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Fuel Cell Technologies Available Today

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Agenda

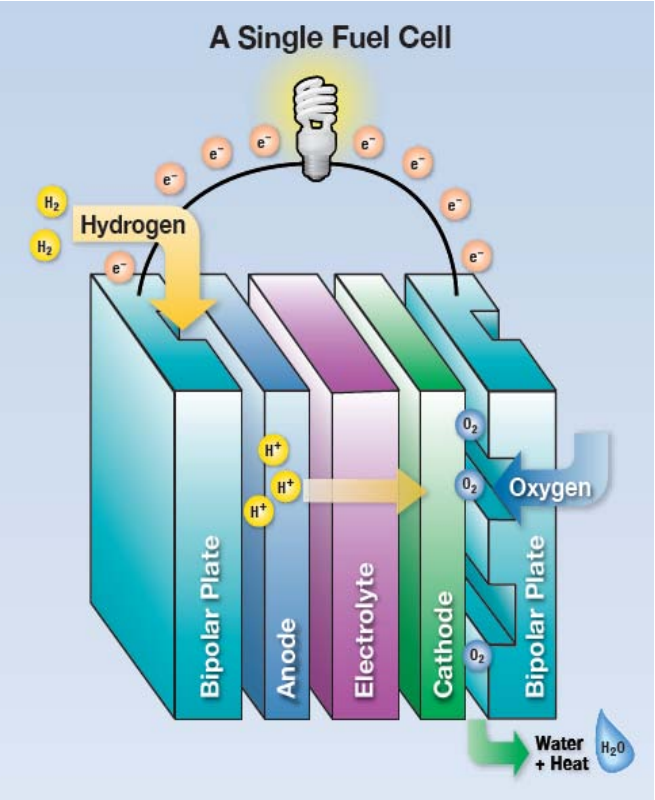
- DOE Fuel Cell Technologies Program Overview
- Early Market Fuel Cell Deployments
- Fuel Cell Products Available Today
  - Back up
  - Material Handling Equipment (MHE)
  - Soldier Power
- New Early Market Activities
  - Mobile Lighting
  - Airline Transport and Support Equipment
  - Integrating Renewable Energy
- NREL Fuel Cell Power Model

The Administration's Clean Energy Goals

- ✓ **Invest $150 billion over ten years in energy R&D to transition to a clean energy economy**
- ✓ **Reduce GHG emissions 83% by 2050**
- ✓ **Executive Order 13514**
  - **GHG Reductions**

Fuel Cell Types — *Benefits of Fuel Cells*

Fuel cells use an electrochemical process to generate electricity and heat, with low emissions, offering a wide range of energy conversion 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**

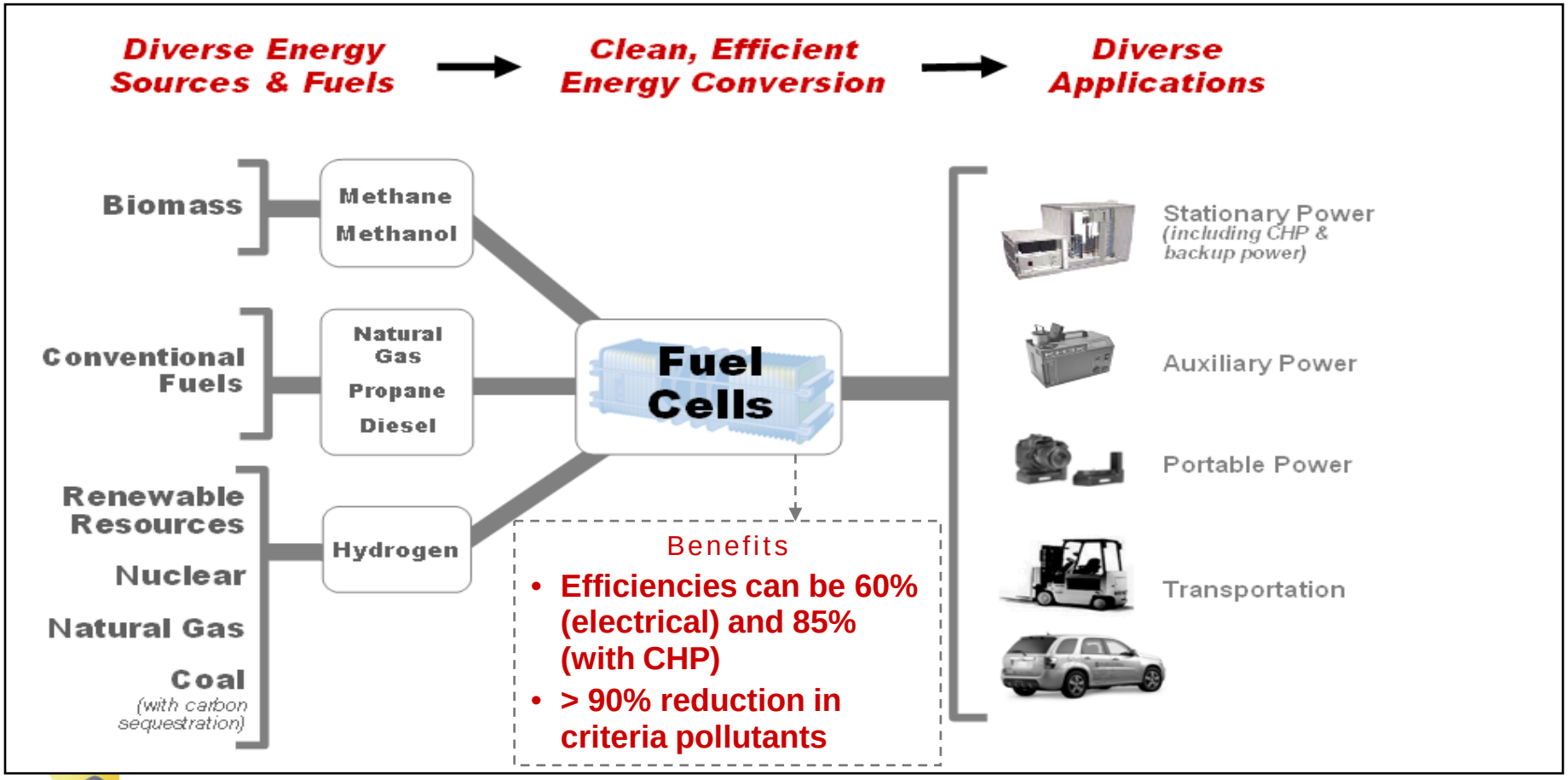
Fuel Cells Help with Our Key Energy Challenges

Resource Diversity

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

Reducing Greenhouse Gas Emissions and Air Pollution:

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



PROGRAM OVERVIEW: Key Targets

The Program has been addressing the key challenges facing the widespread commercialization of fuel cells.

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

Stationary Systems*:* $750 per kW, 40,000-hr durability

Vehicles*:* $30 per kW, 5,000-hr durability

Hydrogen Cost

Proposed target*: ~ $6 / gge (dispensed and untaxed)

Hydrogen Storage Capacity

Target: > 300-mile range for vehicles—without compromising interior space or performance

Technology Validation:

Technologies must be demonstrated under real-world conditions.

Economic & Institutional Barriers

Safety, Codes & Standards Development

Domestic Manufacturing & Supplier Base

Public Awareness & Acceptance

Hydrogen Supply & Delivery Infrastructure

Market Transformation

Assisting the growth of early markets will help to overcome many barriers, including achieving significant cost reductions through economies of scale.

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***Metrics available/under development for various applications**

PROGRAM OVERVIEW: *2010 Progress & Accomplishments*

We've reduced the cost of fuel cells to $61/kW*

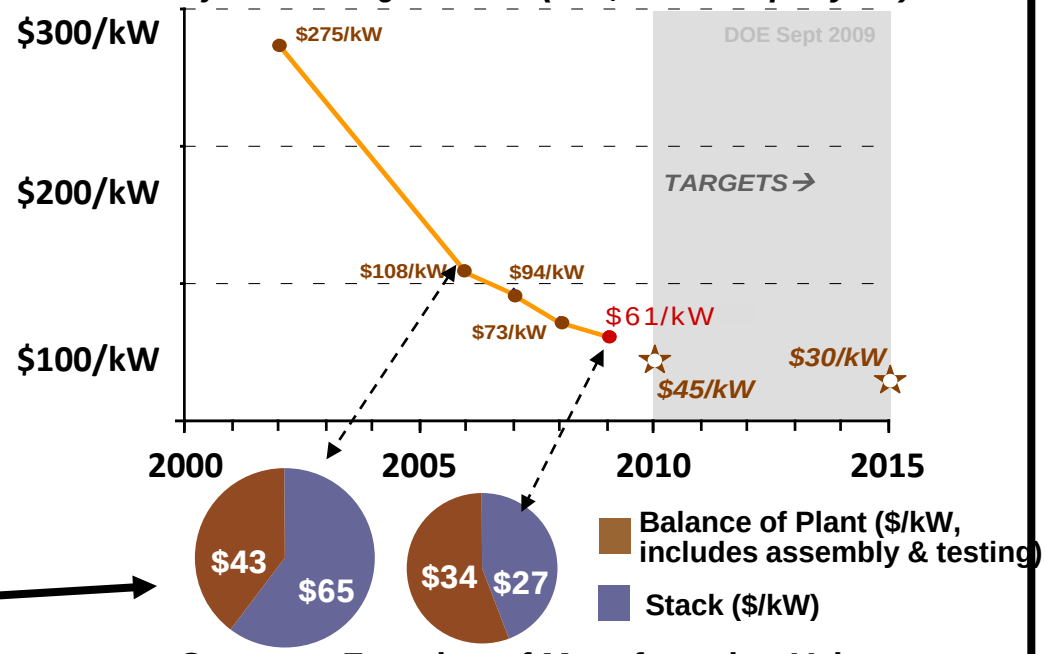
- ***More than 35% reduction in the last two years***
- ***More than 75% reduction since 2002***
- ***2008 cost projection was validated by independent panel****
- **As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs.**

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

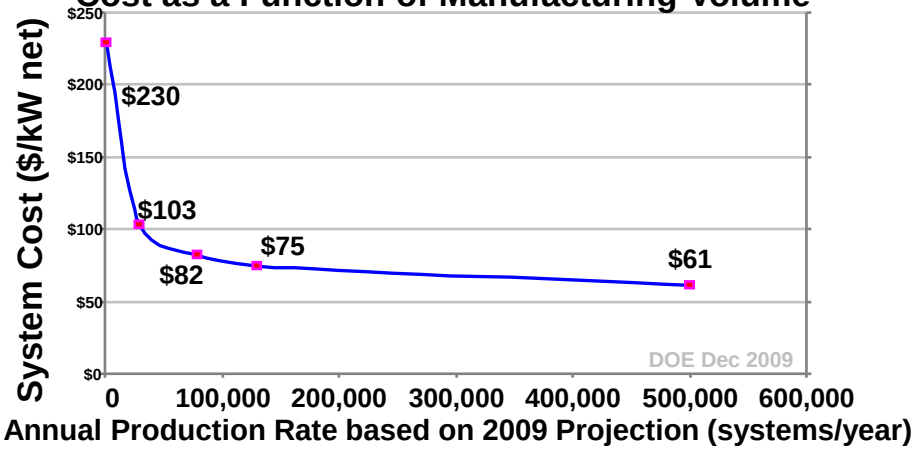
In 2008, an Independent Panel found $60 – $80/kW to be a "valid estimate":
http://hydrogendoedev.nrel.gov/peer_reviews.html

Projected Transportation Fuel Cell System Cost

- projected to high volume (500,000 units per year) -



Cost as a Function of Manufacturing Volume

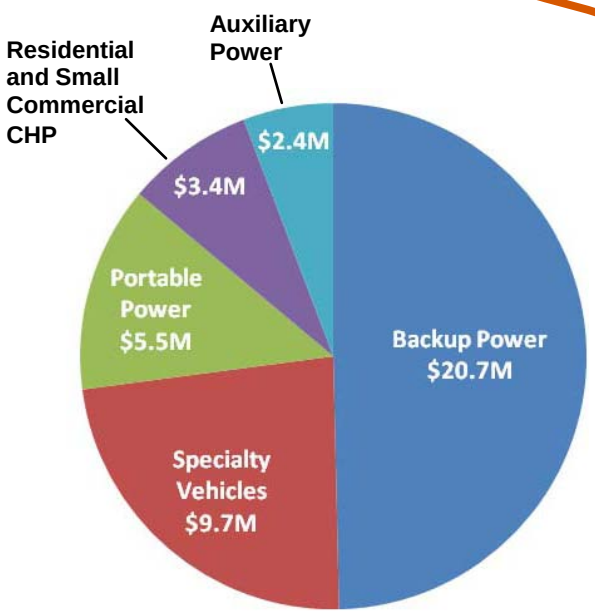


Early Market Fuel Cell Deployments with Industry

DOE announced ~$42 million from the American Recovery and Reinvestment Act to fund 12 projects, which will deploy up to 1,000 fuel cells — to help achieve near term impact and create jobs in fuel cell manufacturing, installation, maintenance & support service sectors.

FROM the LABORATORY to DEPLOYMENT:

DOE funding has supported R&D by all of the fuel cell suppliers involved in these projects.



COMPANY	AWARD	APPLICATION
Delphi Automotive	$2.4 M	Auxiliary Power
FedEx Freight East	$1.3 M	Specialty Vehicle
GENCO	$6.1 M	Specialty Vehicle
Jadoo Power	$2.2 M	Backup Power
MTI MicroFuel Cells	$3.0 M	Portable
Nuvera Fuel Cells	$1.1 M	Specialty Vehicle
Plug Power, Inc. (1)	$3.4 M	CHP
Plug Power, Inc. (2)	$2.7 M	Backup Power
Univ. of N. Florida	$2.5 M	Portable
ReliOn Inc.	$8.5 M	Backup Power
Sprint Comm.	$7.3 M	Backup Power
Sysco of Houston	$1.2 M	Specialty Vehicle

Approximately $51 million in cost-share funding from industry participants—for a total of about $93 million.

Early Market Fuel Cell Deployments with Federal Agencies

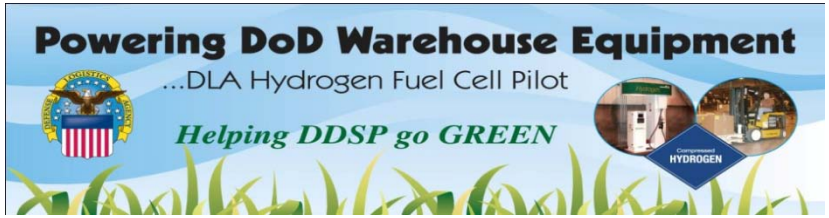
Over 500 kW of back-up power deployed

Examples

- **DLA: material handling equipment and H2ICE shuttle buses**
- **FAA: ground support equipment and backup power**
- **APTO: ground support equipment and H2ICE shuttle buses**
- **Army incl. CERL/TARDEC: backup power, waste to energy, and H2ICE shuttle buses**
- **NPS: renewably generated backup power and H2ICE shuttle buses**
- **ONR/USMC: utility scale renewable hydrogen generation and H2ICE shuttle buses**
- **NASA: backup power and H2ICE shuttle buses**

Market Transformation

American Reinvestment and Recovery Act projects (up to 1,000 fuel cell deployments planned (e.g. forklifts, backup power)



Fuel Cell Products Available Today

Fuel Cells for Stationary Power, Auxiliary Power, and Specialty Vehicles

The largest markets for fuel cells today are in stationary power, portable power, auxiliary power units, and forklifts.

~75,000 **fuel cells have been shipped worldwide.**
~24,000 **fuel cells were shipped in 2009 (> 40% increase over 2008).**
~50 new large (>10-kW) **fuel cells were installed in 2009, and a 4.8-MW fuel cell will be installed in the new World Trade Center.**
More than 1,000 fuel cells **providing combined heat and power for residences are being demonstrated in Japan (the program plans to demonstrate more than 3,000 units).**
Some stationary fuel cells are available with 80,000-hour warranties **on the stack, and some manufacturers report about 40,000 hours between major overhauls.**

Fuel cells can be a cost-competitive option for critical-load facilities, backup power, and forklifts.

Fuel Cell Technologies Available Today
Stationary Power: Combined Heat and Power

- Combined Heat and Power
  - Multiple FC Technologies
  - Heating and Power Needs
  - Multiple Fuel Options
    - Natural Gas
    - Bio Gas
- Value Proposition
  - High Reliability
  - Energy Efficiency (exceeding 85%)
  - No NOX

**Refer to US Fuel Cell Council Product List

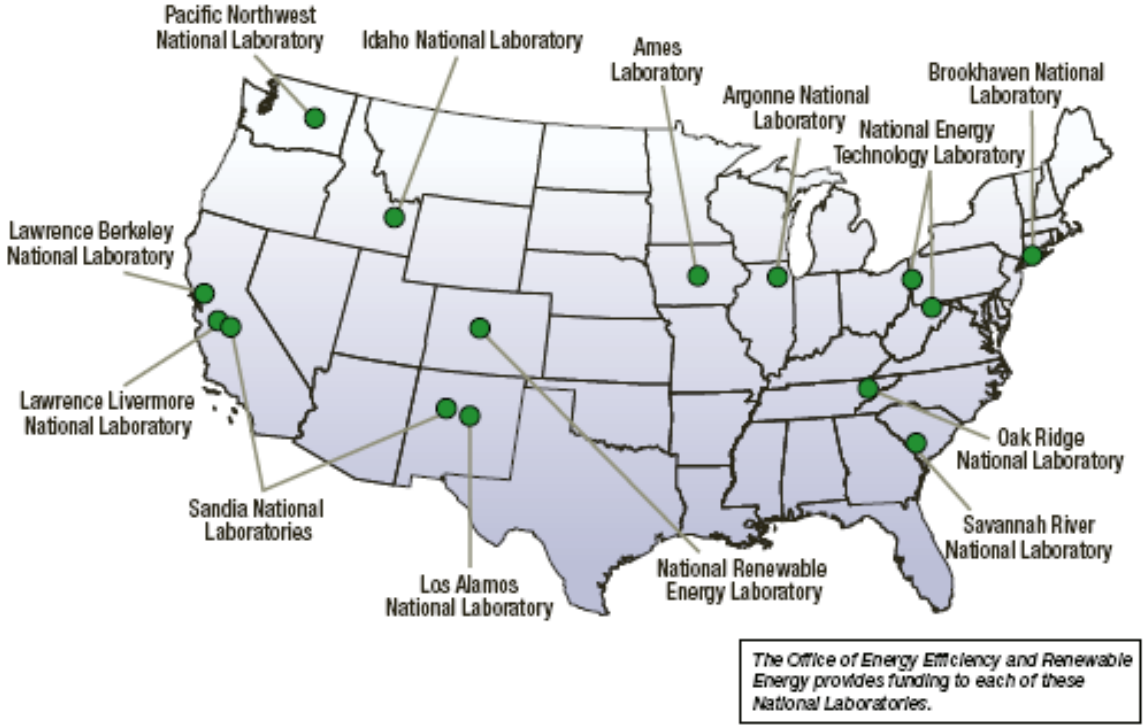
Fuel Cell Technologies Available Today
Stationary Power: Emergency Backup Power

- Emergency Backup Power
  - Telecomm
  - Data Centers
  - Weather Stations (FAA, NOA)

- Value Proposition
  - Energy Efficiency
  - High Reliability/Low Life Cycle Costs
  - No NOX and criteria pollutants

**Refer to USFCC Product List

Fuel Cell Technologies Available Today: Stationary Power: DOE National Laboratories



Goals:

- **Deploy fuel cells and quantify benefits at lab facilities**
- **Develop DOE lab fuel cell expertise across the country**

Ideal sites:

- **Require consistent, reliable, quiet power**
- **Would combine FC installation with planned projects.**

DOE is leading by example by deploying fuel cells at its facilities, a Program is under way determine feasibility at these sites.

Fuel Cell Technologies Available Today
Specialty Vehicles

- Material Handling Equipment
  - PEM Hydrogen Fuel Cells
  - Fork-lifts All classes
    - Stand up Counter Balances

- Value Proposition
  - Quick, easy indoor refills
  - Consistent power across entire shift
  - 10-20% Labor Productivity Savings

**Refer to US Fuel Cell Council Product List

Fuel Cell Technologies Available Today
Soldier Power

- Soldier Power
  - Small Scale PEM/SOFC
  - Battery Recharging
- Value Proposition
  - Light Weight
  - Longer Run Time
  - On Demand Power

**Refer to US Fuel Cell Council Product List

New Market Activities: Mobile Lighting

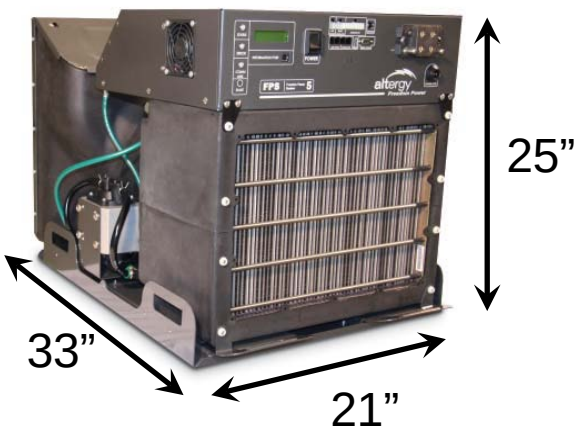
The Technology Works-- Used at 2010 Academy Awards in Hollywood

Lighting Red Carpet Construction

Photo Courtesy of the Academy of Motion Picture Arts and Sciences

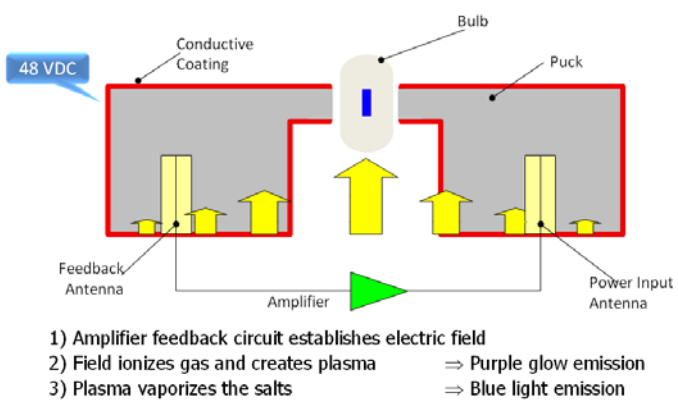
New Market Activities: Mobile Lighting

Fuel Cell Light Combines PEM Fuel Cell with Advanced Plasma Lighting



5kW PEM Fuel Cell

- 43% efficiency (diesel lighting ~ 27% efficient)
- No CO_2, NO_x or particulates emitted
- No moving parts, very quiet operation



Plasma Lighting

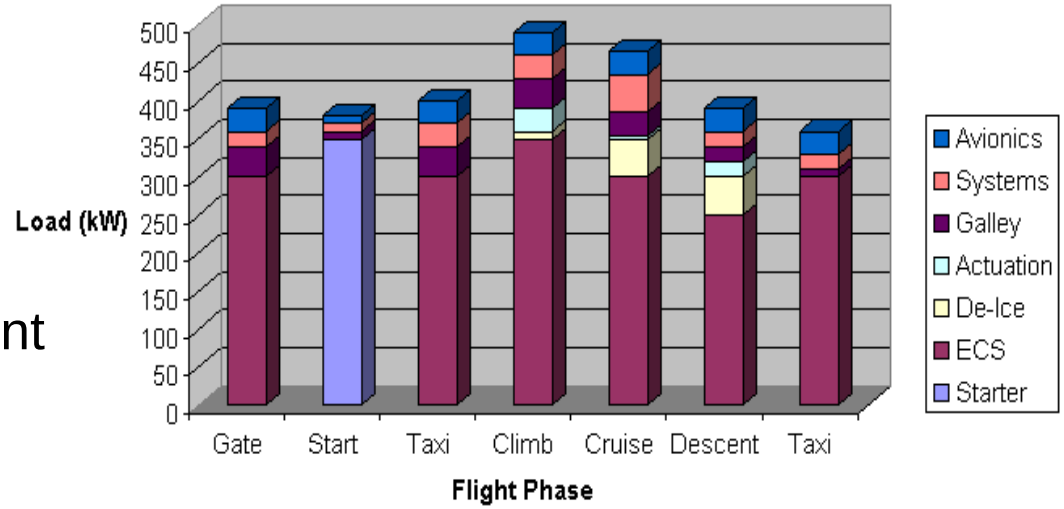
- High efficiency – 120 lumens/watt
- 50,000 hour lifetime
- Color Rendering up to 96 CRI
- 30 second turn-on, dimmable to 20%
- Compact source (1/4”x1/4”)
- No Audible Noise or Flicker
- Programmable
- Indoor and Outdoor Use

New Market Activities: Air Transport Auxillary Power Units

Why do aircraft manufacturers want fuel cell power ?

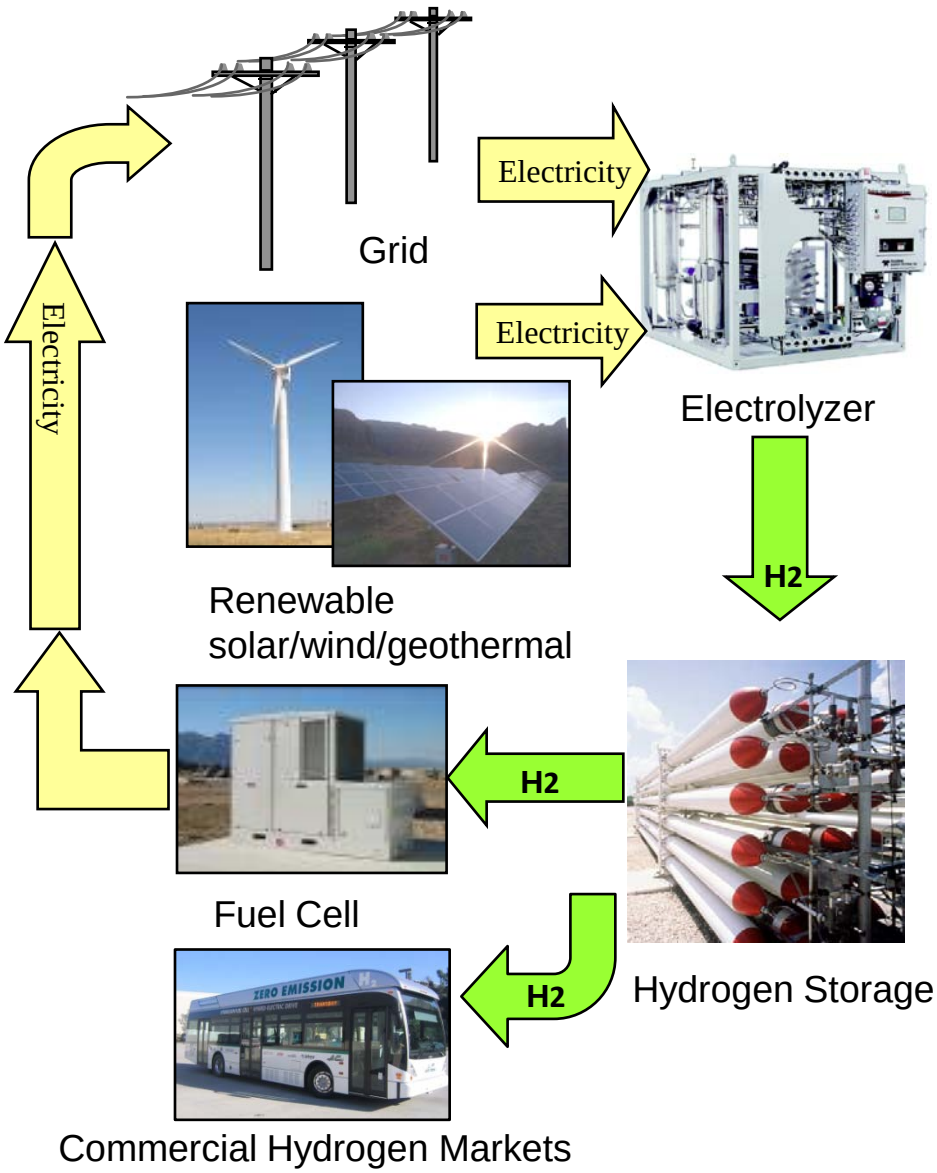
Value Proposition for Fuel Cells

- Greater system efficiency
- Lower CO2 emissions
- No NOx
- Little or No Noise
- Water is byproduct
- Ground Support Equipment



New Market Activities: Integrating Renewables

- Concept: Use hydrogen as energy storage to better integrate renewable solar and wind resources into the electric grid
- System uses stored hydrogen to supplement the electric grid for on-peak electricity production
  - Hydrogen produced via electrolysis driven by renewable electricity and non-peak grid electricity
  - Study seeks to determine the cost of producing on-peak electricity from a hydrogen-based energy storage system
- System elements:
  - Electric Grid
  - Renewable Energy Input
    - Solar (PV), Wind, Geothermal
  - Electrolyzer
    - Conversion of renewables into H2
  - Hydrogen Storage
    - Steel tanks, geologic storage
  - H2-to-electricity Conversion
    - Fuel cells, H2 engine



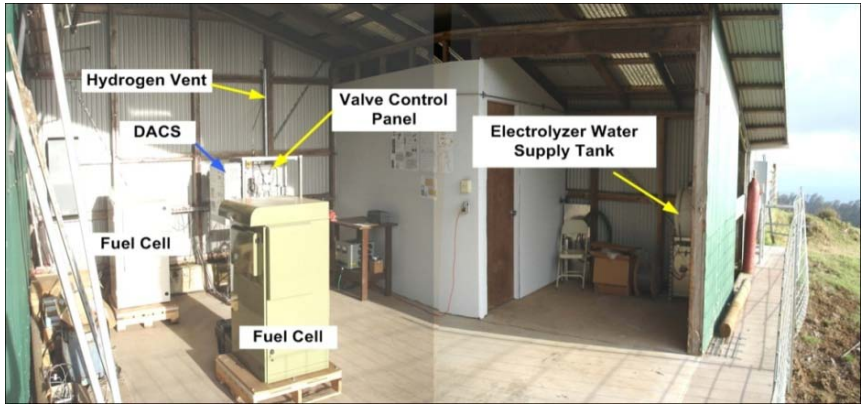
New Market Activities: Integrating Renewables (Hawaii DEMO)

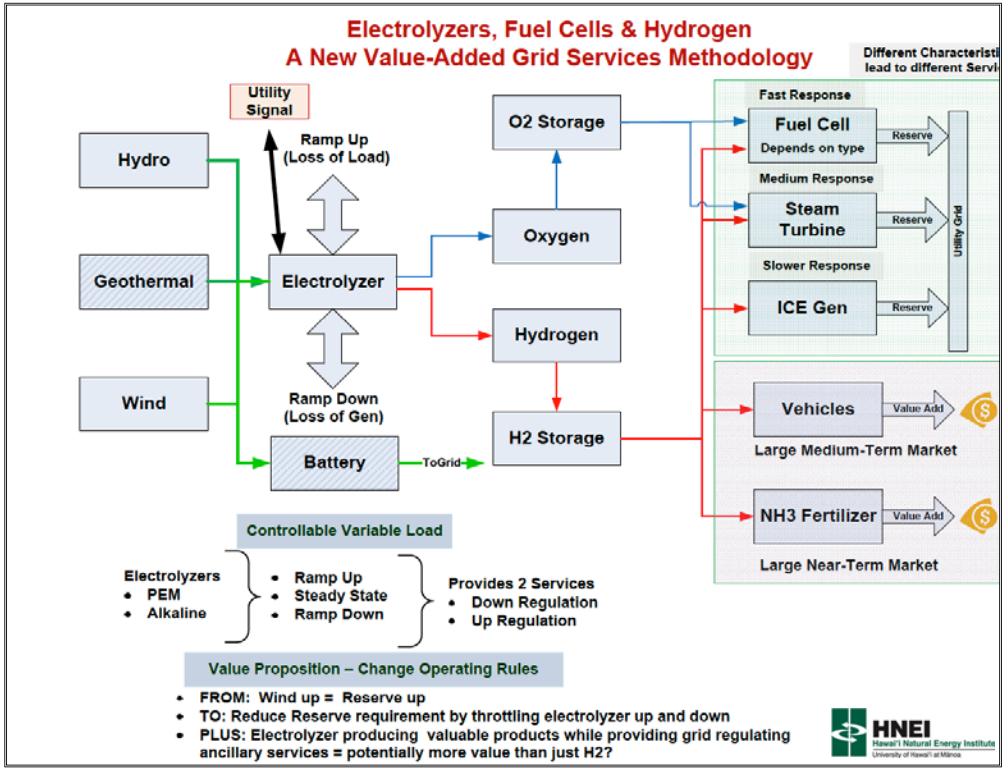
Phase 1

- ~ 250 kW fuel cell system
- ~ 250 kW electrolysis system
- 1 MW gaseous hydrogen compression and storage
- 1 MW LiOn battery, power conditioning, modeling/analysis
- System operations, data collection, electric power

Phase 2 Full Scale Pilot

- ~ 750 kW fuel cell system
- ~ 750 kW electrolysis system
- ~ 2 MW gaseous compression and storage
- 1 MW LiOn battery, power conditioning, modeling/analysis (US ONR)
- System operations, data collection, electric power



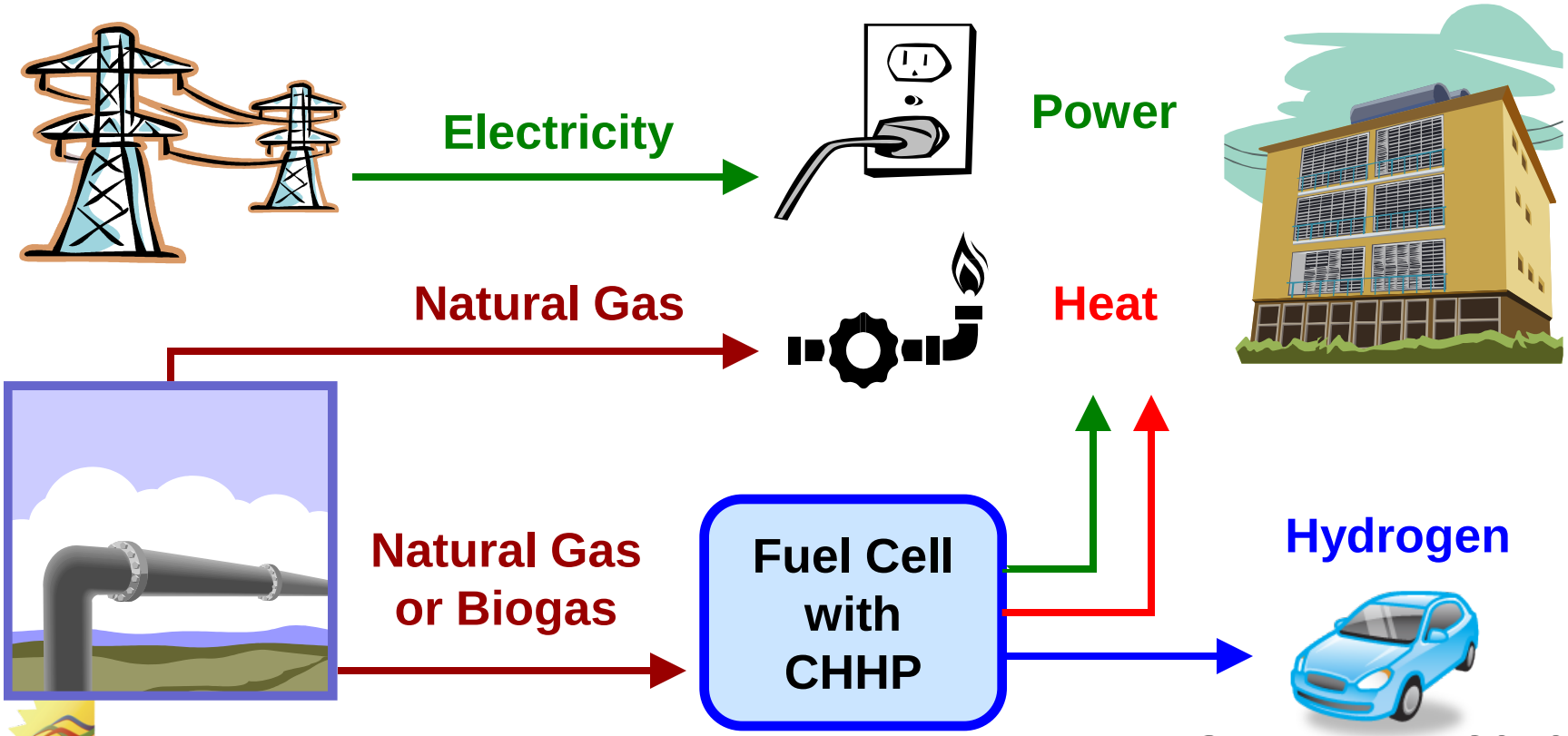


Fuel Cell Power Model

Analysis of Fuel Cell Technologies with Facilities

- Hydrogen infrastructure costs for early transition phase are large, and are relatively high risk due to uncertainty of demand.

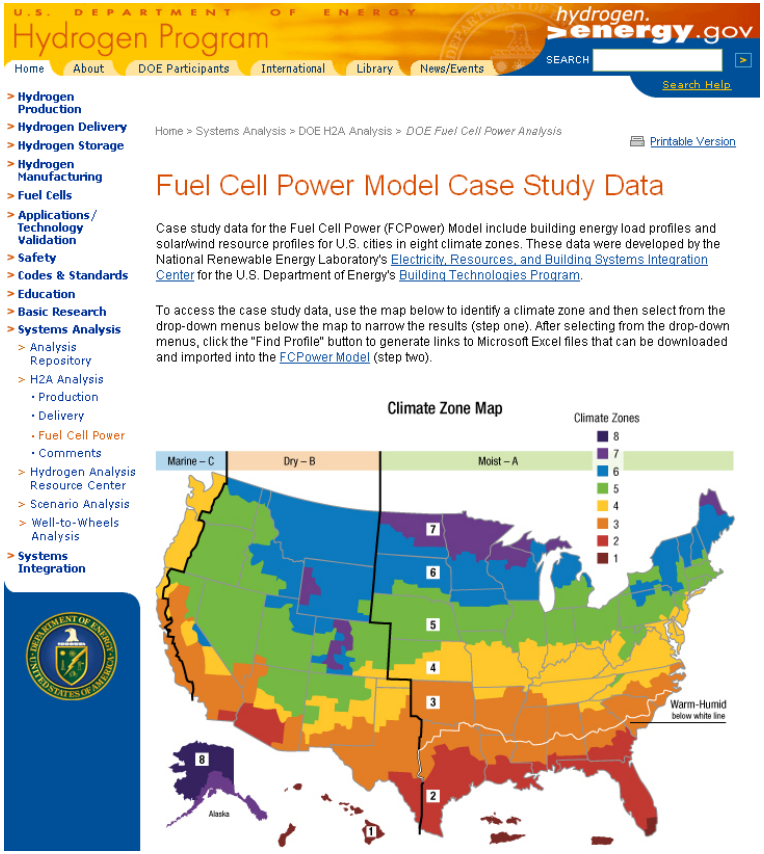
- The Fuel Cell Power Model allows analysis of combined heat, hydrogen and power (CHHP) systems, which may improve hydrogen deployment.



Fuel Cell Power Model

Analysis of Fuel Cell Technologies with Facilities

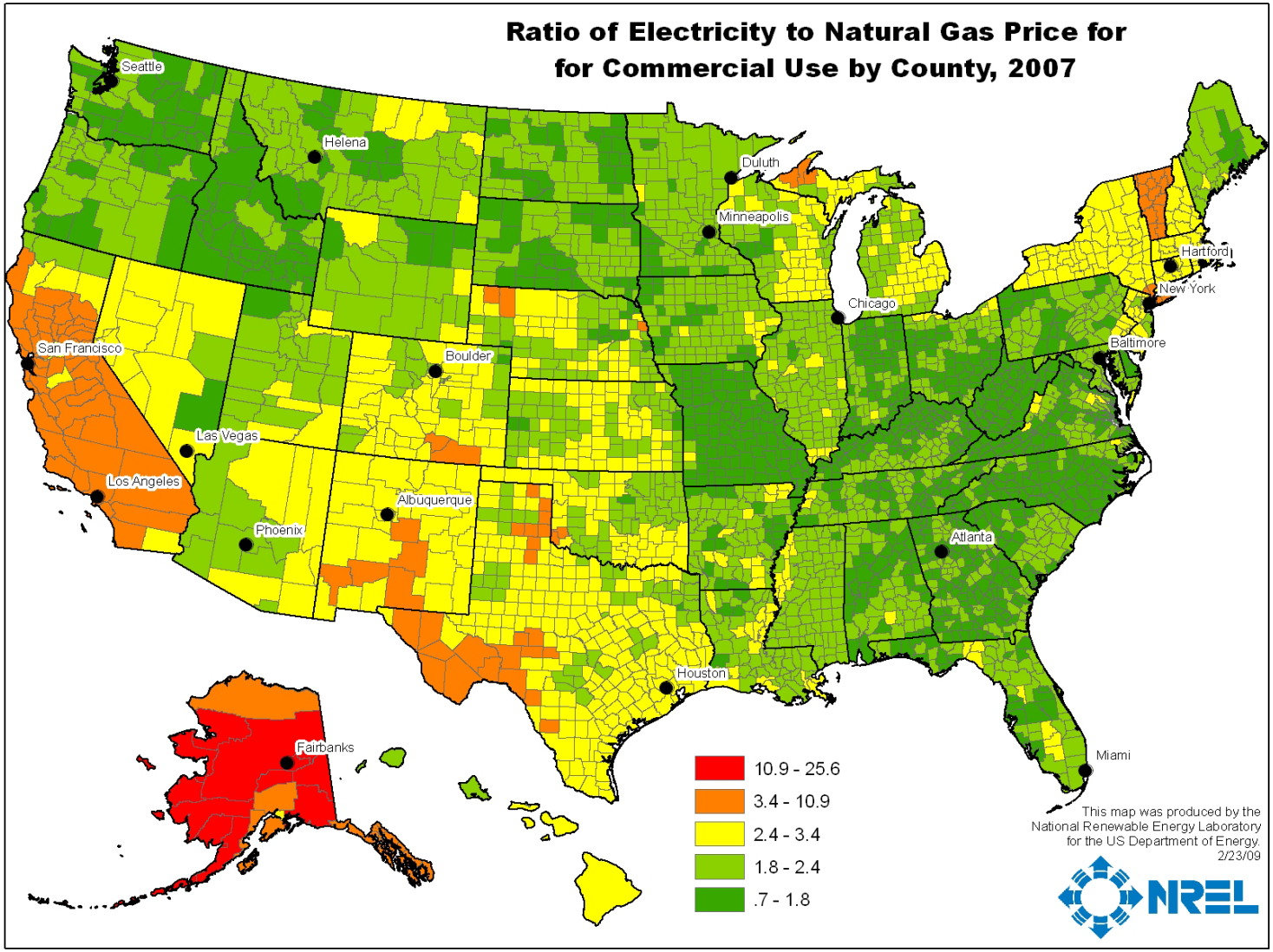
- Version 1.1 Published
  - Molten Carbonate Fuel Cell and Phosphoric Acid Fuel Cell models
  - Users guide
    - ➢ "How to" guide
    - ➢ Fuel cell performance models detailed
    - ➢ Case study descriptions
- Presentations, webinars, one-on-one guidance
  - Training and webinars for first users
  - Electric Utility Consultants, Inc. (EUCI) webinar
  - Market Transformation analysis were completed for several commercial and government entities



- NREL campus
- NASA AMES Research Center
- Los Alamitos Military base
- USPS Distribution Facility San Francisco
- Material Systems Research Institute (MSRI)
- Sandia / LLNL campus

Fuel Cell Power Model

Electricity and Natural Gas Rates



Fuel Cell Power Model

Excel based tool is transparent and easy to use

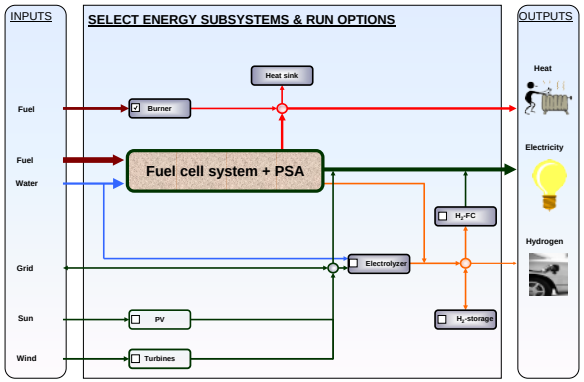
1 Click Process Flow Diagram

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:	

Process Flow Diagram

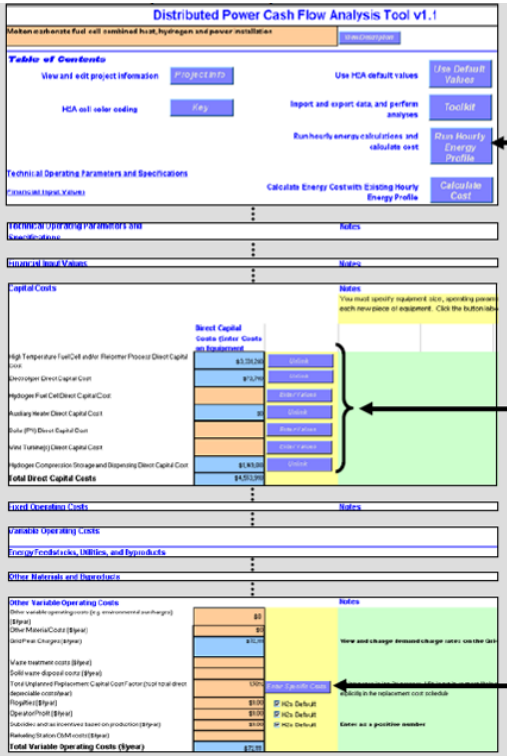
2
- Configure system
- Click *Input sheet* button



System Component Selection	
Peak Burner	TRUE
Fuel Cell System	TRUE
Electrolyzer	FALSE

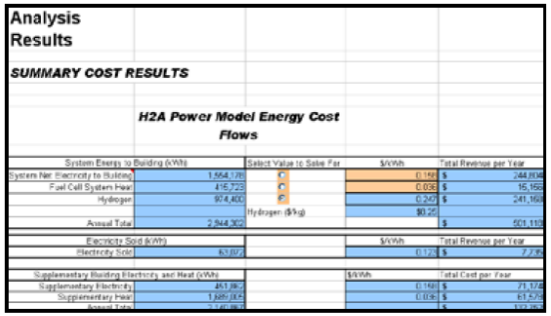
Input Sheet

3 Fill out *Input Sheet* completely
Click *Run Hourly Energy Profile* button



Complete the *Input_Sheet_Template* worksheet from top to bottom. Some values in the *Capital Costs* and *Variable Operating Costs* sections can link to other worksheets; after entering values on those worksheets, click the *Input Sheet* button to return to the *Input_Sheet_Template* worksheet. In the *Other Materials and Byproducts* section, you must click the *Add* button to add materials.

4 View Results



After clicking the *Run Hourly Energy Profile* button in the *Input_Sheet_Template* worksheet, the model runs energy and cost calculations, and you are sent to the *Results* worksheet, where you can view the cost, energy, and emissions results of your system. Also see the *Financial Summary* and *Key Figures* worksheets, the tabs for which are adjacent to the *Results* tab.

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For More Information:

US DOE Fuel Cell Technologies Program

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

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