Cummins Power Generation
10kWe SOFC Power System Commercialization Program
Team Program Overview
November 16, 2001
Pittsburgh, PA
• In 1992, Cummins acquired Onan Corporation
• Commercial Gensets are branded Cummins Power Generation
• Consumer Gensets (RV, Marine) are branded Onan
• Cummins Engine Company renamed Cummins Corporation to reflect diversification and Power Generation focus
Cummins revenues - $6.6 billion in 2000

- Automotive: $3.2 billion
- Power Generation: $1.3 billion
- Filtration: $1.1 billion
- Industrial: $1.0 billion
Cummins Power Generation is the largest volume manufacturer and distributor of premium Gensets in the 3kWe to 12 kWe size range for:

- **Commercial**
  - Standby
  - Peaking
  - Distributed Generation
- **Consumer**
  - Recreational Vehicle (RV)
  - Marine
  - Portable
- **Department of Defense**
• CPG Sales $1.3 billion in 3kWe to 2 MWe range
• $200 million in 3kWe to 12 kWe range
• System meeting SECA program cost and performance targets will displace current reciprocating engine technology in 3-12 kWe range
• Driving factors are low noise, low vibration, high reliability, and low emissions
Cummins Power Generation Products Represent Innovation
• 170 distribution centers worldwide
• Manufacturing sites in U.S., U.K., Singapore, China
Cummins Power Generation leads the industry in generator manufacturing

Cummins Power Generation Americas
Minneapolis Headquarters and Manufacturing
Existing Markets
Identified in SECA Program

• Recreational Vehicle (RV)
• Commercial Mobile
• Telecommunications Standby
CPG Fuel Cell Product Vision
• Base rating 10kWe
• Supplemented by battery boost system
• Control provides load sharing between battery and SOFC
• LP (Propane)
• Simple and cost effective
• Already in use on RV’s for cooking, heating, water heating, refrigeration, Gensets
• Market research indicates customers will accept LP on vehicles to gain benefits
• LP may gain market share as propulsion fuel over Fuel Cell development period
Operating Mode

• Start-up sequence initiated from cold when power need is anticipated
• Development program will minimize start-up time
• Battery boost inverter can power loads during warm-up
• Idle mode during low electrical demand
• Shut down when no power need is anticipated for extended time
Installation

• Same size envelope -- 0.4 m3 (15 ft3) as Diesel Genset
Recreational Vehicle Market
Why do RV’s need Power Generation?

To run:

- Air conditioners
- Microwave ovens
- TV’s
- VCR’s
- Blenders
- Hair Dryers
- Lighting
- Water pumps
- Battery chargers
Why Fuel Cells for RV’s?
- Noise
- Vibration
- Reliability
- Environmentally responsible
Gasoline RV GenSet Noise Levels

4kw - 3 Meters - Uninstalled

- 5.0/6.5 Emerald
- 5.5/7 Marquis
- 4.0 Microlite
- Marquis Platinum

Noise dBA

1980  |  2000
Diesel RV GenSet Noise Levels

7.5 kWe

4kw- 3 Meters - Uninstalled

7.5 Quiet Diesel

12.5 Quiet Diesel

7.5 kWe Noise Levels:
- 1980: 75 dBA
- 2000: 64 dBA

Noise dBA Scale:
- 80
- 79
- 78
- 77
- 76
- 75
- 74
- 73
- 72
- 71
- 70
- 69
- 68
- 67
- 66
- 65
- 64
Commercial Mobile Markets
Commercial Mobile

- Utility boom and lift trucks,
- Telephone repair trucks,
- Emergency and rescue vehicles
- Vendor vans
- Mobile health care
- Product requirements similar to RV
Commercial Mobile
Market Drivers

• High reliability
• Low maintenance
• Low noise
• Increasing awareness of emissions
Telecommunications
Markets
Telecommunication Emergency Power

- Wireless cell site cabinets
- Remote fiber optic network terminal cabinets
- Coax broadband cable cabinets
**Telecommunications Applications**

Wireless cell site with Cummins Genset.

Fiber optic network site with Cummins Genset.
Telecommunications
Market Drivers

- High reliability
- Suitable for long term storage without degradation
- Lower scheduled maintenance
- Low noise for use in residential areas
Cummins Power Generation
SOFCo
10kWe Commercialization Team
• Electronic Controls
• Power electronics
• Fuel systems
• Air handling systems
• Noise and vibration
• System integration
• Manufacturing
• Marketing, Sales, Distribution

Planar SOFC technology
Reformer technology
Material Science
Heat Transfer
Computational Fluid Dynamics
Numerical modeling
Multi-Layer Ceramic (MLC) manufacturing
CPG SOFC System Architecture

- Control
- Power Electronics
- BOP
- Hot Box
- Storage Batteries
- LP Fuel
- Air
- Exhaust
- Wireless Equipment Cabinet
- Genset
- Utility Power
- Antenna
## Team responsibilities

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<th>Responsibility</th>
<th>Description</th>
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<td>System Integration</td>
<td>Control system logic and algorithms, BOP interface</td>
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<tr>
<td>SOFC Fuel Cell / Hot Box</td>
<td>SOFC stack, manifolding, heat exchange, high temp insulation</td>
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<tr>
<td>Balance of Plant (BOP)</td>
<td>Fuel system, air system, insulation, shock and vibration isolation, packaging</td>
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<td>Control</td>
<td>System level control for all sub-systems including SOFC-Battery Load Sharing</td>
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<tr>
<td>Power Electronics</td>
<td>DC Boost and Inverter, Power Conditioning</td>
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<td>LP Fuel Storage</td>
<td>Conventional Pressure Tank</td>
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<tr>
<td>Storage Batteries</td>
<td>Conventional Wet Lead-Acid</td>
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Commercialization of 10 kWe SOFC Power System

Objective: develop a SOFC system including
- SOFC stack
- Balance of plant
- Factory cost of $400/ kWe net by end of Phase III
- Commercialized at earliest possible date

- Phase I -- 4 years
- Phase II -- 3 years
- Phase III -- 3 years
Commercialization of 10 kWe SOFC Power System

• Phase I -- 4 years
• Objectives: develop a fuel cell system capable of:
  1) demonstrating the SECA Phase I requirements at $800 / kW
  2) removing base technology barriers to commercialization in the target markets
Commercialization of 10 kWe SOFC Power System

• Phase II -- 3 years
• Objectives: continued development and improvement to:
  1) demonstrate the SECA Phase II requirements at $600 / kW
  2) releasing the Phase II design to limited production
Commercialization of 10 kWe SOFC Power System

• Phase III -- 3 years
• Objectives: further enhance the fuel cell system to:
  1) demonstrate the SECA Phase III requirements at $400 / kW
  2) release the Phase III design to full production
Program **Benefits** for identified Markets...

- Low noise
- Low vibration
- High reliability
- Clean power
Project challenges...

• Start up time
• Idle fuel consumption
• Power density
• Cost, cost, cost...
SECA Core Technology Program
Cummins Power Generation
10kWe SOFC Power System
Commercialization Program
Program Overview
Pittsburgh, PA
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