



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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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 CO₂ 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 CO₂ Capture

- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90% CO₂ capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding 1,000,000 tons CO₂/year



- ≈28 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and Compression Equipment
- CO₂ to Denbury pipeline for EOR in West Hastings oil field
- Total Project: \$431 Million DOE Share: \$284 Million (66%)

Integrated Cogeneration and Hydrogen Plants

H₂
Export Steam

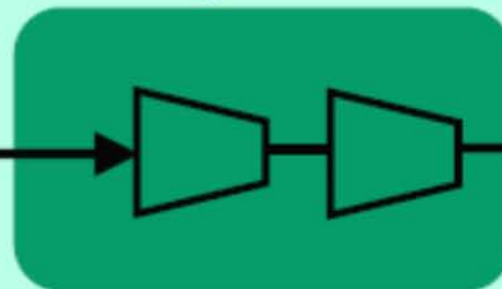


H₂
Power Generation
Export Steam



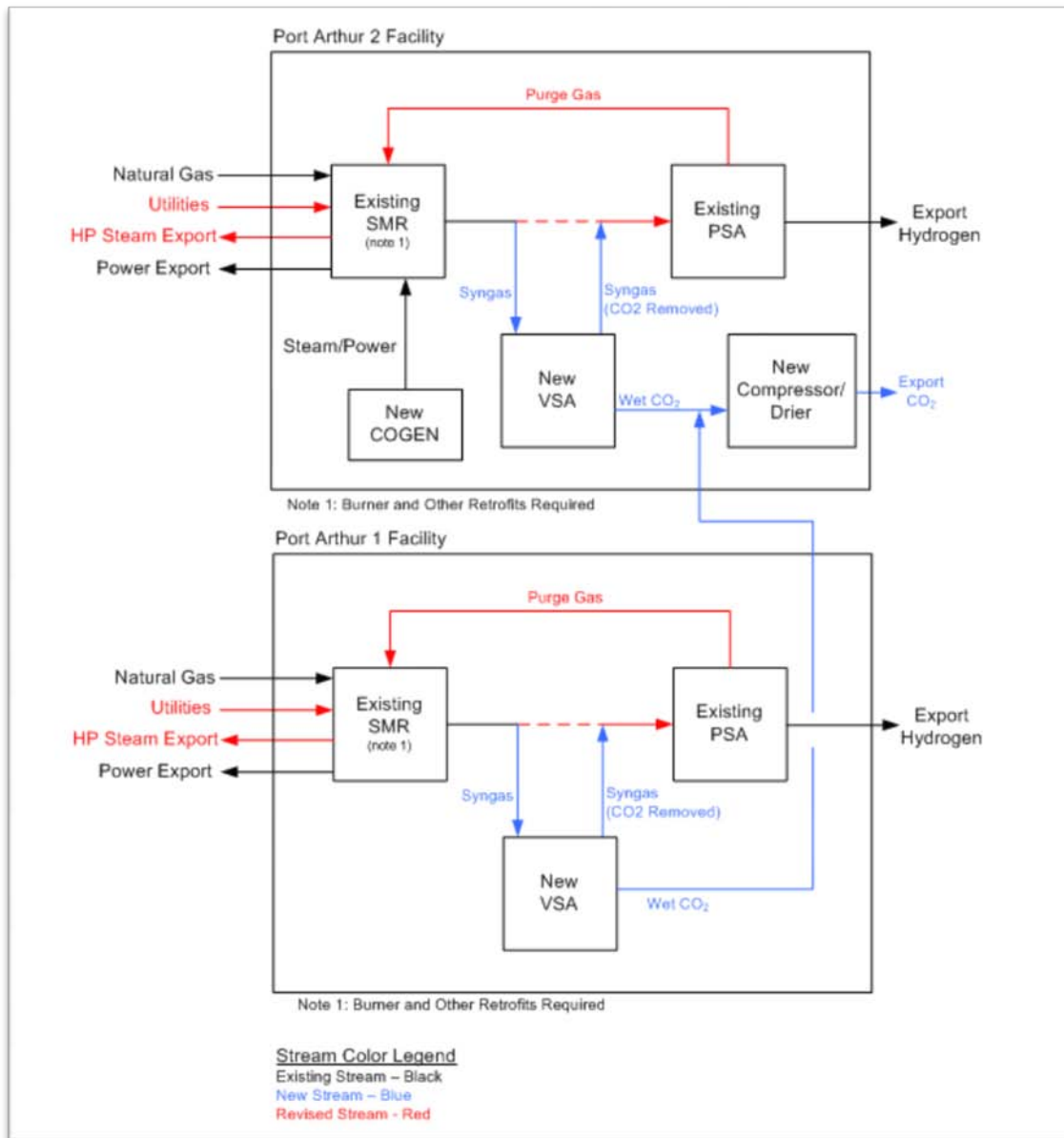
CO₂ Transport
& Storage

CO₂ Removal,
Purification,
Compression

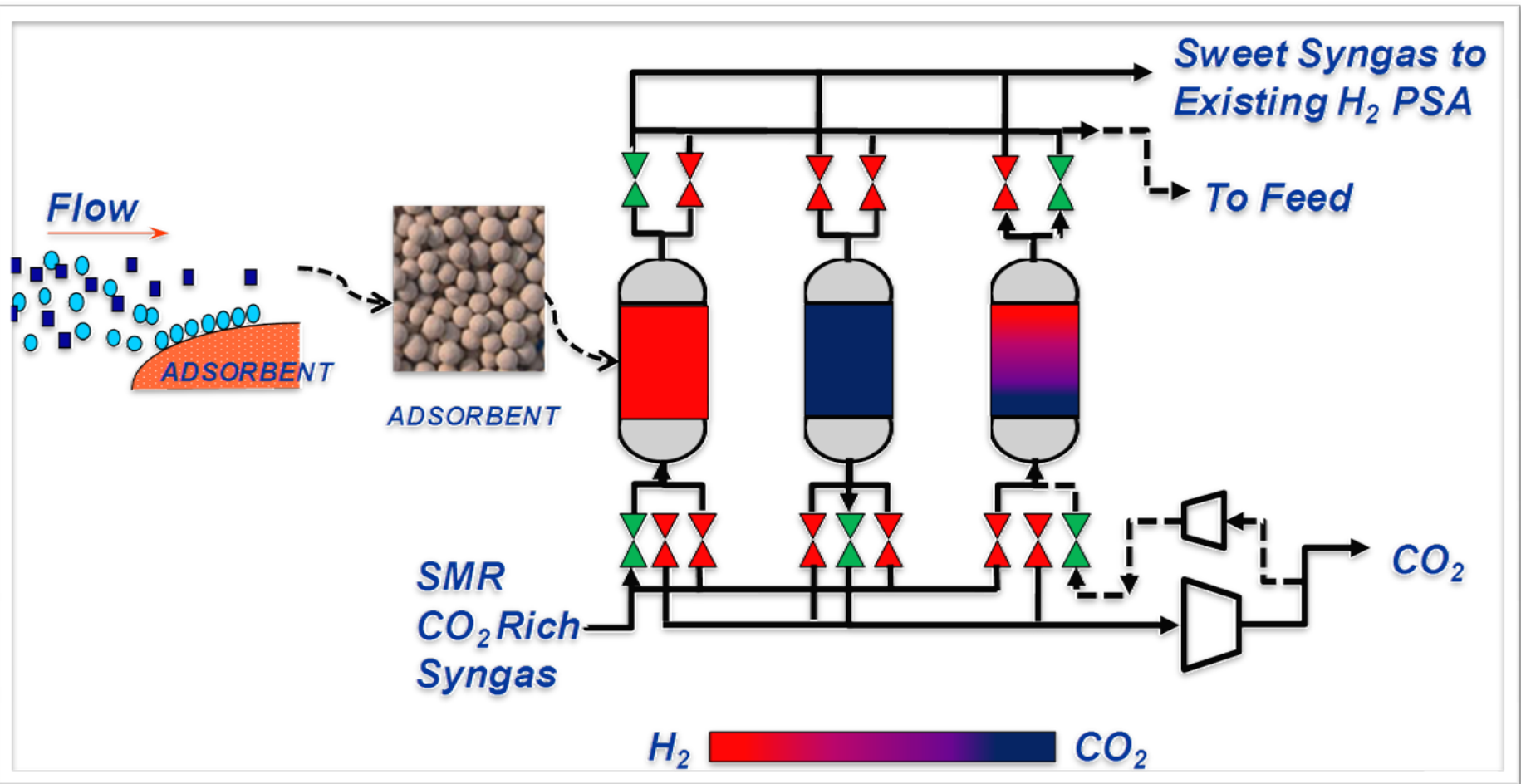


DOE Phase 2 Award,
Industrial Carbon Capture

Simplified CO₂ Capture Block Flow Diagram



Vacuum Swing Adsorption (“VSA”) Process for CO₂ Separation



Key Project Components

- **Vacuum swing adsorption (VSA) vessels**
- **Tri-ethylene glycol (TEG) drier system**
- **CO₂ export compressor**
 - 8 stages
 - Export pressure over 2,000 psig (\approx 140 bar)
- **13 mile (21 km) CO₂ Pipeline connecting to Denbury's "Green"**
300+ Mile (\approx 500 km) CO₂ Pipeline

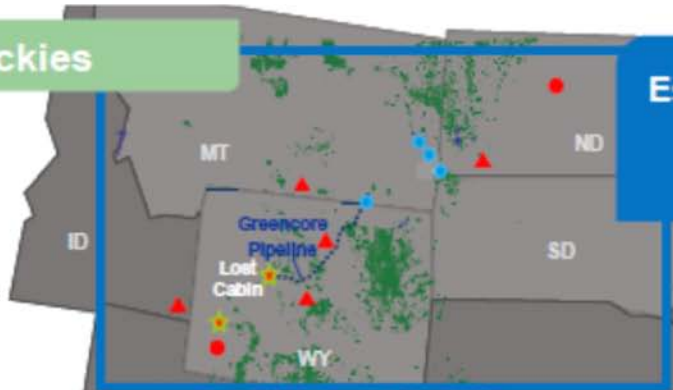
Denbury's 323-Mile "Green" Pipeline



Data source is Denbury, December 2011, CO₂ Flooding Conference

Denbury Core Operating Areas

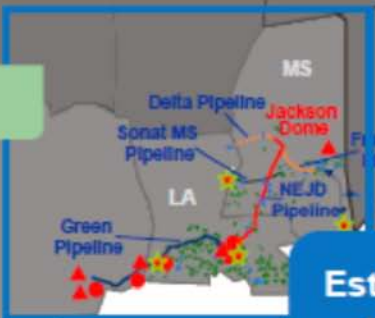
Rockies



Estimated 1.3 to 3.2 Billion Barrels Recoverable

Denbury currently operates 15 CO₂ floods in the Gulf Coast

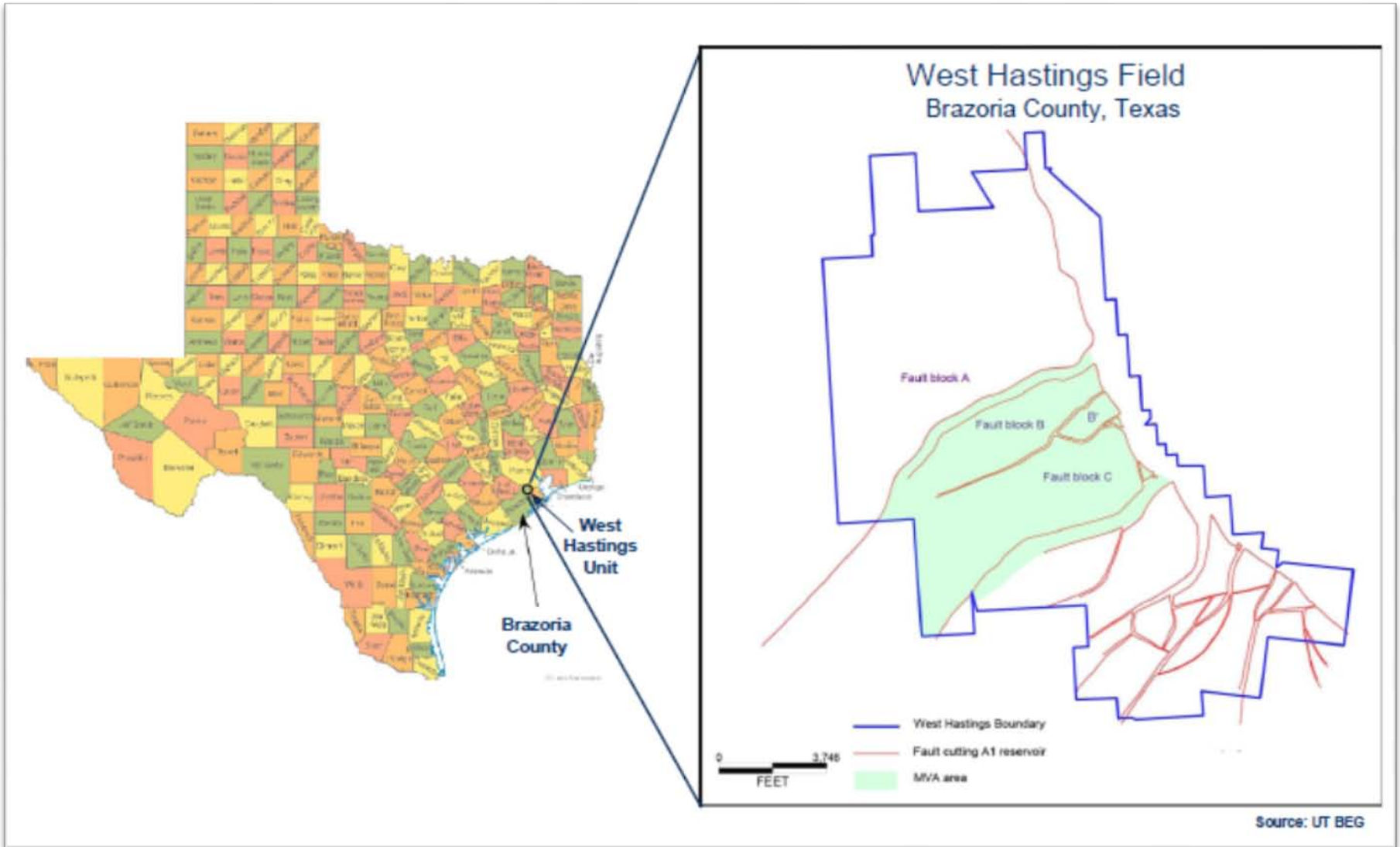
Gulf Coast



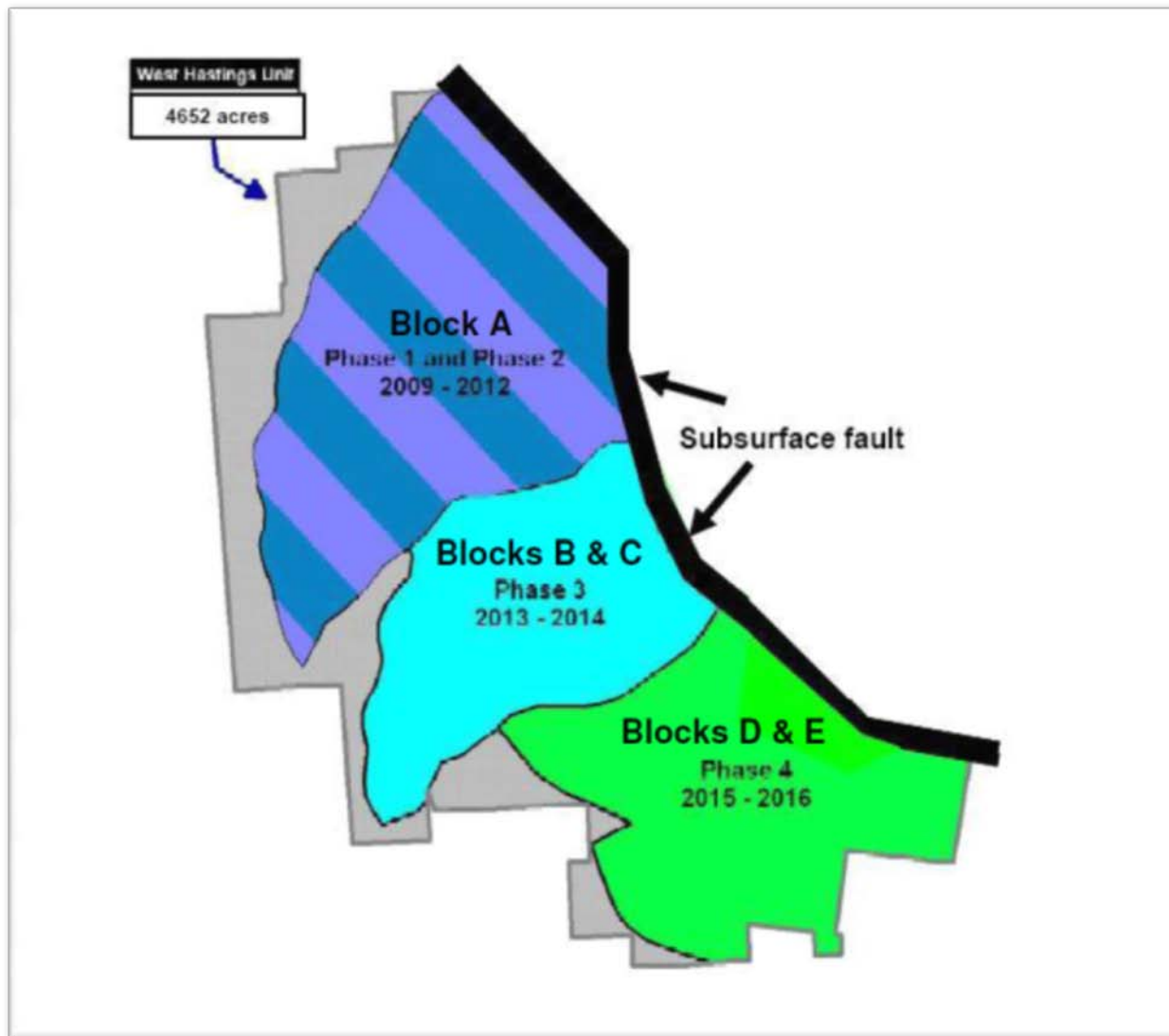
Estimated 3.4 to 7.5 Billion Barrels Recoverable

Source: DOE 2005 and 2006 reports.

MVA Project Area: West Hastings Field



Proposed Phased Implementation Schedule for CO₂ 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 CO₂ 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 CO₂ Surge Tank



Erection of Cooling Tower



Construction Photos

North side of Cogen



East/ West rack at Blower area



CO₂ 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

The screenshot shows the U.S. Department of Energy website. At the top, there is a navigation bar with links for 'ABOUT DOE', 'ORGANIZATION', 'NEWS', and 'CONTACT US'. Below this is the 'U.S. DEPARTMENT OF ENERGY' logo and a secondary navigation bar with categories like 'SAFETY & TECHNOLOGY', 'ENERGY BUSINESS', 'ENERGY EFFICIENCY', 'TODAY'S EMPLOYMENT', 'ENERGY & THE ENVIRONMENT', 'NATIONAL SECURITY', and 'SAFETY & HEALTH'. The main content area is titled 'FOSSIL ENERGY' and features a large image of an industrial facility with the text 'Fossil Energy' overlaid. To the left of the image are several sidebar links, and to the right are news articles and a search bar.

The screenshot shows the National Energy Technology Laboratory (NETL) website. At the top, there is a navigation bar with the 'NETL' logo and the tagline 'THE ONLY U.S. NATIONAL LABORATORY DEDICATED TO FOSSIL ENERGY TECHNOLOGY'. Below this is a main content area titled 'Tackling U.S. Energy Challenges' with a large image of an oil rig and the text 'Secure and Reliable Energy'. To the left of the main content is a sidebar with navigation links, and to the right is a sidebar with 'NEWS & FEATURES' and 'EVENTS CALENDAR'.

Office of Fossil Energy
www.fe.doe.gov

NETL
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NATIONAL ENERGY TECHNOLOGY LABORATORY

Questions?
