2008 DOE Hydrogen Program Review
Validation of an Integrated Hydrogen Energy Station

Ed Heydorn

Air Products and Chemicals, Inc.

June 10, 2008

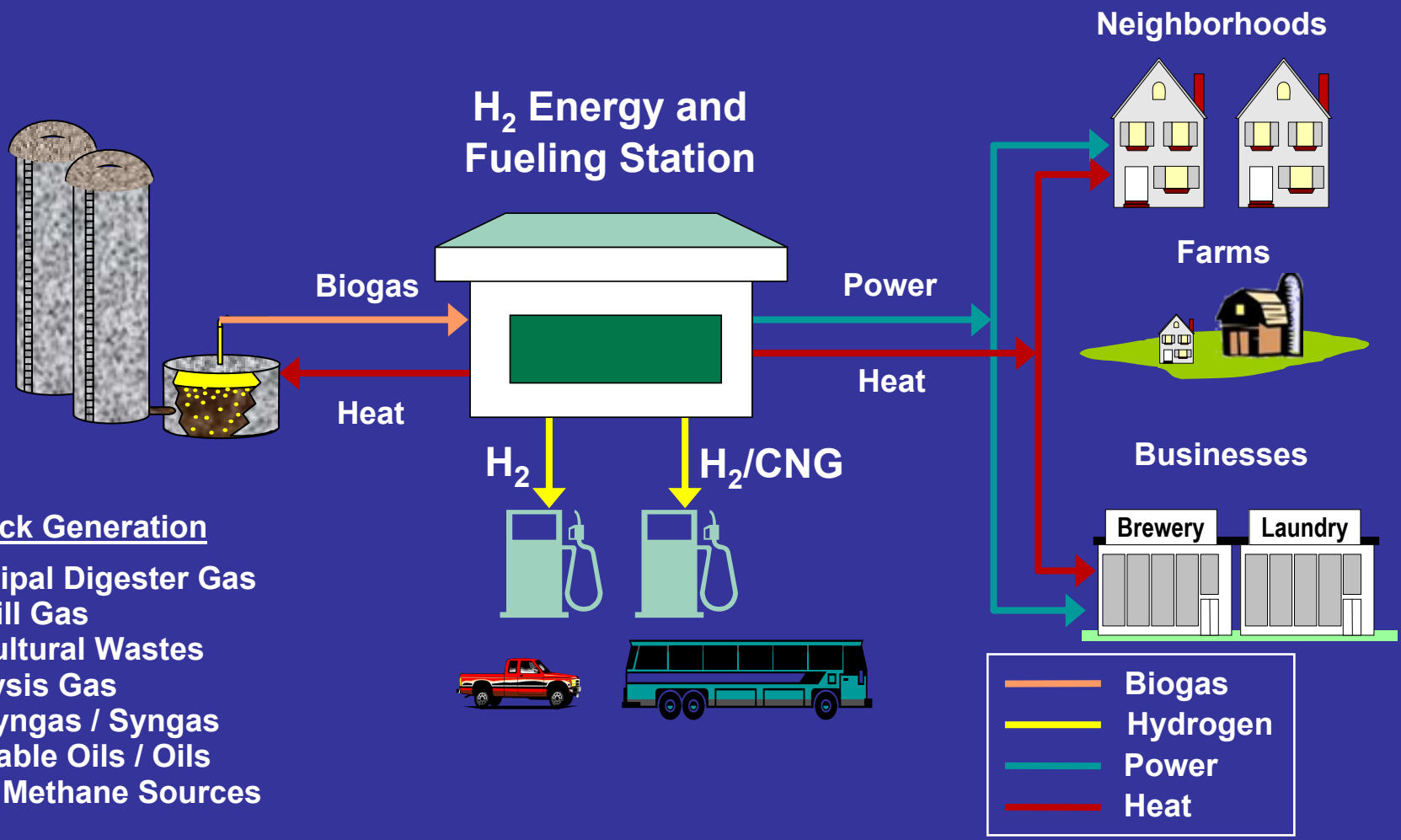
Project TV-06

This presentation does not contain any proprietary, confidential, or otherwise restricted information

FuelCell Energy

AIR PRODUCTS

Hydrogen Energy Station Vision
- High-Efficiency and Renewable -



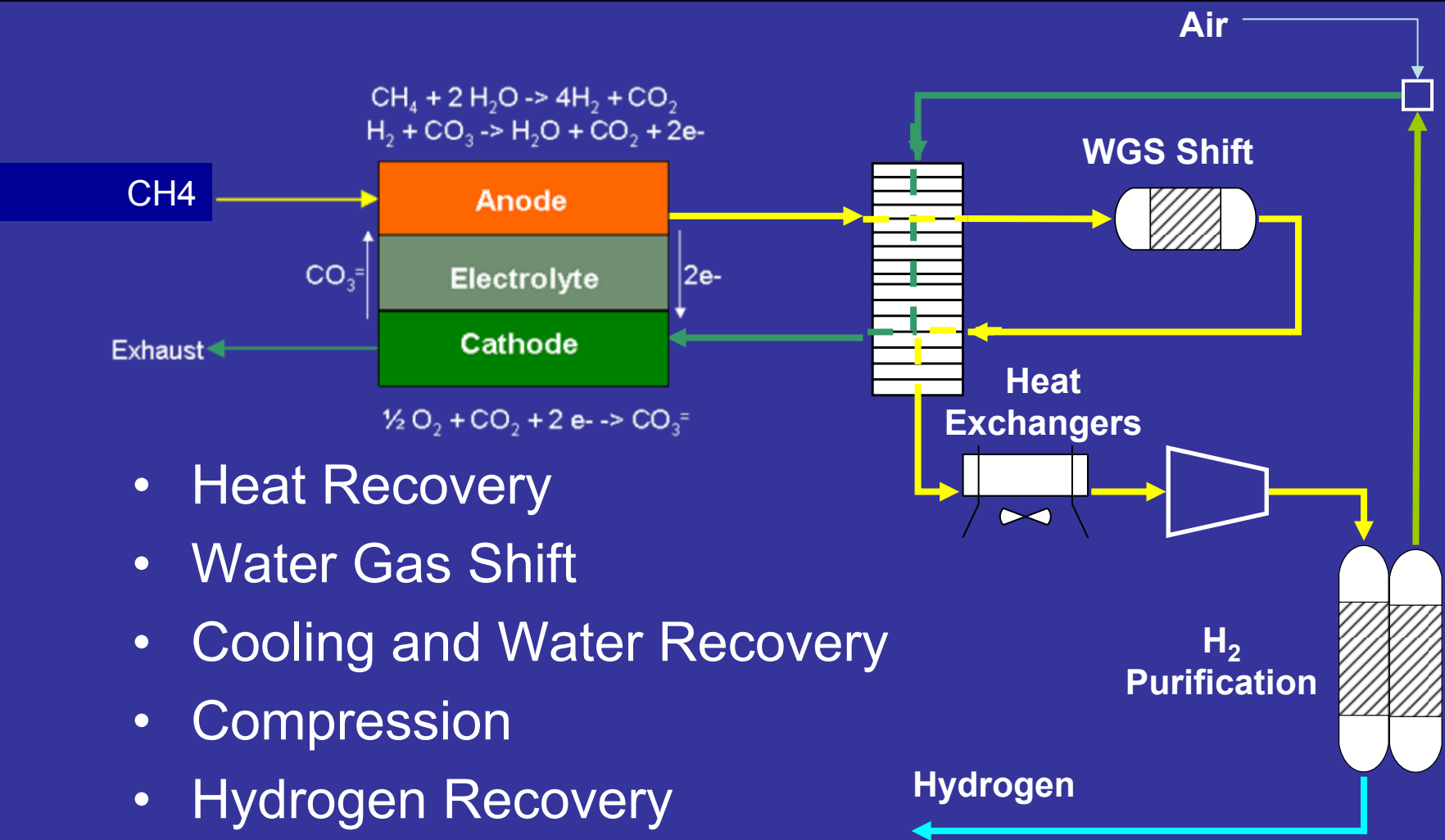
Feedstock Generation

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

FuelCell Energy

AIR PRODUCTS

Hydrogen Co-Production using MCFC



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

FuelCell Energy

AIR PRODUCTS

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: $5.0 MM
  - APCI + Partners: $5.4 MM
- FY07 Spending: $1.3 MM
- FY08 DOE Funding: $1.264 MM

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
- U.S. DOD – Army Corps of Eng

FuelCell Energy

AIR PRODUCTS

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 FY04)
- **Phase 2** – Preliminary System Design (Completed FY06)
- ✓ **Phase 3** – Detailed Design (Completed March 2008) and Construction (In Progress)
- **Phase 4** – Operation, Testing, Data Collection (Scheduled for FY09)

FuelCell Energy

AIR PRODUCTS

Phase 3 – Detailed Design & Construction

- **Detailed Design**
  - Hydrogen Capable DFC – Complete
  - Anode Gas Conditioning – Complete
  - Hydrogen Purification – Complete
  - Integration – Complete
- **Construction/Fabrication**
  - Hydrogen Capable DFC – In Progress
  - Anode Gas Conditioning – In Progress
  - Hydrogen Purification – In Progress

Hydrogen Energy Station
Distributed Power and Hydrogen

FuelCell Energy DFC-300

50%
Power

10%
Heat

End User

Air Products Purification

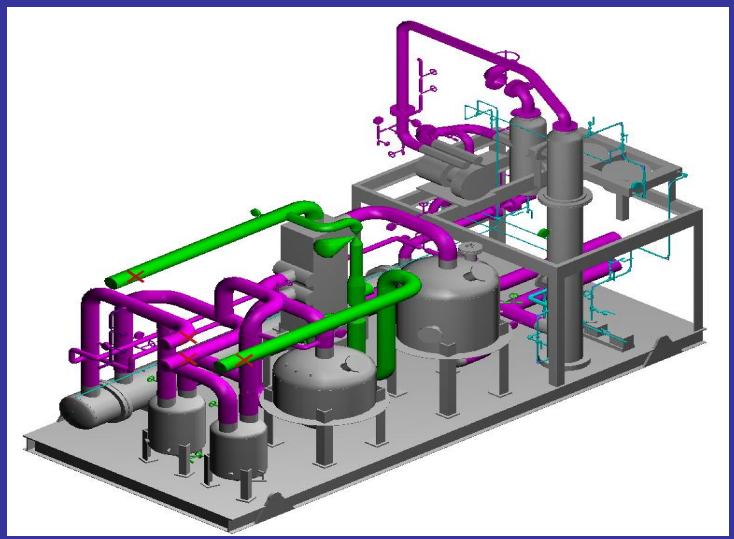
16%
H_2

Hydrogen Filling Station

FuelCell Energy

AIR PRODUCTS

Proto-type Unit Construction nearly complete



HFCIT Electrical Efficiency Target Achieved

- HFCIT Target: >40%
- Net Electrical Efficiency: 50%
  [Net Power/(Total Fuel – H2 Fuel Value)]

Projected Performance – By Phase

	Units	Phase I	Phase II	Phase III
Overall Efficiency (Net Power + Hydrogen Product) / (Fuel)	LHV	60%	66%	66%
Power Efficiency Net Power / (Total Fuel – Hydrogen Product)	LHV	49%	49%	50%
Hydrogen Efficiency (Hydrogen Product – Purification Power) / Hydrogen Product	LHV	68%	77%	77%
Hydrogen Product	Kg/day	~ 88	~ 175	~ 175
Net Power w/o & w/ Hydrogen	kW	~ 247 / 207	~ 300 / 243	~ 300 / 250
Natural Gas Flow	Nm3/hr	~ 55	~ 74	~ 74

FuelCell Energy

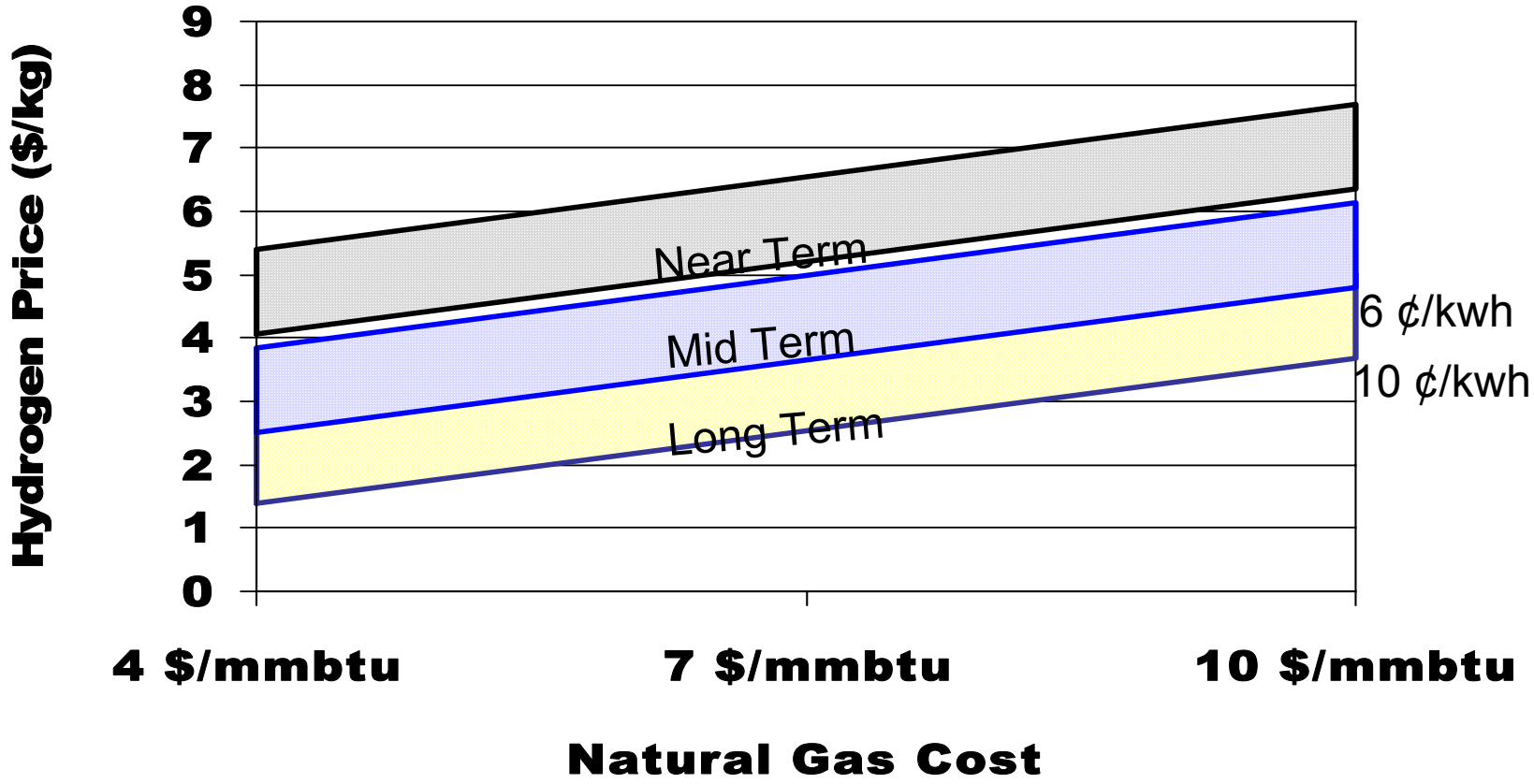
AIR PRODUCTS

HFCIT Targets – Status @ Detailed Design

- Cost of H2 Target: $3.00 /kg
  - Results with NG
    - Near Term: $6.00/kg
    - Near Term with SGIP: $2.50/kg
    - Long Term: $2.25/kg

Assumptions: OROI = 10%; Power = $0.10/kwhr; Utilization = 93%;
NG = 7.00 $/MM btu; Capital Cost Reduction Assumed for Long Term = 50%

Hydrogen Energy Station Economics



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

FuelCell Energy

AIR PRODUCTS

Emissions – Relevance

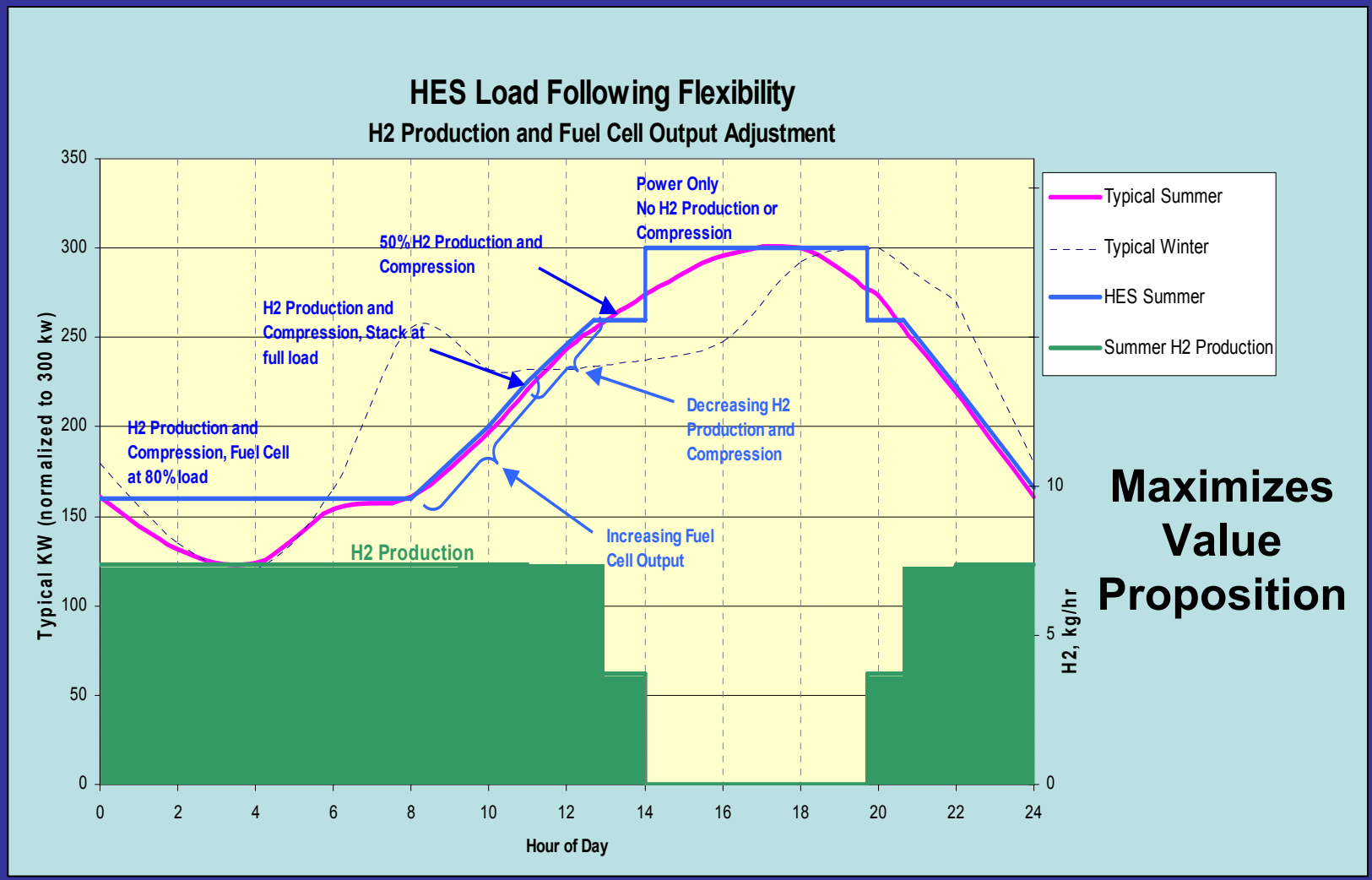
- **DFC Fuel Cells are Clean**
  - Base DFC Unit is CARB ‘07 certified
  - Emissions with byproduct H2 expected to be CARB certified
- **Distributed H2 Production Eliminates Truck Delivery**
  - Reduces related CO2 emissions
  - Reduces related SOx and NOx emissions

Emissions – Projected Performance

	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
DFC Fuel Cell 47% efficiency	**0.016**	**0**	**967**
DFC Fuel Cell – CHP 80% efficiency	**0.016**	**0**	**545**

NO_x and SO_x are negligible compared to conventional technologies

Flexible Co-Production: Load Following



Integrated Hydrogen Energy Station

Integration Issues Resolved

FuelCell Energy

AIR PRODUCTS

Future Work

- Complete Phase 3 (FY08)
  - Fabricate Skids
  - Assemble and Test Complete System at FCE
  - Update Economics
- Phase 4 (FY ‘08 - ’09)
  - Operating Phase

Acknowledgement & Disclaimers

This material is based upon work supported by the Department of Energy (Energy Efficiency and Renewable Energy) under Award Number DE-FC36-01GO11087.