Offshore CO2 EOR as Part of a National CCS Programme: Opportunities and Challenges

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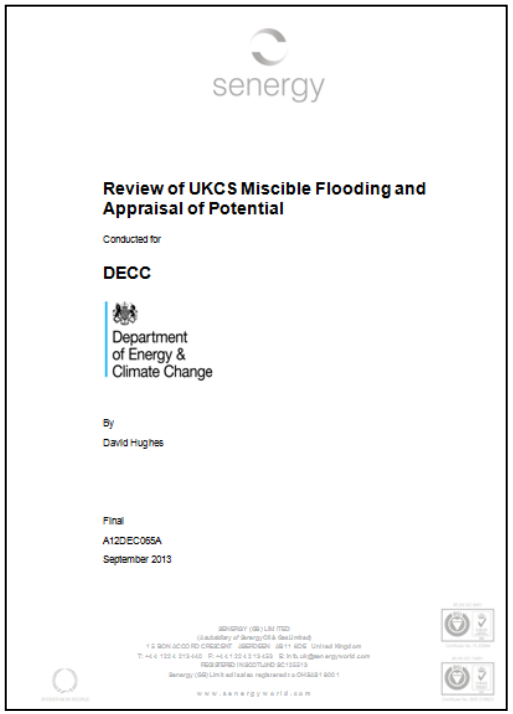
18th February 2014

Introduction

- Substantially material prepared for a new SPE Distinguished Lecture (from September 2014)
- Include more detail of recent UK CO2 EOR screening exercise undertaken for DECC (report available)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Review of UKCS Miscible Flooding and Appraisal of Potential

Conducted for

DECC

Department of Energy & Climate Change

By

David Hughes

Final

A12DEC055A

September 2013

- DECC/ PILOT/ Oil & Gas UK initiative
- Presented to industry 1 October 2013
- For copy of 'DECC Miscible Flooding' report (8 MB) email david.hughes@senergyworld.com

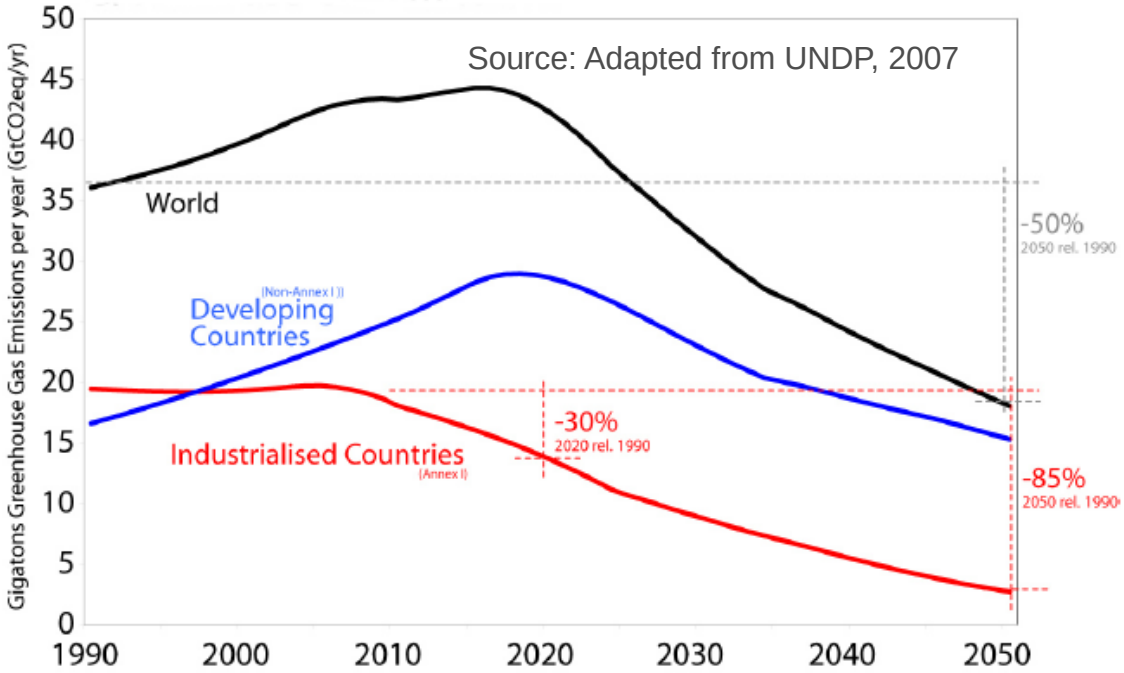
Opening remarks: Geological Storage of CO2

- New business stream for oil industry
- Store liquid/supercritical CO2 in depleted oil and gas fields and also in saline aquifers
- Synergies with existing operations through reuse of infrastructure etc. and opportunity to increase hydrocarbon recovery
- Contributes to the fight on climate change
- Has value through Cap and Trade arrangements or through avoiding carbon taxes
- But comes with regulations and liabilities
- Uses all our skills

Outline of Talk

- Worldwide requirement for CO2 emissions reductions and role of carbon capture and storage (CCS)
- Specific UK targets
- Expected amounts and locations of captured CO2 from national CCS programme
- Types and locations of storage sites including estimate of UK CO2 enhanced oil recovery (EOR) potential
- Challenges of implementing CO2 EOR offshore
- Discussion

Worldwide CO2 Equivalent Emissions and Reduction Requirement



- Emissions reductions pathway consistent with limiting temperature rise to 2°C (1990 baseline)
- 85% reduction in developed countries
- 50% reduction overall

Inter-governmental Panel on Climate Change (IPCC) Fifth Assessment Report

Lower gear?

Carbon concentrations and future temperature rises

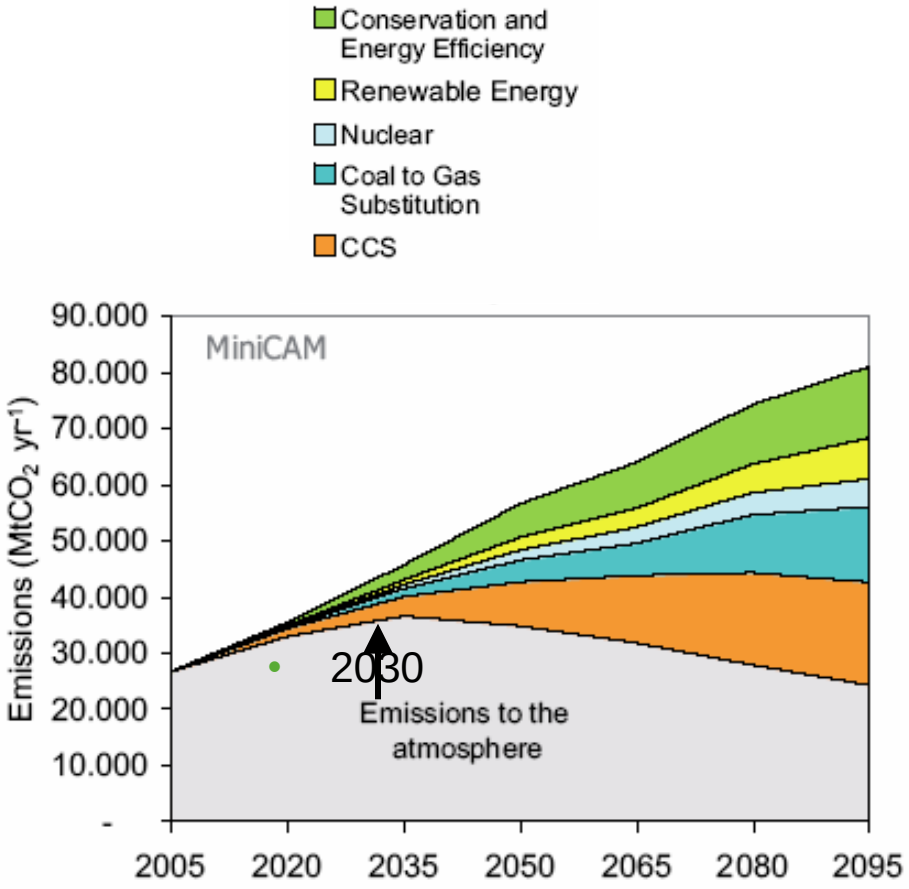
CO_2 emissions, parts per million	Temperature above pre-industrial levels in 2100, °C
425-485	1.3-1.7
485-535	1.7-2.2
535-585	2.0-2.4
585-710	2.3-3.0
710-1000	3.0-4.0
>1000	>4.0

Source: IPCC

- From second order draft of the IPCC Working Group III contribution to the IPCC's Fifth Assessment Report (published in Economist 20th July 2013)
- Compares with 445-490 ppm giving likely rise of 2.0-2.4°C in Fourth Assessment Report

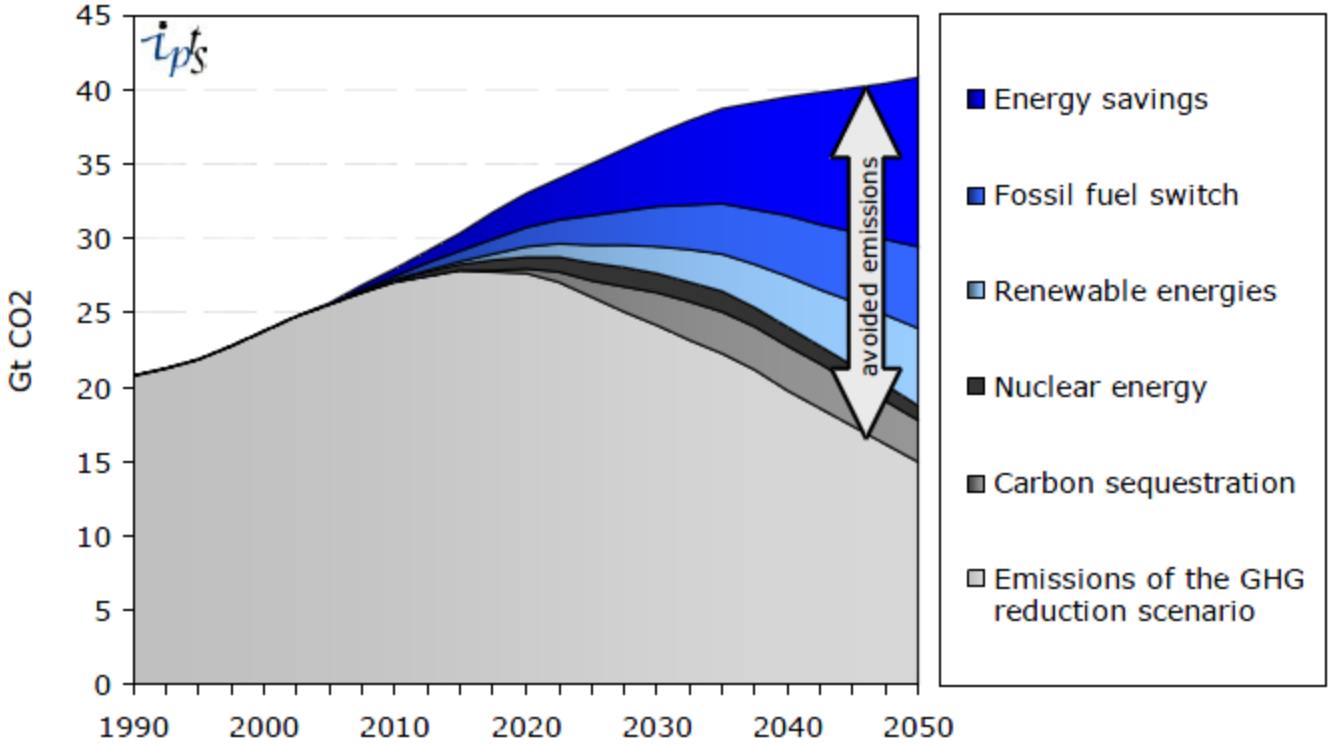
IPCC 2005 Prediction of Requirement for Carbon Capture and Storage (CCS)

- From ~2030 amount of CO2 that requires to be stored is ~4 billion tonnes/year, rising to ~18 billion tonnes/year in 2095
- c.f. 4.0 billion tonnes/year oil production and 3.0 billion tonnes oil equivalent/year gas production in 2011



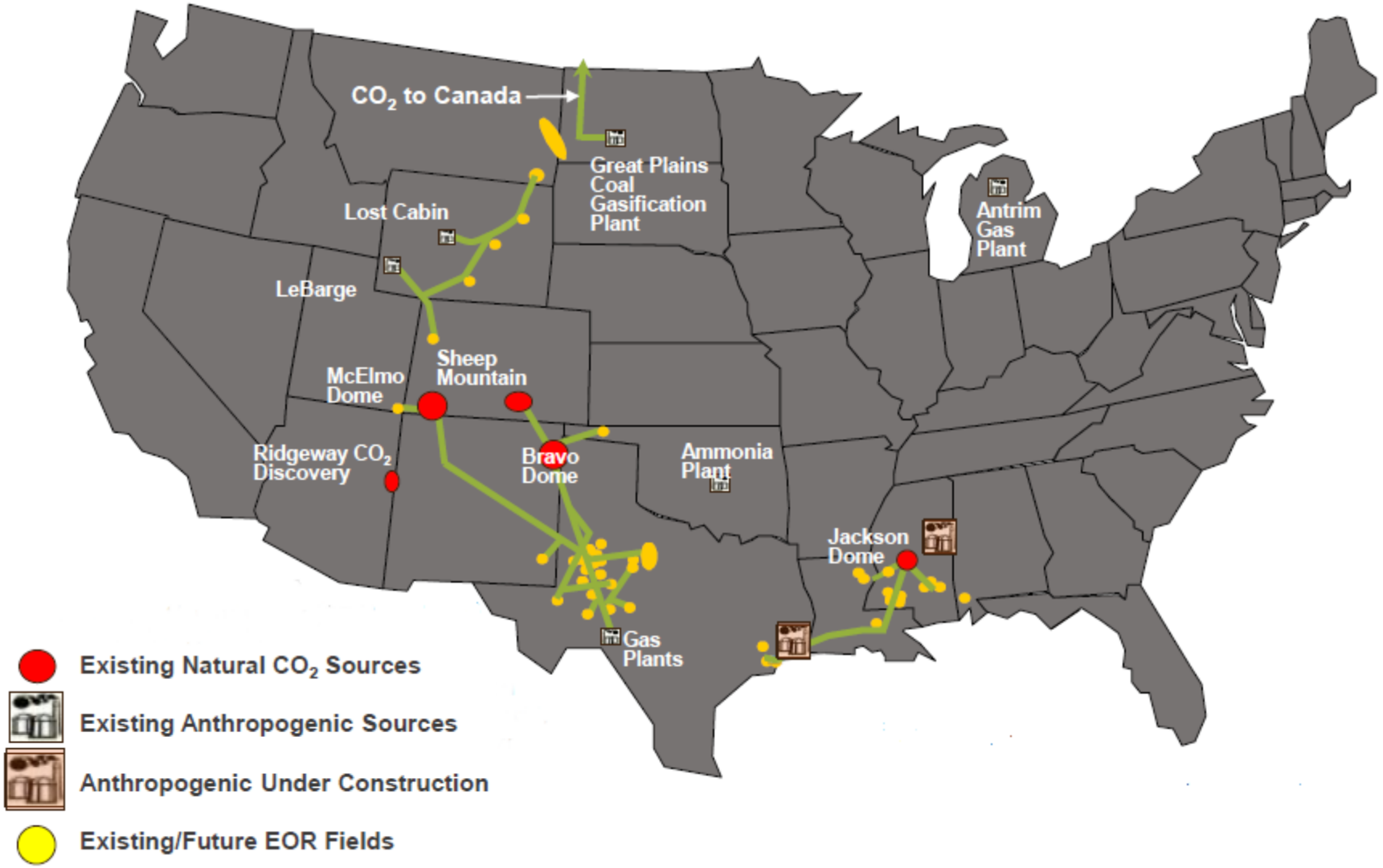
From IPCC Special Report on Carbon Dioxide Capture and Storage 2005 and BP Statistical Review, 2012

European Union (EU) 2007 Prediction of Requirement for CCS

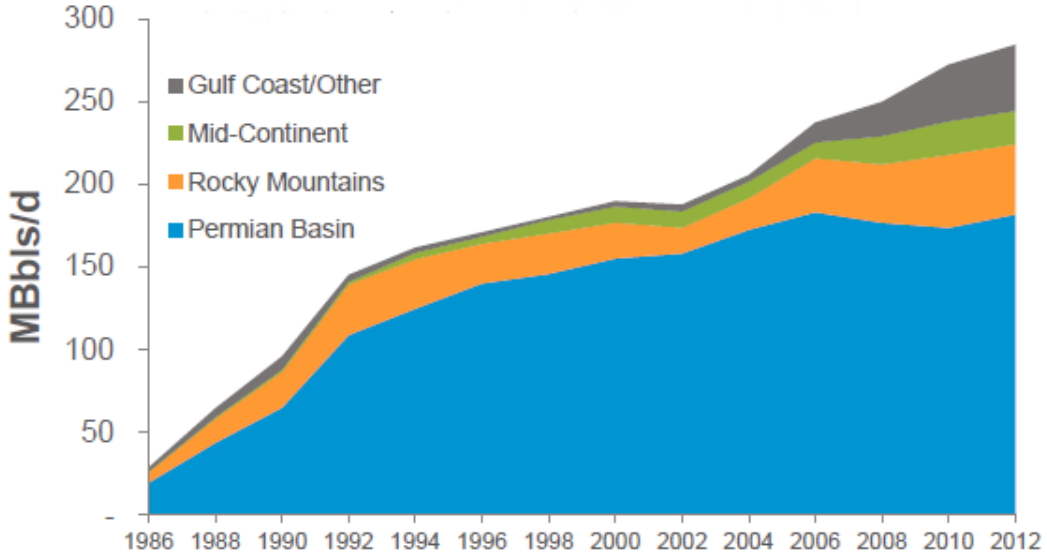


- EU prediction suggests requirement for ~3 billion tonnes per year of CO2 storage

CO2 Flooding is a Major Enhanced Oil Recovery (EOR) Process in USA

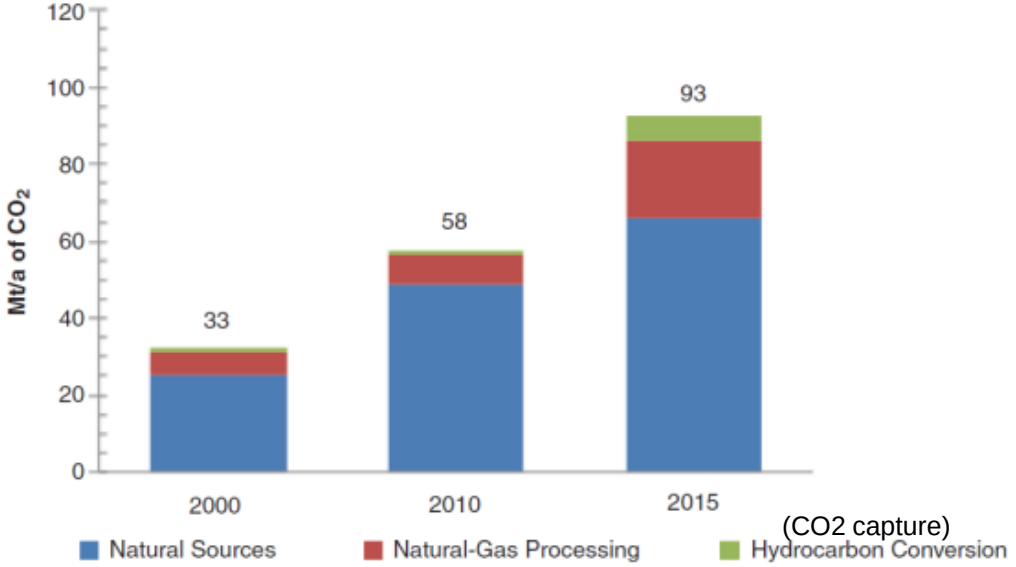


USA CO2 EOR and CO2 Supply



- ~120 projects
- ~300,000 stb/d

- ~75 million tonnes per year



(CO2 capture)

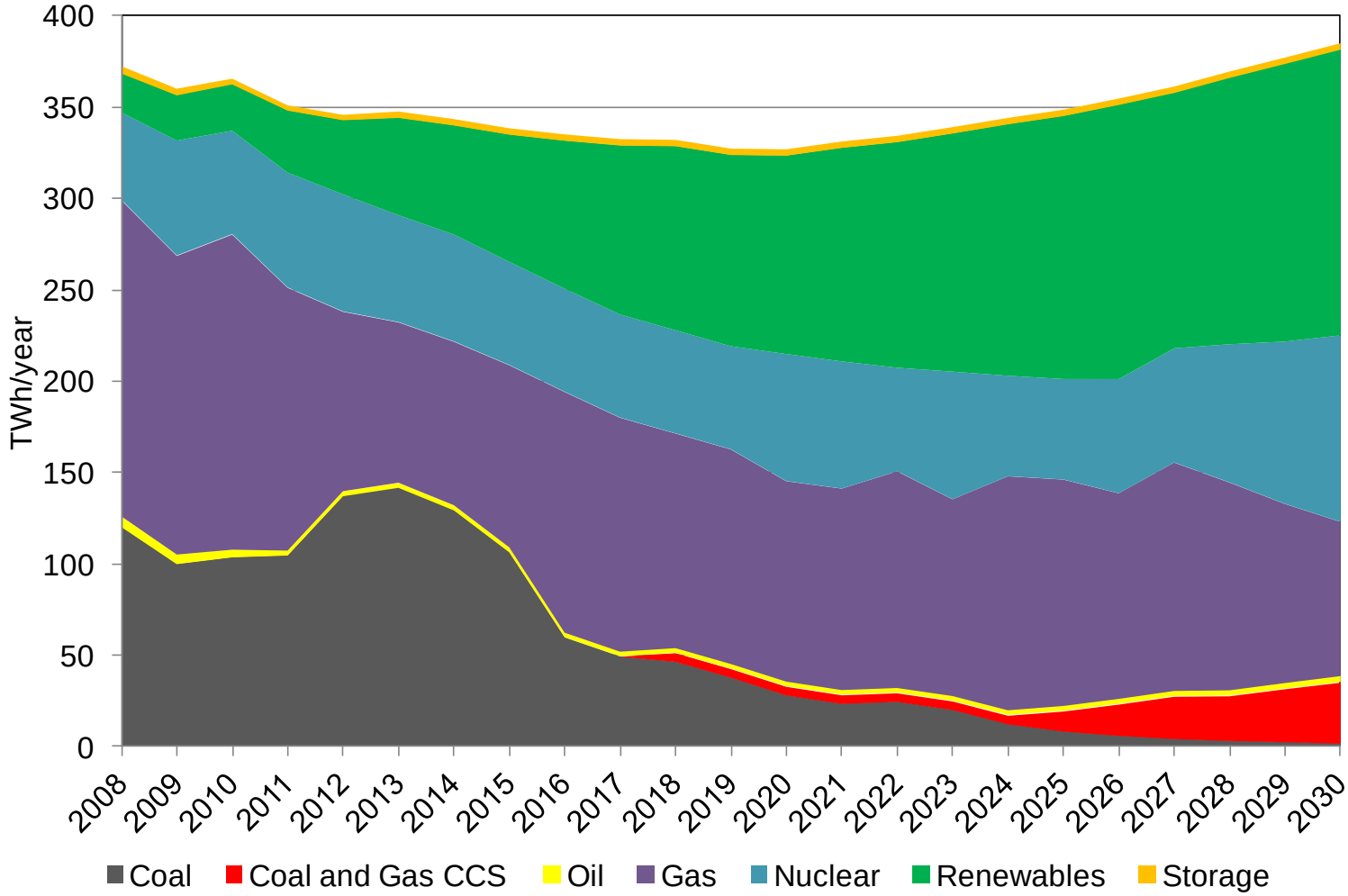
UK Commitment to Reduction in CO_2 Emissions

- Under Kyoto Protocol, UK committed to reducing greenhouse gas emissions by 12.5% from their 1990 levels by 2012 – actually achieved 25.7% (provisional figure)
- UK implemented legal requirement for 80% reduction in 1990 emissions by 2050, with interim target of ~34% by 2020
- Capture of CO_2 emitted from fossil fuelled power plants seen as one means of reducing emissions, with geological CO_2 storage in depleted oil and gas fields, and saline aquifers

Contribution to UK CO2 Emissions From Power Sector

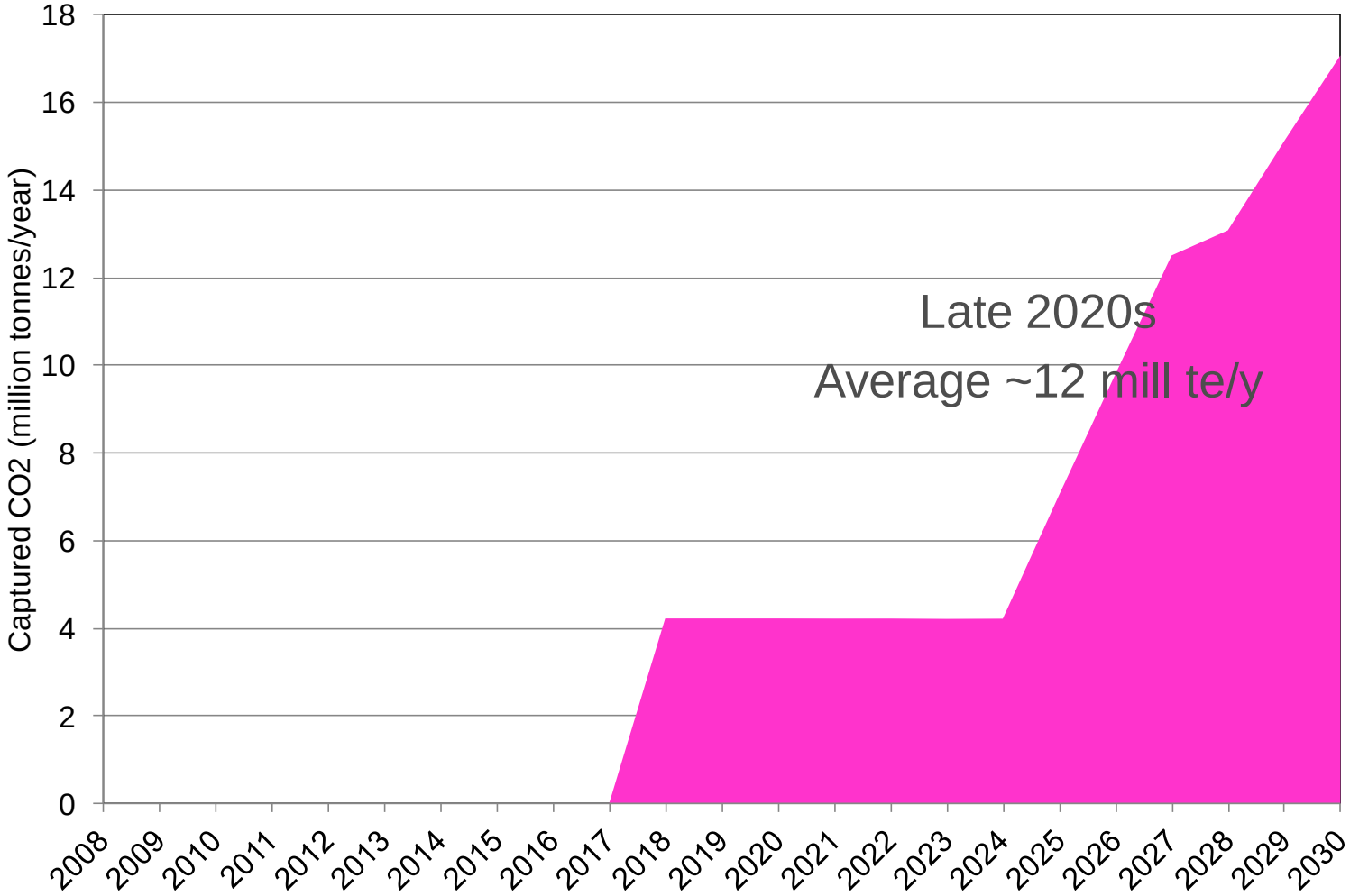
- UK CO2 emissions 2012 479 million tonnes
- About 1/3 from fossil fuelled power stations
- Many coal-fired power stations due to close

UK Power Generation Prediction by Fuel (DECC, September 2013)



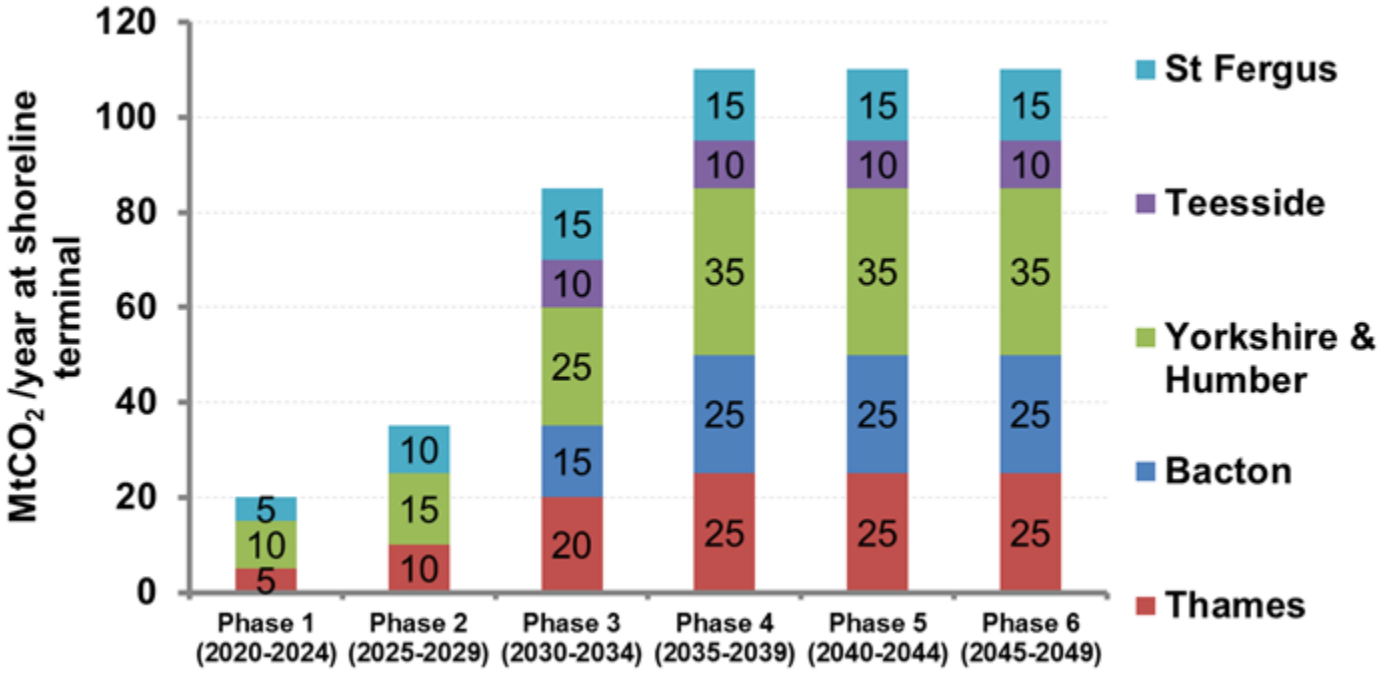
From DECC – Updated Energy and Emissions Projections 2013, September 2013 (Reference Scenario)

CO2 Captured from CCS in UK Power Generation Prediction



Derived from DECC – Updated Energy and Emissions Projections 2013, September 2013 (Reference Scenario)

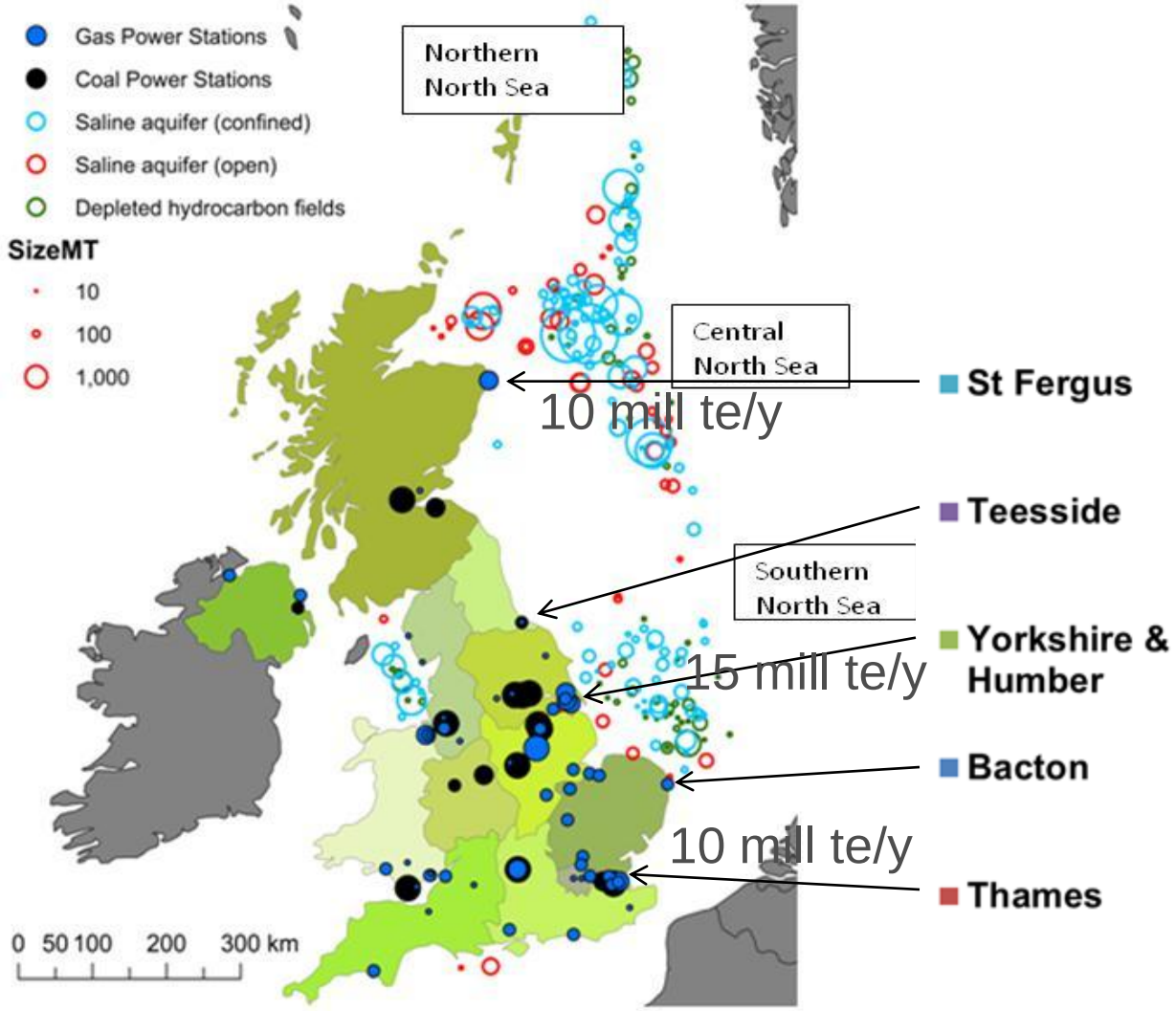
More Bullish Outlook for CCS in UK from Energy Technology Institute (ETI)



- ETI predicts 35 million tonnes/year 2025-30
- Rising to 110 million tonnes/year 2035-50

Source: A Picture of CO2 Storage in the UK – learnings from ETI's UKSAP and derived Projects, ETI, June 2013

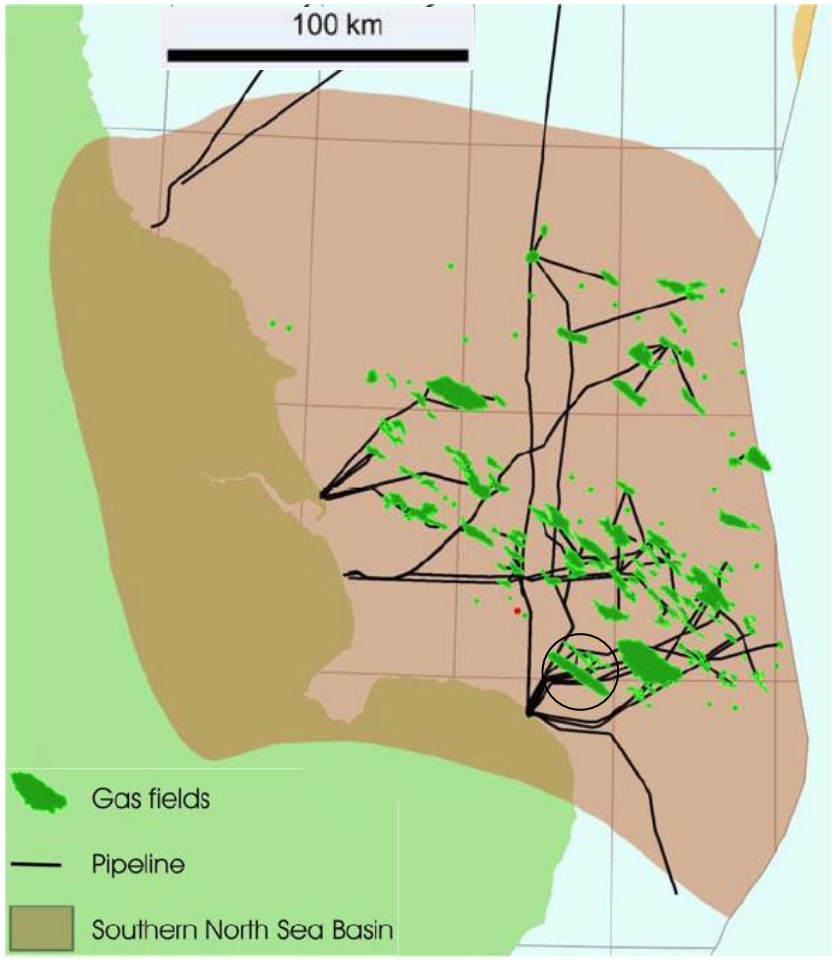
ETI Appraisal of Sources and Potential Sinks of CO2 Around North Sea (Amounts in late 2020s)



Source:
www.co2stored.co.uk
:

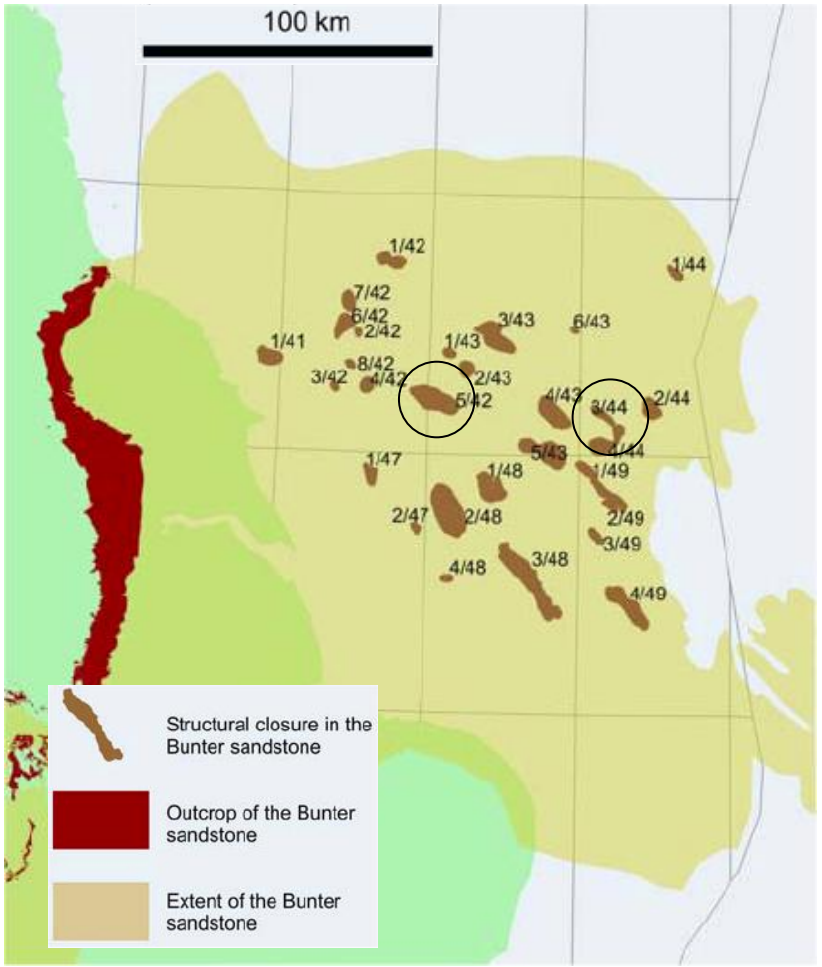
Southern North Sea (SNS) Gas Fields CO2 Storage Potential

- 53 fields most Permian Leman Sandstone
- Proven geological trap for hydrocarbon gas
- Near to CO2 sources
- Existing infrastructure
- Well and pressure depletion may have compromised trap
- Aquifer influx may reduce capacity
- CO2 capacity ~2.8 billion tonnes



SNS Bunter Sandstone CO2 Storage Potential

- 29 closed structures (2 under appraisal)
- Good porosity (average 18.7%) and permeability
- 650-9800 ft deep
- Near to CO2 sources
- Good seal (mudstones and evaporites) - gas bearing in places proves trap (or not!)
- Some existing infrastructure
- Cut by faults which may leak
- CO2 capacity ~14.3 billion tonnes



Material on SNS gas field and aquifer storage from: An assessment of carbon sequestration potential in the UK – SNS case study, Michele Bentham, January 2006, Tyndall Centre

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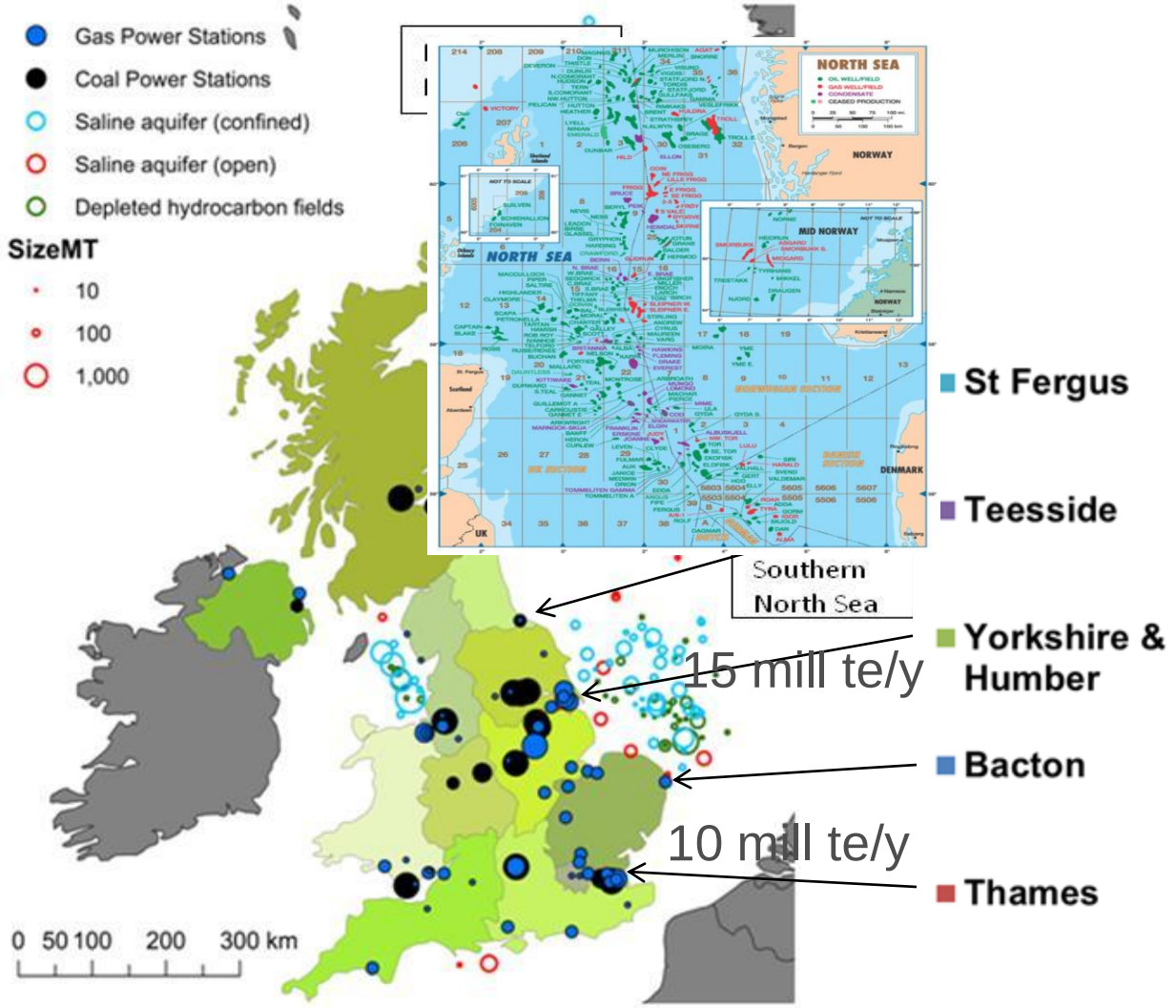

Source:
www.co2stored.co.uk
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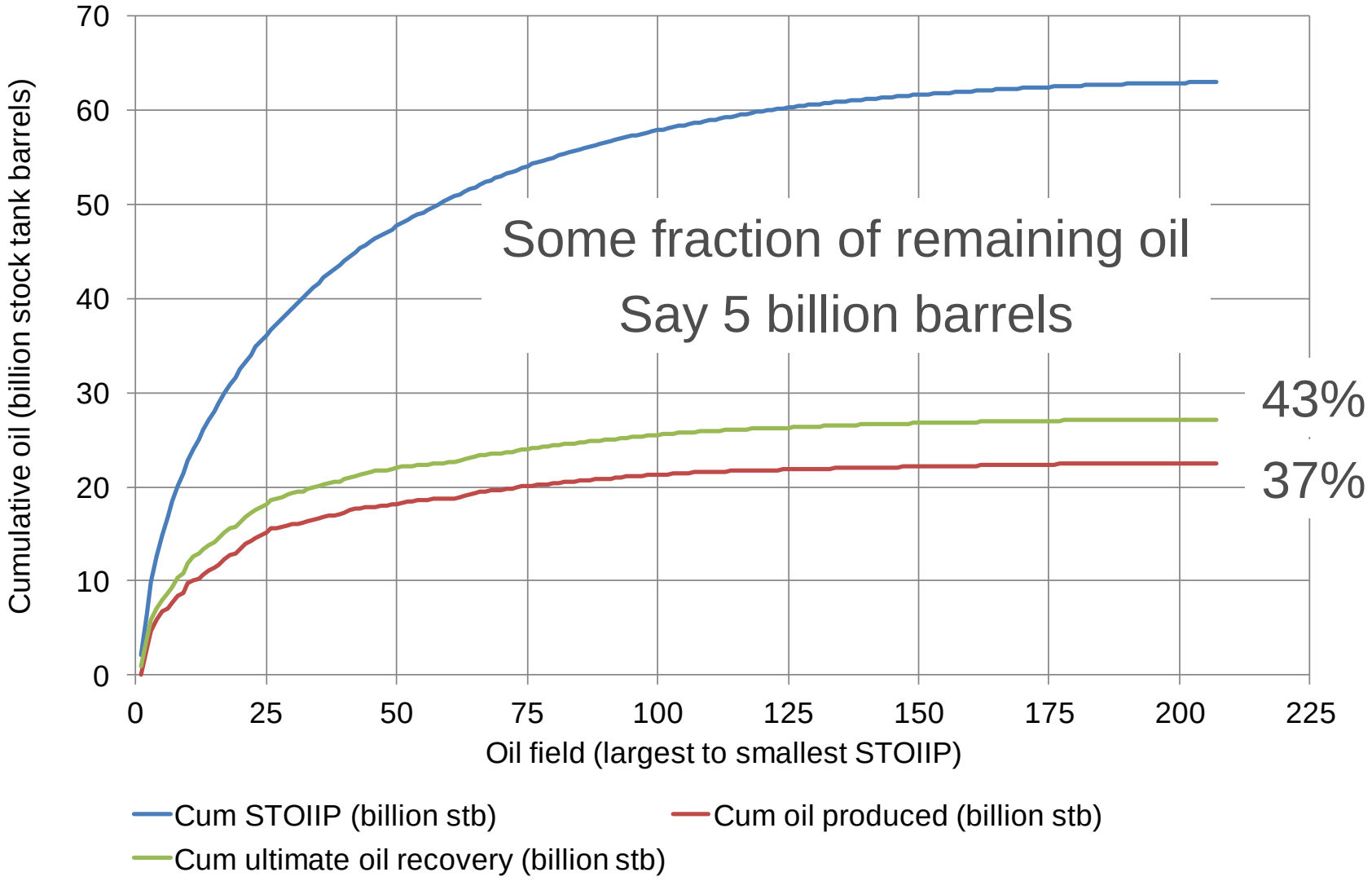
UK Oil Production and the EOR Prize



How does CO2 EOR work?

- CO2 acts as a solvent flushing oil from rock
- Most efficient above the so called minimum miscibility pressure (MMP)
- CO2 may be more or less dense than the oil, but always less dense than water
- Efficiency of displacement is limited by heterogeneity and gravity override
- Expected incremental recovery 5-15% of oil initially in place
- Between 2 and 5 incremental barrels per net tonne of CO2 injected, but significant recycling of CO2 required

Screening for CO2 EOR Potential

- All 119 UK fields with oil initially in place >100 MMstb screened (database made available by DECC)
- Screening parameters considered include:
  - Ratio operating pressure/CO2 MMP
  - Ratio oil density/CO2 density
  - Ratio oil viscosity/CO2 viscosity
  - CO2 efficiency (stb/tonne)
- Results are aggregated into overall score
- Best candidates, 2nd rank candidates and 3rd rank candidates identified
- Potential incremental recovery calculated

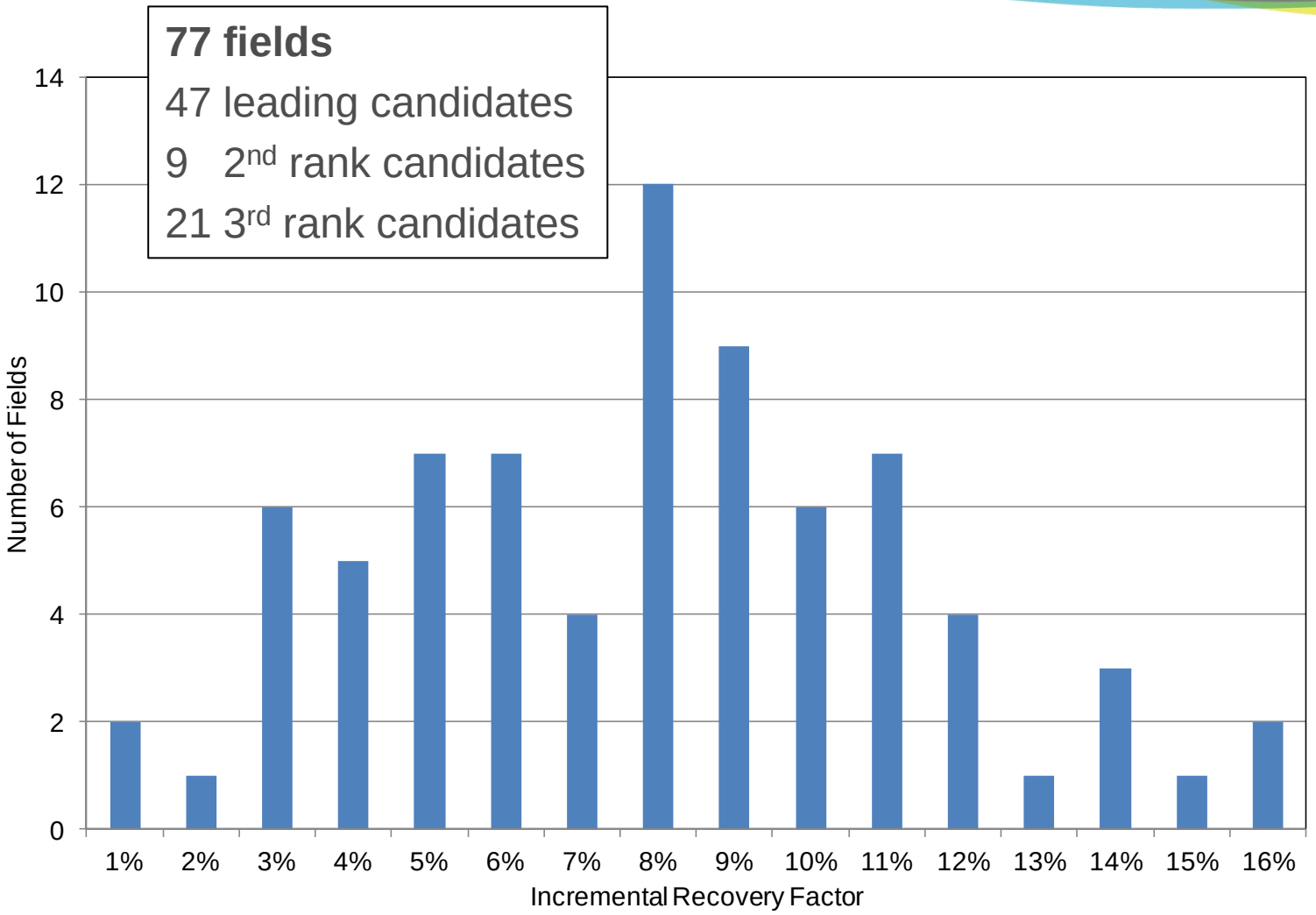
Estimated Incremental Recovery Potential and CO2 Stored by Category

Category	Estimated Incremental Recovery (MMstb)	Estimated Net CO2 Stored (million tonnes)
Best candidates	1879	885
Second rank candidates	231	77
Third rank candidates	984	474
Total	***3058***	***1435***

- Leading Operators (best and second rank candidates)
  - BP
  - Apache
  - Nexen
  - Talisman
  - Taqa

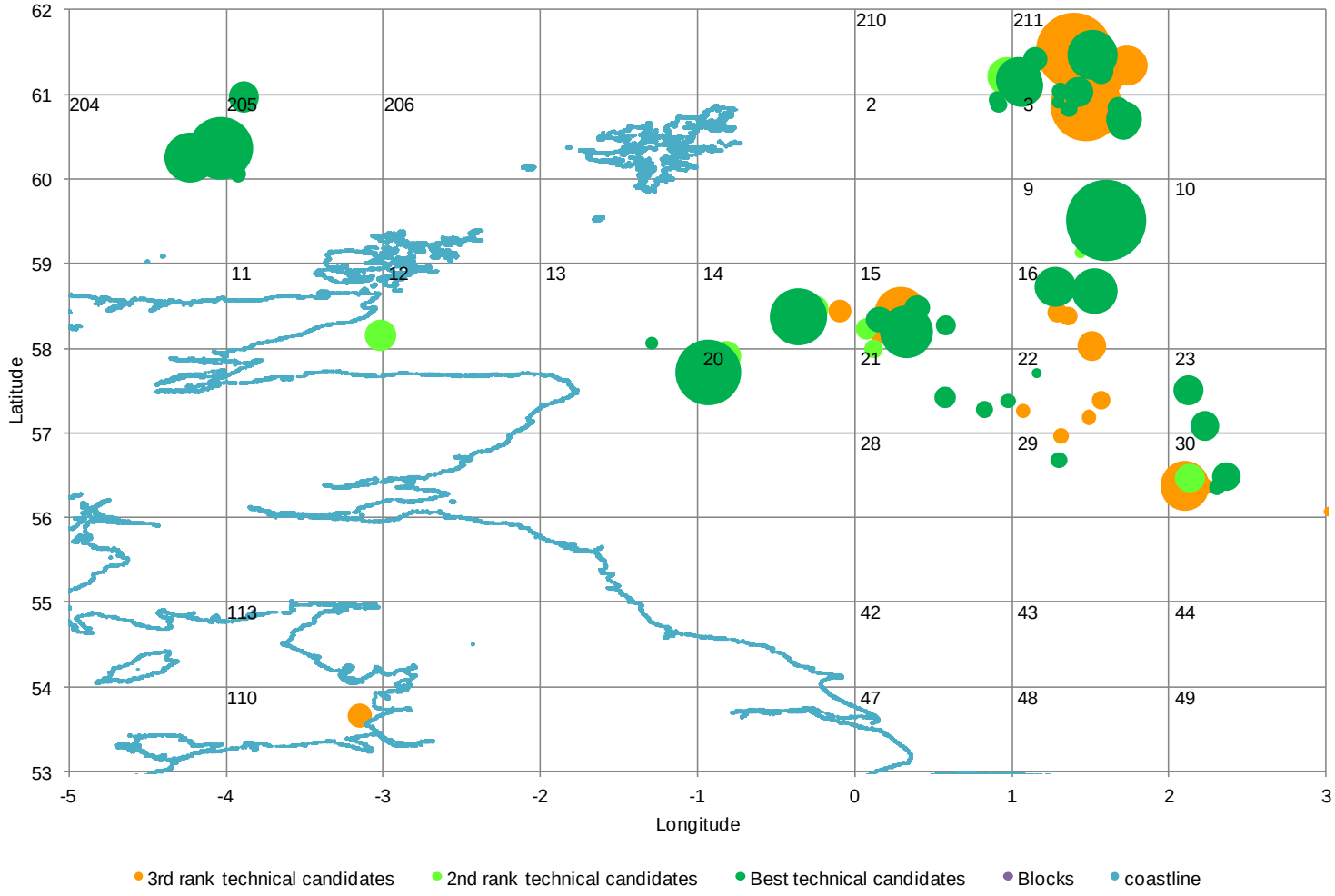
Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

Incremental Recovery Factor Distribution



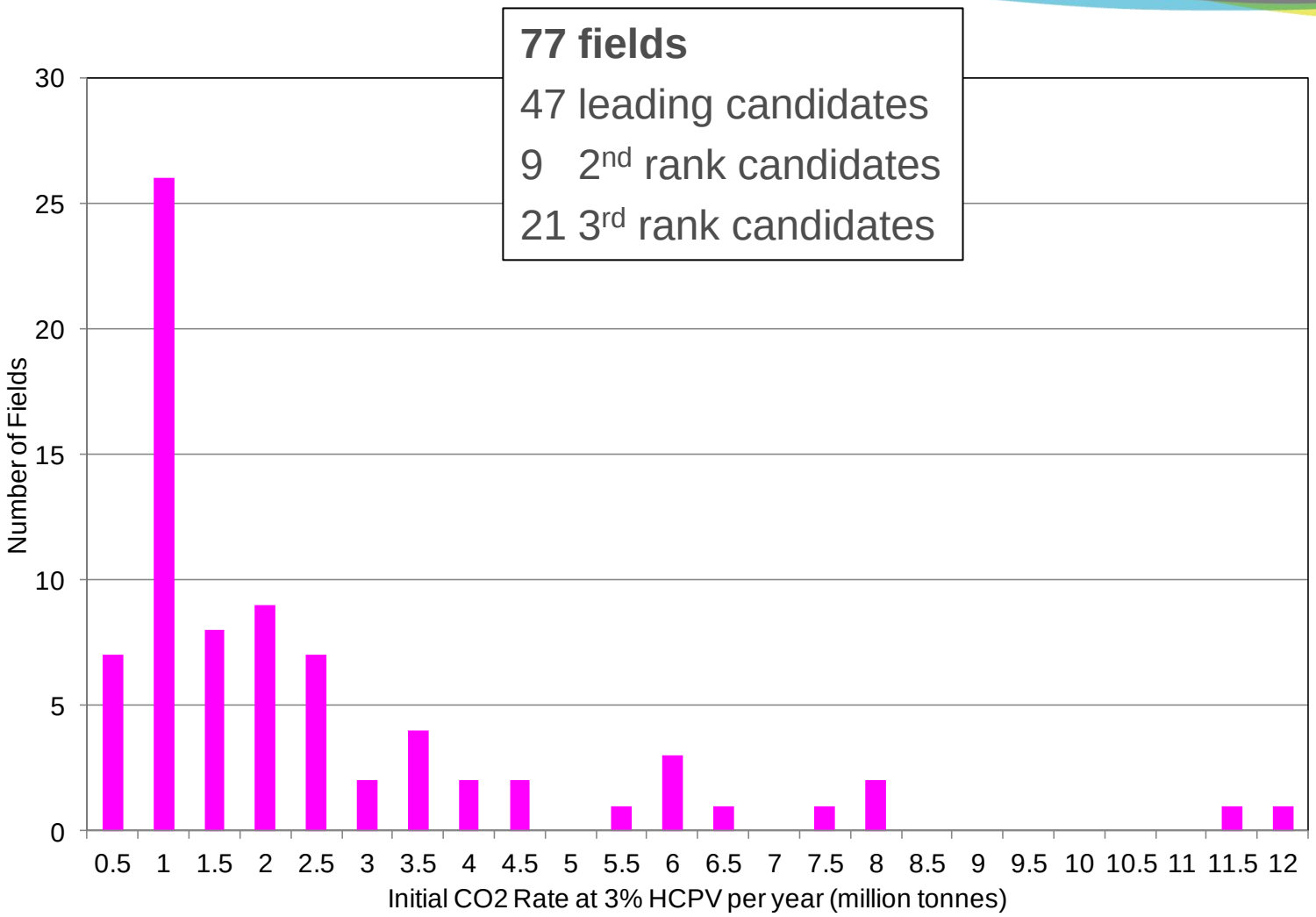
Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

UK Potential for CO2 EOR (potential proportional to area of circles)



Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

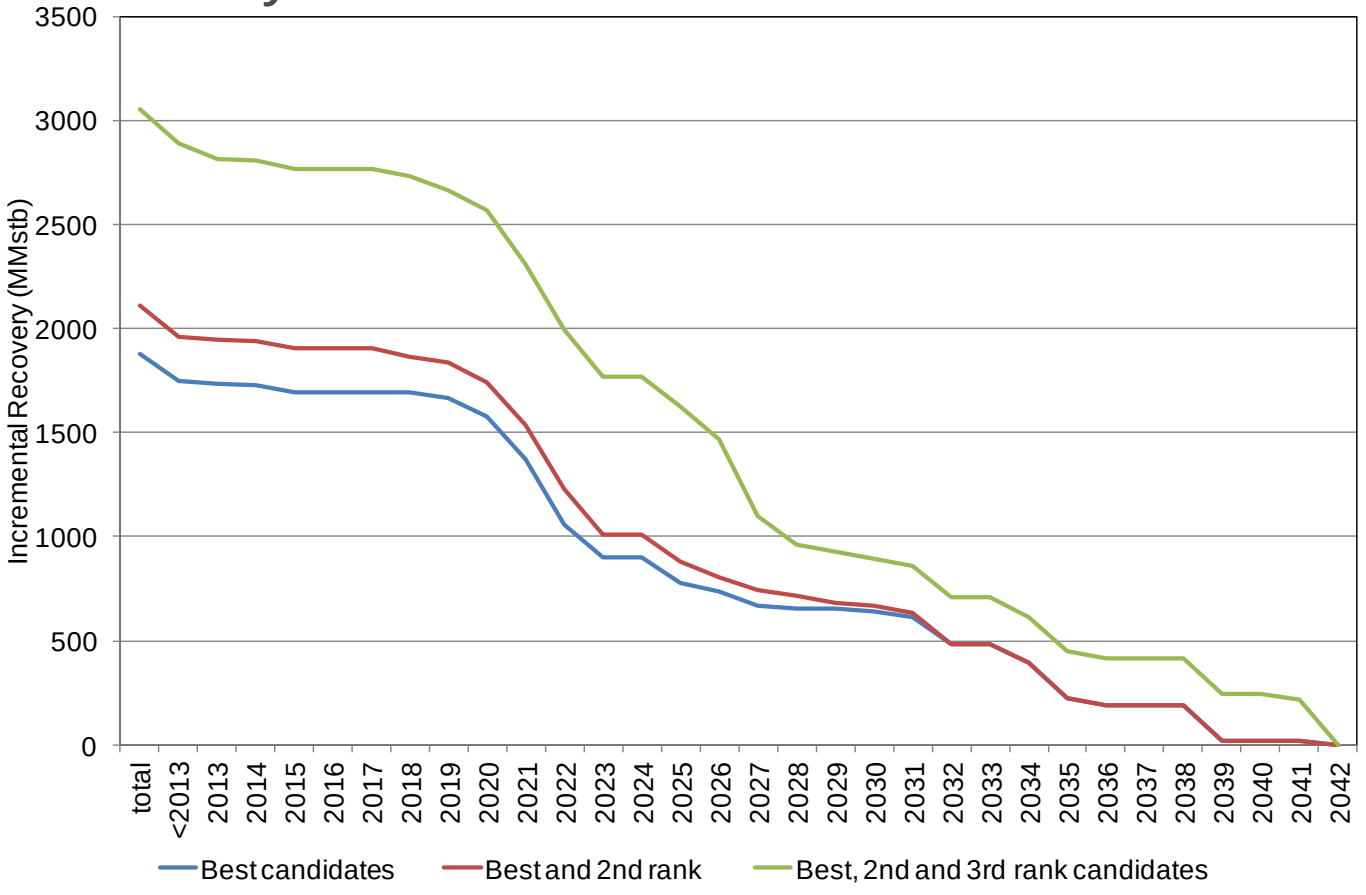
Initial CO2 Import Rate at 3% HCPV per year (No Hub Constraint, All Candidates)



Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

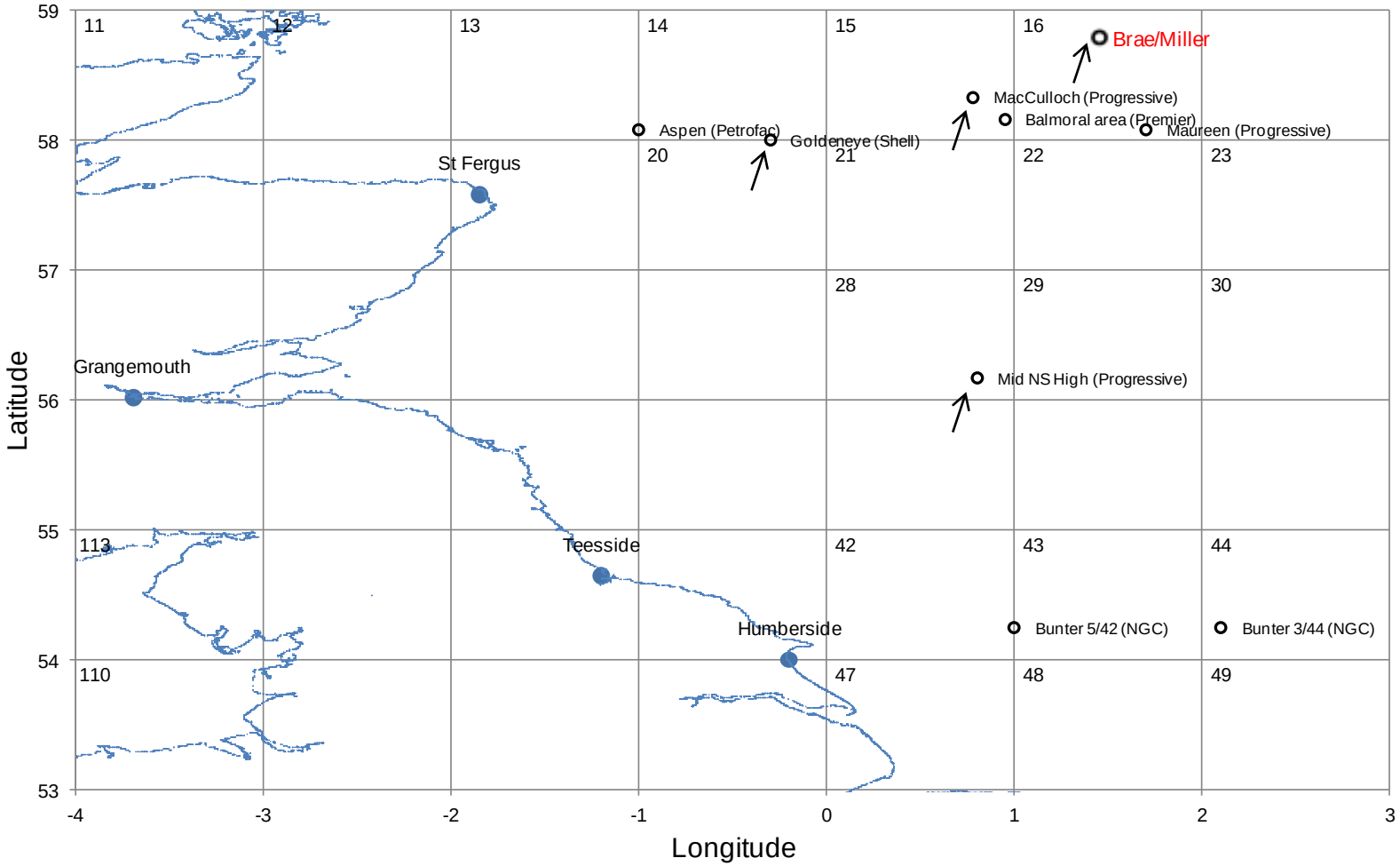
Decline in Potential in Operating Fields as Fields Reach their COP Dates

- ~2/3rds of potential is in fields that will have ceased production by late 2020s



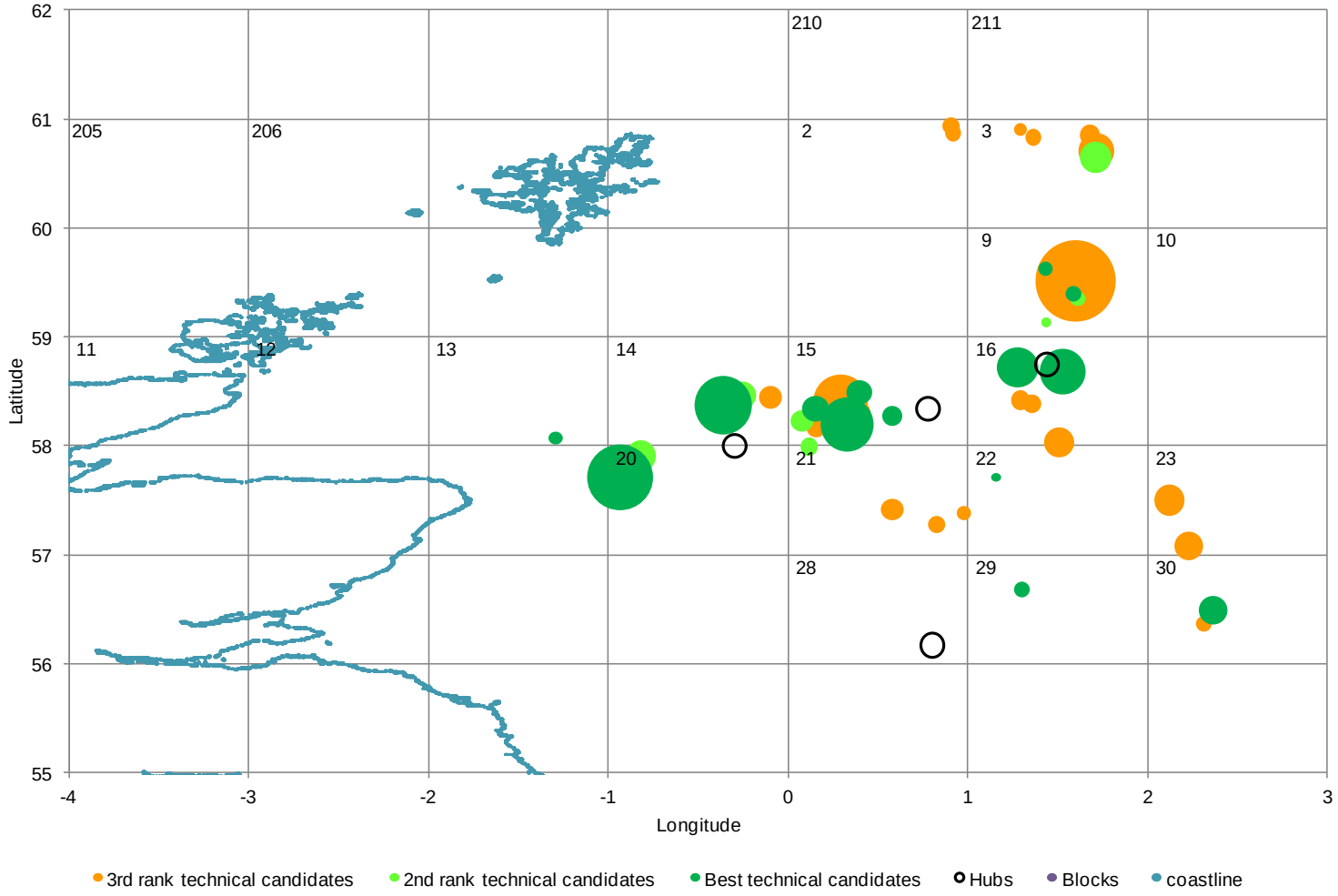
Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

Map Showing Agreements for Lease for CO2 Storage Granted by Crown Estate



Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

UK Potential for CO2 EOR (Hub Constrained)



Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

Estimated Incremental Recovery Potential and CO2 Stored by Category (Hub Constrained)

Category	Estimated Incremental Recovery (MMstb)	Estimated Net CO2 Stored (million tonnes)
Best candidates	683	336
Second rank candidates	221	106
Third rank candidates	653	354
Total	***1557***	***796***

- Leading Operators (best and second rank candidates)
  - Nexen
  - Talisman

45 fields

15 leading candidates

13 2nd rank candidates

17 3rd rank candidates

Source: PILOT Miscible Gas EOR Workshop, October 2013 (DECC)

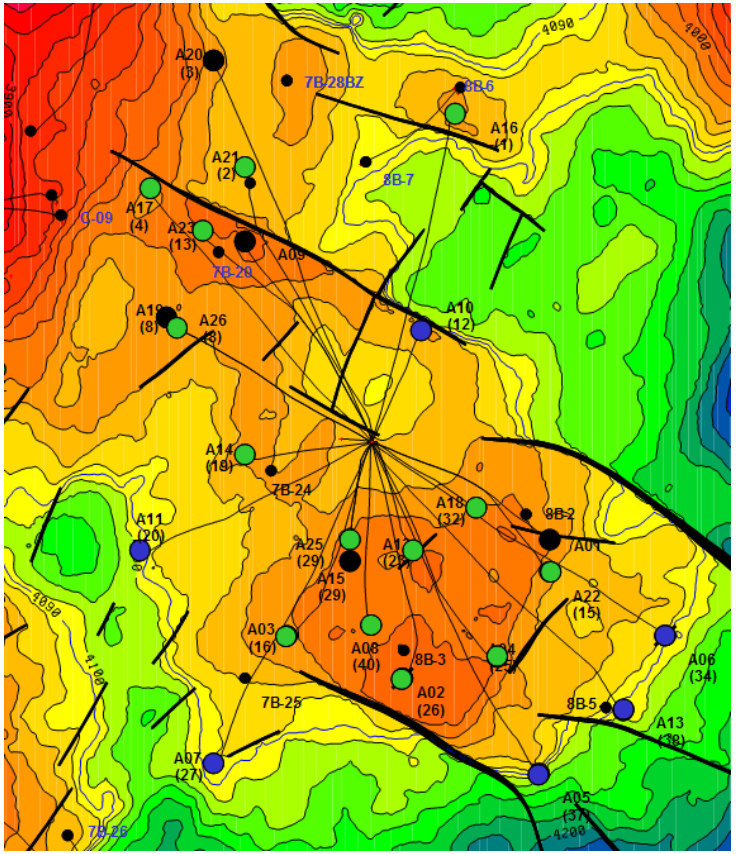
CO2 EOR Onshore - Advantages

- Mature CO2 supply network
- High well density, pattern flood, relatively cheap to redrill/refurbish
- Relatively low secondary recovery (35-45%)
- Phased implementation
- Large surface area available for facilities

CO2 EOR Offshore - Challenges

- Limited CO2 supply at present but significant quantities likely to become available on 5-10 year timescale (i.e. early to mid 2020s)
- Fewer wells, peripheral floods, expensive new wells and workovers
- High secondary recovery (up to 70%) therefore smaller target
- Single implementation (i.e. no chance to introduce the project in phases or to undertake pilot)
- Existing facilities mainly incompatible with high CO2 content in fluids
- Limited weight and space for new facilities

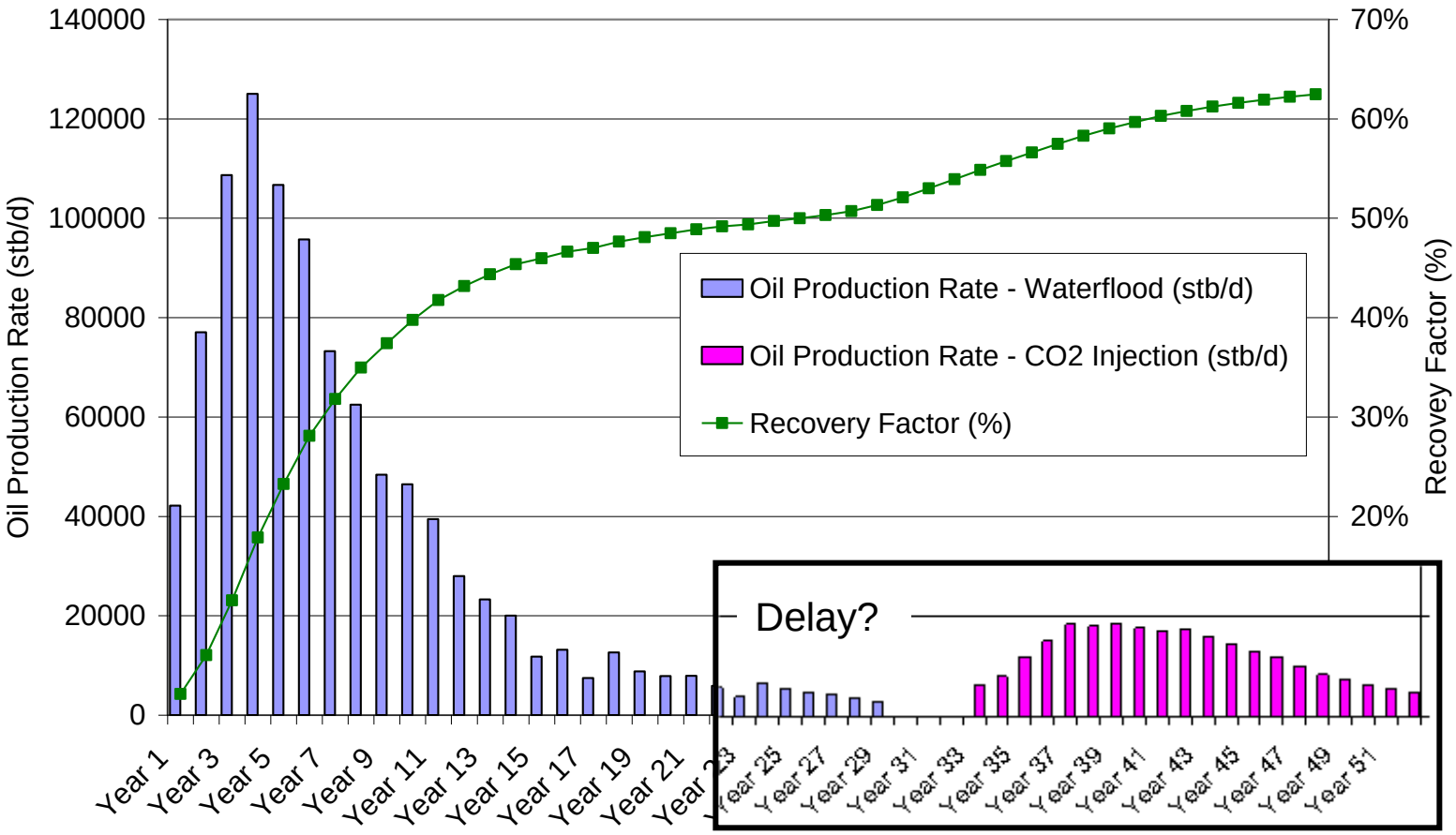
Well Density – Onshore vs. Offshore



- Onshore high well density
- ~2 million barrels per well

- Offshore fewer wells
- ~30 million barrels per well

Typical CO2 EOR Response in North Sea Oil Field

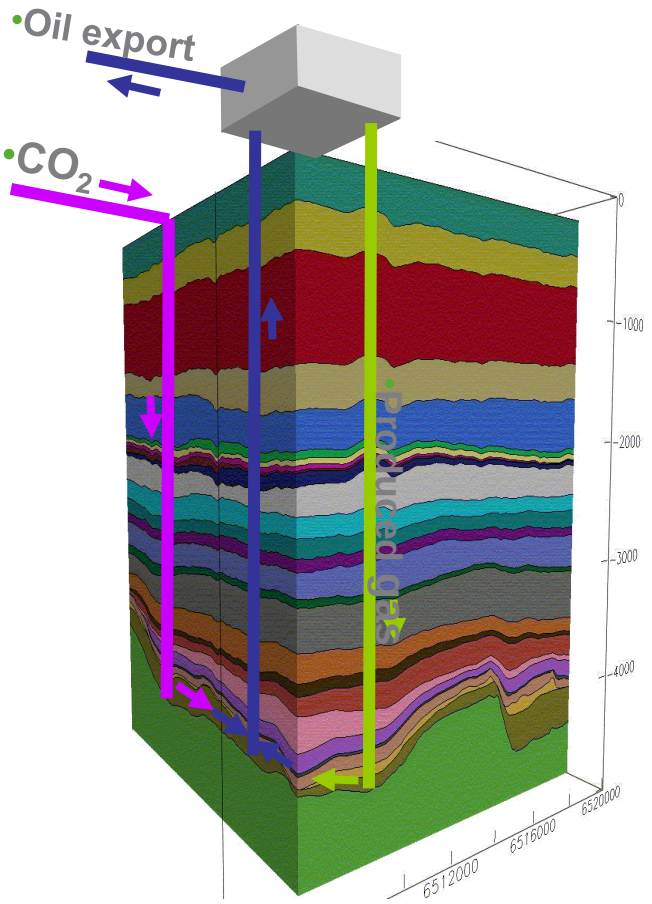


Offshore CO2 EOR Implementation (Capital Expenditure)

- Additional ~20 years from existing facilities
- CO2 reception facilities and controls
- Flow lines to injectors (CO2 and water) and control valves
- Gas/liquid separation facilities capable of handling high content CO2 in produced fluids
- Separation of CO2 and hydrocarbon gas (or just separate enough for fuel gas)
- Dehydration and compression of produced gas for reinjection (increasing CO2 content in produced gas)
- Start-up CO2 pumps
- Production well tubing needs replacing with stainless steel (to deal with produced CO2)
- Baseline measurements for subsequent monitoring

Assure Storage of Injected CO2 in EOR Project (to meet regulations)

- Measure amounts injected and produced to maintain inventory
- Keep average reservoir pressure below initial pressure
- Assess CO2 seal capacity and seismic risk over storage period
- Model long-term migrations and reactions, if any
- Monitor for potential leakage via wells or geological pathways during injection period
- Abandon wells in a manner consistent with long-term secure CO2 storage

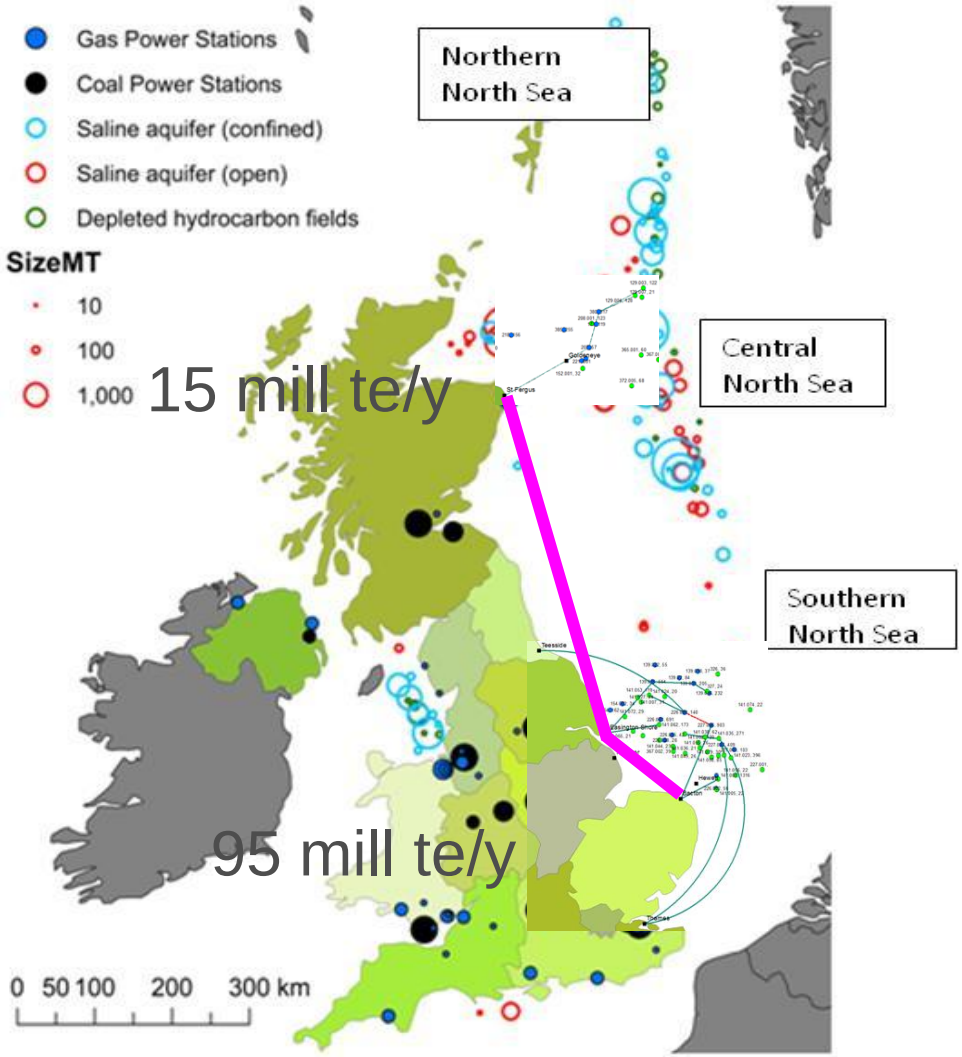


To conclude: So what does the future hold for CO2 EOR in the North Sea?

- Supply of CO2 will (in all probability) develop from CCS
- Initial CCS projects will plan for storage only, but proximity and availability of CO2 likely to provide opportunities for EOR initially possibly in the smaller/medium sized fields
- If successful, redevelopment of larger mature fields may occur
- New specialist CO2 operators may emerge
- Once EOR phase complete some extra opportunity to store additional CO2
- Adjustment of tax regime may be needed to make offshore EOR economic
- Regulation around CO2 storage (over and above O&G regulations) may be a significant burden

Big Decision

- Bulk of CO2 captured in south (2035-50 numbers from ETI)
- Saline aquifer storage nearby
- but EOR opportunity in oil fields in north
- Trunk pipeline required
- Who should pay?
- Up to £1 billion?



Source: www.co2stored.co.uk

Discussion

- That concludes my talk
- Thank you to Senergy (www.senergyworld.com) for allowing me to make this presentation
- Discussion

UK Competition Projects

- Shell/SSE – Peterhead, existing 340 MW CCGT, post-combustion capture, 1 million tonnes per year, stored in Goldeneye (Blocks 14/29a, 20/4b and 20/3b)
- Alstom/Drax/BOC/National Grid – White Rose, Selby, 450 MW (gross), Oxyfuel, 2 million tonnes per year, stored in Bunter Block 5/42
- Other projects
  - 2Co Energy/National Grid – Don Valley, Hatfield
  - Summit Power/Petrofac/National Grid/Siemens – Captain Clean Energy Project, Grangemouth
  - Progressive Energy/GDF SUEZ/Premier Oil/BOC – Teesside Low Carbon Project