Development of a Turnkey H2 Refueling Station

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This presentation does not contain any proprietary or confidential information.
Program Objectives

- To demonstrate the economic and technical viability of a stand-alone, fully integrated H₂ Fueling Station based on reforming of natural gas
  - To build on the learnings from the Las Vegas H₂ Fueling Energy Station program.
  - Optimize the system. Advance the technology. Lower the cost of delivered H₂.

- To demonstrate the operation of the fueling station at Penn State University
  - To obtain adequate operational data to provide the basis for future commercial fueling stations

- To maintain safety as the top priority in the fueling station design and operation

Goal for Past Year: Complete Phase 2 – Subsystem Development (Accomplished scheduled tasks)
H₂ Fueling Station at Penn State

Feedstocks
- H₂
- NG

Fueling Station
- Electrolysis
- PSA
- Ref.
- H₂ Generator
- Compression

Vehicles
- PTI, CATA, Penn State

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Budget

Total Project Budget:
- $8.929 MM

Cost Sharing:
- DOE - $5.169MM
- APCI and Partners – balance.

FY2004 Funding
- $938,000 Obligated by DOE
Technical Barriers and Targets

DOE Technical Barriers

- Technical Validation (Section 3.5.4.2 of HFCIT Program Report), Task #3.
  - B. Storage (fast fill)
  - C. H₂ Refueling Infrastructure (cost of H₂; interface for fast-fill)
  - D. Maintenance & Training Facilities (train personnel for H₂)
  - E. Codes & Standards (lack of adopted codes & standards)

DOE Targets

- H₂ Production (Table 3.1.2 of HFCIT Program Report), Task #3.
  - Cost of H₂:
  - Efficiency
    - PSA: 82% by 2005.
    - Overall: 68% by 2005.
**Three Phase Industry-DOE Project**

**Phase 1: Conceptual Design & Economic Evaluation**
- Formulated & costed subsystem conceptual designs
- We believe we can demonstrate the roadmap to providing H2 fuel equivalent to gasoline prices
- Completed, on-schedule.

**Phase 2: Subsystem Development**
- Develop Subsystems and Test Components
- Advance every aspect of station
- Begin station aesthetics work

**Phase 3: System Deployment**
- Scale-up & detailed engineering
- Fabricate & install at Penn State
- Operate and Test – Vehicles Filled
- 6 Month Operations
Approach for Phase 2 – Sub-System R&D

Comprehensive Development Program

- Work has been organized by sub-system
- Combination of simulation, lab R&D, Real-world component testing, collaboration with vendors, and engineering design work
- Significant progress towards DOE Targets and Barriers
- Budget constraints required a re-adjustment of schedule, but not scope of reformer development
Goals:
1. Advance the most cost effective natural gas reforming technology for fueling station applications.
2. Complete preliminary design.
Reformer

- **Phase 1 – Advanced SMR chosen by comprehensive technical and cost evaluation**
  - Evaluated SMR, POX, ATR, CPOX
  - Received 10 quotations for commercial or near-commercial systems
  - Advanced Technology SMR’s are more cost competitive than the other evaluated technologies for small scale reforming applications used in hydrogen fueling stations

- **Operation and testing of Las Vegas H2 Energy Station**
  - Nothing better than real-world operating data
  - Incorporating lessons learned

- **Engineering Design Underway**
  - Optimization of desulphurization, reformer, and shift catalysts
  - Improved heat recovery system
  - Improved Efficiency

- **Work Slowed – budget constraints**
  - To be completed in late FY2004.
Task 2.3. Purifier Development

Goals:
1. Choose PSA Supplier
2. Conduct Lab and Field Testing of PSA Sub-System
3. Complete technical and economic analysis of ability to hit targets
Purifier (PSA) Development

- PSA Supplier Chosen – Air Products
  - Highest H₂ Recovery at <2 ppm CO in H₂
  - Lowest capital cost
  - Maintainable

- Air Products PSA: Innovative in Multiple Areas and Functions
  - Exotic adsorbents developed for higher recovery
  - Cycle optimization to reap benefits of new adsorbents
  - Valve development for rapid cycles
  - Process/Material/Mechanical integration
  - Low cost manufacturing / systems assembly (DFMA)
  - Lab and operating plant data collected
PSA Economics

● Engineering Work Completed
  ➢ System components specified
  ➢ Mechanical design & manufacturing improvements implemented
  ➢ System running at APCI H₂ Facility

● Goals Met
  ➢ Achieved 2 – 4x reduction in cost of PSA when compared with commercially available units
  ➢ New PSA Unit Much smaller than commercially available units
  ➢ Efficiency Exceeds DOE 2005 Target of 82%
Goals:
1. Use Sacramento and Las Vegas as starting point. Make dispenser less “industrial” and more aesthetic.
2. Establish cost targets and plan to achieve them.
3. Identify metering alternatives and test plan. Implement test plan.
Dispenser Development

- **Component Selection Completed**
  - Good for classified area – Class 1 Div 1.
  - Custom microprocessor based controller
  - High Pressure
    - Vessels good for 7,000 psig
    - Other components selected for 14,000 – 20,000 psig

- **Flow Meter**
  - Test skid built and in service. Test program underway.
  - 10 Meters Investigated
  - 3 Chosen for Test. All 3 Tested to Date.
    - Several meters achieve acceptable steady-state flow accuracy
    - However, best measured batch accuracy to date is +/- 8%
  - Over All Fill Speeds
    - None performs to acceptable accuracy
    - Testing continues
  - Interfacing with NIST to help write certification rules
Dispenser Progress

- Customer Feedback used to Improve Aesthetics & User Interface
  - Familiar look is better than “space-age”

- DFMA underway

- Cost Reduction
  - Factor of >2 reduction from starting point

- DOE Barriers Addressed:
  - B. Storage – Fast Fill
    - Ramp-rate control implemented
    - System will fill an empty auto in 1 minute with communication
  - C. Infrastructure – Communications
    - Communications implemented that will enable safe fast fill: hard-wire and infrared communications developed. Barrier – which vehicle?
Task 2.5. Siting, System Integration

- APCI Developed Preliminary Plot Plan for Site

- APCI, Penn State, and PTI Chose Site
  - Choice: At current CNG vehicle filling site
  - East end of PSU campus, by Beaver Stadium
    - Meets needs of PTI – for test track
    - Near ECEC where fuel cell research is done (Dr. Wang)
System Integration: Safety Reviews and Training

● Safety
  - APCI has >40 years experience in safe design, construction, & operation of H2 plants.
    - > 10,000 H2 fuel fills complete to date (>80 per week now)
    - Leader in Management of Change, Near Miss Reporting, and Quantified Risk Assessment Procedures
  - PHR: Phase 1
  - HAZOP: Phases 2 & 3
  - All applicable industry codes will be followed
  - APCI participates in SAE, ICC, ISO, HFPA, IETC, and EIHP2 committees

● Site Selection and Personnel Training
  - Site concurrent with existing CNG filling station
  - Personnel will be trained in H2 handling and maintenance of H2-related equipment
System Integration Summary

- **PFD, Process Specs, and Plot Plan Developed**
- **Efficiency Target Met**
  - Integrated Station with Advanced SMR, Novel PSA, and Optimized Process
  - Meets DOE 2005 Target of 68% Overall Efficiency (LHV)
- **H₂ Refueling Station Costs**
  - Las Vegas Station is Starting Point
  - Costs Reduced for Penn State Station.
  - Studied effect of scaling:
    - To larger H₂ production per generator
    - To mass production of stations (100 units)
  - $2.72/kg H₂ Price at Dispenser is feasible based on this program’s technology*
    - Meets DOE 2005 Target of $3.00/kg H₂
    - Pathway Re-Validated that a Stand-Alone H₂ Station can be Technically and Economically Feasible

* DOE HFCIT assumptions: 690 kg/day, 11% capital factor, >100 units annually, $4/MMBTU(HHV) NG, 90% utilization
Future Work

- **Scheduled Phase 2 Activities Are Complete**
  - PSA – continue data collection in field
  - Dispenser
    - Ongoing activity – flow meter testing
  - Cost and schedule estimates for Program have been updated
    - On target

- **Re-Scheduled Phase 2 Activities On-Track**
  - Reformer
  - Integration of H₂ Generator Sub-systems

- **Goals for Next Year (by May 2005):**
  - Complete Detailed design of station
  - Install & Start-Up Station – H₂ Supply, storage, compression, dispensing – In October 2004
  - Complete development and detailed design of H₂ Generator by Spring 2005
Response to 2003 Questions

● **Next Generation Station**
  - Build on learnings of Las Vegas Station
  - Advance technology – improve efficiency
  - Address all aspects of H₂ refueling facility design
  - Reduce cost of H₂ delivered

● **Technical Advancements**
  - PSA System Efficiency Increased
  - H₂ Generator Efficiency Increased
  - Dispenser Metering Advanced
  - System Integration Optimized
  - Results in Reduced Cost of Dispensed H₂

● **Vehicles**
  - Sourcing of vehicles not part of this program
  - Significant effort spent with PSU and State of PA
    - Proposal Approved by PA DEP for funding vehicle conversions and stations operating costs
      - by PSU H₂ Institute, PSU PTI, CATA, Air Products
  - Contract changed to include CNG/H₂ blend dispenser and to match the timing of station start-up with vehicle availability