

# 2007 DOE Hydrogen Program Review Validation of an Integrated Hydrogen Energy Station

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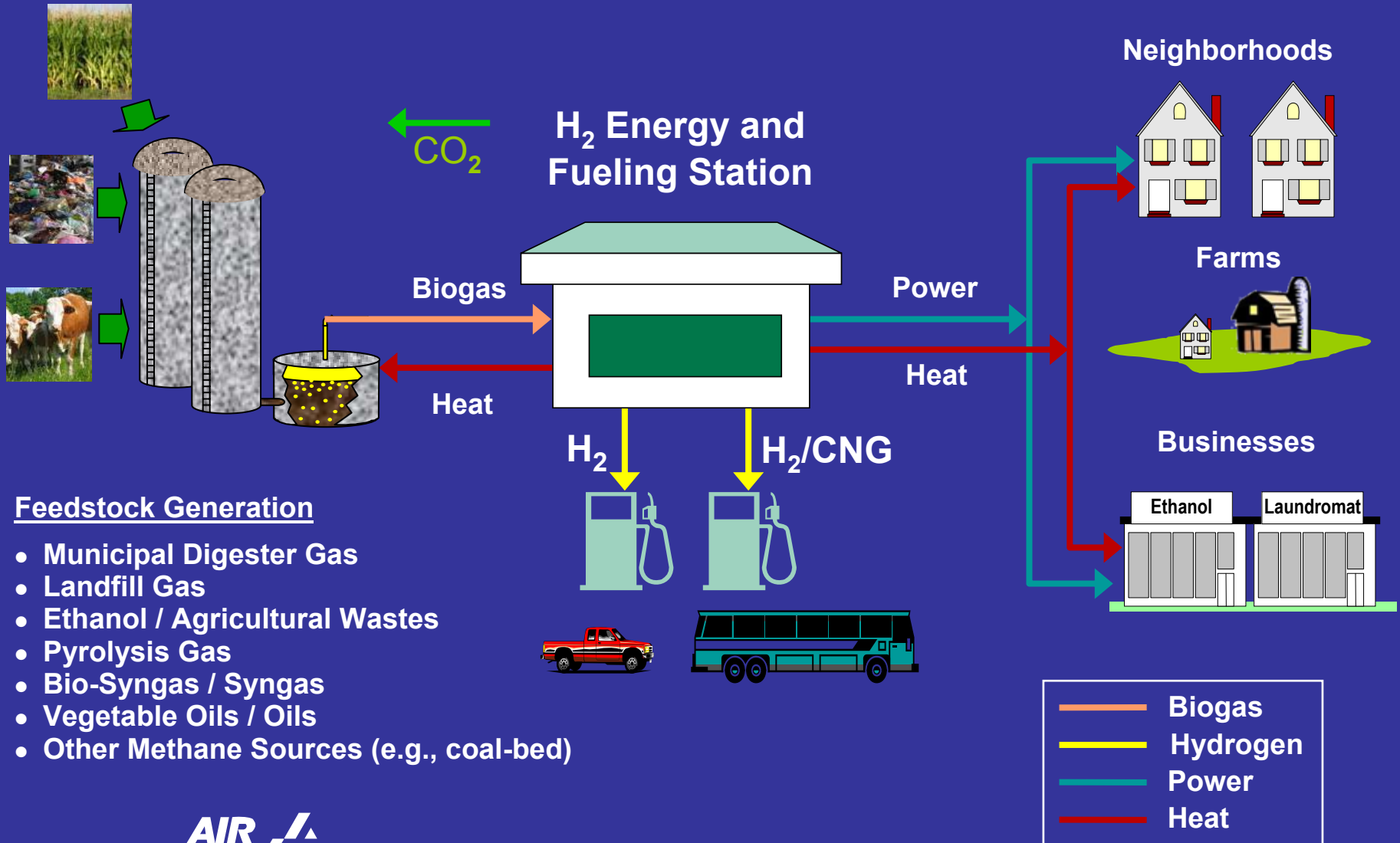
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Project TV-06

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# Hydrogen Energy Station Vision

## - High-Efficiency and Renewable -



# Hydrogen Energy Station Distributed Power and Hydrogen

FuelCell Energy DFC-300



35%  
Power

10%  
Heat

End User



Air Products Purification



30%  
H<sub>2</sub>

Hydrogen Filling Station



# Overview – Integrated Hydrogen Energy Station

## Timeline

- Start – Sep. 30, 2001
- End – Mar. 31, 2009
- 20% Budget Complete
- 75% Schedule Complete

## Budget

- Total Project Funding
  - DOE share: \$5.2 MM
  - APCI + Partners: \$5.2 MM
- FY06 Funding: \$1.3 MM
- FY07 Funding: \$2.1 MM
- Proposed Mod for Digester Gas Under Review

## HFCIT Barriers

- C. H2 Fueling Infrastructure
- I. H2 & Power Co-Production

## HFCIT Targets

- Cost of H2: \$3.00 /kg
- Electrical Efficiency > 40%

## Partners

- FuelCell Energy
  - MCFC, Fuel Prep, WGS
- NFCRC – Outreach / Validation
- OCSD – Host Site (CA)
- CA – ARB, AQMD, CEC, SCE
- Alternative Feedstocks - Various

# Objectives by Phase

- Overall - Determine the economic and technical viability of a hydrogen energy station designed to co-produce power and hydrogen
- Phase 1 - Feasibility: Evaluated PEM and HTFC (Completed FY03-04)
- ✓ • Phase 2 - Preliminary System Design (Completed FY-06)
- ✓ • Phase 3: Detailed Design and Construction In Progress (FY07 – 08)
- Phase 4: Operation, Testing, Data Collection Future Work (FY08 – 09)

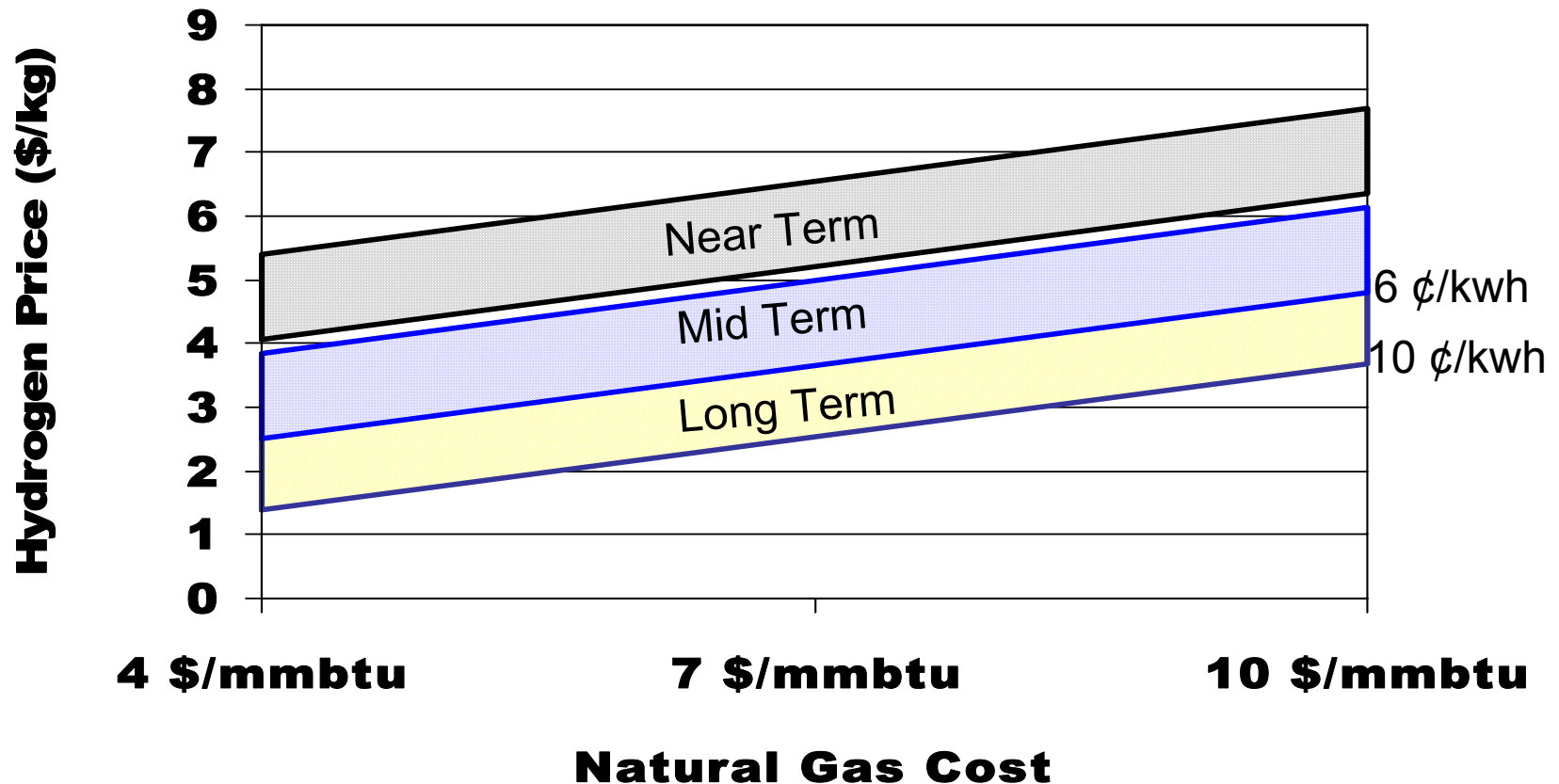
# Phase 2 - Preliminary Design

- Hydrogen Purification Development Completed
- PFD Completed
- Preliminary H & M Balance Completed
- Preliminary P&ID (Rev 0) Completed
- Preliminary Hazards Review (PHR) Completed
- Estimate for Phases 3 & 4 Completed
- Updated Economics
- Developed Host Site Short List
  
- Phase 3 **Go Decision** Executed

# Purification Development Program

- Investigated >25 Technologies
- **Selected Advanced PSA Process**
  - Cycle Simulation Completed
  - Adsorbent Mix Selected
  - Lab Testing Completed
  - Pilot Plant Verification Completed
  - Optimized PSA System
  - **Patent Applications in Progress**

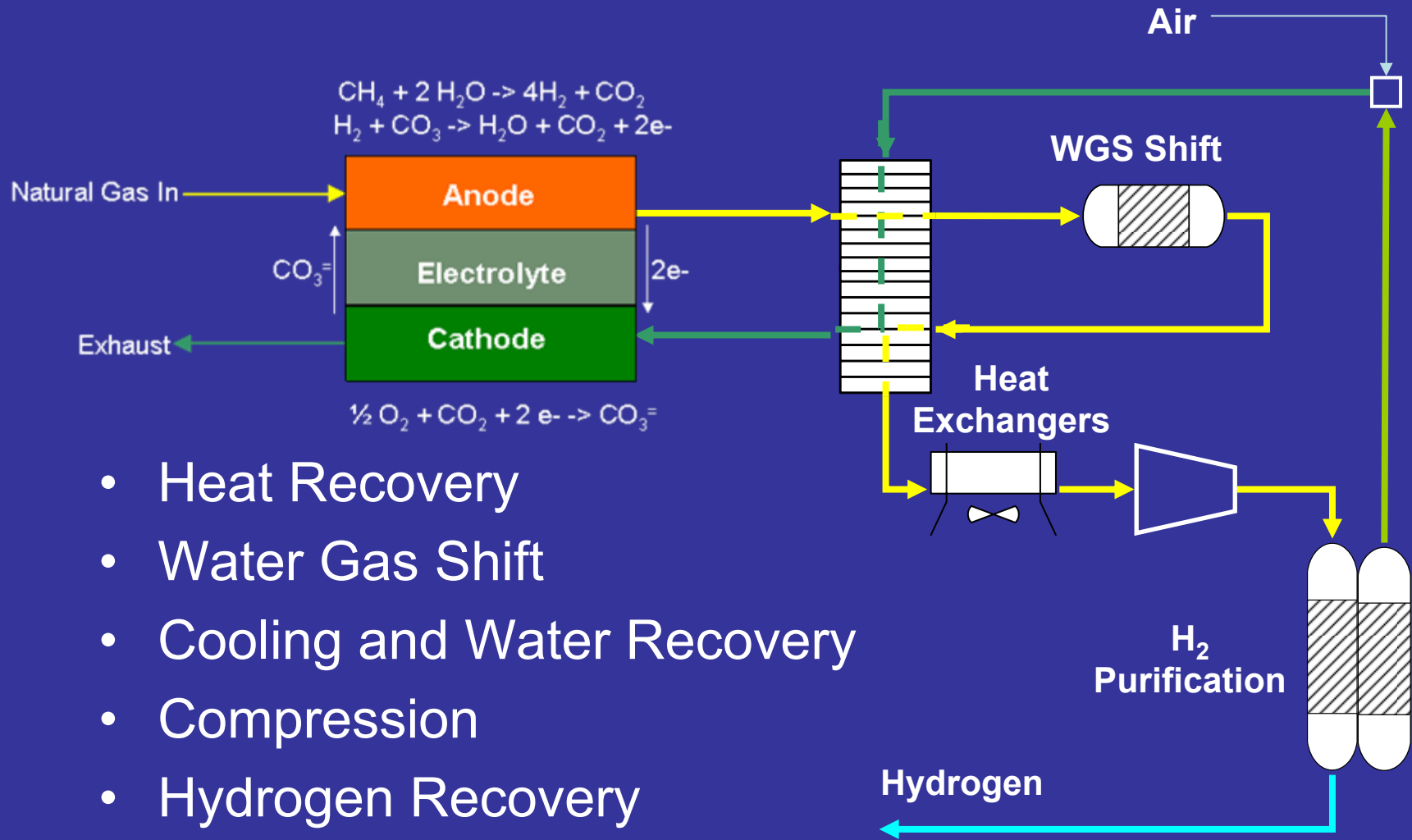
# Hydrogen Energy Station Economics



Basis: Feedstock = NG; 1200 kW Power; 700 kg/day hydrogen; No heat sale



# Hydrogen Co-production using MCFC



- Heat Recovery
- Water Gas Shift
- Cooling and Water Recovery
- Compression
- Hydrogen Recovery
- Tailgas Integration

# Phase 3 – Detailed Design & Construction

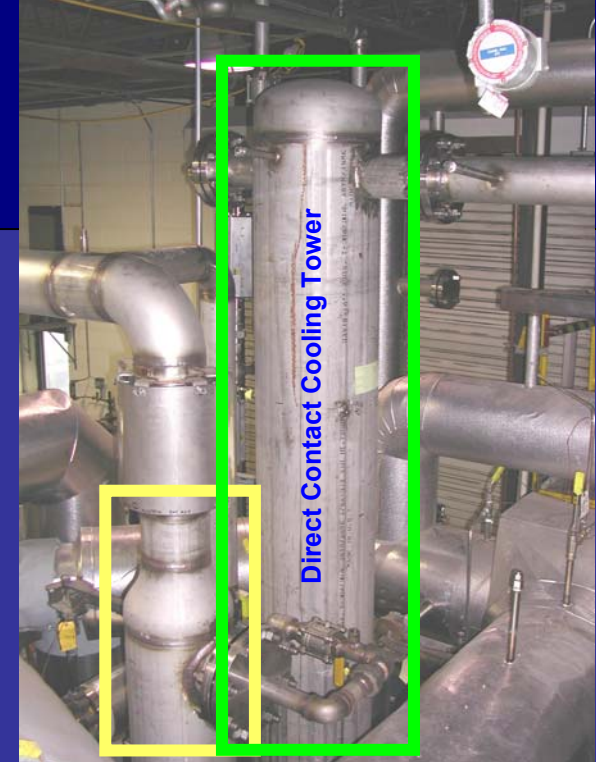
- **Detailed Design**
  - Anode Gas Handling - Complete
  - WGS Reactor - Complete
  - Hydrogen Purification - Complete
  - Integration - Complete
- **Site Selection - OCSD**
  - Orange County Sanitation District
  - Fountain Valley, CA
  - Sewage Treatment
  - Replace ICE stationary emitter with HES

# Anode Gas/Cooling Components

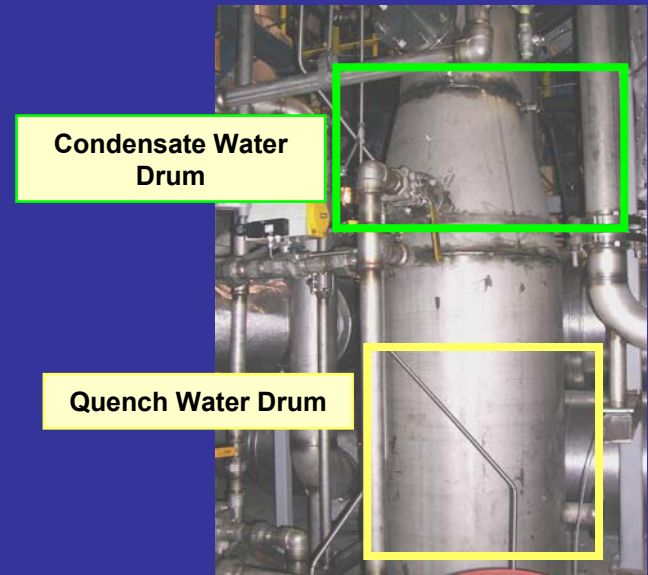
- Fuel Cell Operation at H<sub>2</sub> Export Design Conditions
- Heat Exchanger Train
- Direct Contact Cooling Tower
- Shift Reactor at high space velocity
- Electrolyte Filter

# Direct Contact Cooling Tower

- Lower Cost / Lower Pressure Drop compared to Air Fan
- Heat of Condensation Provides Useful Hot Water (~170 F)
- Lower portion of tower provides water suitable for humidifying fuel and quench.



Quench Tube



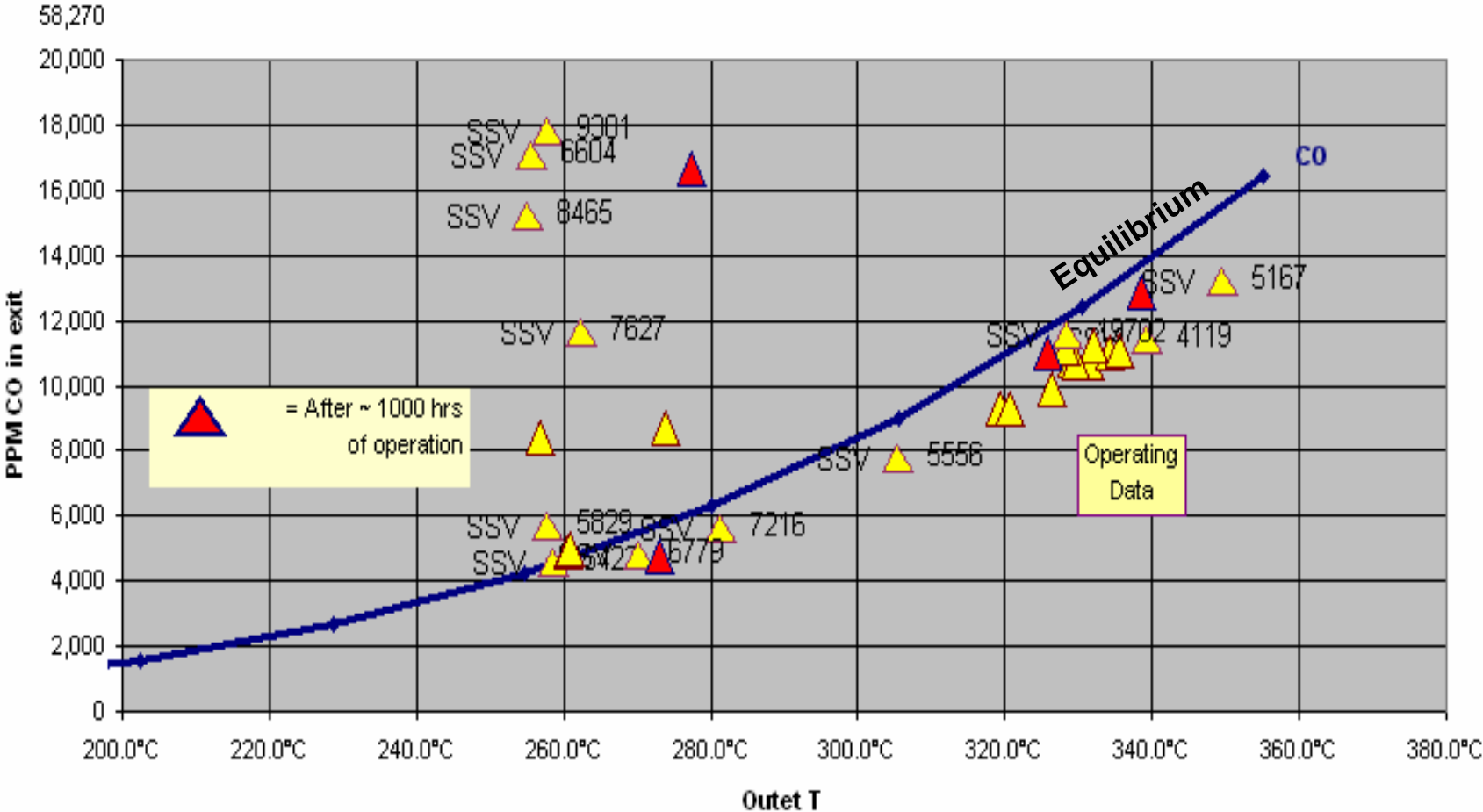
Condensate Water Drum

Quench Water Drum

# WGS Reactor Performance Data

SSV ▲ 3324

Outlet T impact on Shift

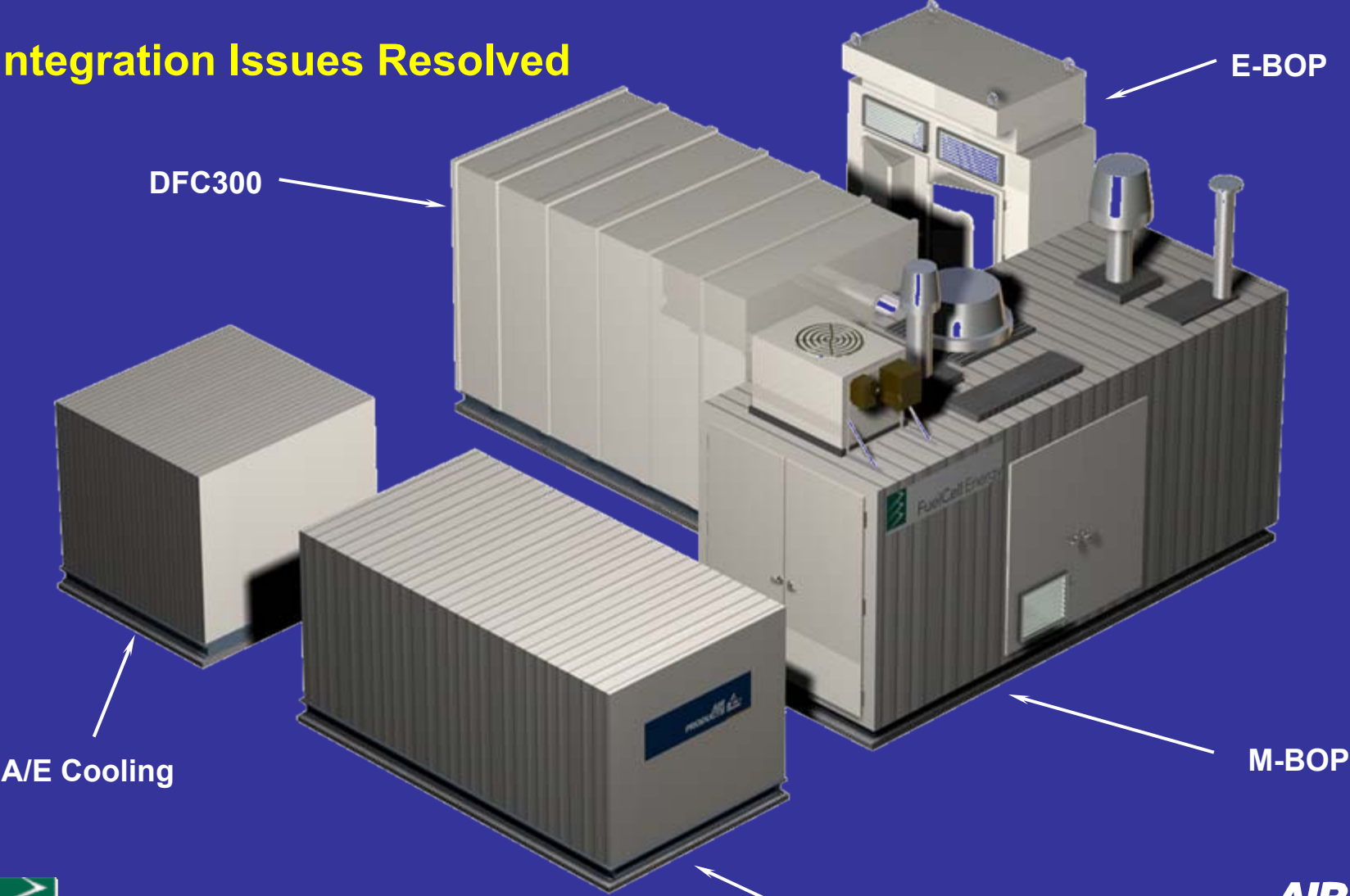


# Purification System Design

- PSA System Design Completed - PFD, P&ID, H&MB
- **Performance: 80+% Recovery @ FC Grade**
- Compressor Specified and Selected
- Process Control Strategy Developed
- Equipment Quotes and Fabrication Estimates Completed
- Installation Costs Estimated

# Integrated Hydrogen Energy Station

## Integration Issues Resolved

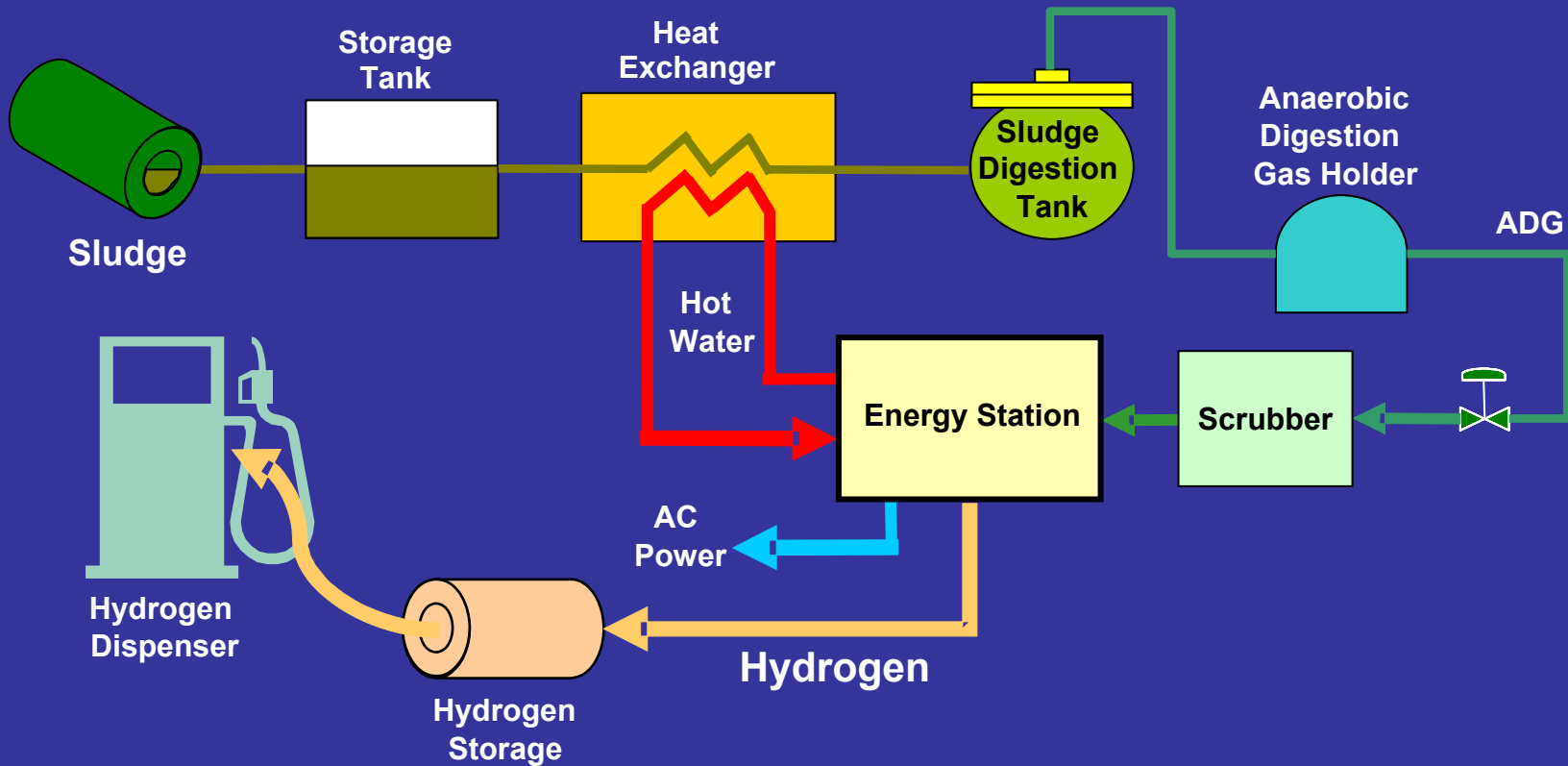


# Future Work

- **Modify Agreement for Digester Gas**
- Complete Phase 3 (FY07)
  - Order Equipment
  - Fabricate Skids
  - Assemble and Test Complete System at FCE
  - Update Economics
  - Go-No Go for Phase 4
- Phase 4 (FY '08 - '09)
  - Install at Selected Site
  - 6 Month Demonstration



# Digester Configuration



# Examples of Digester Gas Fed DFC® Plants

## Wastewater Treatment, Santa Barbara, CA



## Kirin Brewery, Japan



## Sierra Nevada Brewery, California

# Digester Gas Process Impact

- Requires Feed Compression
- **Requires Fuel Prep Equipment**
  - Remove H<sub>2</sub>S from feed (main contaminant)
  - Remove trace contaminants (Siloxanes, Other sulfur compounds)
  - Reduce moisture in feed
- **Design Provided at NO COST to Project**
- Deoxidizer added to DFC unit
- Increased CO<sub>2</sub> to PSA
  - Compressor power increases
  - Slightly lower H<sub>2</sub> recovery

# Digester Gas Performance Impact: Minimal

	Units	NG	Biogas
Overall Efficiency – “Tri-Gen” (Net Power + Hydrogen + Heat) / (Fuel)	LHV	76%	70%
Overall Efficiency – H2 + Power (Net Power + Hydrogen Product) / (Fuel)	LHV	66%	63%
Hydrogen Product	Kg/day	~ 175	~160
Net Power	kW	~ 250	~ 240
Heat Export	kW	~ 75	~ 50

**Biogas has no impact on MCFC**

**Small impact on PSA performance due to higher CO2 in gas to PSA**

# Acknowledgement & Disclaimers

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# Thank you

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