

Offshore Enhanced Oil Recovery (EOR): **State of the Art and Experience** **Current UK Direction**

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- Size of the prize (concentrating UKCS)
- Worldwide status of EOR
- Offshore EOR activity
 - Away from North sea
 - In and around North Sea
- Newer processes and UK strategy going forward
- Conclusions

Acknowledgement:

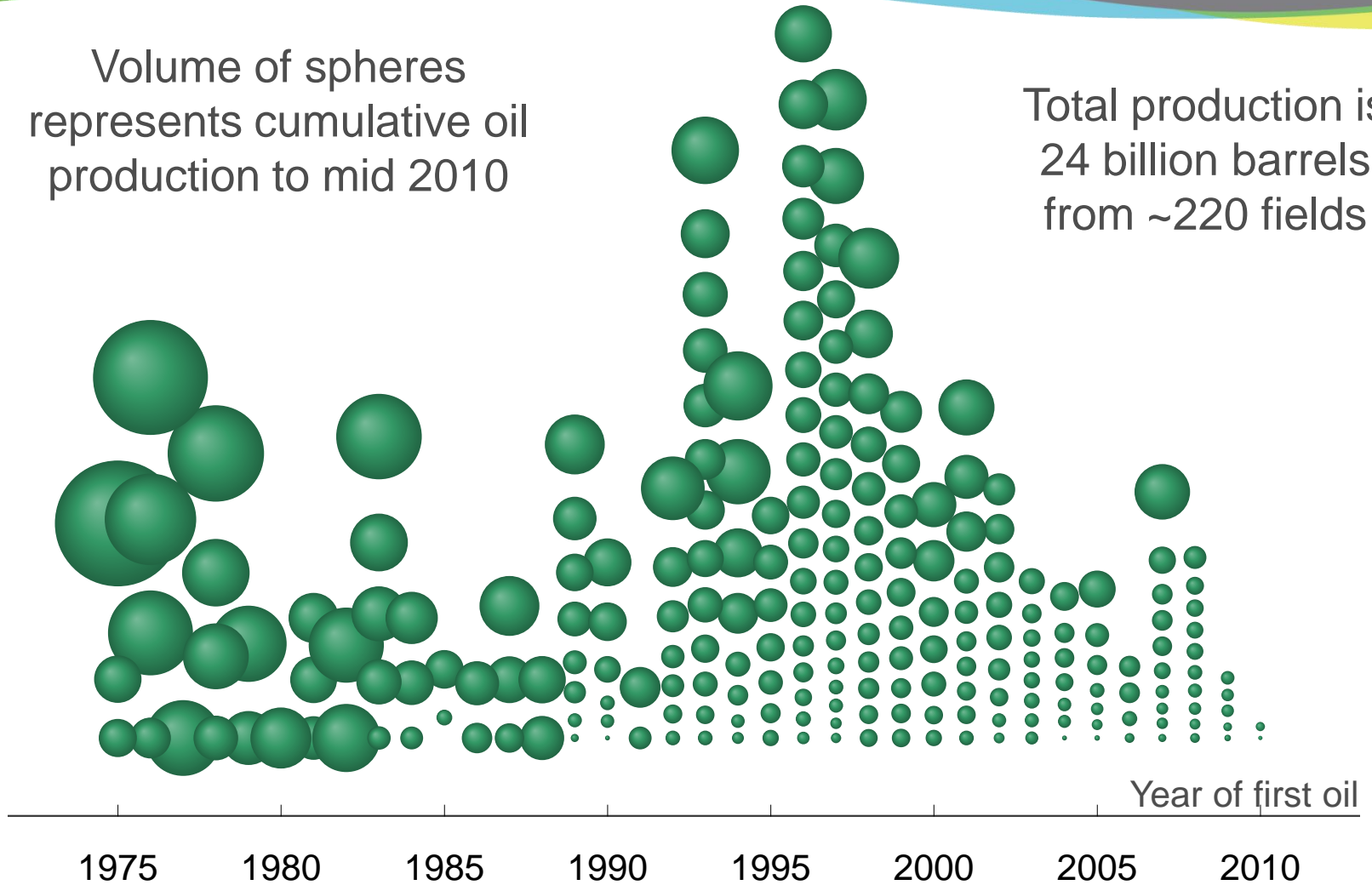
Although I'm not representing the UK Department of Energy and Climate Change (DECC) today, Senergy does assist them in relation to EOR strategy and technologies and I have their permission to report their latest position

Production from UK Offshore Oil Fields to Date



Volume of spheres represents cumulative oil production to mid 2010

Total production is 24 billion barrels from ~220 fields

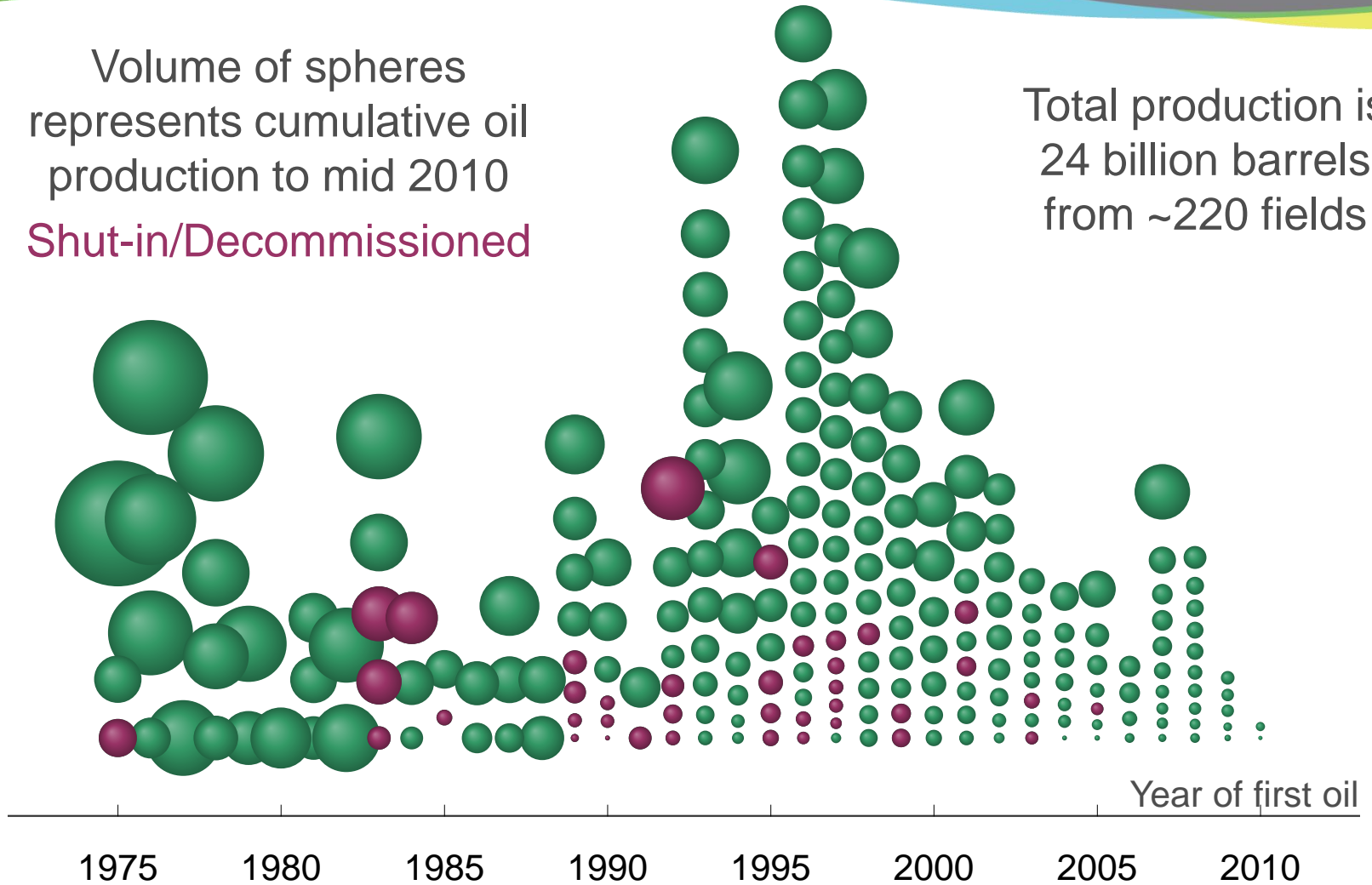


Production from UK Offshore Oil Fields to Date



Volume of spheres
represents cumulative oil
production to mid 2010
Shut-in/Decommissioned

Total production is
24 billion barrels
from ~220 fields

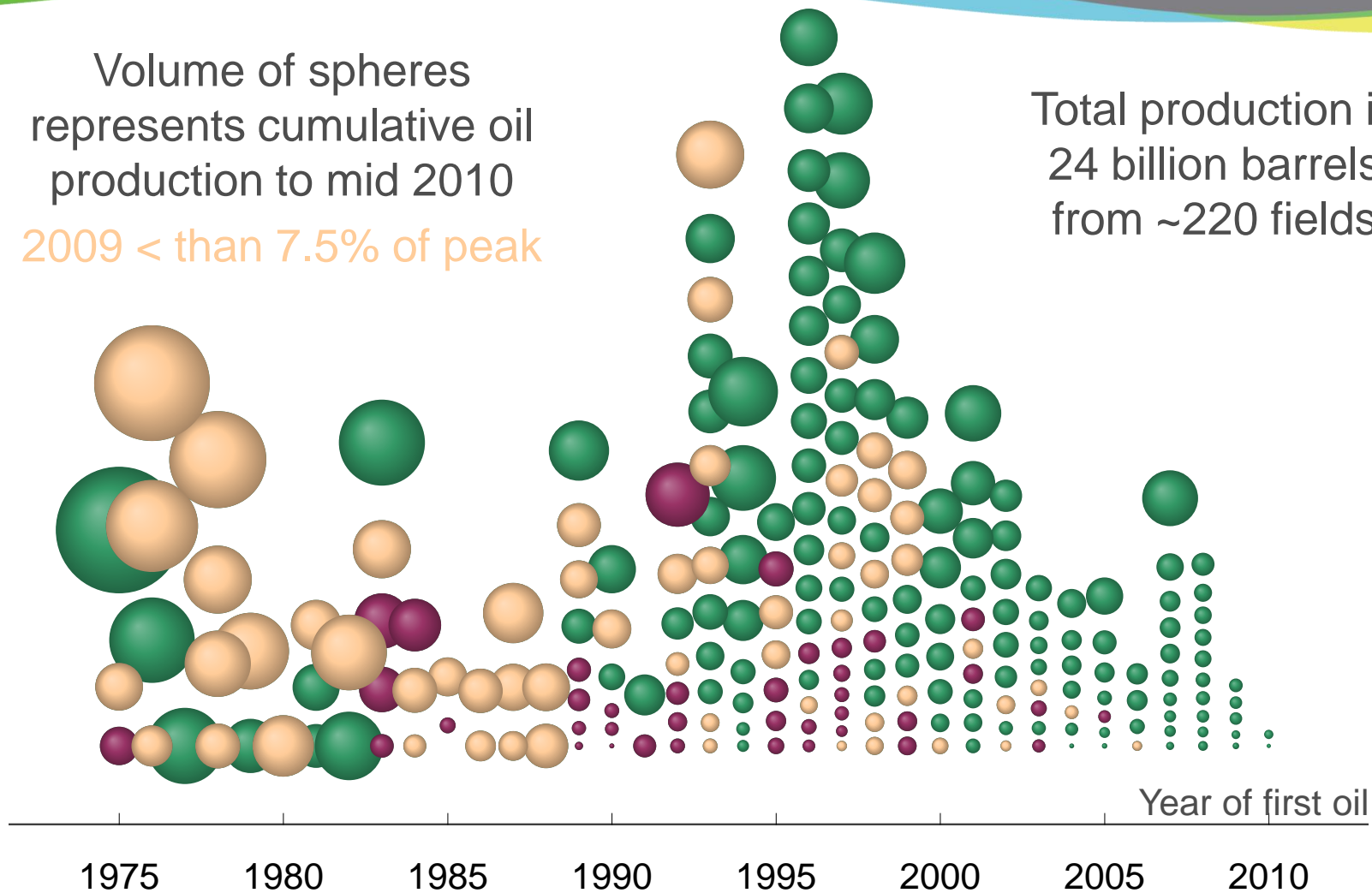


Production from UK Offshore Oil Fields to Date



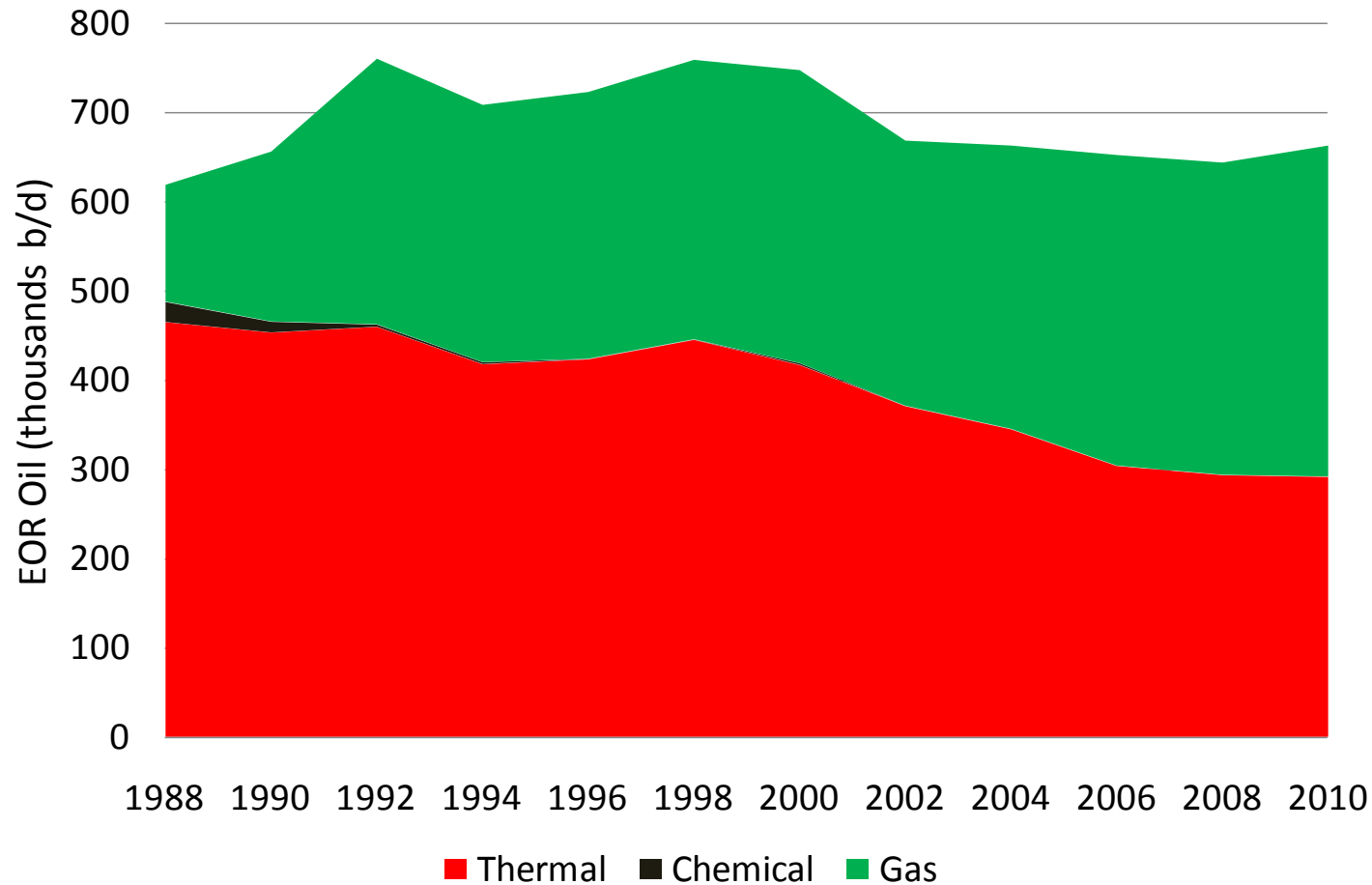
Volume of spheres
represents cumulative oil
production to mid 2010
2009 < than 7.5% of peak

Total production is
24 billion barrels
from ~220 fields

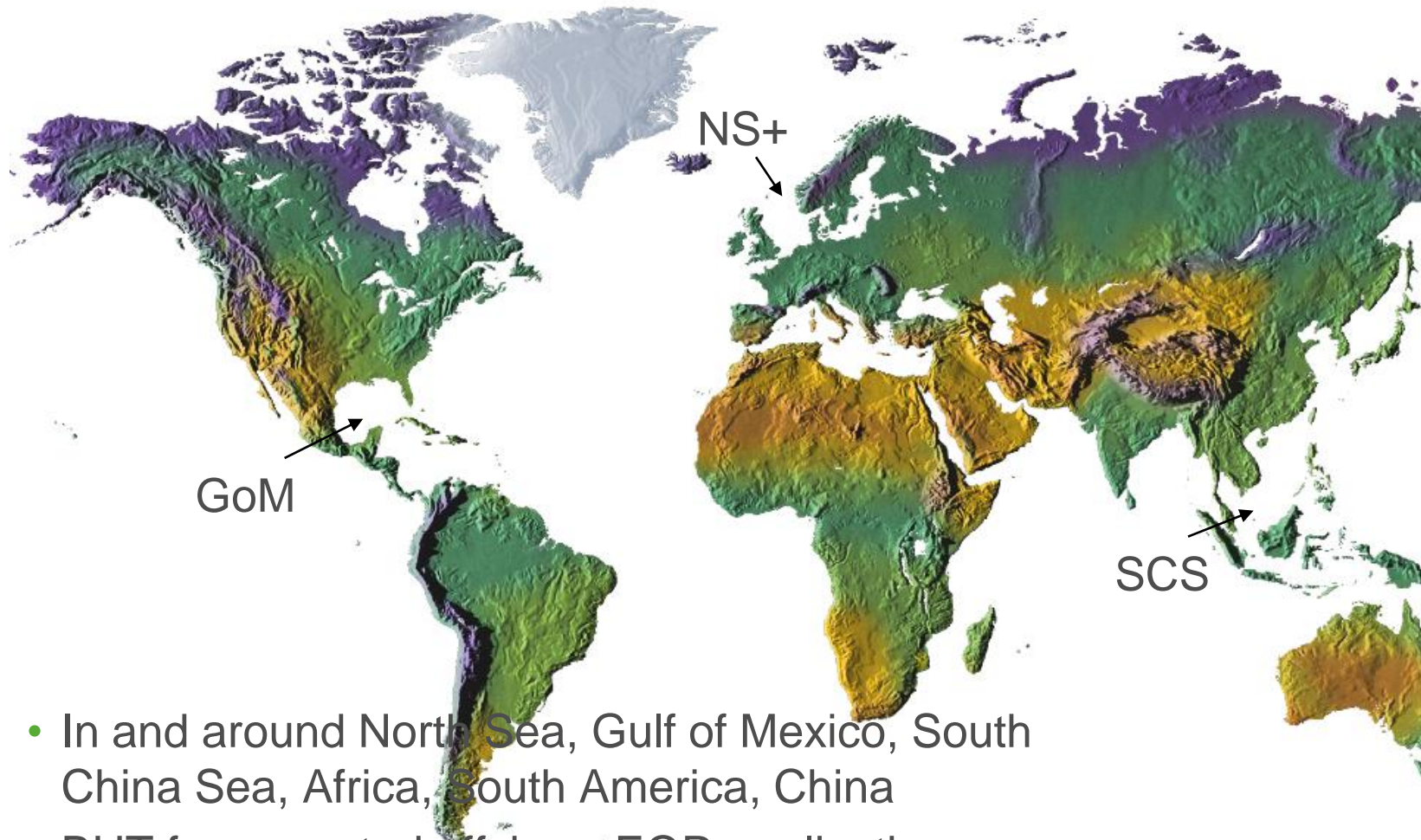


- Biennial review published in Oil and Gas Journal in April 2010
- Incomplete
- Worldwide EOR production amounts to ~ 3% of worldwide oil production (OGJ, 19 April 2010)
- ~900 MMstb per year (~240 MMstb per year from USA)
- USA split 45% thermal/55% gas (mainly CO₂)
- Most of rest (led by Canada) is thermal
- Main trend going forward (particularly noticeable in USA) is likely to be a massive expansion of CO₂ EOR if large amounts of CO₂ become available from wide scale adoption of CCS
- Chemical EOR not popular
- Both Government and IOC funded EOR R&D declined

Progress of EOR in USA (from O&GJ, April 2010)



- Chemical EOR dwindled to only 3 small projects in 2010
- Decline in thermal, increase in gas (mainly CO₂)



- In and around North Sea, Gulf of Mexico, South China Sea, Africa, South America, China
- BUT few reported offshore EOR applications

What's Reported on Offshore EOR Away from North Sea? (not comprehensive)

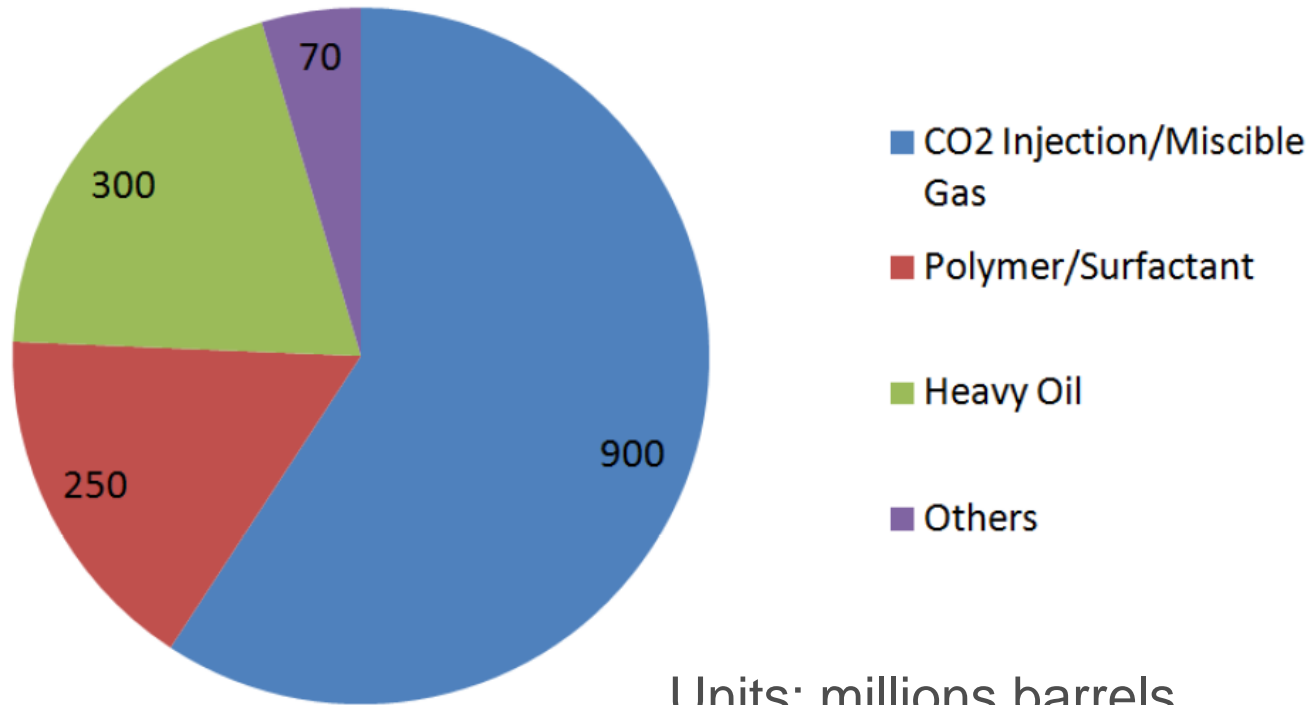


- offshore China, polymer, Bohai Bay (heavy oil field), 10-10000 cp, good experience of offshore chemical handling
- offshore Angola, polymer, Dalia/trial in Camelia (3-7cp oil)
- offshore Malaysia, alkaline-surfactant single well test, Angsi I-68, softening of water required, a lot on methodology but no results published (Petronas)
- Lake Maracaibo, alkaline-surfactant-polymer, La Salina (high acid number, 14.7cp, water softening even of low TDS lake water required)
- GoM, N2 injection Cantarell, Ku-Maloob-Zappfield (Petroleos Mexicanos)
- offshore Malaysia, immiscible CO2 (50%)/HCG reinjection, Dulang (Petronas)
- offshore Sarawak, CO2, Baronía RV2 (Petronas/Shell) – planned pilot
- Not a lot!

- NCS, Microbial, Norne (Statoil) – little recent information
- UKCS, HCG, Magnus (BP) – ongoing
- NCS, HCG, Gullfaks (Statoil) – also a number of other techniques trialed (and a number including surfactant-polymer still under consideration)
- UK,N,D CS, HCG, Alwyn North, Beryl, Brae South, Brage, Brent, Ekofisk, Oseberg Ost, Siri, Smorbukk South, Snorre, Statfjord, Thistle, Ula
- UKCS, polymer, Captain (>80cp, high perm) – pilot ongoing
- UKCS, Bright Water, Strathspey, ultimately 317 Mstb expected at cost of \$3.5-4 per stb (Chevron) (also trialed in Arbroath)
- UKCS, Low Salinity, Clair Ridge – planned and announced, other initiatives ongoing
- Detailed CO₂ EOR evaluations in Forties, Miller, Gullfaks, Ekofisk and other fields but so far no trials, pilots of full scale implementation but further detailed studies ongoing

- Traditional
 - Gas (HC, CO₂, N₂)
 - Chemical (alkaline, surfactant, polymer, gels)
 - Thermal (may be relevant for viscous/heavy oils)
 - MEOR
- New techniques
 - Low salinity/hardness water flooding
 - 'Weak gels' or linked polymer solutions or LPS (in fact fair amount of field application as colloidal dispersion gels (CDG))
 - Bright Water (thermally activated strong gel)
 - Combinations

Results of UK DECC Consultation with Industry - EOR Prize by Process



From Jonathan Thomas, DECC, North Sea EOR – A UK Perspective, IEA EOR Workshop and Symposium, October 2010

- 2Co Energy (backed by same investors as Denbury Resources) have made a submission for funding from EU under NER300 for CCS project which involves studying the potential to use the captured CO2 for EOR in Talisman's CNS fields ([2Co Energy press release 9 May 2011](#))
 - Other UK submissions also have an element of using captured CO2 for EOR
- 7 submissions for NER300 funding for CCS projects from the UK alone (4 in NE England, 3 in Scotland), each capturing up to 5 million tonnes CO2 per year! ([DECC press release 10 May 2011](#))

First UK CCS Project (awaiting sanction)

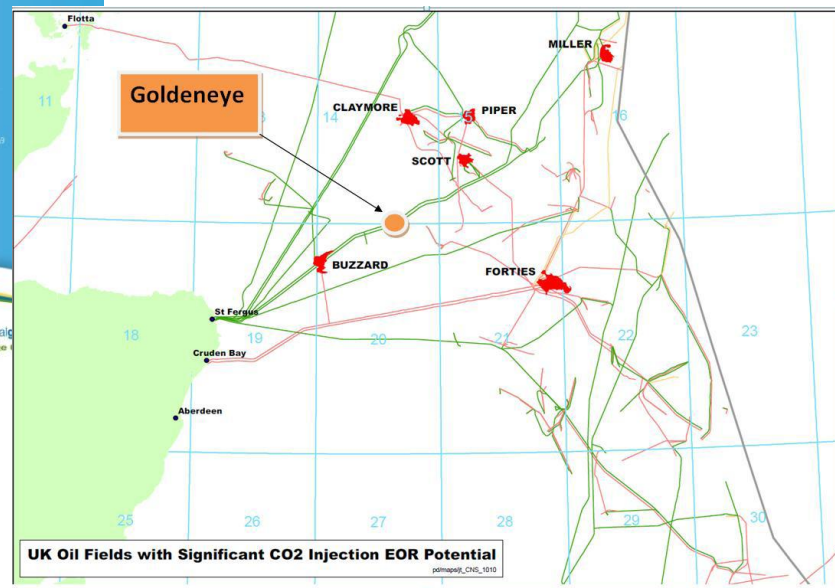


The ScottishPower Carbon Capture and Storage Consortium Project

SCOTTISHPOWER nationalgrid
Carbon Capture & Storage



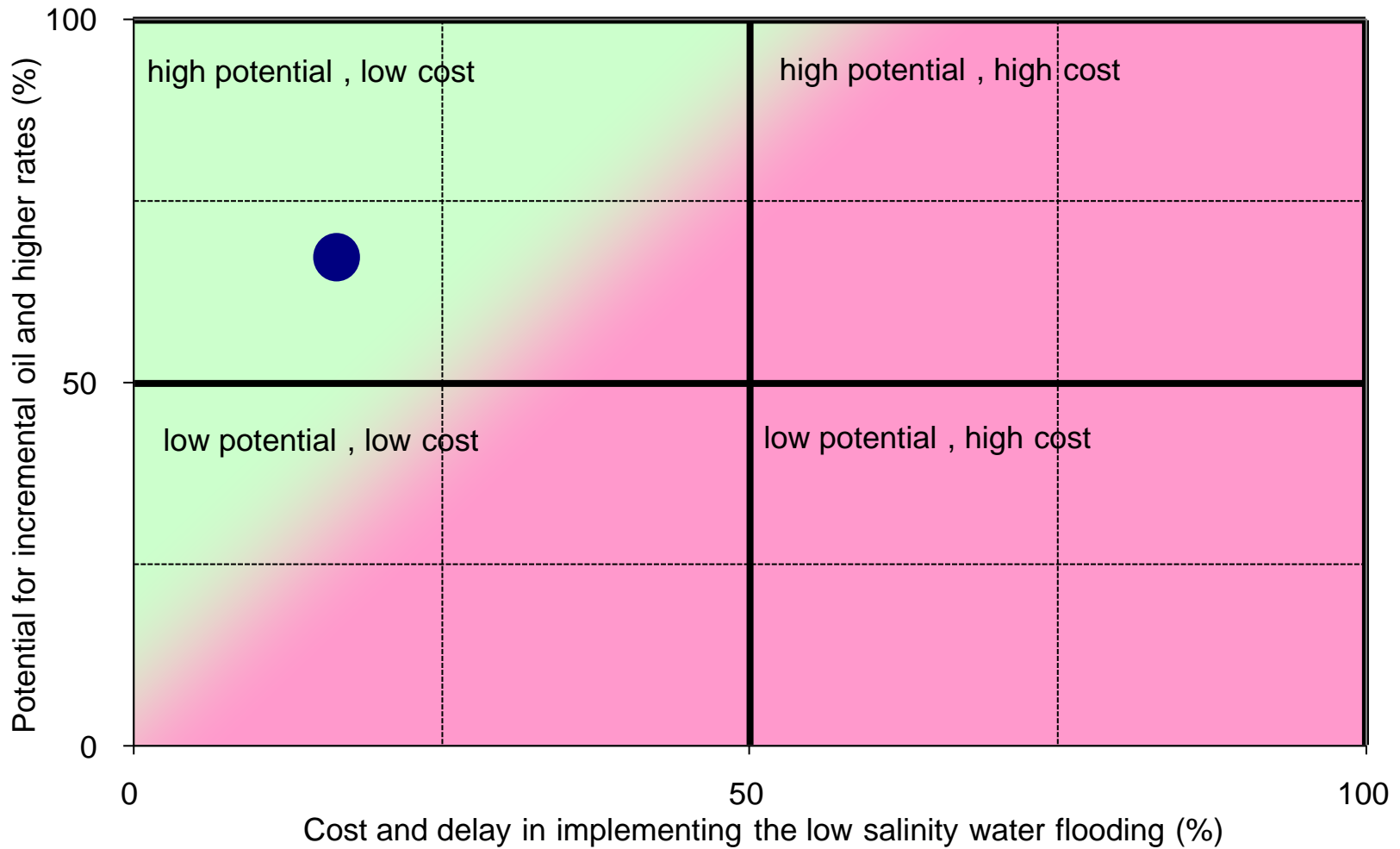
From Jonathan Thomas, DECC,
North Sea EOR – A UK
Perspective, EAGE EOR
Symposium, April 2011



Systematic Methodology to Rank Potential Low Salinity Opportunities



Factors	Value	Certainty	Flag
Petrophysical			
Formation type	<i>sandstone</i>	<i>high</i>	
Kaolinite content of formation	<i>between 6% to 15%</i>	<i>fair</i>	
Kaolinite widespread in the reservoir	<i>widespread (>70% reservoir volume)</i>	<i>high</i>	
Wettability	<i>intermediate or mixed</i>	<i>high</i>	
Residual oil	<i>>20%</i>	<i>high</i>	
Permeability	<i>medium (order of hundreds of mD)</i>	<i>high</i>	
Porosity	<i>high (>20%)</i>	<i>high</i>	
Core samples available	<i>plenty of good quality from relevant zone</i>	<i>high</i>	
Facilities			
Fresh water source	<i>plant on the platform</i>	<i>high</i>	
Available space and weight capacity for the necessary kit	<i>yes</i>	<i>high</i>	
Possible to lay/adapt existing pipeline for fresh water delivery	<i>not sure</i>	<i>high</i>	
Pilot area available	<i>yes</i>	<i>high</i>	
PVT			
Oil properties - polar content - acid or basic	<i>crude oil</i>	<i>high</i>	
Oil viscosity	<i>low</i>	<i>high</i>	
Reservoir temperature	<i>low</i>	<i>high</i>	
Connate water composition	<i>high salinity</i>	<i>high</i>	



Strategy to Assess Suitability of Fields for Chemical (Water-Augmented) EOR Processes



EOR Method	Injected Water Treatment	Oil Composition	Reservoir/Formation
Low salinity	Reduce salinity and hardness	Important but mechanism not known - probably has to contain polar components	Distributed clays (kaolinite or illite/mica) need to be present. Must be no or minimal swelling clays (montmorillonite/chlorite)
Alkaline	Reduce hardness	Has to contain acid groups. As a guide acid number >0.2 mg KOH/g	Must be no or minimal swelling clays
CDG/LPS	Not clear if treatment required	Probably not important	Wide-ish pore/pore throat size distribution. On water wet side. High-ish Sorw
PAM/HPAM	Reduce salinity and hardness	Not important but requires adverse mobility ratio	Temperature < 70°C Must be no or minimal swelling clays Requires moderate heterogeneity
Xanthan	Requirement to add biocide	Not important but requires adverse mobility ratio	Temperature < 90°C Must be no or minimal swelling clays Requires moderate heterogeneity
Surfactant	Need to adjust salinity and hardness to obtain optimal performance but not necessarily to low values. Addition of a co-surfactant or alcohol changes the optimal salinity/hardness	Surfactant 'cocktail' has to be formulated to work with the specific oil	The lower the clay content the lower the adsorption

- Amount of offshore EOR to date very disappointing
- We know where the remaining oil is (no need for exploration); we have infrastructure in place; but time limited opportunity
- Traditional and some newer EOR processes to consider
- Requires additional skills; training and experience an issue; no track record; IOCs have cut back on R&D
- Most likely requires more central planning and sharing of research and experience
- Implementation of facilities to adjust water chemistry (hardness and salinity) could act as a gateway to the implementation of other water based methods (either singly or in combination)
- Climate change imperatives are likely to make significant supplies of CO₂ available

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