



Demonstration Projects: Taking It Commercial

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U.S. DEPARTMENT OF

ENERGY

National Energy
Technology Laboratory

Strategic Center for Coal

Critical R&D Challenges to Near-Zero Emissions from Coal

Near-Term Plants

Pulverized Coal

Power generation

Improve efficiencies

Minimize criteria pollutants

Minimize water usage

Minimize greenhouse gases



Future Plants

Advanced Coal

Power and multiple products

Improve reliability

Maximize efficiencies

Near-zero criteria pollutants

Near-zero water usage

Near-zero greenhouse gases

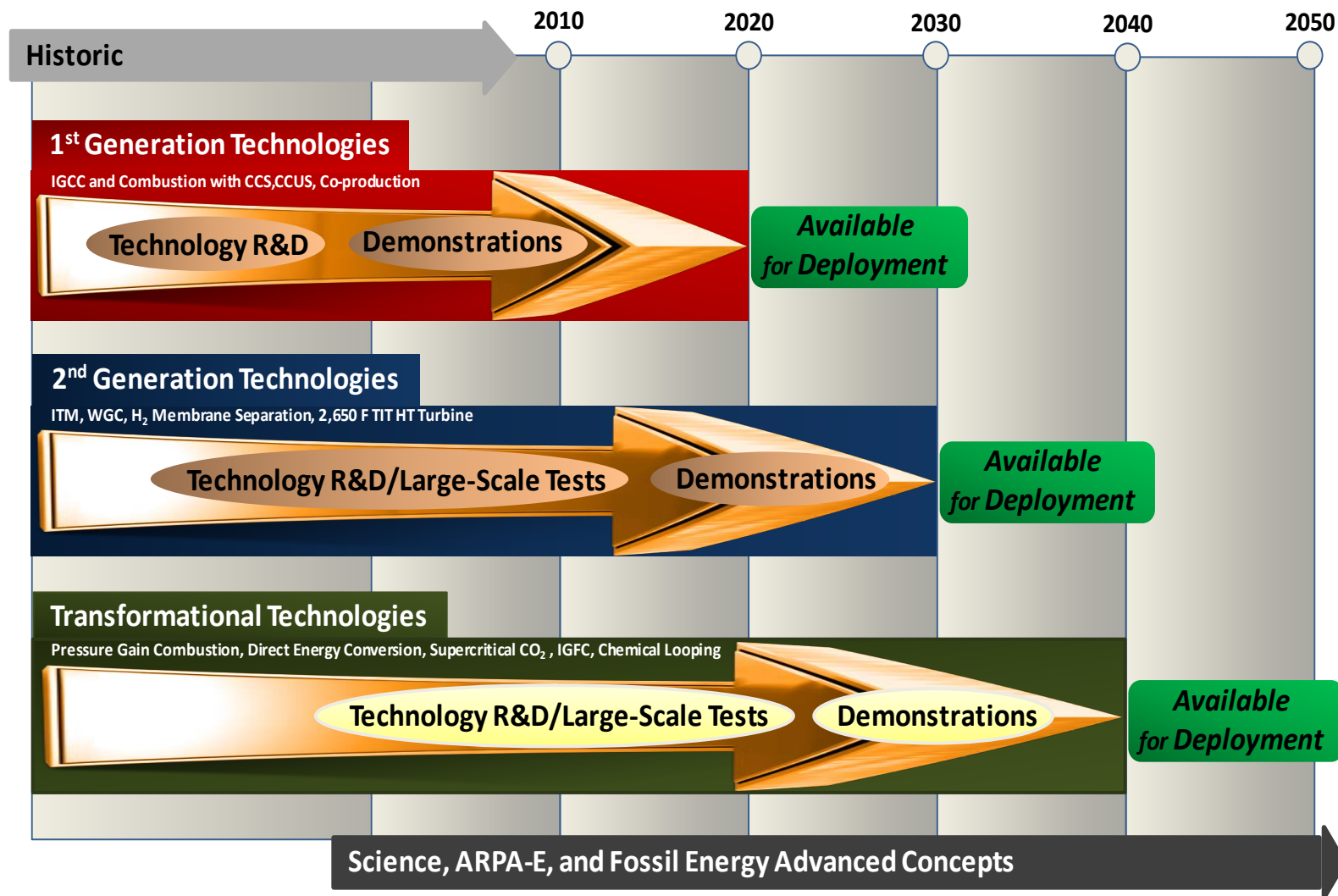
Technology Bridge to Near-Zero Emissions

2005 – 2020

2020 – 2050

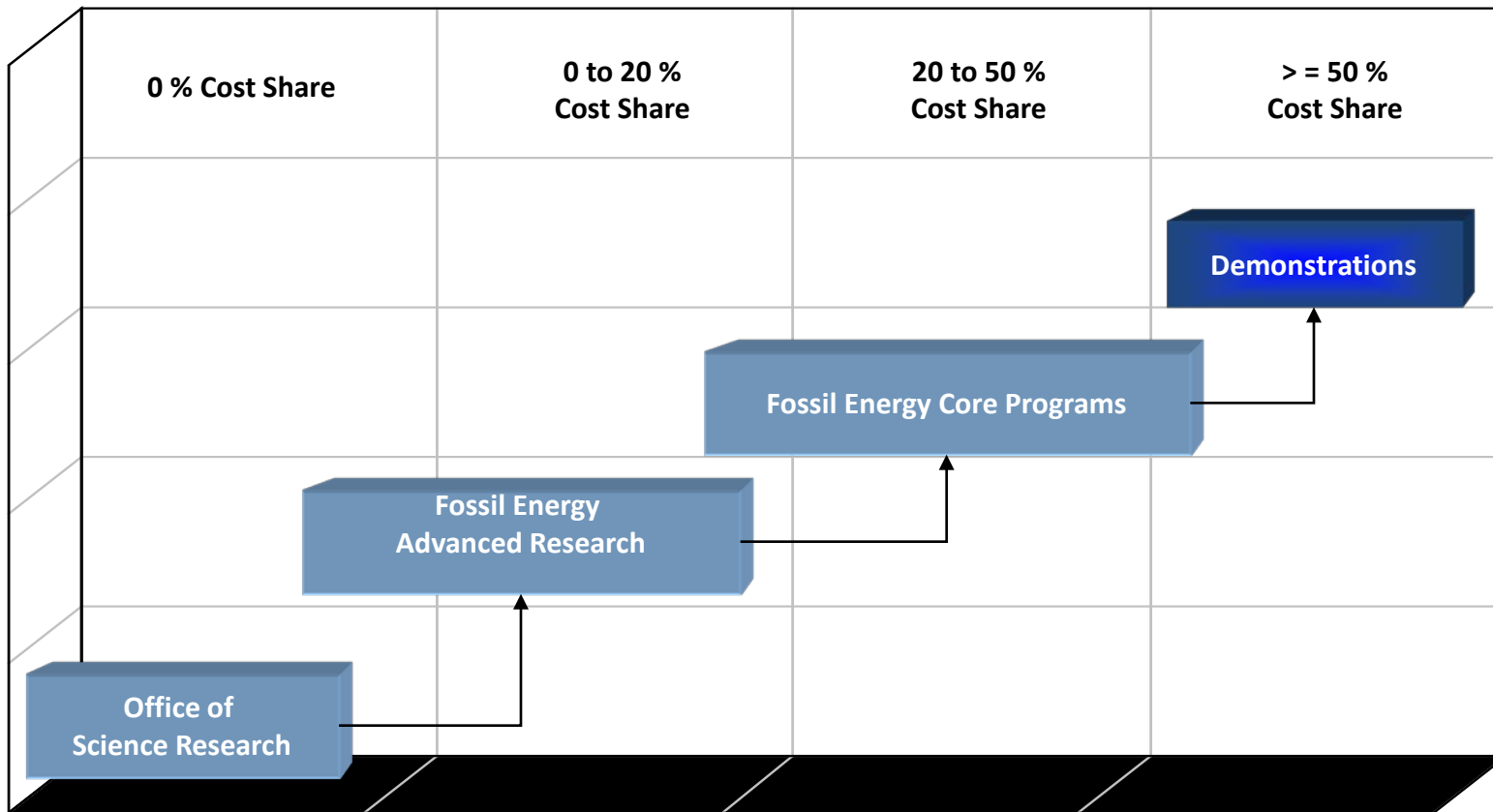


CCRP Technology Development Timeline



Cost Share Ensures Commercial Relevance

DOE Research Programs



Basic Research

Applied Research

Bridges basic research & technology development programs

Process & Engineering Development

Pilot plants, Proof-of concept (POC) units, Mini-demonstrations

Demonstration & Commercialization

Industry Participation & Cost Sharing Increases

U.S. Global Competitiveness

Emissions Control & Efficiency Improvements

Notable Program Successes

Advanced Pollution Controls

- Installed on 75% of U.S. coal plants
- 1/2 to 1/10 cost of older systems

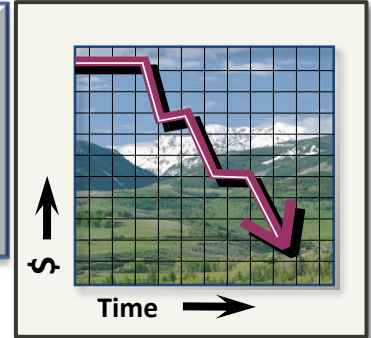
Flue Gas
Desulfurization (FGD)
Scrubbers



Low-NO_x Burners

HAPS & Hg Data

- Quantified Hazardous Air Pollutant (HAPs) Levels
- Basis for Mercury (Hg) Regulations



Advanced Coal Power Systems

- First large (265 MW) Circulating Fluidized Bed Combustion (CFBC) power plant
- Two “super-clean” Integrated Gasification Combined Cycle (IGCC) power plants



Jacksonville CFBC

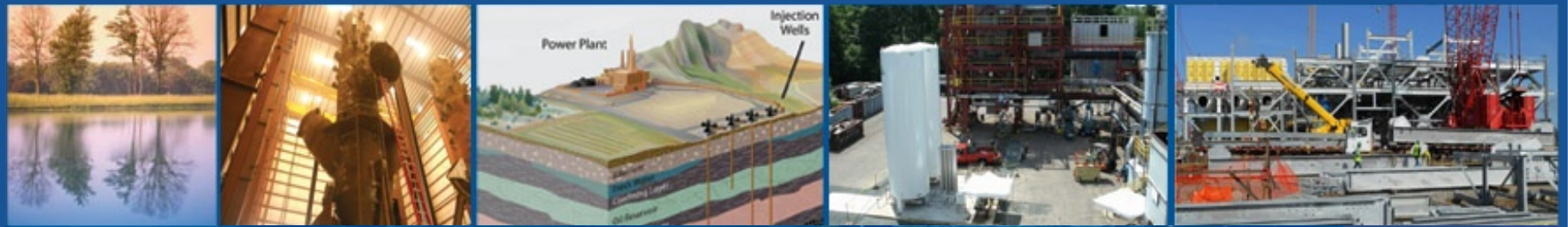


Wabash IGCC



Tampa IGCC

Return on Investment from Fossil Energy RD&D



FE RESEARCH — THE RETURN ON INVESTMENT

<i>\$111 billion in benefits¹</i>	<i>37 million add'l tons of avoided SO₂, 16 million add'l tons of avoided NO_x¹</i>	<i>1.2 million jobs created¹</i>	<i>12-fold increase in shale gas production²</i>	<i>10-fold increase in EOR using CO₂ injection³</i>	<i>50–70% cost reduction in mercury control at coal-fired power plants⁴</i>
<i>\$13 return for every \$1 invested³</i>		<i>Thousands of researchers trained</i>			
<i>2000–2020</i>	<i>2000–2020</i>	<i>2000–2020</i>	<i>2000–2011</i>	<i>1985–2010</i>	<i>2000–2008</i>
<i>Clean Coal program</i>	<i>Clean Coal program</i>	<i>Clean Coal program</i>	<i>Natural Gas & Petroleum Technologies program</i>	<i>Natural Gas & Petroleum Technologies program</i>	<i>Mercury Control program</i>

¹Bezdek, R. (2010). Costs and Benefits of DOE Investments in Clean Coal Technology: Implications for CCS. Presented at the Washington Coal Club, Washington, D.C., retrieved from www.washingtoncoalclub.org/docs/20100720_Bezdek.ppt. ²Newell, R. (2011). Shale Gas and the Outlook for US Natural Gas Markets and Global Gas Resources. ³Koottungal, L. (2010). 2010 Worldwide EOR Survey. Oil & Gas Journal, 108(14), 41–53. ⁴http://www.netl.doe.gov/technologies/coalpower/ewr/mercury/pubs/NETLHgR_Darticlefuelprocessingnov09.pdf.

Major CCS Demonstration Projects

Project Locations & Cost Share

- CCPI
- ICCS Area 1
- FutureGen 2.0

FutureGen 2.0

Large-scale Testing of Oxy-Combustion w/ CO₂ Capture and Sequestration in Saline Formation
 Project: ~\$1.65B – Total; ~\$1.0B – DOE
SALINE – 1 MM TPY 2017 start

Archer Daniels Midland

CO₂ Capture from Ethanol Plant
 CO₂ Stored in Saline Reservoir
 \$208M – Total, \$141M – DOE
SALINE – ~0.9 MM TPY 2014 start

Summit TX Clean Energy

Commercial Demo of Advanced IGCC w/ Full Carbon Capture
 ~\$1.7B – Total, \$450M – DOE
EOR – ~2.2 MMTPY 2017 start

Southern Company

Kemper County IGCC Project
 Transport Gasifier w/ Carbon Capture
 ~\$2.01B – Total, \$270M – DOE
EOR – ~3.0 MM TPY 2014 start

HECA

Commercial Demo of Advanced IGCC w/ Full Carbon Capture
 ~\$4B – Total, \$408M – DOE
EOR – ~2.6 MM TPY 2019 start

NRG

W.A. Parish Generating Station
 Post Combustion CO₂ Capture
 \$775 M – Total
 \$167M – DOE
EOR – ~1.4 MM TPY 2016 start

Air Products and Chemicals, Inc.

CO₂ Capture from Steam Methane Reformers
 EOR in Eastern TX Oilfields
 \$431M – Total, \$284M – DOE
EOR – ~0.93 MM TPY 2012 start

Leucadia Energy

CO₂ Capture from Methanol Plant
 EOR in Eastern TX Oilfields
 \$436M - Total, \$261M – DOE
EOR – ~4.5 MM TPY 2017 start



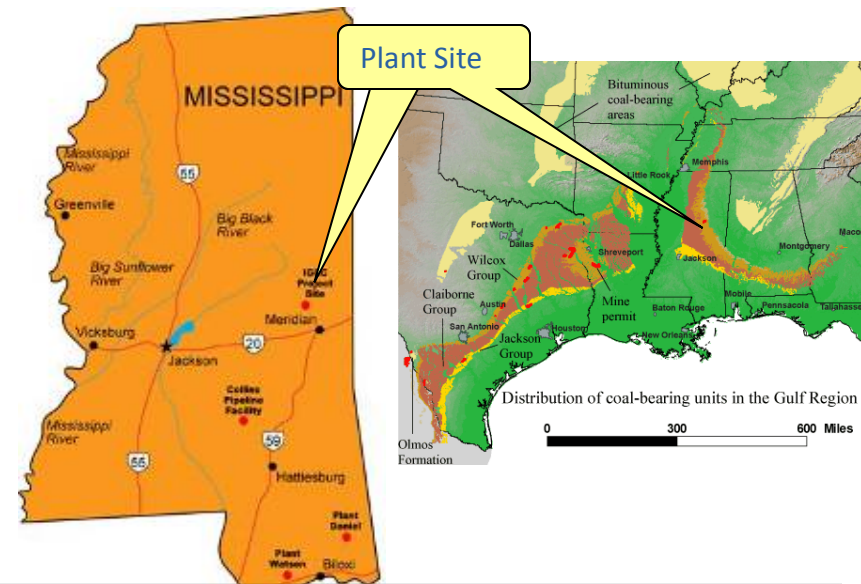
Southern Company Services, Inc. CCPI-2

Advanced IGCC with CO₂ Capture

- Kemper County, MS
- 582 MWe (net); 58 MWe duct firing; 2 TRIG™ gasifiers, 2 Siemens combustion turbines, 1 Toshiba steam turbine
- Fuel: Mississippi lignite
- ~67-69% CO₂ capture (Selexol® process); 3,000,000 tons CO₂/year
- EOR; Denbury Onshore LLC, Treetop Midstream Services LLC
- Total DOE Project: \$2.01 Billion; DOE Share: \$270 Million (13%)
- Total estimated plant cost: ~\$4.1 Billion

Key Dates

- Project Awarded: Jan 30, 2006
- Project moved to MS: Dec 5, 2008
- NEPA Record of Decision: Aug 19, 2010
- Initiate excavation work: Sept 27, 2010
- Operations: May 2014



Status

- Plant construction >73% complete; ~6,000 construction personnel on site
- CO₂ off-take agreements signed
- Lignite mine under development
- Subsystems (water treatment, cooling towers) to begin pre-commissioning
- Combustion turbine startup: Aug/Sept 2013
- Gasifier heat-up: Dec 2013

Liberty Mine

Treated Effluent Reservoir

Ash Management Area



Kemper IGCC Project
March 2013

Lignite Storage Dome

Gasification Area

Water Treatment
Area

Gas Cleanup Area

Combined Cycle Area





Air Products and Chemicals, Inc. ICCS Area 1

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 ~925,000 tonnes CO₂/year
- ~30 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and compression equipment
- CO₂ to Denbury pipeline for EOR in Texas at West Hastings oilfield
- Total Project: \$431 Million
DOE Share: \$284 Million (66%)



Key Dates

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

Status

- PA-1 initiated operation: March 3, 2013
- PA-2 initiated operation: Dec 16, 2012
- Total CO₂ delivered (8/21/13): 445,139 tons
- Full project capacity achieved: April 2013



Air Products and Chemicals, Inc: Port Arthur 2

Archer Daniels Midland Company ICCS Area 1

CO₂ Capture from Biofuel Plant

- Decatur, IL
- CO₂ is a by-product (>99% purity) from production of fuel grade ethanol via anaerobic fermentation
- Up to 90% CO₂ capture; dehydration (via triethylene glycol, TEG) and compression; ~900,000 tons CO₂ /year
- Sequestration in Mt. Simon sandstone formation
- Total Project: \$208 Million
DOE Share: \$141 Million (68%)



Key Dates

- Phase 2 Awarded: Jun 15, 2010
- FEED Complete: Apr 2011
- NEPA FONSI: Apr 2011
- Construction start: May 2011
- UIC Class VI Injection Well Permit: Jan 2014;
- Sequestration start: July 2014

Status

- Construction ~50% complete
- Substation construction in progress
- Two monitoring wells drilled: Nov 2012
- Commissioning compression & dehydration: July 2013

ADM ICCS Project Photos (June 2013)

Photos: Courtesy of ADM



Four Compressor Train



Compressor & Auxiliaries



Dehydration System

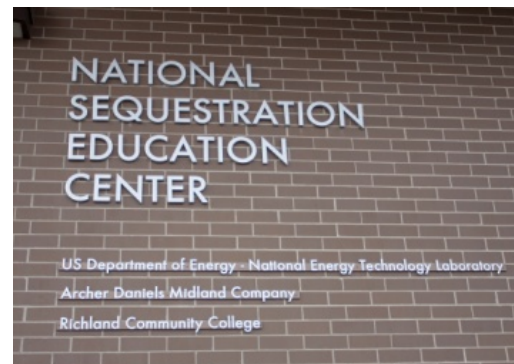


8" High Pressure transmission Line

National Sequestration Education Center

Richland Community College

- Public outreach, training, & education initiative to engage local communities to understand CCUS & related environmental benefits
- National Sequestration Education Center (NSEC) - a new education and training facility <http://nsec.richland.edu/>
 - 15,000 ft² center - classrooms, training, and laboratory facilities
 - Opened September 2012
 - Associate degree program with carbon sequestration specialty
 - Operates Sequestration Technology Educational Learning Array in the Visitor's Center – Interactive program to learn CCUS



For More Information

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National Energy Technology Laboratory



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Back-Up Slides

on 5 Remaining Major Demonstration Projects

Clean Coal Power Initiative (CCPI)

- **NRG**
- **Summit**
- **HECA**

FutureGen 2.0

Industrial Carbon Capture & Sequestration (ICCS)

- **Leucadia-Lake Charles**

W.A. Parish NRG Energy CCPI-3

Advanced Post Combustion CO₂ Capture

- Thompsons, TX (near Houston)
- 240 MWe slipstream at NRG Energy's W.A. Parish power plant (project scale up from original 60 MWe to improve economic)
- Fuel: PRB sub-bituminous coal
- 90% CO₂ capture (KM CDR Process[®]) 1,400,000 tonnes CO₂/year
- EOR: Hilcorp West Ranch oil field
- Total DOE Project: \$775 Million (est.)
DOE Share: \$167 Million (21.5%)



Key Dates

- Project Awarded: May 2010
- Air Permit: Dec 2012
- NEPA Record of Decision: May 2013
- Financial Close: Feb 2014
- Construction: Feb 2014
- Operation: May 2016

Status

- EOR Host Site acquired: Oct 2011
- 240 MWe FEED completed: Feb 21, 2012
- MHI initiated detailed design: Dec 2012
- NRG-Petra Nova signed engagement letter with a debt financing provider: Dec 2012

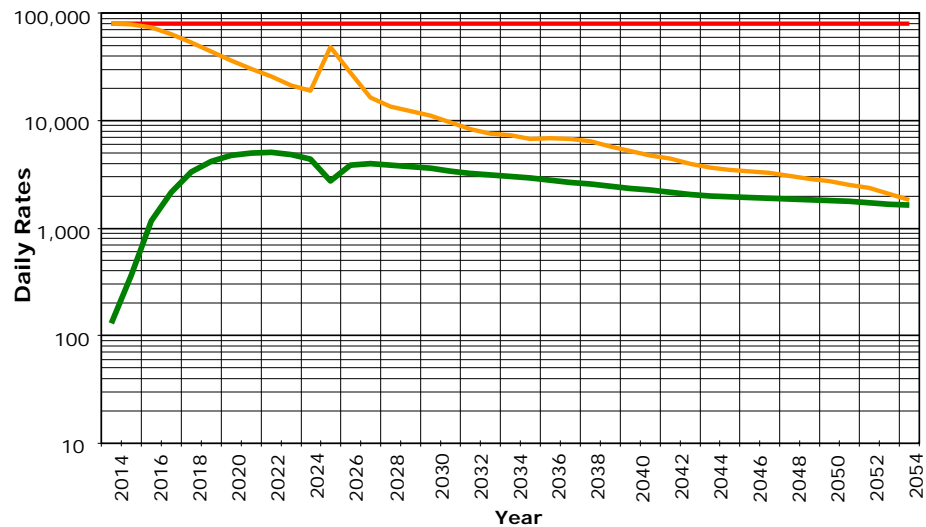
Scaling up the Project - EOR

- NRG & Hilcorp concluded that the proposed 60MW sized project's 20,000 MCF/day CO₂ production rate was too small to induce meaningful oil production.

120 MWe Model Results (40,000 MCF/Day)



215 MWe Model Results (80,000 MCF/Day)



— Gross CO₂ Injection Rate (MCFD) — Net CO₂ Injection Rate (MCFD) — Oil Response BOPD (400MM OOIP)

- NRG & Hilcorp determined that the best-sized application to support the CO₂ miscible flooding requirements of the candidate oil fields is 200-250MW.

Co-optimization of CO₂ production with enhanced oil recovery response.

WA Parish Site Overview



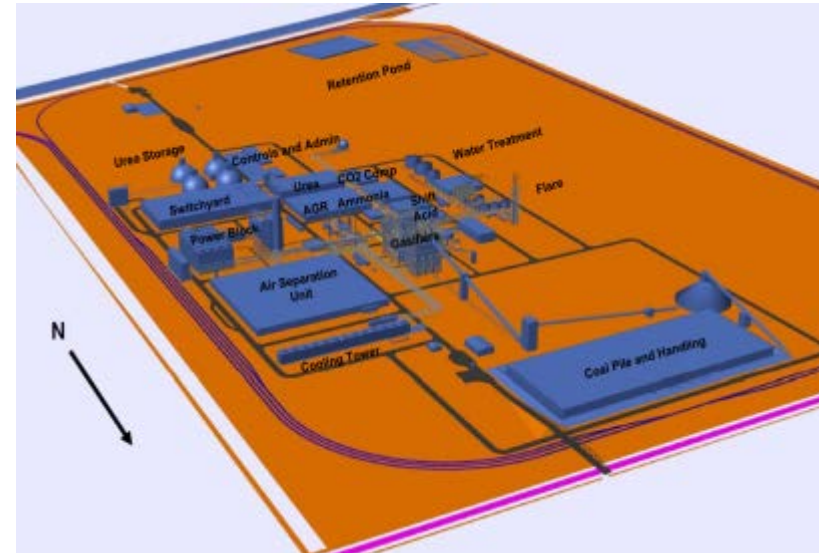
Summit Texas Clean Energy, LLC CCPI-3

Advanced IGCC-Polygen

- Penwell, Ector County, TX
- 200 MW (net), 0.7 MMT/yr Urea; greenfield IGCC with Siemens gasification & power Block
 - SFG-500 gasifiers (2 x 50%)
 - High H₂ SGCC6-5000F combined cycle (1 x 1)
- Fuel: PRB sub bituminous coal
- 90% CO₂ capture – ~2,700,000 tons CO₂/year
 - 2.2 MM tonnes EOR; 0.5 MM to Urea production
 - 2-stage Water Gas Shift, Linde Rectisol[®] AGR
- EOR: Permian Basin oil fields
- Total DOE Project: \$1.727 Billion
DOE Share: \$450 Million (26%)
- Total Plant Cost ~\$2.9 Billion

Key Dates

- Project Awarded: Jan 2010
- Air Permit; Dec 2010
- NEPA Record of Decision: Sep 2011
- Financial Close: Oct 2013
- Construction: 4th Q2013
- Operation: Nov 2017



Status

- Urea contract: Jan 2011
- CO₂ contract(s): Nov 2011
- Power off-take contract: Dec 2011
- Chexim signed for debt financing MOU: Sep 2012
- Sinopec signed EPC agreement: Dec 2012

Summit Texas Clean Energy, LLC

Plant Site



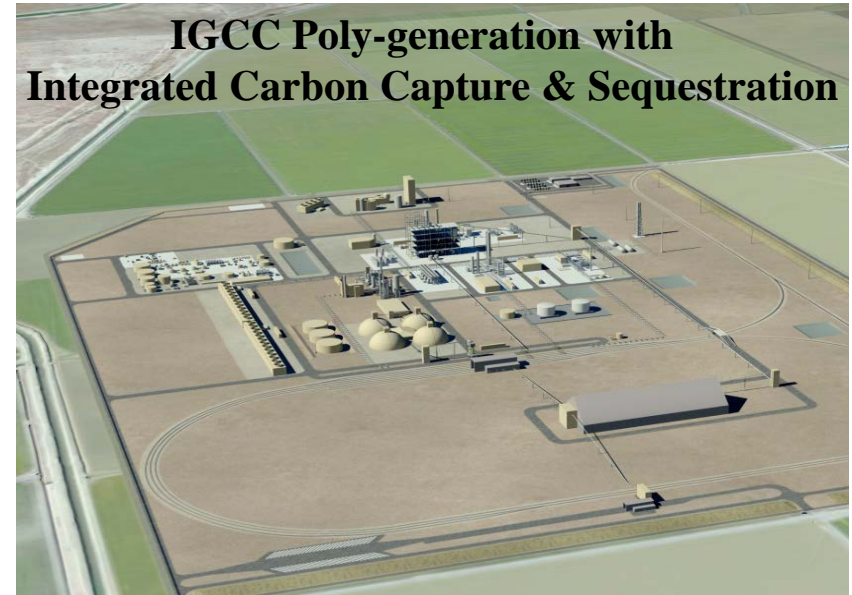
**Northwest Border of Pennwell Site
(Facing East)**

Kinder Morgan CO₂ Interconnect

Hydrogen Energy California

Advanced IGCC-Polygen

- Kern County, CA
- Up to 300 MWe (net) with load following;
greenfield IGCC, 1.0 MT/yr Urea/UAN
 - MHI oxygen-blown gasifier (1 x 100%)
 - MHI G-class air cooled combustion turbine (1)
- Fuel: Sub-bituminous coal/petcoke
- 90% CO₂ capture – 3,020,000 tonnes CO₂/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 Billion DOE - \$408 Million (10%)
- Total Plant Cost: ~\$5 Billion



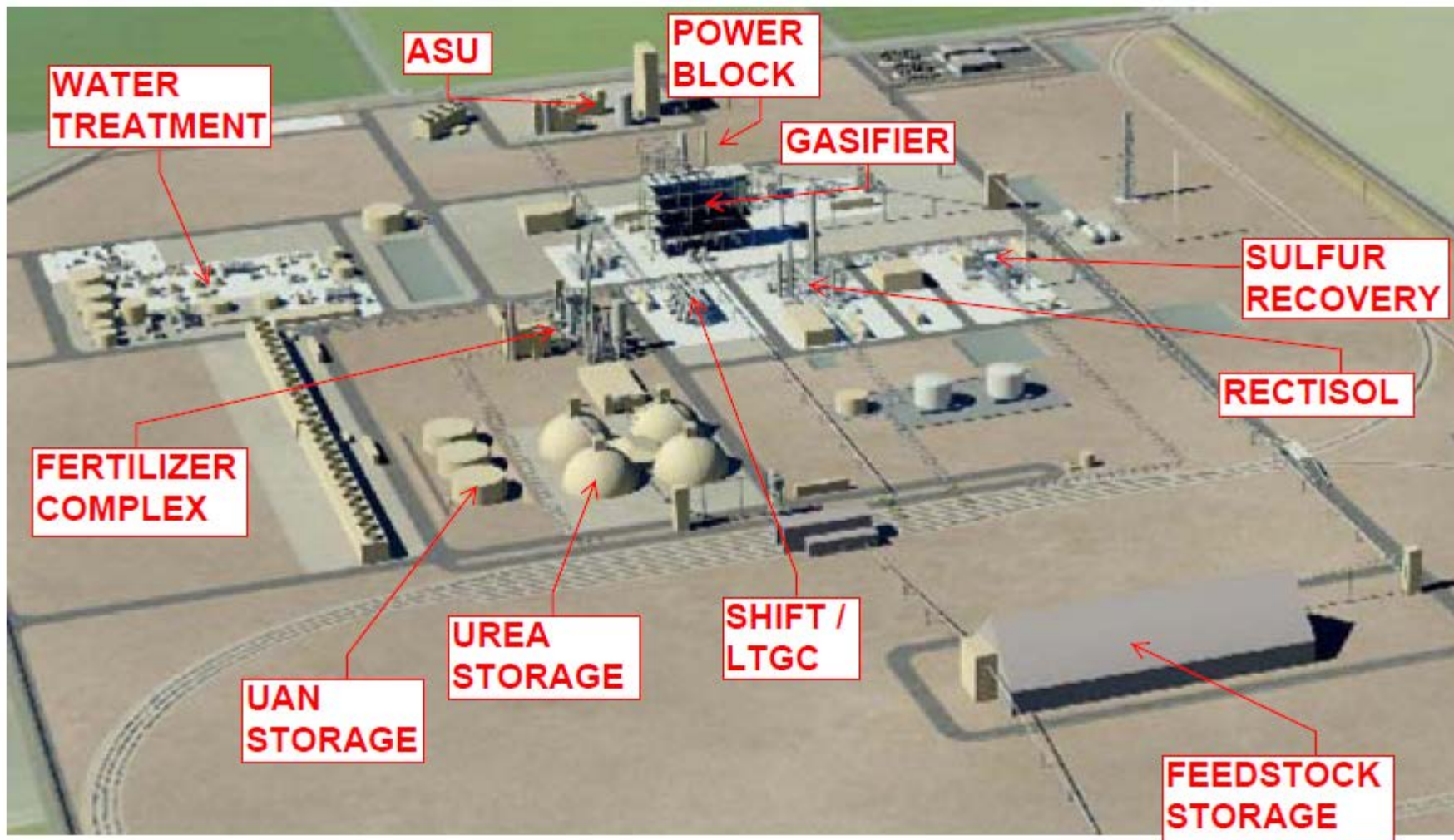
Key Dates

- Project Awarded: Sep 2009
- New Owner, SCS Energy: Sep 2011
- Financial Close: Jun 2014
- Start of Construction: Jan 2015
- Start of Operation: Jul 2019

Status

- Power/Fertilizer/CO₂/EPC discussions in progress
- FEED completion: Apr 2013
- Draft PSA/EIS: Jun 2013
- Final Determination of Compliance (air permit): Jul 2013

HECA Plant Layout



FutureGen 2.0

Oxy-combustion with Geologic Storage

- Morgan County, IL (western IL)
- 168 MWe repowering of an existing steam turbine generator at Ameren's Meredosia Energy Center
- Fuel: Illinois bituminous/PRB blend
- 90+% CO₂ capture (cryogenic separation)
1,000,000 tons CO₂/year
- Geologic Storage, Mt. Simon Sandstone saline formation - ~30 miles east of power plant
- Total DOE Project: \$1.78 Billion
DOE Share: \$1.05 Billion (59%)



Key Dates

- Project Awarded: October 2010
- NEPA Complete (Planned): Fall 2013
- Financial Close: Summer 2014
- Construction: Fall 2014
- Operation: Summer 2017

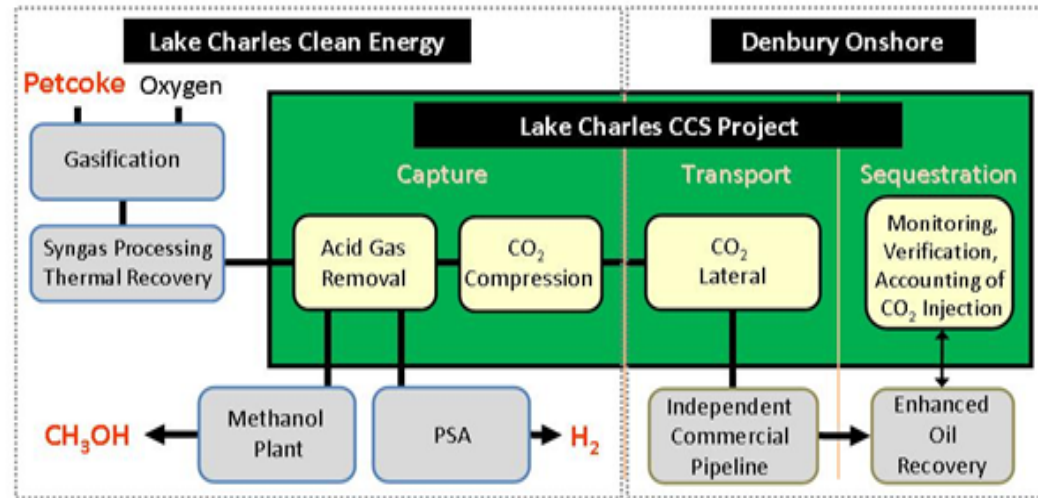
Status

- Storage site selected: Oct 2011
- Pre-FEED completed: April 2012
- Preliminary PPA approved by ICC: Dec 2012
- Power plant project novated to FGA: Jan 2013
- Phase II (NEPA, Permitting, and Design) authorized: Feb 2013

Leucadia Energy, LLC ICCS Area 1

Petcoke Gasification to Methanol

- Lake Charles, LA
- GE Energy Gasification
(4 gasifiers: 3 hot/1 spare)
- 700 mmgal/yr methanol; 110 mmscfd H₂
- Fuel: Petcoke
- 89% CO₂ capture (Rectisol® process);
4,500,000 tonnes CO₂/year
- CO₂ to Denbury pipeline for EOR in Texas
at West Hastings oil field
- Total Project: \$436 Million
DOE Share: \$261 Million (60%)



Key Dates

- Phase 2 awarded: Jun 17, 2010
- Complete CCUS FEED: Jul 2011
- NEPA ROD: Oct 2013
- Financial close: Oct 2013 (est.)
- Construction: Oct 2013 (est.)
- Operation: Mar 2017 (est.)

Status

- Product off-take contracts finalized (BP, APCI)
- NEPA EIS in progress; Draft EIS public meetings - Apr 2013
- FEED in progress for gasification plant