Carbon Dioxide Capture and Storage. What, Why, and Where?

Essential for our future, or a Trojan horse for big oil?

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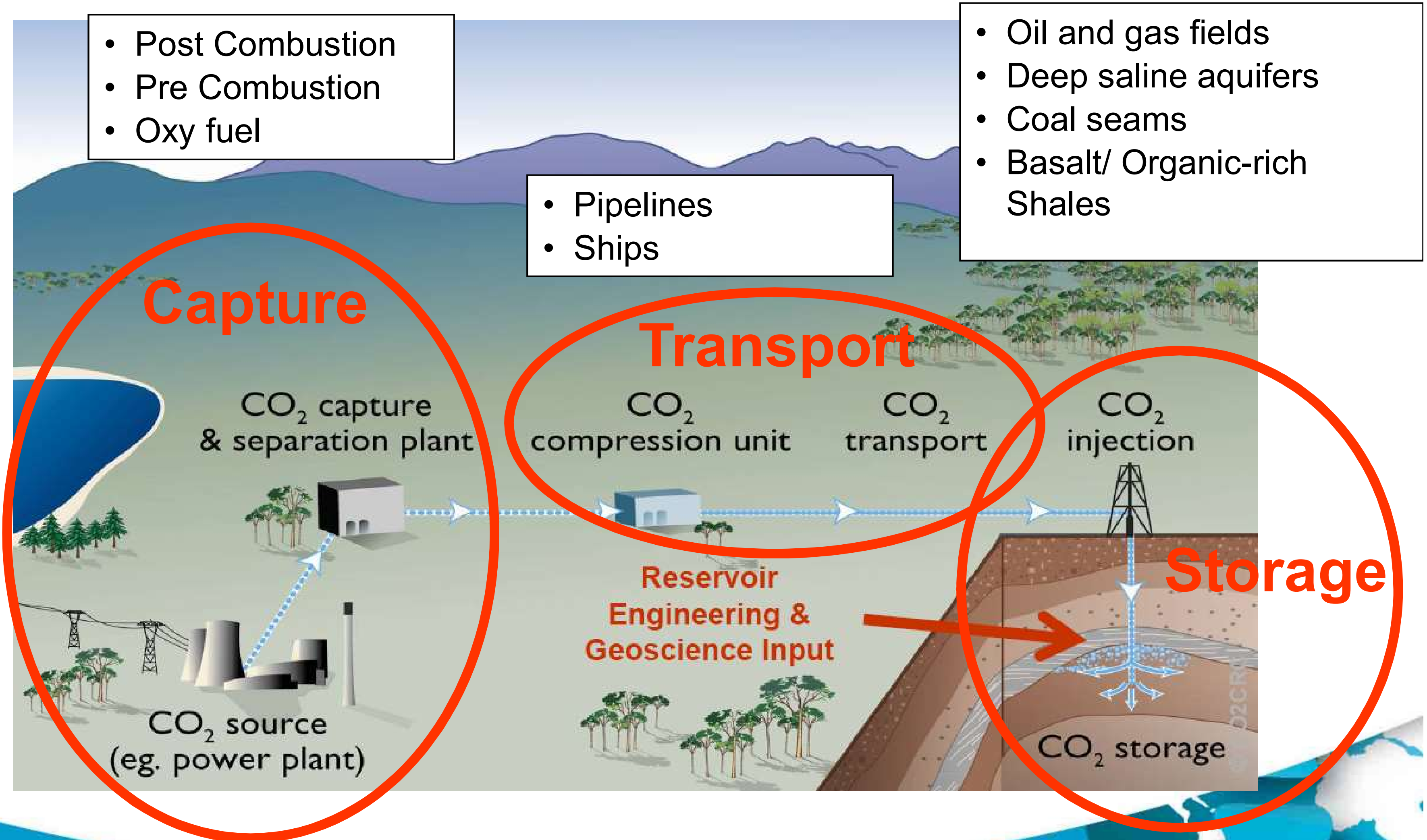
IEAGHG

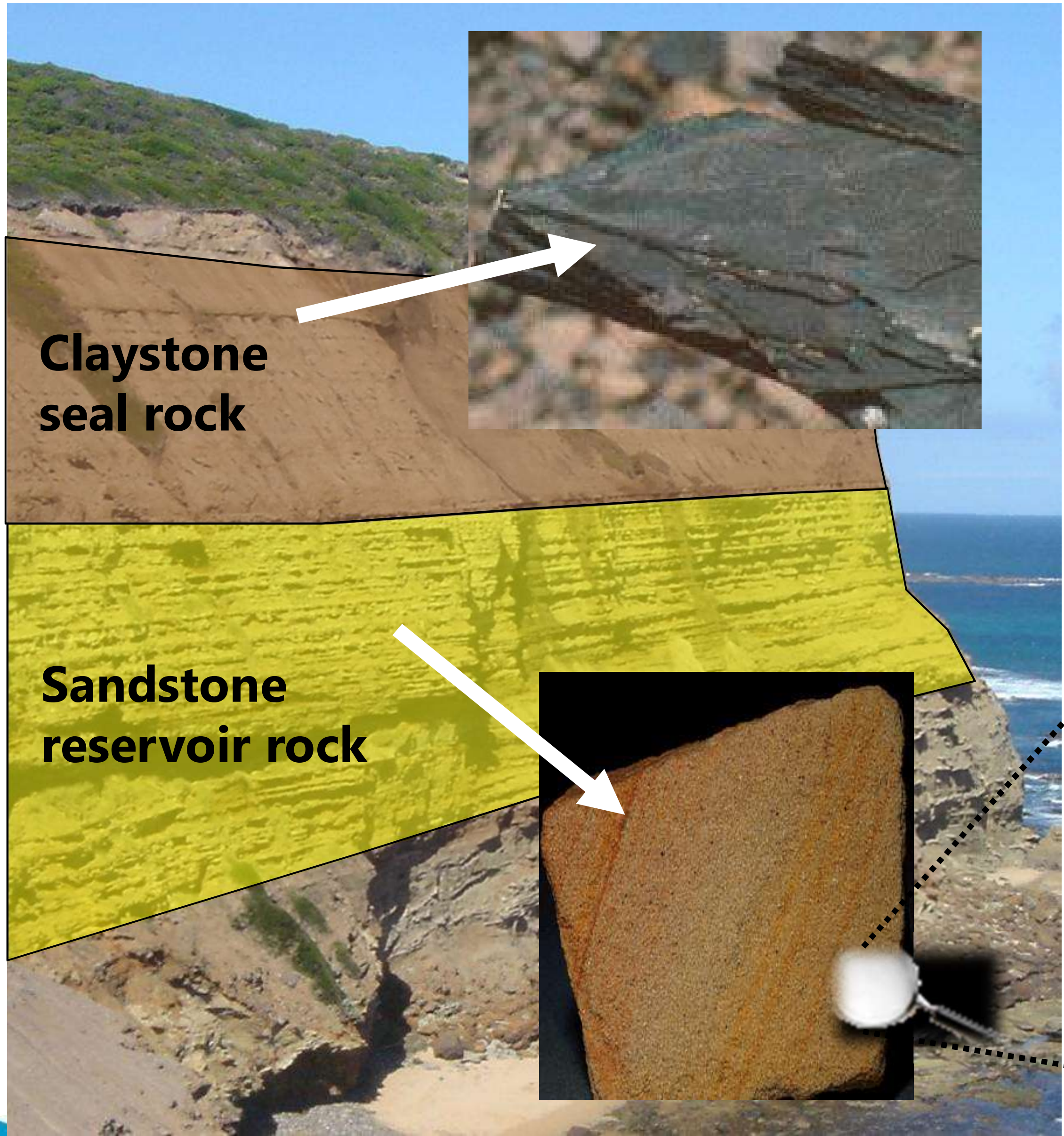
Stroud District Green Party

13 April 2018

CO_2 Capture and Storage (CCS)



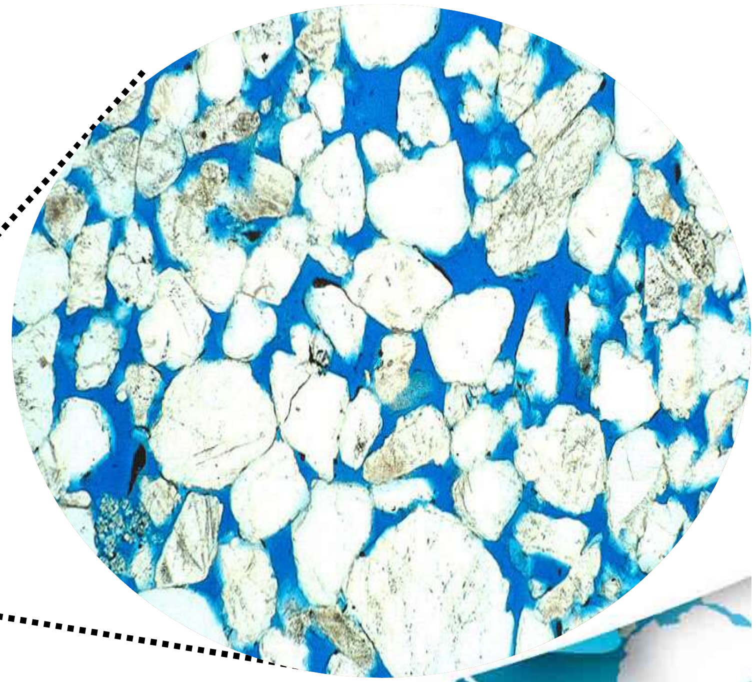
Geological storage of CO_2



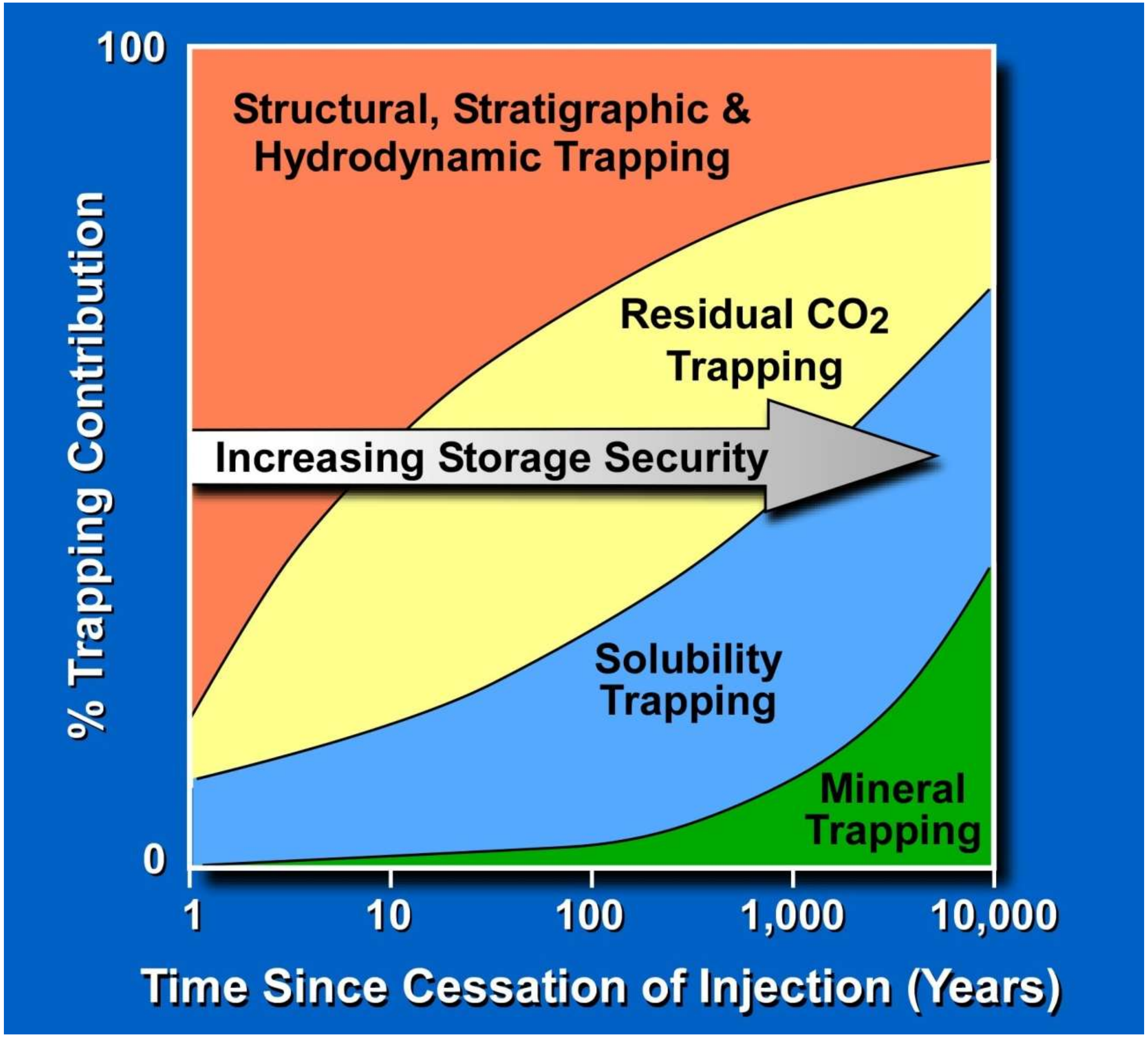
What do we need?

SEAL ROCK – non-porous, e.g. claystone

RESERVOIR ROCK – porous, e.g. sandstone

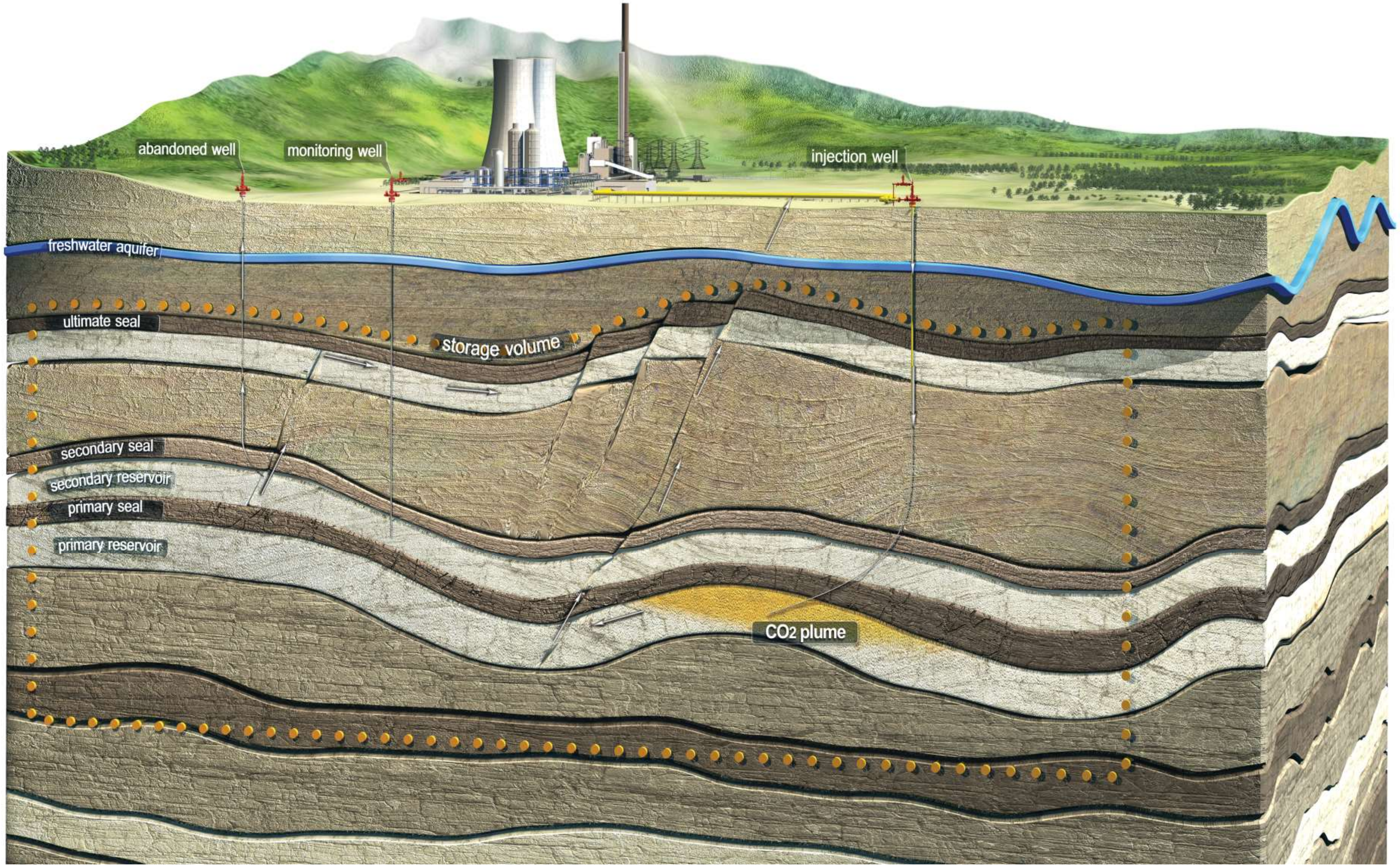


CO_2 Storage Trapping Mechanisms



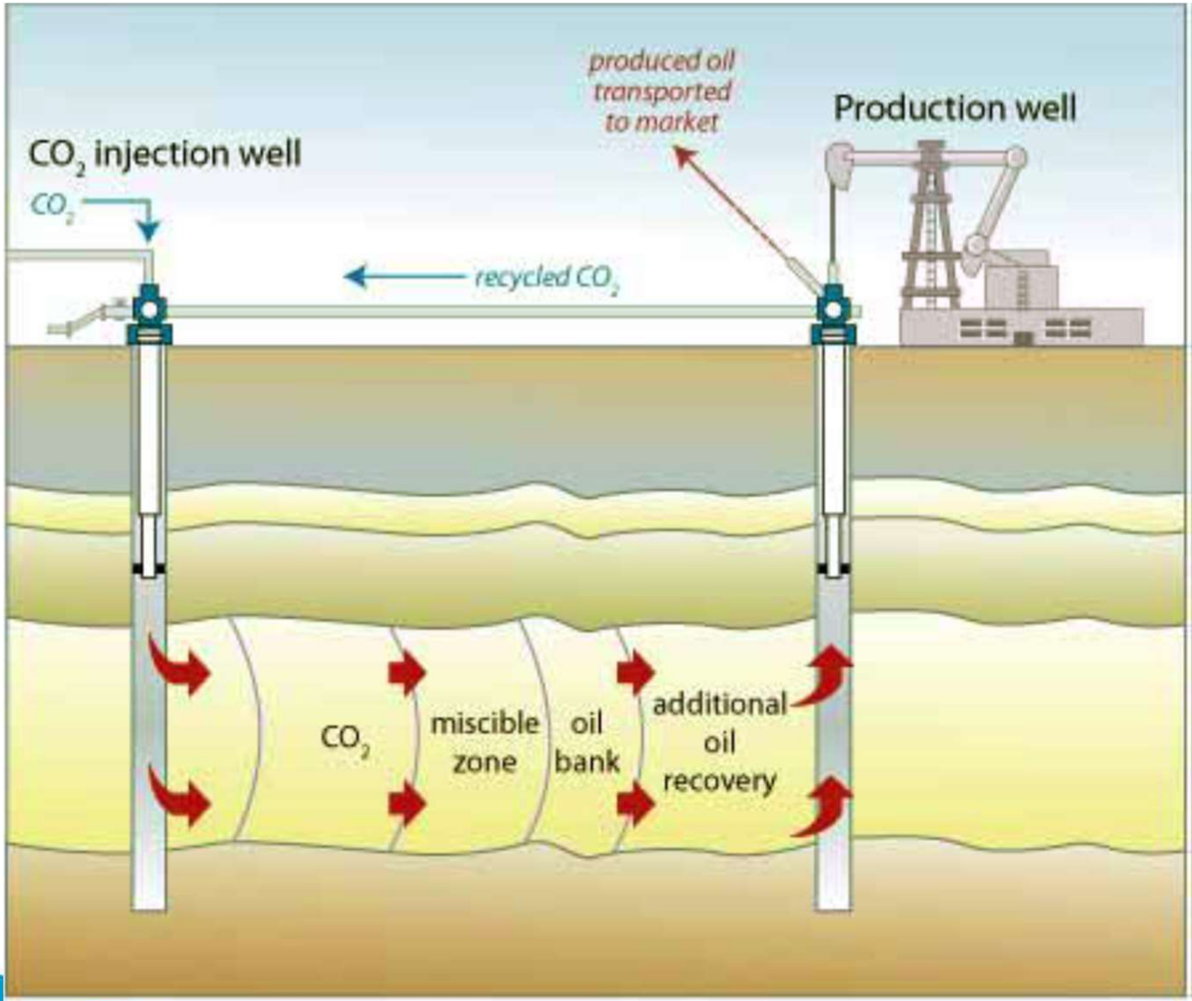
From IPCC SRCCS, 2005

CCS in scale



Source: DNV

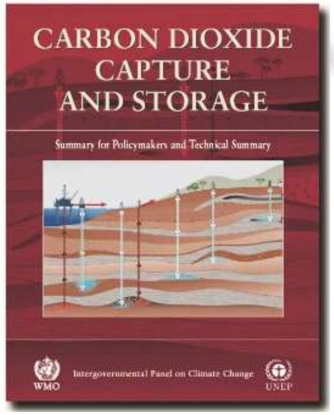
Oil & Gas Reservoirs: EOR with CO_2 Storage



- Proven containment (seal held oil & gas)
- Data rich (lots of wells, seismic)
- Objective: produce more oil (CO_2 storage secondary, but also occurs!)

Courtesy Kaldi, 2009

IPCC Special Report on CCS (2005)



- "Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1,000 years. "

- "For well-selected, designed and managed sites, the vast majority of the CO2 will gradually be immobilized by various trapping mechanisms and, in that case, could be retained for up to millions of years. Storage could become more secure over longer timescales. "

IPCC Guidelines for GHG Inventories

- Apr 2006
- Vol 2 Energy, Chp 5 - CO2 Transport, Injection and Geological Storage

- Each site will have different characteristics
- Methodology

    Site characterisation – inc leakage pathways

    ↓

    Assessment of risk of leakage – simulation / modelling

    ↓ ↑

    Monitoring – monitoring plan

    ↓

    Reporting – inc CO2 inj and emissions from storage site

- For appropriately selected and managed sites, supports zero leakage assumption unless monitoring indicates otherwise

Regulation of CCS

- London Convention 2006
- OSPAR 2007
- Japan 2007
- EU CCS Directive 2009
- EU ETS Directive 2009
- US EPA Class VI rule 2010
- US EPA GHG 2010
- UNFCCC CDM 2011
- ISO TC265 2011-on

Why CCS ?

IPCC Fifth Assessment Report Synthesis Report

2nd November 2014
Copenhagen

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Key Messages

→ **Human influence on the climate system is clear**

→ **The more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts**

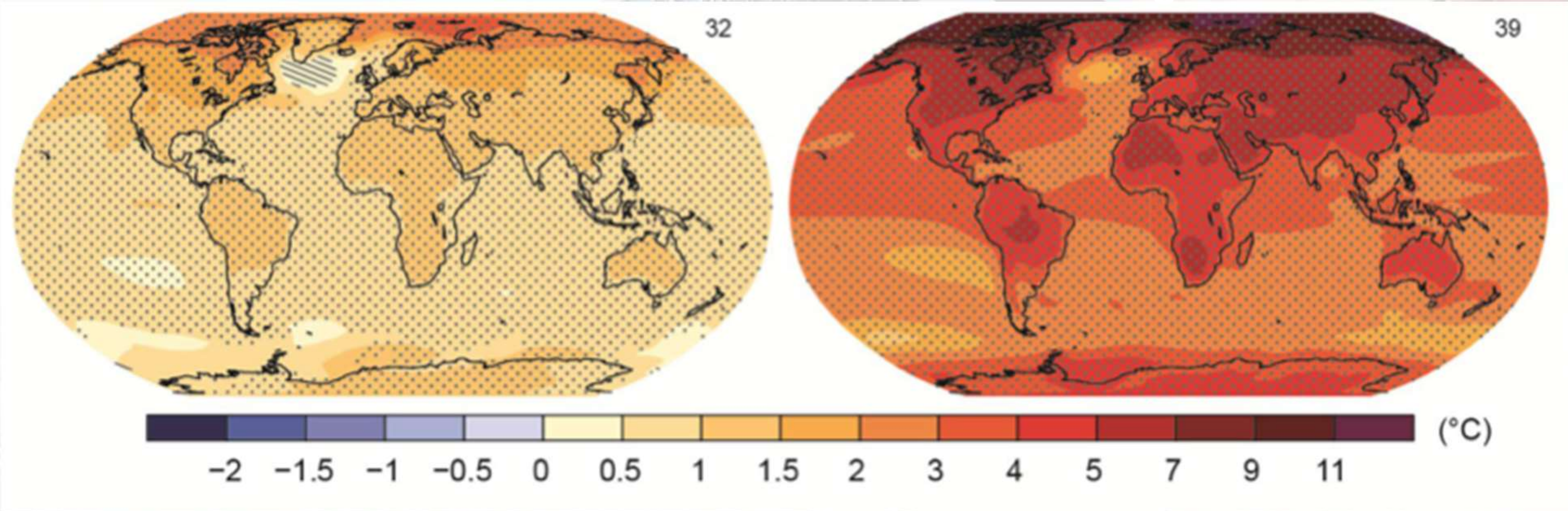
→ **We have the means to limit climate change and build a more prosperous, sustainable future**

AR5 WGI SPM, AR5 WGII SPM, AR5 WGIII SPM

The Choices We Make Will Create Different Outcomes

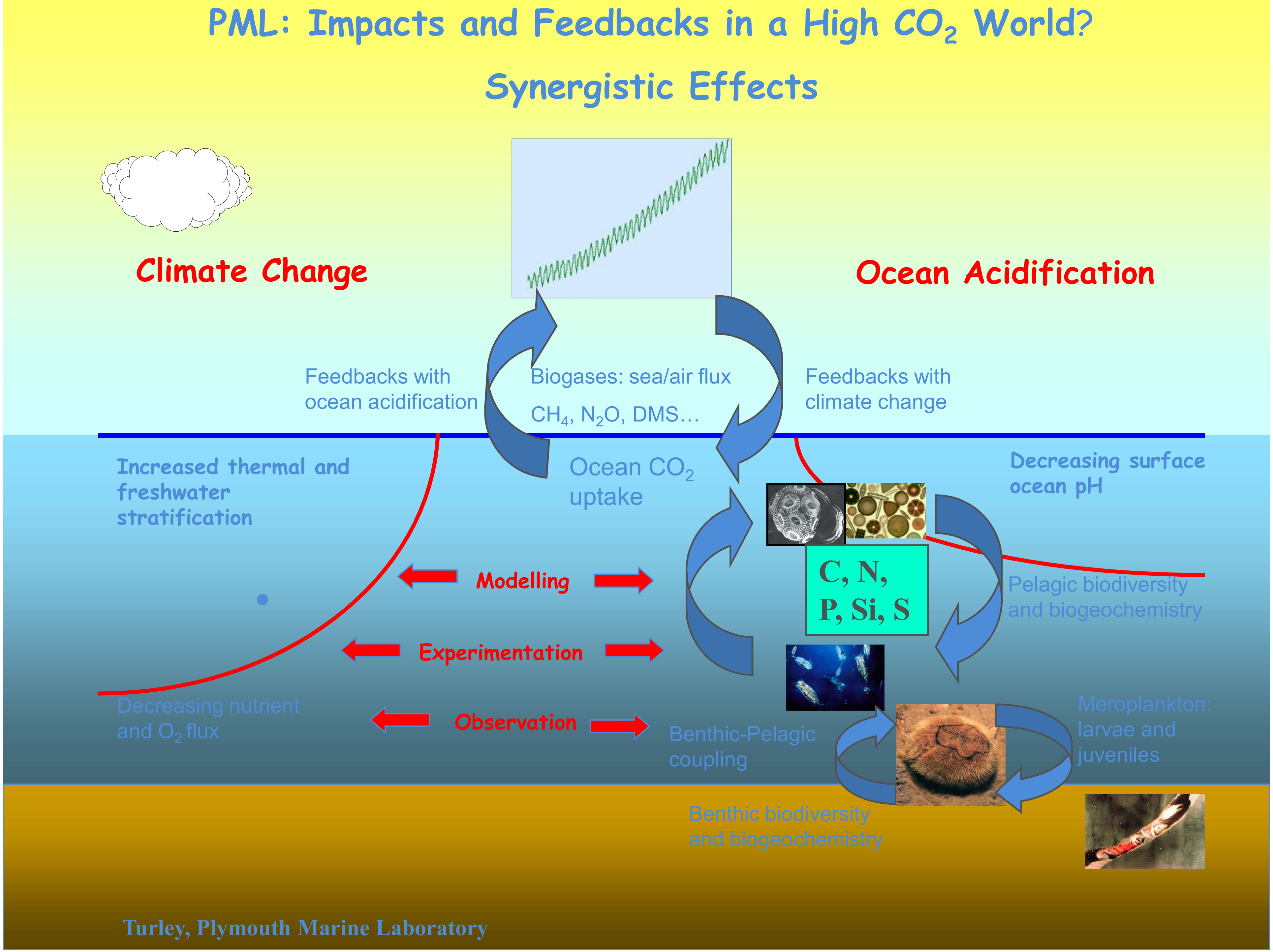
With substantial mitigation

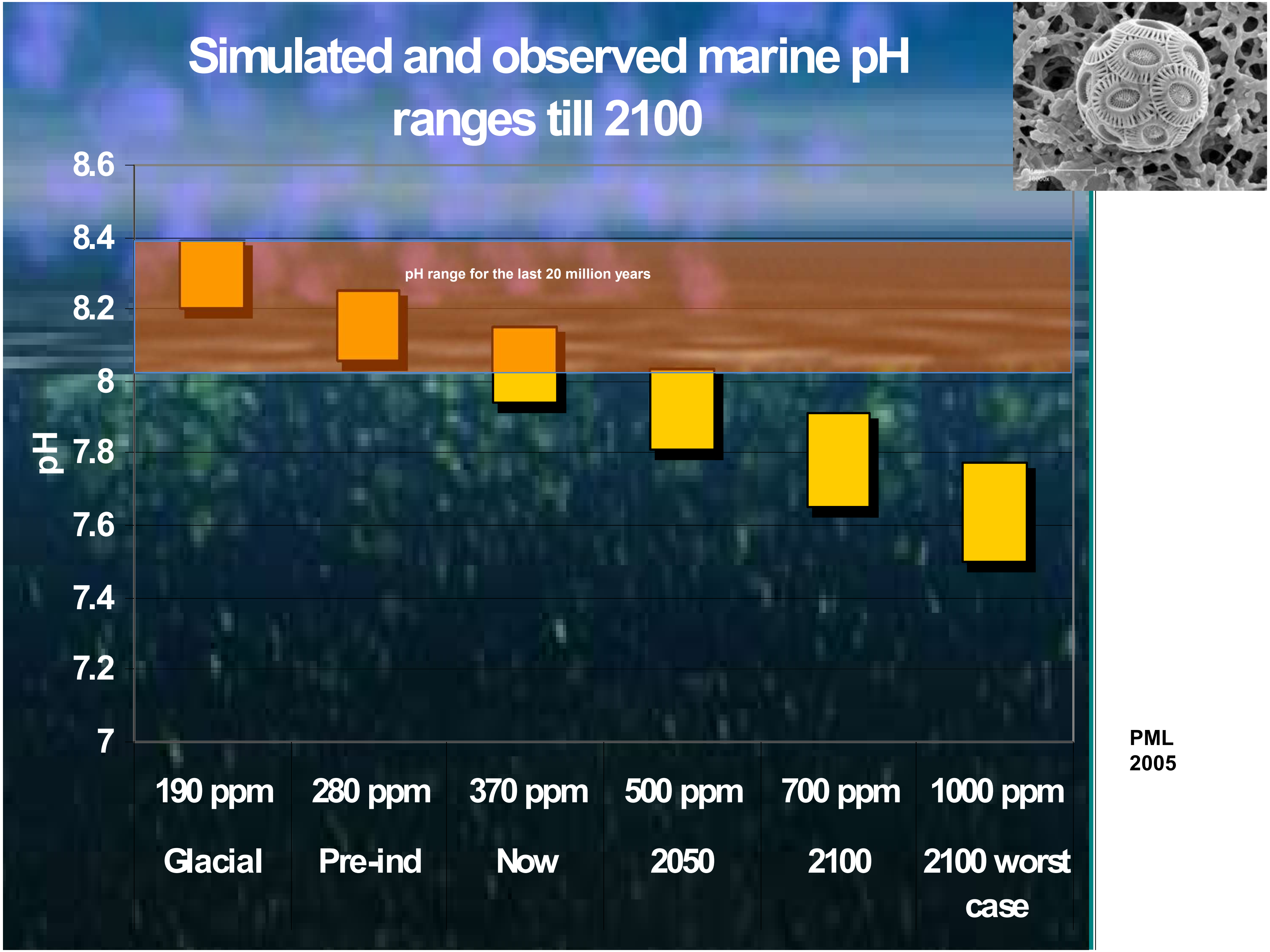
Without additional mitigation



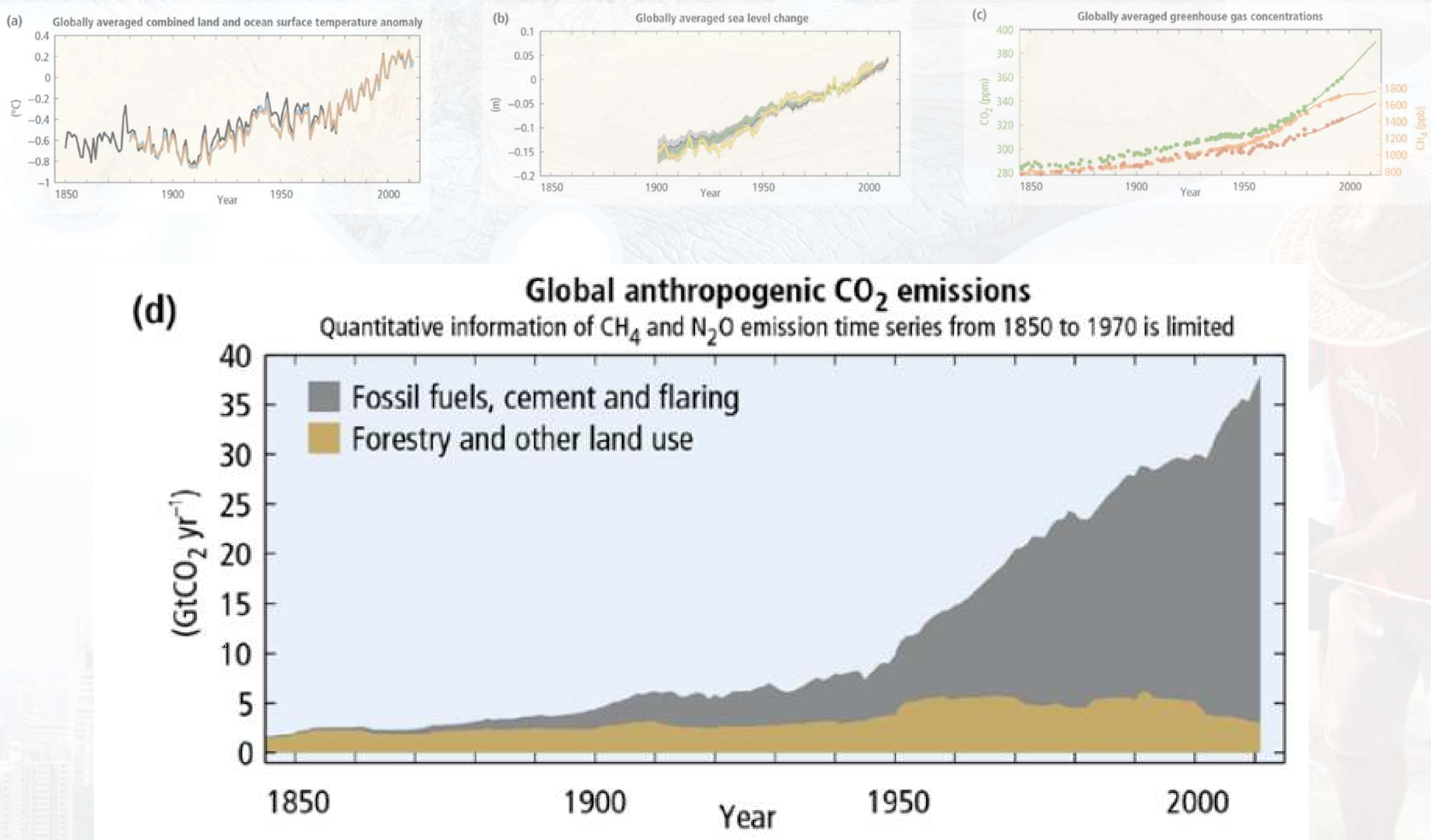
Change in average surface temperature (1986–2005 to 2081–2100)

AR5 WGI SPM


PML: Impacts and Feedbacks in a High CO_2 World?
Synergistic Effects
Climate Change
Ocean Acidification
Feedbacks with ocean acidification
Biogases: sea/air flux
CH_4, N_2O, DMS…
Feedbacks with climate change
Ocean CO_2 uptake
Increased thermal and freshwater stratification
Decreasing surface ocean pH
Modelling
Experimentation
Observation
C, N, P, Si, S
Pelagic biodiversity and biogeochemistry
Decreasing nutrient and O_2 flux
Benthic-Pelagic coupling
Meroplankton: larvae and juveniles
Benthic biodiversity and biogeochemistry
Turley, Plymouth Marine Laboratory


Simulated and observed marine pH ranges till 2100
pH range for the last 20 million years
pH
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
190 ppm
Glacial
280 ppm
Pre-ind
370 ppm
Now
500 ppm
2050
700 ppm
2100
1000 ppm
2100 worst case

PML
2005


(a)
Globally averaged combined land and ocean surface temperature anomaly
(°C)
Year
(b)
Globally averaged sea level change
(m)
Year
(c)
Globally averaged greenhouse gas concentrations
CO_2 (ppm)
CH_4 (ppb)
Year
(d)
Global anthropogenic CO_2 emissions
Quantitative information of CH_4 and N_2O emission time series from 1850 to 1970 is limited
Fossil fuels, cement and flaring
Forestry and other land use
($GtCO_2$ yr^{-1})
Year

AR5 SYR SPM

Sources of emissions

Energy production remains the primary driver of GHG emissions

2010 GHG emissions

AR5 WGIII SPM

Mitigation Measures

More efficient use of energy

Greater use of low-carbon and no-carbon energy

- Many of these technologies exist today

Improved carbon sinks

- Reduced deforestation and improved forest management and planting of new forests
- Bio-energy with carbon capture and storage

Lifestyle and behavioural changes

AR5 WGIII SPM

ipcc INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

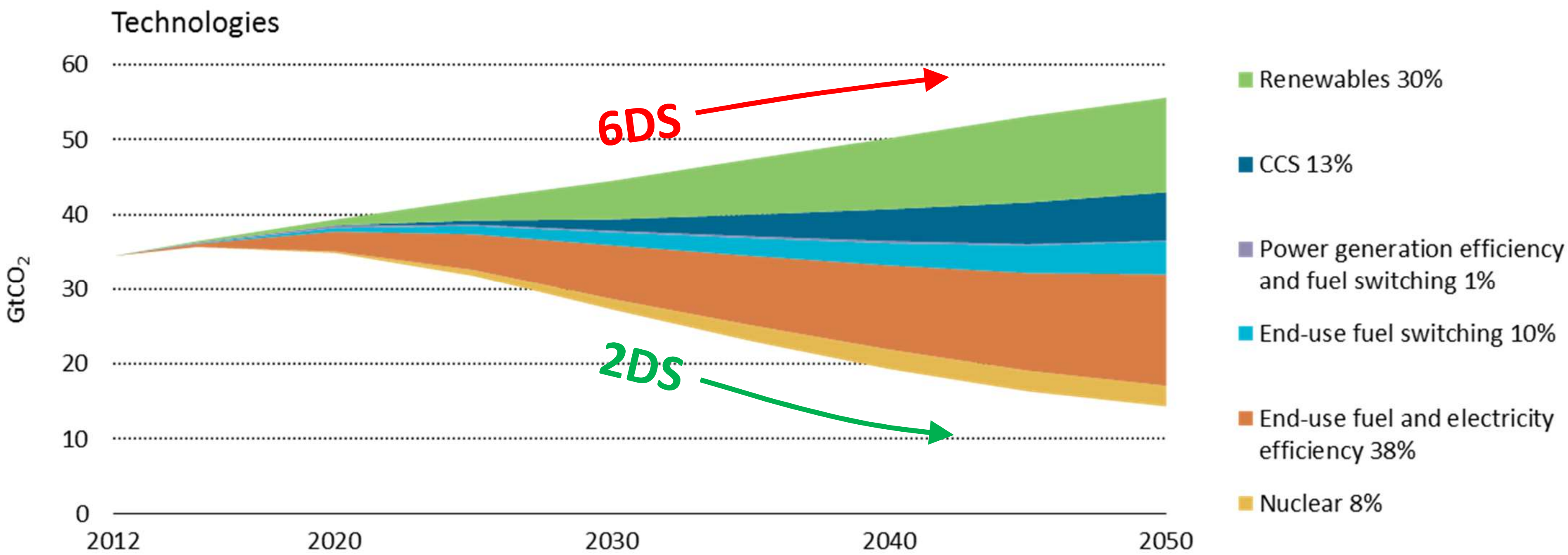
IPCC AR5 – Role of different low-carbon energy technologies

Mitigation cost increases in scenarios with limited availability of technologies [d] *[% increase in total discounted [e] mitigation costs (2015–2100) relative to default technology assumptions]*				
2100 concentrations (ppm CO_2-eq)	no CCS	nuclear phase out	limited solar/wind	limited bioenergy
450 (430 to 480)	138% (29 to 297%) 4	7% (4 to 18%) 8	6% (2 to 29%) 8	64% (44 to 78%) 8

IPCC AR5 SYR from Table 3.2 (2014)

A portfolio of technologies is required to get from here to there

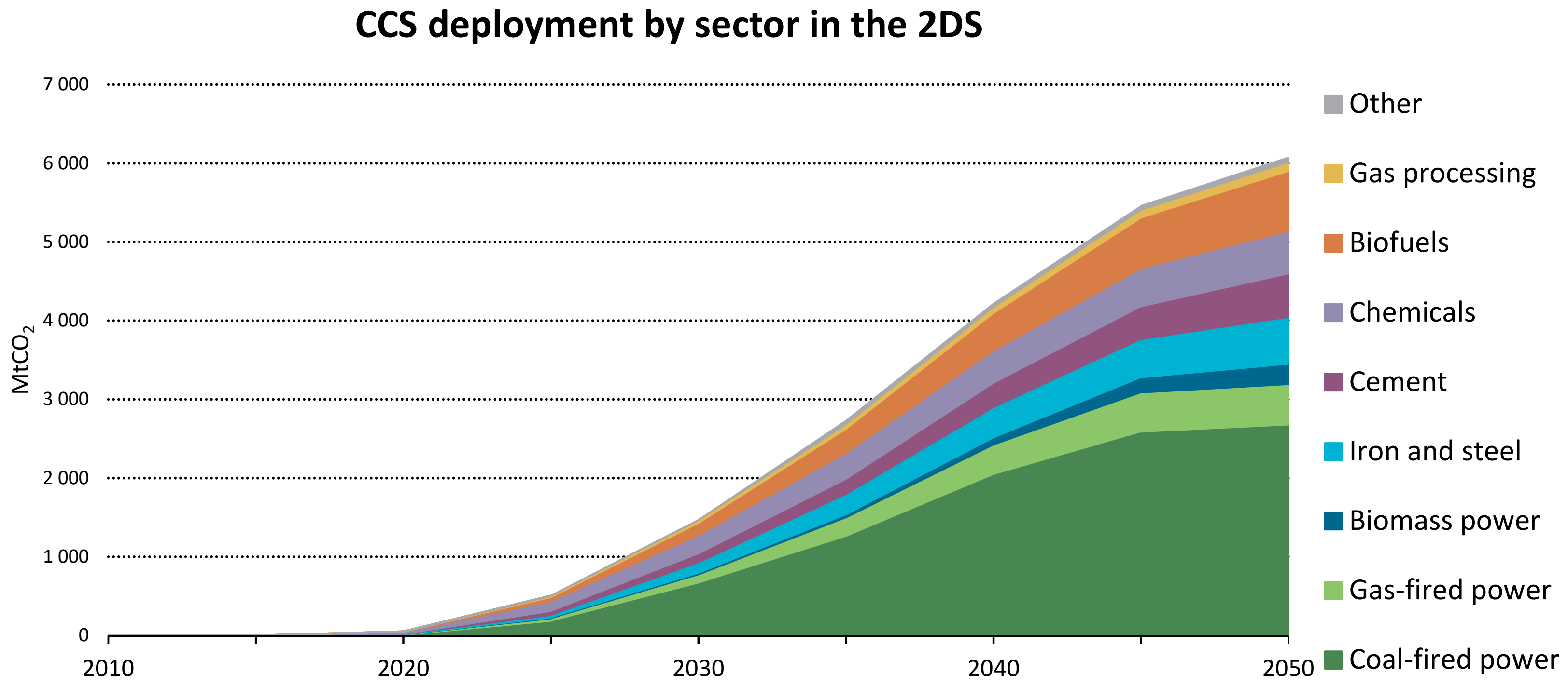
ETP 2015



Percentages represent cumulative contributions to emissions reduction relative to 6DS

International Energy Agency
Secure • Sustainable • Together

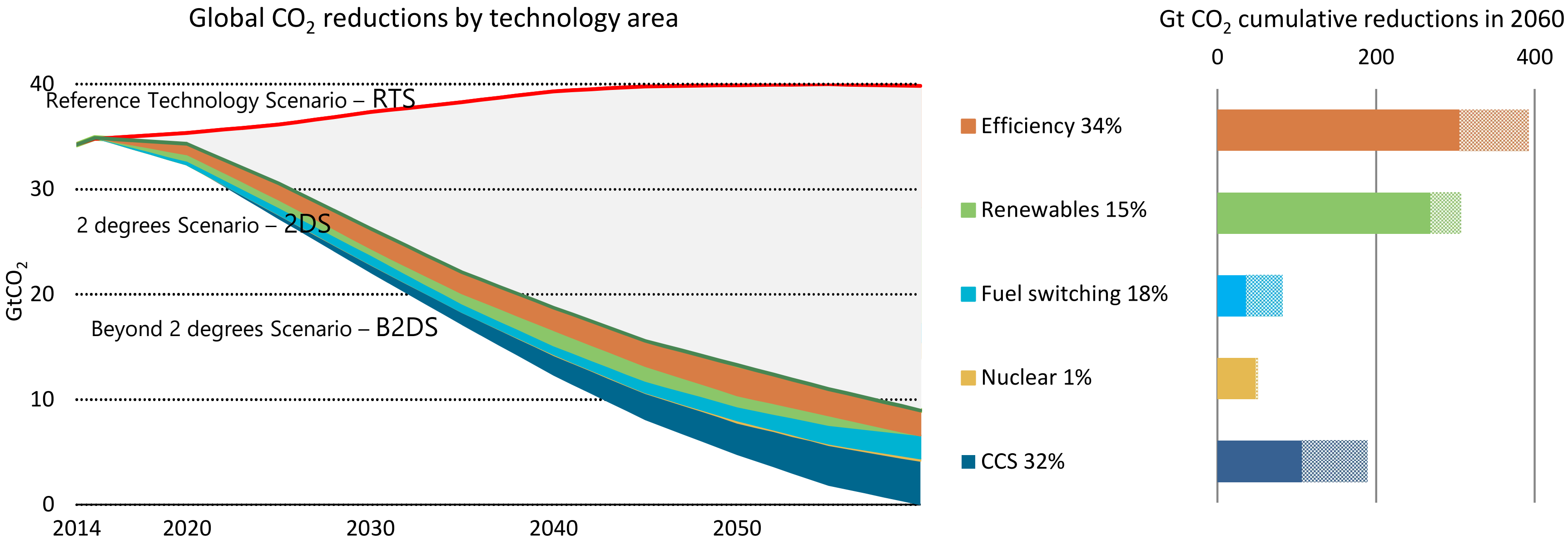
IEA: 94Gt CO_2 captured and stored in 2DS



- From 50Mt in 2020 to 6Gt in 2050
- A total of 94Gt captured and stored through 2050
  - 52Gt → 56% power
  - 29Gt → 31% process industries
  - 13Gt → 14% gas processing and biofuel production

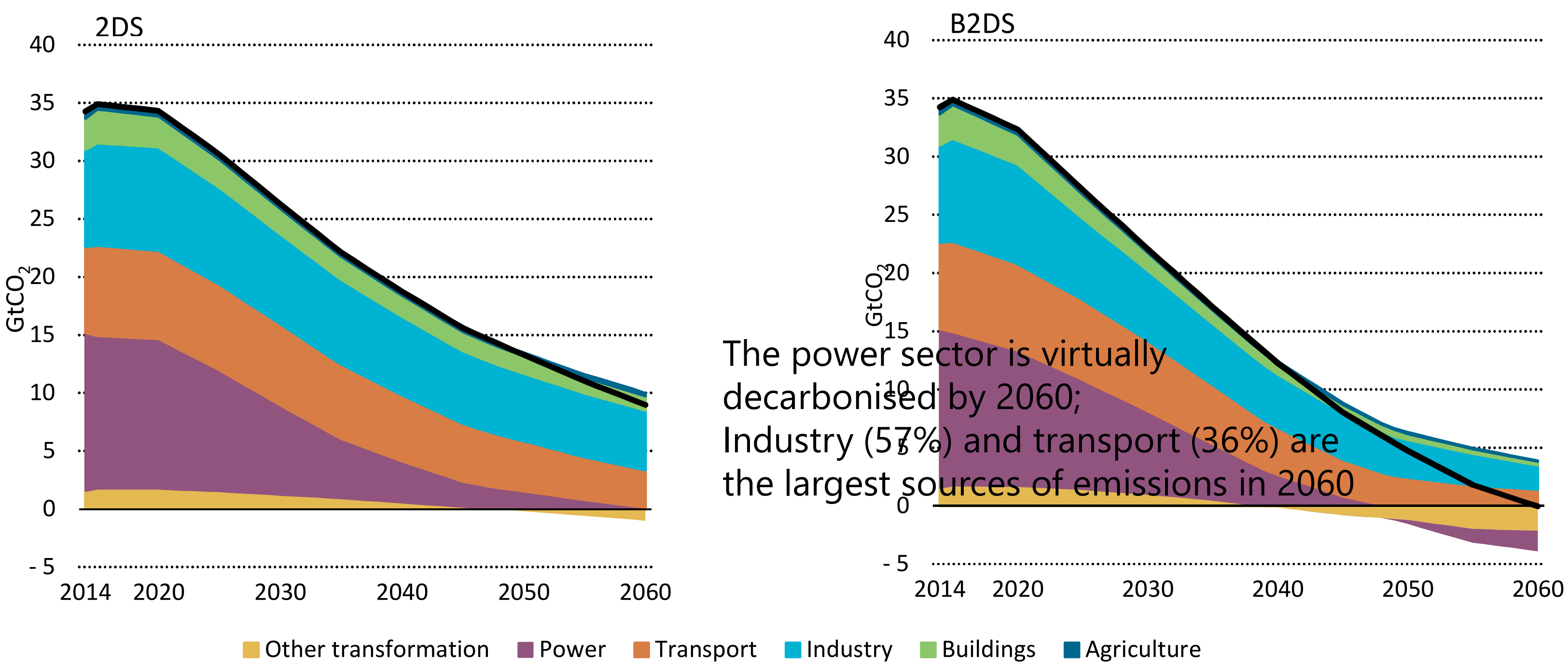
CCS plays a leading role in the energy transformation

Technology area contribution to global cumulative CO_2 reductions



Pushing energy technology to achieve carbon neutrality by 2060 could meet the mid-point of the range of ambitions expressed in Paris

Remaining CO_2 emissions in the 2DS and B2DS

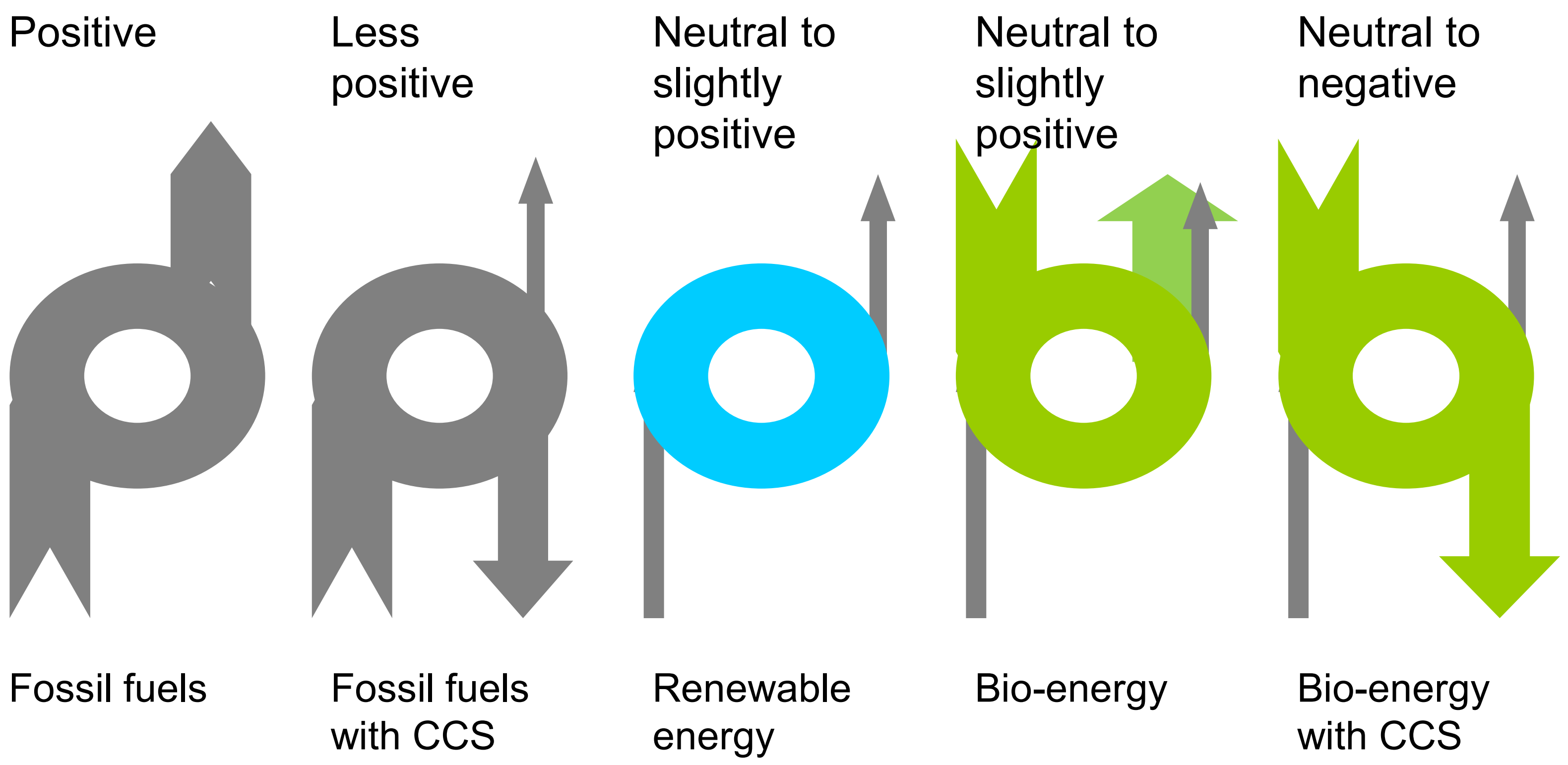


The remaining CO_2 emissions in industry and power must be targeted for the B2DS
Negative emissions are necessary to achieve net-zero emissions in 2060

CCS and Renewable Energy

- **CCS on fossil-fuel power stations is flexible and can load-follow - supports intermittent renewables on the grid**
- **Bio-CCS (Bio Energy and CCS – BECCS)**
- Concentrated Solar Power – provide heat for CO2 capture processes (R&D)
- Geothermal and CCS (R&D)

Why Biomass and CCS - the net carbon balance



Koornneef, ECOFYS 2010

Where is CCS happening?

Some CCS Projects

- Norway

1996 Sleipner 1Mt/y CO_2 from Nat Gas processing

2008 Snohvit 0.7Mt/y CO2 from LNG

2013 Port Arthur Project

- H2 Plant – SMR operated by Air Products
  - Consists of 2 Trains of SMR

- Retrofit capture VSA
- Operational 2013
- 1mt CO_2 pa to EOR

2014 Worlds first integrated coal fired power plant with CCS

- **SaskPower's Boundary Dam Coal PS, Saskatchewan, Canada**
- 110MWe Retrofit
- Shell/Cansolv Post combustion capture technology.
- EOR, and storage at Aquistore
- Started operation October 2014
- 2016 - International CCS Knowledge Centre

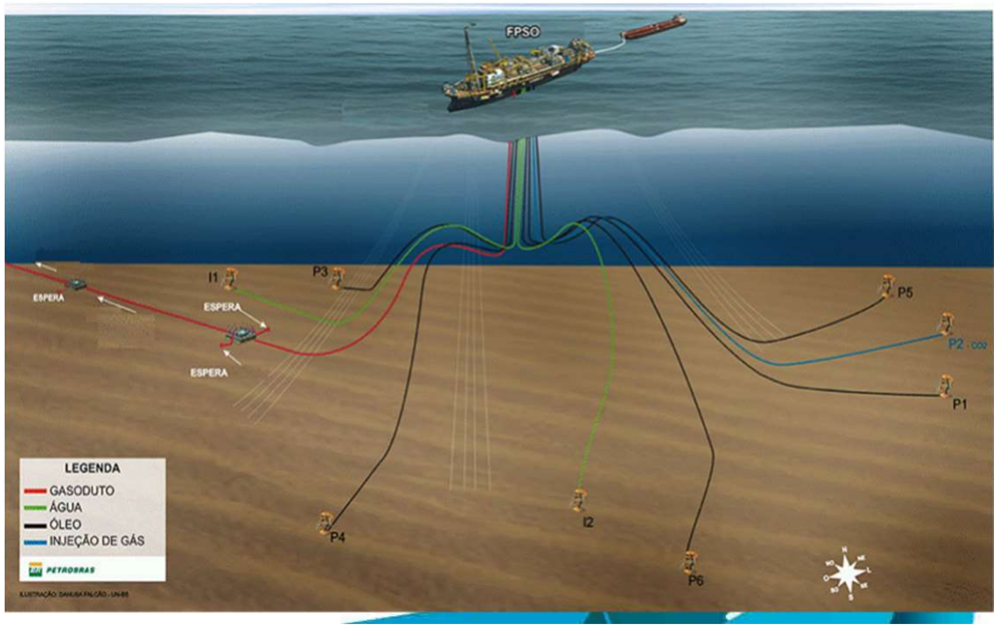
2015

Quest, Shell, Canada

H_2 Refining
1Mt CO2 pa to DSF storage

Lula, Petrobras, Brazil

Offshore gas separation and
CO2-EOR
FPSO
Deep: 2000m water depth,
3000m beneath seabed



2017

Petra Nova,
NRG Parish, USA

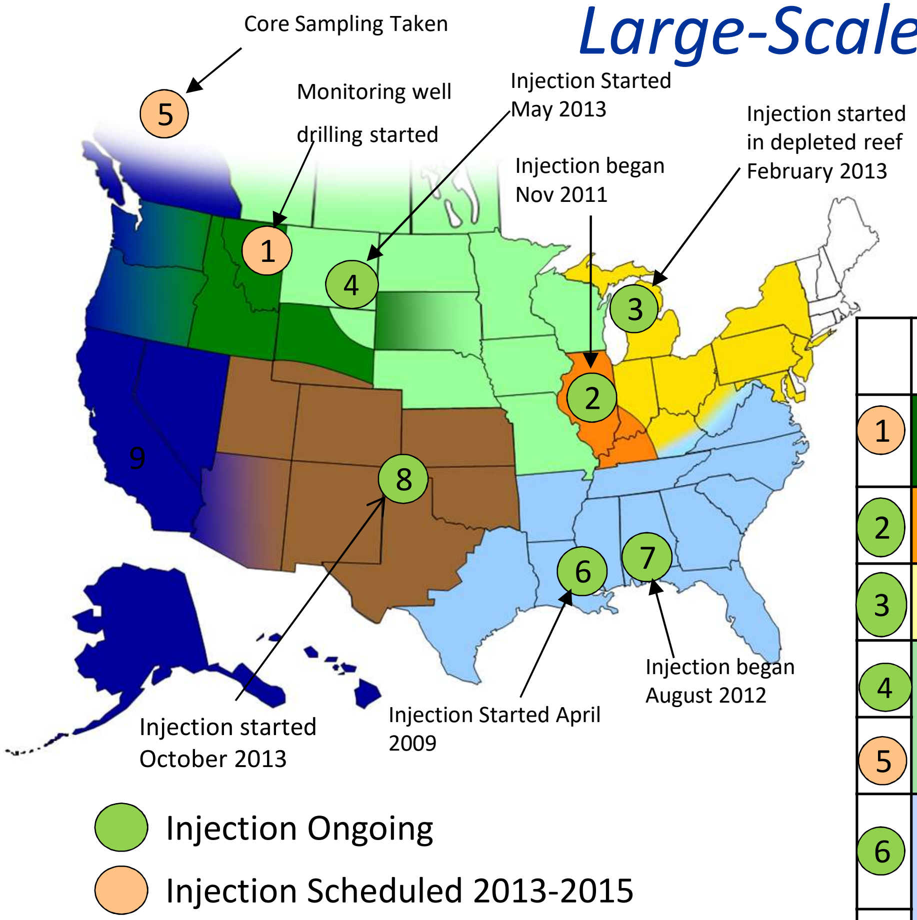
- Refit of existing coal fired unit
- Operational Jan 2017
- MHI amine based PCC technology
- 250 MW slip stream, 90% capture
- 1.6Mt pa CO_2 for EOR

ADM's Illinois Industrial CCS Project

- 1Mt pa CO_2 to DSF
- Operational April 2017
- Bioethanol = BioCCS

RCSP Phase III: Development Phase

Large-Scale Geologic Tests



Note: Some locations presented on map may differ from final injection location

- ✓ *Large-volume tests*
- ✓ *Four Partnerships currently injecting CO_2*
- ✓ *Remaining injections scheduled 2013-2015*

	Partnership	Field Project – Geologic Formation	Metric Tons Injected to Date
1	Big Sky	Kevin Dome- Duperow Formation	0
2	MGSC	Illinois Basin Decatur- Mt. Simon Sandstone	> 850,000
3	MRCSP	Michigan Basin - Niagaran Reef	> 234,000
4	PCOR	Bell Creek - Muddy Sandstone	> 741,000
5	PCOR	Fort Nelson - Sulfur Point Formation	0
6	SECARB	Early Test (Cranfield Field) - Tuscaloosa Formation	> 4,300,000
7	SECARB	Anthropogenic Test (Citronelle Field) – Paluxy Formation	> 100,000
8	SWP	Farnsworth Unit - Morrow Formation	> 102,000
	WESTCARB	Regional Characterization	

Courtesy NETL 2014

National Research Projects: Norway, Sweden, Finland, France, Germany, the Netherlands & UK (Scotland). Nordic CCS Centre

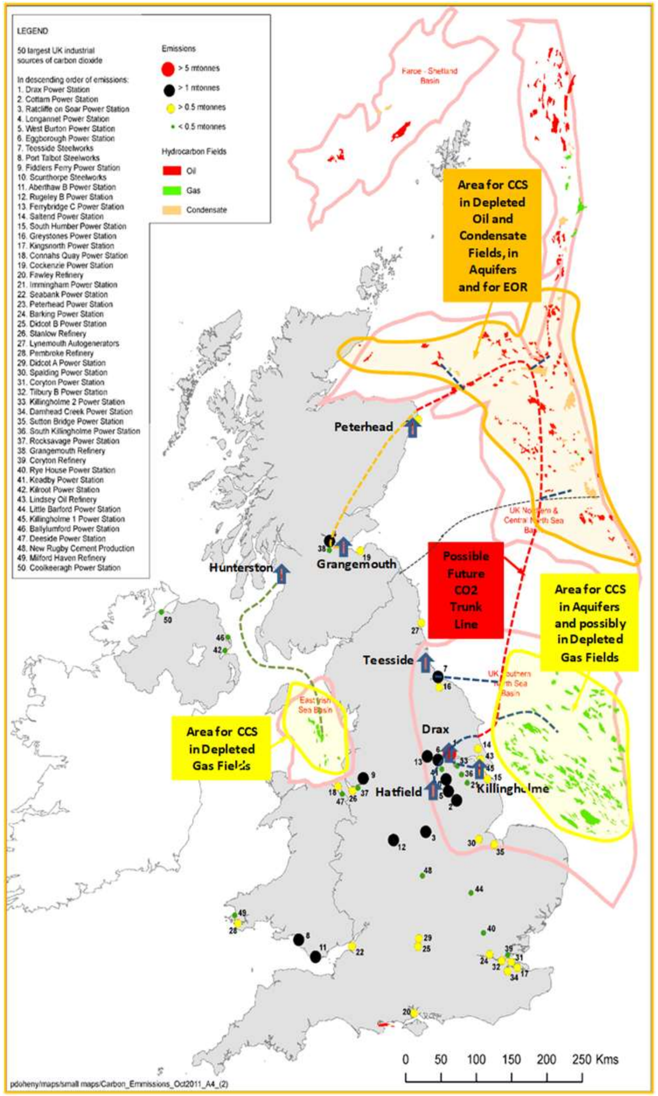
Capture Pilot Plants:
Germany (2)
Netherlands (2)
France (1)
UK (3)
Italy (1)
Norway (2)
Poland (1)

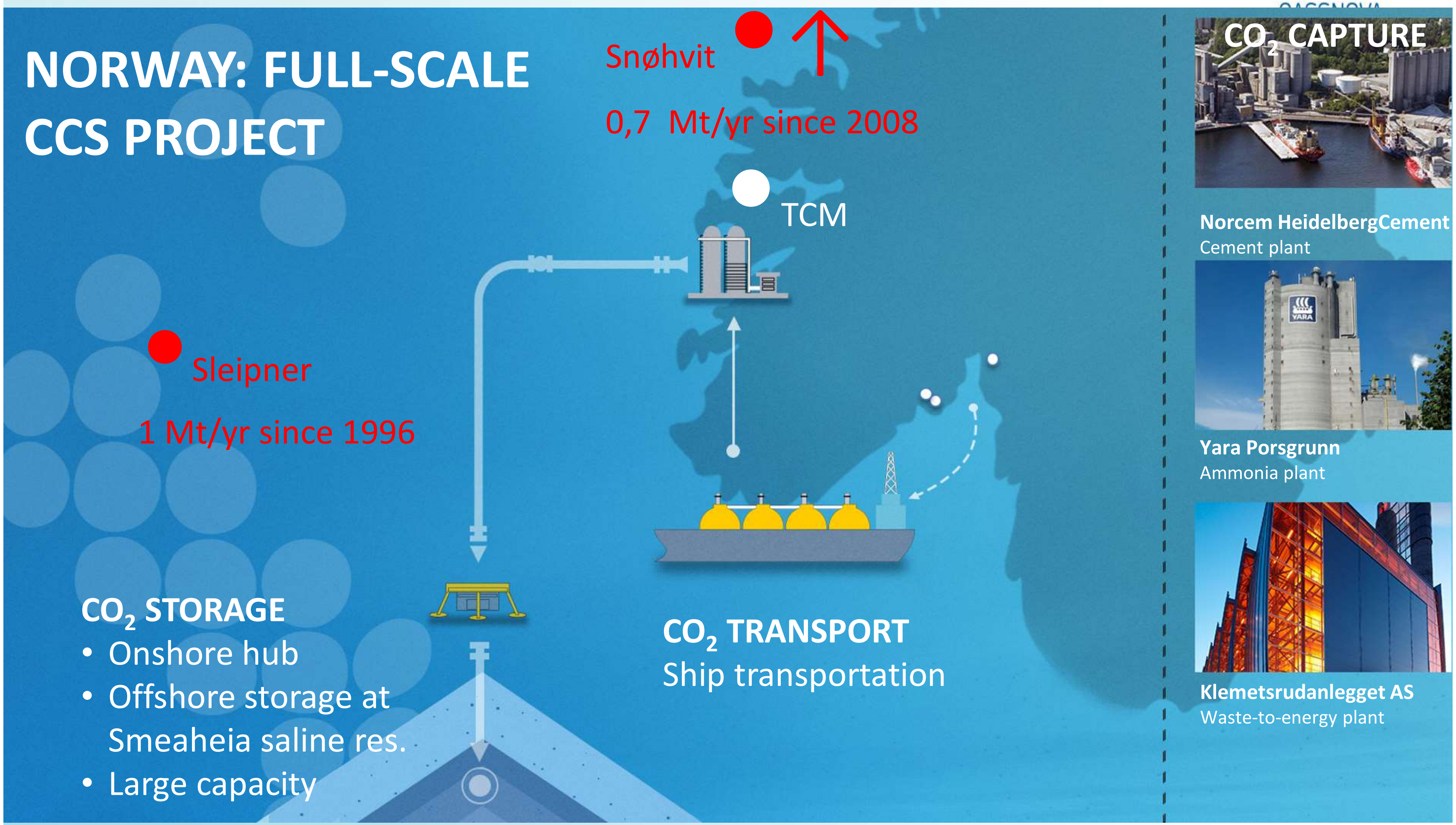
Why CCS is important for the UK: potential for growth and jobs

DEPARTMENT OF ENERGY & CLIMATE CHANGE
Office of Carbon Capture and Storage

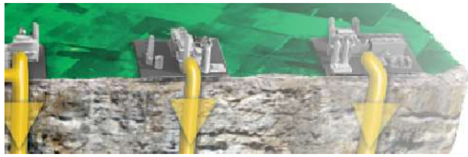
- **Clusters of CO2 emitters**

- **Clusters of CO2 sinks (e.g. oil fields in N North Sea Gas fields in South Aquifers throughout)**





Niels Peter Christensen. GASSNOVA 2017



The challenges to integrating capture, transport and storage

Economics

- Low or inexistent carbon price
- Unvalued benefit of CCS technology learning
- Limited business opportunity (EOR, small scale use)

Policy

- Uncertainty about long term climate mitigation goals
- Lack of political recognition of the role of CCS
- Lack of or limited incentives for CCS

Technology

- High cost of capture
- Technical complexity of adding capture
- Commercial risks related to storage
- Complex commercial arrangements

Stakeholder views

- Opposition to projects in some jurisdictions
- Unfavorable views on CCS as perpetuating a fossil fuel world
- Concerns over risks of CO_2 escape
- Lack of understanding by financiers

For more information

- http://www.ccsassociation.org/
- http://www.globalccsinstitute.com/
- https://ukccsrc.ac.uk/
- http://www.sccs.org.uk/
- www.ieaghg.org
- https://www.gov.uk/guidance/uk-carbon-capture-and-storage-government-funding-and-support

Thank You

Any questions?

www.ieaghg.org