Versa Power Systems, Inc.

Robert A Stokes
Solid Oxide Fuel Cell Applications

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President & CEO

A Presentation to the
Hydrogen Technical Advisory Committee
Arlington, Virginia
February 17, 2011

Outline

- Market Overview
- Company Overview
- SOFC Technology
- Cell, Stack, Scale-up, System and Manufacturing Status
- Commercialization Considerations

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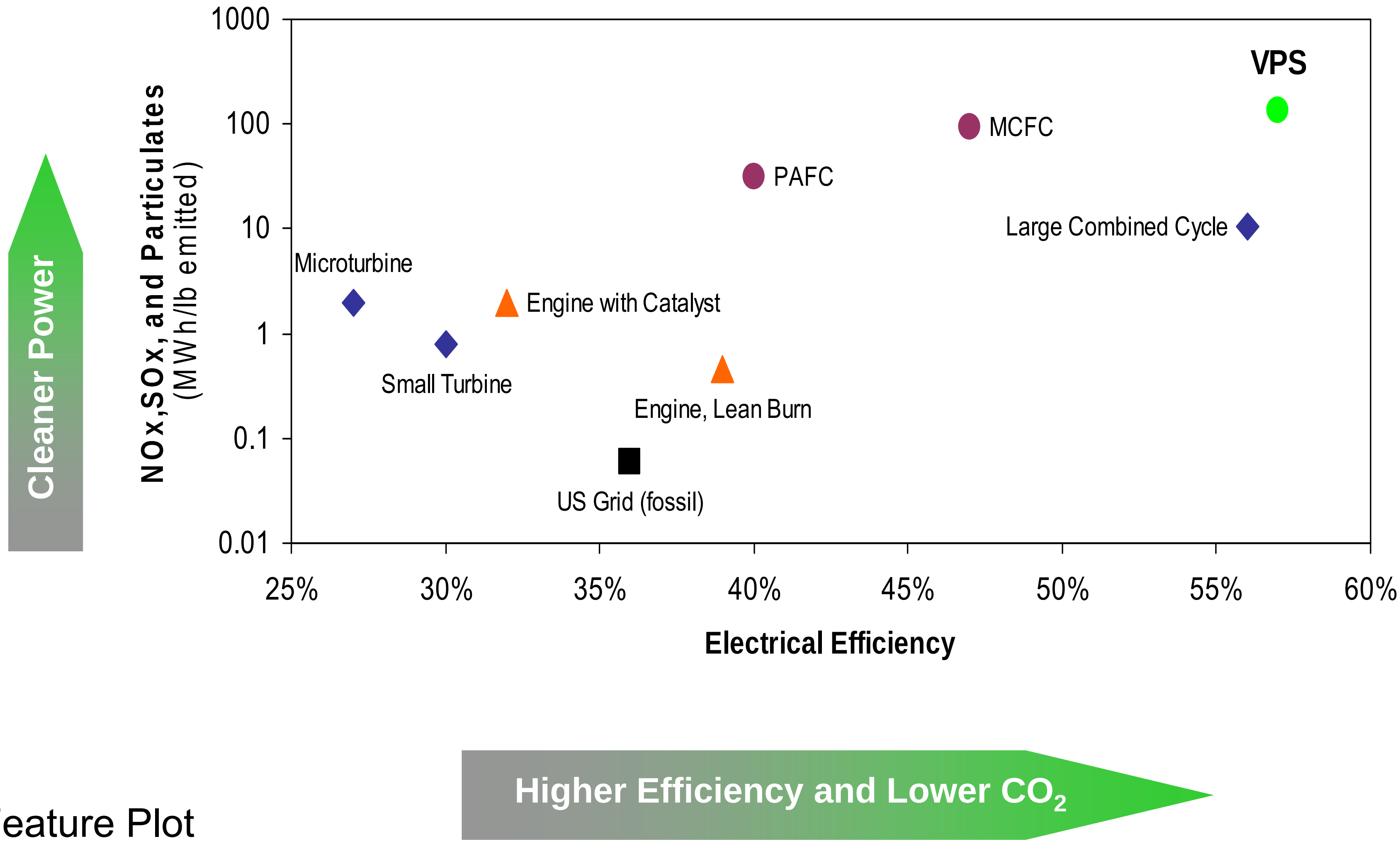
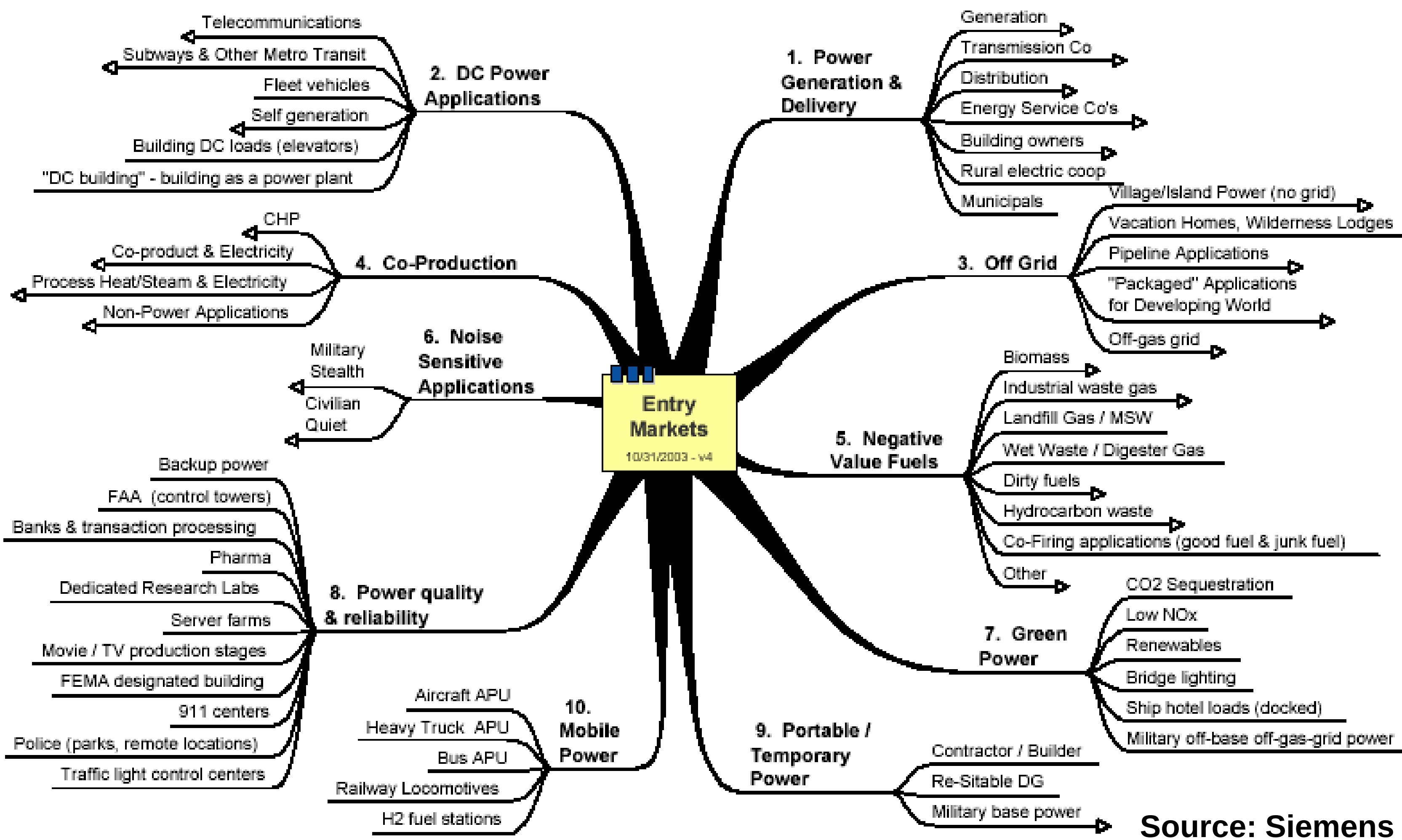
The Solid Oxide Fuel Cell's competitive edge: the cleanest power with the highest efficiency.



Feature Plot

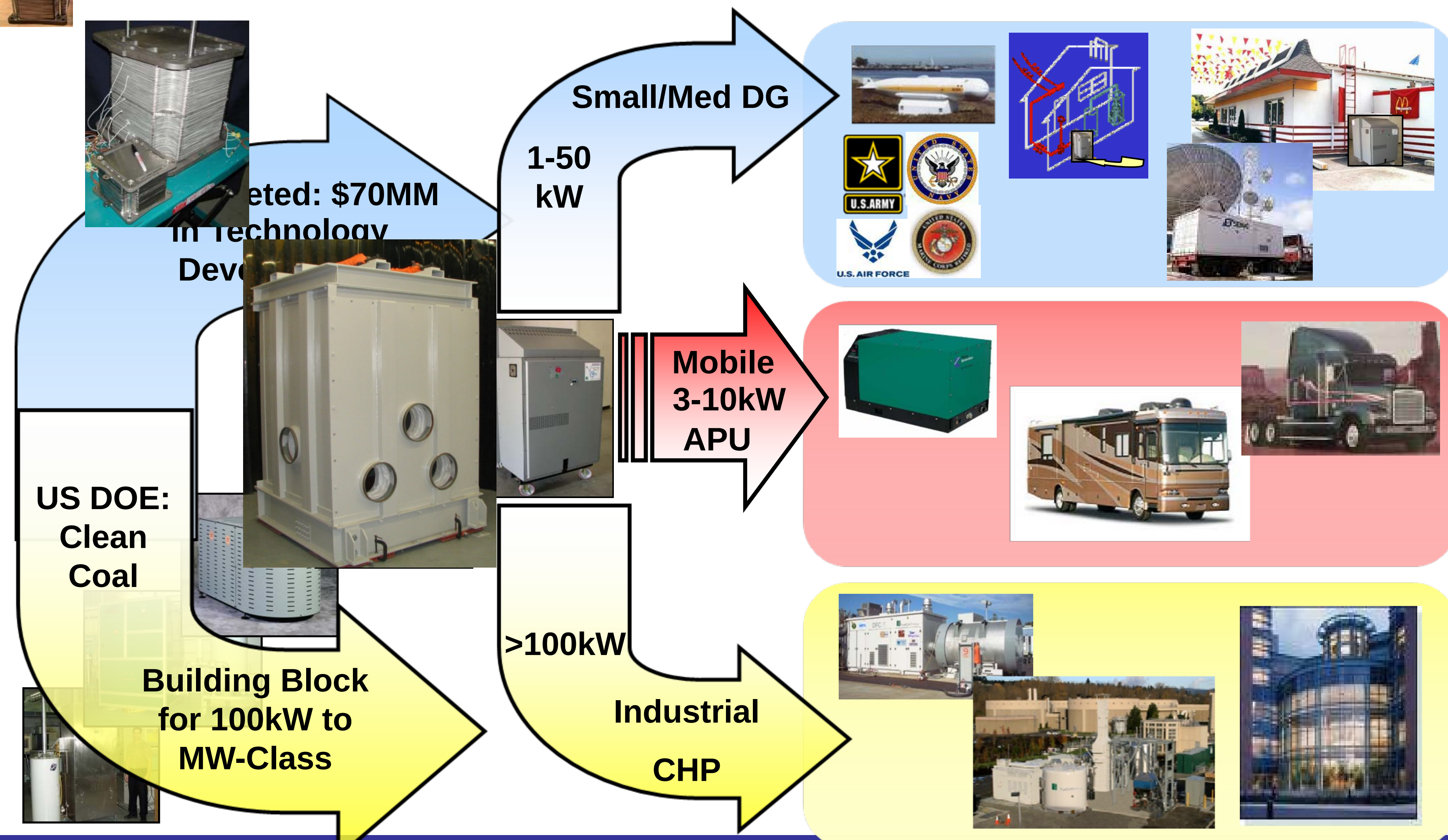
The definition of disruptive- the potential SOFC Markets



Source: Siemens

Many potential markets/applications: choose one and focus

What Are The Markets....today



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Company Overview

- A developer of planar solid oxide fuel cells
- Privately held company
- Headquartered in Littleton, Colorado
- SOFC development facilities in Colorado and Alberta, Canada
- Activities in both stationary and mobile SOFC development
- Annual contract revenue from the U.S DOE and DOD is approximately $11 MM

Versa Power Systems

VPS's 32,000 square foot facility contains product development infrastructure

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SOFC Technology Advantages

- High Electrical Generation Efficiency
- Low Environmental Impact
  - Low SOx, NOx, CO2 Emissions
  - Quiet
  - Vibration-less
- Siting Flexibility
- Fuel Flexibility
  - Propane
  - Natural Gas
  - Coal-derived Fuel Gas
  - Methanol
  - Naphtha
  - Bio-gases
- Cogeneration Potential
  - High Quality Exhaust Heat
- Manufacturing equipment commercially available

Challenges for Commercialization

- The specific metrics vary based on application
  - Cost
  - Life
  - Thermal Cycling
  - Challenges of introducing a new disruptive product into the market space of incumbent product lines

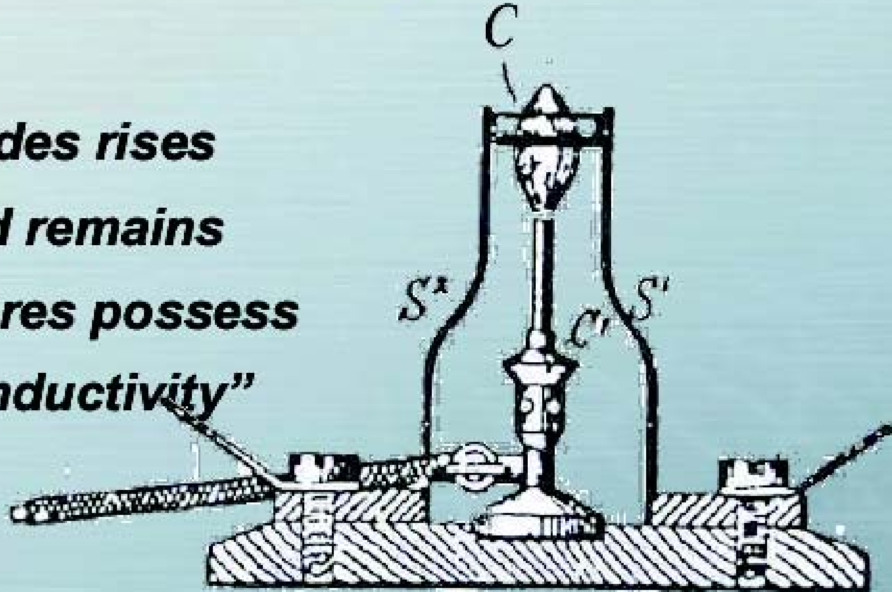
Ceramic Ion Conductors: Early Work

- **Walther Nernst (1897)**

"that the conductivity of pure oxides rises very slowly with temperature and remains relatively low, whereas the mixtures possess an enormously much greater conductivity"

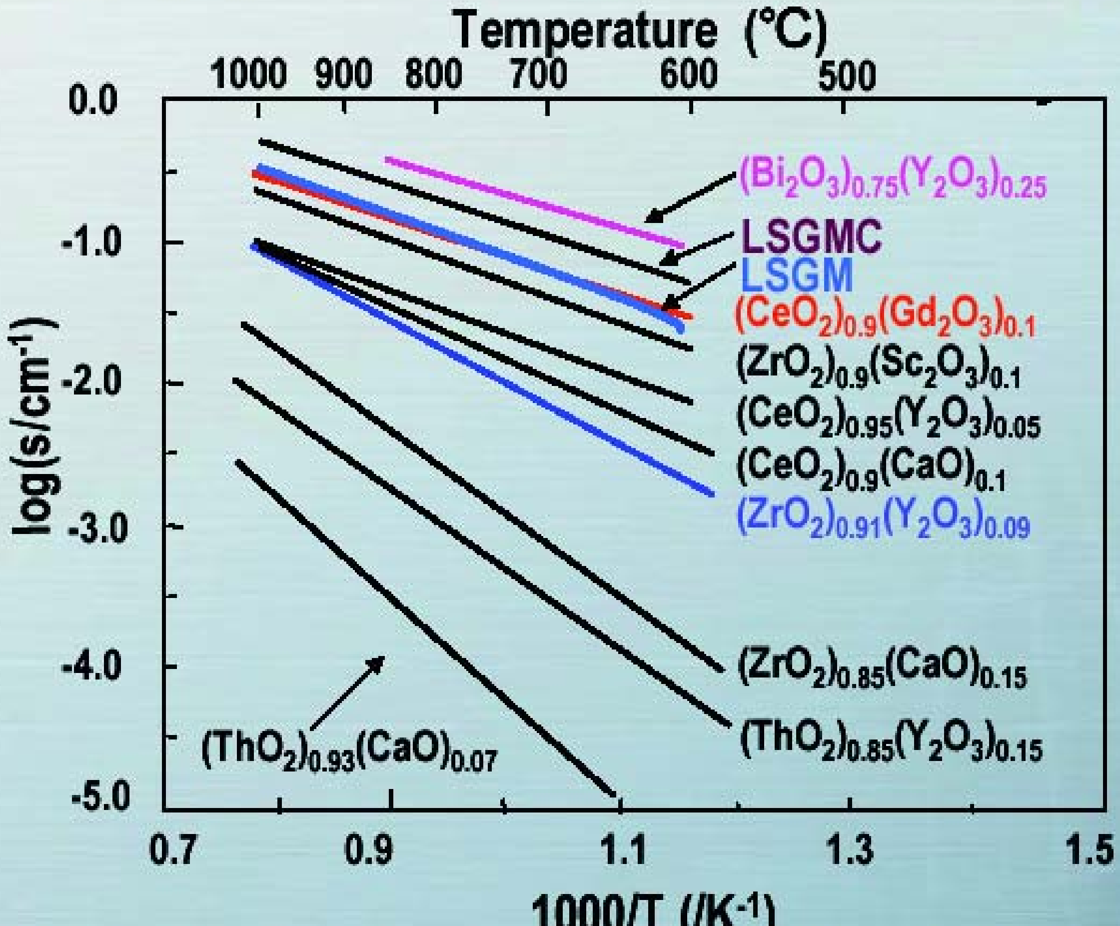
Initially:
"lime, magnesia, and those sort of substances;"

Later:
"Nernst mass (85% ZrO_2 + 15% Y_2O_3)"



W. Nernst
"Electrical Glow-Light"
U.S. Patent 623,811
April 25, 1899

Comparison of Oxide Ion Conductivity



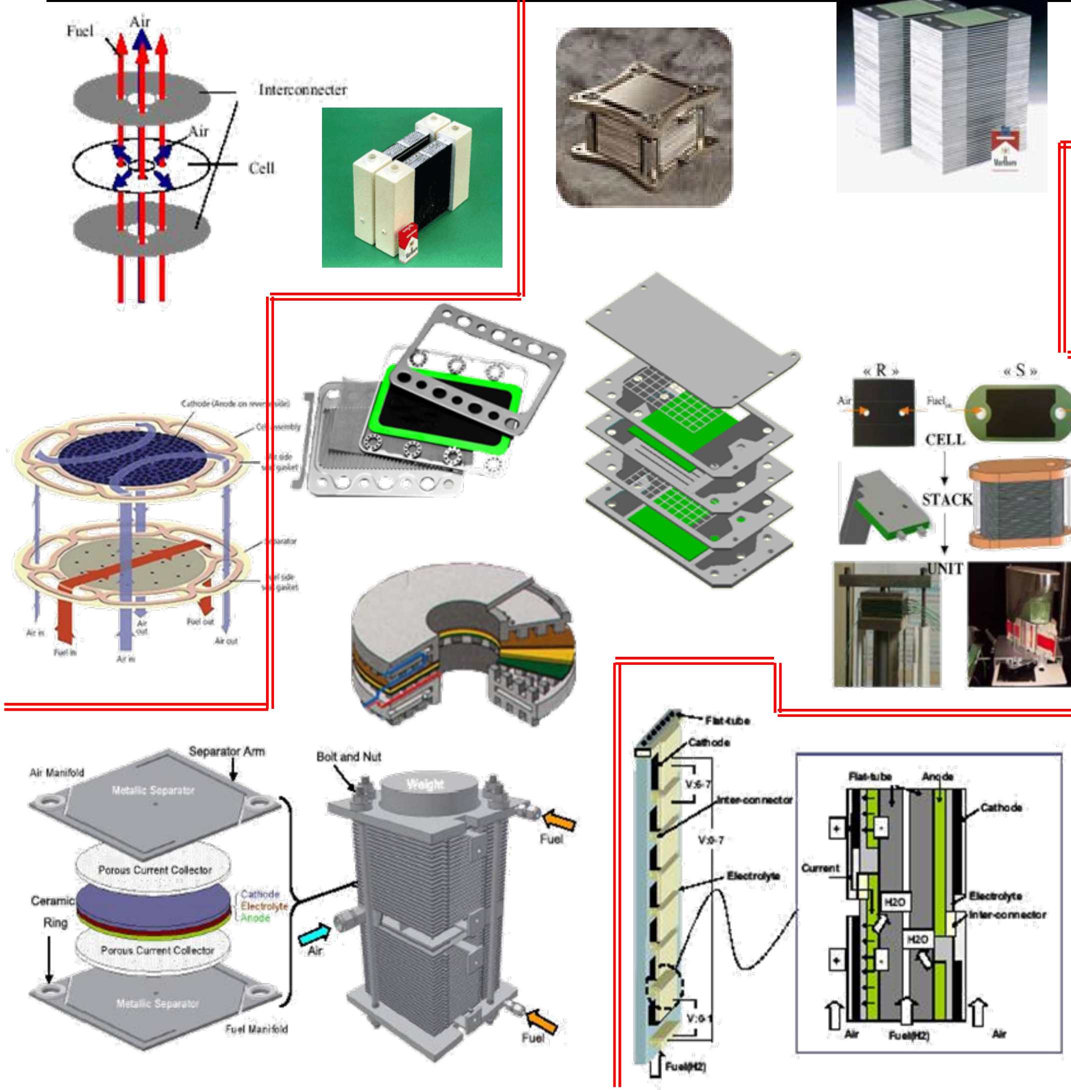
(LSGMC: $La_{0.8}Sr_{0.2}Ga_{0.8}Mg_{0.115}Co_{0.085}O_3$; LSGM: $La_{0.9}Sr_{0.2}Ga_{0.8}Mg_{0.1}O_3$)

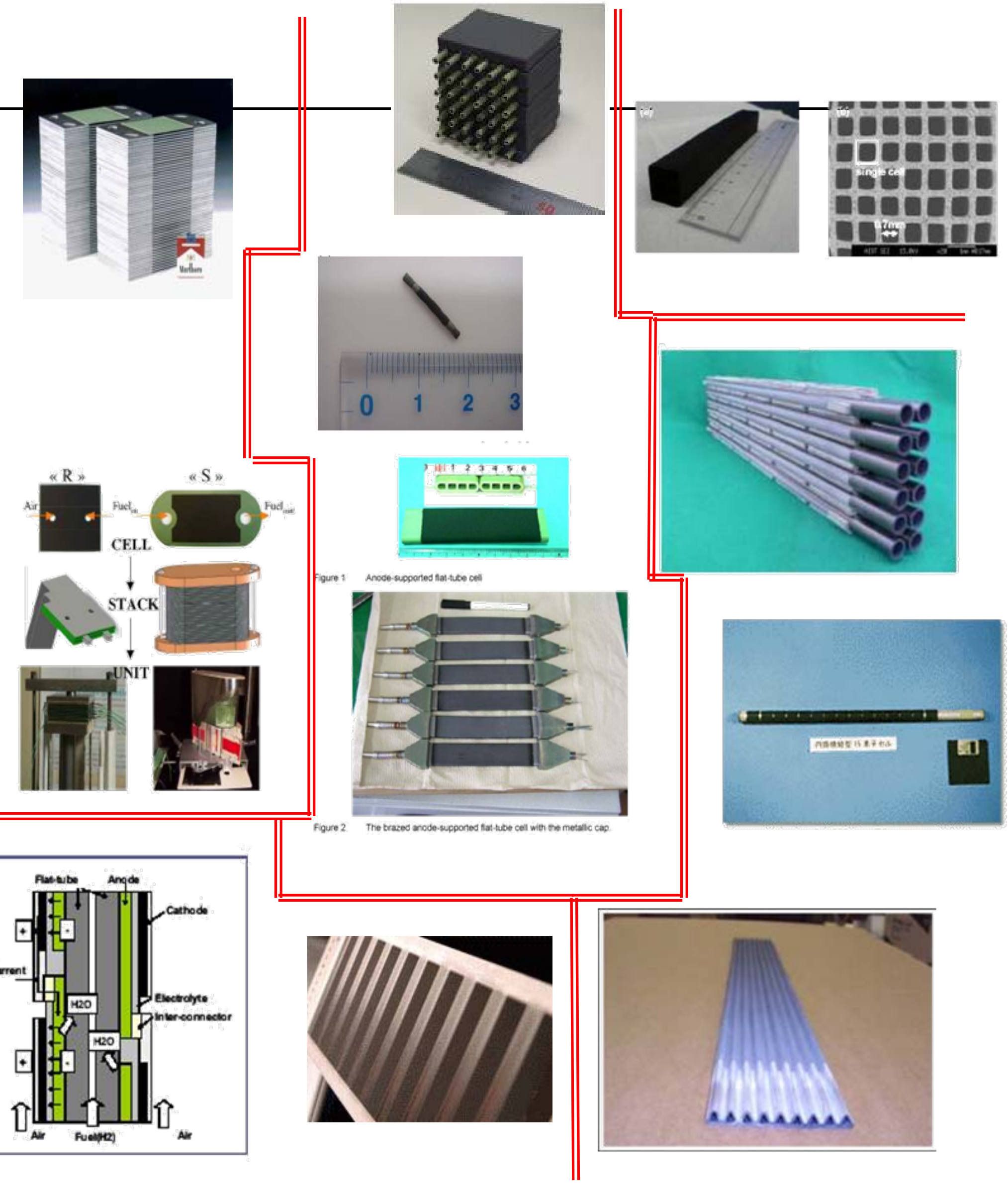
Zirconia-based Electrolyte Materials

- Very low electronic conduction (energy band gap: >7 eV)
- Very high thermodynamic stability (decomposition Po2 at 1000°C: 10-35 atm)
- Easily doped with lower valence cations (such as Ca2+, Y3+, Sc3+) to create oxygen vacancies
- Doped material is highly oxide ion conductive (conductivity: >0.1 (ohm·cm)-1 at 1000°C)

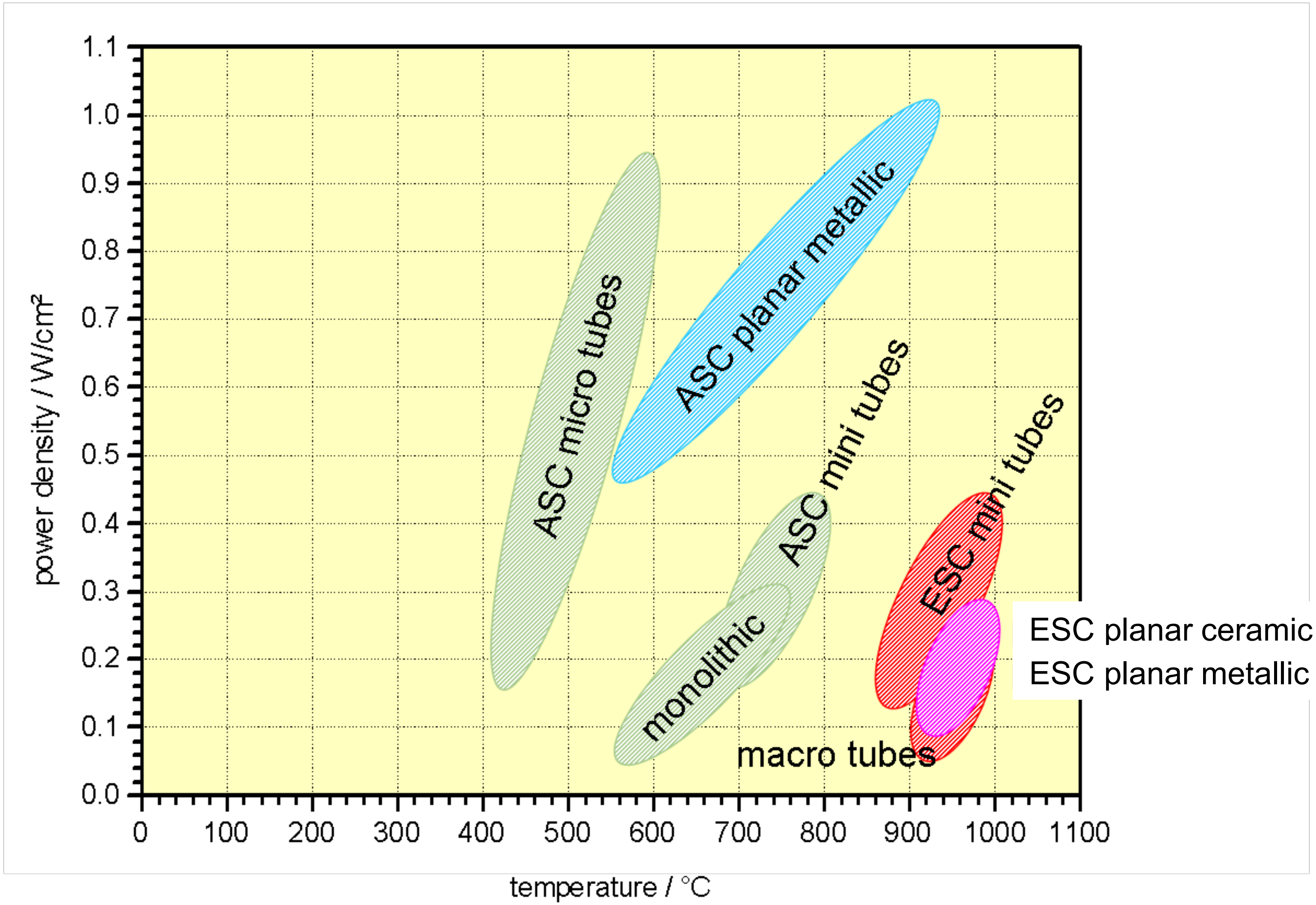
Zirconia-based materials are still the most widely used for electrolytes of SOFCs

Many SOFC Stack Designs





Power density vs. Temperature



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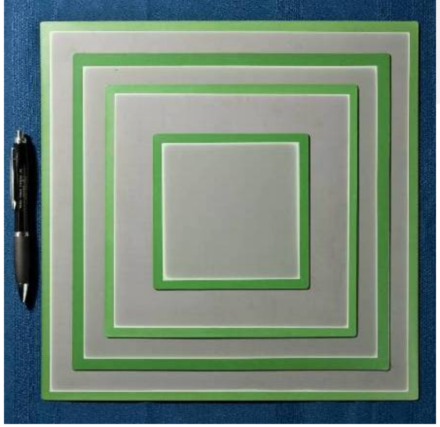
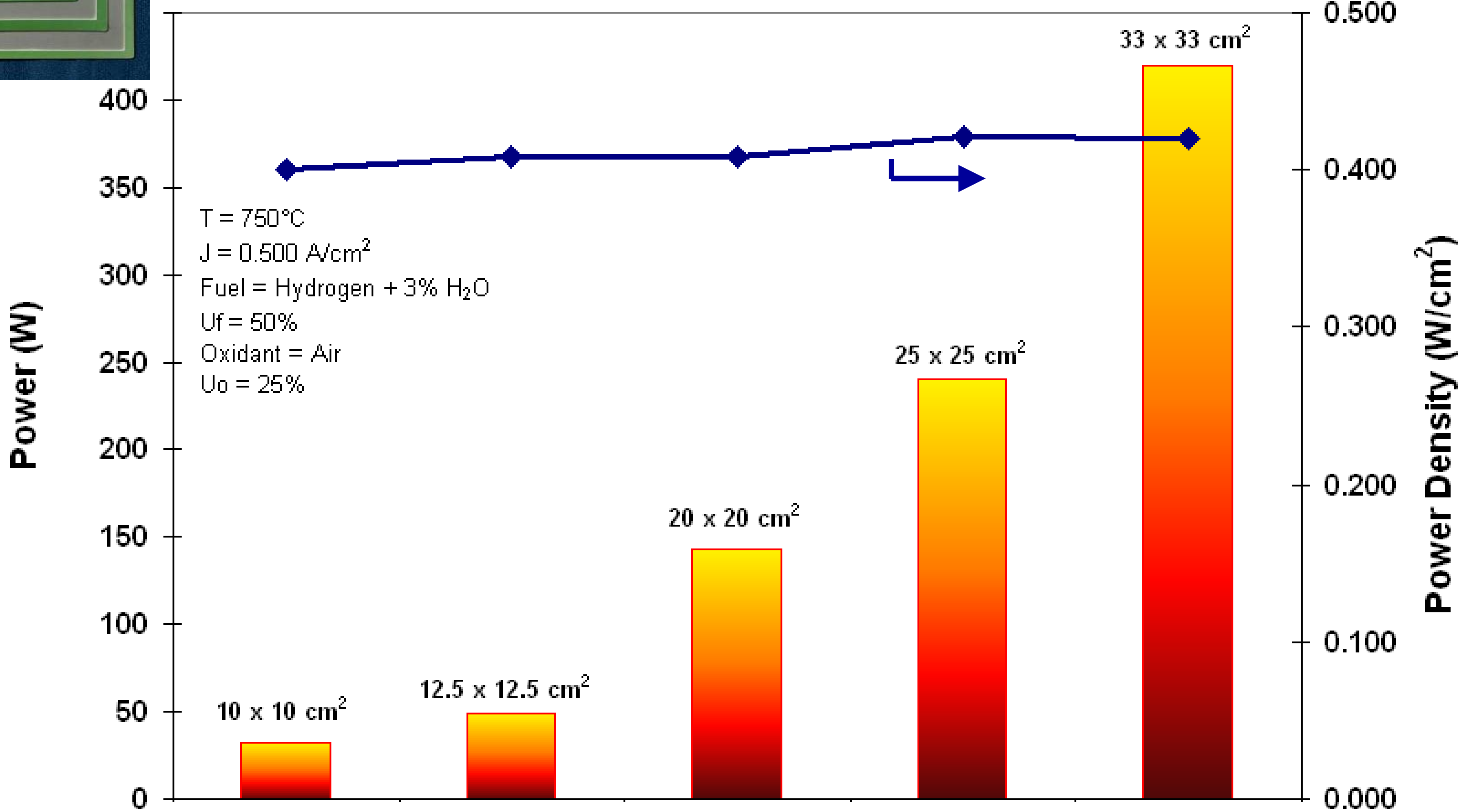
Cell Scale-Up Development

- The established Tape casting/Screen Printing/Co-firing (TSC) process proved to be flexible enough to allow a >8X increase in cell active area (121 → 1000 cm2) without appreciable changes in performance or yield
- 25 x 25 cm2 cells (550 cm2 active area) are being used for stack development



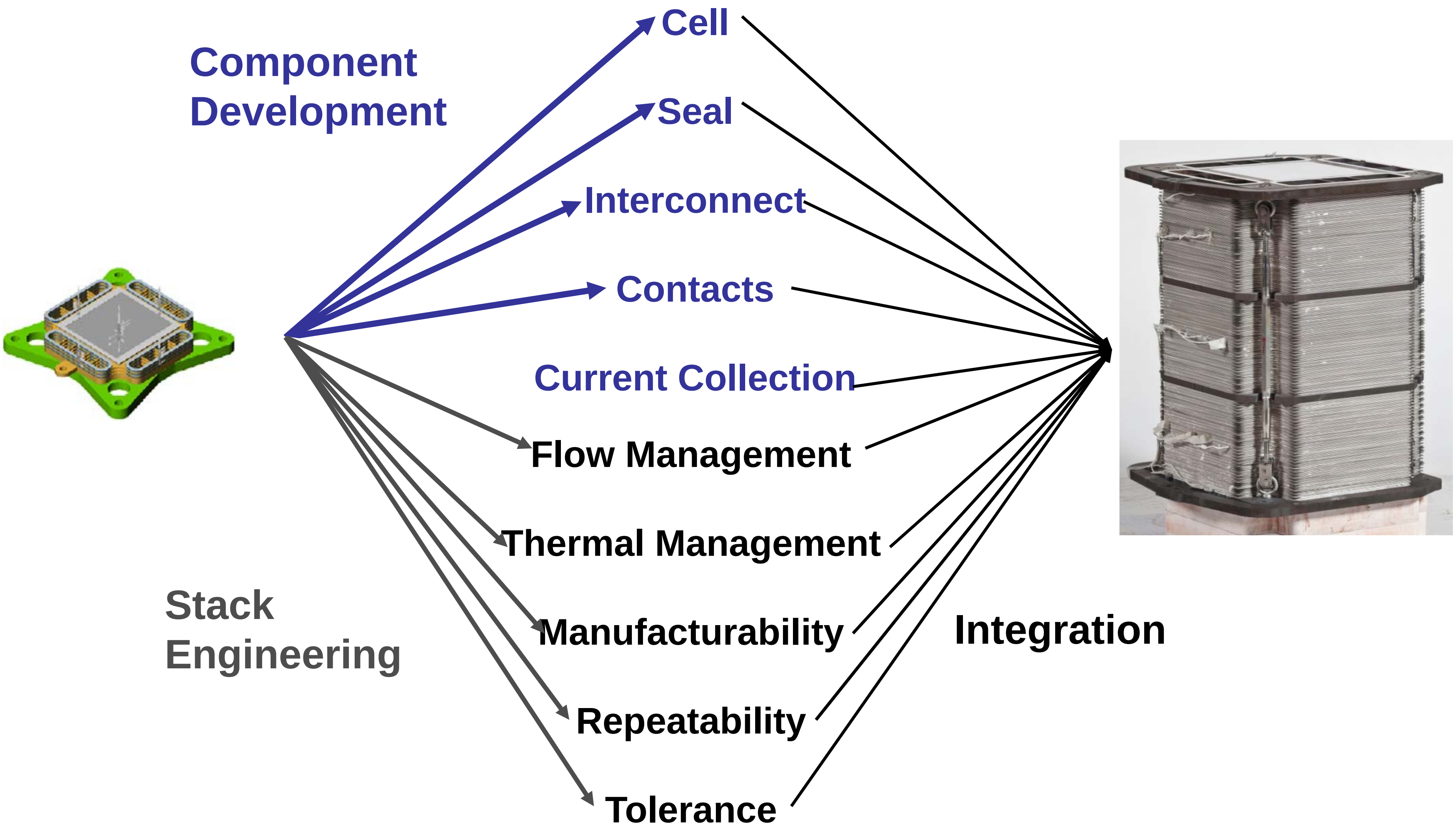
Cell Power Progression at 0.500 A/cm2

Stainless Steel Current Collectors, Cross-Flow Gas Delivery



Power (W)	32	49	143	241	420
Cell Voltage (V)	0.80	0.82	0.82	0.84	0.84

Stack Development Strategy

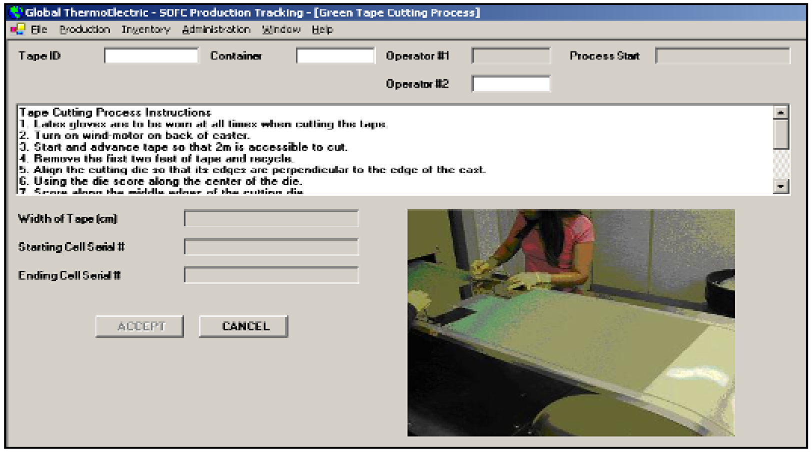


Overall- the manufacturing capacity and proprietary processes, scalable for volume production, to deliver low-cost products

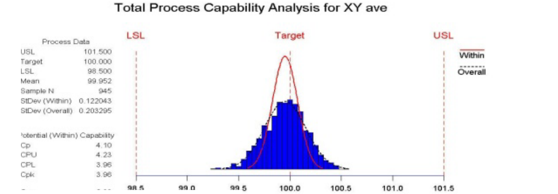
Tape Casting

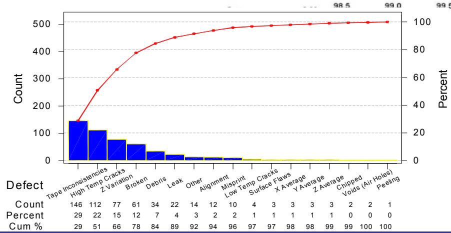
Screen Printing

Co-sintering



Process Tracking Database

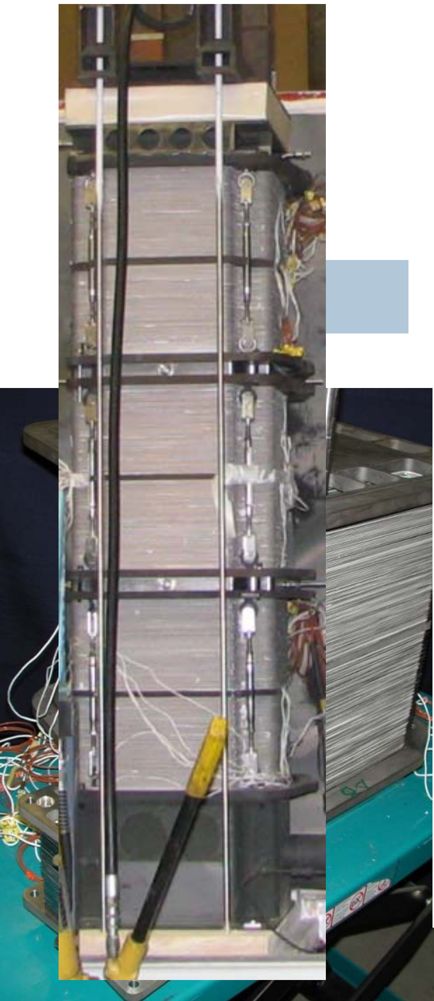




Statistical Process Control

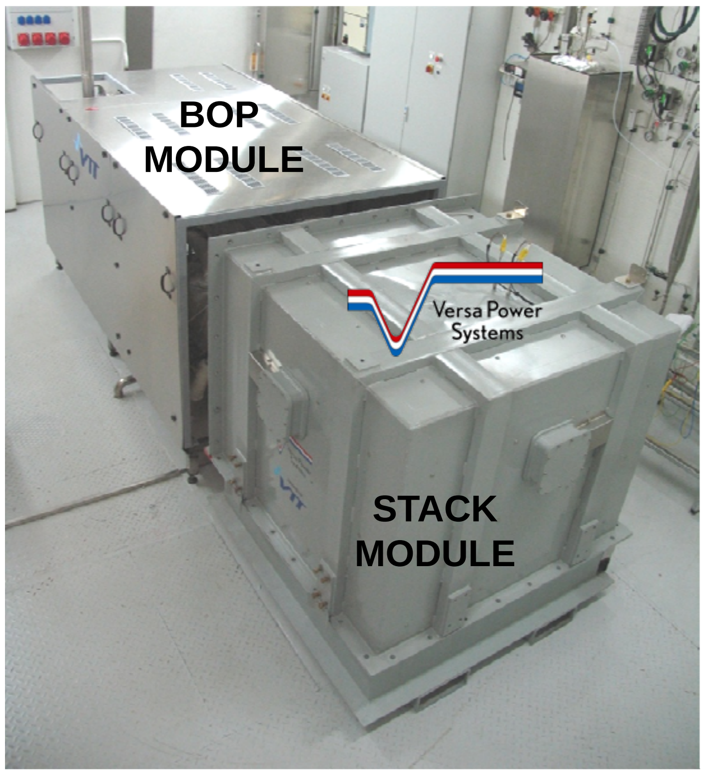
From Stack Block to 250 kW, System Integrated Power Module

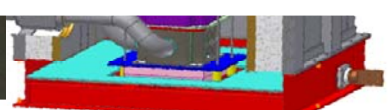
Stack Tower



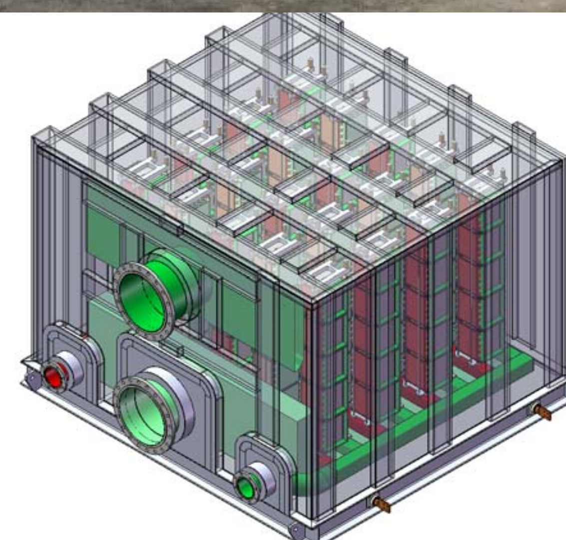
Stack Module Development

2010/2011: Stack Module System Integration (10 to 50kW)





2012-2013: 250kW Power Module & System Integration



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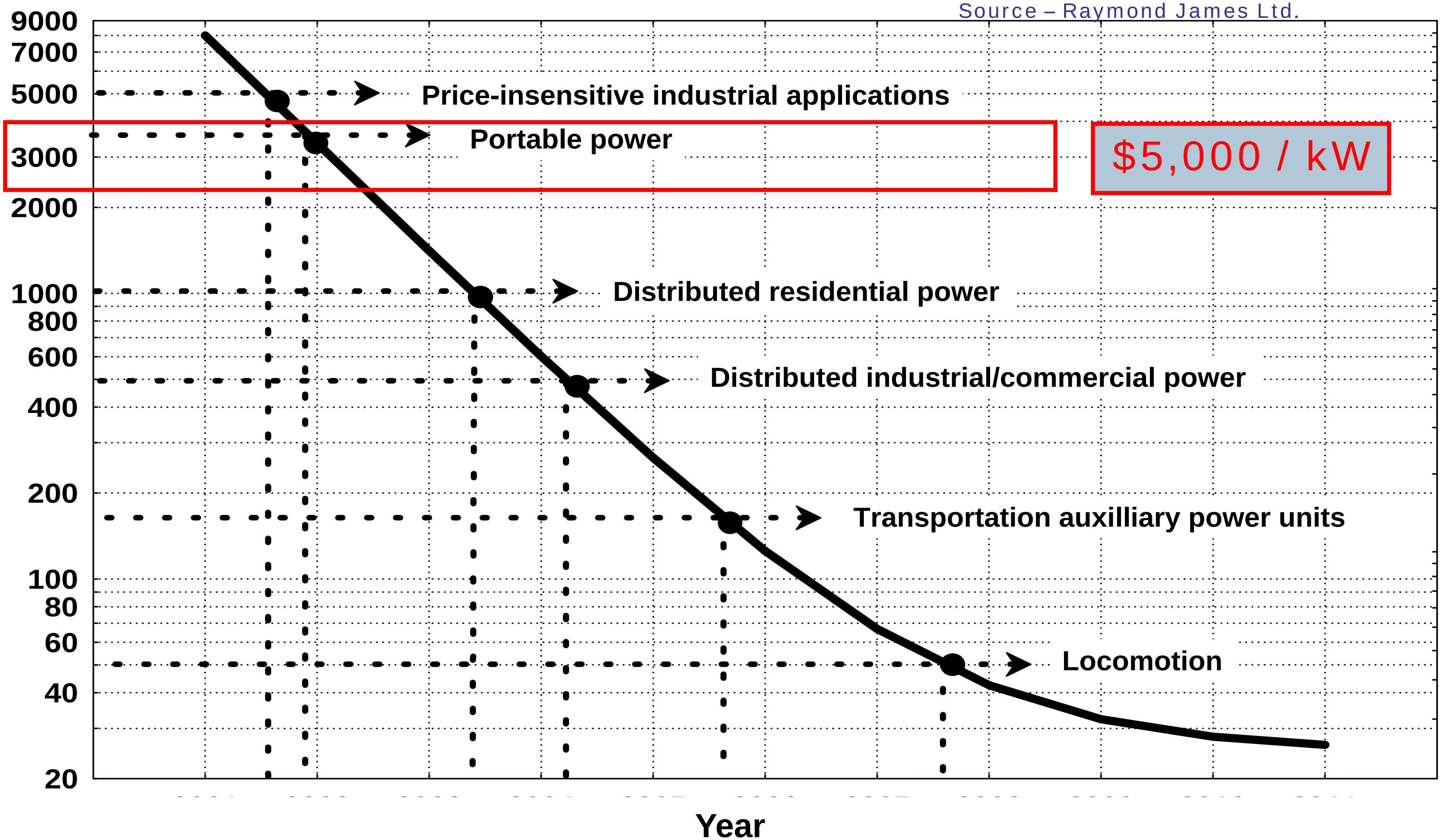
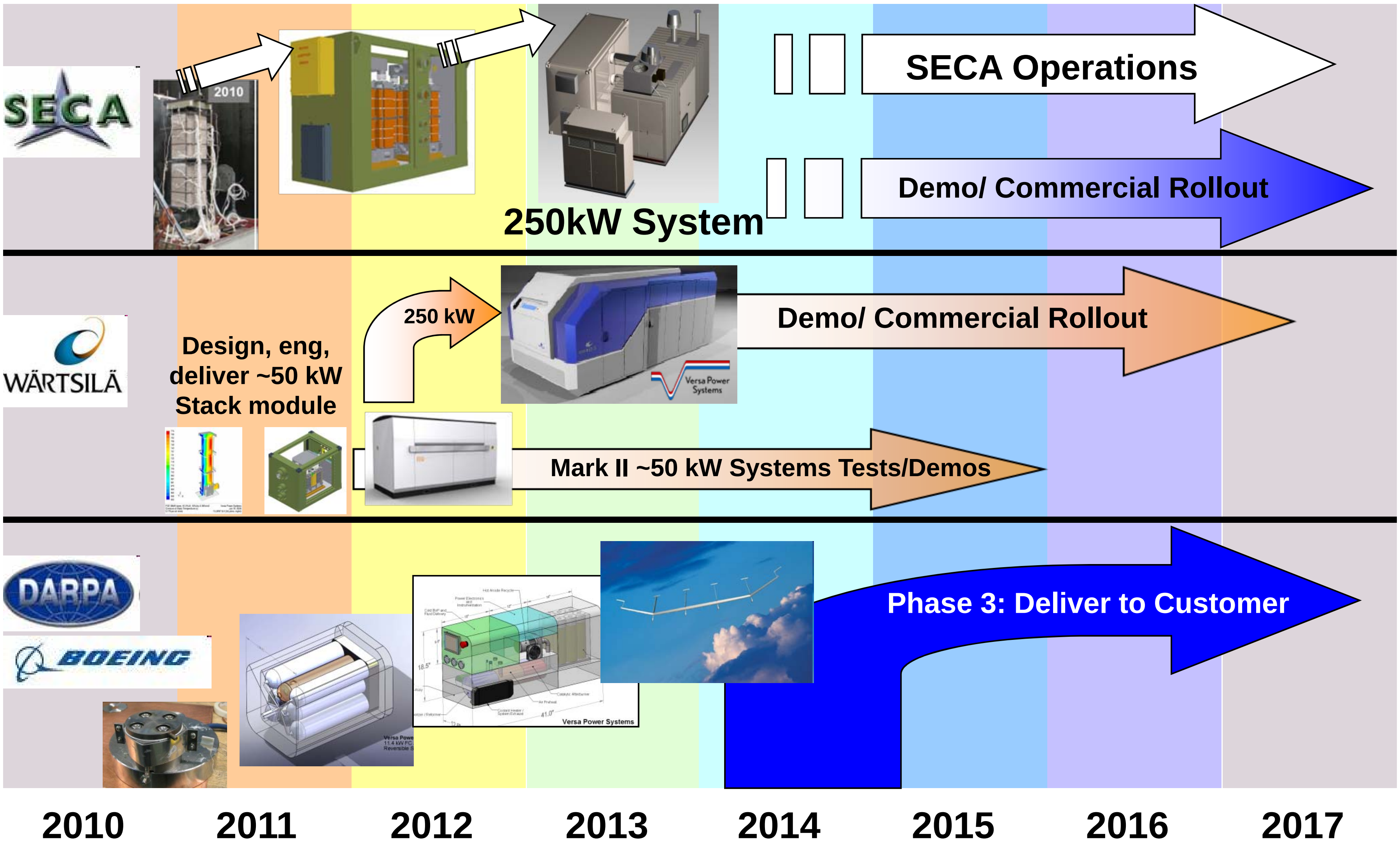
Fuel Cells Price Points



The VPS Product Development & Delivery Timeline

SECA Phase 3, Wärtsilä and DOD-DARPA/Boeing Phase 2



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Media

DOD-DARPA/Boeing Contract

Boeing Wins DARPA Vulture II Program

ST. LOUIS, Sept. 16, 2010 -- The Boeing Company [NYSE: BA] on Sept. 14 signed an agreement with the U.S. Defense Advanced Research Projects Agency (DARPA) to develop and fly the SolarEagle unmanned aircraft for the Vulture II demonstration program. Under the terms of the $89 million contract, SolarEagle will make its first demonstration flight in 2014.

"SolarEagle is a uniquely configured, large unmanned aircraft designed to eventually remain on station at stratospheric altitudes for at least five years," said Pat O'Neil, Boeing Phantom Works program manager for Vulture II. "That's a daunting task, but Boeing has a highly reliable solar-electric design that will meet the challenge in order to perform persistent communications, intelligence, surveillance and reconnaissance missions from altitudes above 60,000 feet."

Under the Vulture II agreement, Boeing will develop a full-scale flight demonstrator, including maturation of the critical power system and structures technologies. **Key suppliers for the program include Versa Power Systems** and QinetiQ.

During testing, the SolarEagle demonstrator will remain in the upper atmosphere for 30 days, harvesting solar energy during the day that will be stored in fuel cells and used to provide power through the night. The aircraft will have highly efficient electric motors and propellers and a high-aspect-ratio, 400-foot wing for increased solar power and aerodynamic performance.

SolarEagle is one of Phantom Works' rapid prototyping efforts, which also include Phantom Ray, a fighter-sized, unmanned, advanced technology demonstrator scheduled to make its first flight in early 2011, and the hydrogen-powered Phantom Eye demonstrator, a High Altitude Long Endurance aircraft designed to stay aloft for up to four days, also scheduled to make its first flight in 2011.

A unit of The Boeing Company, Boeing Defense, Space & Security is one of the world's largest defense, space and security businesses specializing in innovative and capabilities-driven customer solutions, and the world's largest and most versatile manufacturer of military aircraft. Headquartered in St. Louis, Boeing Defense, Space & Security is a $34 billion business with 68,000 employees worldwide.

The Vulture Unmanned Air System (UAS); now re-named SolarEagle

Versa Power Systems

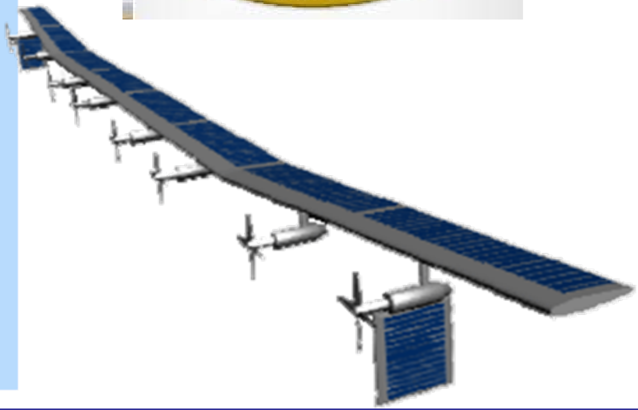
VPS has teamed with Boeing Company on a DARPA-sponsored project to demonstrate unmanned air systems (UAS) using VPS' solid oxide technology as the energy storage and conversion platform

Phase 2: 2010-2014– Subscale Flight Demonstration

The Team

- BOEING
- Versa Power Systems
- SPECTROLAB
- QinetiQ

- **Break the mindset that aircraft are defined by launch, recovery, and maintenance cycles**
  - Unmanned Air Vehicle
  - Operate like a satellite for 5 years at a time
- **200X Voyager Endurance Record**
- **Pseudo-satellite benefits**
  - Increased platform availability
  - Consistent and persistent coverage
  - Smaller fleet size
- **Fundamental issues**
  - Energy cycle: collection or refueling
  - Reliability: ultra-reliable or repairable system

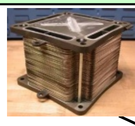


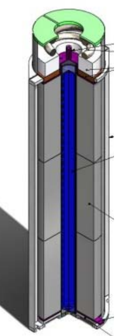
Power Density Progress & its Impact on Commercial Product Potential

Distributed Generation (DG) Stacks (DOE SECA)

VPS High Power density Stack

Residential (DG) Stacks (DOE)

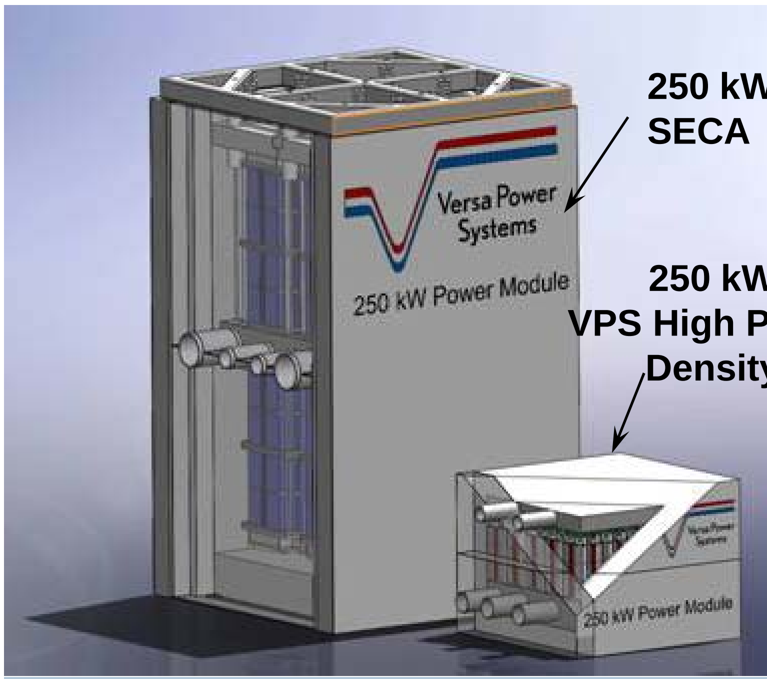




	Baseline Residential 390 mA/cm²	64 cell DG-Coal based 390 mA/cm²	92 cell DG-Coal based 450 mA/cm²	Today: 20 cell Sept 10 390 mA/cm²	Projected: 270 cell projected 390 mA/cm²
Gross Power (W)	1,200	11,000	18,000	157	2238
Power to Weight Ratio (W/kg)	69	61	72	216	472
Power to Volume Ratio (W/L)	225	175	200	775	1689

The VPS High Power Density Stack is the Foundation of the DARPA Program: opens the door for ultra-compact systems of the future

250 kW Stack Modules: 1/4th the size of SOA

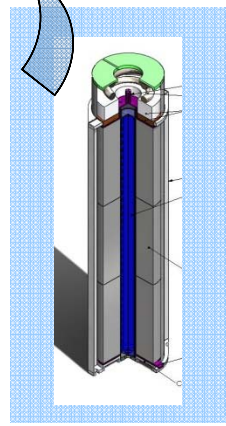


250 kW SECA

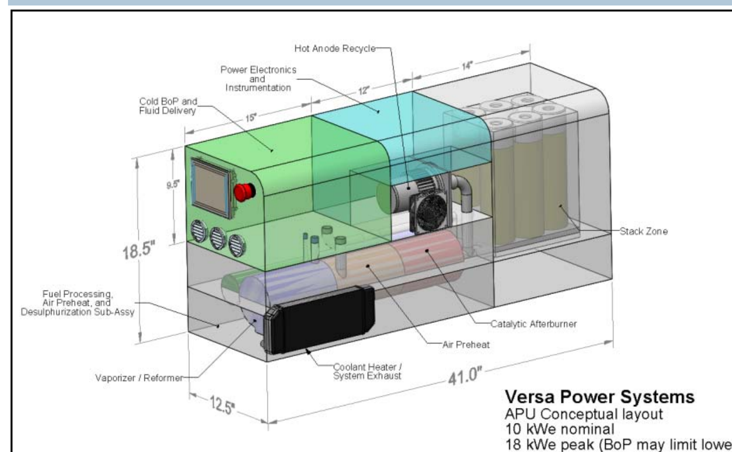
250 kW VPS High Power Density

The High Power Density Stack:

- Compact and lightweight
- Modular
- High voltage / Low current



Mobile: 10 kW, military & commercial APUs Gensets with 1/10th the weight

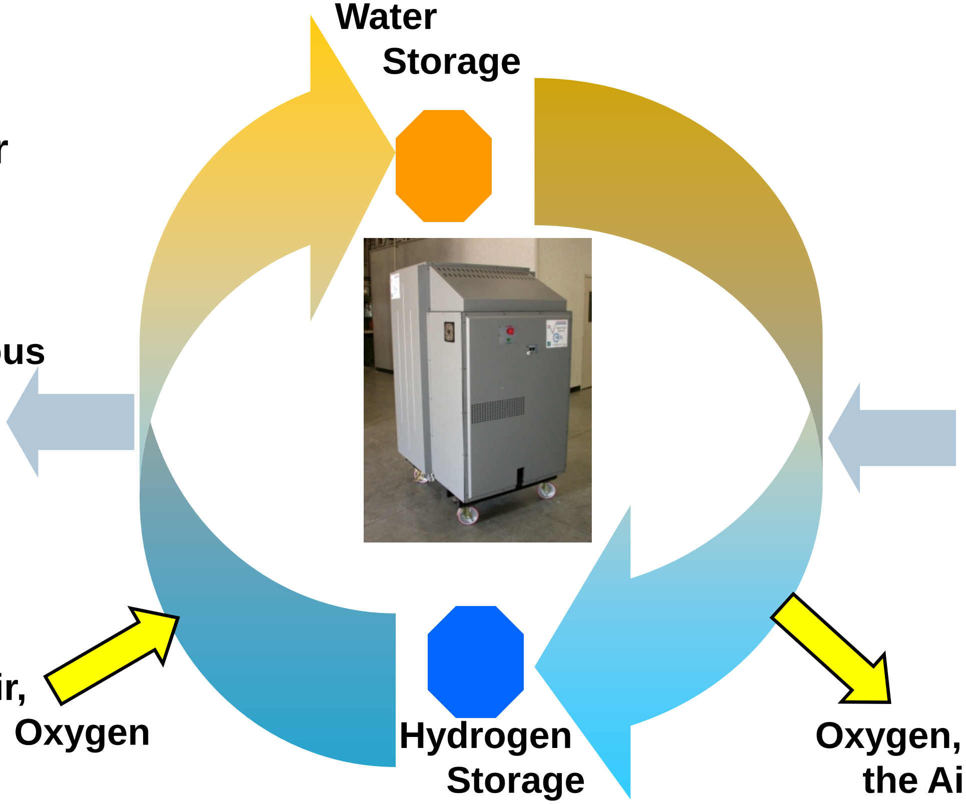


Low Cost

- 10x less material (weight)
- Automated assembly

Enable Reliability for Renewables: Solving the Energy Storage Problem

The VPS
Fuel Cell / Electrolyzer



Source:

- Wind
- Solar

- Unitized Cell
- High energy density
- High round trip efficiency

Applications

- Continuous Power for Renewables
- Grid Support: load level, peak-shave
- Hydrogen commodity production

Summary

- SOFCs offer many advantages over conventional power generation technologies, as well as a bridge to the “hydrogen economy”
- SOFC developers utilize a range of talents in their organizations, including: materials scientists, electrochemists, chemical engineers, mechanical engineers, electrical engineers, manufacturing engineers
- R & D opportunities exist within all of these specialties
- The main challenges that exist for SOFC developers are cost, lifetime and durability for a given market/application
- SOFCs have the potential to address very large power generation markets