Fuel Cell Technologies Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

GovEnergy 2011

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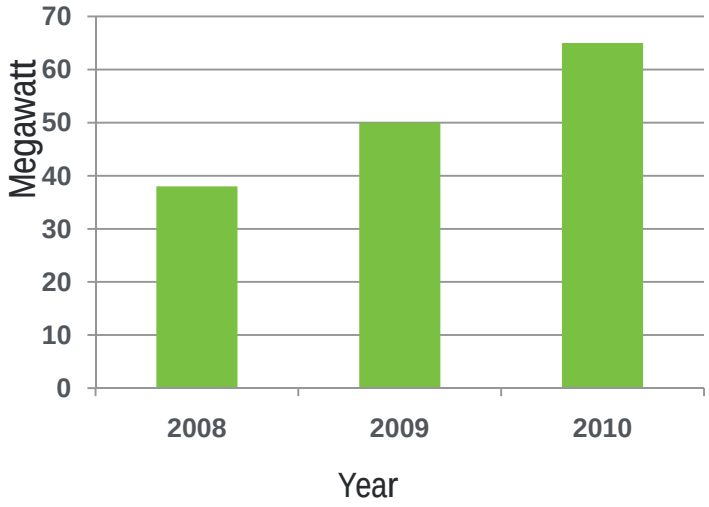
Market Transformation and
Intergovernmental Coordination Manager
Fuel Cell Technologies Program

Goal

- The Program's goal is to ensure expansion of hydrogen and fuel cell system use by:
  - Lowering the life cycle costs of hydrogen and fuel cell power and
  - Identifying and reducing the barriers impeding full technology commercialization.

Total Megawatts Shipped Worldwide for Stationary Fuel Cells*



Verizon Call Center - Garden City, NY

7 Fuel Cells installed in 2005:

- Electrical power
- Backup power
- Exhaust recovered for cooling and heating

Fuel Cell Market Overview

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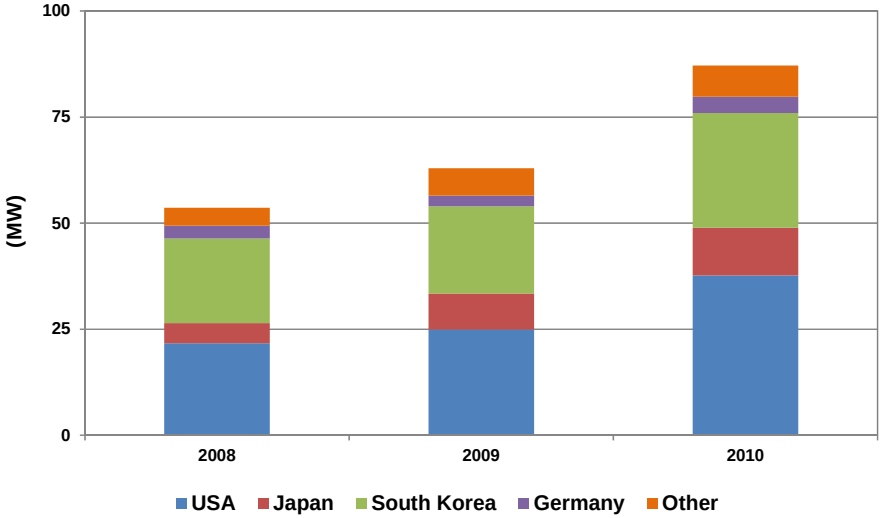
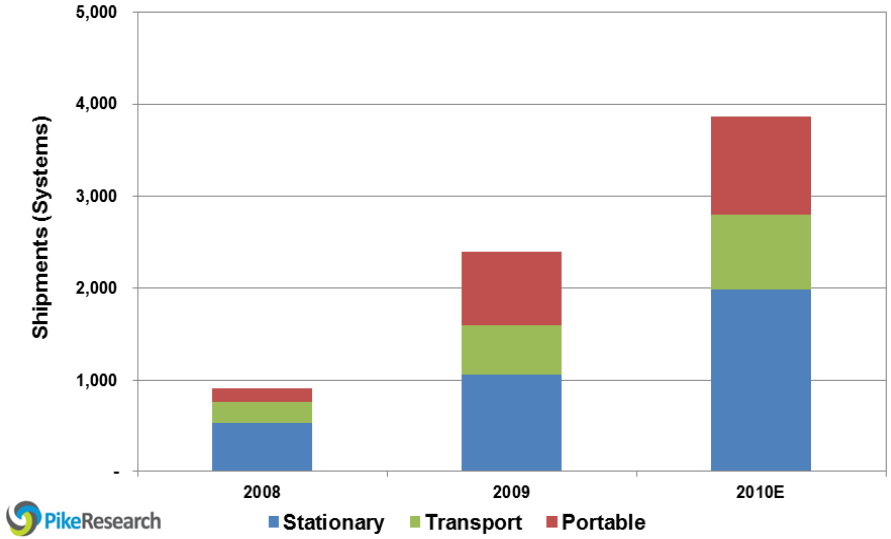
Megawatts Shipped, Key Countries: 2008-2010



North American Shipments by Application



PikeResearch

Fuel cell market continues to grow
- **~36% increase in global MWs shipped**
- **~50% increase in US MWs shipped**

Various analyses project that the global fuel cell/hydrogen market could reach maturity over the next 10 to 20 years, producing revenues of:
- **$14 – $31 billion/year for stationary power**
- **$11 billion/year for portable power**
- **$18 – $97 billion/year for transportation**

Widespread market penetration of fuel cells could lead to:
- **180,000 new jobs in the US by 2020**
- **675,000 jobs by 2035**

FuelCells2000, Pike Research, Fuel Cell Today, ANL

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/program_plan2010.pdf

Assessing Impact – DOE Fuel Cell Technologies Program

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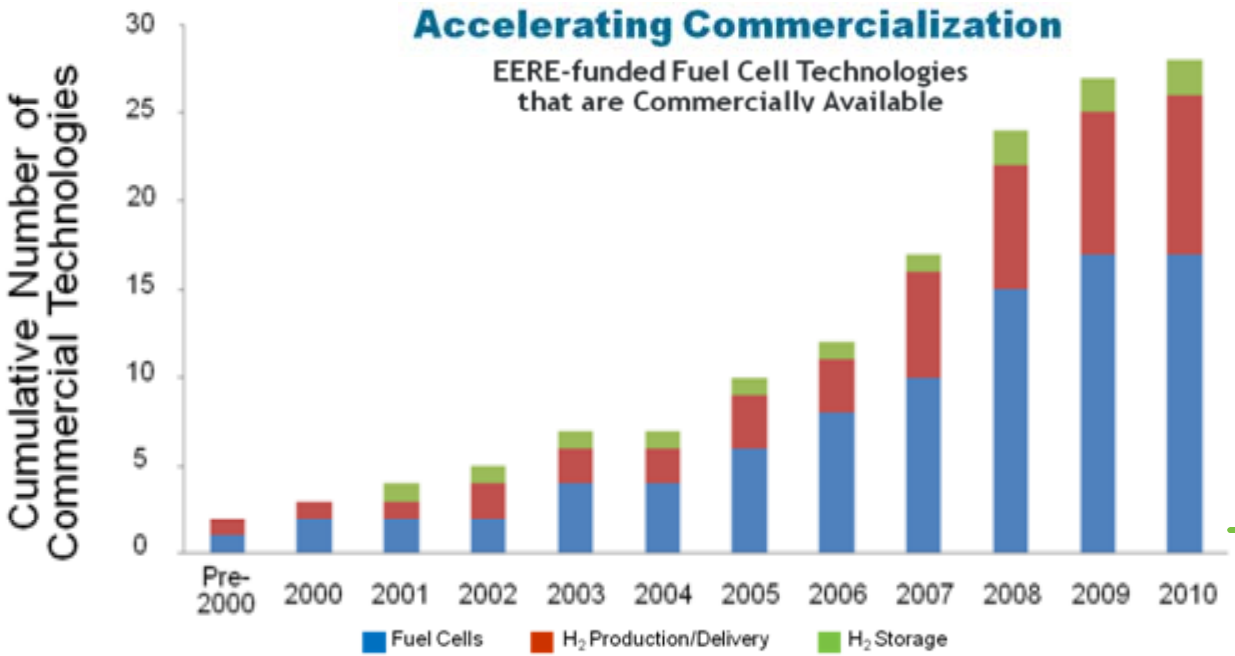
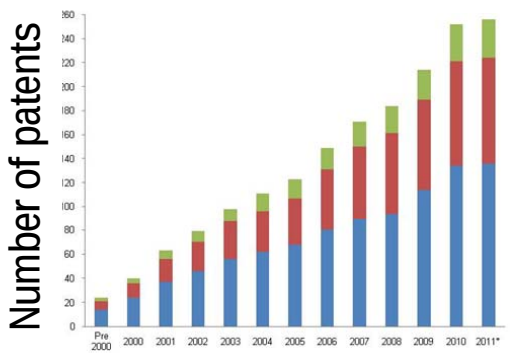
DOE funding directly led to ~30 hydrogen and fuel cell technologies in the market.



Source: DOE FCT Commercial Pathways report, PNNL
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_success_hfcit.pdf

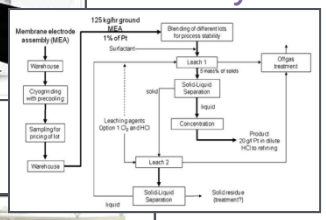


256 PATENTS resulting from EERE-funded R&D:

- 136 fuel cell
- 88 H_2 production & delivery
- 32 H_2 storage

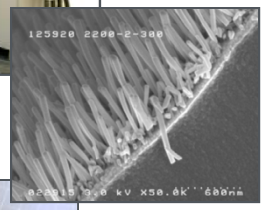
Examples

BASF Catalysts

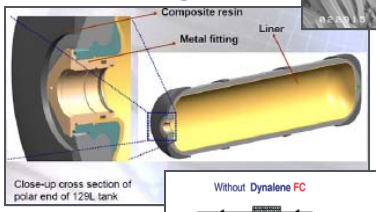


Proton

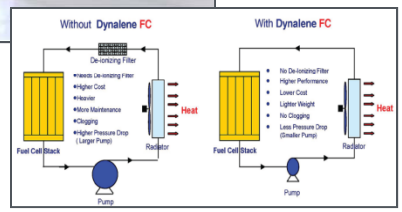
3M



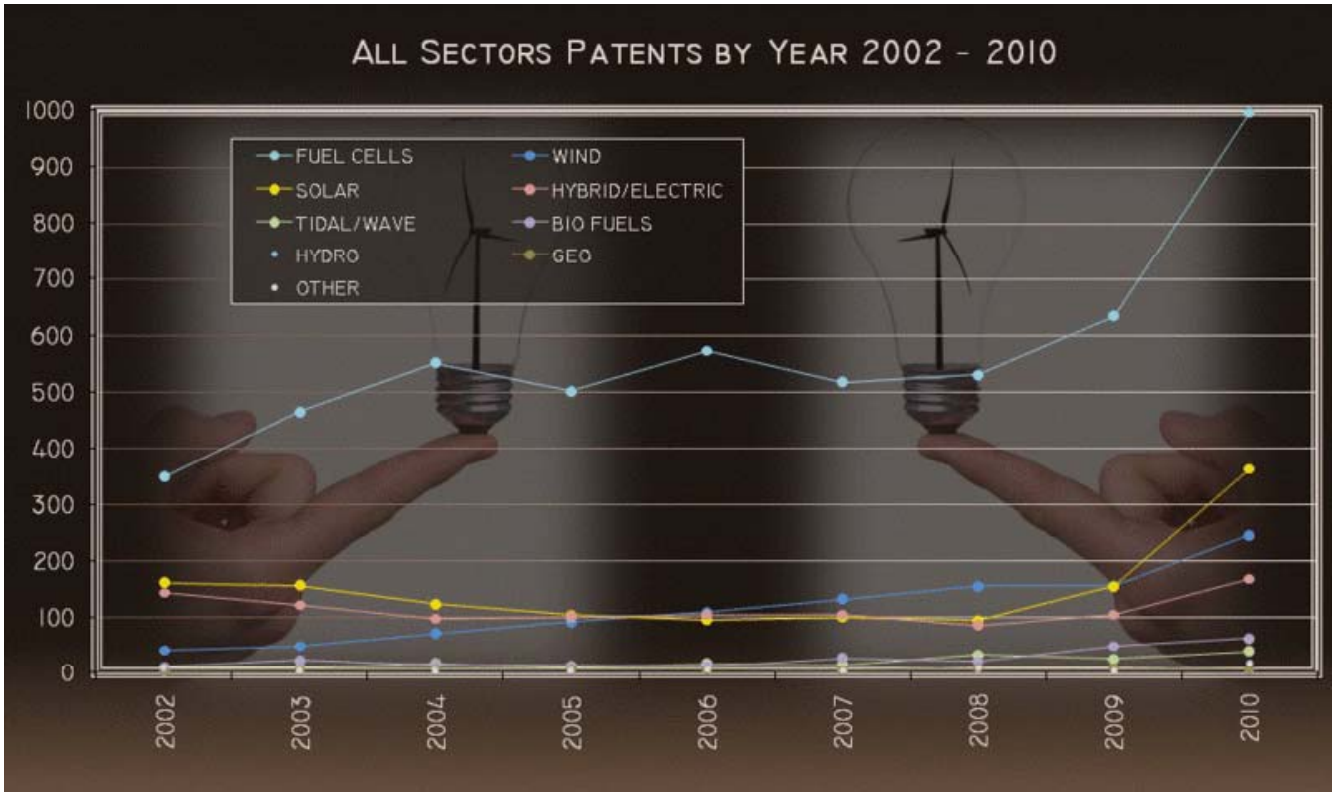
Quantum Technologies



Dyanlene, Inc.



Fuel Cell Patents Reflect Emerging Industry



Clean Energy Patent Growth Index[1] fuel cell patents lead in the clean energy field (since 2002), with nearly 1,000 fuel cell patents worldwide in 2010.

- **3X more than the second place holder, solar, with just ~360 patents.**
- **Number of fuel cell patents grew > 57 % in 2010.**

[1] http://cepgi.typepad.com/heslin_rothenberg_farley_/

Federal Policies Promoting Fuel Cells

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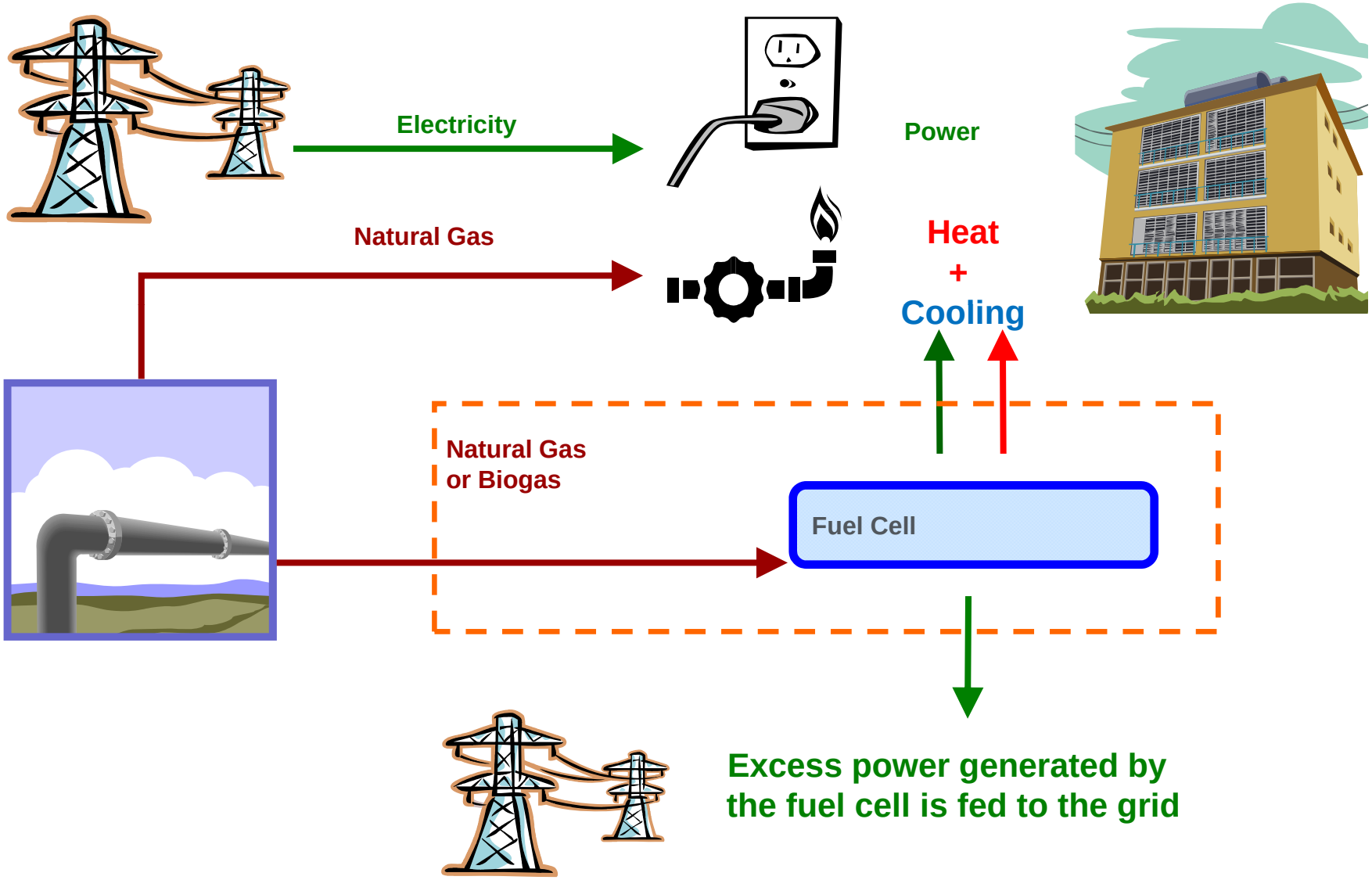
Investment Tax Credit	Emergency Economic Stabilization Act of 2008	Offers tax credit of 30% for qualified fuel cell property or $3,000/kW of the fuel cell nameplate capacity. Feature a 10% credit for combined-heat-and-power-system property.	Equipment must be installed by Dec. 31, 2016.
Grants for Energy Property in Lieu of Tax Credits	American Recovery & Reinvestment Act of 2009	Allows facilities with insufficient tax liability to apply for a grant instead of claiming the Investment Tax Credit (ITC) or Production Tax Credit (PTC). Only entities that pay taxes are eligible.	Capped at $1,500 per 0.5 kilowatt (kW) in capacity. Fuel cells must be greater than 0.5 kW and CHP 50MW or less. Construction must begin by expiration date, 12/31/2011.
Loan Guarantee Program	Energy Policy Act of 2005	Amount varies. Program focuses on projects with total project costs over $25 million.	Full repayment is required over a period not to exceed the lesser of 30 years or 90% of the projected useful life of the physical asset to be financed.
Residential Renewable Energy Credit	American Recovery & Reinvestment Act of 2009	30% tax credit. Fuel cell maximum: $500 per 0.5 kW Raises ITC dollar cap for residential fuel cells in joint occupancy dwellings to $3,334/kW.	Fuel cells must have electricity-only generation efficiency greater than 30% and 0.5 kW minimum. Expires Dec. 31, 2016.
Modified Accelerated Cost-Recovery System (MACRS)	The Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010	Fuel cell property placed in service between 9/8/2010 1/1/2012 qualifies for 100% first-year bonus depreciation. For 2012, bonus depreciation is still available, but at 50% of the eligible basis.	The property must have a recovery period of 20 years or less under normal federal tax depreciation rules and been acquired and placed in service between 2008 – 2012.

Hydrogen Fueling Facility Credit (EXPIRED)	Increases the hydrogen fueling credit from 30% or $30,000 to 30% or $200,000.
Manufacturing Credit (EXPIRED)	Creates 30% credit for investment in property used for manufacturing fuel cells and other technologies

Overview of Combined Heat-Power



Potential Reduction in Emissions

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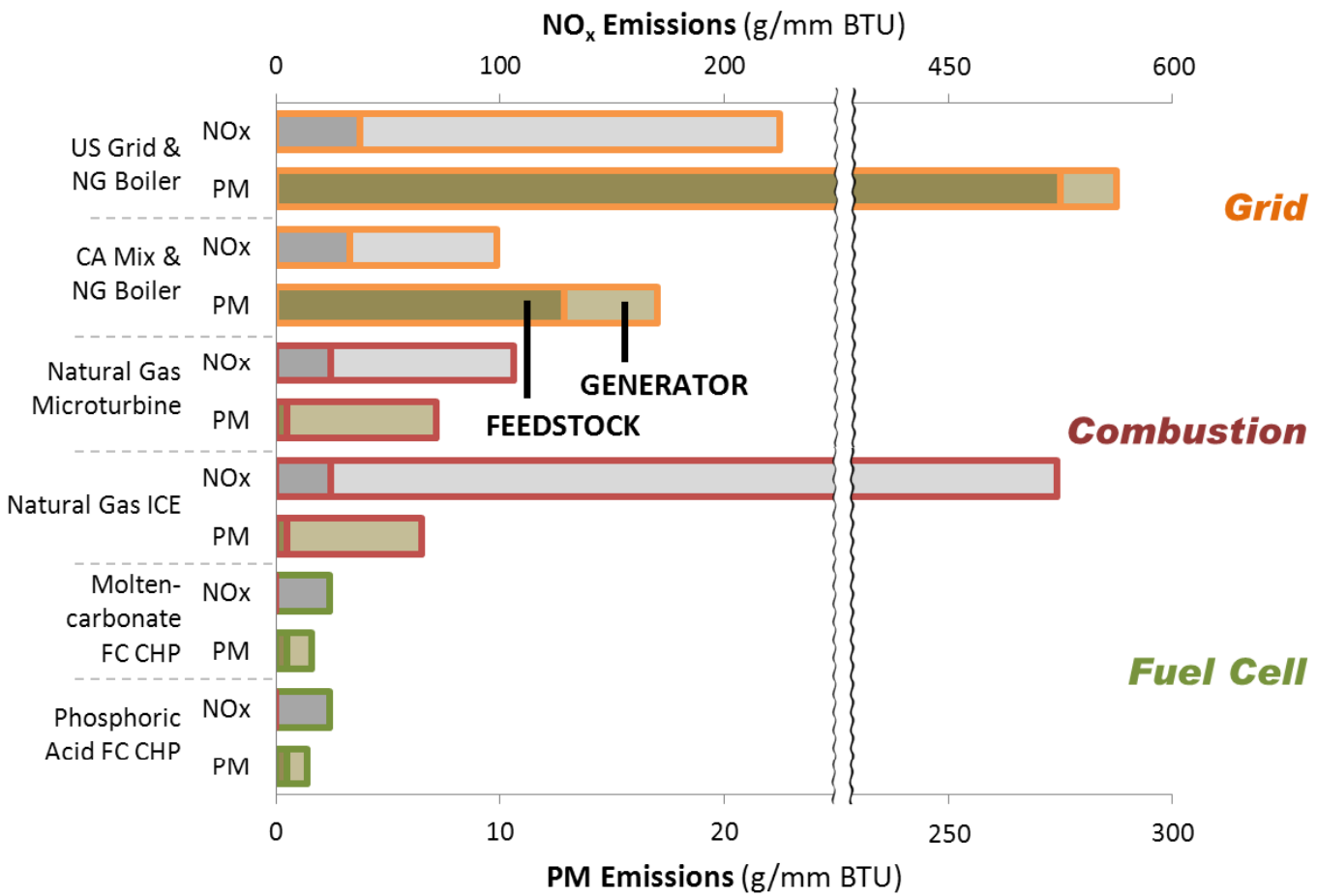
NO_x and PM Emissions from CHP and Competing Technologies



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.***

Stationary Power Fuel Cells for Combined Heat & Power (CHP) Applications

A 400-kW fuel cell (grey box) meets 85 percent of the energy needs of this Price Chopper supermarket in Albany. The installation reduces the building's carbon footprint by 71 tons, provides energy security for perishable items, and saves more than 4 million gallons of water each year. (Photo courtesy of UTC Power)

Primary Power CHP Deployments

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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
- Supervalue (Albertson's/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)

Assessing the Potential for Micro CHP

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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

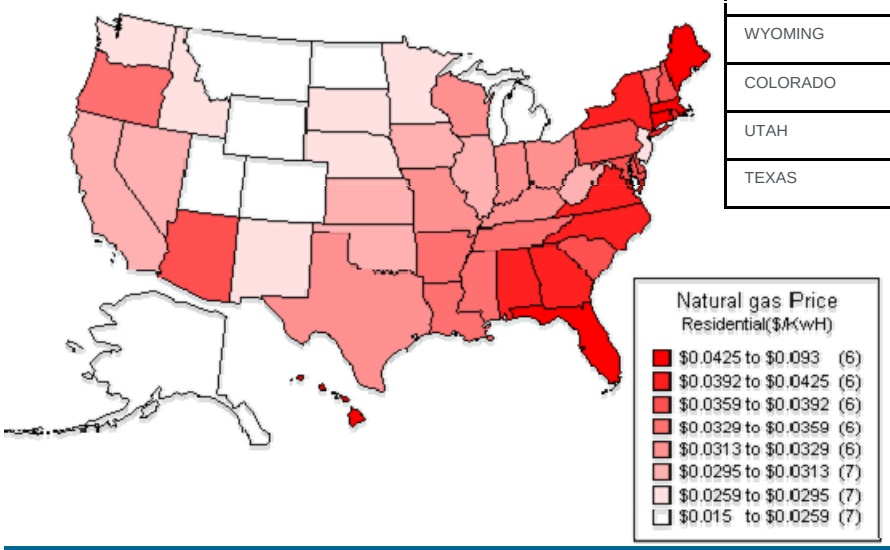
Price of natural gas

Expensive Electricity

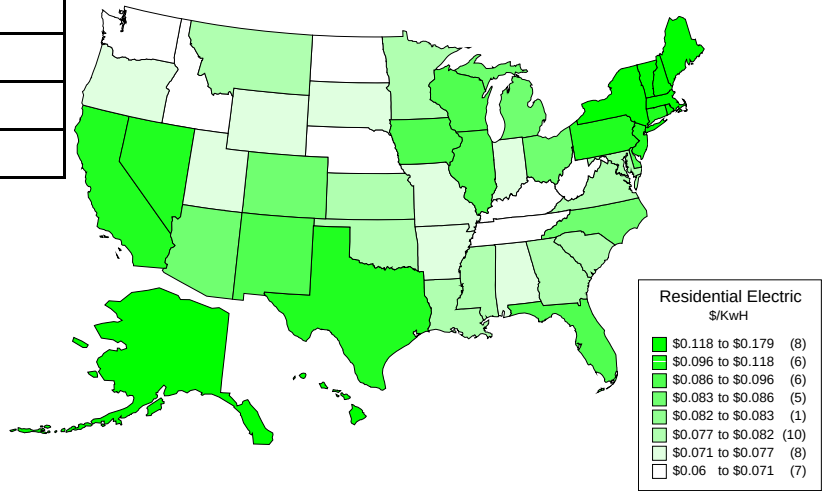
Electricity Cost ($/kWh)	
HAWAII	$ 0.235
CONNECTICUT	$ 0.194
NEW YORK	$ 0.181
MASSACHUSETTS	$ 0.165
NEW JERSEY	$ 0.159
ALASKA	$ 0.153
MAINE	$ 0.151
NEW HAMPSHIRE	$ 0.150
CALIFORNIA	$ 0.146
VERMONT	$ 0.146

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



Stationary Fuel Cells – Cost analysis

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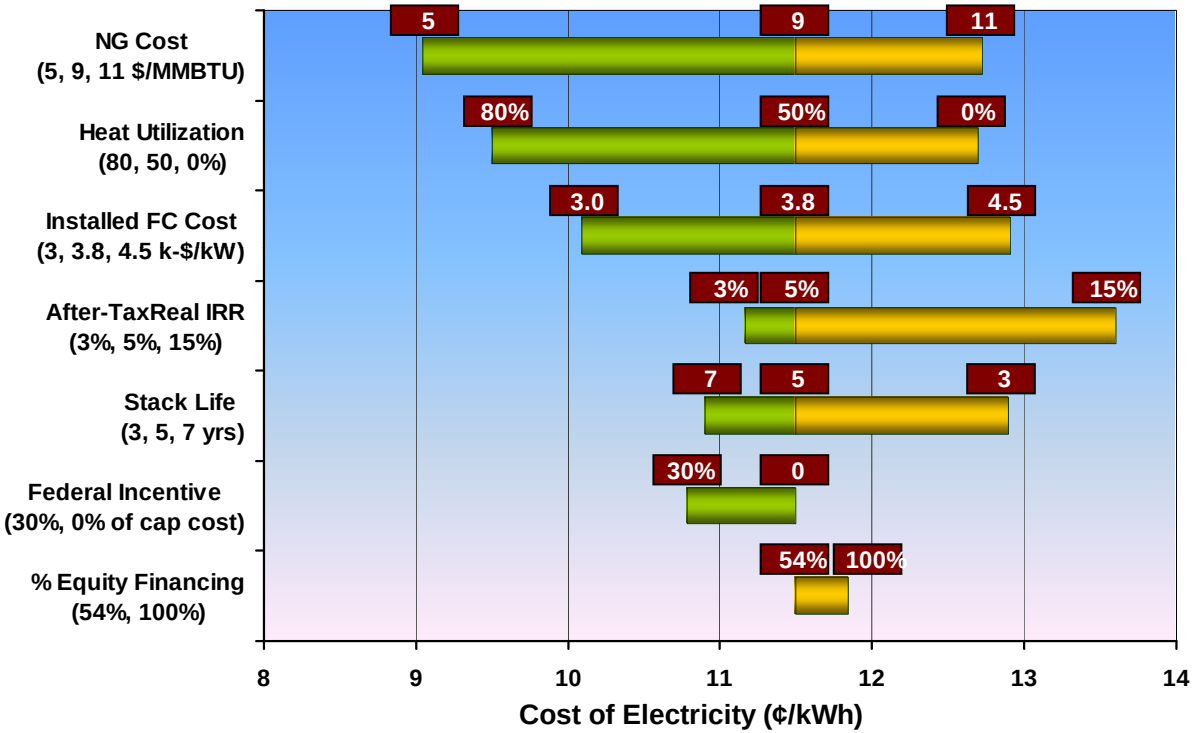
Analysis efforts are underway, to provide information on potential costs and benefits of a variety of stationary fuel cell applications.

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

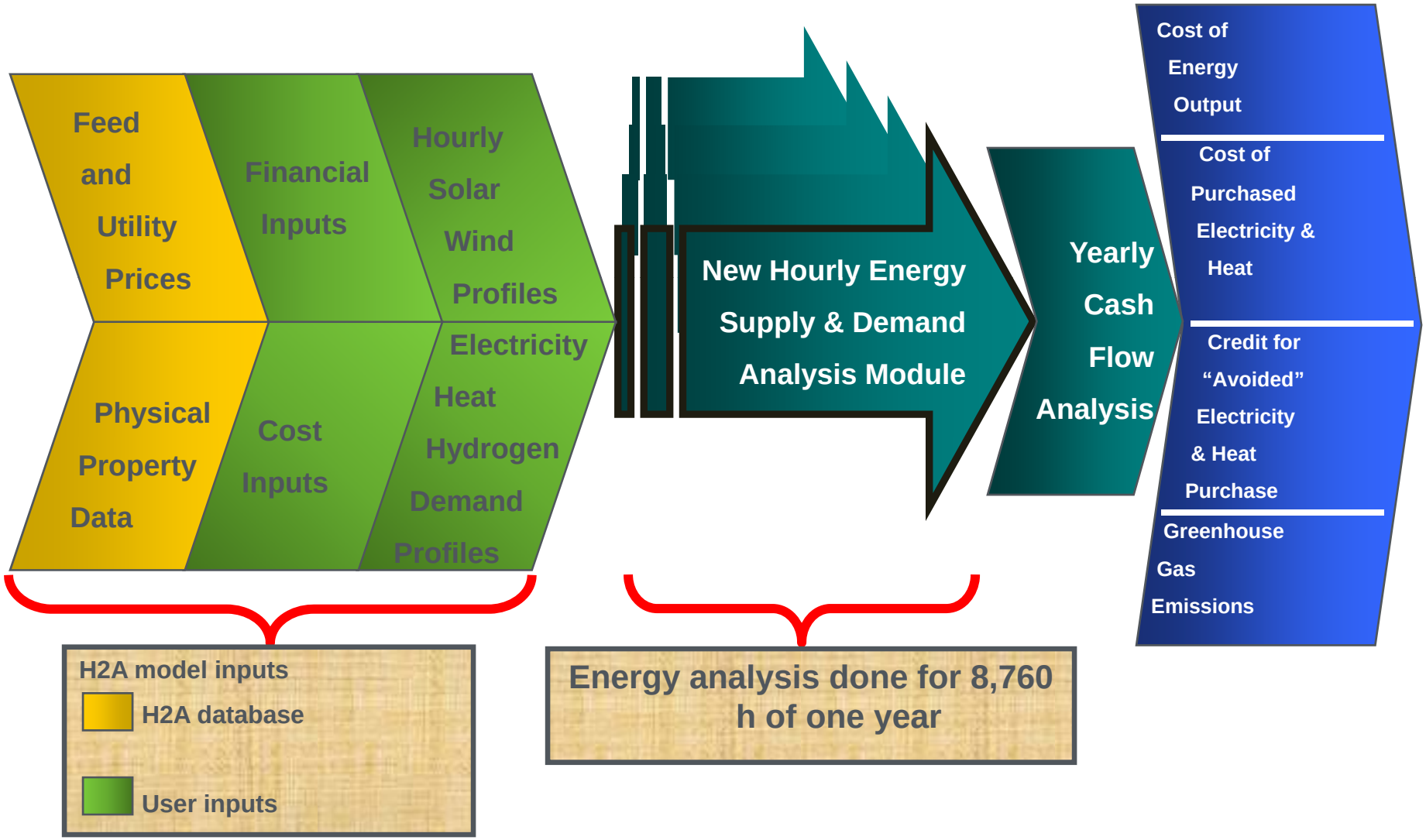
Operation Assumptions

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

FCPower Model Hourly Energy Analysis Module



Spark Spread is an important factor

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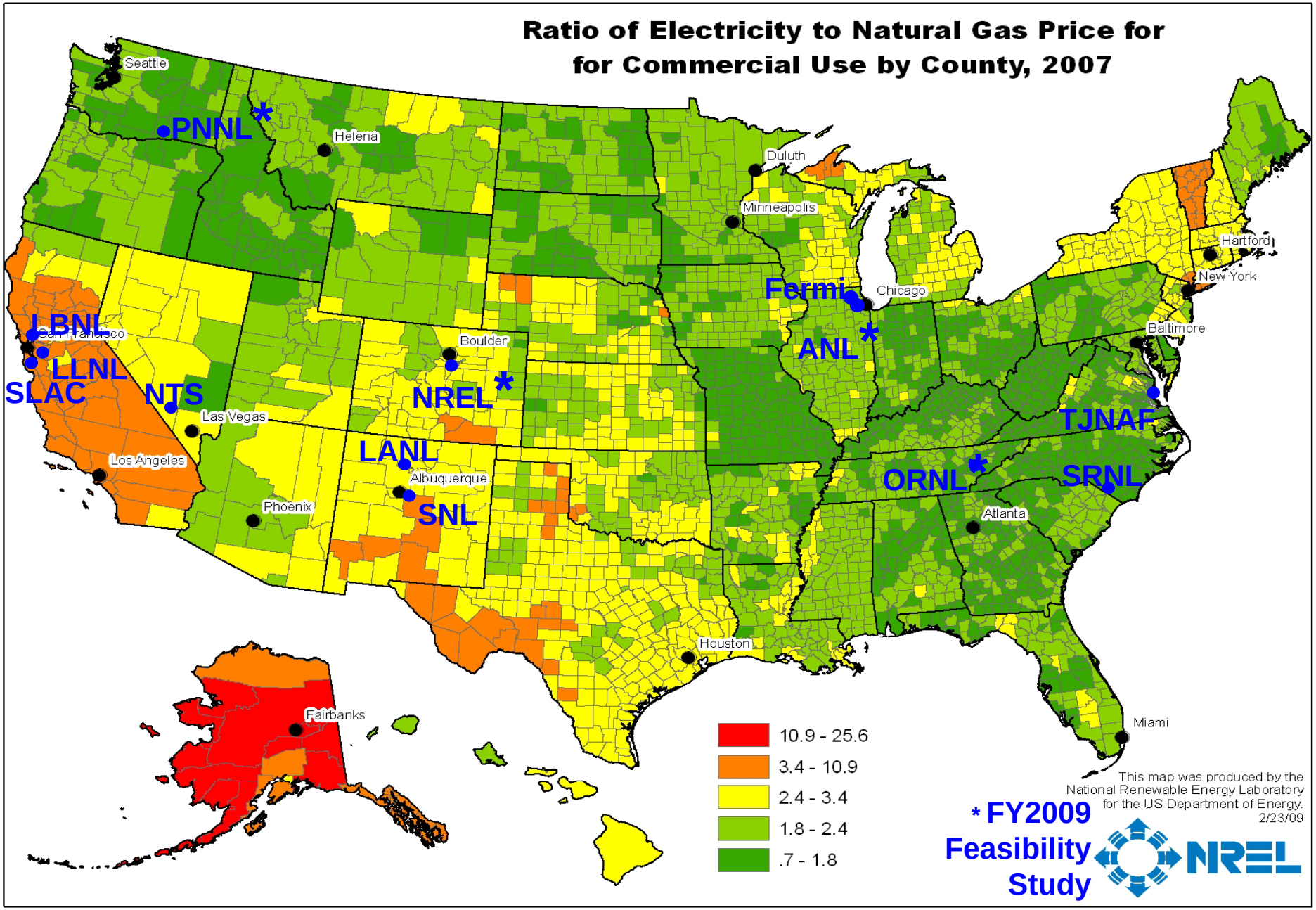

Micro CHP

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MicroCHP costs are becoming competitive with grid power and ROIs are estimated at under 5 yrs.

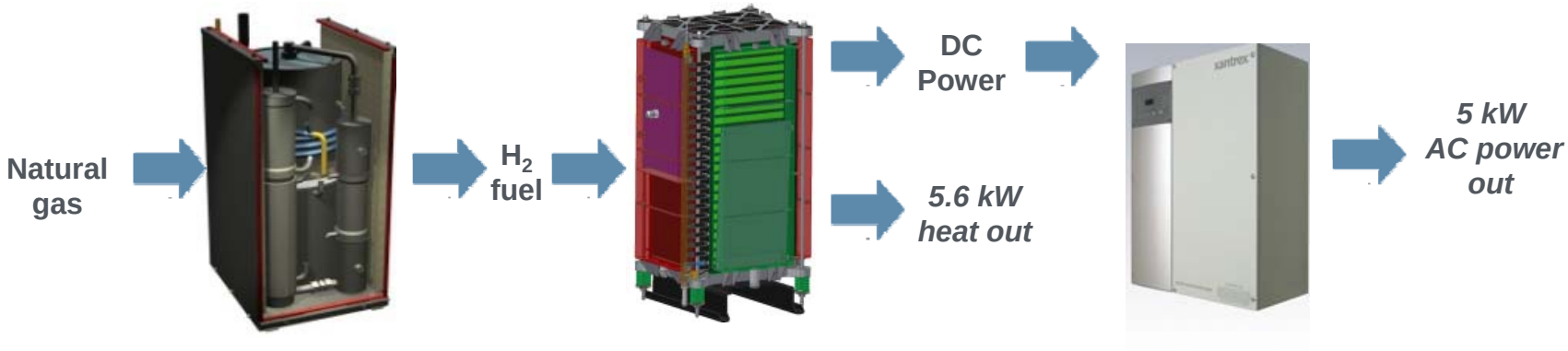
Deployment areas are where a business case can be made with pay back periods which meet industry needs.

Project Details

- ✓ 38 units
- ✓ 5 kW units
- ✓ Prove business case for MicroCHP applications

- **Next Steps**
  - Gather material performance data.
  - "Real world" evaluation operations and testing of equipment.

How Does the 5 kW FCS CHP System Work?



Fuel Processor

- Extracts H2 from NG or Propane
- Uses commercially available catalyst
- Operates near maximum achievable efficiency

Cell Stack

- Converts chemical energy directly to electrical energy
- Electrochemical reaction produces usable high-grade heat and water as byproduct
- Robust and durable design, allows use of “dirty” hydrogen

Inverter & Controls

- Commercially available inverter
- Certified for applicable codes and standards
- Allows GC/GI operation and multiunit load sharing capability

Cleaner Energy Than the Grid

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Power from the Grid

Natural Gas

Efficiency: 35%
4223 therms

Natural Gas

Efficiency: 80%

2175 therms

Environmental Impact
8.35 lbs CO_2 per hour
34 Tons per Annum

Power from Fuel Cell CHP

Electrochemical Conversion

Natural Gas

Efficiency: up to 90%

Electricity → 43.8 MWh per year ← **Electricity**

Heat → 51.3 MWh per year ← **Heat**

6,398 therms total

3,840 therms total

Environmental Impact
5.3 lbs CO_2 per hour
22 Tons per Annum

5kW Fuel Cell CHP system provides:
40% reduction in fuel and **37%** reduction in CO_2

Fuel Cell CHP

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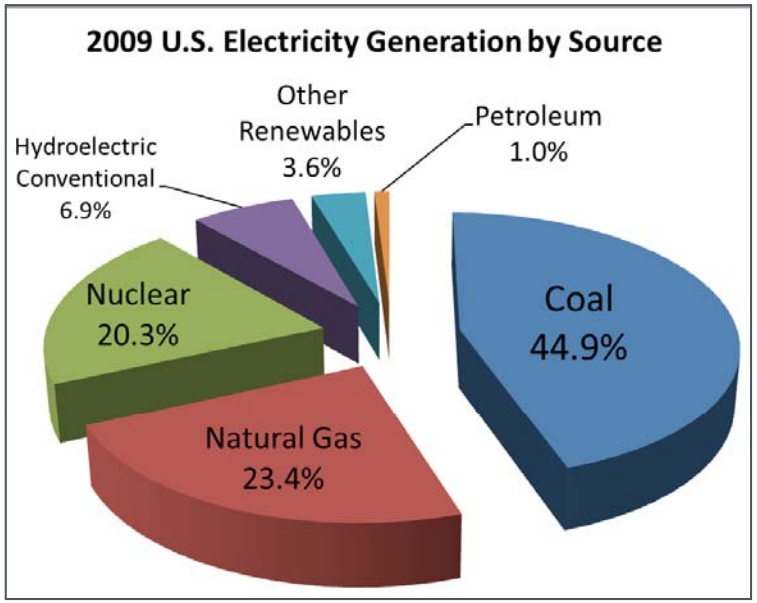
5kW Fuel Cell microCHP

- Energy Production:
  - 43 MWh electricity annually
  - 51 MWh of heat annually
- Overall environmental impact using NG to fuel **20,000** 5kW fuel cell systems to produce:
  - 860,000 MWh of power per year



GHGE	*Existing Grid**	*5 kW FCS Production*	*Reduction in GHG vs the Existing Grid*	*% Reduction*
CO_2	***680,000 tons***	***440,000 tons***	***240,000 tons***	***35%***
NOx	***1,497 tons***	***0***	***1,497 tons***	***100%***
SOx	***3,033 tons***	***0***	***3,033 tons***	***100%***

*Source: Griffin, Jaramillo and Matthews, "Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation," Environmental Science and Technology. Vol. 41, No. 17. 2007

Small Store or Restaurant MICRO CHP

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Commercial Business Case Example

Example Commercial Restaurant

- 2,500 ft², 24/7 operation
- Heat used for washing in kitchen and restroom
- Desire for backup power capability
- 400,000 kWh electricity usage
- 6,000 therms annual gas usage
- $72,000 annual electric bill (before CHP)

Savings with Installation of CHP System	
CHP annual net electric savings	$5,007
CHP annual avoided heat costs	$1,400
Total savings per year	$13,538
CHP System Cost	
CHP @ $10 per watt	$50,000
Installation and Sales Tax	$15,500
Less Federal tax credit	($15,000)
Less SCE SGIP rebate	($12,500)
Net System Cost	$38,000
CHP Capital Payback	3.8 Years

ENVIRONMENTAL BENEFITS

CO2 reduction	40%
SOX and NOX	Eliminated
Fuel Required	40% Less

Revenue losses resulting from Grid-Outages NOT Accounted for

California Financial Return Model (w/ SGIP)

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Private Residence, Santa Barbara, Calif.

(1) 5KW Fuel Cells to offset heat and power

Requirements: Power, hot water & space heating

Annual electricity usage: 123,556 kWh

Annual gas usage: 1,632 therms

Annual electric bill before implementation: $39,011

Savings with Installation of 5 kW FCS CHP	
Annual Net Electric Savings	
annual net electric savings	*$ 8,419*
annual net avoided heat costs	*$ 1,608*
Total savings per year	*$10,027*
System Cost	
$56,000 per system	*$ 56,000*
Installation and Sales tax	*$ 17,028*
Extended Warranty	*$ 3,950*
SGIP	*($ 12,500)*
Less Federal tax credit	*($ 5,000)*
Net System Cost	*$ 59,478*
Capital Payback:	4.9 years

Environmental Impact of the fuel cell

CO_2 Reduction	*36%*	*Offset 12 tons of carbon emissions this year*
SOx & NOx	*Undetectable*	
Fuel Reduction	*40%*	

Planting
4 acres of trees

Removing
3 cars from the road

5 kW Fuel Cell vs. Solar – Investment and Environmental Comparison

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The 5 kW CHP Fuel Cell Delivers 2.5 Times More Heat and Power

	5 kW Fuel Cell	Solar
$50,000 installed capacity (after government incentives)	*5 kW (AC)*	*5kW PV + 278 sq. ft. Thermal*
Annual Production – Electricity	*43,000 kWh*	*8,244 kWh*
Annual Production - Heat	*51,000 kWh*	*29,330 kWh*
Combined Heat and Power	*94,000 kWh*	*37,574 kWh*

CO_2 Reduction from Grid & Heating			*Fuel Cell Advantage*
CO_2	*79,200 lbs/yr*	*34,672 lbs/yr*	*2.1x reduction*

* Grid assumes coal fired power plant and heating with natural gas

CERL Emergency Backup Deployments

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- 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.

9 Sites Chosen:

- **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**

5 kW Fuel Cell vs. Solar – Payback and Production Comparison (Residential)

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High Efficiency

	5 kW Fuel Cell	*Solar PV (27KW) Thermal 472 Sq. Ft*
Electric Production - Annual	*43,800 kWh*	*43,800 kWh*
Heat Production	*51,000 kWh*	*51,000 kWh*
Space Required	*34 sq. ft.*	*3,182 sq. ft.*

Financial Payback

Total Installed & Sales Tax	*$ 82,850*	*$ 233,141*
Rebate	*$ 12,500*	*$ 9,500*
Tax Credit	*$ 5,000*	*$ 52,700*
Net System Cost	*$65,350*	*$ 170,941*
Utility Savings (Year One)	*$ 14,838*	*$ 8,211*
Payback	*~ 4.4 years*	*~ 16.6 years*

Example of ITC Benefit to a Fuel Cell Project

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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

Tax Status of Owner	Tax-exempt (Case 1: Energy User Purchases and Installs System)	Taxpayer (Case 2: Energy User Holds Service Contract for System)
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

The President's Clean Energy Standard (CES)

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Announced by President Obama at the 2011 State of the Union Address
CES Goal: By 2035 80% of America's electricity will come from clean energy sources

Potential for both CHP and WHP to play a critical role…

Opportunities for both combined heat and power (CHP) and waste heat to power (WHP) in the CES*:

- ✓ **Include natural gas fired CHP (cogeneration) and WHP as clean generating electricity sources. (20% CHP generation by 2030 would reduce annual carbon dioxide emissions by over 800 million megatons).**
- ✓ **CHP and WHP should be considered "supply side" generation technologies.**
- ✓ **CHP provides benefits for thermal energy efficiency and should be afforded additional clean energy credits (i.e. 41% of energy consumed in private residences and 38% of energy in commercial buildings is used for heating).**
- ✓ **Natural gas fueled CHP and WHP facilities should be awarded full clean energy credits.**
- ✓ **CHP and WHP are commercial technologies that are ready to be deployed.**

***Source: United States Clean Heat and Power Association**

Next Steps:

1. Continue to deploy fuel cell CHP and WHP technologies
2. Highlight high efficiency gains in CHP and WHP technologies
3. Industry is seeking proposed federal legislation?

Financial Benefits of CHP Projects

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Financial Sources & Grants

- Federal Investment Tax Credits (ITC's) or Grants in lieu of ITC's (an energy services contract with a third-party project developer is required for a tax-exempt customer to benefit)
- State Tax Credits
- State and Local Incentives and Grants
- Utility Incentives and Grants
- Net Metering
- Demand Response and other Capacity Payments
- Energy Conservation Credits (White Tags)
- Renewable Energy Credits (Mandatory and Voluntary)
- Internal Cash Flow From Operating Efficiencies
- Private Capital (Debt and Investor Equity – also requires an energy services contract with a third-party project developer)
- Green Procurement Requirements

Thank you

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