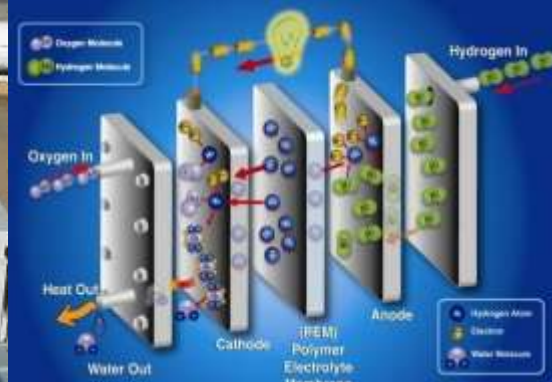


Fuel Cell Technologies Program

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



2011 Joint Service Power Expo

May 3, 2011

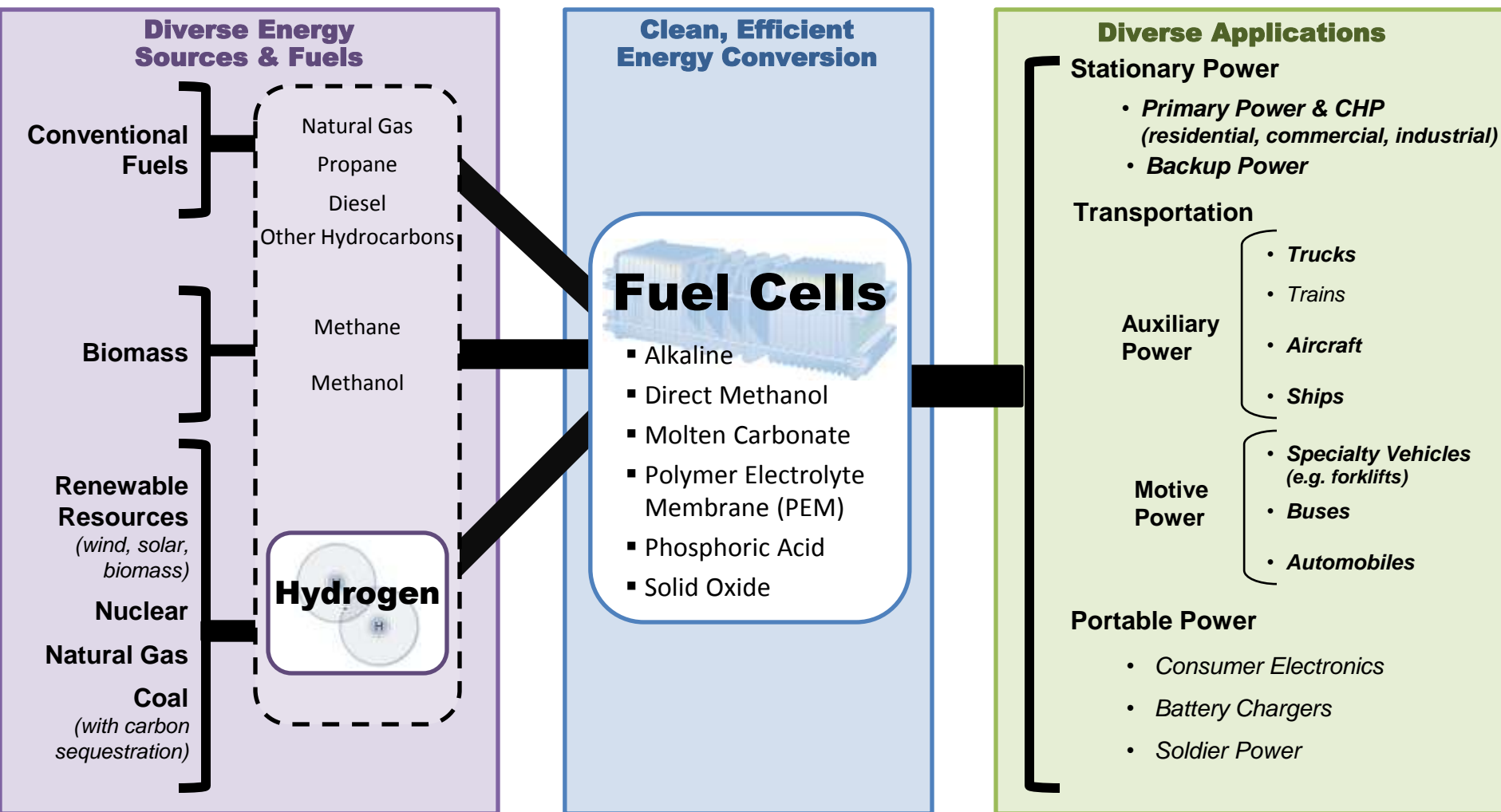
Pete Devlin

Market Transformation and Intergovernmental
Coordination Manager

John Christensen P.E. (Speaking on behalf of
Pete Devlin)

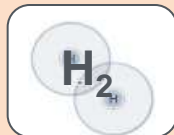
NREL Consultant to DOE

- US DOE Fuel Cell Technologies Program
 - Progress against targets
- Market Transformation Activities
 - Material Handling Equipment Deployments
 - Critical Backup Power Deployments
 - Renewable Hydrogen for Transportation Applications
- DOD/DOE MOU Workshops
- Summary



Energy Storage for Renewable Electricity

Intermittent Renewables
(solar, wind, ocean)



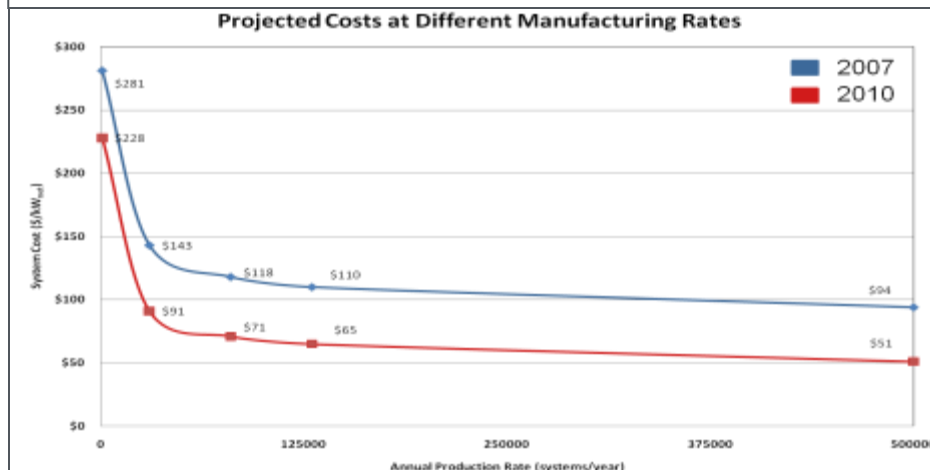
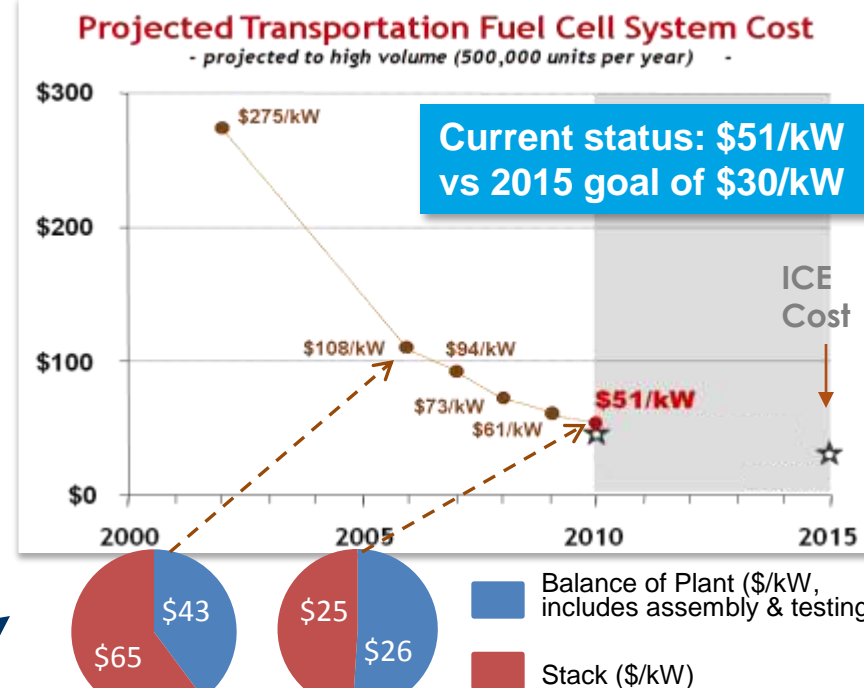
Fuel Cells or Turbines

Grid Power or Distributed Power

Projected high-volume cost of fuel cells has been reduced to \$51/kW (2010)*

- *More than 30% reduction since 2008*
- *More than 80% reduction since 2002*
- *2008 cost projection was validated by independent panel***

As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs.



*Based on projection to high-volume manufacturing (500,000 units/year).

**Panel found \$60 – \$80/kW to be a “valid estimate”:
http://hydrogendoedev.nrel.gov/peer_reviews.html

Deployments

Examples of Early Market Applications

Fuel Cells for Backup Power ...

- Provide longer continuous run-time, greater durability than batteries
- Require less maintenance than batteries or generators
- *May provide substantial cost-savings over batteries and generators*



A 1-kW fuel cell system has been providing power for this FAA radio tower near Chicago for more than three years.

(Photo courtesy of ReliOn)

Fuel Cells for Material Handling Equipment ...

- Allow for rapid refueling — much faster than changing-out or recharging batteries
- Provide constant power without voltage drop
- Eliminate need for space for battery storage and chargers
- *May provide substantial cost-savings over battery-powered forklifts*



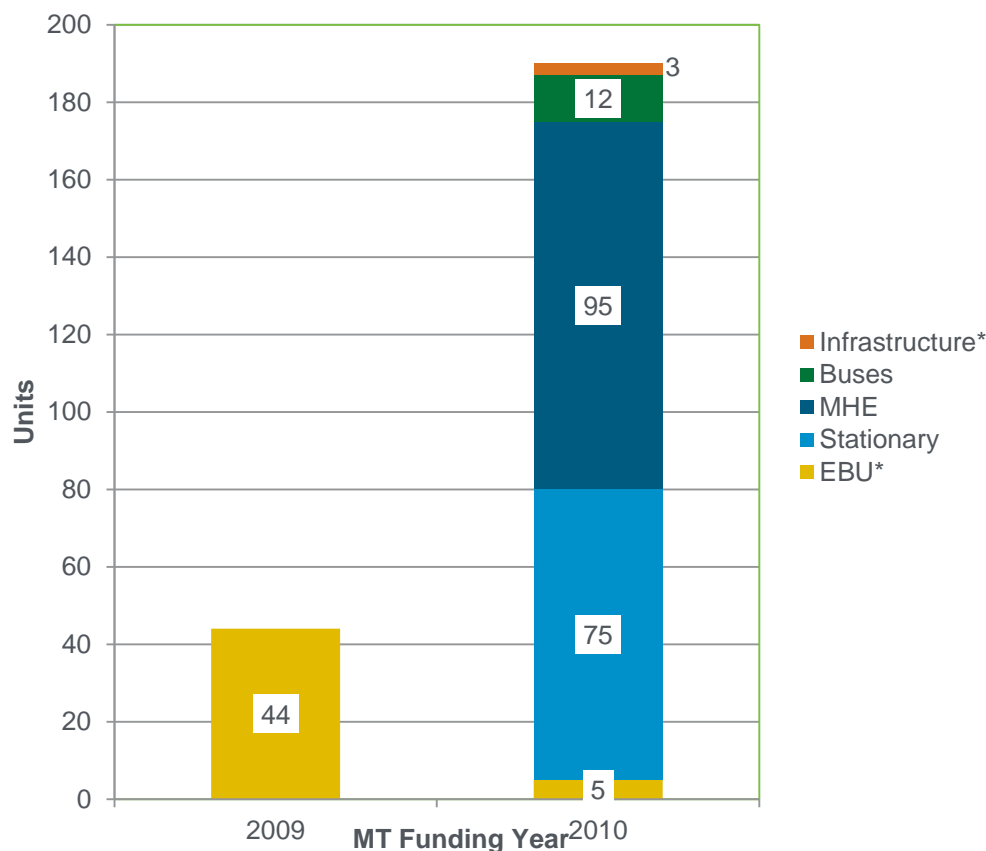
Photo courtesy of Hydrogenics

Fuel Cells for Data Centers ...

- Provide high-quality, reliable, grid-independent on-site critical load power
- Improve the effectiveness of data center power use by 40%, with combined heat-and-power (for cooling and heating)
- Produce no emissions
- Have low O&M requirements
- Can be remotely monitored



Market Transformation Hydrogen and Fuel Cell Deployments*



Total Deployments by Type*

2009 Deployments (\$5 Million)

- 44 EBU Units

2010 Deployment (\$15 Million)

- 5 Mobile Light Stands
- 75 Micro CHP Units
- 95 MHE Units
- 12 HICE Buses
- 1 Electrolyzer
- 1 Mobile Refueler
- 1 Hydrogen Reformer (Landfill Gas)

* Figures include Market Transformation funding only, ARRA and Other are excluded

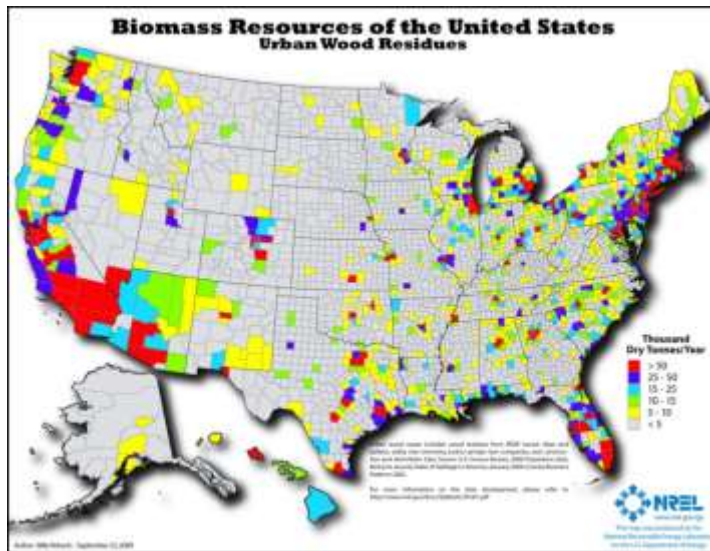
*DOE ARRA Projects Not Included

Waste To Energy Example

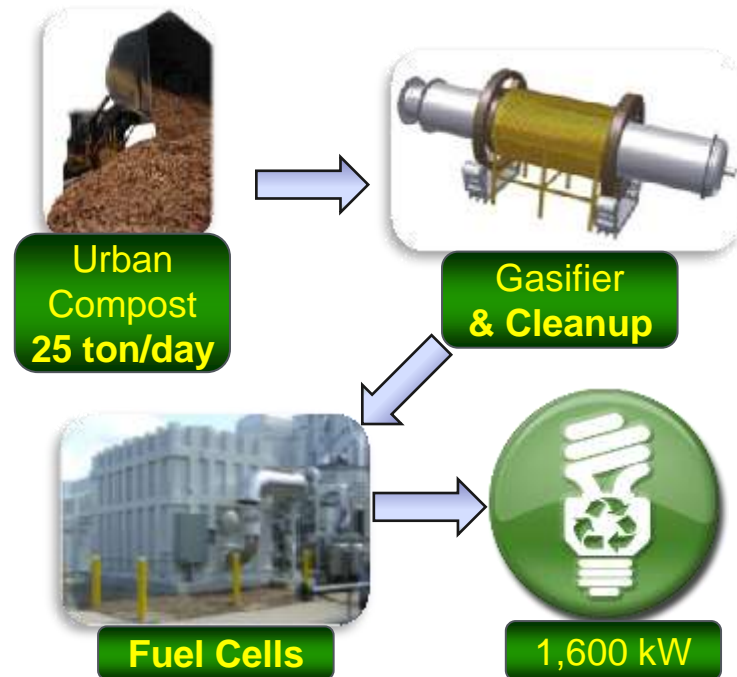
Los Alamitos Joint Forces Training Base (JFTB)



Los Alamitos JFTB



National Renewable Energy Laboratory
Innovation for Our Energy Future



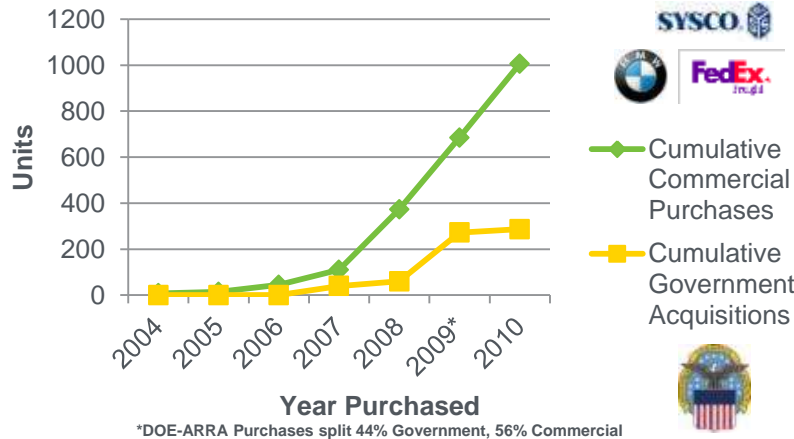
Resource potential for Los Alamitos

- 300 tons/day
- 19,200 kW

Urban wood waste is an abundant feedstock around the US

Government Assistance as a Catalyst for Industry Adoption

Cumulative Fuel Cell MHE Equipment Purchases

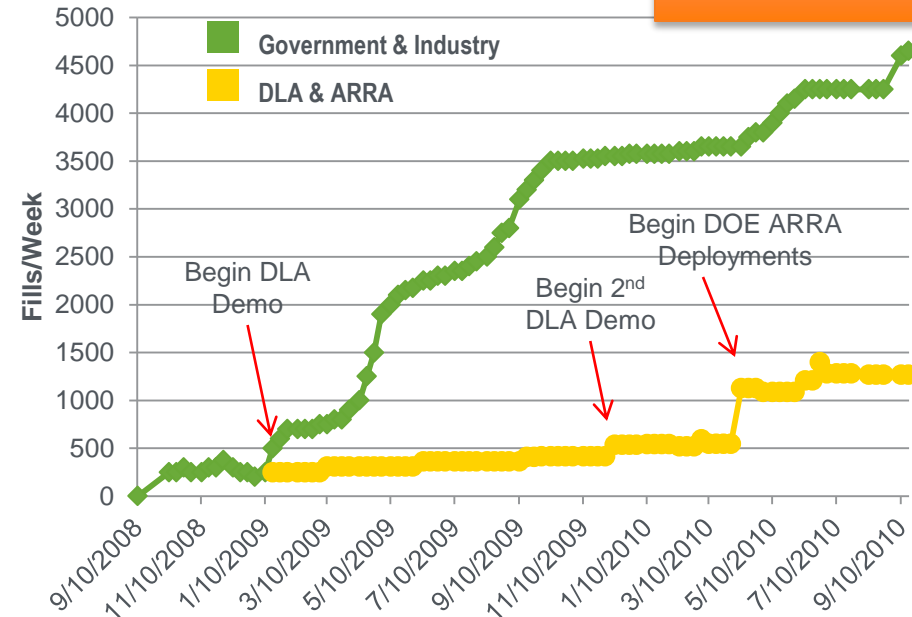


Fuel Cell MHE Market Example

- Early Procurement (2007-2009)
 - DLA began early fuel cell powered forklift procurements, 99 units
 - Multiple OEMs across sites in PA, GA, CA, and WA (Army)
- DOE-ARRA-funded Projects (2009)
 - Received over 50% cost share from industry
- Fully Integrated Fuel Cell Forklifts (2011)
 - Two forklift OEMs have announced plans to design a new class of forklifts around fuel cells

H₂ Refuelings

Today's market increasingly driven by market demand



YR	Commercial Purchases	Cumulative Commercial Purchases	Government Acquisitions	Cumulative Government Acquisitions
2004	8	8	0	0
2005	6	14	0	0
2006	31	45	0	0
2007	65	110	40	40
2008	263	373	20	60
2009*	312	685	212	272
2010	321	1006	15	287

Emerging Market Opportunity

- Value Proposition
 - Quick, easy indoor refills (3-10min)
 - 20-90 min/day for battery charging
 - Consistent power across entire shift
 - 10-20% Labor Productivity Savings



Deployments

- ✓55 at DLA DDSP, Susquehanna, PA
- ✓20 at DLA DDWG, Warner Robins, GA

The Defense Logistics Agency Susquehanna, PA depot has chosen to support full transition from their first adopter fuel cell project. This means purchasing MHE units under firm fixed price contracts.

- Next Steps
 - Program extension beyond demonstration which ends in Feb 2011
 - DDSP will release RFP to purchase 15 additional units

Advantages of Fuel Cells for Backup Power:

1. Provide longer continuous run-time, greater durability than batteries
 - Fuel Cells will last 15 years or more, depending on actual use
2. Require less maintenance than batteries or generators
3. Monitored remotely
4. Nearly 25% reduction in lifecycle costs for a 5-kW, 52-hour backup-power system*



Bundled DOD Multi Site Back-Up Power Project to Reduce Overall Cost of Deployment

Project Details

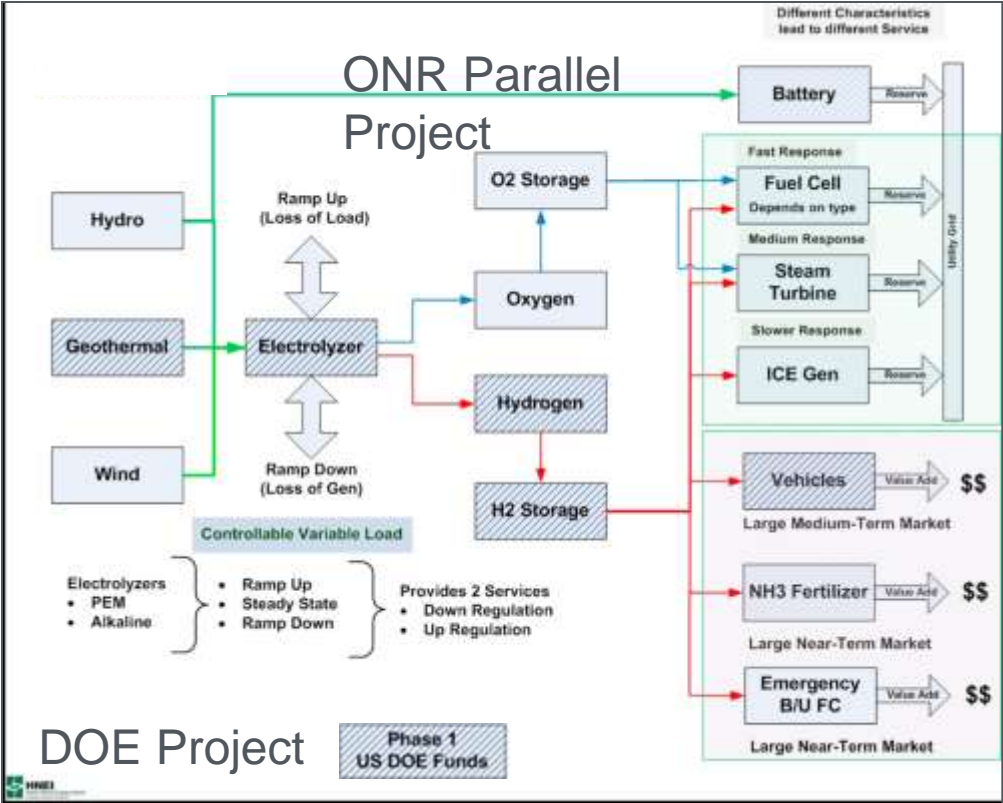
- ✓ 9 Host Sites
- ✓ 20 Separate Buildings
 - ✓ 44 Units
 - ✓ ~220kW

- U.S Army Aberdeen Proving Ground, MD
- U.S. Army Fort Bragg, NC
- U.S. Army Fort Hood TX
- U.S. Army National Guard Ohio
- U.S. Army Picatinny Arsenal , NJ
- NASA Ames Research Center, CA
- USMC AGGC 29 Palms, CA (2 Buildings)
- US Military Academy West Point, NY.
- Cheyenne Mountain Air Station

*SOURCE: Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets, Battelle Memorial Institute, 2007 (www.hydrogenandfuelcells.energy.gov/fc_publications.html)

Grid Integrated Hydrogen Energy System

To help combat large amounts of variable generation from renewable sources a grid integrated hydrogen system is proposed to use hydrogen for energy storage.



- Grid Integrated H₂ Energy System Benefits
- Provide hydrogen fuel to bus companies.
 - Demonstrate electrolyzers as a grid management tool.
 - Ability to respond quickly to increased and decreased loads.

Deploy Hydrogen buses and inform the general public on the benefits of Hydrogen Fuel

- ✓ **USMC Camp Pendleton**
- ✓ **Joint Base Pearl Harbor-Hickam**
- ✓ **Army CERL: Program Manager**



Project Details

- 12 Ford HICE Buses
- 8 Different Sites
- H2 from Renewables
- DOD and Lab Sites, including one University Site
- Emphasis on Outreach
- 1000 + Impressions since 1st deployment in June



- **Next Steps**
 - More Outreach Events planned for all sites (12 Month Outreach Programs)

Enhance Energy Security MOU

The purpose of this MOU is to identify a framework for cooperation and partnership between DOE and DOD to strengthen coordination of efforts to enhance national energy security, and demonstrate Government leadership in transitioning America to a low carbon economy.



Aviation APUs Workshop: 9/30/2010

- To begin discussing collaboration across DOD and DOE in keeping with the MOU
- To motivate RD&D for APU applications

Waste-to-Energy Workshop: 1/13/2011

- To identify DOD-DOE waste-to-energy and fuel cells opportunities
- To identify challenge and determine actions to address them

Shipboard APUs Workshop: 3/29/2011

- Hosted by ONR on March 29th, 2011
- Included USCG and Military Sealift Command

Goal

- **Develop a comprehensive hydrogen and fuel cell approach for aircraft**
- **Including onboard APU, GSE, ground transportation, and mobile lighting**



Boeing 787

Benefits of Fuel Cell APUs

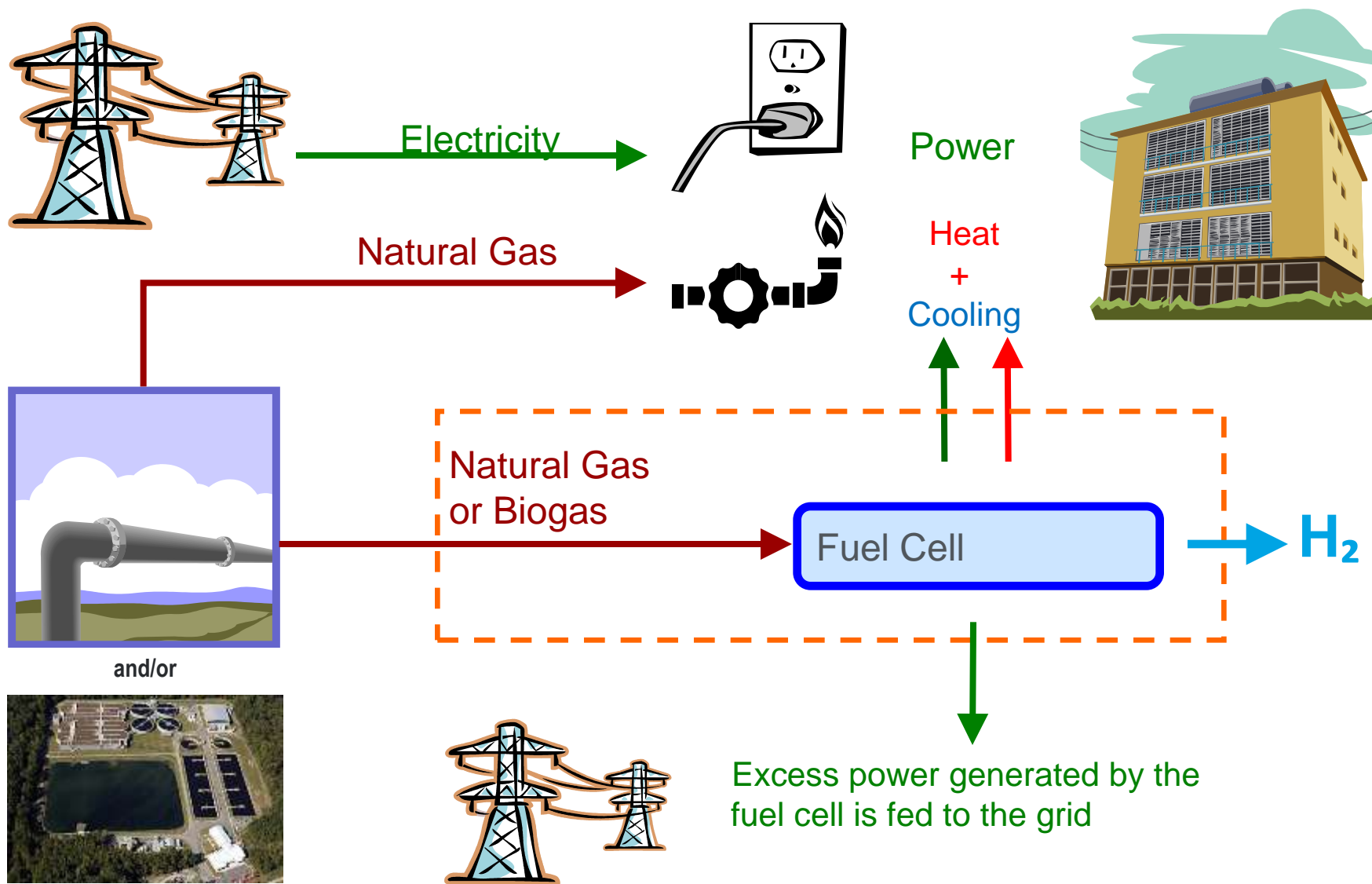
- ✓ Increased efficiency
- ✓ Reduced emissions
- ✓ On-board water generation
- ✓ Combined-heat-and-power opportunities
- ✓ Reduced generator size & weight

This year's focus

- Evaluate APUs size and configurations of fuel cell systems and scenarios.
- Evaluate technologies to provide peak power (PEM, high-temp. PEM, ultra-capacitors, turbines, batteries, etc.)
- Identify and quantify efficiency, cost, and emissions benefits of fuel cells in practice

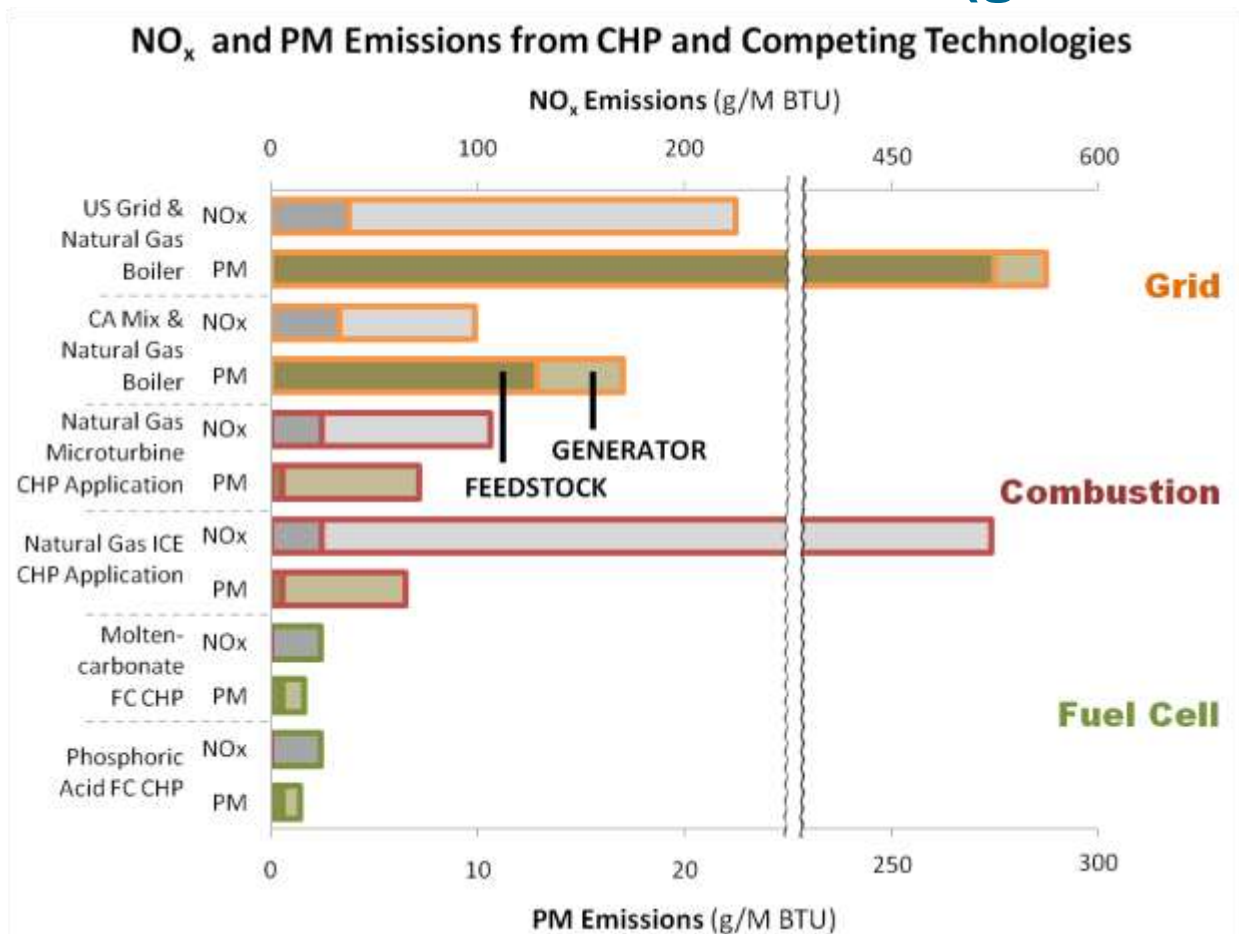
To date

- Aircraft Working Group
- Aircraft APU Workshop
- PNNL/SNL analysis
- Launched SBIR topic
- Issued RFI topic



Stationary fuel cells offer significant reductions in criteria pollutant emissions.

Criteria Pollutant Emissions (g/M BTU)



Criteria Pollutant Emissions from Generating Heat and Power. *Fuel cells emit about 75 – 90% less NO_x and about 75 – 80% less particulate matter (PM) than other CHP technologies, on a life-cycle basis.*

Goal

- Compare LFG-produced hydrogen and delivered hydrogen in “real world” evaluation of MHE equipment.

Landfills generate landfill gas (LFG) from active microorganisms interacting with the waste. This gas can be converted into hydrogen and used to provide energy or fuel, effectively **turning trash into power.**



*BMW Manufacturing site.
Courtesy of Waste Management World*

Landfill Gas to Hydrogen Benefits

- ✓ Reduced emissions
- ✓ Additional power supply
- ✓ Additional vehicle fuel source

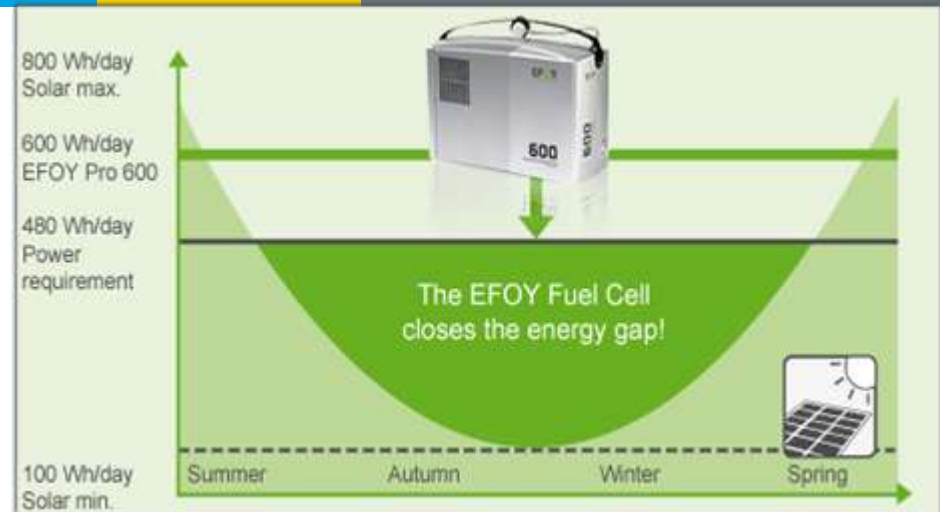
- **Potential Fuel Savings using Shipboard Fuel Cell to replace auxiliary gas turbines**
 - ONR demonstrated 48% efficiency @ 10W/l for molten carbonate ship service fuel cell operating on reformed JP5, and achieved 36W/l power density with improved reformer operating on low sulfur F76, JP5 and JP8.
- **Future Opportunities: Fuel savings for DDG 51 ship class with mechanical drive or hybrid electric drive:**
 - 15% fuel savings from 3-6MW fuel cell install
 - 12K bbls/ship/yr fuel savings
 - 20% fuel svngs. from 3-6MW fuel cell w/hybrid electric drive
 - 16K bbls/ship/yr fuel savings
 - 3.8 – 5.1% Total Maritime Fuel Savings (35 ship installs)
 - Total Maritime Fuel Consumption ~11M bbls/yr
- **Biofuel reforming would improve power density and performance, and help achieve SECNAV energy goals and sail Great Green Fleet in 2016.**



Bomse, Conner, Douglass, Partos, "Shipboard Fuel Cell (SFC) Thrust, CME D0008923.A1/Final", Center for Naval Analysis, Sept 2003

FC Battery Chargers

- Flexibility
- Long run times
- Grid independent
- Quiet
- Light weight
- Reduced down time
- Enables & complements intermittent renewables



FC Soldier Power

- Light weight
- Efficient
- Quiet
- Low heat
- Design flexibility

Battery Power Alone

Total weight = 9.5 kg (20.9 lb)



DMFC Battery Hybrid

Total weight = 2.73 kg (6 lb)



72 hour mission example

Thank you

For more information, please contact

Pete Devlin

peter.devlin@ee.doe.gov

hydrogenandfuelcells.energy.gov

Back Up

Combining modern PEM fuel cells and high efficiency plasma lighting, fuel cell mobile lighting provides superior performance.



Fuel Cell Mobile Light used at 2011 Golden Globe Awards (courtesy of SNL)

Benefits of Fuel Cell Mobile Lighting

- ✓ 40 hour duration (lighting)
- ✓ 3 kW of AC power available
- ✓ Illuminates 50 yds x 75 yds
- ✓ Suitable for indoor/outdoor use
- ✓ Very quiet! 43 dB noise level at 23 ft

Next Steps

- Real World deployments at SFO, State DOT (CA, CT), and the entertainment industry
- Publicize and further commercialize
- Continue to improve technology

Fuel Cells for MHE using bio-methanol will have lower infrastructure costs.

Project Details

- ✓ 75 units
- ✓ 4 locations
- ✓ Engage Key Industry Stakeholders:
Nissan



• **Next Steps**

- Gather material handling equipment (MHE) performance data.
- “Real world” evaluation and testing of equipment.

Emerging Market Opportunity

- Combined Heat and Power and Combined Heat Hydrogen and Power
 - Efficiencies from 75% to over 85%
 - Multiple fuel sources (e.g. natural gas, biogas)

Verizon Case Study

- Project Details and Results
 - 1.4MW CHP system
 - Natural gas supplied
 - 97% Availability since mid 2005
 - Near 100% reduction in CO₂, NO_x, and SO_x
 - Applied to critical prime power functions
 - Avg. total electrical loads of 2.5MW
 - 292,000 sq-ft facility



Photo credit: Verizon Communications.

During the cooling season, the high-grade waste heat from the fuel cells is used by two lithium bromide absorption chillers, contributing about 33% of the energy required for cooling.

The Food Industry is an emerging market for stationary fuel cells



Announced Supermarket Deployments: Nine Sites Include

- **Whole Foods**
 - 3 sites
- **Price Chopper**
 - 3 sites
- **SUPERVALU(Albertsons/Shaws)**
 - 2 sites
- **Ahold (Stop & Shop)**
 - 1 site

• Completed Food Producer Deployments:

- **Coca-Cola (800 kW)** – another 800 kW under construction
- **Gills Onions (600 kW)**
- **Pepperidge Farms (1.45 MW)**
- **Sierra Nevada Brewery (1 MW)**

- “**Green Communities**” Goal – To leverage
 - residential, mixed-use, light commercial, municipal or state sites that have committed to mitigating their environmental impact.



- identify communities that have adopted energy efficiency and conservation plans that are capable of leveraging their existing or planned investments with the deployment of hydrogen and fuel cells systems.

Potential Projects

Community requires system capable of integrating with existing renewable energy generators to produce hydrogen to fuel new fuel cell bus fleet

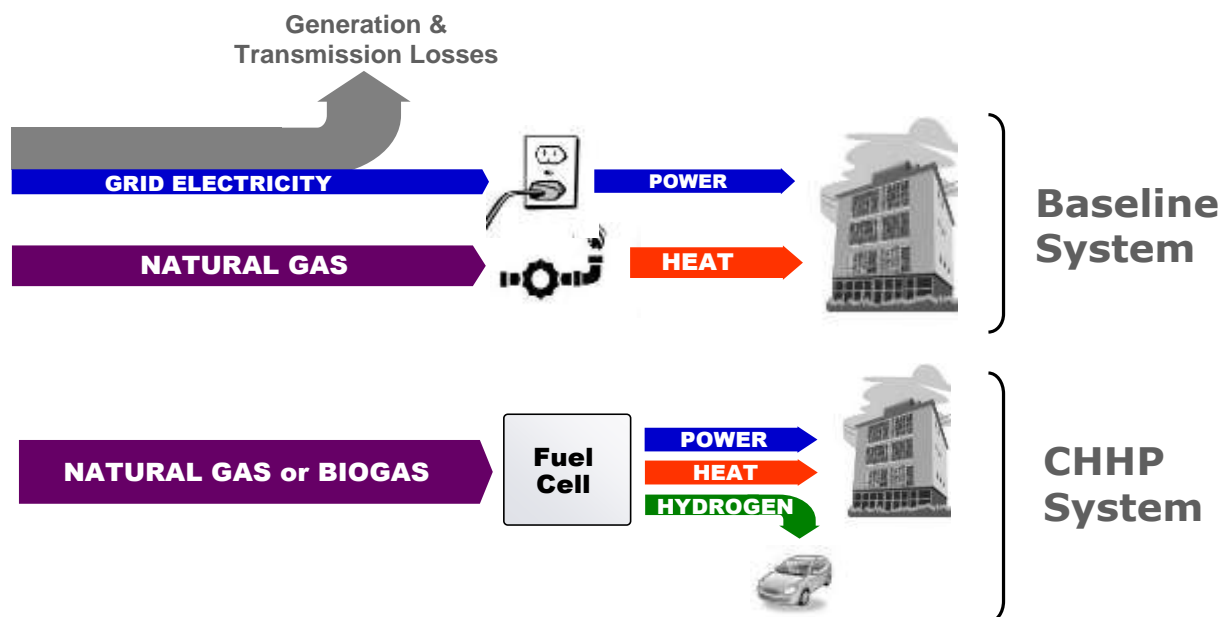
Fuel cell co-generation plant could provide sufficient electric power and heat to meet community's requirements and help achieve energy efficiency and GHG emissions goals adopted by community.

Installation of electrolyzer would allow community to store and sell excess renewable energy production, generating a new revenue stream and fully utilizing renewable resources.

We are participating in a project to demonstrate a combined heat, hydrogen, and power (CHHP) system using biogas.

- System has been designed, fabricated and shop-tested.
- Improvements in design have led to higher H₂-recovery (from 75% to >85%).
- On-site operation and data-collection planned for FY09 – FY10.

Tri-Generation (CHHP) Concept



Combined heat, hydrogen, and power systems can:

- Produce clean power and fuel for multiple applications
- Provide a potential approach to establishing an initial fueling infrastructure