Ultra Efficient Combined Heat, Hydrogen, and Power System

DE-EE0003679
FuelCell Energy, Inc.
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U.S. DOE Industrial Distributed Energy Portfolio Review Meeting
Washington, D.C.
June 1-2, 2011

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FCE Overview

- **Leading fuel cell developer for over 40 years**
  - **MCFC, SOFC, PAFC and PEM (up to 2.8 MW size products)**
  - **Over 700 million kWh of clean power produced world-wide (>50 installations)**
  - **Renewable fuels: over two dozen sites with ADG fuel**
  - **Ultra-clean technology: CARB-2007 certified**

Danbury, CT

- **Highly innovative approach to fuel cell development**
  - **Internal reforming technology (45-50% electrical efficiency)**
  - **Fuel cell-turbine hybrid system (55-65% electrical eff.)**
  - **Enabling technologies for hydrogen infrastructure**
    - **Co-production of renewable H_2 (60-65% eff. w/o CHP)**
    - **Solid state hydrogen separation and compression**

Torrington, CT

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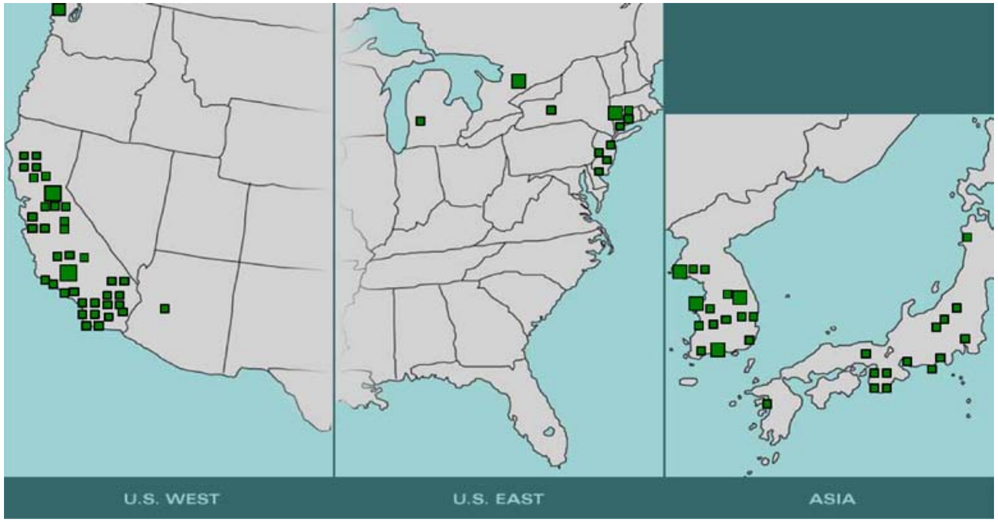
Market Leadership

Markets

- 111 MW installed/backlog
  - Korea/Asia: 70 MW
  - California/West Coast: 33 MW
  - Northeast/Canada: 6 MW
  - Europe: 2 MW

- Targeted applications
  - Grid Support: 70 MW
  - **Renewable/Wastewater**:21 MW
  - Manufacturing: 6 MW
  - Hotels: 2 MW
  - **University** & Hospitals: 5 MW
  - Government: 5 MW
  - Gas Pipeline: 2 MW



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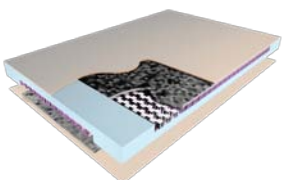
FuelCell Energy Products



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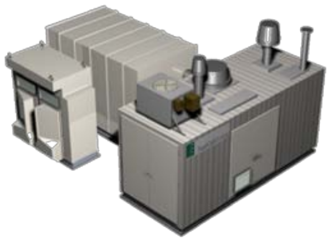
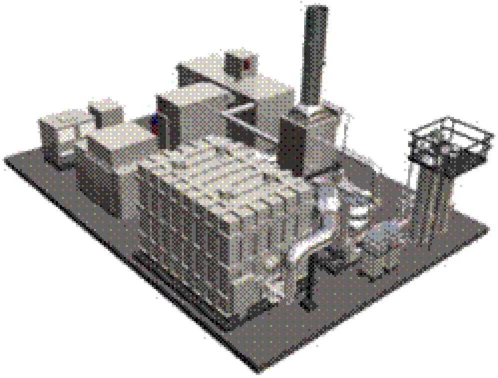
Stack



DFC300
(300 kw)
Single Module Power plant



DFC1500 (1400 kw)
Four Module Power plant

DFC3000
(2800 kw)
Two 4-Stack Modules

Building block approach provides scalability and a common cell/stack component across product lines

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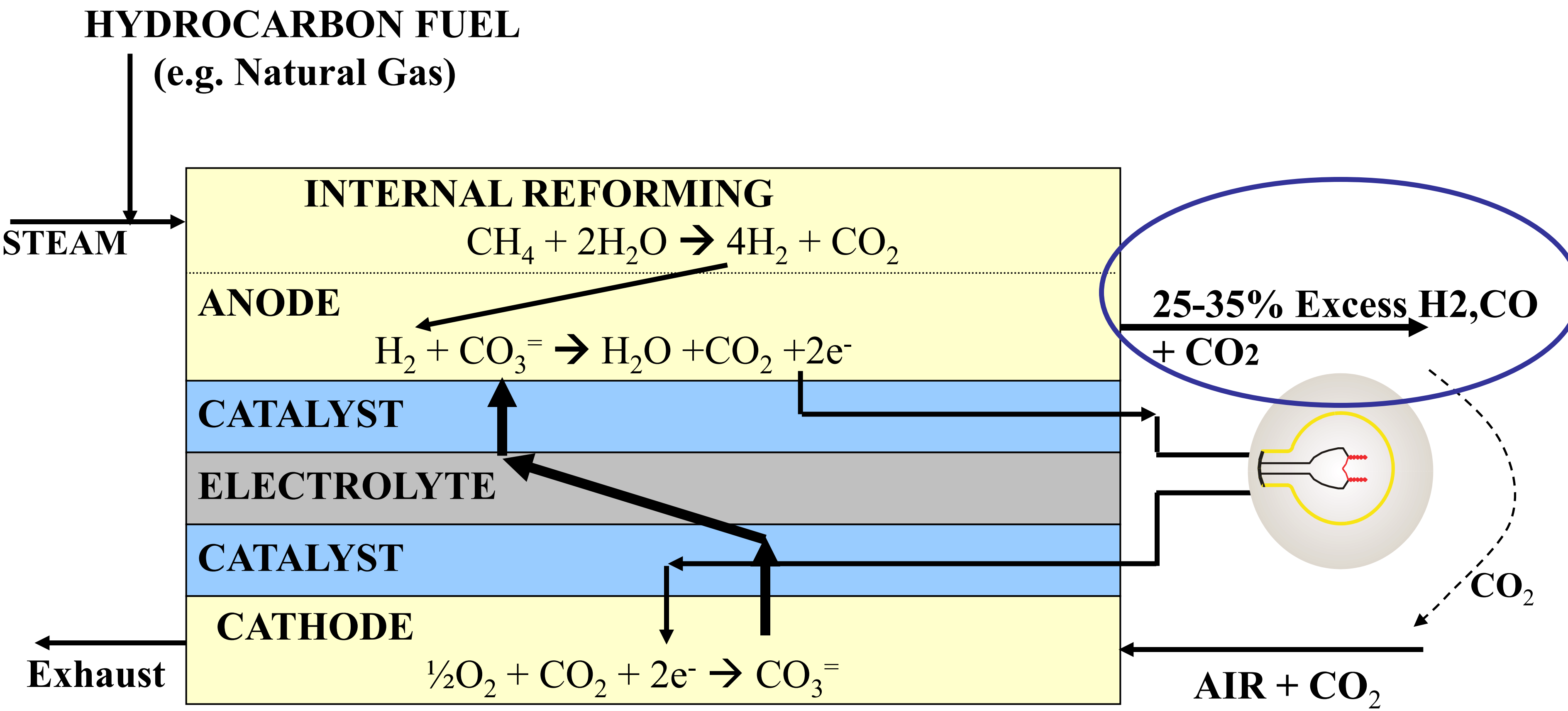
Operation – Carbonate DFC® Technology



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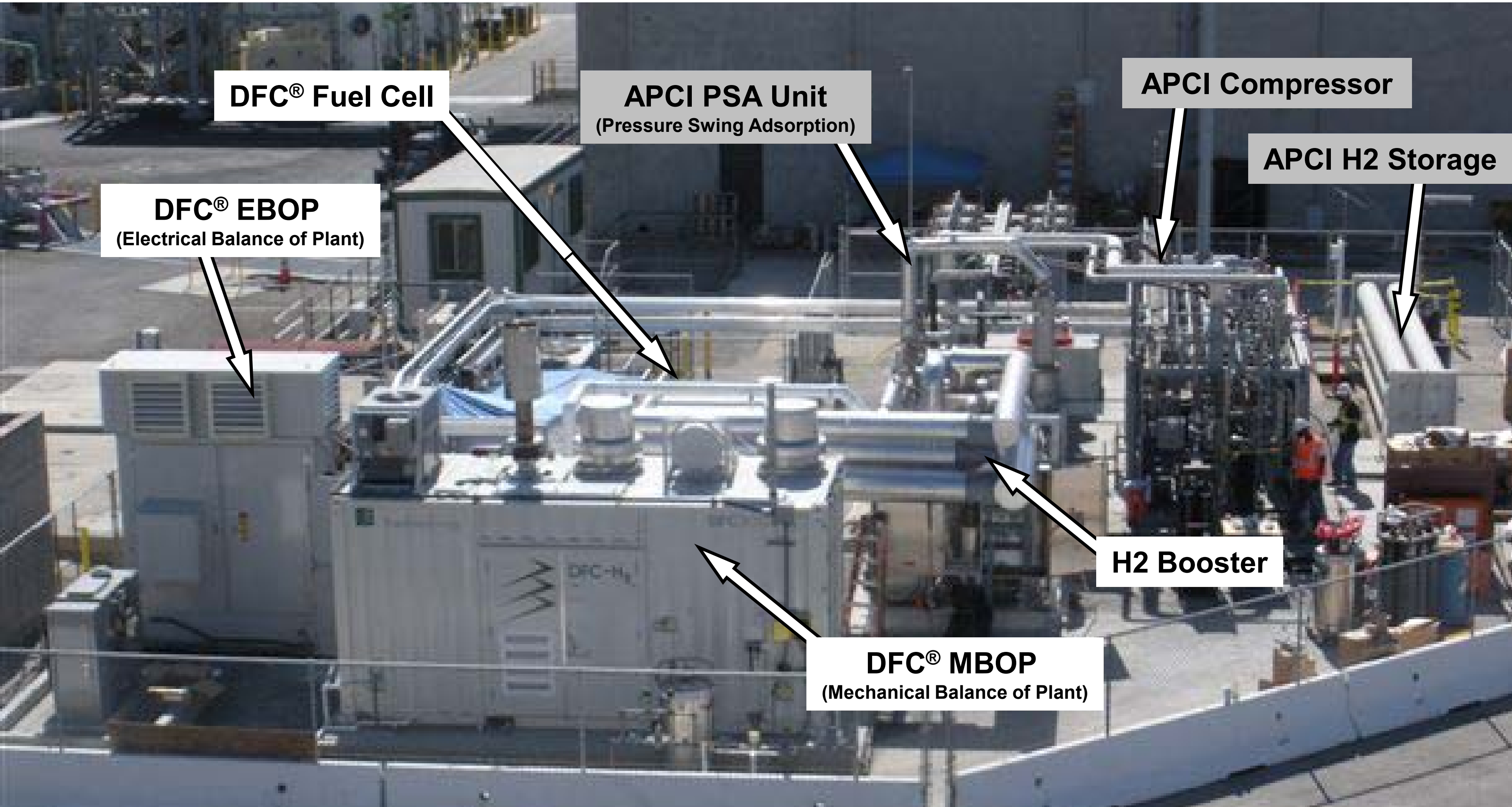
CHHP Technology Demonstration at Orange County Sanitation District (OCSD) Fountain Valley, California



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Unit producing over 250 lb/day of renewable H_2 from waste water anaerobic digester gas

AIR PRODUCTS

Project Team

- FuelCell Energy
  - Pinakin Patel
  - Fred Jahnke
  - Matt Lambrech
- ACuPowder / Abbott Furnace
  - Ed Daver
  - Krishna Patel
- ITP Program Managers
  - Bob Gemmer
  - Jerry Parker

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Executive Summary

- Goal – reduce gross utility costs for copper powder manufacturing by up to 25%, energy use by 50%
- Proposed solution - coproduce low cost reducing gas, power and heat on site for reduction of copper powder (CHHP)
- Benefits
  - Ultra efficient on-site generated hydrogen and CO2 mixture replaces currently imported liquid hydrogen and liquid nitrogen and reduces purchased power
  - High value co-products (H2/CO2) make process very competitive
- Status
  - Laboratory testing by manufacturer successful
  - Commercial furnace test equipment being installed

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Project Objective

- Demonstrate the use of low cost reducing gas from fuel cell to replace purchased liquid gases
- Maintain high reliability and copper product quality

Concerns

- CO_2 replaces N_2 currently used and potentially could change product properties
- Risks for integration with existing commercial process
- Uses emerging technology
  - High temperature fuel cell anode exhaust gas recovery
  - Returning furnace off gases to fuel cell

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State of the Art

- ACuPowder purchases liquid H2 / N2 for reducing gas to produce over 2 million lbs/month of copper powder
- Power purchased from grid
- Unused H2 in furnace exhaust is vented

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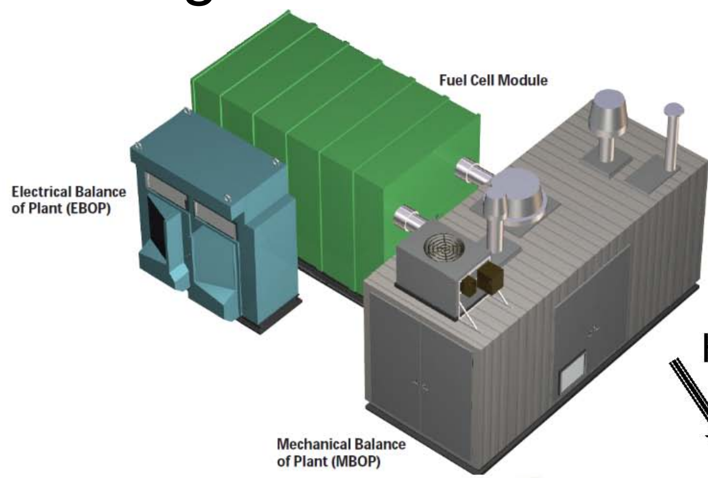
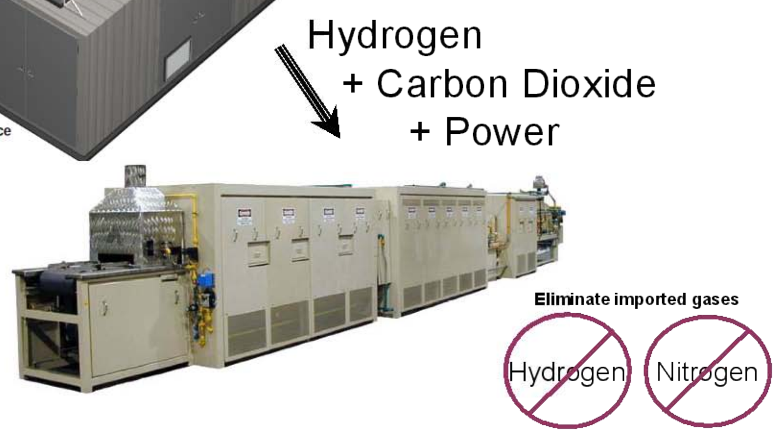
Technical Approach

- CHP to CHHP using high temperature DFC® fuel cell
- Recover and condition anode exhaust (H_2+CO+CO_2+H_2O) to produce low cost reducing gas on-site
- Recover furnace exhaust gases for use in fuel cell





- Higher efficiency
- Lower emissions
- **Much higher value added with no change in product quality**

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Technical Approach

- **Why believe will be successful**
  - Thermodynamics indicate N2 and be replace by CO2 for copper
  - “Endo” gas, a mixture of CO and H2 with some CO2, was used before liquid H2 available
  - Gas produced by fuel cell has H2 content similar to current reducing gas
- **Innovations**
  - Build on emerging H2 co-production technology
  - Use of waste stream from fuel cell for high value reducing gas
  - Return unused hydrogen and CO2 from furnace to fuel cell to increase efficiency
  - Co-producing inert gas (CO2 replaces N2) as well as hydrogen
  - Low reducing gas production costs (H2 separation not needed)

Transition and Deployment

- Working with major supplier to industry

ACuPowder International, LLC
901 Lehigh Avenue, Union, NJ 07083 USA
Phone: (908) 851-4500 Fax: (908) 851-4597
ACuPowder

ACuPowder is source for multiple metal products and alloys (More than 90 years industry experience, >50% market share)

- Antimony,
- Bismuth,
- Brass,
- Bronze,
- Copper,
- Copper Alloys,
- Custom Alloys,
- Graphite,
- Infiltrants,
- Manganese,
- MnS+,
- Nickel,
- Nickel Flake,
- Nickel Silver,
- Phos-Copper,
- P/M Lubricants,
- Silicon,
- Silver Flake,
- Tin and
- Tin Alloys..

Transition and Deployment

- Perform study for selecting industry segments to improve manufacturing and energy efficiency using CHHP technolgy
- ACuPowder parent company can use CHHP system at other facilities
- Joint presentation / paper at MPA (Metal Processing Association) and other industry groups
- Develop business model for disruptive technology
  - Who owns
  - Value proposition
- CHHP technology scale up to megawatt size

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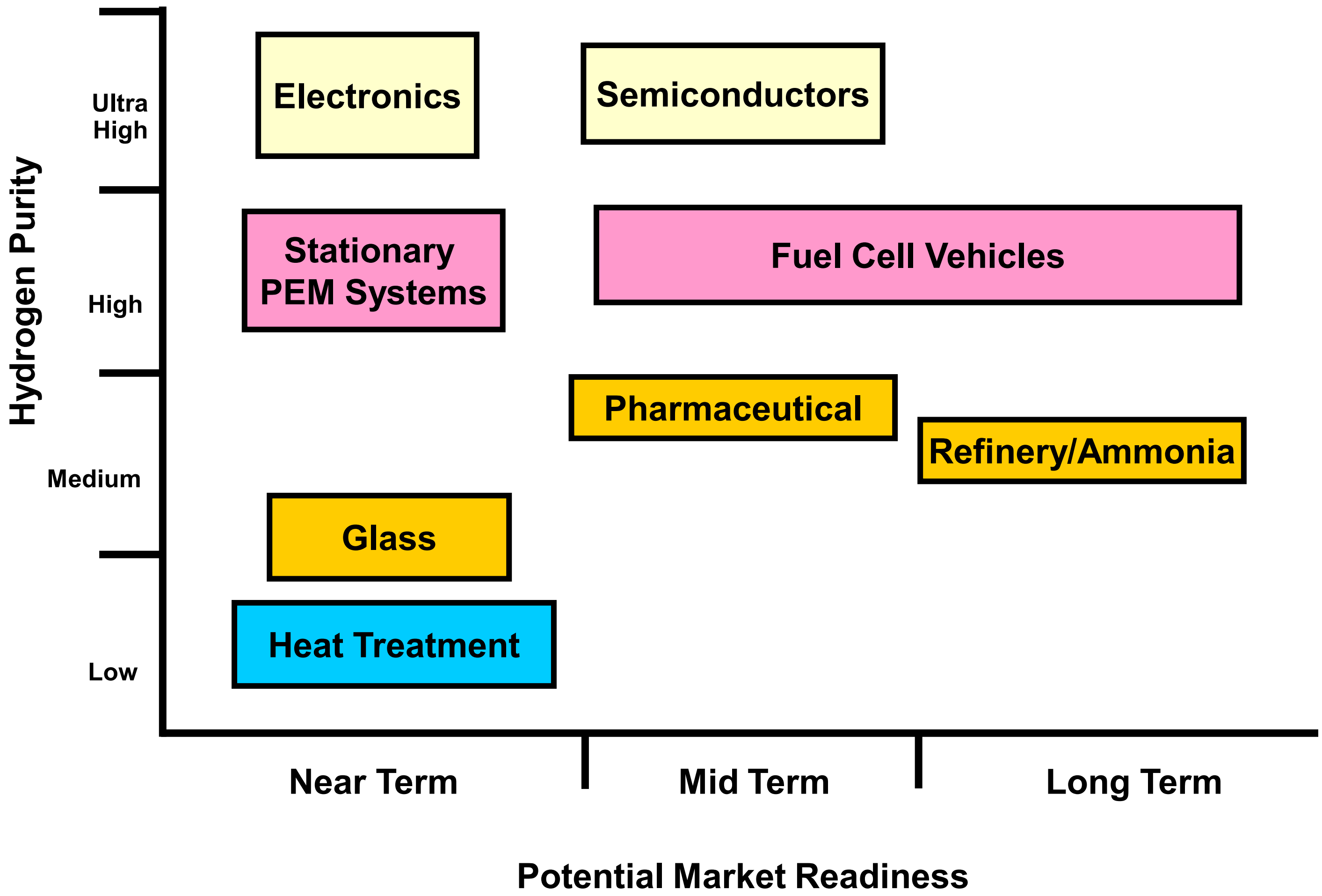
Transition and Deployment



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Measure of success

Project Addresses Most Important Operating Cost

RELATIVE IMPORTANCE OF TYPICAL ANNUAL OPERATING COSTS

Operating Cost	**Range** (% of Total)	**Guideline** (% of Total)
Furnace Depreciation	5% - 15%	10%
Facility Space Costs	5% - 15%	10%
Atmosphere & Utilities	40% - 55%	50%
Operator & Maintenance Labor Costs	5% - 15%	10%
Inspection & Rework	5% - 20%	8%
Replacement Parts	10% - 15%	12%
		100%

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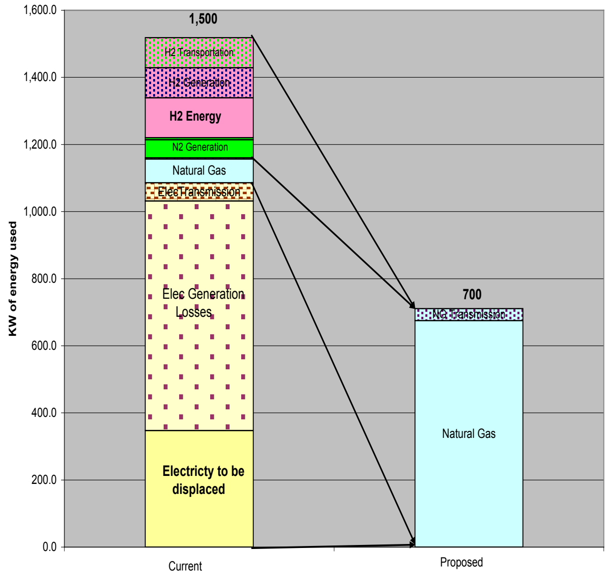
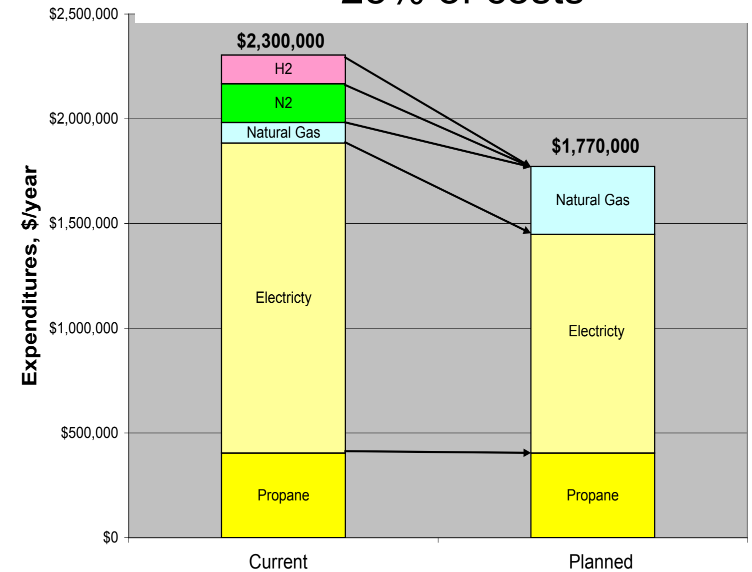
Measure of success

- Success criteria
  - Maintain product quality (match properties, satisfy customers)
  - Substantially reduce gross utility costs (up to 25%)
  - Attain ultra high efficiency (60-75% power+ reducing gas)
  - No new emissions of criteria pollutants

Societal Benefit
50% reduction in energy



Gross Utility Savings ~$500,000
25% of costs



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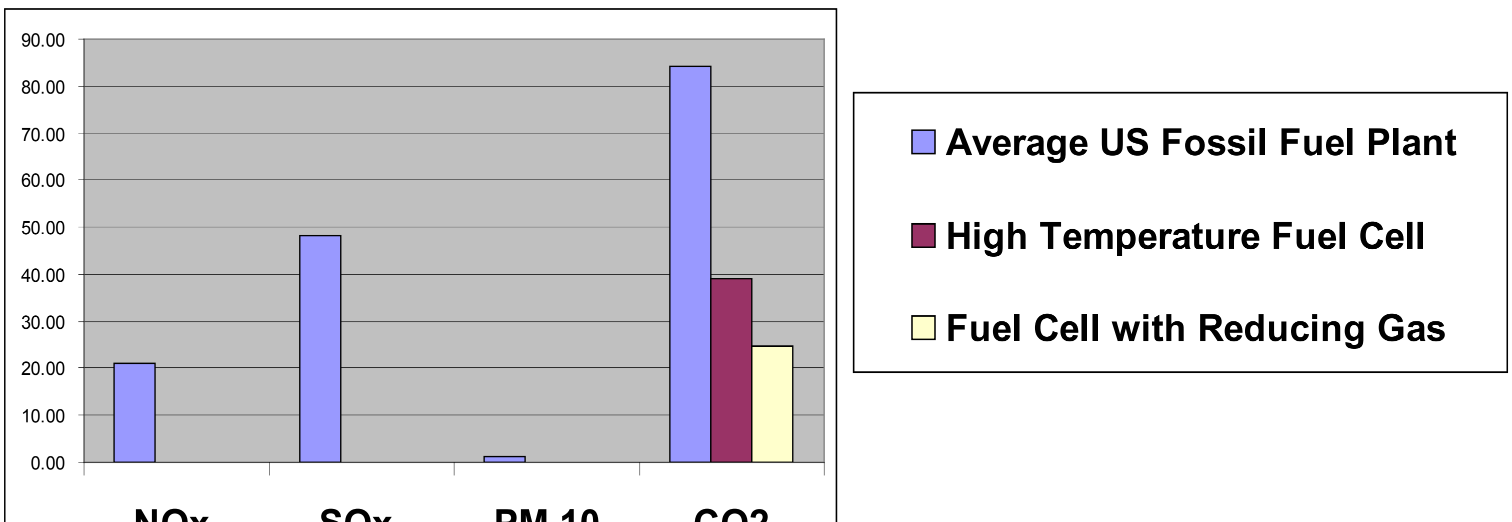
Benefits

- 25% Utility Savings (12% operating cost)
  - On-site power, low cost reducing gas, heat
  - Increased competitiveness - Keeps jobs in USA
- Large emissions reductions – Societal benefits

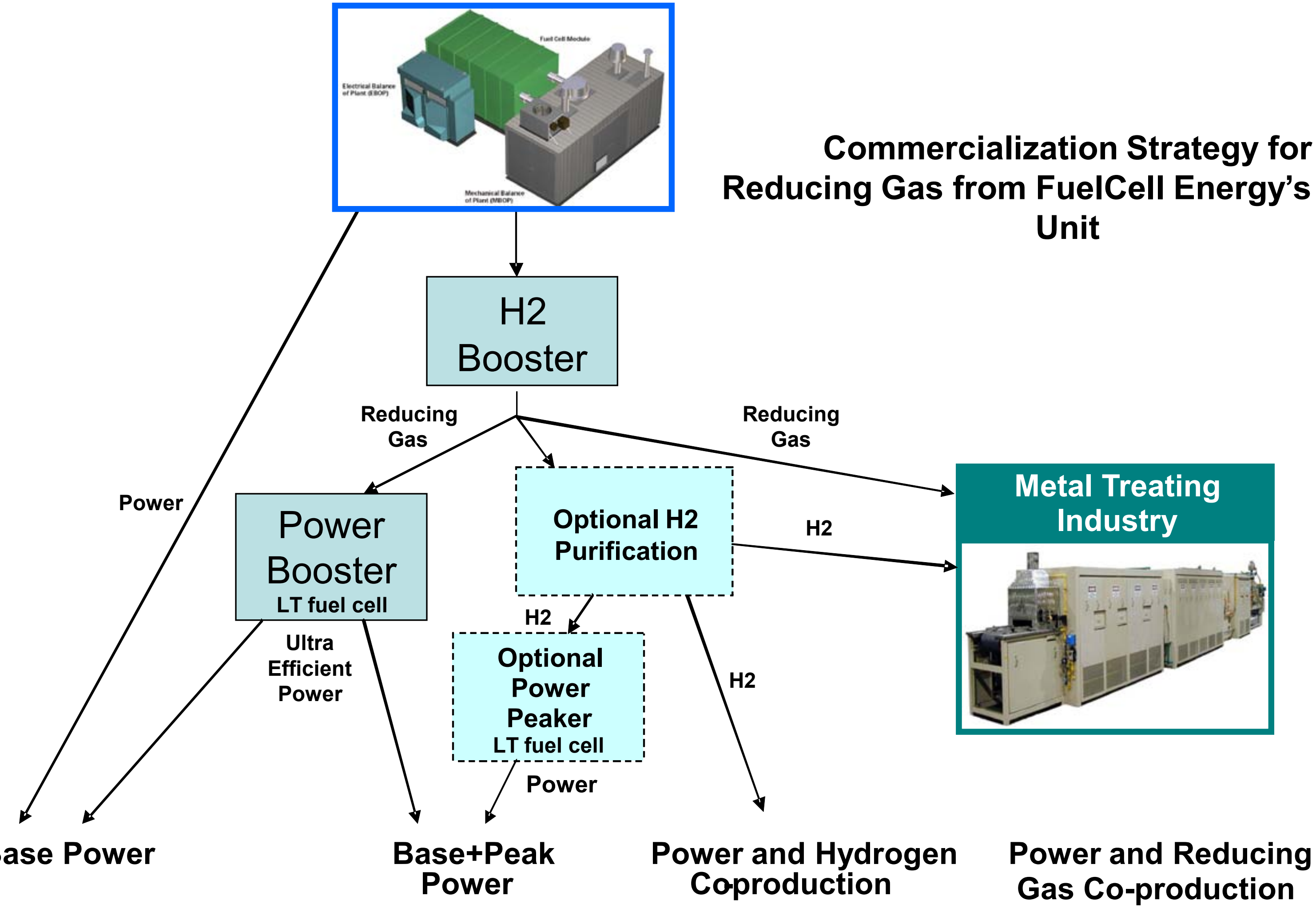


		Savings yearly tons		
Savings from Planned unit (~345 kw)	7.27	16.70	0.39	2,065

Savings for NOx and SOx 25 t/yr at 10,000 $/t = $250,000 emission credit

Commercialization Approach

Commercialization Strategy for Reducing Gas from FuelCell Energy's DFC® Unit



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Commercialization Approach

- Expand commercial DFC® products to include CHHP
- Use technology for multiple markets
  - Industrial H2 market (near term) ($10 billion)
  - Clean distributed power (mid term) (>$100 billion)
  - Backup/Load following power (future)
  - Transportation (future)
- Develop distributor system
  - H2 / Industrial Gas Companies
  - Utilities
- Develop sales options
  - equipment sales
  - over-the-fence supply contracts

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Commercialization Approach

Expand commercial DFC® products to include CHHP

	DFC300®	DFC1500®	DFC3000®
			
Co-product			
Power, kW	**250**	**1,000**	**2,000**
Hydrogen, kg/day	**125**	**500**	**1,000**
Heat, mmBtu/hr	**0.5**	**2.0**	**4.0**
Peaker Capacity			
Peak Power (8 hrs/day), kw	**500**	**2,000**	**4,000**
Refueling Capacity			
Fork Lifts/FC Cars, 0.5 kg/day	**300**	**1,200**	**2,400**

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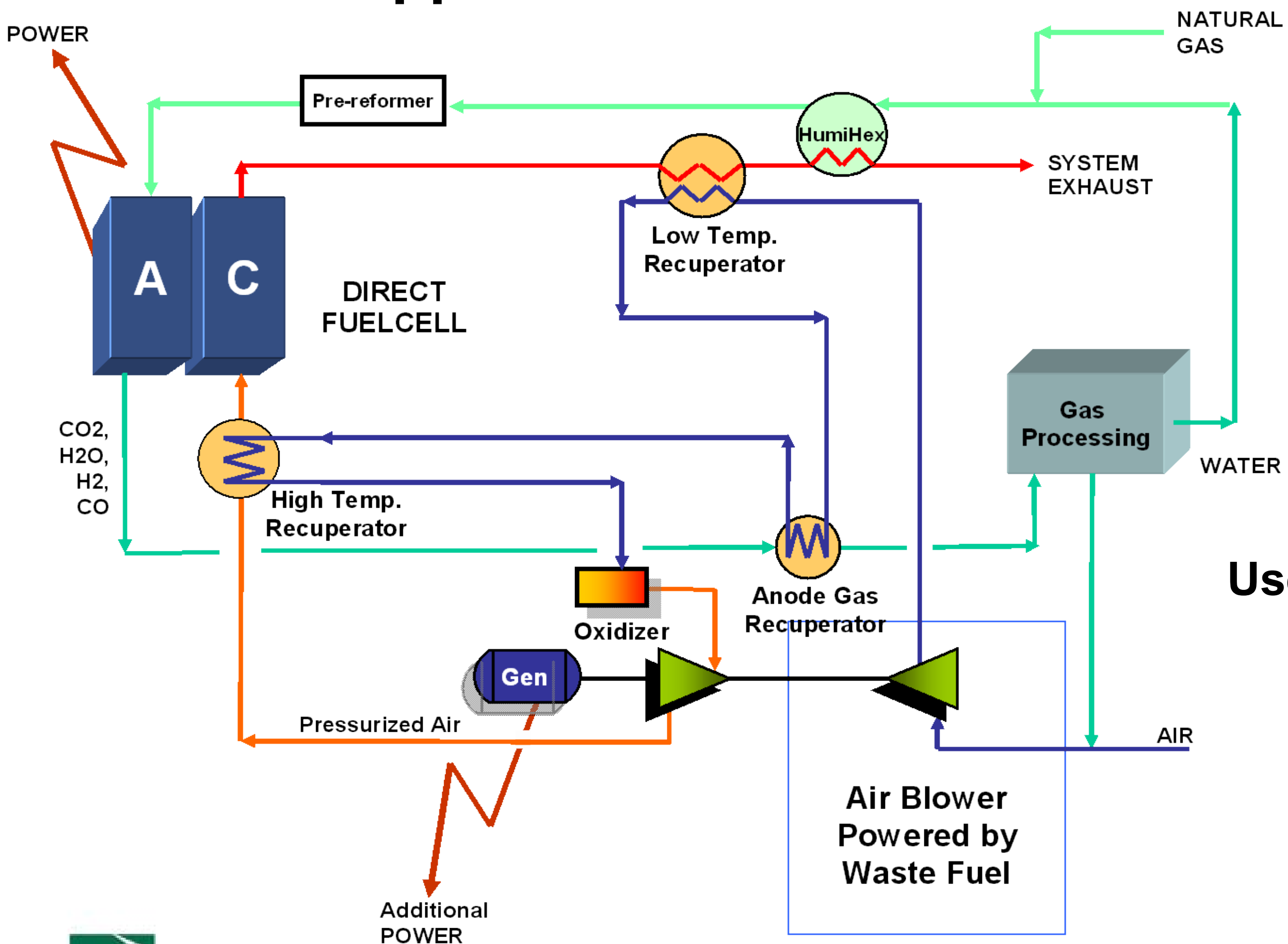
Hybrid Power Generation with > 60% Electrical Efficiency for CHP Applications



Use of Waste Fuel in High Efficiency Engine/Turbine

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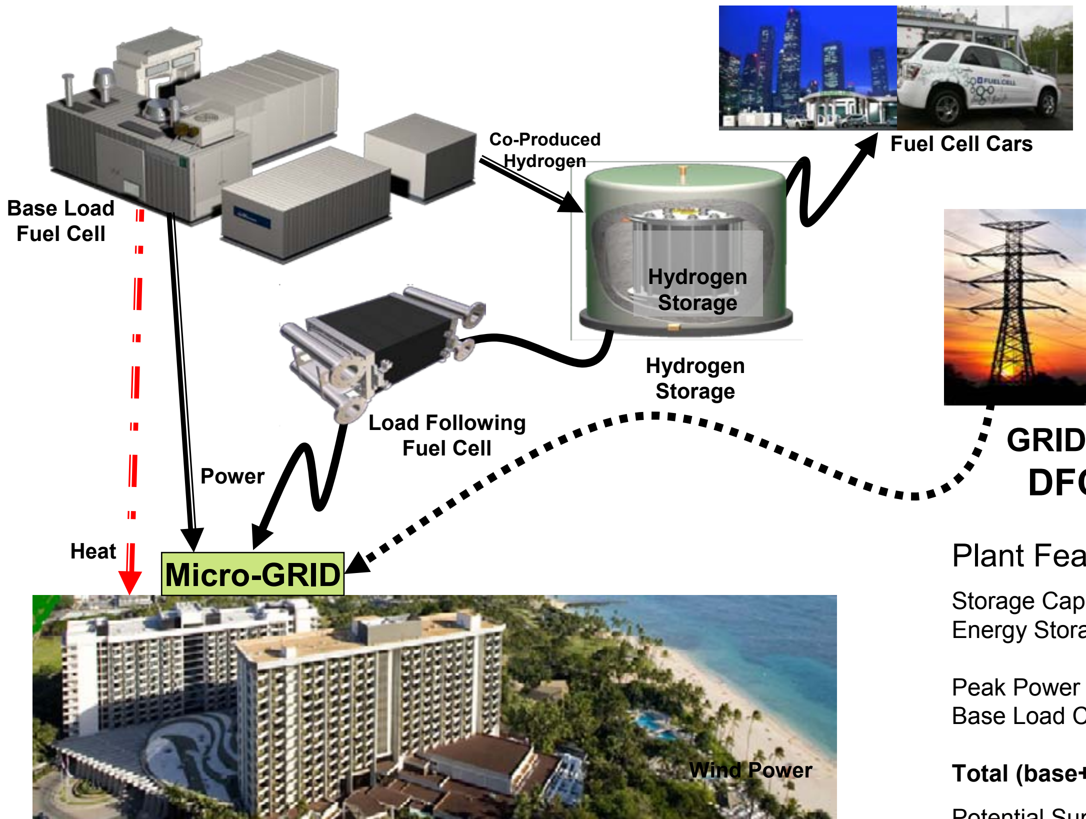
Combined Hydrogen Heat and Power (CHHP) for Micro-Grid Applications



DFC-H2® Peaker Demonstration Project

Plant Features

Storage Capacity:	2.5 MWh (or larger)
Energy Storage Medium:	H2 produced on-site (300 lb/day ~ 2 day storage tank)
Peak Power Capacity:	300 kw for 8 hrs/day
Base Load Capacity:	300 kW (24/7, DFC® 300 unit)
Total (base+peak) Capacity:	**600 kW**
Potential SuperPeak of Peaker	300 kw
Potential Superpeak Capacity:	900 kW for 2 hrs
Fuel:	Pipeline / Renewable Gas Mixture; optional Biogas (ADG)
Emissions related to Peak Power:	nil
Emission related to Base Power:	Exceeds CARB Standards

Distributed Generation with waste heat recovery providing over 80% CHHP eff

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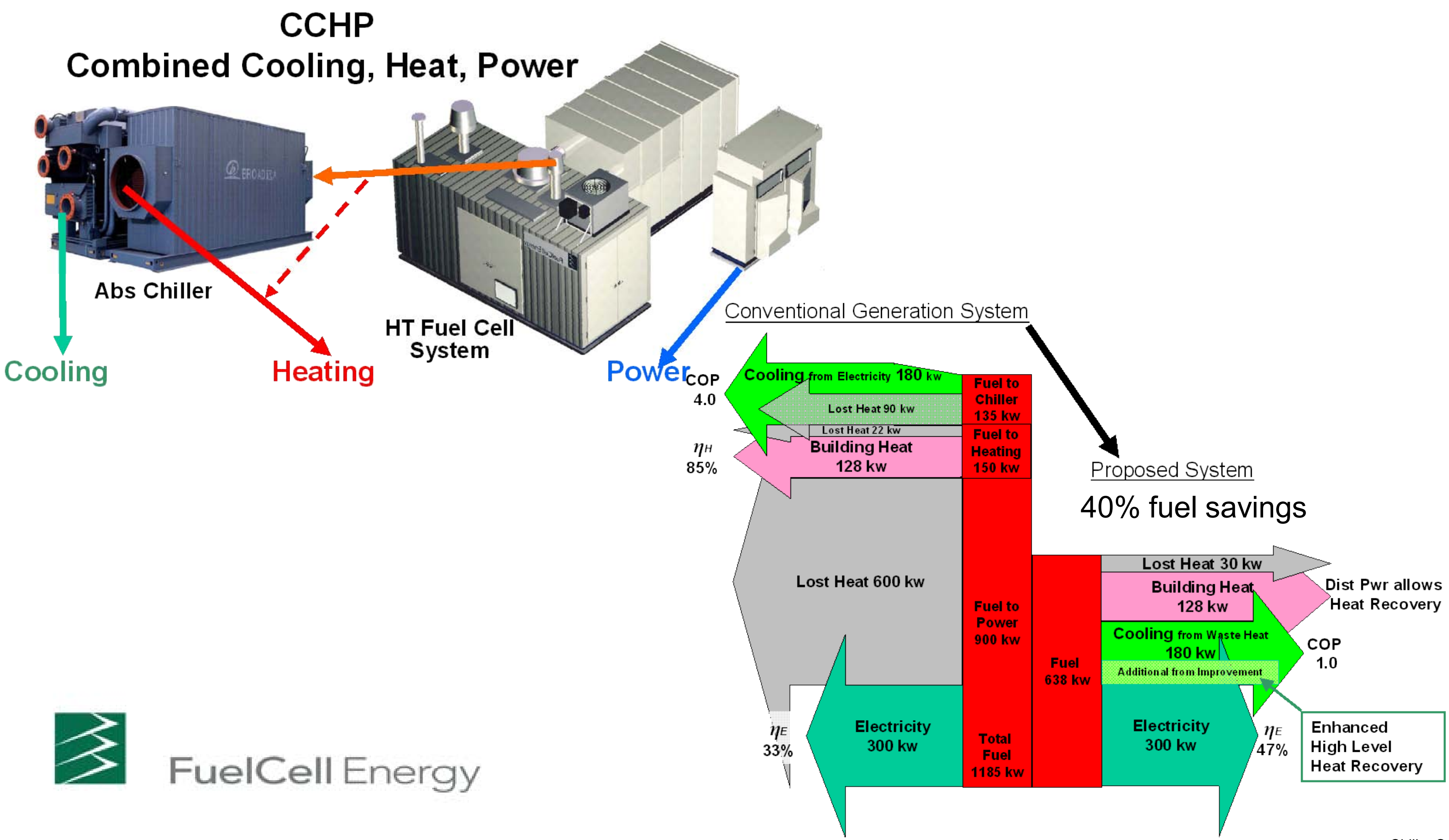
Combined Cooling Heat and Power (CCHP) Applications



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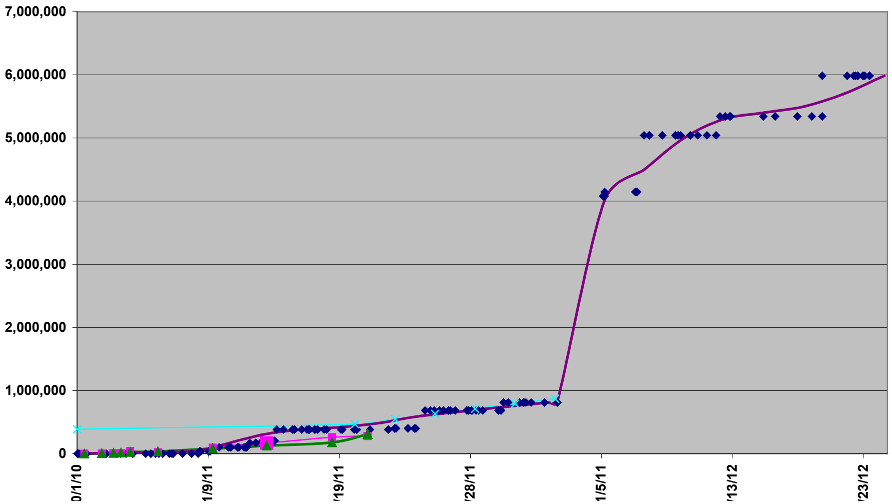
Project Management and Budget

- **Key Milestones**
  - Quality testing with low cost reducing gas
    - Laboratory
    - Commercial Furnace (bottled gases)
  - Economic review
  - Installation
  - Operation and Testing



Project Budget			
	FY11	**FY12**	**FY13**
DOE Investment	**$508,228**	**$2,275,959**	**-**
Cost Share	**<u>$303,611</u>**	**<u>$2,895,794</u>**	**-**
Project Total	**$811,838**	**$5,171,754**	**-**

Results and Accomplishments

- **The extensive lab test performed in four months of 2011 has revealed that the properties of copper powders using conventional H-N gas mix and FCE gas mix are identical in all respects. ***
- **The management at ACP is highly optimistic for the completion of both phases of this CHHP project with full installation of commercial FCE in 2012.***
- Completed risk assessment and test plan for testing at larger size in the production furnace using simulated fuel cell gas.
- Completed material and energy balances for different operating scenarios. Economic analysis in progress.
- Rutgers University interested in supporting outreach with NJ State entities for the project.

*** manufacturer's (ACuPowder) statements**

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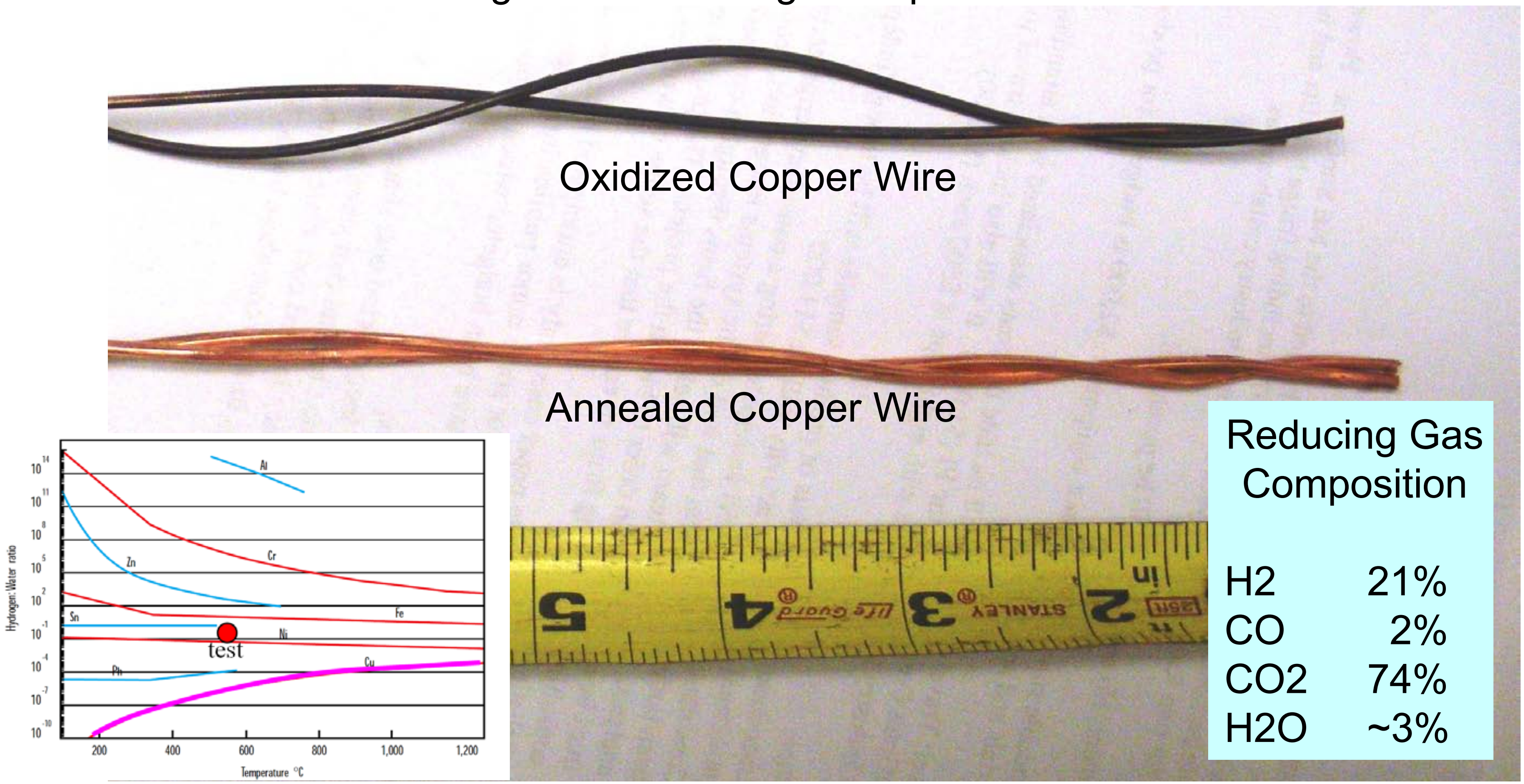
Results and Accomplishments

Pre-feasibility Test Done at FCE

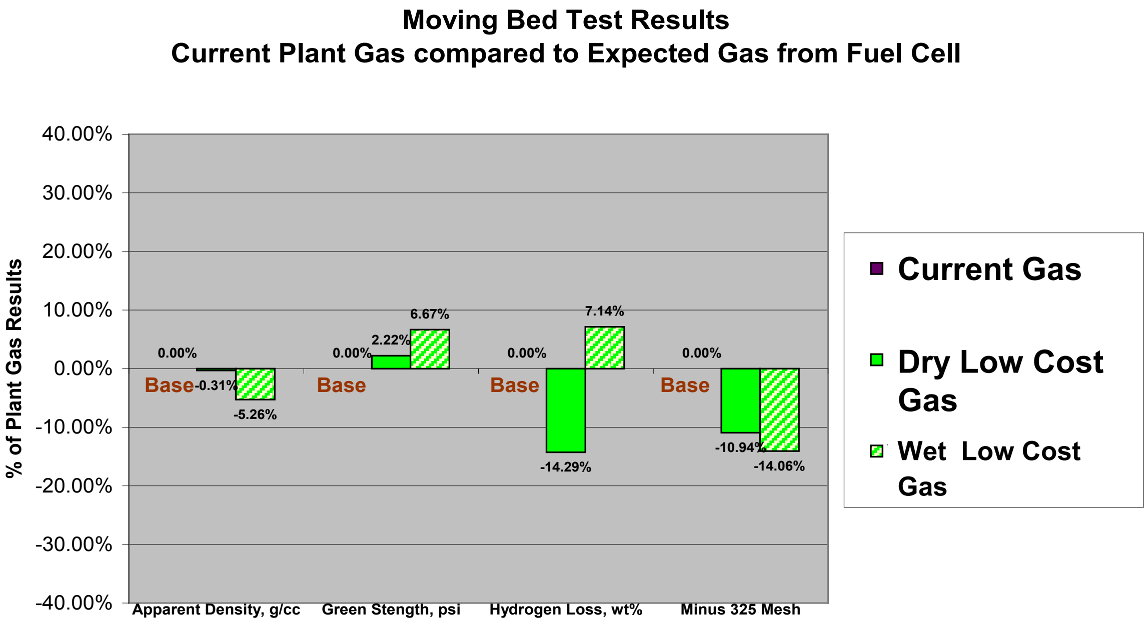
Test of Bright Annealing of Oxidized Copper Wire using Reducing Gas from a High Temperature Fuel Cell



Reducing Gas Composition

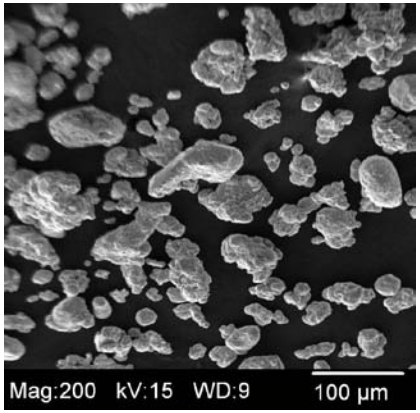
H_2	21%
CO	2%
CO_2	74%
H_2O	~3%

Laboratory Results - Successful

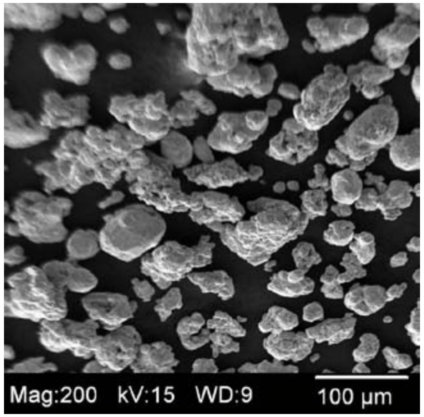


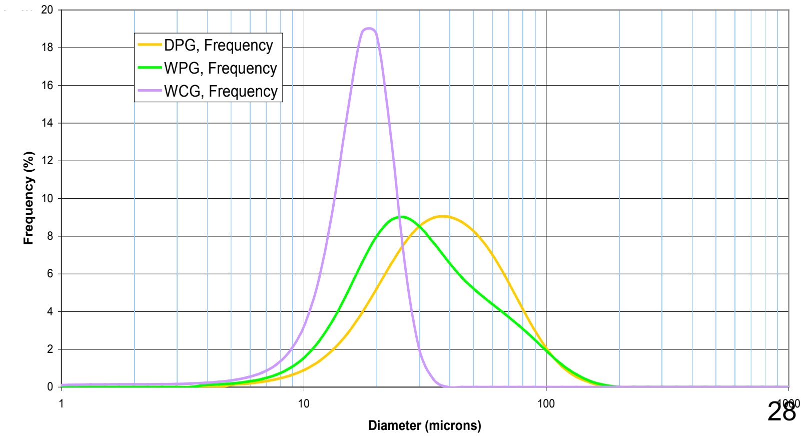
Quality of copper product maintained with low cost reducing gas

Current Gas



Low Cost Gas





Results and Accomplishments

Potential Installation Locations at ACuPowder Site in Union, NJ

Path Forward

- Key Remaining Tasks
  - Commercial Furnace Test
  - Economic Validation
    - Firm up cost with site specific quotes
    - Confirm economics valid with firm costs
  - Install CHHP system
  - Operate and Test
    - Confirm and report performance and cost benefits
  - Implement Commercialization Plan

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Thank you

Questions?

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