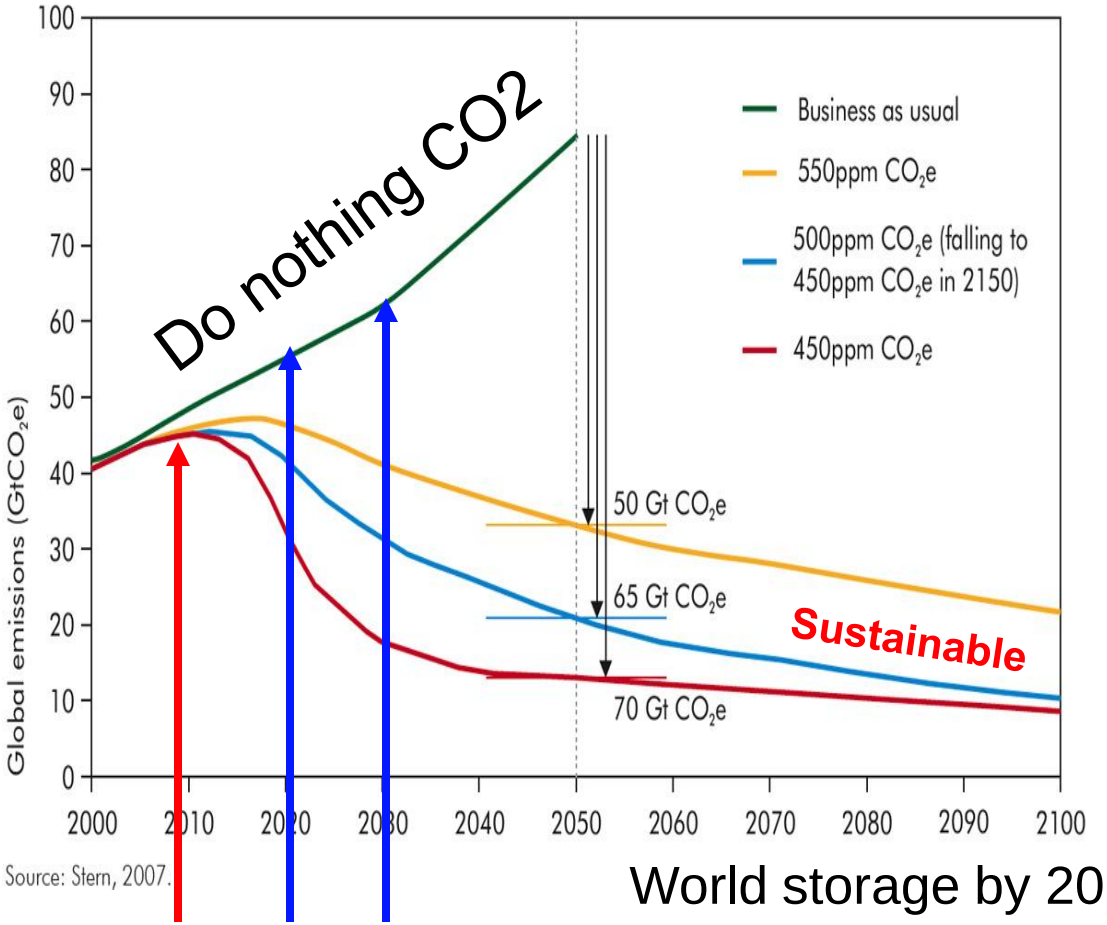
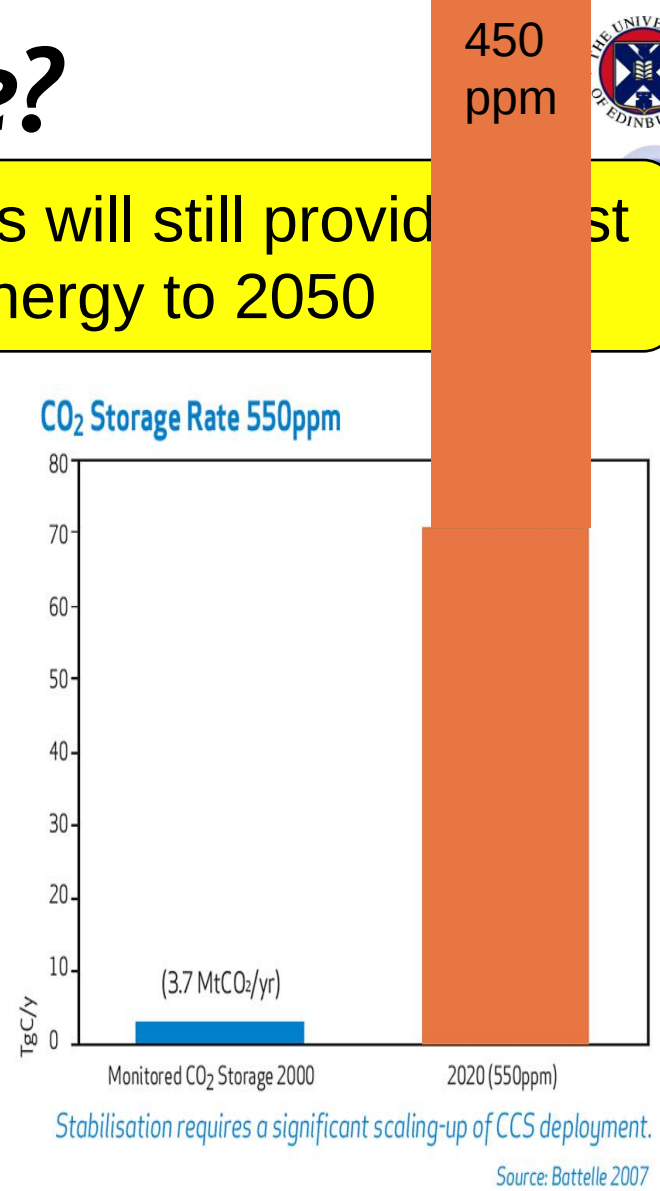
Coal or climate?

Stuart Haszeldine
University of Edinburgh

Fossil fuels will still provid st of world energy to 2050





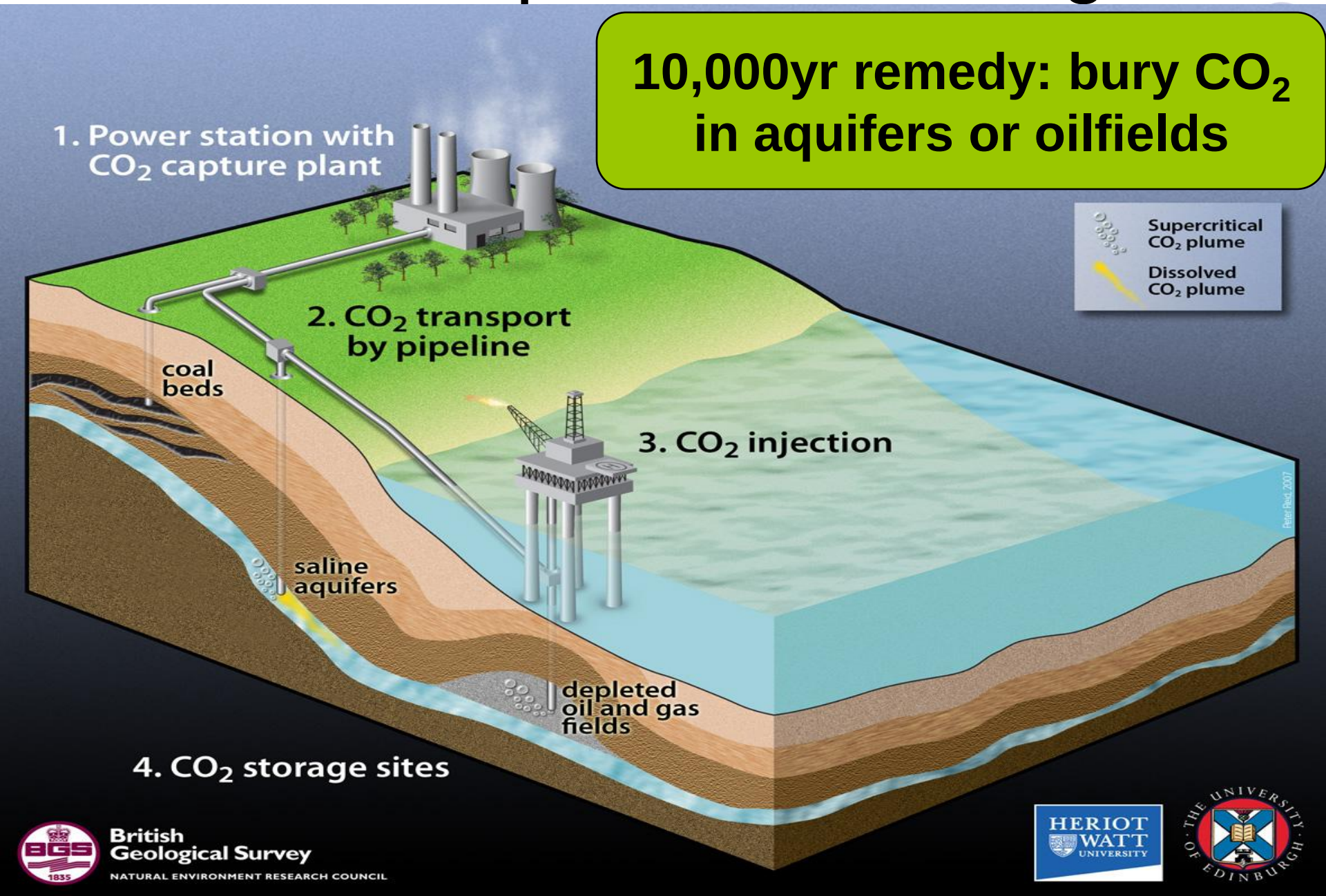
Here NOW No Not here

World storage by 2020
450ppm = 54 x 2.4 GW

at From 2020
coal, 22/yr gas

CO2 capture and storage

10,000yr remedy: bury CO_2 in aquifers or oilfields



How Much Delivery, When

How much Deliver, When

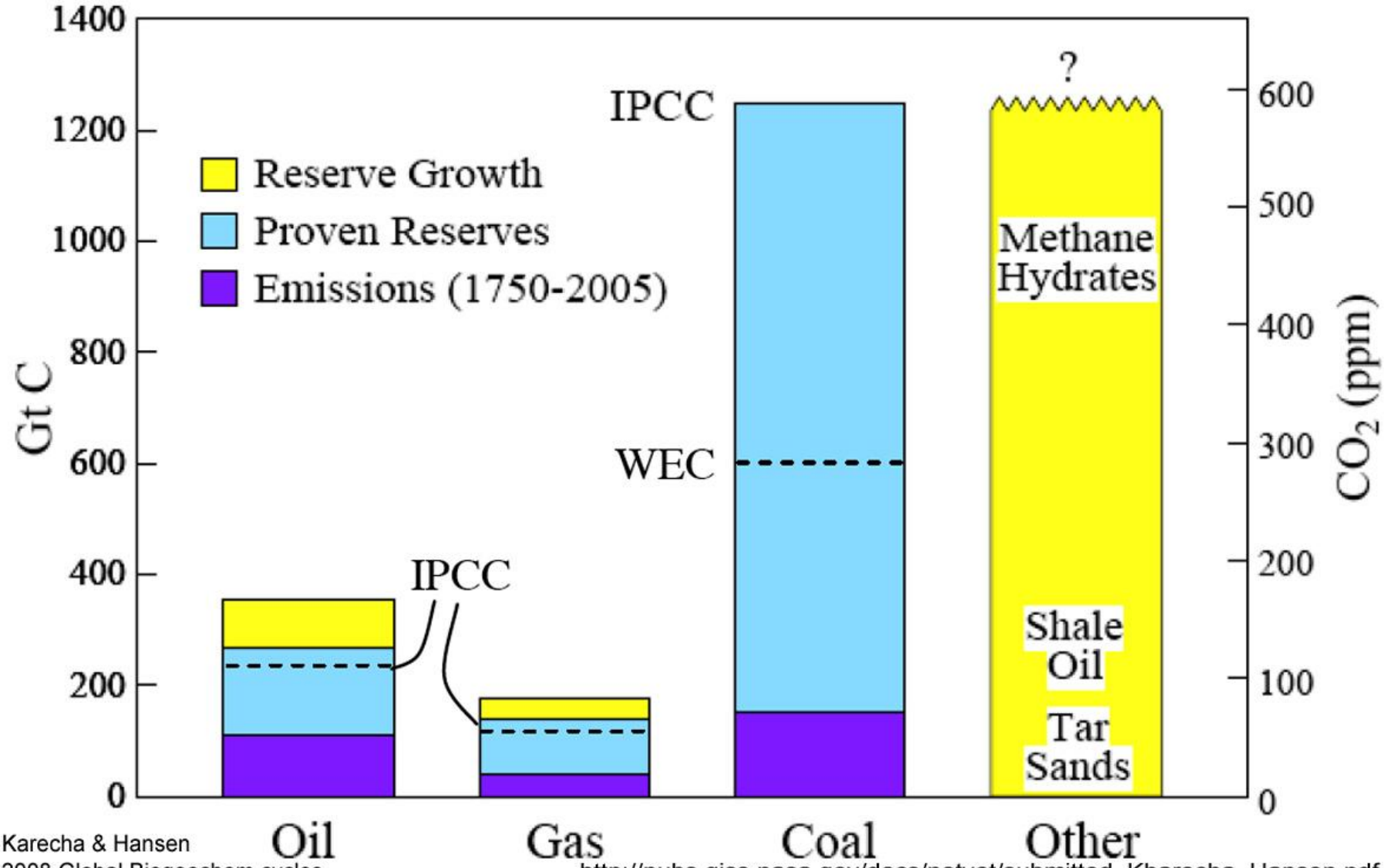
Transitional long short ?

Growth potential

Sustainability impacts

Obstacles research needs

Fossil fuel :90% remains to burn



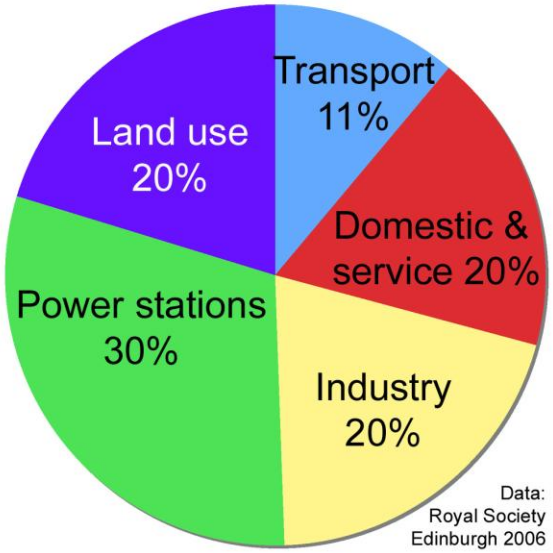
Karecha & Hansen
2008 Global Biogeochem cycles

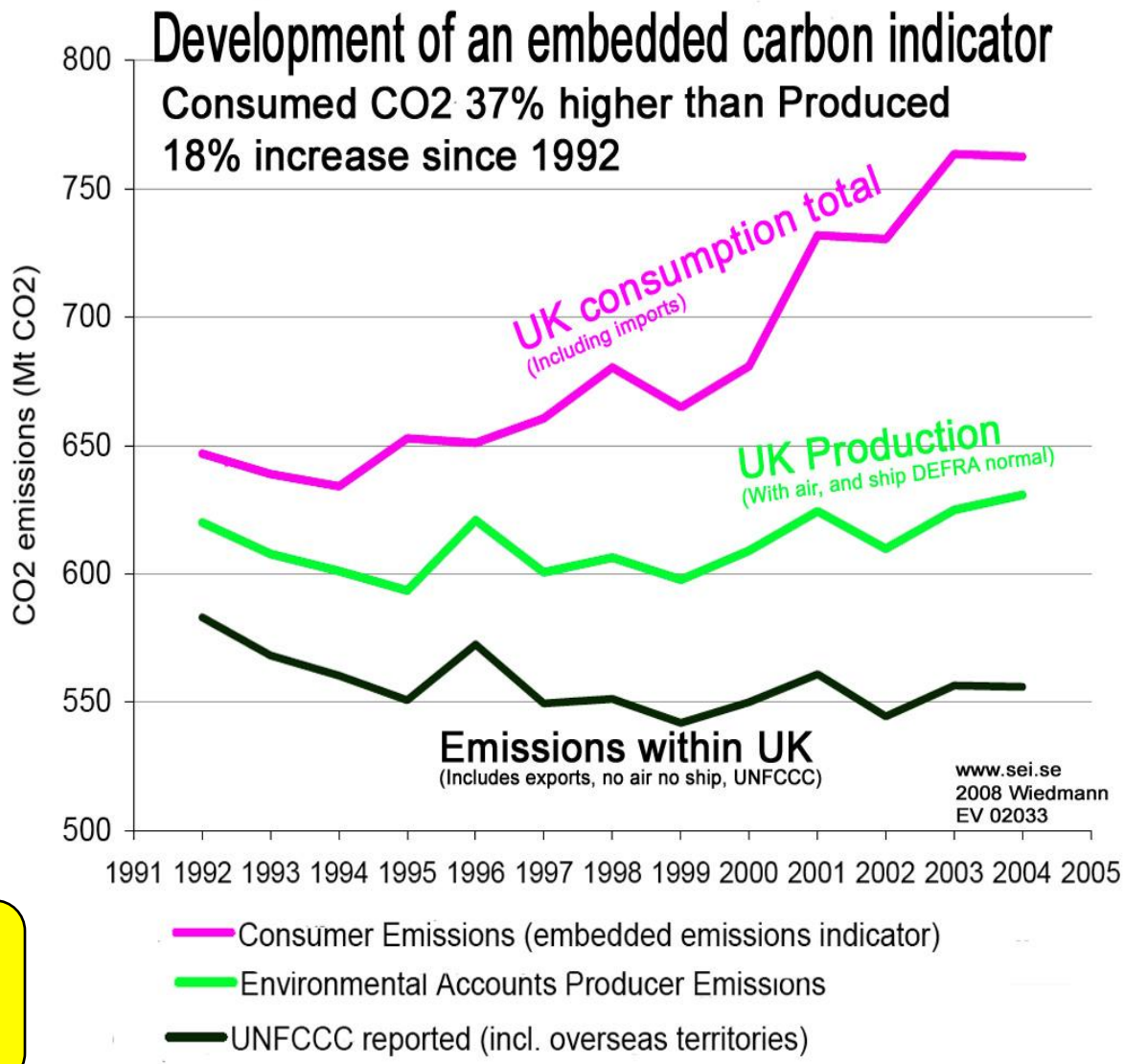
http://pubs.giss.nasa.gov/docs/notyet/submitted_Kharecha_Hansen.pdf

Only 10% fossil resource already used

CO2 from power. Huge imports

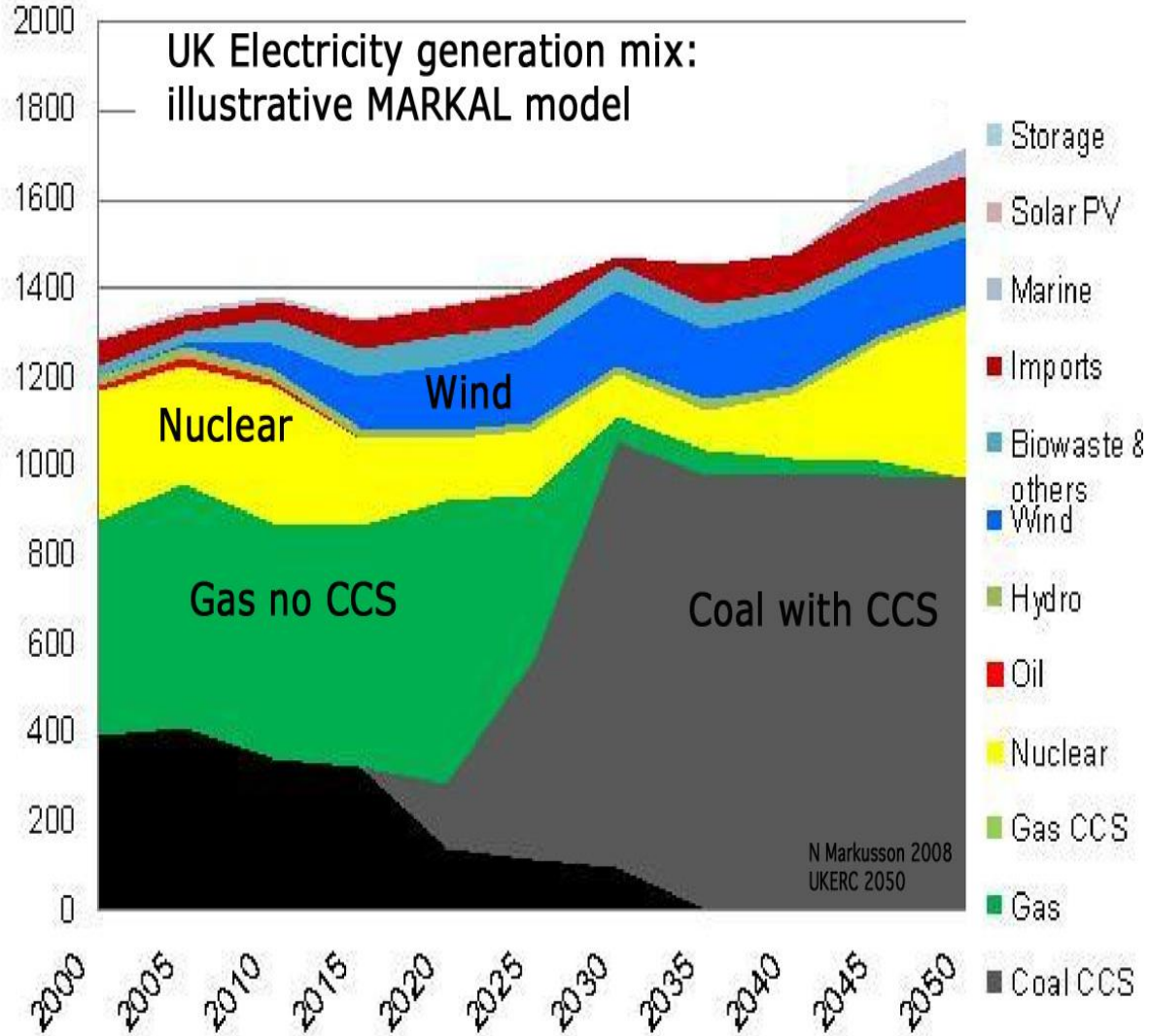
Scottish CO2 emissions 2002





UK emissions are INCREASING

CCS in the national electricity mix



Will CCS be competitive in price? The UK Energy Research Centre 2050 project has used a MARKAL cost model, to quantify the future energy system mix.

Dr Nils Markusson has elicited best-available CCS cost data, which are run by researchers at Kings College London. This illustrative scenario image, shows electricity generation into the future

CCS typically 20-50% world CO2

Scottish Centre for Carbon Storage
www.geos.ed.ac.uk/sccs

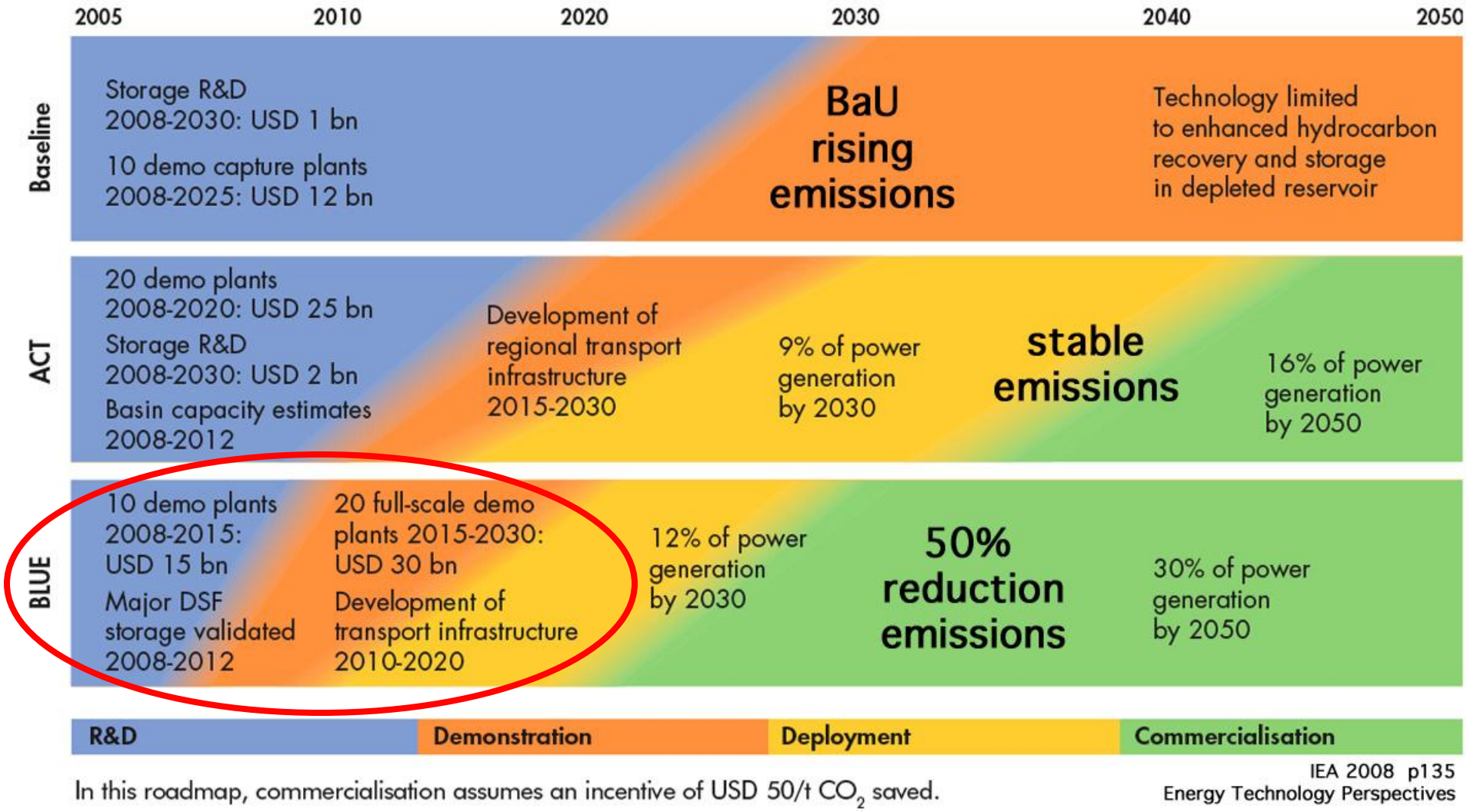
When How Much ?

Can deliver from 2015

Ambition 2020 routine in EU

Ambition 2030 to be routine in world

IEA Roadmap

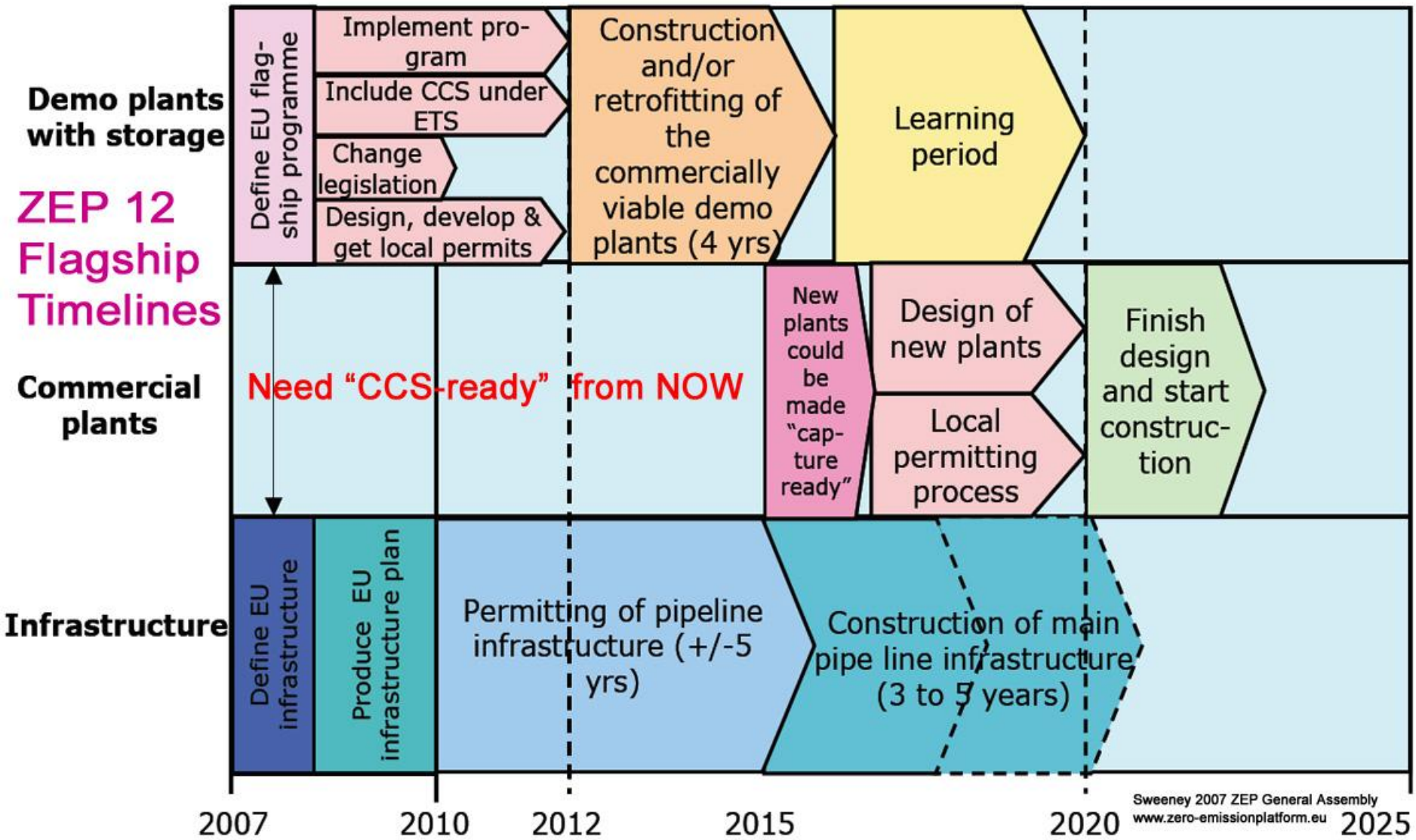


In this roadmap, commercialisation assumes an incentive of USD 50/t CO_2 saved.

IEA 2008 p135
Energy Technology Perspectives

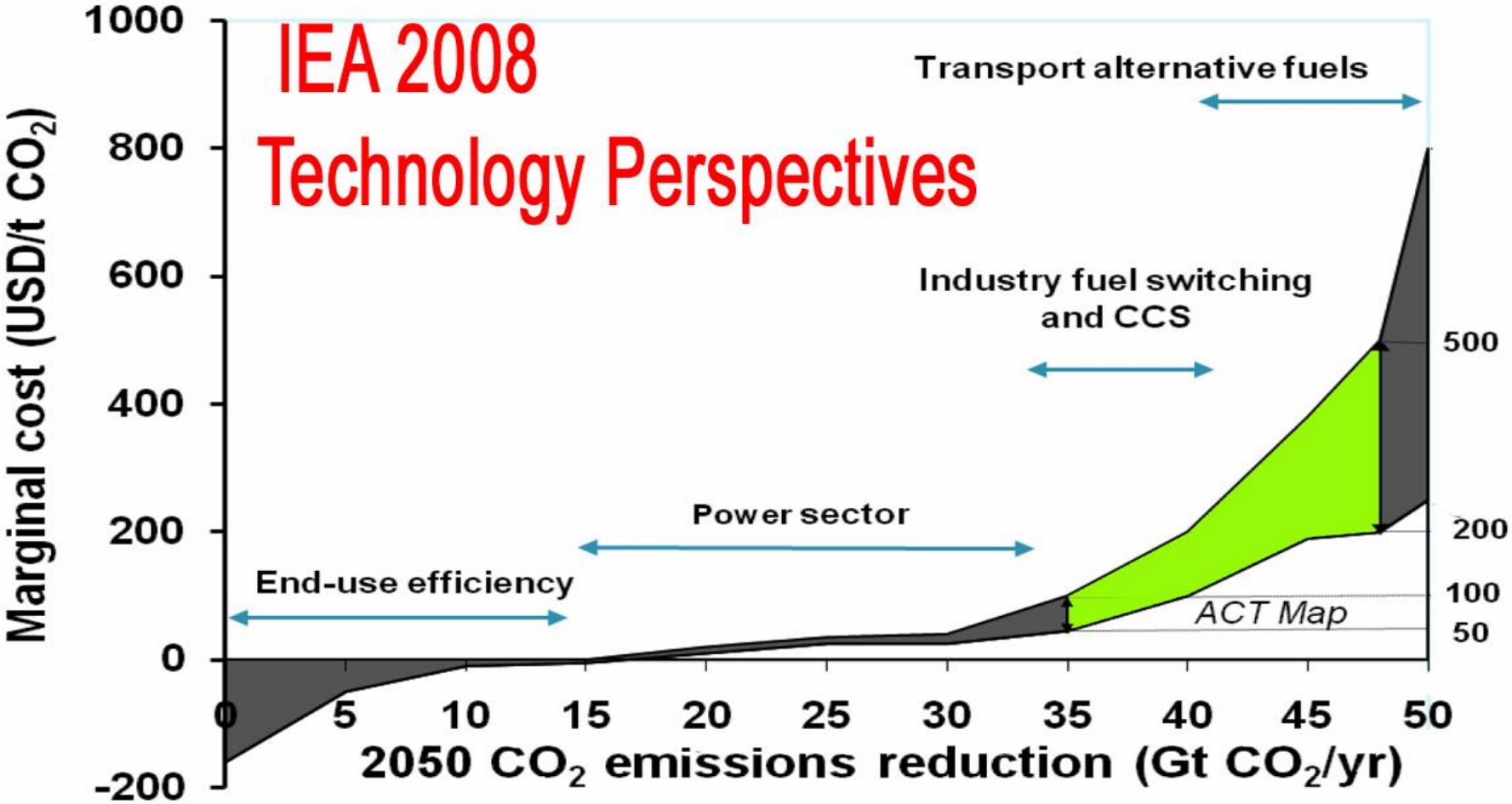
IF: CCS is to deliver for >25% decarbonisation
THEN : 20 plants needed by 2015 (G8); 20/yr coal, 22/yr gas

EU industry : ZEP roadmap



On track for 2020, if OpEx funded

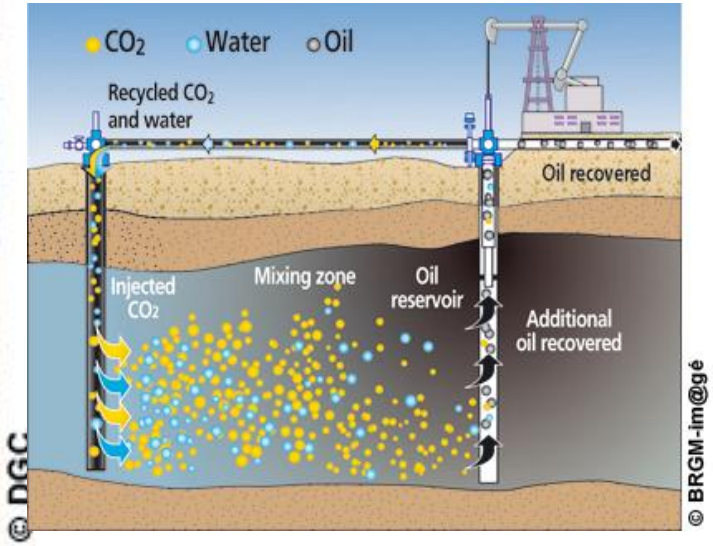
CCS dominates after 2030 >35Gt



By 2050: For **level** CO2 emissions **$50/ton** abatement
For **decreased** CO2 emissions **$200/ton** abatement

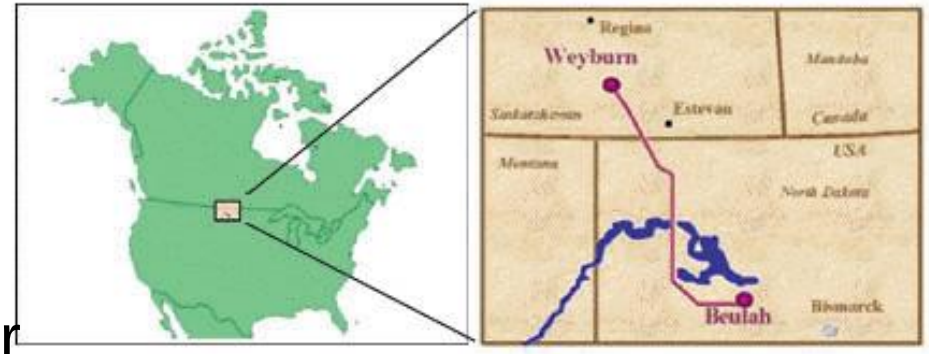
Dakota: Beulah gasification 1984

Inject for Enhanced Oil Recovery



Brown COAL gasification since 1984, CO2 pipe, 330 km

Since 2000, 1 Mt CO2 /yr, 152 bar

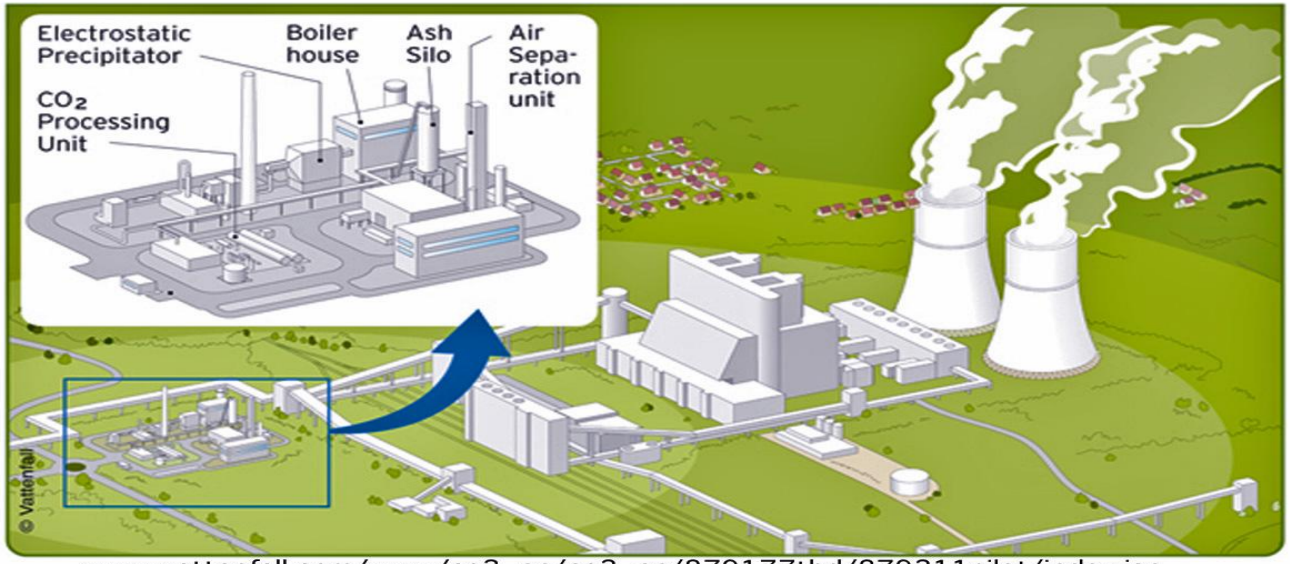


CCS is happening 2008

2008 E Germany
Schwarze Pumpe

Vattenfall 50 MW

Oxy-fuel COAL



www.vattenfall.com/www/co2_en/co2_en/879177tbd/879211pilot/index.jsp

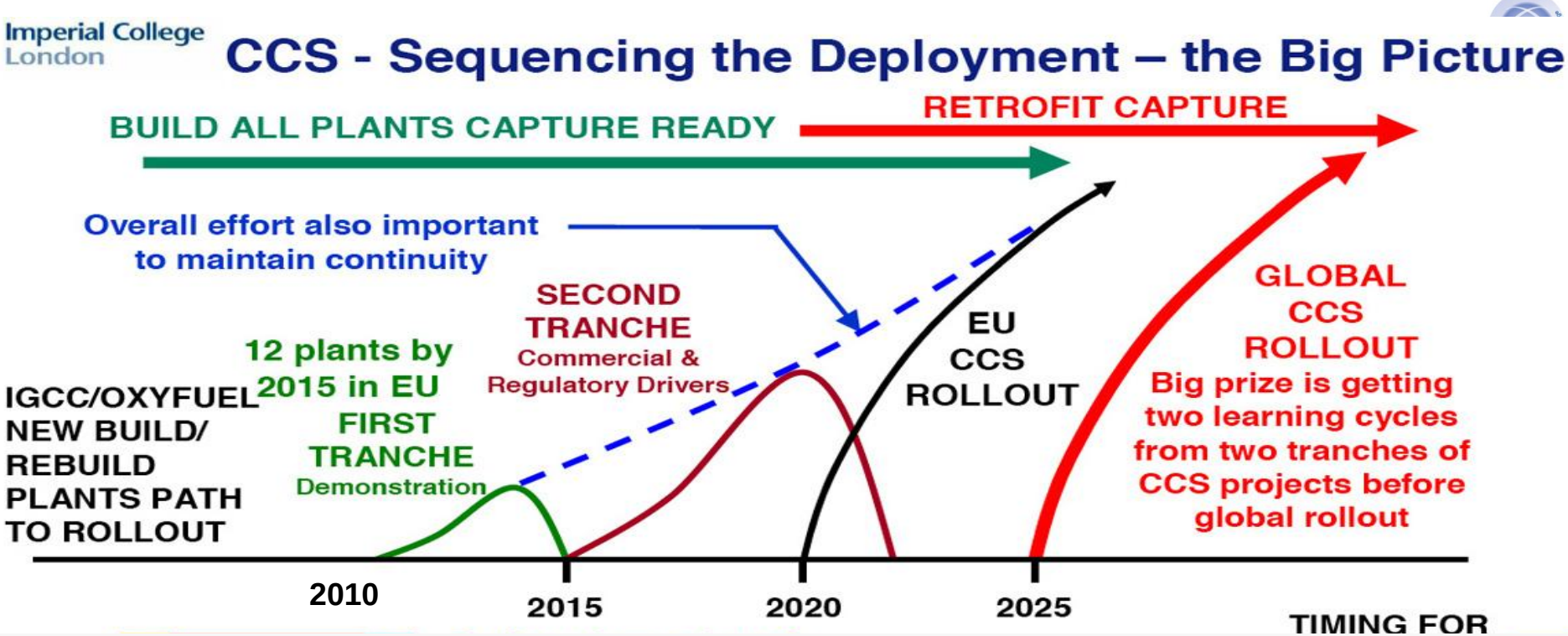
2013 BP Abu Dhabi

Masdar 1.7Mt CO2/yr
420MWe

Pre-combustion GAS

Short and medium timescales

Pilot Plant: Cycles of learning

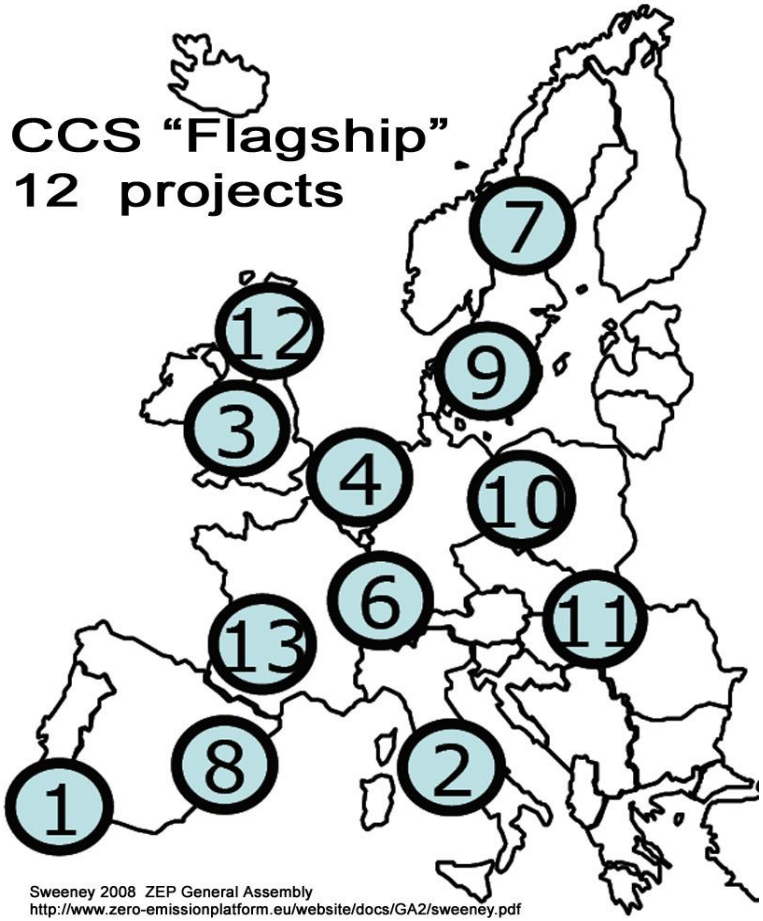


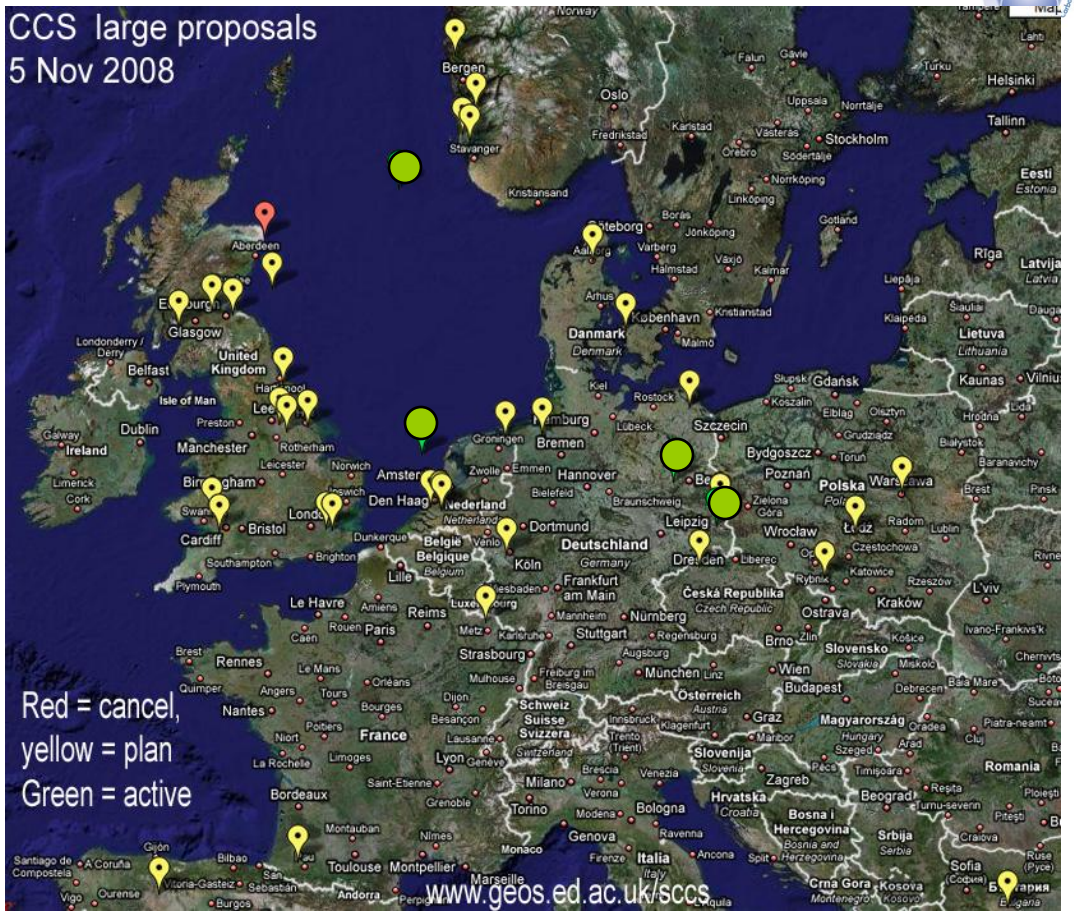
Imperial College London
Power plant design series

Gibbins and Chalmers 2008

Energy Policy

Europe: 12 CCS projects

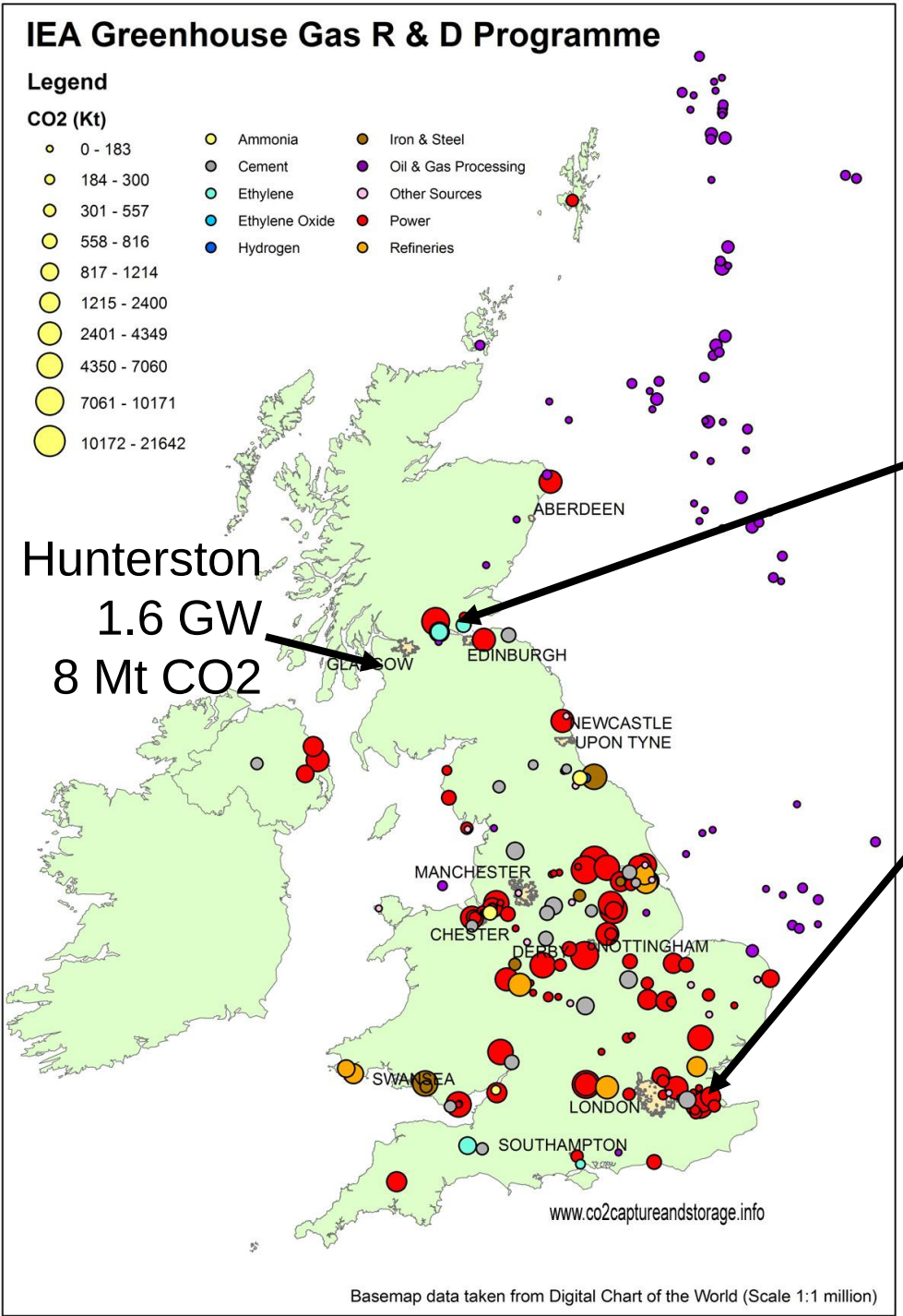




12 full-size pilot plant in EU by 2015

UK competition CCS 2008

0.4 GW, soon after 2014



Hunterston
1.6 GW
8 Mt CO2

Longannet 10 Mt CO2 /yr coal
Scottish Power

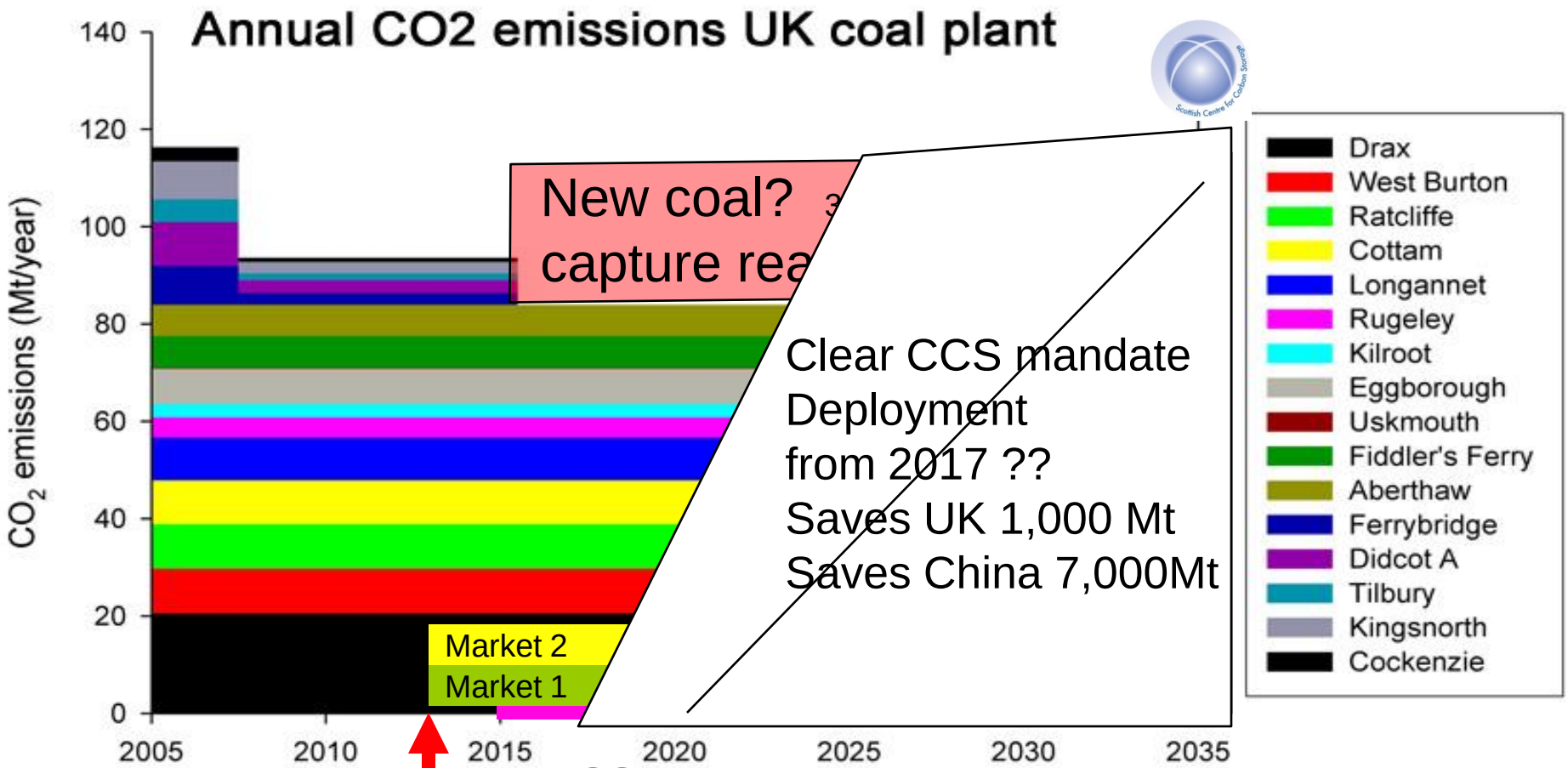
BP Alternative Energy
Withdrawn

Kingsnorth 1.6 GW, 8Mt CO2
E.ON

One small project

But what is Plan B ?

Capture -ready V deployment



EU-ETS auctions

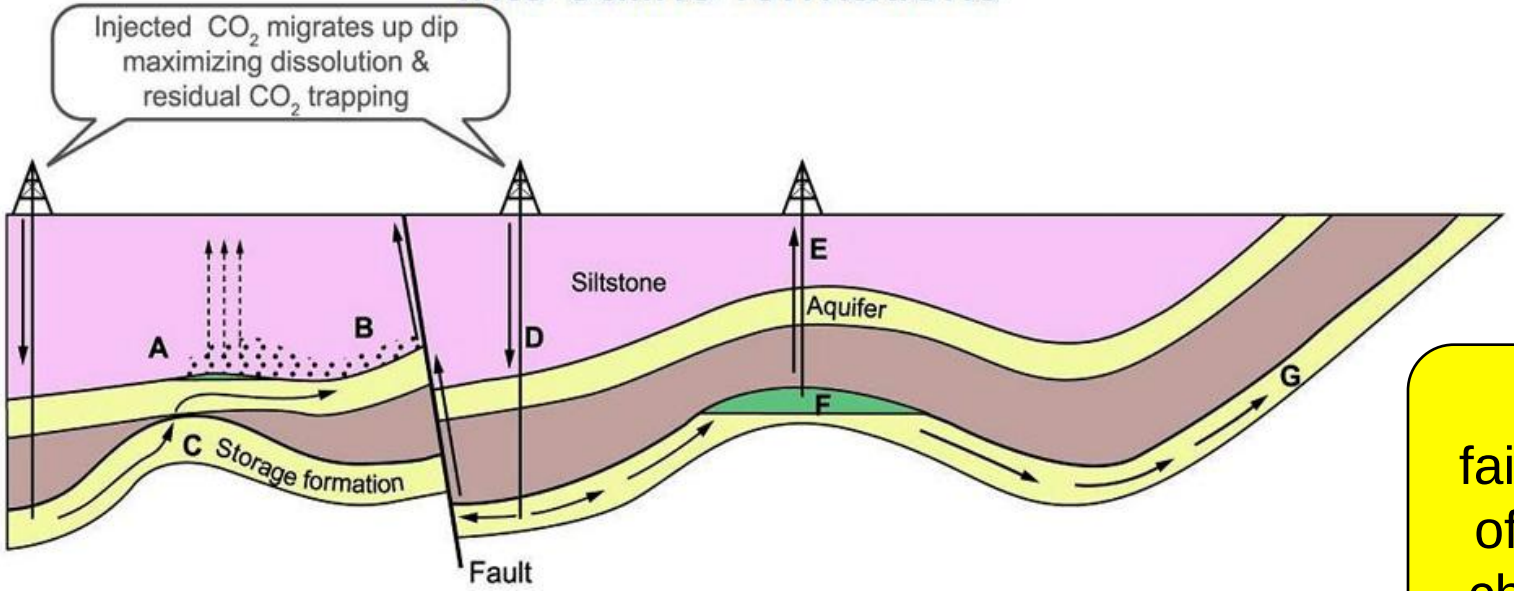
£ 3,000 M per year

DECC competition

Create a second market route to fund UK CCS projects by EU-ETS

Sustainability

Potential leakage routes and remediation techniques for CO2 injected into saline formations



All failures of site choice

Potential Escape Mechanisms

A. CO_2 gas pressure exceeds capillary pressure & passes through siltstone	**B.** Free CO_2 leaks from A into upper aquifer up fault	**C.** CO_2 escapes through 'gap' in cap rock into higher aquifer	**D.** Injected CO_2 migrates up dip, increases reservoir pressure & permeability of fault	**E.** CO_2 escapes via poorly plugged old abandoned well	**F.** Natural flow dissolves CO_2 at CO_2 / water interface & transports it out of closure	**G.** Dissolved CO_2 escapes to atmosphere or ocean

Remedial Measures

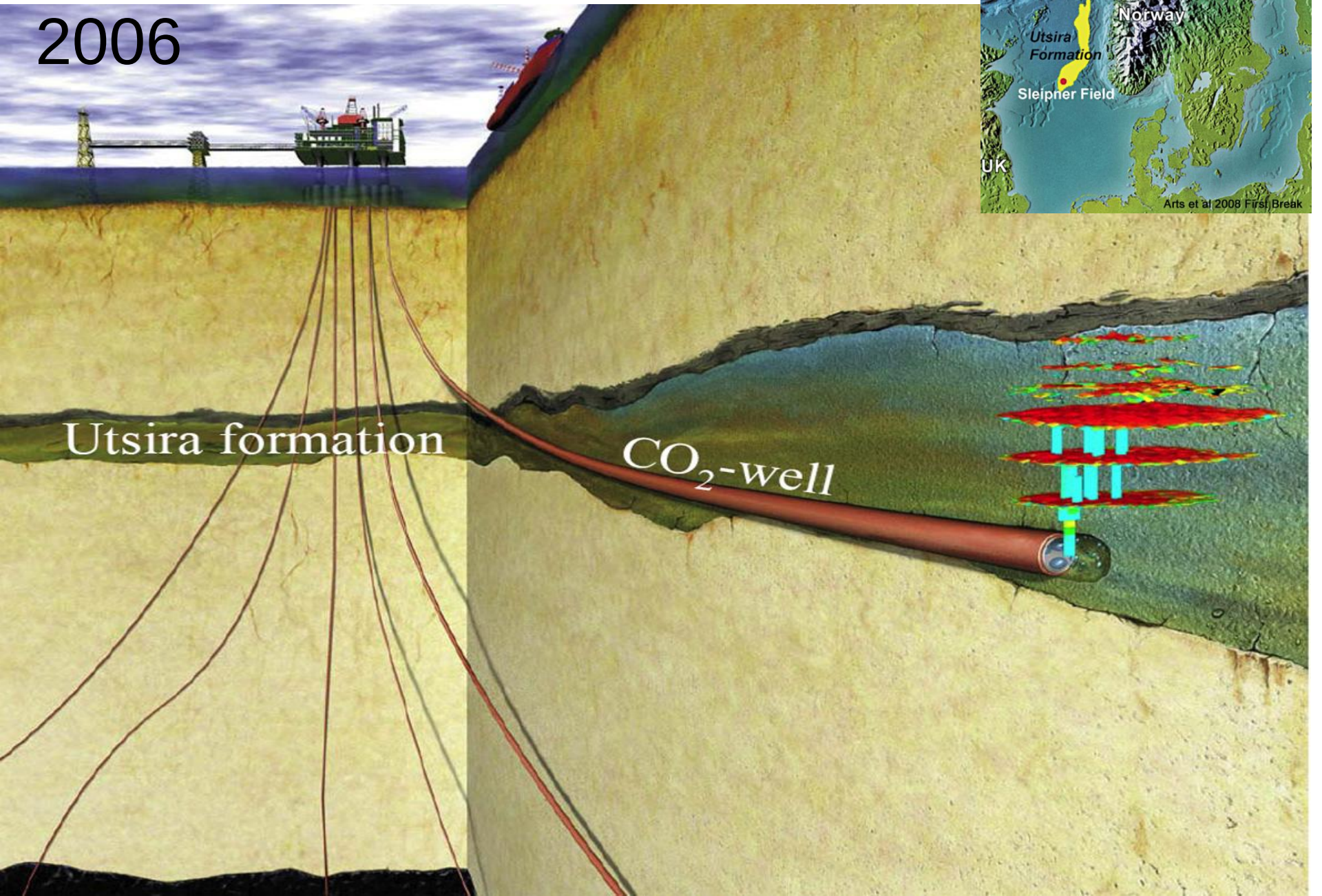
A. *Extract & purify ground-water*	***B.*** *Extract & purify ground-water*	***C.*** *Remove CO_2 & reinject elsewhere*	***D.*** *Lower injection rates or pressures*	***E.*** *Re-plug well with cement*	***F.*** *Intercept & reinject CO_2*	***G.*** *Intercept & reinject CO_2*

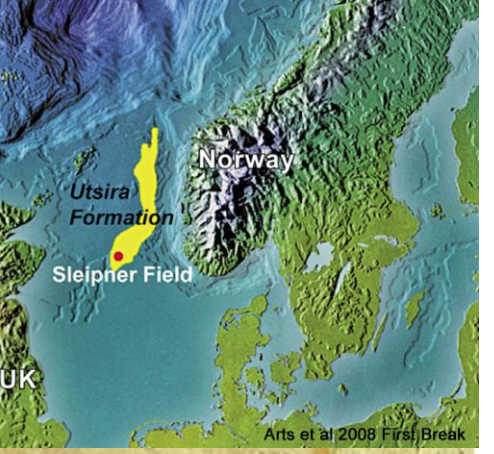
Intergovernment Panel on Climate Change Special Report

SRCCS Figure TS-8

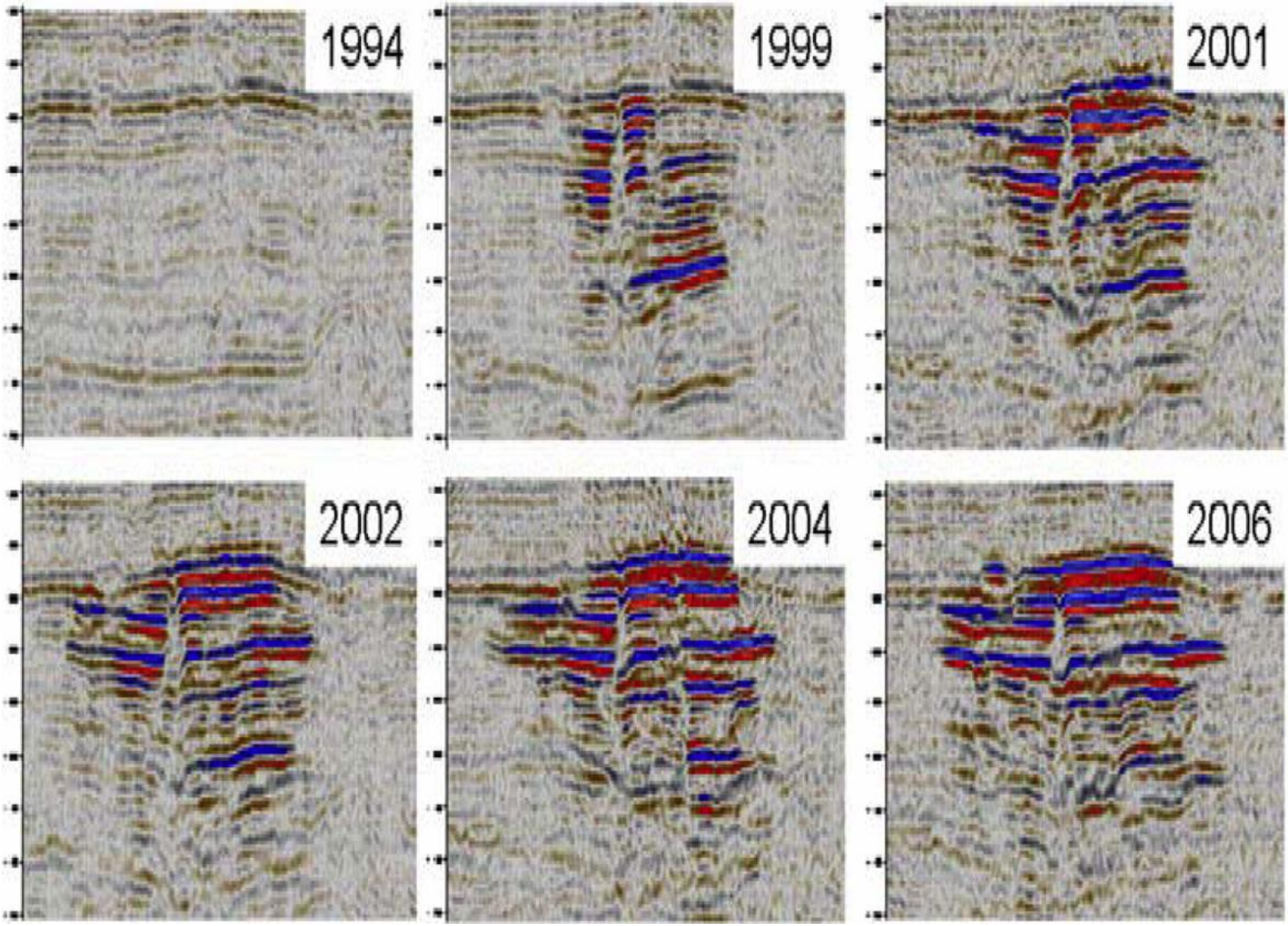
North Sea Saline Aquifer CO2

2006

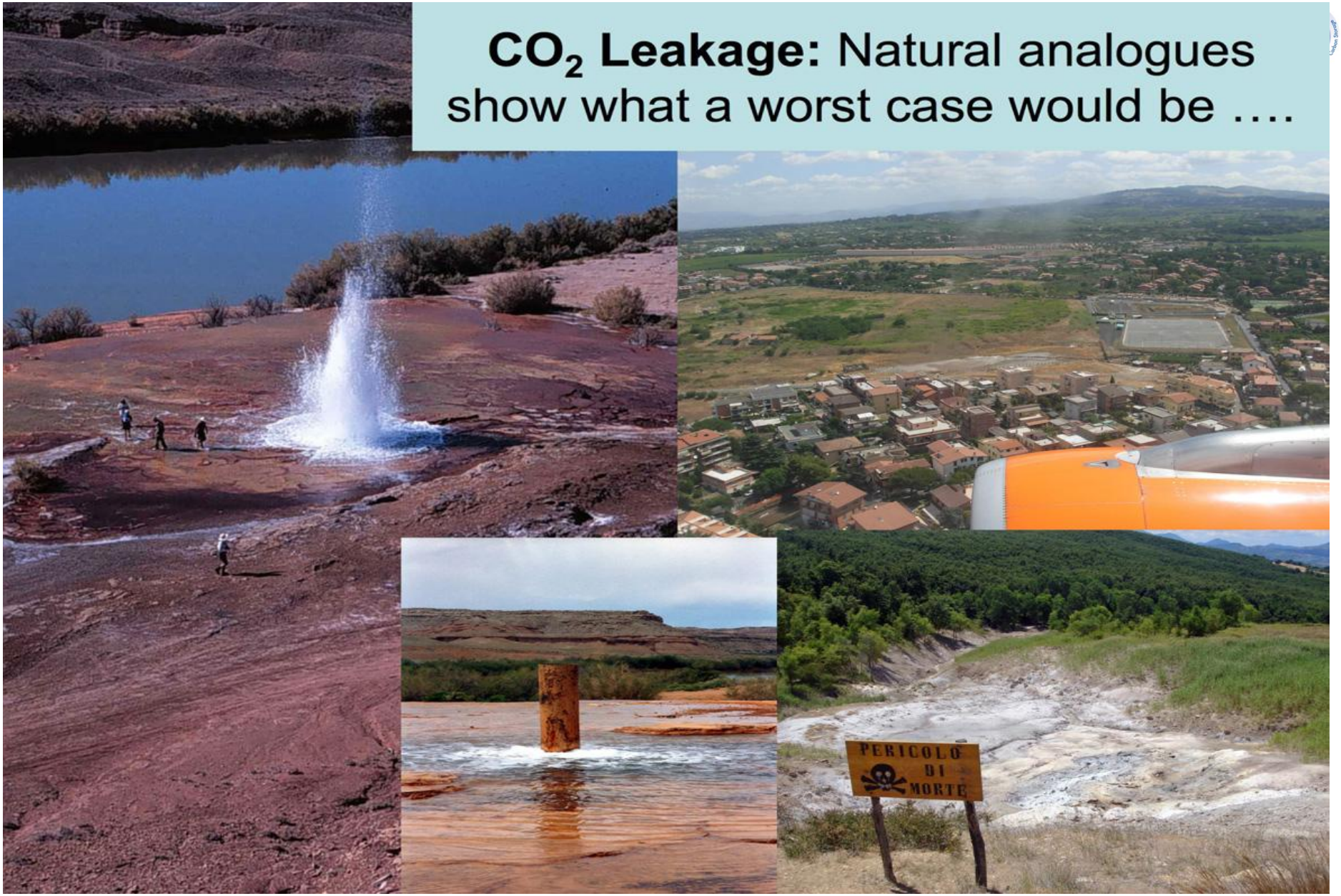




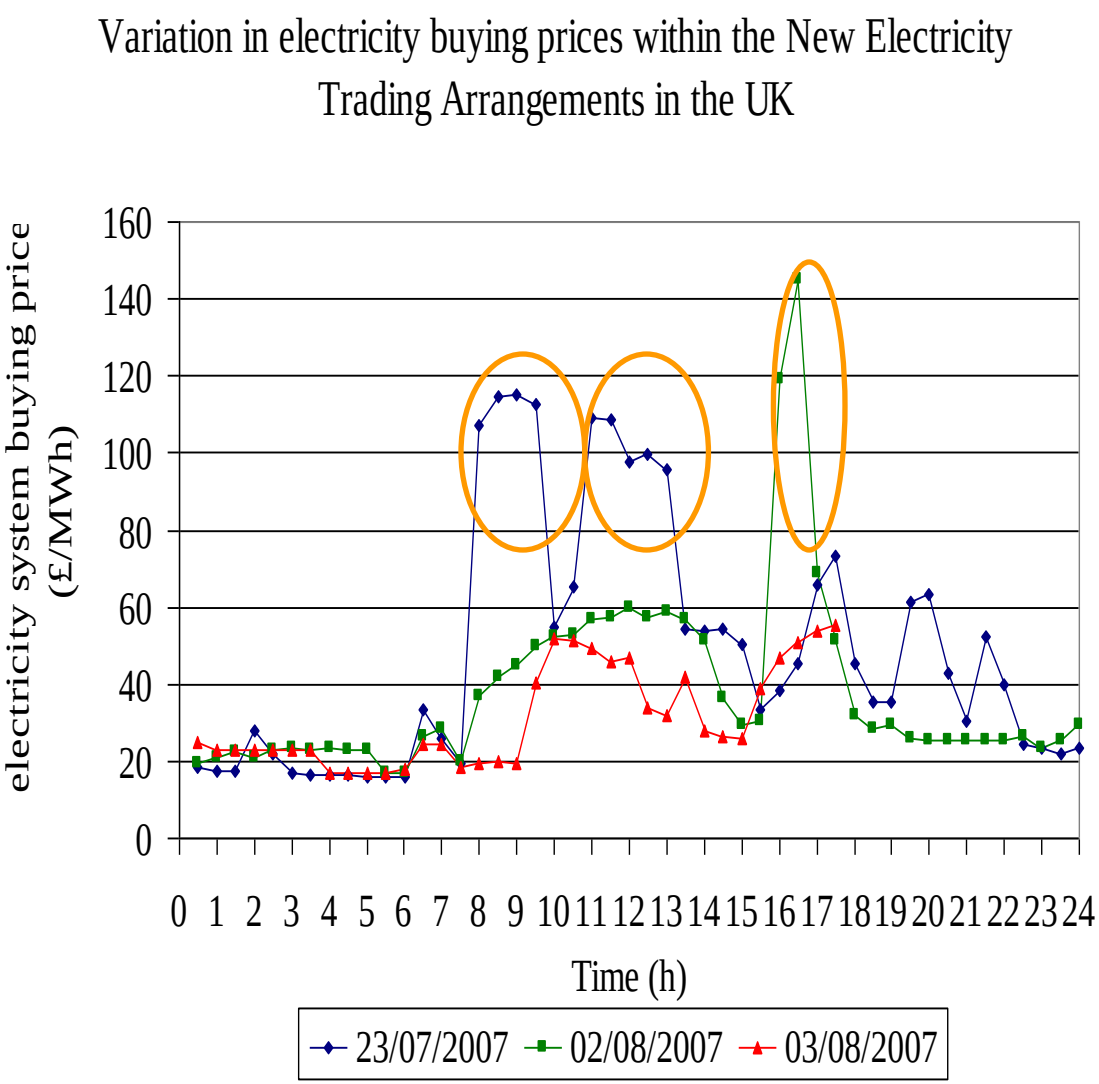
CO_2 stored in the Utsira formation



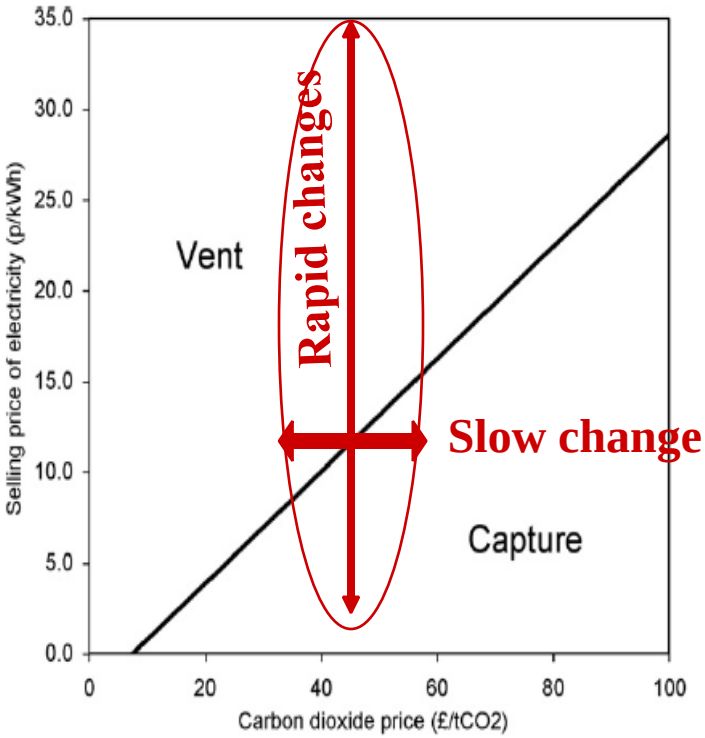
Leakage: naturally



Power plant operation



Arbitrage on price will determine Capture



Chalmers and Gibbins (2007) Fuel

Imperial College London

Make markets to encourage capture of CO2 not venting?

Life Cycle Analysis

CLAIM: capture 90% CO2 at power plant

Supercritical PC no CCS

Total GHG emissions (g CO_2-e / kWh): **868**

Construction	Direct Combustion	Fuel production	Fuel Transport	Other Operation & Transport	Waste Disposal
0.2 %	90.7 %	5.5 %	0.2 %	3 %	0.4 %

ACTUAL: overall 72% CO2 reduction

Supercritical PC with CCS

Total GHG emissions (g CO_2-e / kWh): **244**

Construction	Direct Combustion	Fuel production	Fuel Transport	Other Operation and Transport	Waste Disposal
1.3 %	43.7 %	25.8 %	0.7 %	25.1 %	3.4 %

Production of MEA & other waste

IGCC 160 g CO2 /kWh **- 80%**

Odeh and Cockerill 2007

Key unknown: research

Pace of delvery

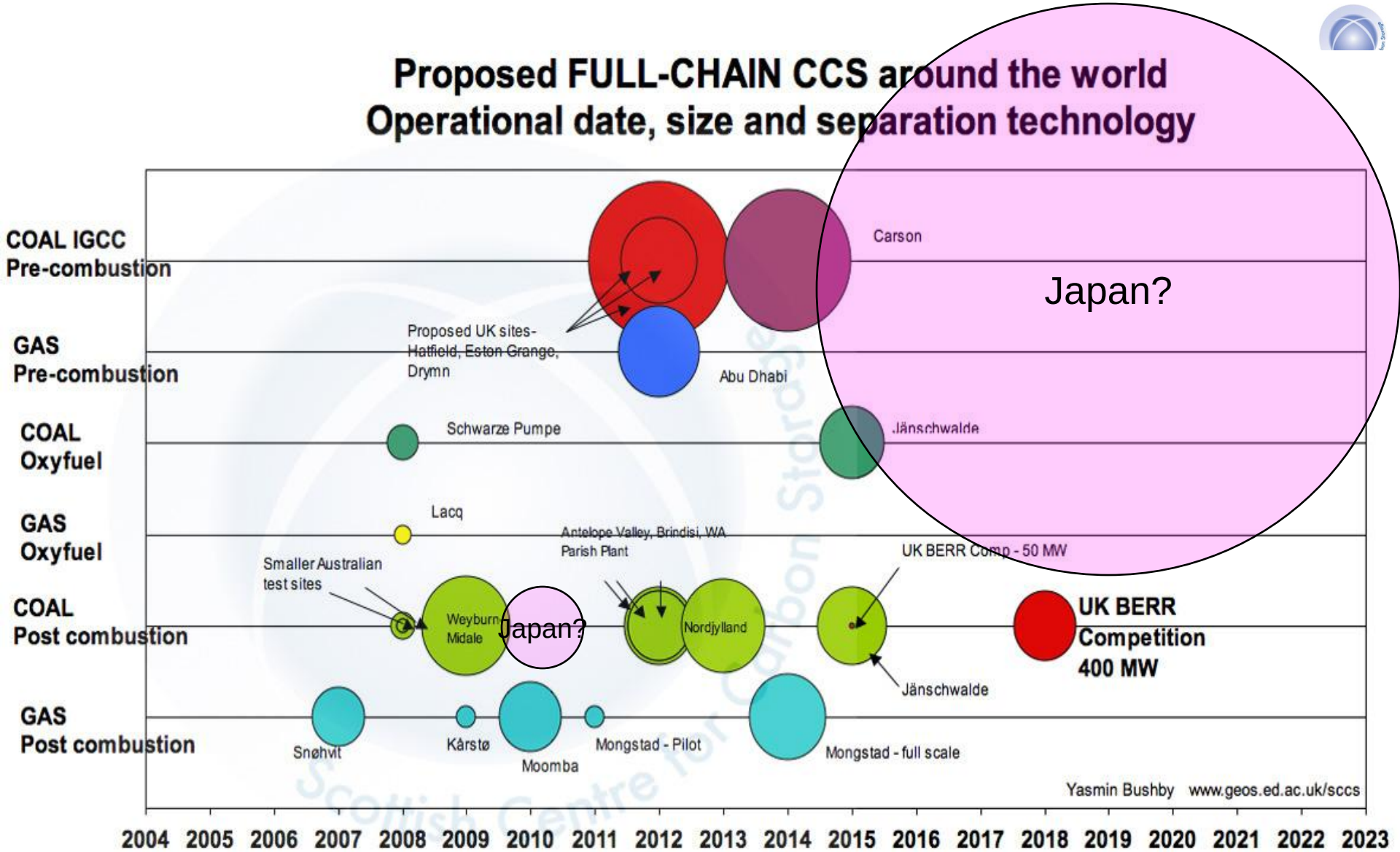
Learning cost of capture (energy & money)

Storage volumes

Public acceptance

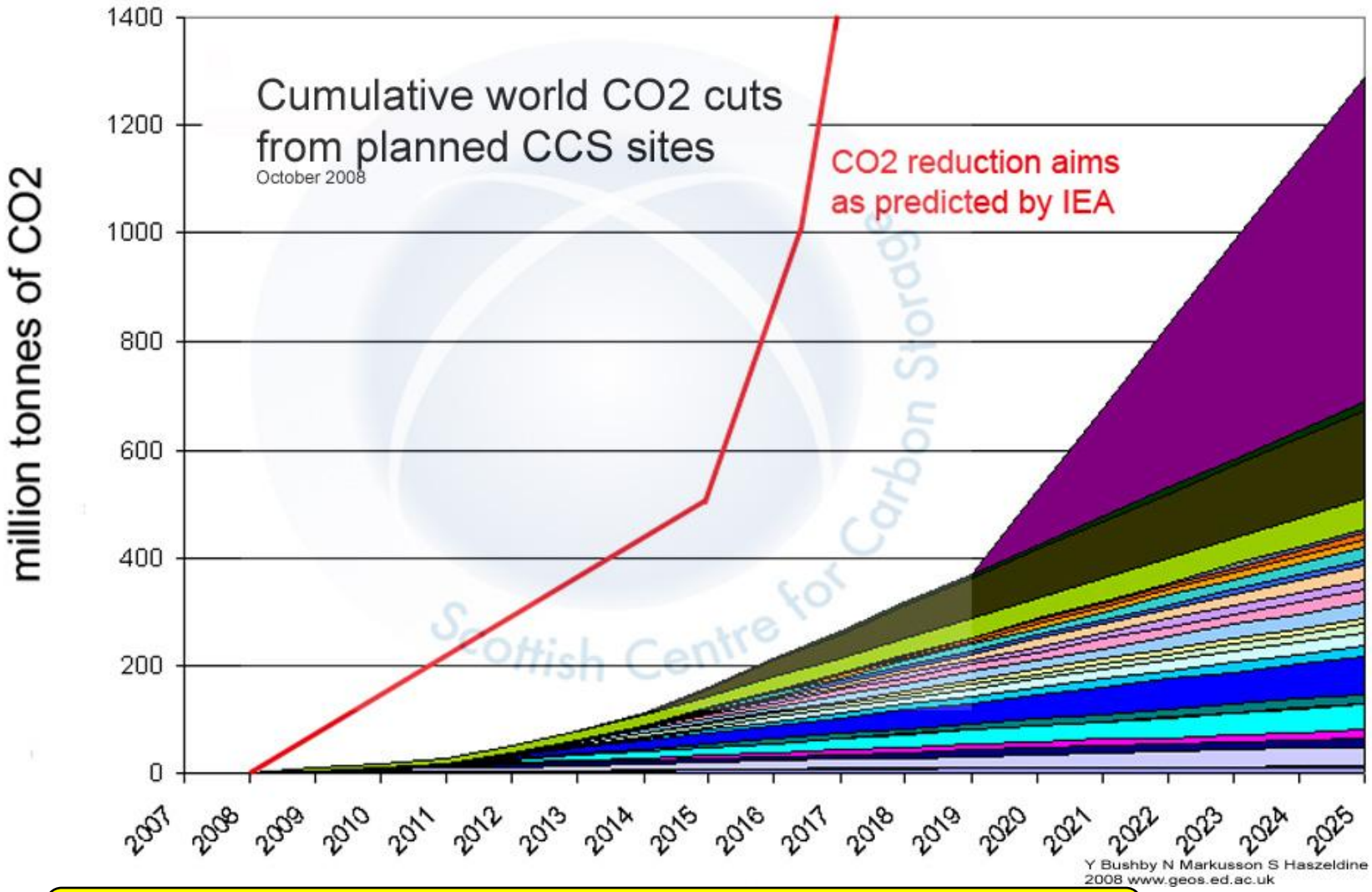
Transport

World activity CCS pilot



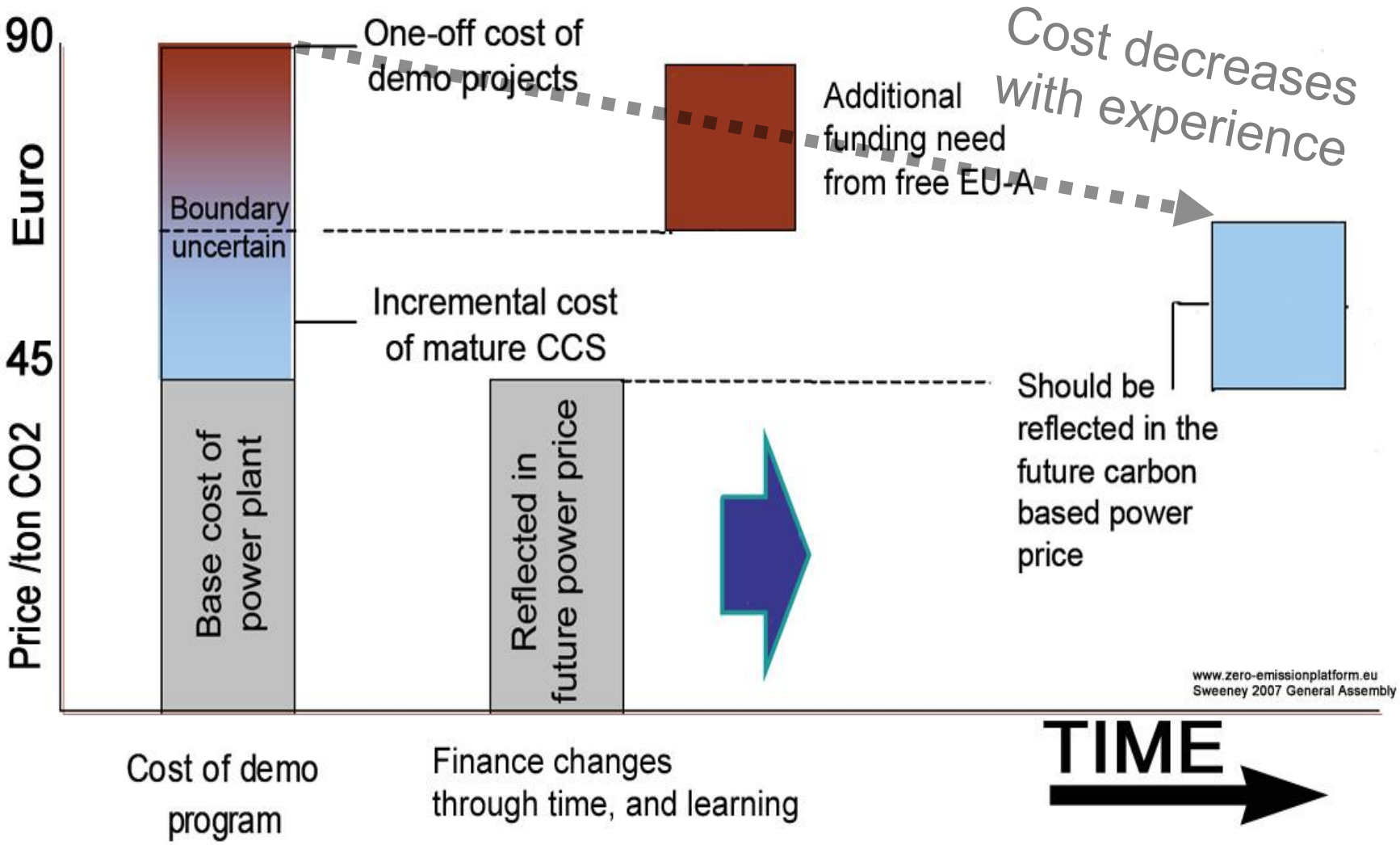
Pre-combustion first (IGCC). UK looks slow

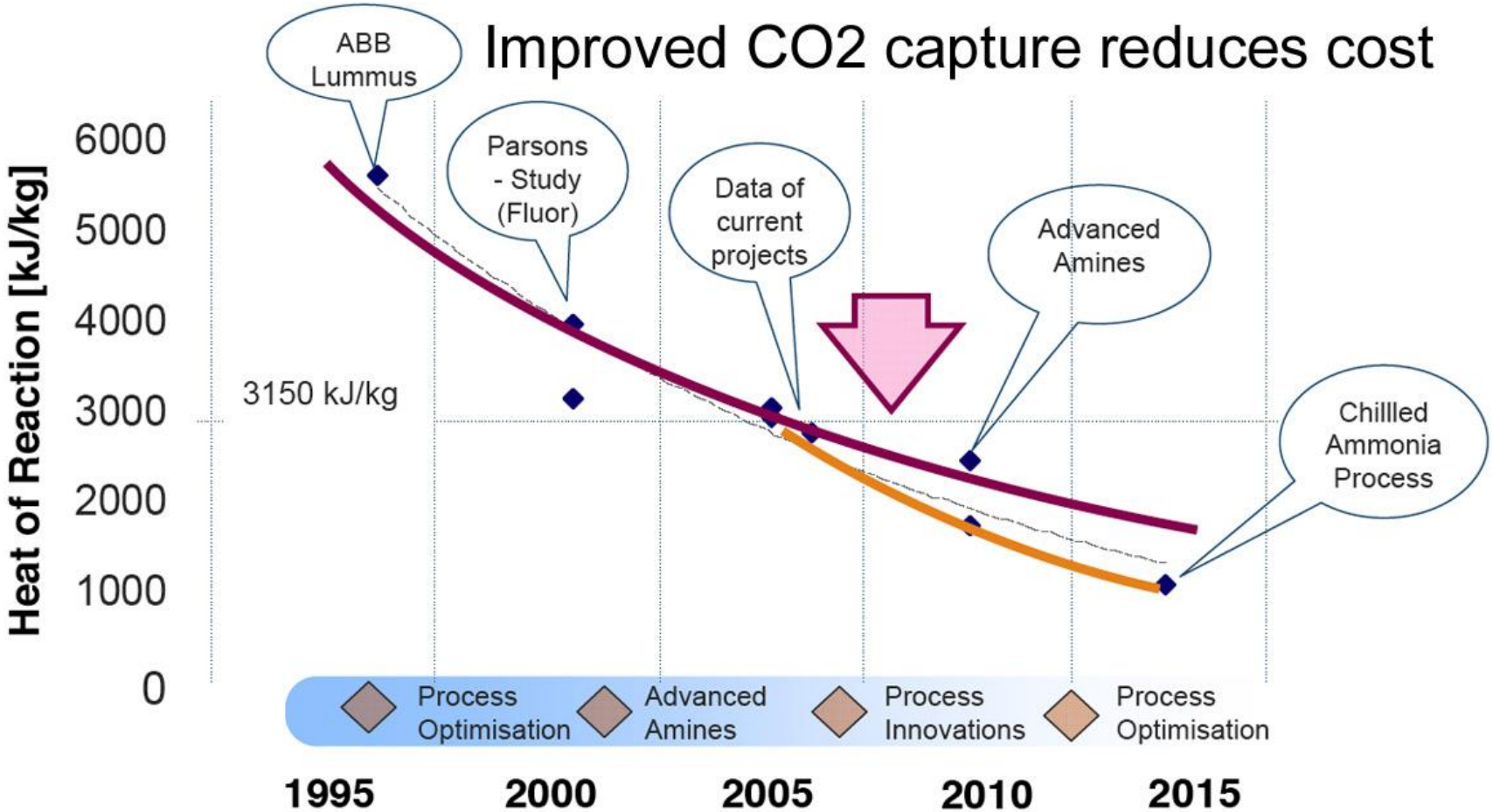
World CO2 cuts from CCS



World pace only 50% need, at best

Funding: Pilot, Rollout





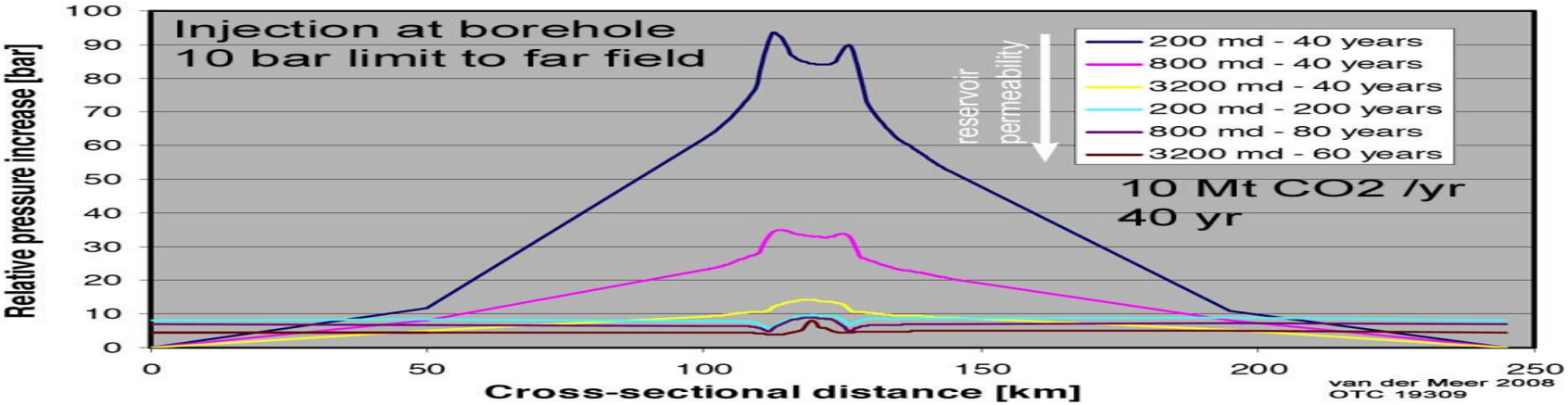
Example claim: chilled ammonia capture

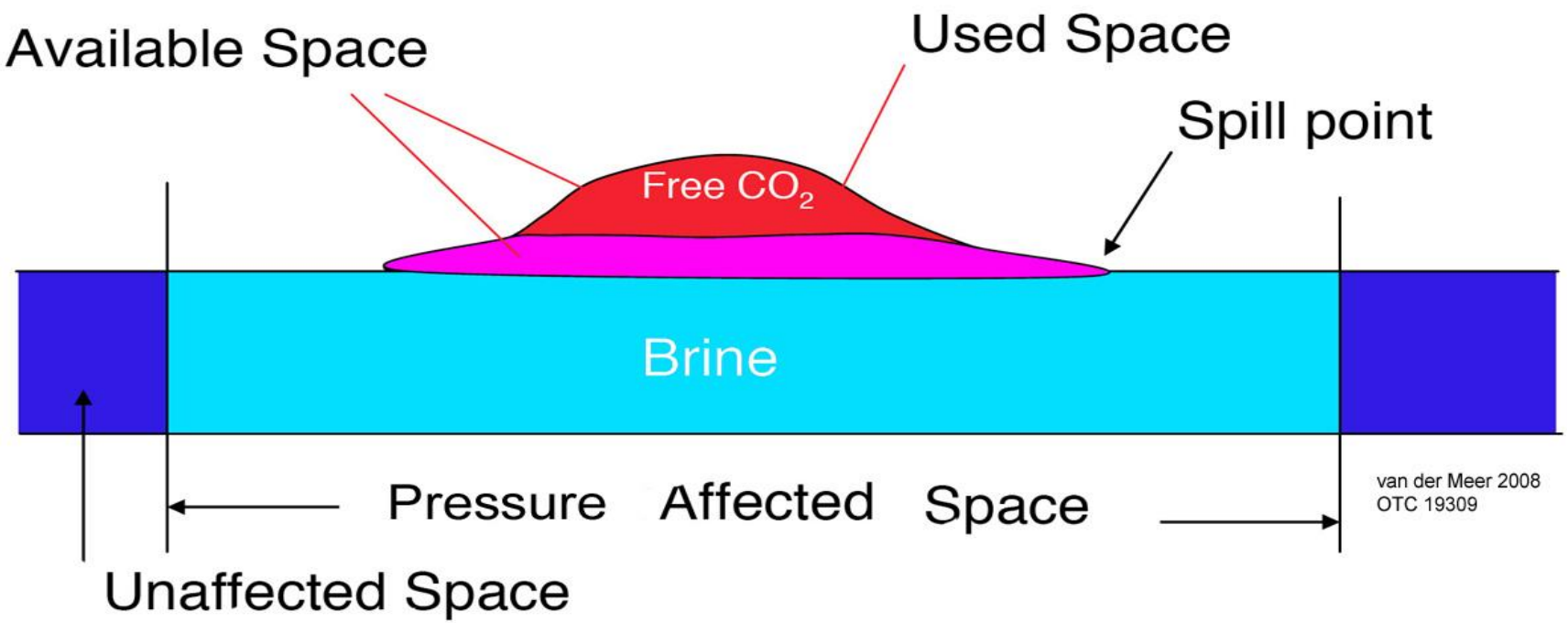
$(NH_4)_2CO_3 + CO_2 + H_2O \leftrightarrow 2\ NH_4HCO_3$

Capture cost MEA € 40 /ton CO_2; **NH_3 € 12 /ton CO_2**

Demo 100,000 t/yr mid 2007 - 2010, **Commercial 2011**

Key unknown: storage volume





World aquifer storage may be 400 yr or 40 yr

Public: Capture Ready coal

Building new coal supercritical power plant - with future ability to capture CO2, but NOT capturing now

Capture-Ready

Power plant fitted,

No specified route or storage site

No date for operation

Complex detailed designs

Risk with Government

Emissions Standard

(500) 350 gCO2/kwh

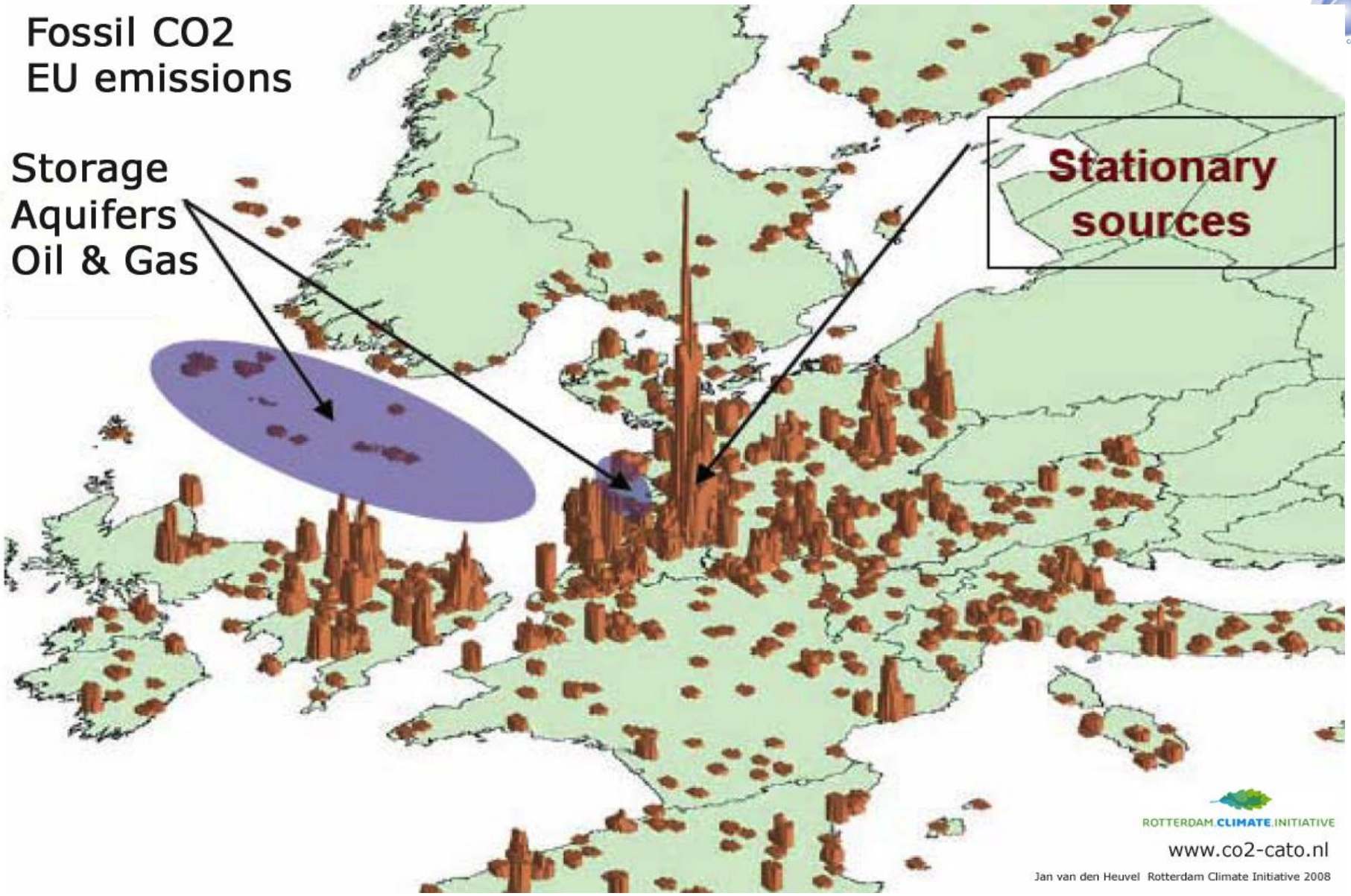
Ramps down

Intended future date

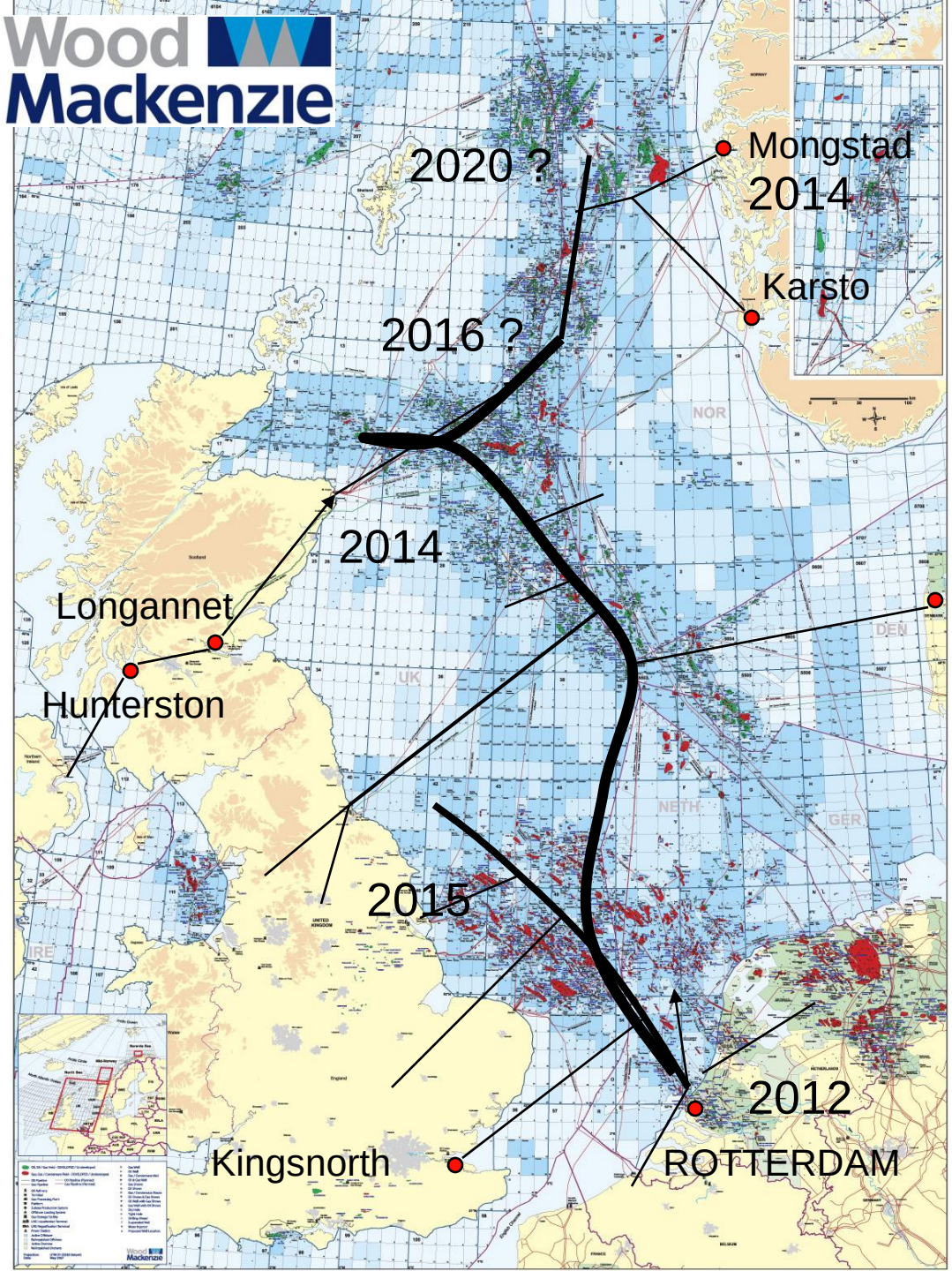
Simple administration

Risk with operator

Transport: EU CO2 emissions



North Sea transport and store



50% of EU CO2 export via Rotterdam ?

Largest storage is in Norwegian and Scottish offshore

How to get a transport network to come north?

RISKS for CCS

Politics: Funding pilot plant

- 500 M tons Emission Allowances for new plant
  ==> 10 x 400 MW coal plant 2013 - 2020
- 500 g CO2 /kW hr electricity emissions standard
- EU Council of Ministers anti EU-A ==> may hypothecate ?

Risk of deferment

No CCS = marginal cost of climate stabilisation + 70%

SUMMARY

- CCS is the only DIRECT CO_2 reduction method
- Top down and bottom up studies agree CCS important
- CCS is RAPID, BIG, COMMERCIAL
- REPLICATION - similar plant worldwide
- RISK: funding pilot plants, political change
- BANKABLE - Pilot plant £5/yr per household
  - Short term from tax hypothecation
  - Medium term from Emissions allowances
- GLOBAL 50 plant / yr (£ 100 Bn) until 2050