Energy & Environmental Research Center (EERC)

COAL SYNGAS CLEANUP FOR COMMERCIALLY VIABLE SOFC PERFORMANCE

22nd Annual Solid Oxide Fuel Cell Project Review Meeting

November 16, 2021

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PROBLEM STATEMENT FROM FOA 2300

Advancing integrated gasification–SOFC to commercialization requires syngas cleanup technology that is:

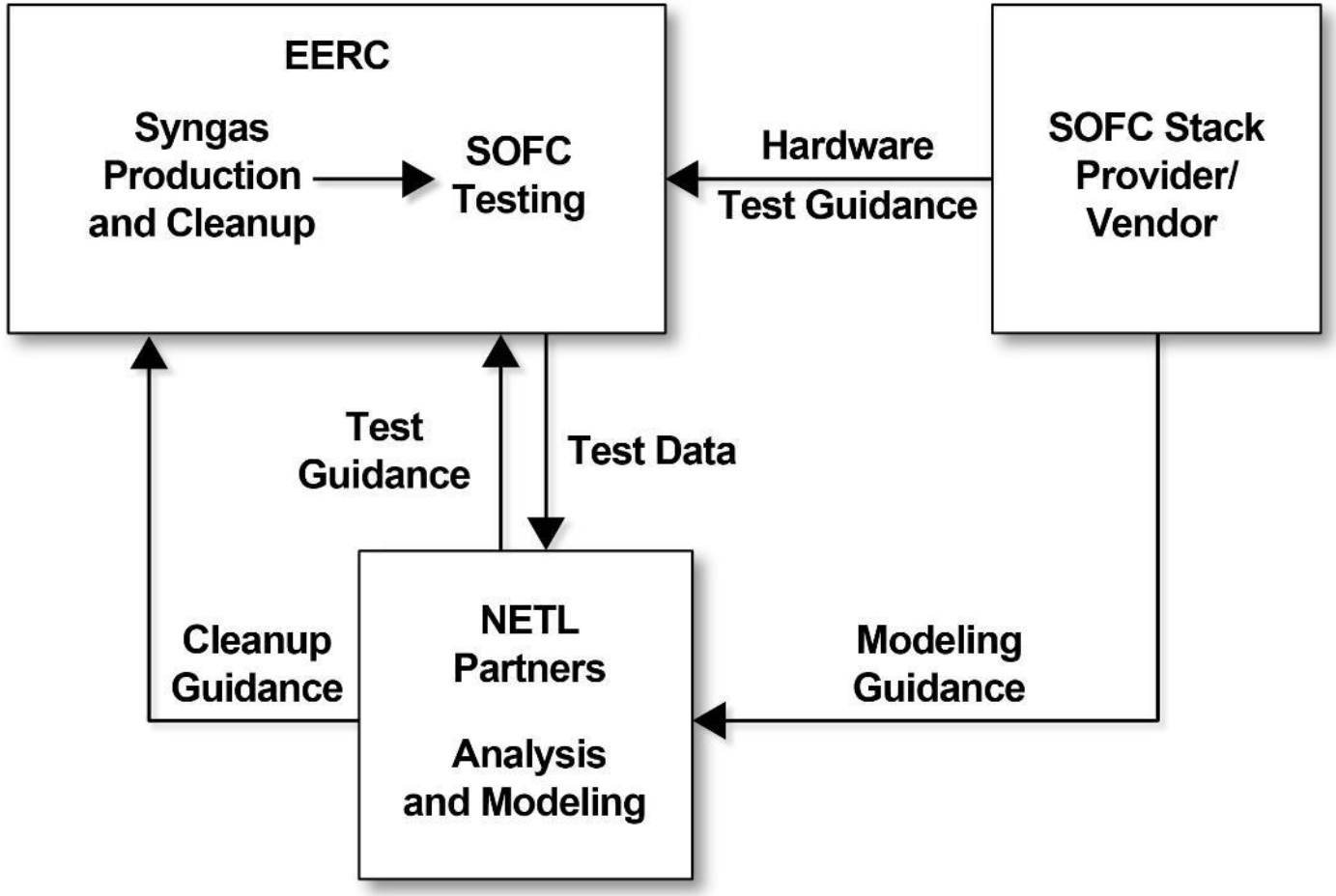
- Capable of consistently delivering coal syngas that matches natural gas in SOFC performance, as measured by % performance degradation per 1000 hours of operation.
- Sufficiently low in capital and operating costs to facilitate commercialization.

EERC TECHNICAL APPROACH

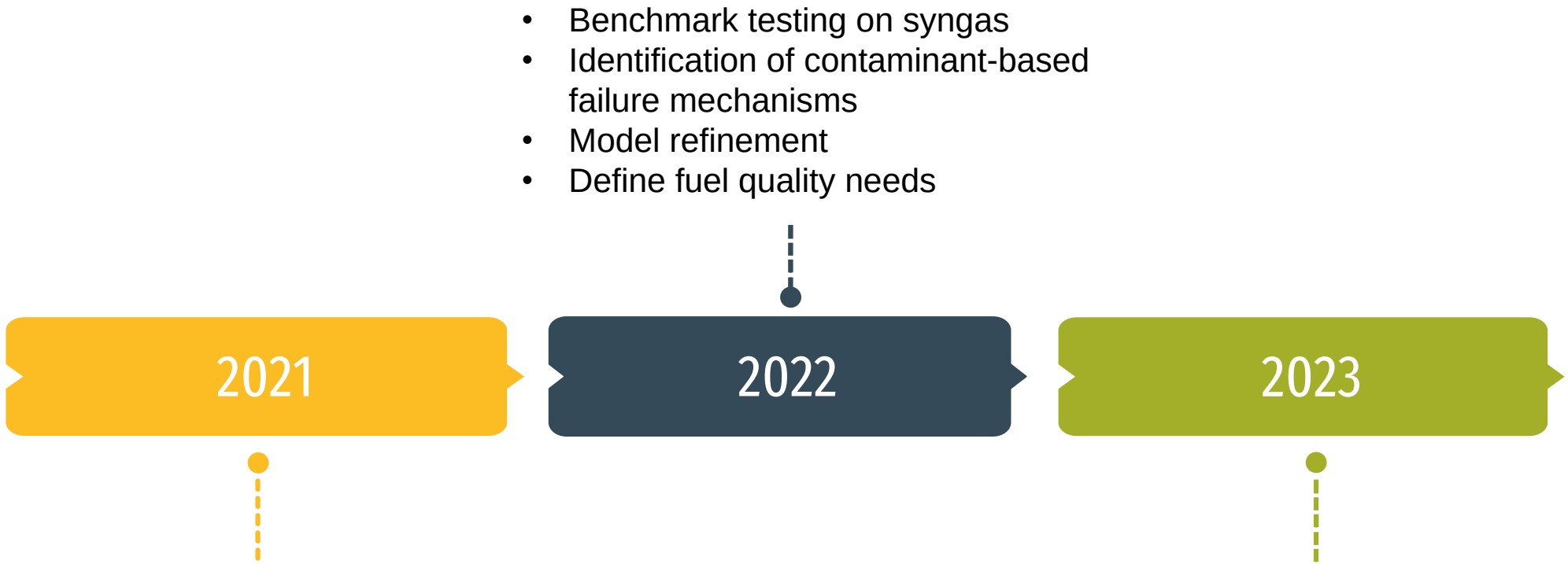
- Establish baseline SOFC performance on natural gas
- Evaluate performance on coal-derived syngas
  - Characterize syngas contaminants
  - Test SOFCs on coal-derived syngas, assess failure mechanisms, compare to performance on natural gas
  - Develop computational models, perform simulations
  - Iterate
  - Define fuel specification that enables satisfactory SOFC performance
- Optimize syngas treatment process at EERC's pilot plant
- Complete techno-economic analysis (TEA) of coal syngas-based SOFC system
- Demonstrate cell performance on optimized syngas

PROJECT TEAM AND ROLES

NETL Partners:
Worcester Polytechnic Institute
Carnegie Mellon University
Ohio Fuel Cell Coalition



PROJECT SCHEDULE



- Identify SOFC supplier
- Baseline testing on natural gas
- Initial model development

- Benchmark testing on syngas
- Identification of contaminant-based failure mechanisms
- Model refinement
- Define fuel quality needs

- Optimize syngas treatment
- TEA
- Cell performance demonstration

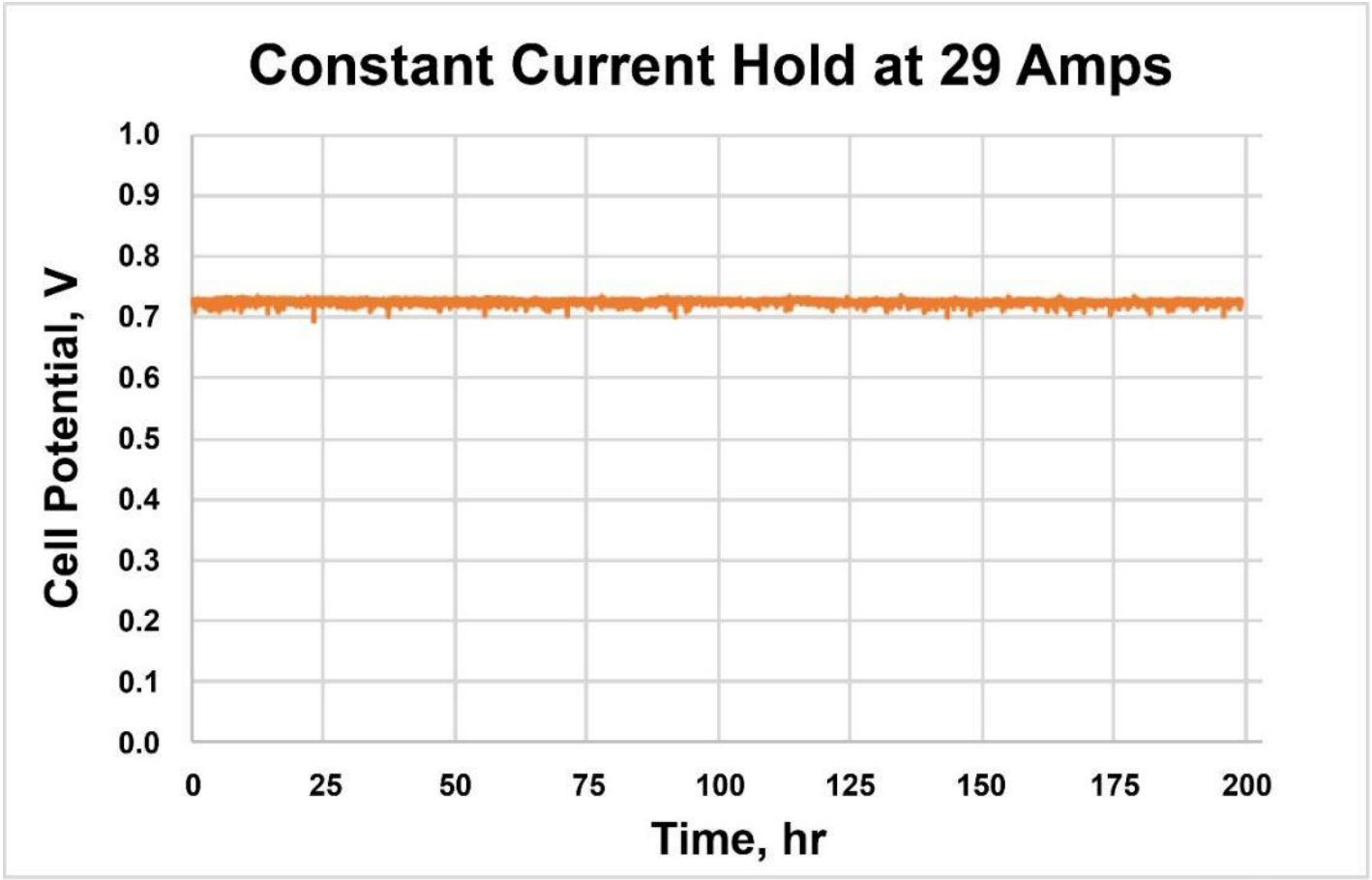
SOLID OXIDE FUEL CELLS

- SPS provided 12 cells and specification data.
  - 66% scale of commercial cells
  - Provided technical support
- Developed test plan and fuel quality guidelines for baseline natural gas tests.
- Modified EERC systems to accommodate geometry.

Cell Geometry	Tubular Cell
Cell Length	~11 inches
Active Area	130 cm^2
Cell Diameter	22 mm

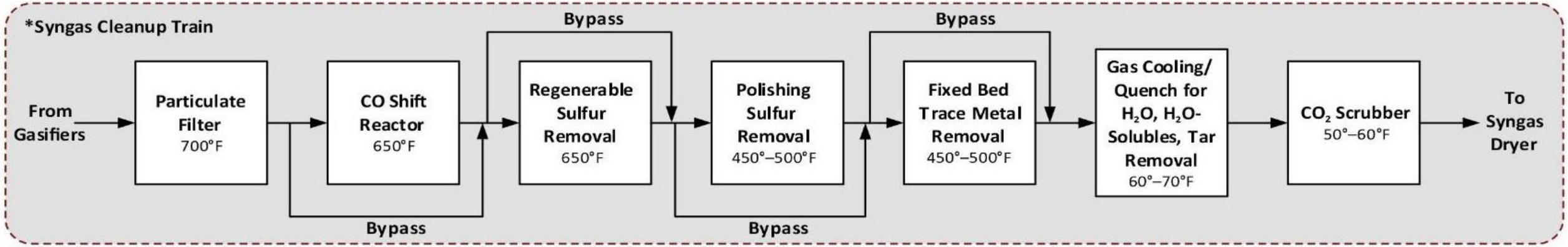
BASELINE SOFC PERFORMANCE

- Initial baseline test on deodorized natural gas.
- Baseline degradation rate of 0.03%/1000 hours.
- SPS degradation rate <0.5%/1000 hours.
- Additional natural gas data will be developed during subsequent testing.



CHARACTERIZE SYNGAS CONTAMINANTS

- Identify problematic syngas contaminants and improve benchmark cleanup train as needed to deliver syngas that matches natural gas performance.
  - Coal-derived syngas was produced, cleaned, and compressed to storage.
  - Contaminant characterized.

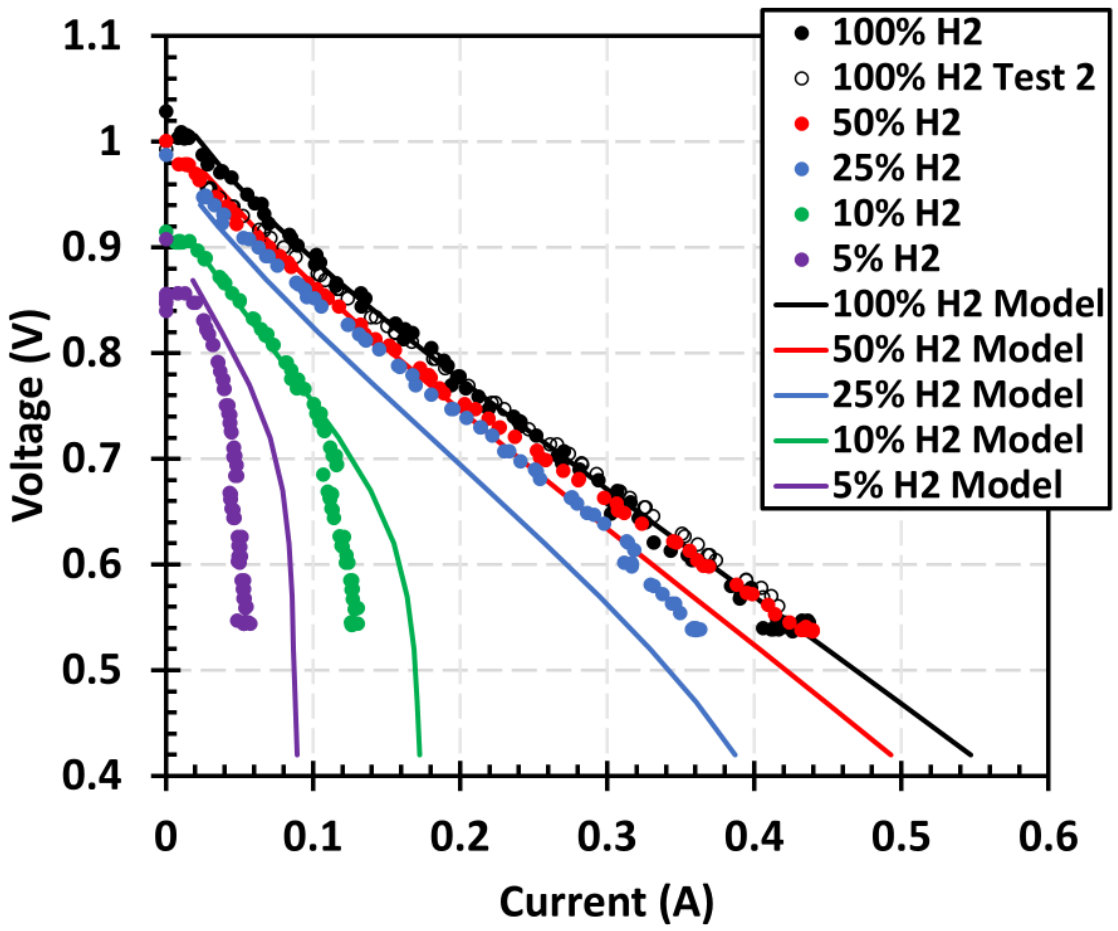


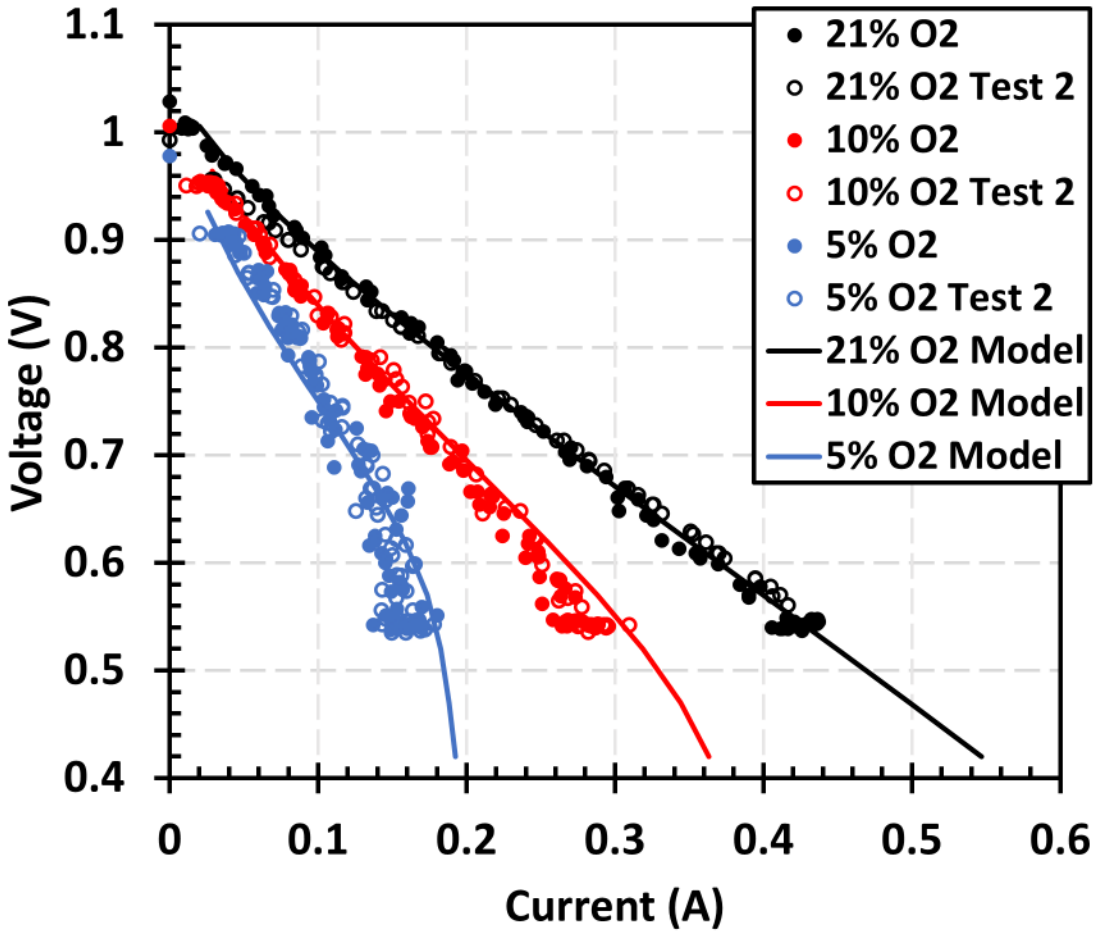
SYNGAS QUALITY: CONTAMINANT LEVEL

Contaminant Type	Acceptable Limit[1]	Measured Level[2]	Detection Method
Antimony (Sb)	1 ppmv	<0.015 ppbv	Method 29
Selenium (Se)	200 ppbv	<0.023 ppbv	Method 29
Cadmium (Cd)	200 ppbv	<0.006 ppbv	Method 29
HCl (gas)	100 ppbv	<50 ppbv	Dräger tubes®
H_2S (gas)	100 ppbv	<5 ppbv	Dräger tubes
Mercaptans (CH_4S – gas)	100 ppbv	<50 ppbv	Dräger tubes
Carbon Disulfide (CS_2 – gas)	100 ppbv	<100 ppbv	Dräger tubes
Arsenic (As)	10 ppbv	<0.024 ppbv	Method 29
Arsine (AsH_3 – gas)	10 ppbv	<5 ppbv	Dräger tubes
Phosphorus (P)	0.5 ppbv	<11.6 ppbv[3]	Method 29
Phosphine (PH_3 – gas)	0.5 ppbv	<0.5 ppbv	Dräger tubes
Silicon (Si)	30 ppbv	<12.8 ppbv	Method 29

[1] Acceptable limit based on currently available data.
[2] EERC syngas analysis performed March 29, 2021.
[3] Detection limit.

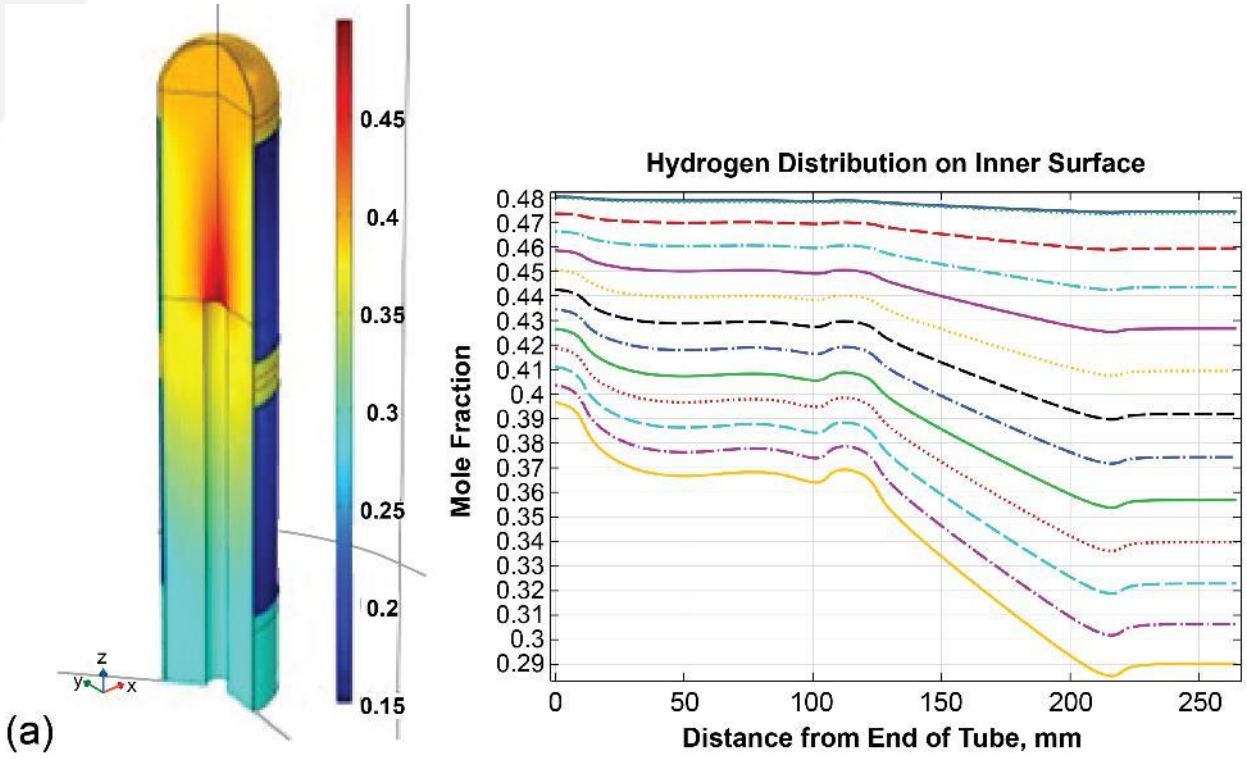
MULTIPHYSICS PERFORMANCE MODEL CALIBRATION

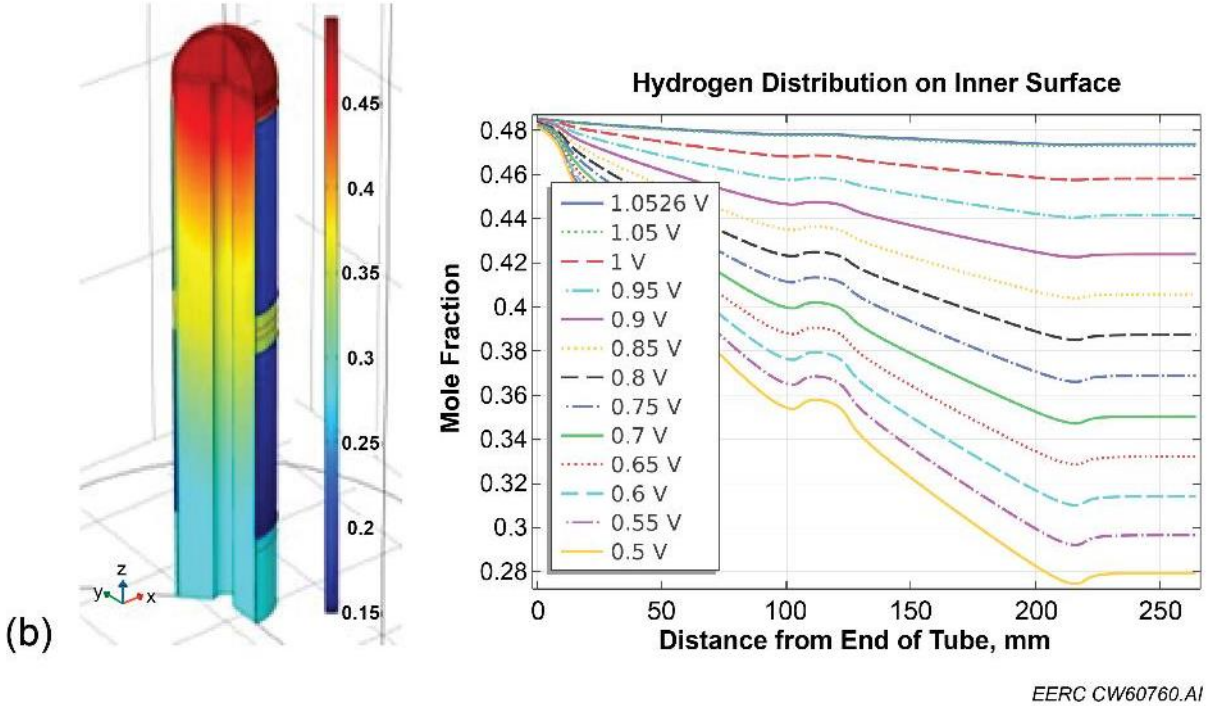




SOFC MULTIPHYSICS PERFORMANCE MODEL

Simulations of fuel distribution along the anode in a tubular cell at different operating voltages based on inserting the inlet fuel tube: a) further from or b) closer to the end of the cell.





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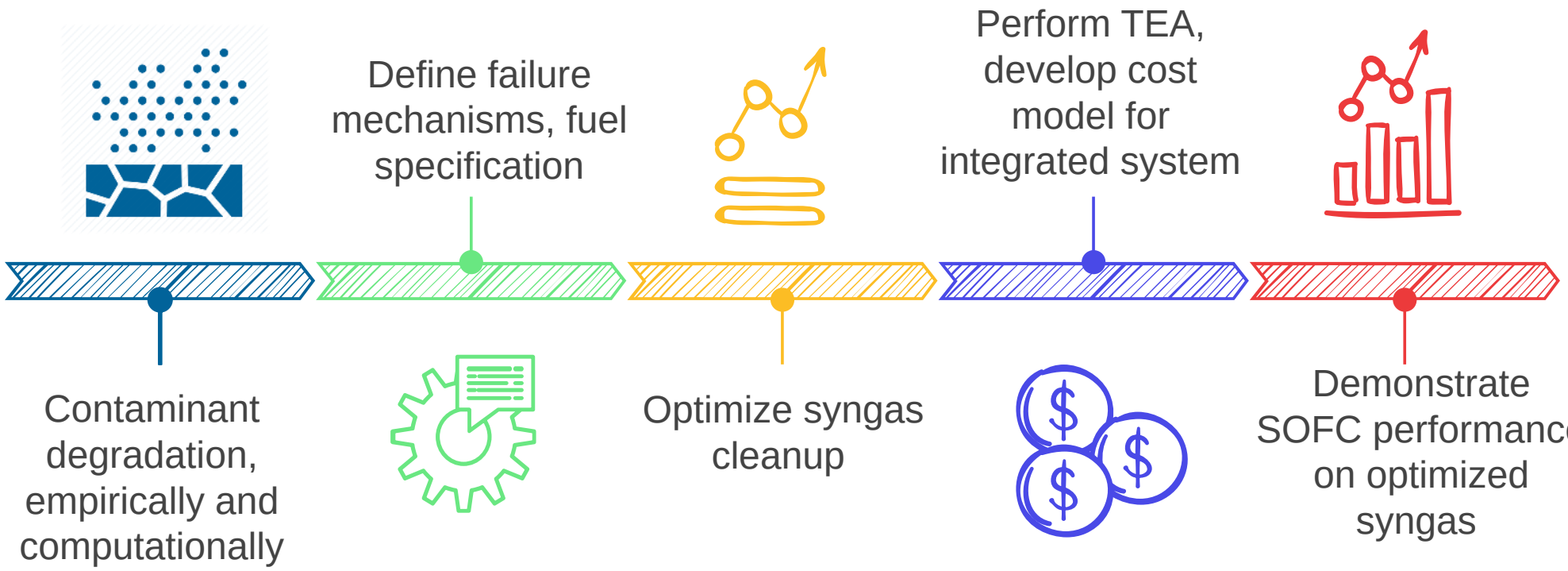
NEXT STEPS


Contaminant degradation, empirically and computationally
Define failure mechanisms, fuel specification
Optimize syngas cleanup
Perform TEA, develop cost model for integrated system
Demonstrate SOFC performance on optimized syngas

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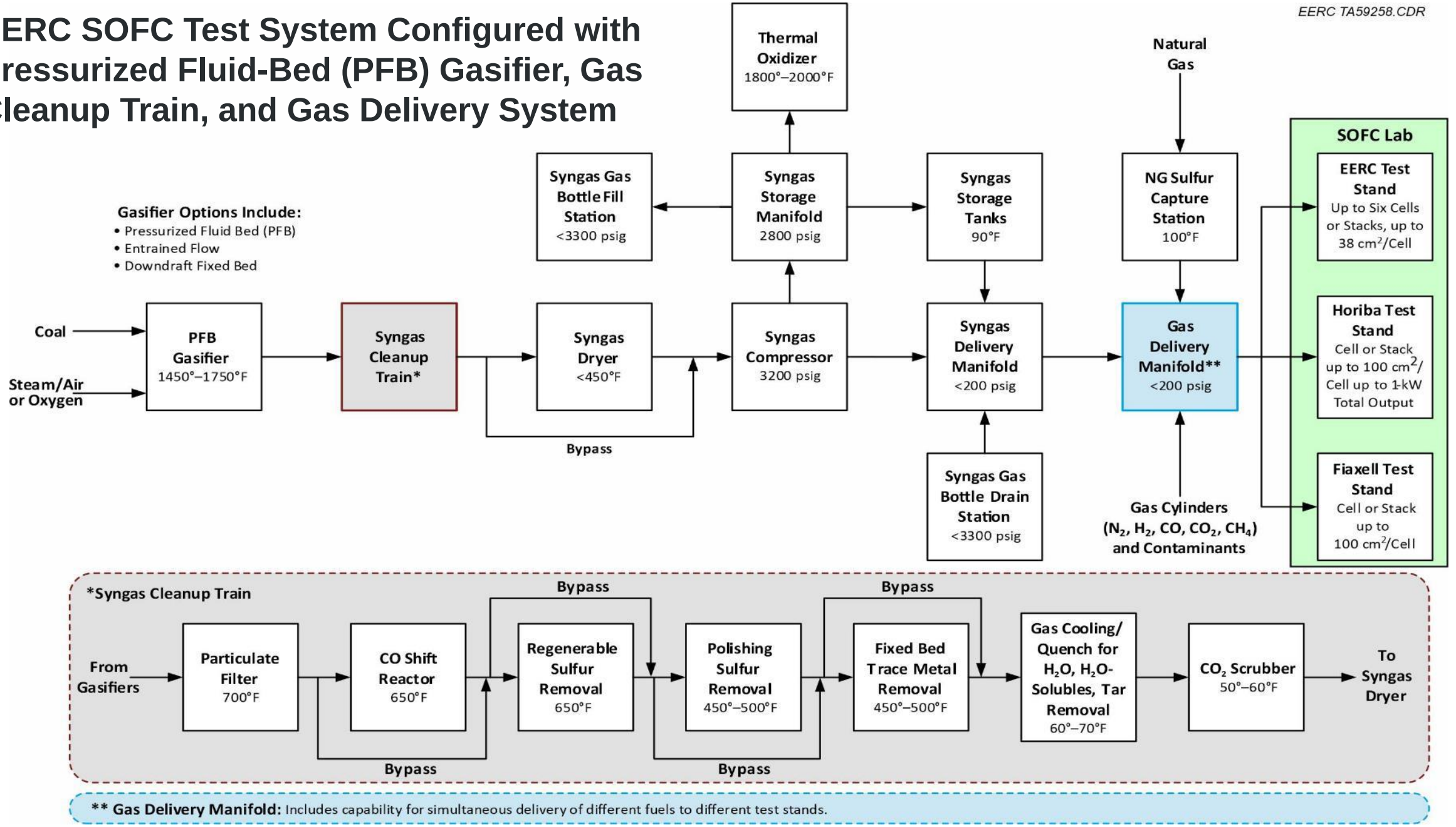
THANK YOU

Critical Challenges. Practical Solutions.

EERC SOFC Test System Configured with Pressurized Fluid-Bed (PFB) Gasifier, Gas Cleanup Train, and Gas Delivery System

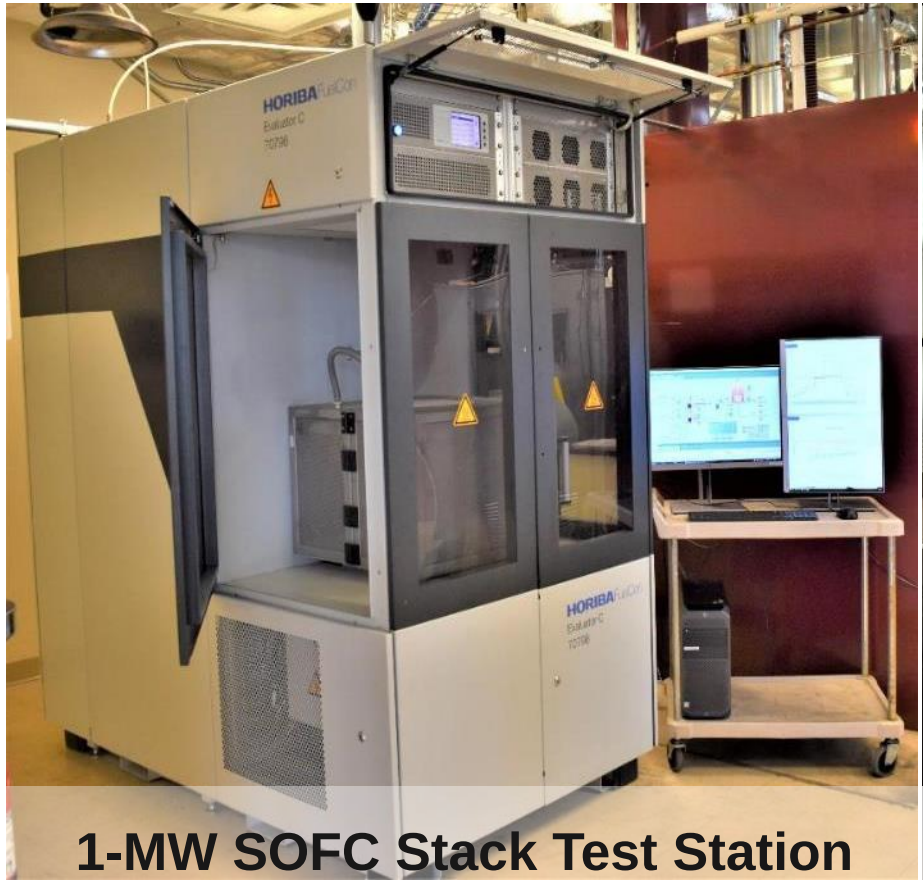


SYNGAS STORAGE AND DELIVERY (SSD)

SSD CAPABILITIES

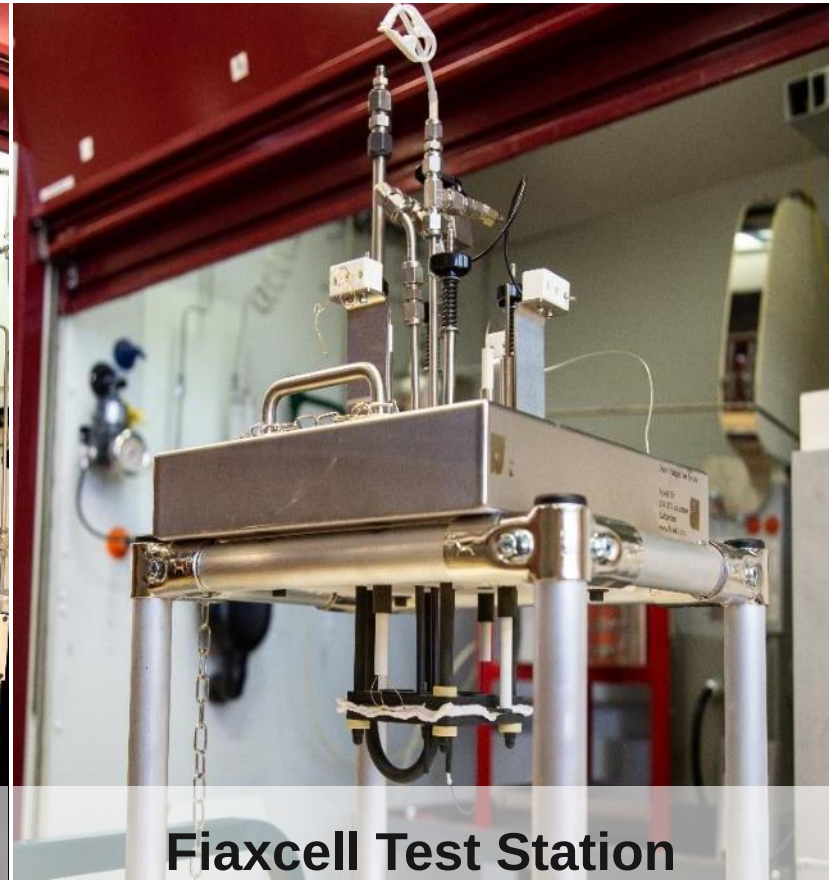
- Storage tank capacity: 20,900 scf at 2600 psi
- Fuel options:
  - Syngas from EERC gasifier (coal, biomass, waste, blend, etc.)
  - Natural gas
  - Mixture of bottled gases (H_2, CO, CH_4, CO_2, N_2, other)
  - Combination of above
- Multiple SOFC test stands can be operated at any given time

SOFC TEST STANDS



1-MW SOFC Stack Test Station

Multicell Test Station



Fiaxcell Test Station