Power for the Digital Information Age
A Profile of ATP Fuel Cell Awards

Public Fuel Cell Alliance
National Meeting

Gerald Ceasar
Program Manager
Advanced Technology Program

National Institute of Standards and Technology
Technology Administration ✎ U.S. Department of Commerce

Presentation Overview

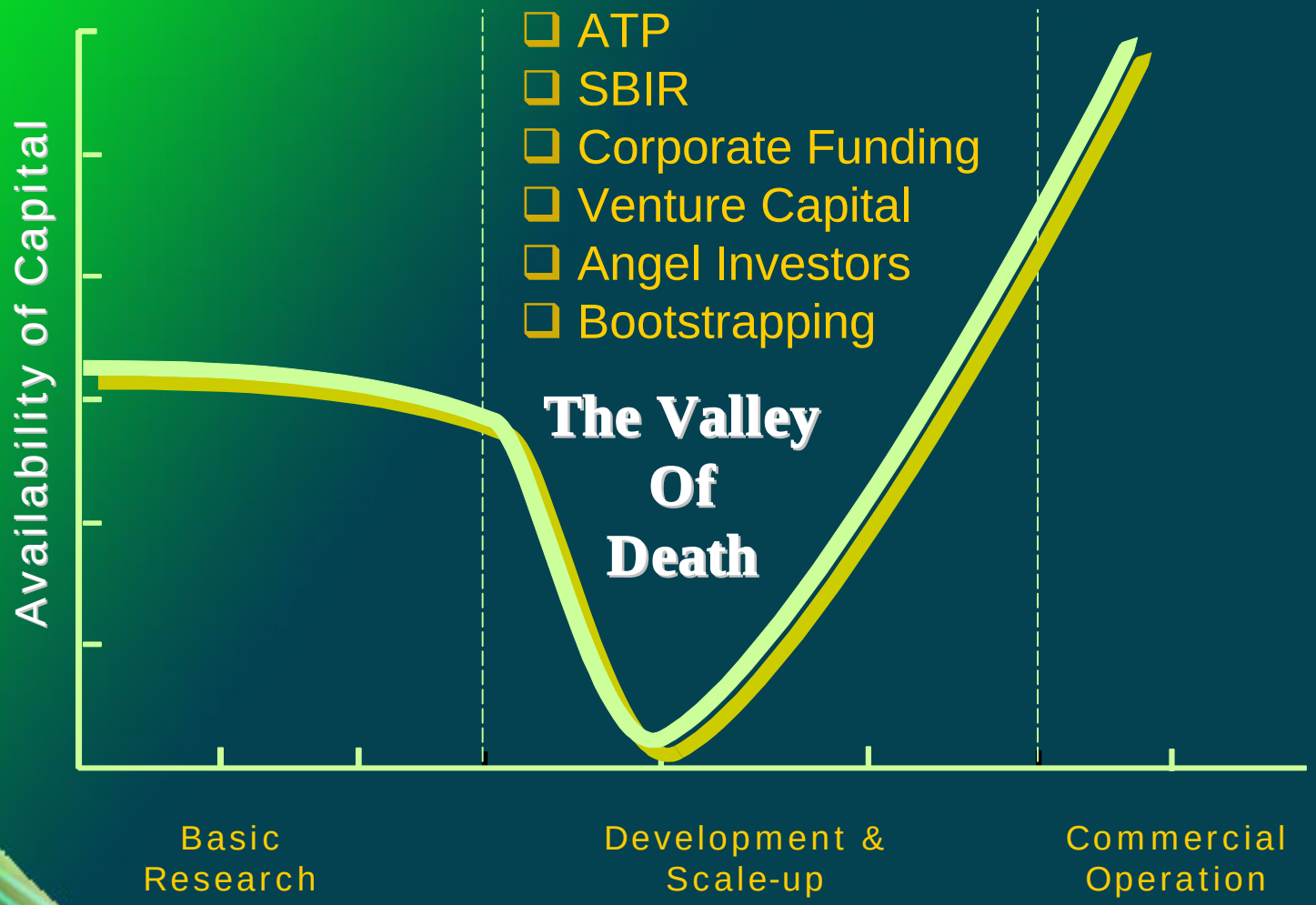
- ATP Overview
- Competition Processes
- Fuel Cells
- Closing Remarks

ATP Overview

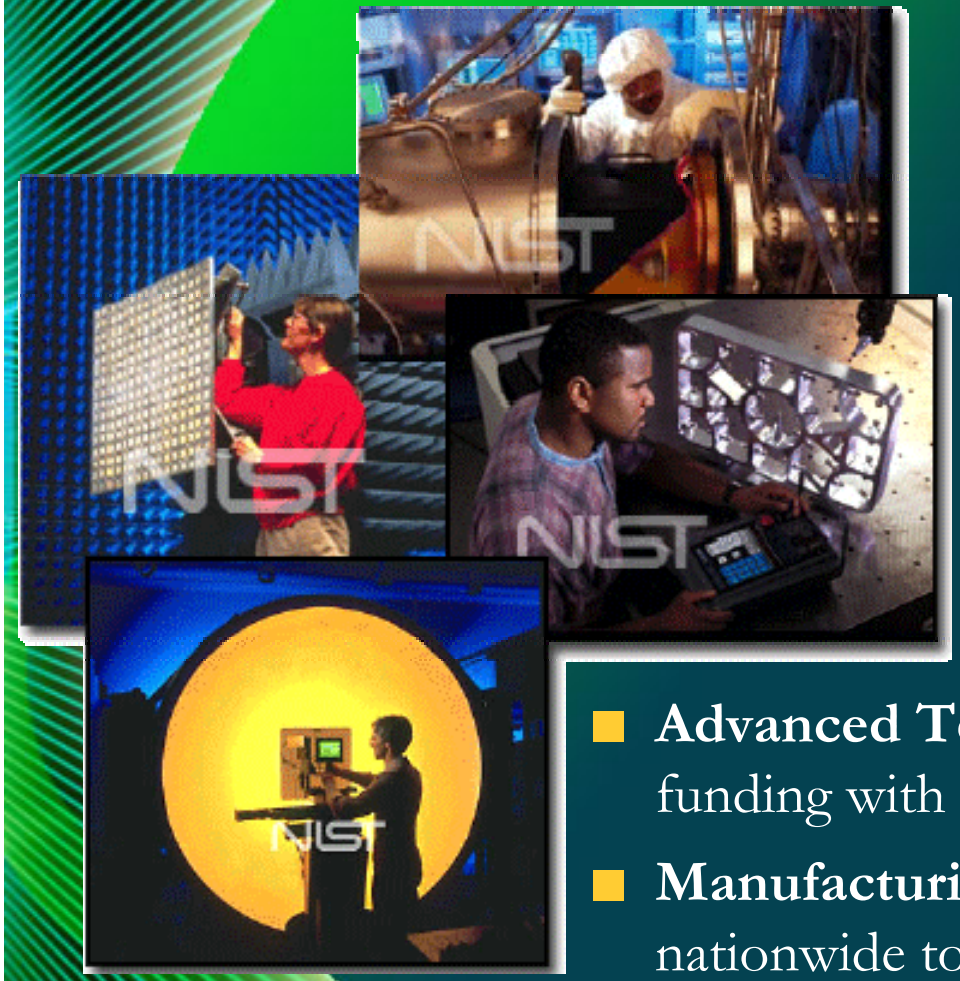
ATP's Mission …

To accelerate the development of ***innovative technologies*** *for* ***broad national benefit*** *through* ***partnerships*** *with the private sector.*

ATP Addresses the Funding Gap



ATP is Part of NIST



NIST assets include:

- $771 million FY 2004 operating budget
- 3,000 employees
- 1,800 associates
- **NIST laboratories**: National measurement standards

- **Advanced Technology Program**: $2,189 million co-funding with industry since 1990
- **Manufacturing Extension Partnership**: 400 centers nationwide to help small manufacturers
- **Baldrige National Quality Award**

NIST Mission …

Gaithersburg, MD

Boulder, CO

Develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.

ATP's Competitions

Since 1990 …

- 768 projects awarded with 1,511 participants and an equal number of subcontractors
- 218 joint ventures and 550 single companies
- $4,371 M of high-risk research funded
  - **ATP share = $2,269 M**
  - **Industry share = $2,102 M**
- Small businesses are thriving
  - **66% of projects led by small businesses**
- Over …
  - **170 universities participate**
  - **30 national laboratories participate**
  - **1,171 patents**

Two Major Criteria

- Scientific and Technological Merit (***50%***)
  - **Technical innovation**
  - **High technical risk with evidence of feasibility**
  - **Detailed technical plan**
- Potential for Broad-Based Economic Benefits (***50%***)
  - **National economic benefits**
  - **Need for ATP funding**
  - **Pathway to economic benefits**

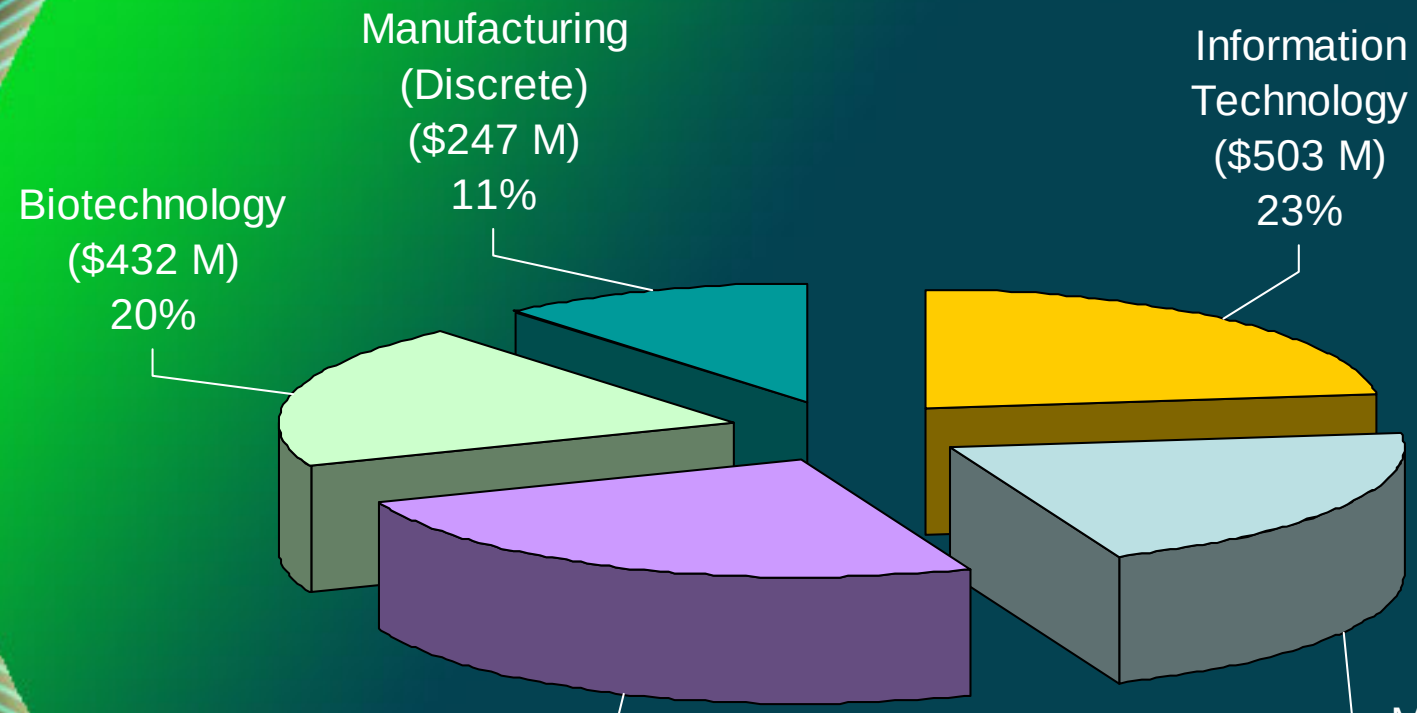
ATP's Competitions

- **General / Open Competitions:** (1990 – present)
  - **Open to any technology / application**
  - **Satisfy ATP selection criteria**
  - **Ensures all good ideas receive consideration**

- **Focused Program Competitions:** (1994 - 1998)
  - **Public forums to define investment opportunities**
  - **Satisfy ATP selection criteria *and* technical/applications scope requirements**
  - **Effective way to**
    - achieve synergy / build technical momentum
    - address critical investment gaps in market place

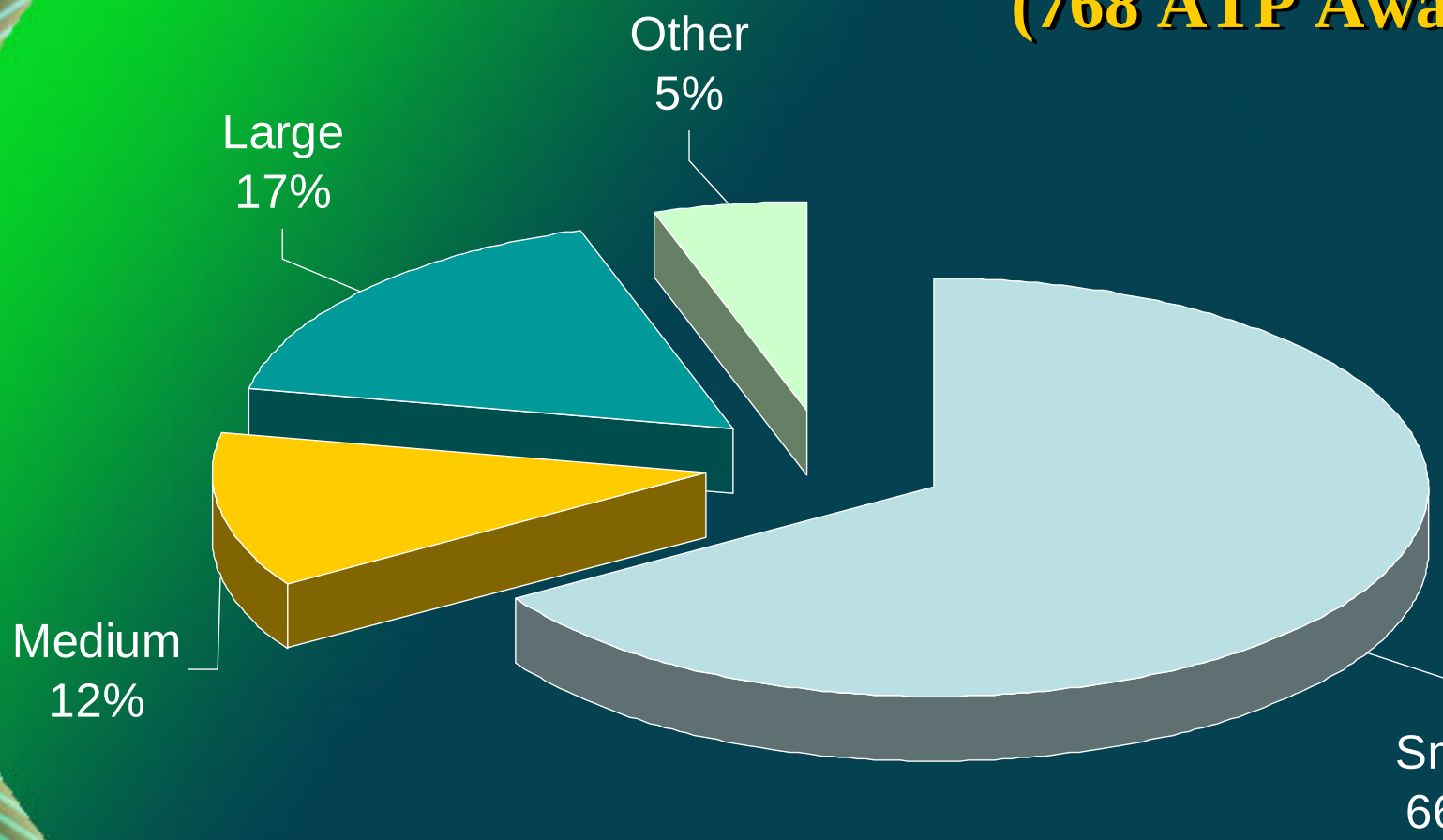
768 ATP Awards by Technology Area

(As a Percent of $2,269 M Awarded)



Forty Four Competitions (1990 – Sept. 2004)

Distribution of Company Size Lead Companies
(768 ATP Awards)



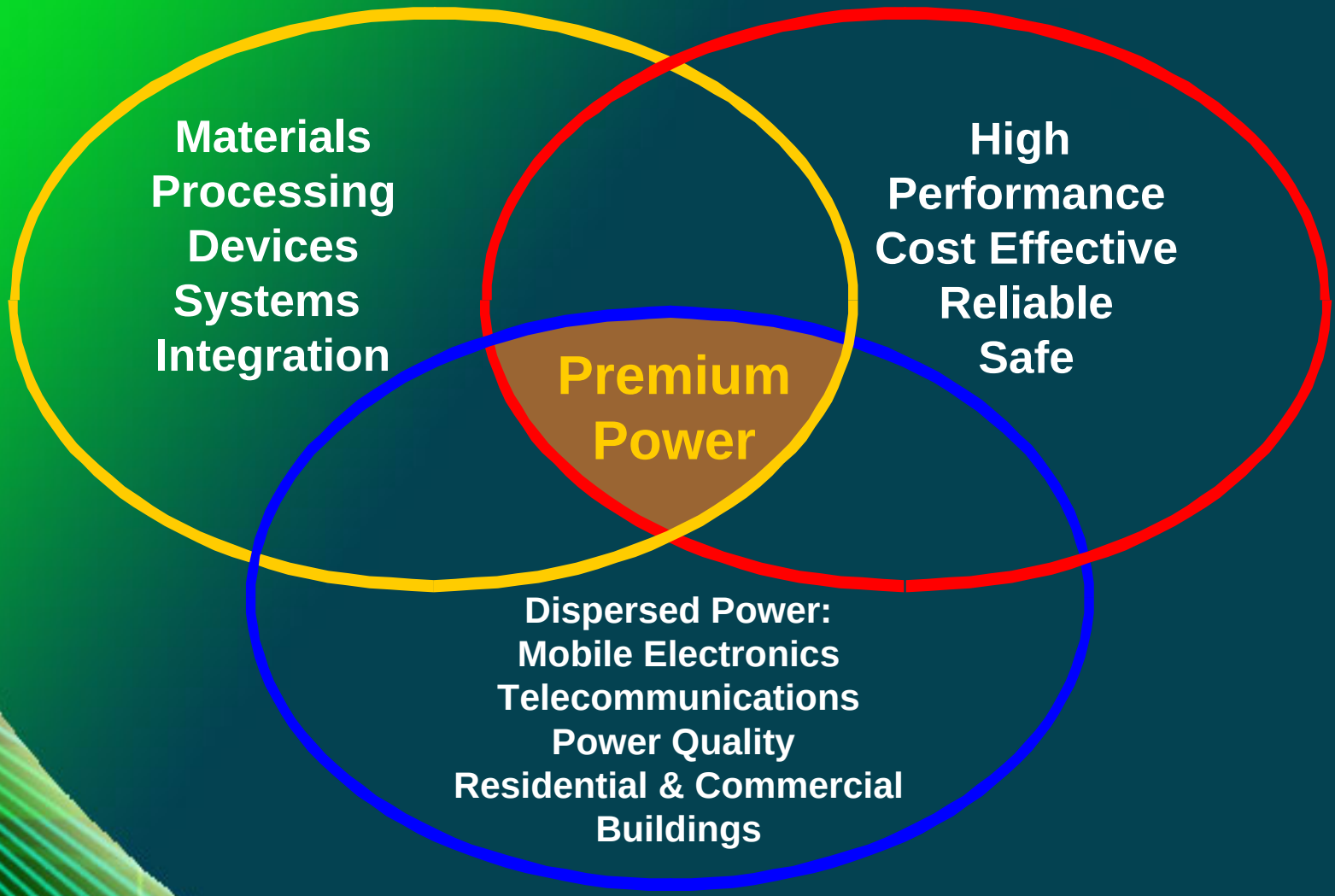
Forty Four Competitions (1990 – Sept. 2004)

Profile of ATP Fuel Cell Awards

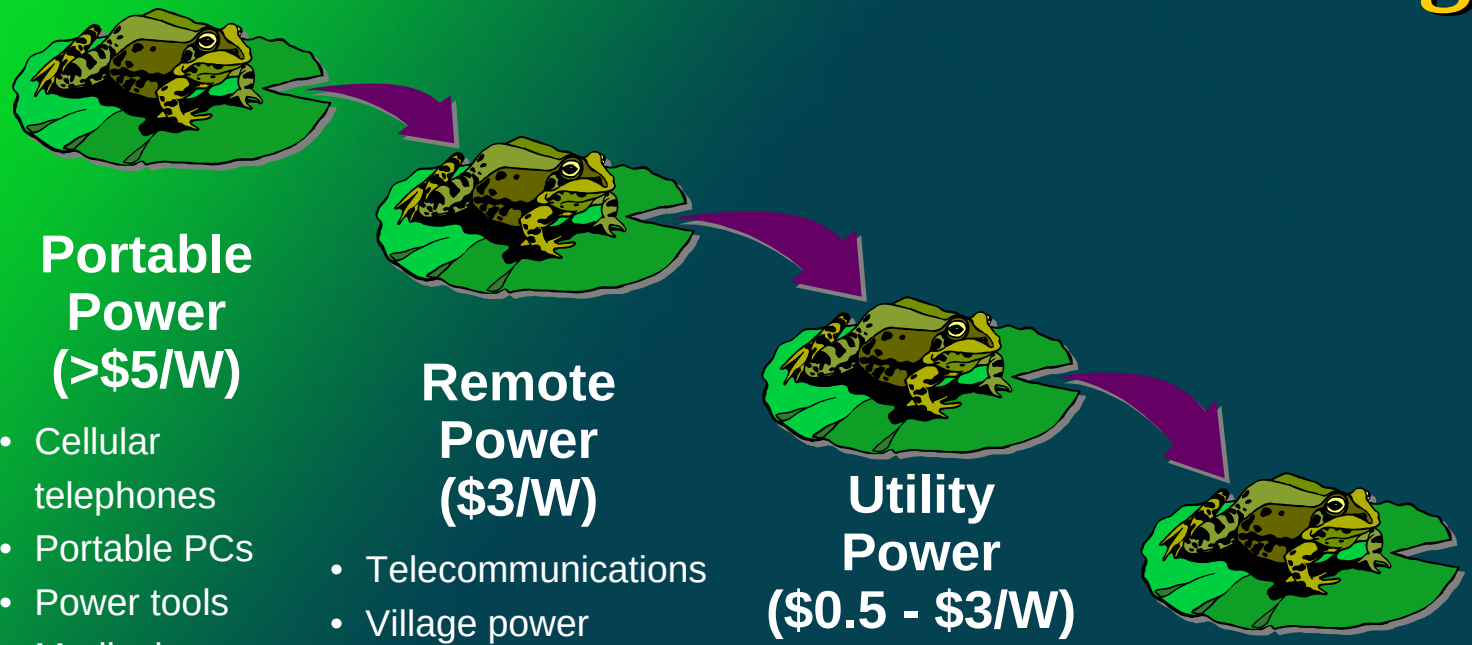
1998 Premium Power Focused Competition

- Jumpstarted ATP's investment in advanced energy technologies
- Today's economy vitally depends on power sources that are *not* connected to a electric grid
- Premium Power aimed at accelerating the development of power technologies important to the digital information age:
  - **Advanced batteries and micro-fuel cells for portable, wireless electronics**
  - **Black-out free distributed electric generation with fuel cells, PV solar cells on-site at homes/buildings**
  - **Powering broadband**

Premium Power Technical Scope



Leap Frogging to Tomorrow's Power Technologies



Cost ($/W)

Portable Power (>$5/W)

- Cellular telephones
- Portable PCs
- Power tools
- Medical

Remote Power ($3/W)

- Telecommunications
- Village power
- Water pumping
- Refrigeration

Utility Power ($0.5 - $3/W)

- Distributed premium power
- Demand supply mgt.
- Residential
- Central utility

Automotive Power ($0.05/W)

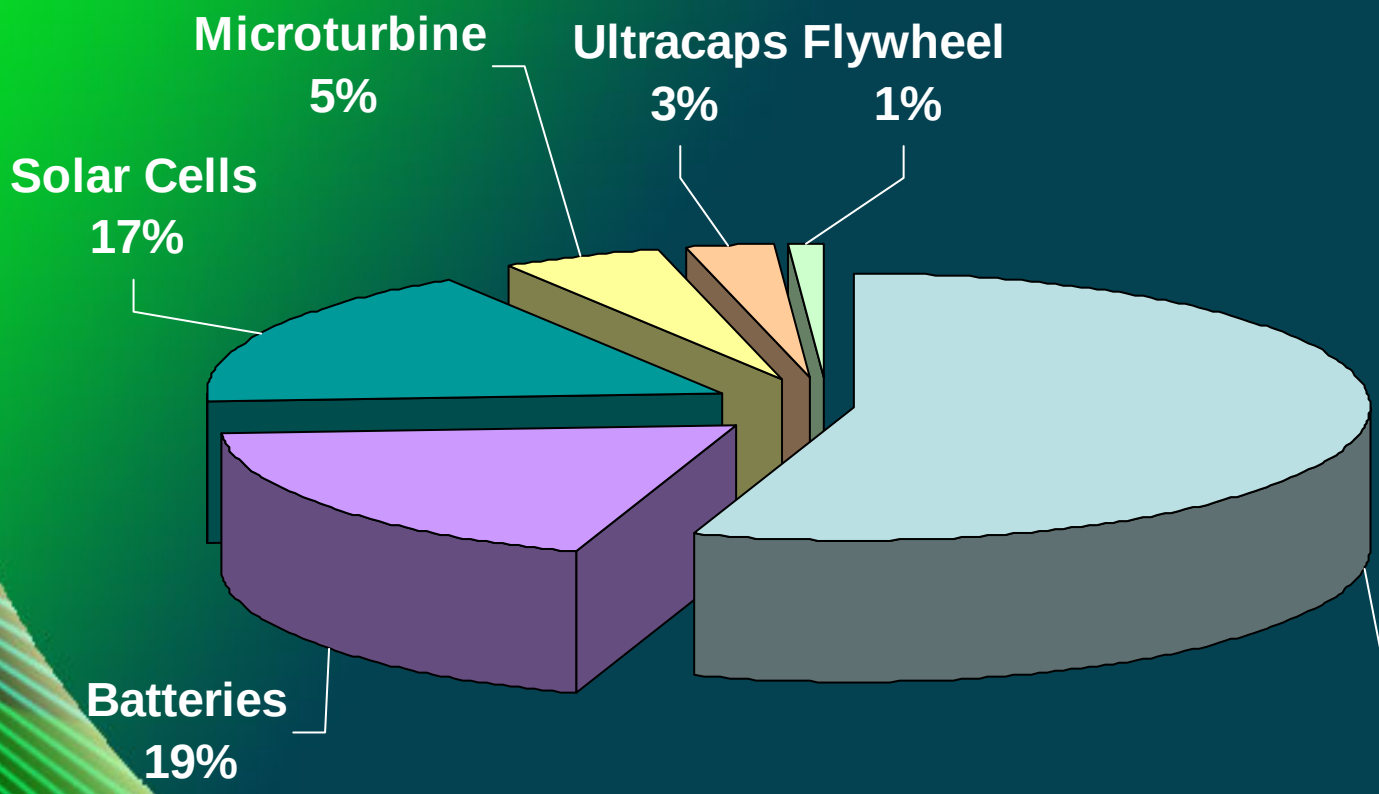
- EVs & HEVs

Technology Learning Curve

Respond to Real Customer Needs

54 Advanced Power Projects
(as a Percentage of $133 M Awarded)

Total Project Costs = $251 M



Total ATP Costs = $133 M

ATP Technology Clusters (1997-2004)

	Advanced Power Technologies	Fuel Cell Technologies
Active or completed projects	54	28
Estimated ATP Funding	$ 133 M	$ 74M
Industry cost-share funding	$118 M	$ 66M
Total Impact	$ 251 M	$ 140 M

Pioneering in PEM and SOFC Fuel Cells for Distributed Power (1998-2004)

- AVISTA Labs
- Plug Power, Polyfuels, SRI
- H Power, Nuvera
- Materials and Systems Research
- Superior MicroPowders (4)
- ECD Ovonics, Crucible Research
- ITN Energy Systems
- Blasch Precision Ceramics
- Microcell
- Plug Power (2)
- Technology Management, Inc. (TMI)
- Tiax
- MesoFuel

Just Announced (Sept. 28, 2004)

- Carbon Nanotechnologies, Johnson Matthey Fuel Cells, Motorola, and Celanese Ventures, "Free Standing" Single-Wall Carbon-Nanotube Fuel Cell Electrode ($7.4M project with $3.6M from ATP)
- Corning and ENrG, Inc., Scalable Planar Solid-Oxide Fuel Cell Technology for Beyond 200kW ($16.0M project with $8.0M from ATP)
- NexTech Materials with NASA Glenn Research Center and SOFCo, High-Power-Density Solid Oxide Fuel Cells for Aerospace Applications ($2.6M project with $2.0M from ATP)

Dream of ages has been brought closer by the Bell System Solar Battery … first announced in 1954.

Something New under the Sun. It's the Bell Solar Battery, made of thin discs of silicon, an ingredient of common sand. It converts sun's rays directly into usable amounts of electricity. The storage batteries beside the solar battery store up its electricity for night

Bell System Solar Battery Converts Sun's Rays into Electricity

Bell Telephone Laboratories invention has great possibilities for telephone service and for all mankind

Ever since Archimedes, men have been searching for the secret of the sun. For it is known that the same kindly rays that help the flowers and the grains and the fruits to grow also send as almost limitless power . . . nearly as much every three days as in all known reserves of coal, oil and uranium.

If this energy could be put to use—instead of going to waste—there would be enough to turn every wheel and light every lamp that mankind would ever need.

The dream of ages has been brought closer by the Bell System Solar Battery. It was invented at the Bell Telephone Laboratories after long research and first announced in 1954. Since then its efficiency has been doubled and its usefulness extended.

There's still much to be done before the battery's possibilities in telephony and for other uses are fully develop But a good and pioneering start h been made.

The progress so far is like the ope ing of a door through which we ca glimpse exciting new things for th future.

Great benefits for telephone serv and for all mankind may come from this forward step in putting the energy of the sun to practical use.

BELL TELEPHONE SYSTEM

Plug Power (ATP Funded, 5/1999 – 5/2002)

http://www.plugpower.com/

- ATP pioneered in funding PEM fuel cells for distributed power generation
- **Key objective**: develop a fuel cell system with up to 2,000 ppm carbon monoxide (CO) tolerance
- **Key approach**: High temperature membrane, advanced components
- Succeeded in producing PEM fuel cells with high-temperature membrane operating at >150 °C (with Celanese Ventures)
- Demonstrated 20,000 ppm CO tolerance with more than 5000 hours stable endurance
- Greatly simplifies reformer and overall system
- Celtec MEA : winner of Frost & Sullivan 2004 Technology Innovation Award

Superior MicroPowders (ATP Funded, 11/1998 – 10/2001)

- ATP is open to ***startup companies*** with ***new ideas***
- ATP funding helped SMP develop a novel spray-based powder manufacturing platform
- Powders are made with controlled size and shape and with precise chemical composition
- New low platinum fuel cell catalysts made by this process
- In 2003 SMP becomes a division of Cabot, a major US chemical company

http://www.cabot-corp.com

CABOT
Superior MicroPowders

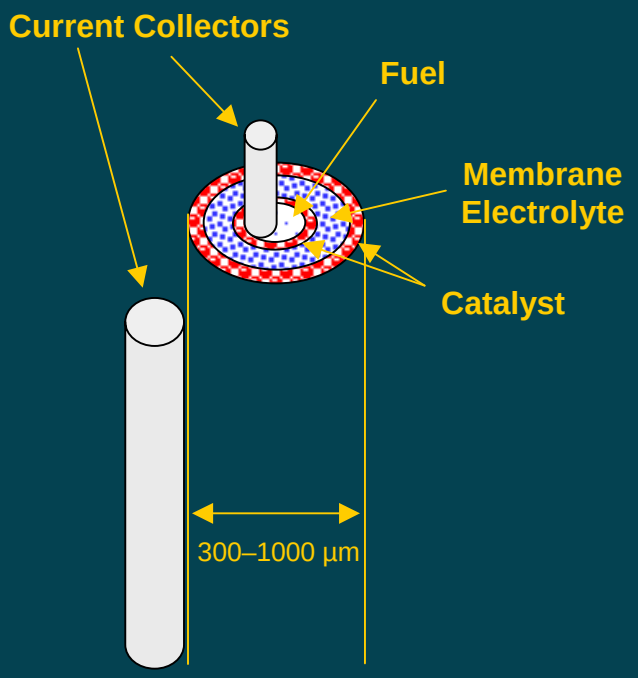
Microcell Corporation

(ATP Funded, 11/2001 – 10/2004)

- ATP is a high-risk funder of novel fuel-cell concepts
- ATP funded after other funding agencies declined as too risky
- **Key objective**: new fuel-cell technology based on a micro-fiber membrane structure, with revolutionary increases in power density
- **Inherently low cost**: one can extrude all the components together
- 1 kW beta unit in late 2004

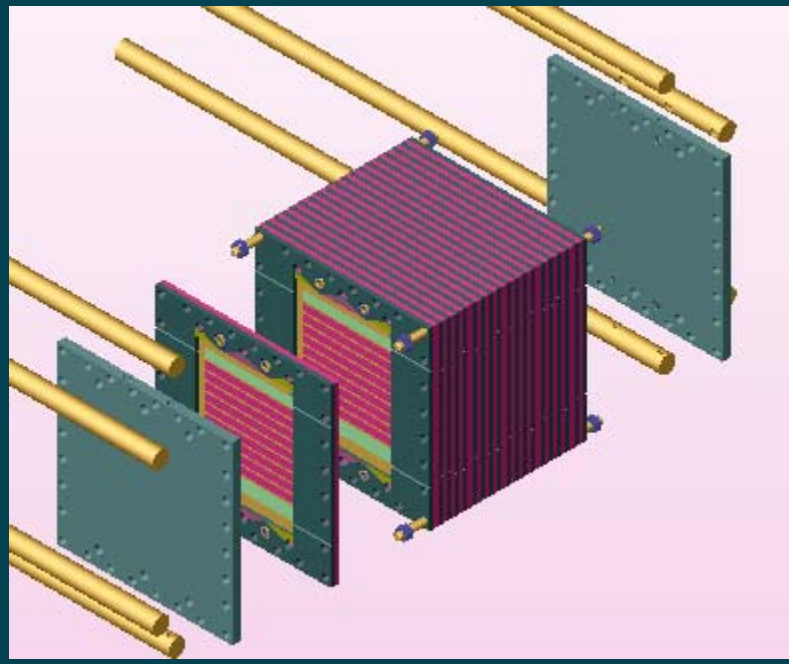
MICROCELL

The World Leader in PEM Microfiber Fuel Cells



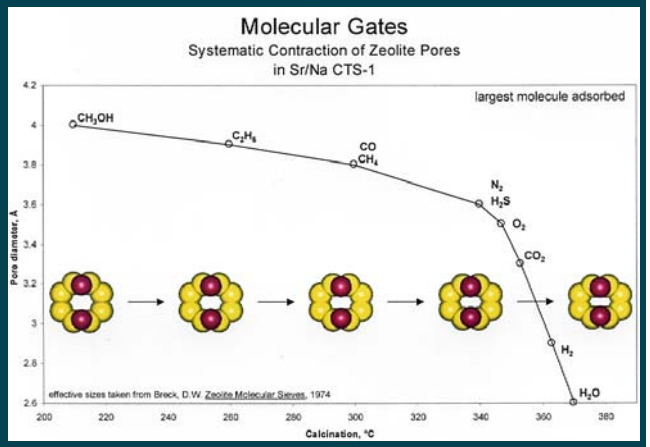
Corning Fuel Cell Stack

- This SOFC fuel cell is a Solid State power generator that converts fossil fuels to electricity at a higher efficiency and with much lower polluting and CO2 emissions than the existing generator technologies.
- This multi-cell design is a unique technology that promises to provide thermal durability, lower cost, and a more efficient build of voltage in larger stack sizes than other SOFCs.
- Corning's aims at becoming a major supplier of Solid Oxide Fuel Cell (SOFC) stacks in the $100B worldwide power generation market



Application of Molecular Gate^R Technology To Oxygen Enrichment of Air and Simplified Purification of Natural Gas

- One-third of U.S. natural gas reserves cannot be used on account of excessive contamination by nitrogen and/or carbon dioxide (N_2 and CO_2)
  - **new purification technology called Molecular Gate^R developed by Engelhard to remove contaminant N_2 and CO_2 from natural gas at the well head in a simplified one-step process**
  - **new family of molecular sieves made with adjustable pore sizes**
  - **separation done by allowing N_2 into the pore and excluding larger CH_4**
- Engelhard started commercialization in 2003
  - **now has 8 systems in operation**



Company: **Engelhard Corp.**
Universities: Cleveland State, U of Massachusetts/Amherst
Start / End: 12/01/99 - 11/30/02
NIST/ATP Funds: $1,800,000
Total Project Cost: $4,500,000

ATP Technology Cluster (2001-2004)

Leading the Way in Funding Micro-Fuel Cell Development

New in 2003:	Integrated Fuel Cell Technology ($1.9M)	High Density, Scalable, Mass Manufacturable Semi-conductor Fuel Cell
	Neah Power($2.0)	Porous Silicon Electrode, All Liquid Fuel Cells
	Motorola/Engelhard ($2.3M)	Hydrogen Generator for a Miniature Fuel Cell Power Source
	Virent Energy ($2.0)	Small-scale Hydrogen Generation
2002:	Lilliputian Systems ($2.0M)	Micro-Solid Oxide Fuel Cell (SOFC) Based Power Supplies for Handheld Electronics
	NexTech Materials ($2.0M)	Direct Fuel SOFC Power Module
	Superior Micro-Powders with Motorola ($2.0)	Membrane Electrode Assemblies for Fuel Cells
2001:	MTI MicroFuel Cell/ E.I.duPont($5M)	Integrated Hybrid Direct Methanol Fuel cell/ Electrochemical Capacitor Power Pack
	T/J Technologies ($2.0M)	Hybrid Ultracapacitor/Methanol Fuel Cell Power Packs for Portable Electronics

Historical Perspective … *a vision from 1973*

"We need a computer that can be used either in the office or at the beach. It will have access to everything—from your office to the Library of Congress."

Allan Kay – '70s Xerox Visionary

MTI MicroFuel Cells (ATP Funded, 10/2001 – 9/2004)

- ATP is a primary funder of small fuel cells for portable electronic devices
- MTI and partner DuPont developing 500 milliwatt, advanced direct methanol fuel cell
- Replacement for Lithium ion batteries (same size)
- Several weeks (rather than few days) of power per fueling (recharge)
- New Mobion product for PDA/Smart Phones just announced

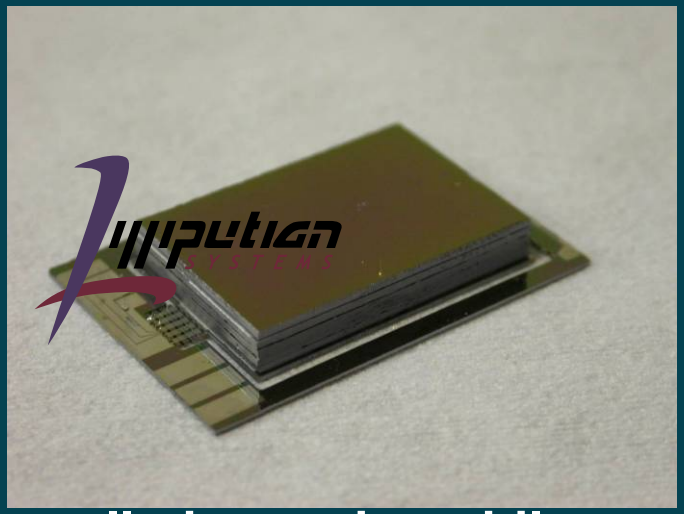
http://www.mtimicrofuelcells.com/

Neah Power Systems (ATP Funded, 10/2003 – 9/2005)

- ATP is a primary funder in the niche of small fuel cells for portable electronic devices
- Neah has unique approach: developing 3-D porous silicon electrodes to increase power density
  - **Enables reduced size, cost-effective production**
  - **Competitive products (PEMs) tend to be oversized and underpowered due to low power density**
- Uses flowing liquid active materials—no membrane
- 2-3X or more energy capacity than lithium-ion batteries – 6-8 hours or more for a notebook computer
  - **Cartridges allow instant refueling, long runtime and freedom of operation**

http://www.neahpower.com
2004 AoA Start Up Company of the Year

Lilliputian Systems (ATP Funded, 10/2002 – 9/2004)



- Lilliputian Systems: silicon based SOFC using butane
- Highest energy density solution on volumetric basis (W/L and W*Hr/L)
  - **Only fuel cell solution scalable to cell phone size while delivering better performance than Li-Ion**
  - **Replaceable cartridges enable "instant recharge"**
- Butane has proven track record for consumer acceptance and safety (lighters, camping equipment, hair dryers, et. al.)

Realizing the 70's Vision with Clean Energy … *Anytime* … *Anywhere*

Closing Remarks

Closing Remarks – Fuel Cells

- ATP has been an early supporter and significant investor in Stationary and Micro-Power fuel cells development
  - **1998-2004: 28 awards = $73.8M ATP / $139.5M total**
- Very high risk technical advances in
  - **Materials development**
  - **Electro-catalytic materials**
  - **Polymer electrolytes (high temperature / CO tolerance)**
- Improvements in
  - **Device design**
  - **Manufacturability and packaging**

Closing Remarks

- Catalyzed entire industry to leap forward
  - **technical achievement**
  - **manufacturability**
  - **creation of business opportunities and joint alliances**
- Projects targeted cost effectiveness, performance, and reliability improvements
- *Not a centrally planned, tops down program but open to companies making the case for their technology and uses*

For Info on ATP and to Join Our Mailing List . . .

- Call toll-free: 1-800-ATP-Fund (800-287-3863)
- Send an e-mail e to: ***atp@nist.gov***
- Visit ATP's website: ***www.atp.nist.gov***
- Contacts:

– ***ENERGY***:

Gerald Ceasar
Tel: 301-975-5069
ceasar@nist.gov

MANUFACTURING:

Richard (Chuck) Bartholomew
Tel: 301-975-4786
richard.bartholomew@nist.gov

List of Projects and Company Leads

Fuel Cell Projects

- 1998 Premium Power Focused Program
  - **Avista Labs:** *Modular 2KVA Fuel Cell Power Plant with Live Replaceable, Self-Hydrating, PEM Smart Cartridges*
  - **H. Power/Nuvera:** *Propane-Fueled Fuel Cell Power System for Telecommunications Applications*
  - **Materials and Systems Research, Inc:** *Reduced-Temperature, Electrode-Supported, Planar (RTESP) Solid Oxide Fuel Cell (SOFC) System for Premium Power Applications*
  - **Plug Power/PolyFuels/SRI:** *Distributed Premium Power Fuel Cell Systems Incorporating Novel Materials and Assembly Techniques*
  - **Superior MicroPowders:** *Preparation and Fundamental Evaluation of Catalytic Materials for Energy* ***Applications***

- 2000 Open Competition
  - **Blasch Precision Ceramics, Inc:** *Self-Propagating High-Temperature Synthesis Of Solid Oxide Fuel Cell Cathode Material*
  - **ITN Energy Systems, Inc:** *Integrated Planar Solid Oxide Fuel Cell Stack Development*

Fuel Cell Projects (cont'd)

- 2001 Open Competition
  - **Microcell Corp:** *Fabrication of Fuel Cells from Microcell Fibers*
  - **MTI Microfuel Cells/DuPont:** *Integrated Hybrid Direct Methanol Fuel Cell/Electrochemical Capacitor Powerpack*
  - **Plug Power, Inc:** *Development of a Highly Reliable and Low Cost Fuel Processing System for Stationary PEM Fuel Cell Applications*
  - **Technology Management, Inc:** *Small,Ultra Efficient SOFC Fuel Cell Systems*
  - **T/J Technologies:** *Hybrid Ultracapacitor/Methanol Fuel Cell Power Packs for Portable Electronics*

Fuel Cell Projects (cont'd)

- 2002 Open Competition
  - **Lilliputian Systems, Inc:** *Micro Solid Oxide Fuel Based Power Supplies for Handheld Electronics*
  - **NexTech Materials:** *Direct Fuel Power Module*
  - **Superior MicroPowders, LLC:** *Elevated-Temperature, Reformate-Tolerant Membrane Electrode Assemblies (MEAs) for Polymer Electrolyte Fuel Cells*
  - **Superior MicroPowders, LLC:** *Development of High Volume Digital Manufacturing of Membrane Electrode Assemblies for Fuel Cells*

Fuel Cell Projects (cont'd)

- 2003 Open Competition
  - **Integrated Fuel Cell Technologies, Inc:** *High Density, Scalable, Mass-Electronics*
  - **Neah Power Systems, Inc:** *Porous Silicon Electrode All Liquid Fuel Cells*
  - **Plug Power Inc:** *Low Cost Fuel Cell System Technologies Development*
  - **TIAX LLC:** *Solid Oxide Fuel Cells (SOFC) Promise to Revolutionize Small-to-medium-scale Power Generation*

Fuel Cell Projects (cont'd)

2004 Open Competition

- **Cabot Superior MicroPowders:** *Enhancing the Performance of Polymer Electrolyte Membrane Fuel Cells*
- **Carbon Nanotechnologies, Johnson Matthey Fuel Cells, Motorola, and Celanese Ventures**, *"Free Standing" Single-Wall Carbon-Nanotube Fuel Cell Electrode*
- **Corning and ENrG, Inc.,** *Scalable Planar Solid-Oxide Fuel Cell Technology for Beyond 200kW*
- **NexTech Materials with NASA Glenn Research Center and SOFCo**, *High-Power-Density Solid Oxide Fuel Cells for Aerospace Applications*

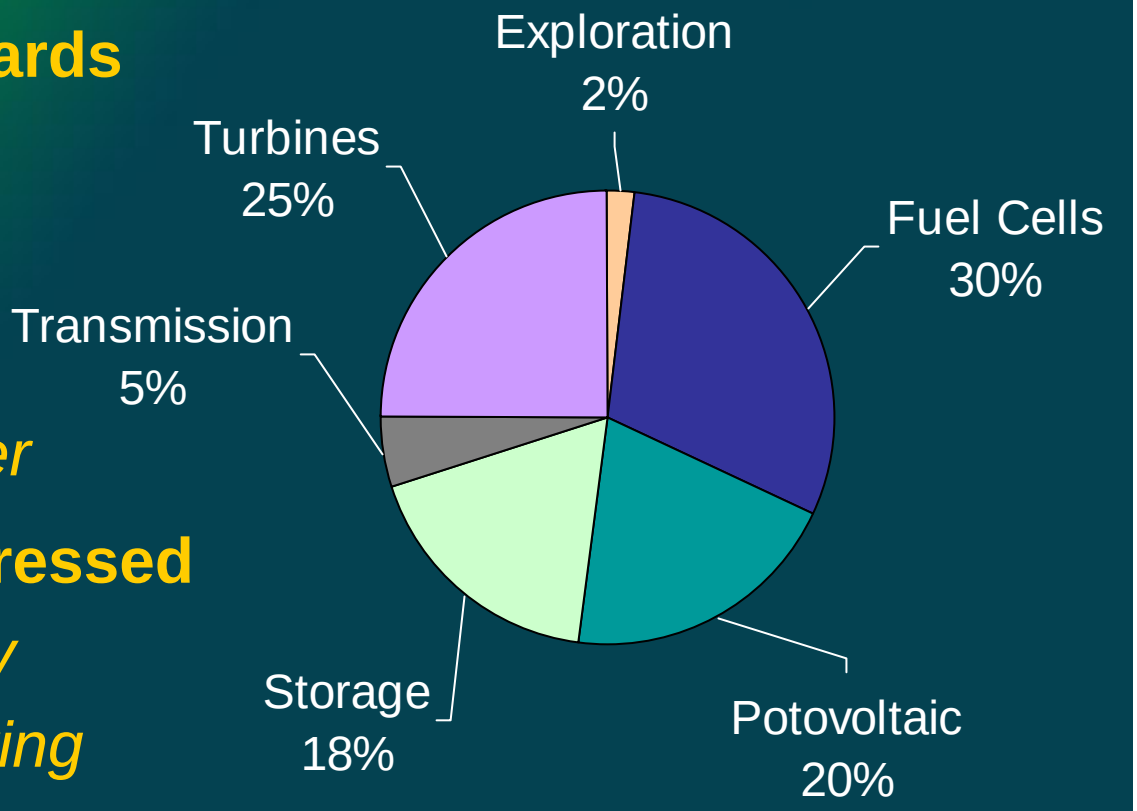
Fuel Cell Projects (cont'd)

- 2003 Open Competition (hydrogen generation)
  - **Motorola/Engelhard:** *Hydrogen Generator for a Miniature Fuel-Cell Power Source*
  - **Virent Energy Systems LLC:** *Small-scale Hydrogen Generation via Aqueous-Phase Carbohydrate Reforming*
- 2004 Open Competition (hydrogen generation)
  - **MesoFuel:** *Compact Pure Hydrogen Generation Systems for PEM Fuel Cell Applications*
- 1997 Open Competition (hydrogen storage)
  - **Ovonic Battery Company (ECD):** *Advanced Magnesium Alloys Production Process (AMAPP)*

Energy-Related Manufacturing Projects

($74.3M from ATP, $143.9M Total Combined)

- Through May 2004, there have been:
  - **736 TOTAL awards**
  - **290 awards in** *Manufacturing*
  - **54 awards in** *Advanced Power*
  - **34 awards addressed by both** *Energy* **and** *Manufacturing*



Energy-Related Manufacturing Projects

Energy	Number of Projects	Total ATP $	Total Industry Cost Share $	Total R&D $	State(s)
Exploration	1	$1,817,984	$645,309	$2,463,293	LA
Fuel Cells	11	$21,515,653	$16,356,521	$37,872,174	MA, NM, NY, NC, OH, WA
Photovoltaic	6	$14,926,692	$13,767,742	$28,694,434	CA, DE, GA, MD, MA
Storage	4	$13,650,468	$15,754,998	$29,405,466	CA, GA, MI, OR
Transmission	2	$3,999,079	$6,351,219	$10,350,298	MA, NJ
Turbines	10	$18,376,321	$16,758,022	$35,134,343	CA, FL, MA, MI, NJ, NC, OR
TOTALS	34	$74,286,197	$69,633,811	$143,920,008	

State	No. of Projects	Total ATP $	Total Industry Cost Share $	Total R&D $	Energy
CA	4	$5,672,551	$4,770,328	$10,442,879	Turbines, Photovoltaic Storage
DE	1	$5,515,975	$5,785,498	$11,301,473	Photovoltaic
FL	2	$5,389,022	$5,608,984	$10,998,006	Turbines
GA	2	$4,402,703	$3,809,057	$8,211,760	Photovoltaic, Storage
LA	1	$1,817,984	$645,309	$2,463,293	Exploration
MA	6	$10,287,714	$11,835,208	$22,122,922	Turbines, Photovoltaic, Transmission, Fuel Cells
MD	1	1,790,000	$1,262,000	$3,052,000	Photovoltaic
MI	2	$9,975,516	$11,778,713	$21,754,229	Storage, Turbines
NC	2	$4,594,389	$3,086,175	$7,680,564	Fuel Cells, Turbines
NJ	3	$5,242,613	$5,510,981	$10,753,594	Transmission, Turbines
NM	3	$5,984,165	$4,132,370	$10,116,535	Fuel Cells
NY	2	$3,613,779	$2,372,821	$5,986,600	Fuel Cells
OH	1	$2,000,000	$245,519	$2,245,519	Fuel Cells
OR	2	$4,000,000	$3,000,124	$7,000,124	Turbines, Storage
WA	2	$3,999,786	$5,790,724	$9,790,510	Fuel Cells
TOTALS	34	$74,286,197	$69,633,811	$143,920,008	