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EAGE EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

Dresden GERMANY

Encouraging EOR Projects in the North Sea

Jonathan Thomas, UK Oil & Gas Authority

14th April 2015 - EAGE 18th European Symposium on Improved Oil Recovery

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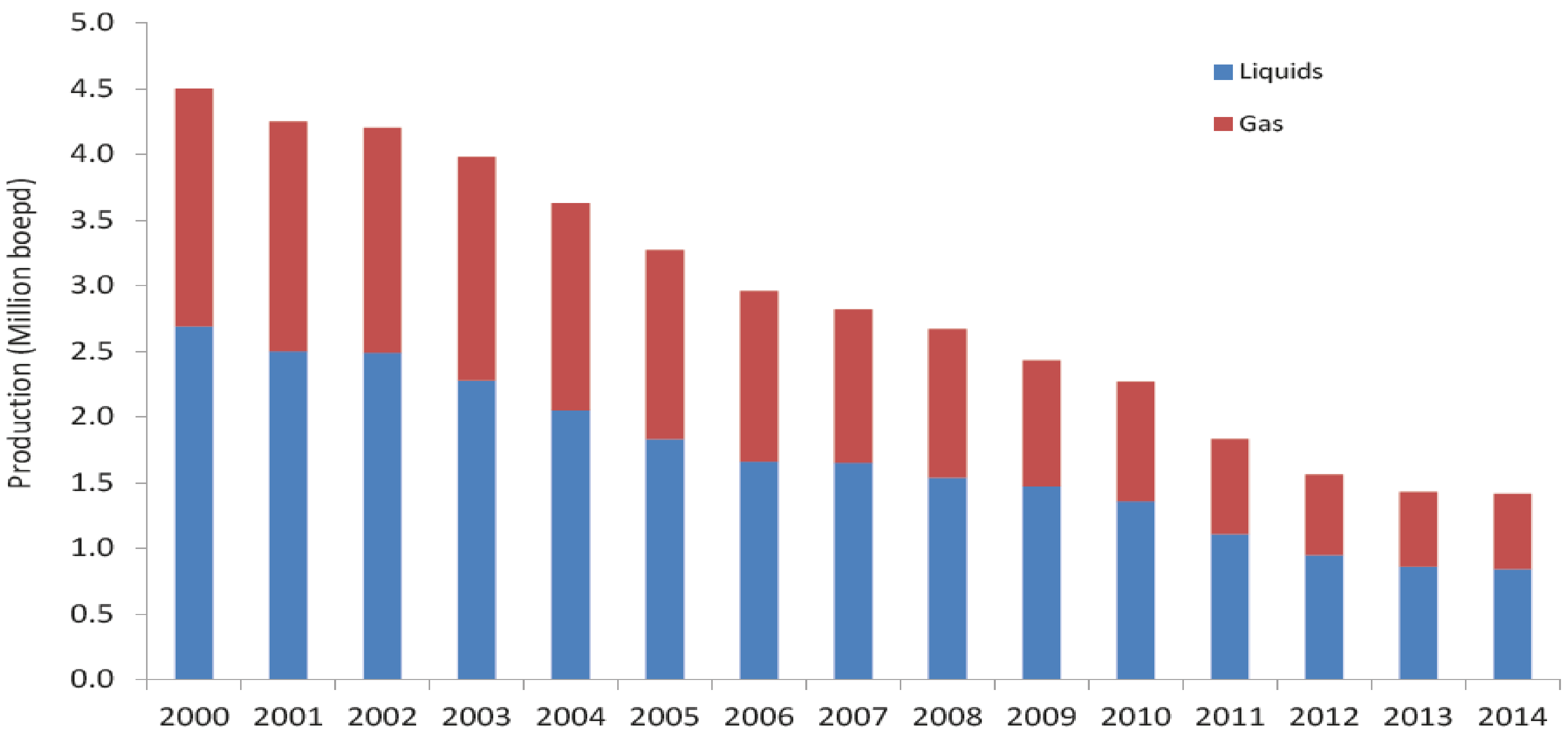
Why we need more EOR

UK oil & gas production



Source: Oil & Gas UK

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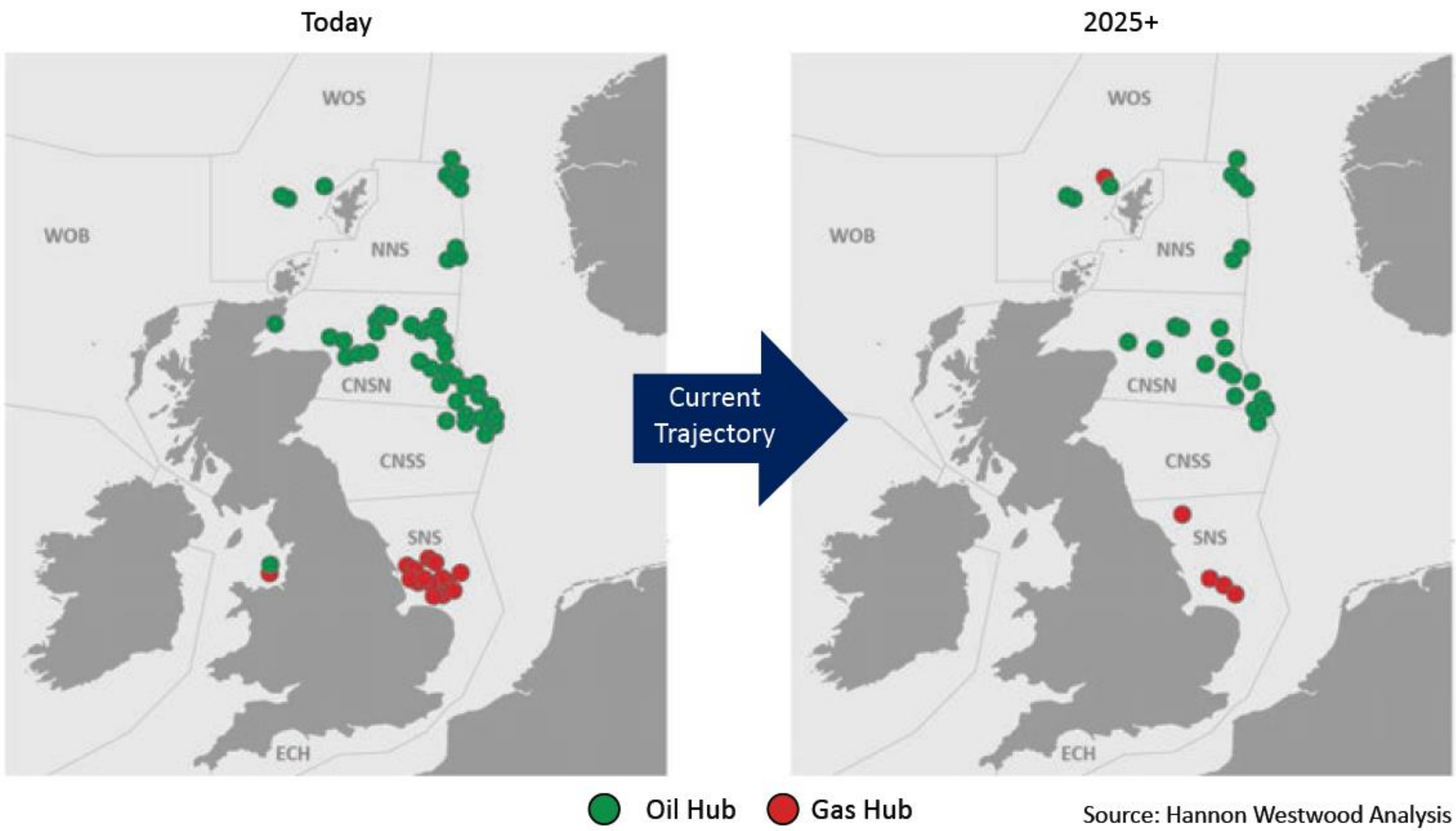
The “window-of-opportunity” is closing



Source: Hannon Westwood Analysis

What is “PILOT” ?

- Government and industry cooperation
- Ensure full economic recovery of our hydrocarbon resources

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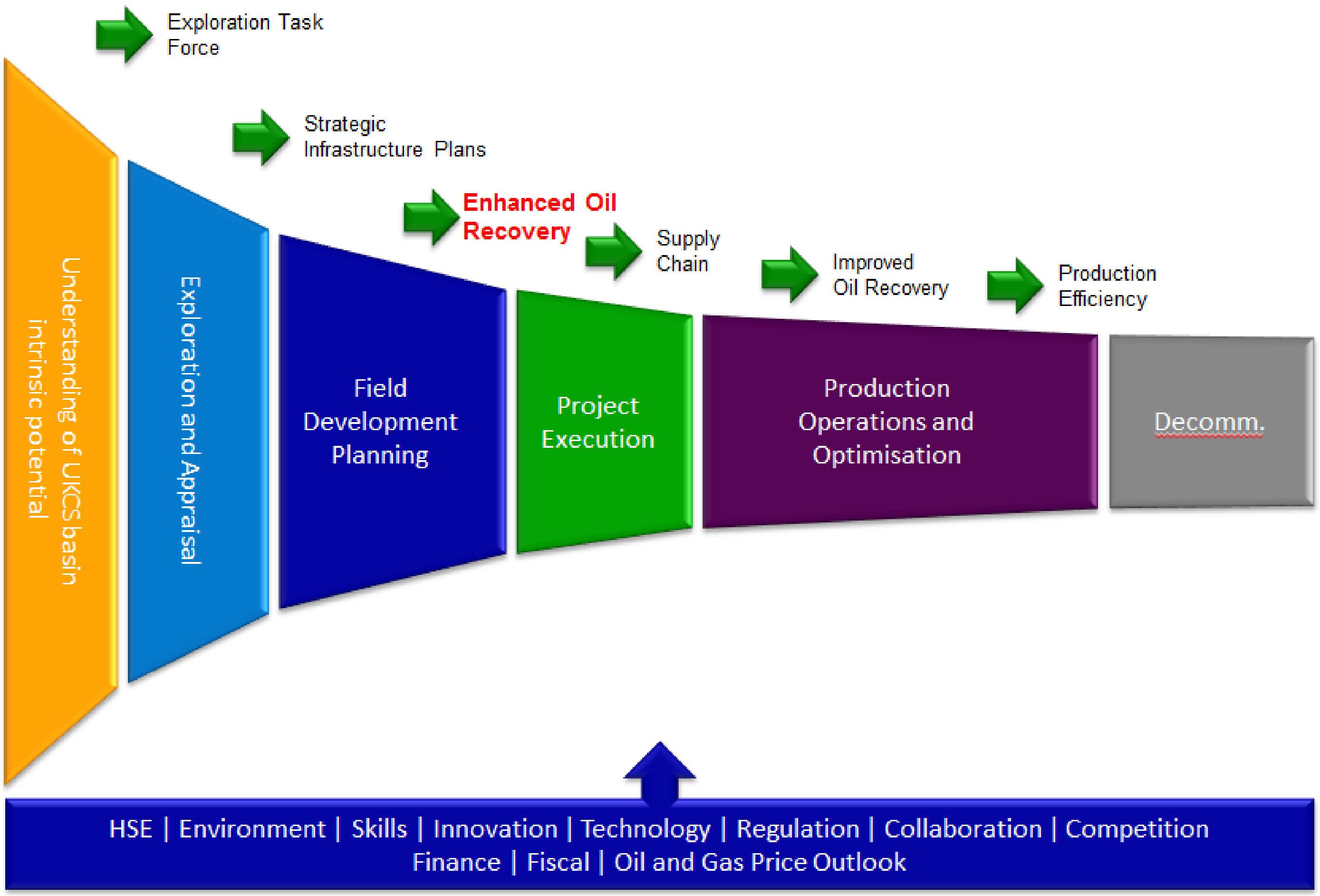
PILOT Work Groups



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PILOT EOR Workgroup

OBJECTIVE (set in 2012)

- To be a catalyst for the development of new EOR Projects in the UKCS
- Facilitate cross-industry collaboration in EOR

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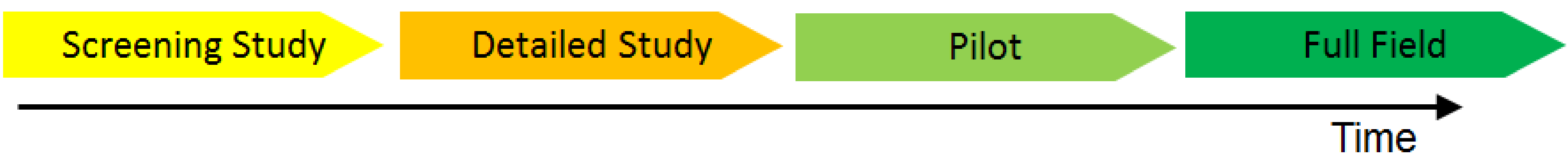
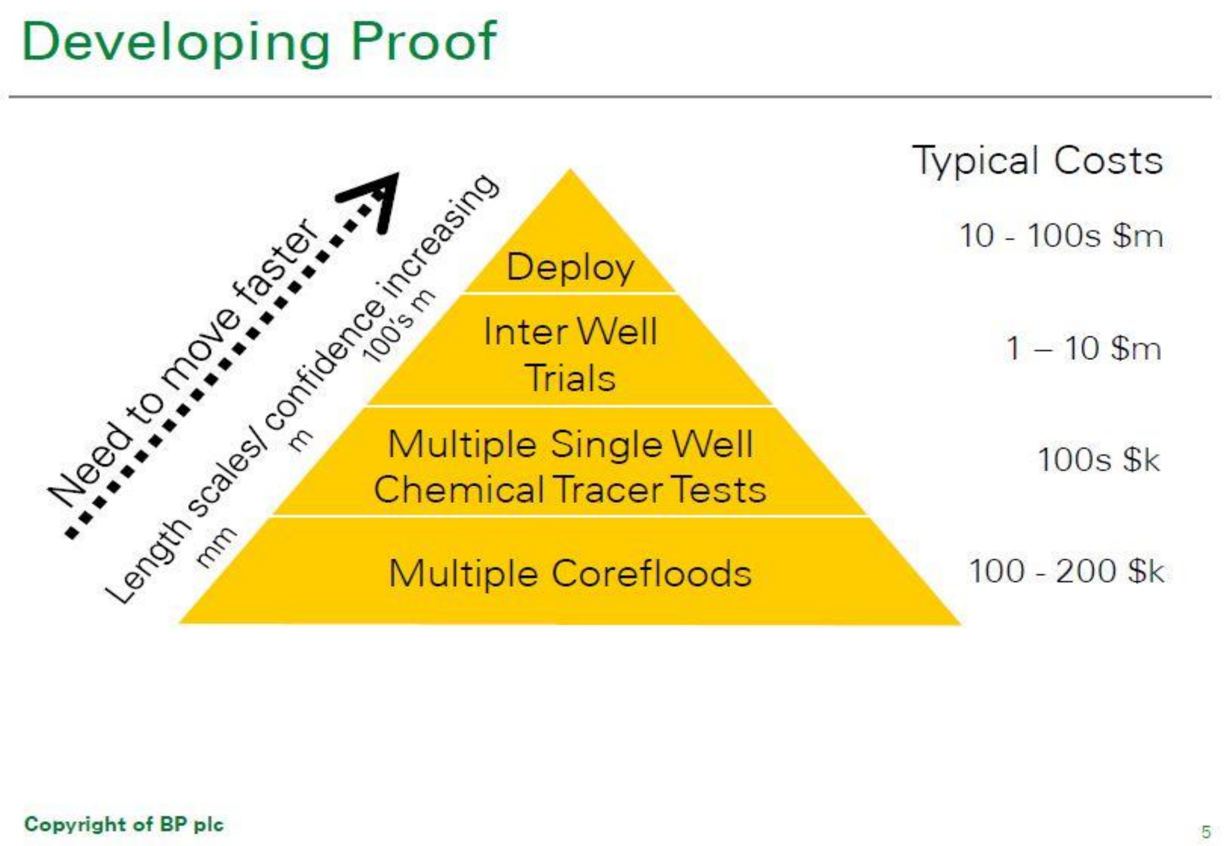
PILOT EOR Workgroup

ASSESSMENT

- Lack of **CONFIDENCE** in EOR
- Many operators are not yet at the **SCREENING** stage
- **URGENCY** - cycle time from screening to implementation has to be accelerated



Move through “Pyramid-of-Proof” …...more quickly



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Phase-1 : Estimating the "Size-of-the-Prize" for EOR

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"*SENEOR*" EOR Screening Tool

	TECHNICAL PARAMETERS												FIELD MATURITY				
	STOIIP (MMstb)	Depth (ft)	Pressure (psia)	Permeability (mD)	Oil Viscosity (cP)	Temperature (degC)	Acid number (mg KOH/g)	Amott-Harvey Wetting Index	Frac Clays	Hetrogeneity (0 none, 1 lot)	Injection water salinity	**Result**	RF to date	EURF	Field Maturity	**Result**	**Incremental Oil (MMstb)**
Input Data >>>>>>	470.3	5123	2572	9336	8.4	60	0.1	0.8	0.015	0.85	36000		54%	59%	92%		
Hydrocarbon miscible																	25.6
Nitrogen and flue gas																	0.0
CO2 miscible																	25.6
Surfactant/polymer																	25.6
Polymer																	15.5
Alkaline																	0.0
In situ combustion																	25.6
Steam drive																	0.0
Bright Water ('strong gel')																	15.5
Low salinity																	0.0
CDG/LPS ('weak gel')																	15.5
													Maximum Incremental Recovery				25.6

I. **Results shared with individual field Operators**
II. **Feedback on incremental recovery volumes and EOR process**
III. **Inventory of EOR Opportunities on the UKCS**

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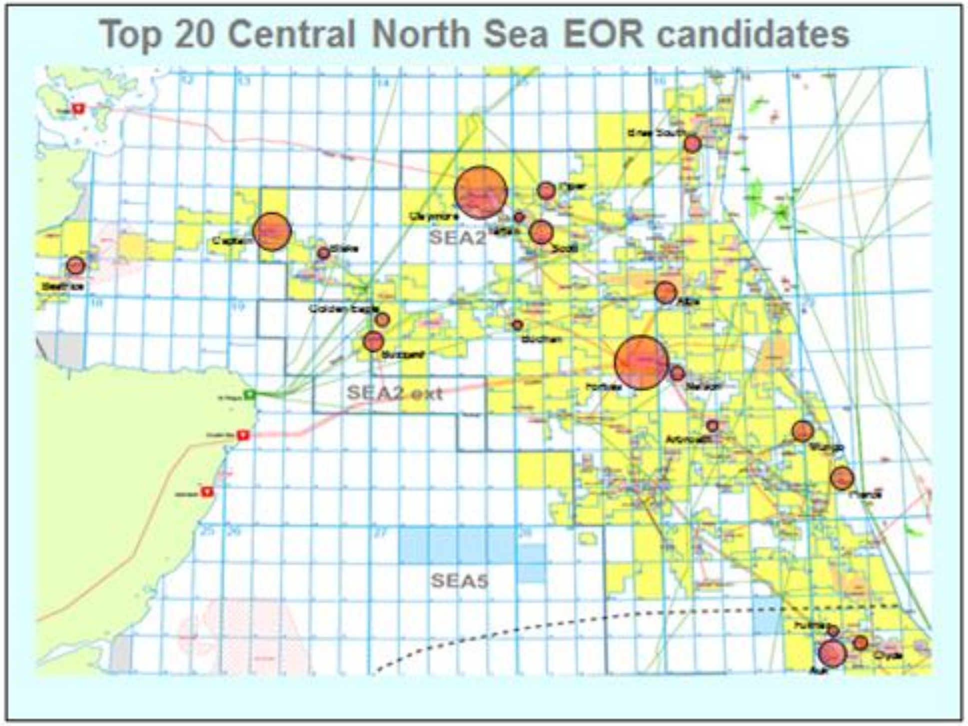
Phase 1 – Estimate the Size of the EOR Prize

UKCS wide EOR screening performed by DECC

EOR Process	*Estimated Recovery (mmstb)*
Miscible Hydrocarbon flood	5400
N2 & Flue gas	500
Miscible CO2	5700
Surfactant/Polymer	4800
Polymer	2100
In-situ combustion	700
Steam drive	600
Brightwater	3100
Low salinity	2000
Colloid Dispersal Gel (CDG)	3100



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EOR “Size-of-the-Prize” Bubble Maps

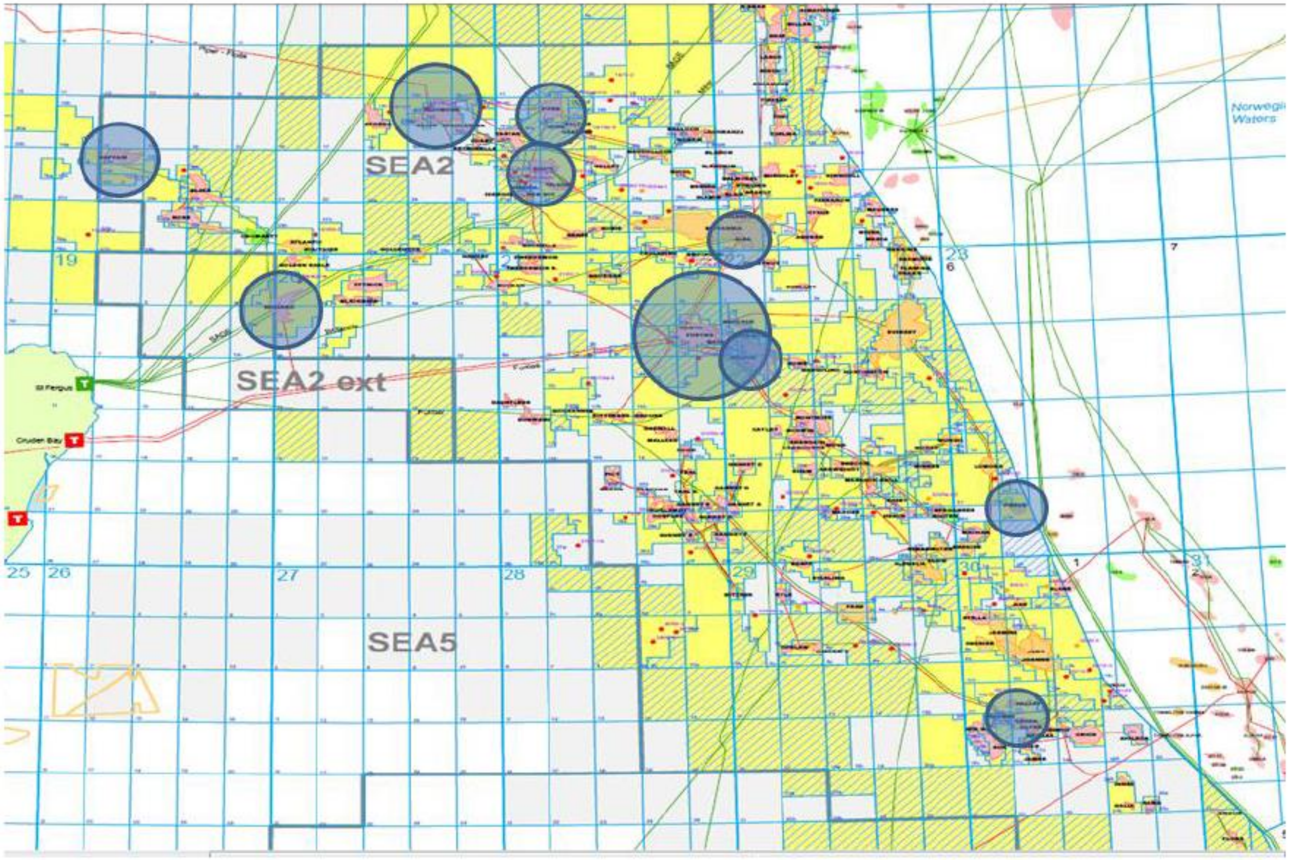

Figure 8: An example “Bubble-Map” of the Distribution of EOR Potential in the Central North Sea (the diameter of each circle is proportional to EOR potential).

Phase-2 : Raising Awareness of EOR Opportunities

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Phase 2 – Raising Industry Awareness of EOR Opportunities

3 separate PILOT EOR Work-streams needed:

- **Low Salinity Waterflood**
- **Chemical EOR (polymer / surfactant)**
- **Miscible Gas (hydrocarbon/CO2)**

For each technology we want to build understanding and knowledge sharing

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Low Salinity EOR Activities

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Low Salinity EOR UKCS Exemplar – Clair Ridge

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The official site of the British Prime Minister's Office

Home > News > PM gives go-ahead for £4.5bn UK oil and gas project

- News Stories
- Press Briefings
- Press Notices
- Prime Minister's Questions
- Speeches and Transcripts
- Statements and Articles

PM gives go-ahead for £4.5bn UK oil and gas project

Thursday 13 October 2011

Clair Ridge project will create hundreds of jobs over the next five years and produce a vital source of domestic oil until around 2050

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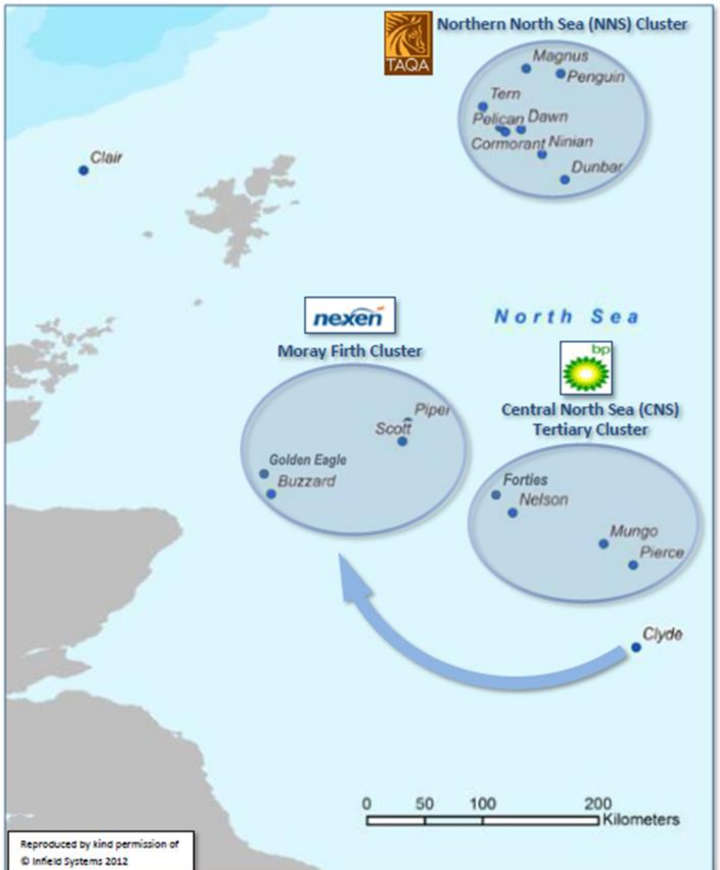
Phase Low Salinity EOR Workgroup Achievements

- 12 operators have participated in a low Salinity EOR collaboration programme
- Established common standards for core testing
- Identified options for brownfield implementation on North Sea platforms

Low Salinity EOR “Clusters”



Cluster Name	Lead Operator
NNS Cluster DECC Estimated Cluster EOR Potential = ~350 MMSTB	TAQA
CNS Tertiary Cluster DECC Estimated Cluster EOR Potential = ~120 MMSTB	BP
Moray Firth Cluster DECC Estimated Cluster EOR Potential = ~270 MMSTB	Nexen

Low Salinity Core Test "Protocol"

Low Salinity Coreflooding: Key requirements for reliable Measurement:

- Core sample preparation
- Initial water saturation
- Use of representative reservoir oil
- Injection water
- Core flood injection rate

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Low Salinity Core Test “Protocol”

Low Salinity Coreflooding: Key requirements for reliable Measurement

Objective:
The following key issues to be addressed when designing a core flood to evaluate low salinity flooding have been developed from observations reported in the open literature and from cumulative experience. Mostly these are what might be considered to be good practice to ensure core is representative of the reservoir state and hence, the low salinity increment that can be characterised as a wettability change will also be representative.

There are exceptions where these suggestions may not be necessary but they are important for most of the laboratory tests carried out.

Core sample preparation: The EOR increment is only seen in cores containing active clays. Core samples should be prepared in such a way as to minimise disruption to any clays. Drying the core or soxhlet cleaning which can dry cores prior to core flooding should be avoided. Using preserved and/or restored cores to obtain a representative wetting state both have merits and potential drawbacks. These options would need to be considered on a case-by-case basis but it is important to avoid obtaining an initial unrepresentative strongly wetting state.

Initial water saturation: Representative connate water saturation with the correct composition needs to be uniformly distributed in the core. The EOR increment is dependent on the injectant divalent cation composition being less that the “resident” brine and if no Swi is in place early tests showed that no low salinity EOR increment was observed.

Use of representative reservoir oil: If core floods are carried out with refined oil containing no polar compounds, no incremental oil is seen. Therefore, reservoir crude oil should be used. Using dead crude oil tends to “smear” out oil production over time and, could, if EOR increment is low, result in no oil bank formation; Ideally, live reservoir oil in equilibrium with the water should be used. Using live reservoir oil would also help to ensure the correct pH is obtained during ageing and flooding.

Injection water: The EOR increment is dependent on the injectant salinity being below a threshold value AND on the divalent cation concentration being less that the “resident” brine. The EOR increment increases as salinity is reduced so maximum benefit will be obtained with the **lowest** salinity possible without impairing permeability. The “operating range” should be determined by measuring permeability change with varying water composition (swelling tests). These tests and the core test to define EOR benefit should be carried out using combinations of the potential source waters that might be blended to obtain the low salinity water.
Measuring single phase permeability of the core sample after the core flood is useful to confirm any permeability change under more reservoir realistic conditions than estimated from the swelling tests.

There is no convincing evidence that the differences in sea water and common North Sea reservoir brines will significantly affect the relative permeability in the secondary flood. However, given that the low salinity effect is dependent on the change in brine composition during flooding, using representative water for the secondary flood prior to a tertiary low salinity flood is preferable.

Core flood injection rate: Unrepresentative flow rates should be avoided. For tertiary tests, during the high salinity flow period that might result in an unrealistic low remaining oil saturation and hence a low EOR benefit. The details of experimental methodology and test interpretation would result in an inaccurate estimate of the low salinity EOR benefit but if these the key requirements are not met, any measurement will almost certainly be incorrect. Pairing a secondary and tertiary low salinity core flood provides data that can be a good consistency check

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Further Guidance (added August 2014)

When carrying out unsteady state constant flow rate coreflood tests it is common to carry out “a bump” or increases in flow rates at the end of the test to produce any oil retained by core-scale capillary pressure end effects due to the discontinuity at the core outlet. If the “bumps” that are unrepresentative of deep reservoir flow rates, are carried out before the low salinity tertiary step, the immobile oil that could have been the EOR target as well as the end-effect retained oil may have already been produced. Therefore, “bumps” should be carried out after the tertiary low salinity flood. This means that the effect of capillary end-effect need to be taken into account.

A first estimate of EOR benefit can be obtained by comparing secondary high salinity and tertiary low salinity saturation data from the inlet portion of the core that will be less or not significantly affected by the capillary discontinuity at the outlet core boundary. A better estimate can be made by simulation history-matching the coreflood test. This will require an estimate of capillary pressures either through a separate measurement or estimated from “bumps” post-tertiary low salinity flood.

Low Salinity EOR Workgroup Achievements

- More than half a dozen fields have been screened to date
- Collaborative studies on Brent Sand low salinity response (Liverpool University) and brown field facilities

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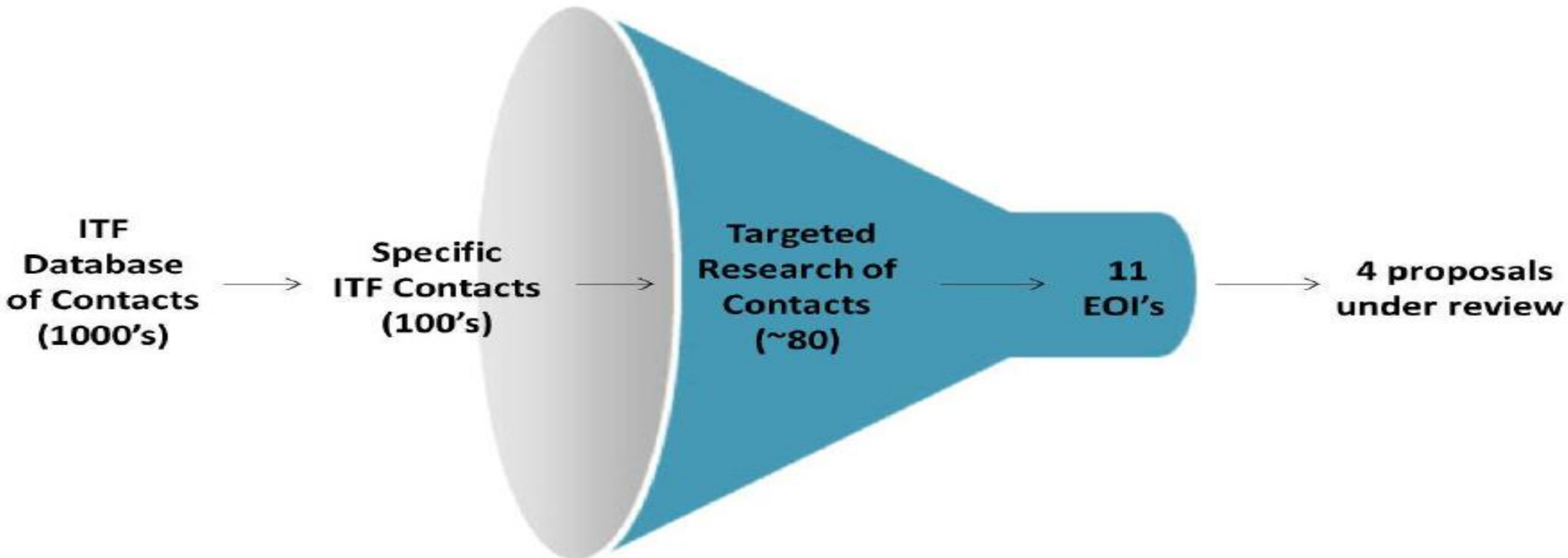
Brownfield Facilities for Low Salinity EOR



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For more detail see:

SPE 172017

Maximising Enhanced Oil Recovery Opportunities in UKCS Through Collaboration

M.P. McCormack, BP Exploration Operating Co.; J.M. Thomas, UK Department of Energy & Climate Change; K. Mackie, Industry Technology Facilitator

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Miscible Gas Injection EOR Activities

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Miscible Gas EOR UKCS Exemplar – Magnus

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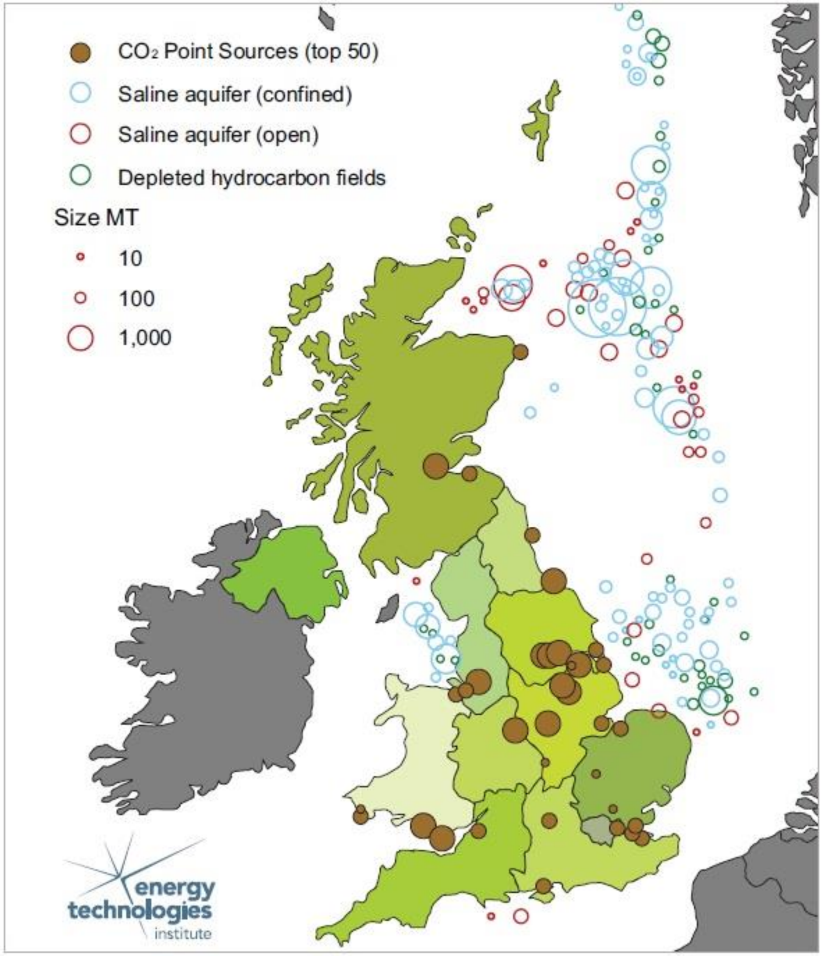
Miscible Gas EOR Workgroup Achievements

- Industry workshop to discuss main issues
- Looked at potential sources of hydrocarbon gas for EOR
- Looking to link the UK CCS Programme with CO2-EOR opportunities in the Central North Sea

Need Joined-Up CCS Policy & CO2-EOR



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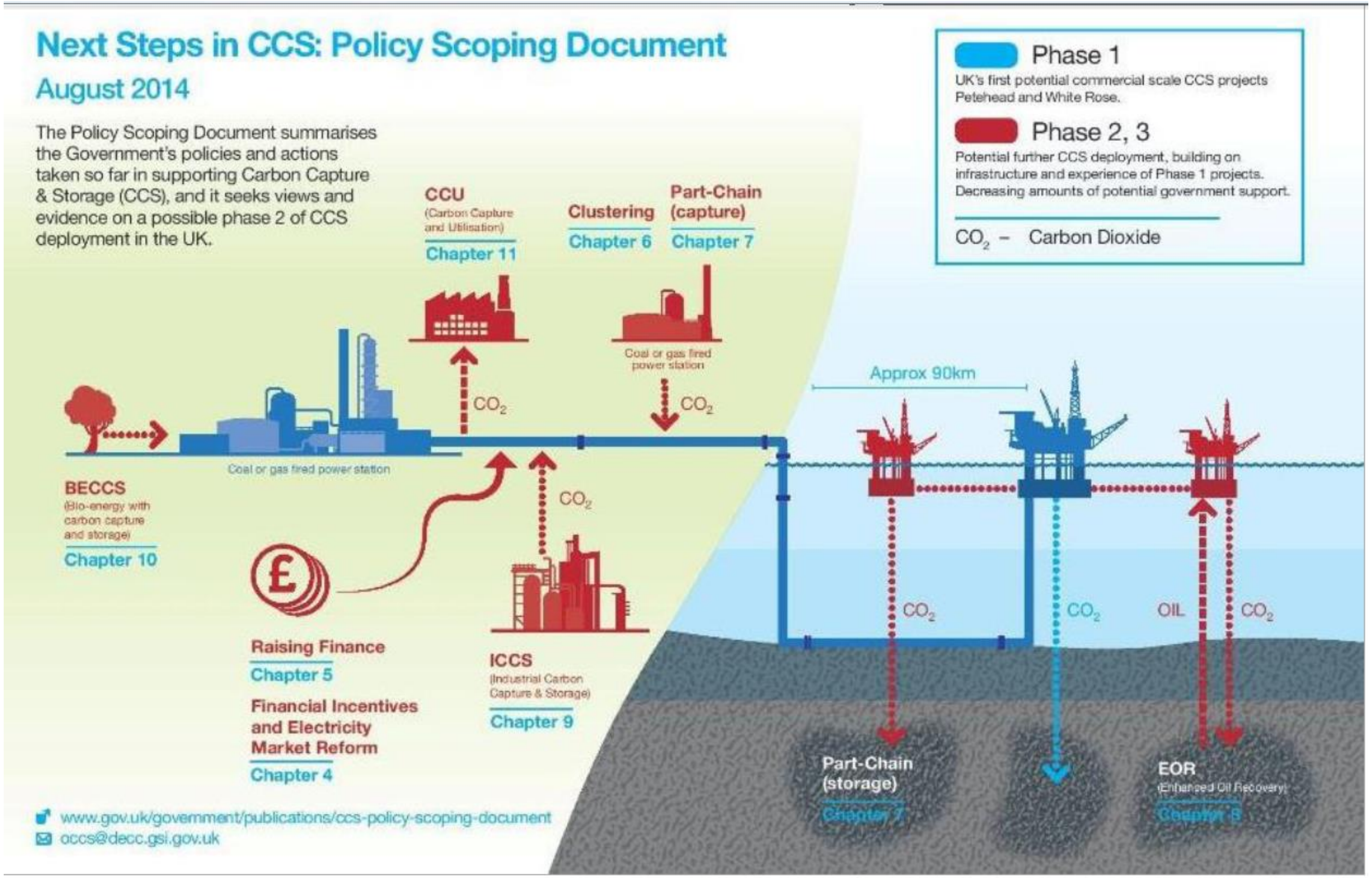
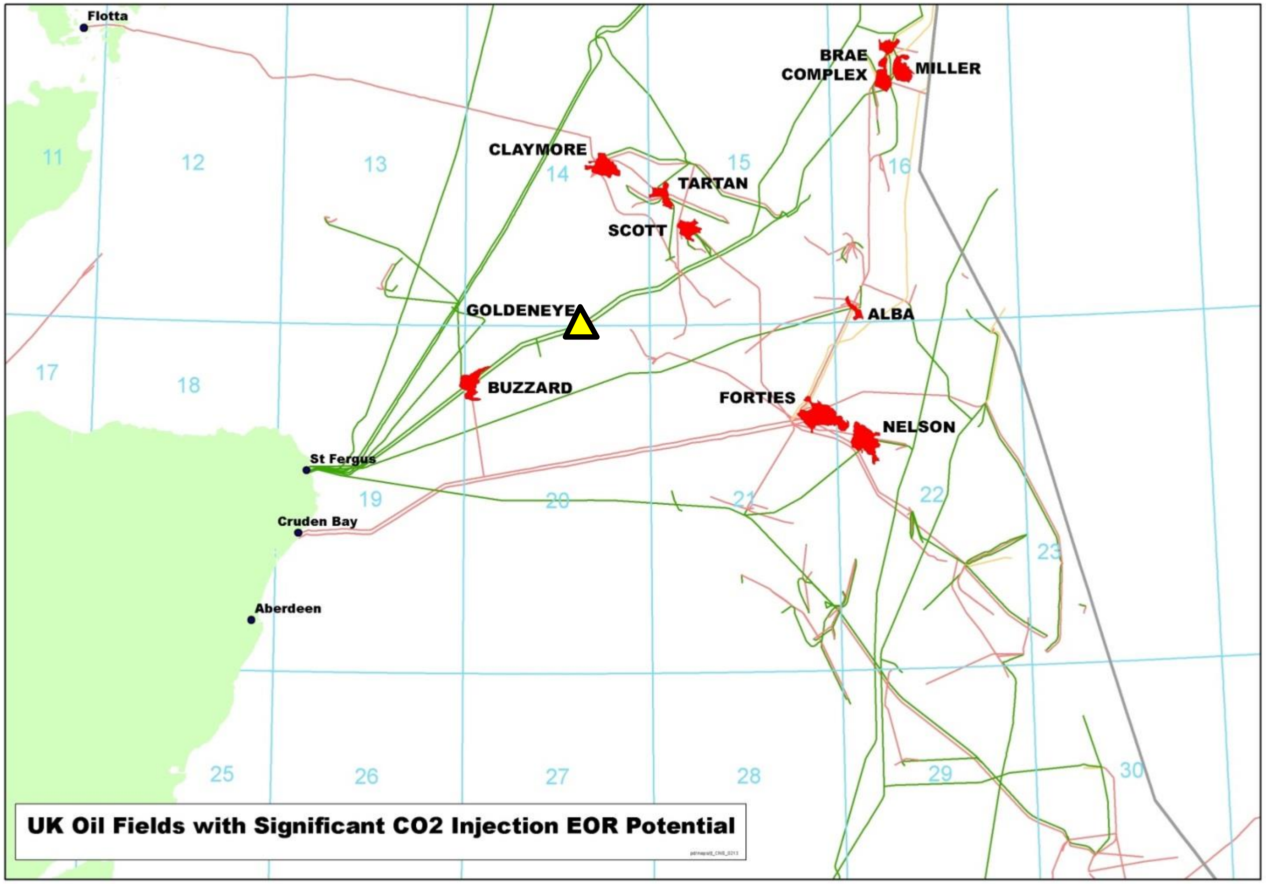
Key CCS Policy Issues



A Conceptual CO2 EOR "Core Area"



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Chemical EOR Activities

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Chemical EOR UKCS Exemplar – Captain

The Polymer Operating Envelope has greatly improved

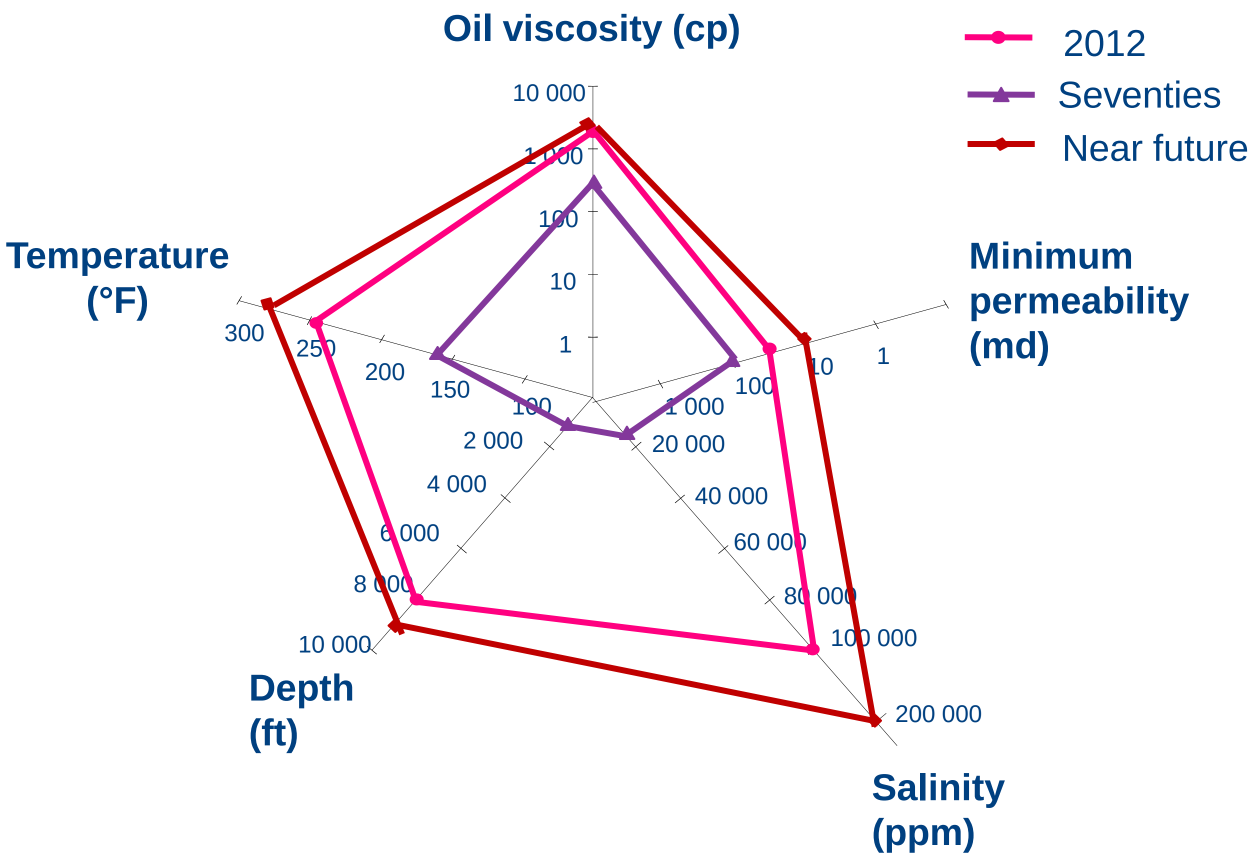
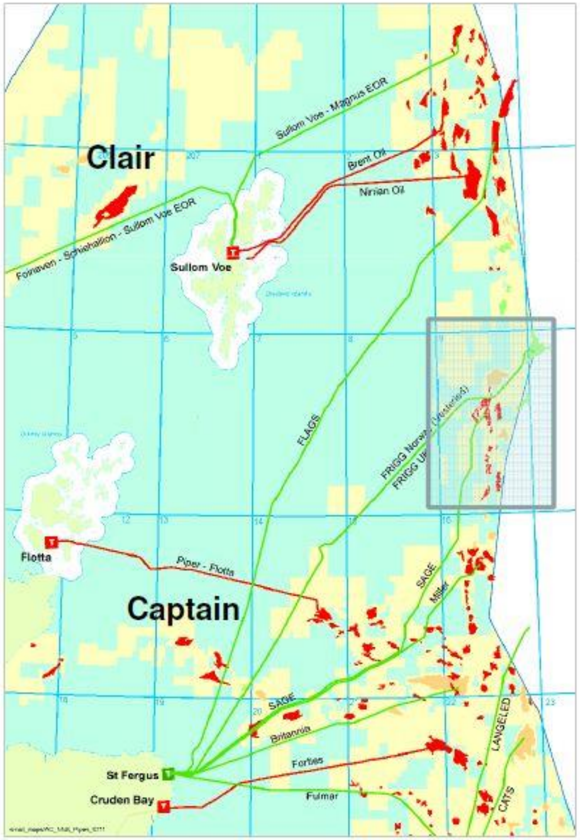
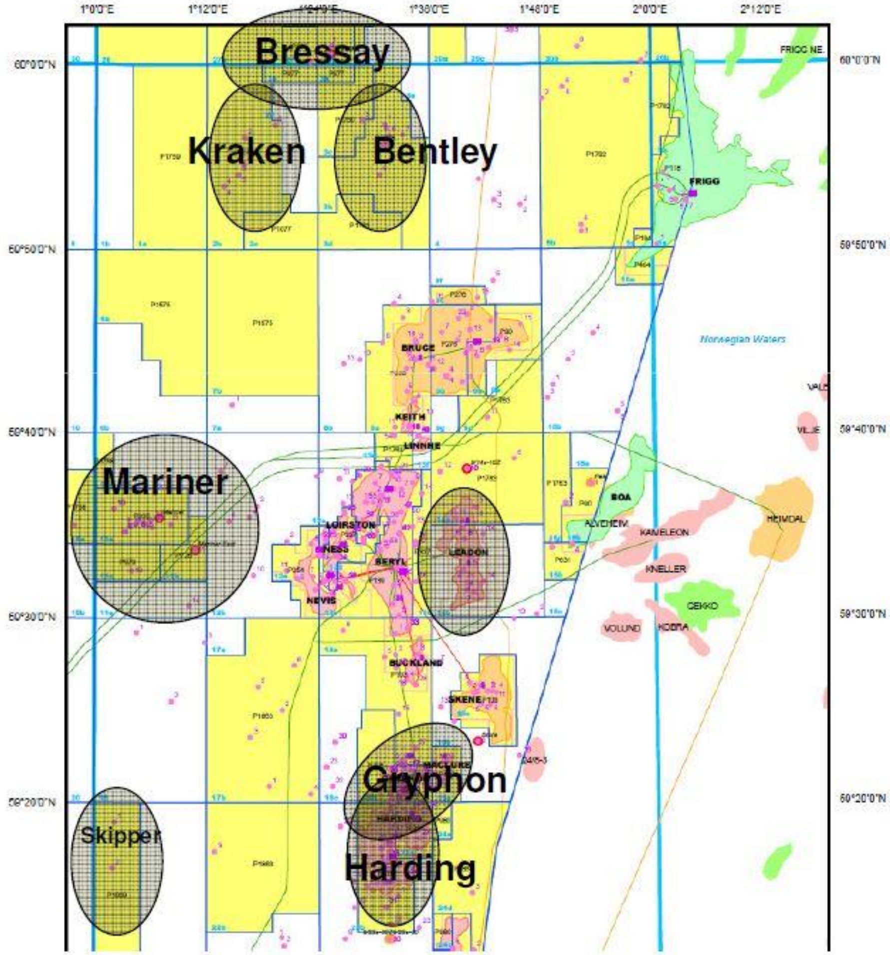


figure provided by SNF

Quad-9 Heavy Oil Fields





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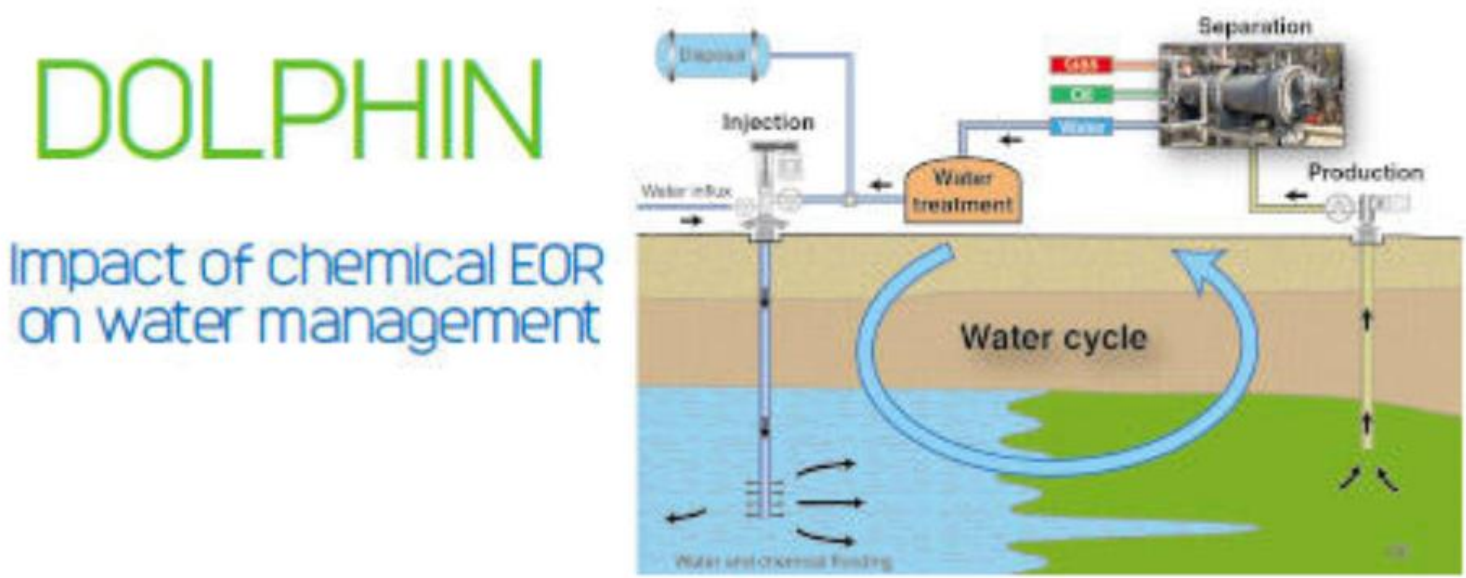
Infrastructure issues

Press releases

- **Impact of chemical enhanced oil recovery on water management - IFPEN launches Dolphin™, an experimental research project with industry**

17 March 2014



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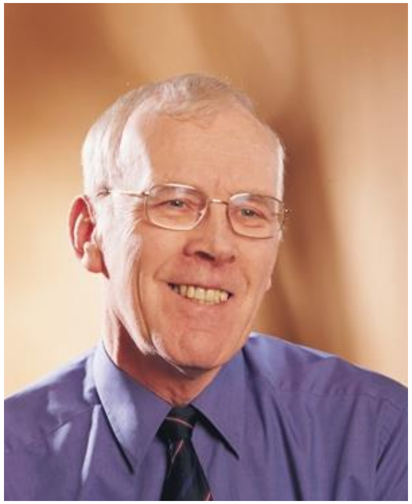
The Wood Review and the OGA

EOR has a vital role

The "Wood Review" stressed the importance of EOR

"industry should be encouraged more in EOR schemes to avoid leaving significant value behind"



24 February 2014

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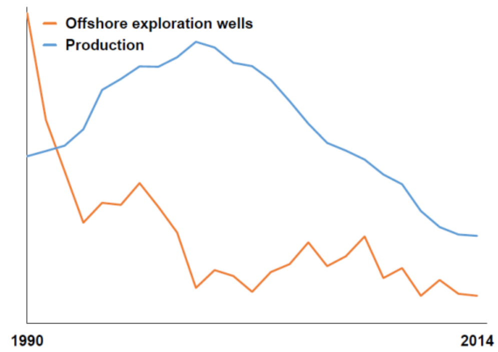
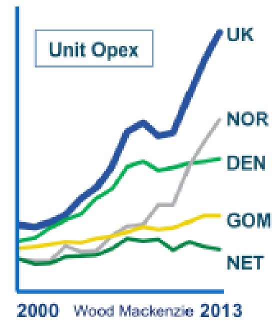
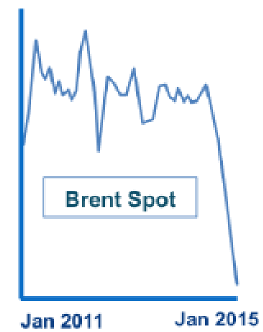
The formation of the OGA

Economic challenges intensified since Wood Review







All parties must now deliver

Leadership Behaviours Culture

Fiscal Reform

Wood Actions

Cost & Efficiency

Three key priorities for the OGA

1. People and skills
2. Trust and relationships
3. Focussed delivery

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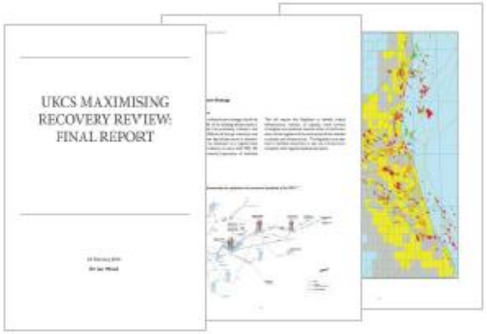
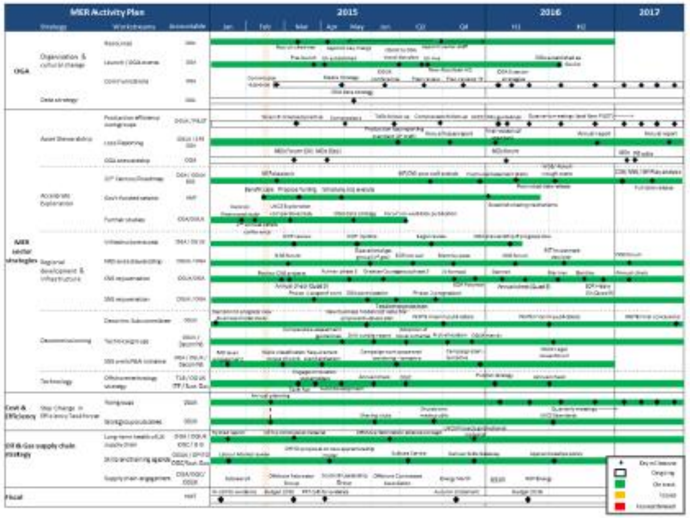
OGA Delivery Plan



Thorough review, clear actions

Interconnected priorities



One integrated plan

Opportunity to create focus and drive delivery

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Phase-3 : More Detailed Engagement

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Summary of PILOT EOR Workgroup Progress

Phase	Objectives	Status
1. Engagement of Industry & Screening of UKCS fields for EOR potential	• To develop a sense of urgency and energise activity in EOR/IOR projects in the UK oil industry & create a forum for the dissemination of knowledge and experience to other operators and third parties. • To identify specific barriers to EOR/IOR implementation on these candidate EOR/IOR projects.	• Basin wide EOR screening complete. • EOR workshops held for Low Salinity, Chemical & Miscible Gas techniques.
2. Scoping synergies between fields by geography & EOR technology	• To identify collaboration opportunities and synergies in the industry, both in subsurface, and in facilities.	• Cluster approach in operation for Low Salinity (NNS & Moray Firth). • Chemical EOR Alliance engagement session held.
3. Initiate major options with operators / suppliers	• To pinpoint candidate EOR/IOR projects in a timely manner. • To generate solutions to the challenges associated with retrofitting a tertiary EOR/IOR scheme, and initiate the necessary developments in subsurface and facilities technology.	• Proposal for EOR assists on top 14 candidate fields. • Proposal for Brownfield Low Salinity facilities JIP underway. • Engagement between DECC / OCCS on CO_2 EOR potential.

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PILOT EOR – Next Steps

- Operators should now be more aware of EOR opportunities in their portfolio
- However, few EOR developments are coming forward
- EOR has a limited window-of-opportunity and more needs to be done

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The DECC “EOR Reviews”

- A structured discussion of the current field status & future options – including EOR
- Based on SPE 109555 “RTL” Process
- Identify barriers to EOR deployment and how to overcome

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The DECC "EOR Reviews"

- A forum for discussion between DECC and operators to promote more EOR activity
- Identify what we both need to do & by when to make EOR happen

Impact of Low Oil Price

- Interest in EOR has dropped down the agenda
- EOR teams have been reduced in size
- Operators are generally more risk-adverse

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Response to Low Oil Price

- Increase emphasis on larger new developments
- Ensure development plan commitments on EOR are honoured
- Closer engagement with operators to progress EOR options and tackle barriers to progression
- Strengthen OGA EOR capability and seek out new technological solutions

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