the Energy to Lead

Overview of Small-Scale Gas-Fired Power Generation Technologies and Demonstrations

John Pratapas, Sam Bernstein, and Jack Lewnard

ARPA-E Workshop

gti

Sterling Engine Demonstrations

Kinematic Sterling

Efficient Home Energy (jv between Whisper Tech and Mondragon)

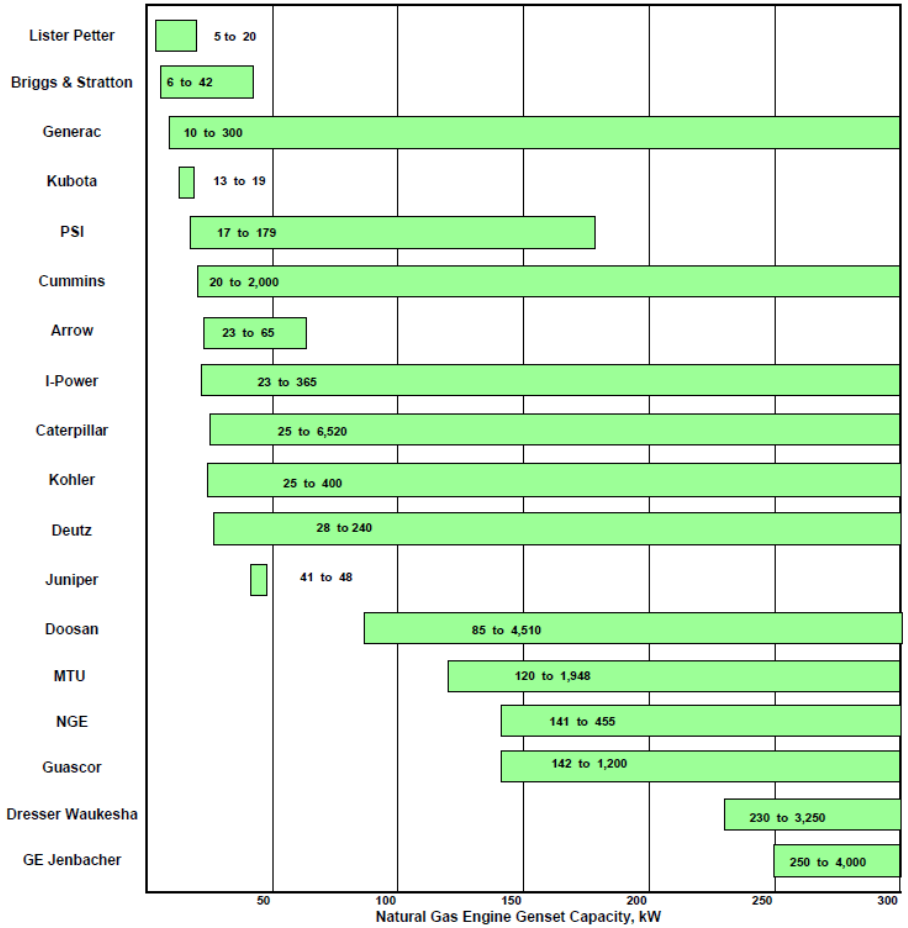
- UK: trials 1999 with National Grid; commercial launch 2005
- Netherlands: Commercial trial with MK IV [running] & MK V [starting]
- Ireland: Commercial trial with MK IV
- Germany: Beta trials with MK IV & MK V
- Spain: Factory 30,000 units/yr

Free Piston

BDR Thermea (merger of Remeha and Baxi)

- 1 kW commercial launch for Baxi's Ecogen and Remeha's Evita in 2010

Internal Combustion Engines (ICE)



- Honda ECOWILL
  - Exlink engine ε=26.3%
  - Japanese launch 2003
  - US 2006
  - Germany 2011

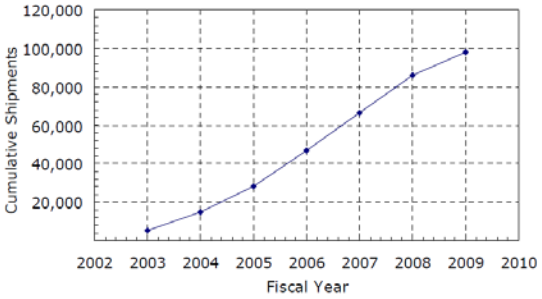


Figure 1 : Cumulative Sales of ECOWILL in Japan

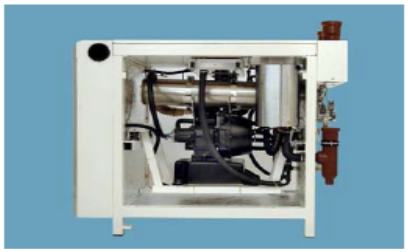
EU: More than 20,000 ICE's Installed

µCHP – Current situation

Current situation of µCHP in the residential sector

- **Available and over the past years successful (only a selection):**

Senertec, Germany	Ecopower, Germany	EC-Power, Denmark
Gas Otto engine	Gas Otto engine	Gas Otto engine
5,5 kW_{el} / 12,5 kW_{th}	1,3 – 4,7 kW_{el} / 4,0 – 12,5 kW_{th}	4,0 – 13,0 kW_{el} / 17 – 29 kW_{th}



- **Available number of systems is limited and doesn't fit partly the requirements**

  ⇨ **Limited distribution of µCHP in the one- and two-family house sector**

Emerging ICE Tests

Advanced Engine Designs

- Tokyo Gas/Mitsubishi modified 1 MW GS16R2 ε=42.5%
- JGA/Yanmar 50 kW turbo-charged homogeneous charge compression ignition (HCCI) ε=42.5%
- DOE ARES ε=50%
- Thermo-chemical recuperation

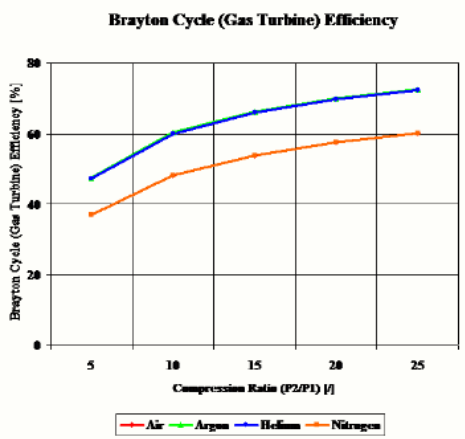
Turbocharger mounted on HCCI engine.

Emerging Engine Concepts

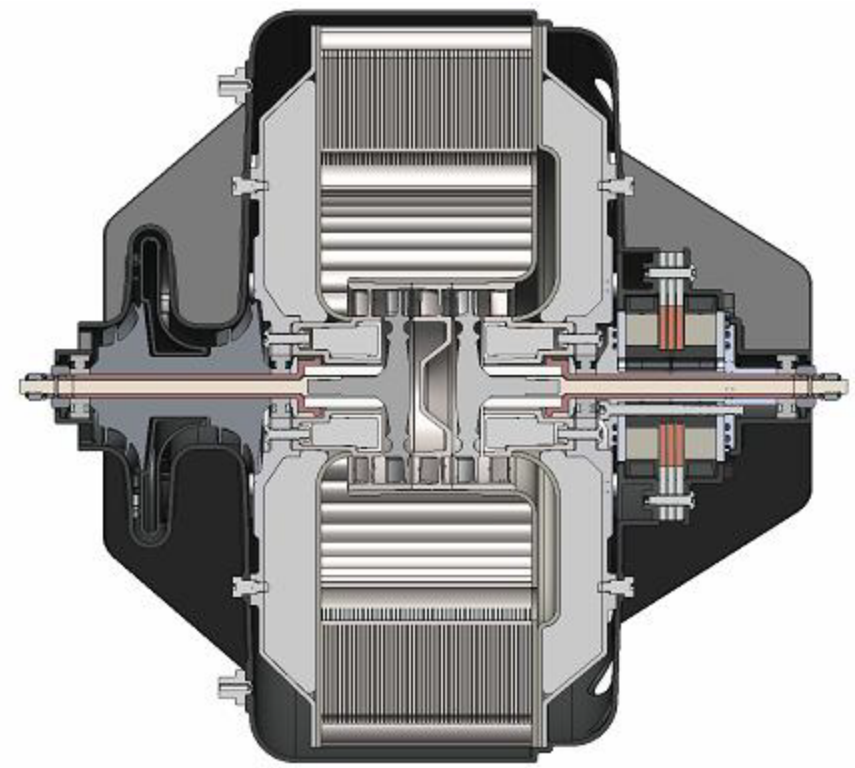
Advanced Engine Cycles

- Supercritical CO_2
  - $\varepsilon > 50\%$
- Noble Gases

Brayton Cycle (Gas Turbine)

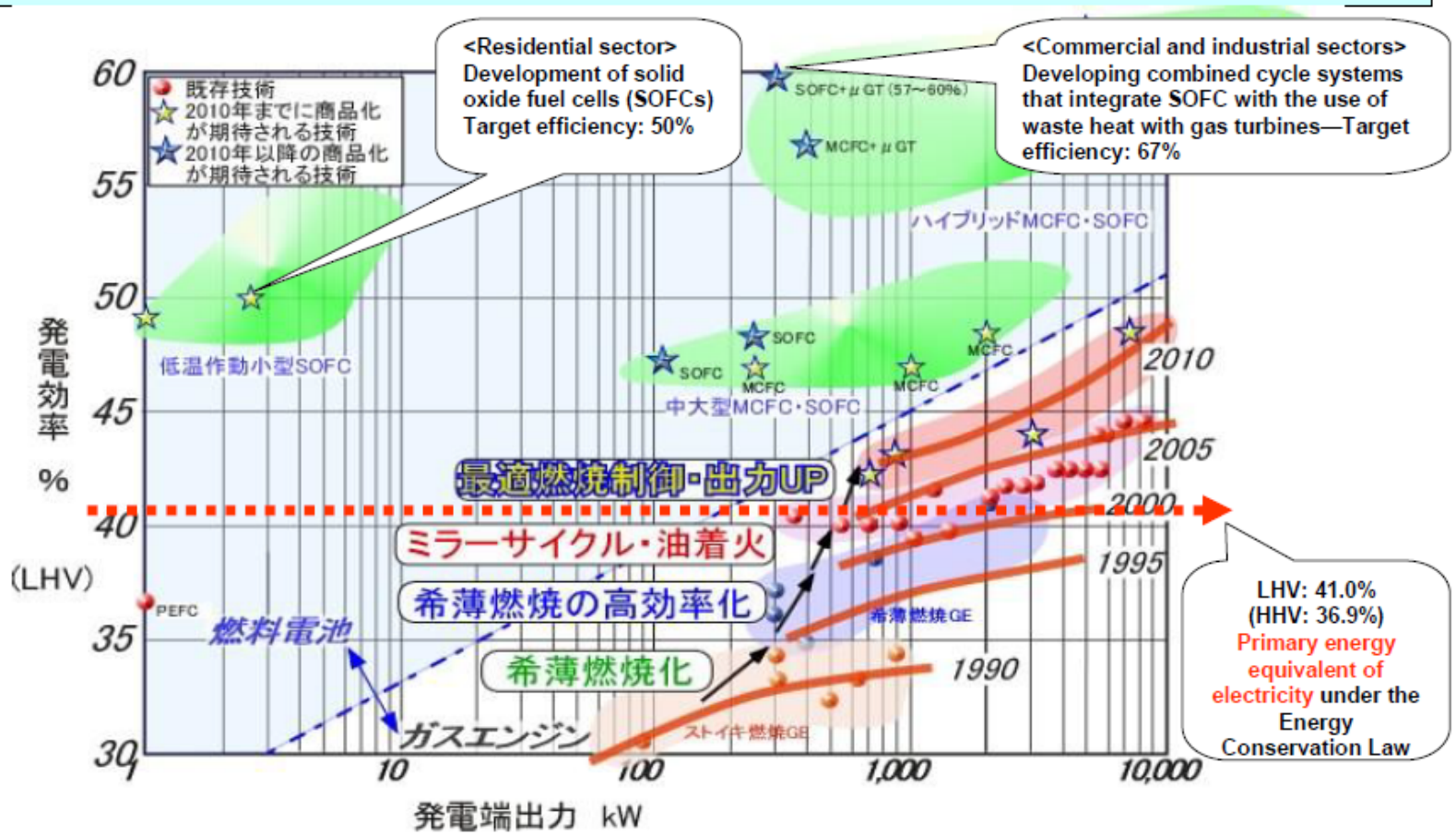


3 kW NRL Recuperated ceramic turbo engine



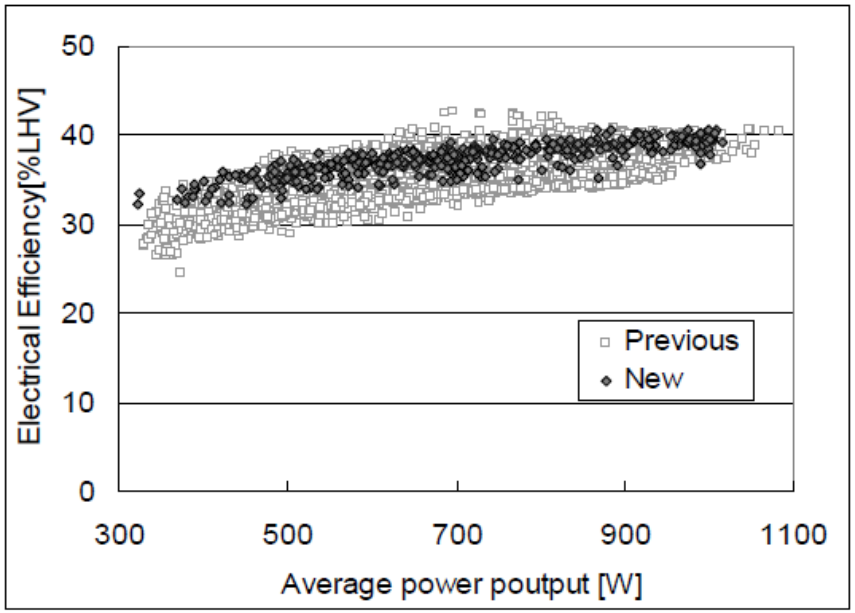
Fuel Cells - Japan

- Introducing cogeneration systems that exceed the average power generation efficiency of grid power (receiving end; LHV: 41%)
- Developing and introducing small to large super-high-efficiency fuel cells (LHV: 50 – 67%)



Tokyo Gas/Panasonic ENE FARM PEM Fuel Cell

- Launch 2005 with 520 units (lease only)
- Commercial 2008
- 1kW, ε =37%
- $30K before subsidy



- Note – over 3300 total PEM fuel cells installed since 2005

Japan SOFC Demonstrations

- Demo start 2007; target commercial date 2015
  - 65 systems installed
  - Kyocera 0.7 kW; 45%
  - Nippon Oil 0.7 kW units for LPG and kerosene
  - Toto 0.7, 2, and 8kW systems
  - Experimental 3 kW micro-tubular SOFC achieved 59% efficiency for DC power

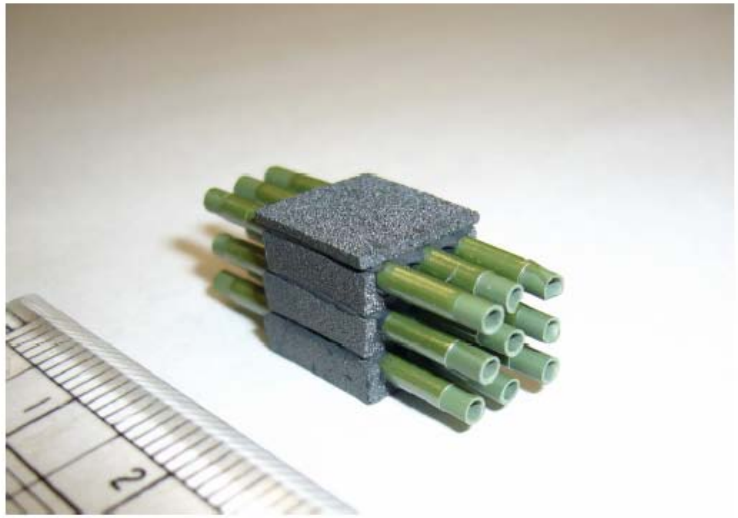
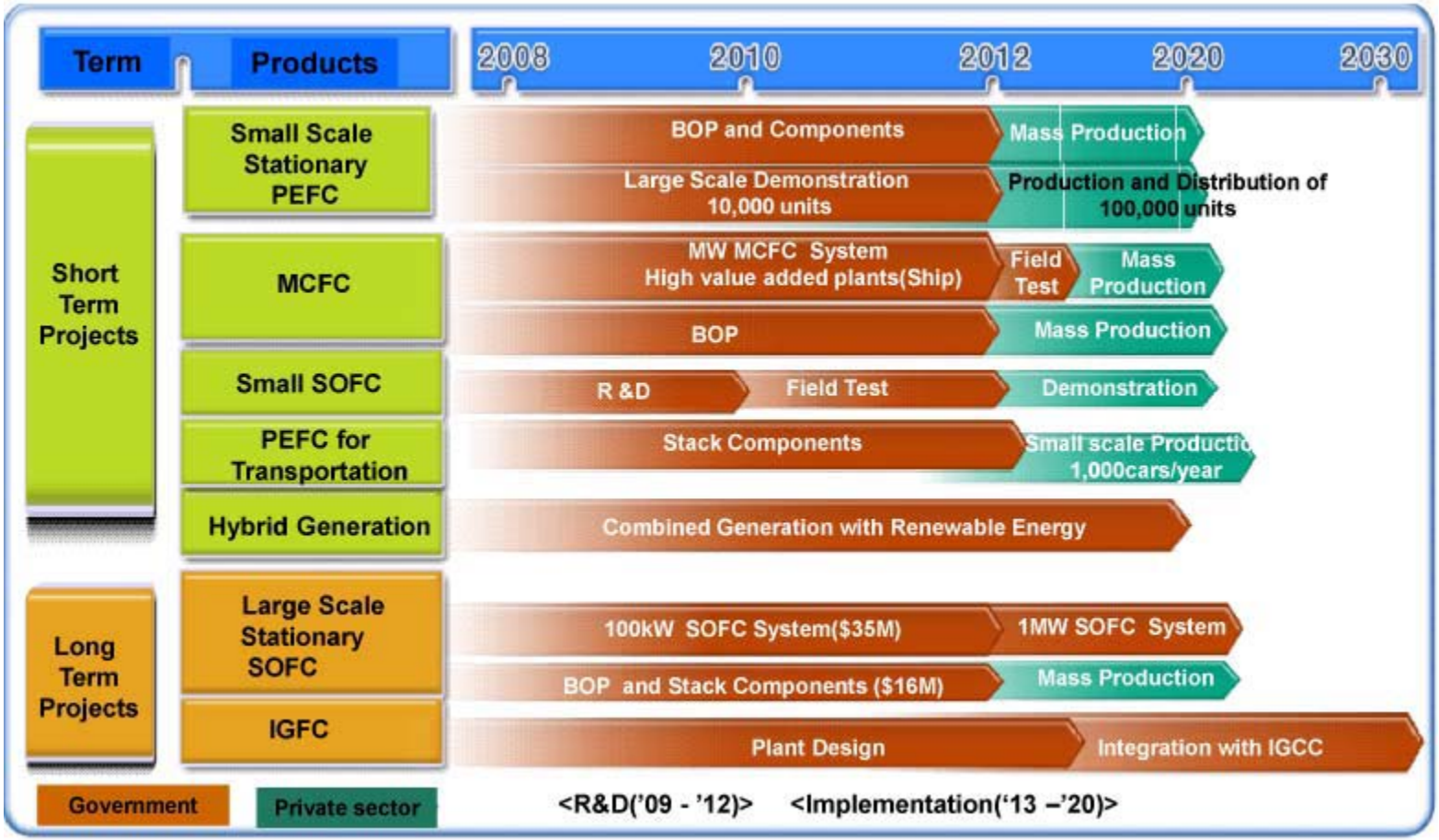


Fig.6 Cube Bundle

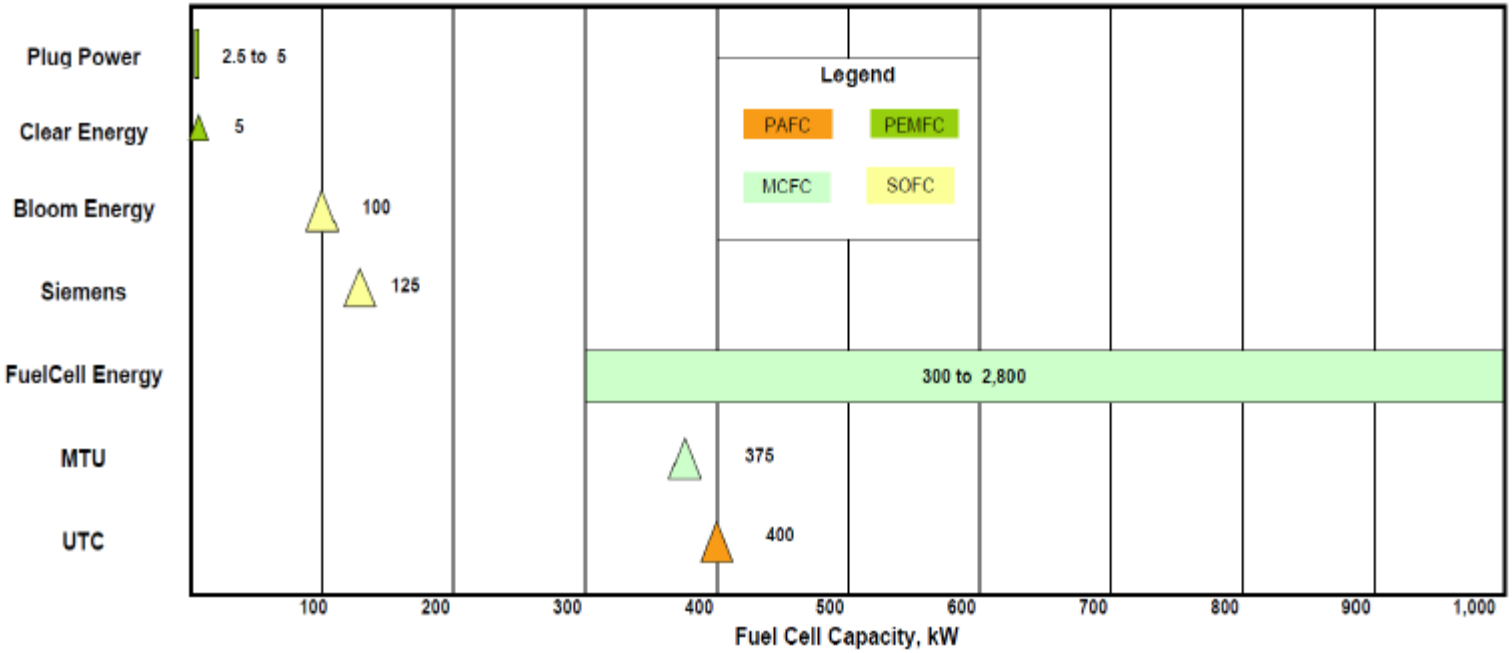
Korean Fuel Cell Roadmap



EU Fuel Cell Demonstrations

- Baxi: 1kW PEM in beta testing
- Valliant/Plug Power: CHP for multi-family dwellings in UK; also developing SOFC
- Ceres Power: 1kW SS fuel cell operating at 500-600C; Centrica placed forward order for 37,500 units
- CFCL: NetGen testing in Australia, New Zealand, UK, Germany; agreements with E.ON and GdF-Suez
- Hexis: Galileo 1000N 1kW, 30% efficiency, primarily testing with E.ON

US Fuel Cell Technologies



Observations

- Diverse technologies are in testing and demonstration globally (EU, Asia and some in NA)
- Electric efficiency, reliability and cost are still issues:
  - CHP emphasis and fewer incentives for net metering in EU, Japan, and Korea reduce importance of efficiency
  - Technical innovation may be possible but government support is needed to encourage innovation and R&D investment
- There are several options which could increase electric efficiency in engines to meet ARPA-E's targets
- Fuel cell efficiencies are attractive; key issue is high cost
  - "Experience curves" for Japanese PEM fuel cells suggest 20% cost reduction for every doubling in production. Mass production (10's millions units) would be required for cost of $1500/kW