



Development of Natural Gas Fuelled Solid Oxide Fuel Cells at Versa Power Systems

***Michael Pastula
Versa Power Systems
Calgary, Alberta, Canada***

2005 AAPG Annual Convention

**Renewable Energy Session
June 19-22, 2005**

Calgary, Canada

Profile of Versa Power Systems

- **Commercialization of low-cost SOFCs for stationary power applications ranging in product size from 3 to 10 kW for applications up to 100 kW**
- **Preferably, initial systems will provide continuous prime or supplemental power using natural gas fuel (today's fuel infrastructure)**
- **The main system benefits provided will be high efficiency, low emissions, low noise, and low maintenance compared to comparably-sized genset solutions**
- **Early adopter segments exist in many main market segments including remote industrial, commercial and light industrial**

SOFC Development Background

- Development started in 1997
- Planar SOFC was determined to have the best commercialization prospects
 - Use of hydrocarbon fuels
 - High power density
 - Manufacturability
- 32,000 sq. ft. Calgary development facility with HQ in Littleton, CO
- 35 people
- 9 US Patents / 81 US and international patents pending





Solid Oxide Fuel Cell Technology

Types of Fuel Cells

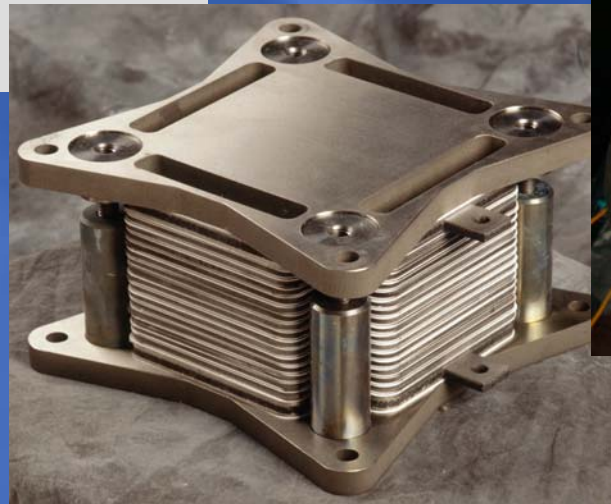
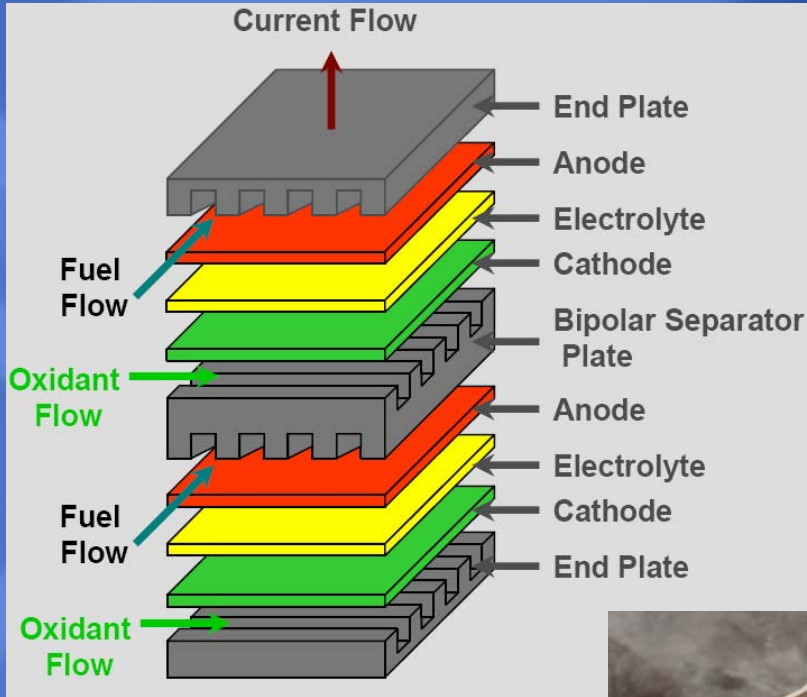
Type	Temp (°C)	Electrolyte	Application
Alkaline	60-90	KOH	Space
Polymer	80-90	Fluorinated sulfonic acid polymer (Nafion)	Space/Transportation
Phosphoric Acid	160-220	Phosphoric Acid	Power Generation
Molten Carbonate	620-660	$\text{Li}_2\text{CO}_3/\text{Na}_2\text{CO}_3$	Power Generation
Solid Oxide	600-1000	$\text{ZrO}_2/\text{Y}_2\text{O}_3$	Power Generation Space/Transportation

SOFC Principle of Operation



- **Anode** – nickel-zirconia cermet, ~ 1 mm thick
- **Electrolyte** – yttria-stabilized zirconia (YSZ), ~ 5 μm thick
- **Cathode** – conducting ceramic, ~ 50 μm thick

Planar SOFC Design



SOFC Developers

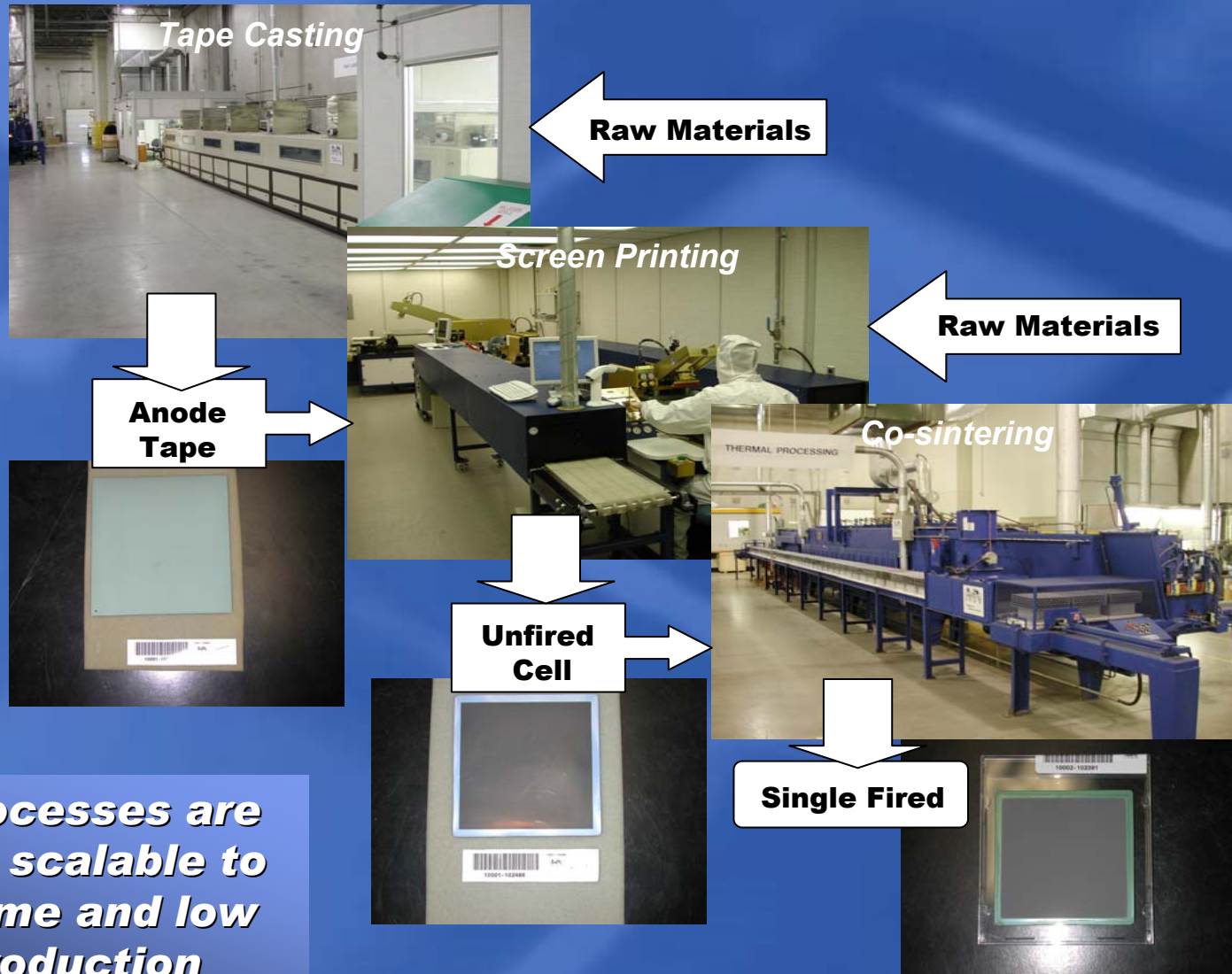
Developer	Partner	SOFC Type	Target Market	System Size
Accumetrics	General Dynamics	Tubular Anode supported	Distributed Power	5-50 kW
Ceramic Fuel Cells Ltd	-	Planar EL supported	Residential Cogen	1-2 kW
Cummins	SOFCo	Planar Anode supported	APU, portable power	5-10 kW
Delphi	Battelle	Planar Anode supported	APU	5 kW
GE	-	Planar Anode supported	Distributed Power	>250 kW
Siemens Westinghouse	Fuel Cell Technologies	Tubular Cathode supported	Distributed Power	2-125 kW
Sulzer Hexis	-	Planar EL supported	Residential Cogen	1-2 kW
Wärtsilä	Haldor Topsøe	Planar Anode supported	Marine Propulsion	250 kW

Cell Manufacturing Process Development

- Early work focused on cell performance and lower operating temperature
- The cell fabrication process evolved from the laboratory to the production floor at an early stage. The leading edge solution.
- The techniques selected are widely used in the electronics industry:
 - **T**ape casting
 - **S**creen printing
 - **C**o-firing

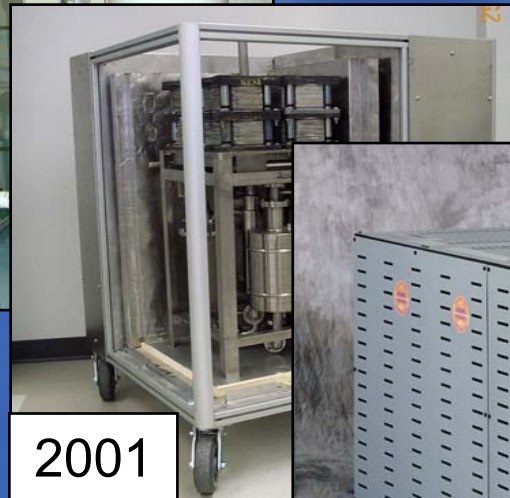
TSC Process

Cell Manufacturing Process Flow



These processes are flexible & scalable to high volume and low cost production

Prototype Systems: kW-class



RP-2

Aurora / 3-1

*Natural Gas Fuel
Grid Parallel*

3 kW Prototype System Run Summary



Peak Net AC Power Output	2.90 kW
Average Net Power Output	2.87 kW
Stack Operating Temperature	735 °C
Fuel Utilization	60%
Air Utilization	45%
Direct Internal Reforming	32%
Peak Net Electrical Efficiency	37.6%
Average Net Electrical Efficiency	36.5%

Foundation for a Commercial Opportunity

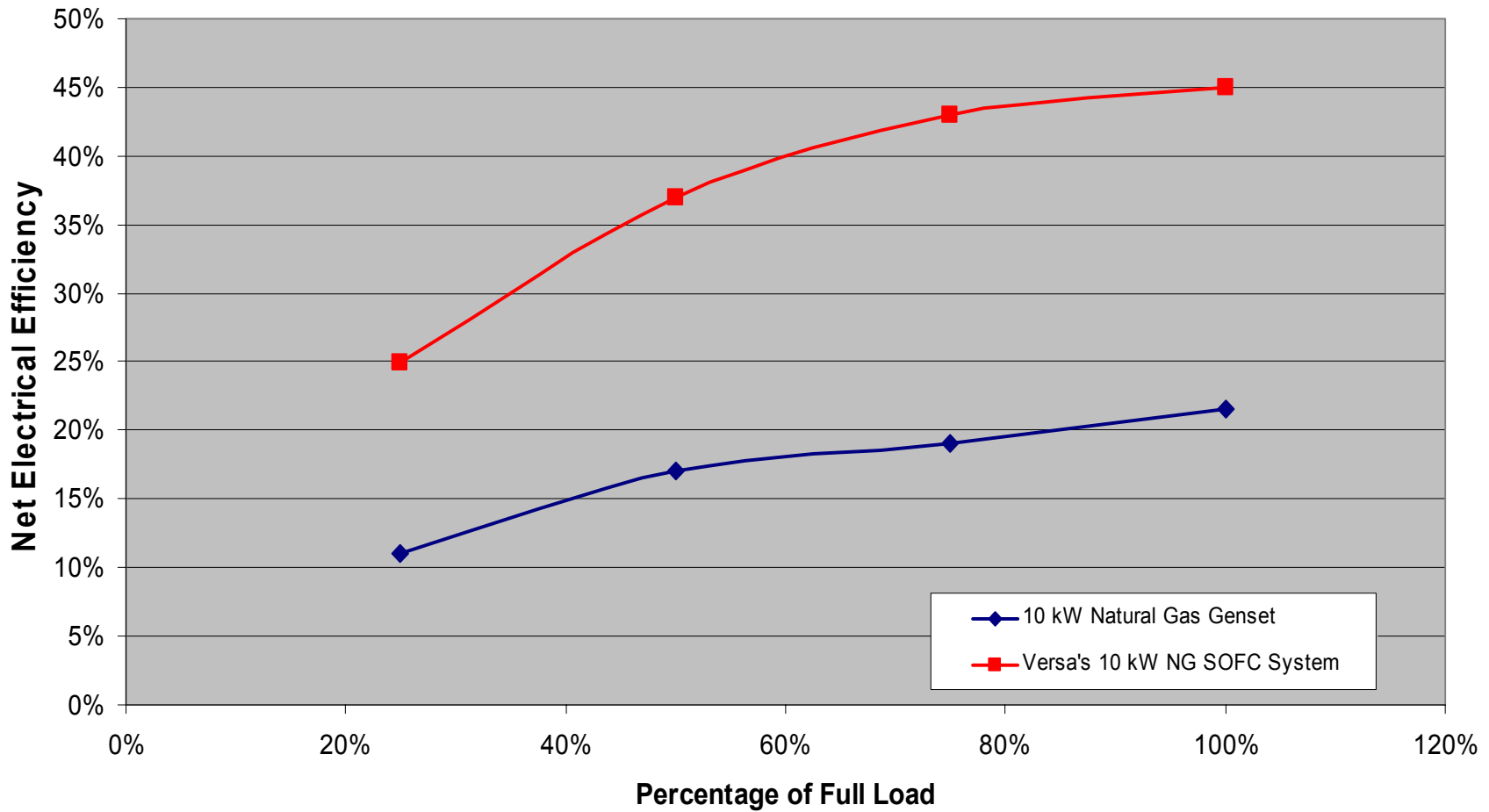
- **Technology Status**
 - **Core competencies**
 - High power density
 - Longevity
 - Thermal cycle capability
- **Commercial preparation**
 - **10kW pre-commercial stationary power plant**
 - 2008/2009
 - Stack, BOP reliability and longevity
 - 40%+ net electrical efficiency

Benefits of Solid Oxide Fuel Cell Technology

- **High Electrical Generation Efficiency**
- **Low Environmental Impact**
 - Low SO_x, NO_x, CO₂ Emissions
 - Quiet
 - Low Vibration
- **Siting Flexibility**
- **Fuel Flexibility**
 - LNG
 - PNG
 - Coal-derived Fuel Gas
 - Methanol
 - Naphtha
 - Bio-gases
- **Size Flexibility**
 - Modularity Permits Wide Range of Unit Ratings
- **Cogeneration Potential**
 - High Quality Exhaust Heat

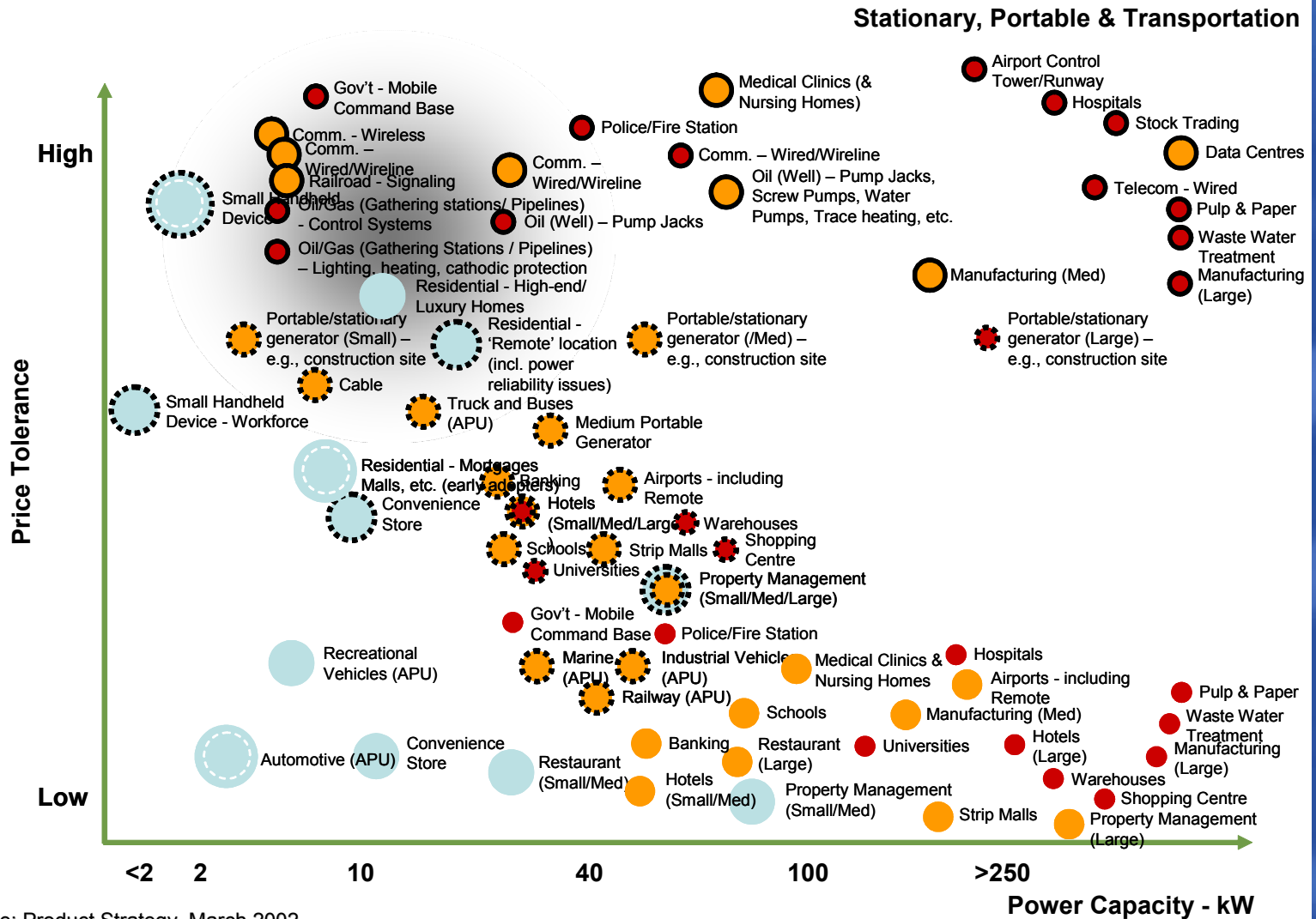


Net AC Efficiencies at Various Load Levels



~50% fuel savings

Many Initial Applications and Markets



Source: Product Strategy, March 2002

Commercial Products

Short Term

- Base load applications
 - Pipeline cathodic protection, SCADA, telecommunications sites
 - Premium, secure power applications
- Subsystem components: defence equipment procurement (stationary and portable)

Medium Term

- Subsystem components: commercial OEM
- Commercial off-grid and grid parallel
- Residential off-grid

Long Term

- Auxiliary power units
- 250kW+ stationary grid support plants
- Commercial and residential grid-parallel

Partnership Strategy

- **VPS is targeting a number of strategic partners to play the following roles:**
 - **Take an ownership position in VPS through R&D investment**
 - **Collaborate on system solutions and technology packaging**
 - **Become a co-respondent to publicly funded R&D program solicitations**
 - **Provide guidance on consumer requirements for targeted applications**
 - **Become a channel partner for market access for specific applications**

Conclusions

- SOFC has distinct advantages for power generation
- Versa Power Systems has a strong technology position, staff and facilities – all oriented towards commercialization
- Versa Power Systems seeks to develop partnerships that will facilitate focused product development such that the next generation of SOFC prototype is very close to customer expectations



Please visit our new website at:

<http://www.versa-power.com/>