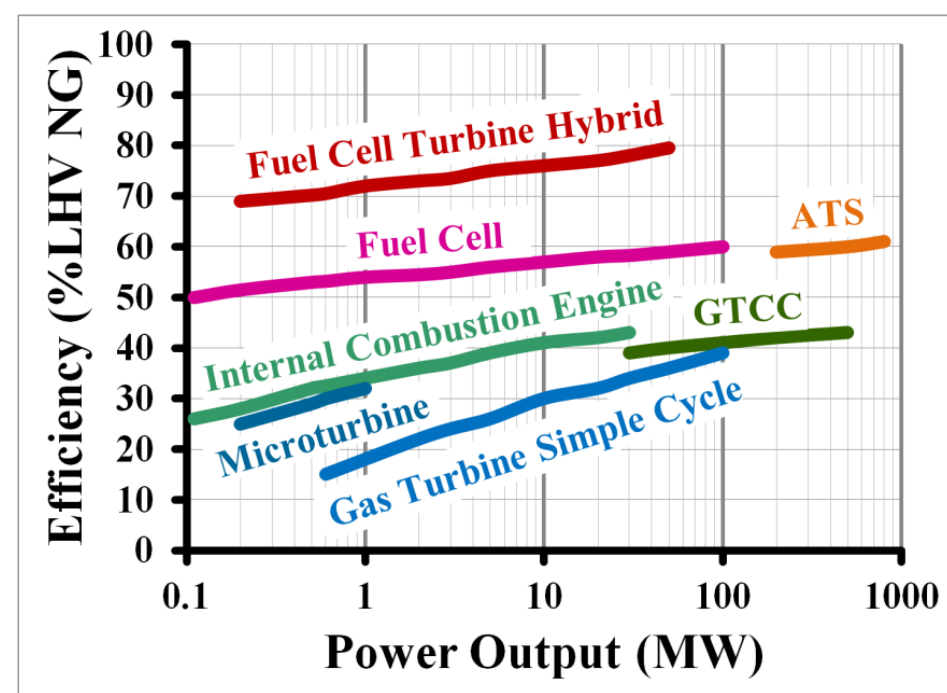


# NETL Insights into Hybrid Power Systems

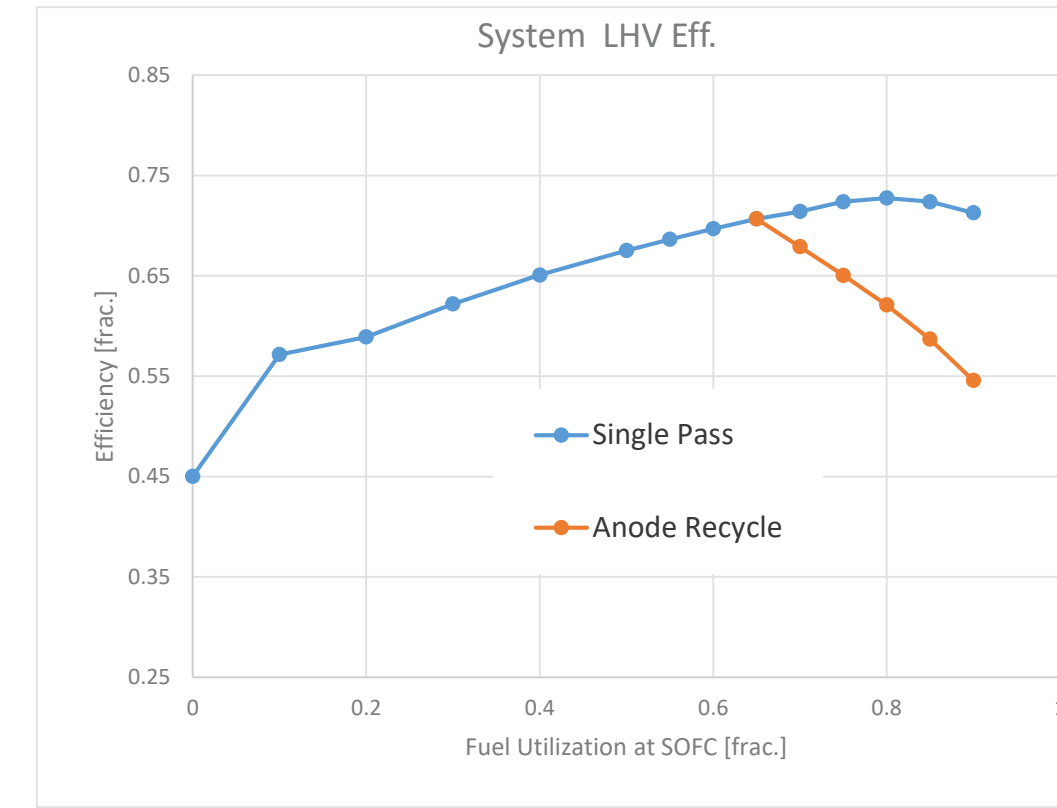


## Opportunities and Overcoming Challenges

### Opportunities: Efficiency, Flexibility, Emissions



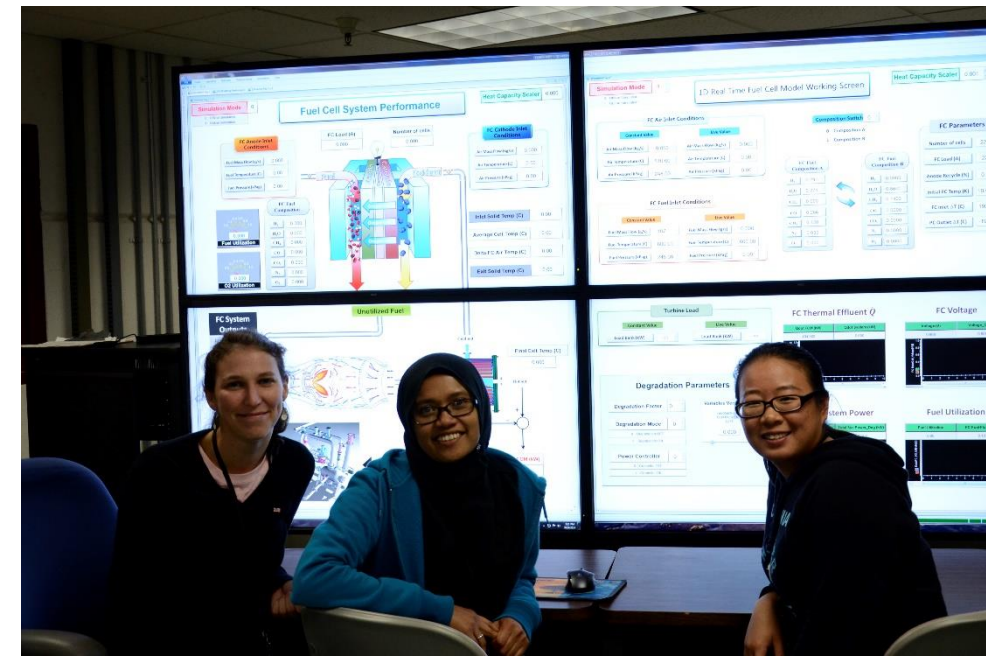
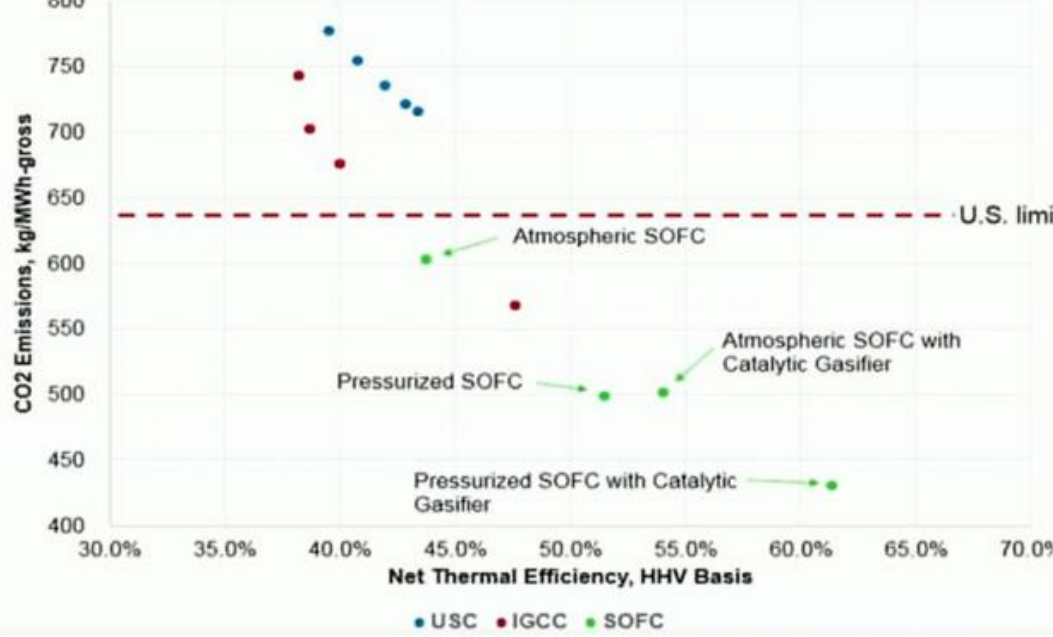
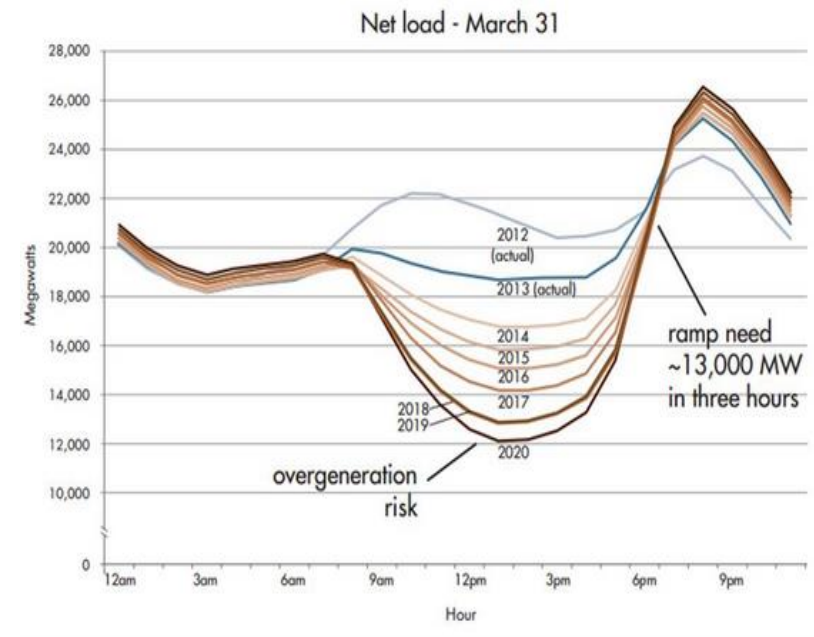
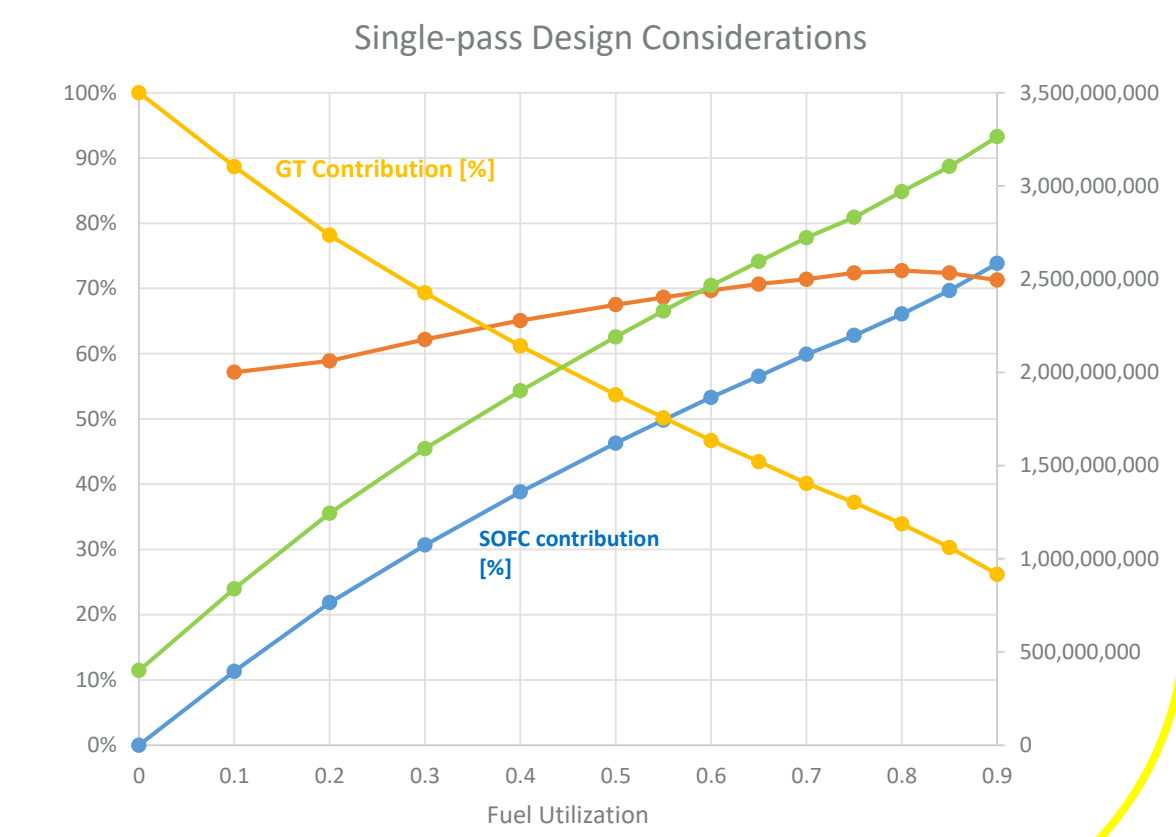
### Efficiency Optimization in Hybrids



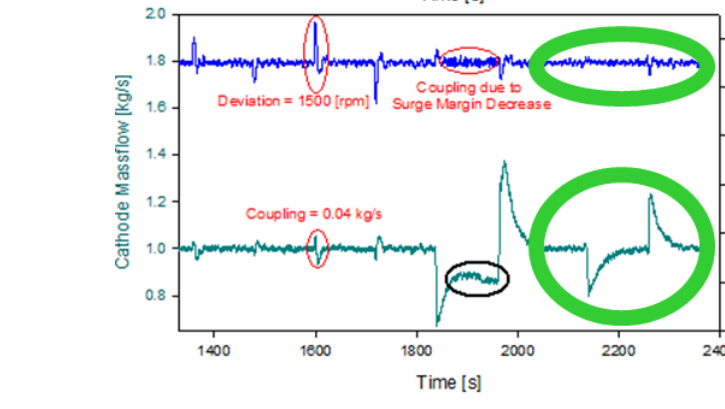
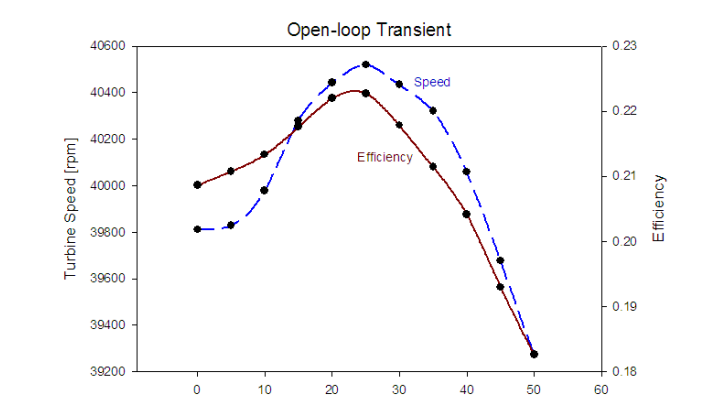
Anode recycle reduces chances of anode material oxidation, but...

Maximum system efficiency is realized at a single pass fuel utilization of 75% to 80% (syngas).

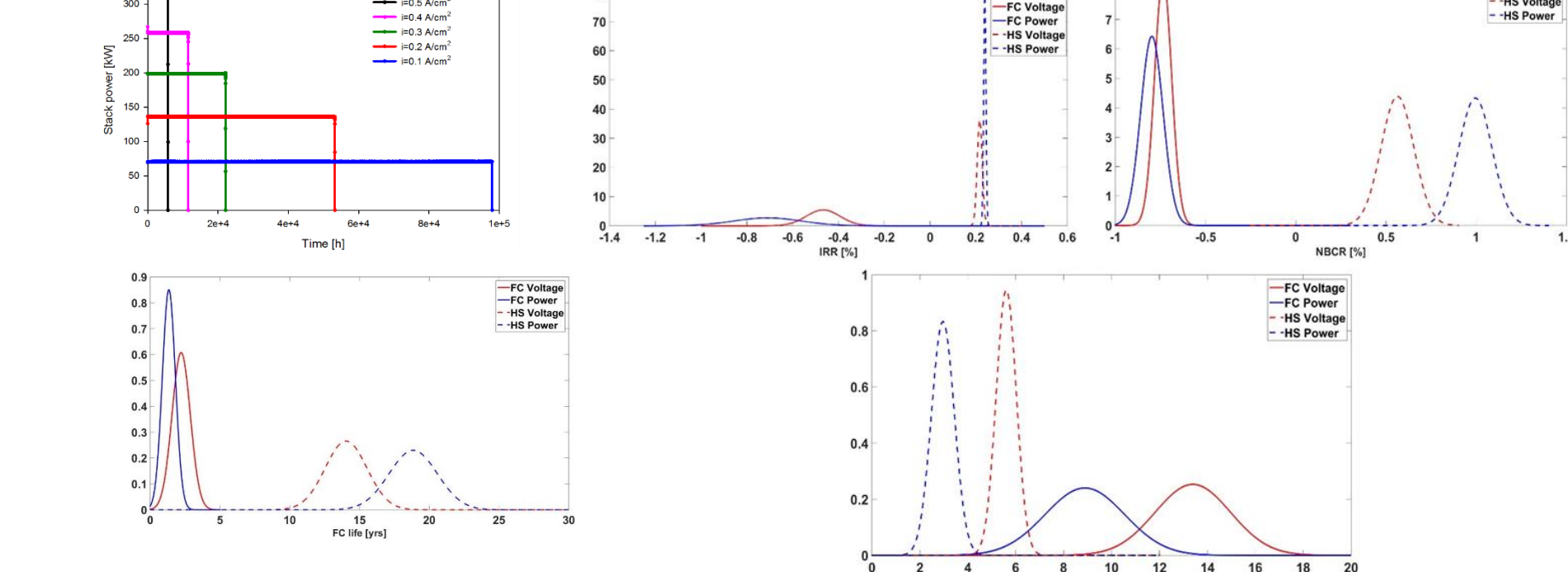
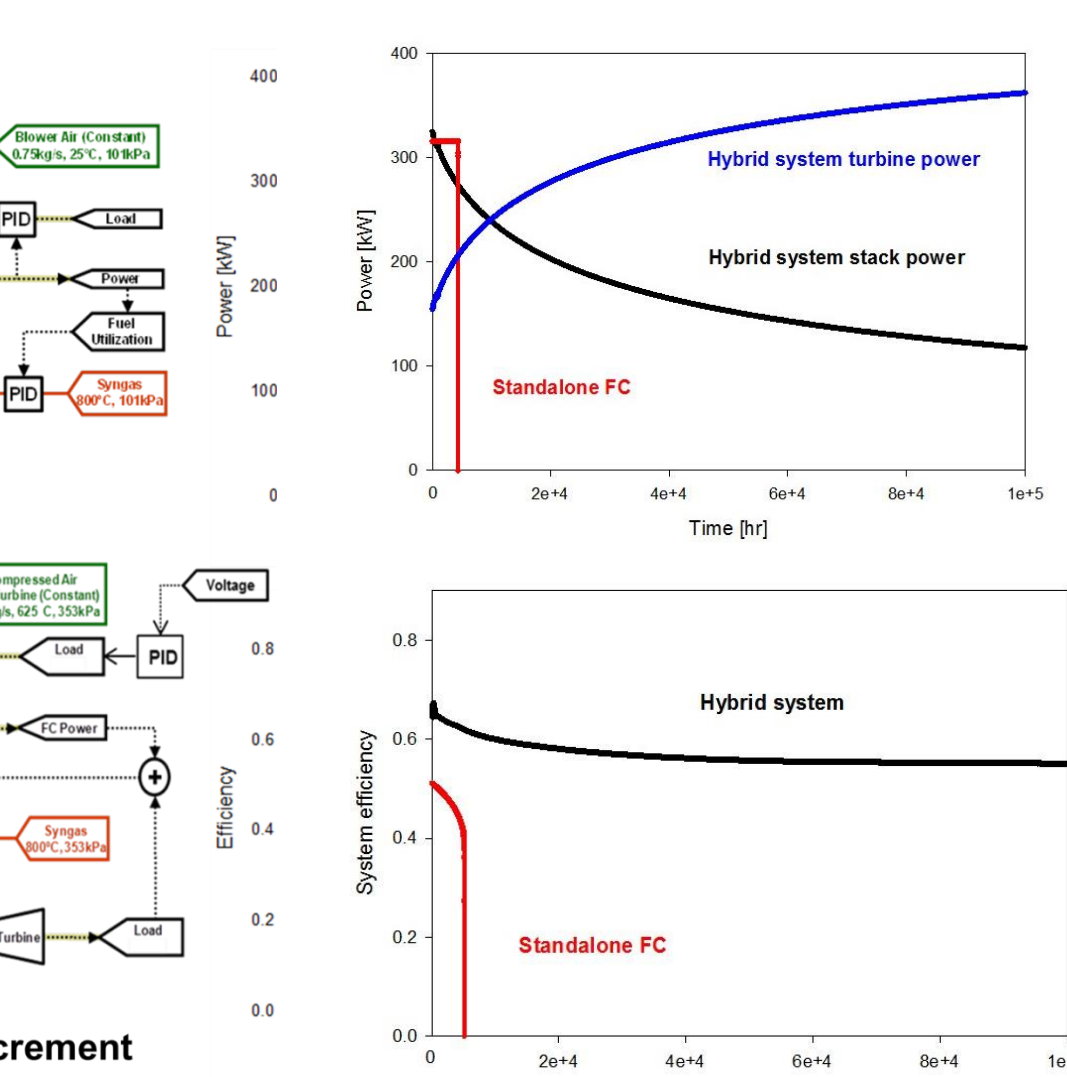
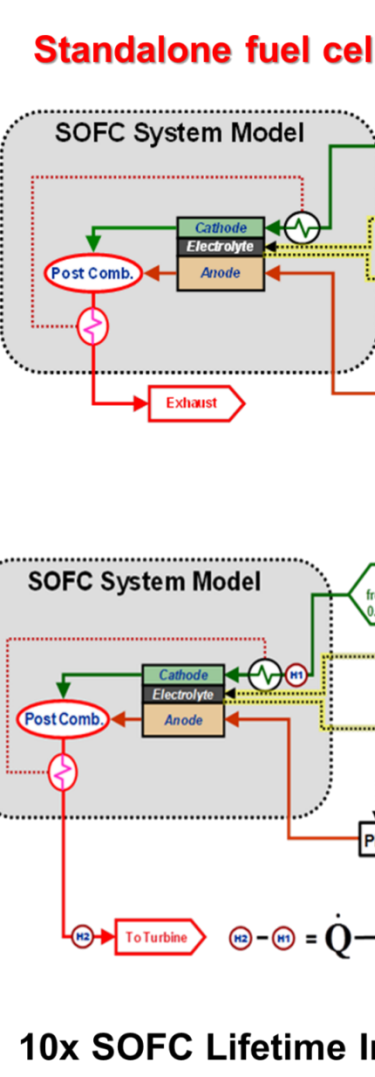
This corresponds to a power split of 65%FC/35%GT



### Challenges: Integration, Controls



### Fuel Cell Life: Comparison with Constant Power

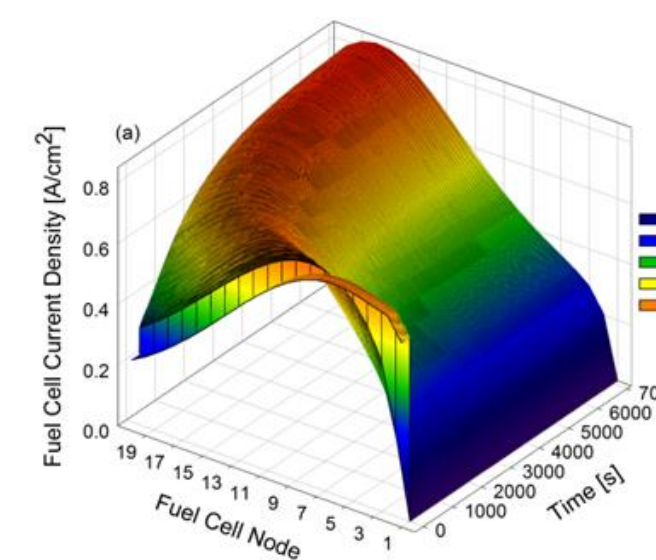
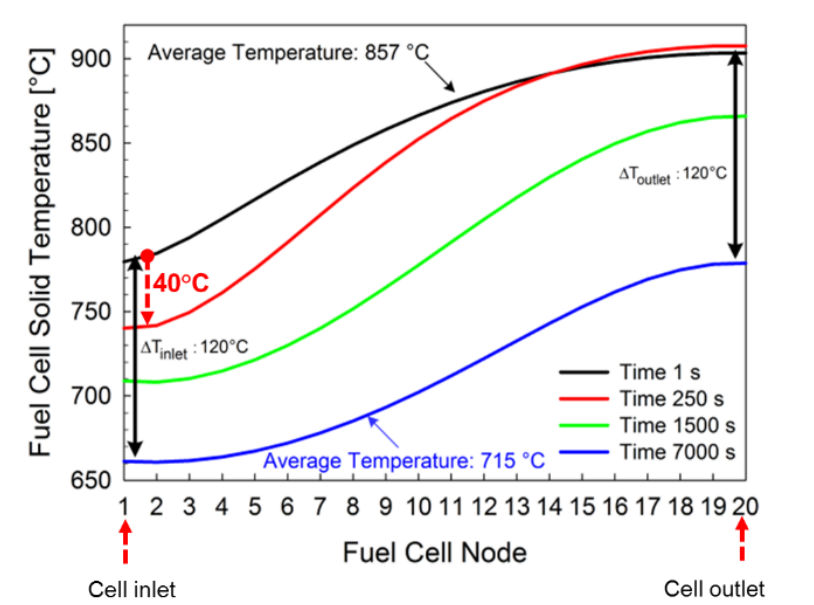
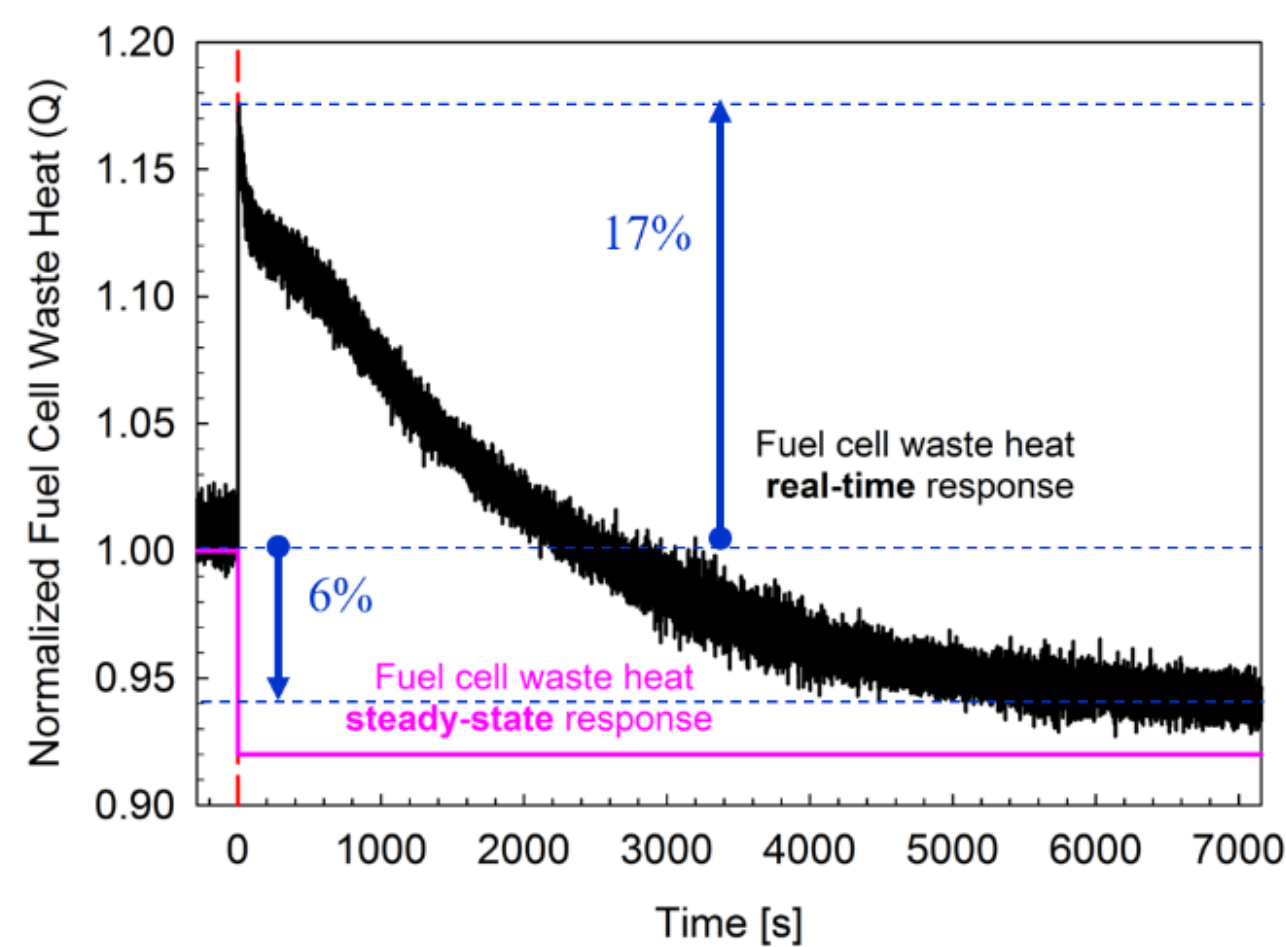


Initial current density [A/cm <sup>2</sup> ]	Lifetime [yr]	PBP [yr]	NPV [% capital cost]
0.5	0.7	-	-538
0.4	1.3	26.5	-1.5
0.3	2.5	7.3	114.2
0.2	6	6.3	181
0.1	11.2	11.2	63.8

Stack cost	Stack lifetime [yr]	PBP [yr]	NPV [% capital cost]
400 \$/kW	11.3	2.9	416
1000 \$/kW		3.3	365
3000 \$/kW		5.2	189

### Fuel Composition Changes Syngas to Humidified Methane

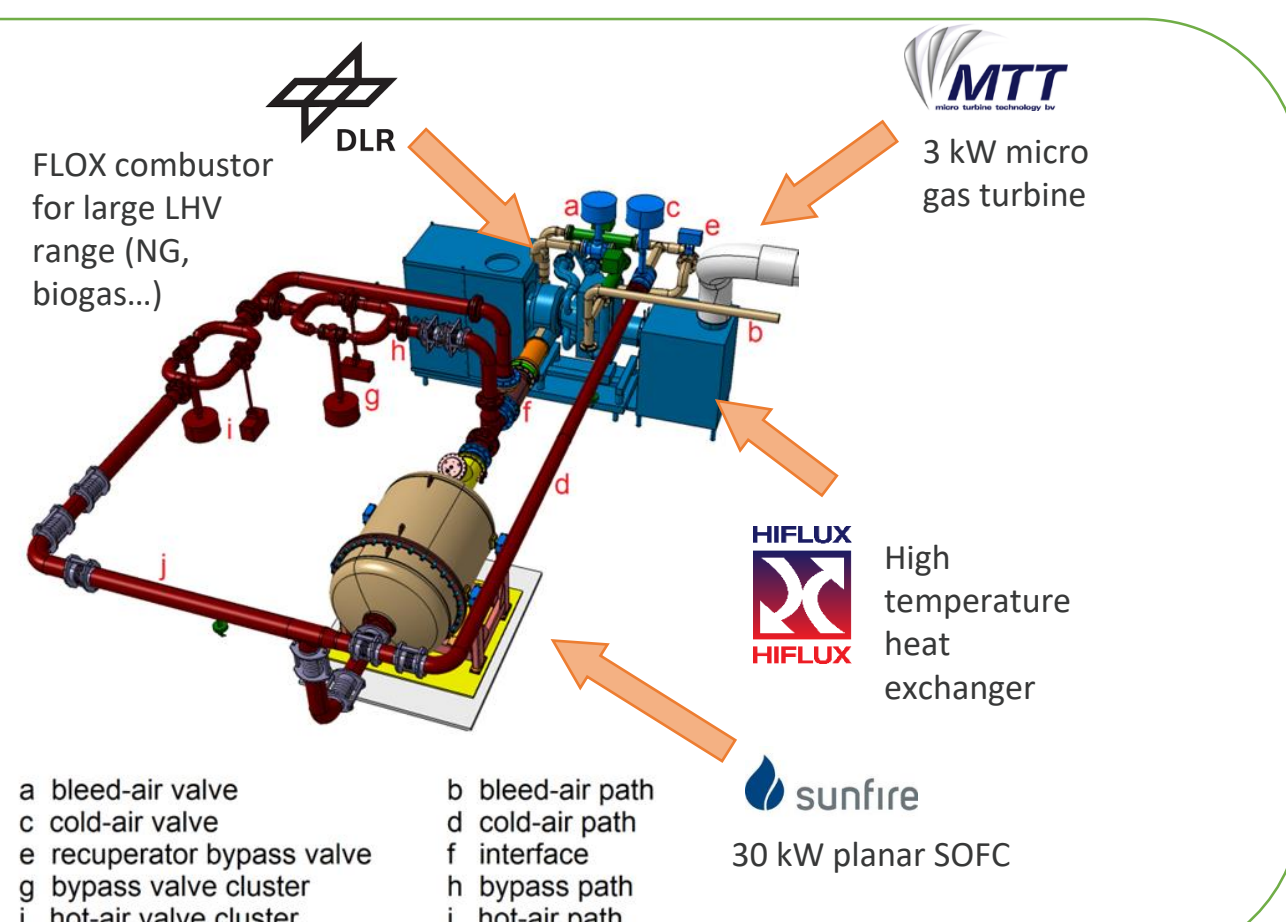
Starting Heat Capacity  
➤ 2.1 GJ for a 400kW Stack



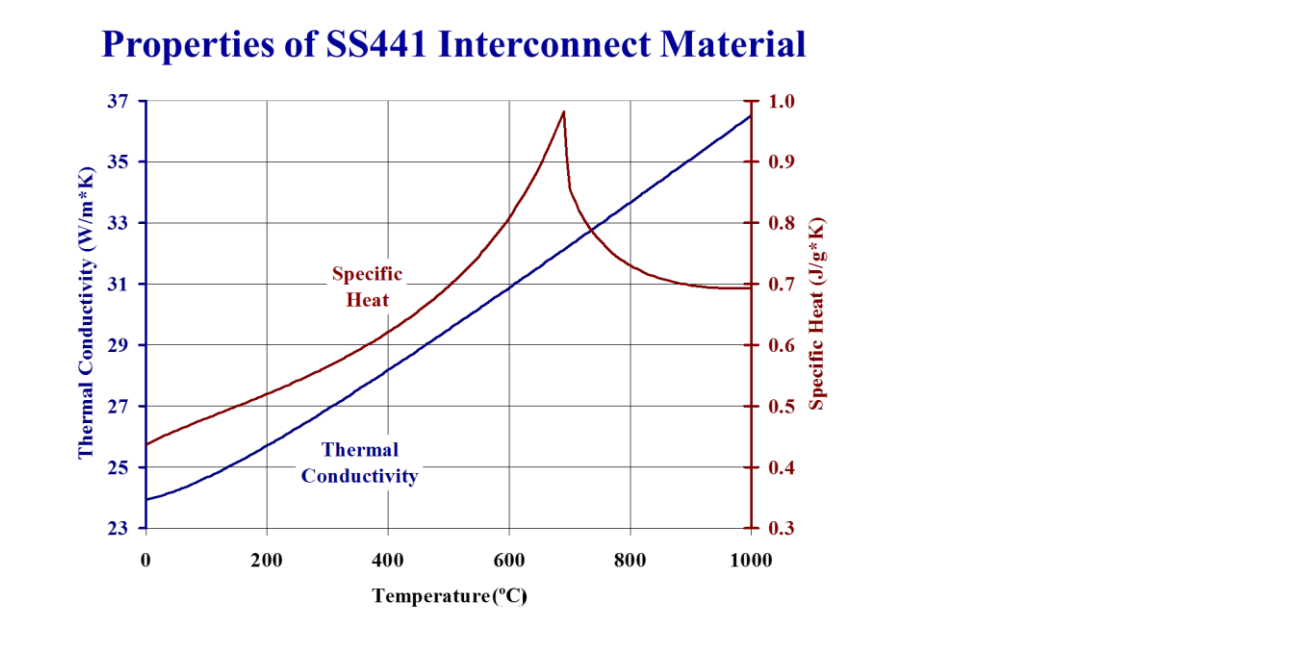
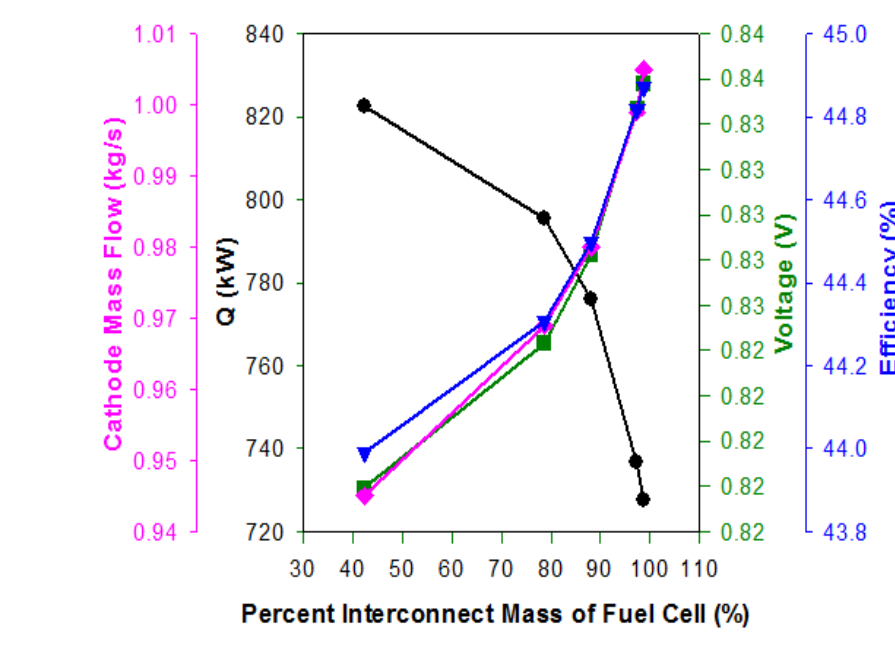
### Polygen Flexibility NPV Increase of 62%

Chen, Y., Adams, T. A., and Barton, P. I., 2011, "Optimal Design and Operation of Flexible Energy Polygeneration Systems," Ind. Eng. Chem. Res., 50(8), pp. 4553-4566.

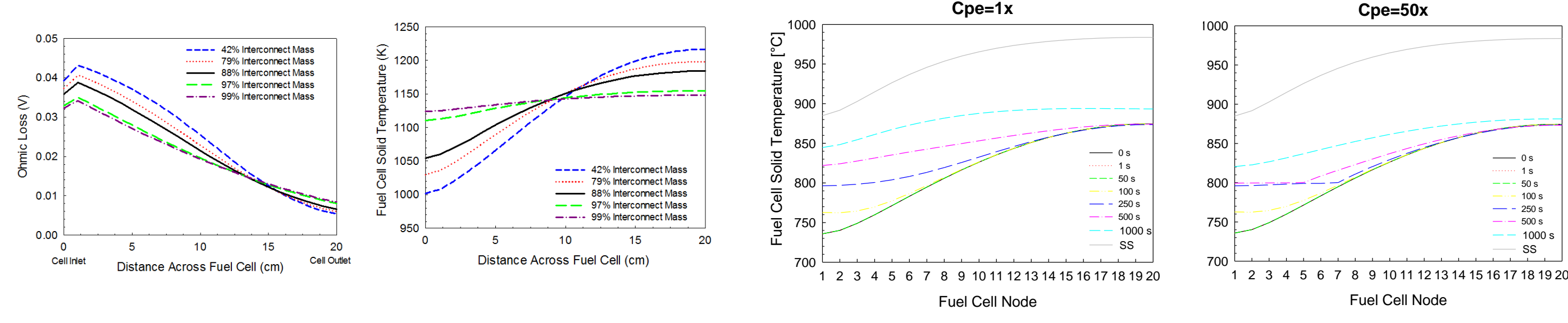
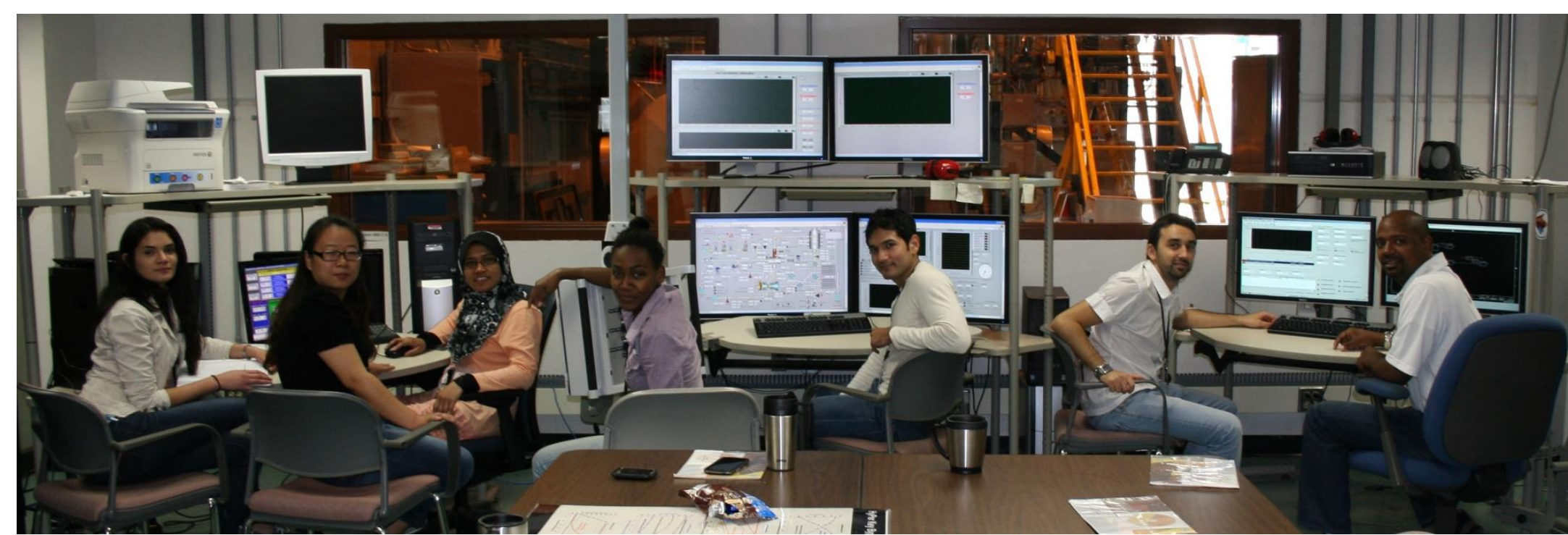
### Demonstration plant of a 33 kW SOFC micro gas turbine CHP system



### Fuel Cells with Thermal Energy Storage



Improving system efficiency and flexibility through integration of thermal energy storage in SOFCs.



Higher system efficiency and load following without risk to the fuel cell