

Next Generation Durable, Cost Effective, Energy Efficient Tubular Solid Oxide Fuel Cell Contract: DE-FE0031674 Ted Ohrn, April 18, 2023



### **Company History**





## SPS acquired Atrex Energy and formed a new company including several former LG engineers and technicians

### **Field Installation Examples**







Cathodic Protection Site in Wyoming

- 600+ systems previously fielded across N America
- 6,000,000+ hours of field operations
- Single unit operations of 35,000+ hours (25X)
- 99+% availability...when it must work in high-intensity cell applications...it will



Wellhead Controls in New York





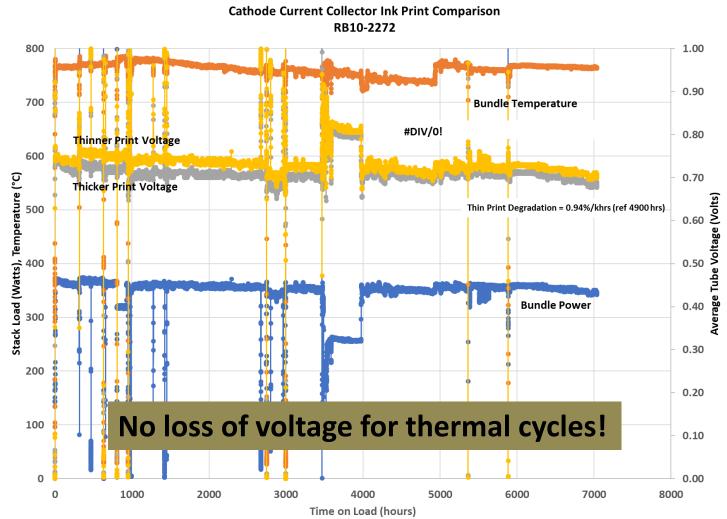
- Develop and optimize a YSZ electrolyte-based solid oxide fuel cell (SOFC) technology for low cost, low temperature (550~650°C), and high energy efficiency operation.
- The developed technology will be implemented and demonstrated in a high efficiency 2-3kW SOFC with applicability to sub-MW system.
- A modular design and cost analysis will be performed.

### 2.1 Cathode Current Collector Development

SPS Special Power Sources

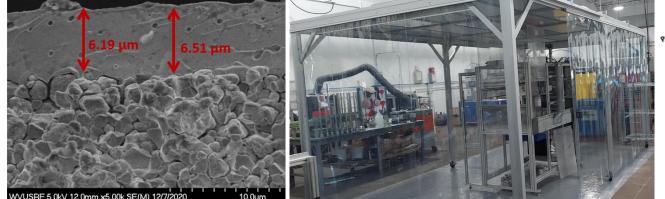
- Screen printed Ag current collector mesh pattern
- Long-term bundle test shows improved and stable performance
- New manufacturing specification developed to reduce cost

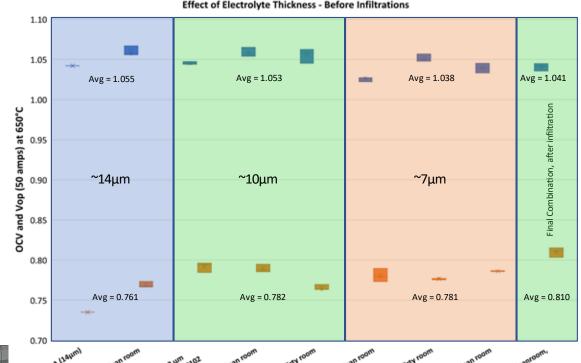




# **2.2 Thin Electrolyte**

- Electrolyte slurry formulated with • different solids loading and applied with varying spray parameters
- Clean room installed to minimize possible • defects caused by the processing environment





Effect of Electrolyte Thickness - Before Infiltrations

10µm electrolyte provides improved performance and sufficient sealing



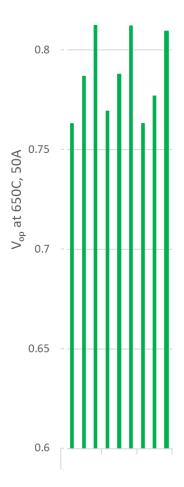
### **2.3 Effect of Cathode Infiltration**



- PrOx infiltration initially chosen
- Cathode delamination issues became evident
- Improved barrier layer developed with better densification



- Robust process developed with 100% pass rate on recent batches
- Additional cost is only ~\$1/tube for ~3.5% improvement



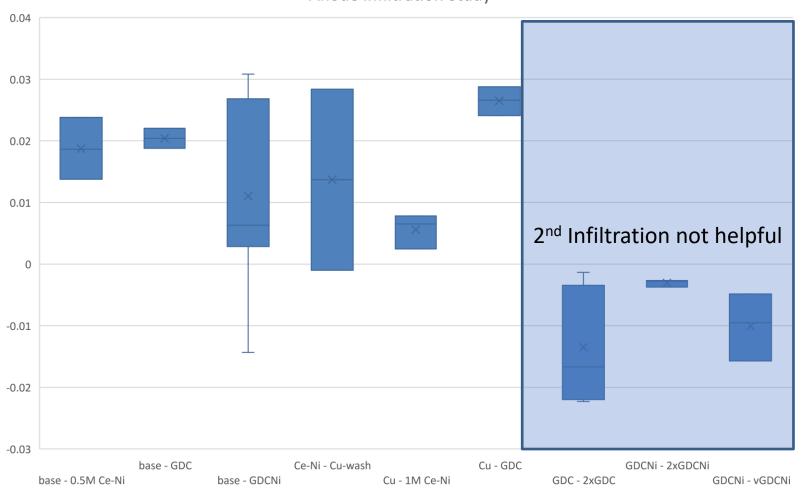
Avg improvement

0.027V

### **2.4 Effect of Anode Infiltration**



- Ce-Ni and GDC showed similar improvement
- Results of Cu-wash were inconsistent, but process kept for carbon formation considerations

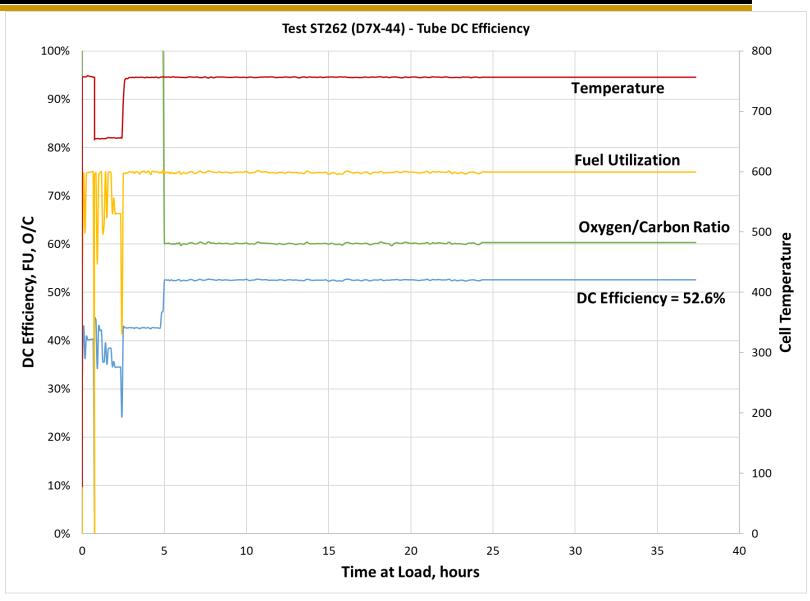


Anode Infiltration Study

### **2.5 Internal Reforming Validation**



- 53% Dceff at standard operating conditions with Natural Gas
- Improved performance reduces CAPEX or OPEX



### 2.5 Internal Reformer Validation - LPG Carbon Prevention with Internal Recycle

0.4

0.8

1.2

650

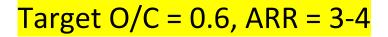
9.0 D/C Ratio

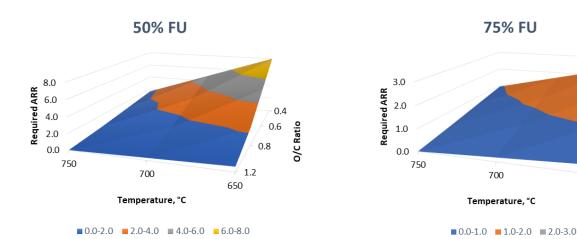


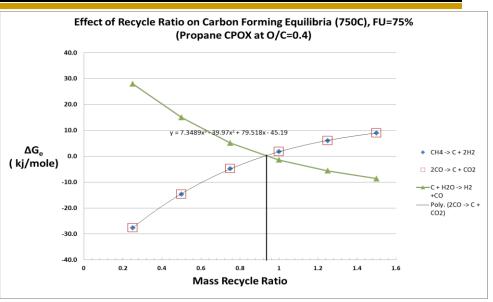
Potential for Carbon Increases with:

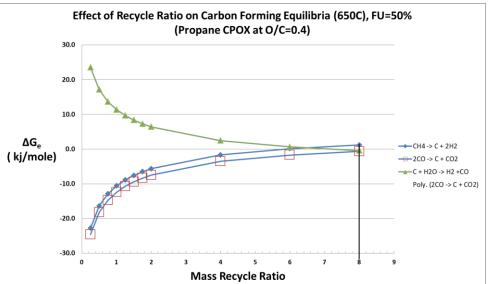
- Lower temperature
- Lower Fuel Utilization (FU)
- Lower CPOX O/C ratio

Anode Recycle Ratio must be increased to compensate.



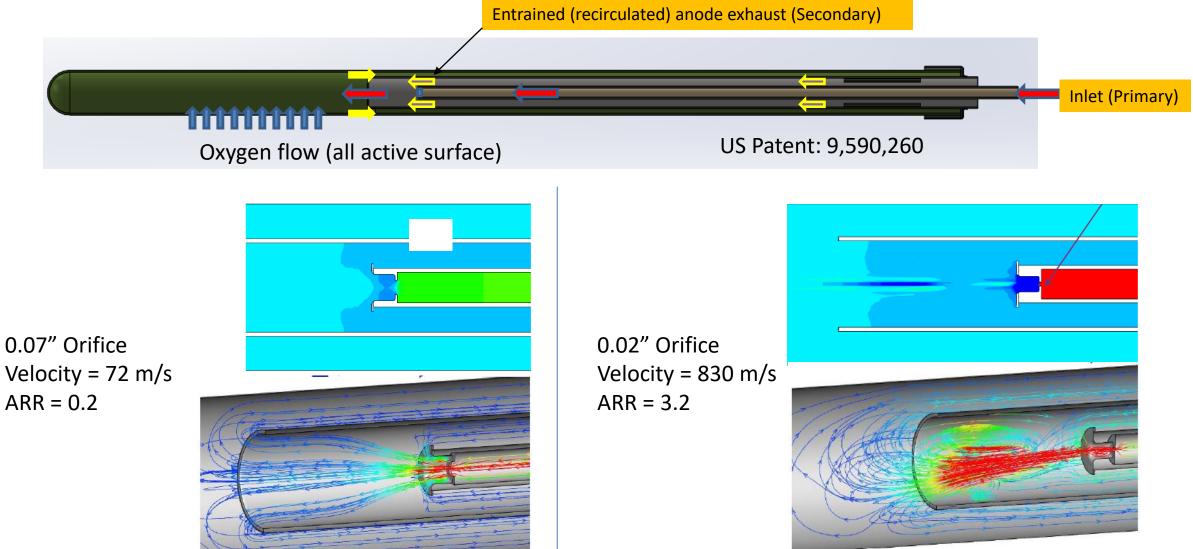






### **2.5 Internal Reformer Validation CFD Modeling to achieve required ARR**



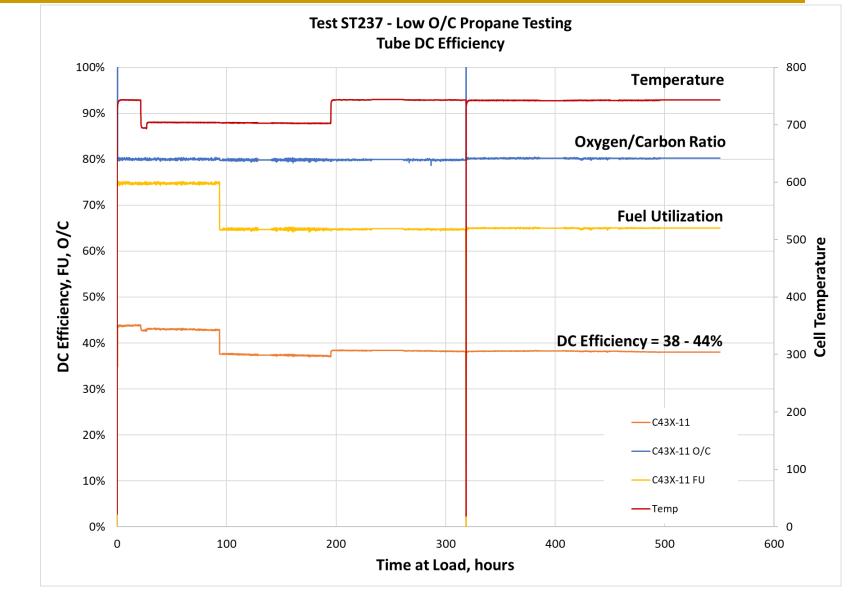


Velocity = 72 m/sARR = 0.2

### Internal Reforming with LPG – Single Tube



 44% Dceff at standard operating conditions with LPG



### Task 2.6 Result of Combined Effects

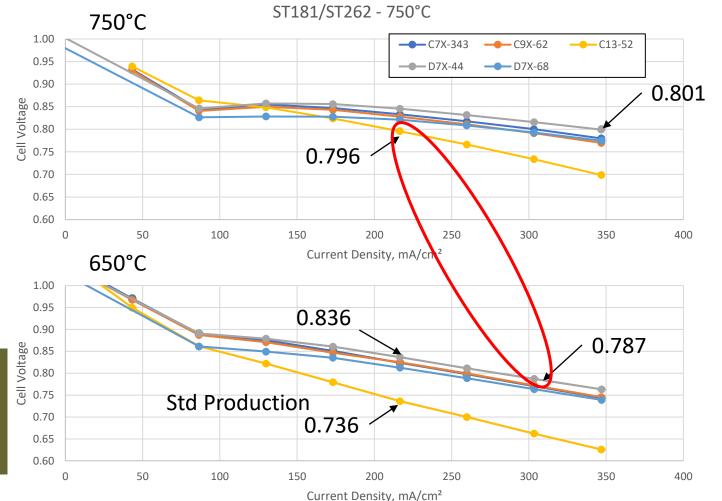
**Final Process** 

- Cells reduced
- Anode/Cathode infiltration
- Thermal treatment to 400C
- Anode Cu wash
- CCC screen print

Higher Power of new tubes at same Vop: → 54% more at same temperature

→ 33% more at 100°C lower temp







# 2.6 Combined Testing5000-hour Bundle Test

Commercial bundles operation 750-775°C Targeting low temperature operation 650C-700°C

Test started week of 5/9/2022 Completed 5000 hours Dec 13, 2022

20 tube bundle in a <u>full system</u> Capable of 625W rated power

DC efficiency > 40%

### **Performance Summary – nearing 8000 hrs**

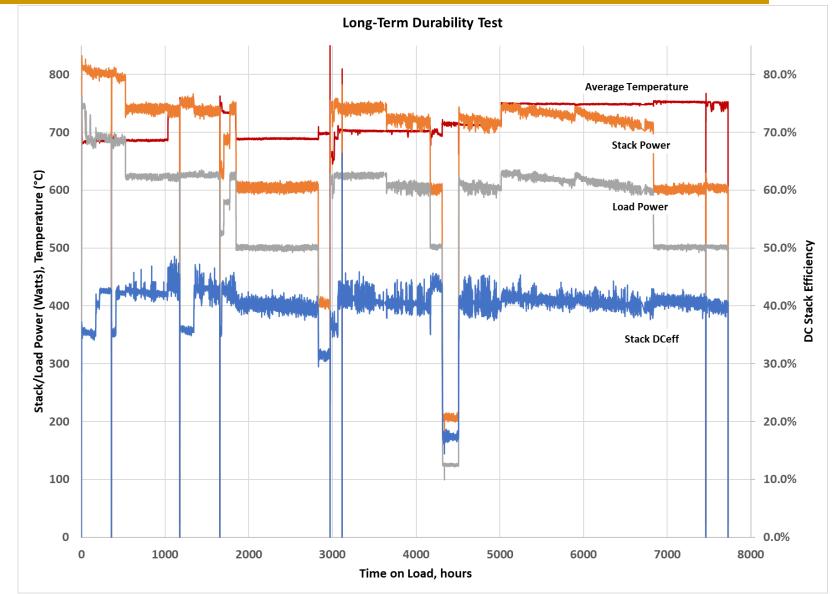


- Operation at 650-750°C
- Power from 25 to 140% of rated power (500W)

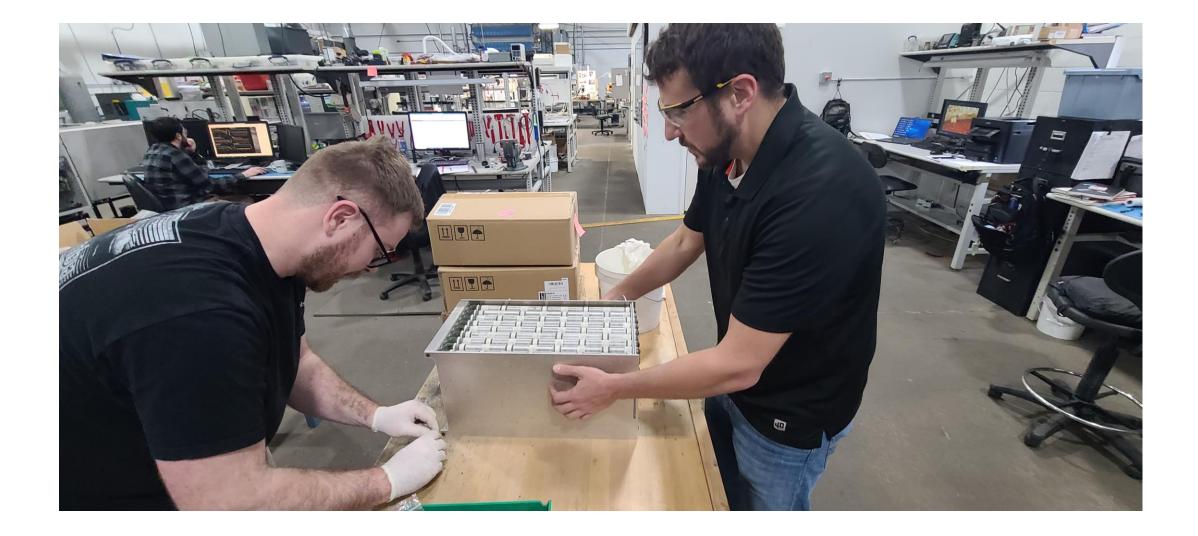
### **Efficiency degradation:**

1850 to 7700 hrs: 0.21%/khrs 5000 to 7700 hrs: 0.70%/khrs

#### Test to restart and continue







### Task 4.4 – Megawatt Performance, Cost, and Reliability Feasibility



Modeling 1 Megawatt using ChemCad

Modeling based in DOE system. "Distributed Generation as a Potential Market for SOFC" Simulate DOE baseline case as benchmark

Use model to simulate similar system with SPS fuel cells for performance comparison

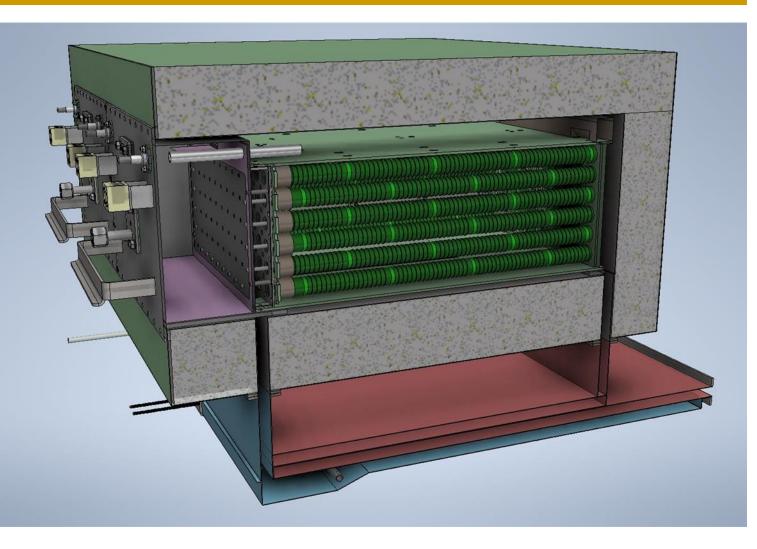
Mechanical Design of 5 to 10 KW Module

Building block for 1 MW system Use for costing purposes

### SPS 2.5kW Hot Box Concept

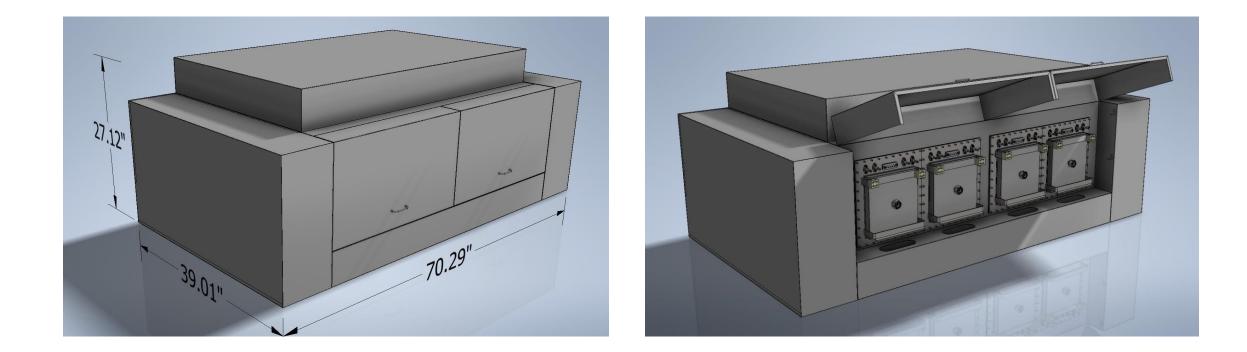


- Original design cost estimated
- New concept design also being developed for comparison



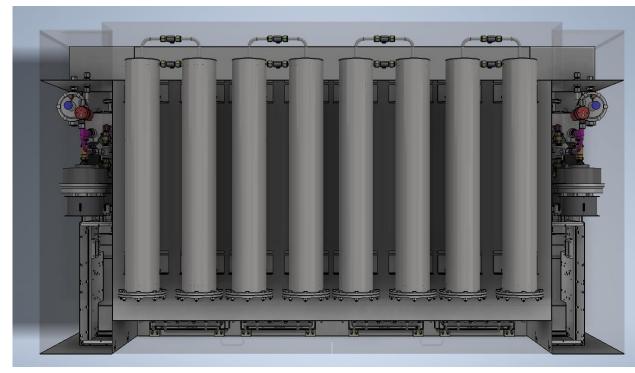
### SPS 10kW System Concept

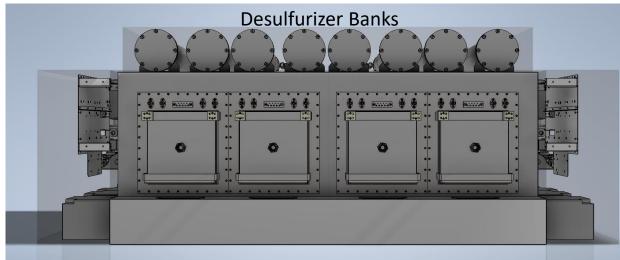




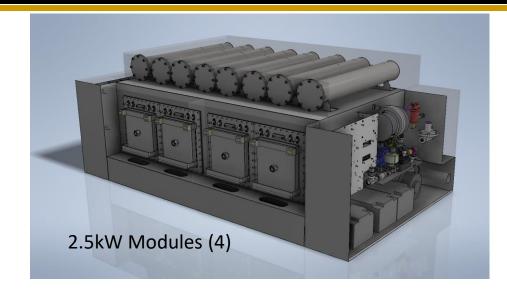
Concept based on 2 (two) parallel 5kW system, each using 2 (two) 2.5kW modules Desulfurization on the top, Controls on the side

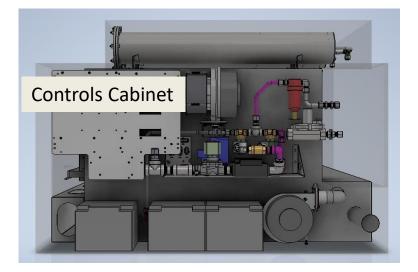
### SPS 10kW System Concept





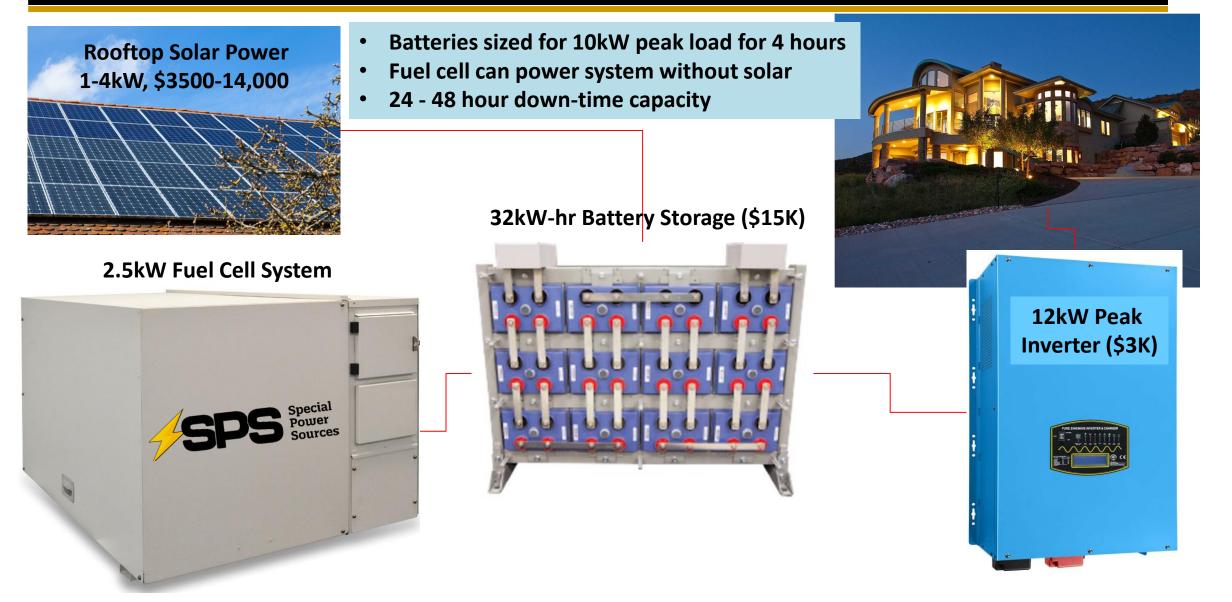






### **Off-Grid, Fuel Flexible Energy System**









- Improved fundamental cell technology has been demonstrated at single tube and system scales which has improved power output by 33% while operating at 100°C lower temperature, or 54% while operating at the same temperature.
- SPS patented internal recycle arrangement is being developed to operate heavier hydrocarbon fuels directly in a compact, high efficiency system.
- System testing is ongoing to prove out long-term durability of cell improvements.
- System designs at 5 and 10kW are being developed for cost study as well as toward pursuing commercial opportunities.

### Acknowledgement



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