



CCUS Moving Ahead: Recent Technical Advances

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IEA-MOST Workshop

Advances in Deployment of Fossil Fuel Technologies

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Beijing, China

What is our remit?



All Greenhouse
Gases – Focus on
CO₂

Our
Remit
Covers



Fossil Fuels &
BioCCS

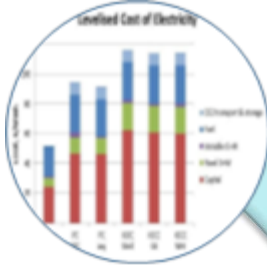


Power Sector and
Major Industrial sectors

What do we do?



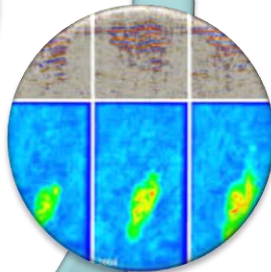
Assessing Mitigation Options
– Focus our R&D CCS



Tracking Capture Technology
Developments/Costs



Monitoring Geological
Storage Performance



Providing Members and Policy
Audience with Independent
Technical Input



Our Core
Activities
Are:



United Nations
Framework Convention on
Climate Change



Commercial Application of CCS (to date)



Sleipner
1Mt/y CO₂



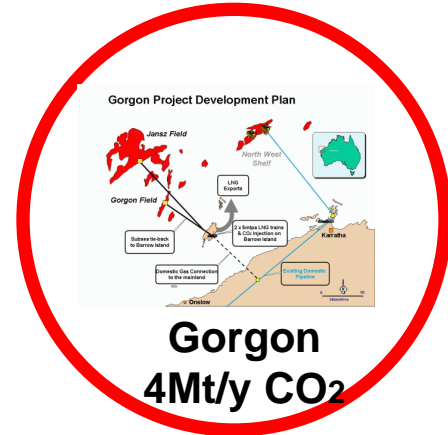
Weyburn
2.5 Mt/y CO₂



In-Salah
1.2 Mt/y CO₂



Snohvit
0.7Mt/y CO₂



Gorgon
4Mt/y CO₂



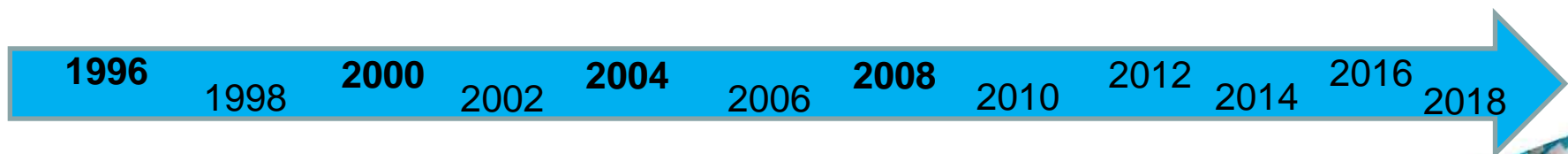
350km overland pipeline

150MW
e



160km sub sea pipeline

- Major Scale up in Storage experience
- 600MWe power plant
- Pressure Management involved



Boundary Dam, 110MWe



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 – 1M MTPY 2017 start

Archer Daniels Midland

CO₂ Capture from Ethanol Plant
CO₂ 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 CO₂ Capture
\$775 M – Total
\$167M – DOE
EOR – ~1.4M MTPY 2016 start

Air Products and Chemicals, Inc.

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

Leucadia Energy

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



U.S. DEPARTMENT OF
ENERGY

Fossil
Energy

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 “Green” pipeline for EOR in Texas at West Hastings oil field
- Total Project: \$431 MM; DOE Share: \$284 MM (66%)



Key Dates

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

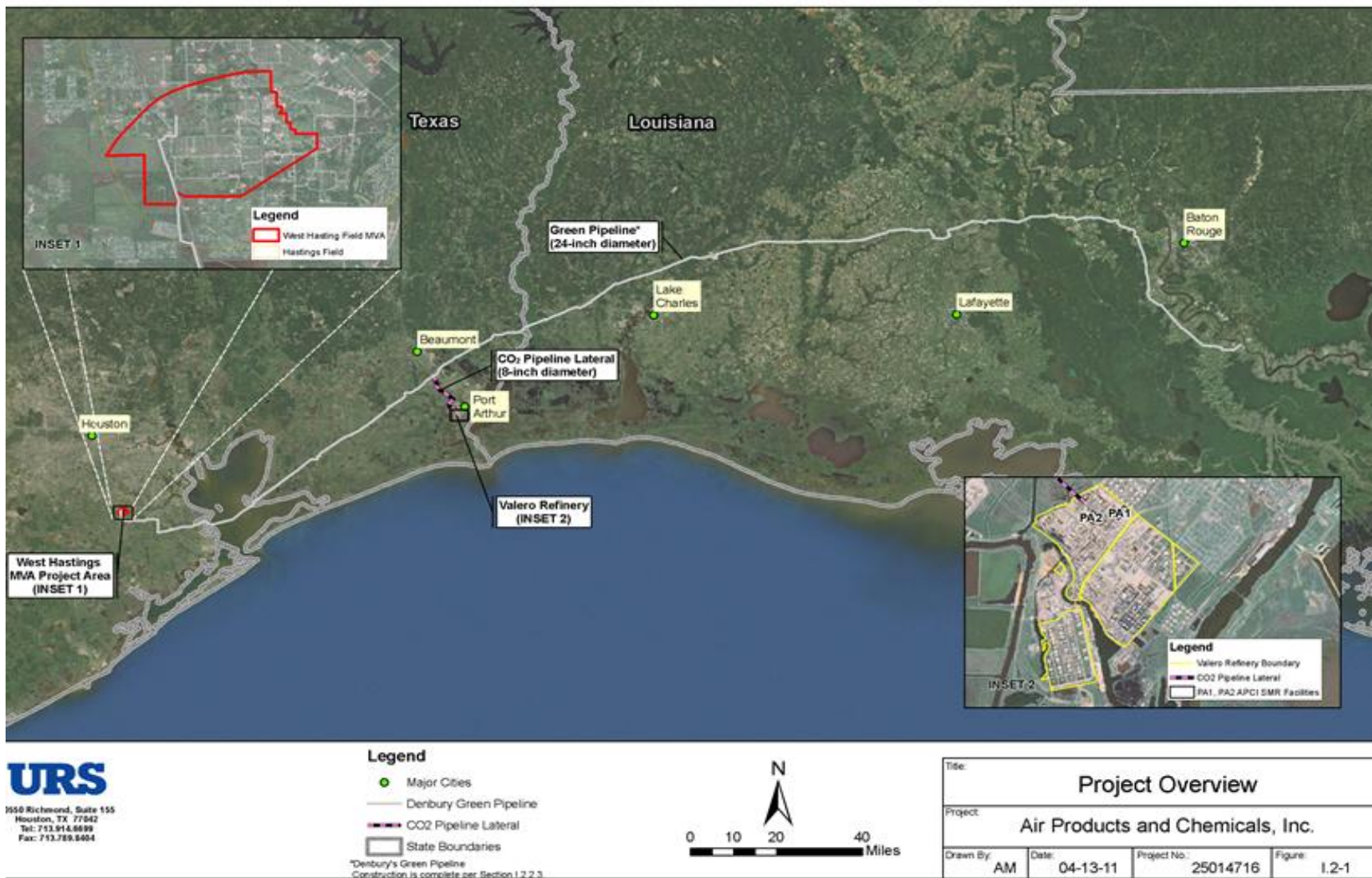
Status

- PA-1 initiated operation: Mar 3, 2013
- PA-2 initiated operation: Dec 16, 2012
- Full capacity achieved: Apr 2013
- CO₂ compressor trip; damage to internals; May 29, 2013; CO₂ compressor restart: July 1, 2013
- Has operated at >100% of design when necessary
- **1MM tonnes CO₂ delivered on 4/24/14**
- **1,111,076 tonnes CO₂ delivered as of 6/9/14**



Air Products and Chemicals, Inc. - Port Arthur 2

CO₂ Transportation to Sequestration Site (from Final Environmental Assessment)



US Industrial CCS Drivers



CO₂-EOR OPERATIONS, CO₂ SOURCES: 2014

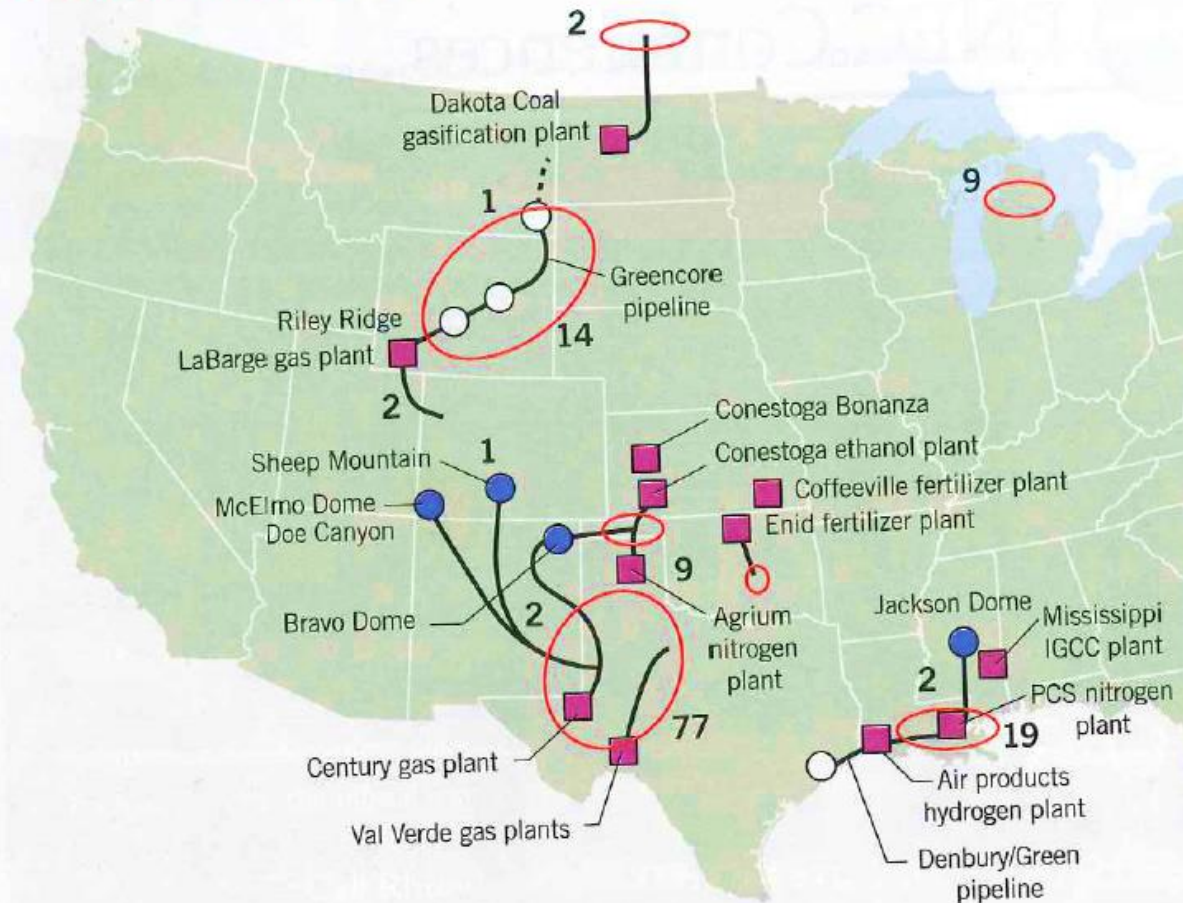


FIG. 1

Oil production, 2014

CO ₂ -EOR projects	136
Oil production, 1,000 b/d	300

CO₂ supplies, 2014

Number of sources	17
• Natural	5
• Industrial	12
CO ₂ supply, MMcfd	3.5
• Natural	2.8
• Industrial	0.7

136 Number of CO₂-EOR projects

- Natural CO₂ source
- Industrial CO₂ source
- CO₂ pipeline
- CO₂ proposed pipeline

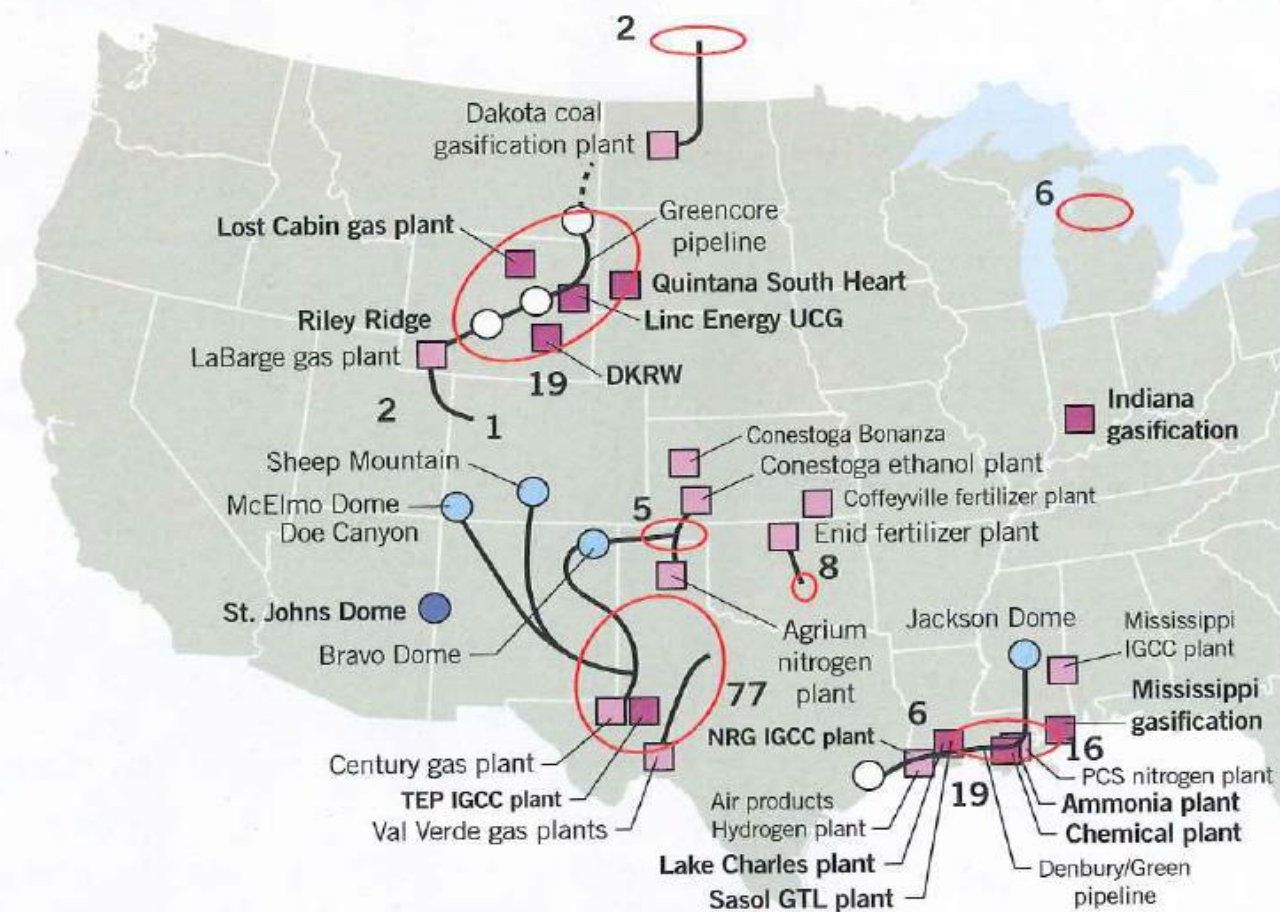
Source: Advanced Resources International Inc. based on OGI EOR/Heavy Oil Survey 2014 and other sources

CO₂-EOR Driving Expansion Of Industry CCS.



PROJECTED CO₂, EOR OPERATIONS, AND CO₂ SOURCES: 2020

FIG. 4



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

147 Number of CO₂-EOR projects

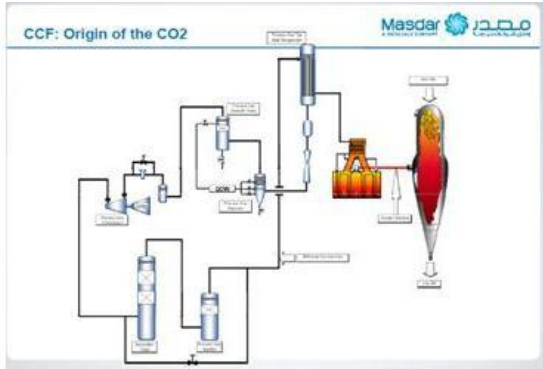
● Natural CO₂ source

■ Industrial CO₂ source

— CO₂ pipeline

..... CO₂ proposed pipeline

ESI CCS Project Technical Overview



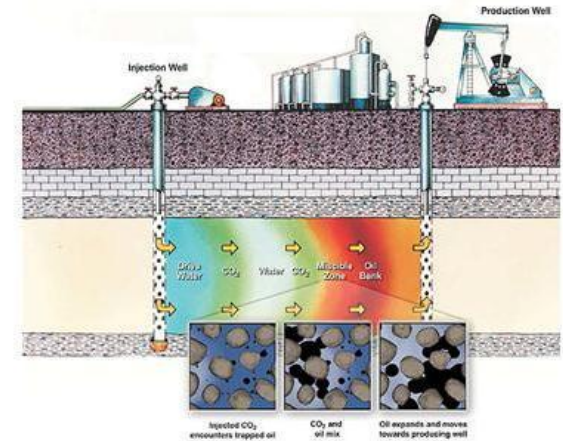
CO2 Source (ESI) and Capture



CO2 Transportation



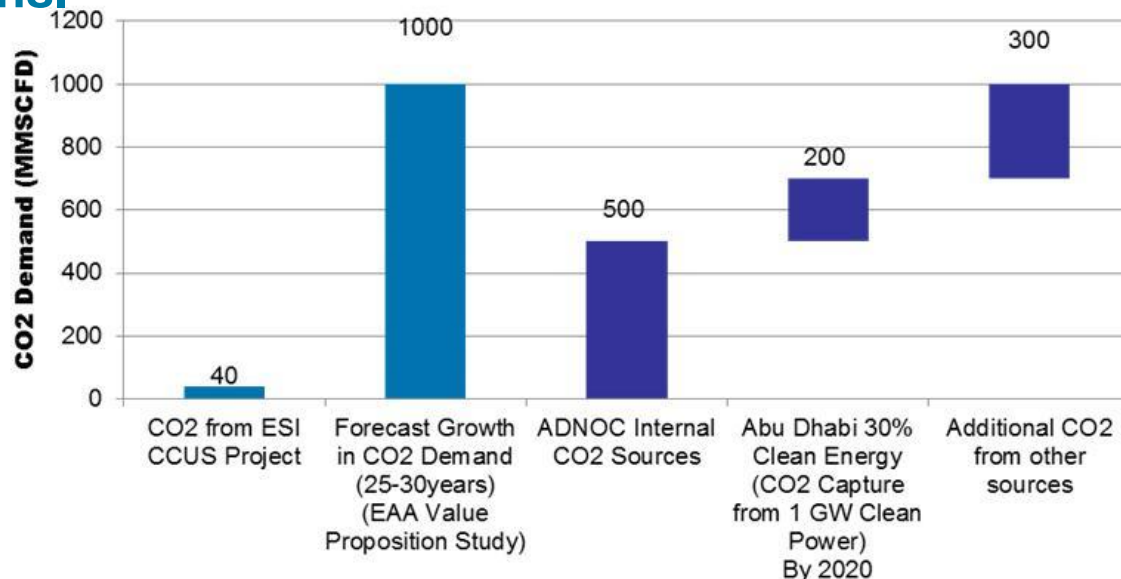
CO2 Compression & Dehydration



CO2 Injection in Rumaitha & Bab fields

Abu Dhabi CCS: Future Potential

- **CO₂ as an EOR agent has been endorsed:**
 - Success of the ESI CCS Project and Rumaittha / Bab Injection are key to future development.
- **Changing landscape in Abu Dhabi with potential CO₂ targets for field testing and development:**
 - CO₂ capture linked to ADNOC field demand and performance;
- **Whilst preliminary, the EAA CCS Value Proposition study forecast a growing CO₂ demand in the next 25-30 years, based on ADNOC estimations.**



Some Examples of CCS Research in Steel Industry



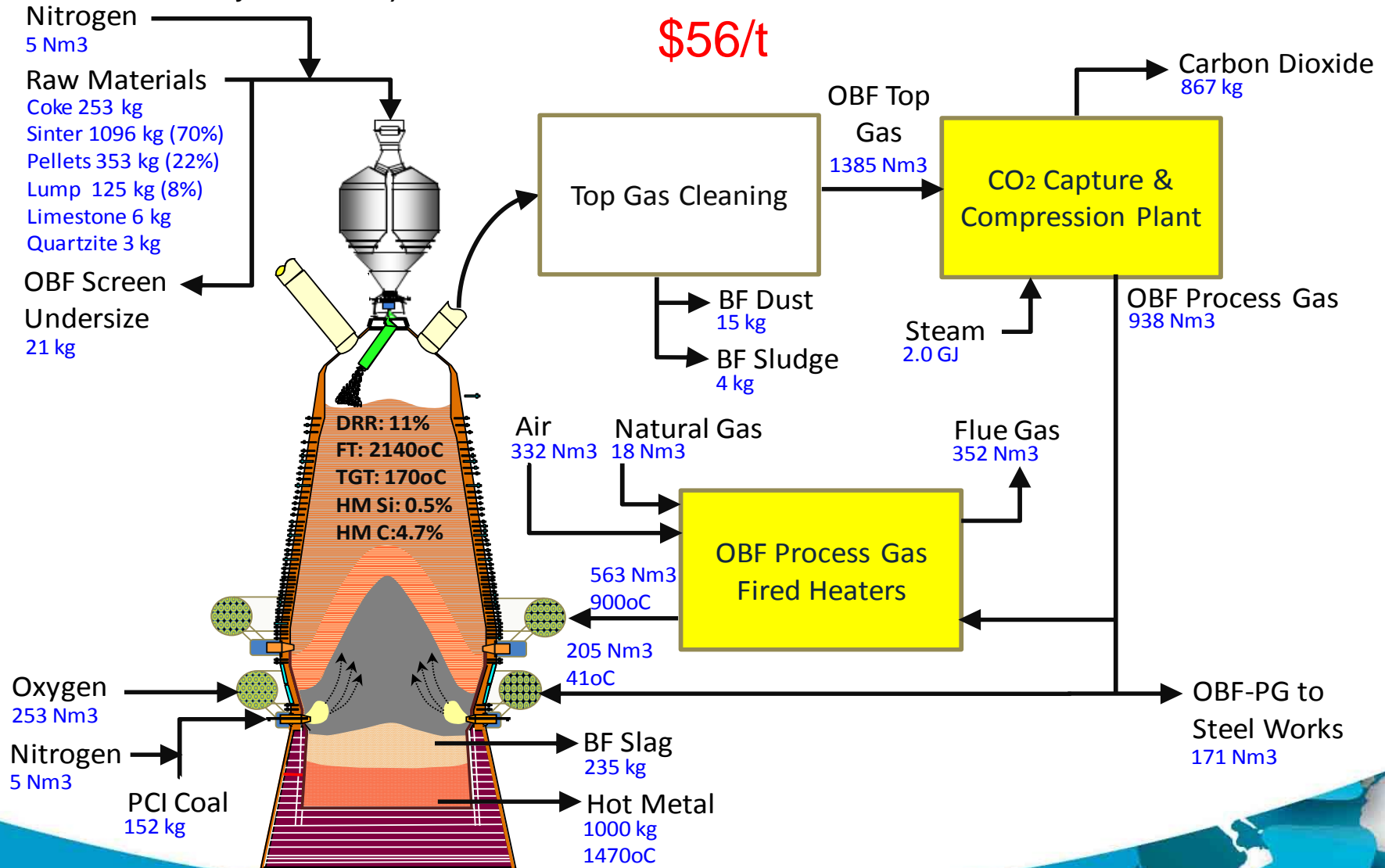
- ULCOS Project - Europe
 - Developing oxy blast furnace with top gas recycle and capture – pilot scale blast furnace
- Japan - COURSE 50 Project
 - Demonstrate post combustion capture from blast furnace – 30tpd pilot scale
- Korea
 - Demonstrate ammonia scrubbing of blast furnace gas, 2nd stage pilot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

Oxy-Blast Furnace Operation



CO₂ avoided
\$56/t

(Picture of OBF courtesy of Tata Steel)



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
 - Also testing:
 - Fixed bed absorbers & Membranes

CO₂ Capture at Cement Plants



Oxy-combustion Pilot Plant Project

- Feasibility of oxy-combustion at cement plants investigated by Lafarge, FLSmidth and Air Liquide
- Pre-calcliner pilot plant at Dania, Denmark successfully modified and operated with oxy-combustion
 - 2-3t/h raw meal (~1t/h CO₂)
 - Pre-calcliner accounts for 90% of CO₂ from carbonate decomposition and 60% of fuel-derived CO₂ from a cement plant
- Feasibility and costs of retrofitting oxy-combustion calcliner to Lafarge commercial cement plant at Le Havre was assessed
 - €62/t CO₂ captured (consistent with IEAGHG studies)
- Technology now ready to move into the demonstration phase
 - Next stage would be a 1-2 year FEED study
 - Currently no viable business case for CCS at European cement plants



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 7th March 2014
- Early bird closes 13th June 2014



Thank you, any Questions?

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