SCCS

Linking IPCC and UNFCCC

Understanding carbon balance

World action
European actions
State actions

Being developed (in the North Sea)

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SCCS

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25 Nov 2014

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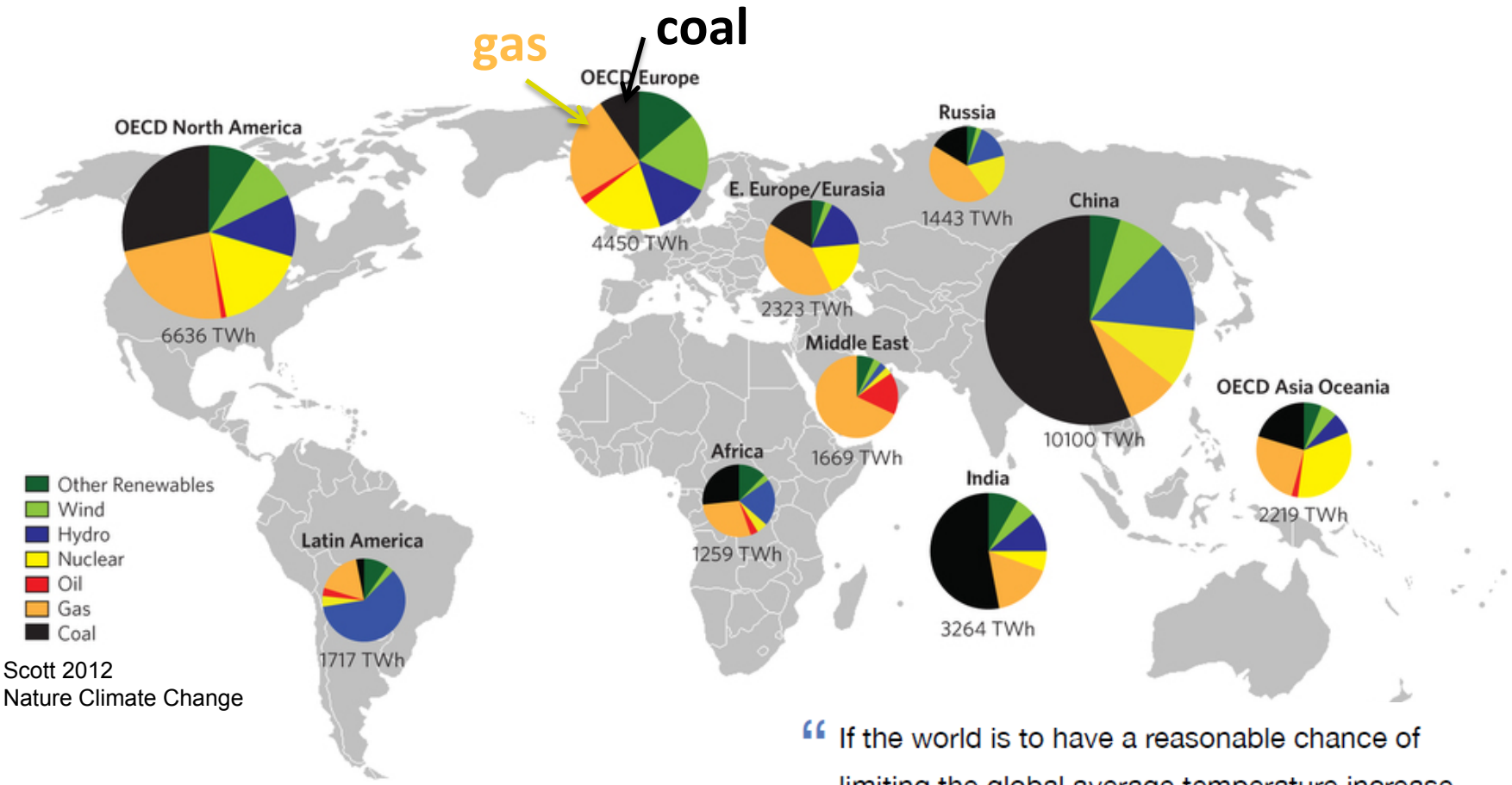
The case for coal cleanup : view in 2030



Scott 2012
Nature Climate Change

Projected electricity sources in 2030
(International Energy Agency 2011)

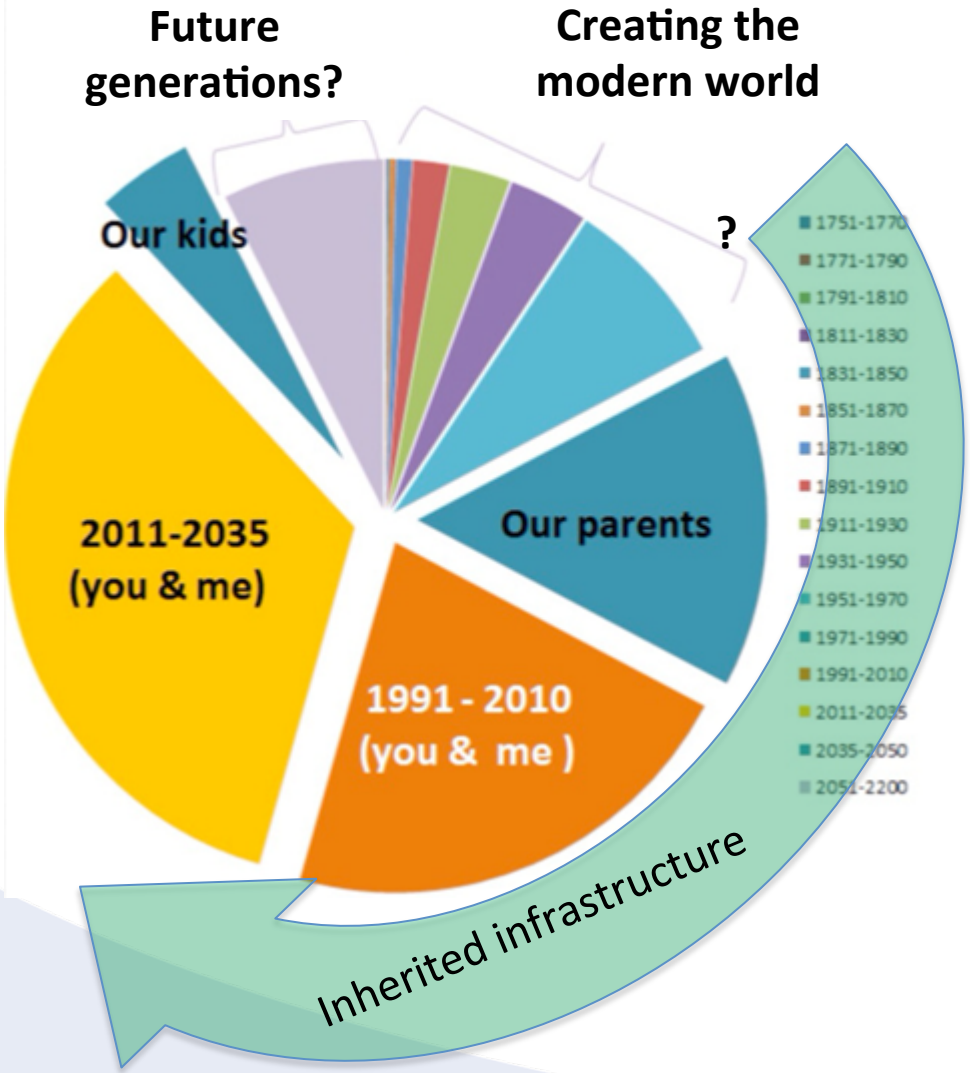
> "If the world is to have a reasonable chance of limiting the global average temperature increase to 2°C … less than one-third of proven reserves of fossil fuels can be consumed prior to 2050, unless CCS technology is widely deployed."
> *World Energy Outlook 2012, IEA*

In 2030 fossil fuels : coal gas oil
Still supply more than 50% globally, EU 33%

CCS is essential to Transition

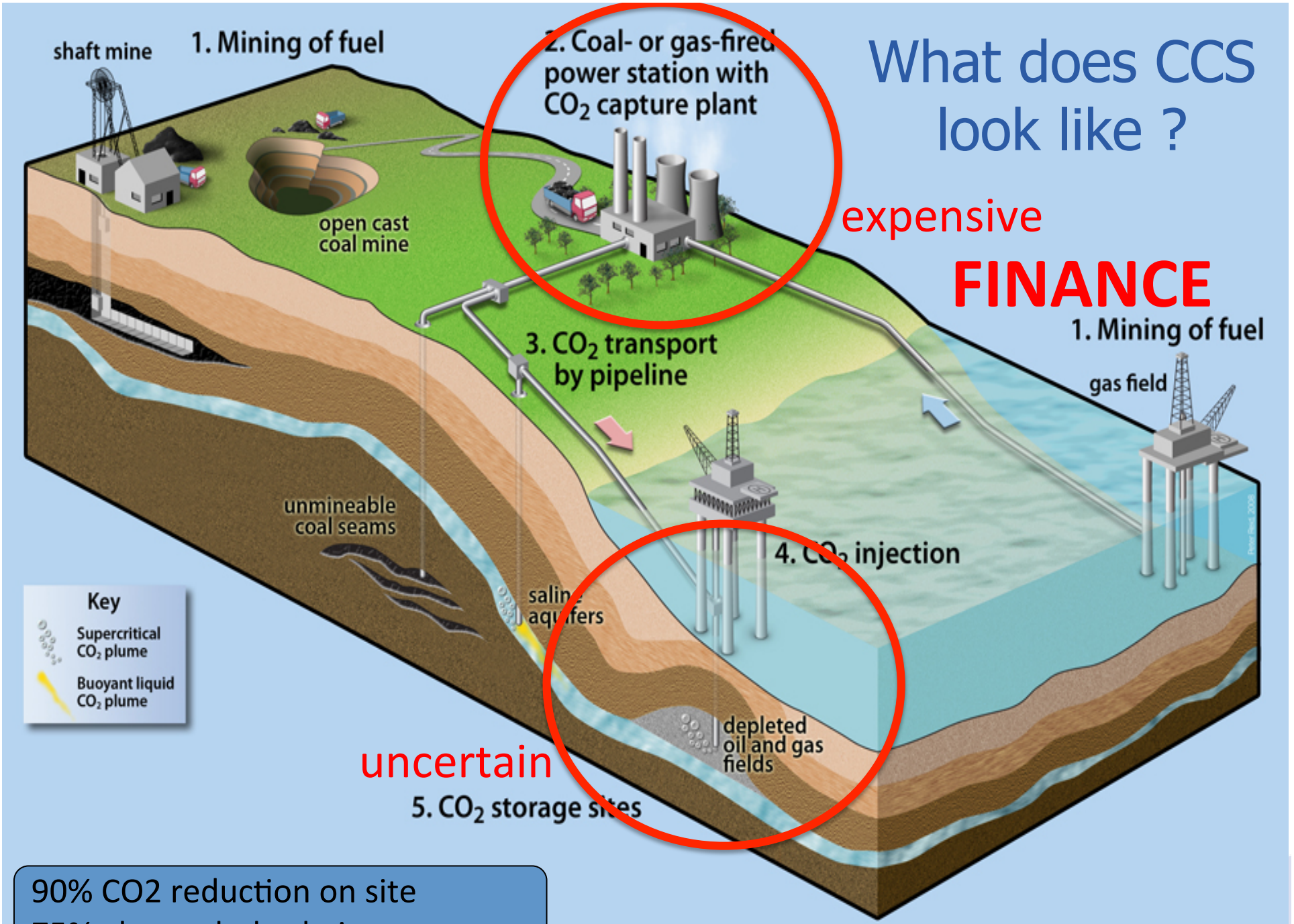
Carbon budgets for 2˚C

Base image source: Lars Boelen



Fossil resource = **10-50 times greater**

What does CCS look like ?



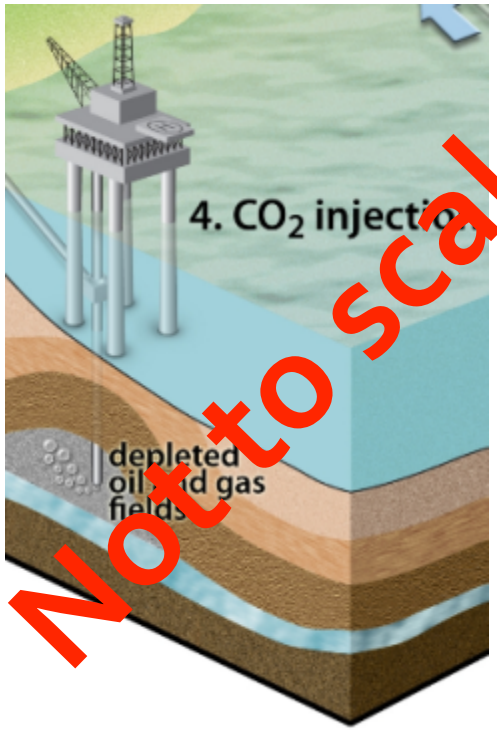
expensive

FINANCE

uncertain

90% CO2 reduction on site
75% along whole chain

Storing CO_2



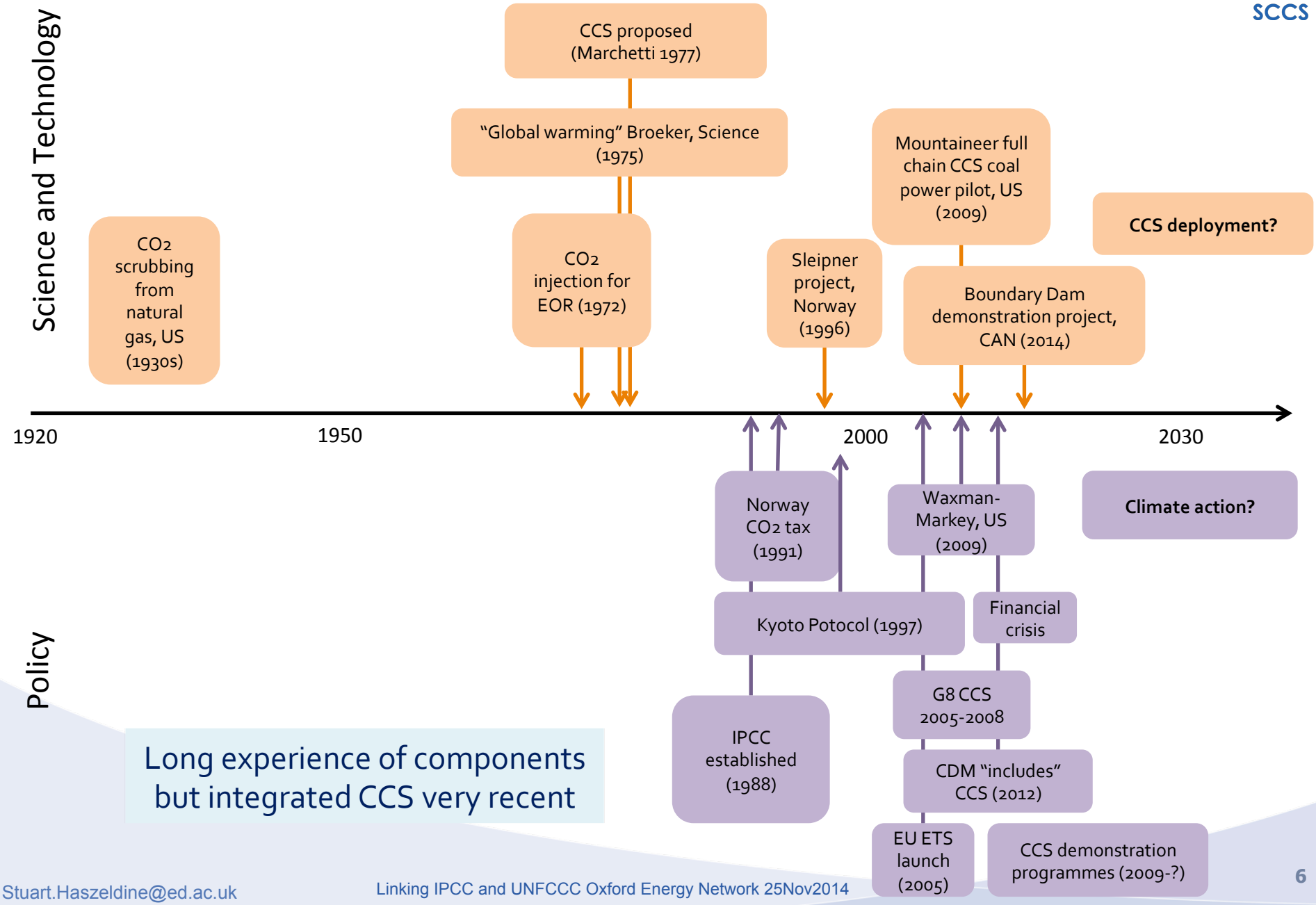
Not to scale

Eiffel Tower 325m

2500m

CO_2 capture project

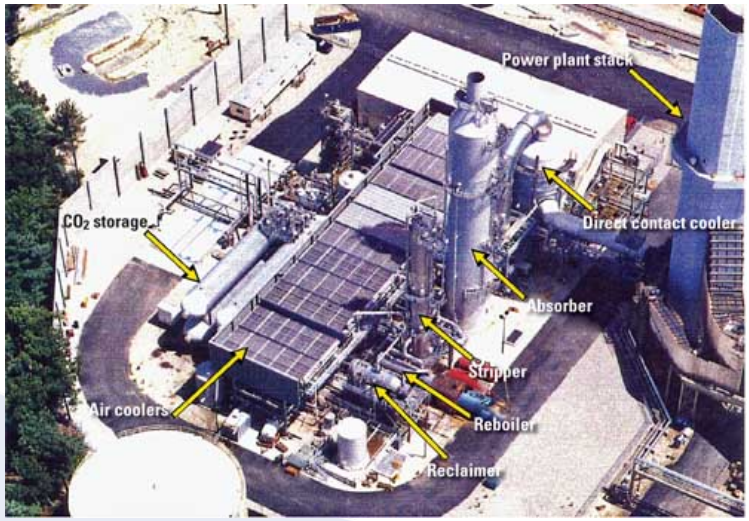
CCS – a brief history



Long experience of components but integrated CCS very recent

Existing CO2 capture

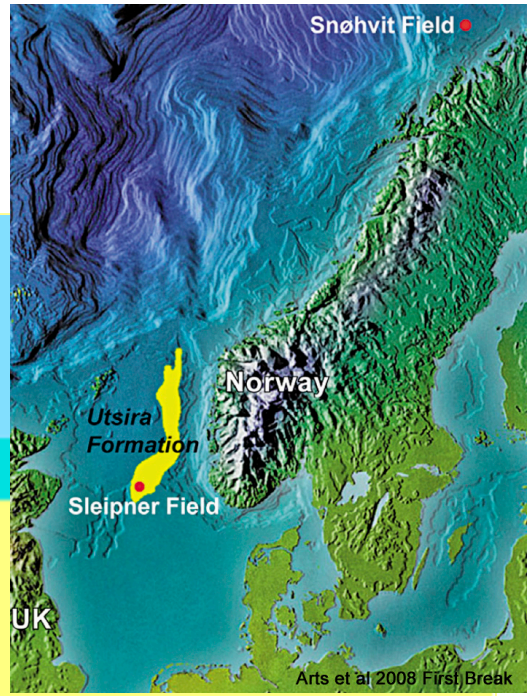
2.5 Million tonnes CO2/yr since 2005
Great Plains gasifier, Beulah, North Dakota
Pipeline to EOR injection. No leaks



1970's Dow Chemical
CO2 separation econamine 100,000 t/yr
gas turbine CO2 Fluor Daniel in Florida Light and Power, Bellingham, Massachusetts

CCS exists and operates
Payment for increasing size is the problem

CO_2 injection and storage since 1996 : Sleipner



Sleipner A

Sleipner T

0

500m

1000m

1500m

2000m

2500m

CO 2 Injection W ell

Utsir a For mation

CO 2

Sleipner Øst Production and Injection W ells

1 Mt CO_2 / yr

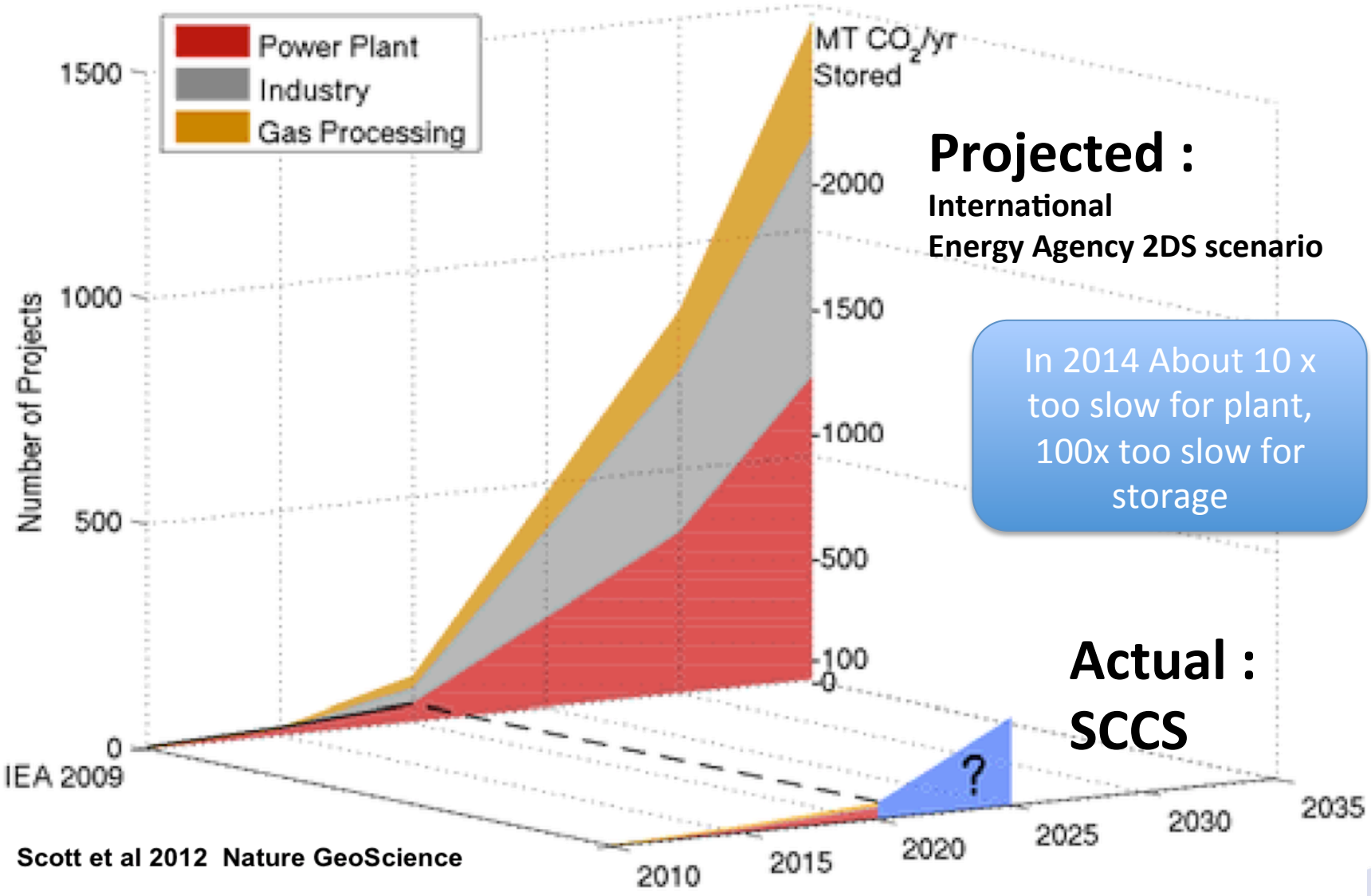
0 500m 1000m 1500m

Heimdal Formation

http://carnot-online.org/Document_Library/Tore_Torp.pdf

Stuart.Haszeldine@ed.ac.uk

Globally, CCS is slow



Projected :
International Energy Agency 2DS scenario

In 2014 About 10 x too slow for plant, 100x too slow for storage

Actual : SCCS

But ……

Many plans, promises, designs and …… very little to show

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12 May 2012 Last updated at 02:29

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Whatever happened to carbon capture?

By Richard Black
Environment correspondent, BBC News, Bergen, Norway

The process was patented back in the 1930s, and it is reckoned to be one of the most important technologies we have for tackling greenhouse gas emissions.

So you might well ask: "Whatever happened to carbon capture and storage (CCS)?"

The International Energy Agency (IEA) forecasts global energy demand increasing by at least one-third by 2035.

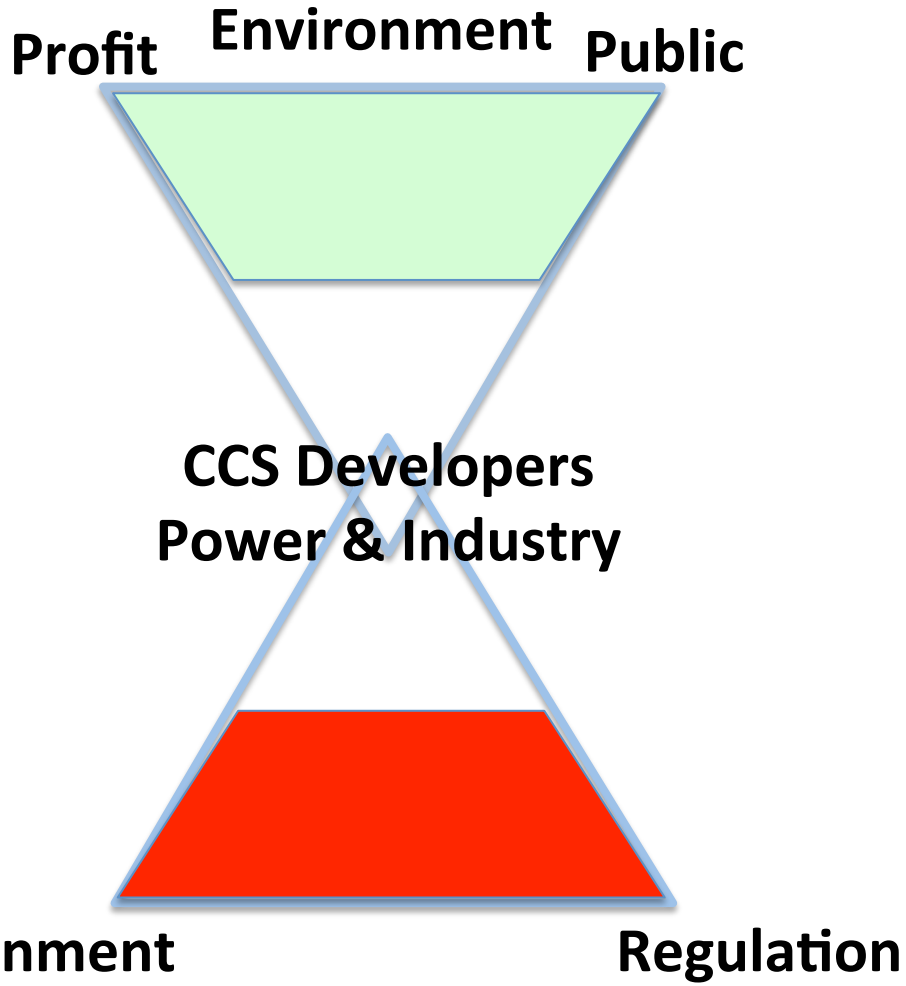
The majority of that increase will come from burning fossil fuels; and without capturing and storing some of the carbon dioxide (CO2) emissions that result, this implies a significant addition to global warming.

To meet the internationally agreed target of keeping the temperature rise since pre-industrial times below 2C (3.6F), the IEA calculates there should be about 1,500 full-scale CCS plants in operation by 2035.

University students can now study CCS; but when will it come fully out of the lab?

Related Stories

European CCS disconnect : finance to benefit



CCS : targets, politics and funding,
not yet flowing to green economy benefits

Agreements in 2014

IPCC AR5 Synthesis 1 Nov 2014
For 450 ppm CO2e, CCS saves 138% of extra costs.

For 550 ppm, CCS saves 39% extra costs.

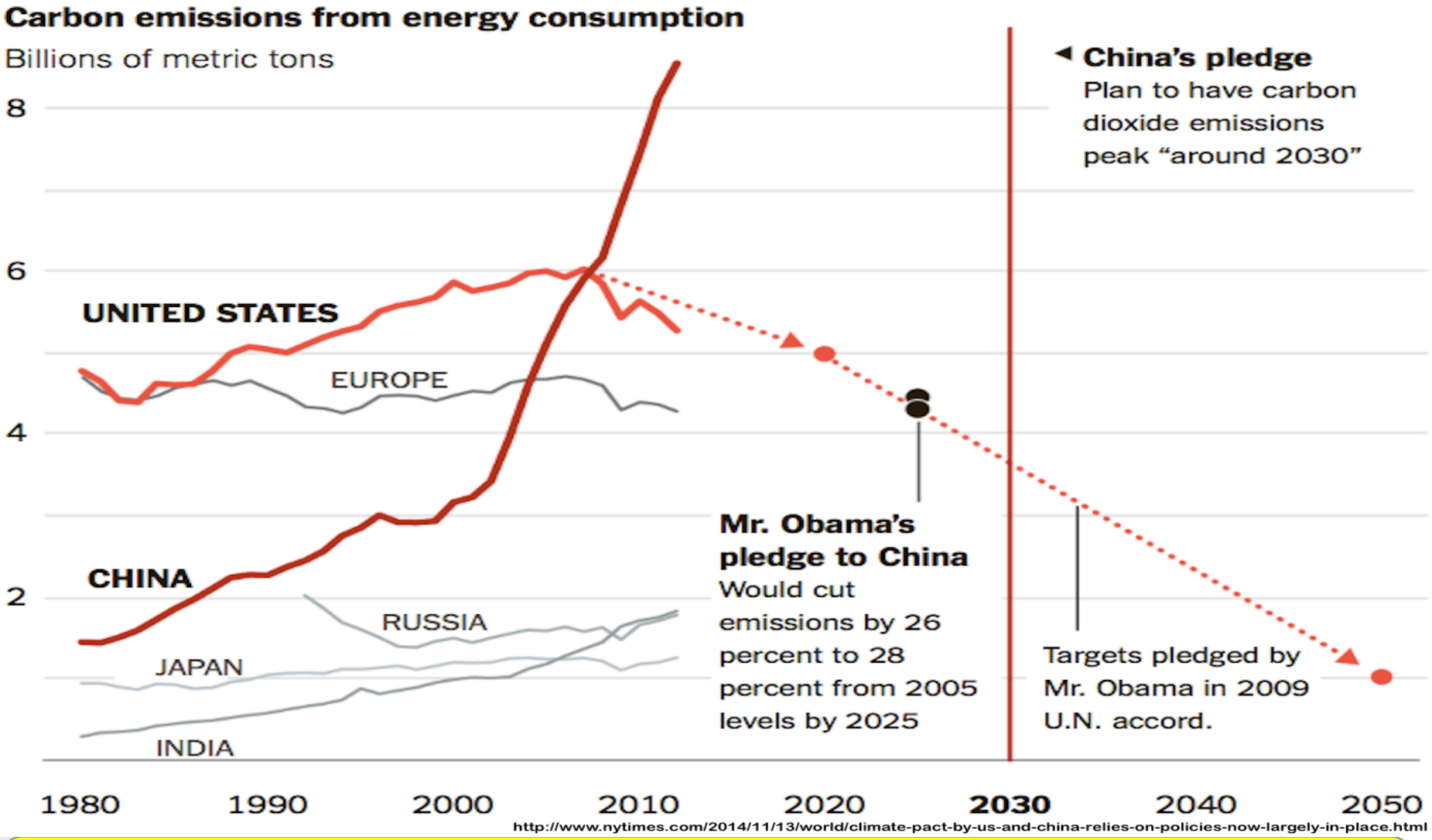
G20 16 Nov 2014
support strong and effective action to address climate change. Parties communicate their intended nationally determined contribution to COP21 by the first quarter of 2015. At UNFCCC, adopt successfully a protocol, another legal instrument or an agreed outcome with legal force

USA-China bilateral 11 Nov 2014
U.S. goal will double the pace of carbon pollution reduction from 1.2 percent per year on average during the 2005-2020 period to 2.3-2.8 percent per year on average between 2020 and 2025

China will succeed in peaking its emissions before 2030 based on its broad economic reform program, plans to address air pollution, and implementation of an energy revolution. Energy from zero-emission sources to around 20 percent by 2030

CCS : targets, and politics aligning for Paris UNFCCC
450 ppm missed

Does China-USA actually mean anything ?



USA : good time to reduce carbon (low cost shale)
China: continues immense emissions growth

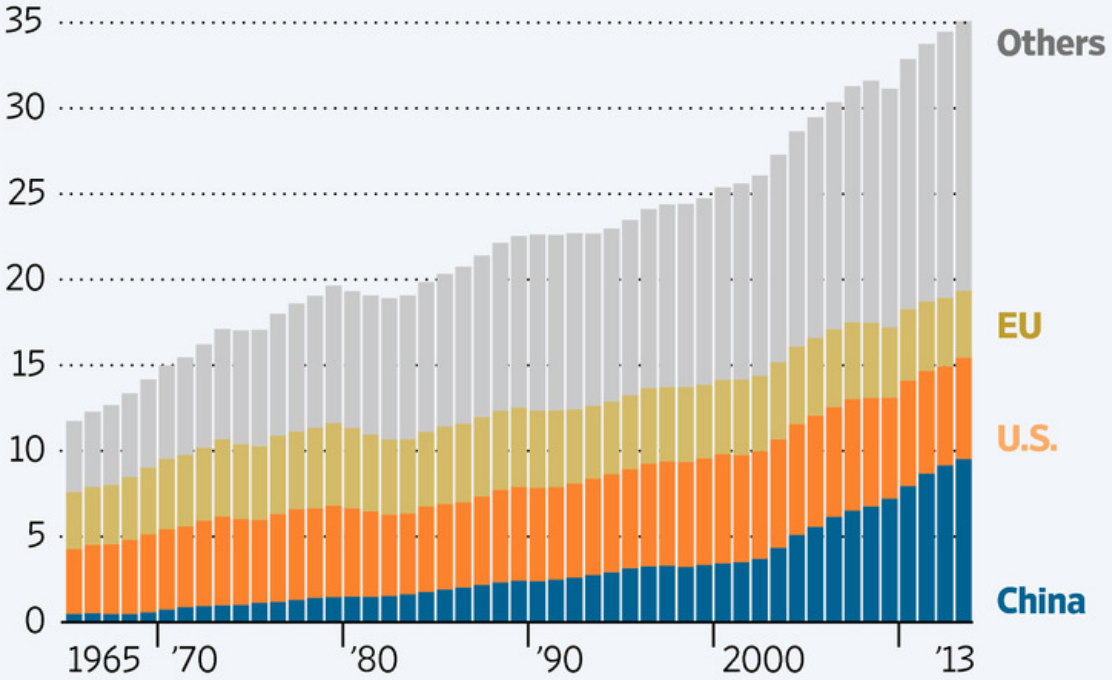
Who is in control ?

Emission Control

The U.S. and China, the two largest producers of carbon dioxide, agreed on long-term goals for reducing emissions of the gas and their reliance on the fossil fuels that produce it.

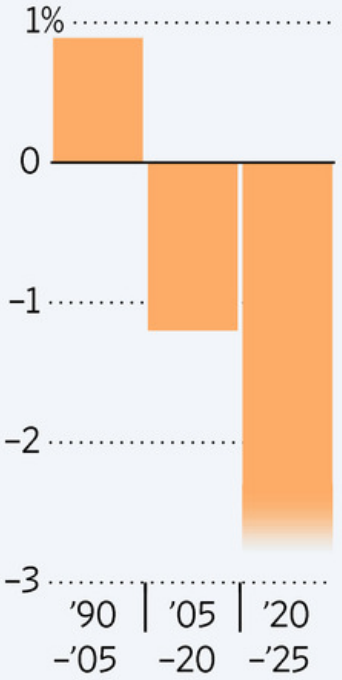
HISTORICAL EMISSIONS

Carbon-dioxide production, in billions of metric tons

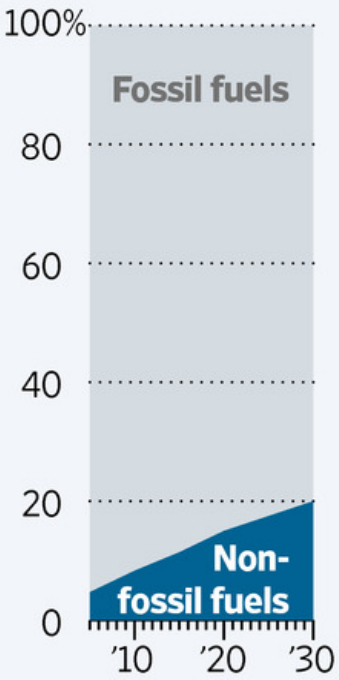


FUTURE TARGETS

Avg. annual change in U.S. emissions



Share of China's energy from...



Sources: BP Statistical Review; The White House; China State Council Five-Year Plan for Energy Development

The Wall Street Journal

China : maybe 12 Gt C /yr (30 Gt CO2) by 2030. Global limit is 2Gt

Meanwhile …..

In a smaller, more democratic continent

2030 EU Energy package - Oct 2014

Greenhouse emissions cut by **40%** by 2030, compared with 1990

Renewable ALL-energy to **27%** of total energy by 2030, across the EU – but not by country. Targets relate to past and to GDP

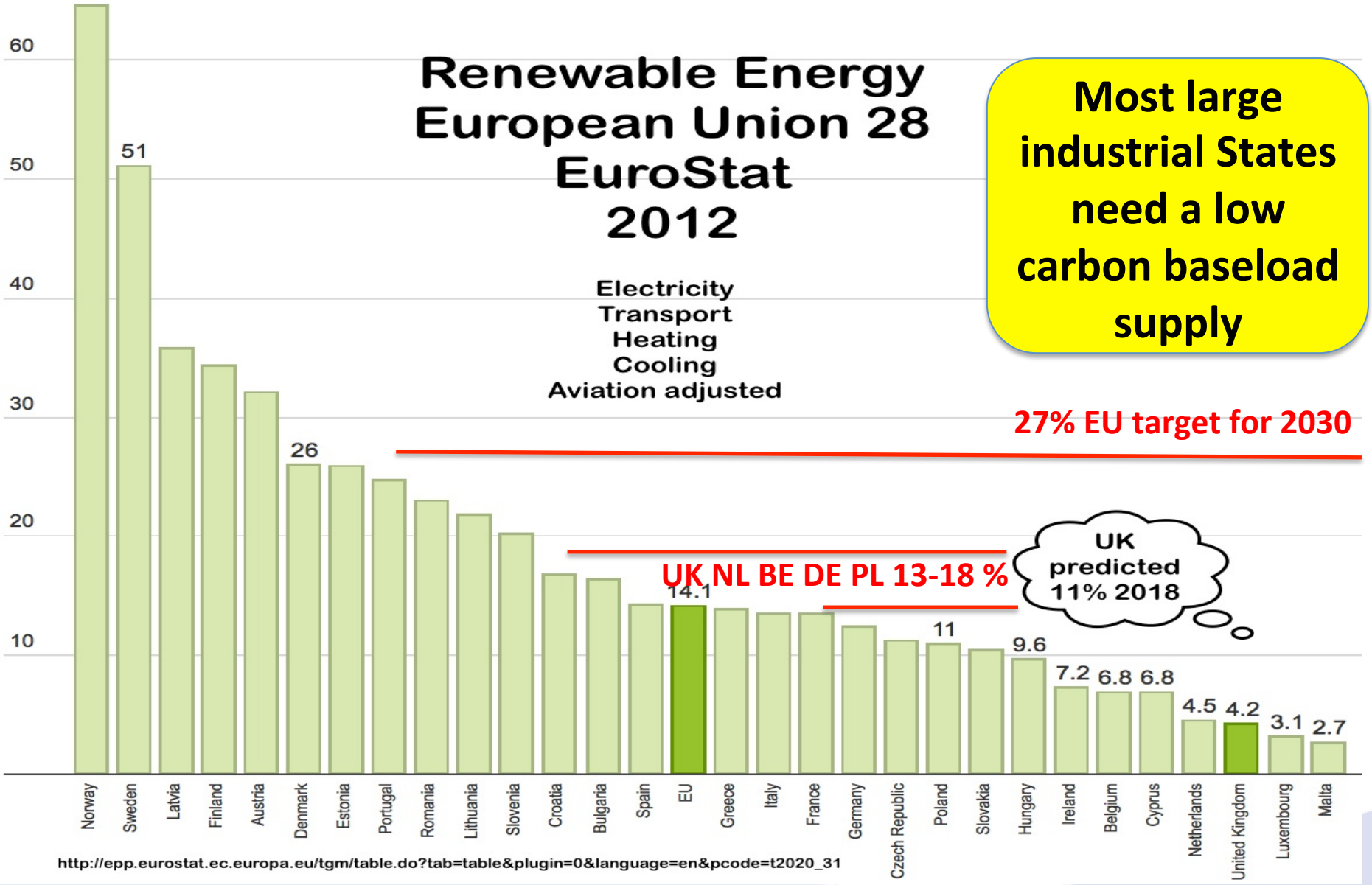
Energy Efficiency (EE) improvements to **27%** by 2030

Interconnectors Electricity of 10% existing capacity for all states

- **EU-ETS** cap reduced annually **2.2%** from 2021. MSR introduced. 2% gift annually to Poland and low GDP states – modernise and efficiency
- 2020 and 15% by 2030 – using **PCI**'s. Gas interconnectors, gas storage and re-gasification – using PCI's (Project of Common Interest)
- **NER 400** renews NER 300, for **CCS,** renewables and industry

States can decarbonise by whichever means is most appropriate
UK can develop CCS, EE, nuclear, for consumers instead of RES

UK, NL, BE, DE, PL renewable ALL-energy still small



Perceived (or actual?) problems for EU CCS

- No CCS targets for 2030 (unlike RES)
- Poor value / unclear immediate benefits for developers
- CAPEX Multi-finance is needed – Electricity companies have small profits
- OPEX finance insufficient (unlike RES) - EU-ETS is too low value
- Insurance during and after operations
- Liability worries about CCS Directive handover to State

Solve all these by DOING projects

- Business structures – existing projects are single developer
  - Commercialisation pilot projects are integrated A to B
  - Transition enabled projects – 3rd party access, A to B to C
  - Full market needs counterparty risk, and market maker A to Z
- Storage assessment into future developments – offshore expensive
- Europe falling behind USA, Canada, China, in developing technology

UK CO_2 capture proposals 2007

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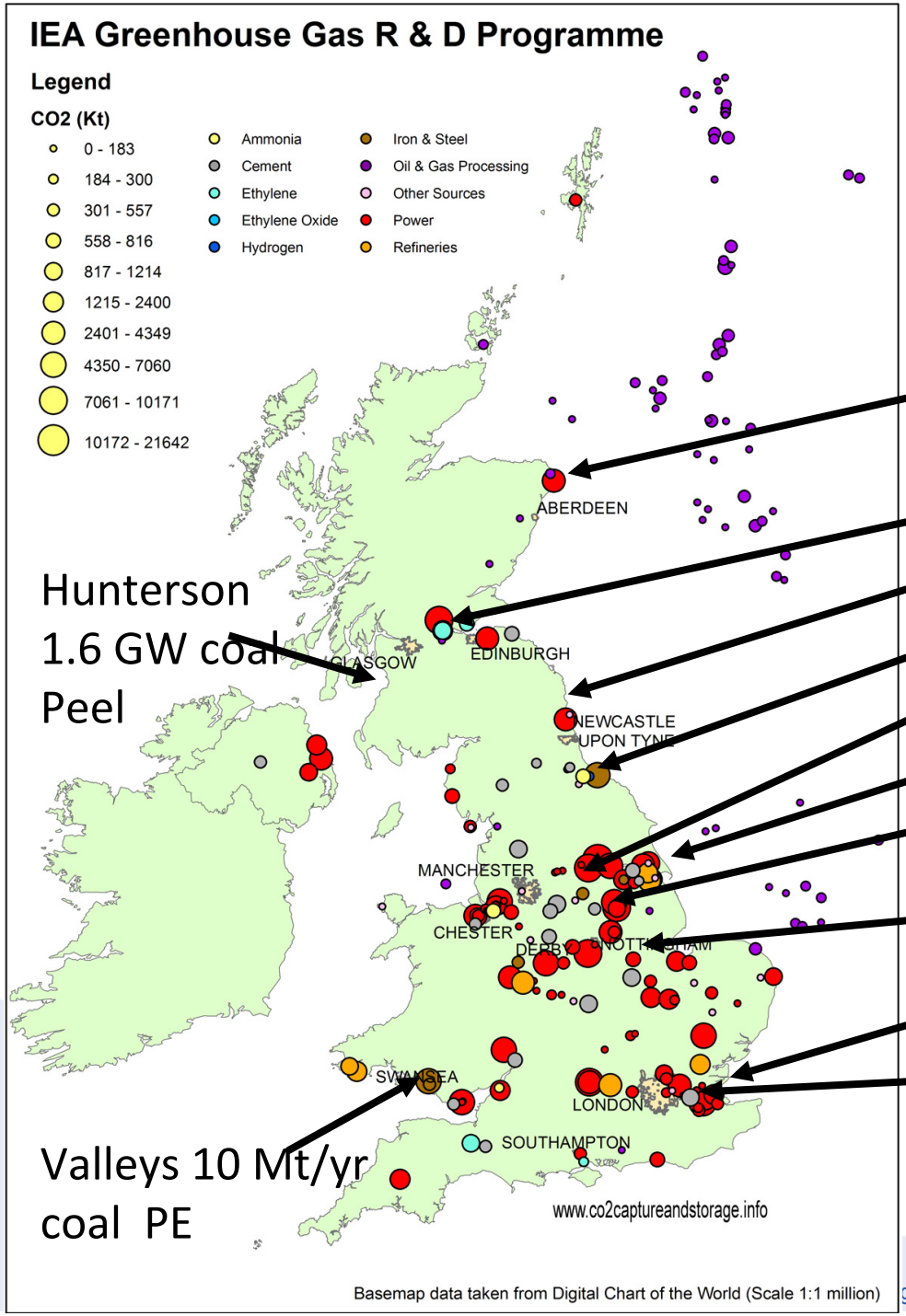


Hunterson 1.6 GW coal Peel

Valleys 10 Mt/yr coal PE

12.9 GW, 20% UK baseload

Peterhead 1.5 Mt/yr gas SSE/BP

Longannet 10 Mt/yr coal SP

Cockenzie 4.1 Mt/yr coal SP

Blyth 2.4 GW coal RWE

Tees-side 10 Mt/yr coal PE

Ferry Bridge 10 Mt/yr coal SSE

Immingham 1.2 GW CHP Conoco

Hatfield 900 MW Powerfuel

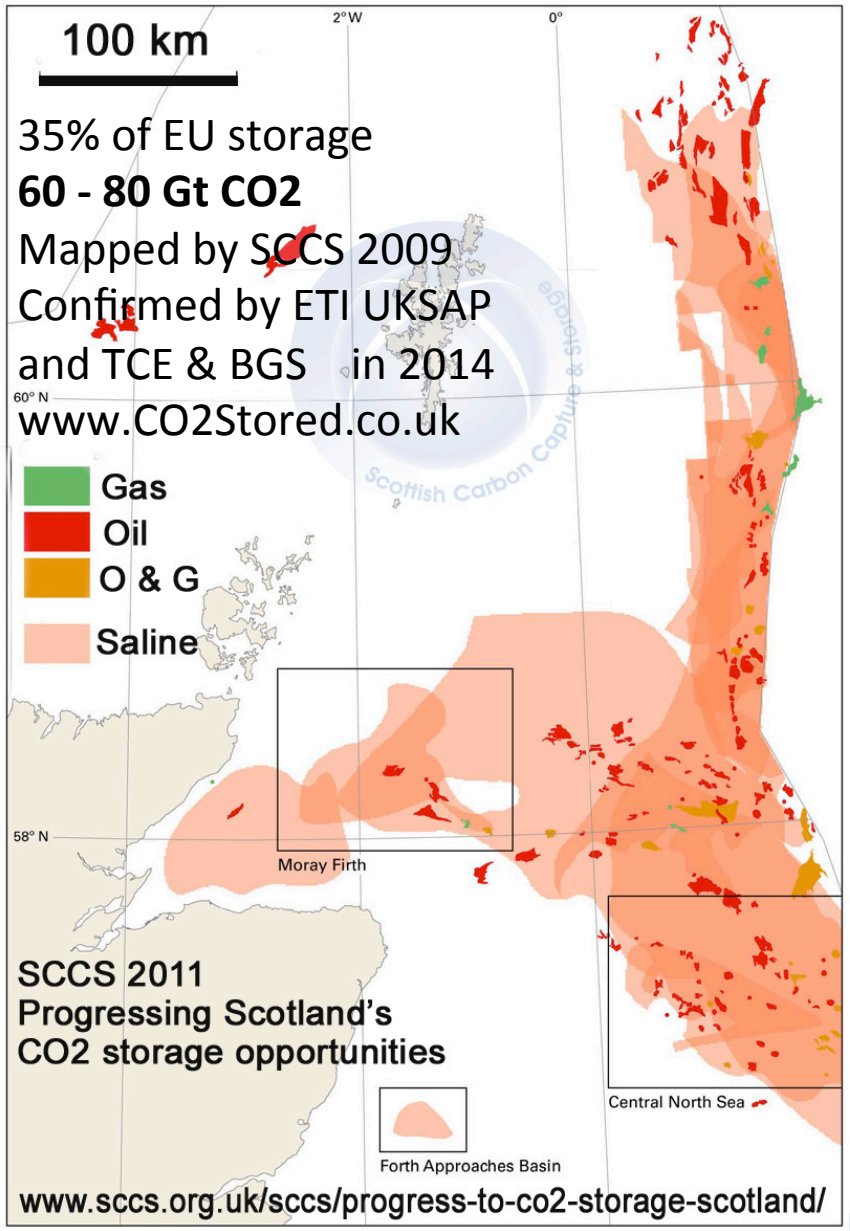
Killingholme 900MW coal E.ON

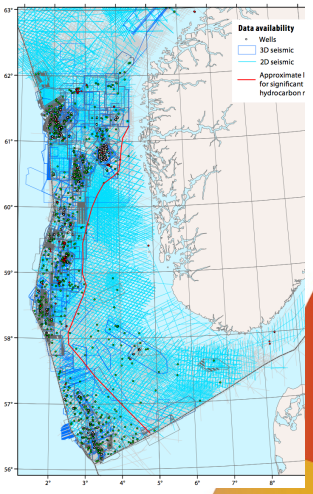
Kingsnorth 1.6 GW coal E.ON

Tilbury 1.4GW coal RWE

MANY projects have failed
Due to cost, or boredom
Complex finances

We KNOW North Sea storage is available





NORWAY

72 Gt CO2 Storage P50. Filtered by modelling and oil conflict. EOR not included – adds >3 Gt

A selection of North Sea solutions

Anchor project - full operation end 2018

Proven storage

Additional storage

Follow on CCS project – full operation end 2020

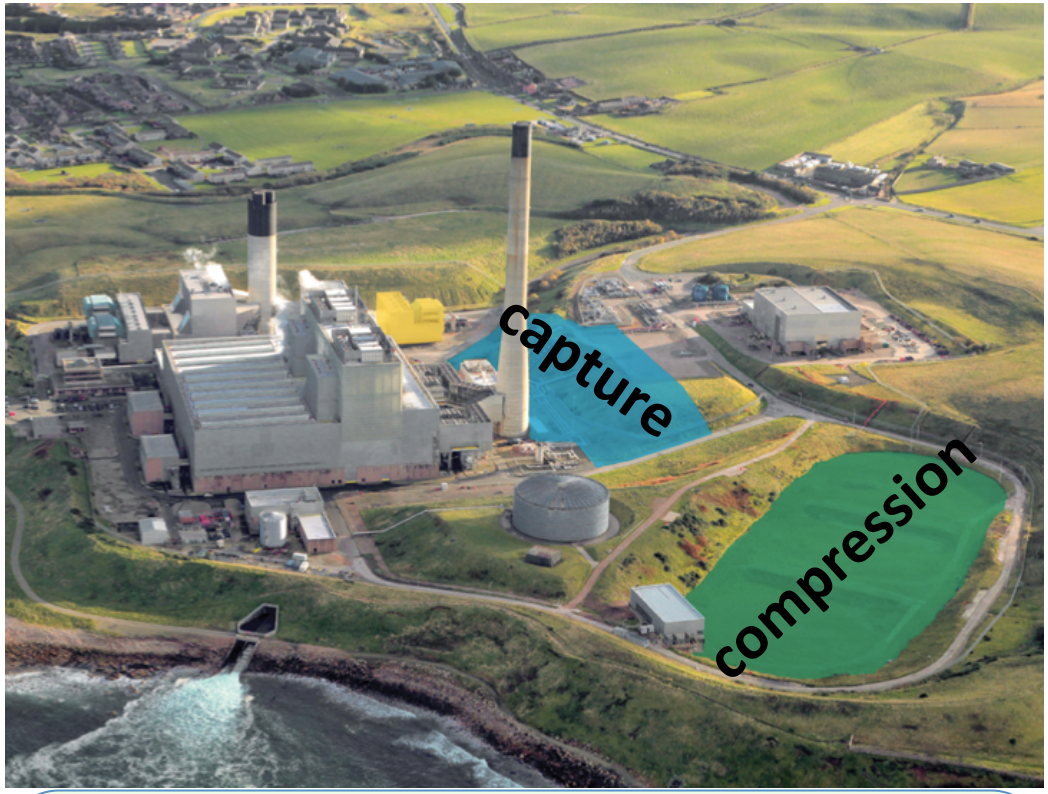
Enables additional industry decarbonisation

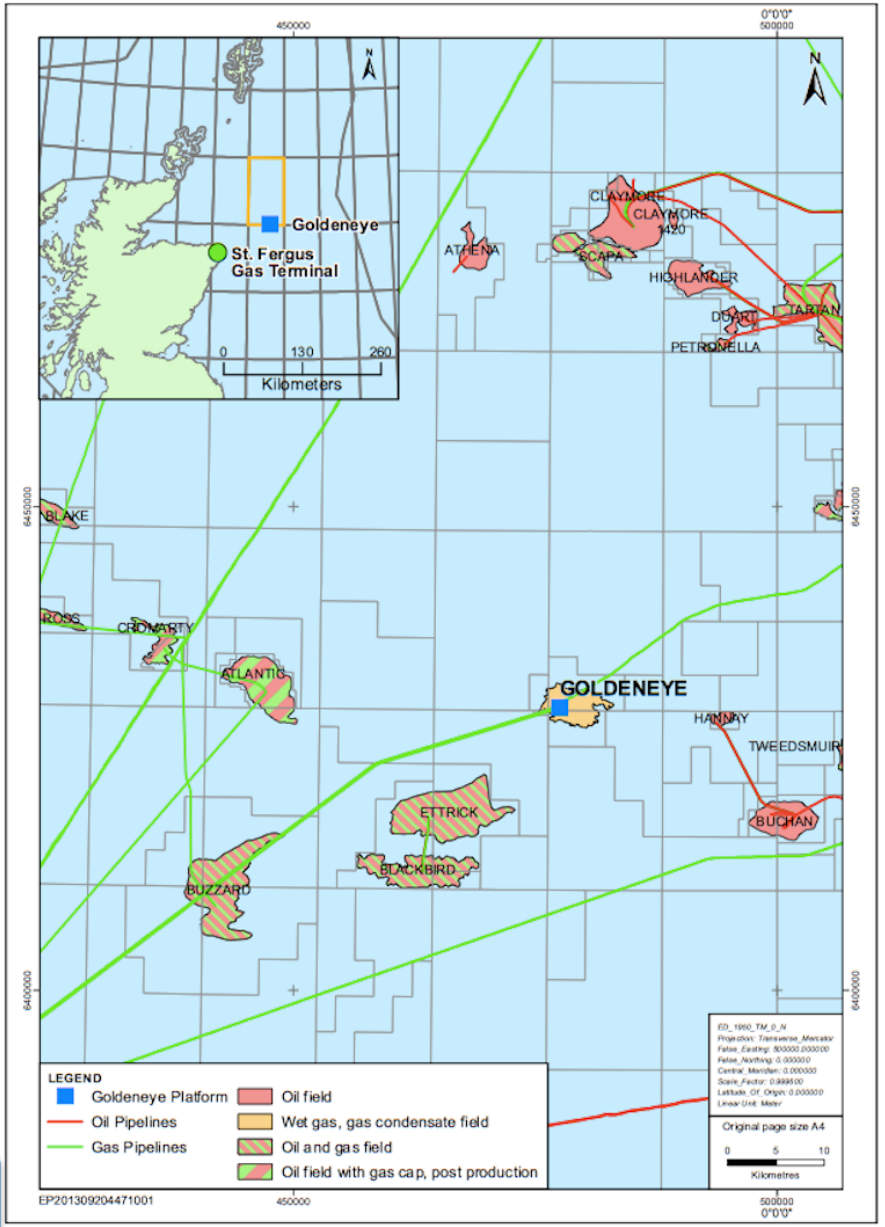
Acceleration possible by CO2-EOR to + ve NPV

BENEFITS
Extra energy security

Job protection, job creation

Where is an anchor project ?





PETERHEAD retrofit existing gas turbines. Re-use existing pipe and platform. Depleted gas field shares same aquifer as oilfields.

Takes CO2 to multiple storage offshore

CCS is happening – in Scotland

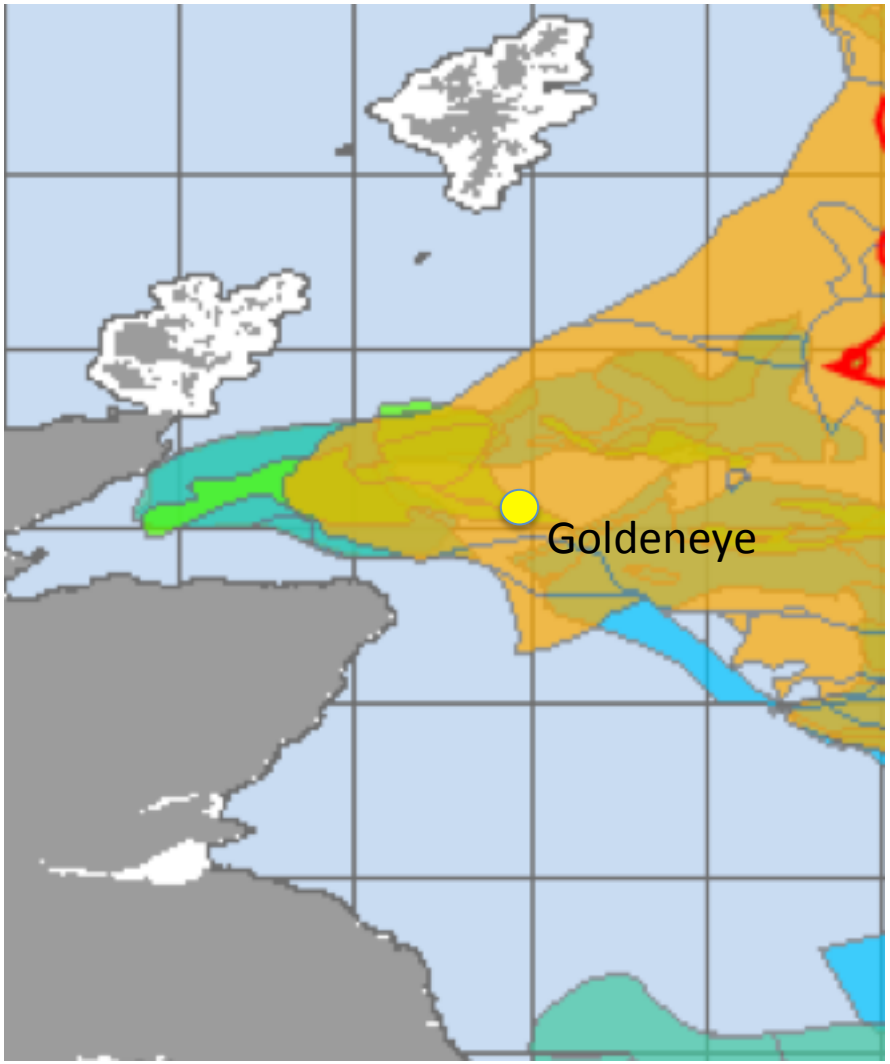
Peterhead to Goldeneye will capture 1 M tonnes CO2/ yr from 2018
First CCS in the world on gas-fuelled power plant

Is secure storage available at acceptable cost ?

CO2 MultiStore Joint Industry Project
Captain Sandstone: outer Moray Firth

- Containment of CO2 for two and more sites in a multi-user regional store
- Identify risks, and work on reduction
- Impact on existing hydrocarbon operations
- Inform licensing, leasing and monitoring
- Capture knowledge and transfer to other regional storage sites

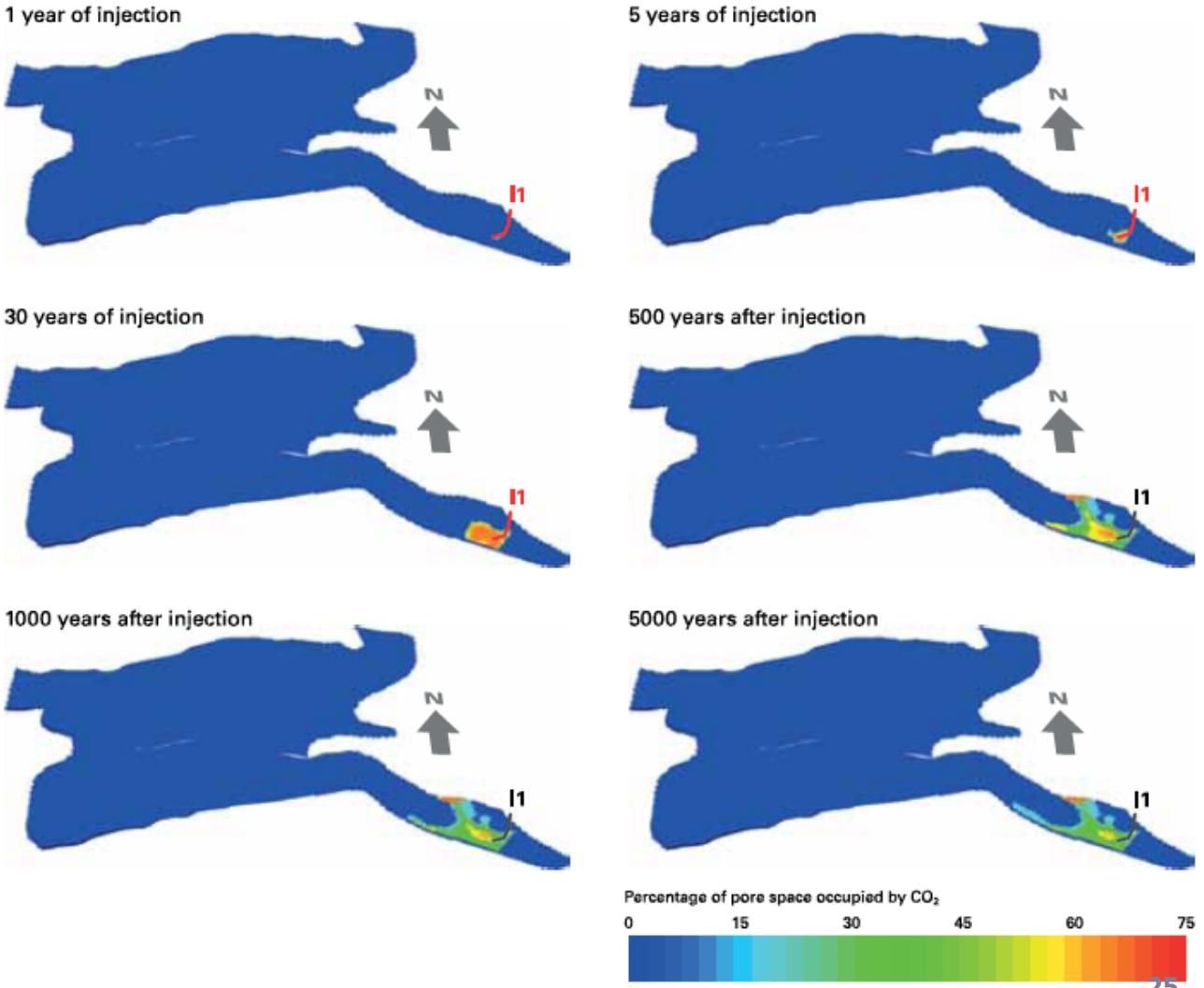
Output e.g Captain Sandstone
P10 600 Mt, P50 450 Mt, P90 350 Mt
Over-, under-lying reservoirs P50 2,500 Mt
ie, region all UK gas power for 40 yr



Captain (green) underlain and overlain by four additional reservoirs (SPE 148426)

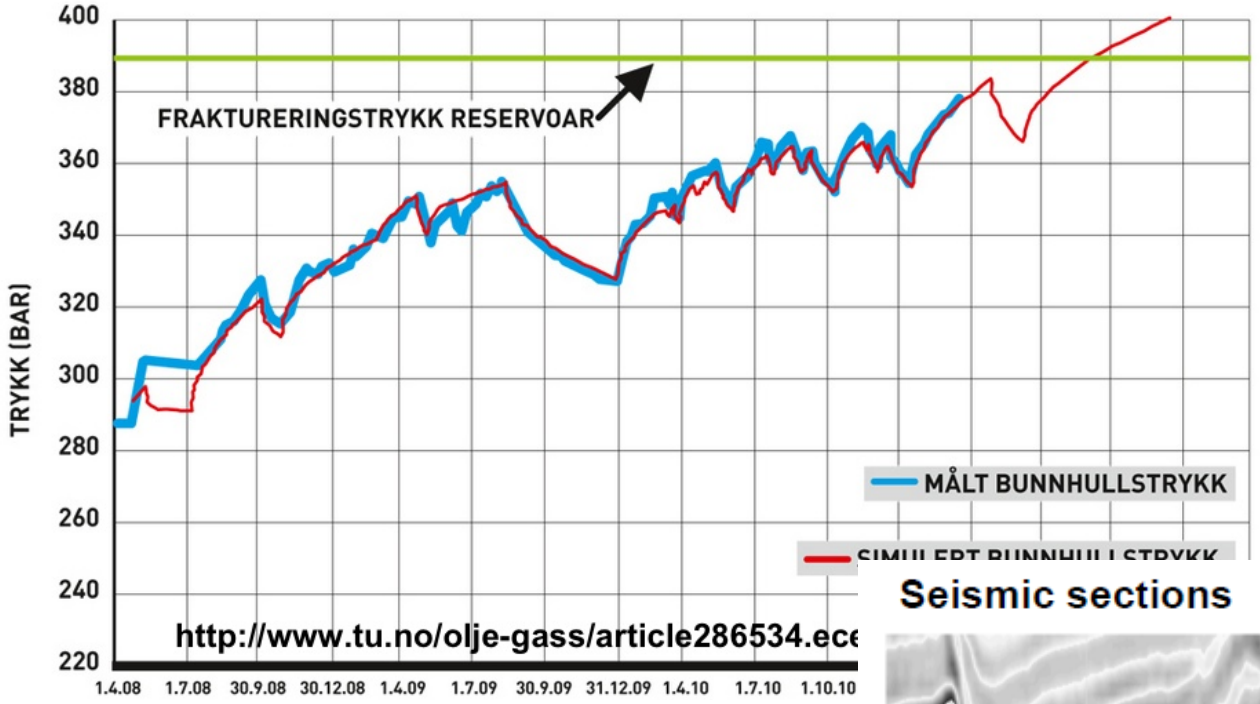
Modelling CO_2 injection – Captain Sst.

Simulation of single well injection for 30 years, then 5,000 years storage



www.sccs.org.uk/working-papers.html

Lessons learned : Snøhvit

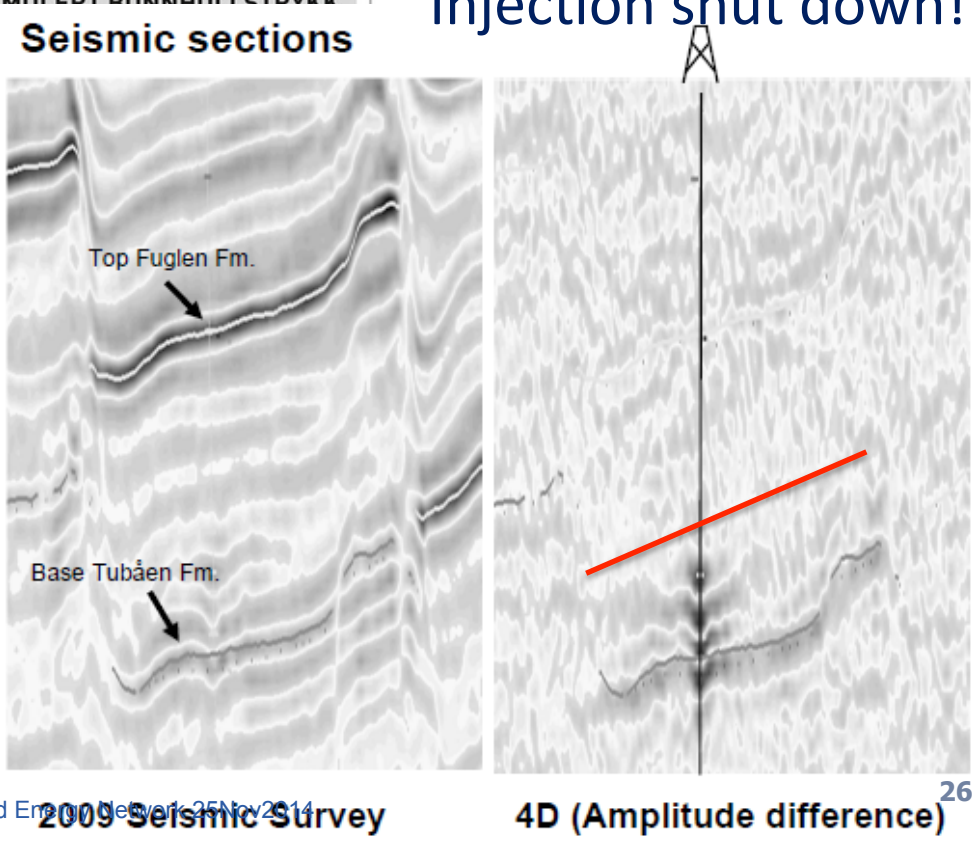


Significant pressure build up occurred over 2 years.

Injection shut down!

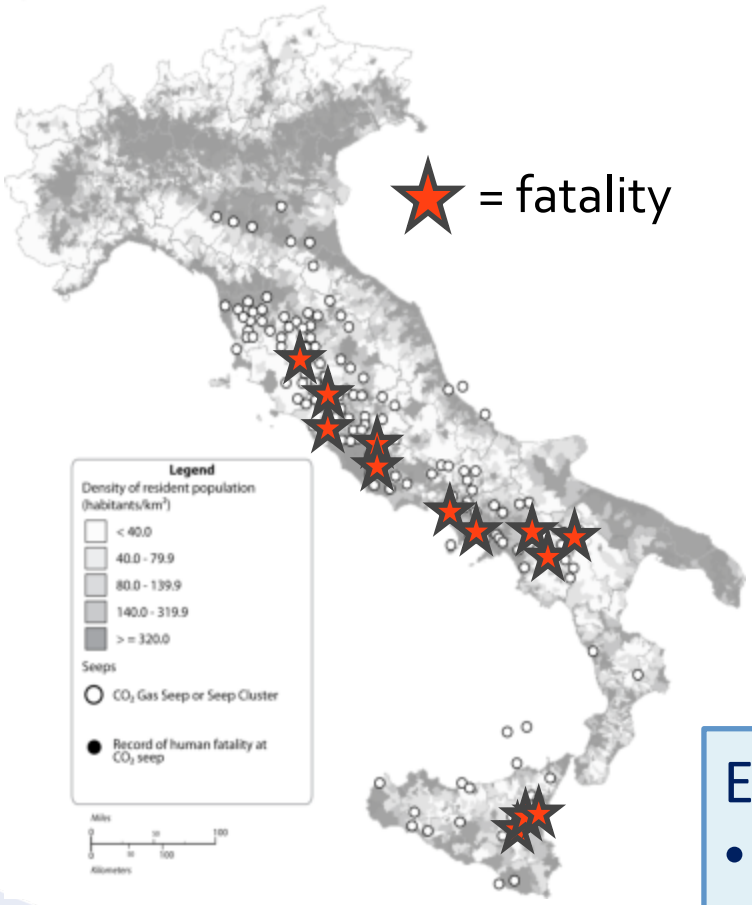
Repeat seismic in 2009 showed CO_2 confined to lower reservoir.

Well was successfully re-entered and perforated higher in the reservoir in 2011.



Real or imagined danger; Natural CO2 in Italy

Italy: Over 300 natural CO_2 seeps = 15% global non-volcanic natural CO_2 leakage



Roberts, Woods, Haszeldine. PNAS 2011

19 deaths (13 seeps) in 50 yrs:

1 in 36 million deaths/yr

UK lightning = 1 in 10 million

UK car crash = 1 in 20,000

UK lottery = 1 in 13 million

Offshore storage danger → 0

Excess concerns → to over-regulation?

- 'Permanence' required
- Costly Monitor and Verify?
- Long-term liability - Government

Is storage secure?

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YES

- More than 50 natural CO2 storage sites globally
- More than 20 global pilots of CO2 storage injection
- Injection CO2-EOR since 1976
- Commercial sized injection at Sleipner, Snovhit, In Salah, Decatur ……..

- Theory calculation of dissolution, residual saturation, dispersion

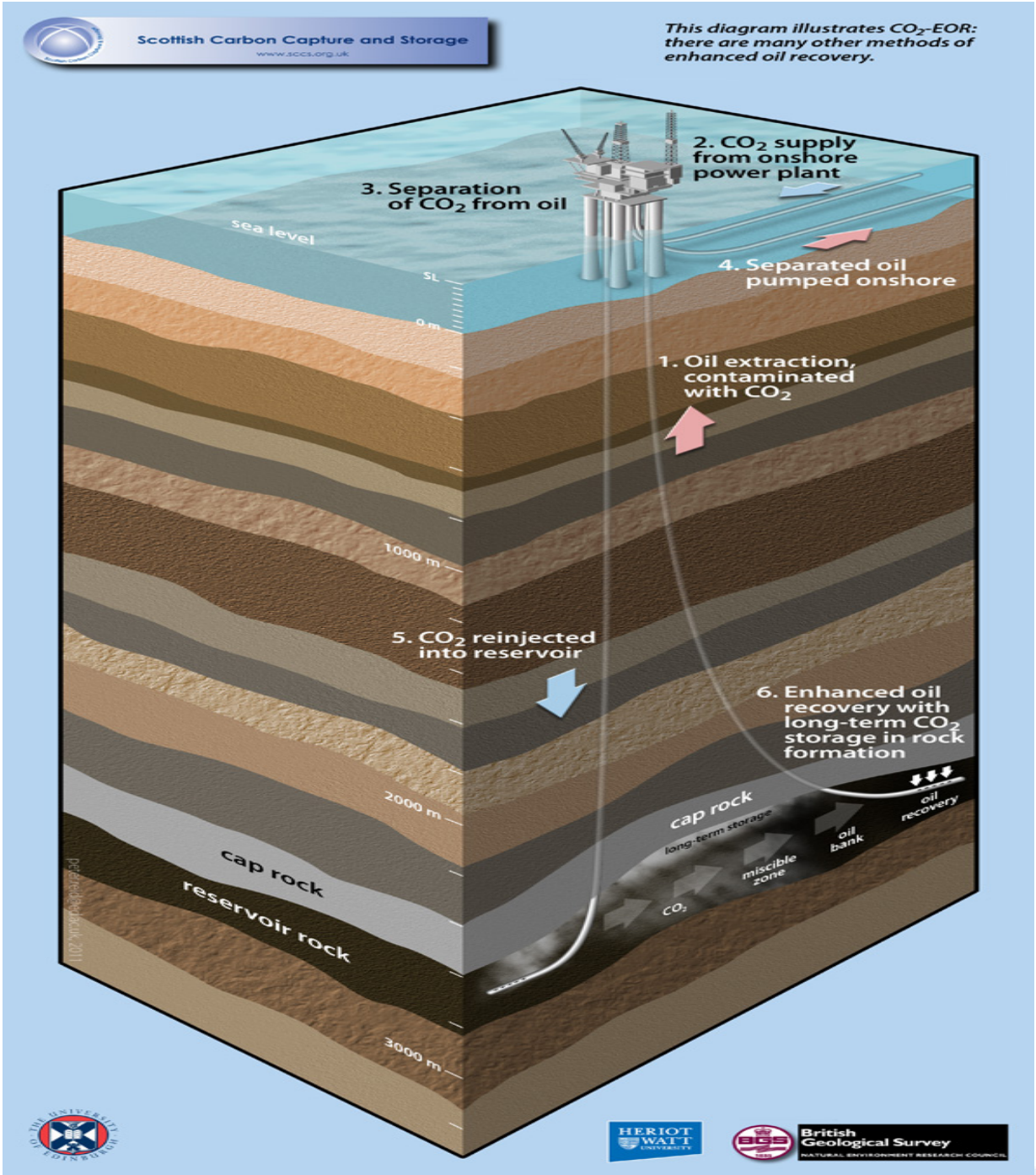
- Laboratory measurements confirm theory

- Practical tests confirm or better than theory

- QICS seabed injection test : no marine effects, and 85% CO2 retention

Tees-side : 60% UK chemical industry

UK's most dense industrial zone. Many existing CO2 producers : ammonia, fertiliser eg
1 tonne= 2.6 t CO2 → 0.36 with CCS
Existing (small) CO2 export port. Pipelines. Ready for CCS 4 – 50 Mt CO2/yr



Paying CO2-EOR

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- Acquire CO2, 2 - 5 Mt/yr
- Transport Ship or pipe
- Convert offshore platform
- Inject CO2, recycle
- Produce 5-20% extra oil
- 10 – 20 yr life
- Rapid dissolution CO2
  ➔ secure retention

Needs low tax CAPEX
Needs low cost CO2
Same tax revenue
£90 Billion UK tax

Can CCS rollout be accelerated : using EOR ?

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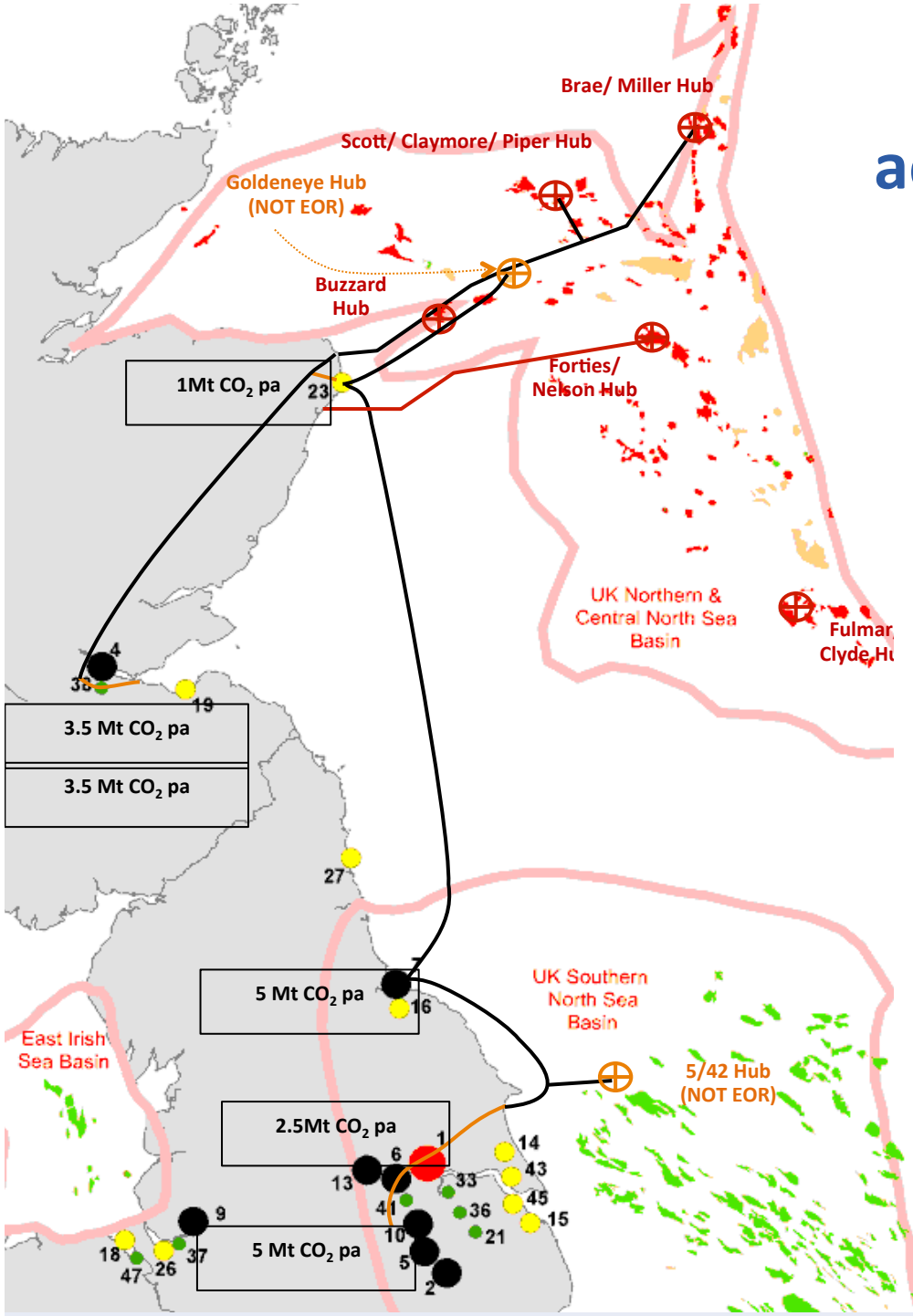
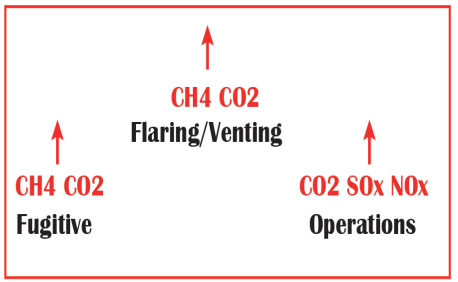
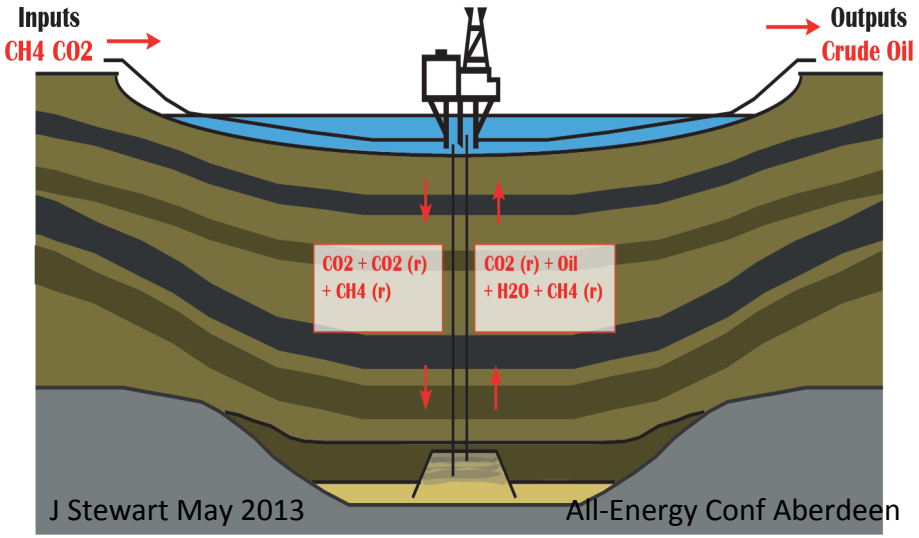


Carbon balance can be regulated

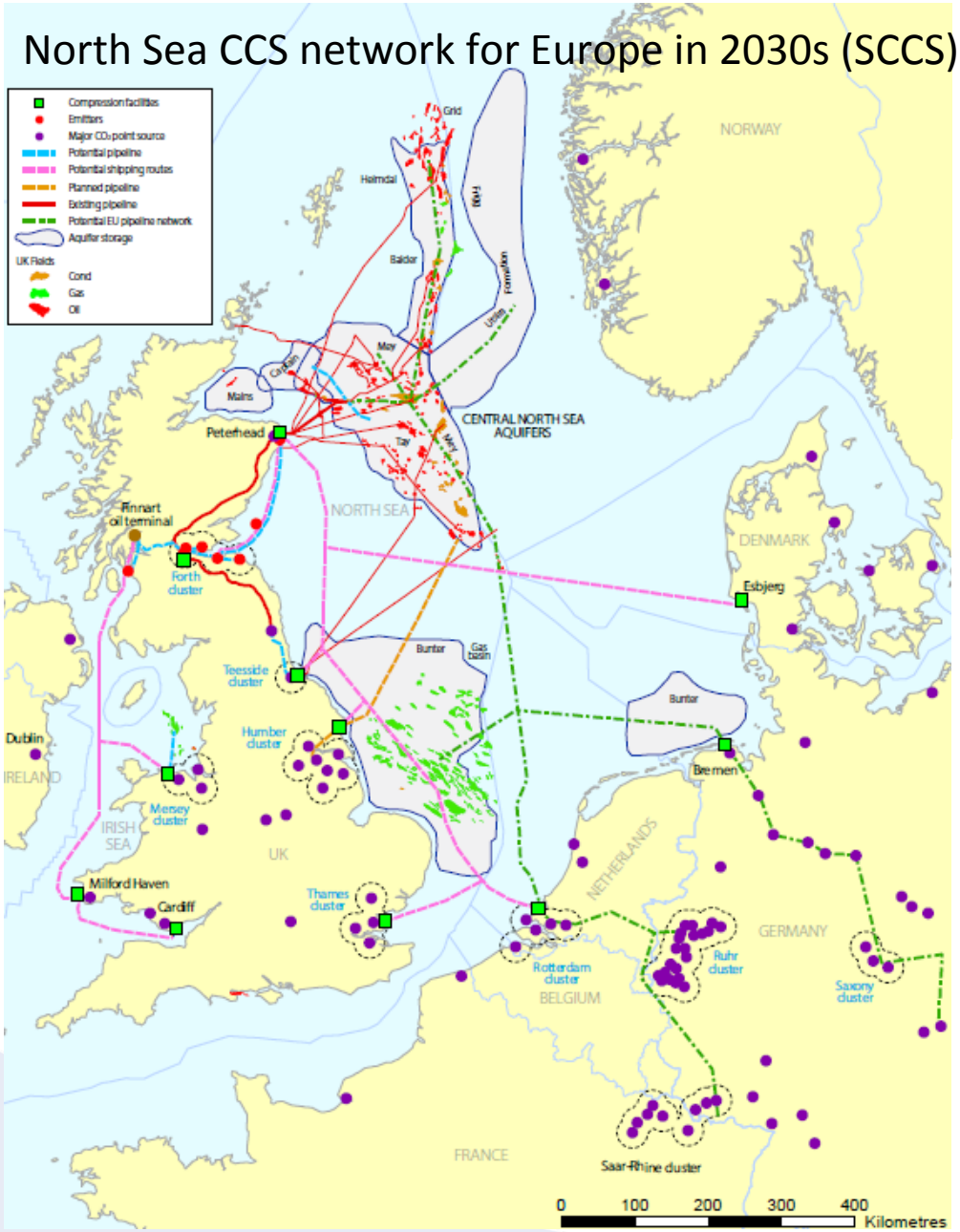




J Stewart May 2013 All-Energy Conf Aberdeen

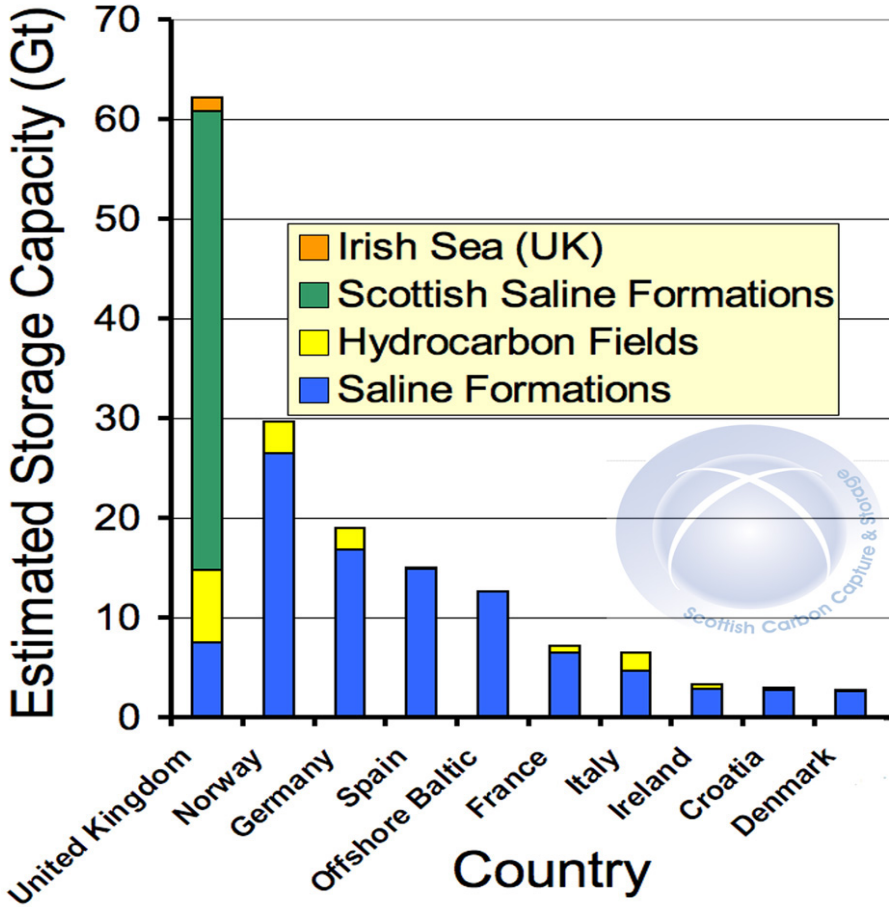
CO2-EOR – unlocks 1 to 3 Billion barrels of extra oil, UK & NO. Produces £ 37 Bn tax, PROFIT on CCS, installs pipes and capture by 2021

North Sea CCS network for Europe in 2030s (SCCS)

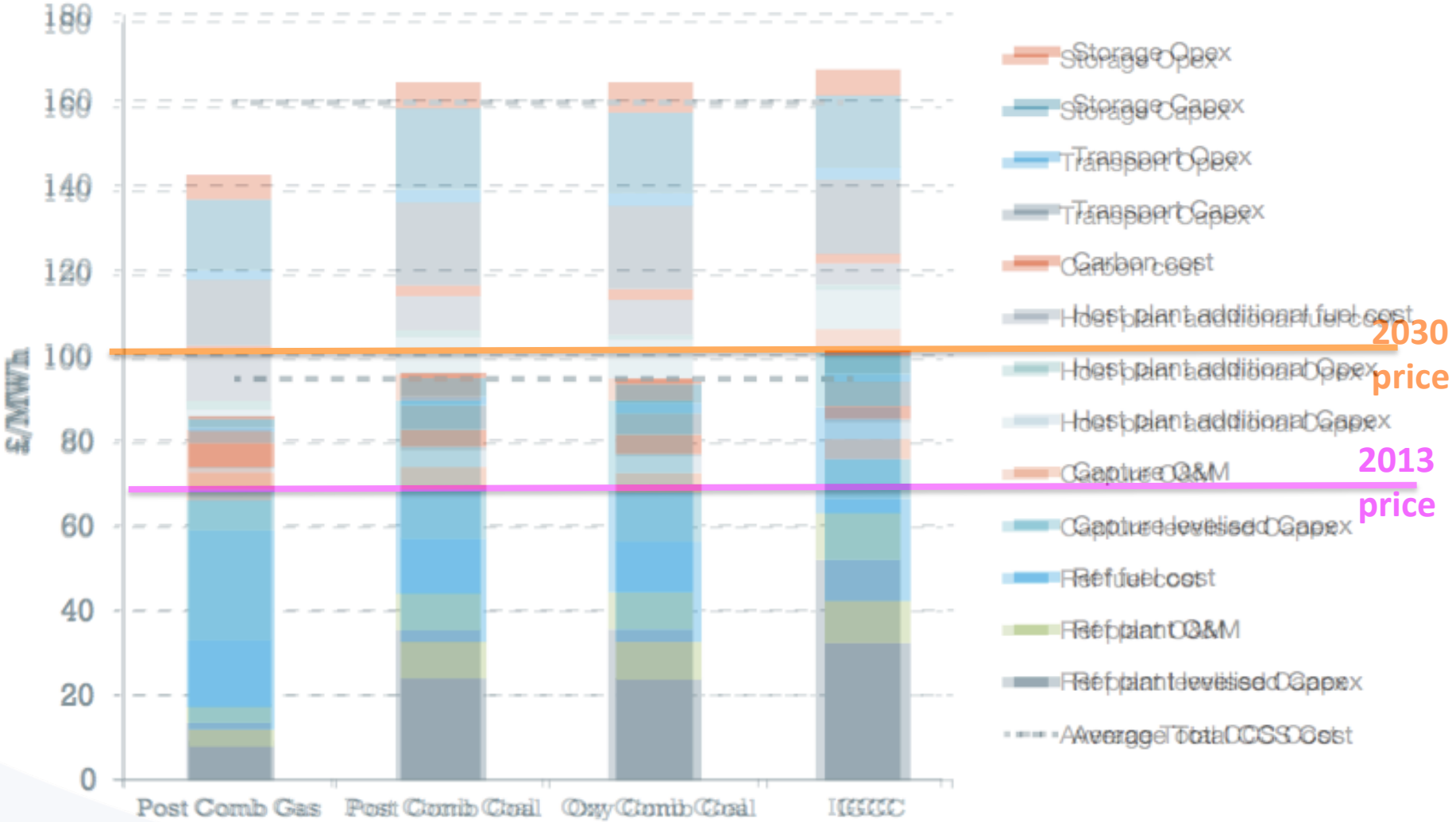


Vision of 2030

Power sites in NW Europe
Connected to offshore ex-oilfields and saline storage.
Connects Germany and Poland



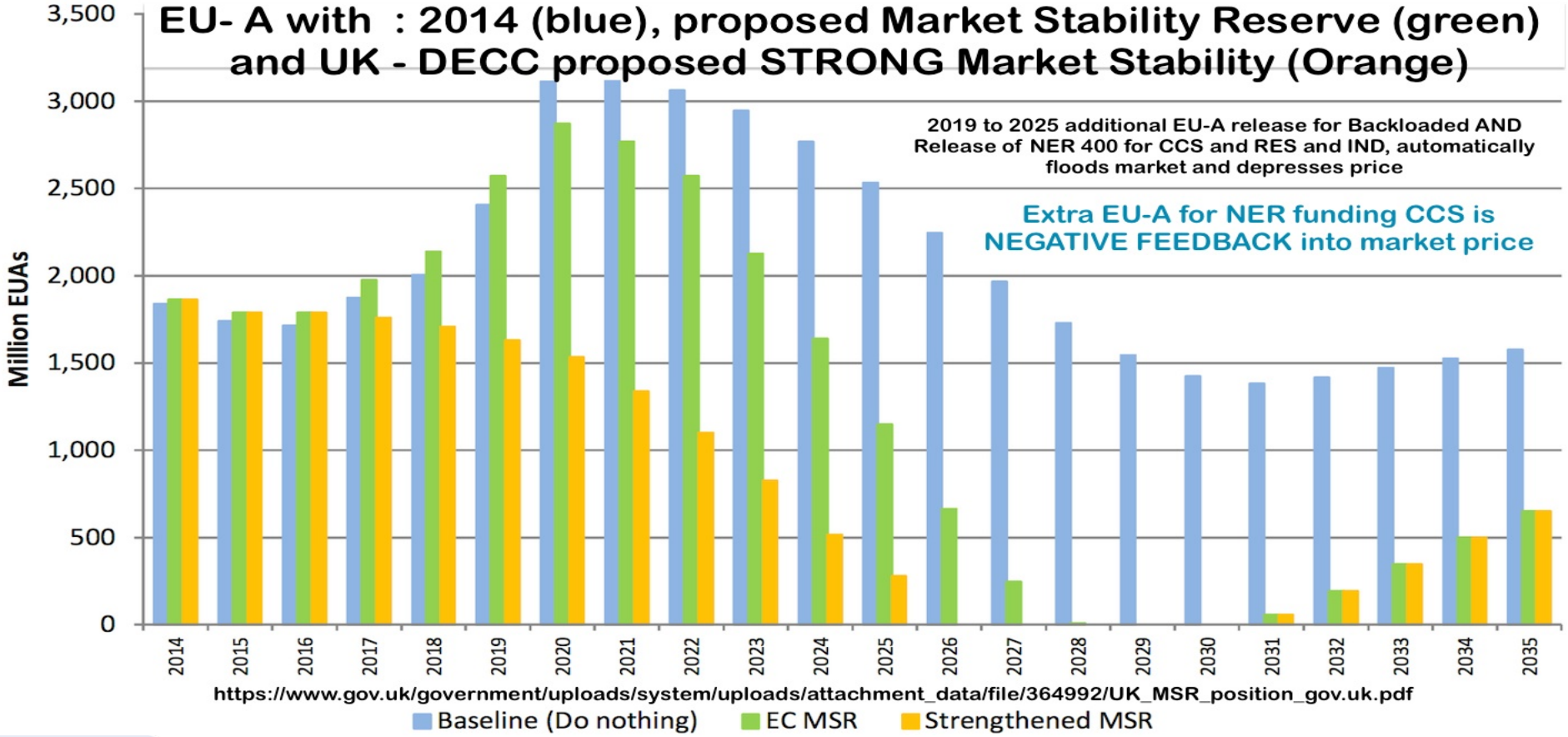
CCS is currently expensive – price will decrease



Learning by serial build – globally – UK "plan" 13 GW by 2030
Wholesale cost 20-30% more, Retail cost 10-15% more

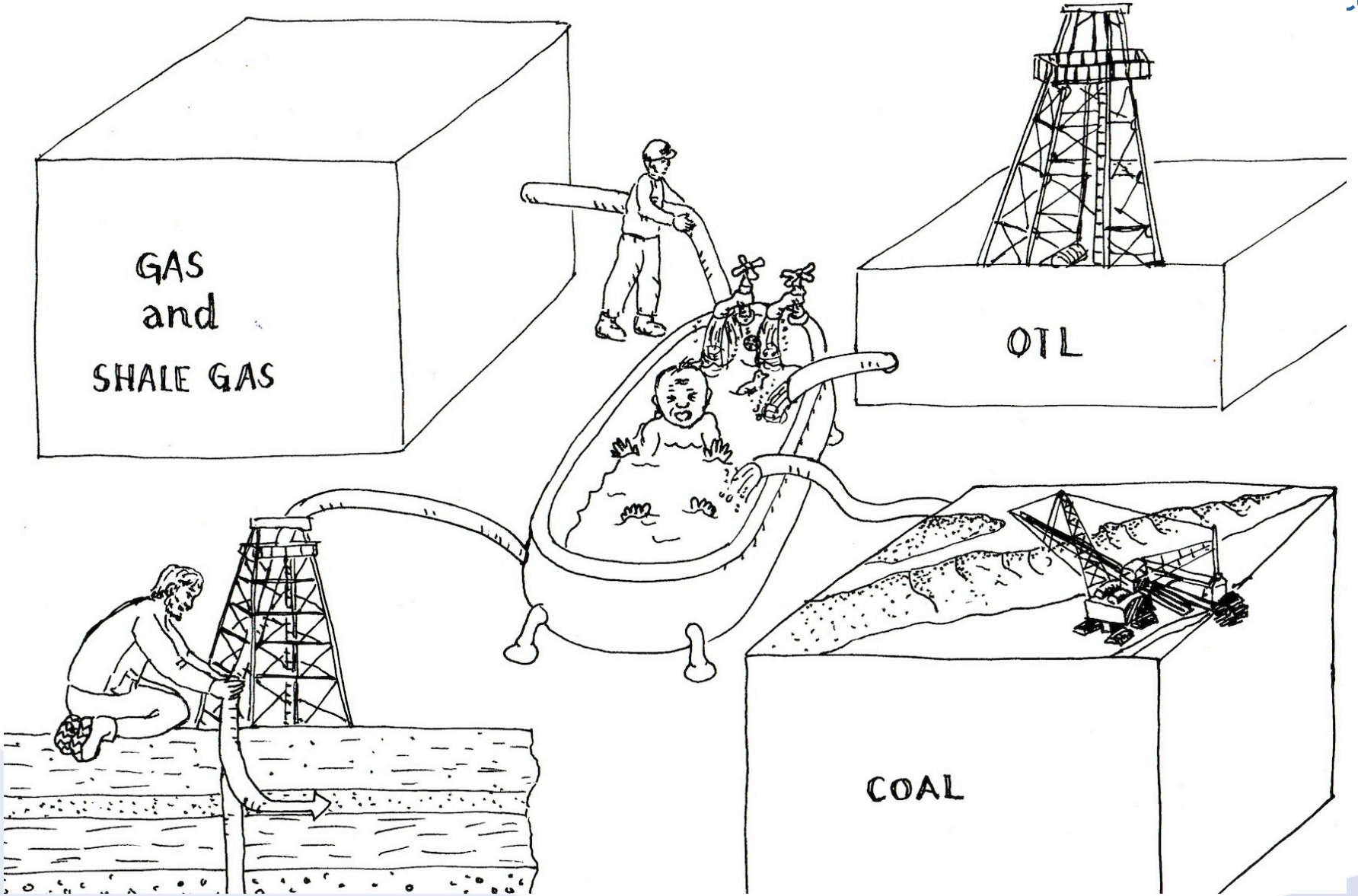
Paying for CCS : EU-ETS, Targets, FiP

NER400 is helpful. But CCS is not the least-cost action. So is not the development-of-choice.
An economy-wide tax, with over-allocated permits, **EU-ETS is NOT ENOUGH to operate CCS**

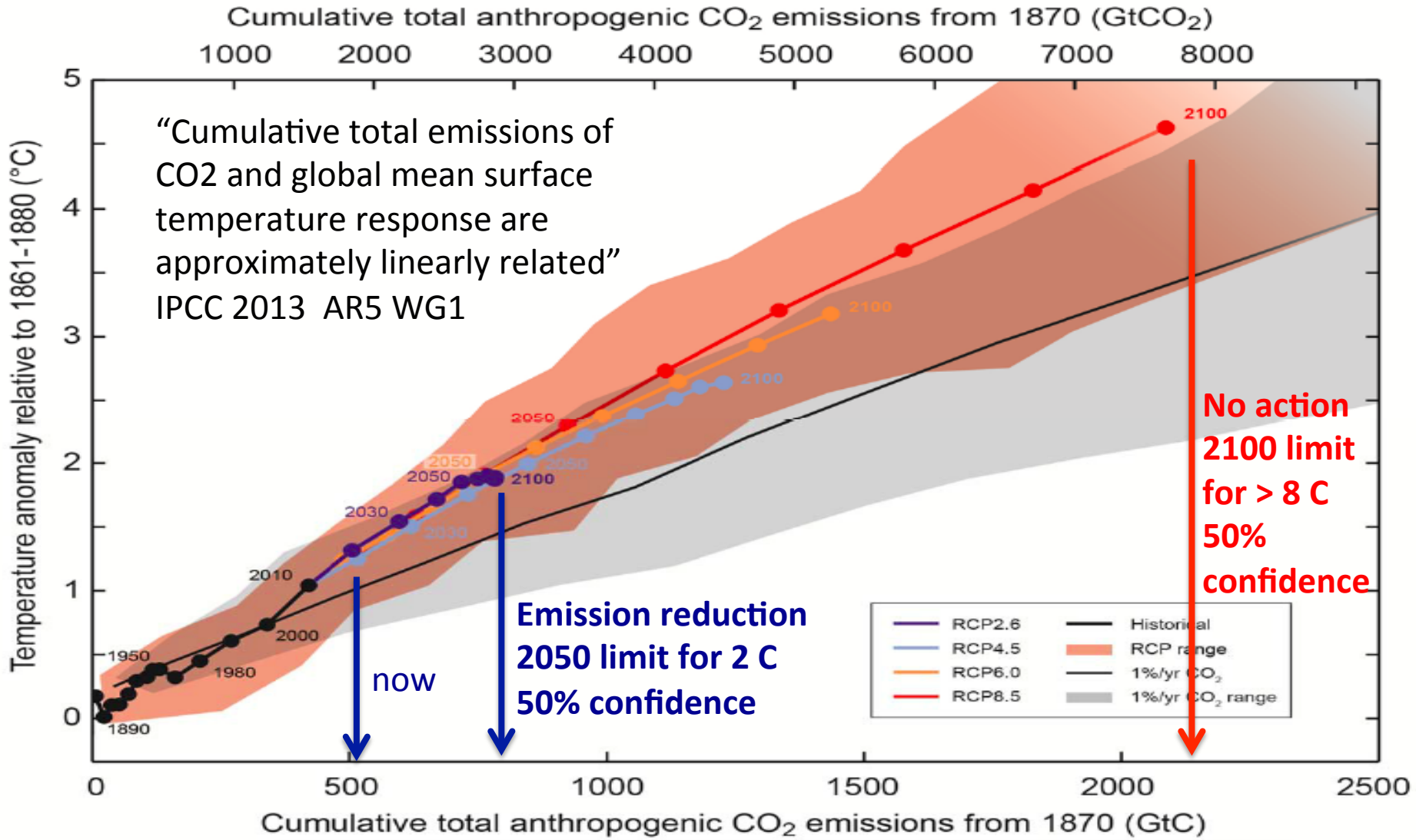


CCS needs an <u>EU target</u>, like RES, EE, GHG
<u>State</u> OpEx payments by FiP, needed to make CCS projects viable

Balancing fossil fuel emissions with storage

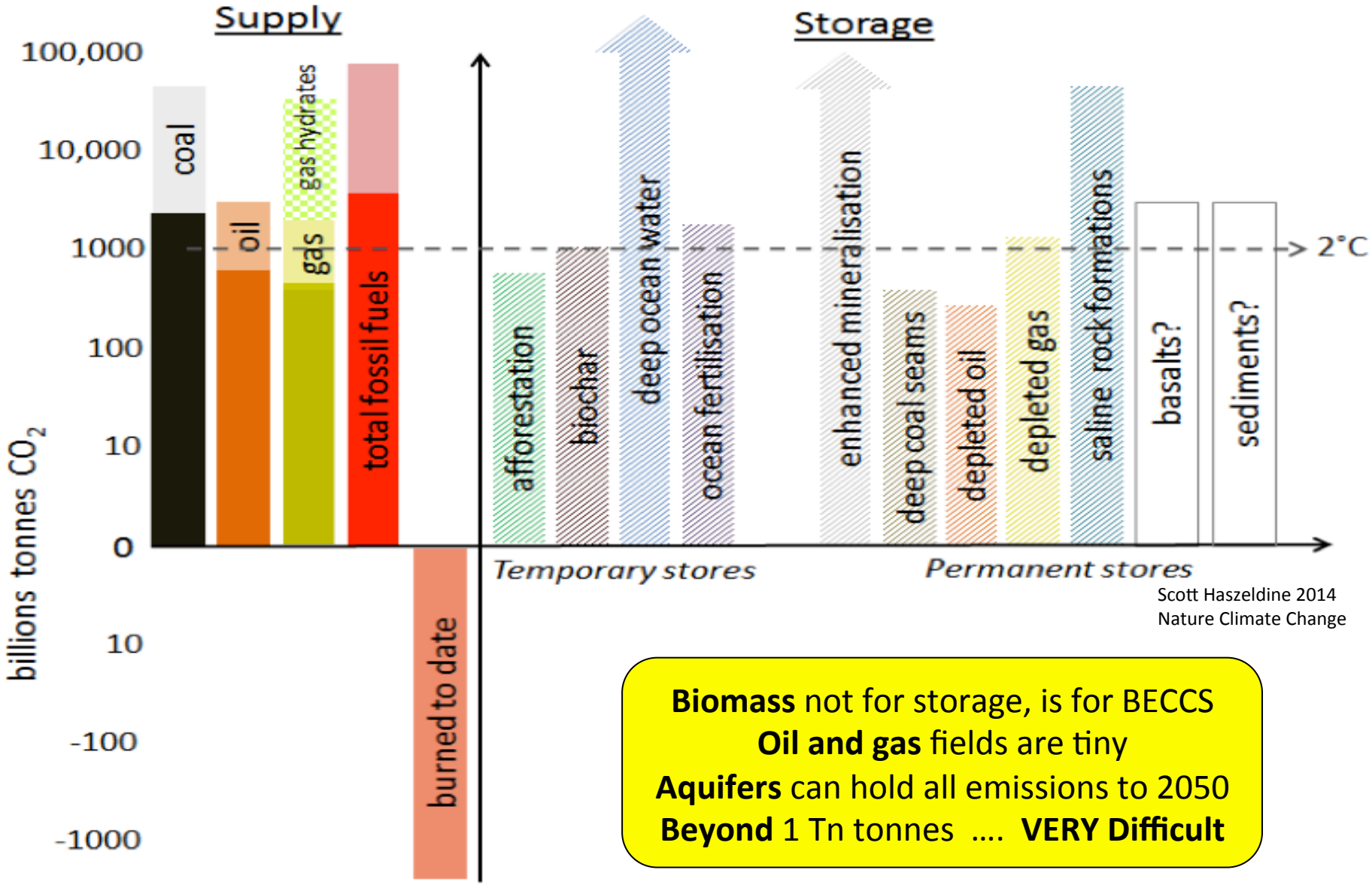


Climate and unburnable carbon



TOTAL emissions of fossil carbon have to be contained
Not just the rate of emission : CCS, RES, E Efficiency buy time
Forcing response uncertain for double CO2 → 2C or 4C ?

GeoEngineering CDR Global carbon storage



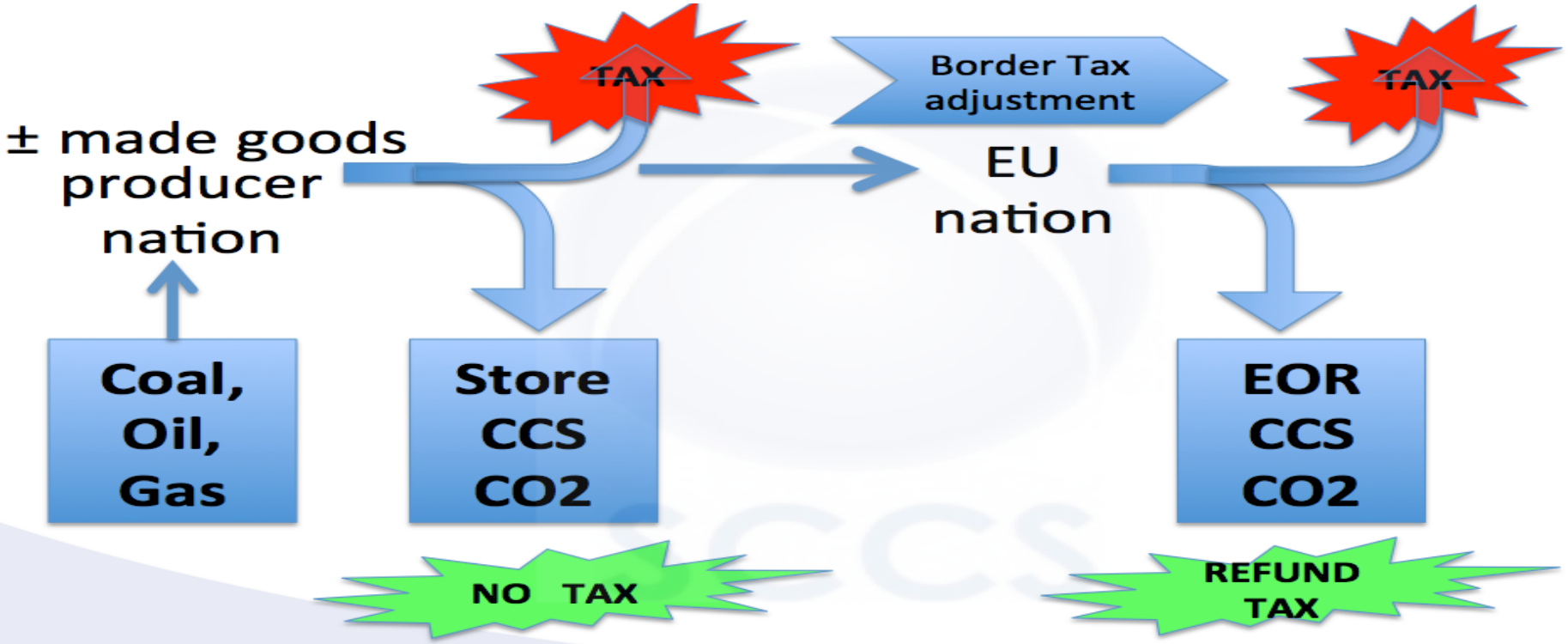
Scott Haszeldine 2014
Nature Climate Change

Biomass not for storage, is for BECCS
Oil and gas fields are tiny
Aquifers can hold all emissions to 2050
Beyond 1 Tn tonnes …. **VERY Difficult**

Leveraging onto China: Need STORAGE market

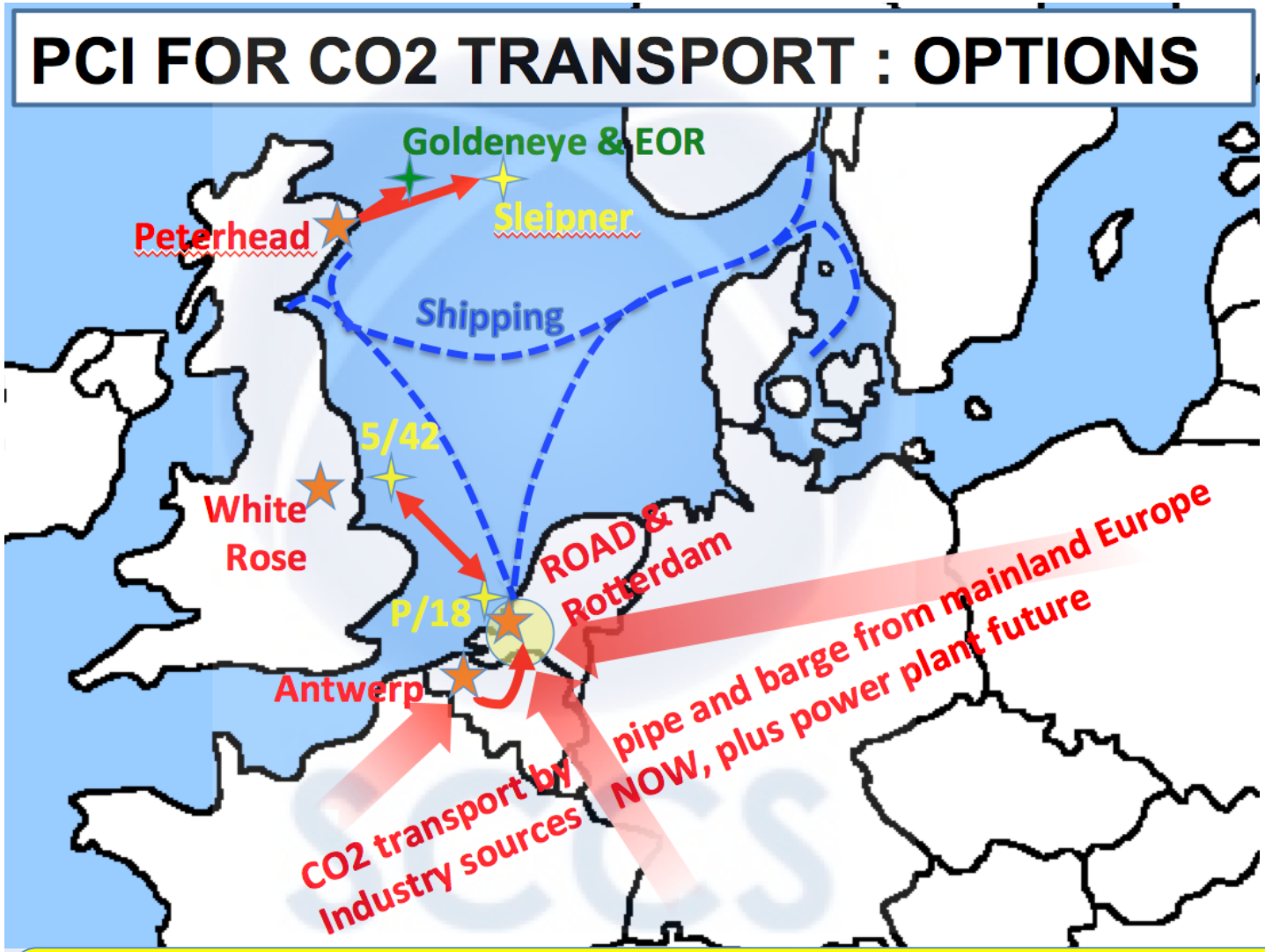
EU-A taxes consumers, Only works on part of the economy
Does not engage producers in storage, or embedded energy

Remedy : **STORAGE MARKET : via extraction certificate**



Environmental certificate IMPLICITLY levied at border – fuels and goods.
Refunded on PROOF of matching storage tonnage within EU28
Big Carbon then competes to develop reliable storage, and reduce costs

How to get North Sea NETWORK built ?



North Sea develops:

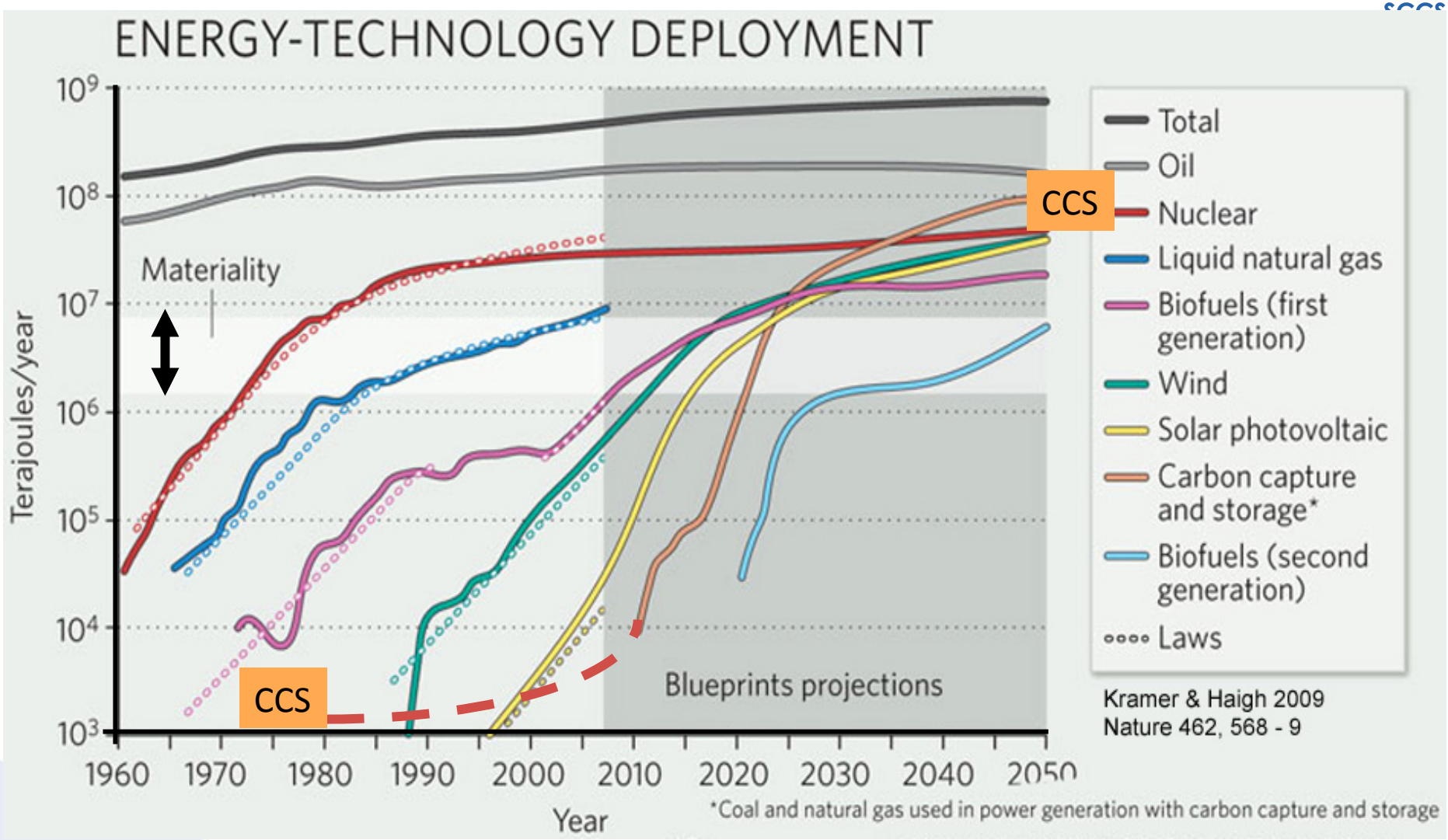
- **SEVERAL ship routes offshore**
- **Sources CO2 from power and industry**
- **Deepwater ports to import from EU**
- **Existing pipes to proven storage**
- **CO2-EOR for Oil Co market builds ships, pipes and storage**
- **CO2-EOR for £37 Bn tax profit**

Project of Common Interest : to build flexible shipping & barges to deepwater port, NOW, followed by onshore pipes. Helps reduce carbon for UK, NL, BE, DE, PL, NO, DK. P18, Goldeneye (Captain) & Sleipner are resilient storage destinations. EU2030 can fund this

Full-scale full chain CCS projects

Multiple projects globally, 22$_{(GCCSI)}$ planned in construction

Learning rates – fast start, expect decades



CCS was projected to be un-precedented rapid growth**. ADD 15 years, to base scale**
BUT : Requires projects to be built, circulation of information, slowed by capture types

Final commentary

SCCS

- **CCS is workable, affordable and proven**

CCS is the least cost method of rapid whole-system transition

- **Governments and finance rules are the problem**

The time (and front-end-cost) of Transition are underestimated
Technology is not the problem
The pace of financial investment is 10-100x too slow

- **World Energy Council Nov 2014**

capital is available in the private sector to the required scale, but the patterns of investment will need to change radically in terms of the type of energy source, technology, and infrastructure. Above all, investors and developers will have to invest way beyond their comfort zones, and they will need better help from governments, regulators, and international financial institutions than is currently envisaged.

- **Solutions : Focused Carbon certificates; market rules to enable investment**

UK is "leading" but RoW is much too slow for carbon balance

END