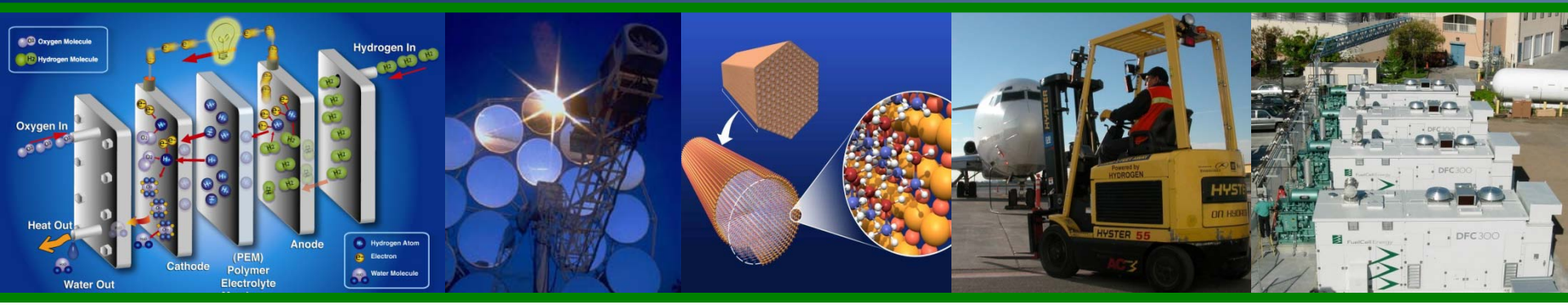
U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy



Stationary Fuel Cells: Overview of Hydrogen and Fuel Cell Activities

Pete Devlin

Fuel Cell Technologies Program

United States Department of Energy

Federal Utility Partnership Working Group

April 14th, 2010

Outline

- DOE Fuel Cell Market Transformation Overview
  - Overview of CHP Concept
  - Stationary Fuel Cells for CHP Applications
- Partnering and Financing (Sam Logan)
  - Example Project

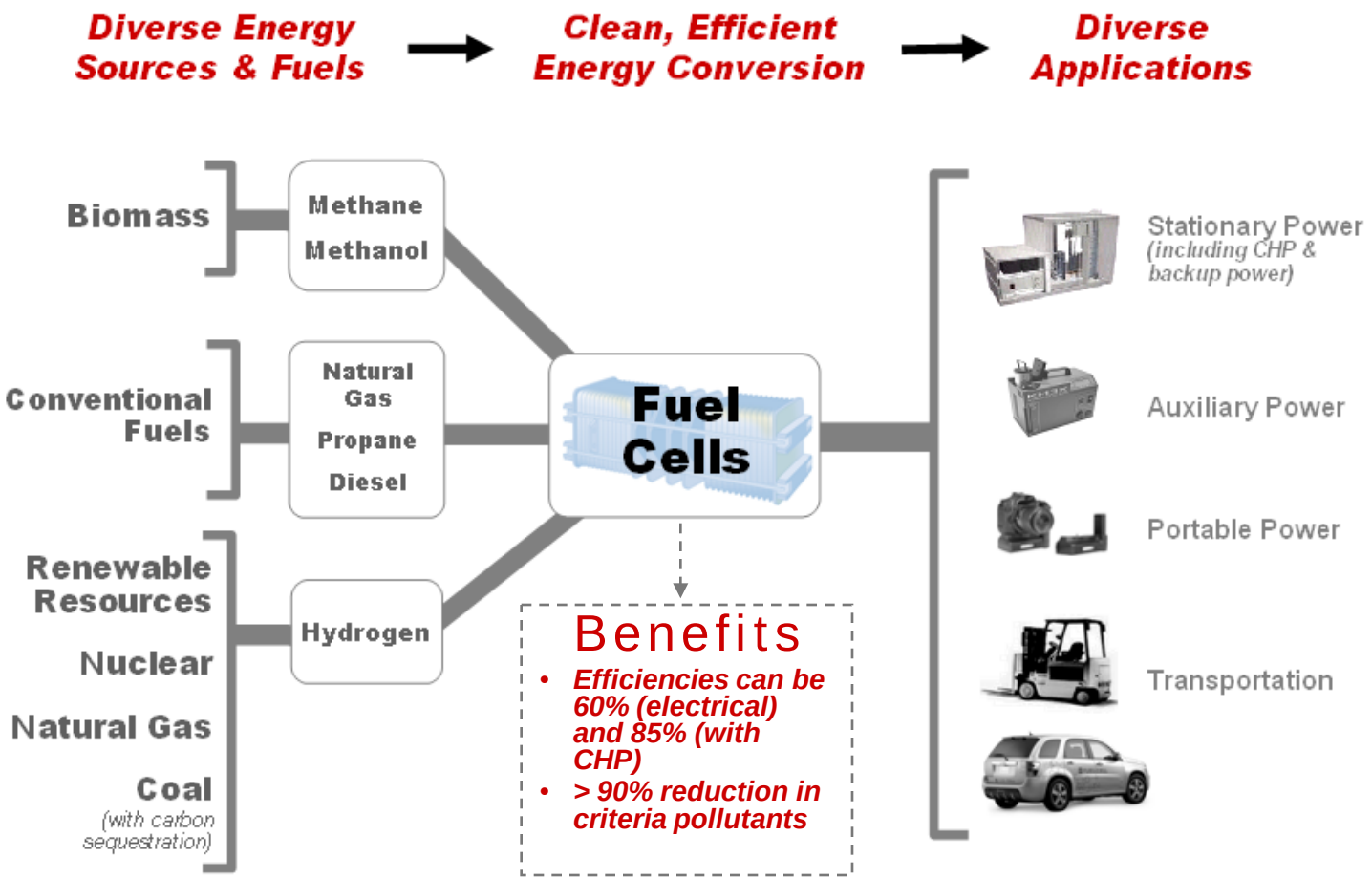
Fuel Cells: Addressing Energy Challenges

Energy Efficiency and Resource Diversity

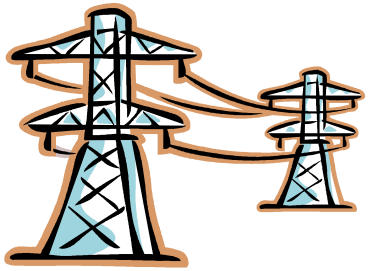
→ ***Fuel cells offer a highly efficient way to use diverse fuels and energy sources.***

Greenhouse Gas Emissions and Air Pollution:

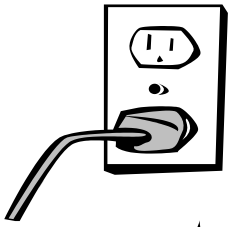
→ ***Fuel cells can be powered by emissions-free fuels that are produced from clean, domestic resources.***



Overview of CHP Concept

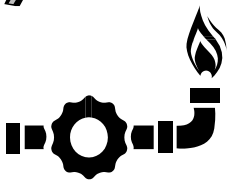


Electricity

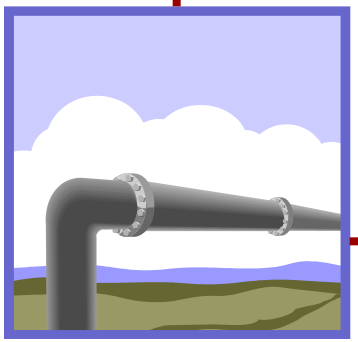


Power

Natural Gas

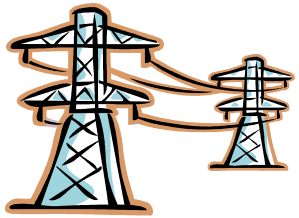


Heat



Natural Gas or Biogas

Fuel Cell



Excess power generated by the fuel cell is fed to the grid

Stationary Fuel Cell Product Example

400 kW Phosphoric Acid Fuel Cell

1 Fuel Processor

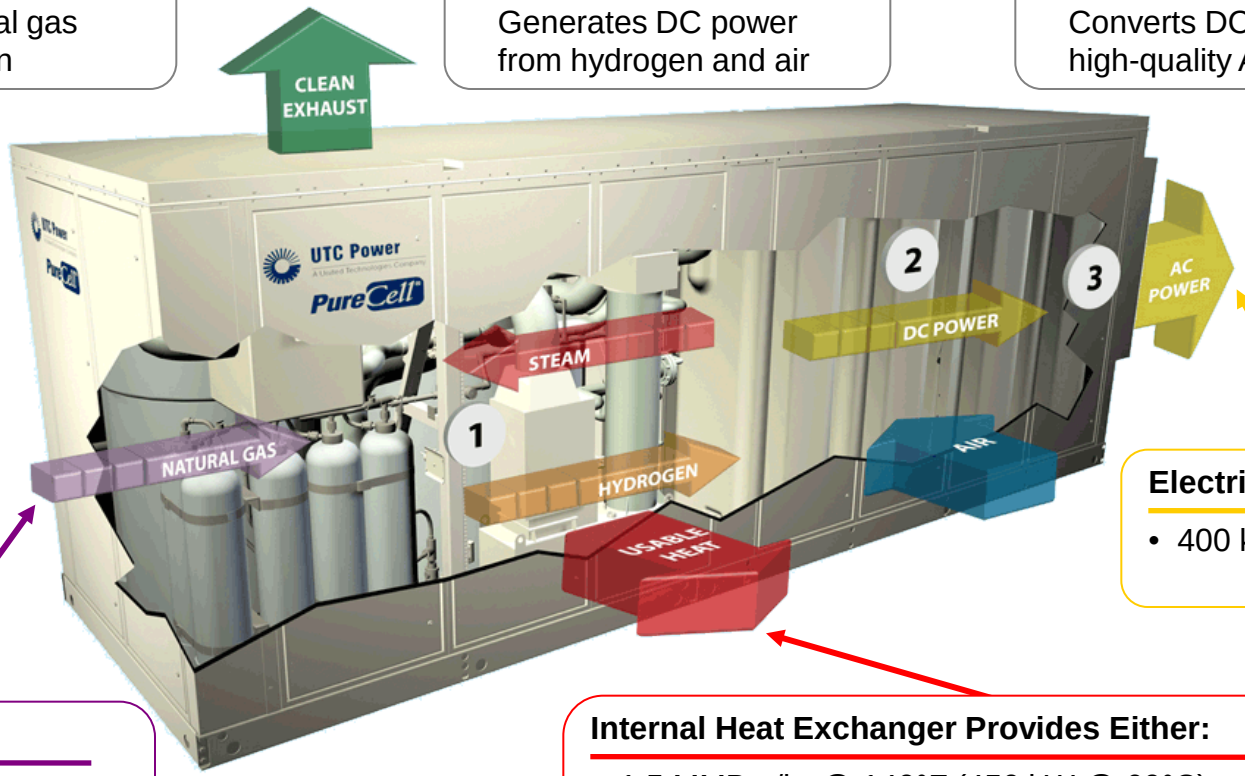
Converts natural gas fuel to hydrogen

2 Fuel Cell Stack

Generates DC power from hydrogen and air

3 Power Conditioner

Converts DC power to high-quality AC power



Fuel Input:

Natural gas
3.2 MMBtu/hr (950 kW) LHV
3.6MMBtu/hr (1054 kW) HHV

Internal Heat Exchanger Provides Either:

- 1.5 MMBtu/hr @ 140°F (450 kW @ 60°C)

OR

- 0.7 MMBtu/hr @ 250°F & 0.9 MMBtu/hr @ 140°F (200 kW @ 121°C & 250 kW @ 60°C)

Electric Output:

- 400 kW, 480V, 60 Hz

Stationary Fuel Cell Applications

Key Market Sectors

Data Centers

Supermarkets

Hospitals

Hotels

Educational Institutions

- **Energy intensive**
- **Power, heating, cooling**
- **Benefits**
  - **On-site energy/security**

Stationary Fuel Cell Applications

Assured Power

First National Bank of
Omaha
Omaha, Nebraska

On-Line Emergency Power

Verizon
Garden City, New York

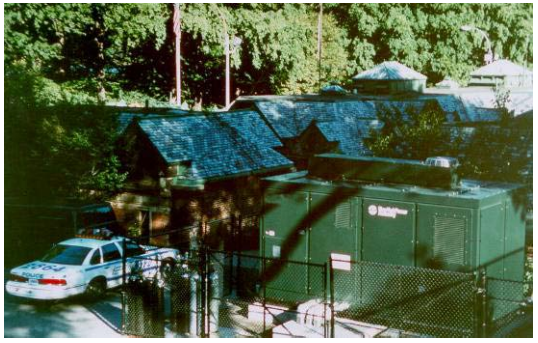
Indoor Green Power / Cogeneration

4 Times Square
New York, New York

Renewable Fuel (ADG)

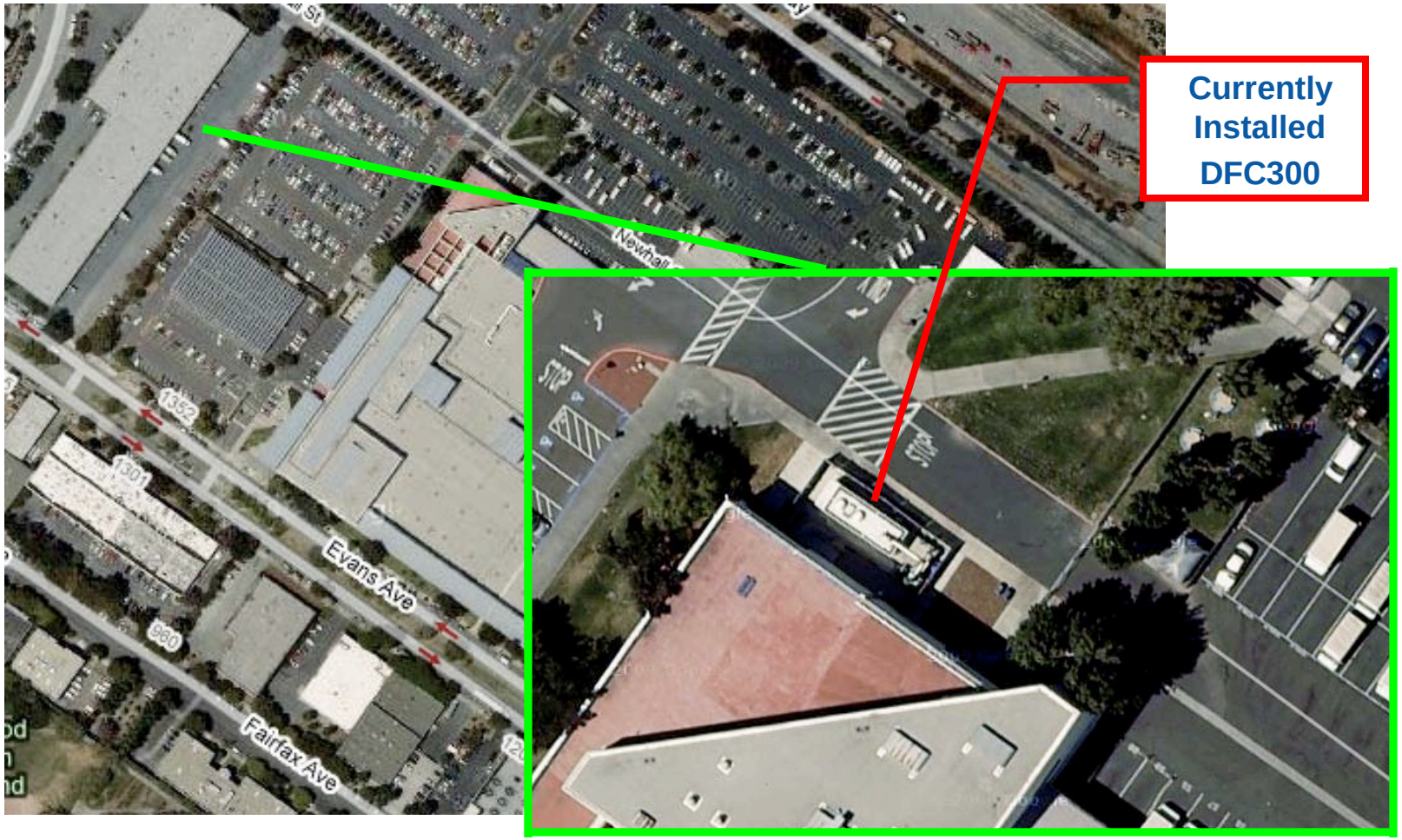
Wastewater treatment plants
New York, New York

Off-Grid Power



Central Park Police Station,
New York, New York

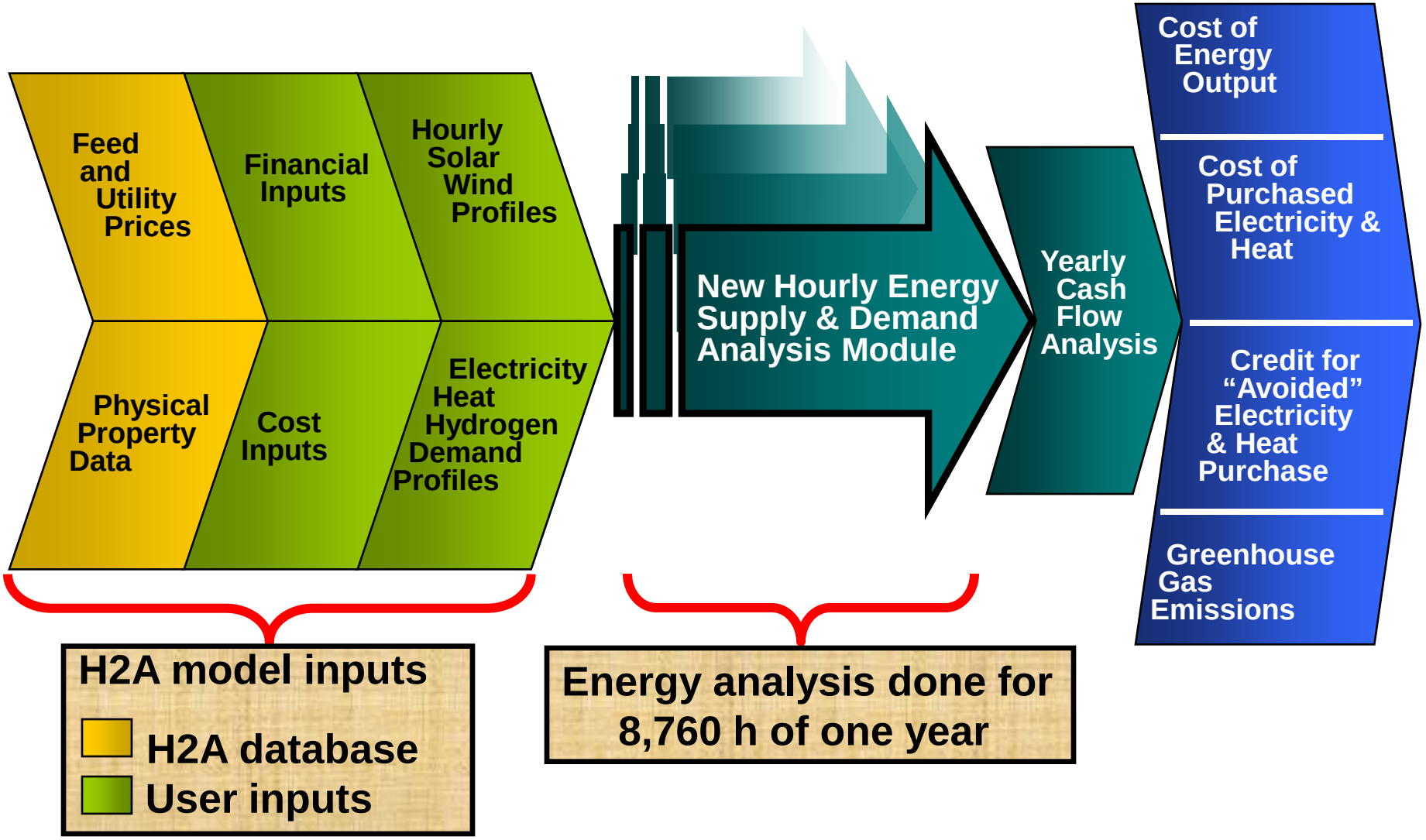
Stationary Fuel Cells Have A Small Footprint



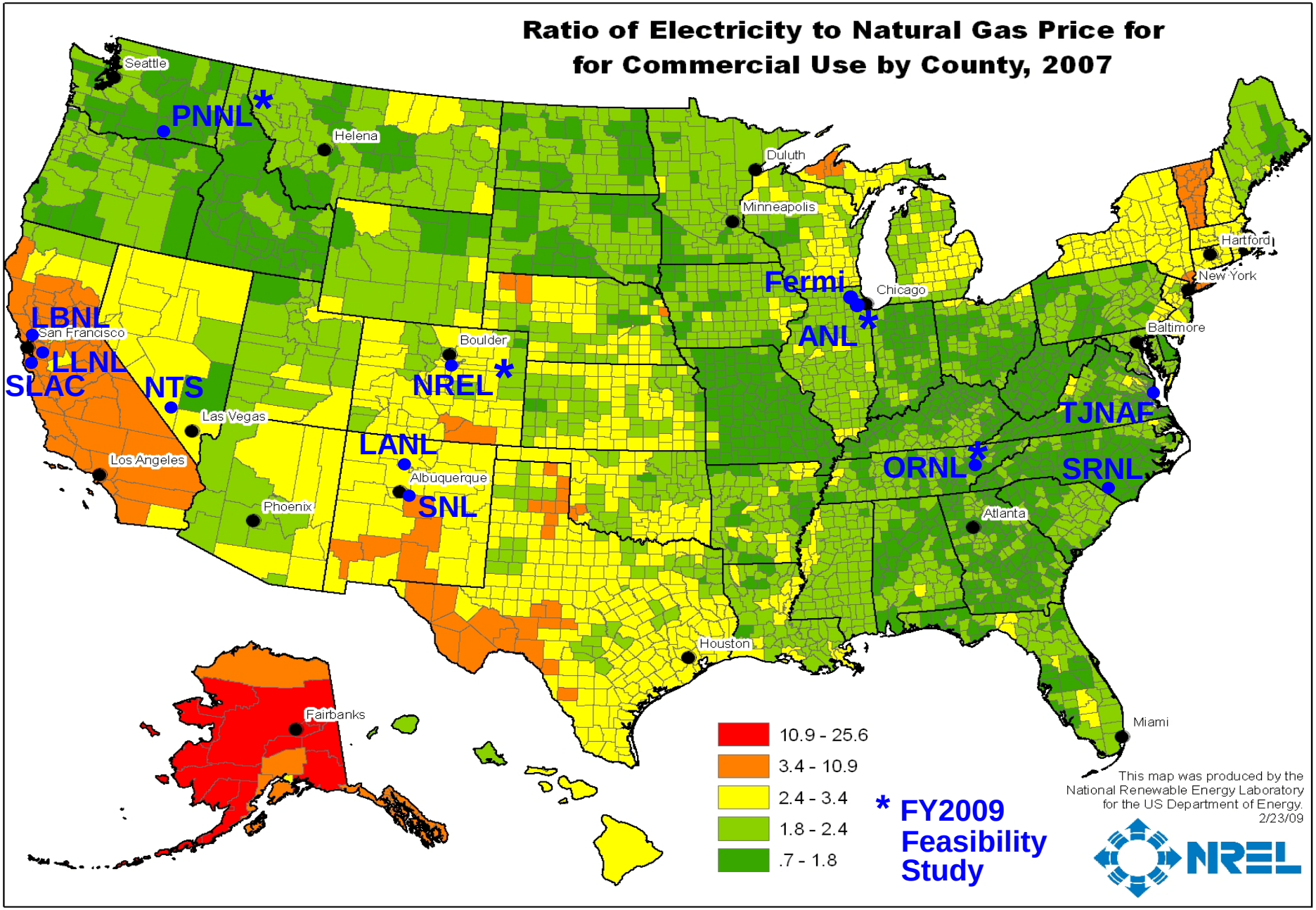
USPS facility in San Francisco, California

300 kW Molten Carbonate fuel cell system.

FCPower Model Hourly Energy Analysis Module

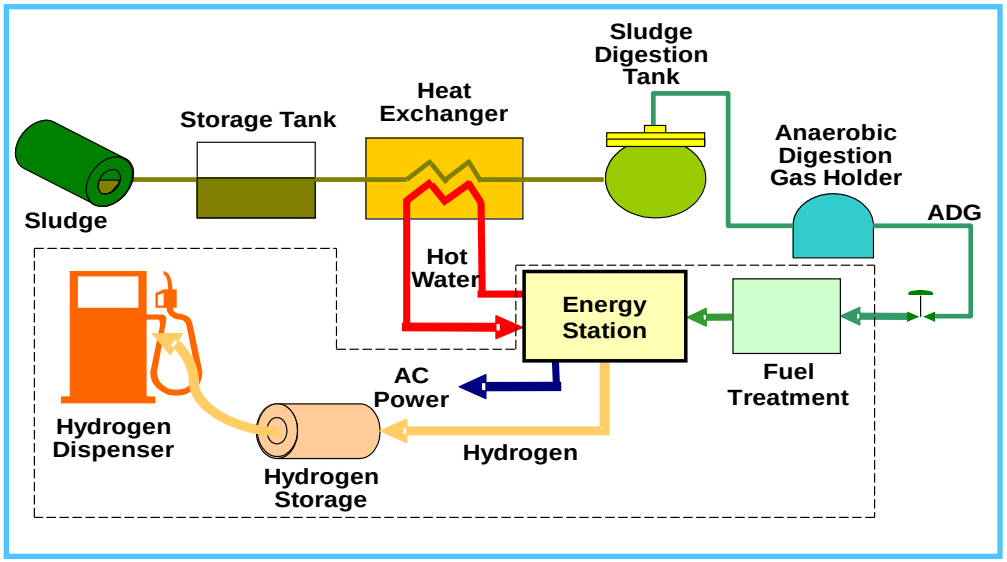


Spark Spread



Preliminary Test Results

- **Fuel cell with water-gas shift in operation > 6,000 hours**
- **Tri-generation results:**
  - **Coproduced 2 to 5 kg/hr hydrogen with > 200 kW electricity**
  - **Estimated hydrogen recovery at 80 to 85%**
  - **Product purity <0.2 ppm CO; <2 ppm CO_2**
  - **Operation with simulated digester gas feed**
  - **PSA operating map developed (cycle time vs. feed rate)**
  - **Implemented automated system to switch to CHP mode when hydrogen tanks are filled.**



Anode Exhaust Processing and H_2 PSA

Public-Sector Partners:

South Coast Air Quality Management District

California Air Resources Board

Partners in Market Transformation

Market Transformation

Providing Tangible Benefits to Federal Energy Consumers

- Distributed CHP Generation...Energy Efficiency
- Reduce Harmful Emissions and GHG
- Increase Energy Security, Reliability & Reduce Demand on Grid
- Comply with Legal Mandates
- Upgrade Facility Infrastructure Reduced Capital Appropriations
- Insulate Against Rising Energy Costs

Market Transformation

Green House Gas Comparison

- ~680lbs per MWH with 65% efficient CHP application …
  - ~50% GHG reduction compared to incumbent technologies

	CO_2 (lb/MWh)	NO_X (lb/MWh)	SO_X (lb/MWh)	PM_{10} (lb/MWh)
Average US Fossil Fuel Plant	2031	5.06	11.6	0.27
Average US Generation	1408	3.4	7.9	0.19
Typical Small Gas Turbine	1494	1.1	0.008	0.08
DFC (Baseline products)	980	0.01	0.0001	0.00002
DFC Potential (at 65% Efficiency)	**680**	**0.007**	**0.00007**	**0.00001**

Data source, FuelCell Energy, UTC, NREL

Financing CHP Projects

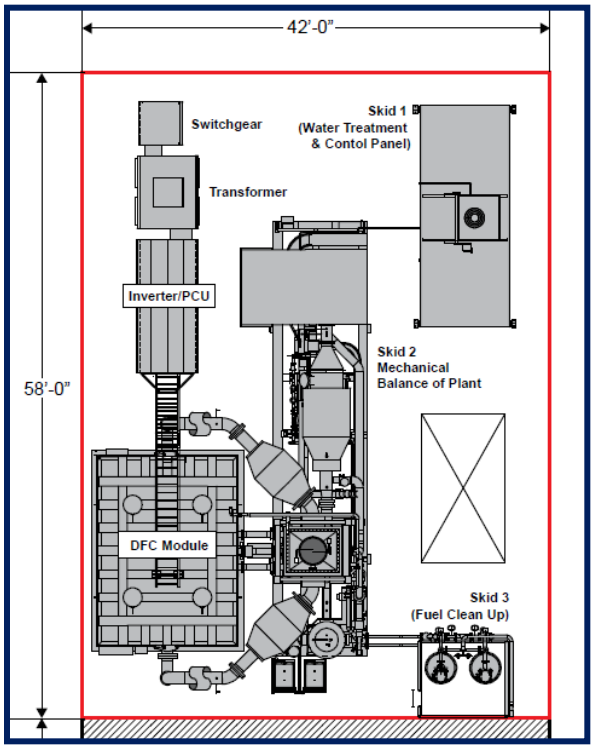
- Federal Investment Tax Credits (ITC's) or Grants in lieu of ITC's (an energy services contract with a third-party project developer is required for a tax-exempt customer to benefit)
- State Tax Credits
- State and Local Incentives and Grants
- Utility Incentives and Grants
- Demand Response and other 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

CHP Project Example Key Assumptions

- Install 1,500 kW Carbonate Fuel Cell
- Government customer in CT
- Utility Rates:
  - Electricity: $0.125 average cost per kWh
  - Natural Gas: $7.00 per thousand cubic feet (Mcf)
  - Average Cost of Heat: $9.30 per million British thermal unit (MMBTU)
- Net Metering Revenue Available
  - Public Utilities Code Section
- CT Clean Energy Fund
  - Up to $2.50/W Installed Capacity
  - Capacity Payment Program
  - Renewable Energy Credits
- Ten-Year Service Contract

Government Owned Example

- 1500kW (net 1400kW) Carbonate Fuel Cell
- 90% Operating Availability
- Long Term Service Agreement & Warranty
- Initial 10 Year Service Term



1500kW Carbonate FC Diagram

	(000)	
Installed CHP System	$	7,862
Incentive Payments	$	(2,475)
Govt Investment	$	5,387
Govt % Investment		69%
Operating Specifications		
Fuel Cell Output kW (EOY)		1,385
Fuel Flow (MMBtu/hr LHV)		10.2
Avg Plant Thermal Recovery (MMBtu/hr)		1.62
Annual Totals		
Power Generation Net (MWh)		10,919
Plant Fuel (MMBtu LHV)		80,417
Plant Thermal (MMBtu)		12,772
Project Revenue (000)		
Avoided Electric Utility Cost - Fuel Cell	$	1,365
Electricity - RECs / Other	$	273
Electricity - Capacity	$	58
Avoided Thermal Cost	$	96
Annual Savings (000)	$	1,792
Operating Costs (000)		
LTSA & Fuel	$	1,150
Net Annual Savings (000)	$	642
Payback Yrs.		8
NPV (000)	$	(1,000)

Developer Owned Example

		(000)
Installed CHP System	$	7,540
Incentive Payments	$	(4,878)
Govt Investment	$	2,662
Govt Investment %		35%
Operating Specifications		
Fuel Cell Output kW (EOY)		1,385
Fuel Flow (MMBtu/hr LHV)		10.2
Avg Plant Thermal Recovery (MMBtu/hr)		1.6
Annual Totals		
Power Generation Net (MWh)		10,919
Plant Fuel (MMBtu LHV)		80,417
Plant Thermal (MMBtu)		12,772
Annual Avoided Costs		
Avoided Electric Utility Cost - Fuel Cell	$	1,365
Electricity - RECs / Other	$	273
Electricity - Capacity	$	58
Avoided Thermal Cost	$	96
Total Avoided Costs	$	1,792
Operating Costs		
LTSA & Fuel	$	1,100
Annual Developer Service Fee	$	325
Net Annual Savings	$	367
NPV	$	(496)

- 1500kW (net 1400kW) Carbonate Fuel Cell
- 90% Operating Availability
- Long Term Service Agreement & Warranty
- Initial 10 Year Service Term

1500kW Carbonate FC Installation

Ownership Cost Comparison

Project Ownership Comparison

(000)	Government	Developer
First Cost	$ 7,862	$ 7,540
Incentives	$ (2,475)	$ (4,878)
Net Gov Investment	$ 5,387	$ 2,662
% Investment	68.5%	35.3%
Annual Avoided Costs	$ 1,792	$ 1,792
Annual Fuel Cell O&M	$ 550	$ 550
Annual Fuel Costs	$ 600	$ 600
Annual Developer Fee		$ 325
Annual Costs	$ 1,150	$ 1,475
Annual Savings	$ 642	$ 317
NPV	($1,000)	($496)

Developer Derived Benefits

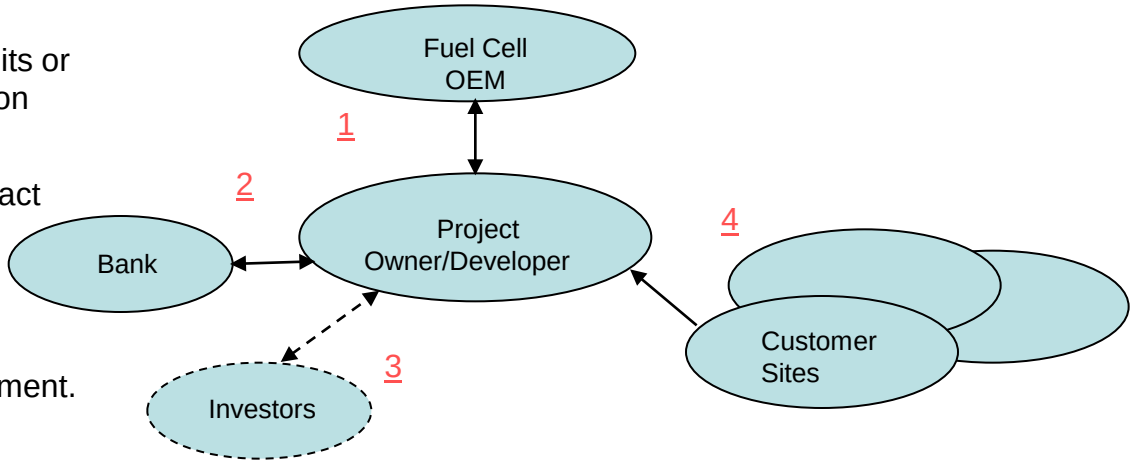
1. Upgrade infrastructure with half the investment.
2. Lower life cycle costs.
3. Site two units for same price as one government owned unit.
4. Gov't investment may be developer financed.
5. Capture benefits of federal tax policy without risk of ownership.
6. Accelerate Market Transformation.

Developer Organizational Chart

1500kW CHP Fuel Cell Project

Financing

- IRS Section 48 Tax Credits or Grant if under construction prior to 31 Dec 2010
- Fed ITC qualifying Contract
- Bankable Transaction…Payment Guarantor
- Other incentive or investment.



Relationships Among Parties

- Project Owner/Developer purchases units from Vendor
- Project Owner/Developer may accept investors) and exchange ITCs for $$ in qualified transaction. ...(Not required for 1603 transaction**.)**
- Project owner to furnish, install, maintain FC units under ITC qualifying Service Agreement. Receives monthly service payments.
- Project owner provides services to Customer through 10-Year Services Agreement

Cash Flows RED Numbers above

1. Project Owner/Developer (e.g. a Limited Liability Company, or LLC) issues PO to Vendor… purchases units on schedule.
2. Bank provides LLC with debt funds for installations and receives monthly debt service.
3. Investors exchange $$ for LLC investment through Operating Agreement...(Not required for 1603 transaction)
4. Customer pays monthly energy service fee (PPA or other form of agreement) to Project Owner/Developer

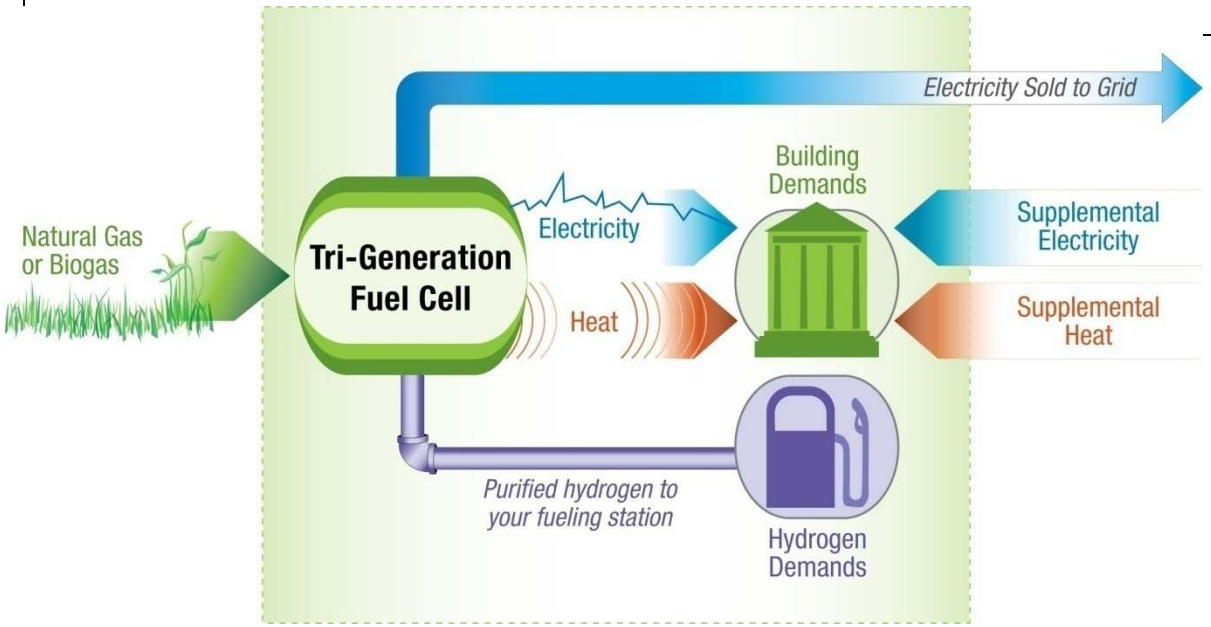
Thank you

Peter.Devlin@ee.doe.gov

Samlogan@loganenergy.com

http://www.eere.energy.gov/hydrogenandfuelcells

FCpower Model



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

Using the Model: Four Simple Steps

Model users are first directed to this screen.

1 **Click Process Flow Diagram**

Title

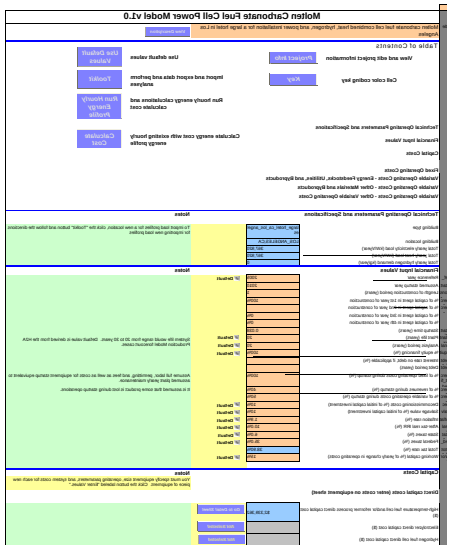
Title:	Molten Carbonate Fuel Cell Case Study
Authors:	Darlene Steward, Mike Penev
Contact:	Darlene Steward
Contact phone:	303 275 3837
Contact e-mail:	darlene_steward@nrel.gov
Organization:	NREL
Date:	1-Aug-09
Web site:	

Simple: *just click!*

2 **• Configure system**
• Click *Input sheet* button

Configure the system on the Process Flow Diagram then click the *"Input Sheet"* button to enter cost & performance values.

Using the Model: Four Simple Steps



3 • Enter cost and performance values using the Input Sheet as "Home Base"

- The "Input_Sheet_Template" sheet is the main model interface
- The subsequent slides will describe each section of the interface
- Tools and defaults are available for most values
- A lot of customization is possible for special case evaluations

4 • Run the model by clicking the "Run Hourly Energy Profile" button

Use default values — *Use Default Values*

Import and export data and perform analyses — *Toolkit*

Run hourly energy calculations and calculate cost — *Run Hourly Energy Profile*

Calculate energy cost with existing hourly file — *Calculate Cost*

Once all inputs are complete, click here