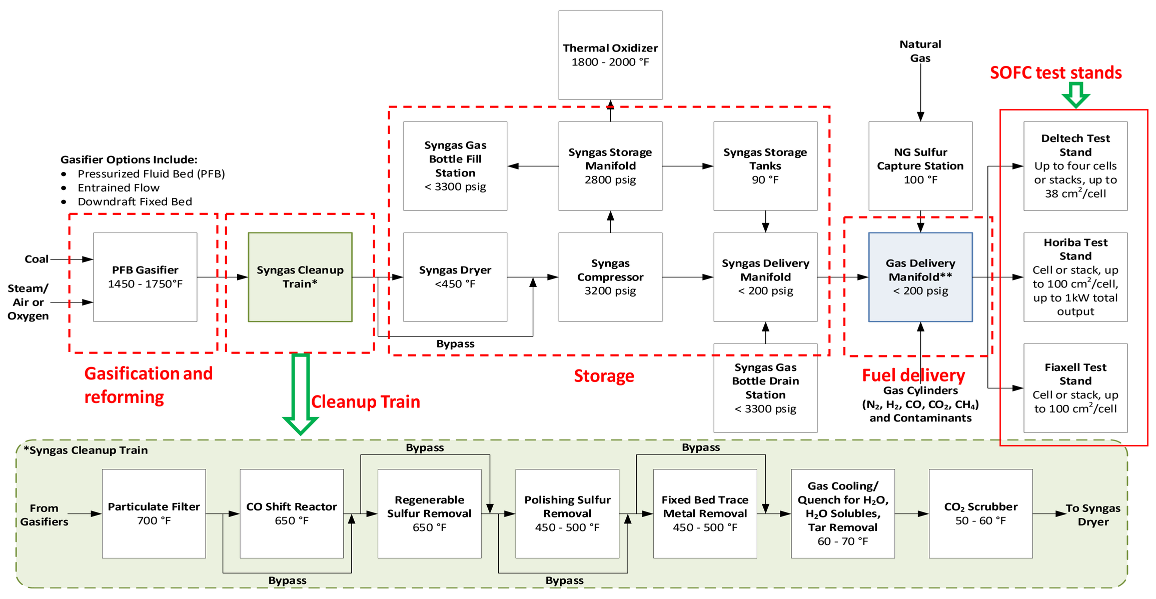
OBJECTIVES

COMPARED TO CONVENTIONAL CALCINATION:

- Design, configure, optimize, and demonstrate long-term operational viability of a syngas cleanup train.
- Produce coal-syngas sufficiently clean as a fuel for SOFC operation, achieving performance equivalent to that of natural gas fuel.
- Simulate thermodynamic and model multiphysics effect of syngas trace contaminants on SOFC performance and durability.
- Conduct a techno-economic analysis (TEA) of the integrated syngas production system.

FUEL PRODUCTION AND CLEANUP TECHNOLOGY

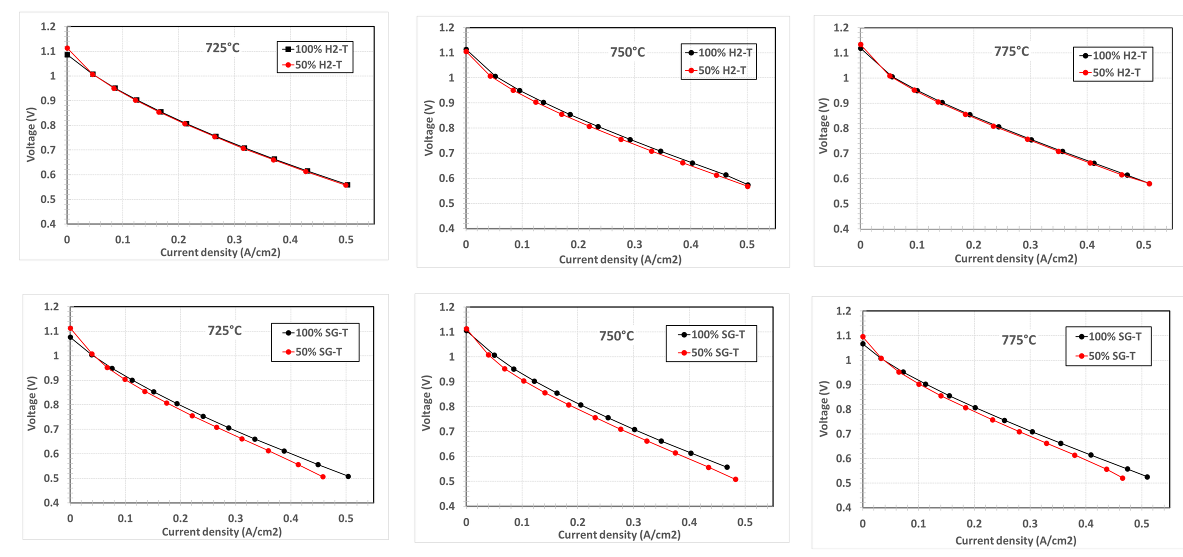
Integrate EERC SOFC test stands with syngas production, cleanup, storage, and fuel delivery system.



SOFC PERFORMANCE VS. TEMPERATURE AND FUEL COMPOSITIONS

Commercially available SOFC cells show comparable performance in syngas gas and H_2 fuel.

SPS Gen-1 cell



COAL-DERIVED SYNGAS QUALITY

EERC Syngas Composition

Syngas Gas Component	Mole %
Hydrogen	59.5%
Carbon Dioxide	0.9%
Ethane	0.0%
Argon	0.4%
Nitrogen	32.5%
Methane	5.2%
Carbon Monoxide	1.7%

CONTAMINANT LEVEL | EERC Syngas vs. Industrial Syngas

EERC Coal-Derived, Cleaned Syngas

Syngas Gas Contaminant	Concentration
Antimony (Sb)	< 1 ppbv
Cadmium (Cd)	< 0.5 ppbv
Arsine (AsH_3)	< 5 ppbv
Hydrogen Sulfide (H_2S)	< 5 ppbv
Phosphine (PH_3)	< 0.5 ppbv
Hydrochloric Acid (HCl)	< 100 ppbv
Selenium (Se)	< 0.5 ppbv
Silicon (Si)	< 1 ppbv
Zinc (Zn)	2.5 ppbv
Benzene (C_6H_6)	< 15 ppmv
Xylene (C_8H_{10})	< 10 ppmv

Industrial Gasifier

Syngas Gas Contaminant	Concentration*
Antimony (Sb)	25 ppbv
Cadmium (Cd)	N/A
Arsine (AsH_3)	150-580 ppbv
Hydrogen Sulfide (H_2S)	~500 ppbv
Phosphine (PH_3)	1900 ppbv
Hydrochloric Acid (HCl)	< 1000 ppbv
Selenium (Se)	150 ppbv
Zinc (Zn)	9000 ppbv
Chromium (Cr)	25 ppbv
Mercury (Hg)	25 ppbv

Eastman Chemical Company's system at Kingsport

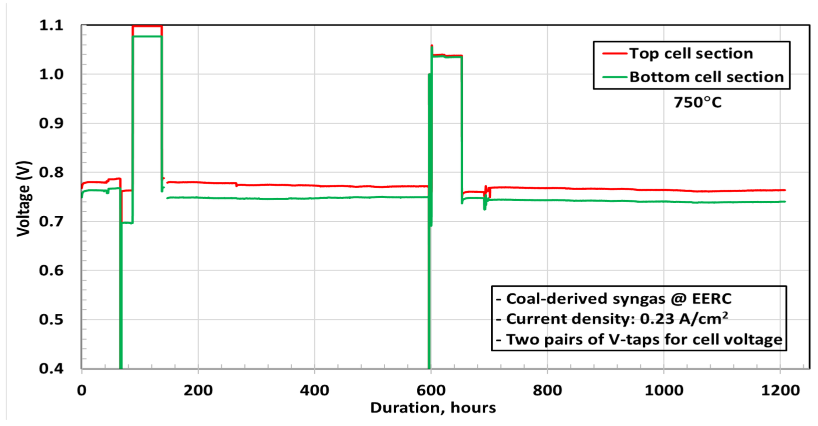
SOFC LONG-TERM DURABILITY TESTS

BENCHMARK DURABILITY TEST:

Stable cell performance under coal-derived syngas fuel during 1000+ hr of testing

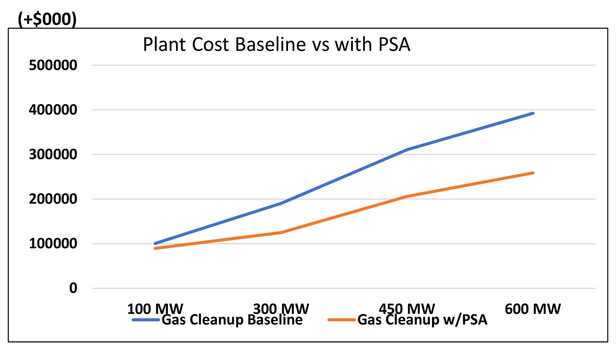
Test Conditions
- 750°C
- Constant current load at 230 mA/cm²
- 75% fuel utilization

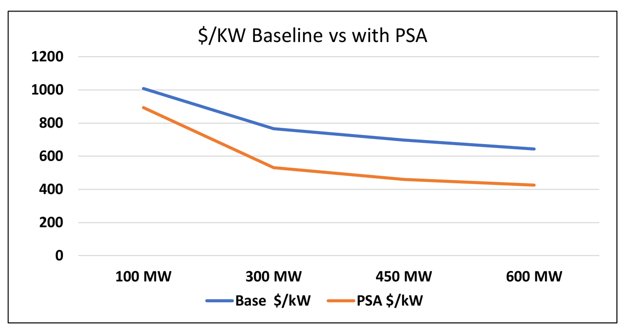
Two pairs of V-taps to monitor voltage of top and bottom cell section, respectively

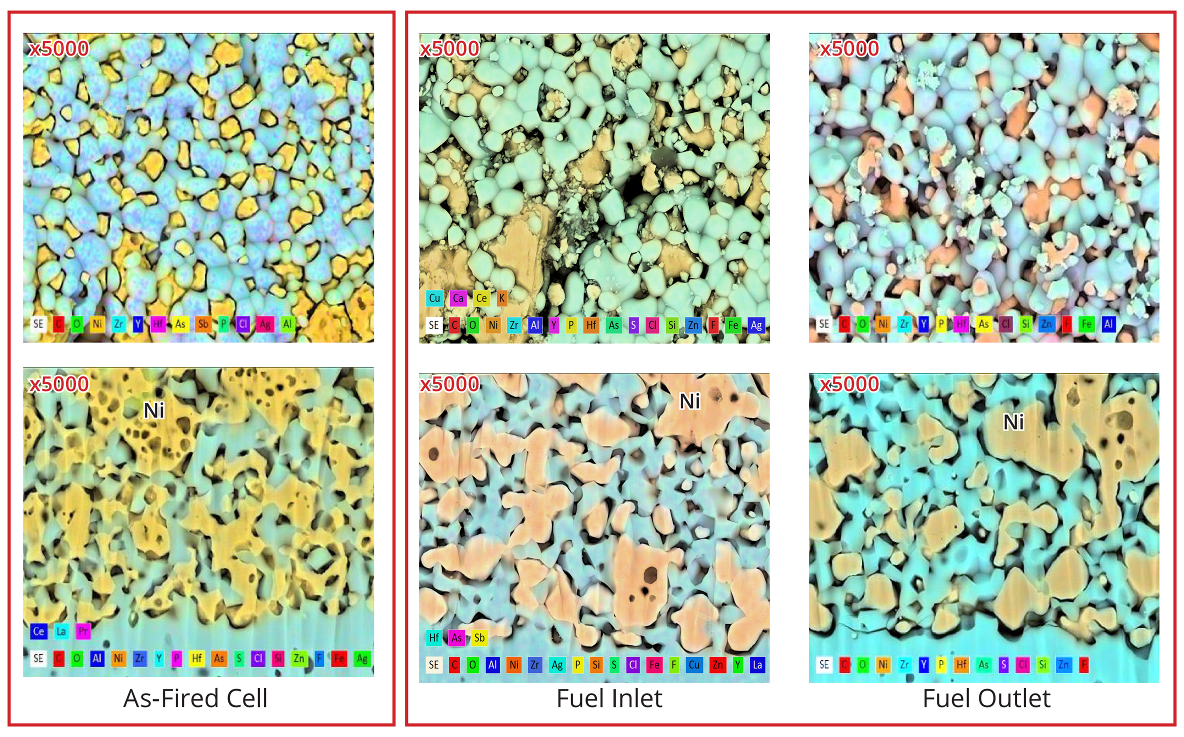


PRELIMINARY TECHNO-ECONOMIC ANALYSIS OF COAL SYNGAS CLEANUP TECHNOLOGY

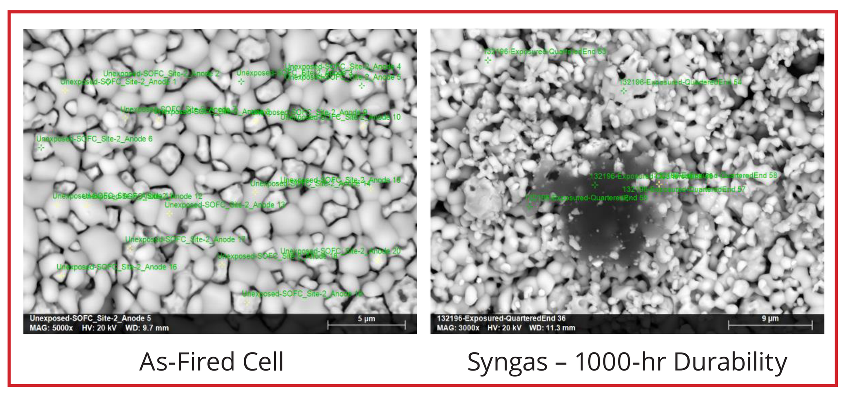
- "Updated Costs (June 2011 basis) for Selected Bituminous Baseline Cases" DOE/NETL-341/082312 report, WorleyParsons & Booz Allen Hamilton
- "Advanced Acid Gas Separation Technology for Clean Power and Syngas Applications," DOE/NETL report (DE-0013363), Air Products and Chemicals



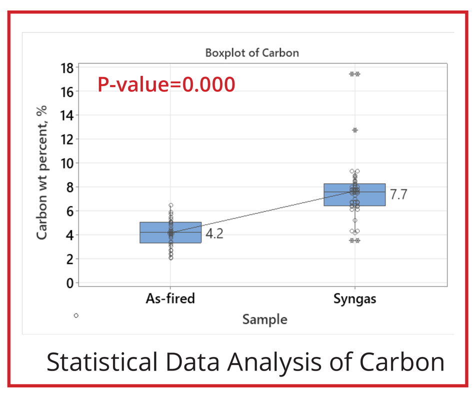




Anode of As-Fired Cell, X15,000 | 1000 hours' Duration in Coal-Derived Syngas, X15,000

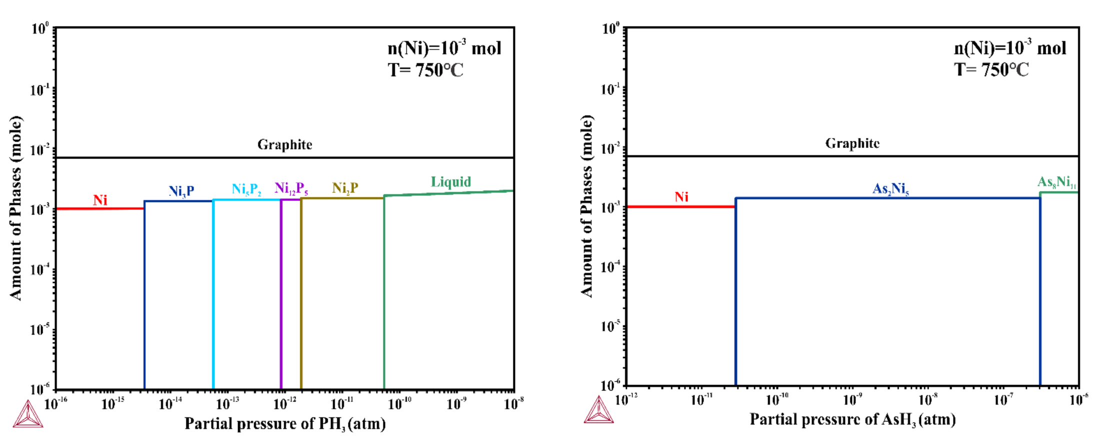


As-Fired Cell | Syngas – 1000-hr Durability



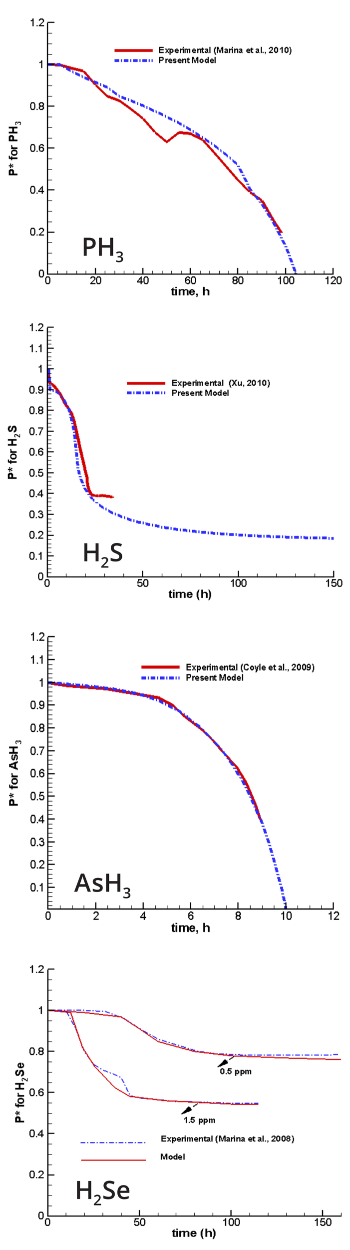
Statistical Data Analysis of Carbon

THERMODYNAMIC SIMULATION OF ANODE MATERIAL'S INTERACTION WITH TRACE CONTAMINANTS IN SYNGAS

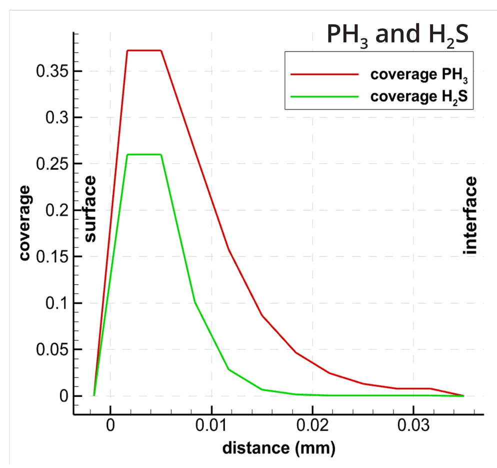


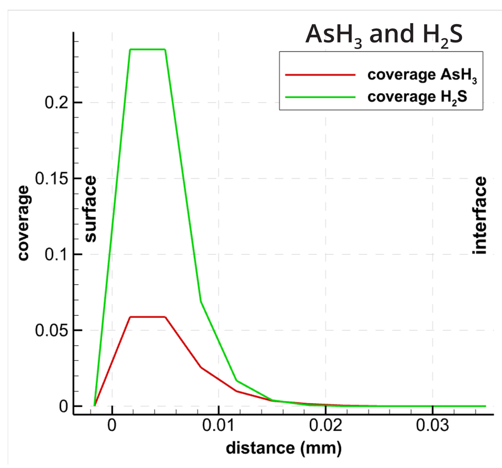
- For P, As: No adjustments needed for surface covering degradation model used in multiphysics simulation in PPB-PPM contaminant range.
- Ongoing: Finishing interaction diagrams for S, Sb, Se, Cl.

SINGLE-CONTAMINANT EFFECT ON SOFC DEGRADATION



MULTICONTAMINANT EFFECT ON SOFC DEGRADATION



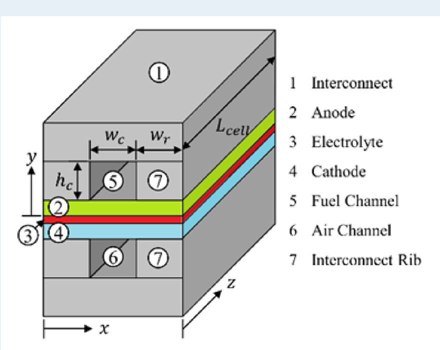


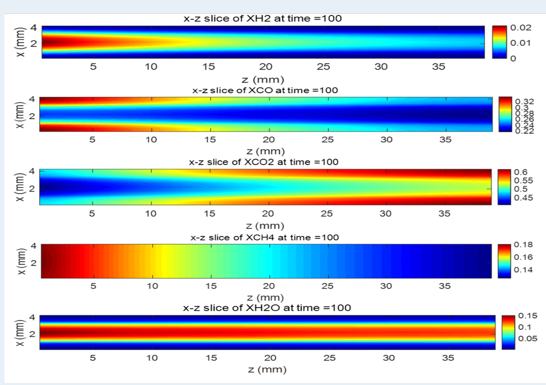
SOFC MULTIPHYSICS PERFORMANCE SIMULATION

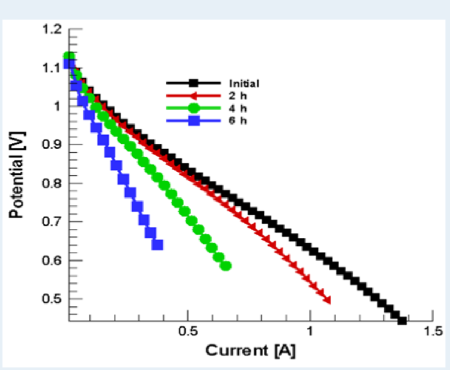
3D PLANAR CELL MODEL USED THAT MATCHES DISTRIBUTIONS IN TUBULAR CELL

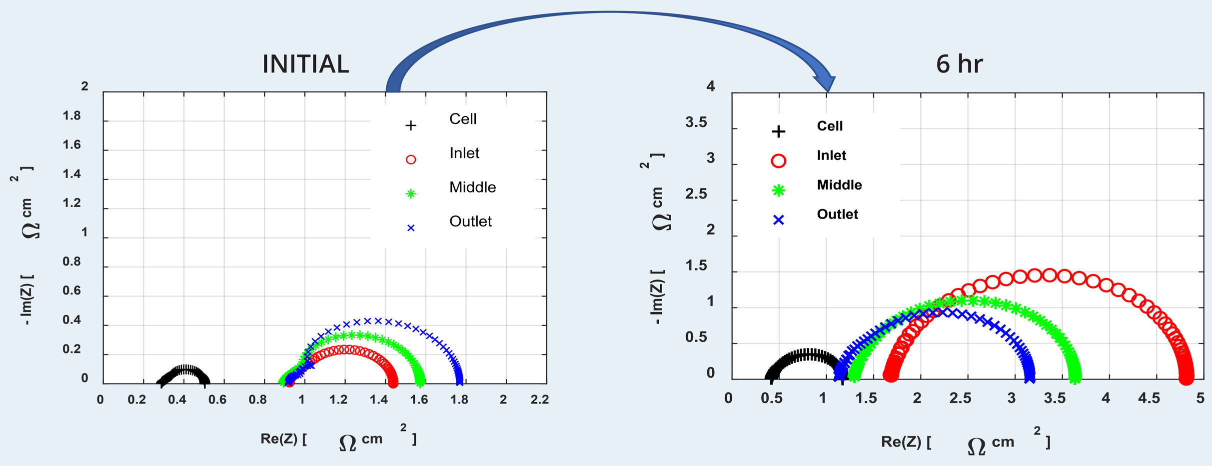
CAPABLE OF COAL SYNGAS STUDIES:
- Includes methane reforming and water-gas shift reactions

CURRENTLY CODED DEGRADATION MODES:
- PH_3, AsH_3, H_2S, H_2Se contamination
- Ni coarsening









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