FUPWG ★ October 25-26 2011 Philadelphia, PA

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Hydrogen and Fuel Cell Activities

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Stationary Fuel Cell Applications

Variety of stationary fuel cell applications highlight positive market potential.

Assured Power

First National Bank of Omaha
Omaha, Nebraska

On-Line Critical Power

Verizon
Garden City, New York

Renewable Fuel (ADG)

Wastewater treatment plants
New York, New York

Off-Grid Power

Central Park Police Station,
New York, New York

Indoor Green Power / Cogeneration

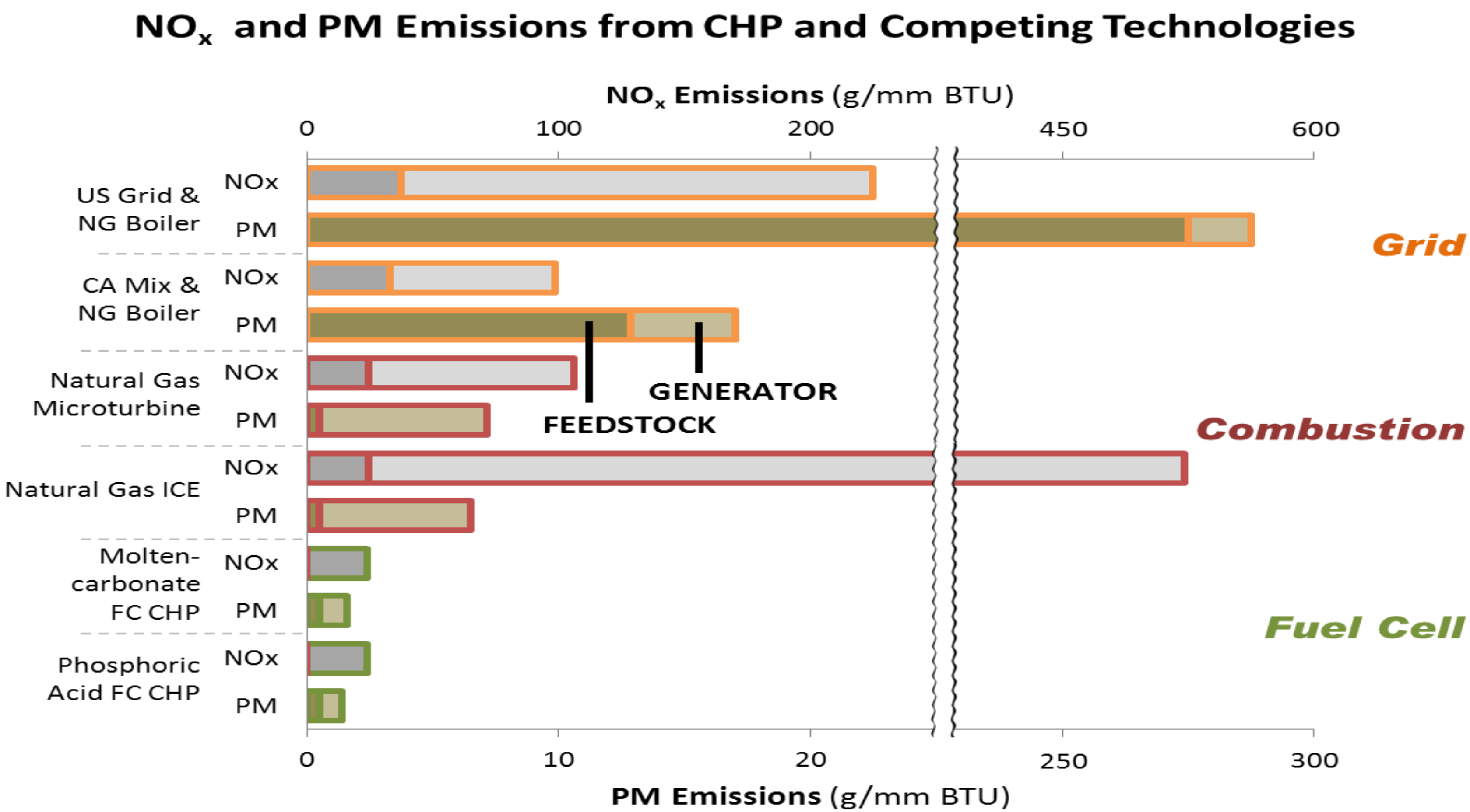
4 Times Square
New York, New York

Data Centers Are A Good Fit

Multiple Uses for FC Energy Streams

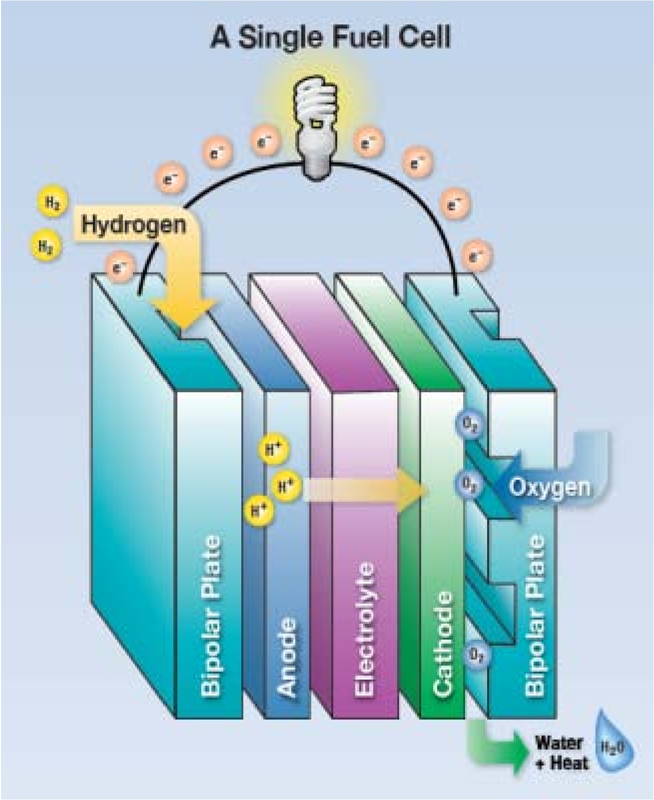
- Power
  - Lighting
  - Air conditioning
- Thermal Energy
  - Adsorption A/C
    - Supplements electric chillers
      - Thermal reduces electricity consumption
      - Reduces grid CO_2 generation
  - Space and water heating
  - Desiccant dehumidification

Potential Reduction in Emissions



Criteria Pollutant Emissions from Generating Heat and Power. ***Fuel cells emit about 75 – 90% less NOx and about 75 – 80% less particulate matter (PM) than other CHP technologies, on a life-cycle basis. In addition, similar to other CHP technologies, fuel cells can provide more than 50% reduction in CO_2 emissions, when compared with the national grid.***

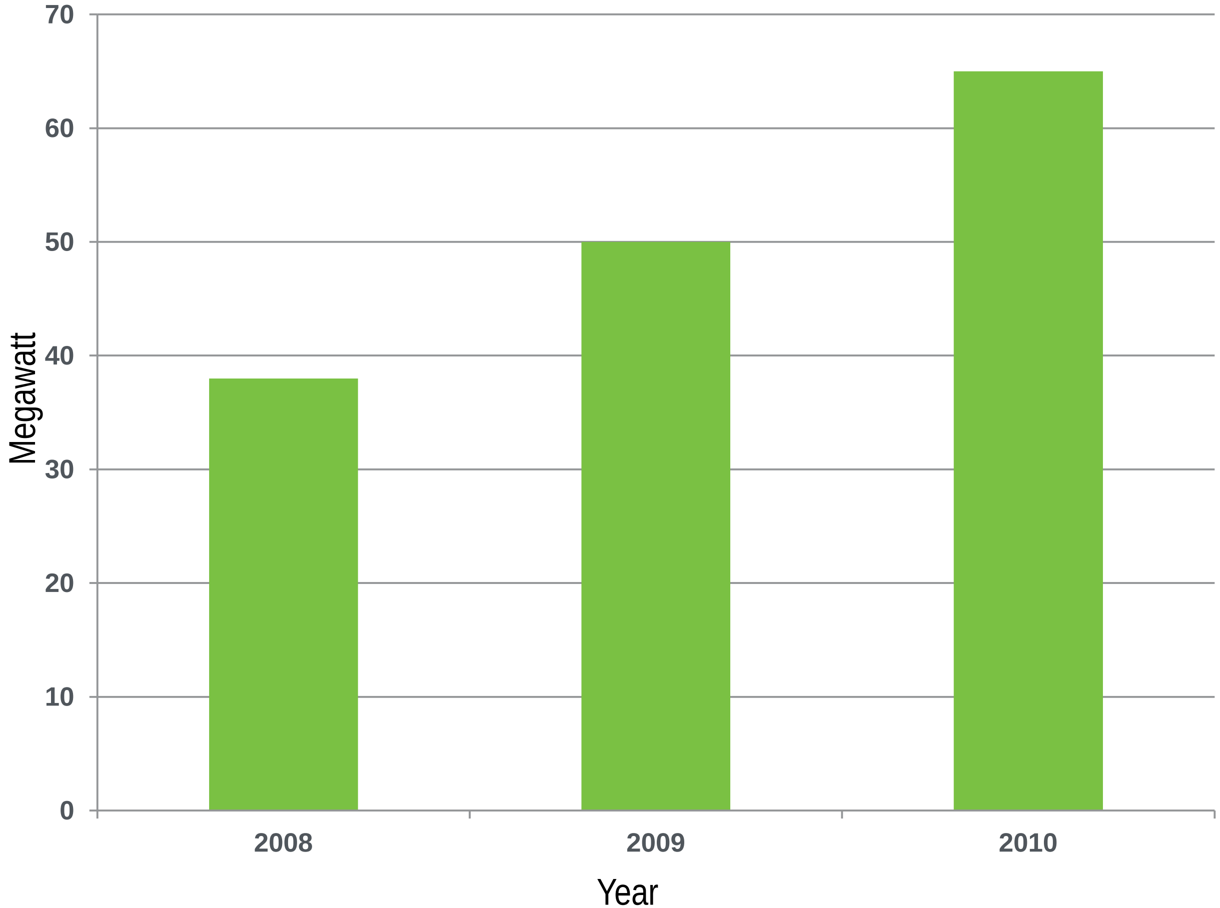
Fuel cells use an efficient electrochemical process to generate electricity and heat, with low or zero emissions, offering benefits in a wide range of applications.



Types of Fuel Cells

- Polymer Electrolyte Membrane (PEMFC)
  - *Pros:* Low-temperature operation, quick start, and high power density
  - *Cons:* Expensive catalysts
  - *Applications:* Stationary generation, specialty vehicles, transportation, portable power
- Phosphoric Acid Fuel Cell (PAFC)
  - *Pros:* Low-temperature operation and high efficiency
  - *Cons:* Low current and power density
  - *Applications:* Distributed generation
- Alkaline Fuel Cell (AFC)
  - *Pros:* Low temperature operation and high efficiency
  - *Cons:* Expensive impurity removal
  - *Applications:* Military and space
- Solid Oxide Fuel Cell (SOFC)
  - *Pros:* High efficiency, multiple fuel feedstocks, usable waste heat, and inexpensive catalysts
  - *Cons:* Slow start-up and corrosion issues
  - *Applications:* Auxiliary Power Units (APUs) and distributed generation
- Molten Carbonate Fuel Cell (MCFC)
  - *Pros:* High efficiency, multiple fuel feedstocks, and usable waste heat
  - *Cons:* Slow start-up and corrosion issues
  - *Applications:* Electric utility

Total Megawatts Shipped Worldwide for Stationary Fuel Cells*



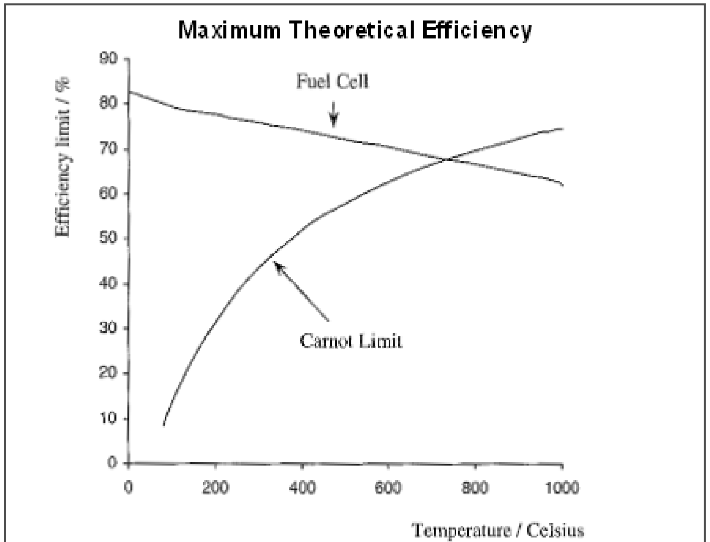
Source: 2011 Pike Research

Preliminary Analysis

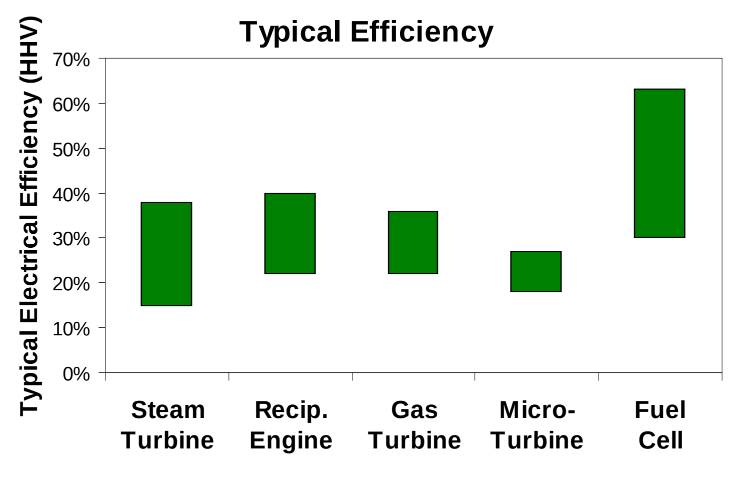
Fuel Cells vs. Combustion

Fuel cells are not heat engines, so their efficiency can exceed the Carnot efficiency

Conventional engines and turbines convert chemical energy into thermal energy prior to conversion to electrical energy. The efficiency of converting thermal energy to electrical energy is bounded by the Carnot efficiency.



Adapted from Larminie and Dicks, Fuel Cell Systems Explained, 2000



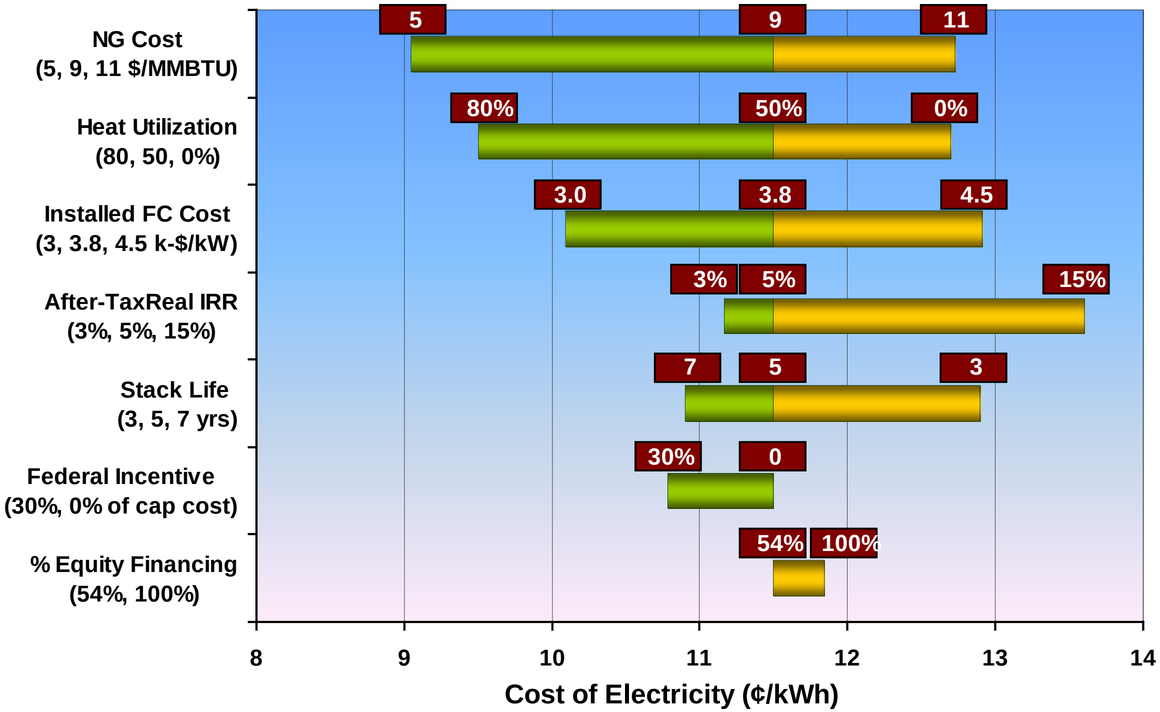
Fuel cells convert chemical energy directly into electrical energy, bypassing inefficiencies associated with thermal energy conversion. The available energy is equal to the Gibbs free energy.

Source: EPA, Catalog of CHP Technologies, December 2008

Stationary Fuel Cells – Cost Analysis

Analysis efforts are underway, to provide information on potential costs and benefits of a variety of stationary fuel cell applications.

Example: Cost of Electricity from Commercial-Scale Stationary Fuel Cell



Performance Parameters

System Electric Efficiency	= 45% (LHV Basis)
System Total Efficiency	= 77% (LHV Basis)
System Size	= 1,400 kW
System Life	= 20 years
Capital cost	= $3.5 million
Installed cost	= $5.3 million

Financial Assumptions

Startup year	= 2010
Financing	= 54% equity
Interest rate	= 7%
Financing period	= 20 years
After-tax Real IRR	= 5%
Inflation rate	= 1.9%
Total tax rates	= 38.9%
Depreciation schedule	= 7 years (MACRS)
Payback period	= 11 years

Stack replacement cost distributed annually

Operation Assumptions

System utilization factor	= 95%
Restacking cost	= 30% of installed cap. cost
Heat value	= cost of displaced natural gas from 80% efficient device

Source: NREL Fuel Cell Power Model

Example for MCFC 1.4 MW

Assessing the Potential for Micro CHP

Inexpensive Natural Gas

Natural Gas Cost ($/kWh)	
WYOMING	$ 0.029
ALASKA	$ 0.030
UTAH	$ 0.032
COLORADO	$ 0.035
MONTANA	$ 0.038
NORTH DAKOTA	$ 0.039
IDAHO	$ 0.040
SOUTH DAKOTA	$ 0.040
NEW MEXICO	$ 0.042
CALIFORNIA	$ 0.042

Price of electricity

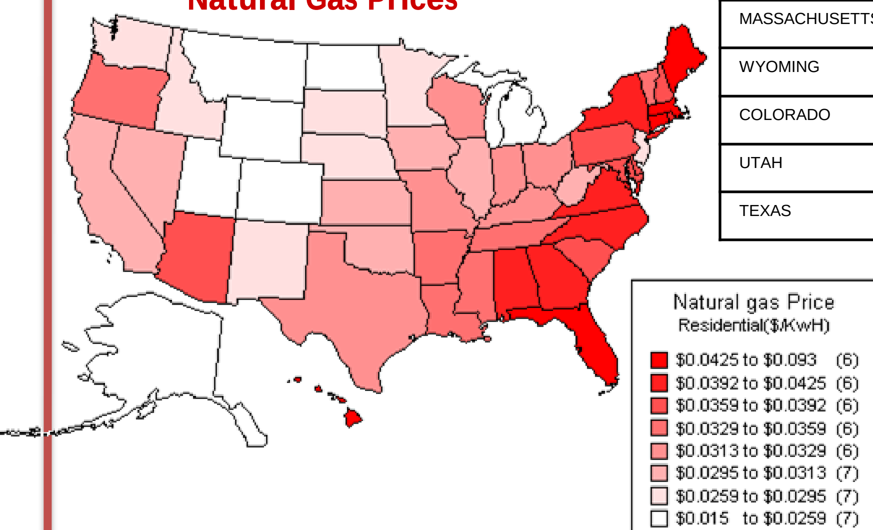
Price of natural gas

Expensive Electricity

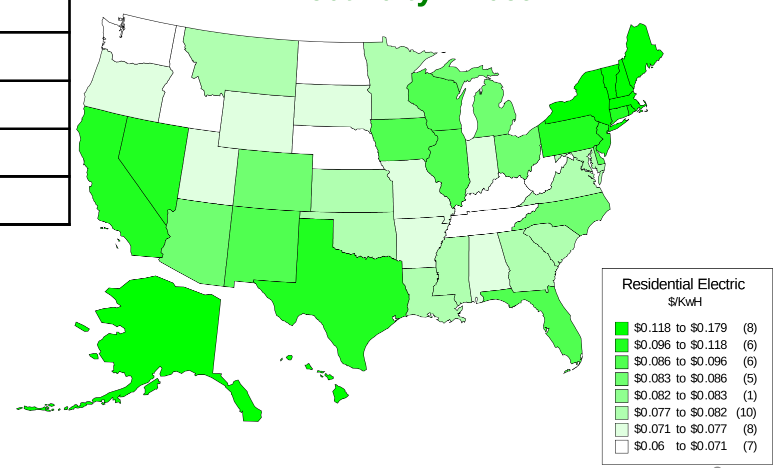
Electricity Cost ($/kWh)	
HAWAII	$ 0.235
CONNECTICUT	$ 0.194
NEW YORK	$ 0.181
MASSACHUSETTS	$ 0.165
NEW JERSEY	$ 0.159
ALASKA	$ 0.153
MAINE	$ 0.151
NEW HAMPSHIRE	$ 0.150
CALIFORNIA	$ 0.146
VERMONT	$ 0.146

Energy Price Ratio	
ALASKA	5.03
CALIFORNIA	3.47
CONNECTICUT	3.33
NEW YORK	3.23
NEW JERSEY	3.03
MASSACHUSETTS	2.88
WYOMING	2.80
COLORADO	2.75
UTAH	2.70
TEXAS	2.68

Natural Gas Prices



Electricity Prices



CERL Emergency Backup Deployments

- Objectives, Goals, and Background of Joint Efforts
  - Bundle emergency backup power needs across multiple DOD and NASA sites to realize price reductions on a per site basis to demonstrate the advantages of fuel cells over incumbent technologies, which include:
    - Longer continuous run-time and greater durability than batteries (fuel cells will last 15 years or more, depending on actual use)
    - Require less maintenance than batteries or generators
    - Monitored remotely
    - Nearly 25% reduction in lifecycle costs for a 5-kW, 52-hour backup-power system**
  - Project funded by DOE and managed by Army CERL.
- Results to Date
  - Project awarded, installations will roll out over the next 12 months across 9 sites and installing over 40 units producing over 220kW of power,
- Next Steps
  - Collect operation data to facilitate future bundled deployments.

<u>9 Sites Chosen</u>:

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

Micro CHP

MicroCHP costs are becoming competitive with grid power and ROIs are estimated at under 5 yrs. Deployments will target areas where a business case can be made with pay back periods which meet industry needs.

Project Details

✓ Up to 50 units

✓ 5 kW units

✓ Prove business case for MicroCHP applications

- Next Steps
  - Review proposals and make awards
  - Gather material performance data.
  - “Real world” evaluation operations and testing of equipment.

Micro-CHP Targets

Targets developed with input from stakeholders and the research community cost and durability are the major challenges

Table 3.4.5 Technical Targets : 1–10 kW_e Residential Combined Heat and Power and Distributed Generation Fuel Cell Systems Operating on Natural Gas			
Characteristic	**2011 Status**	**2015 Targets**	**2020 Targets**
Electrical efficiency at rated power [b]	34-40%	42.5%	>45%[c]
CHP energy efficiency[d]	80-90%	87.5%	90%
Equipment cost[e], 2-kW_{avg}[f] system	NA	\$1,200/kW_{avg}	\$1,000/kW_{avg}
Equipment cost[e], 5-kW_{avg} system	\$2,300-4,000/kW[g]	\$1,700/kW_{avg}	\$1,500/kW_{avg}
Equipment cost[e], 10-kW_{avg} system	NA	\$1,900/kW_{avg}	\$1,700/kW_{avg}
Transient response (10 - 90% rated power)	5 min	3 min	2 min
Start-up time from 20°C ambient temperature	<30 min	30 min	20 min
Degradation with cycling[h]	<2%/1000 h	0.5%/1000 h	0.3%/1000 h
Operating lifetime[i]	12,000 h	40,000 h	60,000 h
System availability[j]	97%	98%	99%

2010 Independent Assessment of CHP Fuel Cell Status & Targets

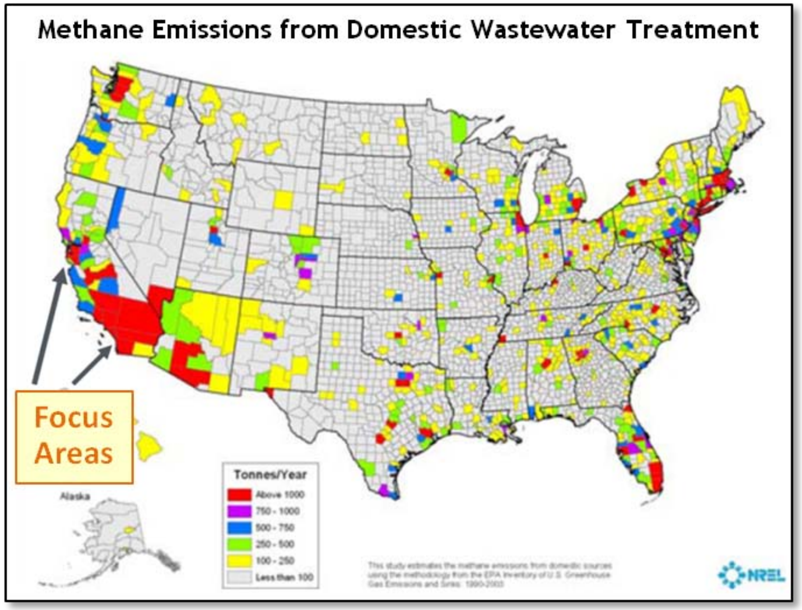
- **Confident that by 2015, LT-PEM & HT-PEM can achieve 40,000 hr**
- **45% electrical efficiency (2020 target) for 1-10kW systems is feasible for HT-PEM, LT-PEM depends on improved catalysts & higher operating temps**
- **SOFT systems are likely to achieve DOE targets for electrical and CHP efficiencies. 90% CHP efficiency is likely to be attainable by SOFC systems.**
- **Confident that by 2020, LT-PEM & HT-PEM can achieve \$450-\$750/kW, while SOFC can achieve \$1000-2000/kW**

Background: Biogas as an Early Source of Renewable Hydrogen

- ***The majority of biogas resources are situated near large urban centers—ideally located near the major demand centers for hydrogen for FCEVs.***
- ***Hydrogen can be produced from this renewable resource using existing steam-methane-reforming technology.***

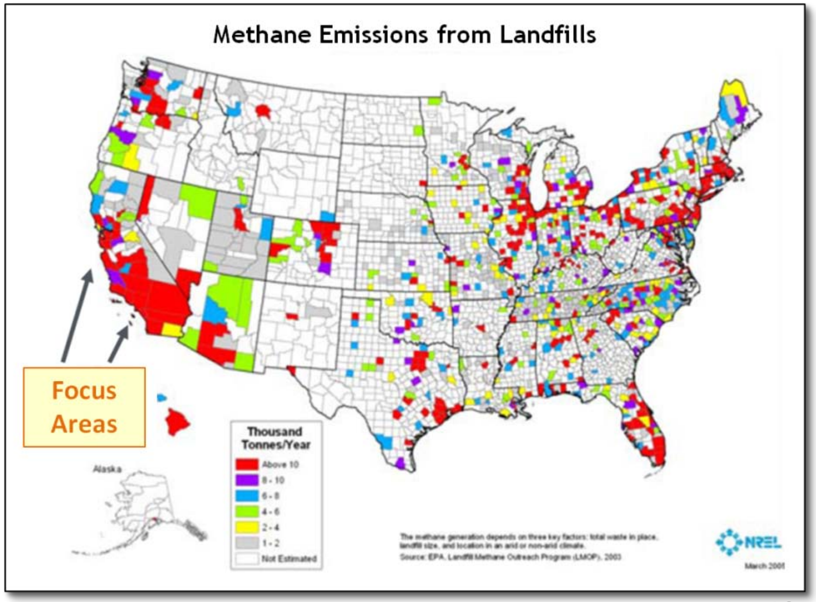
SOURCE: Wastewater Treatment, *could provide enough H_2 to refuel **100,000 vehicles per day.***

- 500,000 MT per year of methane is available from wastewater treatment plants in the U.S.
- ~50% of this resource could provide **~340,000 kg/day** of hydrogen.



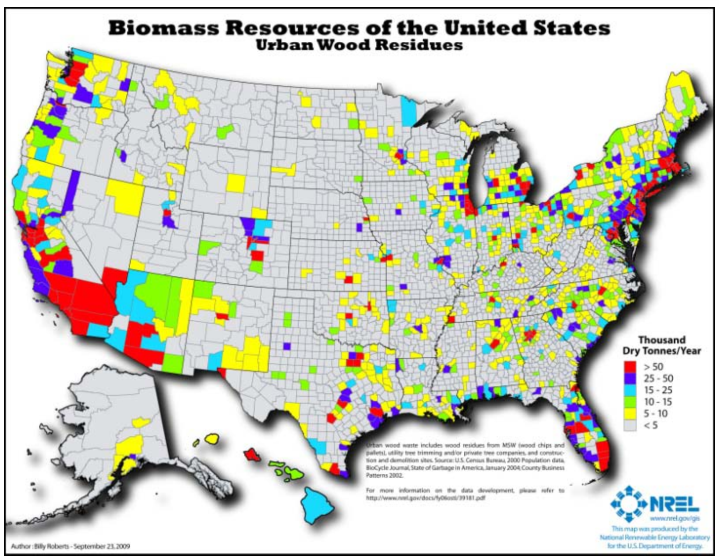
SOURCE: Landfills, *could provide enough H_2 to refuel **2–3 million vehicles/day**.*

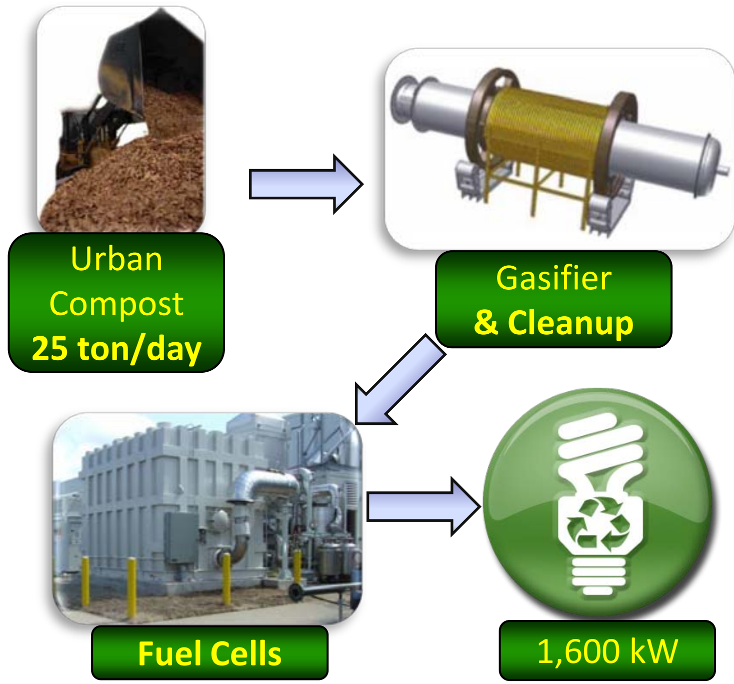
- 12.4 million MT per year of methane is available from landfills in the U.S.
- ~50% of this resource could provide **~8 million kg/day** of hydrogen**.**



Waste To Energy Example

Los Alamitos JFTB



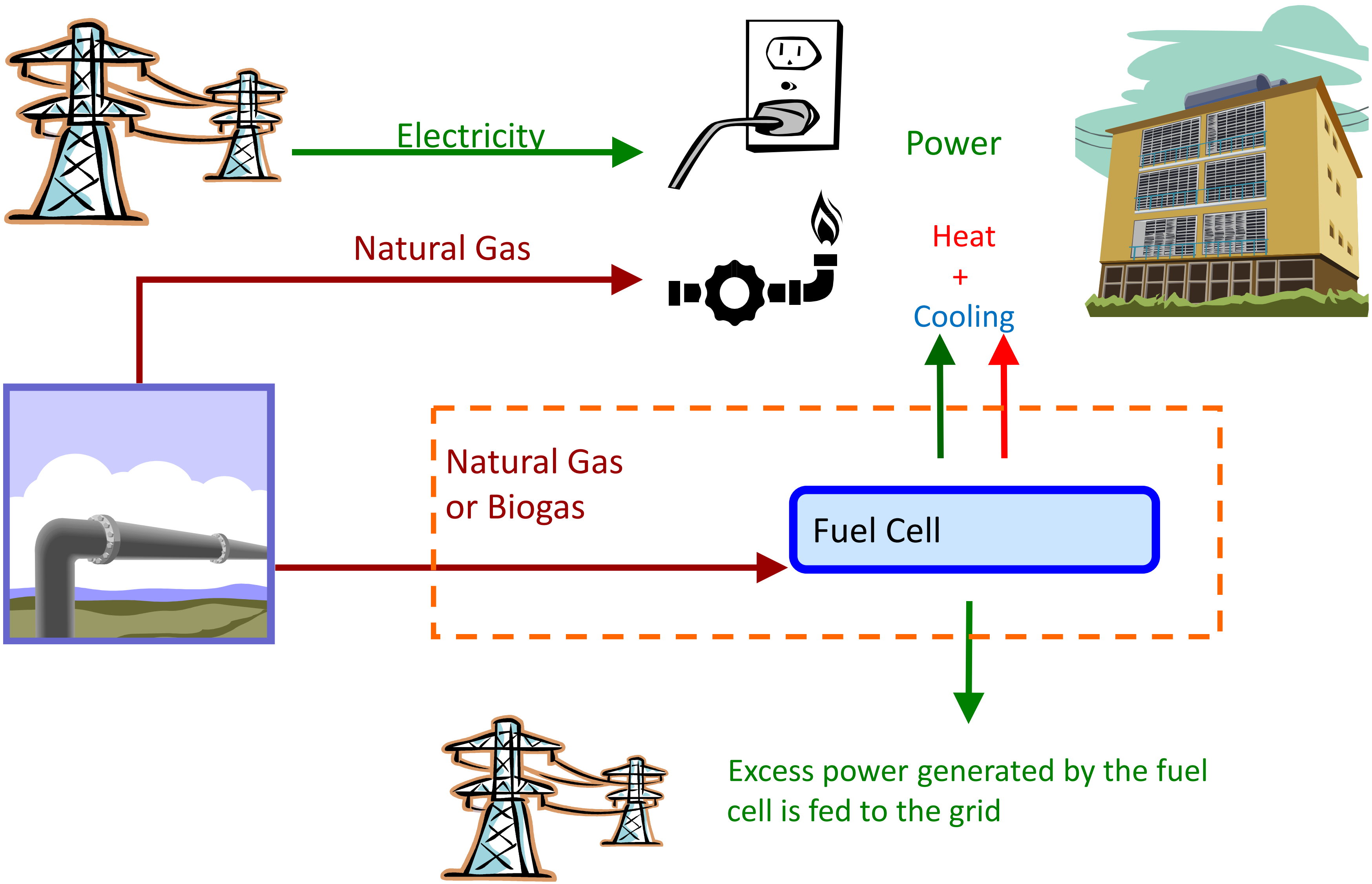


Resource potential for Los Alamitos

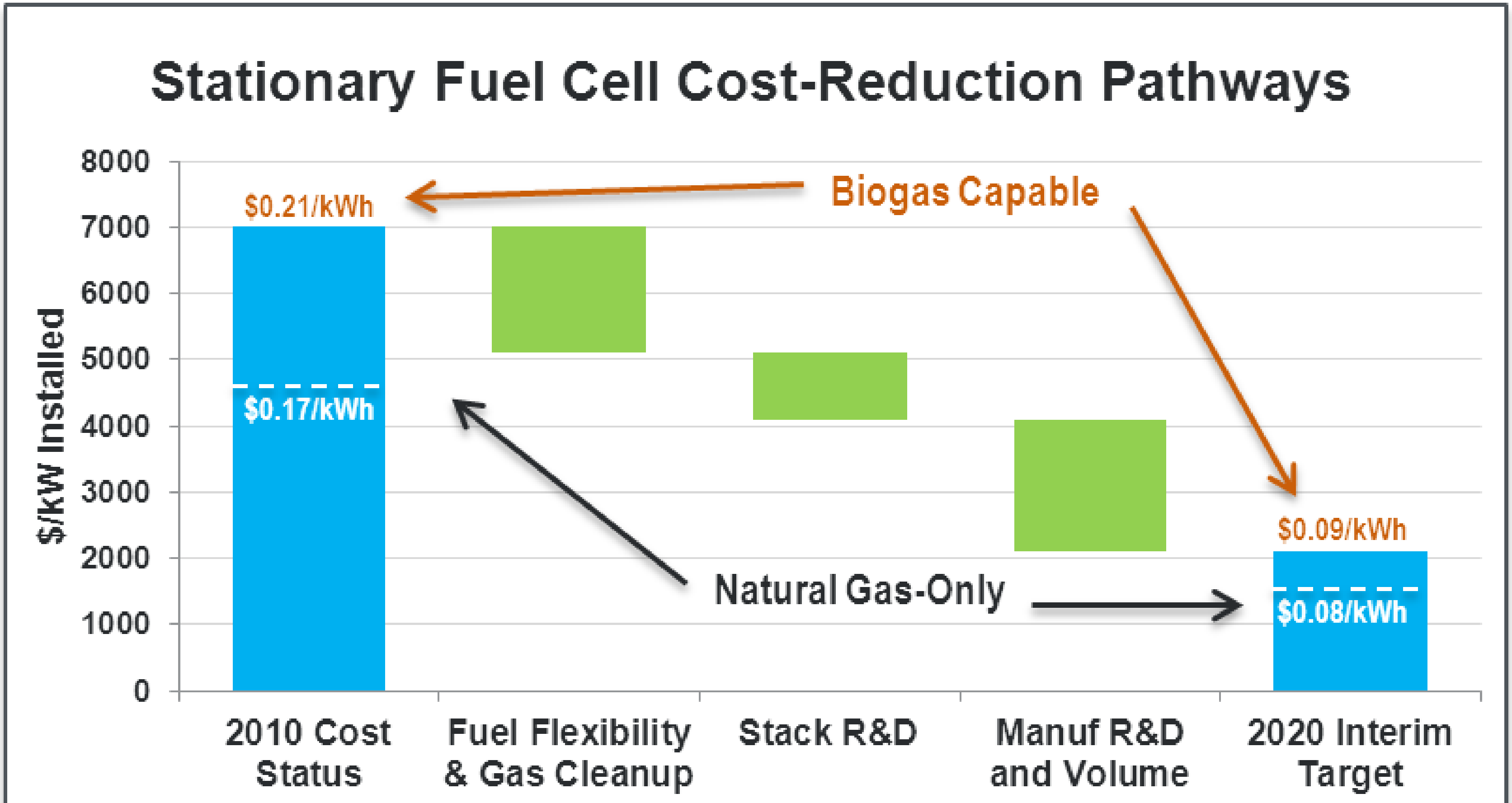
- 300 tons/day
- 19,200 kW

Urban wood waste is an abundant feedstock around the US

Overview of Combined Heat-Power



Cost Goals for Fuel Cell R&D – Stationary Fuel Cell Cost-Reduction



Federal Policies Promoting Fuel Cells

Grants for Energy Property in Lieu of Tax Credits*	**Grant instead of claiming the Investment Tax Credit or Production Tax Credit. Only entities that pay taxes are eligible.**	**Construction must begin by expiration date, 12/31/2011.**
Residential Renewable Energy Credit	**30% tax credit. Raises ITC dollar cap for residential fuel cells in joint occupancy dwellings to $3,334/kW.**	**Expires Dec. 31, 2016.**
Investment Tax Credit	**30% tax credit for qualified fuel cell property or $3,000/kW of the fuel cell nameplate capacity. 10% credit for CHP-system property.**	**Equipment must be installed by Dec. 31, 2016.**
Alternative Fuel Infrastructure Tax Credit	**30% of expenditures.**	**Expires 2/31/2014.**

Fuel Cell Motor Vehicle Tax Credit: $4,000 for LDV, $10,000-$40,000 range for heavier vehicles. Expires 12/31/2014.

Hydrogen Fuel Excise Tax Credit: $0.50/gallon. Hydrogen must be sold or used as a fuel to operate a motor vehicle. Expires 9/30/2014.

Alternative Fuel Infrastructure Tax Credit: $1,000 cap for residential use.

Residential Renewable Energy Credit: Fuel Cell maximum - $500/0.5kW. Fuel cells must have electricity-only generation efficiency greater than 50% and 0.5kW minimum.

Residential Renewable Energy Credit: 30% tax credit. Raises ITC dollar cap for residential fuel cells in joint occupancy dwellings to $3,334/kW. Expires 12/31/2016.

State Policies Promoting Fuel Cells

CA's Self-Generation Incentive Program (SGIP) extends the current program for three year to 2014. SGIP provides a total of $249M of support for CHP, wind energy, waste heat recovery, and energy storage projects in CA, with in-state manufacturers getting a 20% additional incentive credit.

- CHP is eligible for $0.50/W in capital cost incentives.
- Stationary fuel cells will receive $2.25/W.
- Energy storage projects receive $2.00/W.
- Biogas fueled projects received $2.00/W bonus.

Connecticut offers 100% tax exemption for Class I renewable energy systems. An exemption claim must be filed before November 1 of each applicable year.

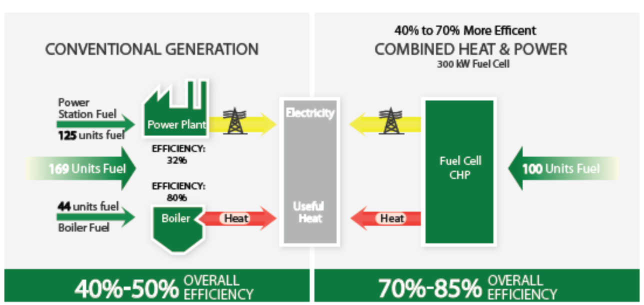
Since 2007, South Carolina offers a 100% sales tax exemption on equipment used to produce or research hydrogen fuel cells.

Ohio's Qualified Energy Property Tax Exemption, passed in 2010 allows for 100% property tax exemption for fuel cell systems <250kW as well as those systems >250kW, though payment in lieu of tax is required.

Procurement Guide

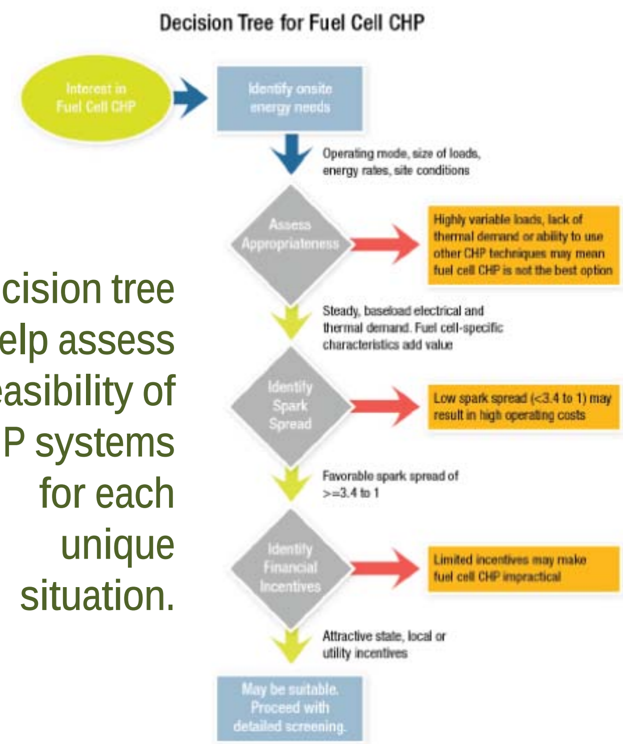
This document is intended to provide federal agencies with initial guidance on how to procure energy from fuel cell combined heat and power (CHP) technology. This document is based on best practices and the experience of agency personnel and laboratory and industry collaborators.

Provides clear guidance on CHP technology – its benefits, ideal usage, and financing options.

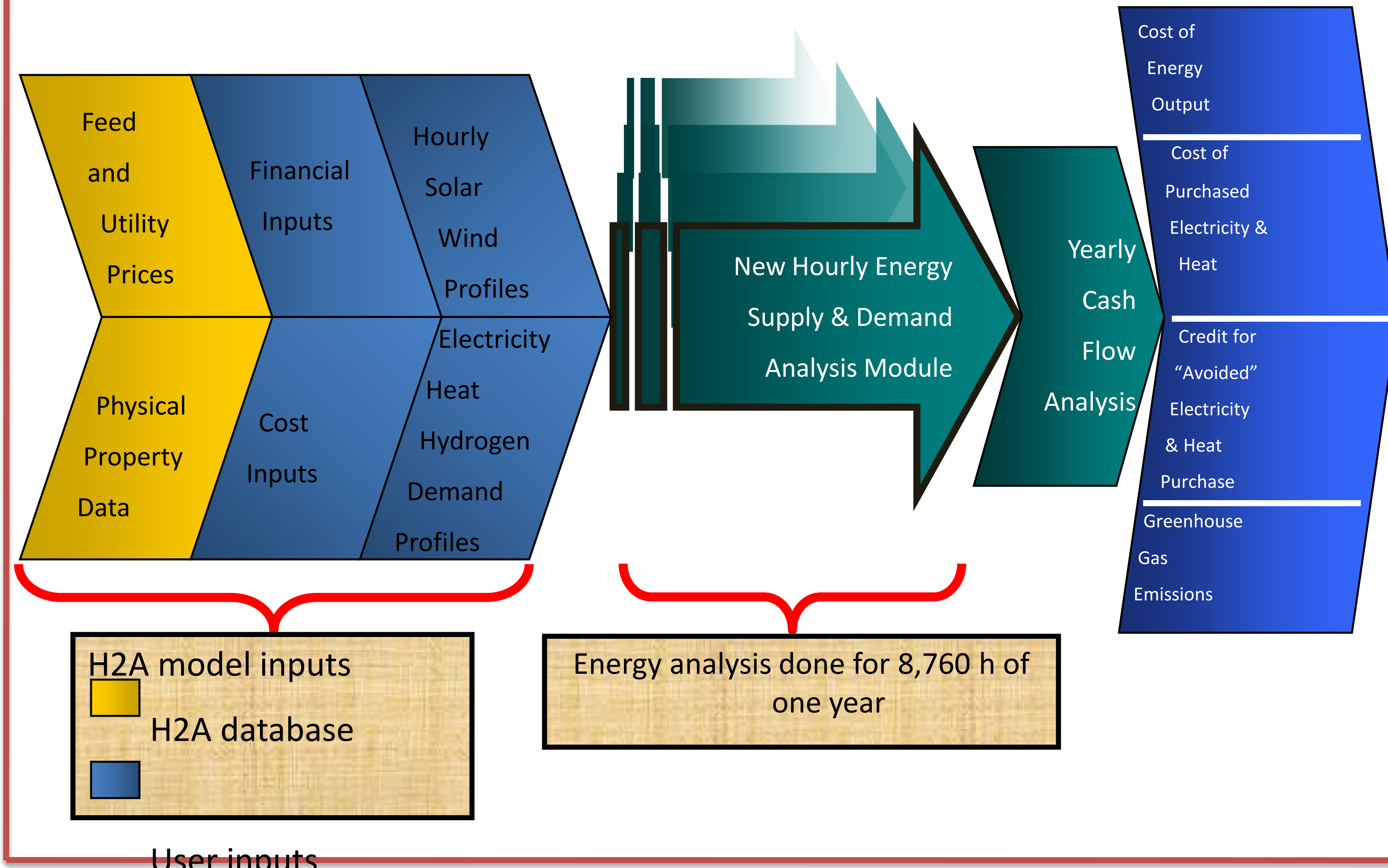


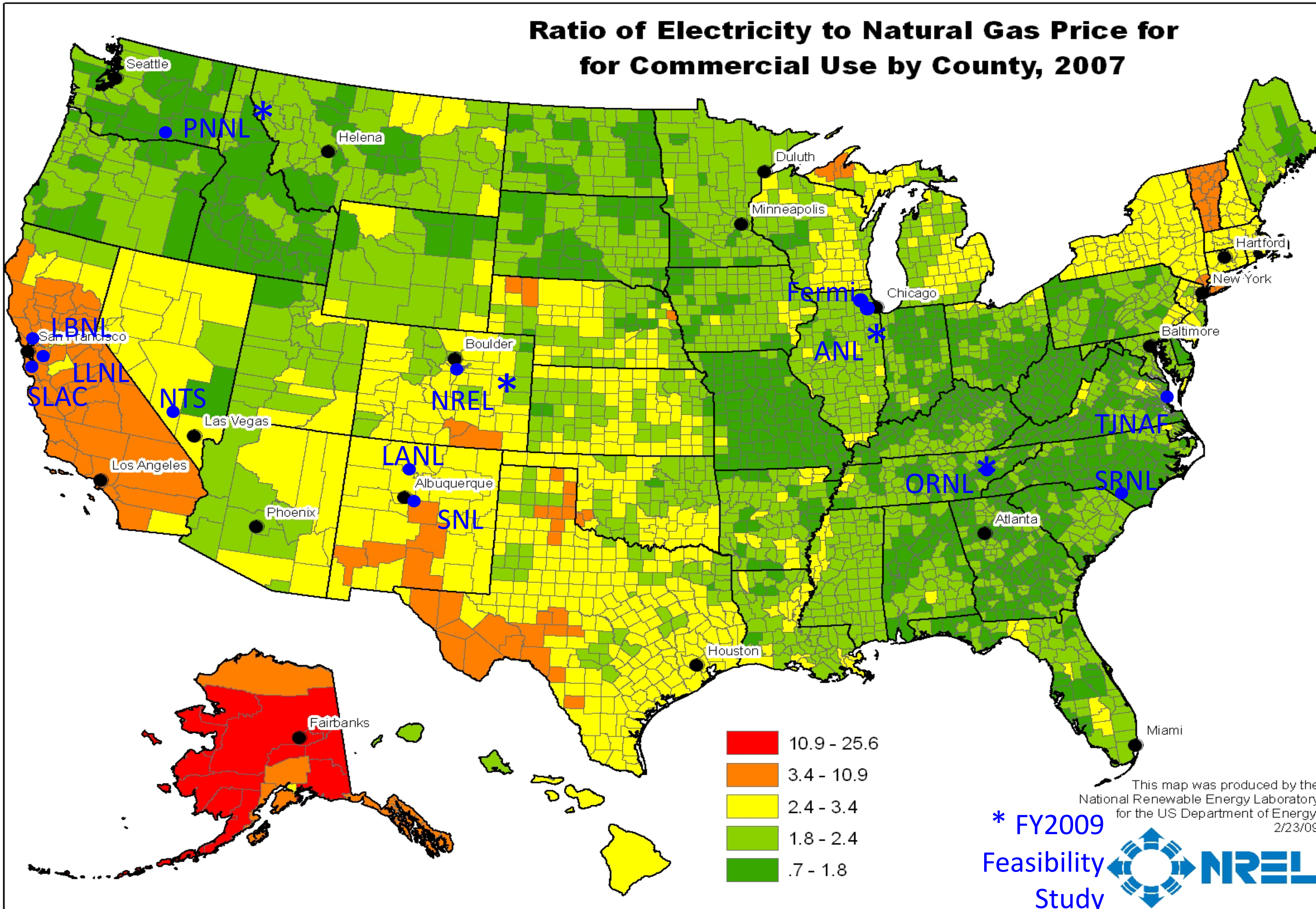
Clear efficiency benefits with CHP

Decision tree to help assess feasibility of CHP systems for each unique situation.



FCPower Model Hourly Energy Analysis Module





Ratio of Electricity to Natural Gas Price for
for Commercial Use by County, 2007
Seattle
PNNL
Helena
Duluth
Minneapolis
Fermi
Chicago
ANL
Hartford
New York
Baltimore
LBNL
San Francisco
LLNL
SLAC
NTS
Las Vegas
Boulder
NREL
TJNAF
LANL
Albuquerque
ORNL
SRNL
Los Angeles
Phoenix
SNL
Atlanta
Houston
Fairbanks
Miami
10.9 - 25.6
3.4 - 10.9
2.4 - 3.4
1.8 - 2.4
.7 - 1.8
This map was produced by the
National Renewable Energy Laboratory
for the US Department of Energy.
2/23/09
* FY2009
Feasibility
Study
NREL

Example of ITC Benefit to a Fuel Cell Project

Example Cost Comparison for a 300 kW Fuel Cell Combined Heat and Power System in California: Fuel Cell Purchase vs. a Ten-Year Fuel Cell Service Contract

	Case 1: Energy User Purchases and Installs System	Case 2: Energy User Holds Service Contract for System
Tax Status of Owner	**Tax-exempt**	**Taxpayer**
Installed Cost		
Purchased Price	$1,500,000	$1,500,000
Installation Expenses	584,000	584,000
Sales Tax (California)	0	105,000
Third-Party Financing Expenses	0	60,000
Installation Cost	$2,084,000	$2,249,000
State Grant (California location and eligibility)[3]	(750,000)	(750,000)
Federal ITC[4]	0	(675,000)
ITC Financing and Transaction Expenses[5]	0	200,000
Net Installation Cost	$1,334,000	$1,024,000
Net Installation cost impact to energy user	**$1,334,000**	**$0[6]**
Annual Energy Operating and Maintenance (O&M) Costs		
Annual Maintenance Cost	$150,000	$150,000
Annual Fuel Consumption	175,000	175,000
Annual Energy Savings	(289,000)	(289,000)
Third-Party Financing Costs[7]	0	117,000
Net Annual Energy O&M Costs	$36,000	$153,000
Cumulative O&M cost impact to energy user (10 years)	**$360,000**	**$1,530,000**
TOTAL COST IMPACT TO ENERGY USER	**$1,694,000**	**$1,530,000**
TOTAL COST IMPACT TO ENERGY USER, Present Value[8]	**$1,525,000**	**$1,126,000**
COST SAVINGS TO ENERGY USER, Present Value	**0**	**$399,000**

The **Investment Tax Credit (ITC) reduces the project developer's up-front costs by 23%** in Case 2 (from $1,334,000 to $1,024,000) compared to the energy user's up-front costs in Case 1, who is ineligible for the ITC. The energy user can indirectly benefit from the tax credit, assuming the developer passes the ITC tax savings through the service contract in Case 2.

Since the contract services in Case 2 are payable over time, the energy user avoids the up-front installation costs of $1,334,000.

The fuel cell provides power and avoids grid charges. Example: Assuming grid charges of $289,000/year, $2.89M grid charges over 10 years—$1.53M service contract over 10 years = **$1.36M grid charges avoided** over 10 years in Case 2.

The use of a service contract in Case 2 by the energy user enables the project developer to acquire, install, and operate the system and pass the ITC tax savings to the energy user. Case 2 will **reduce the life-cycle costs to the energy user by 26%** or $339,000 on a present-value basis over the 10-year life of the project (from $1,525,000 to $1,126,000) when compared to Case 1.

*http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fuel_cell_financing_fact_sheet.pdf

Education & Outreach

Collaborations with universities, governments, and industry help to educate the public about H_2 and fuel cells.

Thank you

For more information, please contact

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