CO$_2$ Capture from Steam Methane Reformers: Commercial Scale Demonstration Project

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Agenda

- Air Products Background
- Port Arthur Carbon Capture Project Overview
- Carbon Capture Project Technology Fundamentals
- 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
Sustainability Commitment and Leadership Examples

Dow Jones Sustainability World and North America Indexes for 2011/12

Carbon Disclosure Project Global and S&P500 Disclosure and Performance Leadership Indexes

Headquarters Silicon Thin-Film Solar Farm is online and generating renewable energy

Top 10% of Sector

One of only 23 companies on both global indexes

Our SunSource® materials in action
Innovation Drives Air Products’ Hydrogen Leadership

- Pioneered onsite industrial gas business model
- Technip alliance
  - [www.h2alliance.com](http://www.h2alliance.com)
- Maintaining 40+% market share
- World’s largest hydrogen plant and pipeline network summer 2012
  - US Gulf Coast
  - 1.2 + BSCFD (1.3x10^6 Nm^3/hr) Capacity
  - ~600 miles (~1000 km) long

Hydrogen Pipeline
- Air Products
- Offgas H_2 Plant
- SMR / POx Hydrogen

Map of Hydrogen Pipeline:
- Houston
- Sweeny
- Texas City
- Lake Charles
- Baton Rouge
- Geismar
- New Orleans
- Gulf of Mexico
- Louisiana
- Texas

Line graph showing Air Products H_2 (BSCFD) from 1990 to 2010.
Port Arthur, TX
Air Products’ Cutting Edge Innovation in Action

- Port Arthur I: Integrated cogen and hydrogen plant
- Port Arthur II: 2007 Plant of the Year
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 in excess of **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
Hydrogen Production at Port Arthur TX

H₂ Export Steam

H₂ Power Generation
Export Steam

CO₂ Transport & Storage

CO₂ Removal, Purification, Compression

DOE Phase 2 Award, Industrial Carbon Capture
The Innovation Continues: Simplified CO₂ Capture Block Flow Diagram

PORT ARTHUR 2
Existing Stream
New Stream
Revised Stream

PORT ARTHUR 1

Natural Gas
Utilities
HP Steam Export
Power Export

Existing Stream
New Stream
Revised Stream
Vacuum Swing Adsorption Process for CO$_2$ Separation

Flow

SMR
CO$_2$
Rich Syngas

H$_2$

CO$_2$

Sweet Syngas to Existing H$_2$ PSA

To Feed

CO$_2$

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Key Project Components

**Capturing CO2 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.
Video: On Location in Port Arthur, TX

• See video at:
  - www.airproducts.com/CO2_capture
Progress and Current Status of Project

- Site Demo – May 2011
- FONSI issued – July 2011
- Pilings – August 2011
- Foundations – September 2011
- Projected CO$_2$ 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
    • $10/tonne for EOR; $20/tonne for sequestration
    • 75 million tonnes is the current limit

• 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 CO$_2$ market does not support current CO$_2$ capture economics without external funding

www.airproducts.com/co2_capture
www.h2alliance.com
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Thank you