World CCS: Current Status, Challenges and Future Directions

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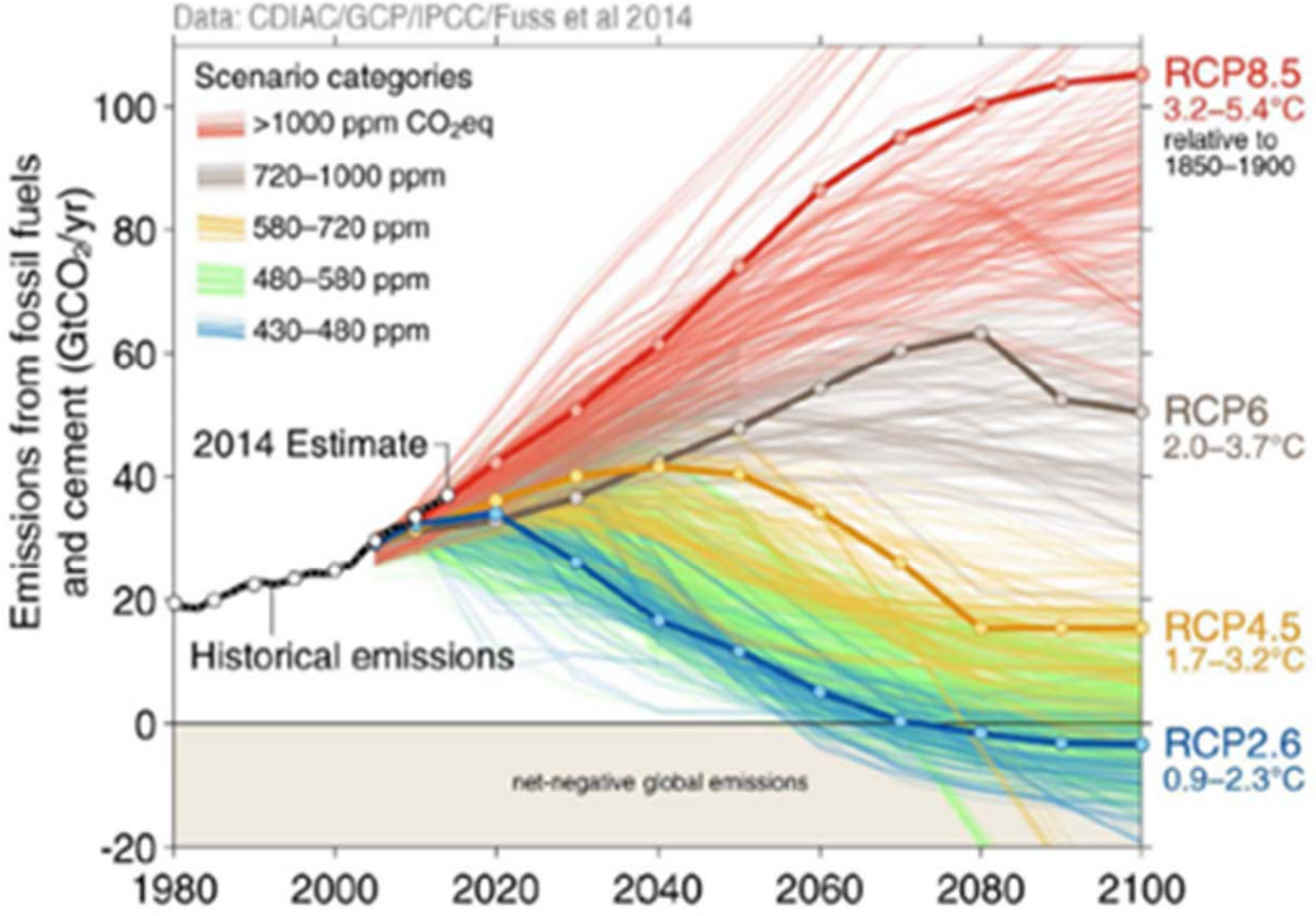
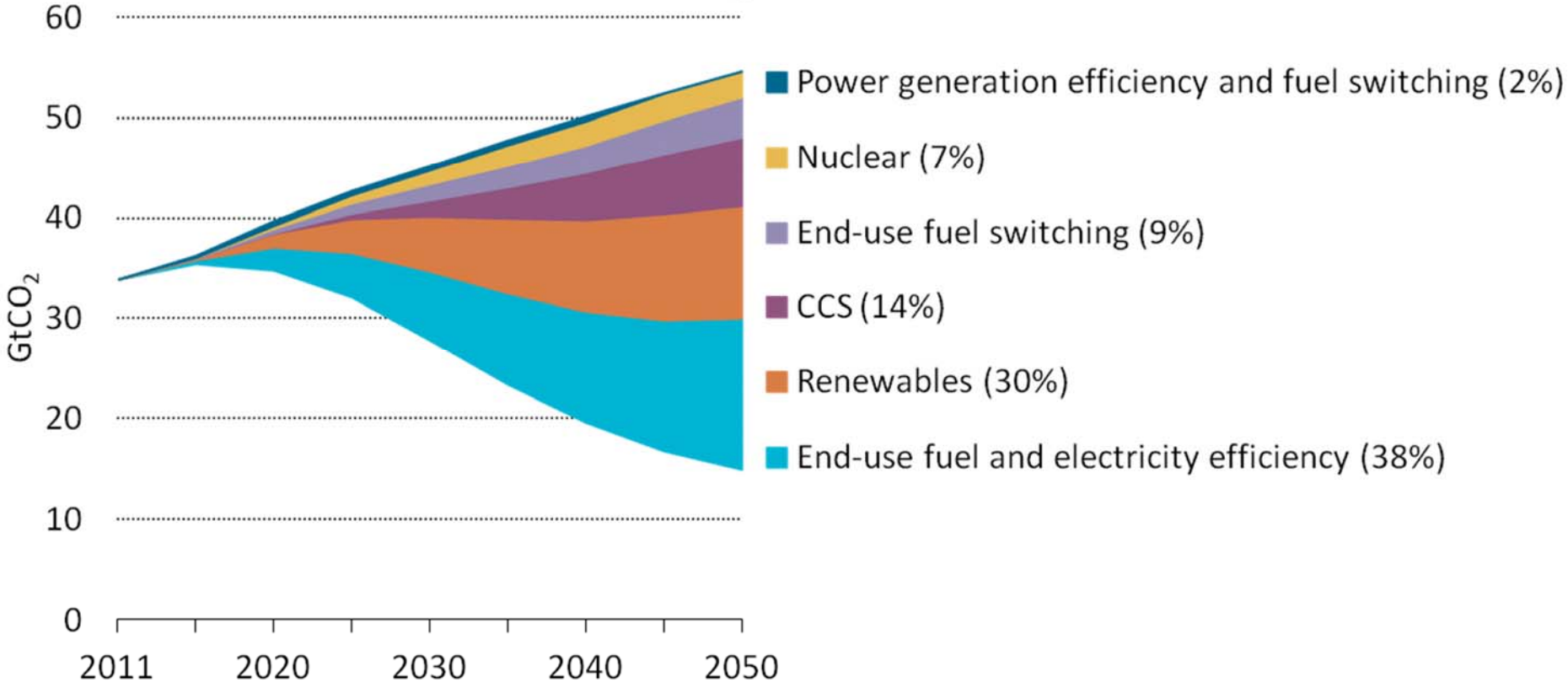
Why are we here?



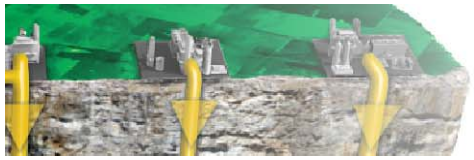
Consequences of not making the 2DS

The potential future effects of global climate change include more frequent wildfires, longer periods of drought in some regions and an increase in the number, duration and intensity of tropical storms. Source: http://climate.nasa.gov/effects/

CCS is one of the key technologies to tackle climate change

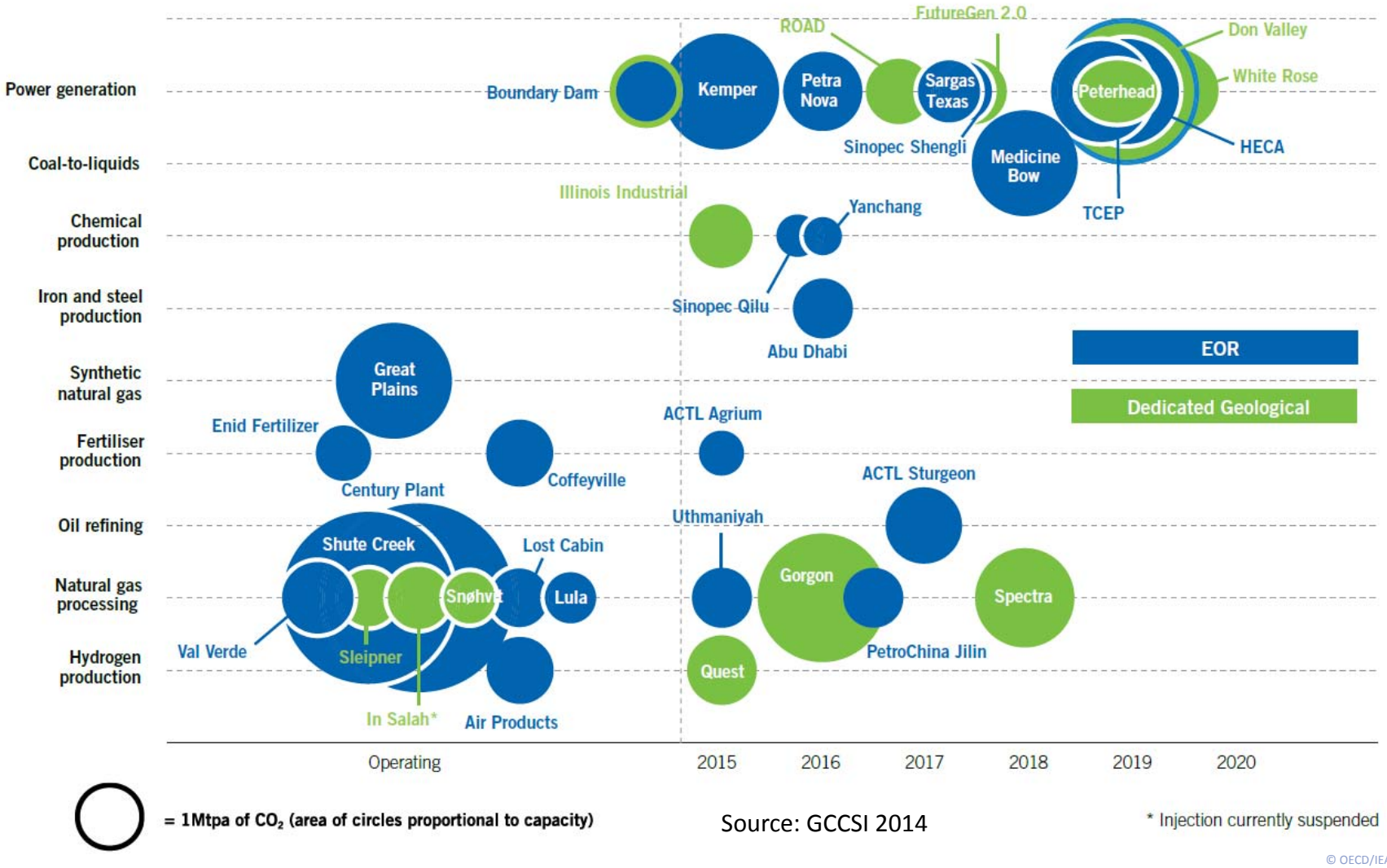


Carbon capture and storage (CCS) contributes 14% of total emissions reductions through 2050 relative to the IEA 6DS scenario



International Energy Agency

Around a dozen projects are at earlier stages of development



Source: GCCSI 2014

Important CCS Projects - Power Sector

Boundary Dam 3, Canada

- Refit of existing coal fired unit
- Operational for 1 year
- CanSolv amine based PCC technology
- 110MWe
- 95% capture
- CO_2 sold for EOR

NRG Parish, USA

- Refit of existing coal fired unit
- Operational in late 2016
- MHI amine based PCC technology
- 250 MW slip stream
- 90% capture
- CO_2 sold for EOR

Important CCS Projects - Power Sector

- Kemper County Project, USA
  - Novel IGCC Technology
  - 524 MW lignite fired – new build
  - 65% of total emissions captured
  - Due on stream late 2016

SMR Based H2 Production CCS Projects

- Large scale demo projects
  - AP Port Arthur Project (USA)
    - Operational - ~1 million tpy CO_2 captured for EOR
  - Shell Quest Project (Canada)
    - Under construction - ~ 1 million tpy CO_2 captured and stored (on-shore) in saline acquifer
- Large scale pilot projects
  - Repsol (Spain)
    - Operational since 2002, 60k tpy CO2 captured for sale as food grade CO2
  - AL Port Jerome Project (France)
    - Under commissioning - ~100k tpy CO_2 captured for sale as food grade CO_2.
  - Japan CCS Tohokamai Project (Japan)
    - Under construction - ~200k tpy CO_2 captured and stored (off-shore) in saline acquifer

Bio Ethanol Based CCS Projects

Decatur CCS project

- 1 Mt CO_2 captured and stored in a deep saline aquifer
- Alstom amine based capture technology
- Now in non operational mode

Industrial CCS Project

- Includes initial CCS project
- Total of 3.6mT/y CO_2 captured
- CO_2 injected into a deep saline aquifer from June 2015
- Uses Amine based capture technology

Key Developments Going Forward (2015 onwards-2016)

- Quest Project start up (October 2015)
- Kemper County IGCC project Start up – late 2015
- Gorgon project start up late 2015
- Announcement of UK Competition results (2016)
    - Peterhead – Gas fired power plant with CCS
    - White Rose – Oxy fired power plant
- FID on Road Project in Netherlands (2016)
- NRG Parish operational in late 2016

IEA ETP2015 – Tracking Energy Progress

- CCS not on track for 2DS
  - positive developments noted (Boundary Dam 3)
- CCS deployment has begun in “sweet spots” where policies and strategic local and commercial interests align
  - CO2-EOR an enabler in some regions e.g. USA and Canada
- “Learning-by-doing” is now also under way for CCS in power generation and some industry sectors.
- Widespread deployment requires the cost gap be closed by determined, parallel action in technology development and market creation.
- Improving and using post-combustion technologies is of particular importance

United States of America

- Significant R,D&D activities underway
- International collaboration high on agenda
  - China co-operation agreements
- Regulatory process for geological storage based on existing underground injection control programme approved in 2010
  - EPA developed specific criteria for Class VI wells:
    - Extensive site characterization requirements
    - Well construction standards
    - Comprehensive monitoring plan
    - Wells Financial responsibility requirements

New regulatory developments

- Clean Power Act, August 2015
  - Sets out emission performance standards for new and existing power plants
  - New natural gas power plants can emit no more than 1,000 pounds (lbs) CO_2 per MWh
  - New coal power plants can emit no more than 1,400 lbs CO_2/MWh,
    - Will require use of carbon capture and storage (CCS)
    - But not 90% capture as at Boundary Dam 3.
    - Probably means that CCS technology under demonstration in USA at or close to scale needed to meet these standards

Global Status of CO2-EOR

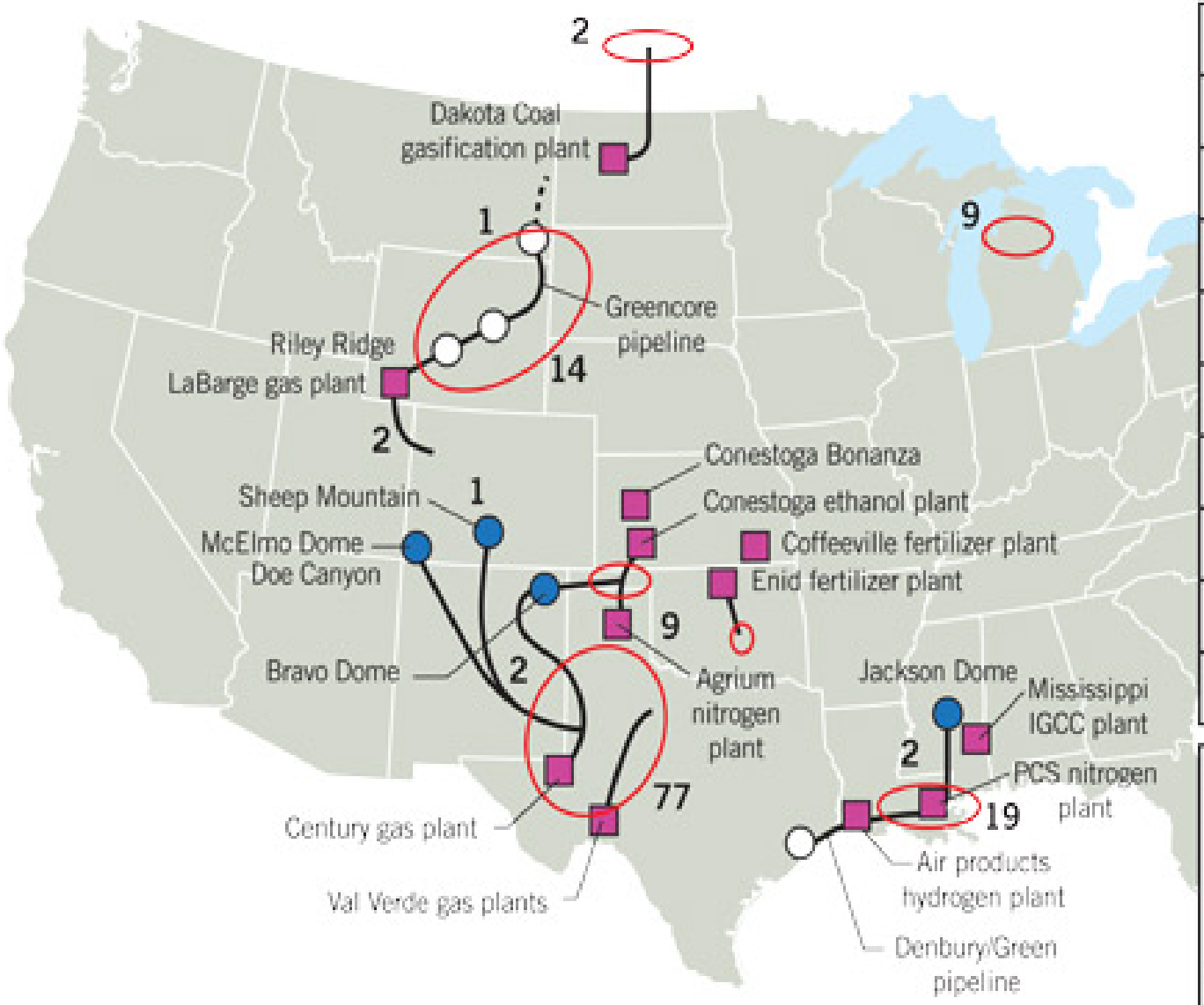
- Principally North America (USA + Canada)
  - USA
    - 136 projects injecting 3.5Mt CO_2
    - Many projects Operating since mid 1980's
    - 3600km pipeline network – mostly non anthropogenic CO_2
    - Regulatory process developed – EPA Class II Wells
    - Drivers
      - » Tax incentives for increased oil production
      - » Readily accessible "cheap" CO_2
      - » Large numbers of small fields with high ROIP levels
      - » High exploration capacity

USA CO2-EOR Experiences

- Commercial technology proven to recover cost effectively additional oil
- Robust regulatory process tested for over 20 years
  - Potential problems with new EPA Class VI wells for CO_2 Storage
  - Limited monitoring under Class II well program
- Safety record industry good
  - US DOT records on pipeline safety
    - Good track record over 20+ years
  - No associated issues – like CBM or unconventional oil and gas
- Not originally as well researched as storage
  - IEAGHG Weyburn-Midale CO2-EOR monitoring and stage project (2000-2012)

CO_2-EOR OPERATIONS, CO_2 SOURCES: 2014

FIG. 1



Oil production, 2014	
CO_2 –EOR projects	136
Oil production, 1,000 b/d	300
CO_2 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 CO_2-EOR projects

Natural CO_2 source

Industrial CO_2 source

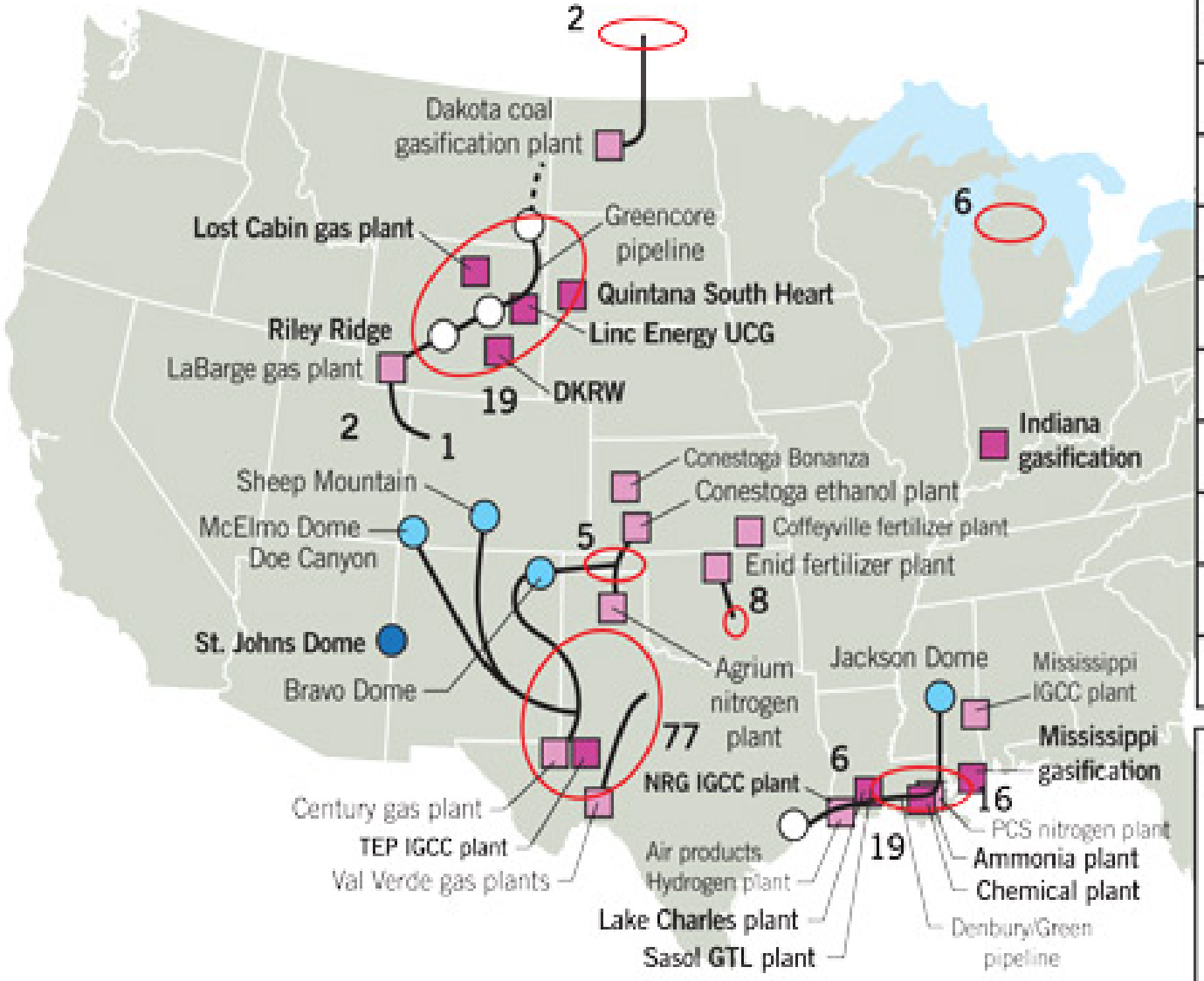
CO_2 pipeline

CO_2 proposed pipeline

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

PROJECTED CO_2, EOR OPERATIONS, AND CO_2 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 CO_2-EOR projects
Natural CO_2 source
Industrial CO_2 source
CO_2 pipeline
CO_2 proposed pipeline

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

Global estimate for storage

- 2009 IEAGHG study gave a global capacity of 140 GtCO_2 storage in depleted oil fields
  - in worlds 10 most prospective basins
- Implications:
  - CO_2-EOR will play a role in meeting global CO_2 storage needs
  - Depleted gas and deep saline reservoirs provide the primary storage resource in the longer term
  - The key roles it is currently playing are:
    - de-risking CCS demonstration projects
    - and developing pipeline infrastructure for future storage operations

CO2-EOR in Europe

- North Sea
  - Studies by Norway and UK, Shell and BP have shown CO_2-EOR be uneconomic in North Sea
    - Large field size, low sweep efficiency
    - High recovery rates using other EOR techniques
    - Large CO_2 volumes to be transported offshore, high infrastructure costs
    - Platform modification costs considered to be high
  - Prospects for near offshore CO2-EOR in Danish Oil Fields explored by Maersk – status unknown
  - UK Cost Reduction Task Force identified CO2-EOR as potential cost saving element for future CCS deployment
    - Tax incentives for brown field CO2-EOR opportunities
    - Opportunities were more limited than in USA
    - Synergies between CCS and CO2-EOR

European CCS Regulations

- OSPAR treaty amended to allow offshore CO_2 storage in 2007
  - Currently export of CO_2 prohibited under London Convention
  - CO_2 for EOR allowed
- European CCS Directive 2009
  - Transposed in Law of Member States in 2011
    - As of September 2015 all bar 2 countries have complied.
  - Directive Reviewed in March 2015
    - Fit for purpose not to revise
    - Additional guidelines required

EU Trading Scheme

- Launched in 2005, the EU ETS is now in its 3rd phase, running from 2013 to 2020.
- Phase 3 changes are:
  - A single, EU-wide cap on emissions applies in place of the previous system of national caps;
  - Auctioning, not free allocation, is now the default method for allocating allowances.
  - Some more sectors and gases are included;
  - 300 million allowances set aside in the New Entrants Reserve to fund the deployment of innovative renewable energy technologies & CCS
    - NER 300 programme.

NER 300/400

- White Rose Project in UK, only CCS project supported under NER 300 in July 2014
- New NER 400 programme being discussed for 2022 onwards
  - Could possibly fund CO2 infrastructure development?

Status of CCS in Europe

- United Kingdom
  - UK Competition £1billion capital funding set aside by Treasury
  - FEED now studies underway
    - Peterhead Gas Fired CCS Power Plant
    - White Rose, Oxy fired CCs power plant
  - Final Investment Decision end of 2015
  - UK Gov. will announce decision in early 2016
- https://www.gov.uk/guidance/uk-carbon-capture-and-storage-government-funding-and-support

Netherlands

- ROAD project currently stalled.
- Rumours are:
  - That funding shortfall has been resolved?
  - That EoN will make a positive announcement at Dutch CCS Seminar on October 16th?
  - The project team is being reassembled?
  - There might be an announcement to go ahead in 2016
  - As its a coal based non storage project there maybe a public backlash ???

Status of CCS in Norway

- Two commercial scale CCS project operating
  - Sliepner (19 yrs) & Snohvit
- Mongstad full scale CCS project cancelled in 2014
- Gassnova – three industrial CCS projects under consideration – decision in 2016

NORCEM BREVIK
(Cement)

YARA
PORSGRUNN
(Fertilizers)

KLEMETSRUD
OSLO
(Waste
incineration)

Capture Technology Lock In?

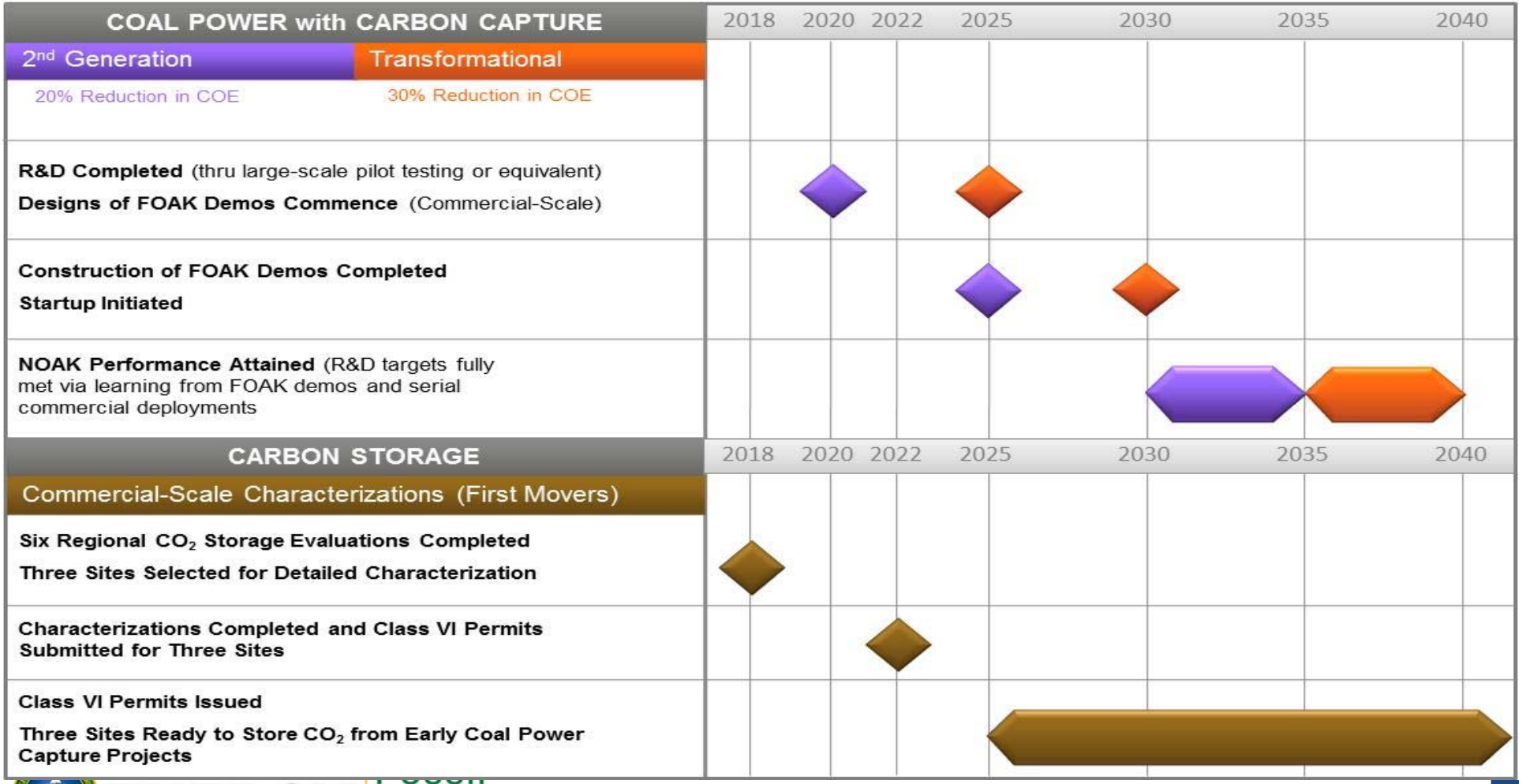
- UK CCS Commercialisation programme
- Competition – Phase 1 with Government Support
  - Demonstrate technology and de risk future projects
- Phase 2 will be a transition phase between heavily & Phase 3
  - Early Phase 2 FID's (pre 2020) may be needed before Phase 1 construction is complete
  - For later Phase 2 projects (early 2020s) Phase 1 projects are operating successfully
- Phase 3 projects (2025-2030) will be cost competitive in their own right.

Capture Technology Lock in?

- Experience from Boundary Dam 3 shows you need capture technology at scale to de risk investment
- Faster you implement the more you limit technology take up.
- Early Phase 2 projects in UK likely to use tested capture technology
  - If you are an investor which would you chose?
    - Amines, or Oxy? or IGGC??
  - As you go into later phases you build tried and tested technology with known costs and cost reduction options
    - Modularisation, reduced redundancy, use existing pipelines infrastructure, CO2-EOR
  - Leaves new capture technology in catch up mode unless you scale up quickly – inherent risk

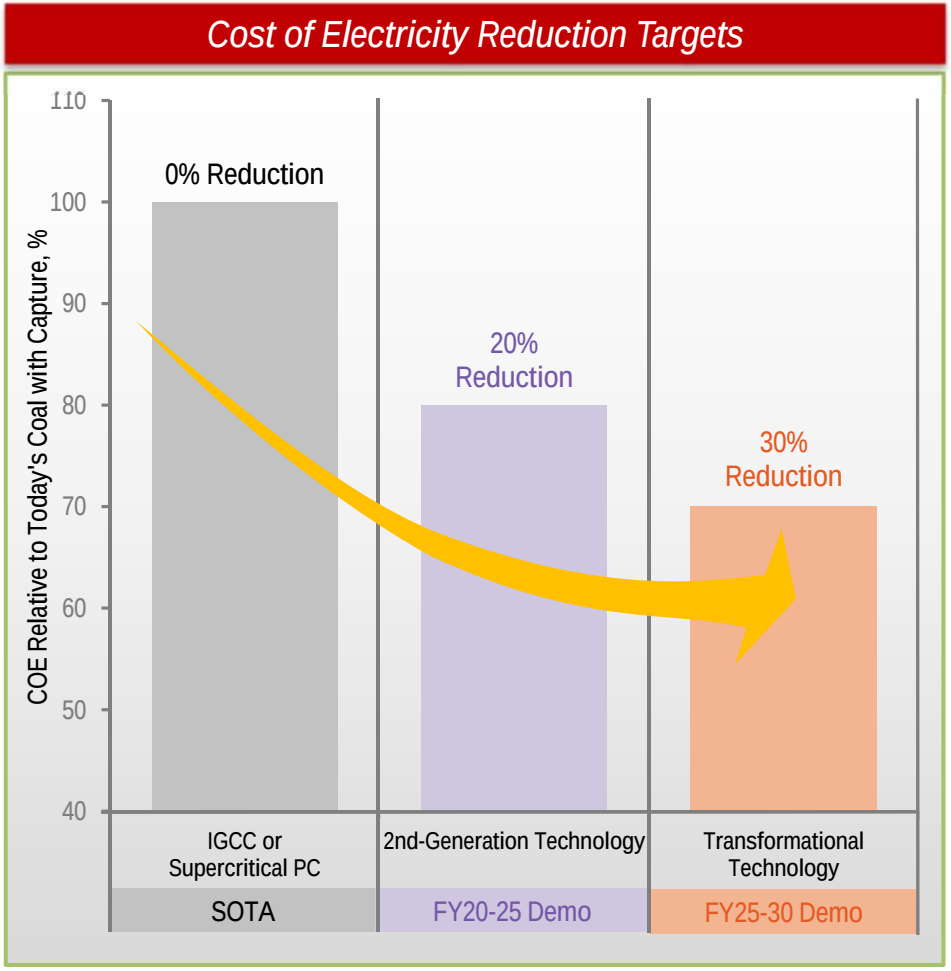
Must go farther and faster

2nd Gen and Transformational Technologies



ENERGY | Energy

DOE R&D Goals



Carbon Capture Program Objectives:

- Large-scale pilot validation
  - 2nd generation by 2020
  - Transformational by 2025
- Demonstration 5 years after each large pilot phase
- Meet 20% reduction by advanced solvents and systems; membranes, and sorbents
- Meet 30% goal through disruptive research in novel materials, advanced manufacturing, process intensification, electro chemical, and other advanced processes

U.S. DEPARTMENT OF ENERGY | Fossil Energy

Summary

- CCS deployment making steady progress
  - Demonstration projects underway in power sector and many industrial sectors
    - More in planning
- No show stoppers yet, plenty of positives
  - Cost reduction possibilities for FAOK and Phase 2 CCs plants
- Need new capture technology for significant cost
  - But rapid technology progress and demonstration at scale needed to avoid technology lock in.

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Call for abstracts opened 1st September 2015

Deadline for submission 10th February 2016

Registration opens 6th April 2016

Draft technical programme 1st June 2016

Early bird registration closes 13th July 2016

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