Demonstration of CO$_2$ Capture and Sequestration of Steam Methane Reforming Process Gas for Large-Scale Hydrogen Production

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Agenda

- Air Products Background
- Port Arthur Carbon Capture Project Overview
- Project Technology
- Project Progress
- Future Market
Who Is Air Products?

- Global atmospheric, process and specialty gases, performance materials, equipment and services provider
- Serving industrial, energy, technology and healthcare markets worldwide
- Fortune 500 company
- Operations in over 40 countries
- ~19,000 employees worldwide
- Known for our innovative culture and operational excellence
- Corporate responsibility commitment
- World’s largest third party hydrogen supplier
- $10B+ company in FY11
Project Overview:  
*State-of-the-Art Carbon Capture from Two Port Arthur, TX SMRs*

- **American Recovery and Reinvestment Act Funding**
  - DOE Funding: $284 MM
  - DOE Cost Share: 66%

- **~1 million tons** of CO₂ to be recovered and purified annually starting late 2012

- Valero providing land, rights-of-way, utilities

- AP supplying compressed and purified CO₂ to Denbury for injection into TX oilfields for enhanced oil recovery
Overall Project Objectives

• DOE Objectives
  - Compliance with the American Recovery Act Objectives
  - Capture at least 75% of the CO$_2$ from a treated industrial gas stream that would otherwise be emitted
  - Project size shall be a large-scale industrial CCS project producing 1 million metric tons/year
  - CO$_2$ must be sequestered in underground geologic formation
  - Monitoring, verification, and accounting (MVA) of sequestered CO$_2$
  - On-stream prior to September 2015

• Additional Air Products’ Objectives
  - No negative impact to Hydrogen business
  - Demonstrate real-world CO$_2$ capture economics
**CO₂ Capture Project**
*Port Arthur I & II: Integrated Cogeneration and Hydrogen Plants*

- H₂ Export Steam
- H₂ Power Generation Export Steam

**CO₂ Transport & Storage**

**CO₂ Removal, Purification, Compression**

DOE Phase 2 Award, Industrial Carbon Capture
Simplified CO₂ Capture Block Flow Diagram

PORT ARTHUR 2

Natural Gas
Utilities
HP Steam Export
Power Export

EXISTING SMR

Purge Gas

Syngas

Syngas (CO₂ Removed)

EXISTING PSA

Export CO₂

Export Hydrogen

Wet CO₂

H₂

CO₂

NEW VSA

PORT ARTHUR 1

Natural Gas
Utilities
HP Steam Export
Power Export

EXISTING SMR

Purge Gas

Syngas

Syngas (CO₂ Removed)

EXISTING PSA

Export CO₂

Export Hydrogen

Wet CO₂

H₂

CO₂

NEW VSA

Existing Stream

New Stream

Revised Stream

HP Steam Export
Power Export

Utilities

Natural Gas

CO₂

NEW COMPRESSOR / DRIER

Air Products
Vacuum Swing Adsorption Process for CO\textsubscript{2} Separation

Flow

ADSORBENT

SMR CO\textsubscript{2} Rich Syngas

H\textsubscript{2} CO\textsubscript{2}

Sweet Syngas to Existing H\textsubscript{2} PSA

To Feed

CO\textsubscript{2}

To Feed
Key Project Components
Capturing CO$_2$ for Denbury’s “Green Pipeline”

- Vacuum swing adsorption (VSA) vessels
- Tri-ethylene glycol (TEG) drier system
- CO$_2$ export compressor
  - 8 stages
  - Export pressure over 2000 psig (~140 bar)
- 13 mile (21 km) CO$_2$ Pipeline connecting to Denbury’s “Green” 300+ Mile (~500 km) CO$_2$ Pipeline

Map shows Denbury’s Green CO2 Pipeline. Data source is Denbury, December 2011, CO2 Flooding Conference.
Progress and Current Status of Project

- Site Demo – Complete
- FONSI issued – Complete
- Pilings – Complete
- Foundations – Complete
- Projected CO₂ Capture On-stream:
  - PA-II SMR: Late 2012
  - PA-I SMR: Early 2013
Project Challenges

• Technical Challenges
  - Integration with existing hydrogen business
  - Technology Scale-up

• Economic Challenges
  - 45Q Tax Credits
  - Schedule
  - Capital
    • Retrofit project within active operating facility
  - Operating and Maintenance Costs
Plan for Future Commercialization

• Technical and economic results from this project are key to determining the most effective commercialization path

• DOE award funding has enabled demonstration
  - Existing CO₂ market does not support current CO₂ capture economics without external funding

• [www.airproducts.com/co2_capture](http://www.airproducts.com/co2_capture)
• [www.h2alliance.com](http://www.h2alliance.com)
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