An Intermediate Temperature Metal-Supported Proton-Conducting Solid Oxide Fuel Cell Stack

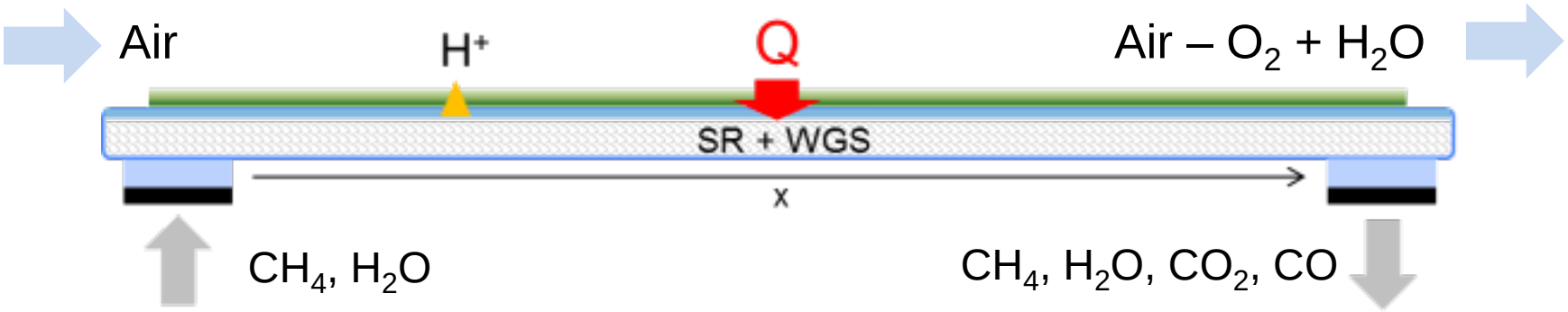
16th Annual SOFC Workshop

July 15, 2015

United Technologies Research Center
UNIVERSITY OF MARYLAND
UCONN
ElectroChem Ventures

Stack Concept

Metal supported p-SOFC with internal CH_4 reforming

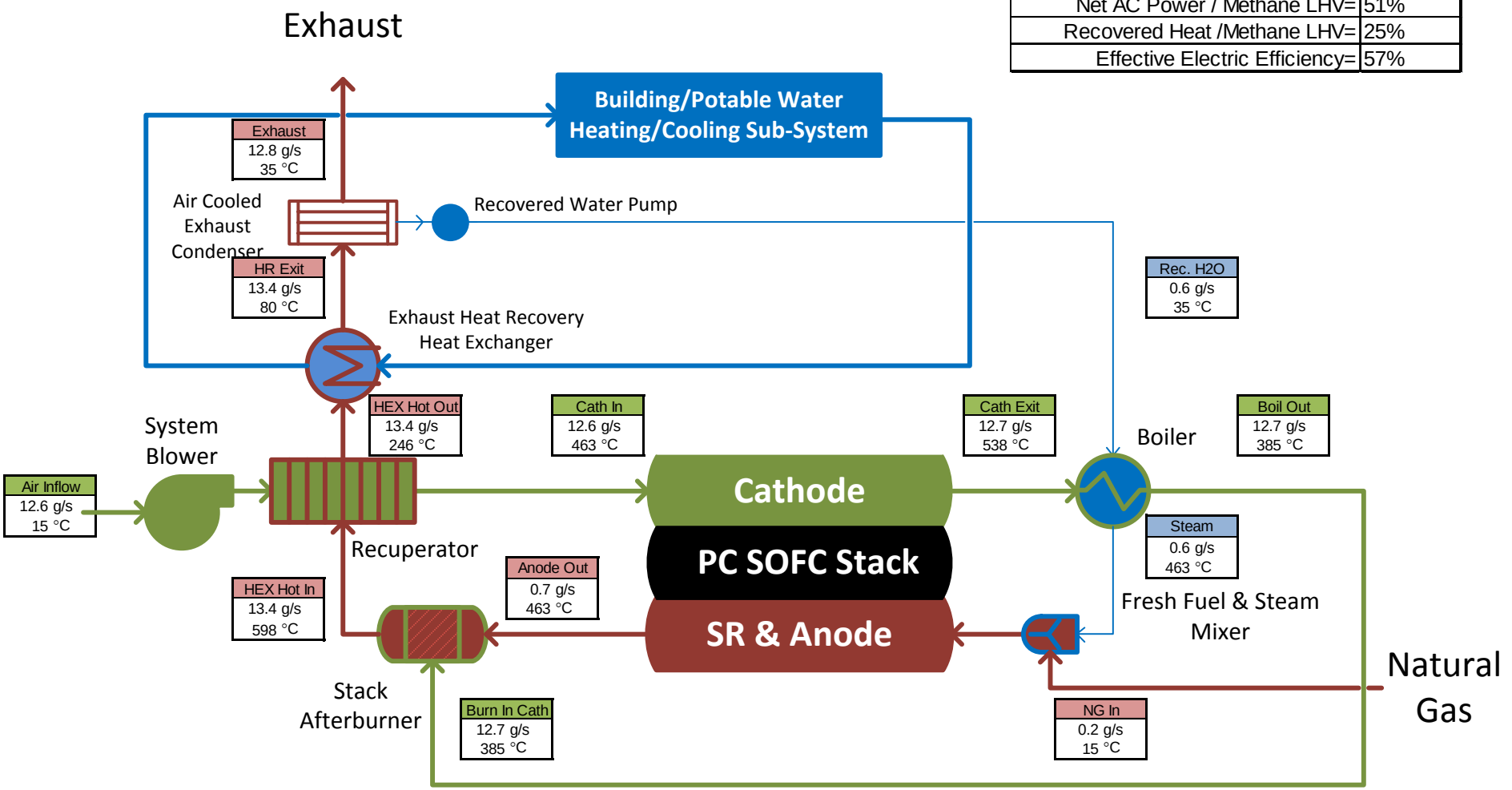


Feature	Lead Organizations
Proton-Conducting Oxide	UNIVERSITY OF MARYLAND, UCONN
Metal Support	ElectroChem Ventures, UCONN, United Technologies Research Center
Internal Fuel Reforming	United Technologies Research Center

System Concept

5 kW Residential CHP System

Performance Summary	
Net DC Power (W)=	5000
Net AC Power / Methane LHV=	51%
Recovered Heat /Methane LHV=	25%
Effective Electric Efficiency=	57%

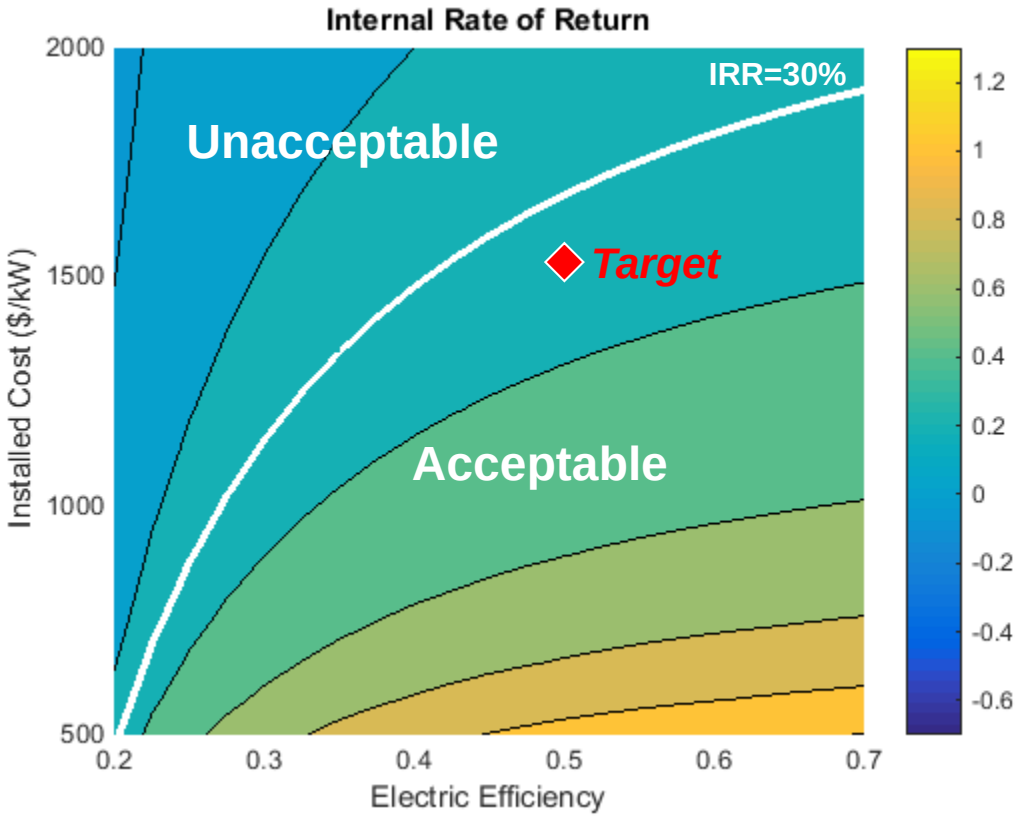


System Value Proposition

Nominal Residential CHP Scenario IRR Sensitivity to Cost & Performance

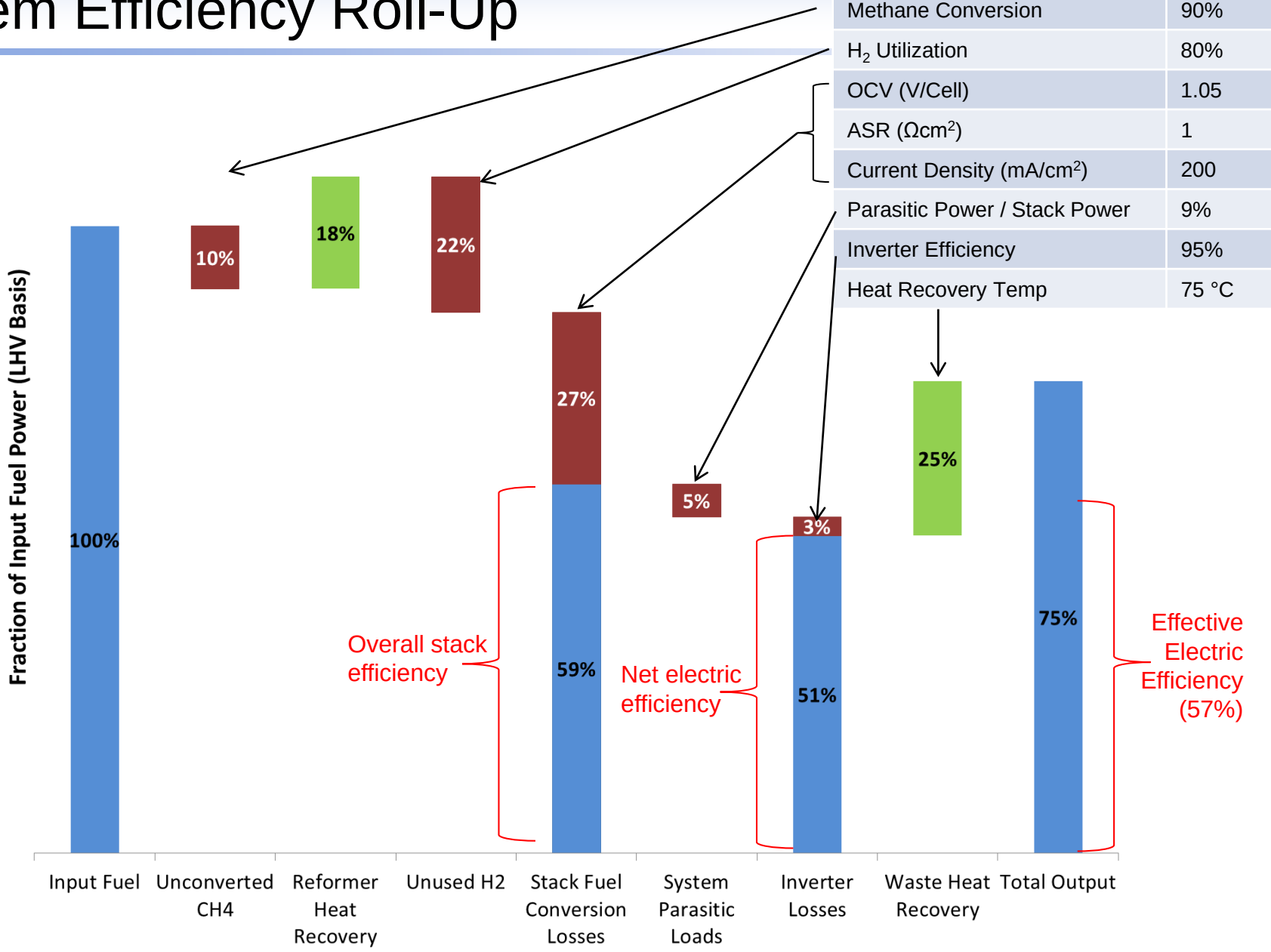
Assumptions

Electricity ($/kW$_e$h)	0.20
Gas ($/kW$_{LHV}$h)	0.04
Maintenance ($/kW$_e$h)	0.02
Life (years)	10
Inflation	3%
Recoverable Thermal / Waste Heat	50%
Electric Capacity Utilization	50%
Thermal Capacity Utilization	25%



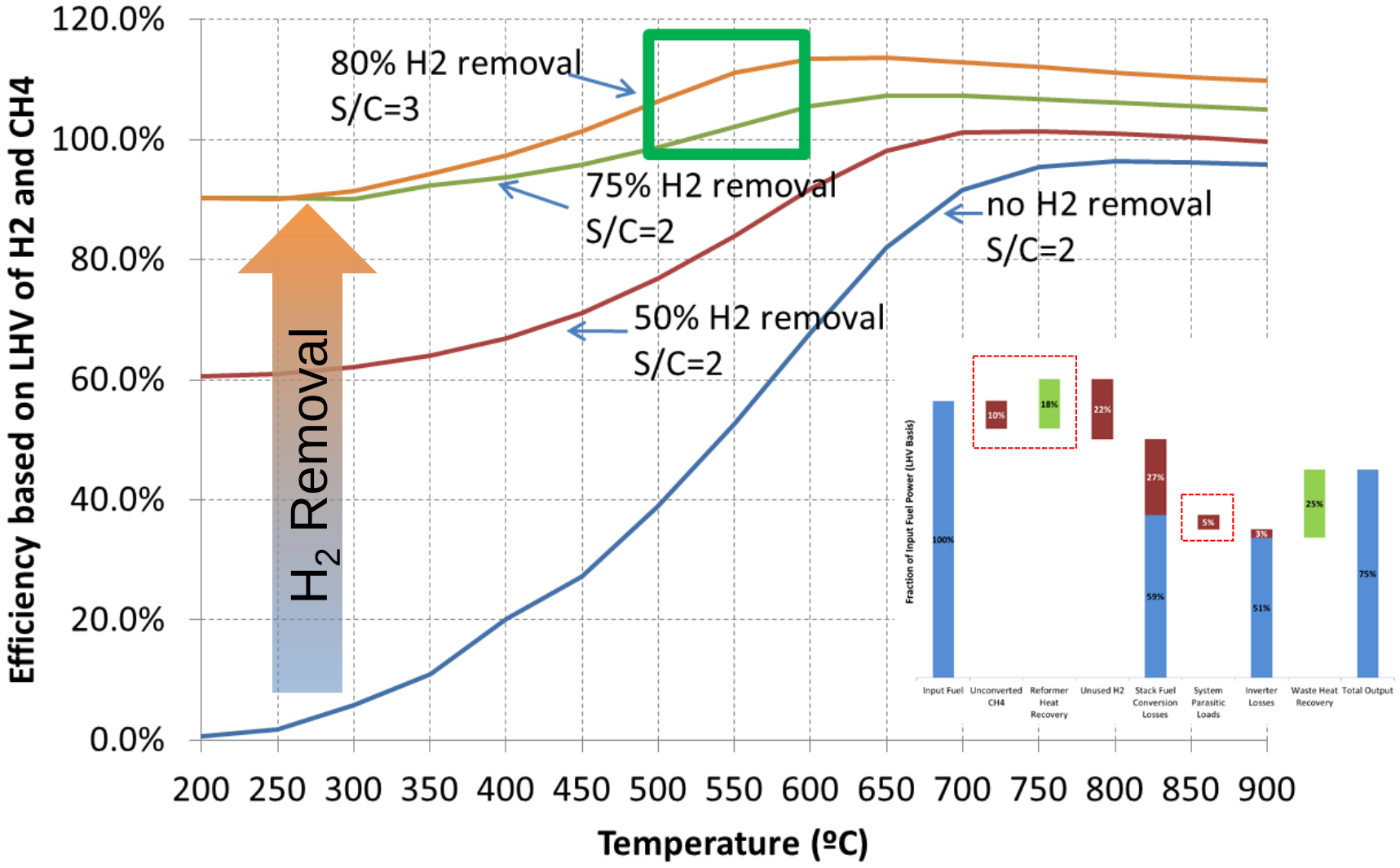
System Efficiency Roll-Up

Assumptions	
Methane Conversion	90%
H_2 Utilization	80%
OCV (V/Cell)	1.05
ASR (Ωcm^2)	1
Current Density (mA/cm^2)	200
Parasitic Power / Stack Power	9%
Inverter Efficiency	95%
Heat Recovery Temp	75 °C



Internal Methane Steam Reforming: Approach

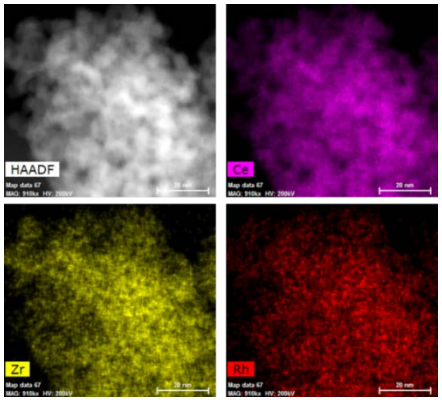
Benefits: Stack Waste Heat Recovery, Parasitic Cooling Power Reduction

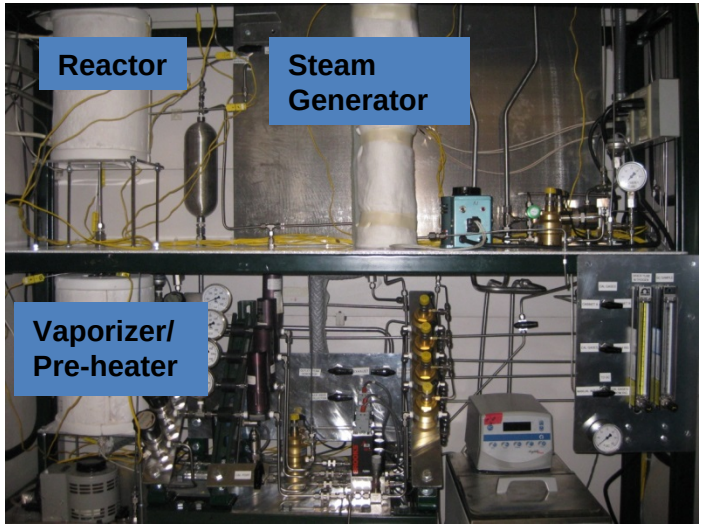


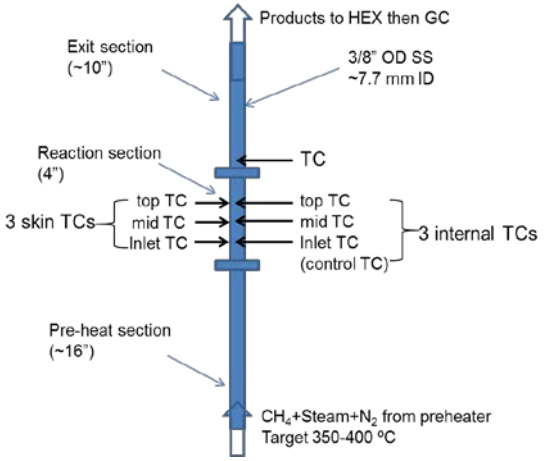
Internal Methane Steam Reforming: Progress

Approach

1. Pick the catalyst
2. Button cell demo with H_2 removal
3. Build full scale reactor
4. Cell/stack testing







Target conversion (without H_2 extraction) achieved with acceptable PGM loading

Catalyst Testing Results

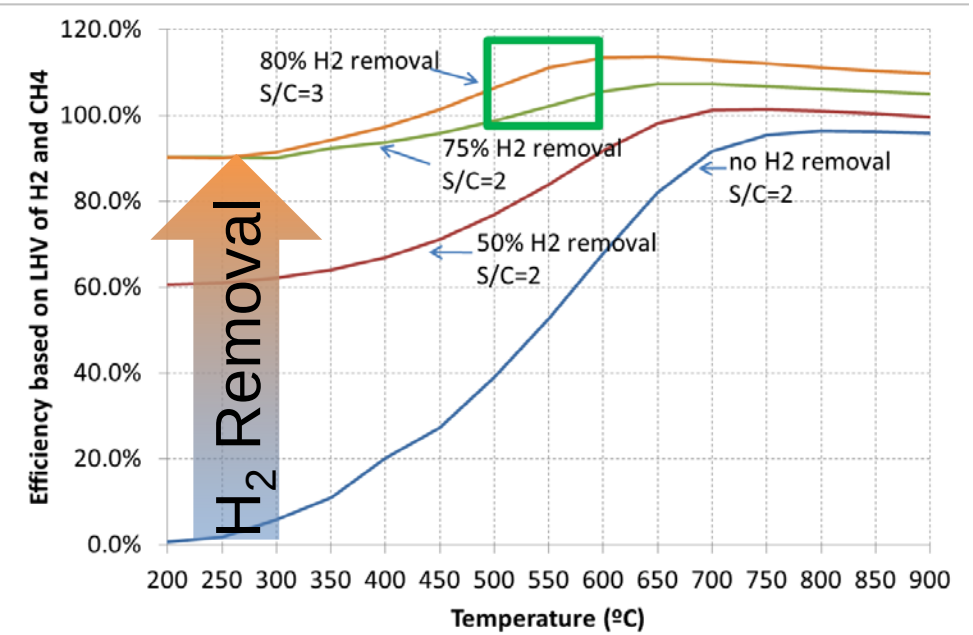
Achieved performance target while satisfying PGM limit

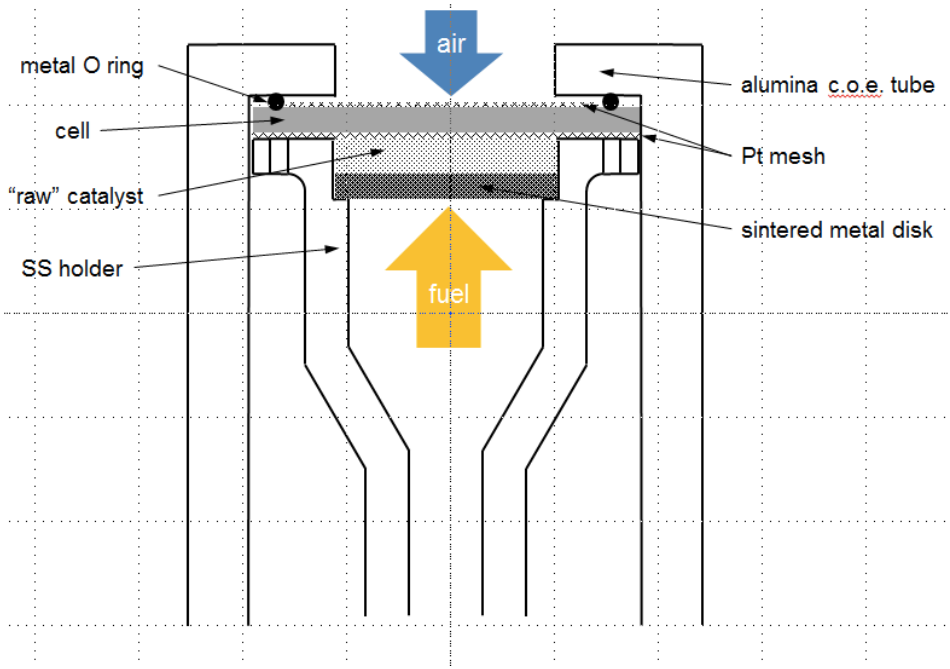
Catalyst	Temp (°C)	W/F (kg/kmol/s)	Steam/ Carbon	X-CH4
Base	550	6	4	27%
UTRC A	500	3	3	24%
UTRC B	500	3	3	30%
UTRC C	500	3	3	38%

Equilibrium Conversion (w/o H_2 extraction) ~ 40%

Button Cell Test Rig

Demonstrate target conversion (90%) with H_2 removal

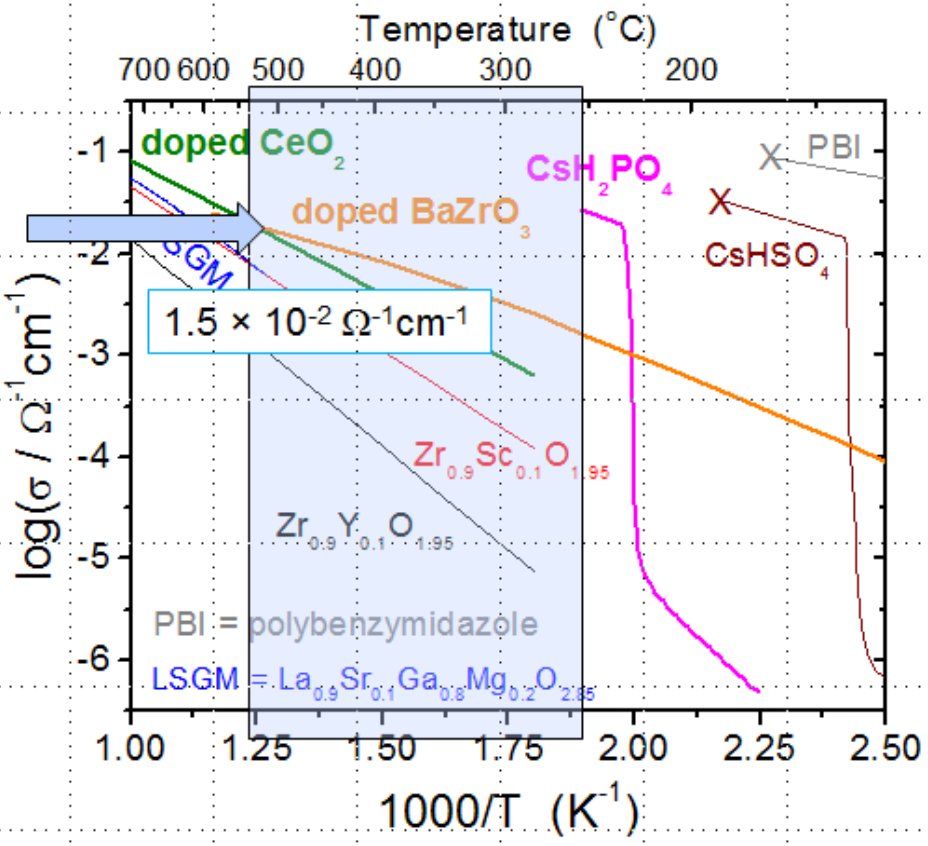




Proton Conducting Oxide

Optimizing electrode & electrolyte composition (in part) via combinatorial material evaluation technique

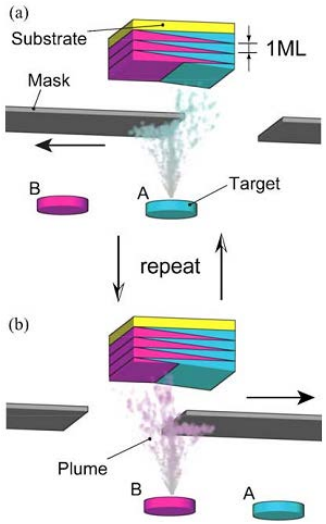
Base Electrolyte

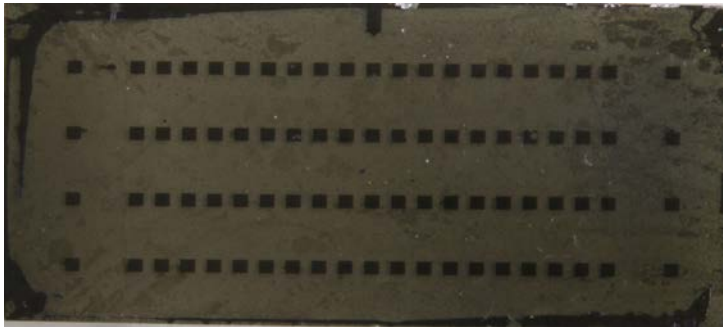


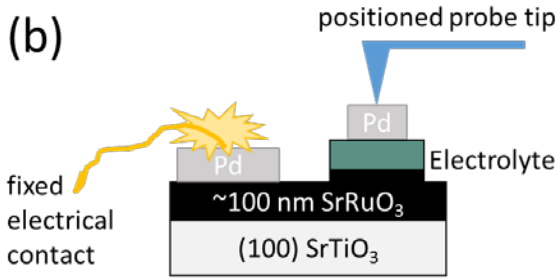
Material Optimization

Composition ranges being investigated

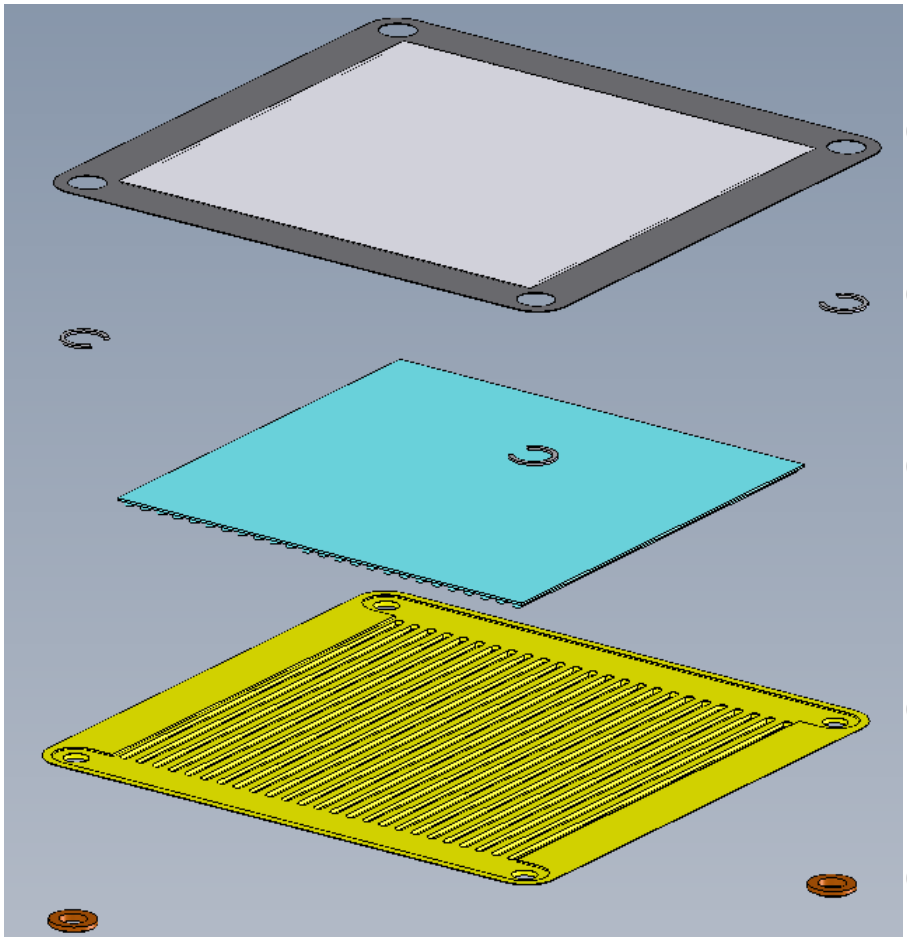
Layer	Potential Compositions
Anode	NI - $BaZr_xCe_{1-x}(Y,Yb,Ho)_yO_3$
Electrolyte	BZC*: $BaZr_xCe_{1-x}(Y,Yb,Ho)_yO_3$
Cathode	LSCF: $(La,Sr)(Co,Fe)O_3$ NBSCF: $NdBa_{0.5}Sr_{0.5}Co_{1.5}Fe_{0.5}O_{5+\delta}$







Metal Support Design



(1) Metal Porous Sheet
(substrate for p-SOFC trilayer)

(2) Metal C-Ring Inserts/Orifices
(3 out of 4 visible)

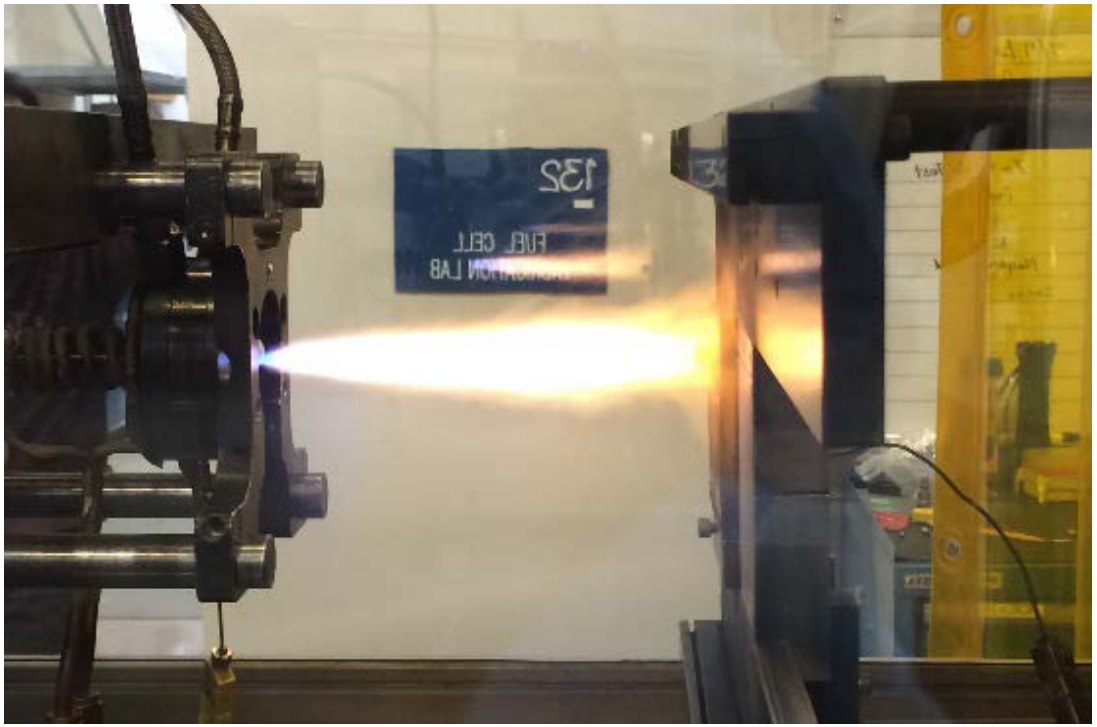
(3) Metal Foam
(substrate for reforming catalyst)

(4) Metal Stamped Dish

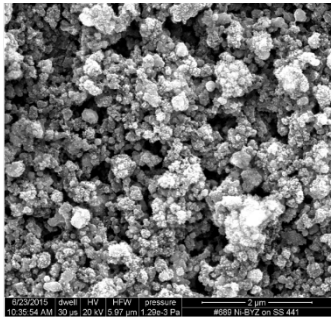
(5) Insulator Couplings
(2 out of 4 visible)

Metal Support Design

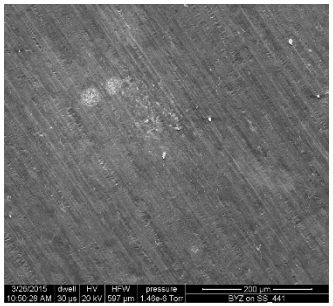
Enabling Fabrication Approach: Reactive Spray Deposition Technology



Anode



Electrolyte



Cathode - Pending

Working to optimize deposition process parameters for different layers (e.g. solvents, concentrations, additives, nozzle location, …)

Stack Concept

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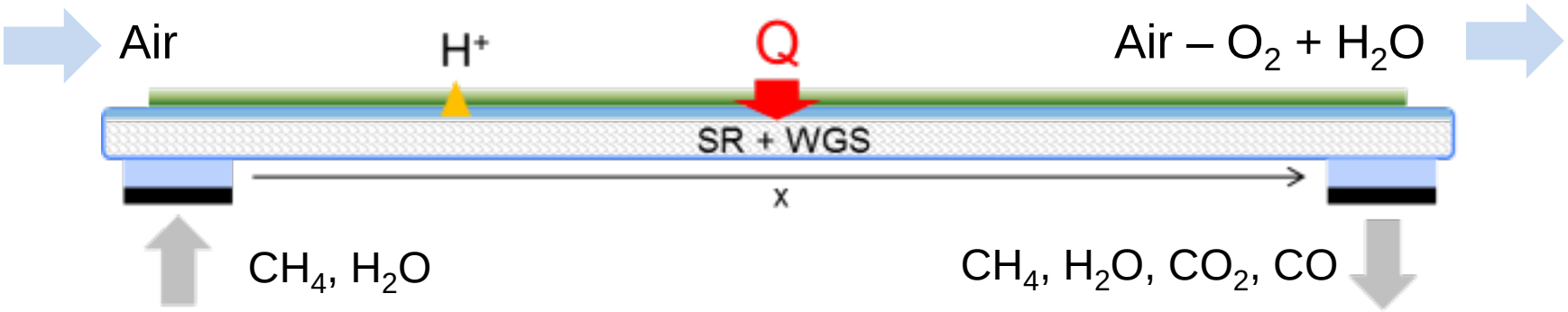

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Internal Fuel Reforming	United Technologies Research Center

Acknowledgements

Organization	Team Member
	Sossina Haile, Sihyuk Choi, Chris Kucharczyk
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arpa·e CHANGING WHAT'S POSSIBLE

John Lemmon, Scott Litzelman, John Tuttle