



Development of a Low Cost 3-10kW Tubular SOFC Power System

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FC_28_Bessette

This presentation contains no proprietary, confidential, or otherwise restricted information

Acumentrics Corporation

Strategic Partners



U.S. Department of Energy
Energy Efficiency and Renewable Energy



- ~ 80 Employees
- Manufacturing since 1994
- Based in Westwood, Mass.
- ~40,000 sq. ft facility
- *Critical disciplines in-house*
 - Electrical Engineering
 - Mechanical Engineering
 - Chemical Engineering
 - Thermal Modeling
 - Ceramics Processing
 - Manufacturing
 - Sales & Marketing
 - Automation
 - Finance

Acumentrics *Battery based UPS*

Uninterruptible Power Supplies for Harsh Environments

Industrial-UPS®
Commercial

Rugged-UPS®
Military

Features:

- Sealed electronics
- Able to withstand vibration
- Unity power factor input
- Wide input 80VAC - 265VAC
- Isolated 120 / 240VAC output
- Hot swap battery case
- Parallelable to 20 kWatts



Overview

Timeline

- Project Start: 4/1/2008
- Project End: 9/30/2011
- Percent Complete: 25%

Budget

- Project Funding (BP1)
 - DOE Share=\$6,041,012
 - Contractor=\$2,013,671
- Funding Received
 - \$2,949,425

Barriers

- Cell Power Density
- Stack Power Density
- Cell Cost Reduction
- System Cost Reduction
- System Efficiency
- Lifetime

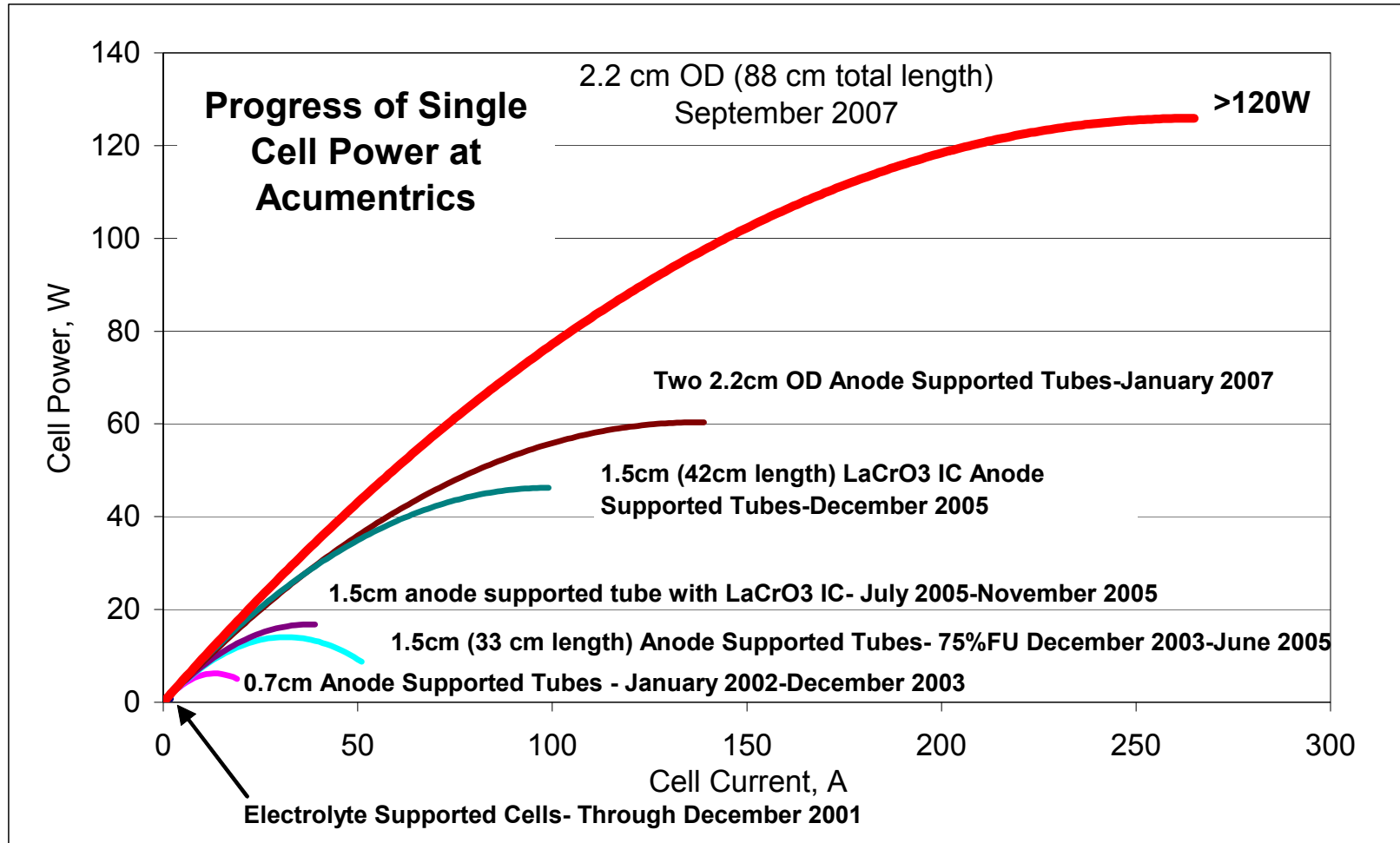
Objectives

- Improve Cell Power & Stability
- Cost Reduce Cell Manufacturing
- Increase Stack & System Efficiency
- Prototype test meeting system efficiency and stability goals
- Integrate to a mCHP Platform

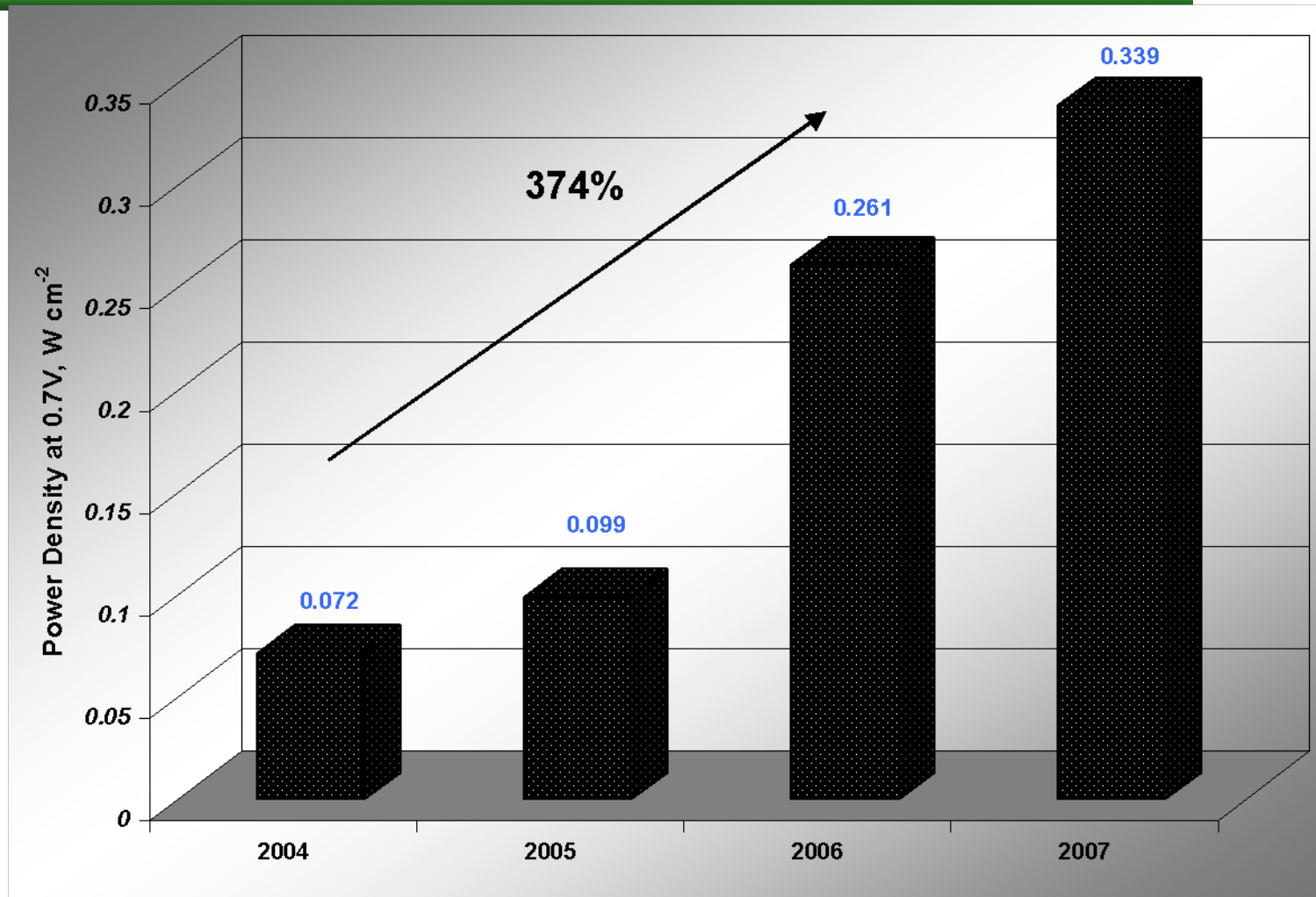
Approach

- Perfect the individual System pieces followed by optimizing their integration:
- **Cell Technology:** Improve power & stability of the cell building block
- **Cell Manufacturing:** Improve processing yield & productivity while decreasing material consumption
- **Stack Technology:** Refine stack assembly and improve integrity while cost reducing component costs
- **System Performance:** Develop simplified controls and BOP to allow for a reliable, highly efficient unit.

Acumentrics Progress



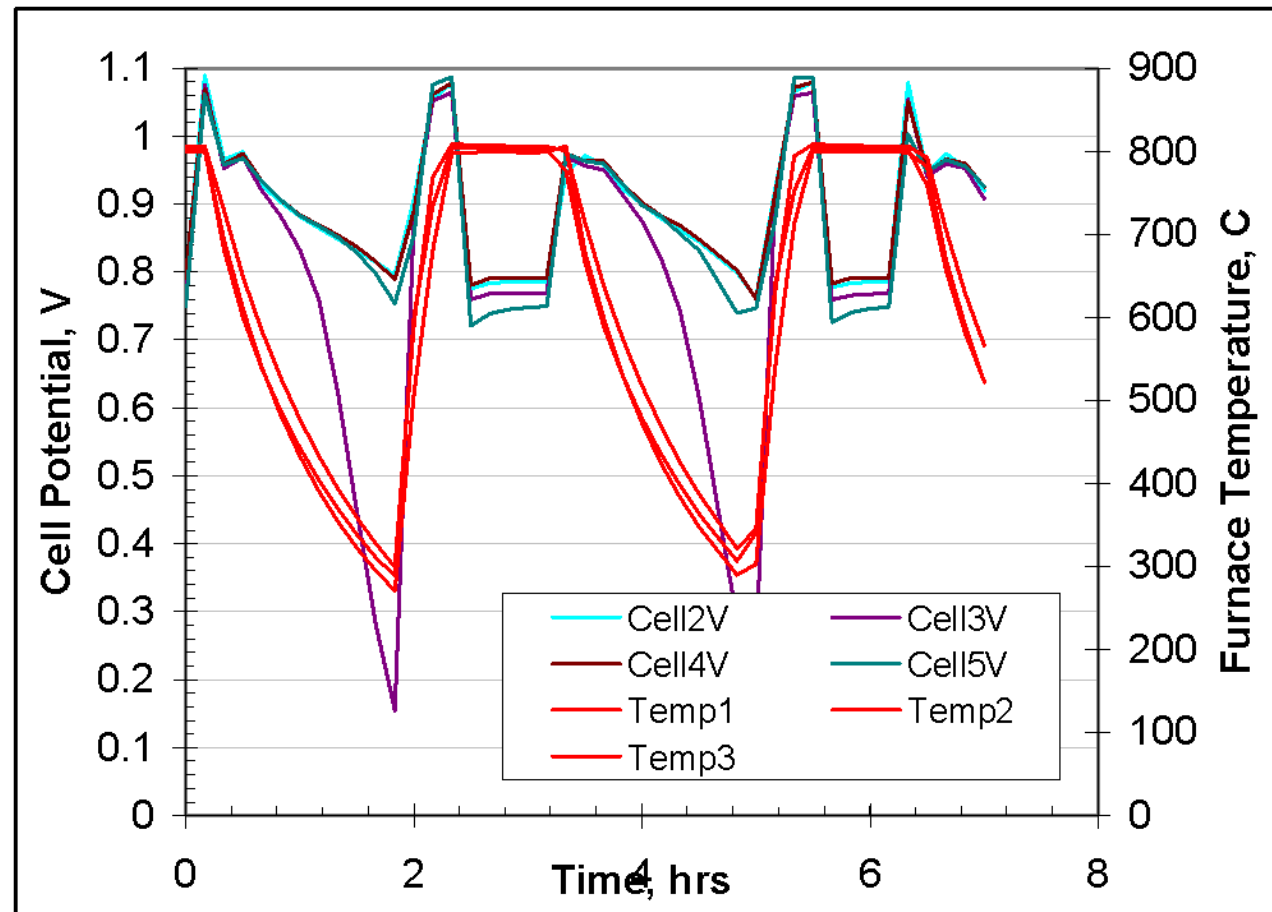
Power Density Improvements



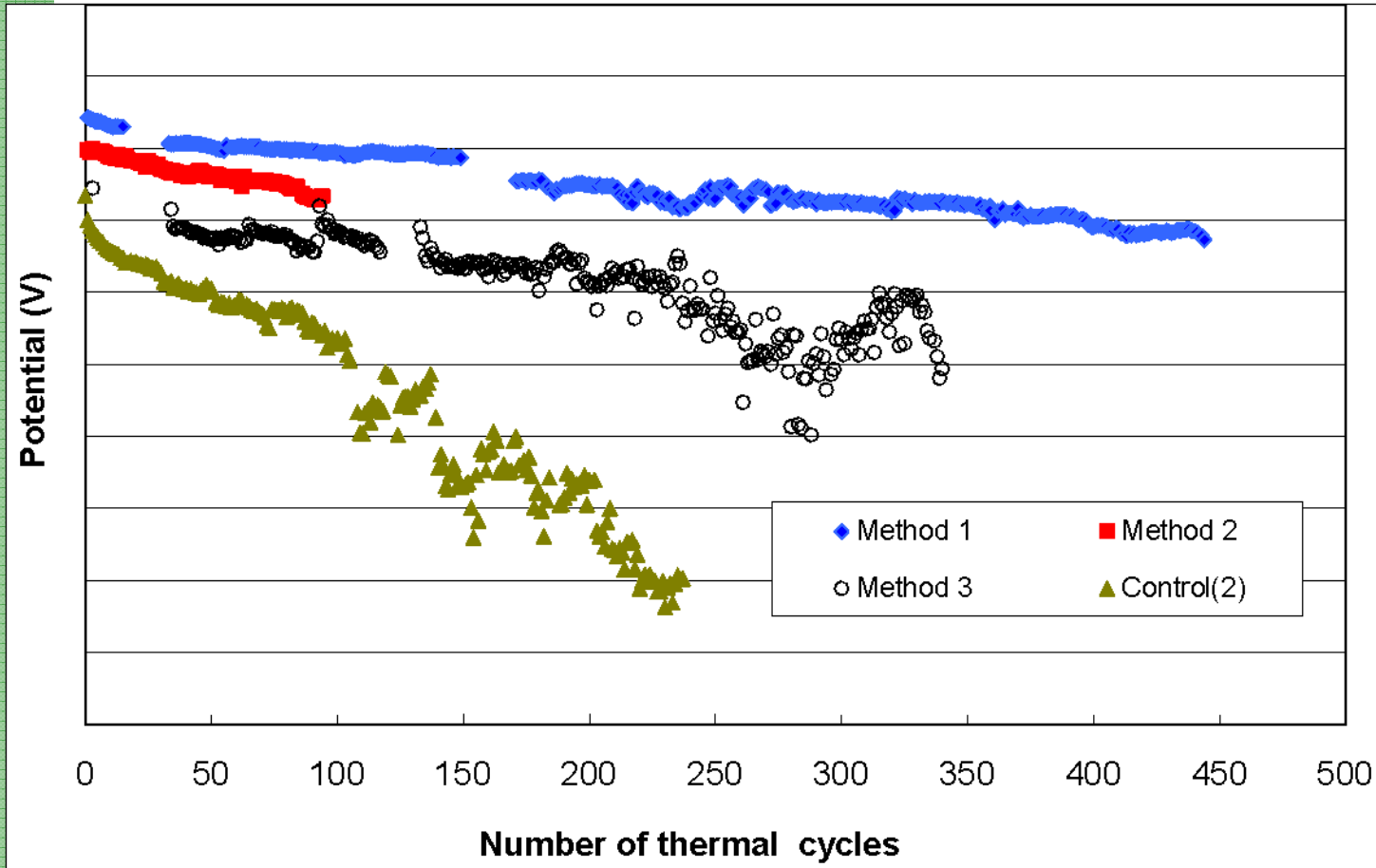
Electrical Testing- Thermal cycles

Loaded Cell performance graphs show a loss rate of about 1%/100TC

~4000hr run time/1500hrs at power

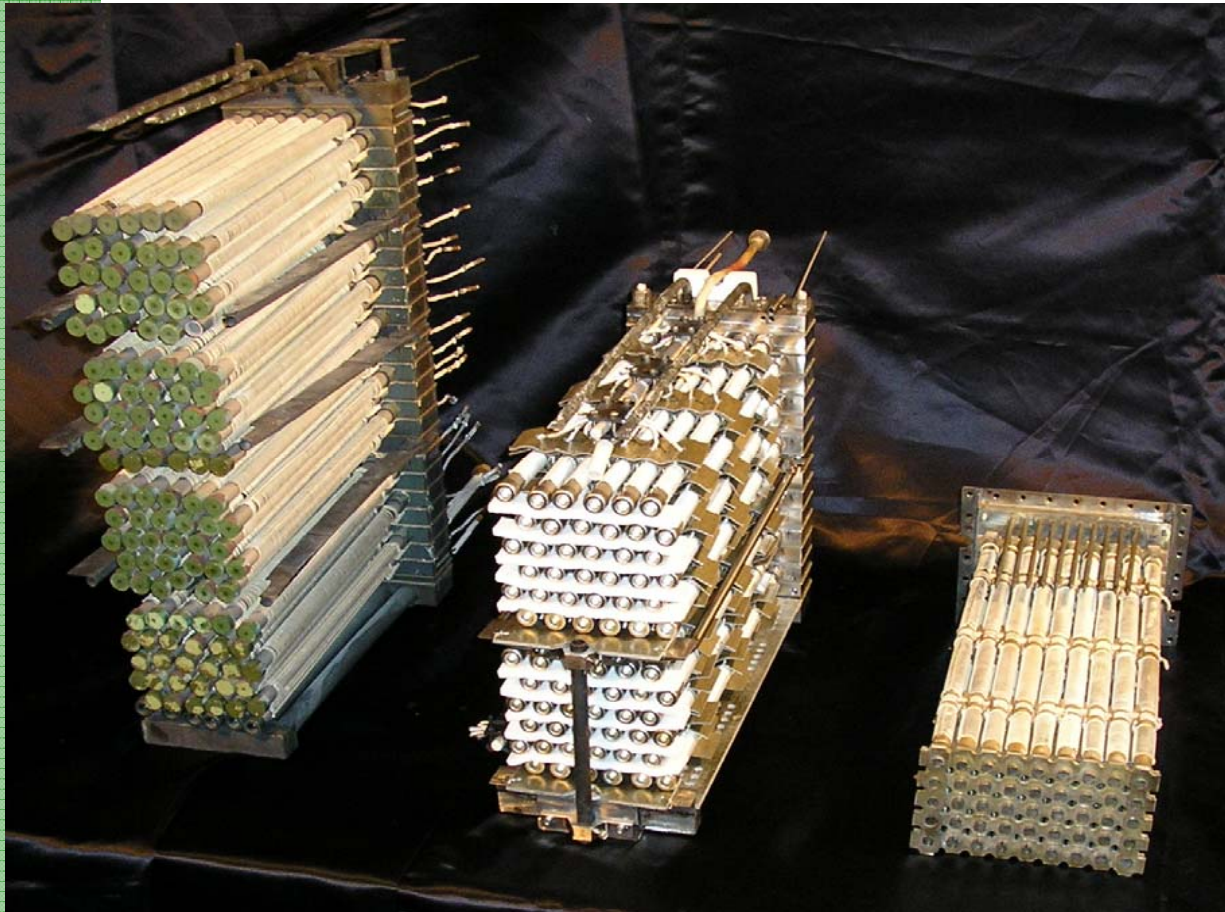


Single Cell Thermal Cycling



- Average of 5 cells
- Shows loaded performance after each thermal cycle
- Degradation from $>10\%/100T/C$ to less than $1\%/100T/C$

Stack Size Reduction



**Number of tubes
for 1.25 kW
reduced from
126 to 72 to 45**

**Weight reduced
75% from 92 to
23lbs**

**Volume reduced
82% from 1.55
to 0.28 cu. ft.**

Tube Fabrication Improvements

Q4 - 2008



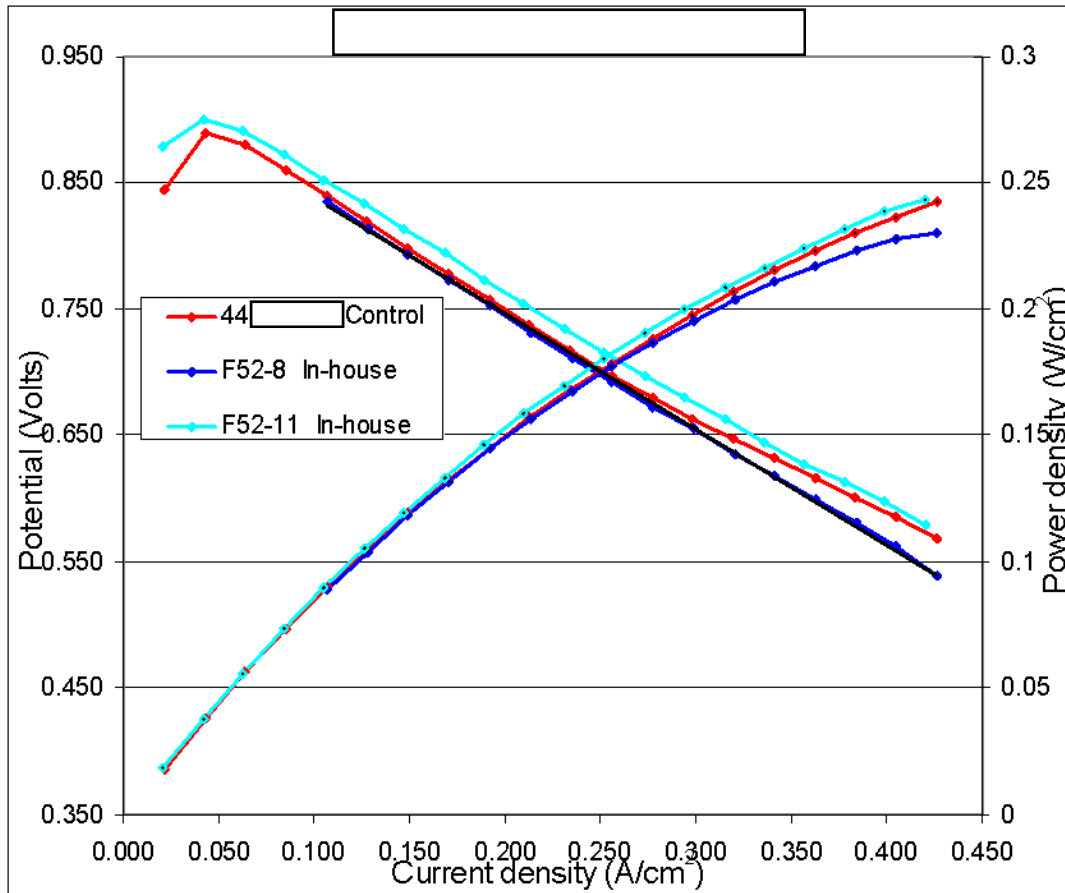
Q1 - 2009



Isostatic pressing implementation:

- Thinner tube substrate wall possible – 45% reduction
- Integral closed end – eliminates one braze joint
- Significant through process yield improvement – 55% to 80%, due to firing orientation
- Simplified process - replaces mixing, extrusion, drying and one cutting operation
- Throughput up to 32 tubes per hour, immediately ready for firing

In-house Isopressed Tubes



- Cells made from in-house isopressed tubes performing well
- Peak power per cell approximately 57 watts on cell test

Tube Wall Thickness Reduction

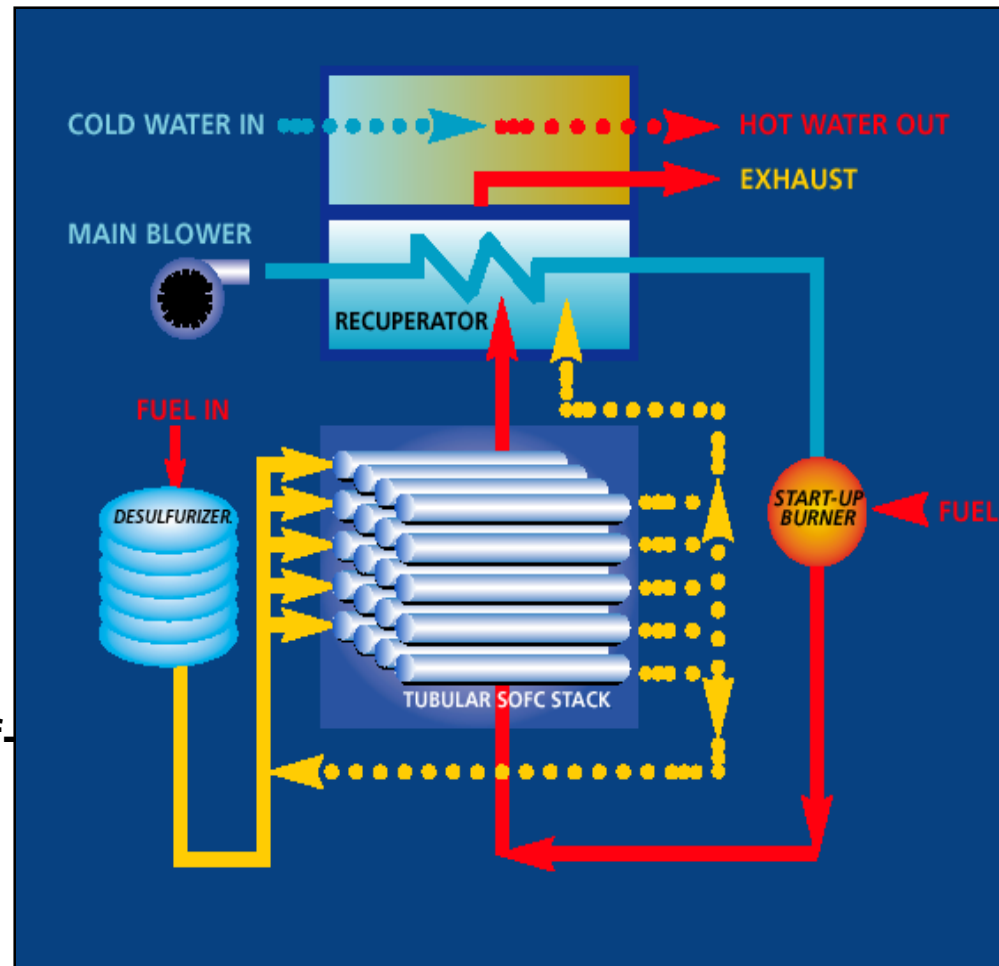
Fabricated and tested 35% and 45% reductions in wall thickness



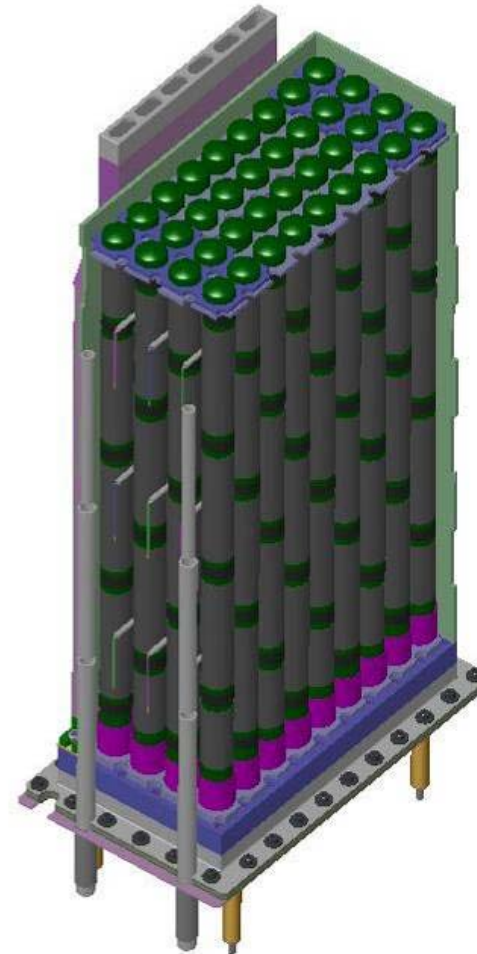
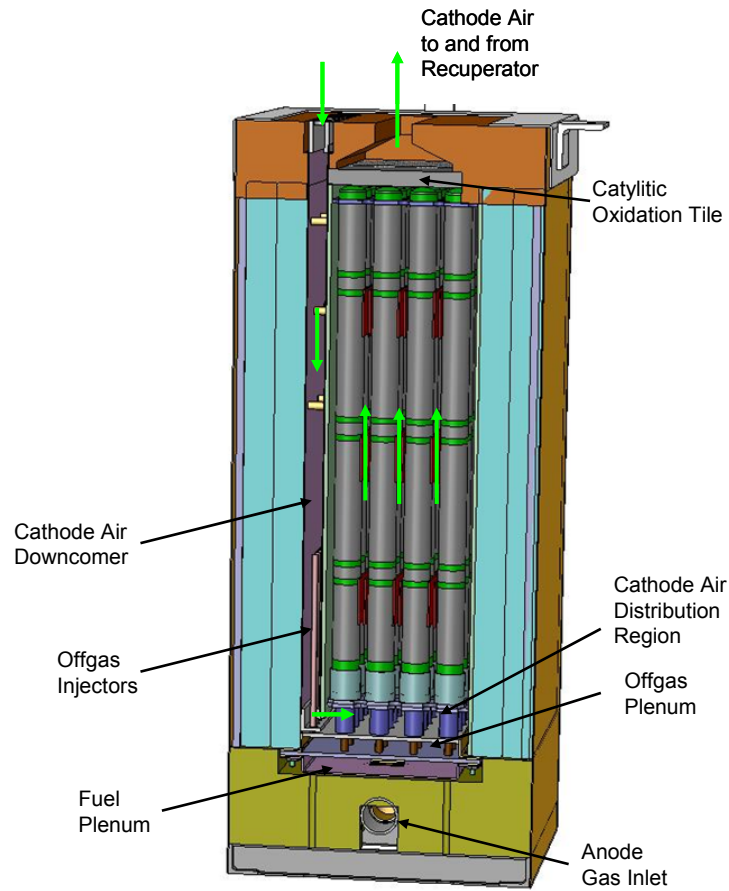
Achieved Equivalent Performance of that with standard wall thickness

System Operation

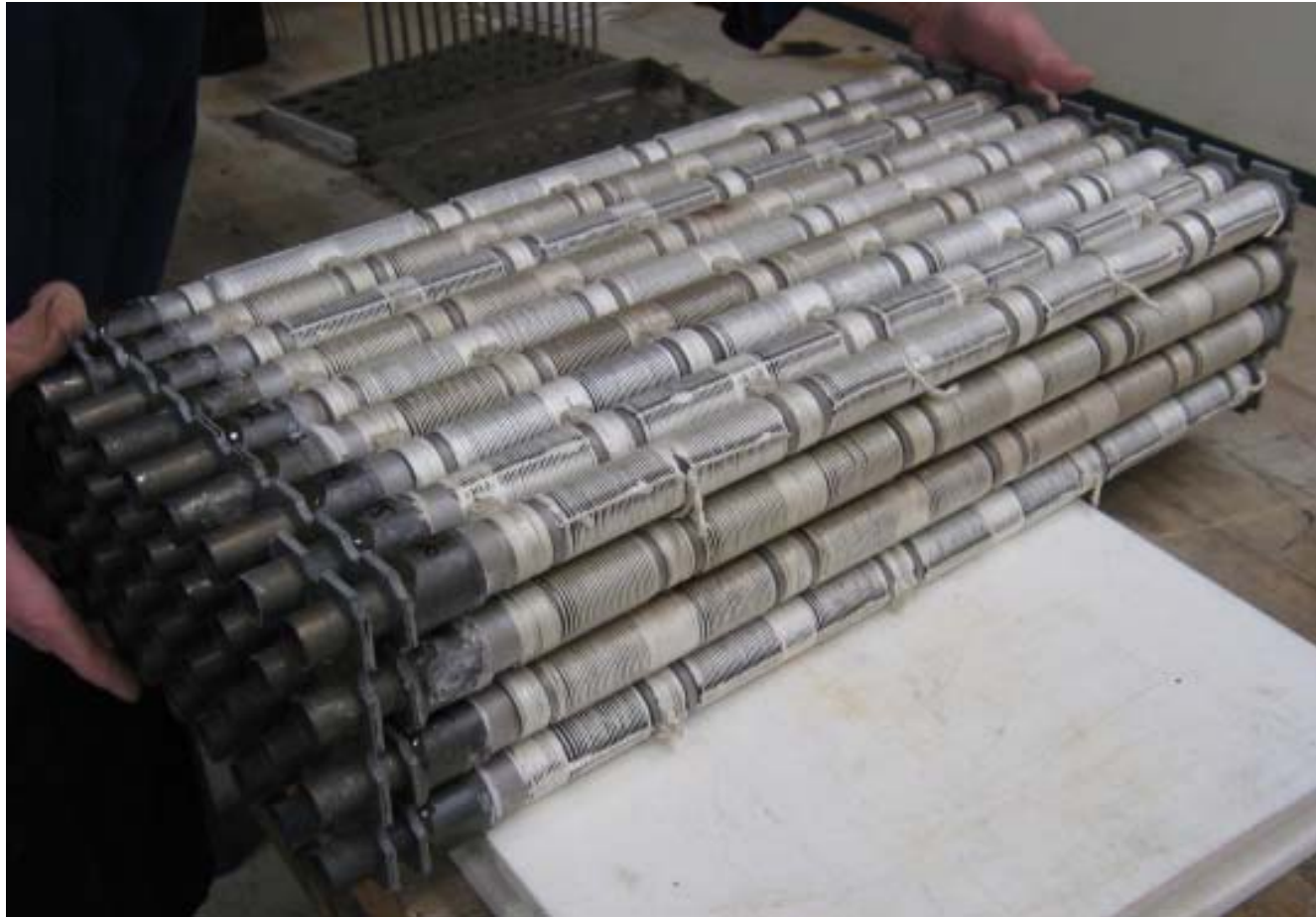
- Tubular Cells
 - Inherent strength and tolerance to rapid temperature change
- High Operating Temperature (800 C)
 - Internal fuel reforming and cogeneration opportunity
- Standard Manufacturing Process
 - Low capex
- Standard Components
 - Standard HVAC balance-of-plant components
 - Leverage 12 years DC/AC conversion experience



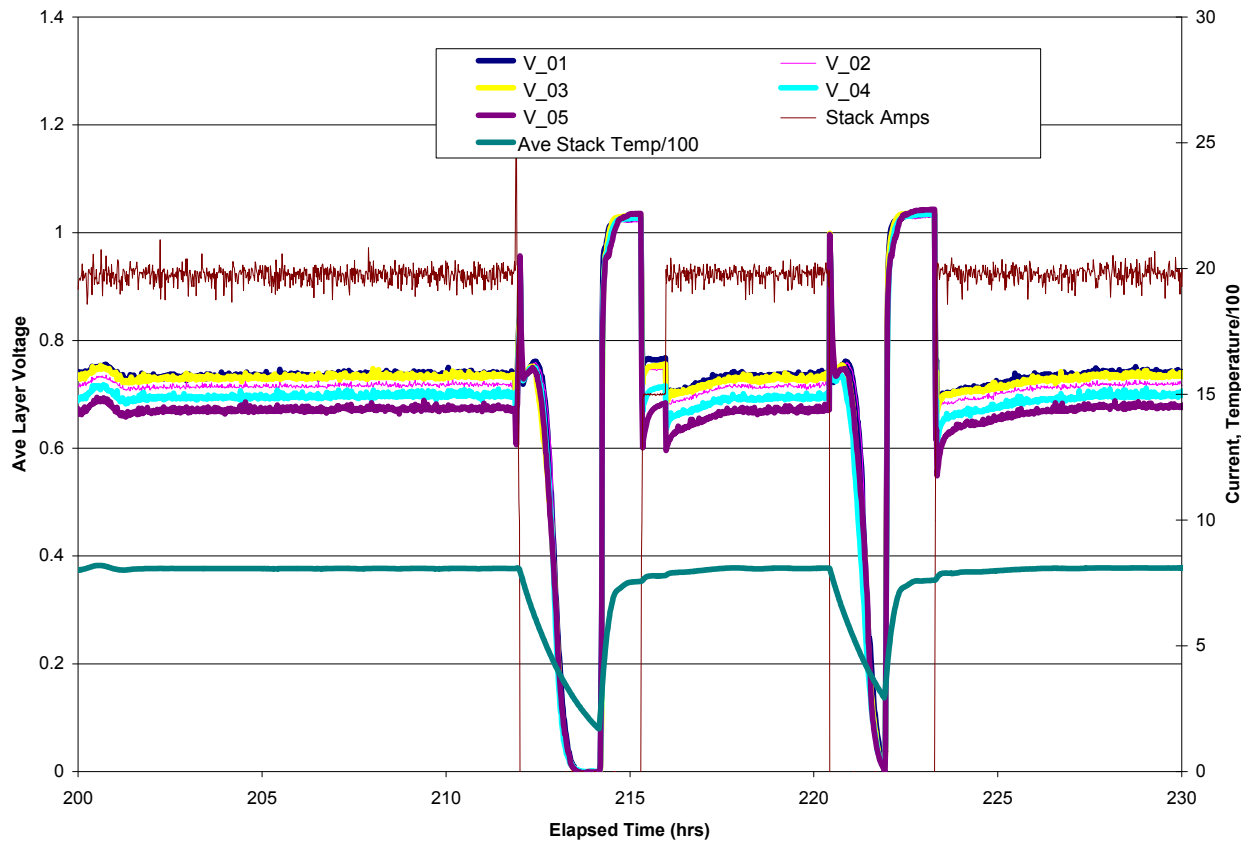
Fuel Cell Module



36 Cell Stack Assembly



Stack Stability Testing



Schedule:

- About an hour down to ~200C
- Less than 30 min back to power
- Run
- Redo

20 thermal cycles

Purgeless cycles

Excellent recovery

Recuperator Advancements

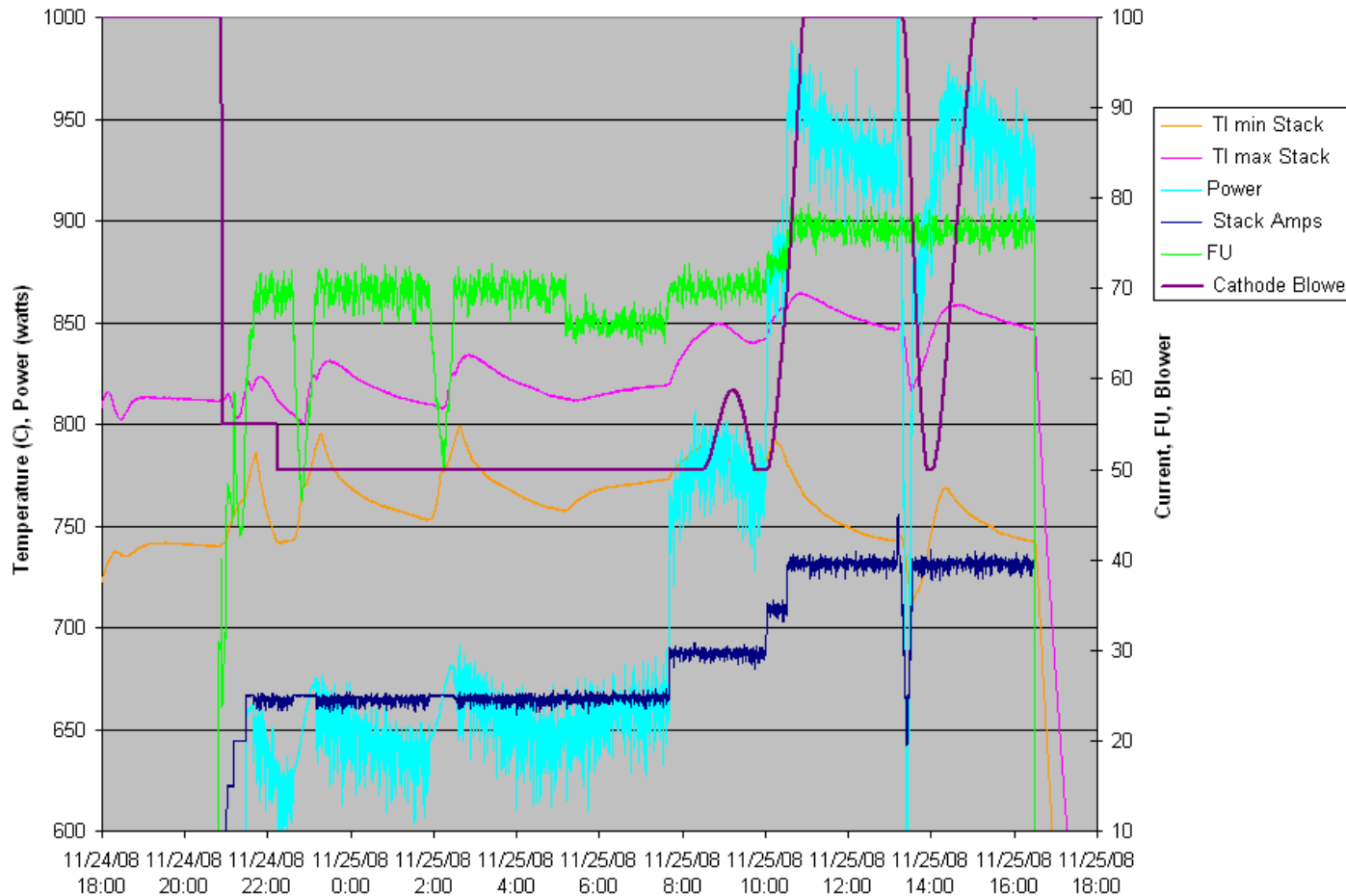
Reductions:

- 94% in Volume
- 88% in Weight
- 74% in Qty 1 Cost

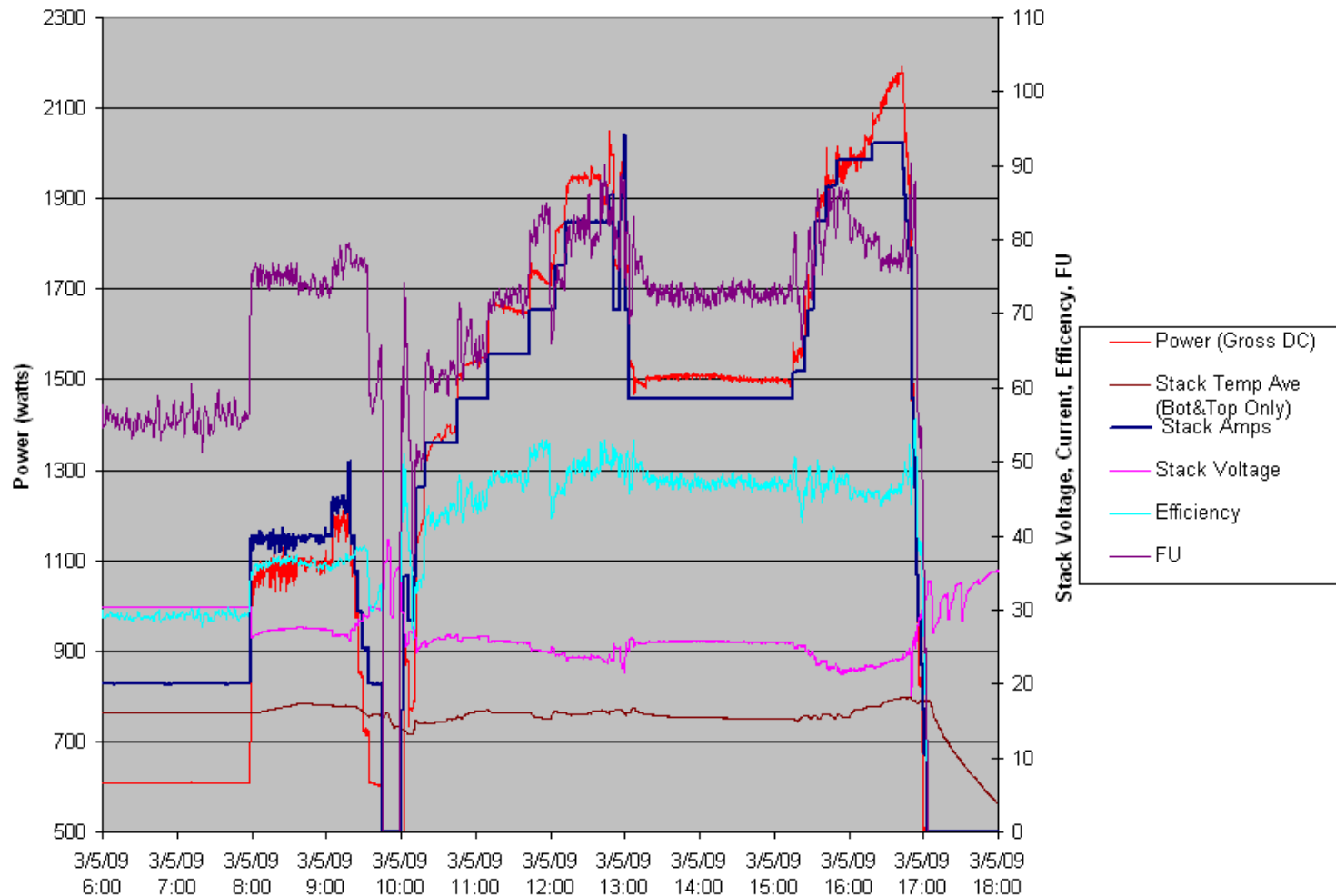


Generation 1	2.0ft ³	143 lbs	\$4200 Qty 1
Generation 2	0.12ft ³	17lbs	\$1100 Qty 1
Generation 3	0.12ft ³	17lbs	\$550 Qty 1

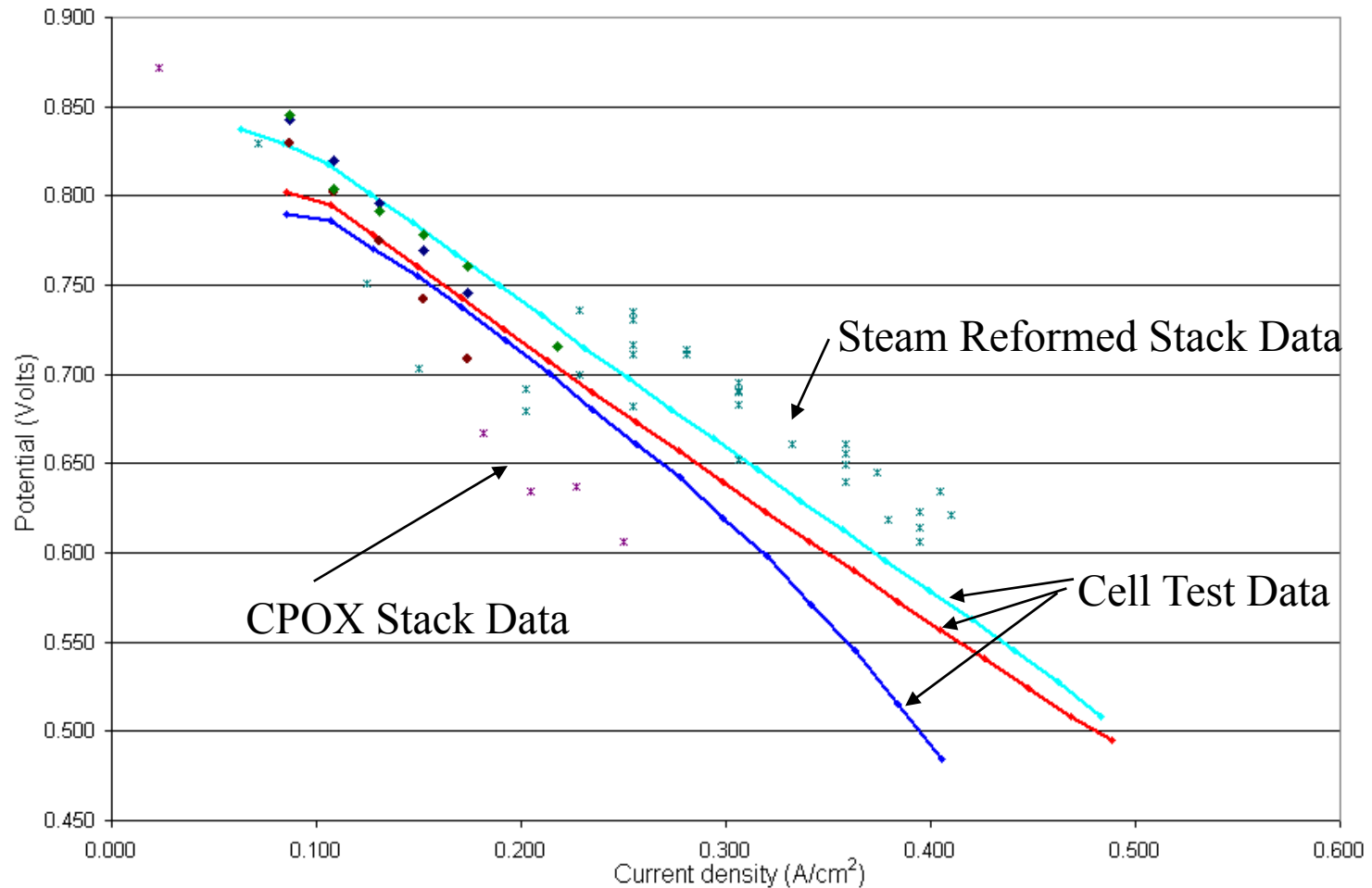
Improved Stack Efficiency- CPOX Results



Improved Stack Efficiency- Steam Reformed Results

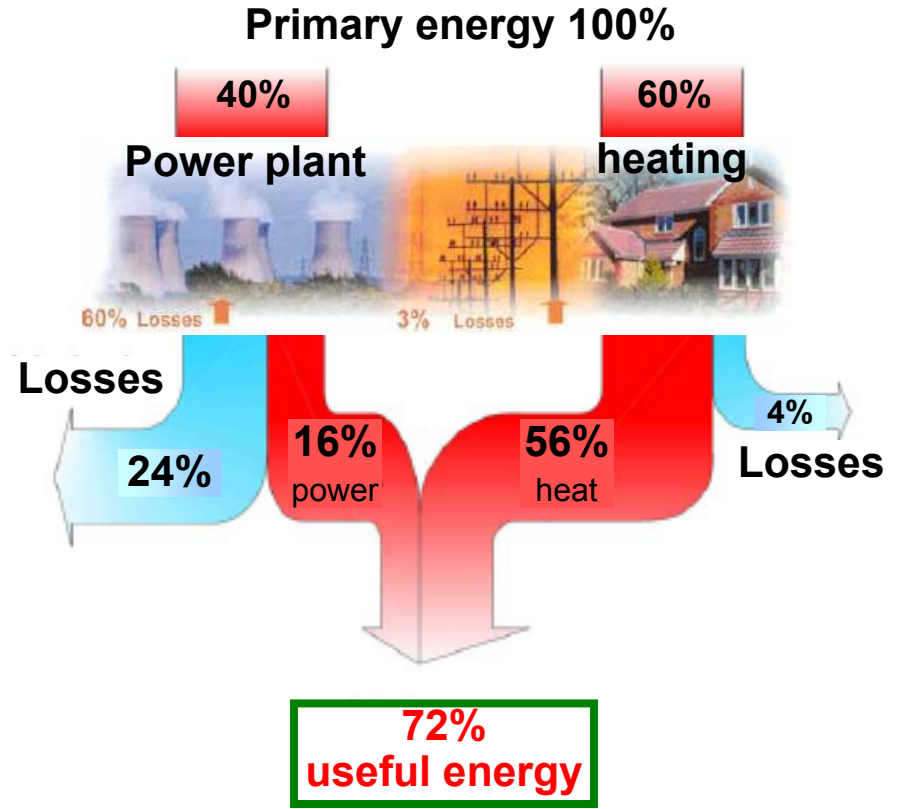
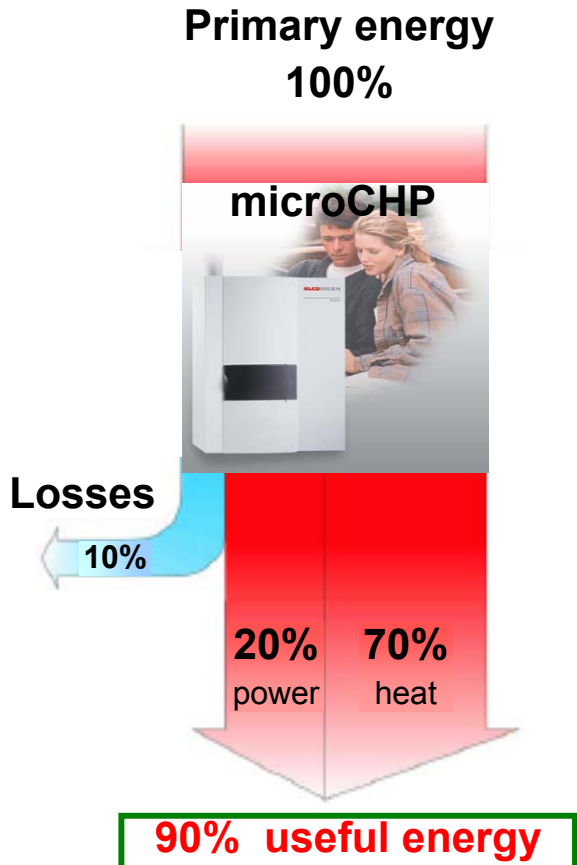


Improved Efficiency: Cell vs Stack Comparison



mCHP vs. power plant and (condensing) boiler

microCHP
simultaneous power and heat production



Common technology
separate power and heat production

- = 10 – 25% lower primary energy consumption
- = 10 – 25% lower CO₂ emissions
- = 10 – 25% lower energy cost

Micro CHP



4 have been built to date

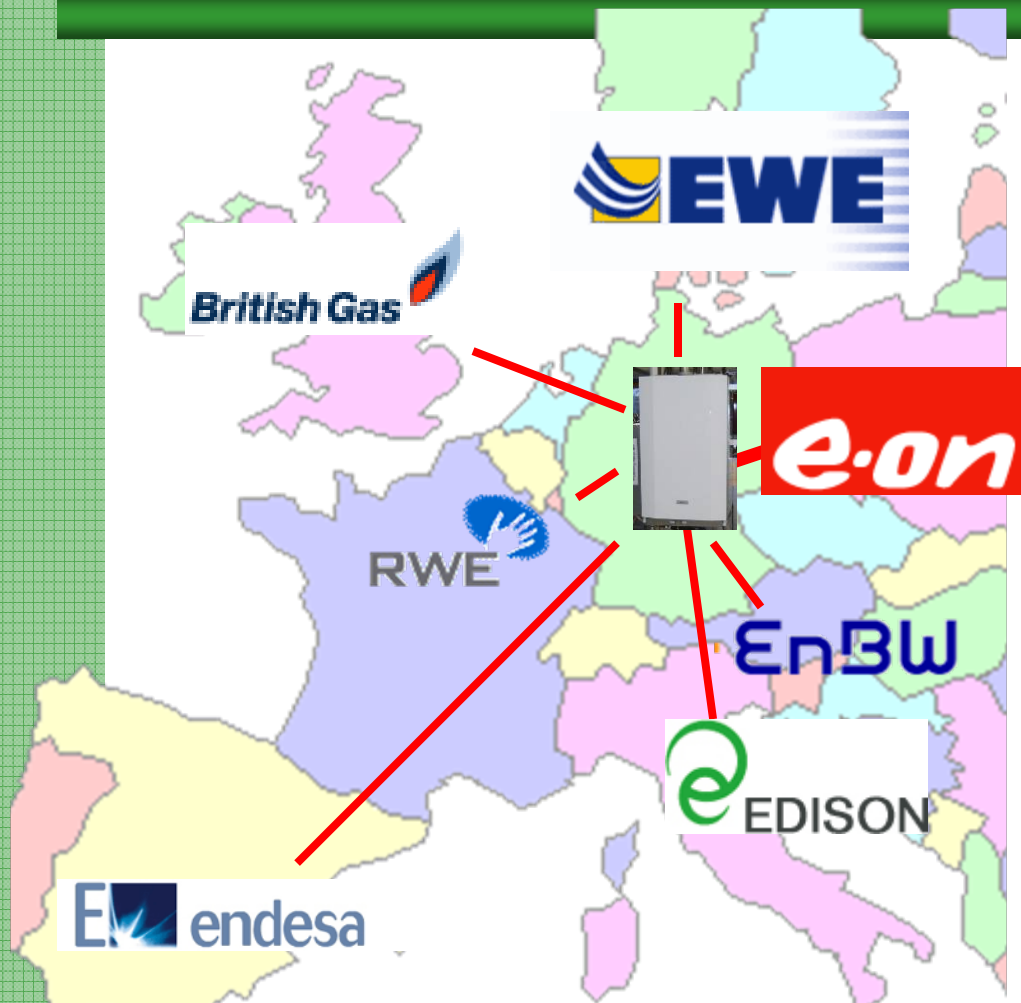
Has undergone & passed CE certification

Undergoing testing this winter in Europe

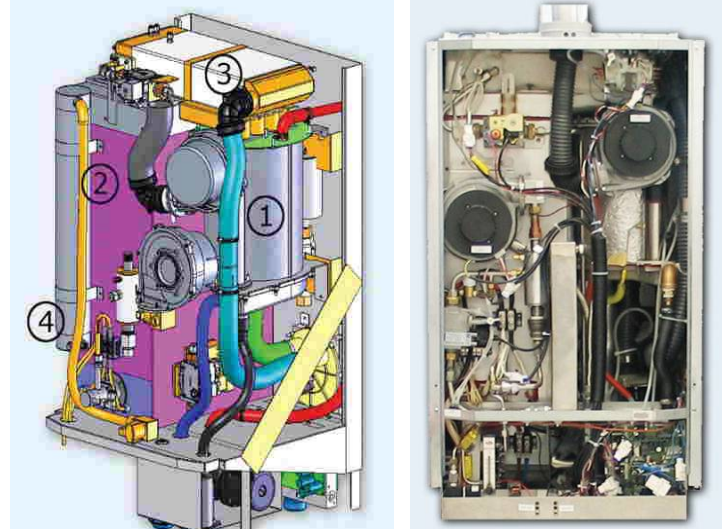
1kWel AC out,
20kWth
Eff(Total)>85%,



1kW Home CHP Appliance



- 25% energy savings
- Prototype delivered 2007
- Demo with major European utilities
- Demonstration & Commercialization Program with Consortium of utilities



- 1 Booster Boiler
- 2 Fuel Cell Stack
- 3 Exhaust Heat Exchanger
- 4 Fuel desulfurizer

Conclusions

- Significant progress in cell stability
- Advanced Cell Manufacturing automation & material reduction while maintaining cell performance.
- Single cells have shown tremendous capability both in thermal cycling and in operation under gradients
- Significant progress in stack size
- Generators and stacks have shown resiliency with purgeless thermal cycles
- The testing of a home heating appliance is currently underway

Thanks to

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- MTS Group
- Technical Staff at Acumentrics