California Hydrogen Infrastructure Project

2006 DOE Program Review

Mark Pedersen
Air Products and Chemicals, Inc.
19 May 2006

Project ID TV11

This presentation does not contain any proprietary or confidential information

AIR PRODUCTS

Overview

Timeline

- Start – Aug. 2005
- End – Sept. 2008
- 15% Complete

Budget

- Total project funding
  - DOE $4.44 million share
  - APCI and collaborators $4.44 million
- DOE Funds received to date ~$400K
  - FY ’05 spending ~$400K
  - FY ’06 spending ~$400K (end of Feb. 2006)

Barriers

- Cost of delivered H2

Partners

- Various collaborators and funding groups including;
  - SCAQMD
  - OEM’s
  - UC Irvine
  - Energy Companies

Objectives

- Demonstrate a cost effective infrastructure model in California for possible nationwide implementation
  - Design, construct and operate seven hydrogen fueling stations
  - Collect and Report Infrastructure Data
  - Document permitting requirements and experiences
  - Validate expected performance, cost, reliability, maintenance, and environmental impacts
- Implement a variety of new technologies with the objective of lowering costs of delivered H2
  - New Delivery Concept (NDC)
  - Hydrogen Based Unit (HBU)
  - High Pressure / High Purity Clean Up Equipment

Approach

- Work with OEM's to determine vehicle usage needs and general station equipment requirements
- Work with OEM's and others to determine preferred locations/areas for fueling station deployment
- Select potential Station Operators and work to locate suitable sites
- Initiate and complete required agreements, determine and address specific site issues including liability, billing, etc.
- Complete detailed Station Design, permits, installation, operation, and maintenance of stations
- Collect and report Infrastructure Data to the DOE once stations put online
- Monitor and collect feedback which can be incorporated to improve station user's fueling experience

Hydrogen Pipeline Fueling Station

Phase I – 350 bar Dispensing
Phase II – 700 bar upgrade

World's first hydrogen pipeline supplied fueling station demonstrating low cost, reliable supply.

High pressure / high purity pipeline supply (~800 psig).

Site specific details and agreements are still in discussion.

Investigating locations in the Torrance area.

Novel Rotary Valve H2 Cleanup System

High Pressure/High Purity/Hydrogen Purifier

- **Demonstrate:** Purification of high purity H2 to ultra-high purity based on physical adsorption system. Cleanup system provides high pressure, high purity to fueling station from existing H2 pipeline. Consists of single train of controls and vessels. Patents pending.
- **Key Advantages:**
  - Rapid Regeneration
  - Very High H2 Recovery (Periodically the adsorbent beds are regenerated with a low volume purge of product H2. No other wastes are generated by the clean up system.)
  - Elimination of thermal regeneration which reduces capital, operating, and maintenance costs. (No utilities required other than power for system controls.)
- **Major Components:** Adsorber Vessels / Vacuum Pump
- **Design Capacity:** 4kg/hr (1,700 SCFH) continuous @ ~800 psig

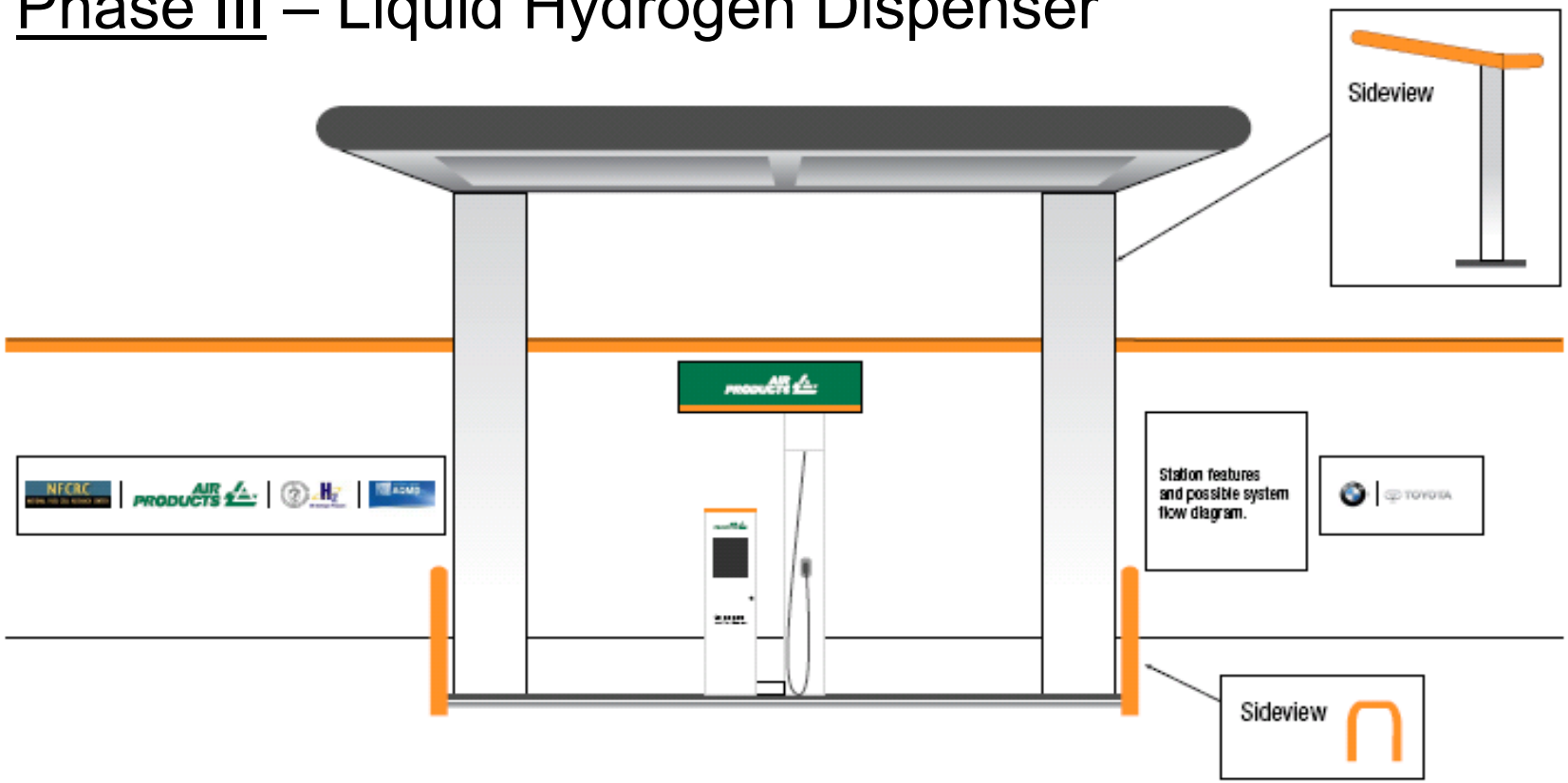
AIR PRODUCTS

UC Irvine Station

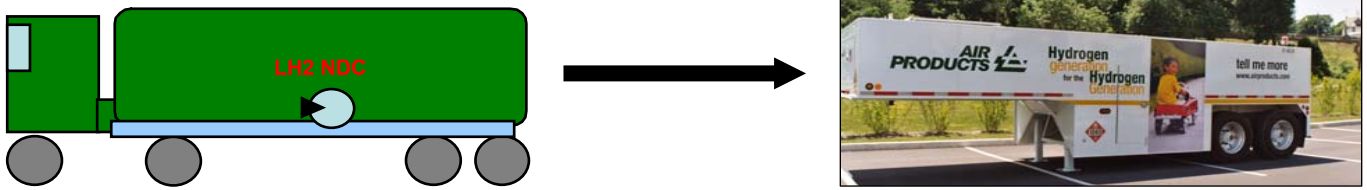
Phase I – 350 bar upgrade

Phase II – 700 bar upgrade

Phase III – Liquid Hydrogen Dispenser



California Bay Area Filling Station



Project: Install and operate Hydrogen Fueler (HF) filling station in Northern California.

Key Objectives:

- Reduce Hydrogen Fueler operating costs for stations deployed in Northern California by reducing the transportation miles between the station and the fill location.
- Improved Reliability of Supply. (Adds backup supply to existing filling station located in S. California).
- High purity from liquid hydrogen supply.

Major Components:

- New Delivery Concept (NDC) Trailer – Patents Pending
- Site improvements to accommodate onsite NDC and Hydrogen Fueler filling including analytical equipment as required

Design Capacity:

- Capable of refilling multiple HF trailers from a single NDC load
- Fast filling – capable of filling an HF-150 trailer in under 2 hours

LH2 New Delivery Concept (NDC)

- **NDC Deployment:**
  - One NDC deployed to support planned HBU Stations.
  - Second NDC deployed to support N. CA Fill Station and to provide backup/ increased reliability to first NDC Trailer and to S. CA Fill Station.

- **Demonstrate:** New method of hydrogen distribution capable of supplying low, medium, and high pressure systems using a single liquid hydrogen trailer. NDC trailer allows for increased integration of the merchant bulk hydrogen, hydrogen fueling stations, and liquid hydrogen supply chains, driving improved operating efficiency. Patents Pending.

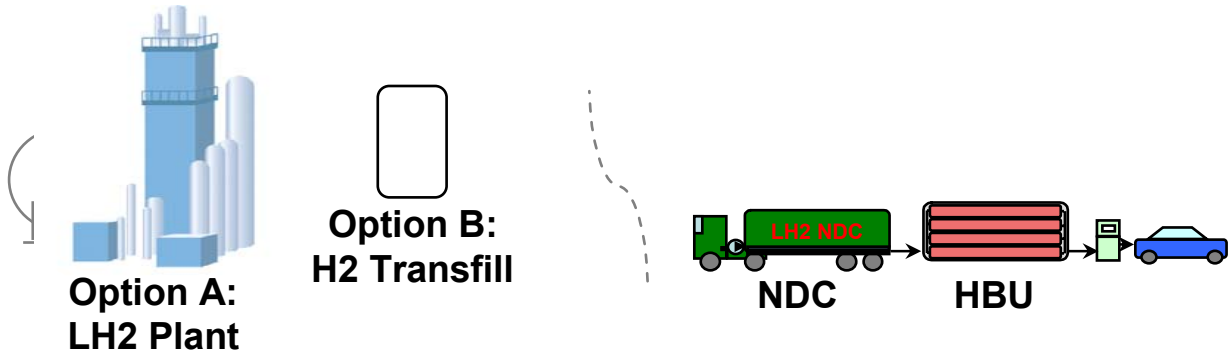
- **Key Advantages:** 10 fold increase in the amount of transported H2 when compared with traditional tube trailers. Gaseous hydrogen delivery with almost liquid hydrogen economics. Greater equipment utilization by taking advantage of existing industrial assets and infrastructure

- **Major Components:** LH2 Trailer w/ onboard pump, vaporization, and controls

- **Design Capacity:** ~15,000 gal. LH2 w/ discharge press. up to 8,000 psig

- **Utilities:** None

Hydrogen Based Unit (HBU)



- **Two HBU Stations Planned:**
  - One in S. CA (LA Area). Station Operator and location TBD.
  - One in N. CA (Sacramento Area possibly). Station Operator and location TBD.
- **Demonstrate:** New approach to reduce costs associated with stationary fueling stations. HBU product is deployed at customer sites in conjunction with New Delivery Concept (NDC) Liquid Hydrogen Trailer. Patents Pending.
- **Advantages:**
  - Minimal Site Space Required. Could be behind buildings, on canopy, or underground. Dispenser can be mounted remotely from storage.
  - No Compression, minimal utilities for controls only, low maintenance, quiet operation.
  - Quick installation with minimal site work.
- **Major Components:** Gas Storage Unit and 350 Bar Dispenser
- **Design Capacity:** 150 to 200 kg H2 @ 7000 psig (ASME Storage)

AIR PRODUCTS

Technical Progress

- **To Date**
  - eRAM design and implementation almost complete
  - Work continuing on finding a suitable location for Torrance Pipeline Station. Equipment Design work complete. Equipment in fabrication.
  - Design, Permitting, Equipment Fabrication complete for UCI Phase I. Design and equipment fabrication started on Phase II. Early design started on Phase III.
  - HF-150 Hydrogen Fuelers: Three units in fabrication and will be completed in coming months. Location and station operator determined for one Station. Station Operators and locations not finalized for other stations.
  - HBU #1 and #2: Design complete. Equipment on order. Station Operators and locations to be determined.
  - NDC #1 and #2: Design complete. Equipment on order.
- **Expected to initiate in coming months**
  - Infrastructure study with the UCI NFCRC
  - Determine potential Station Operators and Locations for;
    - Torrance Pipeline Station
    - HF-150 in LA Area and South Lake Tahoe
    - HBU in LA Area and in N. CA
  - N. CA Fill Station: Site selection and design work
  - Begin work on in-depth study on Cryogenic Compressed Hydrogen (CCH)

Summary

- Demonstrate a variety of technologies in the deployment of Hydrogen Infrastructure
  - Seven Fueling Stations (some involving multiple projects at the same location)
  - Demonstration of low cost delivered H2 options
  - Infrastructure Data Reporting expected to begin in 2006
- To date
  - Equipment design completed in most cases and major equipment with long lead times on order
  - Equipment fabrication begun in most cases
- Site locations and Station Operators to be determined for many of the planned stations

Back-up Slides

(for information purposes only)

Project Tasks

Task 1: Torrance Pipeline Hydrogen Fueling Station

Task 2: Hydrogen Fuelers (HF) and Hydrogen Fueler Refill Capability in Northern California

- **LA Area Hydrogen Fuelers (2)**
- **S. Lake Tahoe Area Hydrogen Fueler (1)**
- **Optional Hydrogen Fueler TBD (1)**
- **Northern CA Hydrogen Fueler Fill Station**

Task 3: Upgrades to Existing Hydrogen Fueling Stations

- **UCI Hydrogen Fueling Station Upgrade**
- **UCI 700 Bar Gas**
- **UCI Liquid Dispenser**
- **Torrance 700 Bar Gas**

Task 4: Hydrogen Based Units (HBU) with Novel Liquid-Gas Delivery Concept (NDC)

- **New Delivery Concept Vehicle**
- **Hydrogen Based Units (2)**

Task 5: Hydrogen Infrastructure Study

Task 6: Infrastructure Data Acquisition, Analysis and Delivery (includes eRAM)

Task 7: Program Management, Risk Mitigation, Safety and Communication Plan and Reporting

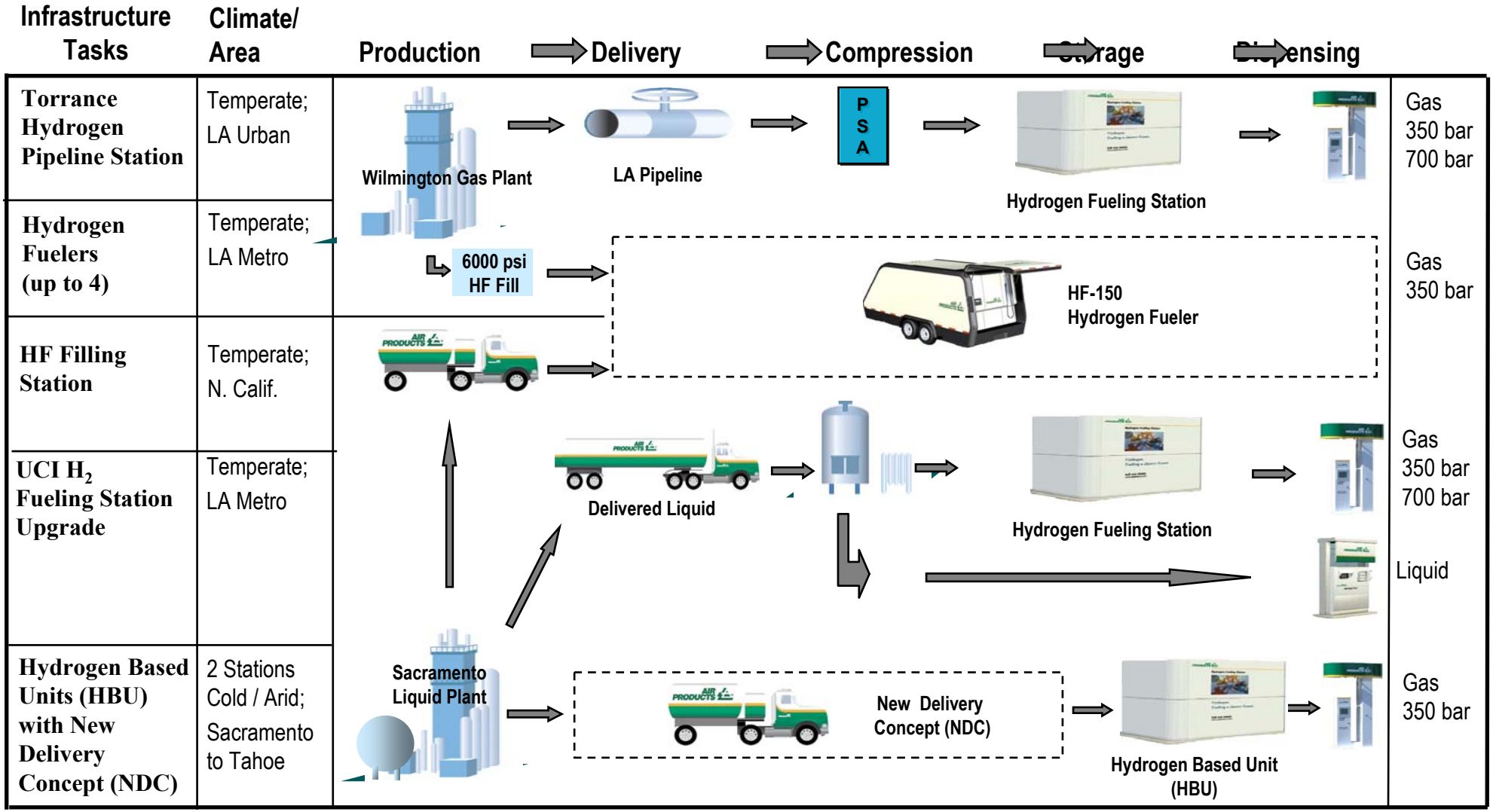


Figure 1- California H_2 Infrastructure Program Overview

Hydrogen Pipeline Fueling Station

- Hydrogen feed from existing pipeline @ 800 psig inlet to metering station with excess flow protection. Includes clean up equipment using proprietary skidded purifier to meet fuel cell purity requirement.
- Series 200 compressor skid, 4 kg/hr flowrate.
- High pressure gas storage (3 vessels, total of 50 kg H2 capacity). Accommodations to double storage capacity in the future.
- Dual dispenser with 350 and 700 Bar. (Upgradeable to 700 bar with addition of booster compressor and minimal site work.) Based on 50% compressor onstream, capacity to dispense ~48 kg/day or approx. 12 cars/day. (6 cars in succession when starting with full storage).

AIR PRODUCTS

UC Irvine Station

- Hydrogen supply from 1500 gallon horizontal liquid hydrogen storage tank, 50 psig.

- Series 200 compressor skid, 2 kg/hr flowrate. (Additional booster compressor will be added for 700 bar dispensing as part of Phase II.)

- High pressure gas storage (3 vessels, total 50 kg H2 capacity). Accommodations to double storage capacity in the future.

- Dual dispenser with both 350 and 700 bar. Based on 50% compressor on-stream, capacity to dispense ~24 kg/day or approx. 6 cars/day. (4-5 cars in succession when starting with full storage). (Liquid Hydrogen dispenser will be added as part of Phase III.)

AIR PRODUCTS

HF-150 Stations

Total of three Hydrogen Fueling Stations planned for installation during 2006.

- LA Area
  - TBD
  - Long Beach
- N. California
  - S. Lake Tahoe

AIR PRODUCTS

Response to Reviewers' Comments from 2005

- Lack of Planning and Detail
  - Presentation given May 2005 was prior to completion of contract with the DOE. Terms had not been finalized.
  - Some project details were still being worked through (ex. locations for some stations).
- Unclear on What is to be Learned
  - Multiple areas will provide valuable information regarding the deployment, operation, and costs of hydrogen fueling stations. This include new equipment to be deployed in the project for the first time including the NDC, HBU, Pipeline Station and purification system. In addition, valuable experience will be gained around issues involving equipment placement and operation in retail settings.
- Cost Reduction Should be First Priority
  - Safety is first priority, followed by cost reduction. The NDC and HBU Stations are expected to show a lower cost delivery method to stations via liquid hydrogen delivery. The planned Torrance Pipeline Station will demonstrate low cost hydrogen supply and will include a novel efficient purification system required for fuel cell vehicle purity.

Publications and Presentations

1. M. Pedersen, “California Hydrogen Infrastructure Project”, Poster Display, National Hydrogen Association (NHA) Conference, Long Beach, CA, March 2006.
2. M. Pedersen, “California Hydrogen Infrastructure Project”, Oral Presentation, DOE H2 Program Annual Merit Review, Washington D.C., May 2005.

Critical Challenges and Issues

- Locating Optimal Sites for Fueling Stations
  - Available space, close to freeways with convenient access (24/7 access preferred), minimize overlap with existing or planned stations (~10 mile separation distance)
  - Completing contracts and legal agreements (primary issues around liability, indemnification, insurance, etc.)
- Challenges in Retail Settings
  - Station Constraints - Limited Space: Stations typically designed to accommodate existing fueling requirements (gasoline), limited parking, specific traffic flow, max. C-store presence, setback distances, etc.
  - Low Station Utilization in early years. Unclear on timing for increased expected usage.
- Codes and Standards
  - Close interaction with local authorities to educate and work through existing codes and standards, areas of conflict and differences.

Acknowledgement & Disclaimers

This material is based upon work supported by the Department of Energy (Energy Efficiency and Renewable Energy) under Award Number DE-FC36-05GO85026. This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This presentation was prepared as a result of work sponsored, paid for, in whole or in part, by the South Coast Air Quality Management District (AQMD). The opinions, findings, conclusions, and recommendations are those of the author and do not necessarily represent the views of AQMD. AQMD, its officers, employees, contractors, and subcontractors make no warranty, expressed or implied, and assume no legal liability for the information. AQMD has not approved or disapproved this presentation, nor has AQMD passed upon the accuracy or adequacy of the information contained herein.