NATIONAL ENERGY TECHNOLOGY LABORATORY

Demonstration of Carbon Capture and Sequestration of Steam Methane Reforming Process Gas Used for Large-Scale Hydrogen Production

or “Port Arthur CCUS”

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NETL/ SCC/ OMD/ MPD

Denbury

AIR PRODUCTS

U.S. DEPARTMENT OF ENERGY

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Industrial CCS Project Objectives and Targets
Large-scale CCS from Industrial Sources (Area 1)

- **Objectives**
  - **Demonstrate advanced CCS technologies**
  - **To progress beyond the R&D stage of readiness**
  - **Integration with comprehensive Monitoring, Verification & Accounting (MVA)**
  - **Demonstrate sequestration option**

- **Target**
  - **Industrial sources**
  - **Industries may produce heat, fuels, chemicals, hydrogen or other useful products with or without electricity production**
  - **1MM tons/yr of CO_2 emission from each plant for CCS**

Who is Air Products?

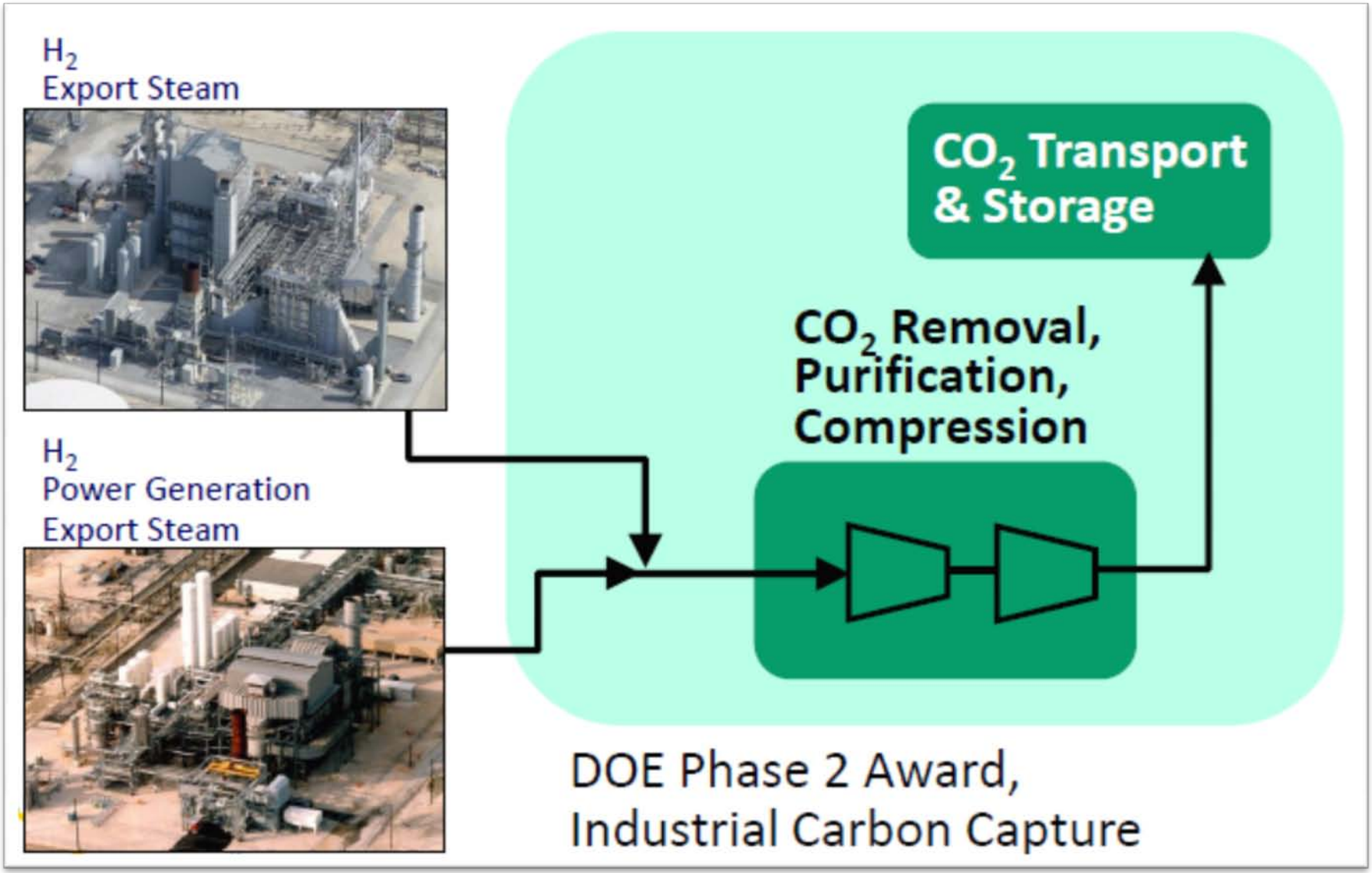
- Global atmospheric, process and specialty gases, performance materials, equipment and services provider
- Serving industrial, energy, technology and healthcare markets worldwide
- Fortune 500 company
- Operations in over 40 countries
- ~19,000 employees worldwide
- Known for innovative culture and operational excellence
- Corporate responsibility commitment
- World's largest third party hydrogen supplier
- $10B+ company in FY11

Air Products and Chemicals, Inc.
Steam Methane Reforming with CO_2 Capture

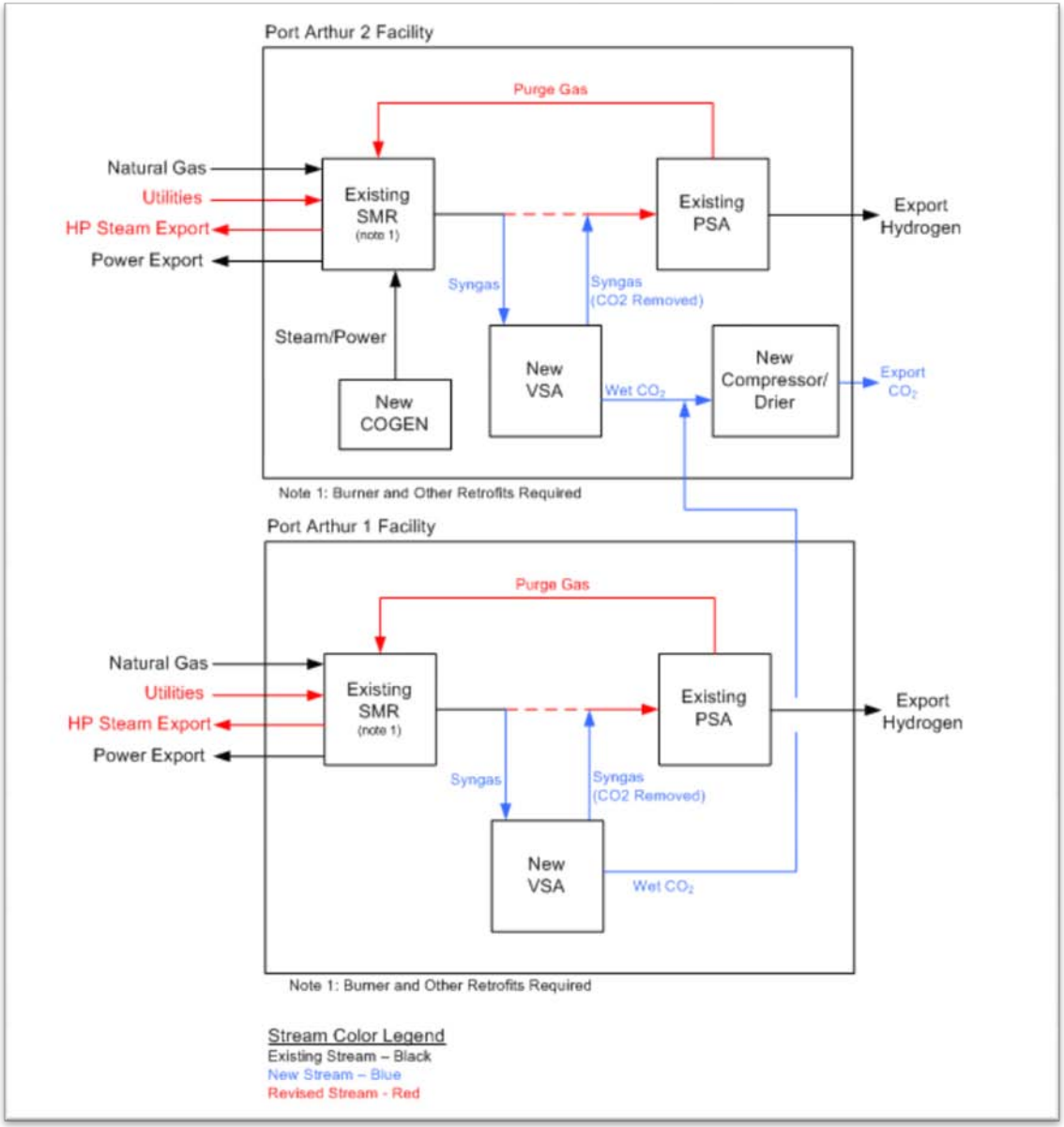
- **Port Arthur, TX (Hydrogen plant at Valero Refinery)**

- **90% CO_2 capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding 1,000,000 tons CO_2/year**
- **≈28 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and Compression Equipment**
- **CO_2 to Denbury pipeline for EOR in West Hastings oil field**
- **Total Project: $431 Million** **DOE Share: $284 Million (66%)**

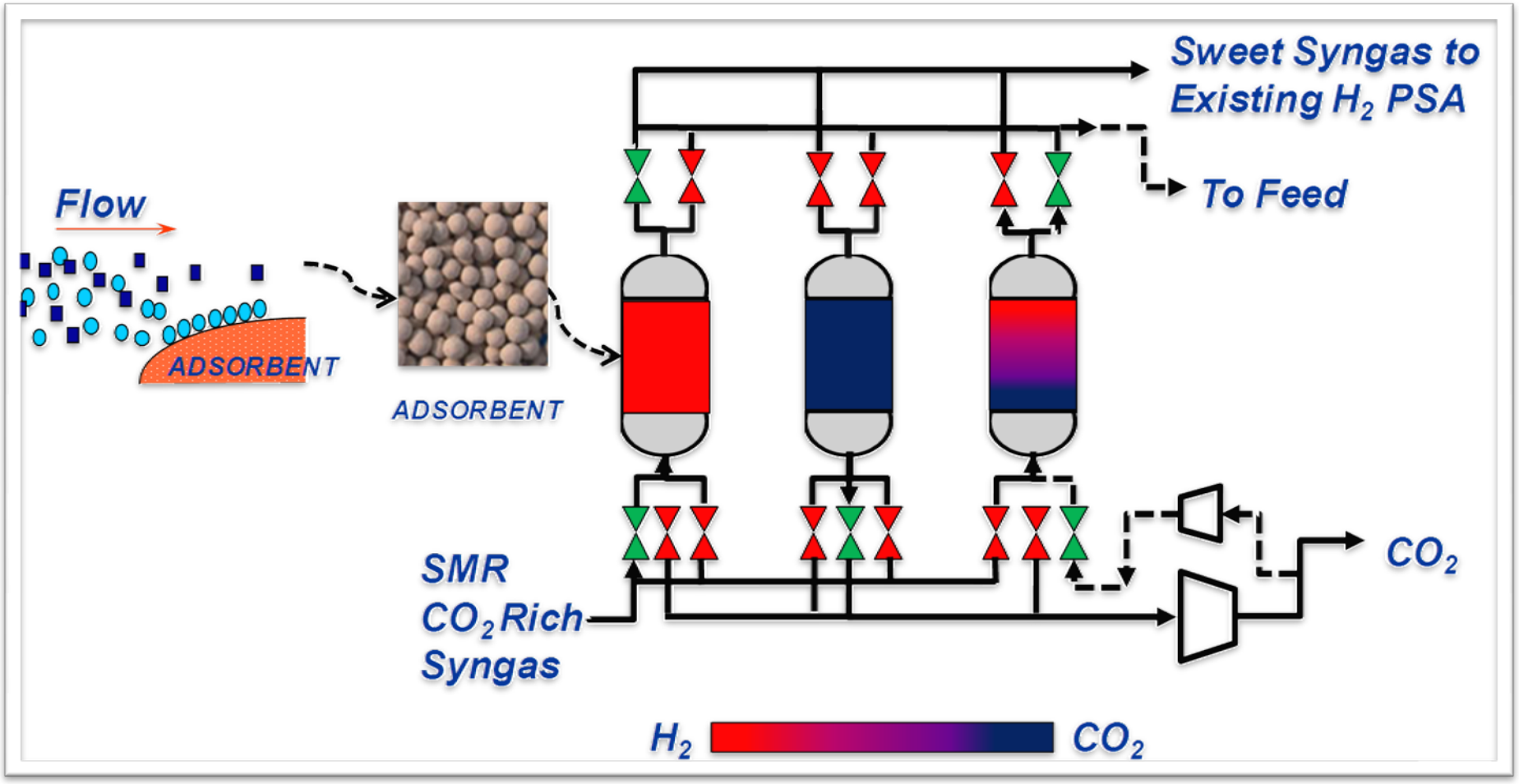
Integrated Cogeneration and Hydrogen Plants



Simplified CO_2 Capture Block Flow Diagram



Vacuum Swing Adsorption ("VSA") Process for CO_2 Separation



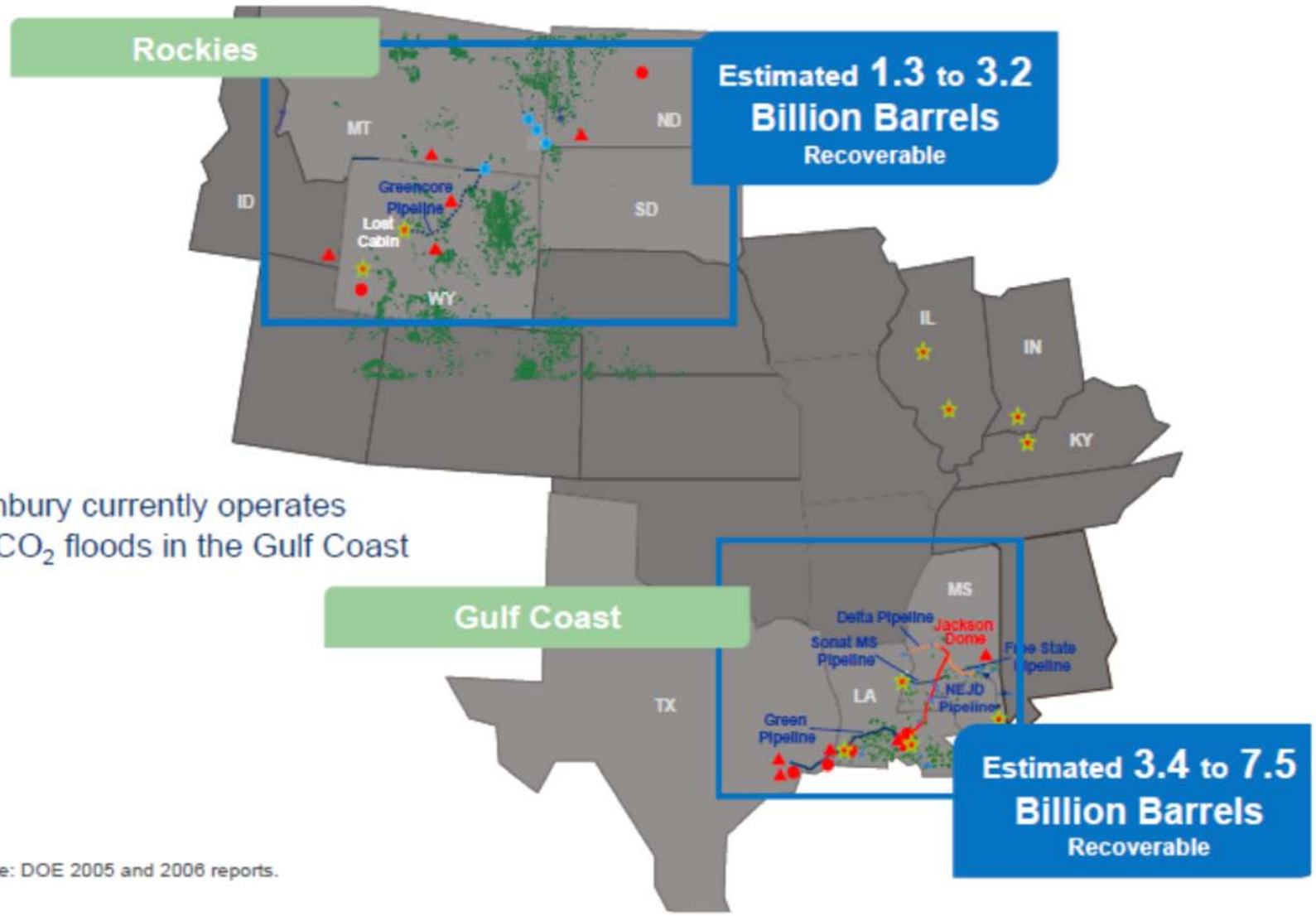
Key Project Components

- **Vacuum swing adsorption (VSA) vessels**
- **Tri-ethylene glycol (TEG) drier system**
- **CO_2 export compressor**
  - 8 stages
  - Export pressure over 2,000 psig (≈140 bar)
- **13 mile (21 km) CO_2 Pipeline connecting to Denbury's "Green" 300+ Mile (≈500 km) CO_2 Pipeline**

Denbury's 323-Mile "Green" Pipeline

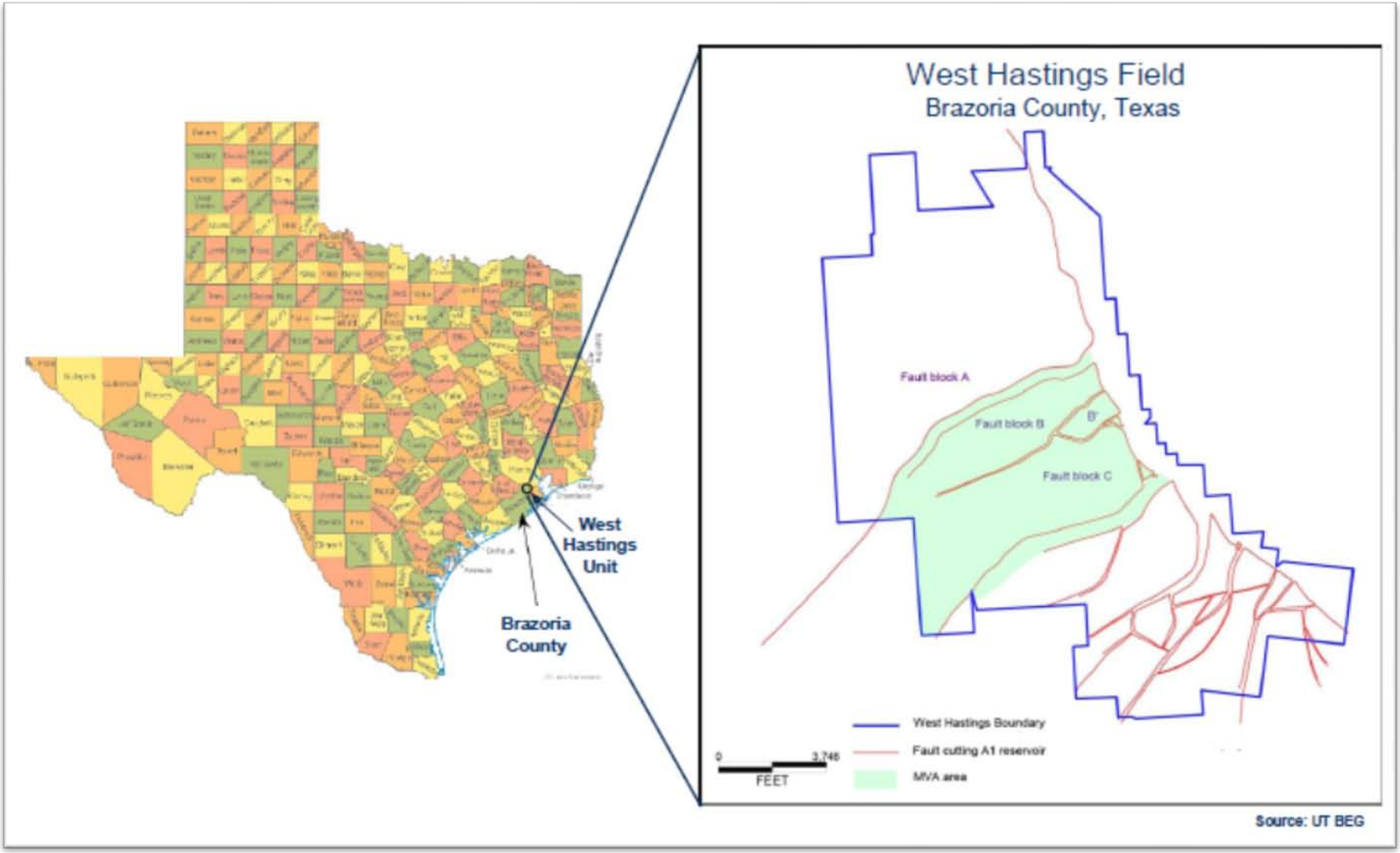
Data source is Denbury, December 2011, CO_2 Flooding Conference

Denbury Core Operating Areas

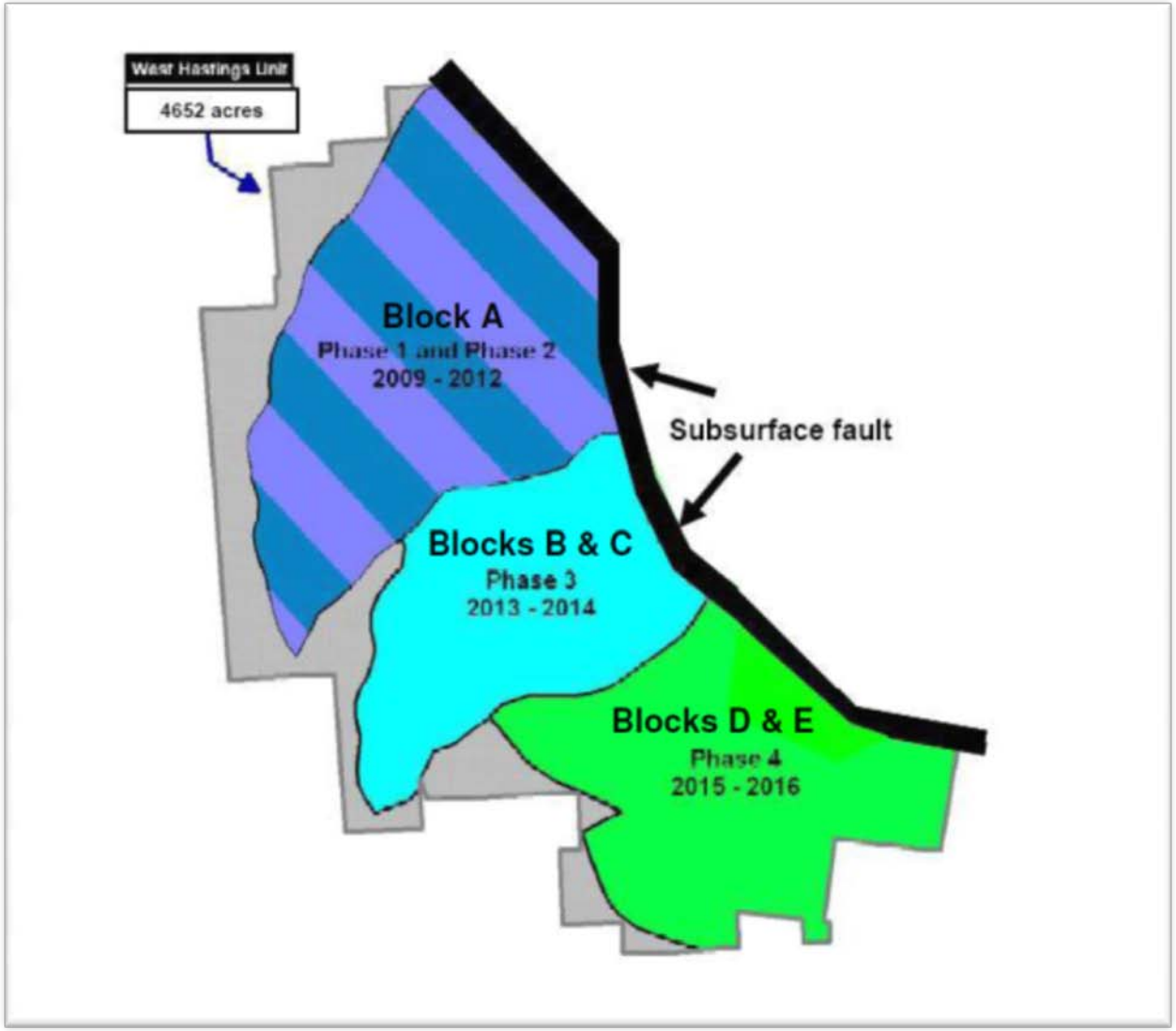


Source: DOE 2005 and 2006 reports.

MVA Project Area: West Hastings Field



Proposed Phased Implementation Schedule for CO_2 Injection into the West Hastings Field



MVA for Hastings Field

- **Primary Components**
  - **Well Integrity**
    - Logging, temperature surveys
    - Detailed well review
  - **Flood conformance**
    - 4-D seismic
    - Well performance
    - Logging
    - Reservoir Modeling
  - **Fault Monitoring**
    - Monitor existing wells that have fault cuts in them
    - Geo/Reservoir modeling
  - **Above-Zone Monitoring**
    - Dedicated observation wells
    - Soil gas monitoring program
    - Ground water monitoring program

Progress-to-Date and Future Milestones

- **Project Phase 1 (Definition) complete: *September 28, 2010***
- **Firm Bid process (FEED study) complete: *November 12, 2010***
- **Commercial Agreements complete: *March, 2011***
- **Site preparation for construction via pipe rack demolition: *April 26, 2011***
- **Texas Commission on Environmental Quality (TCEQ) issued a Permit by Rule (PBR) air permit (No. 95892) to Air Products: *May 20, 2011***
- **TCEQ issued a Standard Permit air permit (No. 95649) to Air Products: *May 27, 2011***
- **NETL issued the FONSI and Final EA for the project: *July 8, 2011***
- **U.S. Army Corps of Engineers (USACE) Galveston District issued Nationwide Permit Verification (No. SWG-2011-00252) to Air Products: *August 17, 2011***
- **Permitted construction initiated via piling: *August 30, 2011 - COMPLETE***
- **Initiation of civil work (i.e. foundations and undergrounds): *October 17, 2011 - COMPLETE***
- **Initiation of mechanical work (i.e. setting of equipment and installation of certain large-bore pipe): *February 22, 2012***
- **Initiation of CO_2 lateral pipeline construction via excavation and horizontal directional drilling: *May 14, 2012 - COMPLETE***
- **Planned start date for the operation phase (500,000 tons/yr capture and injection): *December 1, 2012***
- **Planned start date for full capacity operations (1,000,000 tons/yr capture and injection): *February 5, 2013***
- **Project completion date (for DOE funding period): *September 30, 2015 (Air Products intends to operate beyond DOE involvement period)***

Construction Photos

Installation of guy wire anchor points

Foundation form and preparation

Preparing to set CO_2 Surge Tank

Erection of Cooling Tower

Construction Photos

North side of Cogen

East/ West rack at Blower area

CO_2 Surge Tank Piping and Silencers/ Exchangers

VSA Unit and Piping Support

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

For additional information

Office of Fossil Energy
www.fe.doe.gov

NETL
www.netl.doe.gov

Questions?