



Carbon Capture and Storage - Evaluation of CO₂ Storage Offshore from Scotland

Evaluation of EOR Potential (Single Field and Cluster)

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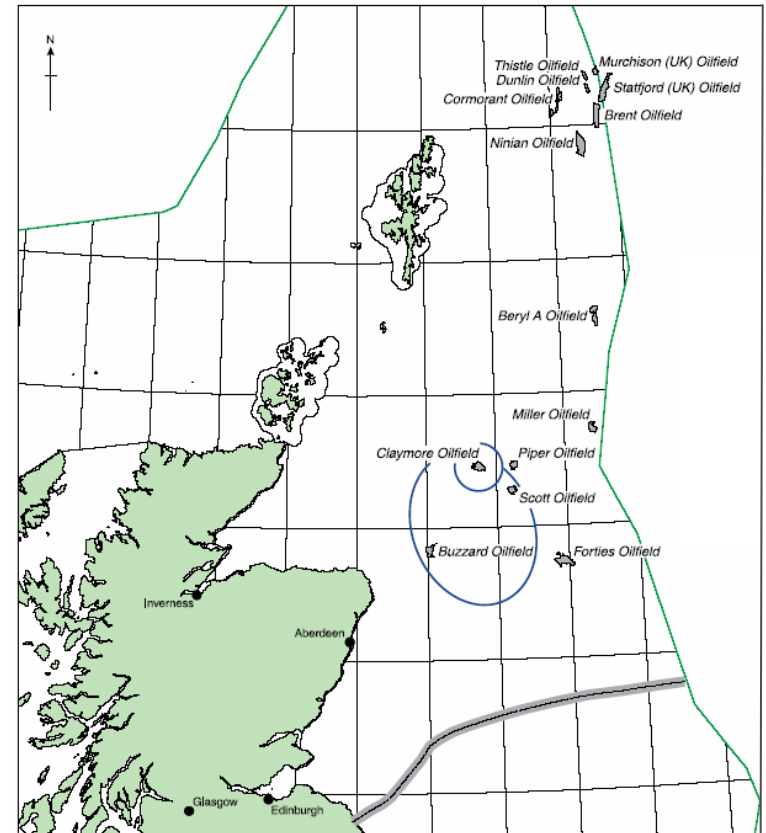
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Background

- Using CO₂ for enhanced oil recovery (EOR) in UK and Scottish North Sea oil fields is often held up as an opportunity to kick start the UK carbon storage industry
- True that supercritical CO₂ is a good solvent and at the pressures and temperatures found in UK reservoirs
- Also often mentioned that CO₂ can be stored in our old oil fields
- But nearly all have been developed by water injection with an approximate balance between amount of water injected and the amount of oil and water produced

Single Field and Cluster CO2 EOR Evaluations

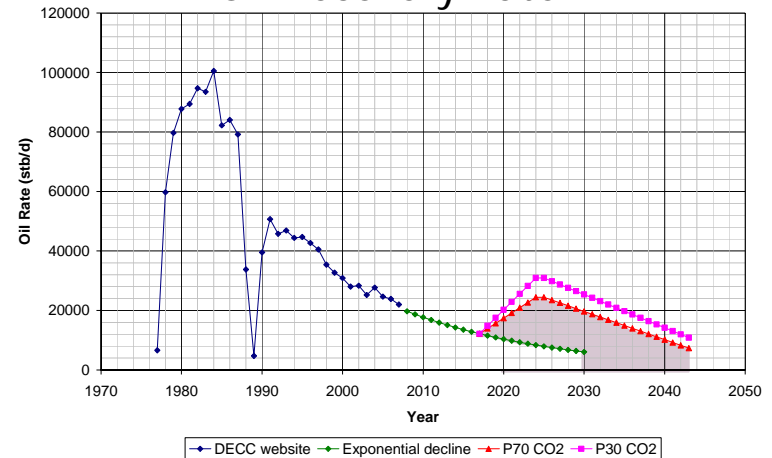
- From screening Piper, Claymore, Scott and Buzzard selected with recommendation that single field evaluation be undertaken on Piper
- Examination of data showed that Piper is not suitable as very high recovery from water flooding (~78%) and low residual water saturation so insufficient target
- Of the remaining three, Claymore is leading candidate so was used for single field evaluation
- Scott deeper and hotter than any CO2 project to date
- Buzzard not clear that the CO2 would be miscible
- Cluster evaluation used Claymore, Scott and Buzzard



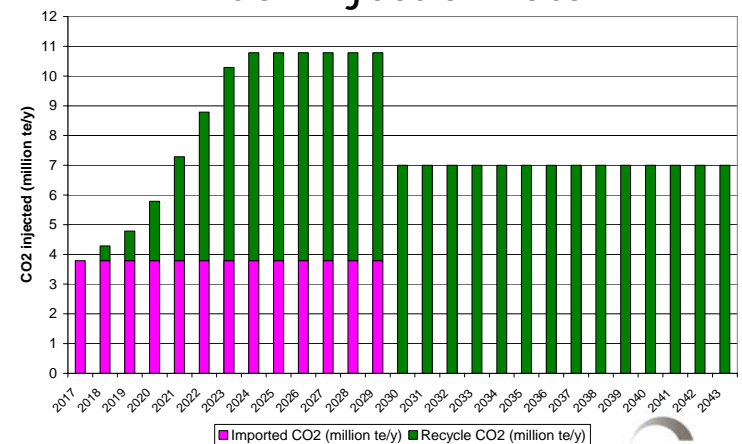
Claymore CO2 EOR Evaluation

- CO2 miscible with reservoir oil at current operating pressure
- Incremental oil recovery profiles constructed for 70% probability (1/7th remaining oil) and 30% probability (1/5th remaining oil)
- Incremental oil 119 million barrels (8% of oil initially in place) for P70

Oil Recovery Rate

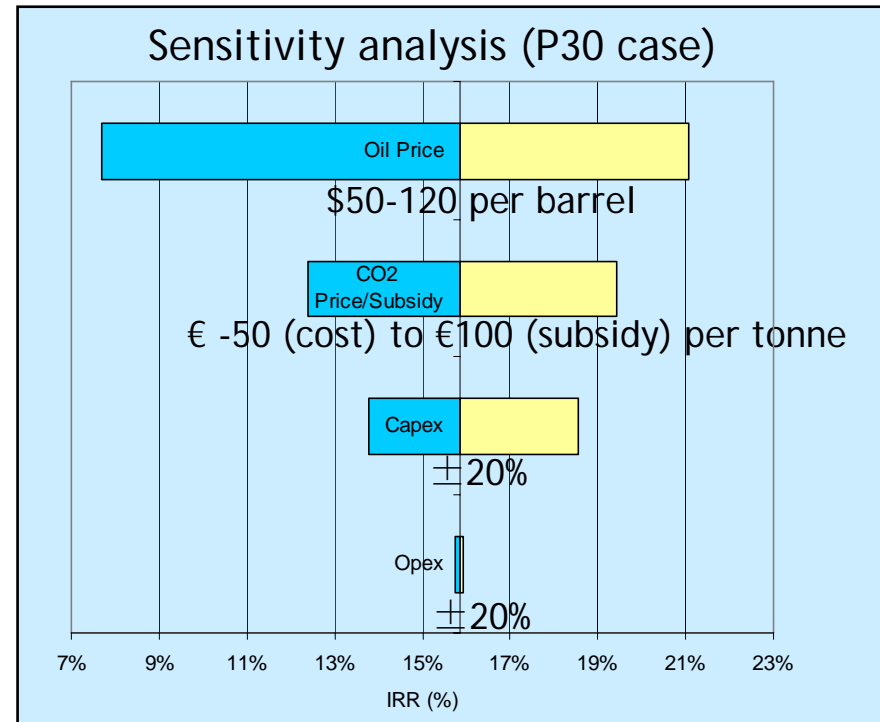


CO2 Injection Rate



Claymore CO2 EOR Economic Evaluation

- Capital costs £1.1- 1.2 billion (new auxiliary CO2 platform, adaptation of existing platform, well upgrades, baseline monitoring)
- Operating costs £90 million per annum (include requirements of measurement, monitoring and verification programme)
- Price assumptions
 - Oil £50 (\$70) per barrel
 - CO2 neither cost nor subsidy
- Discounted cash flow gives internal rate of return 12-16% (before tax)
- Unrisked

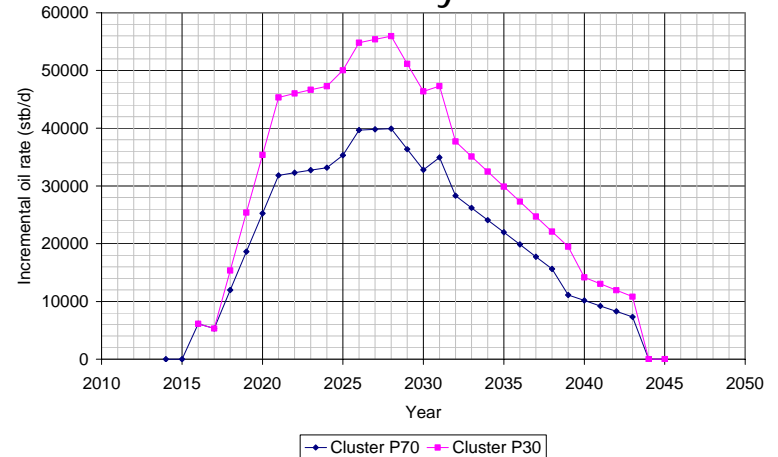


- Oil and CO2 prices subject to market forces
- Project economics can be improved by reducing capital costs and risks associated with converting facilities and wells

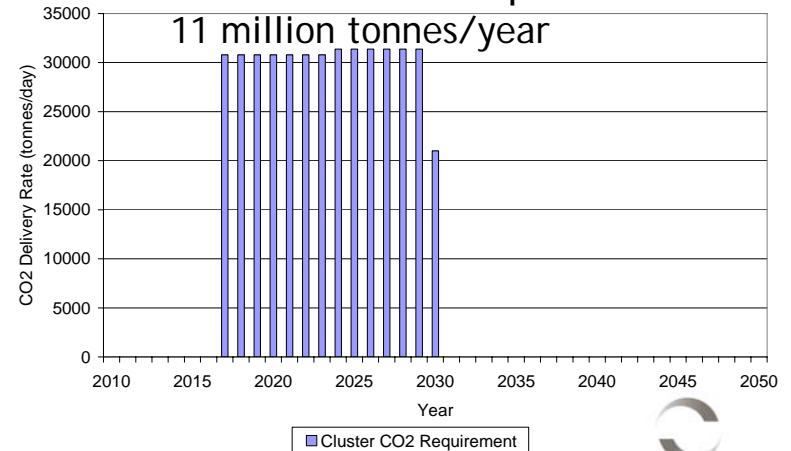
Cluster CO2 EOR Evaluation

- CO2 is miscible with reservoir oil at current operating pressure in Scott; more problematic in Buzzard
- Incremental oil 237 million barrels for P70 and 331 million barrels for P30
- Spread over 2018-2043
- CO2 delivered 155 million tonnes at around

Oil Recovery Rate

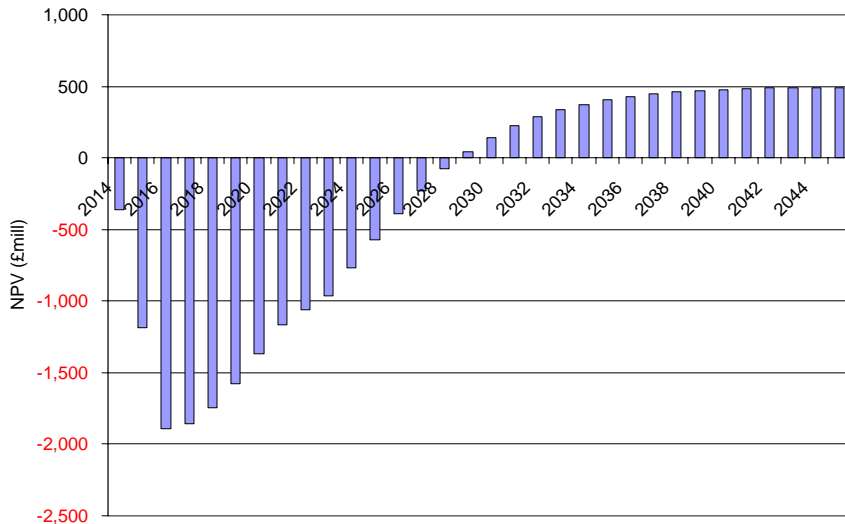


Delivered CO2 Requirement



Cluster CO2 EOR Economic Evaluation

P70 Cluster Discounted Cash Flow



- Capital costs for converting facilities at Scott estimated at £1.2 billion and at Buzzard £700 million (total including Claymore £3.1 billion)
- Operating costs estimated at Scott £45 million per annum and at Buzzard \$55 million per annum

- Price assumptions
 - Oil £50 (\$70) per barrel
 - CO2 neither cost nor subsidy
- Discounted cash flow calculations give internal rate of return 13-18% (before tax)
- Unrisked

IRR Sensitivities

- Oil price \$50 to 200
 - IRR 7% - 33% P70
 - IRR 12% - 40% P30
- CO2 cost/subsidy €-50 (cost) to €100 (subsidy) per tonne
 - IRR <0% - 38% P70
 - IRR 6% - 41% P30



Conclusions from Single Field and Cluster EOR Evaluations

- Contrary to many expectations most North Sea oil fields cannot be used solely for CO₂ storage because produced fluids have been replaced by water
- The redevelopment of a mature North Sea field for CO₂ EOR is a major undertaking equivalent in complexity, scale and cost to the original development
- Each project will need to be the subject of detailed engineering design and economic appraisal including a full assessment of the risks
- Unrisked CO₂ EOR may be viable in the North Sea fields at an oil price of \$70 per barrel or above
- Taking risks into account, it is unlikely that CO₂ EOR will be viable in North Sea fields at an oil price less than \$100 per barrel
- If a subsidy is available for the CO₂ stored then the project could be economic at an oil price significantly lower than \$100 per barrel
- CO₂ EOR has never been applied offshore so early projects will carry significant additional technical and financial risks
- Development of a CCS infrastructure in Scotland could lead to the application of CO₂ EOR in some fields