U.S. DOE's Major Carbon Capture, Utilization & Geologic Storage Demonstration Projects Portfolio

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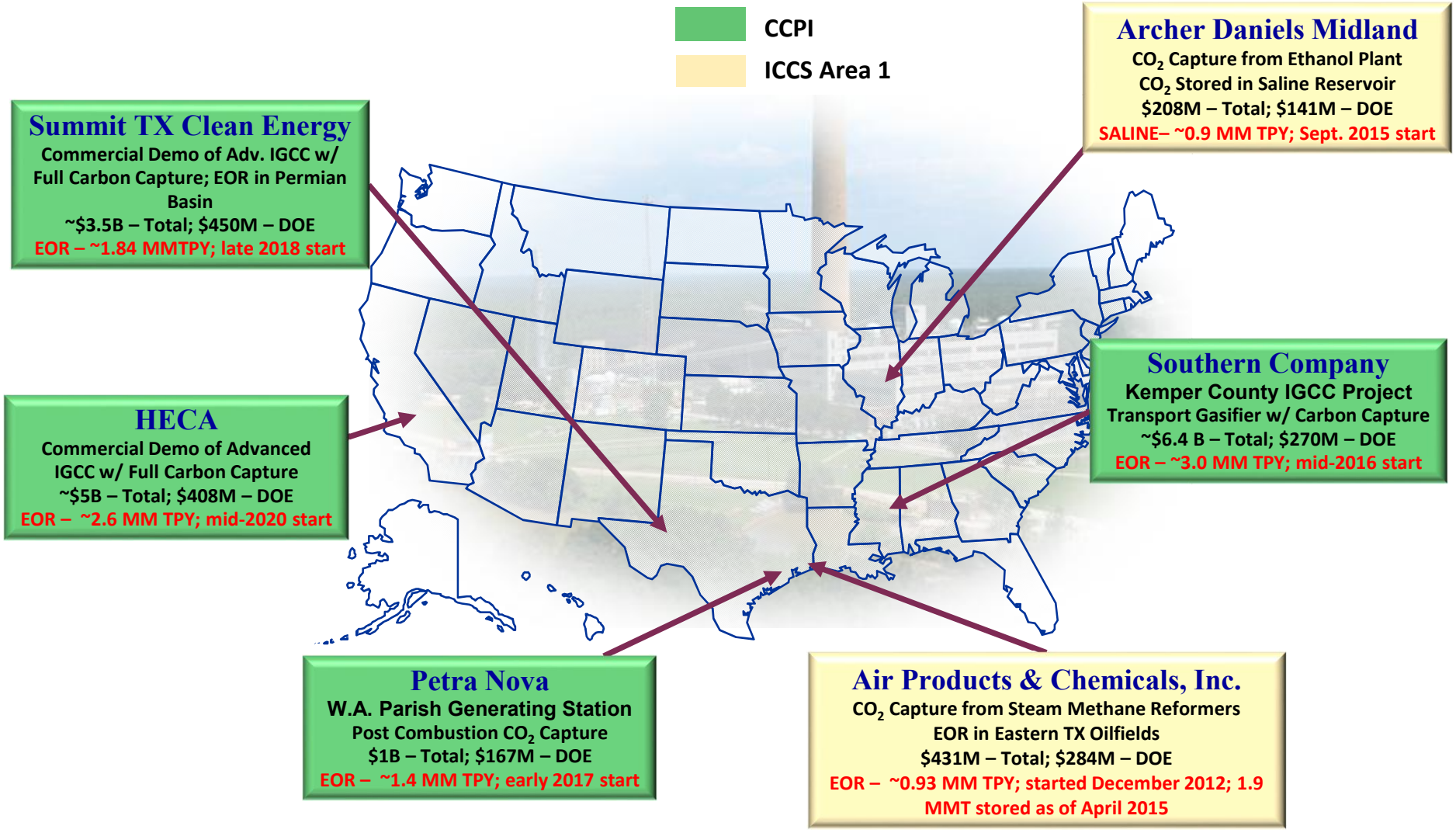
U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

Major CCS Demonstration Projects

Project Locations & Cost Share



Portfolio of Capture & Storage Approaches

	Plant Type		Sequestration			Feedstock
	Power	Industrial	Saline	EOR	Rate*	
Pre-combustion						
HECA (IGCC-Polygen)	X	X		X	2.57	NM Sub-bituminous Coal/Petcoke Blend
Southern-Kemper Co. (IGCC)	X			X	3.0	MS Lignite
Summit Texas (IGCC-Polygen)	X	X		X	1.84	WY Sub-bituminous Coal
Air Products and Chemicals, Inc. (SMR)		X		X	0.925	Natural Gas
ADM (Ethanol Production)		X	X		0.900	Corn Fermentation
Post-combustion						
Petra Nova	X			X	1.4	WY Sub-bituminous Coal

Clean Coal Power Initiative (CCPI)

Industrial Carbon Capture & Storage (ICCS, Area 1)

*Rate in million metric tons per year

Southern Company Services, Inc. CCPI-2

Advanced IGCC with CO_2 Capture

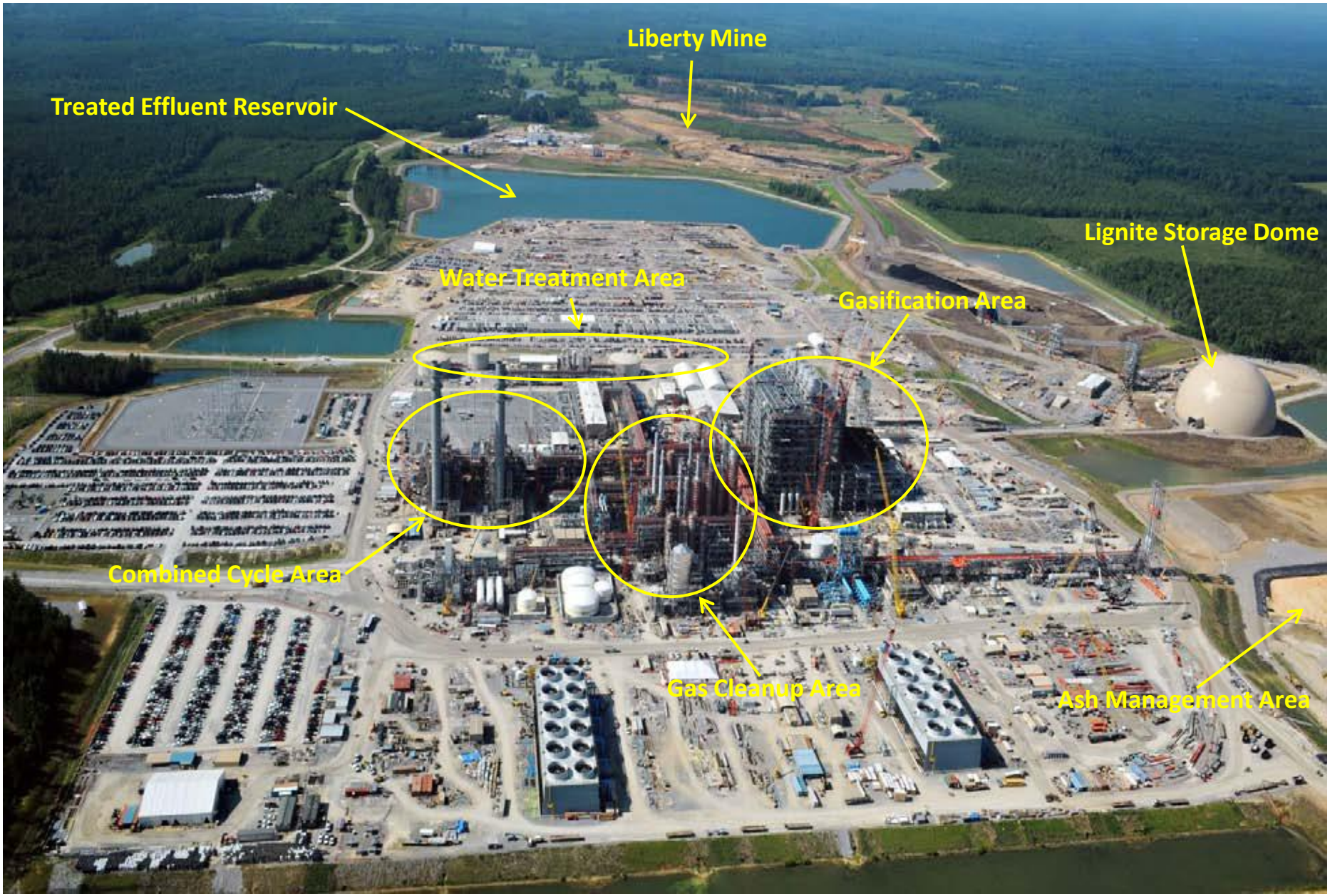
- Kemper County, MS
- 582 MWe (net) with duct firing; 2 TRIG™ gasifiers, 2 Siemens combustion turbines, 1 Toshiba steam turbine
- Fuel: Mississippi lignite
- 67+% CO_2 capture (Selexol® process); 3,000,000 tons CO_2/year
- EOR: Denbury Onshore LLC, Treetop Midstream Services LLC
- Total DOE CCPI Project: $2.01 B; DOE Share: $270 MM (13%)
- Total estimated project cost: ~$ 6.4B

Key Dates

- Project Awarded: January 30, 2006
- Project moved to MS: December 5, 2008
- NEPA Record of Decision: August 19, 2010
- Initiate excavation work: September 27, 2010
- Operations: mid-2016

Status

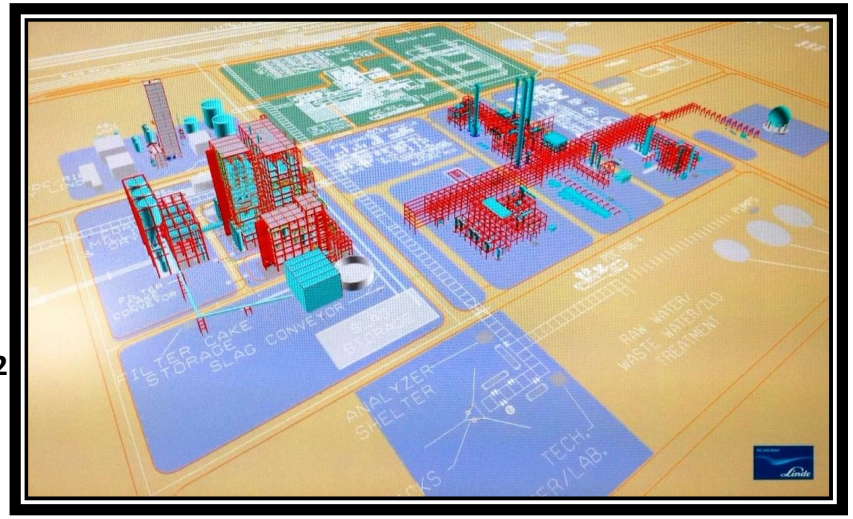
- Plant construction >98% complete; Peak construction labor 6,121
- CO_2 off-take agreements signed
- Lignite mine in commercial operation: June 2013
- Subsystems commissioning in progress
- Combined cycle commercial operation on natural gas: August 2014
- Gasifier “First Fire”: March 2015


Liberty Mine
Treated Effluent Reservoir
Lignite Storage Dome
Water Treatment Area
Gasification Area
Combined Cycle Area
Gas Cleanup Area
Ash Management Area

Summit Power: Texas Clean Energy Project

Advanced IGCC-Polygen

- **Penwell, Ector County, TX (greenfield)**
- **~445 MW_{th} (syngas); 405 MW_e (CC plant); 205 MW_e (net) to utility grid; 0.685 MMTPY Urea Fertilizer**
  - SFG-850 gasifier (1 x 100%)
  - CC plant features high-H_2 SGT6-8000H gas turbine (1 x 1)
- **Fuel: PRB sub-bituminous coal**
- **> 90% CO_2 capture from syngas – ~2.35 MMTPY CO_2 (90% carbon capture from total plant)**
  - 1.84 MMTPY to EOR (Permian Basin); 0.503 MMTPY to Urea
  - 2-stage Water Gas Shift, Rectisol® acid gas removal (AGR)
- **Total DOE Project: $1.727 B; DOE Share: $450 MM (26%)**
- **Total Plant Cost ~$3.5 B (all in)**



Key Dates

- **Project Awarded: January 2010**
- **Air Permit; December 2010**
- **NEPA Record of Decision: Sept. 2011**
- **Financial Close: June 2015 (est.)**
- **Construction Start: July 2015 (est.)**
- **Mechanical Complete: July 2018 (est.)**

Status

- **Urea contract: 2011; CO_2 contracts: 2011; all renewed**
- **PPA: Dec 2011; expired Dec. 2013; renewed Sept. 2014**
- **China Eximbank debt financing MOU: September 2012**
- **Currently updating FEED to incorporate newly available technologies & finalizing EPC contracts**

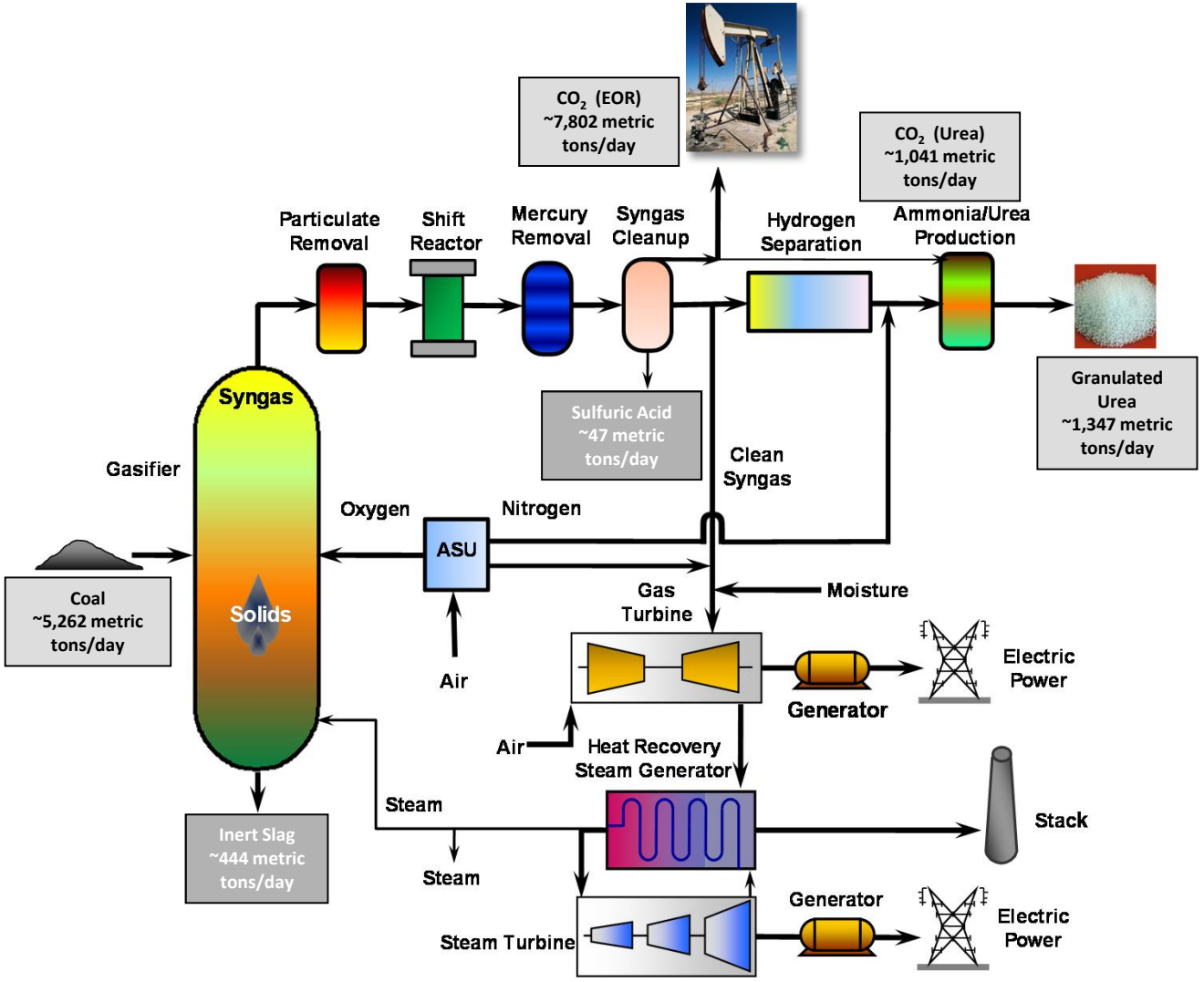
Summit Power: Texas Clean EnergyProject

Advanced IGCC-Polygen with CO_2 Capture

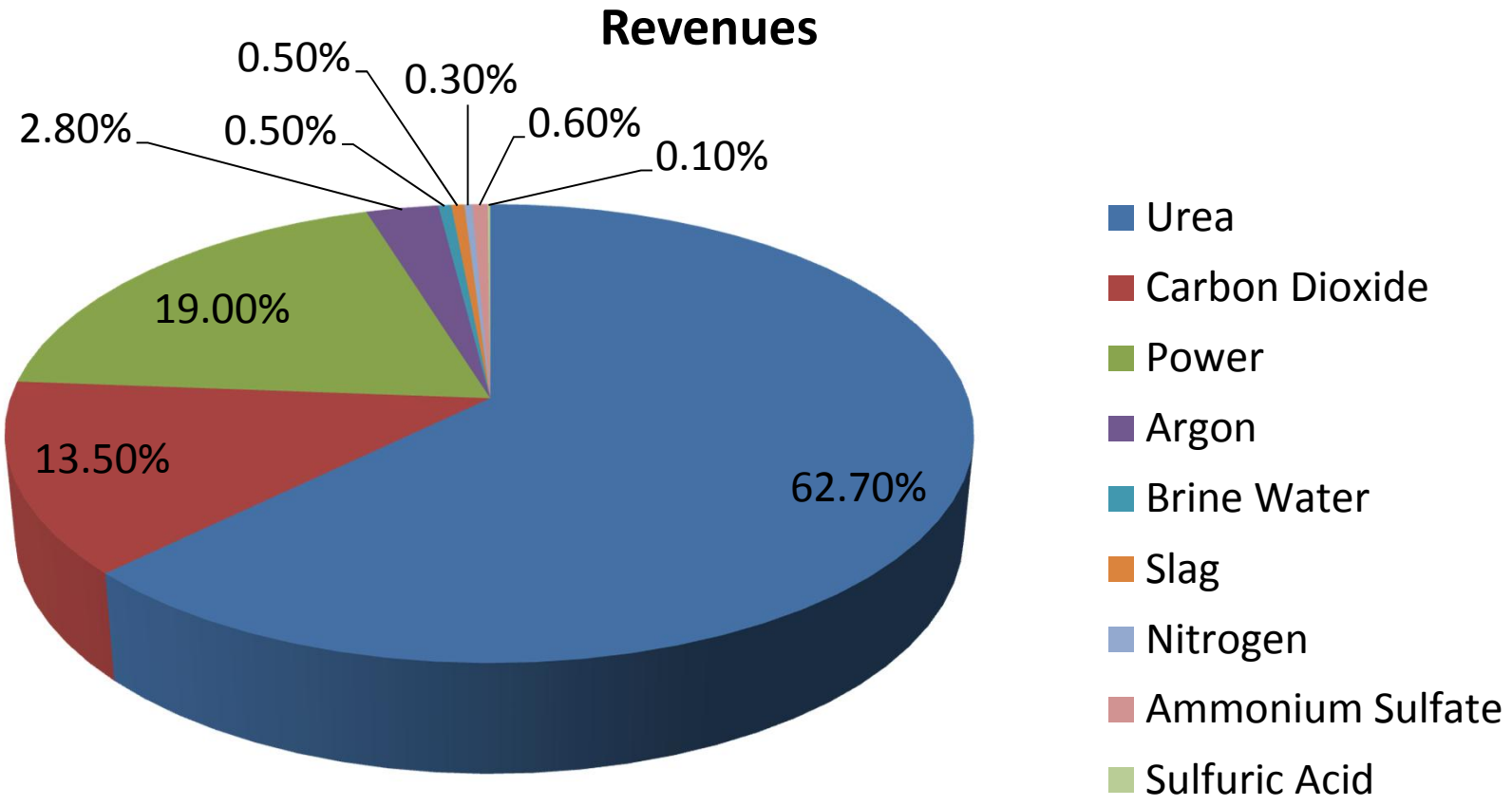
Technologies & Processes – Major Components

- **Gasifier**
  - Siemens SFG-850 (1 Hot/0 Spare)
  - >900 ft^3
  - Fuel (Powder River Basin)
  - 850 MW_{th}
  - Operating Pressure/Temperature: 600 psig/2500°F
- **Combustion Turbine**
  - Siemens SGT6-8000H (230 MWe)
- **Steam Turbine**
  - Siemens SST-900RH (175 MWe)
- **Water-Gas Shift Reactors**
  - 4 Reactors, 2 Trains
- **Linde Rectisol® acid gas & CO_2 capture system**
  - Well-commercialized chilled methanol process – warranted availability
- **Particulate Removal**
  - Candle Filter
- **Sulfur Removal** (99%)
- **Sulfur Recovery**
  - Sulfuric Acid Plant
- **Mercury Control/Removal**
  - Carbon Bed

Summit Power: Texas Clean Energy Project



Summit: TCEP Annual Revenues (2019-2049 avg)

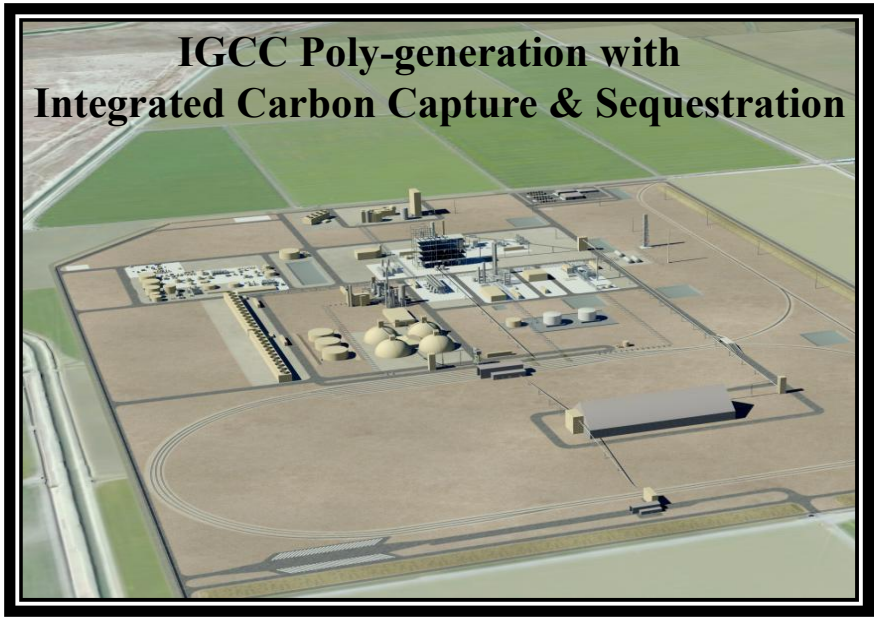


As of February 2015

Hydrogen Energy California

Advanced IGCC-Polygen

- **Kern County, CA (greenfield)**
- **Up to 300 MWe (net) with load following; 1.0 MMT/yr urea/UAN**
  - MHI oxygen-blown gasifier (1 x 100%)
  - MHI G-class air cooled combustion turbine (1)
- **Fuel: Sub-bituminous coal/petcoke**
- **90% CO_2 capture – 3,020,000 tonnes CO_2/year**
  - 2.57 MM tonnes EOR; 0.45 MM Urea production
  - 2-stage Water Gas Shift, Linde Rectisol® AGR
- **EOR: Elk Hills oil field**
- **Use of brackish water for power production; ZLD**
- **Total DOE Project: $4.028 B; DOE Share $408 MM (10%)**
- **Total Plant Cost: ~$5 B**



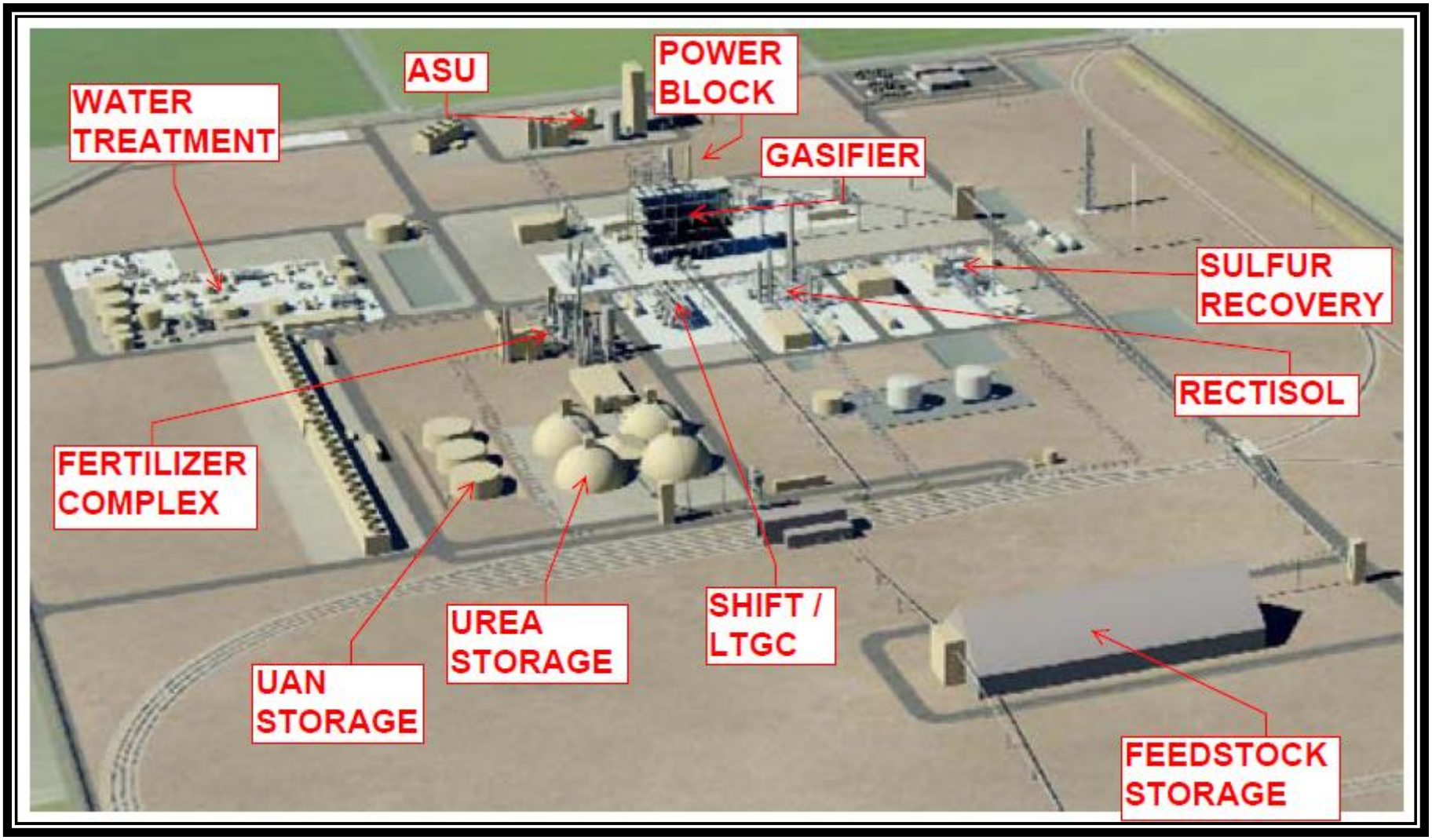
Key Dates

- **Project Awarded: September 2009**
- **New Owner, SCS Energy: September 2011**
- **Financial Close: June 2015**
- **Construction: July 2015**
- **Start of Operation: June 2020**

Status

- **FEED completion: April 2013**
- **Draft PSA/EIS: June 2013**
- **Final Determination of Compliance (air permit): July 2013**
- **Power/Fertilizer/CO_2/EPC discussions in progress**

HECA Plant Layout



Petra Nova – NRG W.A. Parish

Advanced Post Combustion CO_2 Capture

- Thompsons, TX (near Houston)
- 240 MWe slipstream at NRG Energy's W.A. Parish power plant (originally 60 MWe)
- Fuel: PRB sub-bituminous coal
- 90% CO_2 capture (KM CDR Process®) 1,400,000 tonnes CO_2/year
- EOR: Hilcorp West Ranch oil field
- Total Project Cost: ~$1 billion
  DOE Share: $167 million

Key Dates

- Project Awarded: May 2010
- Air Permit: December 2012
- NEPA Record of Decision: May 2013
- Financial Close: July 2014
- Construction: March 2014 (LNTP);
  July 2014 (NTP)
- Operation: January 2017

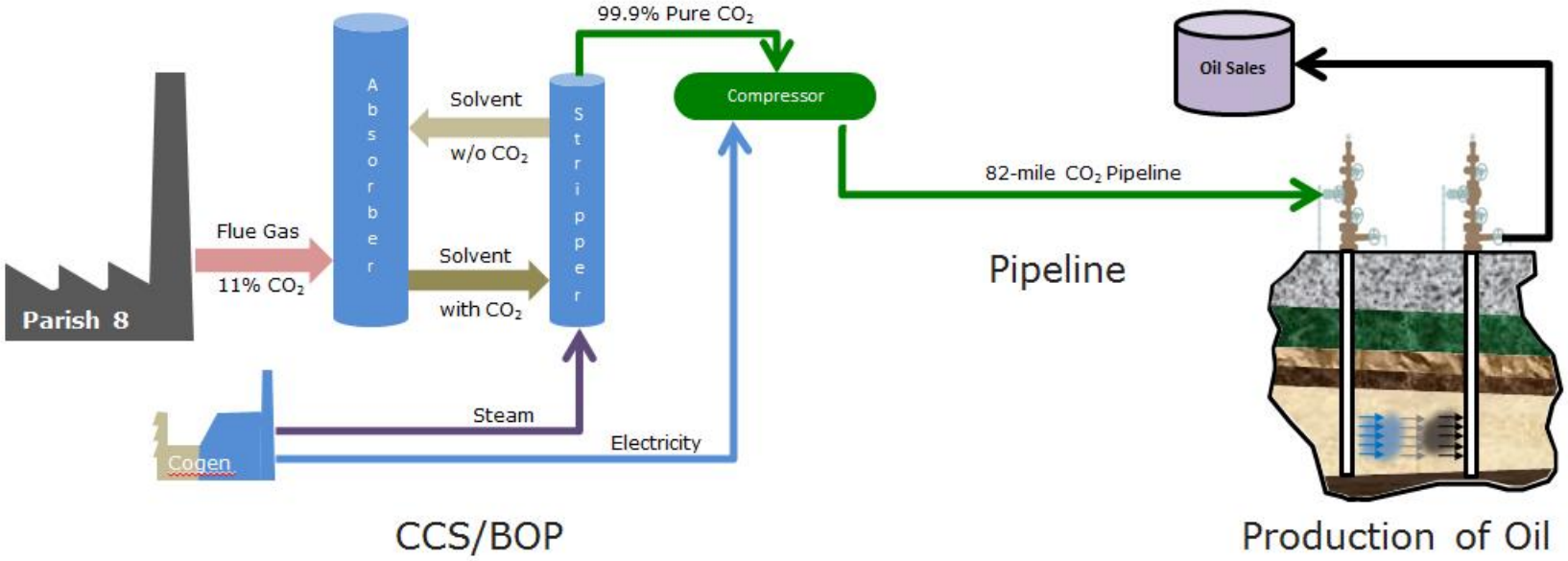
Status

- Start cooling tower foundation: October 2014
- Start absorber foundation: December 2014
- Complete all pilings January 2015
- Start absorber/quencher foundation Feb. 2015
- Overall EPC effort: 45% complete
- Construction: 8% complete

Petra Nova – NRG W.A. Parish

Overview

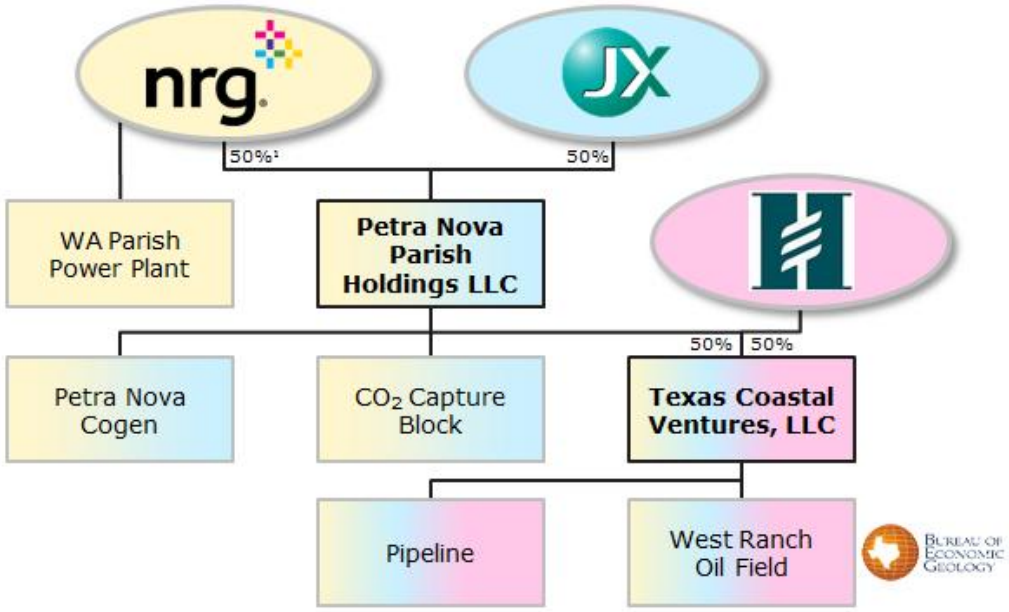
- The project will capture CO_2 and send it to nearby oil fields for carbon dioxide enhanced oil recovery (CO_2 – EOR), which is a long-proven method of producing stranded oil.
- DOE's goals are to demonstrate integration of carbon capture at an existing plant, protocols for CO_2 monitoring to ensure permanence of sequestration, identify areas for cost reduction
- Design will utilize a stand-alone technology natural gas cogen to simplify retrofit, provide flexibility in matching parasitic energy demands, without disrupt existing plant performance.



Petra Nova – NRG W.A. Parish

Partners & Transaction Structure

Project Ownership Structure



Sources	$MM
NRG Equity[2]	$300
JX Nippon Equity	300
Project Financing	250
DoE Grant	167
Total	**$1,017**

Uses	$MM
Parish Site Capital[3]	$637
Oilfield and Pipeline Capital	300
Initial O&M, G&A, Fees, Other	80
Total	**$1,017**

Partner Summary

Hilcorp Energy

- One of the largest privately-held oil and natural gas E&P companies in the US
- Strong track record of implementing new production techniques into mature reservoirs
- Specialized team that has extensive experience implementing CO_2 floods

JX Nippon Oil & Gas Exploration

- Currently conducting oil and natural gas business in 14 countries
- Parent company, JX Holdings, is a leading integrated energy, resources, and materials company

Japan Bank for Int'l Cooperation

NEXI

- Policy-based financial institution
- Wholly-owned by the Japanese government
- Over 25,000 loan and equity commitments valued at over $479 billion

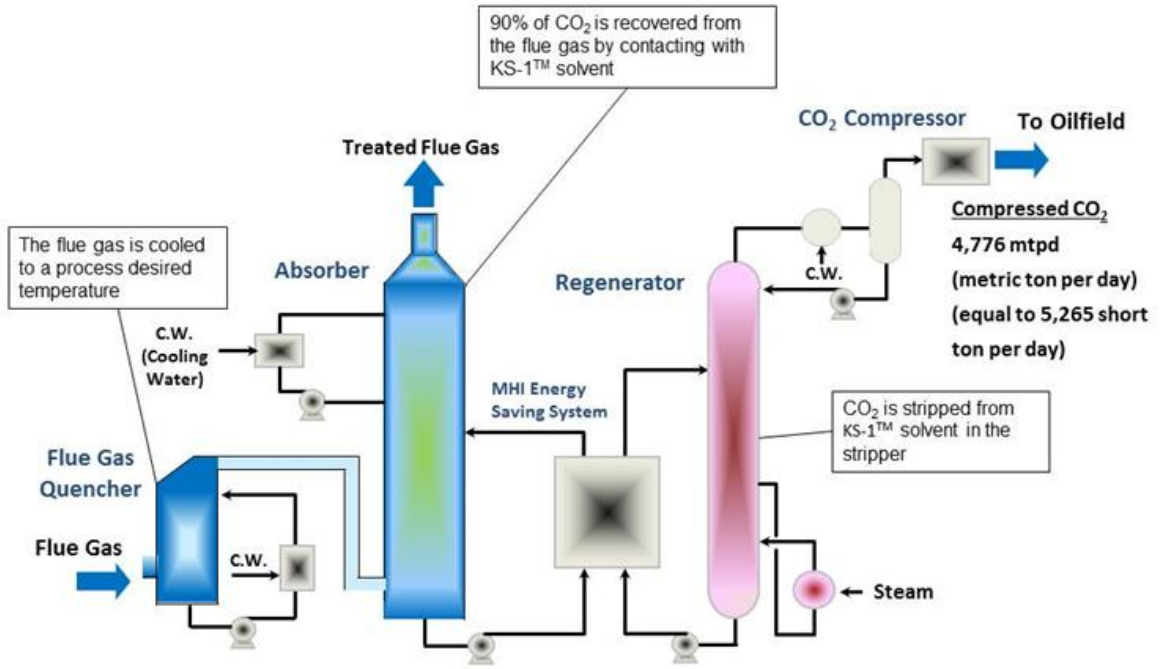
US DoE

- Awarded $167 MM grant
- Funded through Clean Coal Power Initiative

Petra Nova – NRG W.A. Parish

MHI KM-CDR Process®

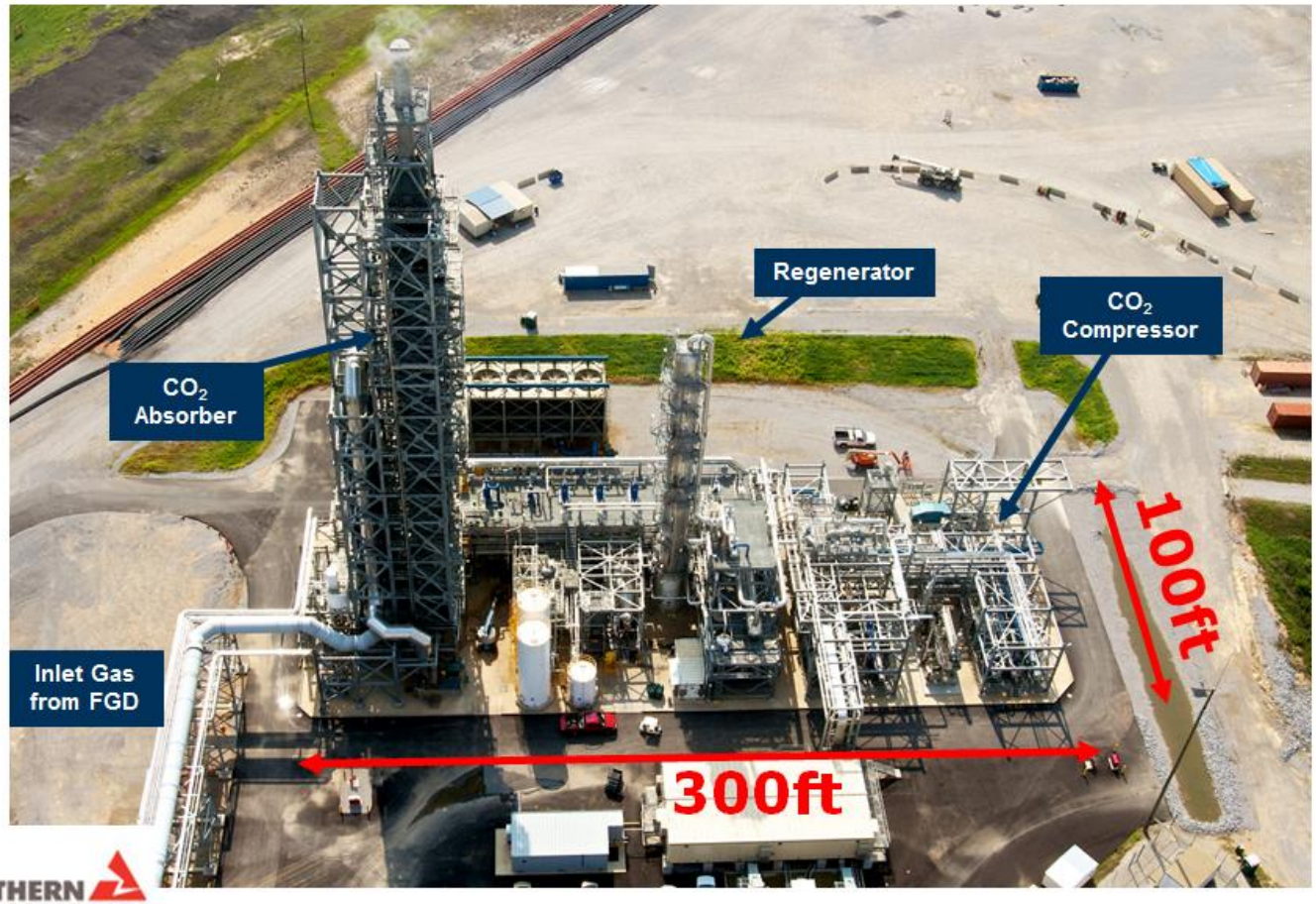
- Kansai Mitsubishi Carbon Dioxide Recovery Process (KM CDR Process™ comes from one of the world's most advanced industrial R&D programs (commenced in 1990 and ongoing).
- Commercially applied since 1999: 11 plants under operation.
- The 'Complete Solution' - hindered amine solvent "KS-1™ " with accompanying proprietary equipment.



https://www.mhi-global.com/products/detail/km-cdr_process.html

US 500 Metric TPD Coal-Fired CCS Demo Project

Successful demonstration of the SoCo 500 Metric TPD Integrated CCS Demo Project has lead to MHI being able to provide guarantees for coal flue gas CDR plants



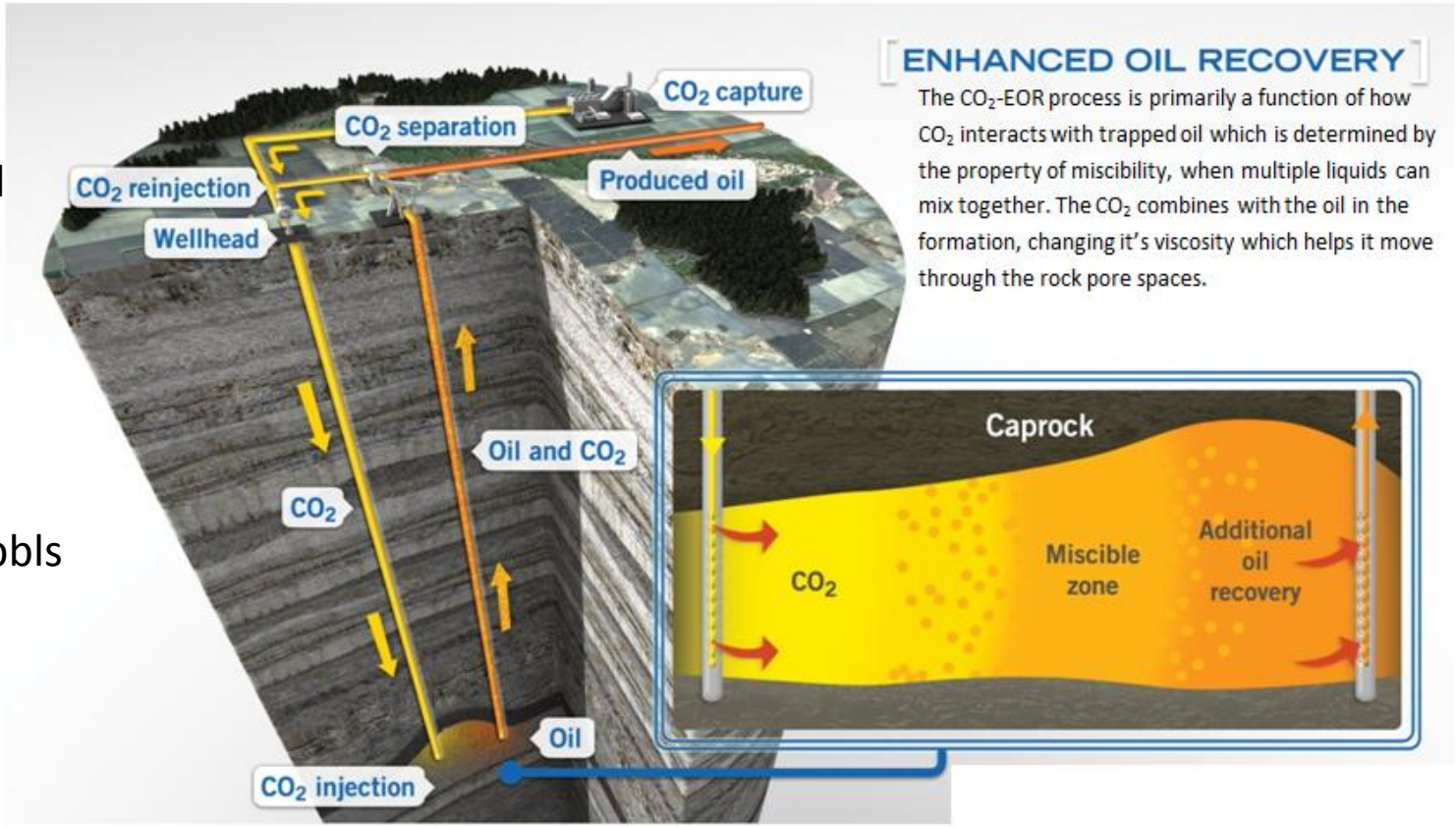
SOUTHERN COMPANY

https://www.mhi-global.com/products/detail/km-cdr_process.html

NETL

Petra Nova: CO_2 - EOR Fundamentals

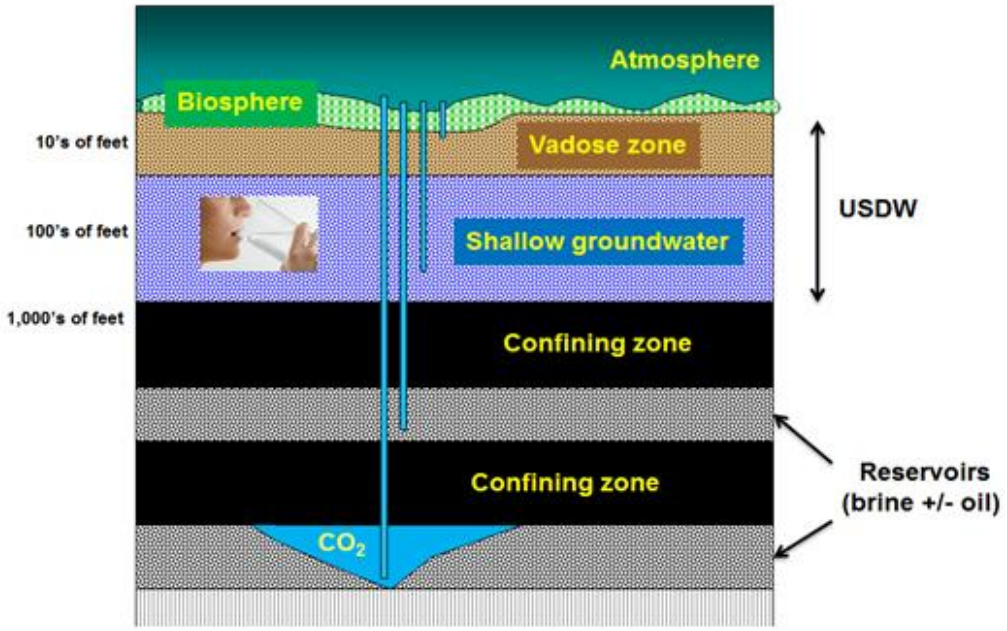
- Large scale CO_2-EOR has been proven successfully since the early 1970s to produce otherwise unrecoverable oil from mature fields (tertiary recovery).
- Its a closed-loop system where the CO_2 produced with the oil is separated and re-injected.
- 1 ton of CO_2 can produce up to 4 bbls of oil.
- 60MM bbls are estimated to be recoverable at West Ranch



http://www.globalccsinstitute.com/understanding-ccs/how-ccs-works-storage

Petra Nova: CO_2 Monitoring Plan

- Monitoring responds to the goals of the DOE Cooperative Agreement.
- Industrial experience indicates that CO_2 retention during EOR is good, however additional monitoring is needed to demonstrate this value as part of a capture and storage project
- The monitoring approach is linked to the site-specific conditions, including geology and past and planned operations.
- Monitoring needed for optimization of operation and surveillance of oil recovery, and for Class II protection of Underground Sources of Drinking Water (USDWs) is enhanced to document isolation from atmosphere.
- Executed under a phased approach:
  - Phase 1 – Field Characterization and monitoring approach
  - Phase 2 – Baseline Monitoring & plan implementation.
  - Phase 3 – CO_2 monitoring (3 years)



Air Products & 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 ~925,000 tonnes CO_2/year
- ~30 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA & compression equipment
- CO_2 to Denbury "Green" pipeline for EOR in West Hastings, TX oilfield
- Total Project: $431 MM; DOE Share: $284 MM (66%)

Key Dates

- Phase 2 Awarded: June 15, 2010
- FEED completed: November 2010
- Permit By Rule (PBR) and Standard Air Permits issued: May 2011
- NEPA FONSI: July 2011
- Construction started: Aug. 2011
- Operation started: Dec. 2012

Status

- PA-1 initiated operation: March 3, 2013
- PA-2 initiated operation: Dec. 16, 2012
- Full capacity achieved: April 2013
- Has operated at >100% of design when necessary
- 1,962,601 tonnes CO_2 delivered as of 5/1/15

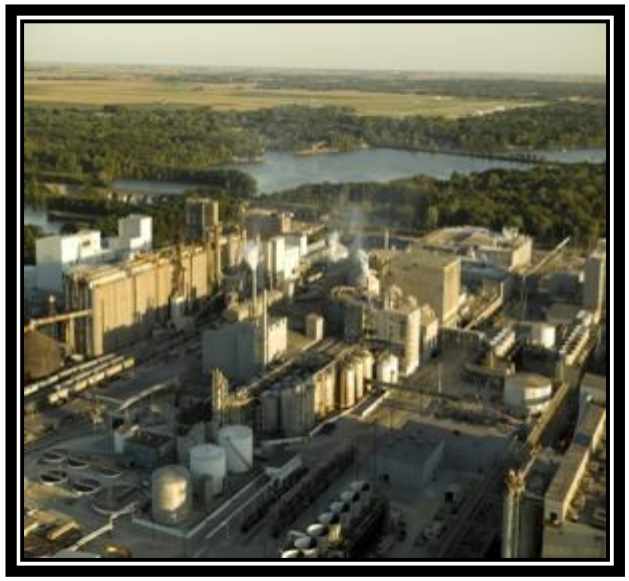
Air Products: Port Arthur 1 Overview

Air Products: Port Arthur 2 Overview

Archer Daniels Midland Company (ADM)

CO_2 Capture from Biofuel Plant

- Decatur, IL
- CO_2 is a by-product (>99% purity) from production of fuel grade ethanol via anaerobic fermentation
- Up to 90% CO_2 capture; dehydration (via tri-ethylene glycol) and compression – ~900,000 tonne CO_2 /year
- Sequestration in Mt. Simon Sandstone saline reservoir
- Total Project: $208 MM; DOE Share: $141 MM (68%)



Key Dates

- Phase 2 Awarded: June 15, 2010
- FEED Completed: April 2011
- NEPA FONSI: April 2011
- Construction started: May 2011
- UIC Class VI Injection Well Permit: Aug. 2014; UIC Class VI Operating Permit: Sept. 2015
- Sequestration start: Sept. 2015

Status

- Construction >85% complete
- UIC Class VI permit submitted: July 2011
- Two monitoring wells drilled: Nov. 2012
- Substation construction in progress
- Commissioning compression and dehydration: July 2013

Successful CCS Demonstrations Providing Foundation for Future Commercial Projects

Location

Archer Daniels Midland Company, Decatur, Illinois

Regional Carbon Sequestration Partnership: Midwest Geological Sequestration Consortium

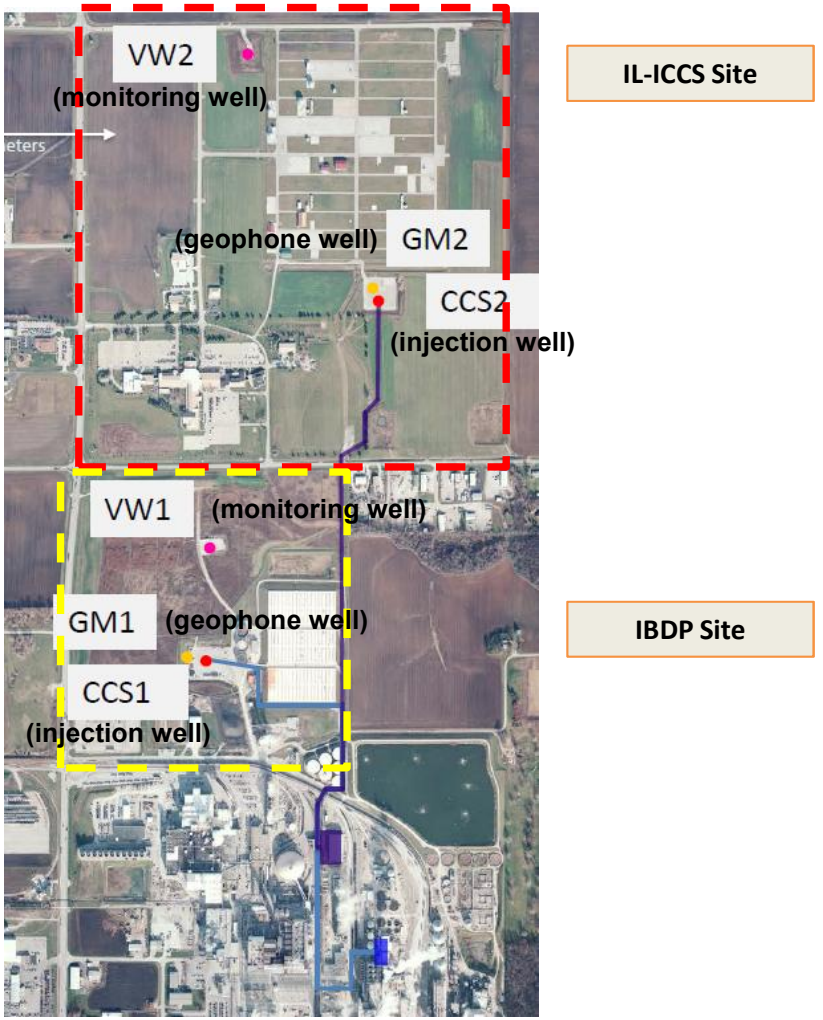
Illinois Basin – Decatur Project (IBDP)

(Large-scale 3-year field test completed 2011-2014; post-injection monitoring in progress)

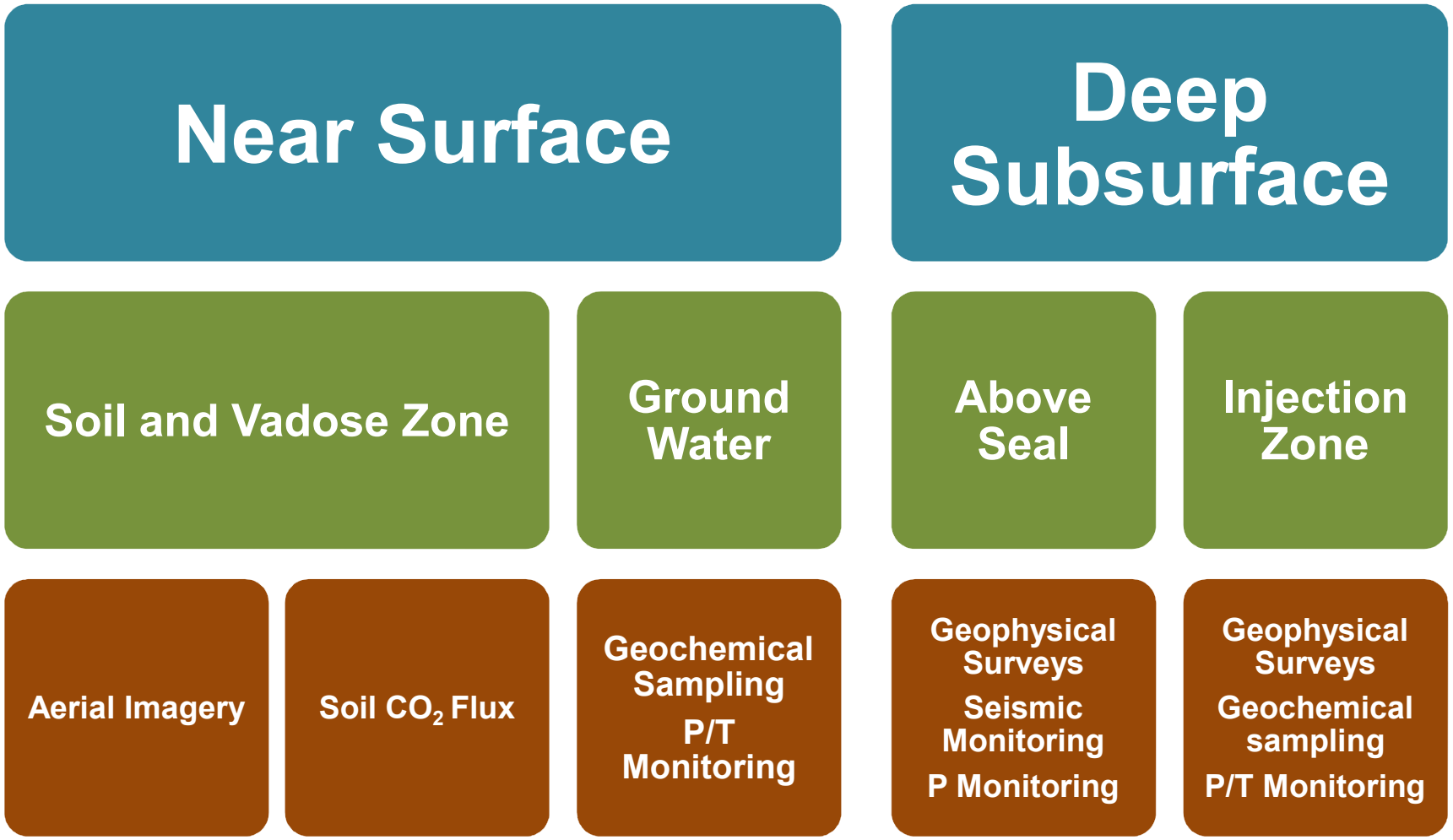
Industrial Carbon Capture and Storage

Illinois Industrial Carbon Capture and Storage (IL-ICCS) Project – 2009 Recovery Act Project

(Commercial-scale demonstration with EPA's first Class VI injection well operating permit, storage to begin September 2015)



ADM: Environmental Monitoring
Planned Framework



ADM: National Sequestration Education Center

Public Education and Community Outreach

- Conducting an integrated communication, outreach, training & education initiative to engage local communities to understand CCUS, Illinois ICCS project & related environmental benefits.
- National Sequestration Education Center (NSEC) at Richland Community College (Decatur, IL) – A new education/training facility:
  - 15,000 sq. ft. center - classrooms, training and laboratory facilities
  - Opened September 2012
- AAS degree in Engineering Technology with a Sequestration Specialty
- AS degree with a Sequestration Concentration (university transfer degree)

For Additional Information

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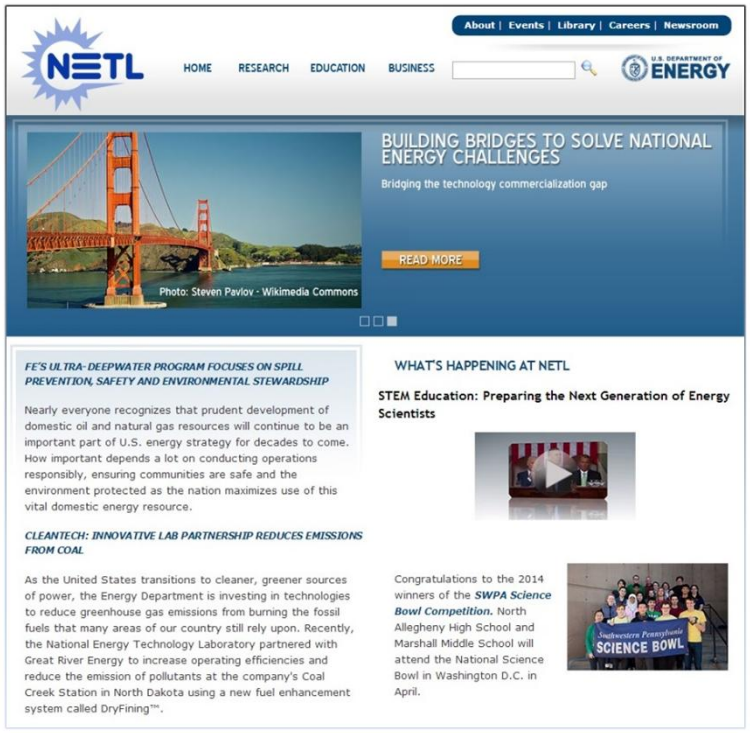

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