Federal Facilities Guide to Fuel Cells

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

Procuring Fuel Cells for Stationary Power: A Guide for Federal Facility Decision Makers

May 8, 2012

Outline

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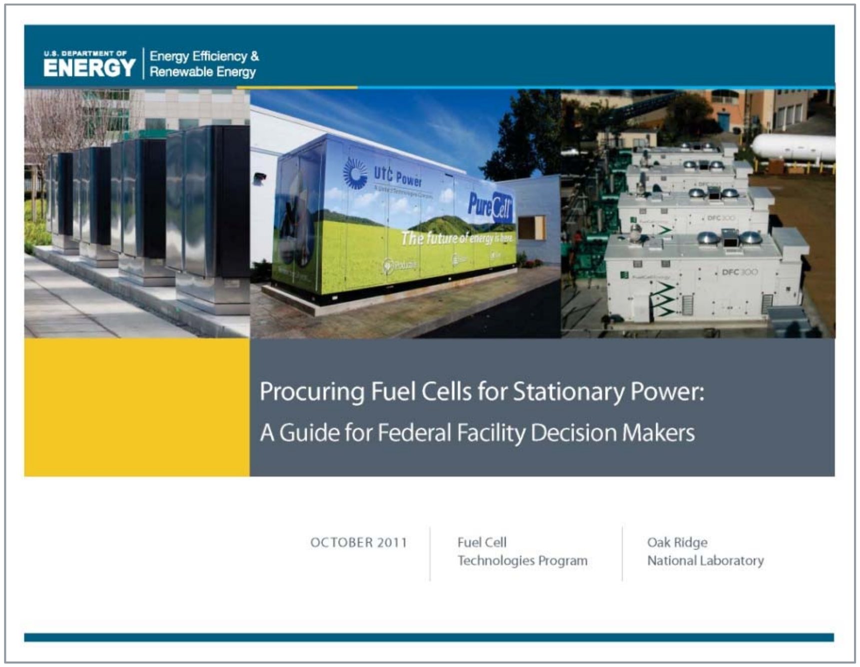
- Distributed Generation and Fuel Cell Power Overview *(Pete Devlin[1])*
- How Does a Fuel Cell Work *(Jacob Spendelow[2])*
- Guide Summary
  - How FC CHP can help Federal Facilities *(Pete Devlin[1])*
  - Third Party Financing *(Greg Moreland[3])*
  - Project Screening *(Joe McGervey[3])*
  - Detailed Planning *(Joe McGervey[3])*
  - Model *(Michael Penev[4])*
  - Project Finance *(Joe McGervey[3])*



1 – DOE
2 – LANL/ DOE
3 – SRA
4 - NREL

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

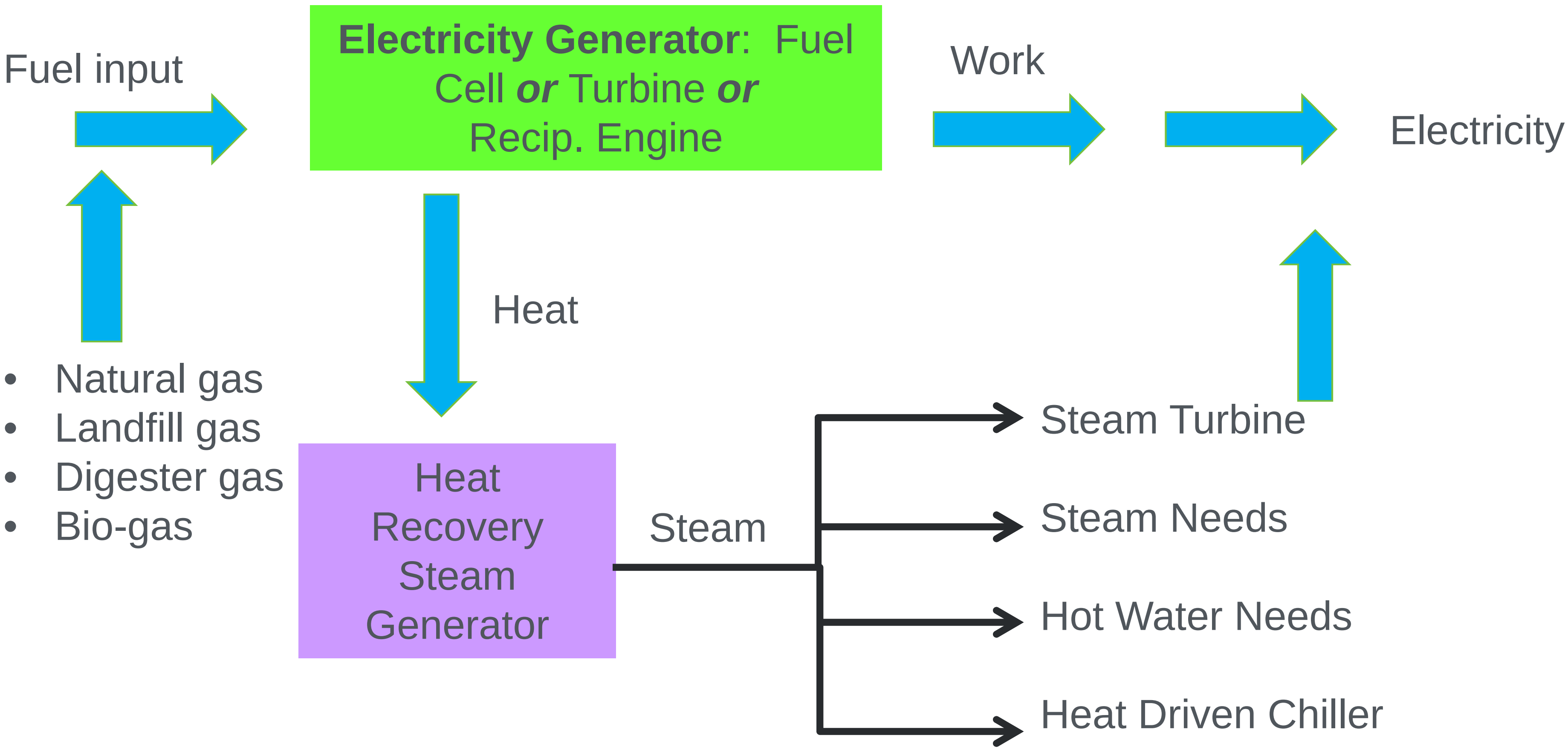
Combined Heat and Power (CHP): A High-Efficiency Solution

CHP is a type of distributed generation (DG) technology that:

- Is located in close proximity to the energy consumer – building, campus or industrial
- Provides at least a portion of the facility's electrical load
- Improves efficiency by capturing thermal energy for use in:
  - Cooling
  - Dehumidification
  - Water and space heating
  - Process heat
- Can be used to provide energy security by avoiding grid outages (requires coordination with utility companies)

UTC Fuel Cells at Verizon Garden City

Fueled CHP Prime Mover System:



CHP Technology Performance

Summary Table of Typical Cost and Performance Characteristics by CHP Technology					
Technology	Steam Turbine	Recip. Engine	Gas Turbine	Microturbine	Fuel Cell
Power efficiency (HHV)	15-38%	22-40%	22-36%	18-27%	30-63%
Overall efficiency (HHV)	80%	70-80%	70-75%	65-75%	55-80%
Effective electrical efficiency	75%	70-80%	50-70%	50-70%	55-80%

* *U.S. Environmental Protection Agency, Combined Heat and Power Partnership, Catalog of CHP Technologies, (December 2008)*

Primary Power Emissions Performance

300 kW Molten Carbonate Fuel Cell

	NO_X (lb/MWh)	SO_X (lb/MWh)	CO_2 (lb/MWh)
Average US Fossil Fuel Plant	4.200	9.21	2,017
Microturbine (60 kW)	0.490	0	1,862
Small Gas Turbine (250 kW)	0.467	0	1,244
Fuel Cell 47% efficiency	0.016	0	967
Fuel Cell – CHP 80% efficiency	0.016	0	545

- NO_x and SO_x are negligible compared to conventional technologies
- Substantial greenhouse gas reduction potential, with or without the cogeneration efficiency

* *U.S. Environmental Protection Agency, Combined Heat and Power Partnership, Catalog of CHP Technologies, (December 2008)*

Fuel Cells for Stationary Power

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- Generate power and heat at high efficiency levels through electrochemical reactions
- No combustion or shaft movement
- Distributed generation (DG) applications provide energy security by avoiding grid outages
- Very quiet and environmentally clean
- Different technologies (based on electrolytes used)
  - Phosphoric Acid
  - Solid Oxide
  - Molten Carbonate
  - Proton Exchange Membrane

"New York's Freedom Tower, the skyscraper being constructed on the site of the World Trade Center, is to use fuel cells to power its heating and cooling systems. New York Power Authority (NYPA) has ordered 12 fuel cells totaling 4.8MW of power to serve the Freedom Tower and three other new towers under construction at the site in Manhattan."

High Efficiency of DG Fuel Cells

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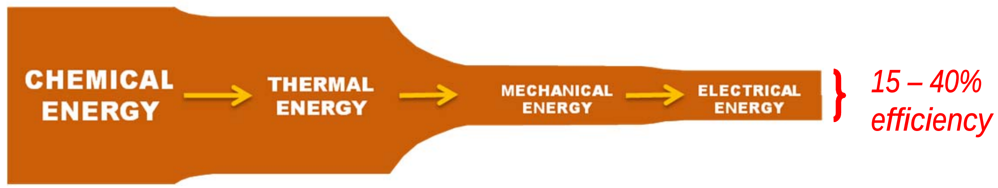
Fuel cells convert chemical energy directly to electrical energy — with very high efficiency — and without criteria pollutant emissions.

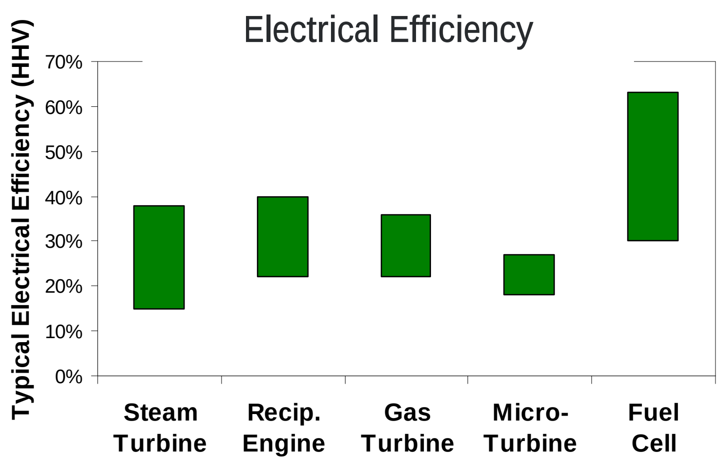
Combustion Engines — convert chemical energy into thermal energy and mechanical energy, and then into electrical energy.

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

Energy Conversion in Combustion Engines



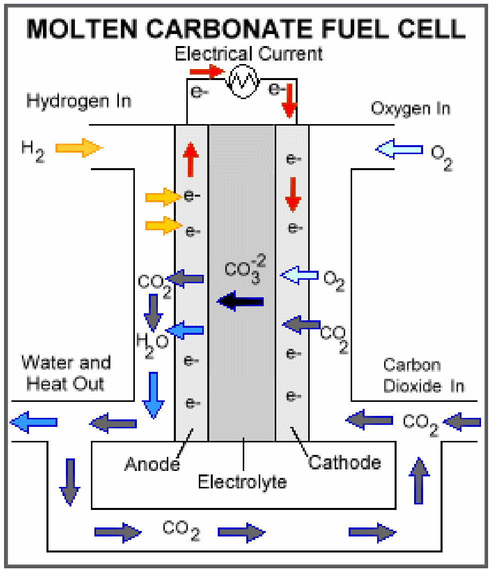
Energy Conversion Fuel Cells

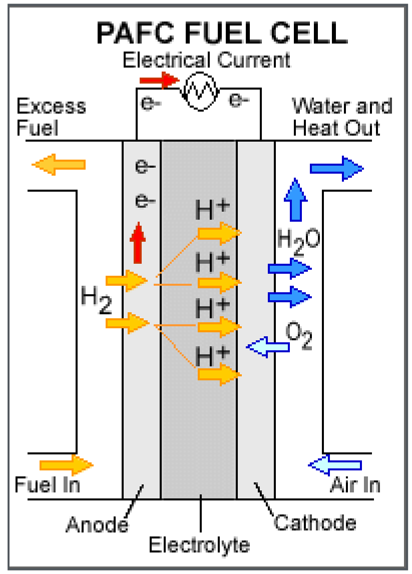


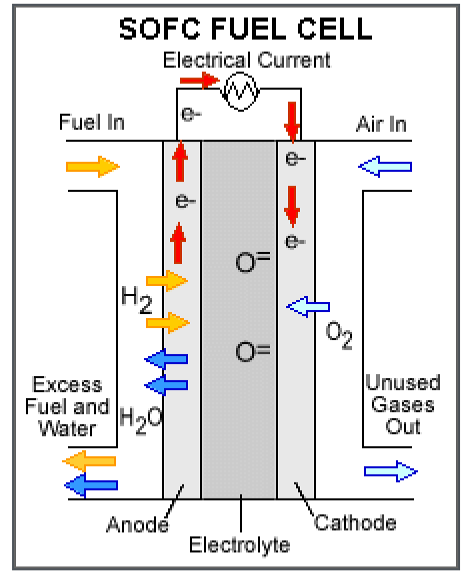
Source: EPA, Catalog of CHP Technologies, December 2008

Fuel cells convert chemical energy directly into electrical energy, bypassing inefficiencies associated with thermal energy conversion

Commercially Available Fuel Cell Technologies for Stationary Power







- *Construction: High-temperature metals, porous ceramics*
- *Operating Temperature: 600-700ºC*

- *Construction: Carbon, porous ceramics*
- *Operating Temperature: 130-200ºC*

- *Construction: Ceramic, high-temperature metals*
- *Operating Temperature: 500-1,000ºC*

Stationary Fuel Cell Product Example

400 kW Phosphoric Acid Fuel Cell

1 Fuel Processor

Converts natural gas fuel to hydrogen

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

2 Fuel Cell Stack

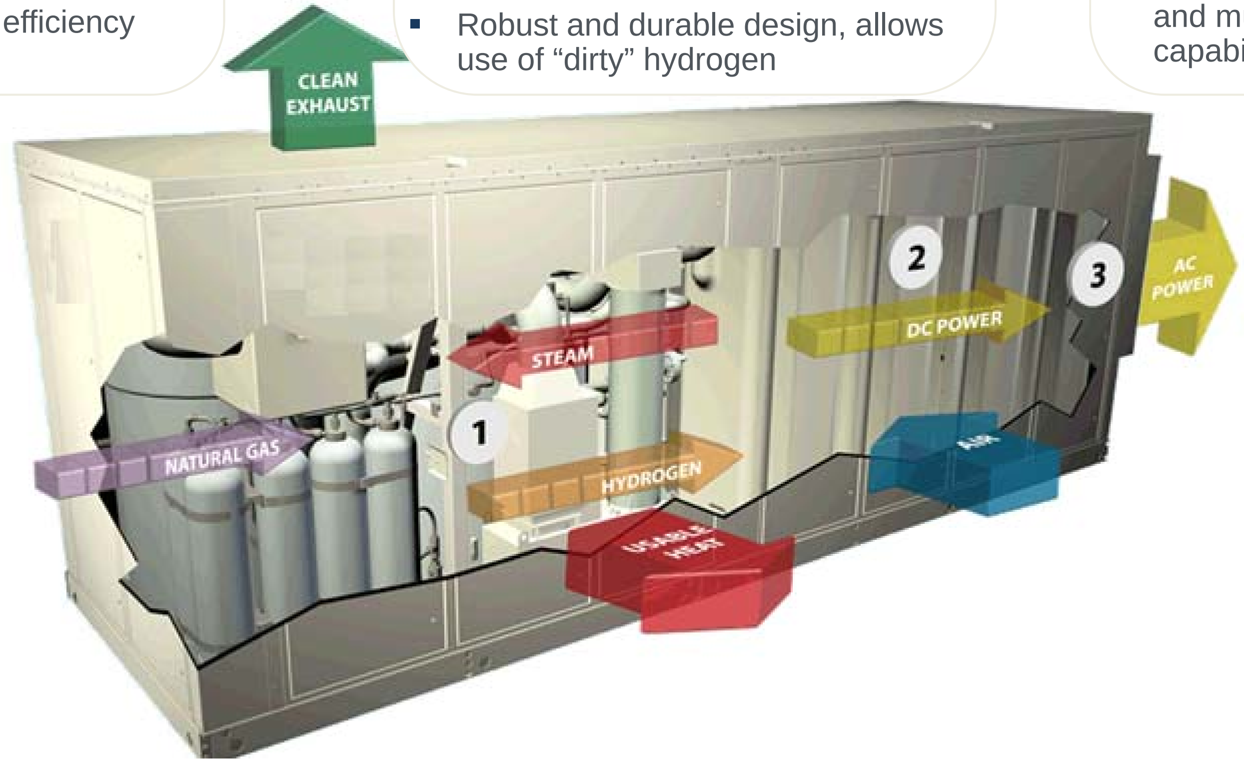
Generates DC power from hydrogen and air

- 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

3 Power Conditioner

Converts DC power to high-quality AC power

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



Source: UTC Power

Fuel Cells can be an Attractive Investment

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3rd Party Financing: Business Case Example

Using absorption chillers, grocery store refrigeration systems can be good applications for the thermal heat from CHP fuel cells.

Project Economic Benefits (15 year cycle)*	
Net Present Value	**$ 775,000**
Internal Rate of Return (IRR)	**18%**
Payback on CHP Capital Investment	**3 Years**
CHP System Capital Investment Cost*	
Fuel Cell CHP @ $4,500 per kW	**$1,800,000**
Installation (incl. chiller)	**726,000**
Less Federal Energy ITC (30%)	**(758,000)**
Less CT Clean Energy Fund Grant	**(1,000,000)**
Net System Cost	**$ 768,000**

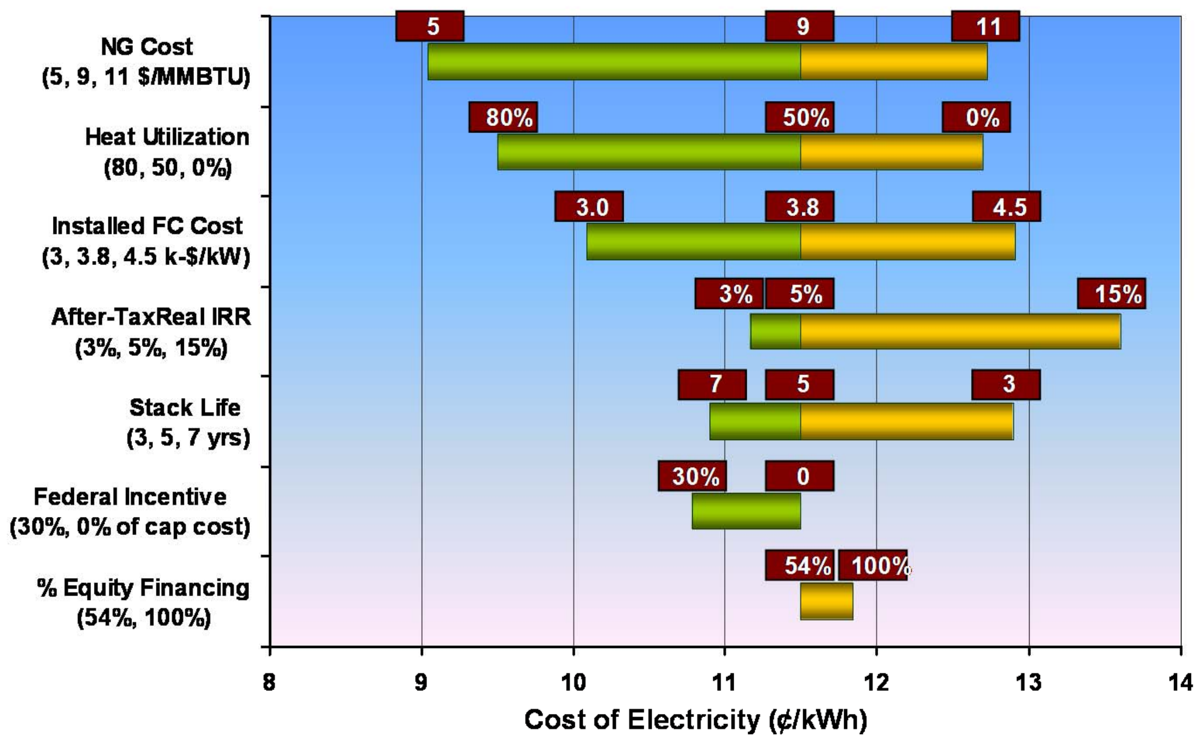
Connecticut Store Location
- 128,000 ft², 24/7 operation
- Utility electricity rate: $0.12 kWh
- Utility natural gas (NG) rate: $15/mmbtu
- CHP input fuel NG rate: $6/mmbtu
- 400 KW fuel cell
- 40 ton absorption chiller (fuel cell heat driven)
- CHP System Generation Capability:
  - 3.3 million kWh annual electricity
  - 785,000 btu/hr thermal
  - 95% Capacity & full heat utilization

Revenue losses and merchandize spoilage losses resulting from Grid-Outages NOT Accounted for

** Analysis provided by the Connecticut Center for Advanced Technology and includes CHP system operating expenses and the sale of Renewable Energy Credits (REC's).*

Source: US DOE 10/2010

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

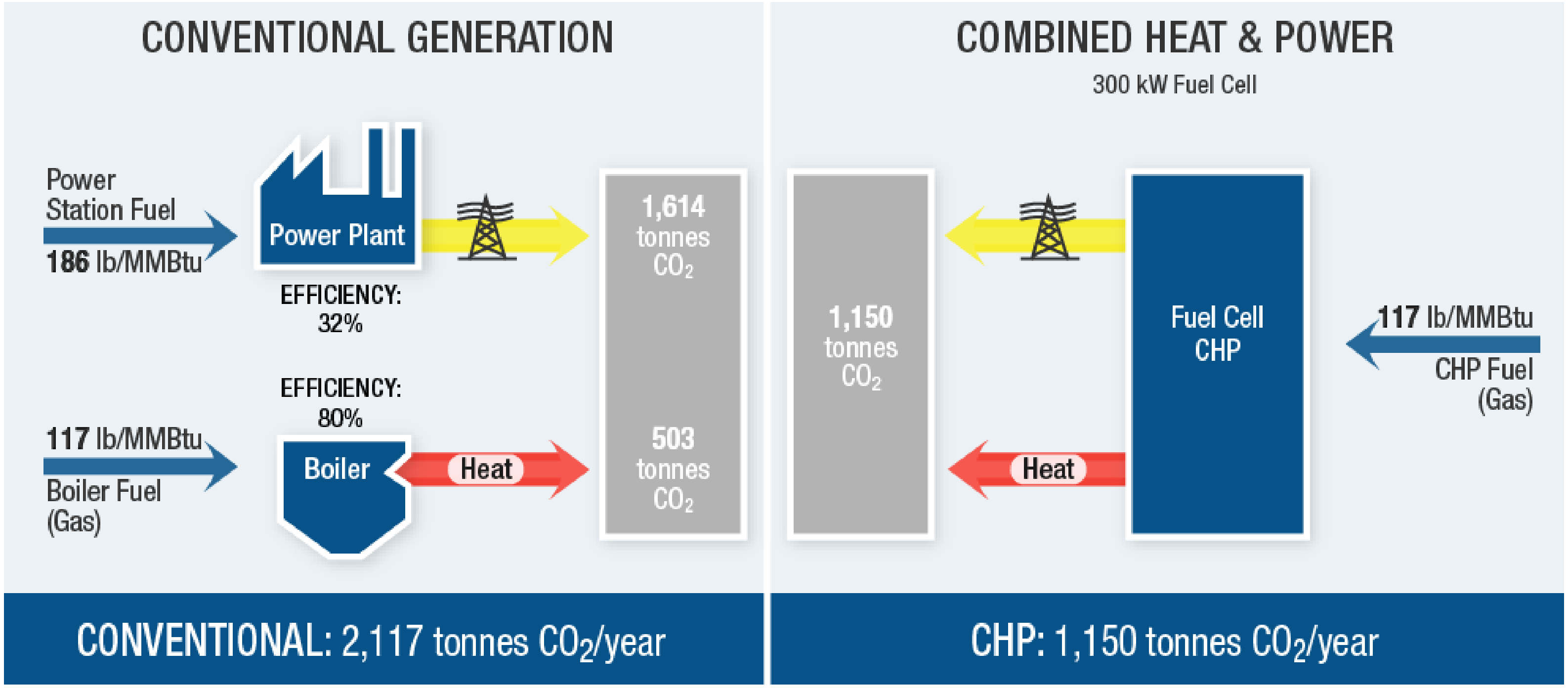
Example for MCFC 1.4 MW

Source: US DOE 10/2010

Advantages of CHP Fuel Cells

Fuel Cell CHP Advantages:

- Reliability Benefits
- Power Quality
- Peak Power
- Environmental Benefits
- Efficiency Benefits
- Infrastructure Resilience
- Energy Security
- Low Natural Gas Prices
- Opportunity Fuels



Stationary Fuel Cell Applications

Assured Power

First National Bank of Omaha
Omaha, Nebraska

On-Line Emergency Power

Verizon
Garden City, New York

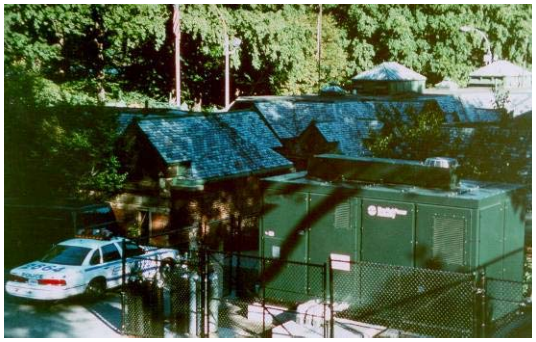
Indoor Green Power / Cogeneration

4 Times Square
New York, New York

Renewable Fuel (ADG)

Wastewater treatment plants
New York, New York

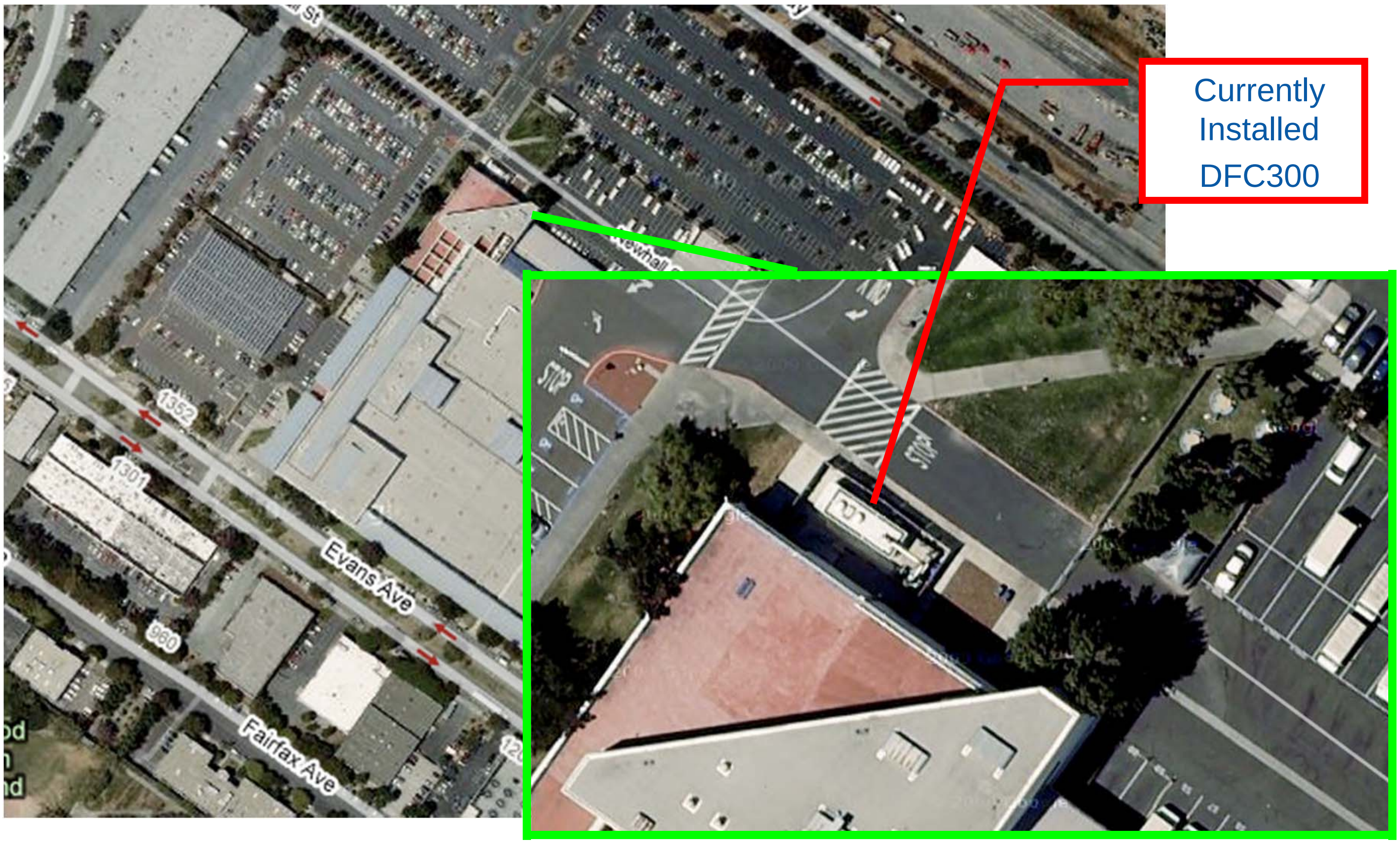
Off-Grid Power



Central Park Police Station,
New York, New York

Stationary Fuel Cells Have a Small Footprint

- USPS facility in San Francisco, California
- 300 kW Molten Carbonate fuel cell system



Examples of agency objectives supported by fuel cell projects:

- Compliance with renewable portfolio standards
- Reduction of air pollution emissions or GHG footprint on an agency-wide basis
- Compliance with general environmental or efficiency goals through general department pursuits or mandatory compliance
- Enhanced program visibility, with implementation of innovative fuel cell technology at one site raising the profile of the entire agency
- Continued leadership by the federal government in the commercialization of clean energy technology

FuelCell Energy Fuel Cell

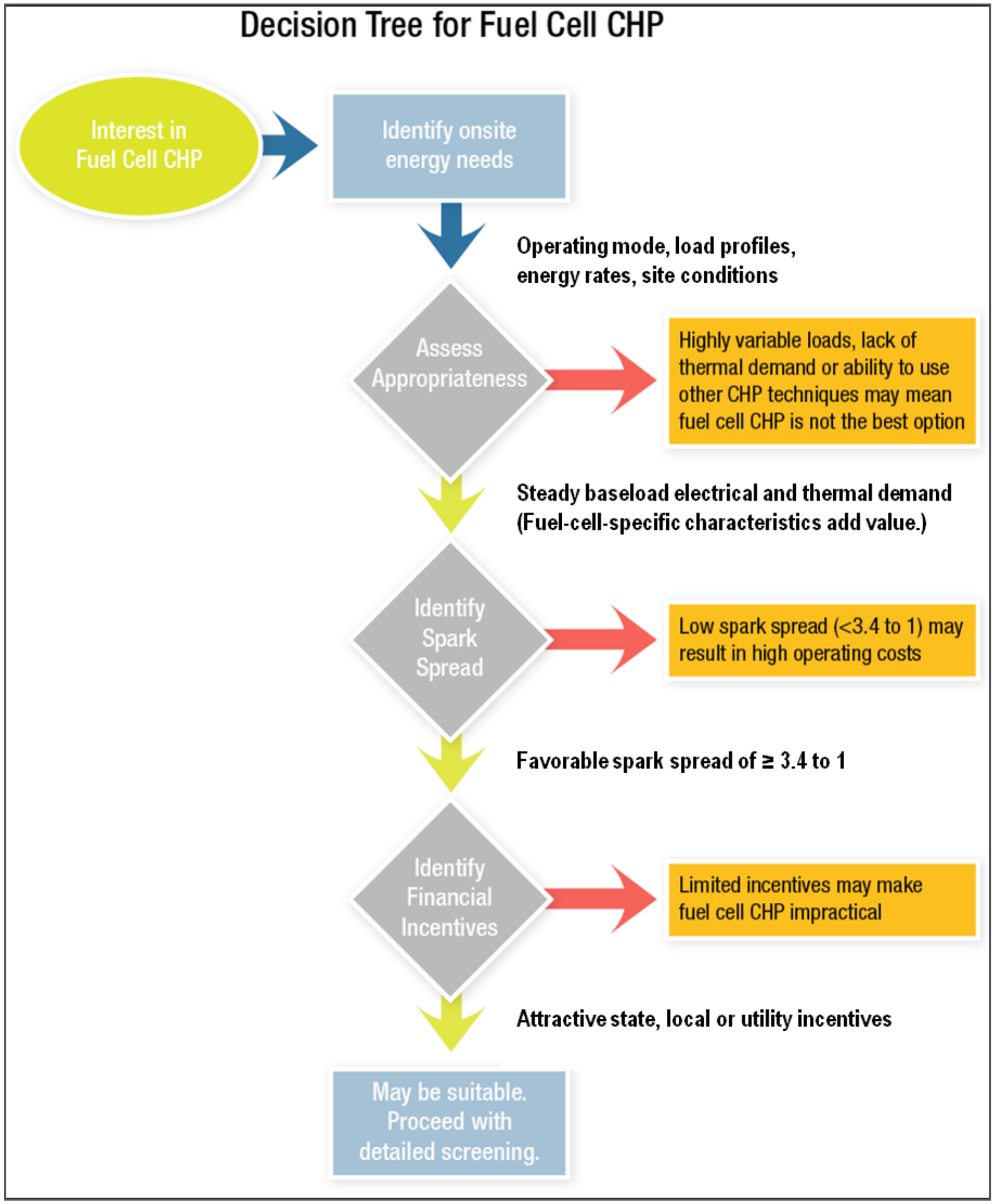
UTC Power Fuel Cell

Bloom Energy Fuel Cell

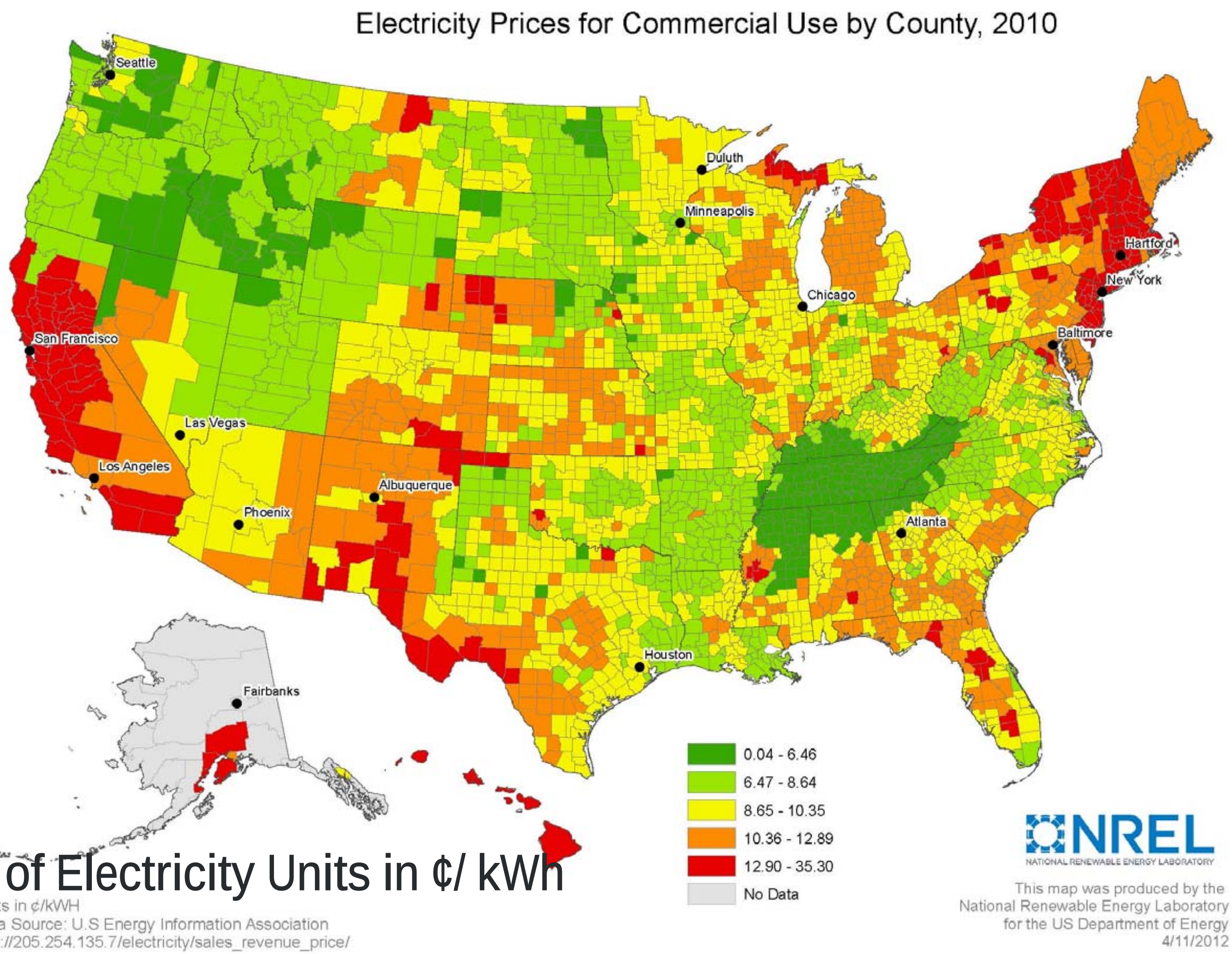
Screening for Fuel Cell CHP

Is the Facility a good match?

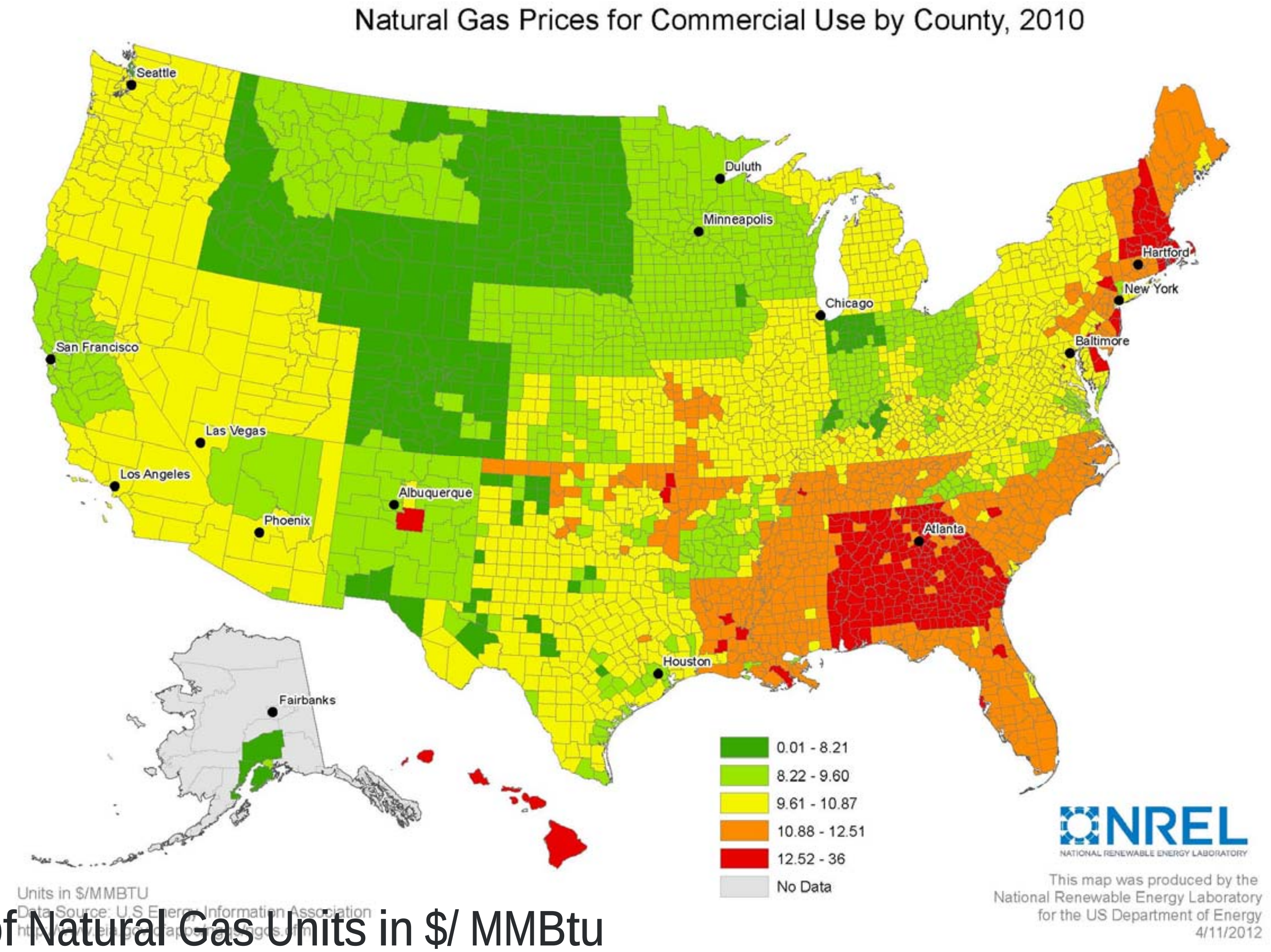
- Average electric load is 100 kW or higher
- Ratio of average electric load to peak load is > 0.7
- Have central, chilled water plants and/or constant cooling needs
- Have a thermal load that must be met on a continuous basis (Examples include a central or district heating system or hot water for a medical facility.)
- Thermal demand is matched to electric load on a daily and seasonal basis
- Operate more than > 6,000 hours per year



Electricity Prices



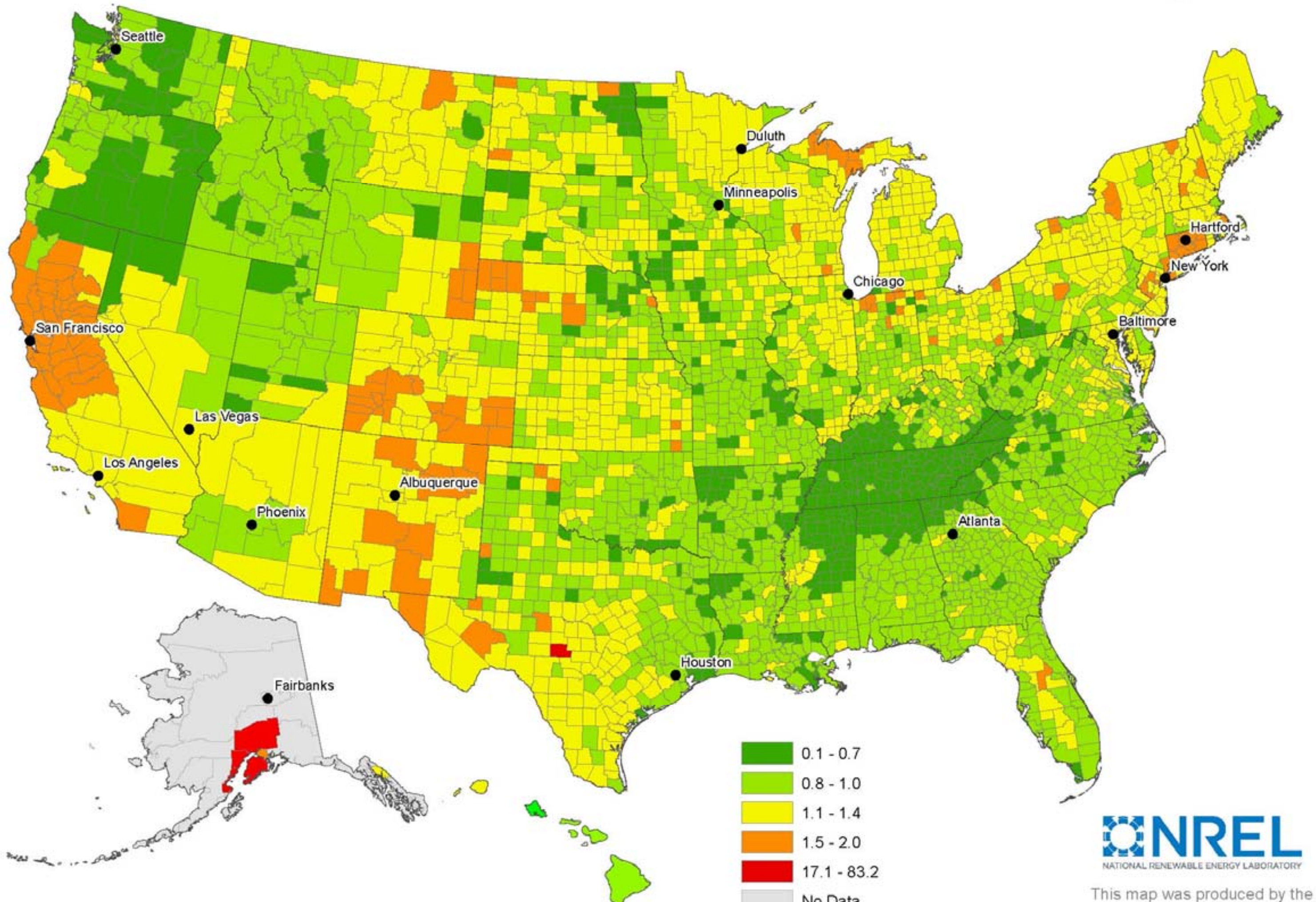
Price of Electricity Units in ¢/ kWh



Price of Natural Gas Units in $/ MMBtu

Spark Spread

Ratio of Electricity to Natural Gas Price for Commercial Use by County, 2010



Units in ¢/kWH and ¢/mfc
Data Source: U.S Energy Information Association
http://www.eia.gov/cfapps/ngqs/ngqs.cfm ; http://205.254.135.7/electricity/sales_revenue_price/

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

This map was produced by the
National Renewable Energy Laboratory
for the US Department of Energy
4/11/2012

Detailed Planning

DIRECTION »	STAFFING »	SITE EVALUATION »	CONSIDERATIONS »
Identify Needs and Goals	Assemble an On-site Team	Evaluate Fuel Cell Options	Consider Project Requirements and Recommendations

DIRECTION

Common Reasons for Considering a Fuel Cell Project

- The agency must meet renewable energy and energy efficiency targets.
- The appropriations are available for improving a facility.
- The project is a good way to meet a site's energy needs.
- The project can provide energy cost savings.
- The project can reduce future energy cost volatility and uncertainty.
- The project will earn credits toward LEED certification.

Potential Goals or Criteria

- Maximize on-site fuel cell energy production
- Maximize the return on investment
- Design fuel cell CHP system to provide all energy for critical function

STAFFING

Initial Team Members

- Fuel cell project manager
- Contracting officer
- Energy manager
- Environmental expert
- Facility manager
- Site managers
- Fuel cell technology expert
- Utility point of contact

Additional Team Members

- Attorney or general counsel (e.g., for contract and authority issues)
- Budget officer
- Facility master planner
- Real estate officer
- Safety officer
- Sustainability officer

SITE EVALUATION

Run FC Power Model

Project Fuel Cell Screening

- Manufacturer's warranty
- Available square footage
- Estimate of the system's size
- Historic building issues
- Incentives (federal, state, local, utility, RECs)
- Siting and site access

Project Fuel Cell Feasibility

- Capacity of the local industry to supply and maintain system
- Utility interconnection issues
- Electrical/mechanical room issues
- Size, condition, and efficiency of existing heating systems.

CONSIDERATIONS

Considerations

- Utility interaction
- Indemnity
- NEPA compliance
- Air Permit
- Controls and Communications
- Buy American Act provision

Project Finance

- Agency Funded Project
- Power Purchase Agreements (PPA)
- Energy Savings Performance Contract (ESPC)
- Utility Energy Services Contract (UESC)
- Advanced Ownership Models

A UTC Power PAFC 400 kW fuel cell installed at the Octagon building on Roosevelt Island in New York. The Octagon is a Leadership in Energy and Environmental Design®(LEED) Silver 500-unit apartment community that made green history by becoming the first residential building in the State of New York to be powered and heated by a 400 kW fuel cell from UTC Power.

Photo courtesy of UTC Power

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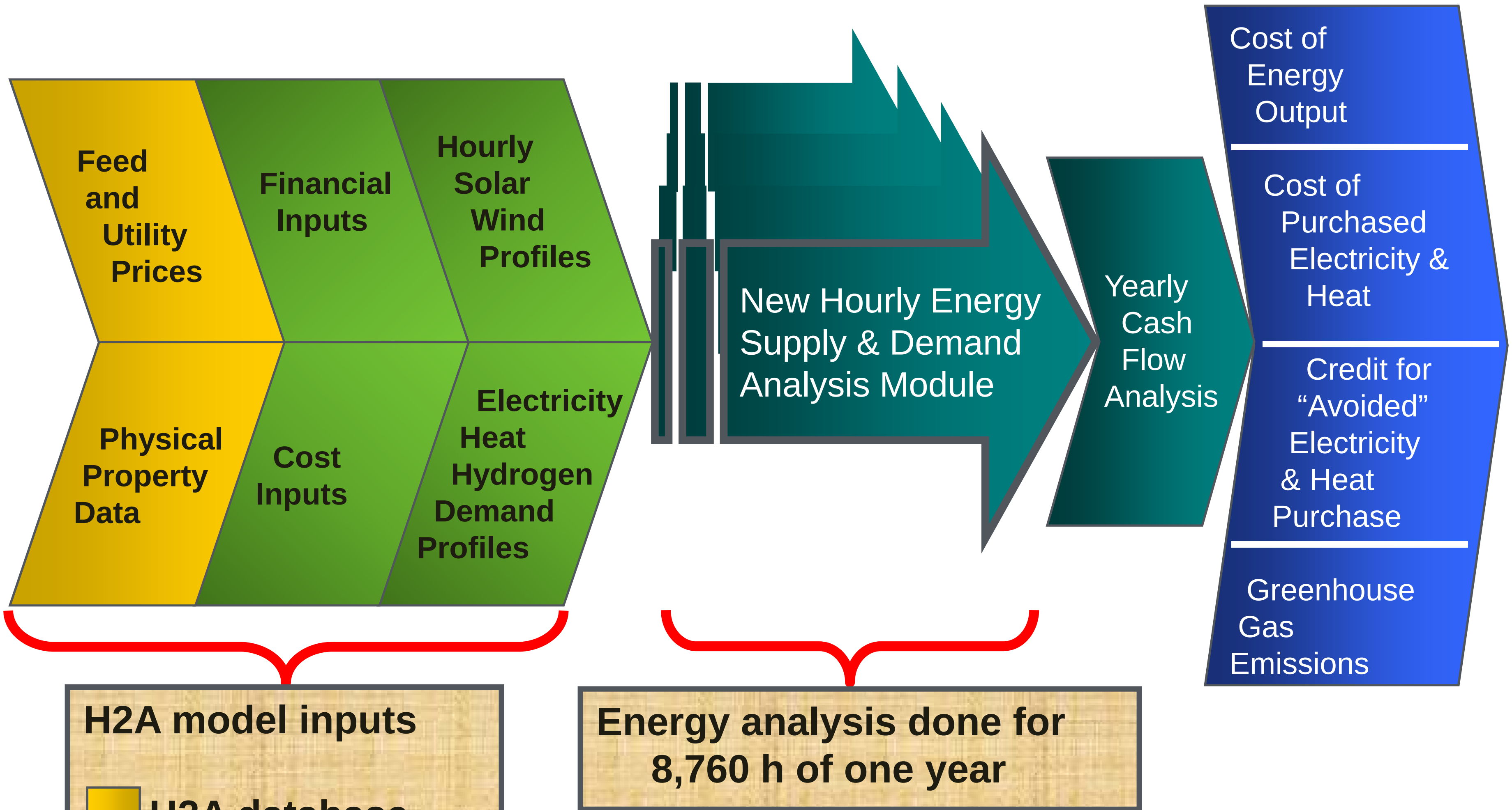

H2A database
User inputs

http://www.hydrogen.energy.gov/fc_power_analysis.html

Agency Funded Project

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Steps for Facilities Managers to Follow

- Secure funding
- Develop the scope of work
- Develop a request for proposal
- Issue a request for proposal
- Evaluate proposals
- Award the contract and design project
- Construct the project
- Commission the system
- Post-commissioning performance

PROS	CONS
• Well-understood mechanism. • Common to many federal capital projects. • Does not incur any financing costs. • Long-term energy-cost reduction. (e.g., loan interest)	• Site is responsible for operations and maintenance arrangements (including inverter replacement), but can purchase an operations and maintenance (O&M) service contract. • No assurance of long-term performance. • Could be more human-resource intensive (i.e., system operations and maintenance) than other options. • Will not be able to apply available tax incentives.

Power Purchase Agreements

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Steps to Follow

- Address PPA-specific issues
- Select a contracting agent
- Issue RFI
- Issue RFQ
- Develop and Issue RFP
- Administer the RFP
- Evaluate the proposals
- Award the contract (issue any needed indefinite delivery, indefinite [IDIQ] task order)
- Design, construct, and commission project
- Monitor performance period
- End contract oversight

PROS	CONS
• Developer is eligible for tax incentives and accelerated depreciation, which should result in reduced energy costs. • Not required to provide up-front capital. • Developer provides O&M • No financial risk on capital equipment. • Long-term electricity or thermal energy price for a portion of the site load - reduces risk of fluctuating energy prices. • Developer has incentive to maximize energy generation of the system . • Can use funds to get a better PPA price or a larger system.	• Transaction costs include a significant learning curve and time investment. • Federal-sector experience is limited. • Civilian agencies are limited to 10-year term • PPA utility contracts (the U.S. Department of DOD has 2922A authority, which permits 30-year terms.) • Site-access issues are complex. • Management and ownership structures are complex. • Contract termination penalties.

Energy Savings Performance Contract

Steps to Follow

- Plan the project
- Perform a preliminary assessment and ESCO selection
- Perform investment grade audit to award
- Design the project
- Construct and install the system
- Commission the system
- Monitor the performance period
- Perform project close out

PROS

- 25-year contract fits with longer paybacks.
- Performance is guaranteed.
- O&M included as part of contract.
- Can require that fuel cell CHP be part of project.
- Project facilitator is assigned (FEMP-funded through initial proposal or preliminary assessment).
- Sale of excess energy is allowed (EISA provision).
- Has discretion to allow ESCO or third-party ownership of the renewable energy conservation measures eligible for federal and state tax incentives

CONS

- Since ESCOs traditionally do not own assets, it is difficult to monetize tax incentives related to fuel cells.
- Not recommended for renewable-only projects.

Steps to Follow

- Introduction: Contract or agreement review
- Perform preliminary study
- Perform agency review
- Project implementation proposal
- Negotiate and accept the proposal

PROS

- UESC is 10 to 25 years
- GSA states that extended utility agreements are allowed
- Utilities now eligible for a ITC
- Interconnection, tariff, and standby issues should be minimal with utility ownership
- Utilities are interested in a wide range of project sizes
- A relationship already exists.
- Utilities often have access to reduced financing rates due to their financial strength.

CONS

- Not all utilities offer UESCs (FEMP is helping utilities launch UESC programs).
- Utility might have limited renewable experience and could be uncomfortable with renewable projects.
- Issues could arise regarding contracts for terms of more than 10 years; 10 years is acceptable for energy efficiency but renewable energy projects usually require a longer contract to be economically feasible.

Key Reports

The DOE Fuel Cell Technologies Program funds the development and publication of key reports

Procuring Fuel Cells for Stationary Power: A Guide for Federal Facility Decision Makers
By Oak Ridge National Laboratory
See report: http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fed_facility_guide_fc_chp.pdf

The Business Case for Fuel Cells: Why Top Companies are Purchasing Fuel Cells Today
By FuelCells2000, http://www.fuelcells.org
See report: http://www.fuelcells.org/BusinessCaseforFuelCells.pdf

State of the States: Fuel Cells in America
By FuelCells2000, http://www.fuelcells.org
See report: ttp://www.fuelcells.org/StateoftheStates2011.pdf

2010 Fuel Cell Market Report
By Breakthrough Technologies Institute, Inc. http://www.btionline.org/
See report: http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2010_market_report.pdf

Annual Merit Review & Peer Evaluation Proceedings
Includes downloadable versions of all presentations at the Annual Merit Review
http://www.hydrogen.energy.gov/annual_review11_proceedings.html

Annual Merit Review & Peer Evaluation Report
Summarizes the comments of the Peer Review Panel at the Annual Merit Review and Peer Evaluation Meeting
http://hydrogen.energy.gov/annual_review11_report.html

Annual Progress Report
Summarizes activities and accomplishments within the Program over the preceding year, with reports on individual projects
www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 14 18, 2012 Arlington, VA
http://annualmeritreview.energy.gov/

THANK YOU

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