



# **Global Developments in Industrial CCS & Overview of IEAGHG Industry CCS Activities.**

John Gale

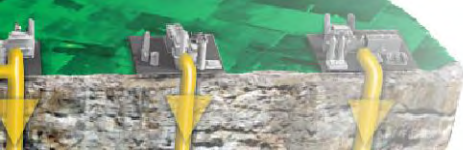
General Manager

IEA Greenhouse Gas R&D Programme

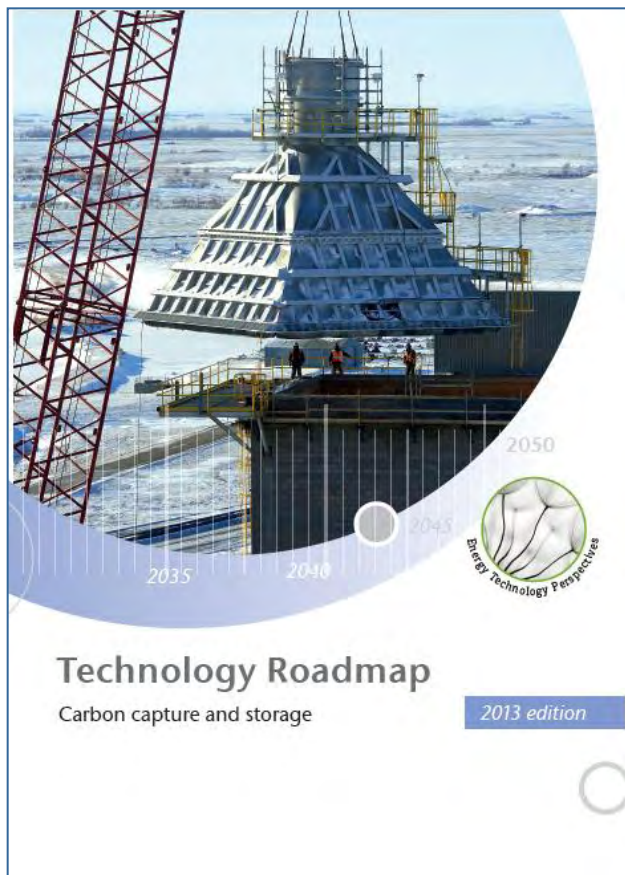
CCS in Industry Workshop

Vienna, Austria

28<sup>th</sup> April 2014



# 2013 CCS Roadmap: Key findings

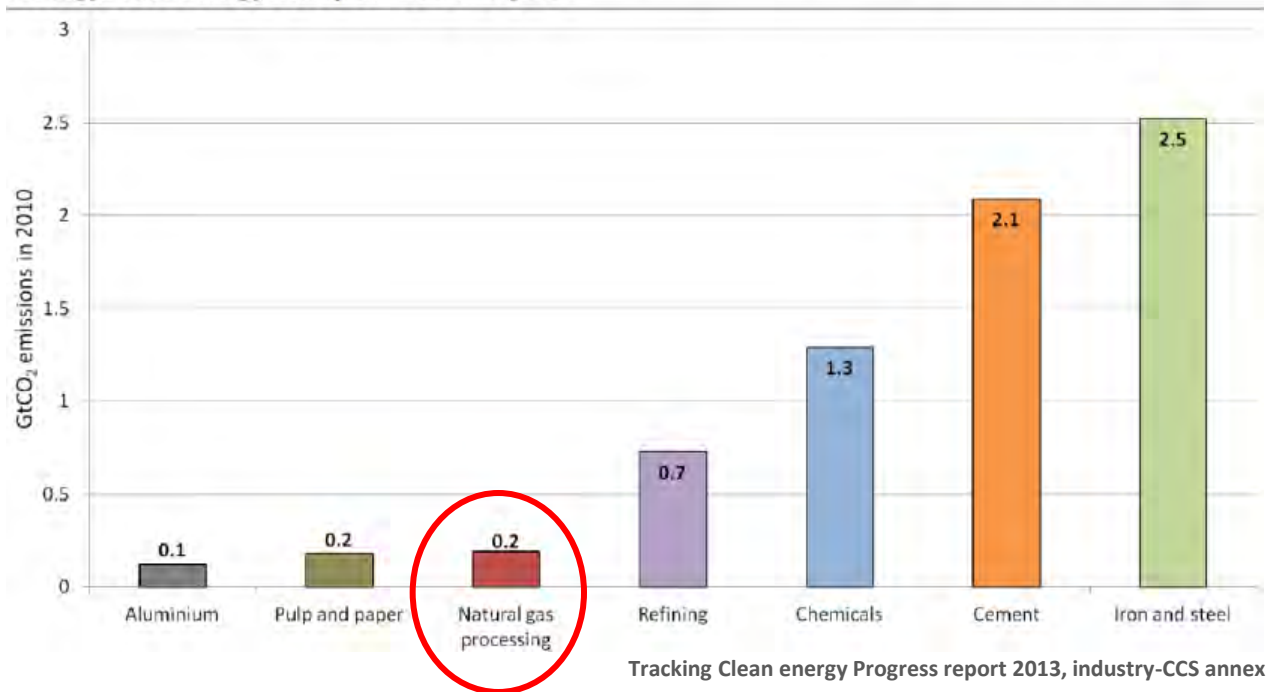


- CCS is a **critical component** in a portfolio of low-carbon energy technologies, contributing 14% of the cumulative emissions reductions between 2015 and 2050 compared with business as usual.
- The individual component technologies are generally well understood. **The largest challenge is the integration** of component technologies into large-scale demonstration projects.
- Incentive frameworks are urgently needed to deliver upwards of **30 operating CCS projects by 2020**.
- **CCS is not only about electricity generation: 45% of captured CO<sub>2</sub> comes from industrial applications between 2015 and 2050.**
- The largest deployment of CCS will need to occur in **non-OECD countries, 70% by 2050**. China alone accounts for 1/3 of the global total of captured CO<sub>2</sub> between 2015 and 2050.
- The urgency of CCS deployment is only increasing. **This decade is critical** in developing favourable conditions for long-term CCS deployment.

# Rationale for CCS: Only large-scale option for many industries



Figure 1. Global emissions from the seven most CO<sub>2</sub>-intense industrial sectors in the IEA  
*Energy Technology Perspectives* analysis



CCS is the only large-scale mitigation option for many industrial sectors.

# Commercial Application of CCS (to date)



**Sleipner**  
1Mt/y CO<sub>2</sub>



**Weyburn**  
2.5 Mt/y CO<sub>2</sub>



**In-Salah**  
1.2 Mt/y CO<sub>2</sub>



**Snohvit**  
0.7Mt/y CO<sub>2</sub>



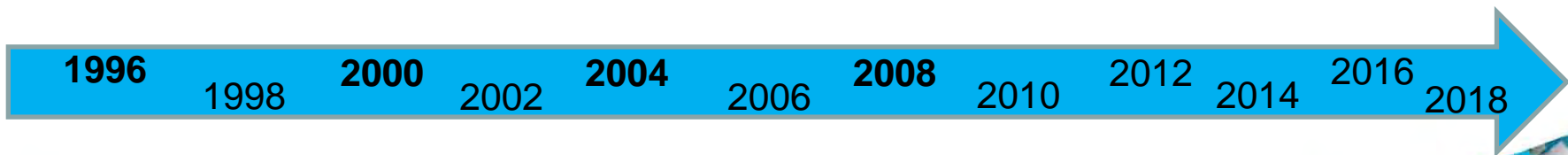
**Gorgon**  
4Mt/y CO<sub>2</sub>



**350km overland pipeline**



**160km sub sea pipeline**



1996

1998

2000

2002

2004

2006

2008

2010

2012

2014

2016

2018



# Industry Sector drivers

- CO<sub>2</sub> removed to meet pipeline standards
  - High purity CO<sub>2</sub> stream
- Additional costs of injection low relative to power plant
  - Norway = offshore emission tax \$35/t
- CO<sub>2</sub> capture plants in close proximity to storage resources
- Industry has gas injection/storage reservoir expertise

# 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/ CO<sub>2</sub> Capture and Sequestration in Saline Formation  
 Project: ~\$1.65B – Total; ~\$1.0B – DOE  
**SALINE – 1M MTPY 2017 start**

### *Archer Daniels Midland*

CO<sub>2</sub> Capture from Ethanol Plant  
 CO<sub>2</sub> Stored in Saline Reservoir  
 \$208M – Total, \$141M – DOE  
**SALINE – ~0.9M MTPY 2015 start**

### *Summit TX Clean Energy*

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

### *Southern Company*

Kemper County IGCC Project  
 Transport Gasifier w/ Carbon Capture  
 ~\$4.12B – Total, \$270M – DOE  
**EOR – ~3.0M MTPY 2014 start**

### *HECA*

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

### *NRG*

W.A. Parish Generating Station  
 Post Combustion CO<sub>2</sub> Capture  
 \$775 M – Total  
 \$167M – DOE  
**EOR – ~1.4M MTPY 2016 start**

### *Air Products and Chemicals, Inc.*

CO<sub>2</sub> Capture from Steam Methane Reformers  
 EOR in Eastern TX Oilfields  
 \$431M – Total, \$284M – DOE  
**EOR – ~0.93M MTPY 2012 start**

### *Leucadia Energy*

CO<sub>2</sub> Capture from Methanol Plant  
 EOR in Eastern TX Oilfields  
 \$436M - Total, \$261M – DOE  
**EOR – ~4.5M MTPY 2017 start**



# Portfolio of Capture and Storage Approaches

	Plant Type		Sequestration			Feedstock
	Power	Industrial	Saline	EOR	Rate*	
<b>Pre-combustion</b>						
HECA (IGCC-Polygen)	X	X		X	2.55	NM Sub-bituminous Coal/Petcoke Blend
Southern-Kemper Co. (IGCC)	X			X	3.0	MS Lignite
Summit Texas (IGCC-Polygen)	X	X		X	2.2	WY Sub-bituminous Coal
Leucadia, Lake Charles (Methanol & Hydrogen)		X		X	4.5	Petroleum Coke
Air Products and Chemicals, Inc. (SMR)		X		X	0.925	Natural Gas
ADM (Ethanol Production)		X	X		0.900	Corn Fermentation
<b>Post-combustion</b>						
NRG Energy	X			X	1.4	WY Sub-bituminous Coal
<b>Oxy-combustion</b>						
FutureGen 2.0	X		X		1.0	IL Bituminous /PRB Coal Blend

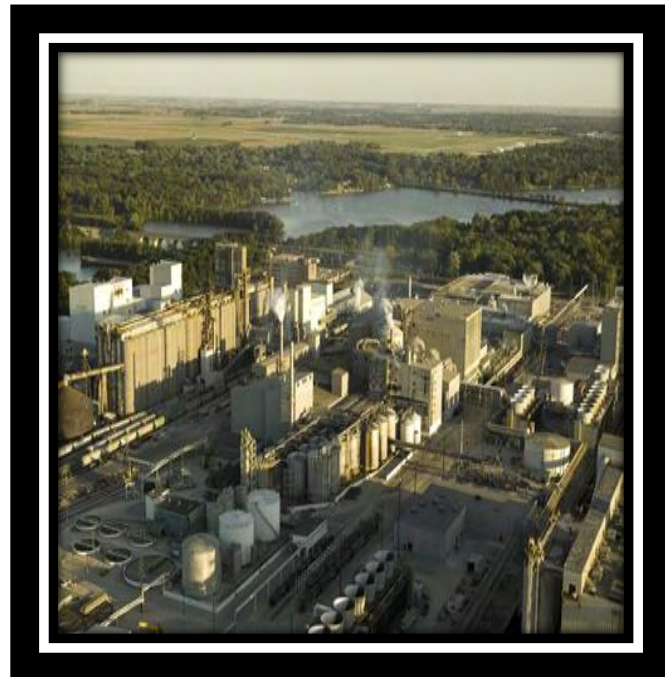
CCPI
  ICCS
  FutureGen 2.0
 \*Rate in million metric tons per year



# Archer Daniels Midland Company (ICCS)

## *CO<sub>2</sub> Capture from Biofuel Plant*

- Decatur, IL
- CO<sub>2</sub> is a by-product (>99% purity) from production of fuel grade ethanol via anaerobic fermentation
- Up to 90% CO<sub>2</sub> capture; dehydration (via triethylene glycol) and compression – ~900,000 tonnes CO<sub>2</sub> /year
- Sequestration in Mt. Simon Sandstone saline reservoir
- 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: Q2 2014
- UIC Class VI Operating Permit: Jan 2015
- Sequestration start: Feb 2015

### Status

- Construction ~60% complete
- UIC Class VI permit submitted: Jul 2011
- Two monitoring wells drilled: Nov 2012
- Commissioning compression and dehydration: began in July 2013

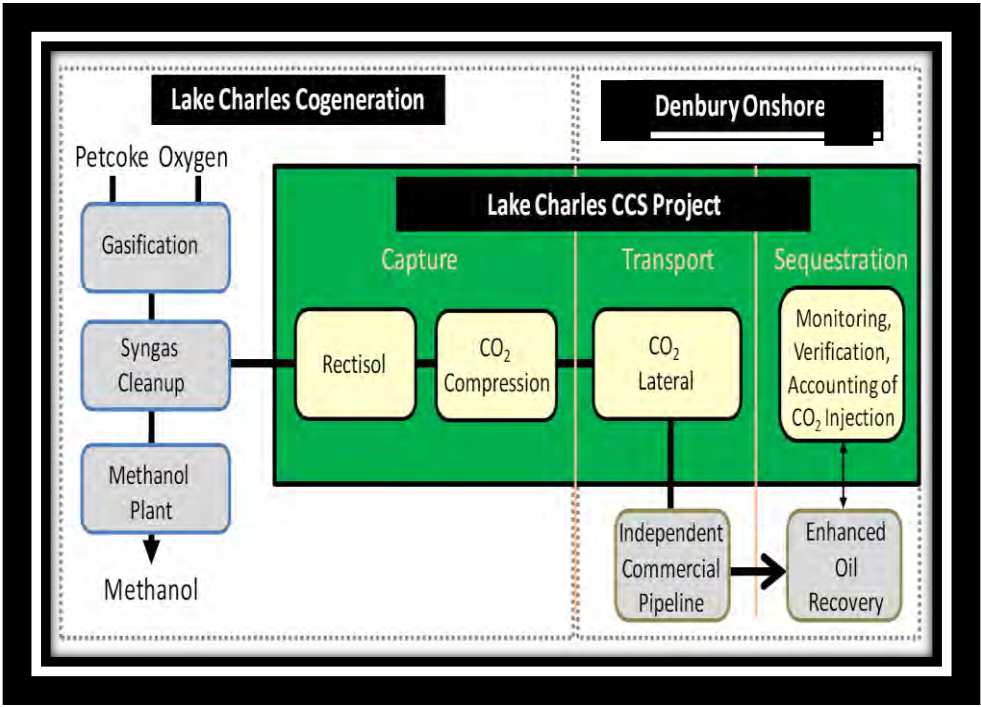




# Leucadia Energy (ICCS)

## *Petcoke Gasification to Methanol*

- Lake Charles, LA
- GE Energy Gasification (4 gasifiers: 3 hot/1 spare)
- 700 million gallons/year methanol; 110 mmscfd hydrogen
- Fuel; Petcoke
- 89% CO<sub>2</sub> capture (Rectisol® process); 4,500,000 tonnes CO<sub>2</sub>/year
- CO<sub>2</sub> to Denbury pipeline for EOR in Texas at West Hastings oil field
- Total Project: \$436 Million



### Key Dates

- Phase 2 awarded: Jun 17, 2010
- Complete CCUS FEED: Jul 2011
- Financial close: March 2014 (est.)
- Construction: March 2014 (est.)
- Operation: Mar 2017 (est.)

### Status

- Product off-take contracts finalized (BP, APCI)
- NEPA ROD released on Dec 28, 2013
- FEED in progress for gasification plant



# Air Products & Chemicals (ICCS)

## *Steam Methane Reforming with CO<sub>2</sub> Capture*

- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90%+ CO<sub>2</sub> capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding ~925,000 tonnes CO<sub>2</sub>/year
- ~30 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and compression equipment
- CO<sub>2</sub> to Denbury for EOR - West Hastings oilfield
- Total Project: \$431 Million  
DOE Share: \$284 Million (66%)

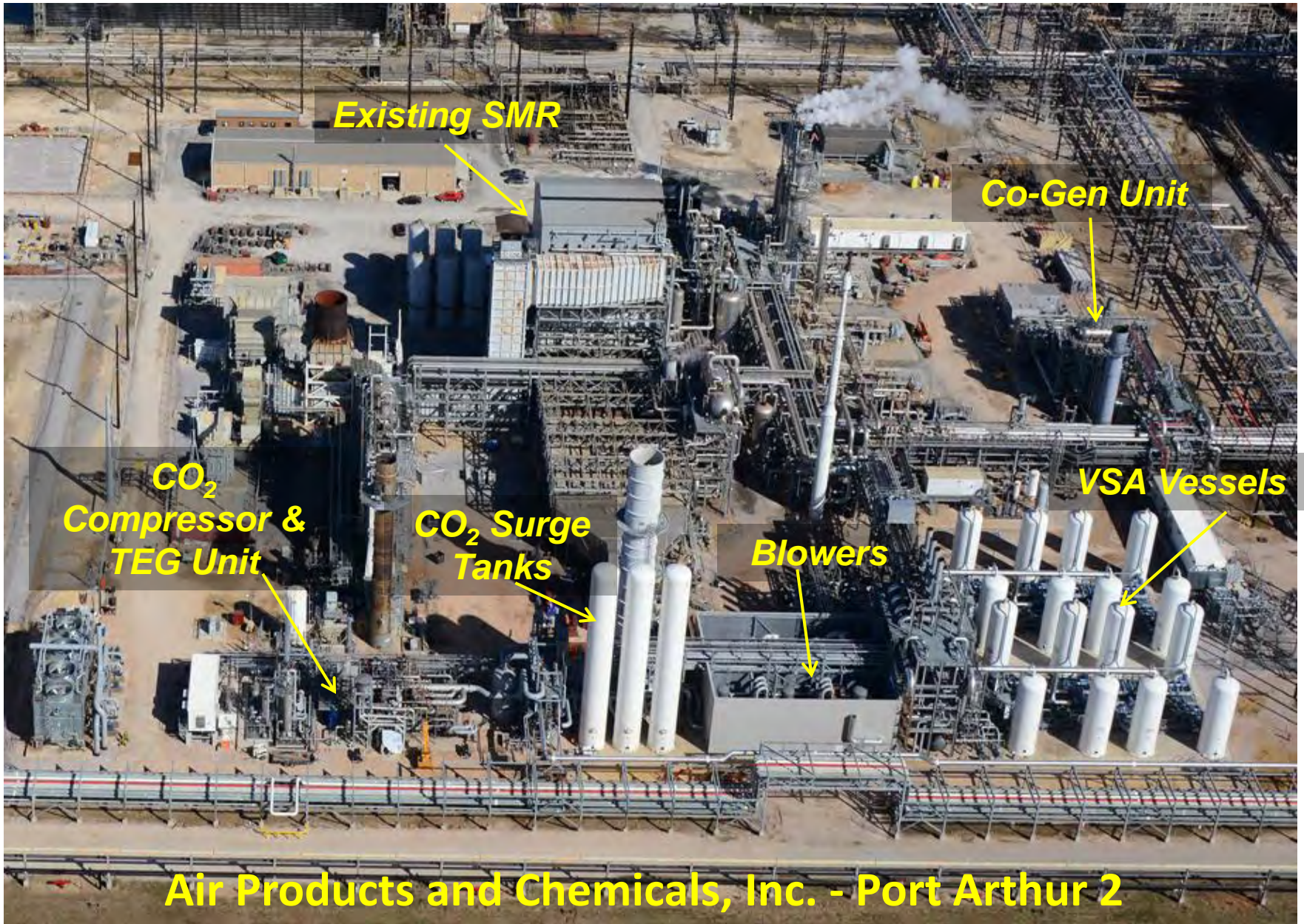


### Key Dates

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

### Status

- PA-1 initiated operation: Mar 3, 2013
- PA-2 initiated operation: Dec 16, 2012
  - Operating continuously since Dec 31, 2012
  - Total CO<sub>2</sub> delivered: 680K tons (Dec 2013)
  - Full capacity achieved: April 2013
- Final MVA report submitted: Feb 2013



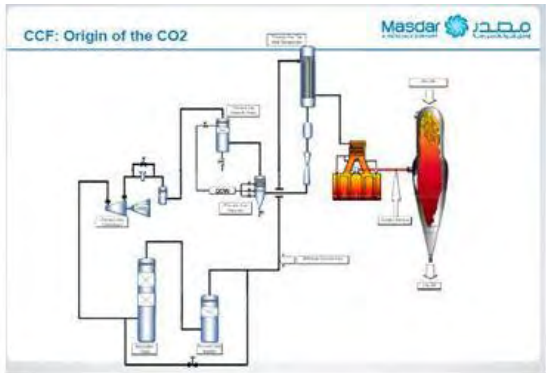
**Air Products and Chemicals, Inc. - Port Arthur 2**



U.S. DEPARTMENT OF  
**ENERGY**

Fossil  
Energy

# ESI CCS Project Technical Overview



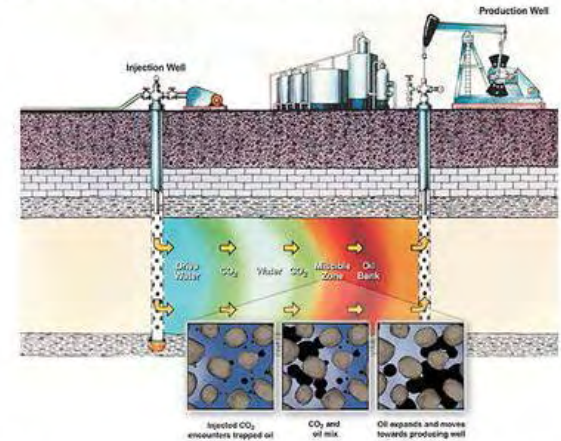
CO2 Source (ESI) and Capture



CO2 Transportation



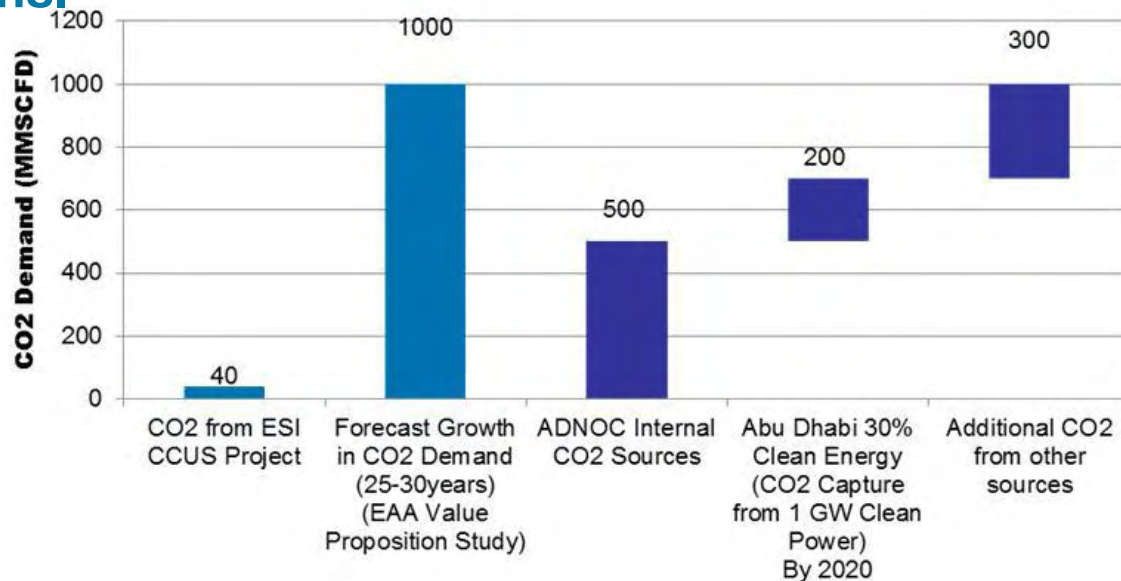
CO2 Compression & Dehydration



CO2 Injection in Rumaitha & Bab fields

# Abu Dhabi CCS: Future Potential

- **CO<sub>2</sub> as an EOR agent has been endorsed:**
  - Success of the ESI CCS Project and Rumaiitha / Bab Injection are key to future development.
- **Changing landscape in Abu Dhabi with potential CO<sub>2</sub> targets for field testing and development:**
  - CO<sub>2</sub> capture linked to ADNOC field demand and performance;
- **Whilst preliminary, the EAA CCS Value Proposition study forecast a growing CO<sub>2</sub> demand in the next 25-30 years, based on ADNOC estimations.**



# EU Zero Emission Platform



## Report 2013

- EU 2011 Roadmap for a competitive low carbon economy in 2050,
- Emission reductions will be required to take place in all sectors,
- CO<sub>2</sub> emissions from the industrial sectors reduced by 34% to 40% by 2030, and by between 83% to 87% by 2050.
- Only CCS can provide the required large-scale emission reductions in EU industry

# US Industrial CCS Drivers



**CO<sub>2</sub>-EOR OPERATIONS, CO<sub>2</sub> SOURCES: 2014**

FIG. 1



Oil production, 2014	
CO <sub>2</sub> -EOR projects	136
Oil production, 1,000 b/d	300

CO <sub>2</sub> supplies, 2014	
Number of sources	17
• Natural	5
• Industrial	12
CO <sub>2</sub> supply, MMcfd	3.5
• Natural	2.8
• Industrial	0.7

**136** Number of CO<sub>2</sub>-EOR projects

- Natural CO<sub>2</sub> source
- Industrial CO<sub>2</sub> source
- CO<sub>2</sub> pipeline
- ⋯ CO<sub>2</sub> proposed pipeline

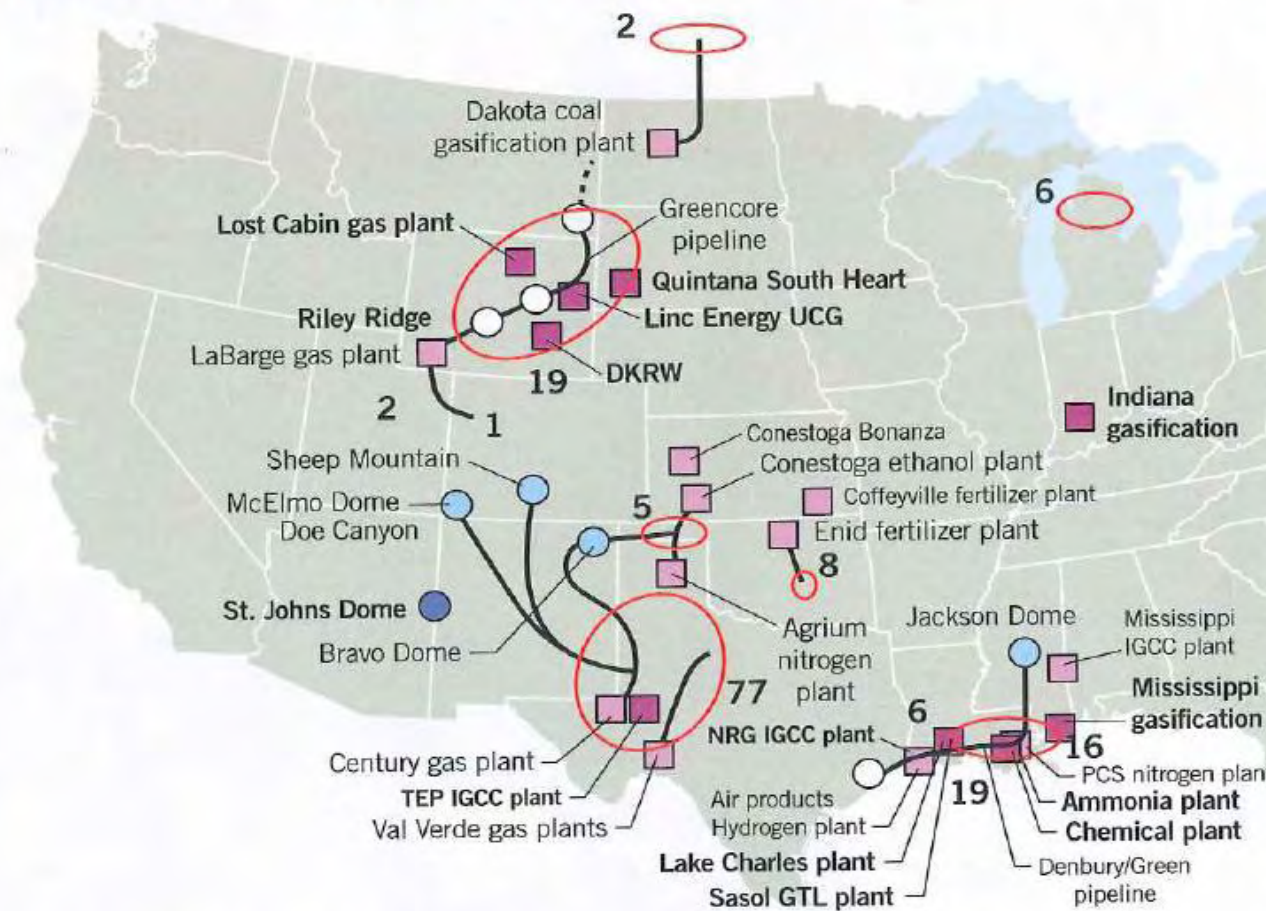
Source: Advanced Resources International Inc. based on OGI EOR/Heavy Oil Survey 2014 and other sources

# CO<sub>2</sub>-EOR Driving Expansion Of Industry CCS.



**PROJECTED CO<sub>2</sub>, EOR OPERATIONS, AND CO<sub>2</sub> SOURCES: 2020**

FIG. 4



Oil production, 2020	
CO <sub>2</sub> -EOR projects	147
Oil production, 1,000 b/d	638
CO <sub>2</sub> supplies, 2020	
Number of sources	30
• Natural	6
• Industrial	24
CO <sub>2</sub> supply, MMcfd	6.5
• Natural	3.4
• Industrial	3.1

<b>147</b>	Number of CO <sub>2</sub> -EOR projects
●	Natural CO <sub>2</sub> source
■	Industrial CO <sub>2</sub> source
—	CO <sub>2</sub> pipeline
⋯	CO <sub>2</sub> proposed pipeline

Source: Advanced Resources International Inc. based on OGI EOR/Heavy Oil Survey 2014 and other sources



# EU Industry considerations



- Core business is making globally competitive products e.g. steel, cement, chemicals.....
- Is there a business case for CCS in industry?
  - Probably not –price on CO<sub>2</sub> currently too low
- Industry has no experience of transport and storage
  - same as power sector initially
- Ideally would like a storage company to handle out of gate storage
  - No market outside North America such as EOR
  - In EU therefore no such companies currently exist

# Infrastructure considerations

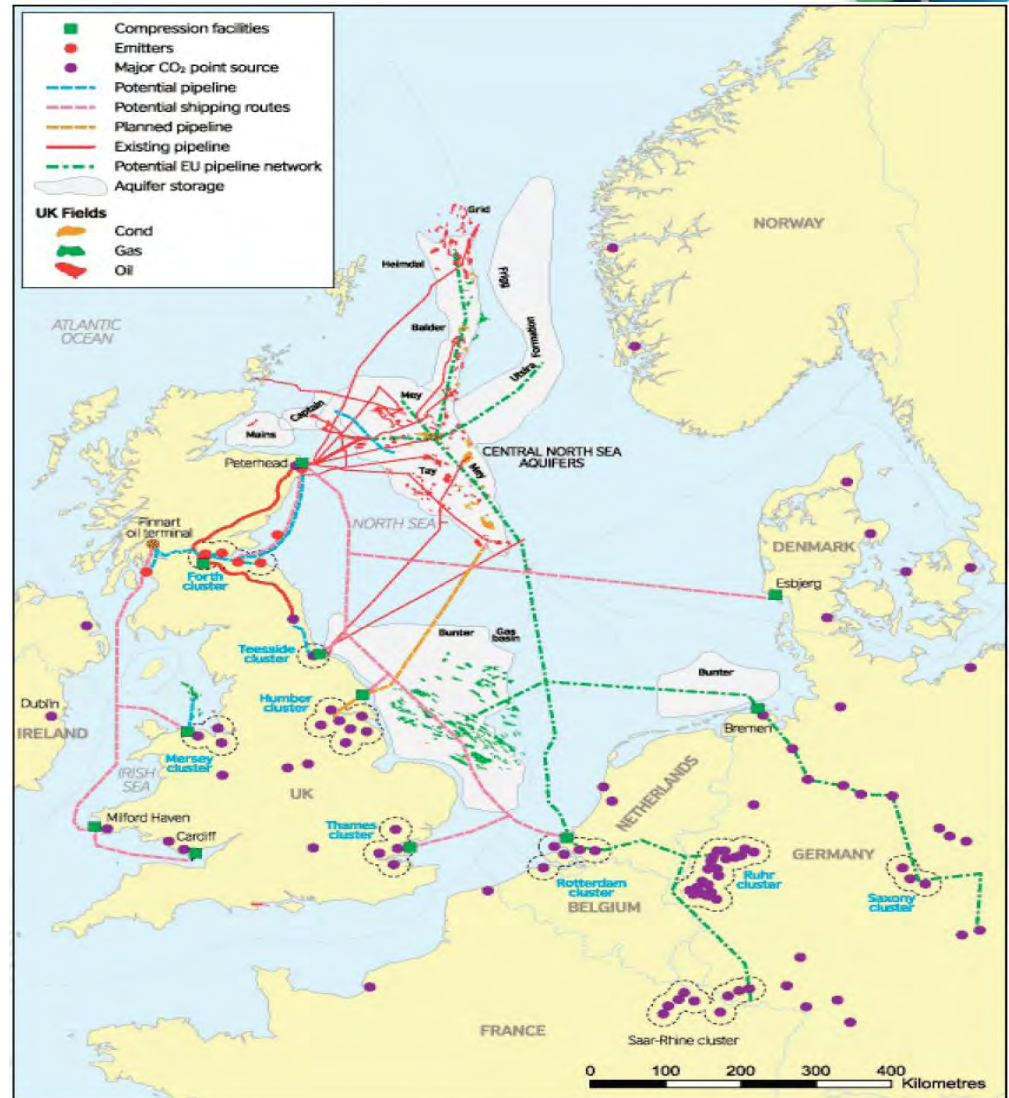


- Each industrial site will be site specific
  - No generalities possible like CCS Ready Guidelines for Power sector
- Need a gas gathering system?
  - More than one stack
  - Central capture plant or multiple?
  - Or do you target most competitive single source – 45% capture enough
- Development of transport infrastructure
  - Strategic planning
  - Who pays?

# Hubs and Clusters



- Port of Rotterdam
- Port of Antwerp (Belgium)
- LeHavre (France)
- Humber side
- Baltic Sea Energy Co-operation (BASREC)



Central North Sea – CO<sub>2</sub> Storage Hub : Enabling CCS deployment in the UK and Europe

# Experience to date



- Experience from demonstration projects in power sector
  - Need to start storage assessments early
  - Highest source of project risk
  - Large up front cost, which you may lose
    - Who pays for those costs and takes the risks?
  - Who undertakes work? – geological surveys or geoengineering contractors
  - Biggest issue regarding public acceptance
    - Security of storage issues

# Some Examples of CCS Research in Steel Industry



- ULCOS Project - Europe
  - Developing oxy blast furnace with top gas recycle and capture
- Japan - COURSE 50 Project
  - Demonstrate post combustion capture from blast furnace – 30tpd pilot scale
- Korea
  - Demonstrate ammonia scrubbing of blast furnace gas, 2<sup>nd</sup> stage pilot testing (~10tpd)

# CCS Research in Cement Industry



- European Cement Research Association (ECRA)
  - Phased development project for pilot scale demonstration of oxy fuel firing of cement kiln in late 2013.
- NORCHEM/CLIMIT & ECRA
  - Pilot scale project for post combustion capture on cement kiln in 2013/14
- ITRI – Taiwan
  - 10 MW Calcium Looping pilot plant constructed in 2013

# Industry CCS activities



- **Steel sector**
  - 1st Steel industry CCS workshop with VDEH in Germany in November 2011
  - Techno- economic assessment of CCS in steel sector – completed 2013
    - Included a case evaluating Oxy-Blast Furnace with TGR & MDEA CO<sub>2</sub> Capture
  - Overview of the current state and future development of CO<sub>2</sub> capture technologies in the Iron Making Process, TR3, April 2013
  - 2nd Steel industry CCS workshop in Japan November 2013 – collaboration with WSA and IETS
- **Cement Industry**
  - Techno- economic assessment completed in 2008
  - Studies on barriers to implementation completed in 2013 (with GCCSI)
- **Oil Refining Sector**
  - Techno- economic assessment to start mid 2014
  - Industrial sources of Hydrogen to start late 2014
- **Natural Gas Processing**
  - CO<sub>2</sub> Capture by novel solid adsorption processes underway
- **Pulp and Paper** - Study in planning for 2015 start



[www.GHGT.info](http://www.GHGT.info)

October 5 - 9  
**TWO THOUSAND FOURTEEN**  
AUSTIN, TX – USA

### Technical Programme

- Two technical sessions  
– 10 papers on CCS in Industry
- 20 industry CCS papers in poster sessions
- One panel discussion session on Industrial CCS



AUSTIN TX

### Key dates

- Registration opened 7<sup>th</sup> March 2014
- Early bird closes 13<sup>th</sup> June 2014