Validation of an Integrated Hydrogen Energy Station

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Air Products and Chemicals, Inc.

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Project ID
#TV006

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Overview

Timeline

- Start – 30 Sept. 2001
- End – 31 Mar. 2011
- 89% Complete

Barriers

- H_2 Fueling Infrastructure
- H_2 & Power Coproduction

Budget

- Total project funding
  - DOE share: $5.95 million
  - APCI + Partners share: $6.59 million
- Funding received in FY09: $0.5 million
- Funding for FY10: $0.25 million

Partners

- FuelCell Energy
  - MCFC, Fuel Prep, WGS
- OCSD – Host Site (CA)
- CA – ARB, AQMD
  - UC Irvine

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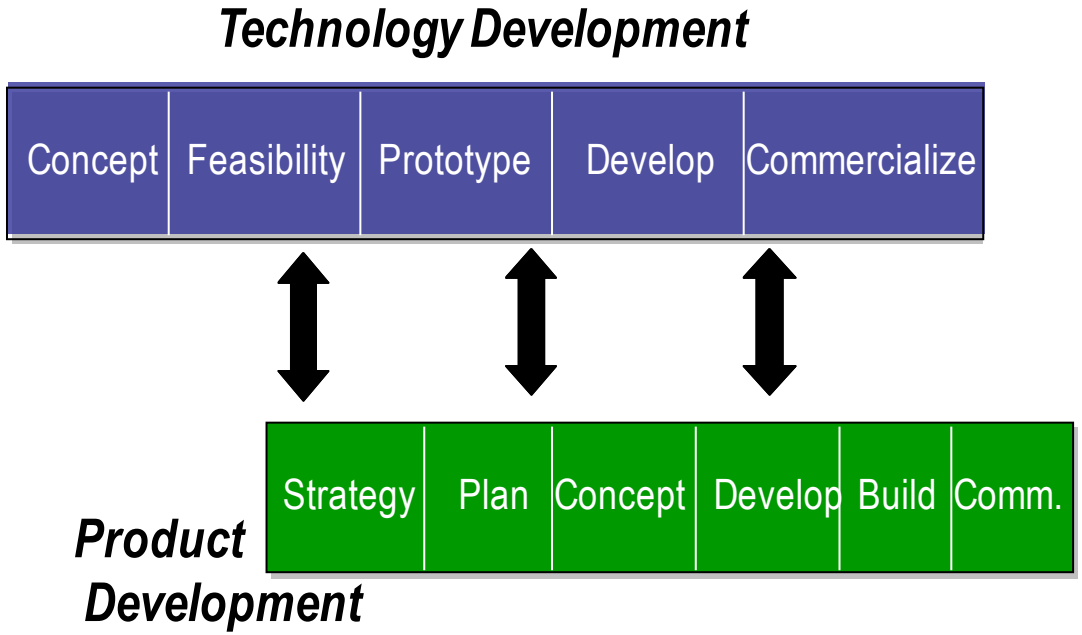
Objectives - Relevance

- **Determine the economic and technical viability of a hydrogen energy station designed to co-produce power and hydrogen**

Utilize technology development roadmap to provide deliverables and go/no-go decision points



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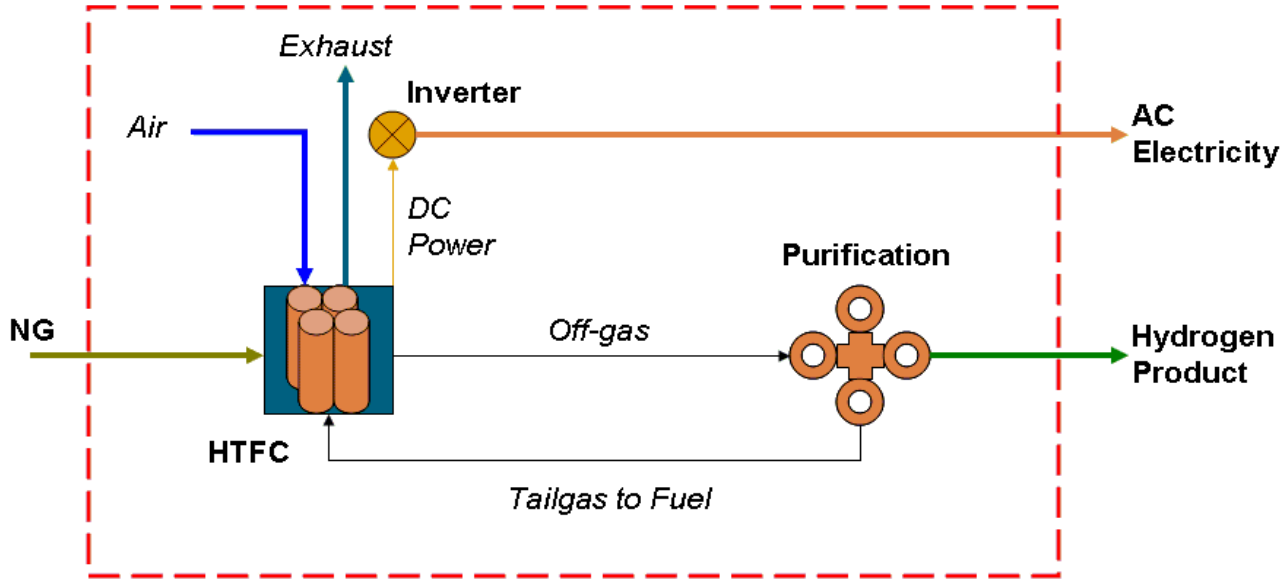
Hydrogen Energy Station Concept



Potential Co-Production Efficiency (LHV): 55 - 60%

Fuel Cell Outlet at High Temperature and Low Pressure

- H_2: 10%
- H_2O: 40%
- CO: 5%
- CO_2: 45%

Hydrogen Product at Low Temperature and High Pressure

- H_2: 99.99%
- H_2O: Rejection and Recycle
- CO: < 0.2 ppm
- CO_2: < 2 ppm

FuelCell Energy

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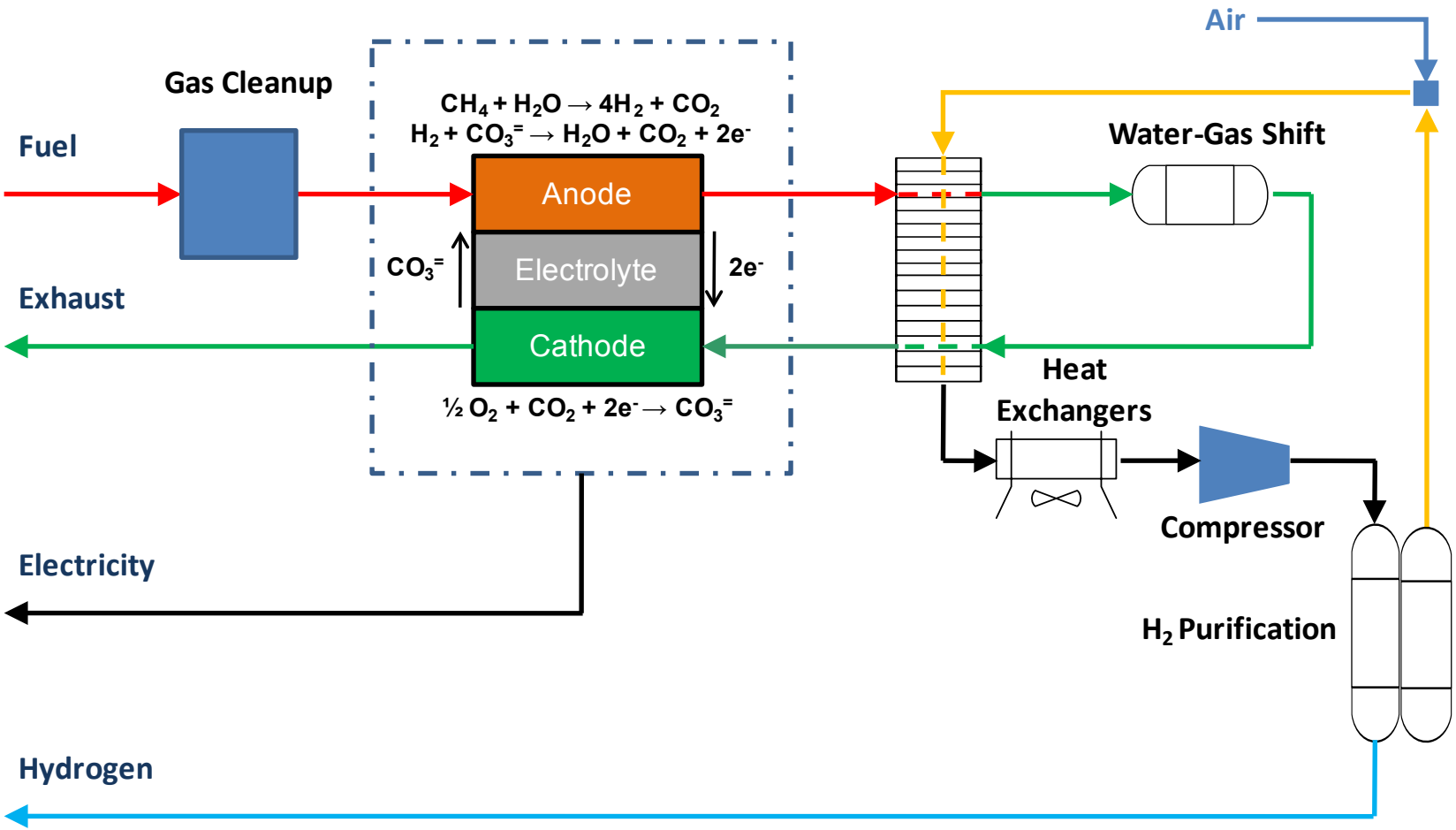
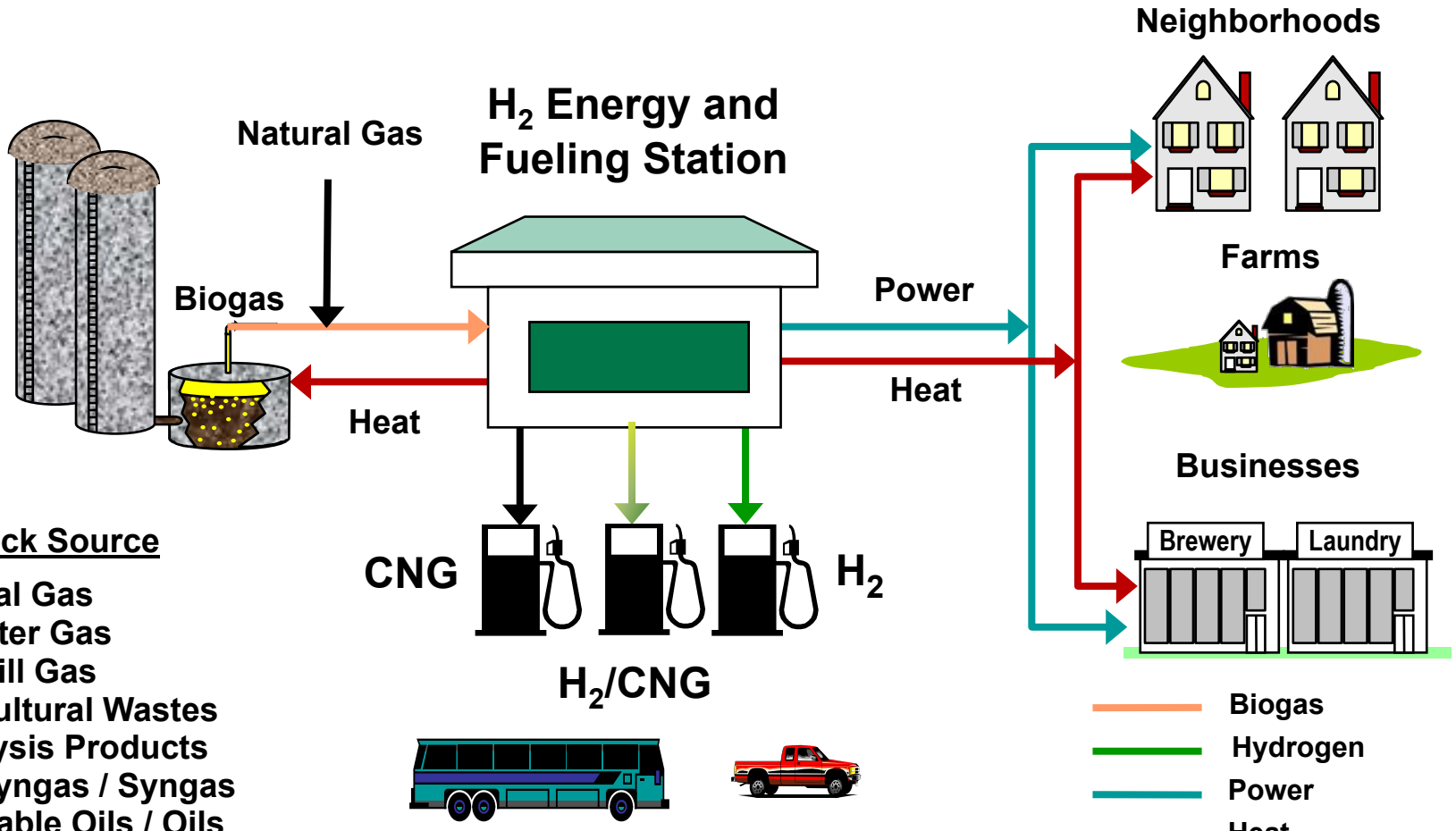
Approach

- DOE Program defined 4 phases:
  - Phase 1 – Feasibility: Evaluate PEM and HTFC
    - Completed FY04
  - Phase 2 – Preliminary System Design
    - Completed FY06
  - Phase 3 – Detailed Design and Construction
    - Design/Fabrication Completed March 2009
    - Shop Validation Test Completed March 2010
  - Phase 4 – Operation, Testing, Data Collection
    - Deployment in CA Summer 2010

Hydrogen Energy Station



Hydrogen Energy Station Vision



Feedstock Source

- Natural Gas
- Digester Gas
- Landfill Gas
- Agricultural Wastes
- Pyrolysis Products
- Bio-Syngas / Syngas
- Vegetable Oils / Oils
- Other Methane Sources

Renewable hydrogen – for onsite requirements or regional distribution

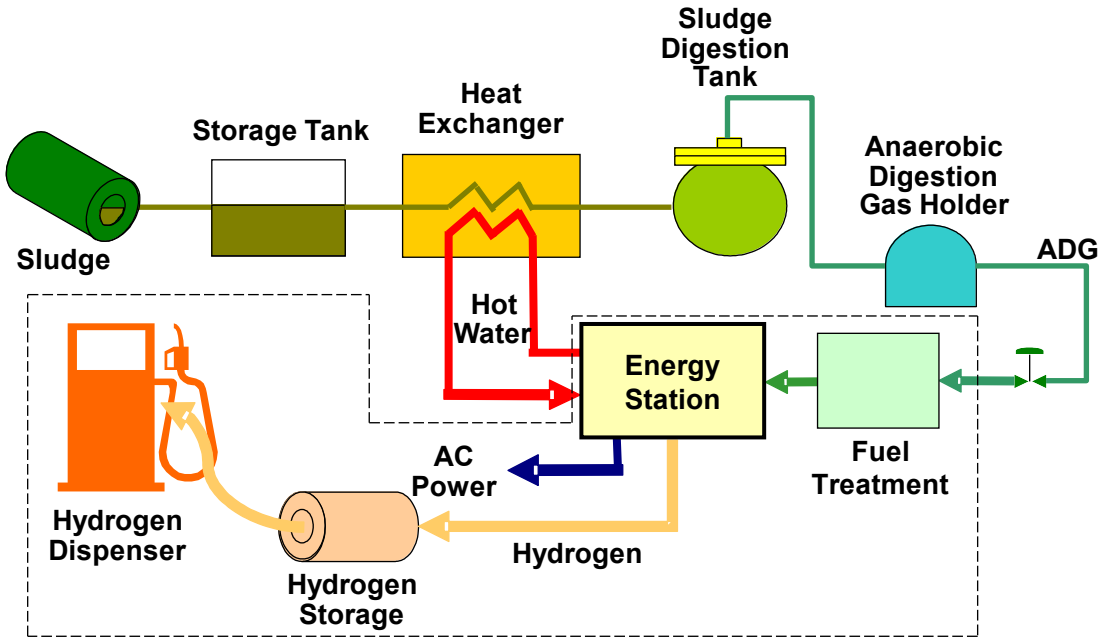
Demonstration of Hydrogen Energy Station Vision

- DOE Program – Natural Gas Feed
- Potential Host Site Identified - OCSD
  - Orange County Sanitation District, Fountain Valley, CA
  - Municipal Wastewater Treatment
  - Existing CNG Refueling Station
  - Ability to Achieve Production of both Renewable Hydrogen and Electricity

California Air Resources Board Grant

Fountain Valley Station

- 100 kg/day capacity, renewable hydrogen supply
- 350 and 700 bar fueling capability
- Host site: Orange County Sanitation District
- Anaerobic digestion of municipal wastewater



- Funding for fuel treatment and fueling station from DOE California Hydrogen Infrastructure Program with Air Products (Cooperative Agreement No. DE-FC36-05GO85026)
- Key subcontractors: FuelCell Energy, Inc. and National Fuel Cell Research Center, University of California, Irvine

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Hydrogen Energy Station Shop Validation Test

2009: Equipment installed at FuelCell Energy's facilities

Hydrogen Ready
Fuel Cell Module

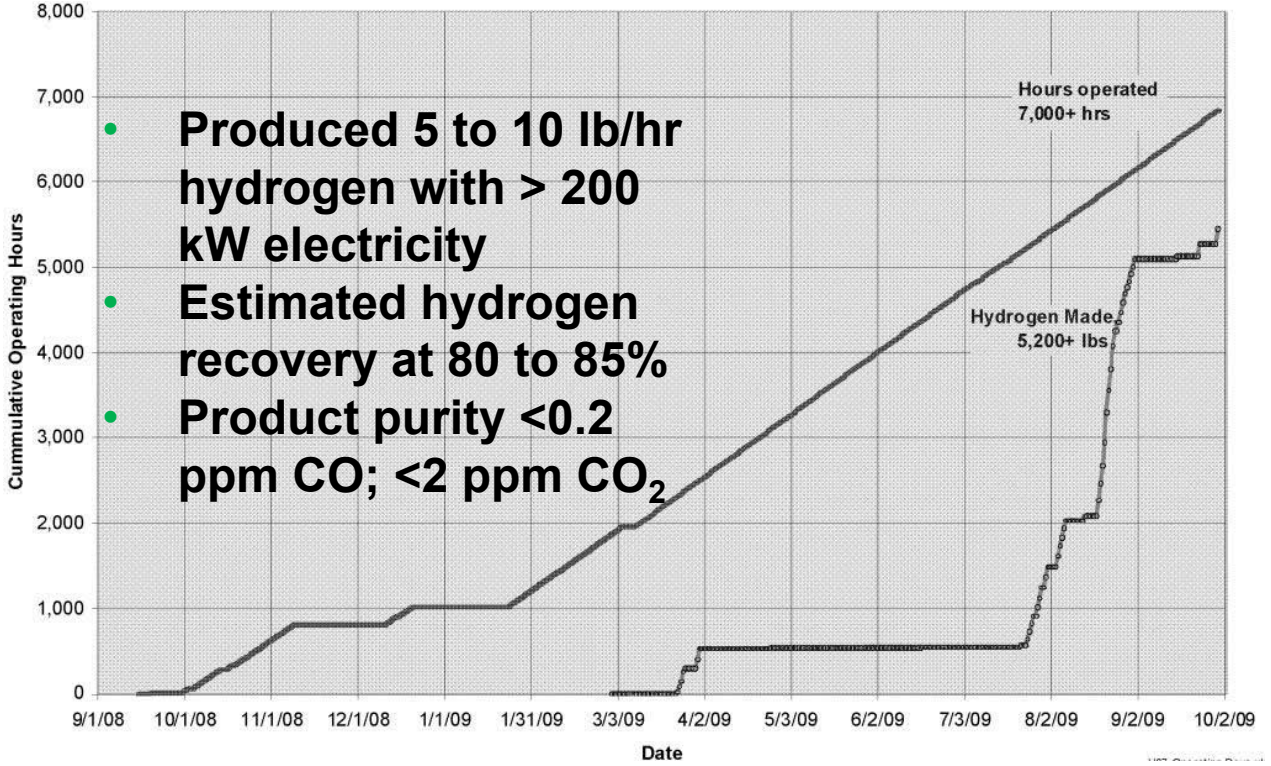
Anode Exhaust
Processing
and H_2 Purification
System

Mechanical
Balance of Plant
(MBOP)

Objectives of Shop Validation Test

- System installation, commissioning, start-up
- Demonstrate variable production of both electricity and hydrogen
- Optimize control system and controls philosophy
- Test and further develop response to upset conditions
  - Rapid de-integration procedure

Successful Completion of Hydrogen Energy Station Shop Validation Test (2010)

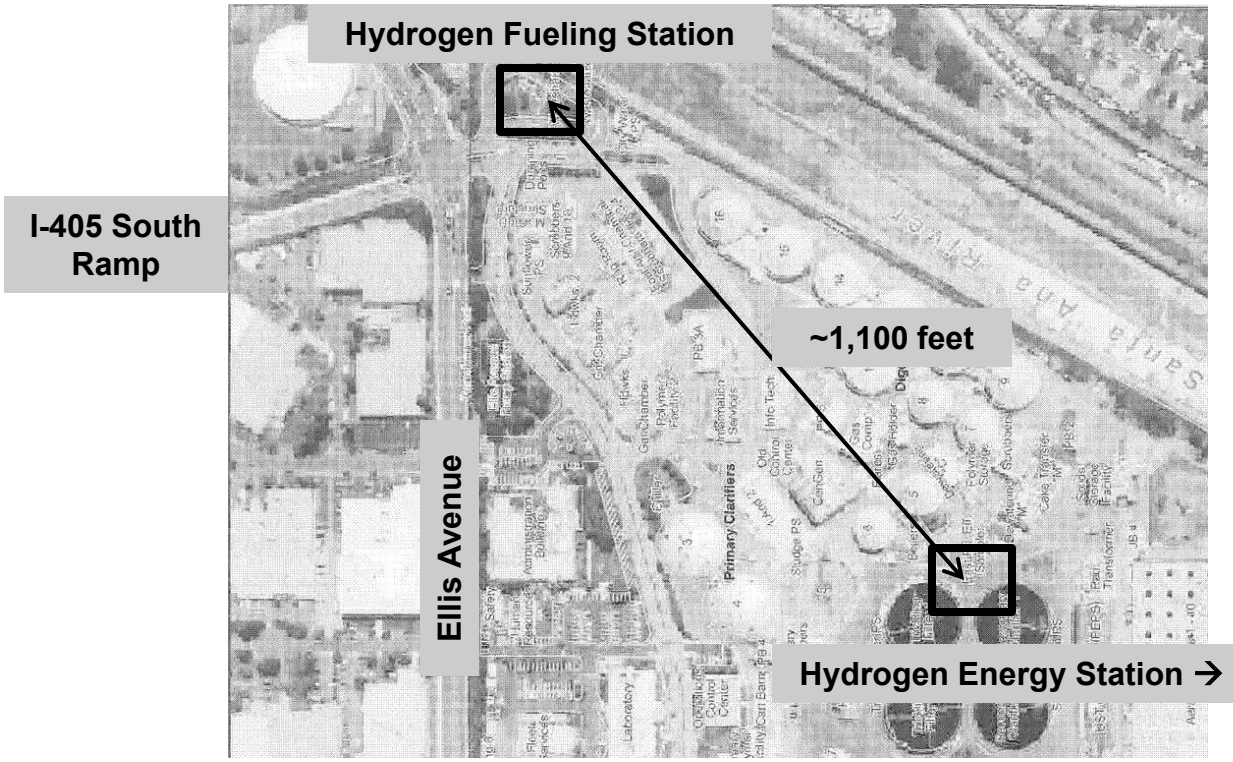


- Produced 5 to 10 lb/hr hydrogen with > 200 kW electricity
- Estimated hydrogen recovery at 80 to 85%
- Product purity <0.2 ppm CO; <2 ppm CO_2

Other Accomplishments:

- Operation with simulated digester gas feed
- PSA operating map developed (cycle time vs. feed rate)
- Implemented automated integration/deintegration

Orange County Sanitation District Site



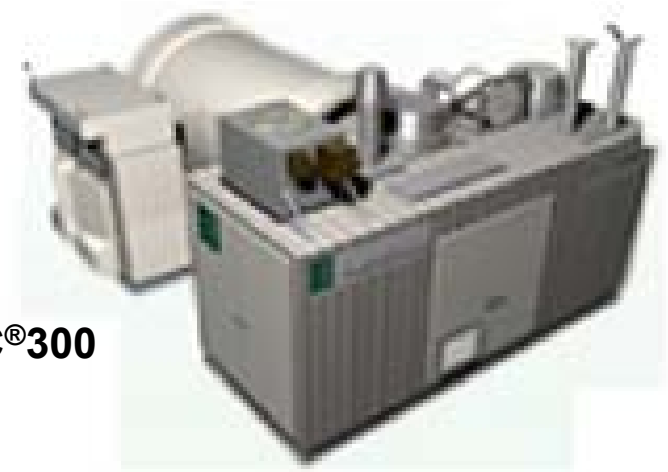
- Anticipated onstream Summer 2010

Collaboration

- **Industry**
  - **FuelCell Energy, Inc. – Subcontractor, Fuel Cell Supplier**
  - **Southern California Gas Co. – Funding to FuelCell Energy**
- **Government/Municipal Entities**
  - **U.S. Department of Energy**
  - **California Air Resources Board**
  - **South Coast Air Quality Management District**
  - **Orange County Sanitation District – Host Site, Site Improvements)**
- **University**
  - **University of California, Irvine – Data Analysis, Education/Outreach Activities within CARB Program**

Future Work

- Installation at Orange County Sanitation District – Lessons learned from shop test, field trial
- Validation of process economics
- Following DOE Program:
  - Product development activities – Process improvements for second generation system
  - Scale-up based on existing fuel cell products –
    - DFC®1500 – 400 to 500 kg/day H_2 plus 1.0 to 1.2 MW and 2 MMBTU/hr heat
    - DFC®3000 – 800 to 1,000 kg/day H_2 plus 2.0 to 2.4 MW and 4 MMBTU/hr heat



DFC®300

DFC®1500

Summary

- **Determine the economic and technical viability of a hydrogen energy station designed to co-produce power and hydrogen**
  - **Concept defined – FuelCell Energy's molten carbonate fuel cell plus Air Products' hydrogen purification system**
  - **Design and fabrication of demonstration unit completed**
  - **Shop test successfully completed at FuelCell Energy's facilities**
  - **Demonstration operation beginning mid-2010 on renewable feedstock at Orange Co. Sanitation District**
    - **Hydrogen refueling station under DOE's California Hydrogen Infrastructure Project**
    - **Other funding: California Air Resources Board, South Coast Air Quality Management District, SoCal Gas**
  - **Validate process economics based on system performance**

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Thank you

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