Solid Oxide Fuel Cell Balance of Plant & Stack Component Integration

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Acumentrics Corporation

Strategic Partners

GENERAL DYNAMICS
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TECHNOLOGY
COLLABORATIVE

Sumitomo
Corporation

NiSource

Northeast
Utilities System

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

Scalable, Ruggedized Power – Combat Proven

Take Almost Any Generator

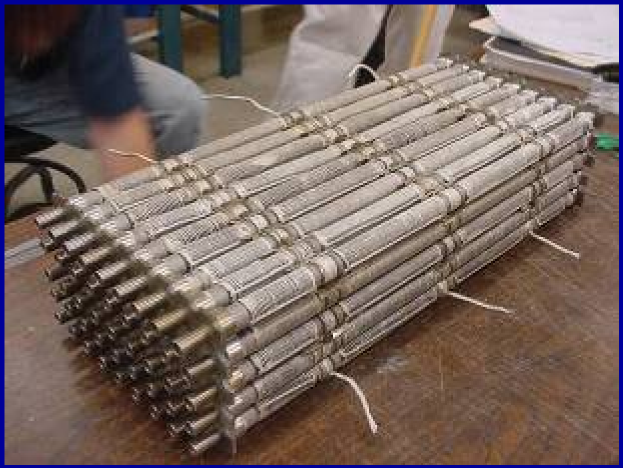
Plug into Clean Power Provided by Acumentrics RUPS

And Be Ready For Continuous Communications & Command

Solar Flare Tests RUPS to 170˚F – 16 hours continuous
General Atomics SkyWarrior

Fuel Cells

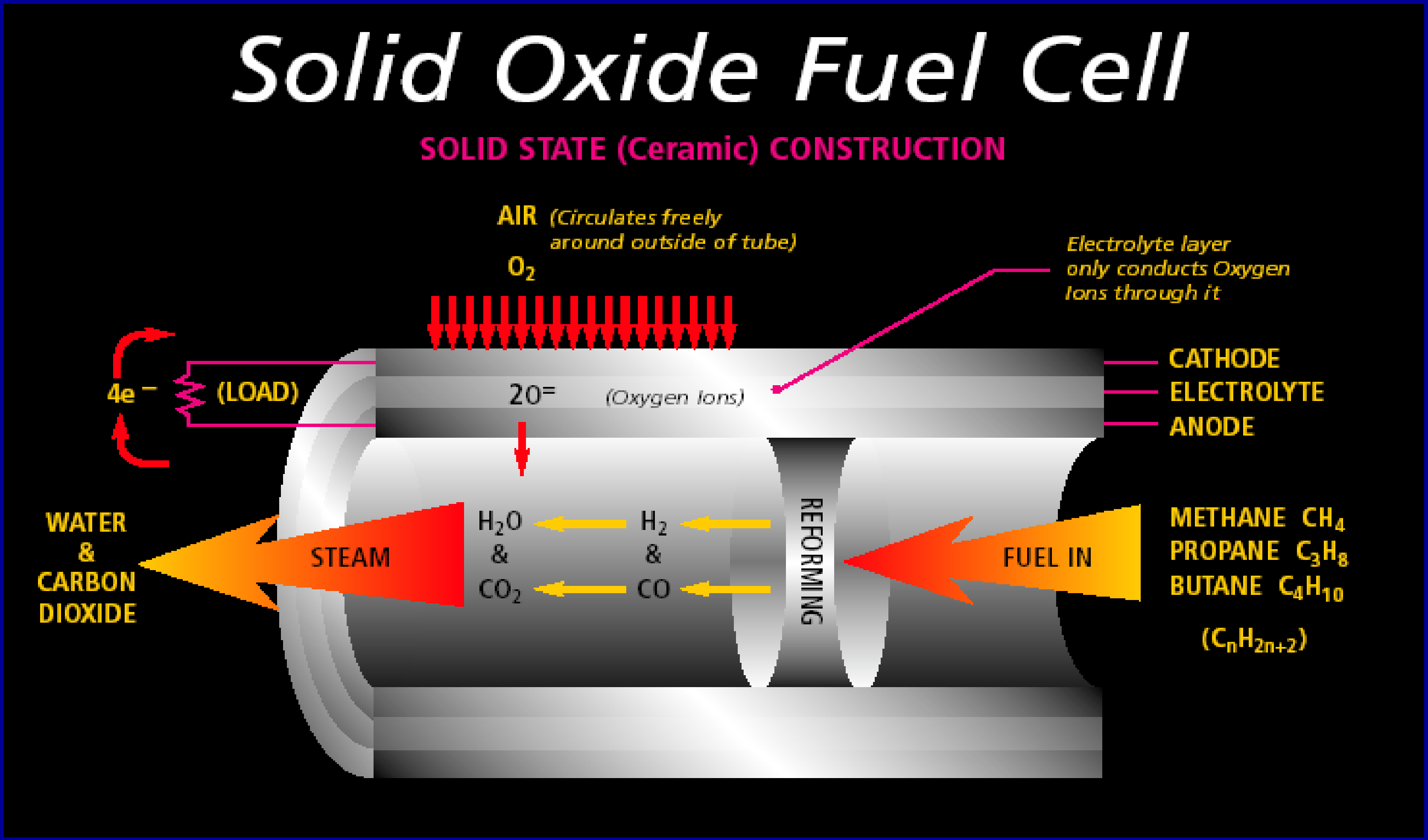
- Made from low-cost nickel oxide
- Uses available fuels: natural gas, propane, synthetic JP-8
- 41 units delivered to the field
- Twice the efficiency of equivalent generators



Stacks during assembly

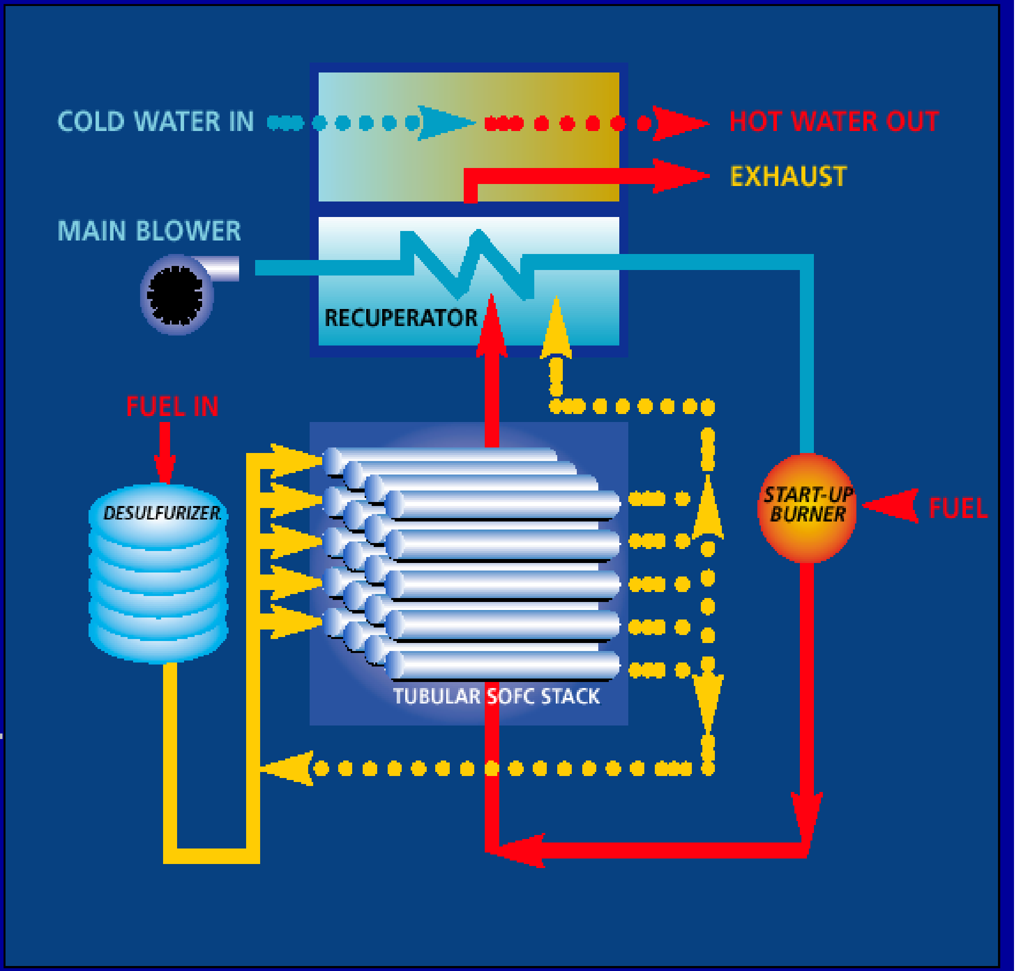
Micro-CHP unit for shipment

How Our Fuel Cell Works



Total System

- 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 16 years DC/AC conversion experience**

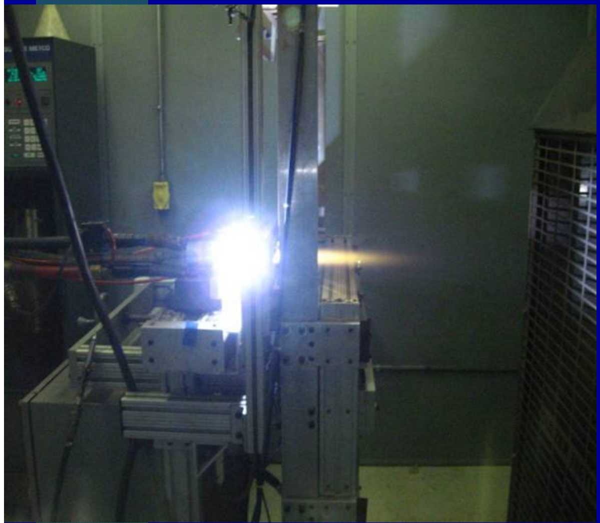


Fuel Cell Manufacturing

Isostatic Press

Automated dip-coating

Automated Cathode Coating



Plasma spray

- **Facility Capable of 176kW/yr**
- **Multiple FC Size Capability**
- **No outside Fabrication Steps**

High Temperature Firing

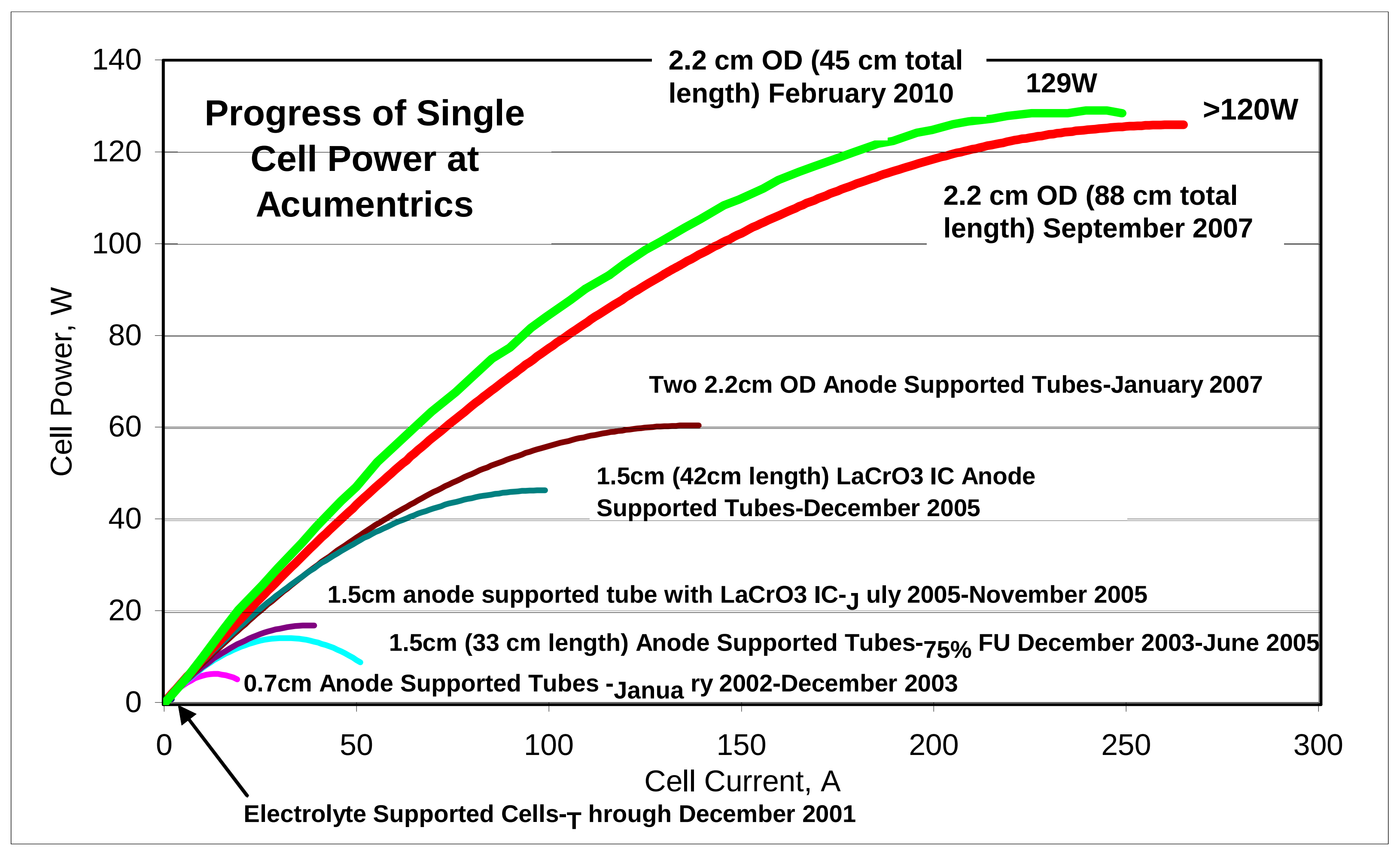
Stack Size Reduction

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

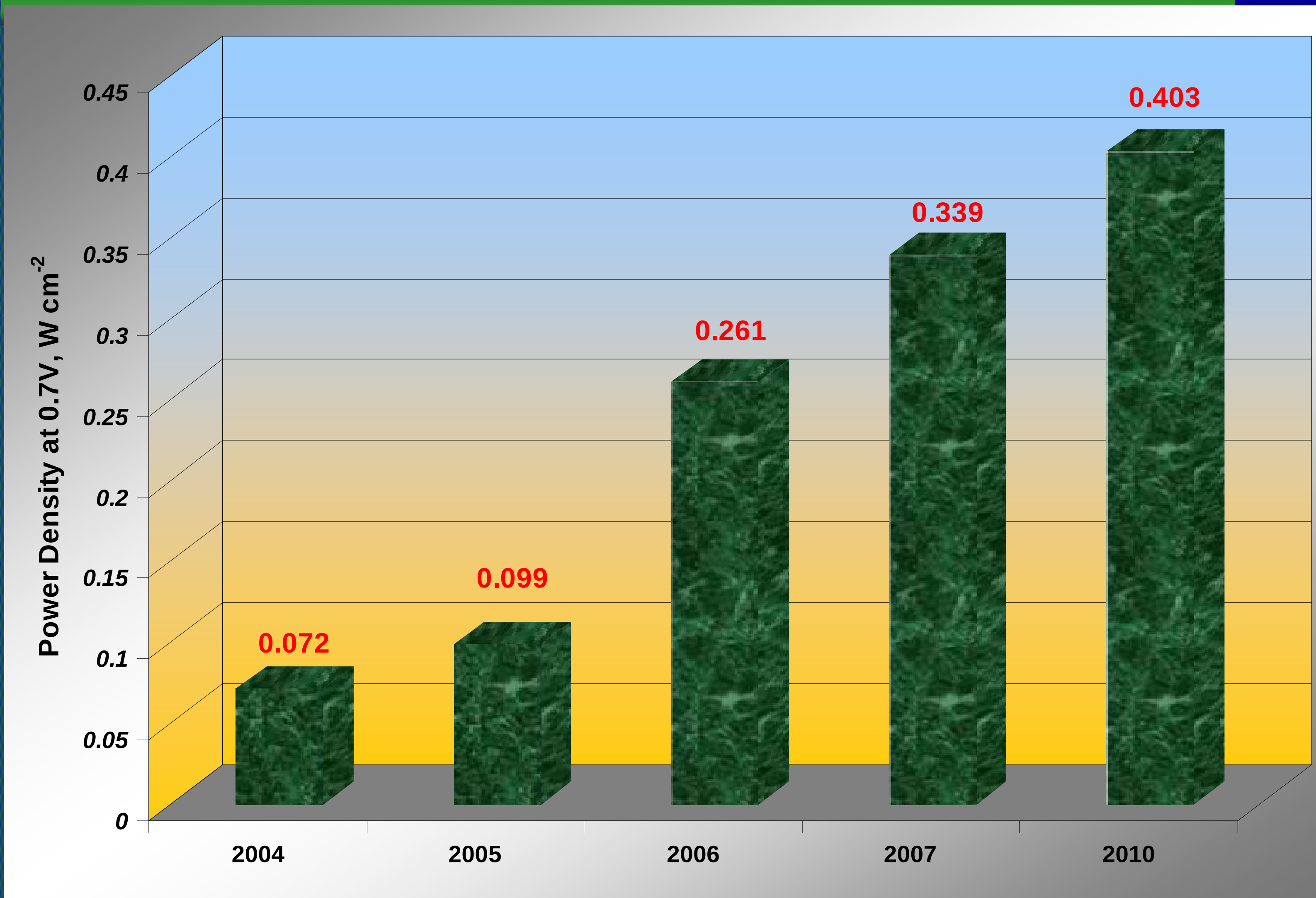
Weight reduced 75% from 92 to 23lbs

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

Cell Performance Progress



Cell Performance Progress

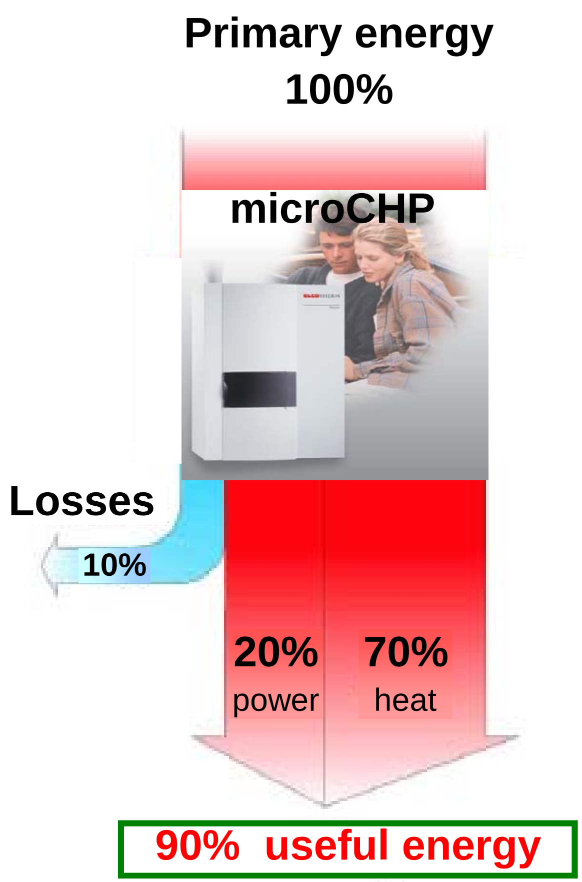


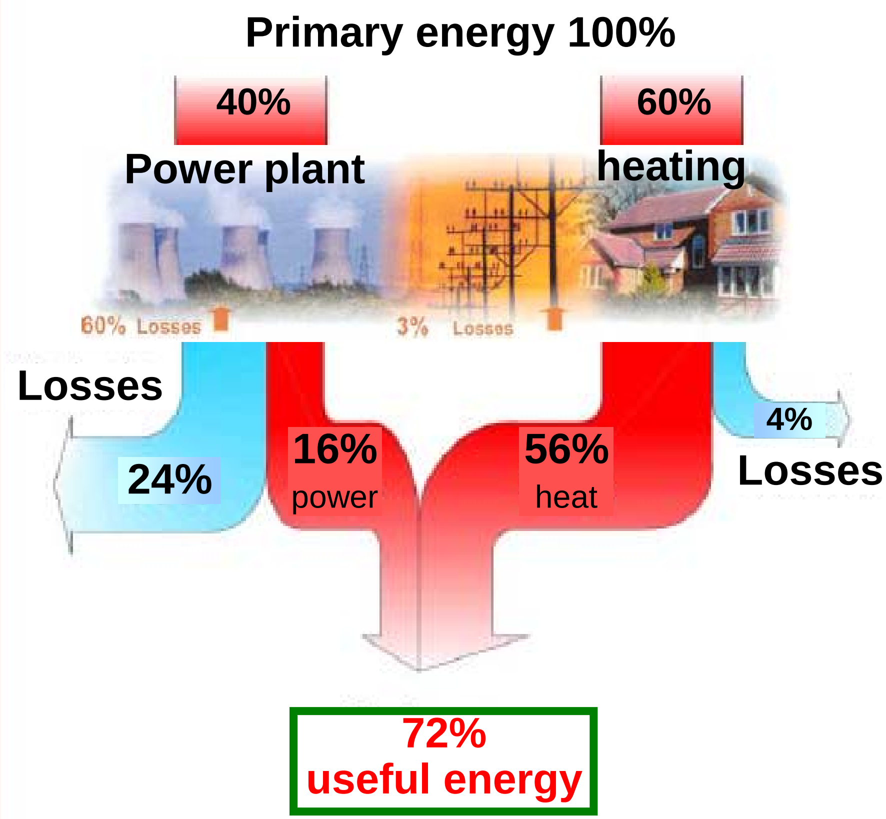
Products

mCHP vs. power plant and (condensing) boiler

Acumentrics

microCHP
simultaneous power and heat production



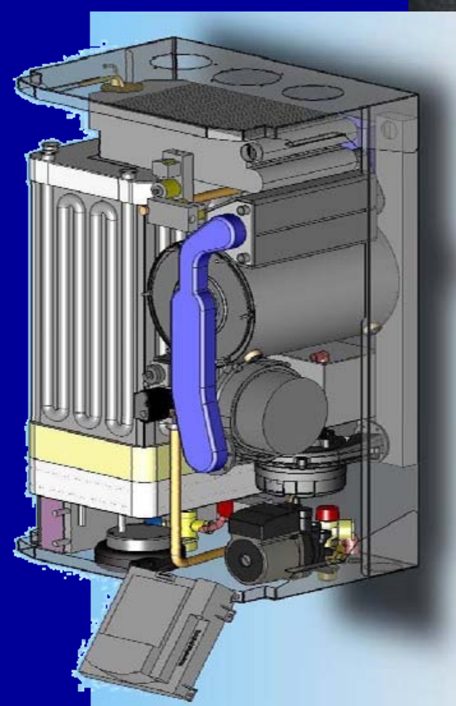


Common technology
separate power and heat production

= 10 – 25% lower primary energy consumption
= 10 – 25% lower CO_2 emissions
= 10 – 25% lower energy cost

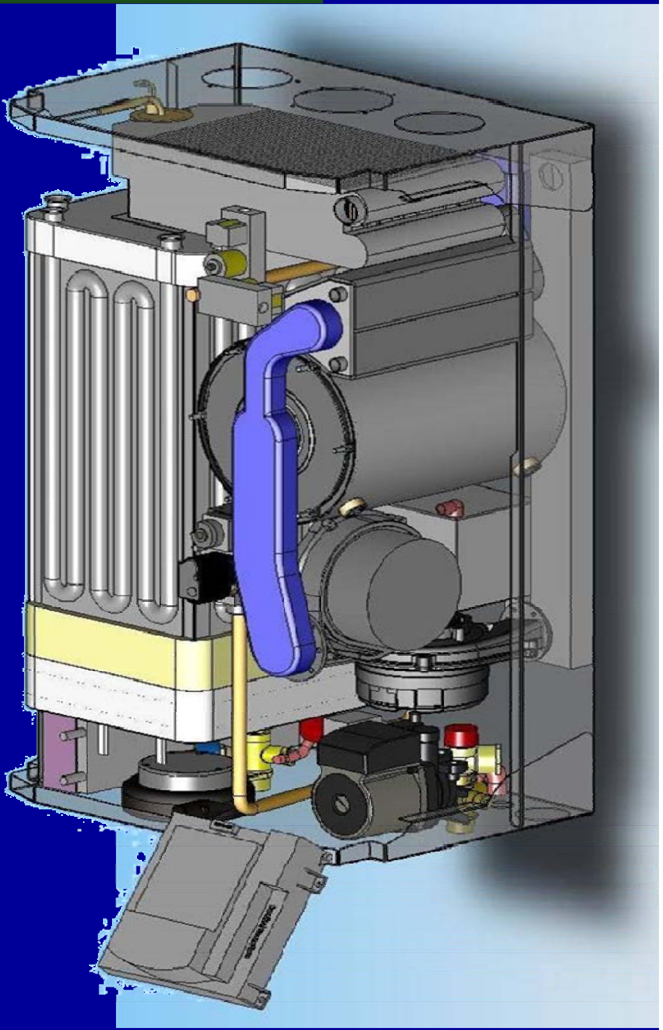
MTS Wall Mounted mCHP

- One kilowatt unit with 20 kW thermal boiler
- Huge achievement to meet space and weight requirements
- 80-90% total efficiency, 33”x22”x18”
- 180lb total, 100lb FC sys

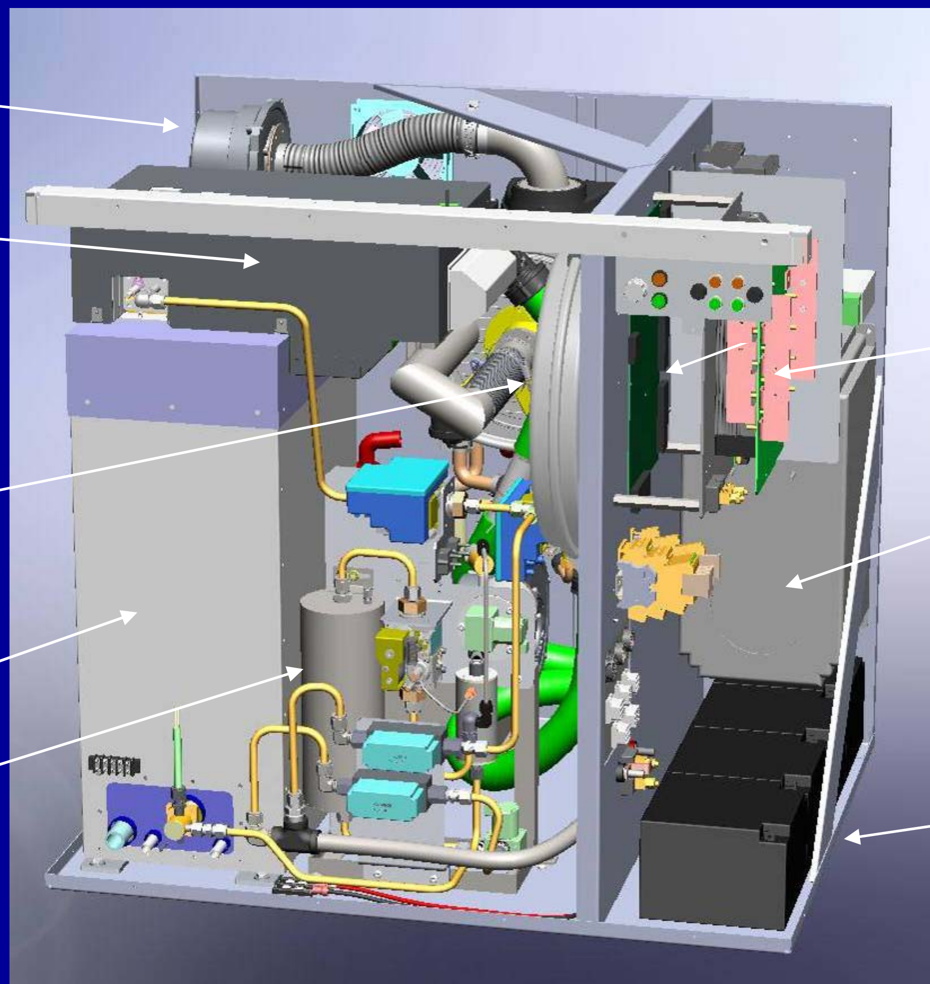


CHP Appliance

- Wall-mount design for apartments and condos; larger floor mounted design
- Tankless water heater
- Incidental power while heating
- Easy on-off
- Multiple prototypes delivered

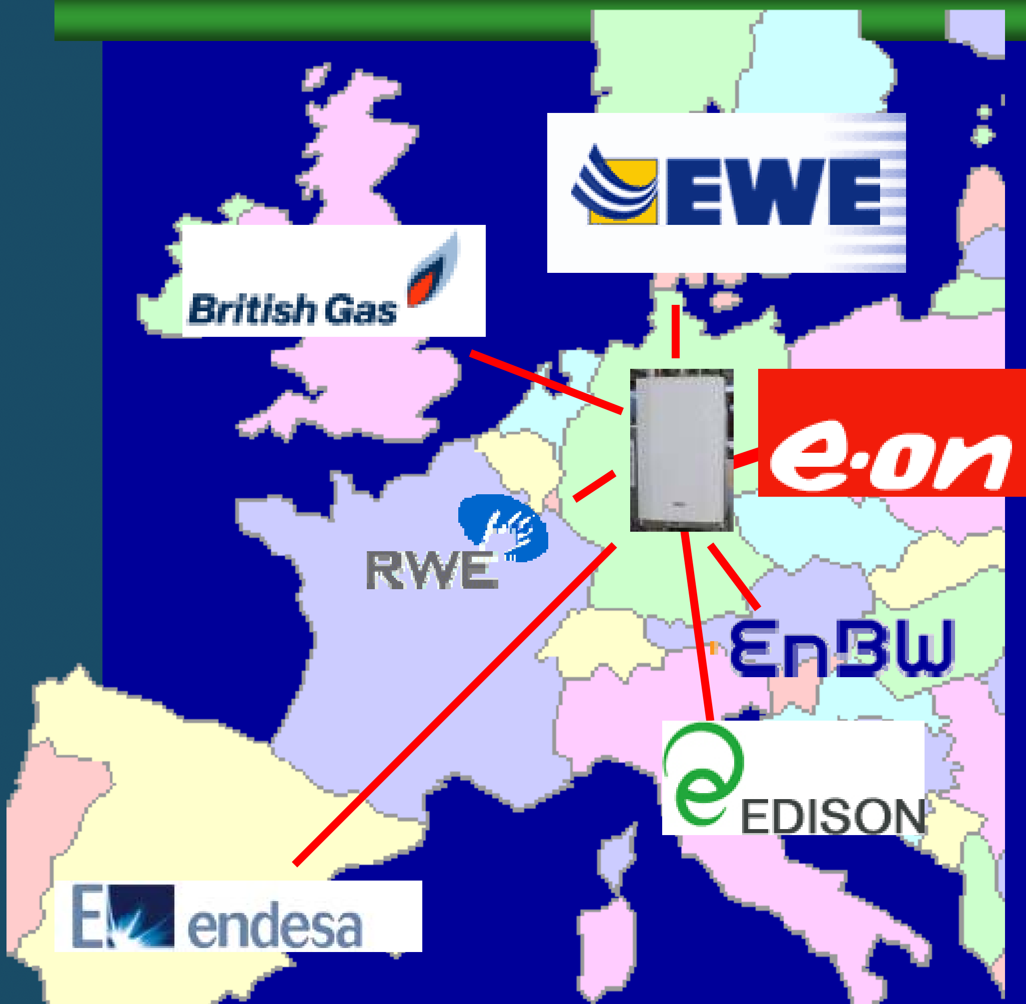


mCHP Layout

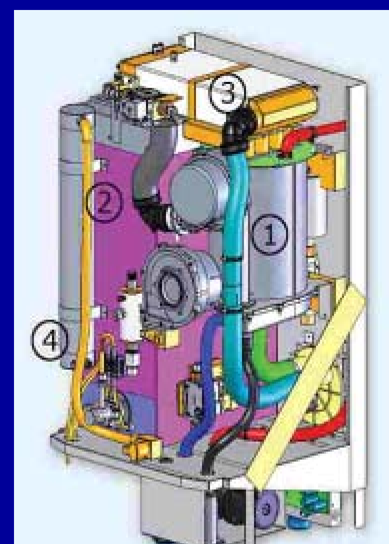


ID Fan
Recuperator
Peak Boiler
Fuel Cell
Desulfurizer
Controller
Inverter
Batteries

European Trials

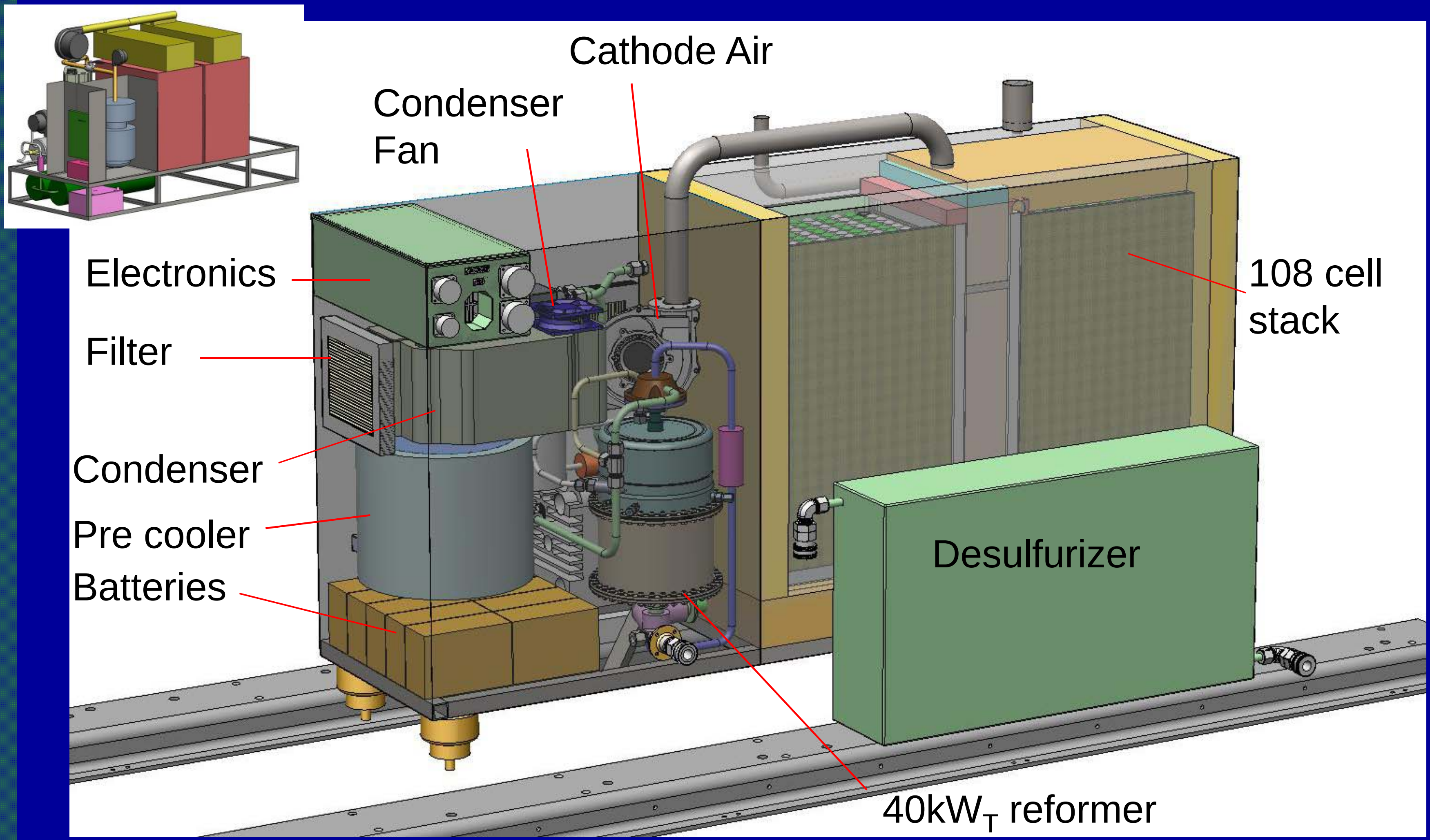


- “Open” lab trials
- Demo with major European utilities
- Demonstration & Commercialization Program with Consortium of utilities



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

JP-8 Fueled 10kW Generator



Balance of Plant Development Needs

- Lack of modulating venturi mix valves for continuous operation
- Lack of low cost combustion blowers with the necessary hours for mCHP life
- Lack of low pressure drop flow meters, especially fuel, for economic solution.
- Low cost NG & LPG sulfur detector
- Metering pumps for liquid fuel operations extremely expensive and unproven life.
- Should note that the average 20yr home furnace only runs 20,000hrs

Power Electronic Development Needs

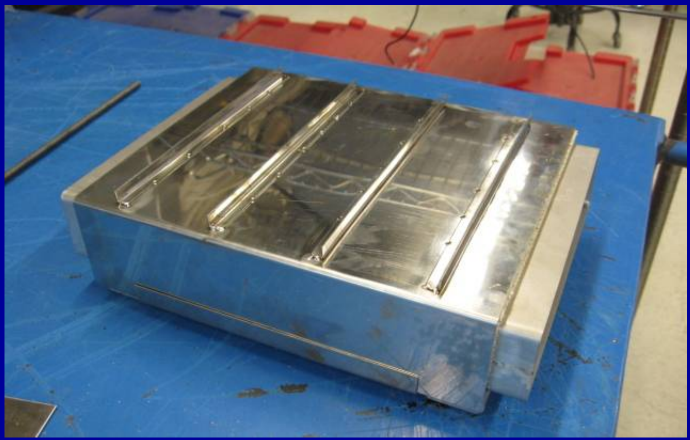
- For $500-$750/kW factory cost, inverters can not cost more that $100/kW
- Solar inverters in 2-3kW range are presently $600-$900/kW cost and $800-$1400/kW price
- The battle of high efficiency and low cost requires integrated design and key trade-offs.
- Fuel cell inverters not only provide DC/AC conversion but also a DC bus for parasitics

Stack Integration Development Needs

- High temperature, high conductivity, low cost wire
- Thin wall, high strength composite refractory materials - mica replacement or joining technique
- High temperature, non-conductive temperature sensors
- Low cost, insulation panels with air jacketing
- Low Cost Recuperators

Recuperator Sizes

- 300 cu. in.
- 17.8 lbs



- 100 cu. in.
- 3.8 lbs

REQUIREMENTS

Exhaust Inlet Temperature – 850 - 950 C
Air Outlet Temperature – 725 - 800 C
Effectiveness – >85%
Total Pres Drop – 1250 Pa
Equal Air & Exhaust Flows
Air Flow – 150 Slpm/ kWe
+100,000 Hours & Hundreds of Thermal Cycles

Manufacturing Development Needs

- DOE has historically not funded manufacturing development in SOFC programs (though they have in PEM)
- As opposed to many PEM developers who buy MEA components, SOFC developers tend to be vertically integrated.
- Automation of cell processing in the SOFC industry is severely behind the level which may be observed for other fuel cell types such as PEM, leading to unnecessarily high cell costs.
- Funds to address scale-up and automation issues in the SOFC industry are limited due to inherent high costs and low ROI. This currently poses one of the most significant barriers to entry for widespread commercialization of SOFC.

Demonstration Needs

- Has been a limited opportunity for funding of demonstration units.
- Very few solicitations have had more than 1-2 units covered, always at 50%
- Should allow for a 10-20 unit demonstration program to allow for significant statistics and different operating cases.
- Large demonstration populations would allow for economy of scale on manufacturing and a better ability to get customers to cover the necessary 50% cost share.

Conclusions

- Good progress being made in mCHP development on all major subsystems and life.
- There is a need for R&D funding around both component development and Demonstrations
- Long term there will be a need to create the same subsidies that have launched the solar industry while still providing R&D dollars.