



# **Carbon Dioxide Capture and Storage – Managing Promises and Resolving Uncertainties Through Science**

Tim Dixon  
IEAGHG

Strengthening the Links Between Fusion and Society, IEA FPCC  
28 January 2014

# IEA Greenhouse Gas R&D Programme (IEAGHG)



- ” A collaborative international research programme founded in 1991 as an IEA Implementing Agreement fully financed by its members
- ” Aim: To provide information on the role that technology can play in reducing greenhouse gas emissions from use of fossil fuels.
- ” Focus is on Carbon Dioxide Capture and Storage (CCS)
- ” Producing information that is:
  - Objective, trustworthy, independent
  - Policy relevant but NOT policy prescriptive
  - Reviewed by external Expert Reviewers



ALSTOM



CIAB



ieaghg



EPR2

Schlumberger

DOOSAN Doosan Babcock



REPSOL YPF

EnBW



INSTITUTO DE INVESTIGACIONES ELECTRICAS

VATTENFALL



Statoil

ExxonMobil

B&W power generation group

BR PETROBRAS

GLOBAL CCS INSTITUTE

JGC

RWE The energy to lead

Partner Organisations:



# IEAGHG Flagship Activities



- “ Technical Studies >250 reports published on all aspects of CCS
- “ International Research Networks
  - “ Risk Assessment
  - “ Wellbore Integrity
  - “ Monitoring
  - “ Modelling
  - “ Environmental Impacts
  - “ Oxy-combustion - conf
  - “ Post-combustion Capture - conf
  - “ Solid Looping
  - “ Social Research
- “ GHGT conferences

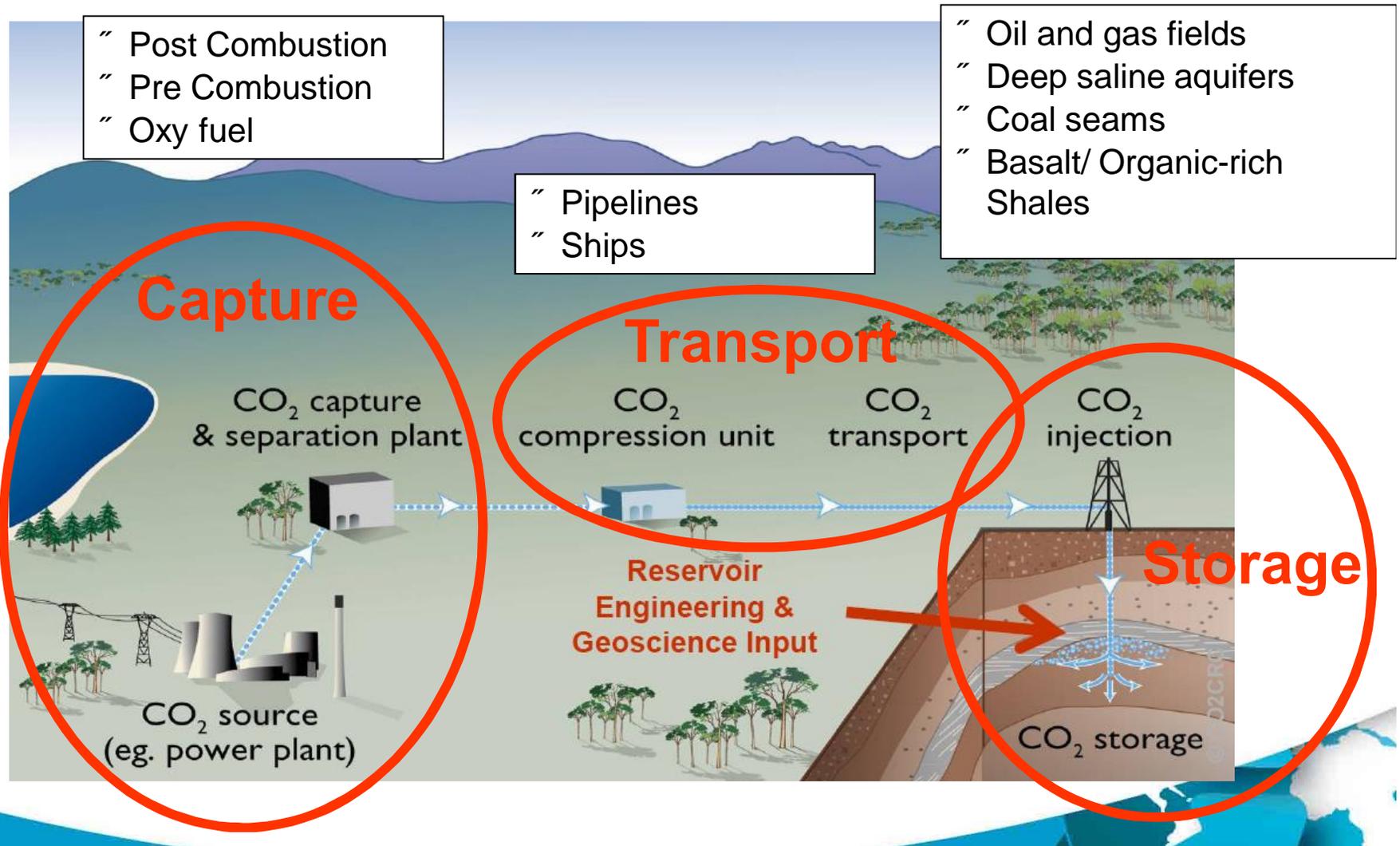


# IEAGHG



- “ Other activities include:
- “ Facilitating R&D and demonstration activities eg IEAGHG Weyburn-Midale CO<sub>2</sub> Monitoring and Storage Project . **Best Practices for Validating CO<sub>2</sub> Geological Storage** published Nov 2012
- “ International CCS Summer Schools - 2012 Beijing, 2013 UK, 2014 University of Texas Austin, USA
- “ Peer reviews, e.g. US DOE, US EPA; CO2CRC
- “ Active in international regulatory developments . **London Convention, UNFCCC, ISO TC265**
- “ Collaborations with IEA, GCCSI, CSLF, CCSA, EU ZEP and others

# CO<sub>2</sub> Capture and Storage (CCS)



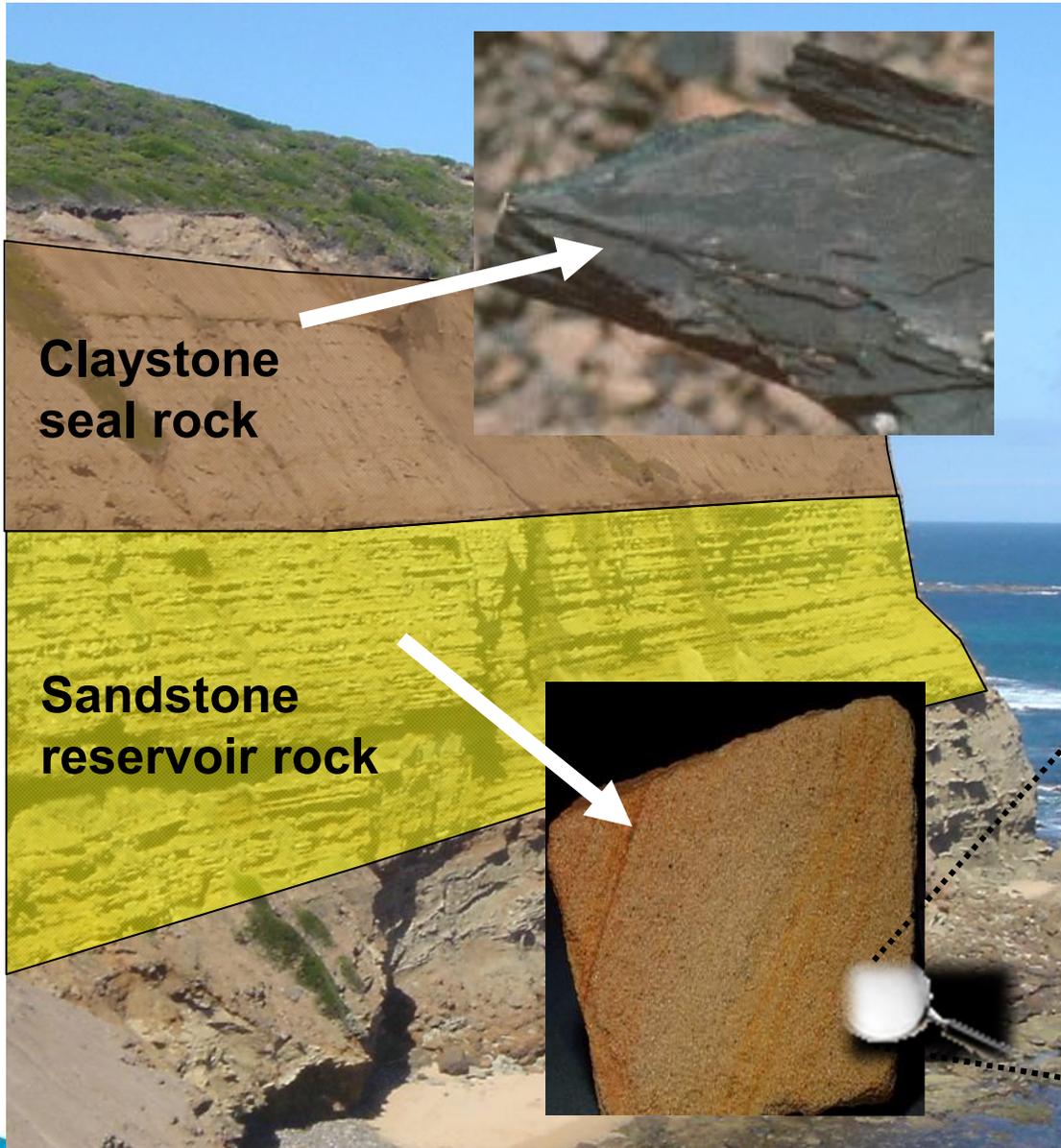
# Geological storage of CO<sub>2</sub>



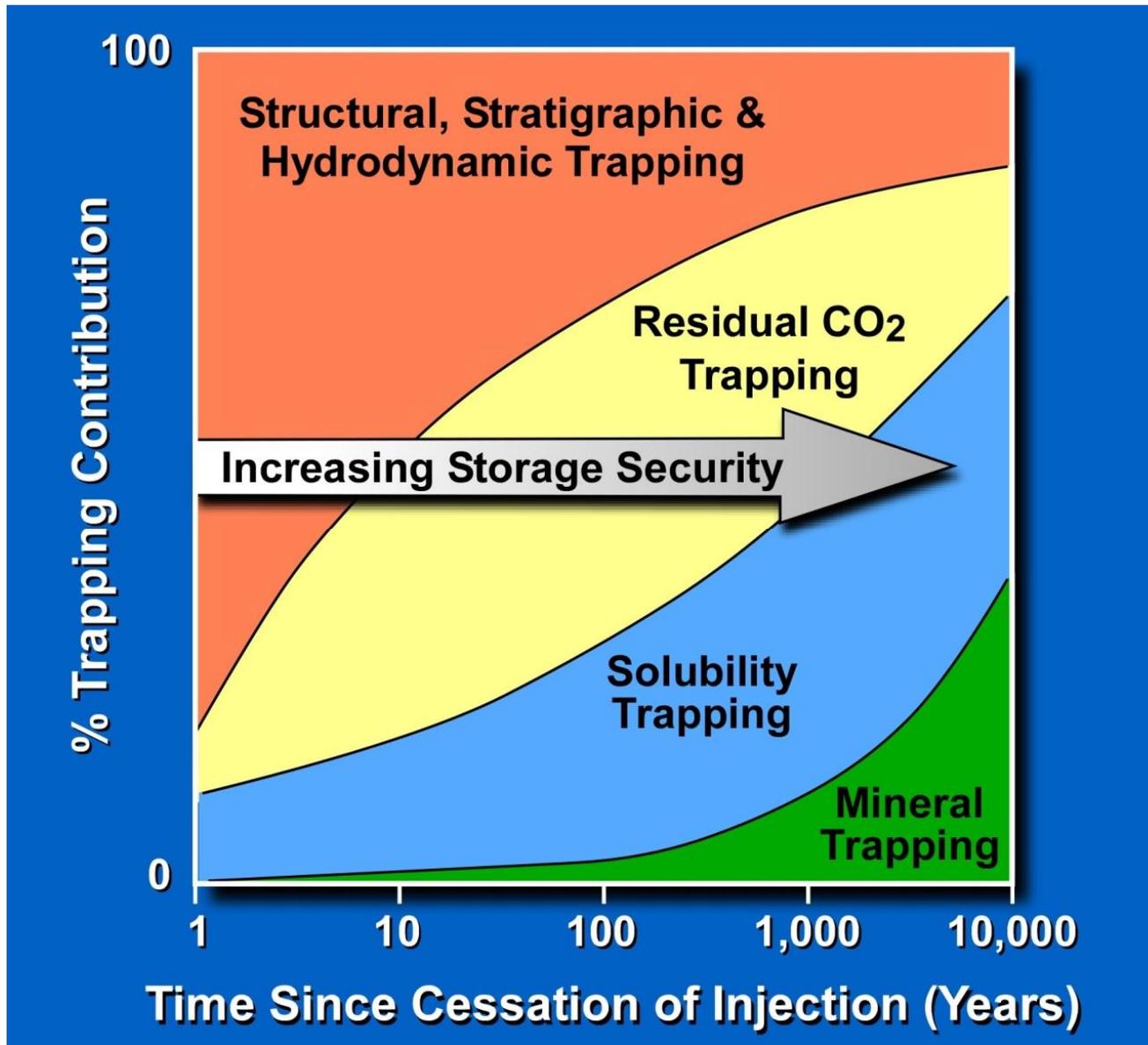
What do we need?

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

**RESERVOIR ROCK** – porous, e.g. sandstone

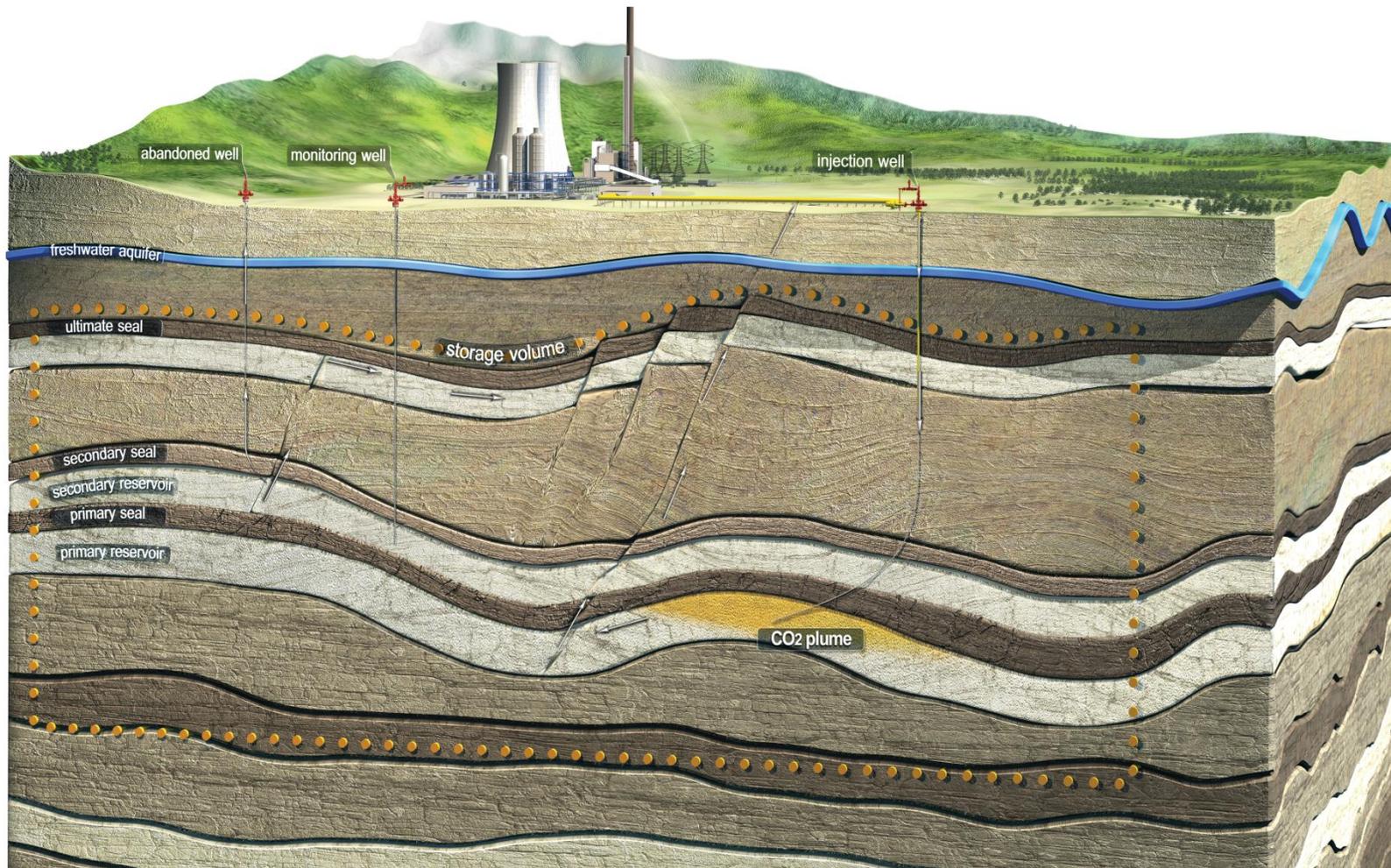


# CO<sub>2</sub> Storage Trapping Mechanisms



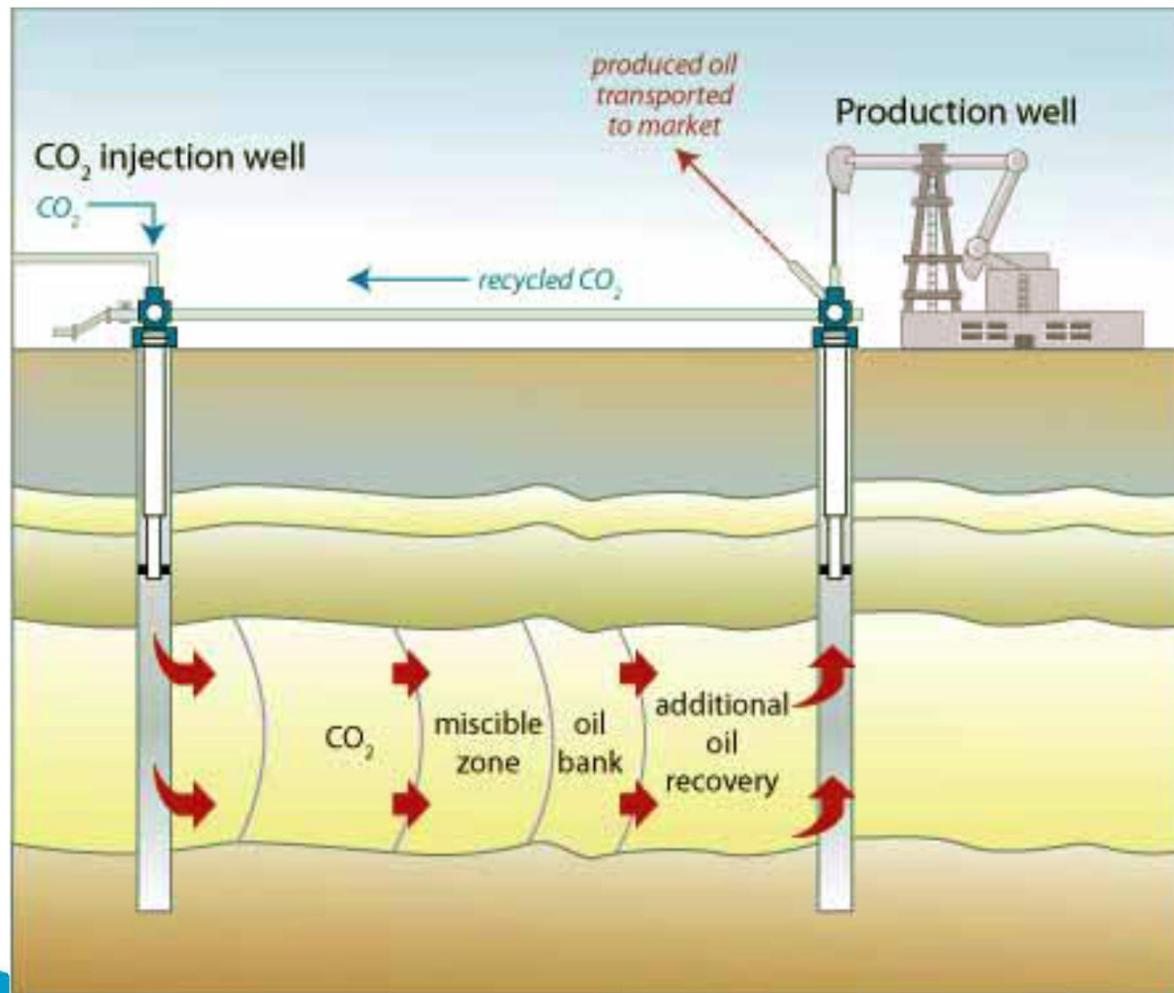
From IPCC SRCCS, 2005

# CCS in scale



Source: DNV

# Oil & Gas Reservoirs: EOR with CO<sub>2</sub> Storage



- " Proven containment (seal held oil & gas)
- " Data rich (lots of wells, seismic)
- " Objective: produce more oil (CO<sub>2</sub> storage secondary, but also occurs!)

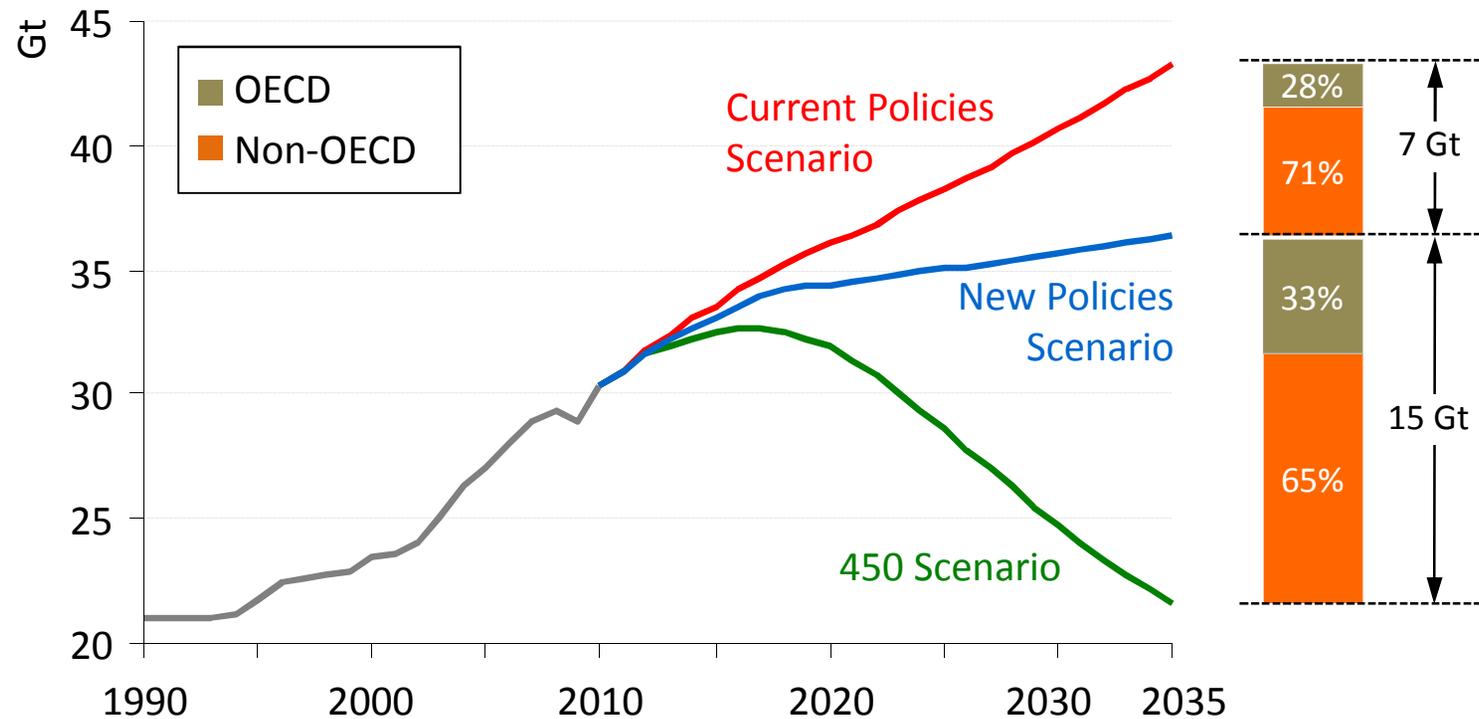


# Why CCS ? Or CCS's 'Promise'

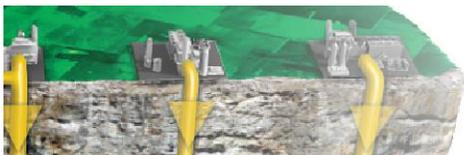


*The 450 Scenario illustrates what the 2°C goal will require*

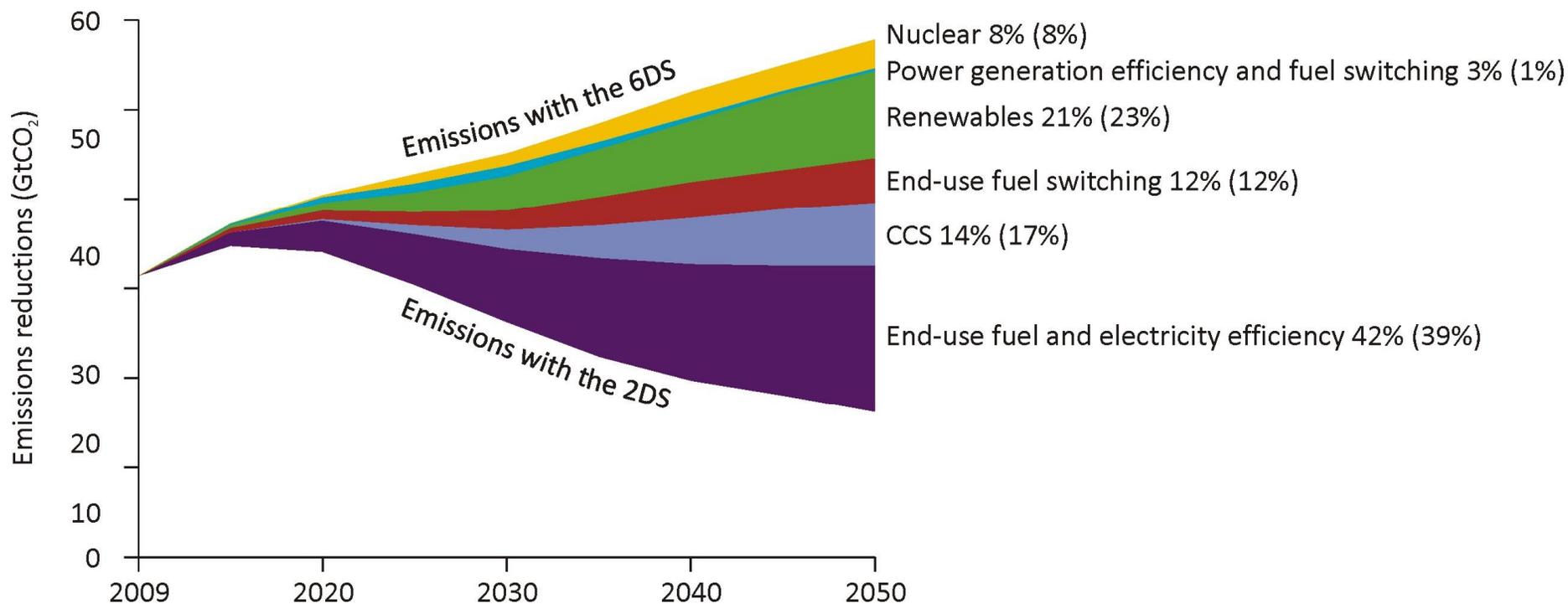
World energy-related CO<sub>2</sub> emissions by scenario



**Restricting the greenhouse-gas concentration to 450 ppm would limit temperature increase to 2°C, compared with 3.5°C in the New Policies Scenario & 6°C in the Current Policies Scenario**

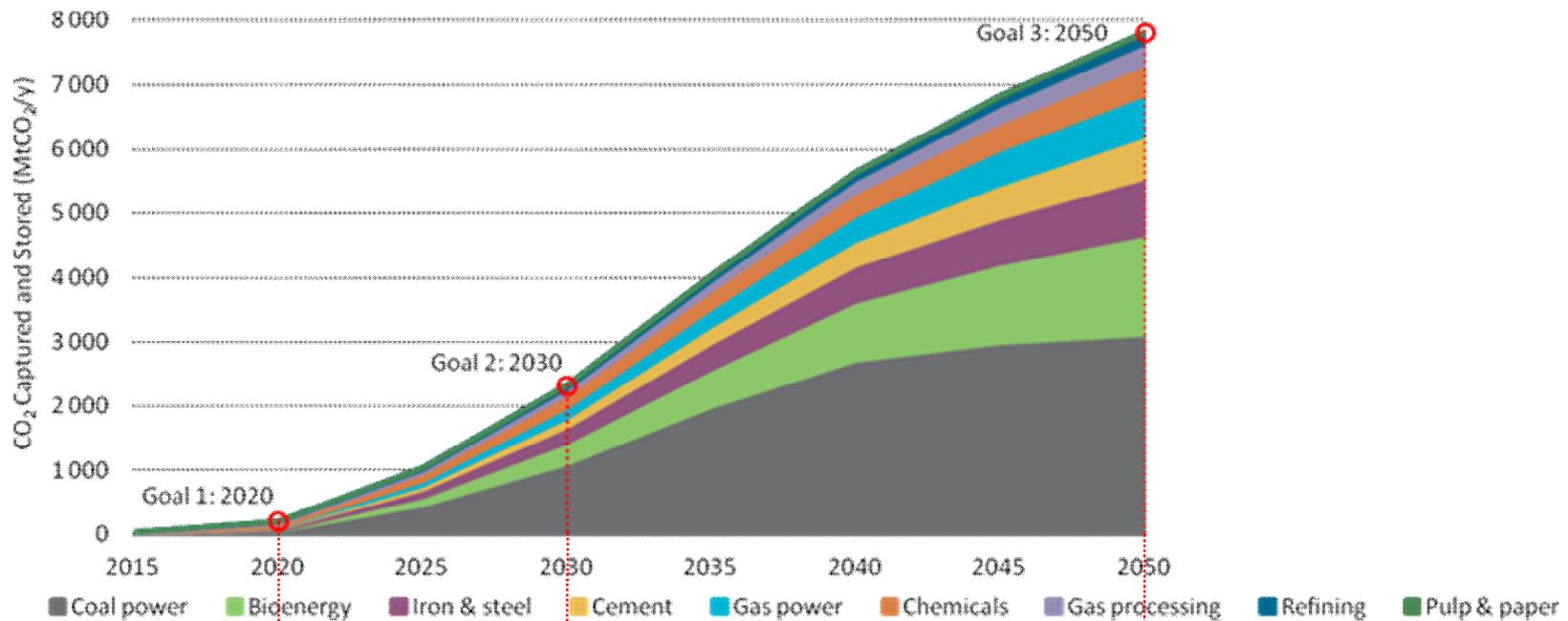


# CCS is one part of a cost-effective emissions reduction portfolio





# IEA vision: 120 Gt of CO<sub>2</sub> stored by 2050



### Goal 1: 2020

Over 30 large projects in operation in power and across a range of industrial processes, storing 50 MtCO<sub>2</sub> per year.

### Goal 2: 2030

Over 2 GtCO<sub>2</sub> is stored per year. CCS routinely used in power and certain industrial applications.

### Goal 3: 2050

Over 7 GtCO<sub>2</sub> stored per year. CCS routinely used in all applicable power and industrial applications.

# Why Biomass and CCS - the net carbon balance



Positive



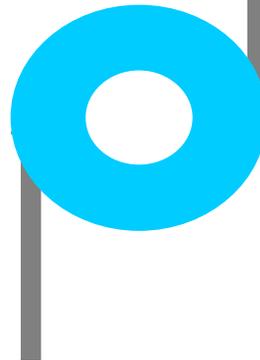
Fossil fuels

Less positive



Fossil fuels with CCS

Neutral to slightly positive



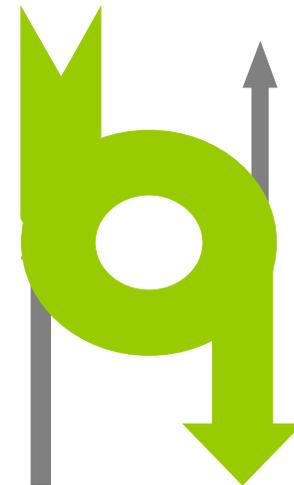
Renewable energy

Neutral to slightly positive



Bio-energy

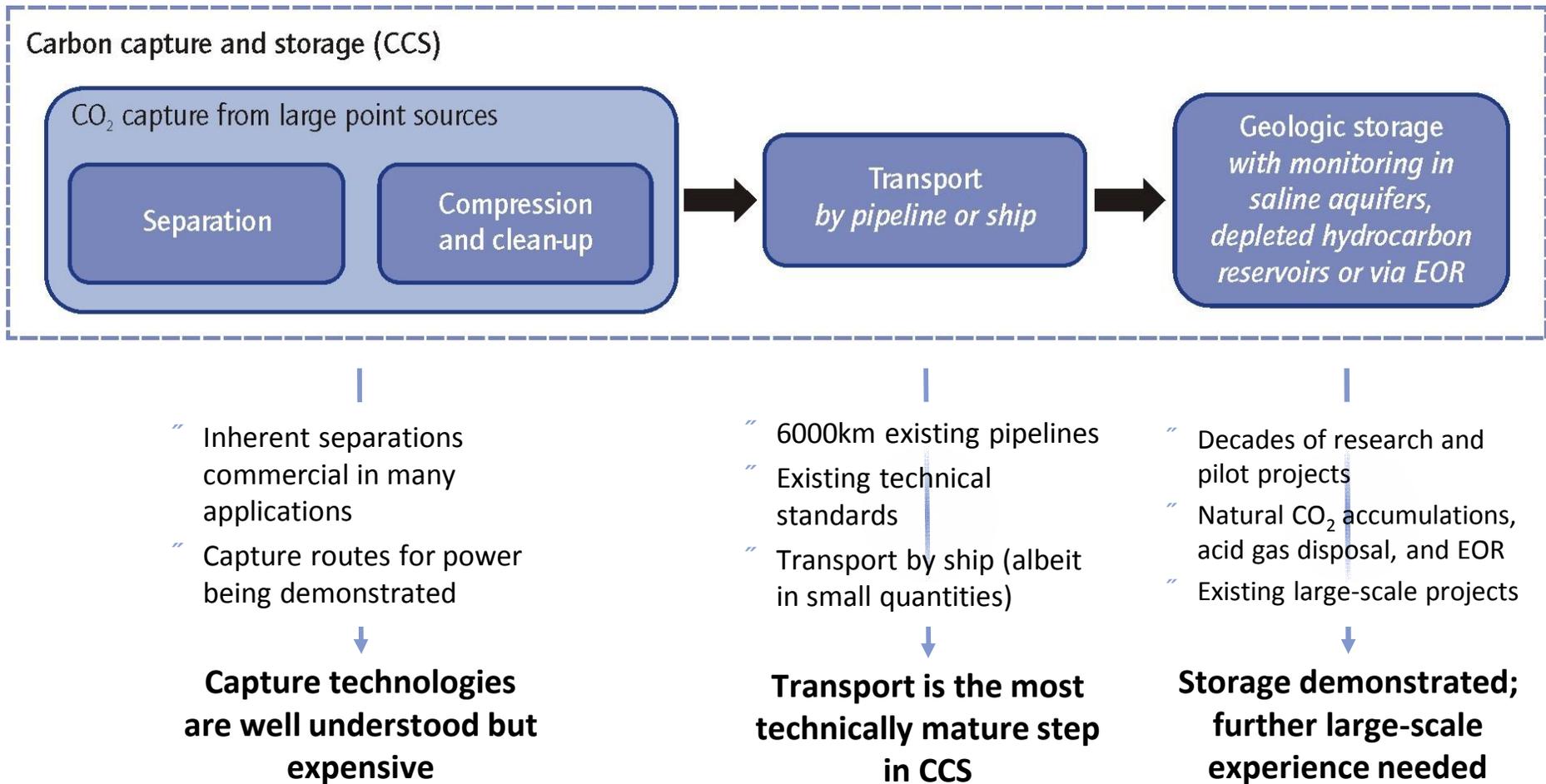
Neutral to negative



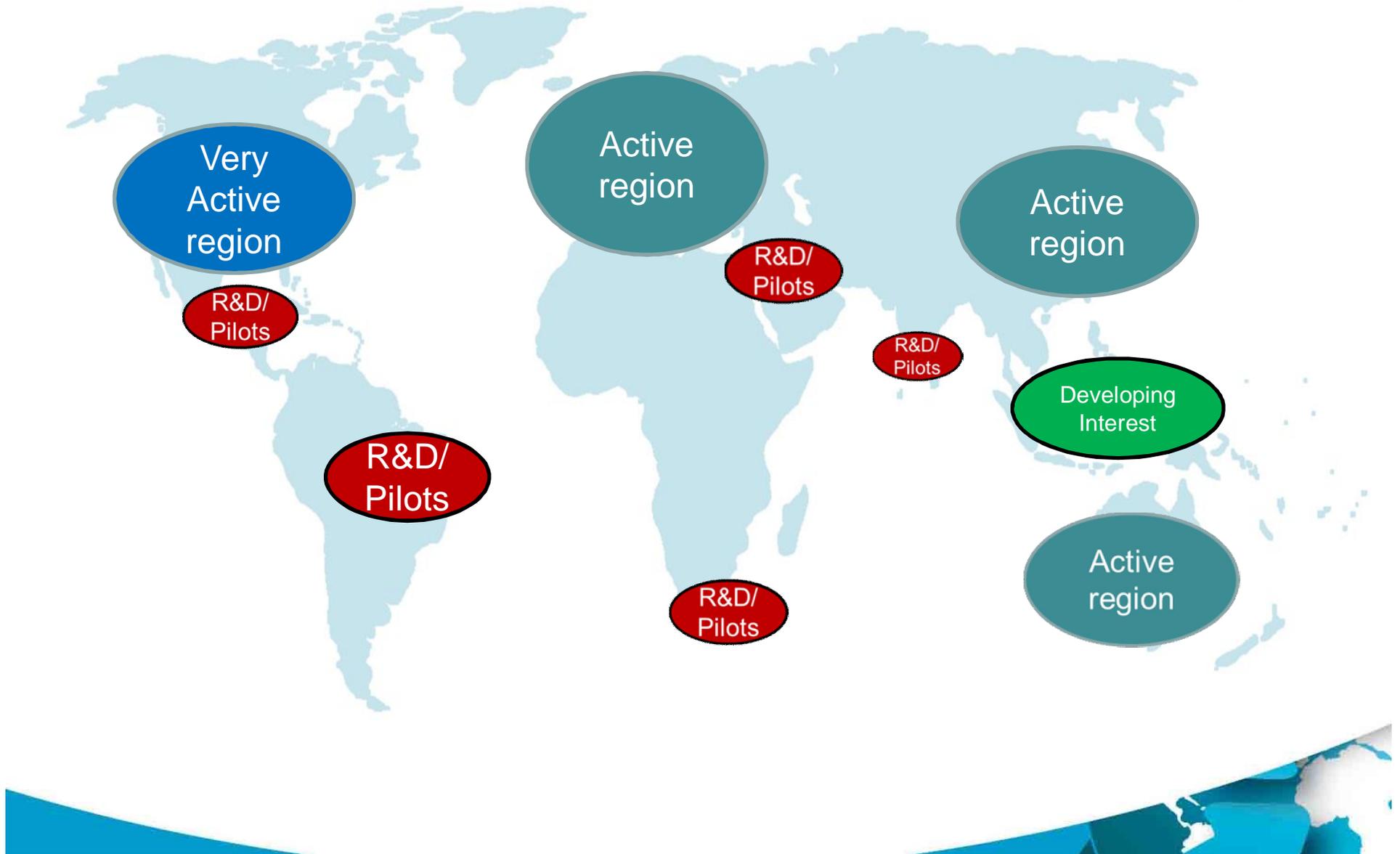
Bio-energy with CCS

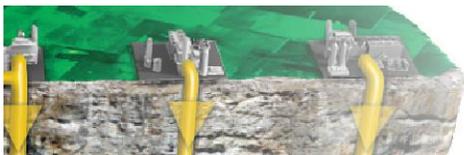


# CCS is ready for scale-up



# Global CCS Update





# 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<sub>2</sub> escape
- “ Lack of understanding by financiers

# Public Perception and Acceptance



## BURIED TROUBLE

Protesters saying "no to CO<sub>2</sub>" are just one roadblock facing carbon sequestration — a strategy that could help prevent dangerous climate change. **Richard Van Noorden** investigates.

Idea of injecting 100,000 tonnes of carbon dioxide into a shopping mall was always going to be a tough sell, so it proved when the Dutch minister of public affairs, Maria van der Horst, came to Barendrecht in December to explain why she vetoed the proposal, made by the petro-

chemists are uncertain about its viability at large scale. "There is lots of research and lots of talking, recycling of information — but little real progress," says Helmut de Gooijer, who works at the Energy Research Centre of the Netherlands. "That slow pace is especially frustrating because the strategy has a limited life."





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**IEA Greenhouse Gas R&D Programme**

# **4th Social Research Network Meeting**

**Hosts : University of Calgary**  
**Sponsors : University of Calgary, PTRC**

Calgary, Canada, 14-15 January 2013

[www.ieaghg.org](http://www.ieaghg.org)

# Aim of Social Research Network



- “ To foster the conduct and dissemination of social science research related to CCS in order to improve understanding of public concerns as well as improve the understanding of the processes required for deploying projects+
- “ Bringing together social science researchers and public engagement practitioners
- “ US DOE Best Practice on Public Outreach(2010)
- “ WRI CCS and Community Engagement(2011)

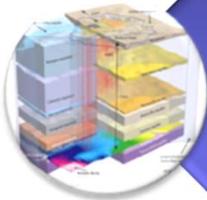
# IEAGHG Weyburn-Midale CO<sub>2</sub> Monitoring & Storage Project (WMP) 2000 to 2012



Commercial EOR operations in Weyburn and Midale oilfields utilise anthropogenic CO<sub>2</sub>



Over 25Mt of CO<sub>2</sub> injected and stored since 2000



WMP has used these sites to study technical aspects of CO<sub>2</sub> geological storage



# News of a ~~leak~~ at the Kerr Farm

January 11, 2011

**THE GLOBE AND MAIL**  
IN PICTURES  
**Carbon capture leak forces Saskatchewan couple to leave farm**  
Published Tuesday, Jan. 11, 2011 6:12PM EST  
Par abandon Saskatchewan farm because of blowouts, dead animals and algae



1 of 30

(Troy Flecko/The Canadian Press)

**Carbon injected underground is leaking: Sask. farmers**



Cattle gathered in a pasture near a pumpjack in an oilfield outside of Weyburn, Sask. on Monday, June 6, 2009.

The Canadian Press  
Published Tuesday, Jan. 11, 2011 11:57AM EST

**CO2 leaks worry Sask. farm**

Story Tools: [EMAIL](#) | [PRINT](#) | Text Size: [S](#) [M](#) [L](#) [XL](#) | [REPORT TYPO](#) | [SEND YOUR FEEDBACK](#)

Last Updated: Tuesday, January 11, 2011 | 8:40 PM ET | Comments: [164](#) | [Rece](#)

The Canadian Press

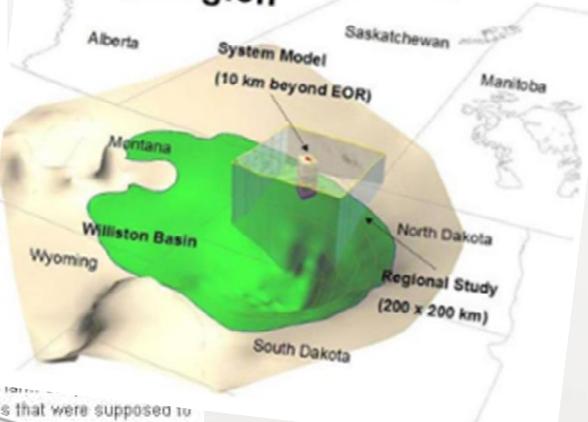
**SCIENCE + TECHNOLOGY**

Week in Pics: The News In Review  
Bacteria: Good, Bad, and Ugly  
The Week: In Animal Photos

**CO2 Levels at Leaking Canadian Carbon Storage Project Could Asphyxiate You In One Place**  
by Matthew McDemott, New York, NY on 01.12.11  
SCIENCE & TECHNOLOGY

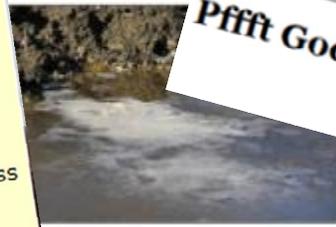
Recommend 18 people recommend this. Be the first of your friends. [Tweet](#) 10

**Study Region**



**Land fizzing like soda pop: farmer says CO2 injected underground is leaking**

By: Bob Weber and Jennifer Graham, The Canadian Press  
Posted: 01/11/2011 10:22 AM | [Comments: 9](#)



Jane Kerr took this picture of what they say is gas bubbling from water on their property.

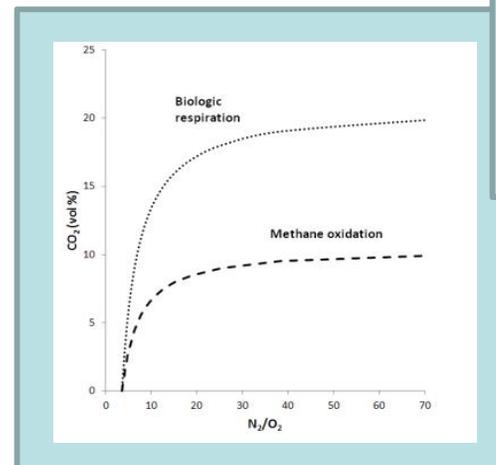
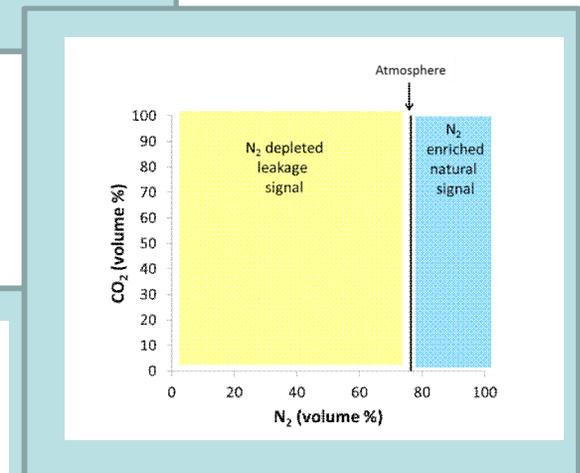
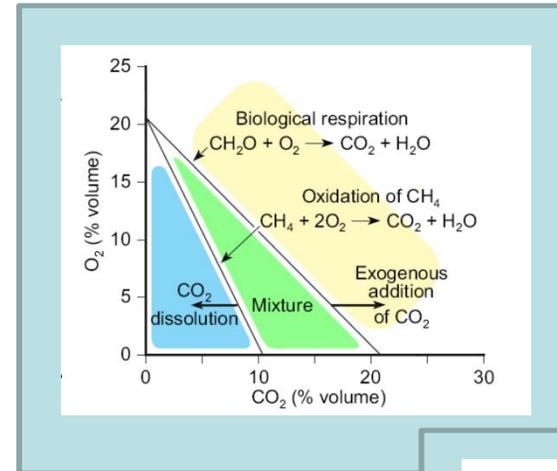
**Pffft Goes Promise Of Pumping CO2 Underground**

Cameron and ... above the Weyburn oilfield. Saskatchewan, have released a consultant's report that claims to link high concentrations of carbon dioxide in their soil to gas injected underground

# Process-Based Soil Gas Method



- “ Developed by University of Texas BEG (Romanak 2012)
- “ Shared in IEAGHG Research Networks
- “ Uses simple gas ratios ( $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2$ ,  $\text{O}_2$ )
- “ Discerns process including methane oxidation
- “ Instant answer- no long-term or complex measurements required
- “ Demonstrated at the Kerr Farm, Cranfield, ZERT



# Leakage Allegation Discounted

On a media release, Ecojustice lawyer Barry Robinson, who represented the Kerrs, accepted the IPAC-CO<sub>2</sub> study's findings while emphasizing its necessity, saying that without a full scale investigation, it has been impossible until now to rule out CO<sub>2</sub> contamination. +

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FOR IMMEDIATE RELEASE

**Long-awaited investigation into CO<sub>2</sub> impacts a 'win for all Canadians'**

DEC 12, 2011 09:37 AM

**ACCN** Canadian Chemical News  
L'Actualité chimique canadienne

## Weyburn CO<sub>2</sub> leak a false alarm



By Tyler Irving  
Posted February 2012

In January 2011, Cameron and Jane Kerr alleged that CO<sub>2</sub> from a nearby experimental carbon storage project was leaking onto their farm near Weyburn, Sask. A year later, two independent investigations have concluded that this is not the case.

The project consists of piping CO<sub>2</sub> from a coal gasification plant in North Dakota into an oil field operated by Canadian oil company Cenovus. Last summer, Cenovus contracted TRUM Environmental to undertake extensive soil and surface water sampling operations on the property. The results, delivered last November, show CO<sub>2</sub> concentrations consistent with what is commonly found in prairie soil gas in summer. Moreover, carbon levels were inversely correlated with oxygen levels, a sign that the CO<sub>2</sub> was produced by biological respiration. Finally, the presence of unstable

<sup>14</sup>C indicated a young carbon source. Since <sup>14</sup>C has a half-life of about 5,730 years, it would have been absent in CO<sub>2</sub> from the several million-year-old coal deposits.

# International regulatory developments – why they started happening

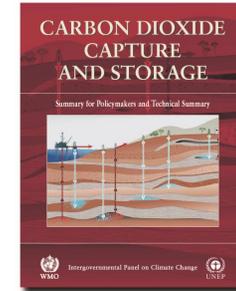


Role of CCS in climate change mitigation?

- “ IPCC Special Report (2005) . CCS contributing 15-55% of CO<sub>2</sub> mitigation to 2100
- “ G8 2005 recognised CCS at highest level, 5 initiatives
- “ IEA Technology Perspectives (2006) . CCS 20-28% of mitigation to 2050. Second only to energy efficiency.
- “ Stern Report (2006) . CCS ~10% mitigation by 2025, ~20% by 2050. Marginal mitigation costs without CCS increase by ~60%.
- “ 2004/5 Ocean acidification realisation



# 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 CO<sub>2</sub> 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

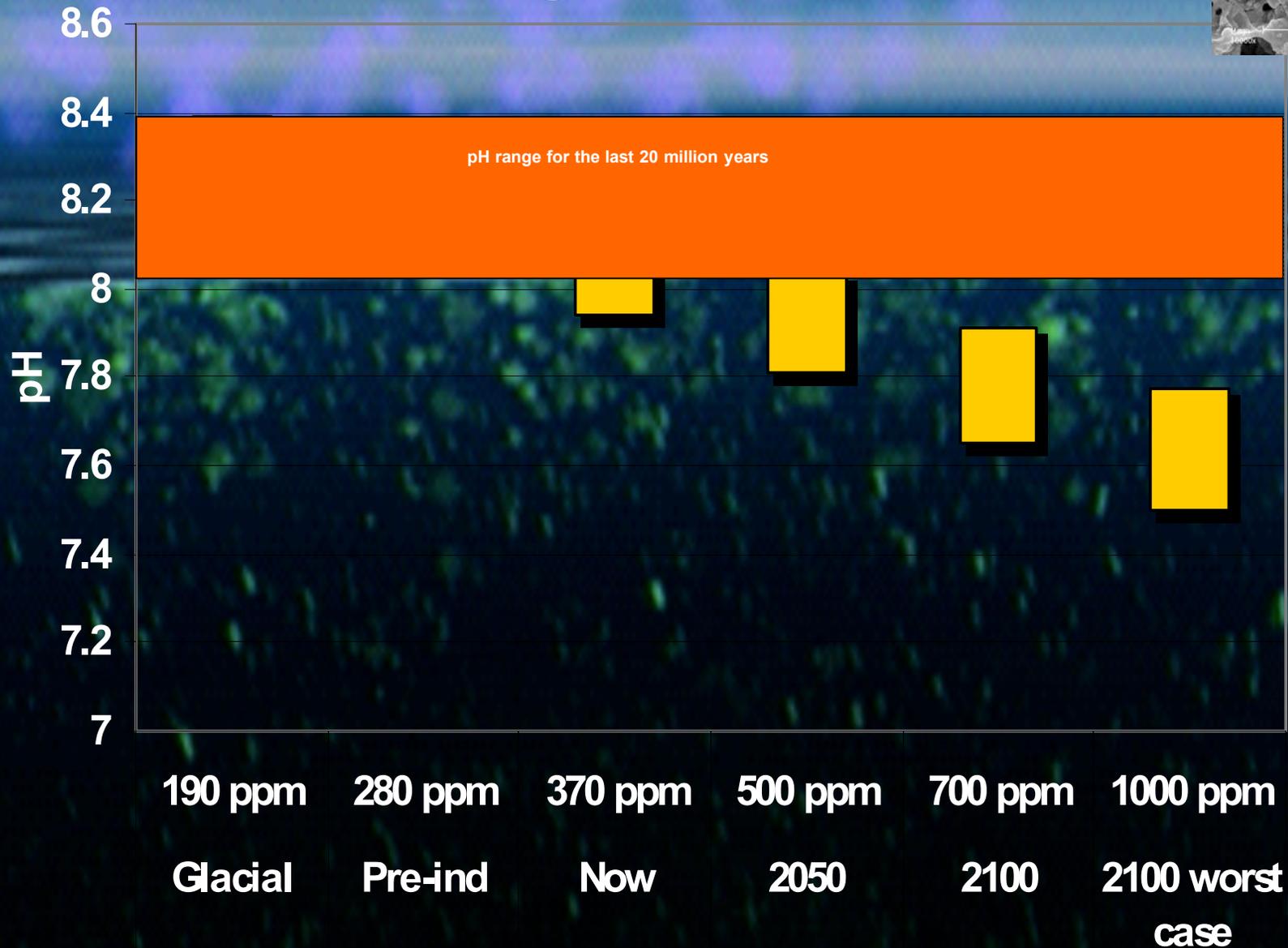
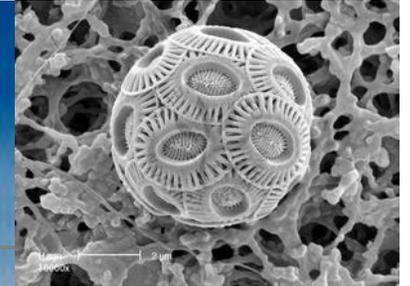
# London Convention and Protocol



- “ Marine Treaty - Global agreement regulating disposal of wastes and other matter at sea
- “ Convention 1972 (86 countries)
- “ Protocol 1996 . ratified March 2006 (43 countries as of Jan 2014)
- “ Prohibited some CCS project configurations
- “ CO2 Geological Storage Assessed by LC Scientific Group 2005/6
- “ 2006 - Risk Assessment Framework for CO2
- “ To allow prohibited CCS configurations . Protocol amendment adopted at 28th Consultative Meeting (LP1), 2 Nov 2006 - came into force 10 Feb 2007 to allow disposal in geological formations
- “ CO2 Specific Guidelines



# Simulated and observed marine pH ranges till 2100



PML  
2005



# EU Developments



EU Spring Council 2007 - Action Plan for Energy Policy for Europe

- “ Stimulate up to 12 CCS demonstrations by 2015
- “ Strengthen R&D and develop technical, economic and regulatory framework to bring environmentally-safe CCS to deployment by 2020

“ **CCS Directive – Environmental protection and enabling regulation**

“ **Emissions Trading Directive – GHG emissions**

“ Drafted Jan 2008 - Adopted 6 April 2009, published 5 June 2009



# UNFCCC and CCS



- United Nations Framework Convention on Climate Change (UNFCCC) - 194 Parties, taking action to reduce GHG emissions
- Kyoto Protocol - 188 Parties, GHG emission limits on developed countries
  - Clean Development Mechanism (CDM)
  - Policy mechanism for rewarding CO<sub>2</sub> reduction in developing countries. Project-based carbon credits.
  - 7,400 projects . 1,400 Mt CO<sub>2</sub>e



# Kyoto Protocol and CCS



## Considering CCS in CDM since 2005

- 2005 CDM Executive Board (EB) considers two new CCS methodologies
- 2005 CMP1 Montreal
  - referred to SBSTA
- 2006 SBSTA Technical workshops - Consideration of technical and policy issues . project boundary, leakage, permanence
- On agenda of each SBSTA meeting
- 2007 and 2008 Submissions from Parties and NGOs . two synthesis reports
- 2008 Decision due at CMP4/COP14 Poznan . **failed**
  - CMP request EB to look at implications
- 2009 EB commission ~~±~~ Experts Reportq
- 2009 Decision due at CMP5/COP15 Copenhagen . **failed**
- 2010 CMP6/COP16 Cancun .....

“ All CCS CDM reports and background <http://cdm.unfccc.int/about/ccs/index.html>

# Key issues of concern



## Included

- “ Timescales of benefits vs liability
- “ Impact on CDM market
- “ Scale and impacts of leakage
- “ Furthering use of fossil fuels . sustainable development
- “ Role of CCS in climate change mitigation
  
- “ Negotiations characterised by a few countries having strong views against CCS . but UNFCCC needs consensus to progress
  
- “ UNFCCC CMP/COP16 (2010) Cancun . progress!
- “ Eligible if concerns can be addressed in CCS-specific regulations

# UNFCCC

## Technical Workshop 2011

Abu Dhabi 7-8 Sep 2011



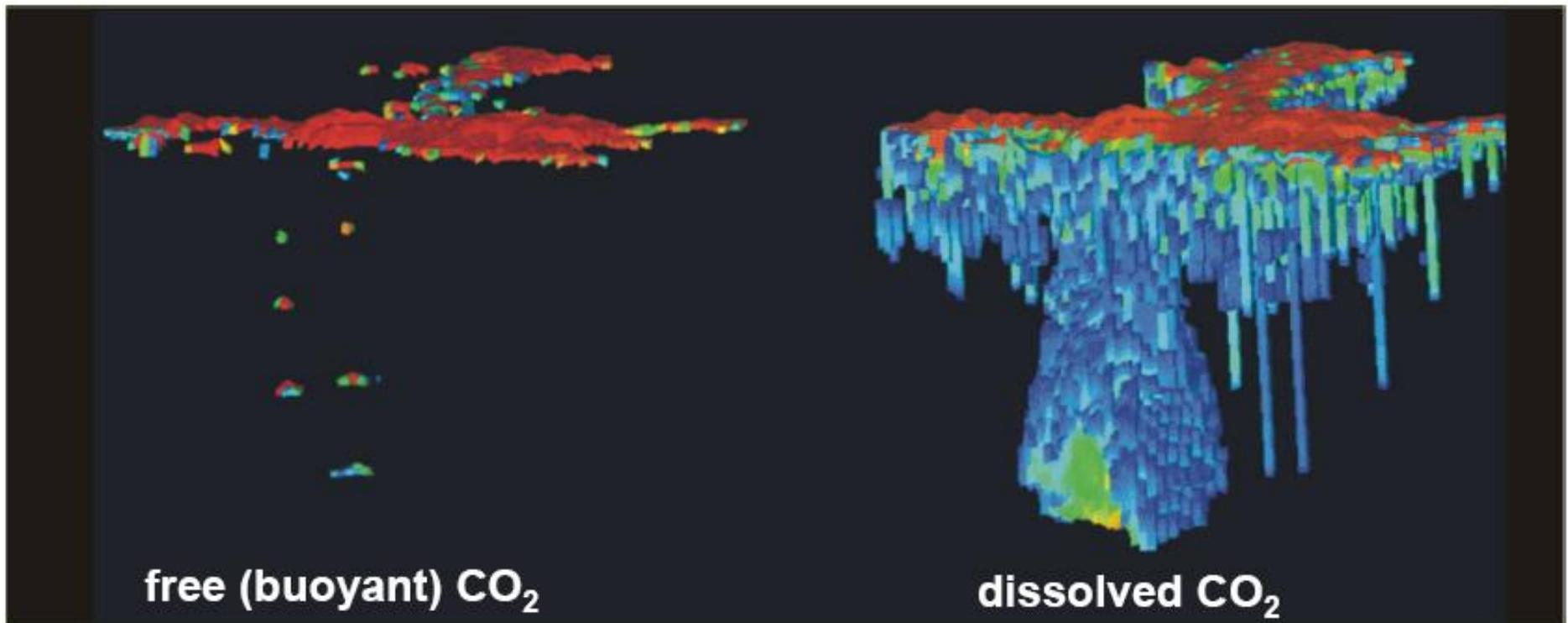
- “ Brought technical expertise to negotiators
- “ Technical experts on site selection; modelling; accounting; project boundaries; transboundary; risk assessment; environmental impacts; monitoring; liability (28 talks, several members of IEAGHG Networks).
- “ Results and experiences from real projects and natural systems, to support modelling and risk assessments
- “ Good Q&As from CCS negotiators and others



Courtesy UNFCCC / K.Romanak,  
BEG, UT

# Sleipner predicted stabilization

(250 years after injection)

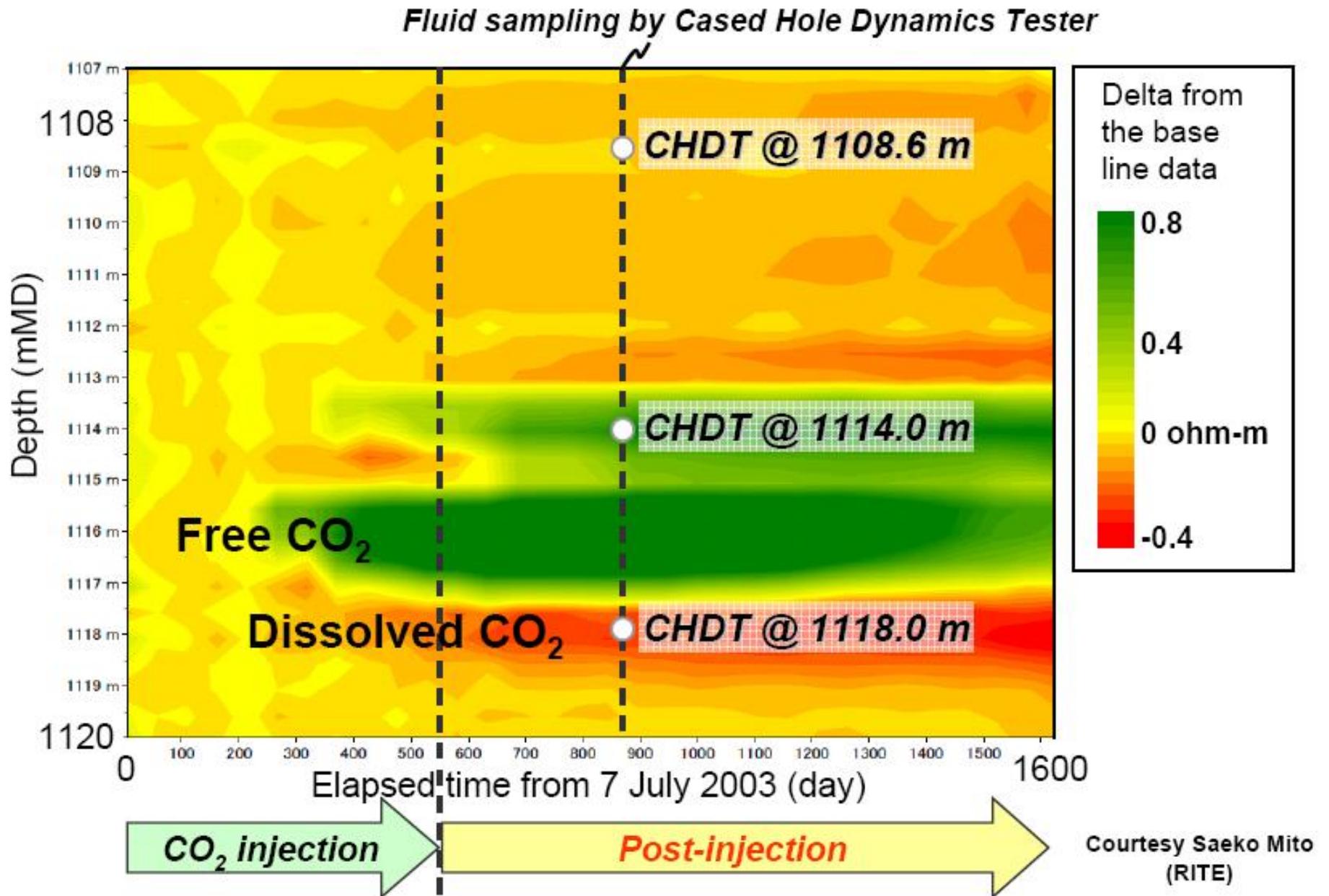


[Courtesy Erik Lindeberg]

Onset of dissolution: gravitational stabilization

# Post-injection monitoring at Nagaoka (Japan)

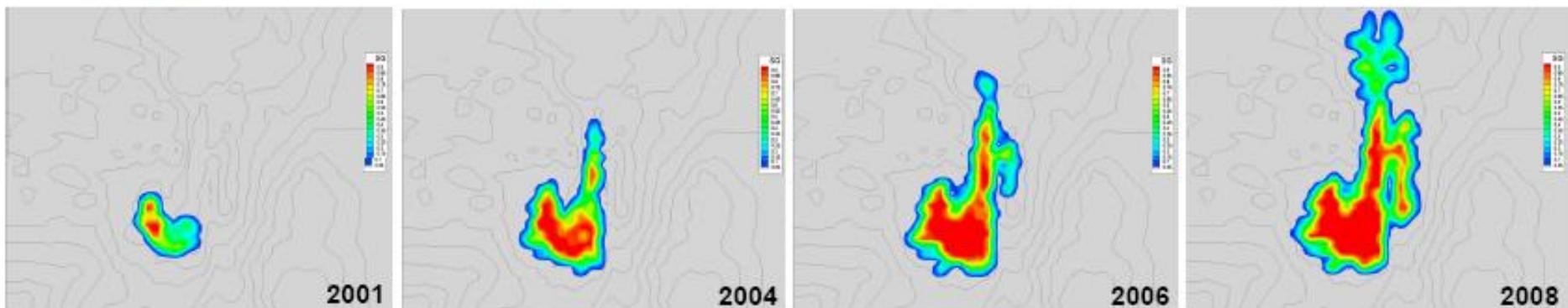
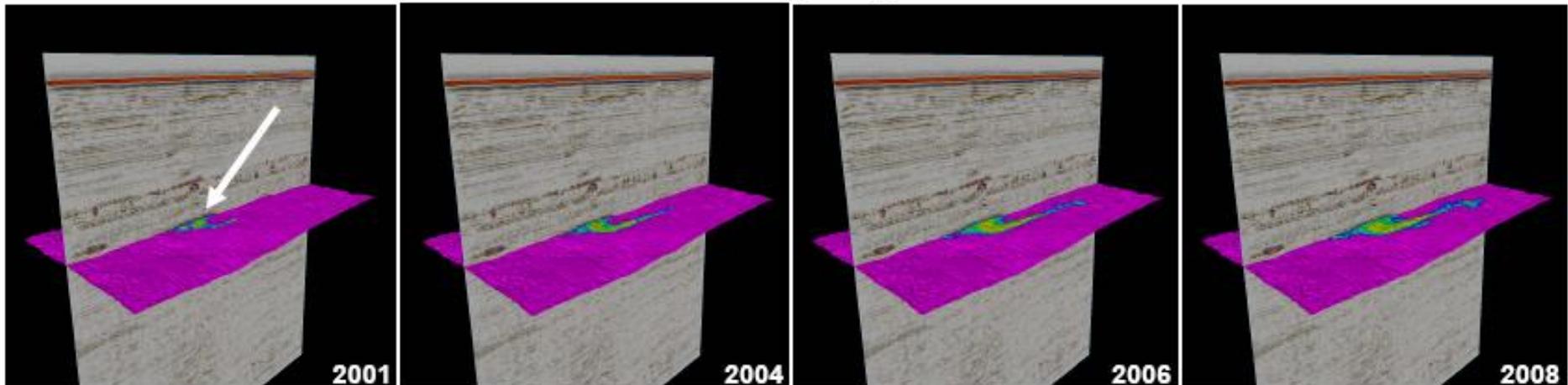
Courtesy A.Chadwick 2011



# History-matching plume migration at Sleipner (3)

Courtesy A.Chadwick 2011

## observed layer growth



## numerical flow simulation of layer growth

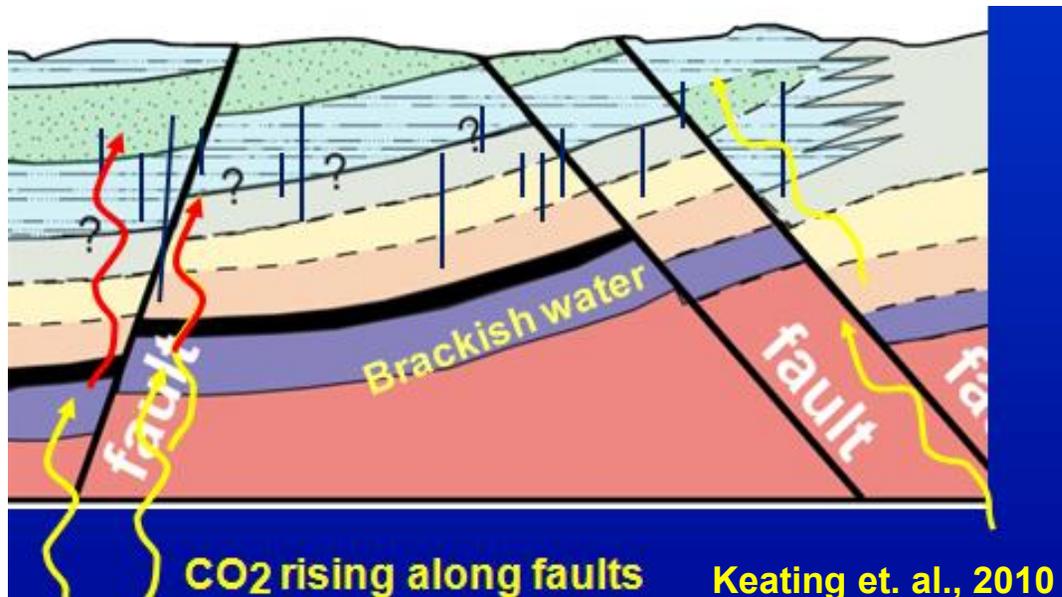
Match imperfect but sufficient to prove understanding of process

Scope for divergence in long-term predictions is limited

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# CO<sub>2</sub> at the surface. Natural Analog Chimayo, New Mexico, USA



“Integrated field, lab and modeling.

“Trace elements are strongly associated with brackish water; in-situ mobilization is negligible

“Mineral precipitation decreases metal concentrations



# CMP7/COP17 Durban (2011) Negotiations on CCS CDM



“ Over 32 hours of formal negotiations . 20 pages . Success!



# Significance of CCS M&Ps from Durban



- “ **Allows CCS to be CDM project activity and earn CERs**
- “ Create incentives / signal for CCS in developing countries
  - ▶ CDM key international mechanism supporting low-C technology in developing countries
- “ Legitimises CCS as valid technology for developing countries
- “ Establishes precedence-setting regulatory framework for CCS funded under international mechanisms





**Thank You**

**Any questions?**

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[www.ieaghg.org](http://www.ieaghg.org)

