A Global Perspective on CO_2 Capture Developments

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General Manager

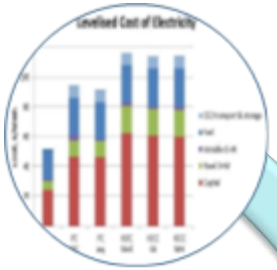
IEA Greenhouse Gas R&D Programme

2014 CO_2 Capture Technology Meeting

Pittsburgh, PA, USA

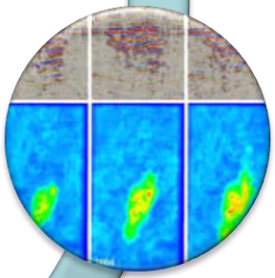
What do we do?

Our Core Activities Are:



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

United Nations
Framework Convention on
Climate Change

Commercial Application of CCS (to date)

Sleipner
1Mt/y CO_2

Weyburn
2.5 Mt/y CO_2

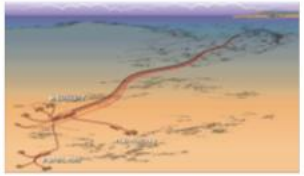
In-Salah
1.2 Mt/y CO_2

Snohvit
0.7Mt/y CO_2

Gorgon
4Mt/y CO_2

350km overland pipeline

150MW e



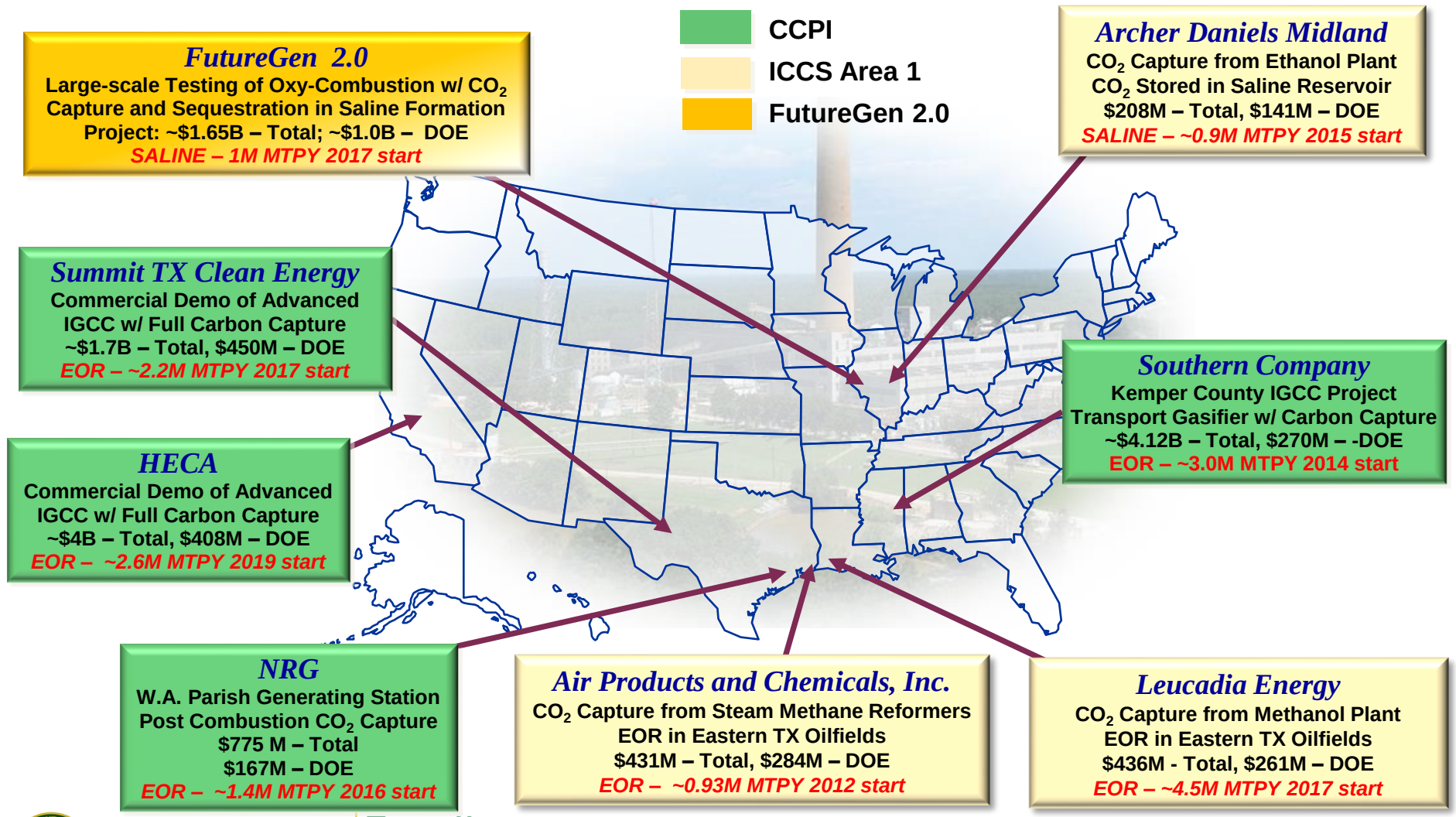
160km sub sea pipeline

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

Boundary Dam, 110MWe

Major CCS Demonstration Projects

Project Locations & Cost Share



FutureGen 2.0
Large-scale Testing of Oxy-Combustion w/ CO_2 Capture and Sequestration in Saline Formation
Project: ~$1.65B – Total; ~$1.0B – DOE
SALINE – 1M MTPY 2017 start

Archer Daniels Midland
CO_2 Capture from Ethanol Plant
CO_2 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

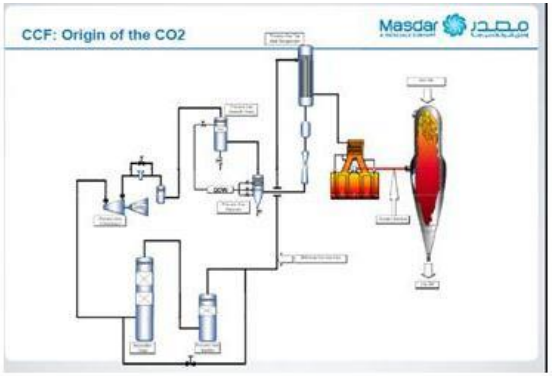
NRG
W.A. Parish Generating Station
Post Combustion CO_2 Capture
$775 M – Total
$167M – DOE
EOR – ~1.4M MTPY 2016 start

Air Products and Chemicals, Inc.
CO_2 Capture from Steam Methane Reformers
EOR in Eastern TX Oilfields
$431M – Total, $284M – DOE
EOR – ~0.93M MTPY 2012 start

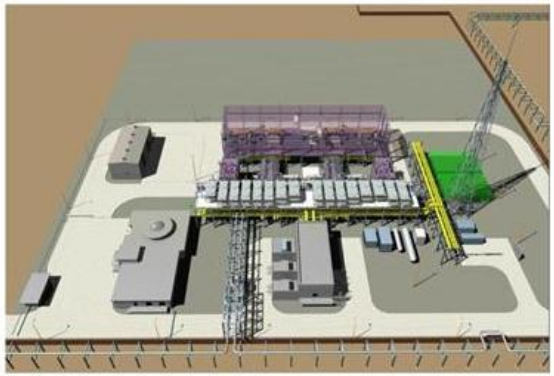
Leucadia Energy
CO_2 Capture from Methanol Plant
EOR in Eastern TX Oilfields
$436M - Total, $261M – DOE
EOR – ~4.5M MTPY 2017 start

U.S. DEPARTMENT OF ENERGY | Fossil Energy

ESI CCS Project Technical Overview

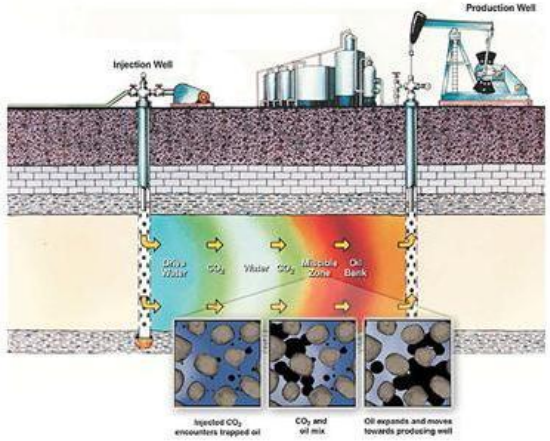


CO2 Source (ESI) and Capture



CO2 Compression & Dehydration

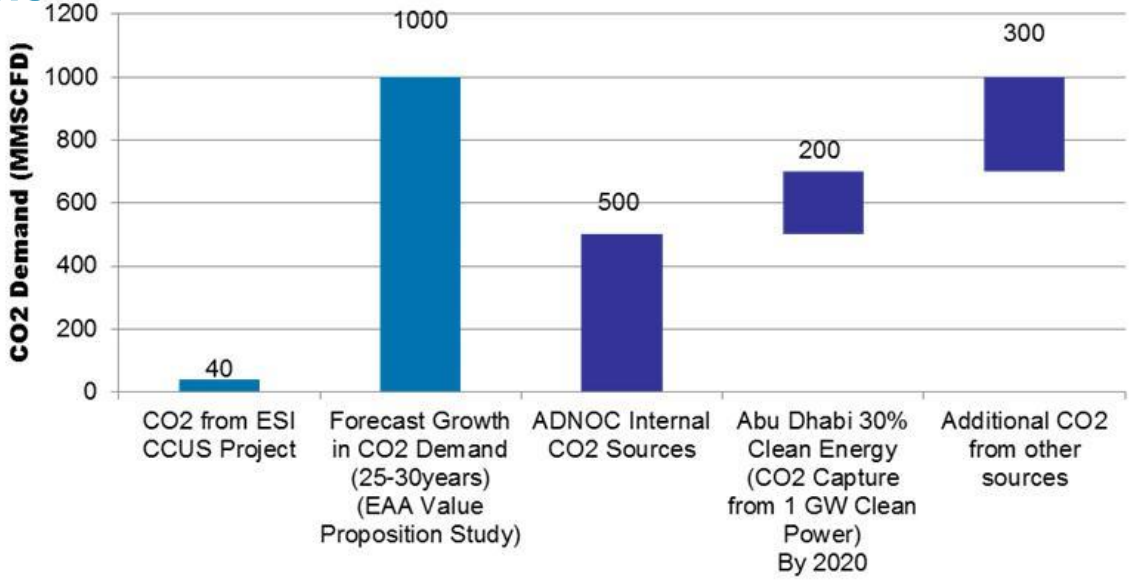
CO2 Transportation



CO2 Injection in Rumaitha & Bab fields

Abu Dhabi CCS: Future Potential

- **CO_2 as an EOR agent has been endorsed:**
  - Success of the ESI CCS Project and Rumaitha / Bab Injection are key to future development.
- **Changing landscape in Abu Dhabi with potential CO_2 targets for field testing and development:**
  - CO_2 capture linked to ADNOC field demand and performance;
- **Whilst preliminary, the EAA CCS Value Proposition study forecast a growing CO_2 demand in the next 25-30 years, based on ADNOC estimations.**

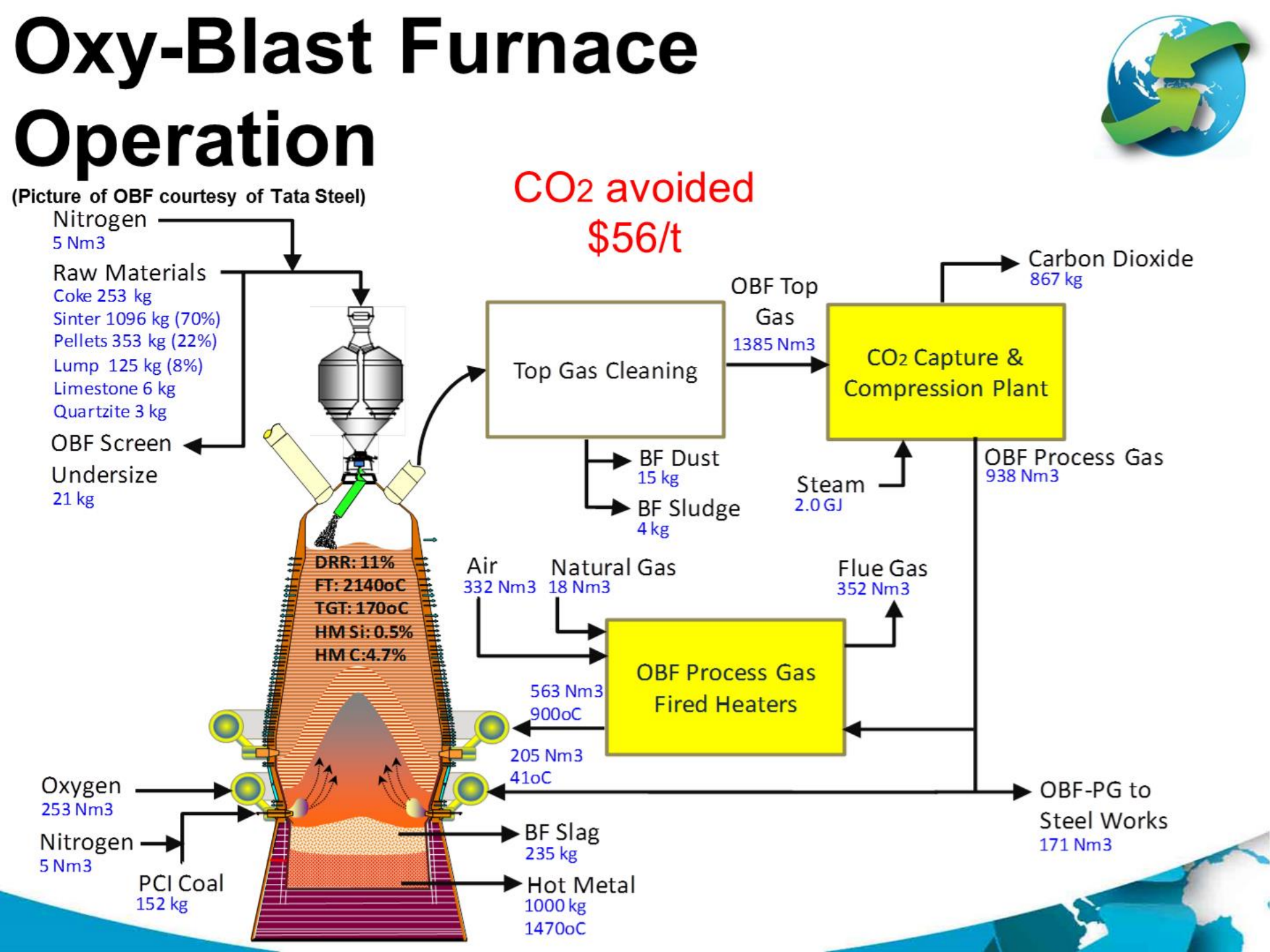


Some Examples of CCS Research in Steel Industry

- 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

(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
- ITRI, Taiwan
  - Pilot scale testing of CLC

CO_2 Capture at Cement Plants

Oxy-combustion Pilot Plant Project

- Feasibility of oxy-combustion at cement plants investigated by Lafarge, FLSmidth and Air Liquide
- Pre-calciner pilot plant at Dania, Denmark successfully modified and operated with oxy-combustion
  - 2-3t/h raw meal (~1t/h CO_2)
  - Pre-calciner accounts for 90% of CO_2 from carbonate decomposition and 60% of fuel-derived CO_2 from a cement plant
- Feasibility and costs of retrofitting oxy-combustion calciner to Lafarge commercial cement plant at Le Havre was assessed
  - €62/t CO_2 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

Summary

- Post combustion capture
  - Proven technology
  - Demonstrated at a scale in 2014
- Pre combustion capture
  - Will be demonstrated at a scale in 2015
- Oxy-fuel combustion
  - Ready for demonstration
    - 2017 earliest

Variable Renewable Energy

- Represents a big challenge in markets with high renewable penetration
- Can capture plants meet flexible demand requirements?
- Or are we stuck with base load operation?
- IGGC with H_2 production/storage might offer a flexible power system

Challenges

- Post combustion capture
  - Need to scale up to 1-1.2GW size for developing country market
- Pre-combustion
  - Need to develop confidence in IGGC technology
    - Bad press in early 90’s
- Oxy-fuel
  - Need to demonstrate
  - Currents size of ASU fits industry market, need to build super ASU’s as multiple units will add cost

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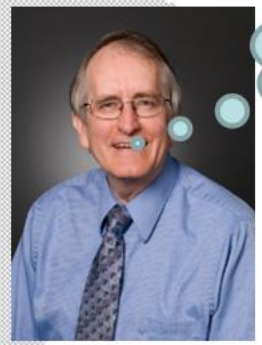

- 340 Oral Papers
  - 2 parallel tracks on capture
- 600 Posters papers
  - 50% on capture

Key dates

- Registration opened 7th March 2014
- Early bird closed 13th June 2014
- 770 Registered at Early Bird

Thank you, any Questions?

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