NYSERDA
Fuel Cell Product Development

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CHP Demo vs. Development

- **CHP – Demo**
  - End user contractors
  - Commercial products
  - Long term Demos.
  - Goals:
    - Megawatts
    - Best practice
    - Mitigate early adaptor risk
    - Establish economic benefits

- **Product Development**
  - Contractors are manufacturers
  - Pre-commercial technology
  - Field test/Demos.
  - Goals:
    - Technology advancement
    - Commercial product development
Power Systems Program
Objectives

• Technology Advancement
  – Improve energy & environmental performance of power systems

• Product Development
  – Create economic benefits for the state: jobs, reduced energy costs, etc.

• Overcome non-technical barriers to adoption
  – Document performance/benefits for policy decisions
### Power Systems Program

**$4 MM SBC + $1 MM Statutory**

<table>
<thead>
<tr>
<th>Solicitation</th>
<th>Response (Proposals)</th>
<th>Projects (Awards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PON 536 (May 2001)</td>
<td>33</td>
<td>17</td>
</tr>
<tr>
<td>PON 669 (March 2002)</td>
<td>34</td>
<td>11</td>
</tr>
<tr>
<td>PON 750 (April 2003)</td>
<td>49</td>
<td>16</td>
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</table>
## Power Systems Program Portfolio

<table>
<thead>
<tr>
<th>Project Category</th>
<th>Number of Projects</th>
</tr>
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<tbody>
<tr>
<td>Fuel Cell Technology</td>
<td>14</td>
</tr>
<tr>
<td>Turbine/Other Generation Tech.</td>
<td>15</td>
</tr>
<tr>
<td>Reliability</td>
<td>6</td>
</tr>
<tr>
<td>Environmental Performance</td>
<td>4</td>
</tr>
<tr>
<td>Barriers and Policy</td>
<td>4</td>
</tr>
</tbody>
</table>
NYSERDA Fuel Cell History

- $3M investment in fuel cell development from 1992-97
- +$7.5M investment since 1998
- Over 90 field test/demos
- Currently Supporting six New York State companies PEM & SOFC technologies
Fuel Cell Project Types

- **PEM technology (8 projects, $5.2M)**
  - Integrated Product Development
    - High temp. stack / CHP products
    - Telecom product
  - Subsystems
    - Fuel processor (propane); Inverters / Power Conditioning
  - Field tests

- **SOFC (4 projects, $1.2M)**
  - Materials
  - Components/Subsystems

- **Direct methanol (2 projects, $700k)**
  - systems
PEM Fuel Cell Field Test/Demonstration

- 3 Phase project to build, test, evaluate and demonstrate Plug Power 7 kW fuel cells
- $6M project ($3M funding provided by through New York State Clean Air Clean Water Bond Act of 1997 matched by equal funding by Plug Power)
- Deploy units at publicly-owned and accessible facilities across the state
- Verify the clean, environmentally friendly nature of PEM fuel cells and garner public support for their early introduction
- Accelerate wide scale commercialization
80 Unit PEM Fuel Cell Demonstration

- Phase 1 - Laboratory evaluation of 24 pre-production prototypes 5/99-3/00
  - Build an experience database for failure mode effects analysis under simulated field conditions
  - Establish operating strategies for selected applications
  - Understand & integrate sub-system modules
80 Unit PEM Fuel Cell Demonstration

- Phase 2 - Initial field evaluation of 6 pre-production prototype units (3/00-7/00)
  - incorporate knowledge gained from phase I, to improve performance and/or reduce cost
  - identify initial field installation/operation issues
  - Maintenance schedules developed
  - Validation of field service procedures
80 Unit PEM Fuel Cell Demonstration

- Phase 3 - Demonstration of 50 Test & Evaluation Units (8/00-12/01)
  - Incorporate information gained and design changes from Phases 1 & 2
  - First factory assembled systems
  - First self-enclosed units
  - Intended to achieve essentially unattended operation
  - Measure performance and emissions
What Did We Learn? – Phase I

**Product Development**

- Average Operating Time: 453 hrs
- Integration of Fuel Processor, Power Module, and Inverter Proved a Significant Challenge
- Full Integration Required Redesign of Some Module Components
- Control Scheme Required Computer Control

**Operations**

- Commissioned and Validated Manufacturing Facility
- Trained Workforce
- Developed Failure Reporting and Corrective Action System (FRACAS)
- Initiated Engineering Change Discipline
What Did We Learn? – Phase II

**Product Development**

- Average Operating Time: 844 hrs between 2 and 7 kWe
- Successful Sub-system Integration
- Detailed Understanding of what it takes to Operate in the Field
- Clearly Defined the Delta Between Where We Were and Where Our Final Target Product Specifications Needed to Be

**Operations**

- Shipping and Deployment Processes and Procedures
- Grid Interconnection with Utilities is a Very Significant Design Consideration
- Began Review and Realignment of Component Manufacturers and Supply Base
- Developed Formal Process for Receiving Product from Manufacturing and Commissioning Systems in the Field

**NYSERDA SPECIFICATIONS**

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Power</td>
<td>1-7 kW&lt;sub&gt;e&lt;/sub&gt; nominal range</td>
</tr>
<tr>
<td>AC Voltage</td>
<td>120 VAC / 240 VAC, 60 Hz</td>
</tr>
<tr>
<td>Grid Interface</td>
<td>Manual operation</td>
</tr>
<tr>
<td>Operating Temp</td>
<td>4 to 40 °C</td>
</tr>
<tr>
<td>Fuel Source</td>
<td>Natural Gas (4 to 12”)</td>
</tr>
<tr>
<td>Altitude</td>
<td>Up to 6000 ft</td>
</tr>
<tr>
<td>Power Quality Steady</td>
<td>ANSI C84 (+-5%)</td>
</tr>
<tr>
<td>Power Quality Trans.</td>
<td>CBEMA curve</td>
</tr>
<tr>
<td>Harmonics</td>
<td>IEEE 519, Sec 11, Table 11</td>
</tr>
<tr>
<td>Steady State Emissions</td>
<td>&lt; 400 ppm CO</td>
</tr>
</tbody>
</table>
What Did We Learn? – Phase III

Product Development

• Average Operating Time: 927 hrs between 2 and 4 kWe at an Average Eff. of ~ 20% Exposed to the Elements

• First Factory Assembled Systems Integrating Fuel Processor, Power Module and Inverter on Single Skid; “Design Lock”

• UL Listed, CSA Certified, Easily Grid Interconnectable

Operations

• Over 90% Reduction in Manufacturing Defects

• Reduction in Factory Certification Test Cycle Time from 3 Weeks to 25 Hours

• Developed “Requisition to Decommission” Processes: Master Build Schedule, Lean Manufacturing, Design Documentation and Control, Quality, Test & Verification, Shipping and Receiving, Field Service, Customer Support and Hotline

• Recognized Data Collection as a Significant Organizational Challenge
What Did We Learn? – Phase III Cont.

Overview of Phase III Data Collection

Capacity Factor from 60% to 98%
Average Efficiency from 16% to 20%
Average # of Failures/System from 10 to 2
System Availability from 35% to 82%
Case Study – Watervliet Arsenal 2002

Installation and Commissioning
• One Day Per Site from Flatbed to Exporting Power to the Grid

Operation (as of April 31, 2002)
• Average System Run Time = 2,400 hrs.
• Average Availability = 96.7%
• Capacity Factor = 100%
• Average Efficiency = 26.1%
• Over 60 MW-hrs of electricity produced

Manufacturing Capabilities
• Ability to Fill Customer Orders from Purchase to Exporting Power in Less than 12 Weeks

Organization
• New Product Development Process
• Technology Development Process
• Research and Development and System Architecture
• Supply Chain/Extended Organization
SOFC

Low-Cost Yttria-Stabilized Zirconia Powders

• Refractron Technologies, Inc., Newark, NY

• Powders to be used by MA/COM to manufacture SOFC components for McDermott Technologies/Cummins Power Corp. DOE SECA Program

• Powders currently being evaluated by ENrG, Inc. in Alden, NY
SOFC
Planar Strip-Cell

- ENrG Inc., Alden, NY, working with NYS OEM/Stack Manufacturer
- Demonstrate mass-fabrication of planar strip-cell SOFCs using thin, flexible, high-performance ceramic electrolyte.
SOFC
Low-Cost Ceramic Recuperator

• Blasch Precision Ceramics, Inc. Albany, NY
• Developing recuperator for Acumentrics Corp, Westwood, MA, tubular SOFC to improve efficiency
# Power Systems Program Accomplishments

<table>
<thead>
<tr>
<th>Accomplishment</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Products Launched</td>
<td>6</td>
</tr>
<tr>
<td>Jobs Created</td>
<td>425</td>
</tr>
<tr>
<td>Peak Load Reduction (2003)</td>
<td>&gt;30MWe</td>
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<tr>
<td>Leveraged Development in NY</td>
<td>+$25MM</td>
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