# How Can the North Sea Oil and Gas Industry be Revitalised?

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University of Aberdeen

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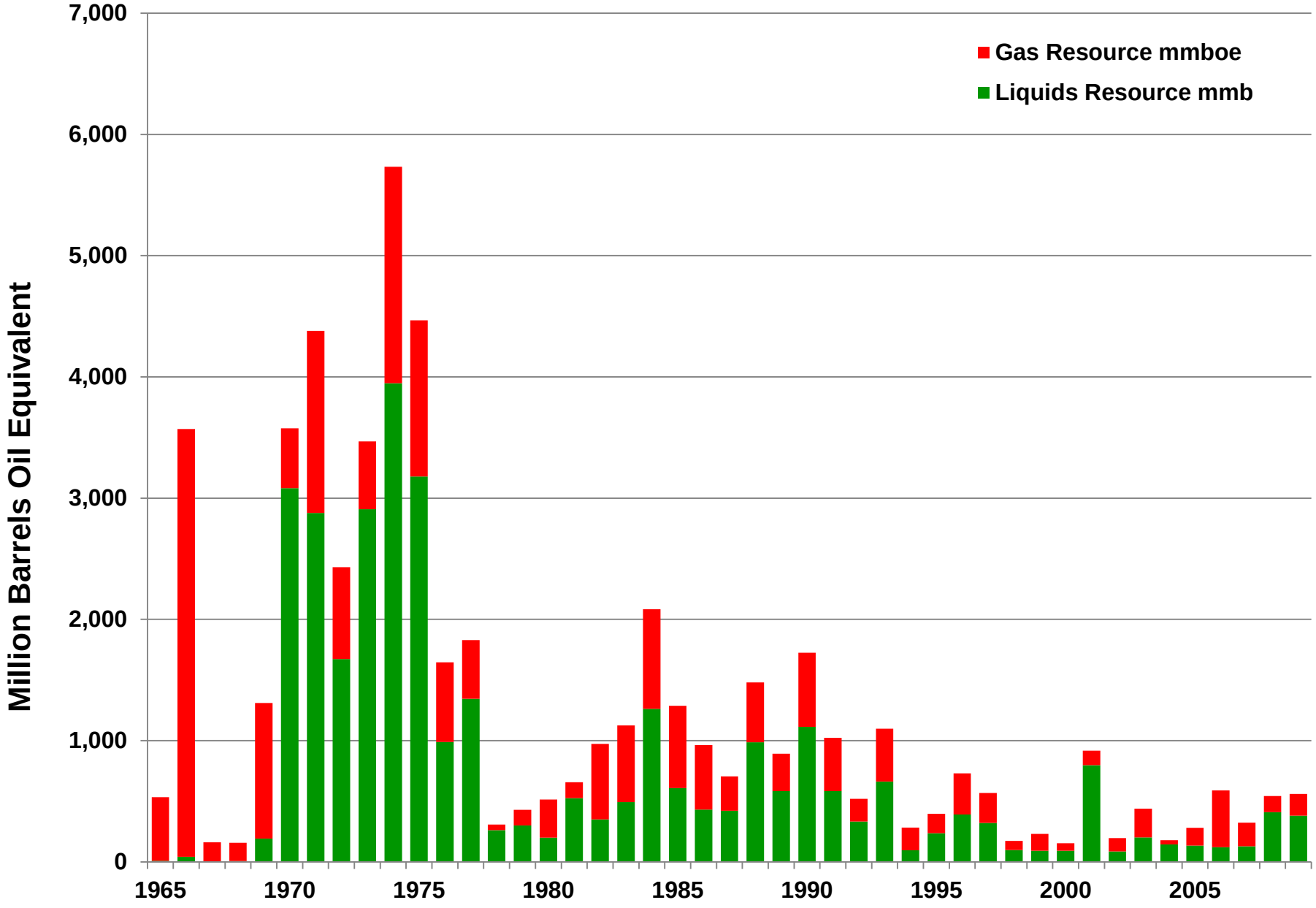
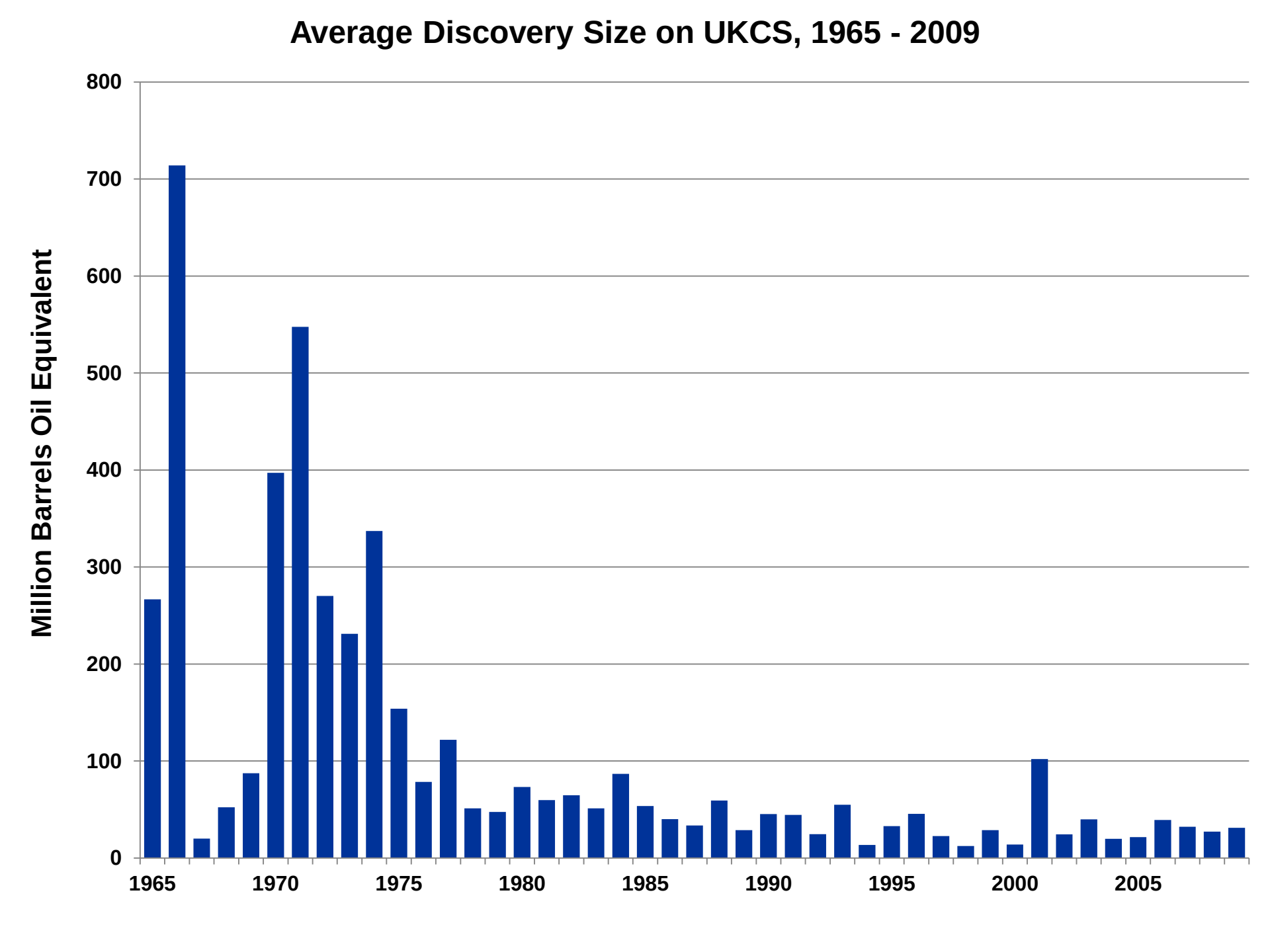
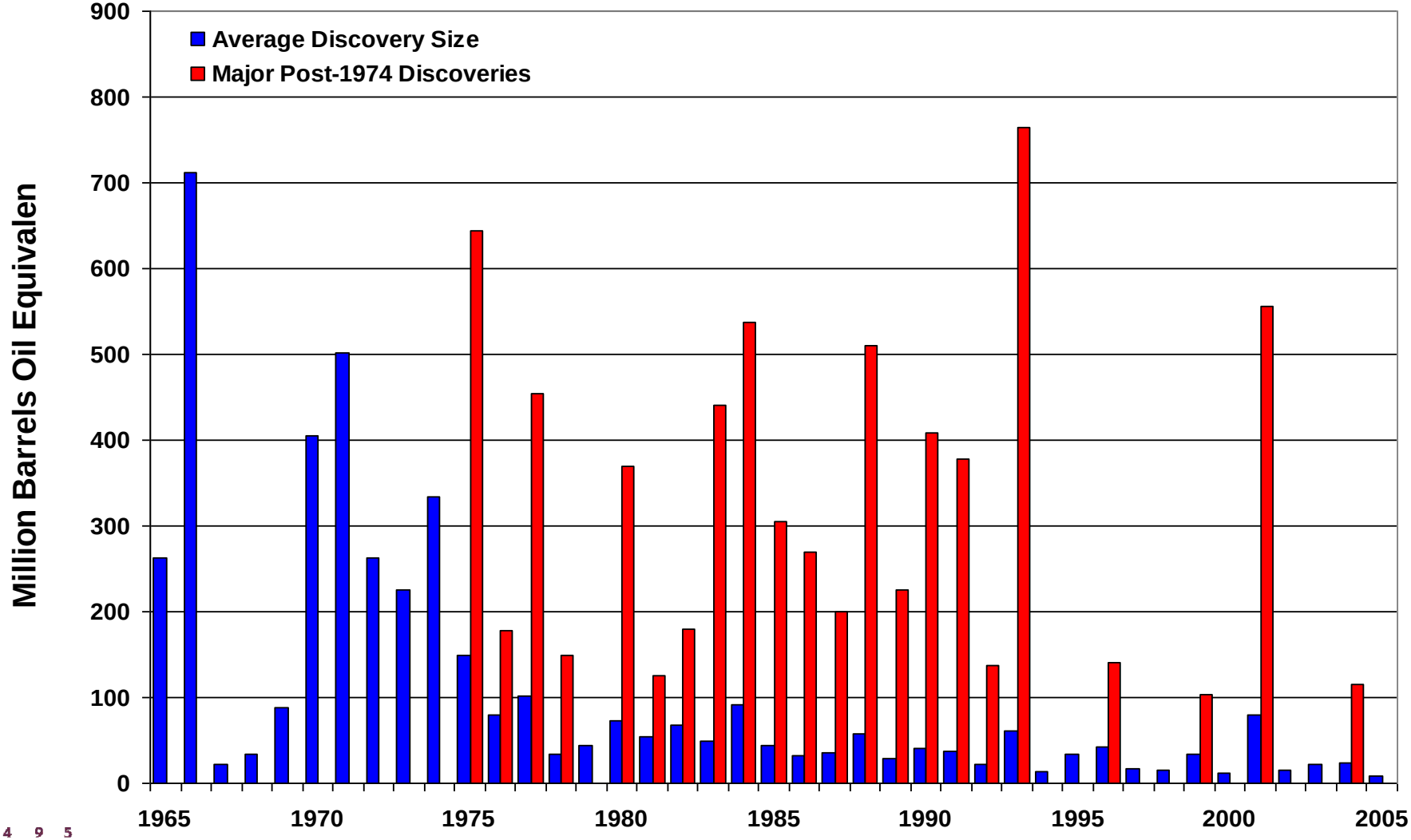
# Resource Discovery on UKCS, 1965 - 2009




Average Discovery Size on UKCS, 1965 - 2009
Million Barrels Oil Equivalent
800
700
600
500
400
300
200
100
0
1965
1970
1975
1980
1985
1990
1995
2000
2005

# Average Discovery Size on UKCS, 1965 - 2005, with Major Post-1974 Discoveries

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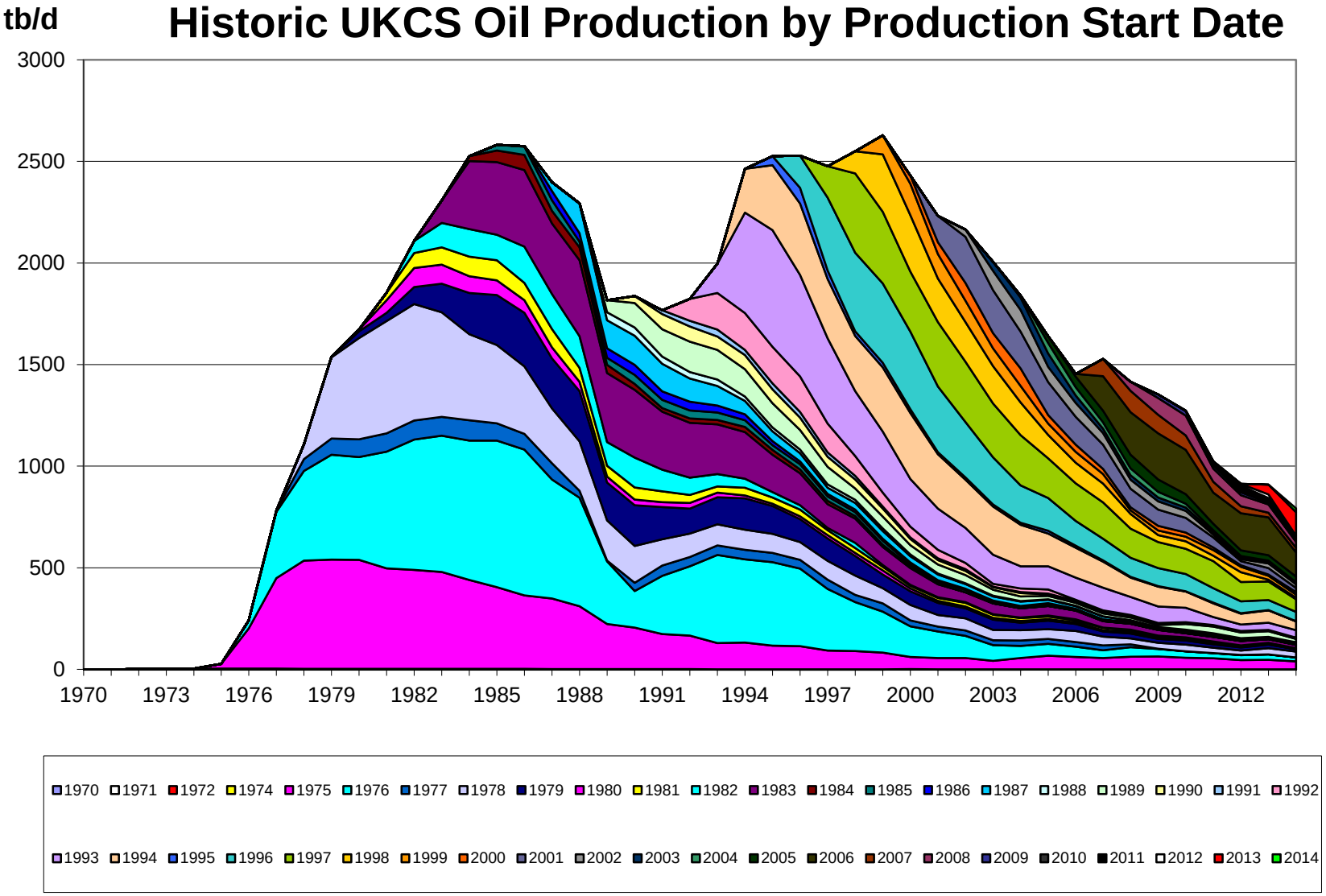
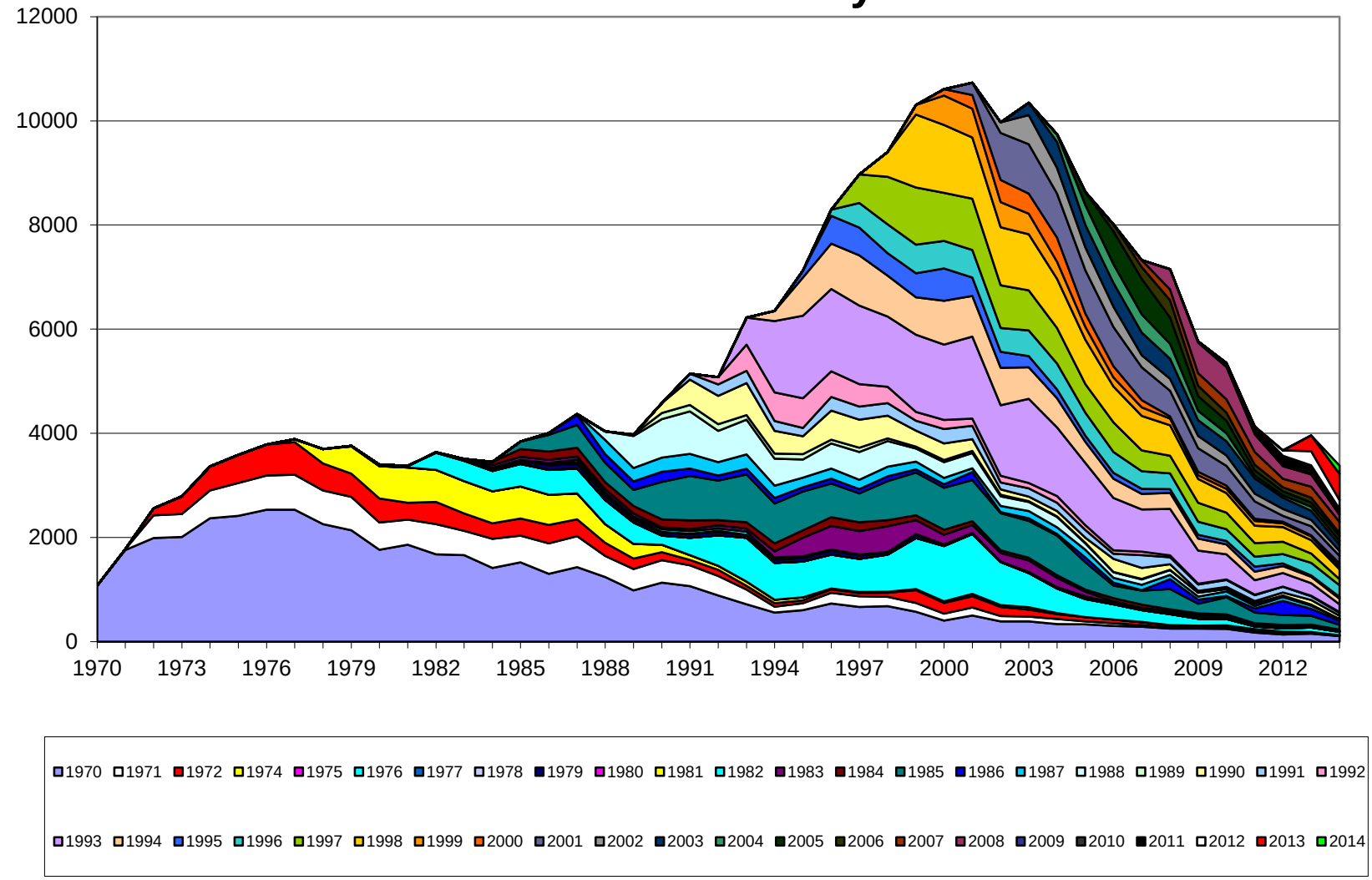
# Historic UKCS Oil Production by Production Start Date



# Historic UKCS Gas Production by Production Start Date

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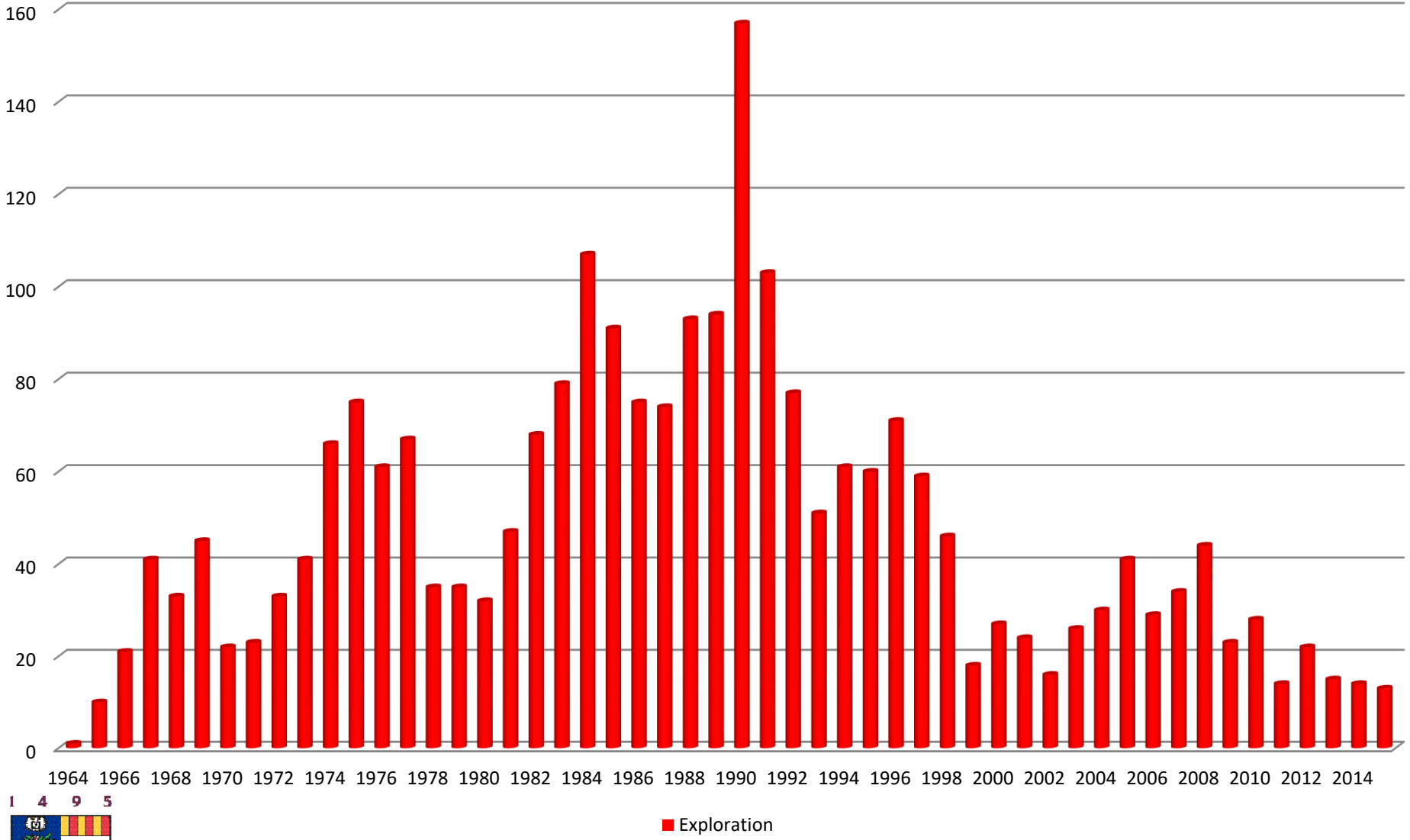
# Exploration Wells Drilled in UKCS 1964-2015

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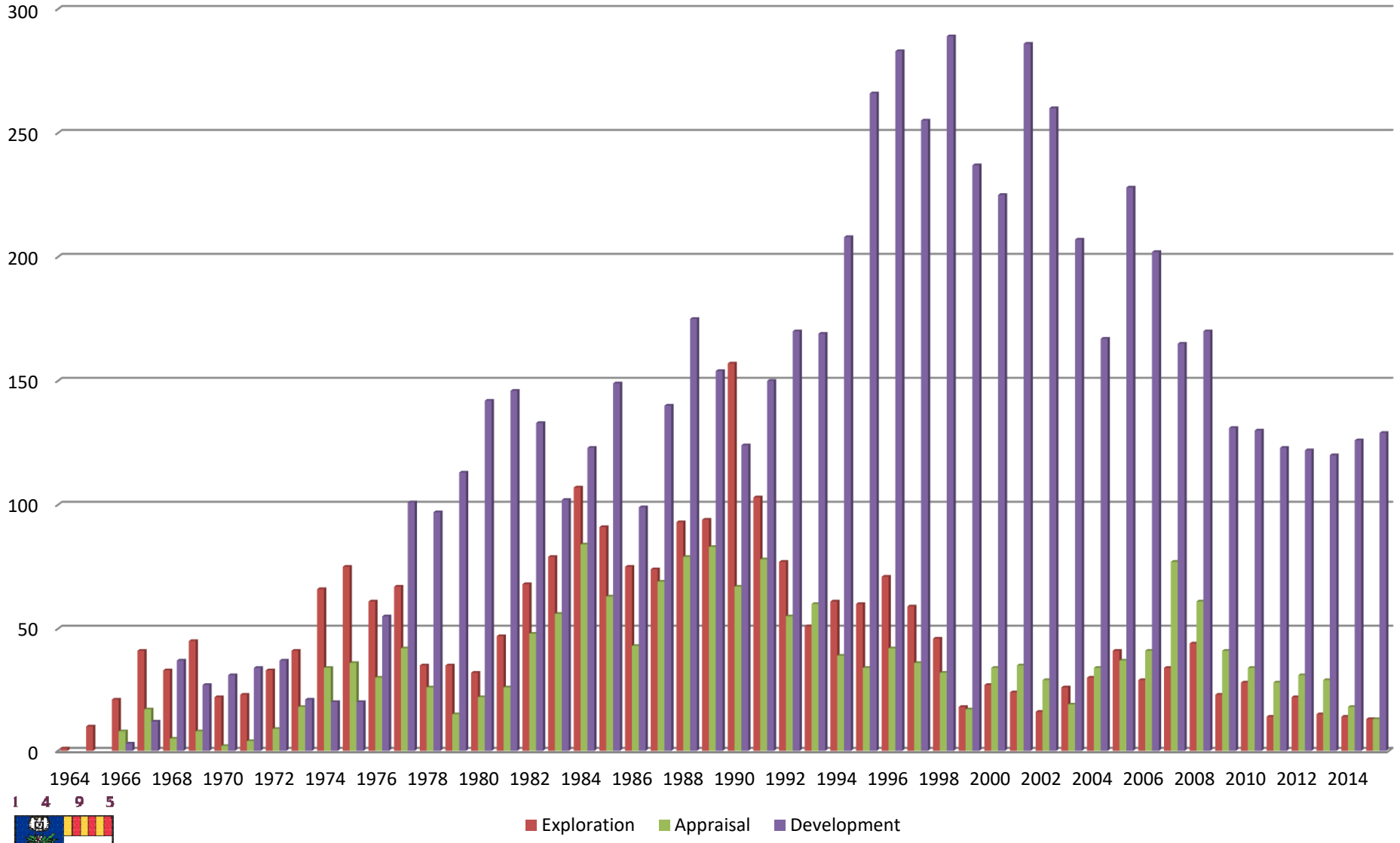
Source: OGA

# Total Wells Drilled in UKCS 1964-2015

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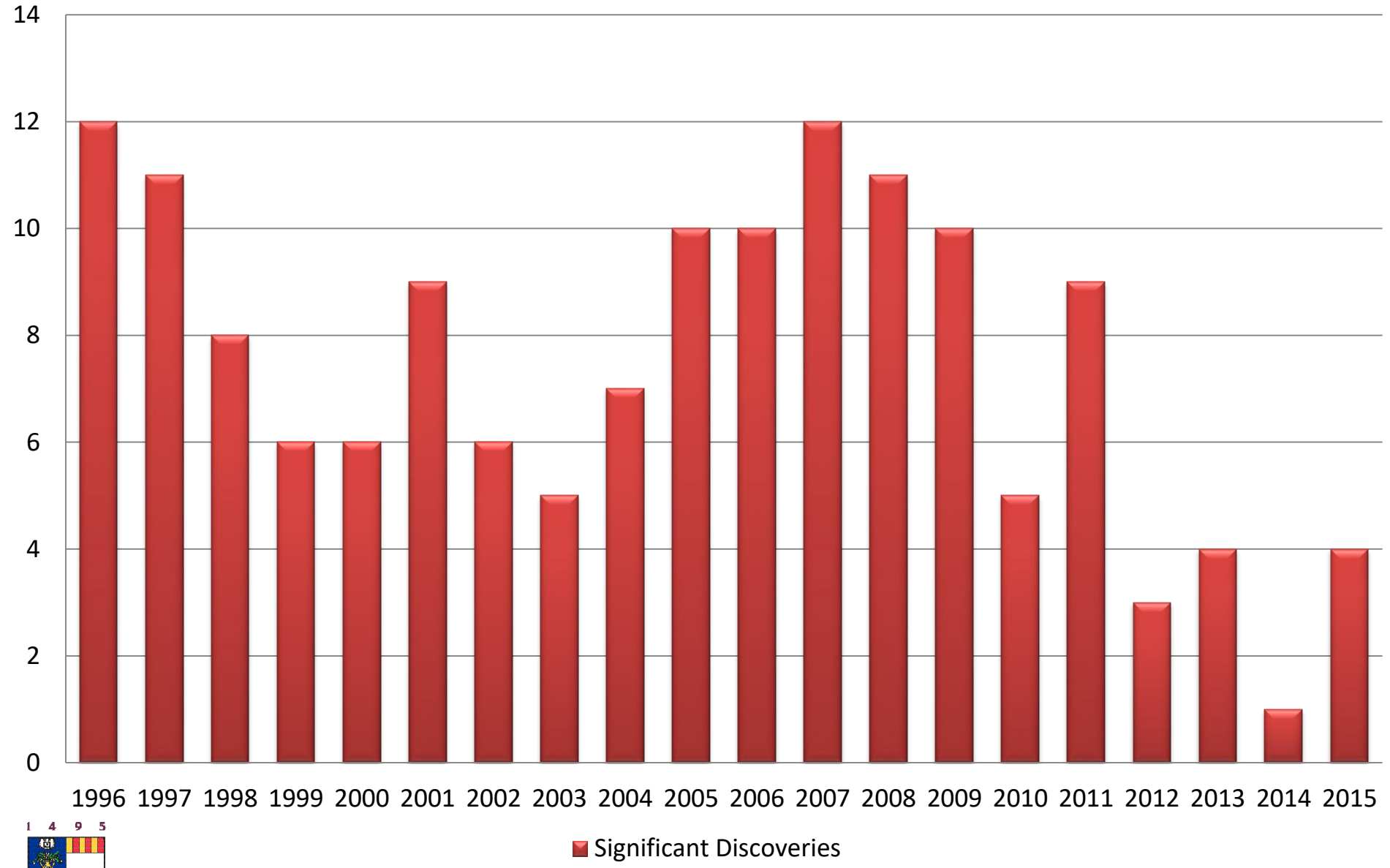
Source: OGA

# Significant Discoveries

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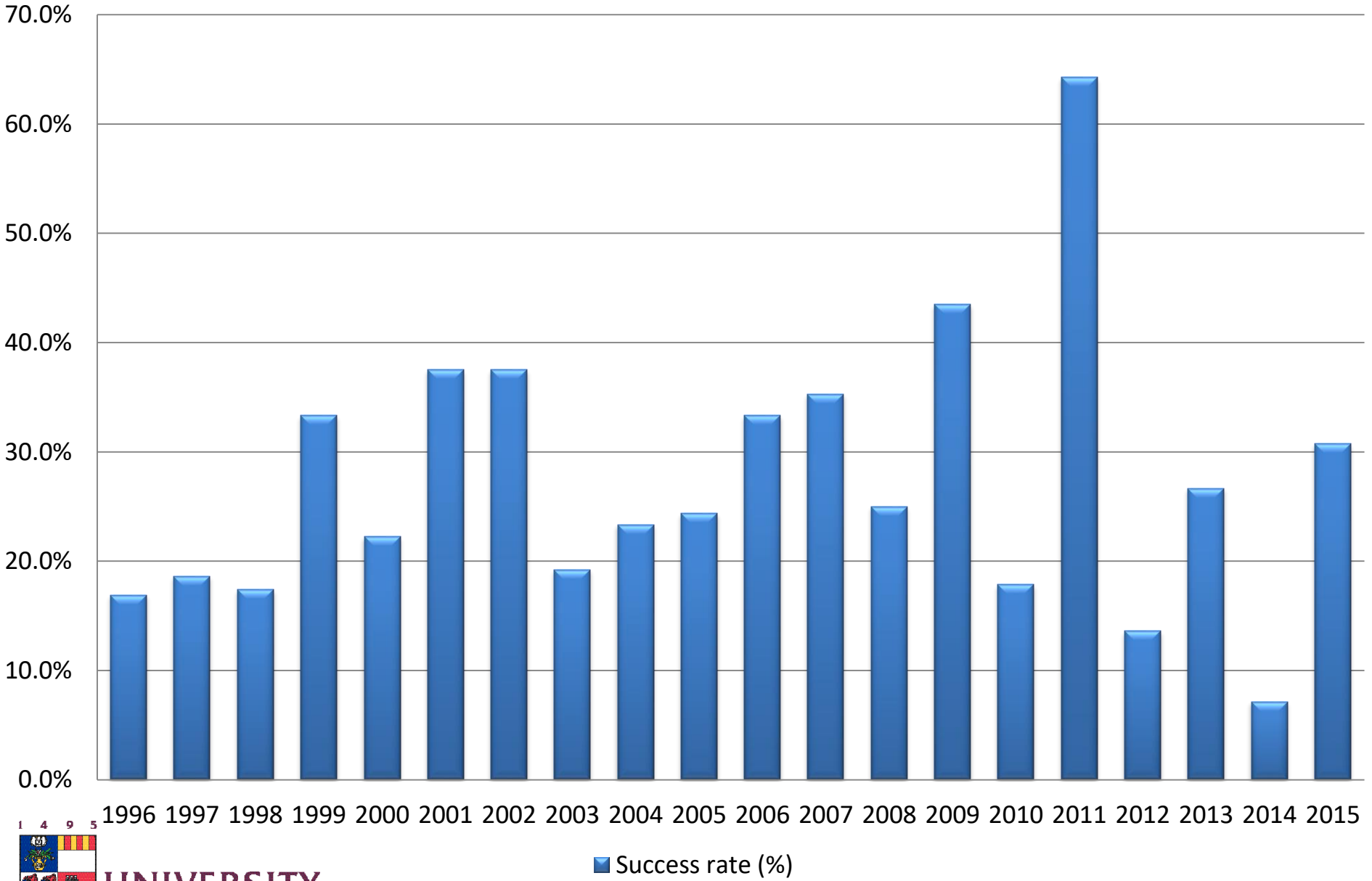
Source: DECC

# Exploration Success rate (%)

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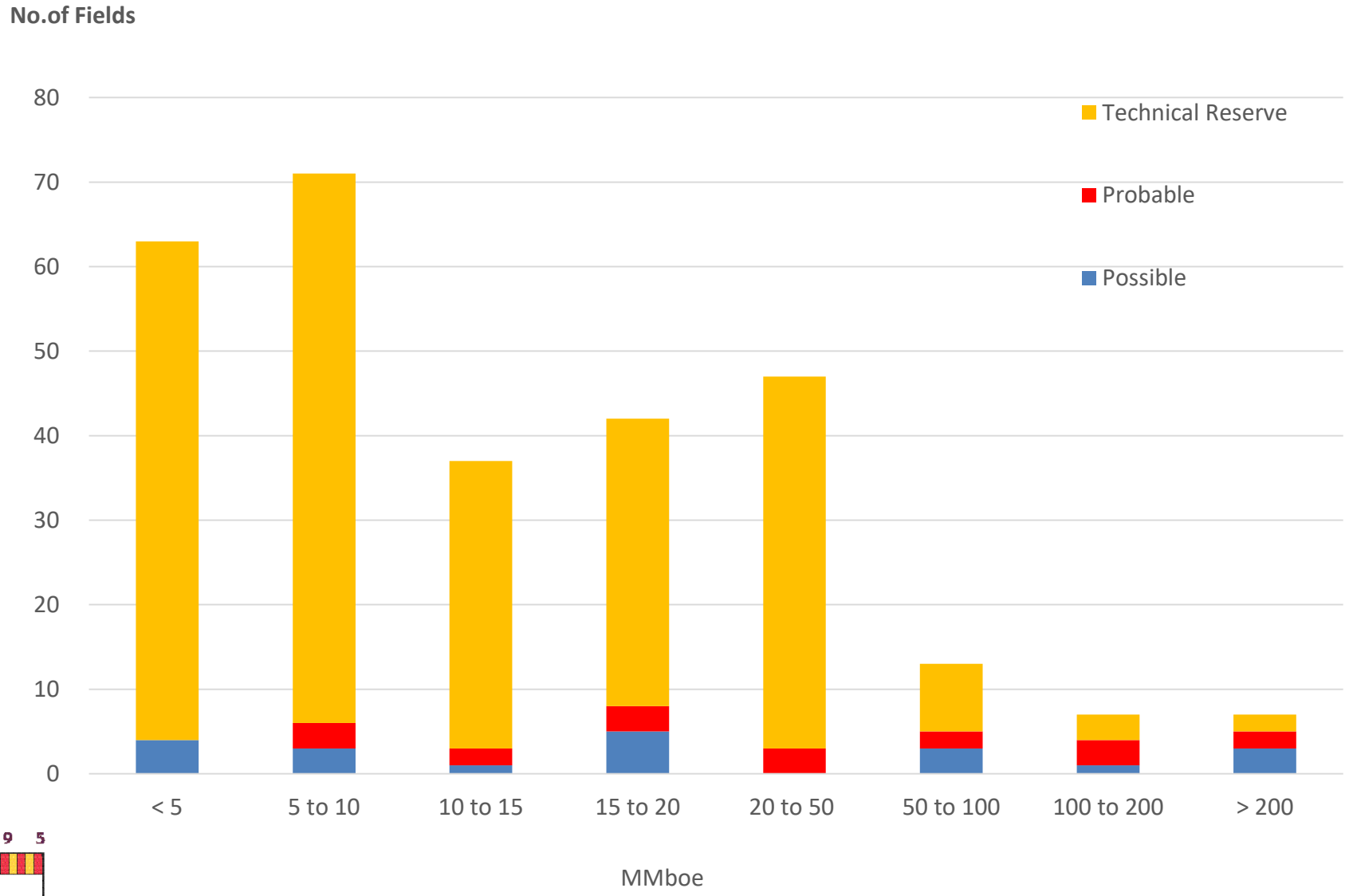
Source: DECC

# Undeveloped Discoveries

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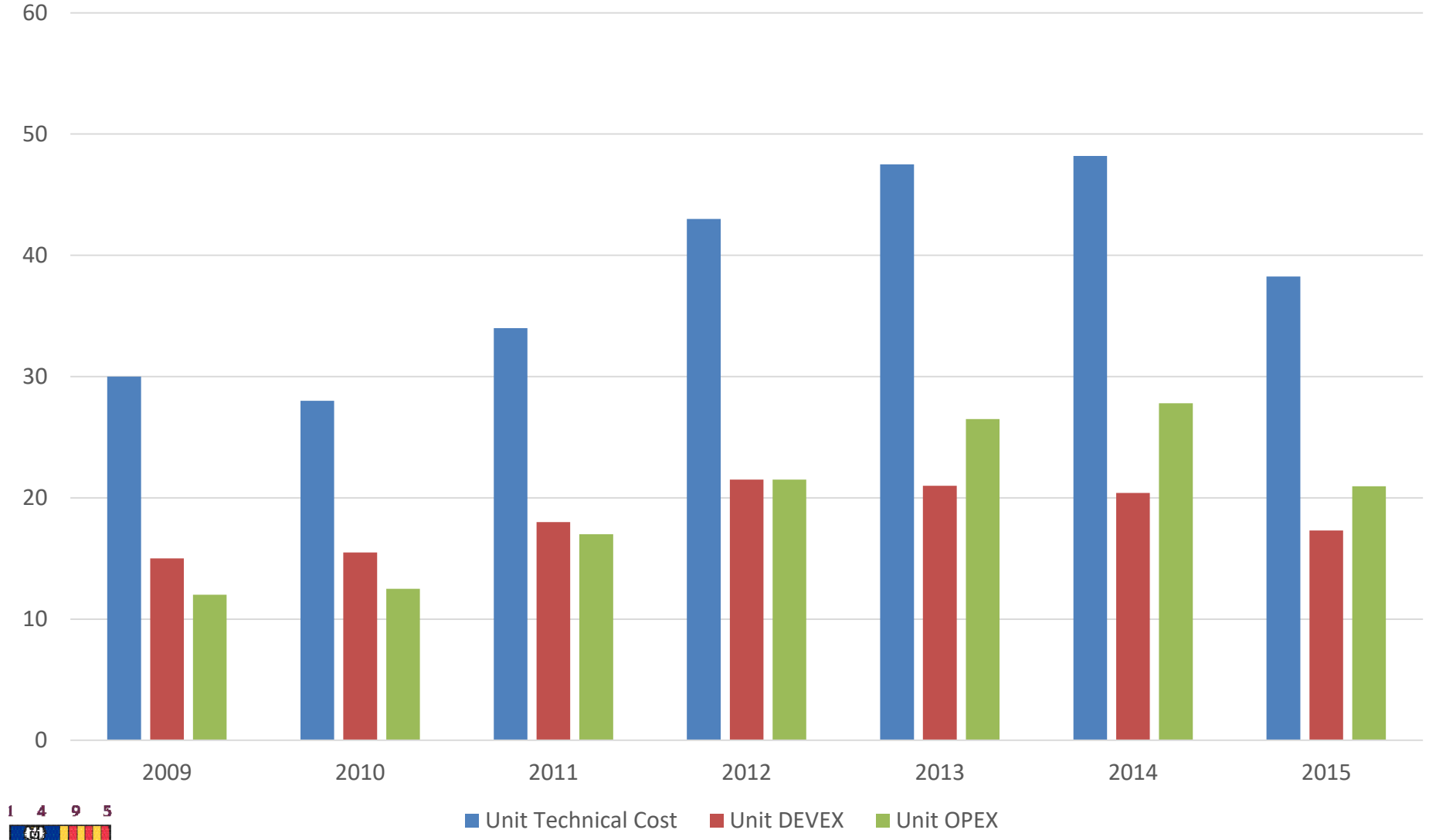
# Unit Cost ($/boe, MOD)

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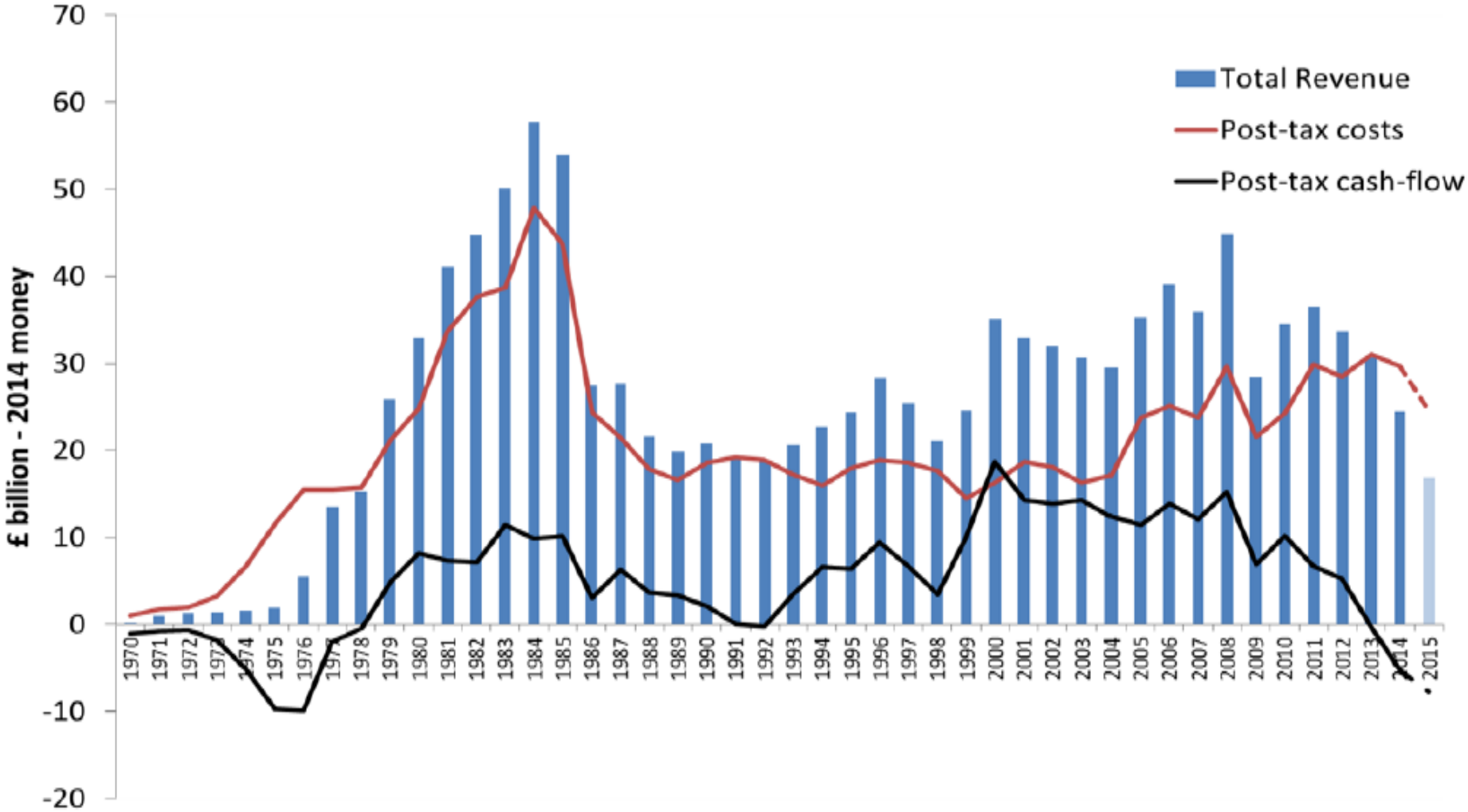
Source: OGUK

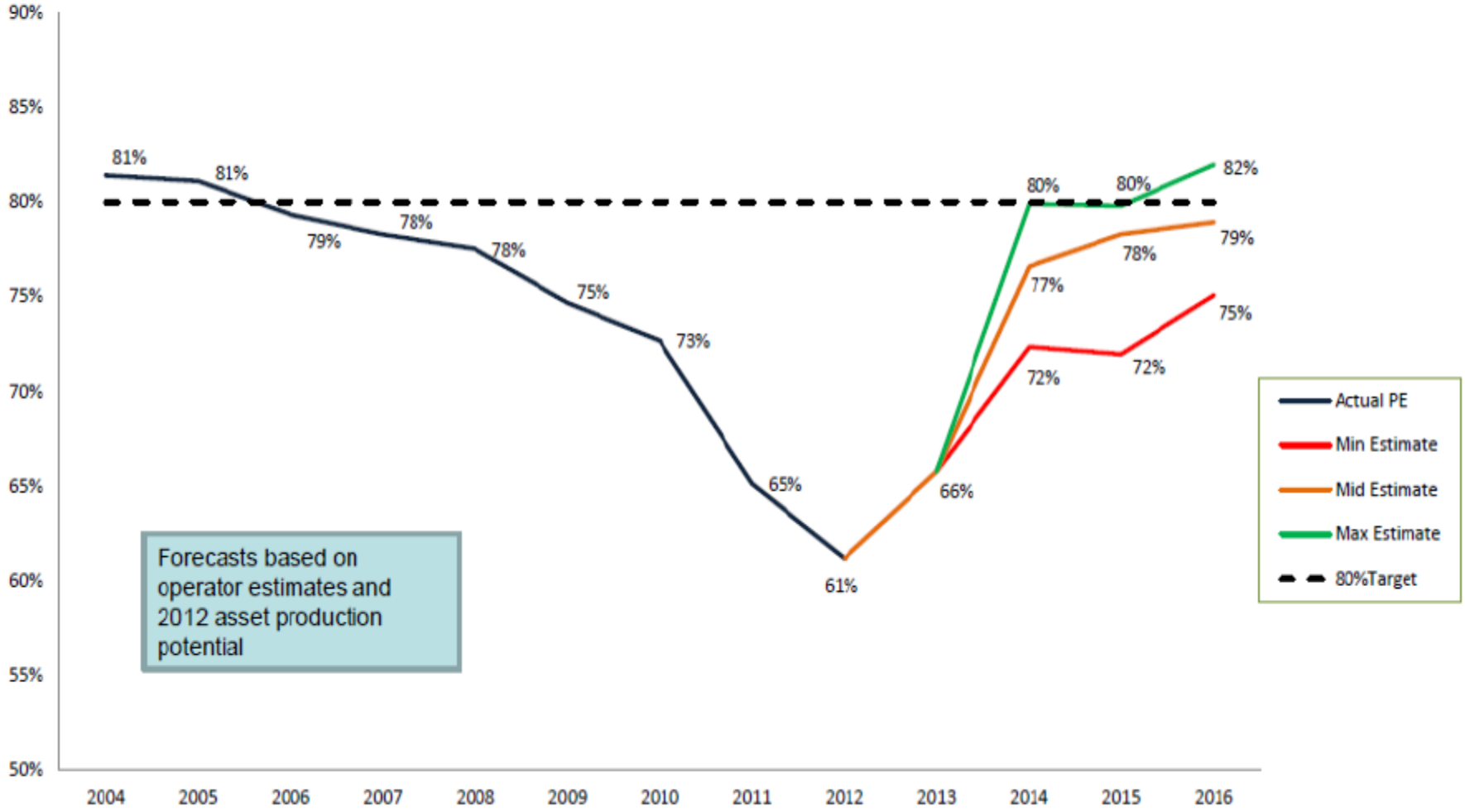
# Cash Flows from the UKCS



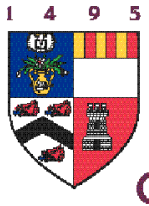

Source: Oil & Gas UK

# Production efficiency

## UK Continental Shelf PE (actual and forecast)



# Economic Model

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Large financial simulation model incorporating Monte Carlo technique for risk analysis. Model incorporates all evolving taxation arrangements since 1960's. Large field database with following features:

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a) Historic production, investment costs (drilling and facilities separately), operating costs (tariffs separately), decommissioning costs.

b) Data on sanctioned fields, probable and possible fields and incremental projects relating to future activity. These incorporate key data and expected phasing through time.

c) Currently numbers of fields are as follows:

| | |
|---|---|
| (i) Sanctioned fields | 379 |
| (ii) Incremental projects | 171 |
| (iii) Probable fields | 23 |
| (iv) Possible fields | 20 |

d) Separate database of fields classified as technical reserves. Information from private and public sources. Total number currently is 254. Some were formerly in possible category where substantial data exist. For many only data relate to location, type (oil, gas, condensate), block number, and expected size of reserves.

e) Future incremental projects. Current incremental projects are generally planned to be executed over 3-year period. Future incremental projects are modelled to continue trends in sizes, costs, types, and locations experienced over the last few years. A 5-year running average of past trends employed to make projections. Such data includes the considerable numbers of incremental projects where there is no directly attributable income.


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# New discoveries modelled according to the following procedures:

a) Exploration effort based on combination of (i) trend since 2000 and (ii) prospective oil/gas price behaviour (sustained). ($90, 58 pence and $70, 45 pence)

b) Success rates based on combination of (i) experience in period since 2000 and (ii) size of effort. In relation to (ii) it is assumed that higher effort is associated with more discoveries but lower success rate than with medium effort. Similarly with medium. For whole of UKCS success rates:

under High Effort = 25%

Medium Effort = 28%

Technological progress maintains these success rates in the period to 2050.

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c) The aggregate historic data on (i) exploration effort and (ii) discoveries were disaggregated according to main regions, namely SNS, CNS/MF, NNS, WOS and IS. Regional trends were established for exploration effort, discoveries and success rates. This includes splitting according to type (oil, gas and condensate).

d) Using the above information the Monte Carlo technique was employed to project discoveries in all 5 regions in the period to 2045.

e) In the Monte Carlo modelling it was assumed that the size distribution of discoveries would be lognormal following historic evidence. The SD was set at 50% of the mean value. The mean size of field declines through the period, again based on historic evidence. Monte Carlo modelling was also used to calculate the field development costs. For each region the average development cost (per boe) of fields sanctioned recently and the probable and possible fields was calculated. The SD was assumed to be 20% of the mean.

# Investment Hurdle Criteria

NPV (post tax) / I (pre tax) ≥ 0.3/ ≥ 0.5
with discount rate
of 10% in real terms

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# Operation of Model

The model calculates the post-tax returns on the probable and possible fields, and the new discoveries as they are made. If they pass the investment hurdle they go ahead. The fields in the technical reserves category are then tested. Generally there is no knowledge of the possible timing of any developments.

# Operation of Model

To determine the order in which they may be developed each field is given a number and the Monte Carlo technique is used to draw randomly from a uniform distribution.

A selected field is then tested against the investment hurdle criterion. If it passes and the total for the year is within the financial and capacity constraint the development proceeds.

# Operation of Model

If it fails the investment hurdle it does not proceed. Generally it was found that in the early years not many technical reserves fields were called on. In (much) later years when the numbers of fields in the probable, possible and new discoveries categories were low more technical reserves were called on. But many failed investment hurdle.

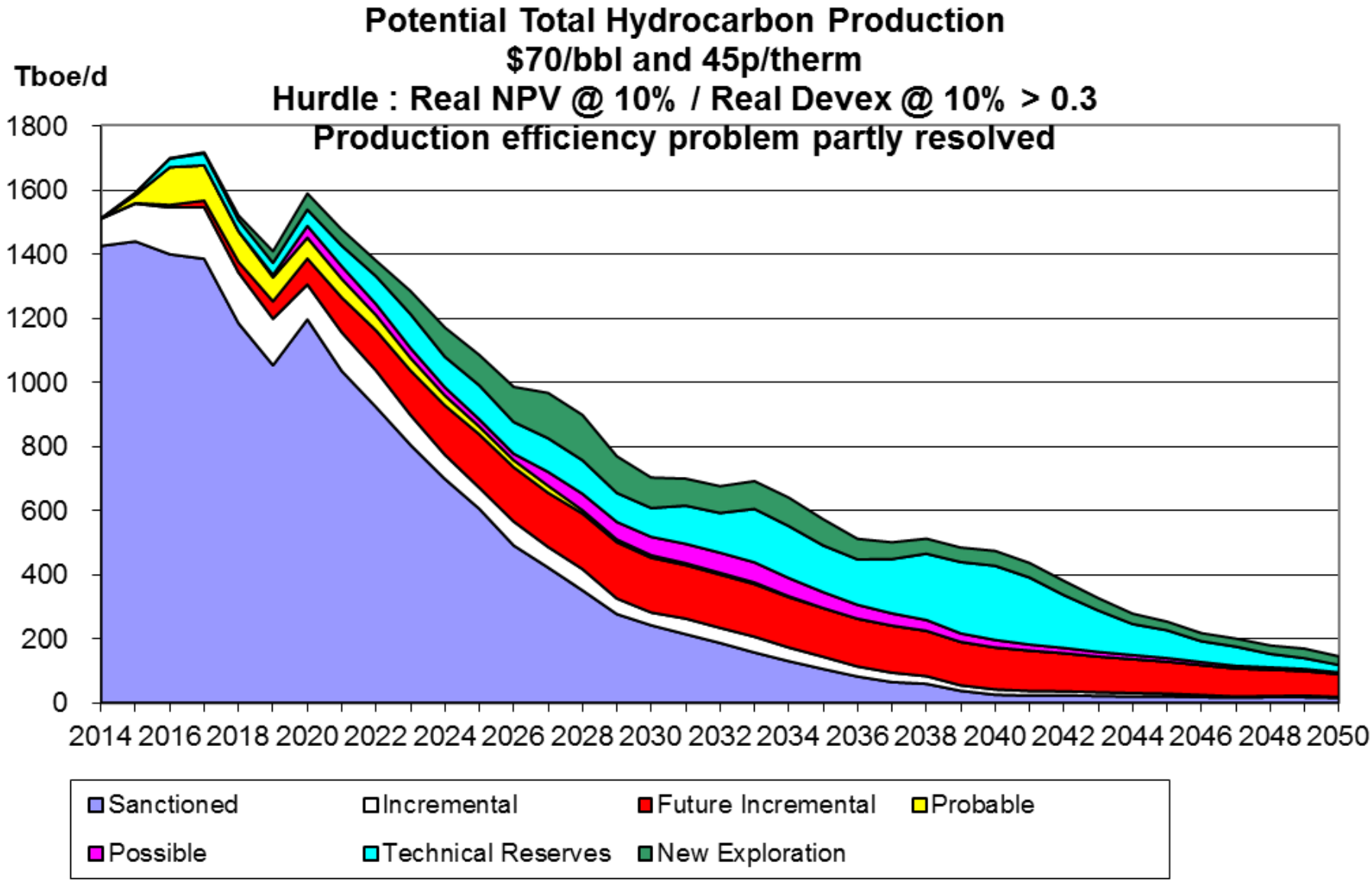
# Production Efficiency Assumptions

Two cases are modelled. The first, termed Production Efficiency Problem Largely Resolved, assumes that over the next 5 years production efficiency in sanctioned fields is at 72% and subsequently at 80%. The “loss” of production in the interim is recovered in the period to 2025 as a set amount each year based on the average loss.

# Production Efficiency Assumptions

The second case, termed Production Efficiency Problem Partly Resolved, assumes that over the next 5 years production efficiency in the sanctioned fields averages 60% after which it recovers to 80%. The “loss” of production in the interim is not recovered.

# Some Results of Future Activity in the UKCS using Financial Simulation including Monte Carlo Technique

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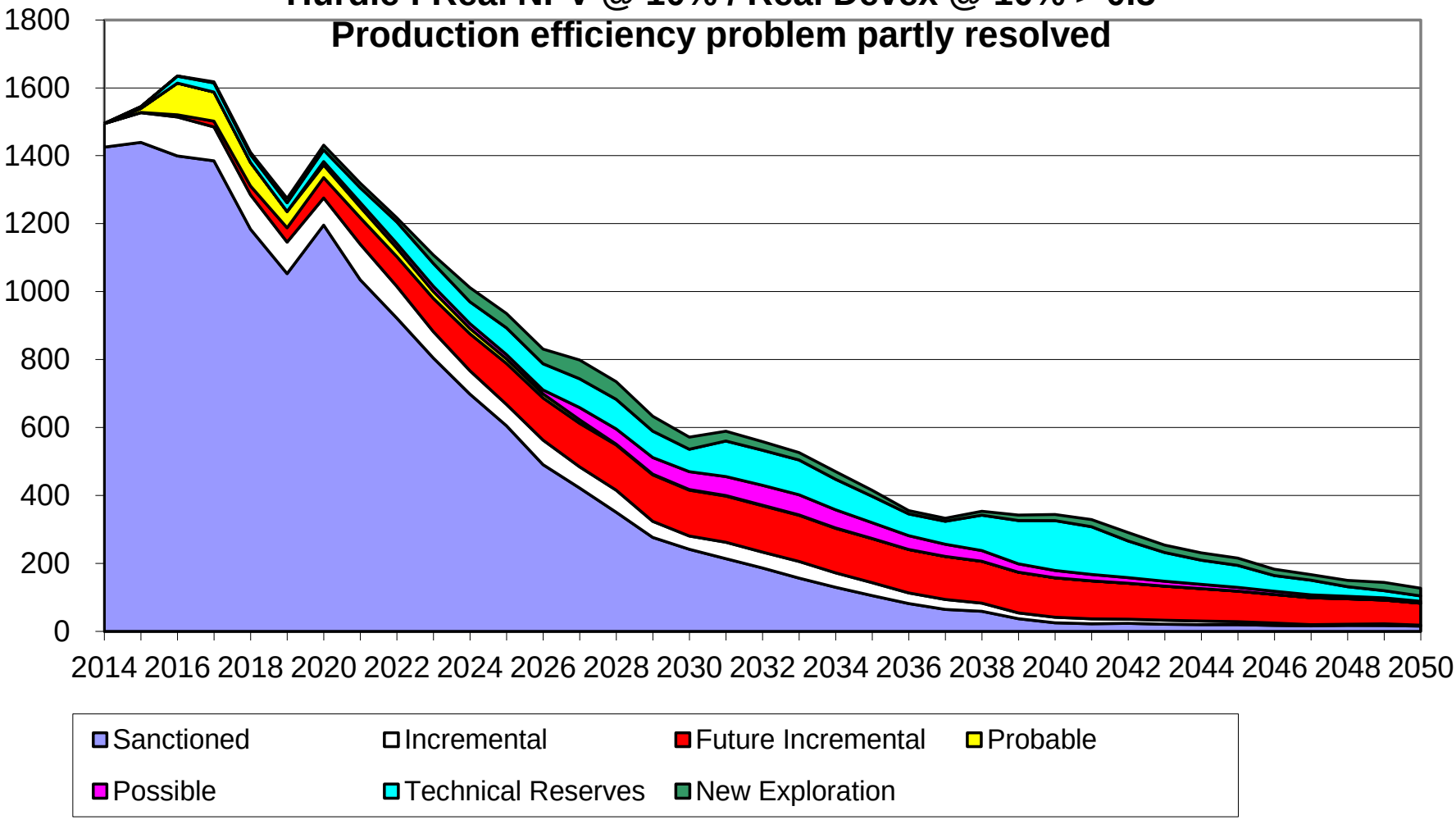
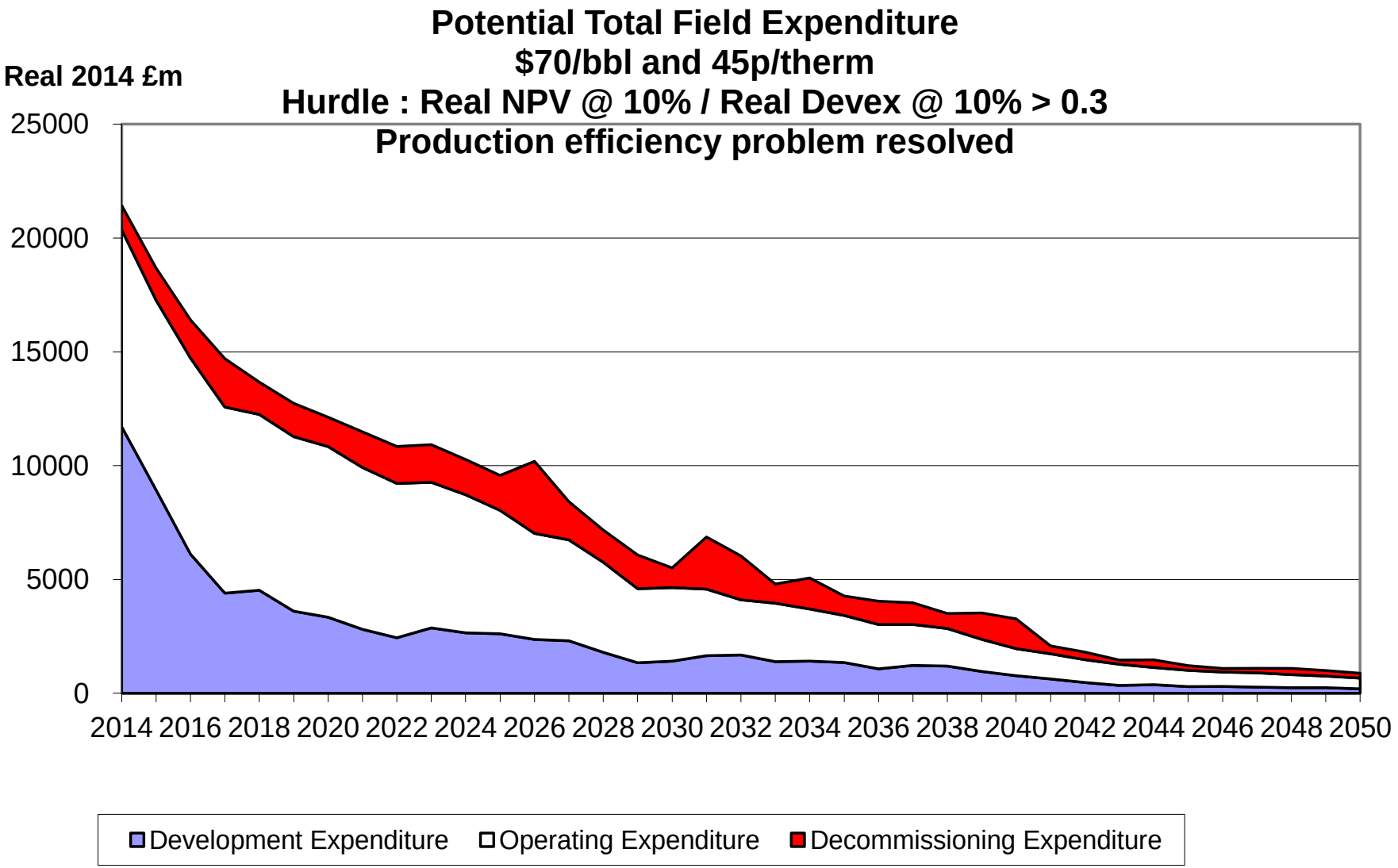
# Potential Total Hydrocarbon Production
## $70/bbl and 45p/therm
## Hurdle : Real NPV @ 10% / Real Devex @ 10% > 0.5
## Production efficiency problem partly resolved



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# Cumulative Hydrocarbon Production (UKCS)

| Real Price | 2014-2050, bn boe | |
|---|---|---|
| $70, 45 pence | NPV/I > 0.3 | NPV/I > 0.5 |
| Production Efficiency Problem Resolved | 11.9 | 10.4 |
| Production Efficiency Problem Unresolved | 11.0 | 9.5 |

# Cumulative Expenditures (£bn.2014)

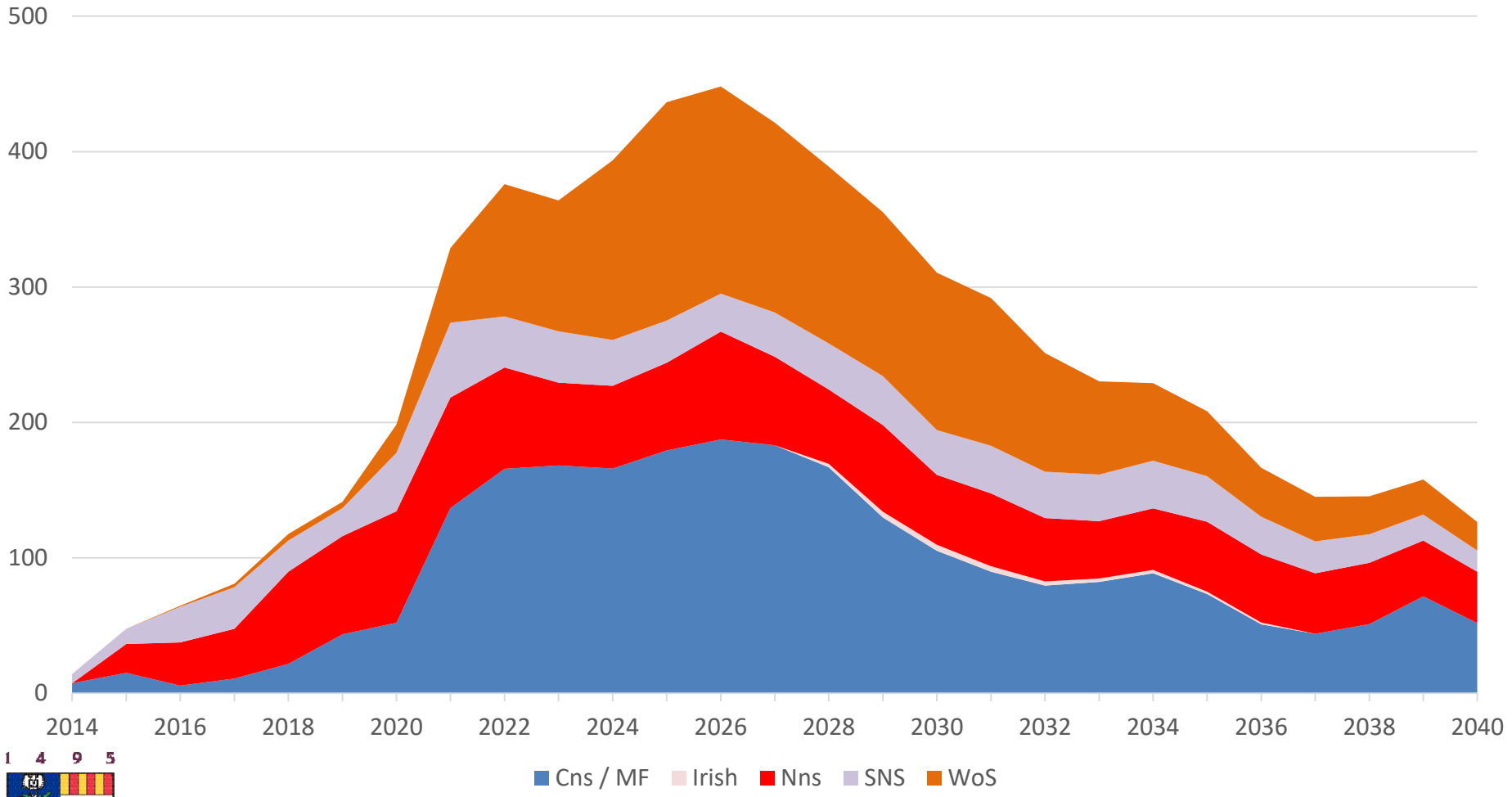
| | |
|---|---|
| Development | 81.4 |
| Operating | 135.0 |
| Decommissioning | 41.8 |
| **TOTAL** | **258.2** |

| UK Oil and Gas Reserves and Resources (bnboe) | | | |
|---|---|---|---|
| | Low | Central | High |
| Reserves | 3.9 | 6.3 | 8.2 |
| Contingent Resources | 0.6 | 1.4 | 2.6 |
| PAR | 1.5 | 3.6 | 7.2 |
| Undiscovered Resources (Risked) | 1.9 | 6.0 | 9.2 |

Source: OGA, July 2016

Investment Allowance of 62.5%, plus Cost Reductions of 15% and SC at 20%
$70/bbl and 45p/therm

## Change in Potential Hydrocarbon Production
## SCT 20% Uplift 62.5% Devex and Opex reduced by 15%
## $70bbl and 45p/therm
## Hurdle : Real NPV @ 10%/Real Devex @ 10% > 0.3

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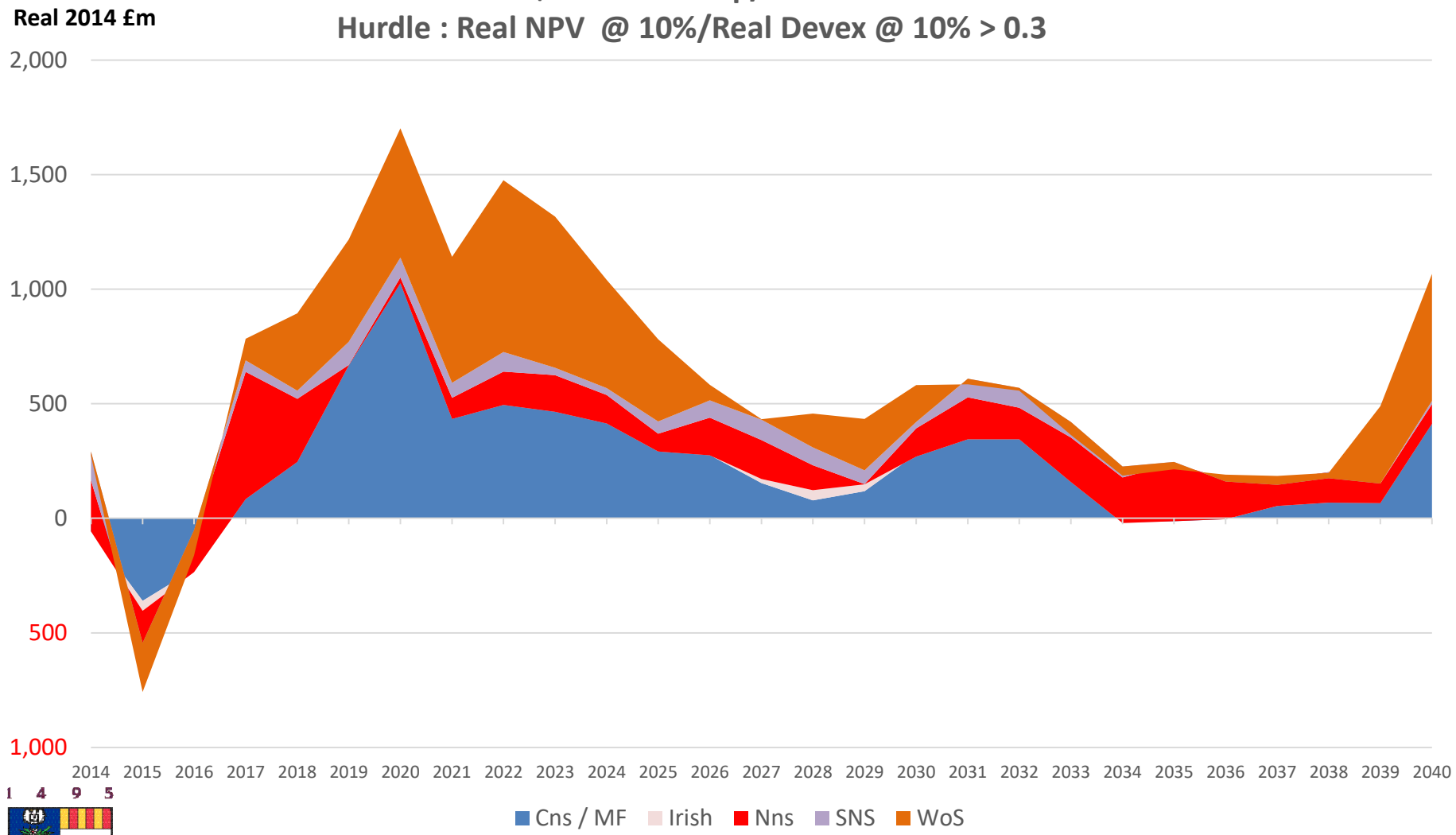
# Change in Potential Development Expenditure
## SCT 20% Uplift 62.5% Devex and Opex reduced by 15%
## $70bbl and 45p/therm
## Hurdle : Real NPV @ 10%/Real Devex @ 10% > 0.3

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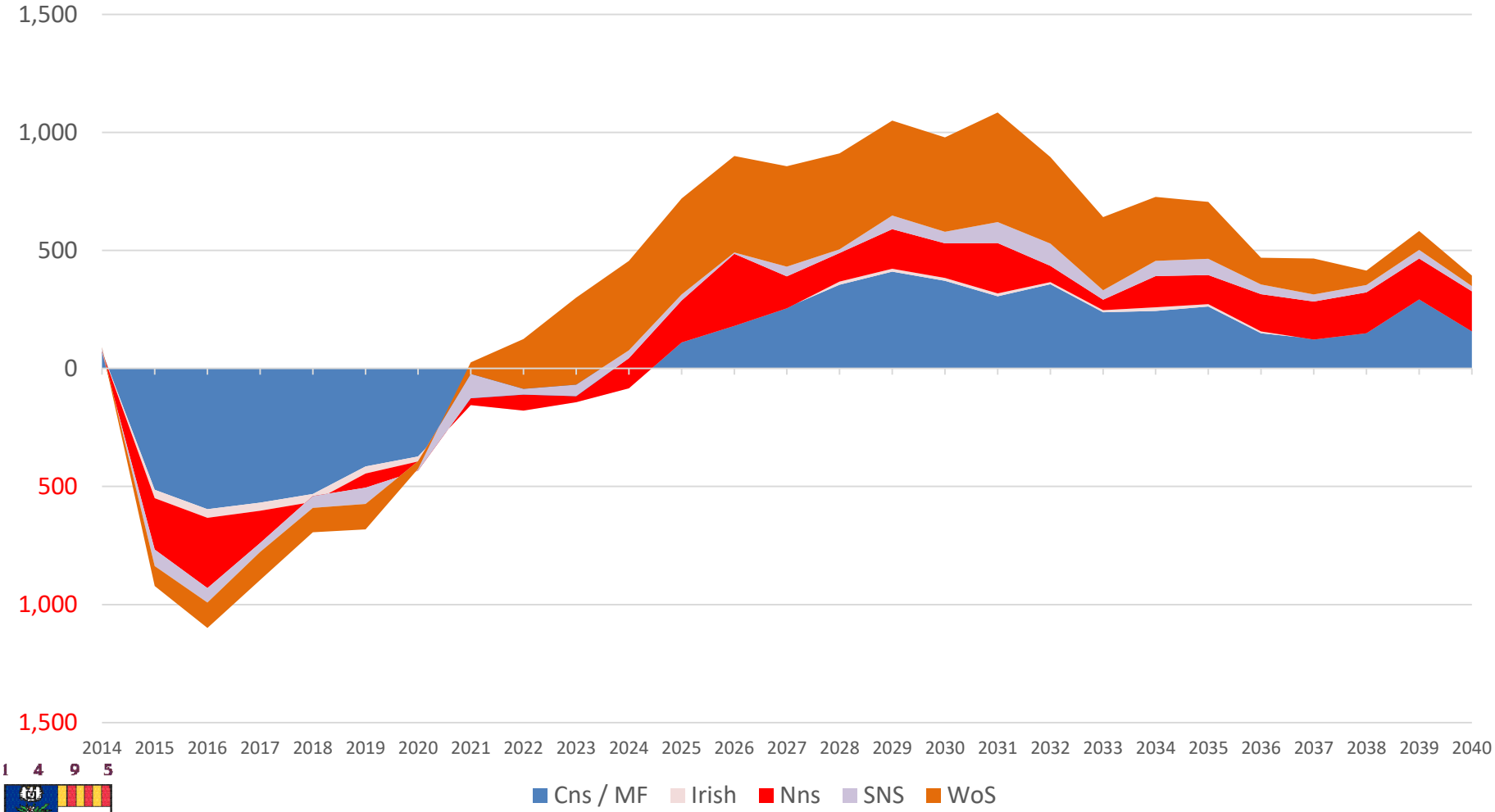
# Change in Potential Operating Expenditure
## SCT 20% Uplift 62.5% Devex and Opex reduced by 15%
## $70bbl and 45p/therm
## Hurdle : Real NPV @ 10%/Real Devex @ 10% > 0.3

Real 2014 £m

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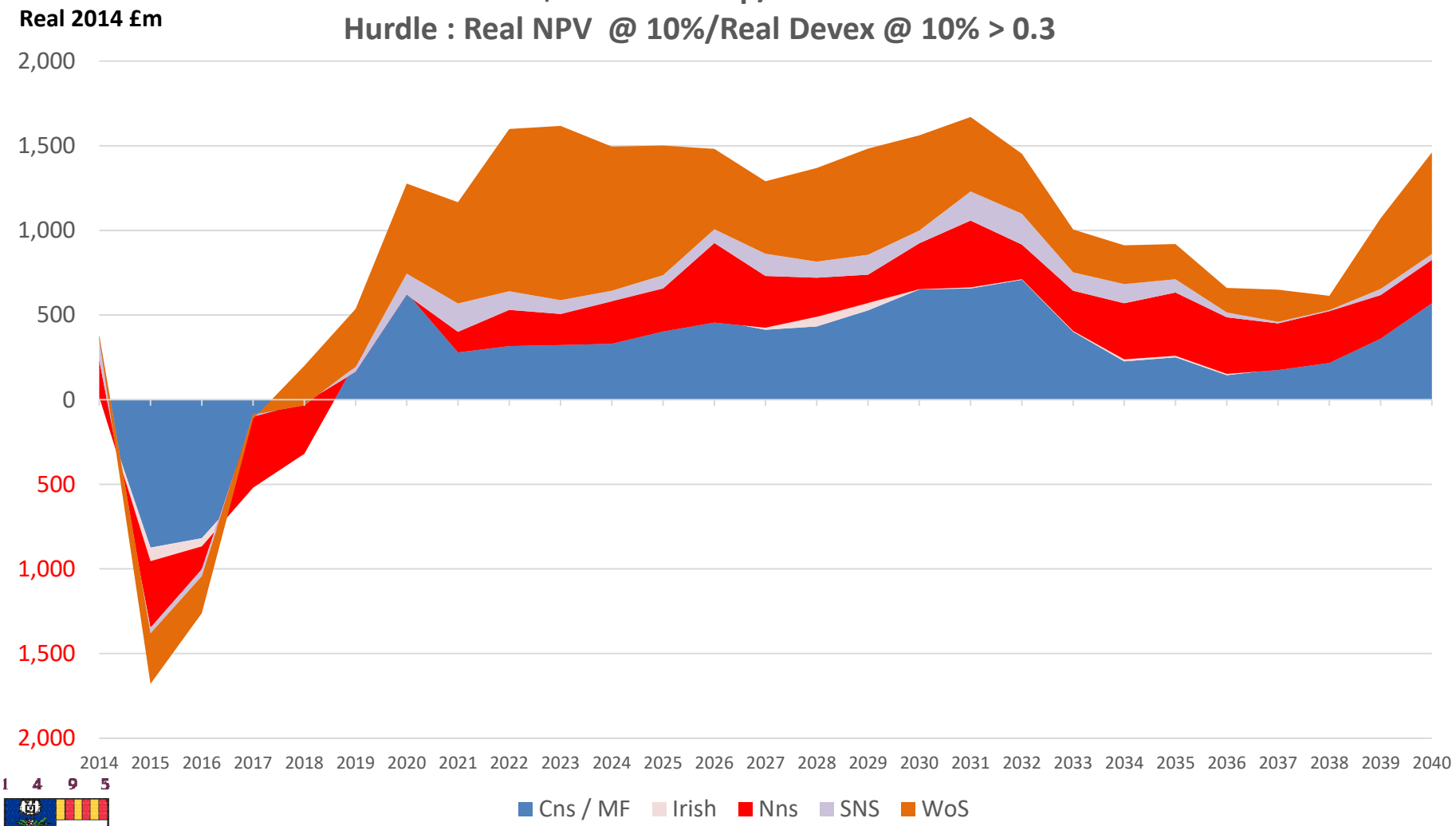
# Change in Potential Total Expenditure
## SCT 20% Uplift 62.5% Devex and Opex reduced by 15%
## $70bbl and 45p/therm
## Hurdle : Real NPV @ 10%/Real Devex @ 10% > 0.3

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# Change in period 2015-2050
## from 62.5% investment allowance + SC at 20% + cost reduction of 15%

| | |
|---|---|
| Cumulative production | + 2.8 bnboe |
| Cumulative field investment | + £22 bn |
| Cumulative field opex | + £23.4 bn |
| Cumulative decommissioning | + £2.8 bn |

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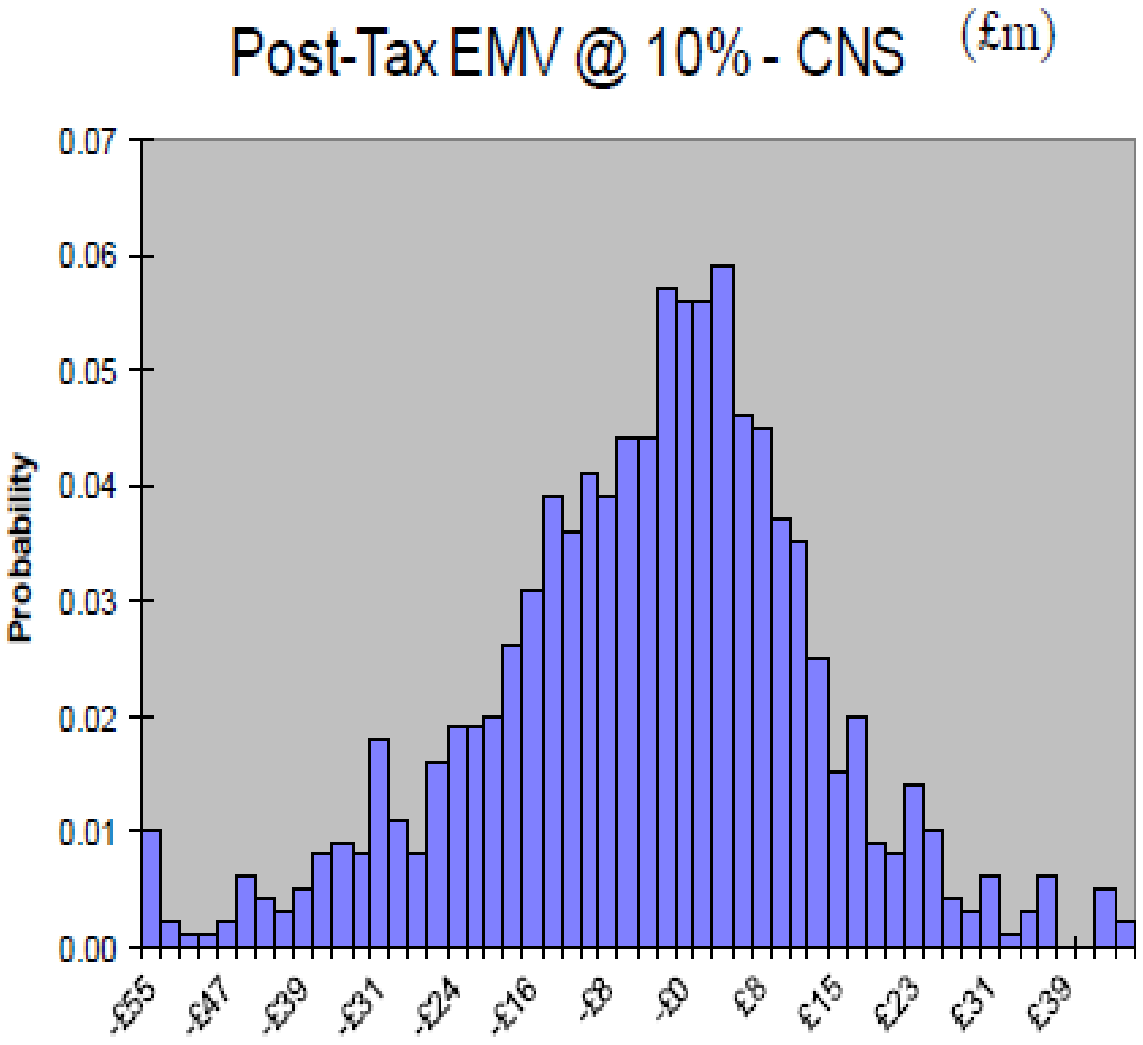
# Assumptions for Monte Carlo Modelling by Region After Cost Reductions

| | | Central North Sea | Southern North Sea | Northern North Sea | West of Shetlands |
|---|---|---|---|---|---|
| Exploration success | | 34.2% | 35.3% | 40% | 50% |
| Chance of Oil | | 82% | 0% | 88% | 75% |
| Chance of Gas | | 18% | 100% | 12% | 25% |
| Appraisal success | | 47.4% | 30% | 50% | 55.6% |
| Reserves | Average | 39.1 mmboe | 16.4 mmboe | 16.5 mmboe | 112.6 mmboe |
| | Minimum significant size | 8.5 mmboe | 3.55 mmboe | 3.6 mmboe | 24.4 mmboe |
| | Maximum significant size | 110 mmboe | 50 mmboe | 50 mmboe | 320 mmboe |
| Well costs for E & A | | £24.68m. | £14.1m. | £24.68m. | £30.85m. |
| Average devex per boe | | $23.67 | $11.392 | $17.152 | $15.82 |
| Minimum devex per boe | | $9.47 | $4.56 | $6.86 | $6.33 |
| Maximum devex per boe | | $37.88 | $18.23 | $27.44 | $25.32 |

# CNS - Project (Fast) Limited IA - Initial Price $55 p/b and 40p/therm Reduced Costs

| Post-Tax EMV@10% Statistics | |
|---|---|
| Trials | 1000 |
| Mean | -4.59 |
| Median | -3.07 |
| Standard Deviation | 18.31 |
| Variance | 335.08 |
| Skewness | -0.37 |
| Kurtosis | 2.56 |
| Coefficient of Variability | -3.99 |
| Minimum | -102.31 |
| Maximum | 72.96 |
| Range | 175.27 |
| Mean Standard Error | 0.58 |
| Trimmed Mean (98%) | -4.49 |

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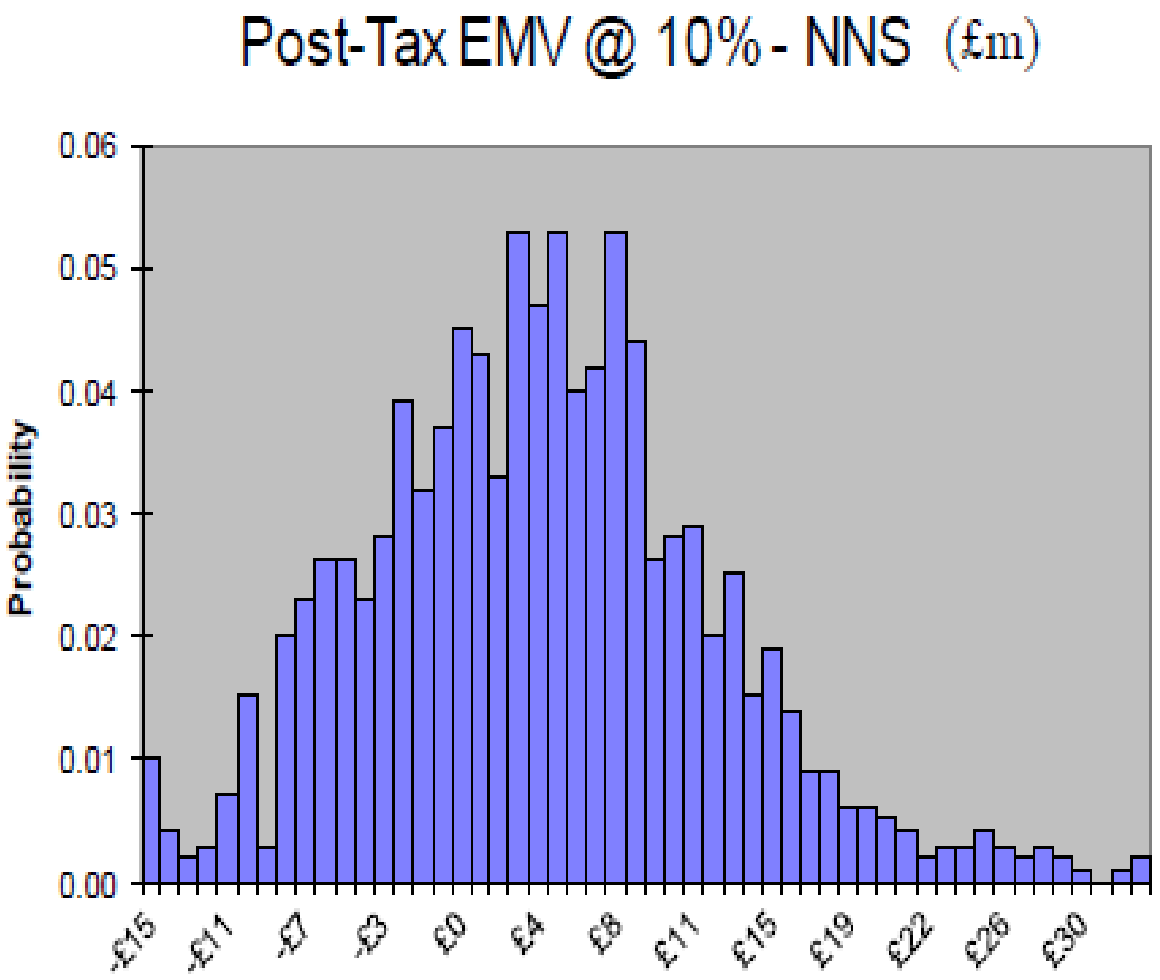
# NNS - Project (Fast) Limited IA - Initial Price $55 p/b and 40p/therm Reduced Costs

| Post-Tax EMV@10% Statistics | |
|---|---|
| Trials | 1000 |
| Mean | 3.99 |
| Median | 3.63 |
| Standard Deviation | 8.95 |
| Variance | 80.10 |
| Skewness | 0.96 |
| Kurtosis | 3.84 |
| Coefficient of Variability | 2.24 |
| Minimum | -20.92 |
| Maximum | 68.09 |
| Range | 89.01 |
| Mean Standard Error | 0.28 |
| Trimmed Mean (98%) | 3.84 |

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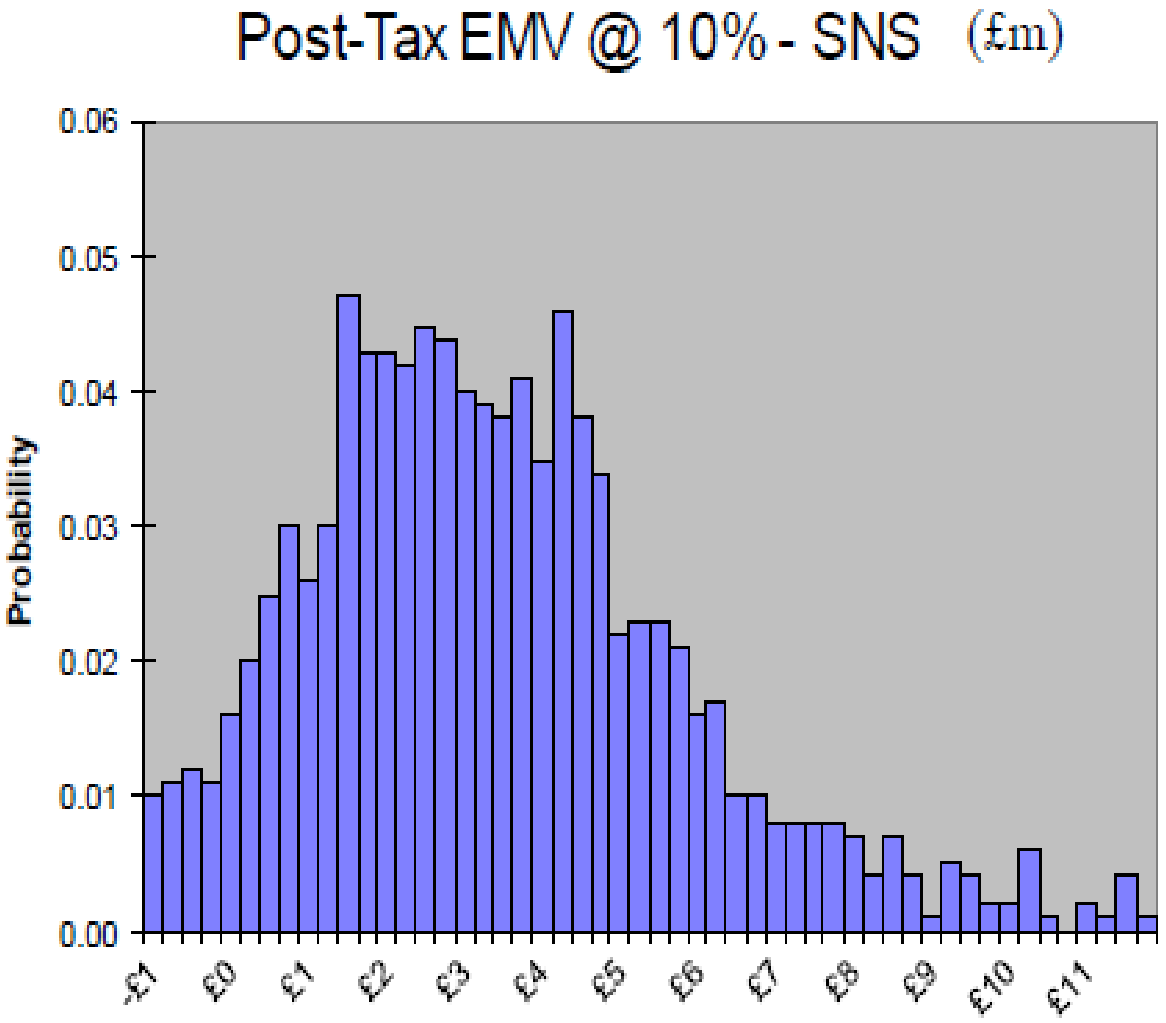
# SNS - Project (Fast) Limited IA - Initial Price $55 p/b and 40p/therm Reduced Costs

| Post-Tax EMV@10% Statistics | |
|---|---|
| Trials | 1000 |
| Mean | 3.42 |
| Median | 3.10 |
| Standard Deviation | 2.51 |
| Variance | 6.32 |
| Skewness | 1.10 |
| Kurtosis | 2.39 |
| Coefficient of Variability | 0.73 |
| Minimum | -2.16 |
| Maximum | 17.48 |
| Range | 19.64 |
| Mean Standard Error | 0.08 |
| Trimmed Mean (98%) | 3.37 |

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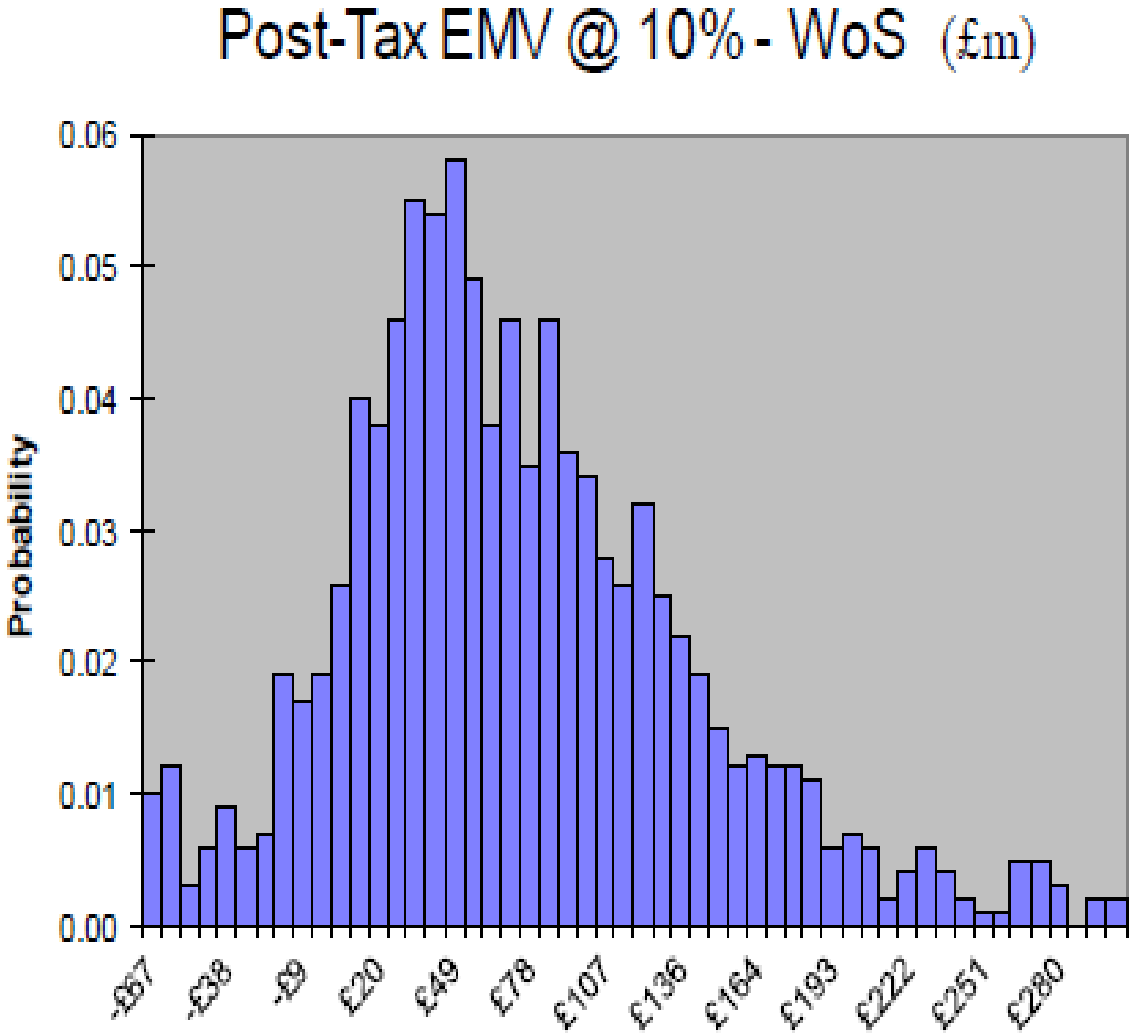
# WoS - Project (Fast) Limited IA - Initial Price $55 p/b and 40p/therm Reduced Costs

| Post-Tax EMV@10% Statistics | |
|---|---|
| Trials | 1000 |
| Mean | 71.72 |
| Median | 60.17 |
| Standard Deviation | 72.99 |
| Variance | 5327.65 |
| Skewness | 1.02 |
| Kurtosis | 3.27 |
| Coefficient of Variability | 1.02 |
| Minimum | -149.83 |
| Maximum | 571.80 |
| Range | 721.63 |
| Mean Standard Error | 2.31 |
| Trimmed Mean (98%) | 70.69 |

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# Rates of Tax on Income and Rates of Effective Relief for Investment in the UKCS

| | Tax on Income | Relief for Investment |
|---|---|---|
| 1. Non-PRT fields | | |
| (a) 2015 terms | 0.3+0.2 = <u>0.5</u> | 0.3+0.2+0.625 (0.2) = <u>0.625</u> |
| (b) 2016 terms | 0.3+0.1 = <u>0.4</u> | 0.3+0.1+0.625(0.1) = <u>0.4625</u> |
| 2. PRT fields | | |
| (a) 2015 terms | 0.35+0.3(0.65)+0.2(0.65) = <u>0.675</u> | 0.35+0.3(0.65)+0.2(0.65)+0.625 (0.2(0.65)) = <u>0.75625</u> |
| (b) 2016 terms | 0.3+0.1 = <u>0.4</u> | 0.3+0.1+0.625(0.1) = <u>0.4625</u> |

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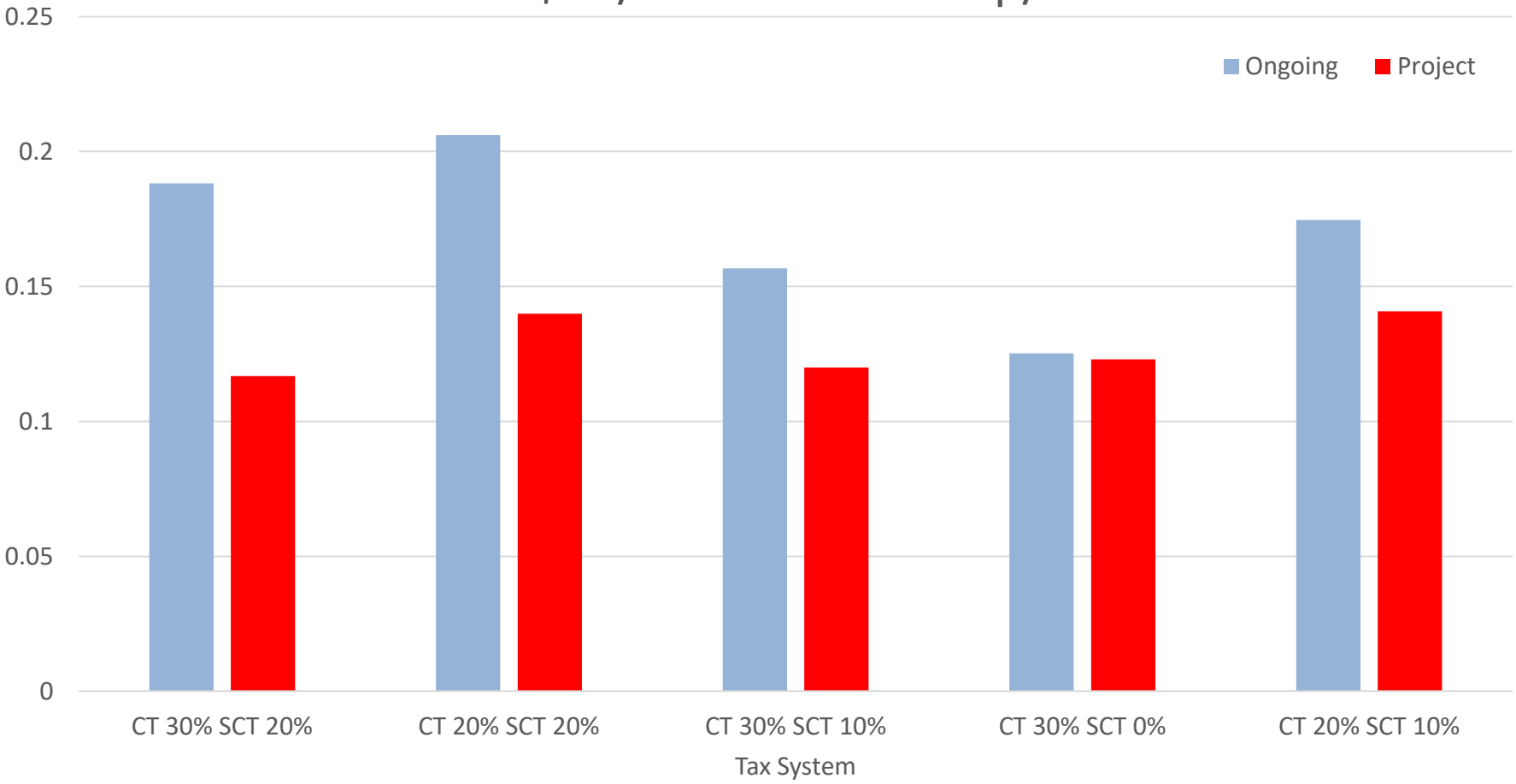
# Results of Modelling Returns to Investment in Oil/Gas Fields under Different Tax Schemes

# CNS Oil 10 Mboe
# Real Post-tax NPV @ 10% / Real Devex @ 10%
# Oil Price $50/bbl Gas Price 40p/therm

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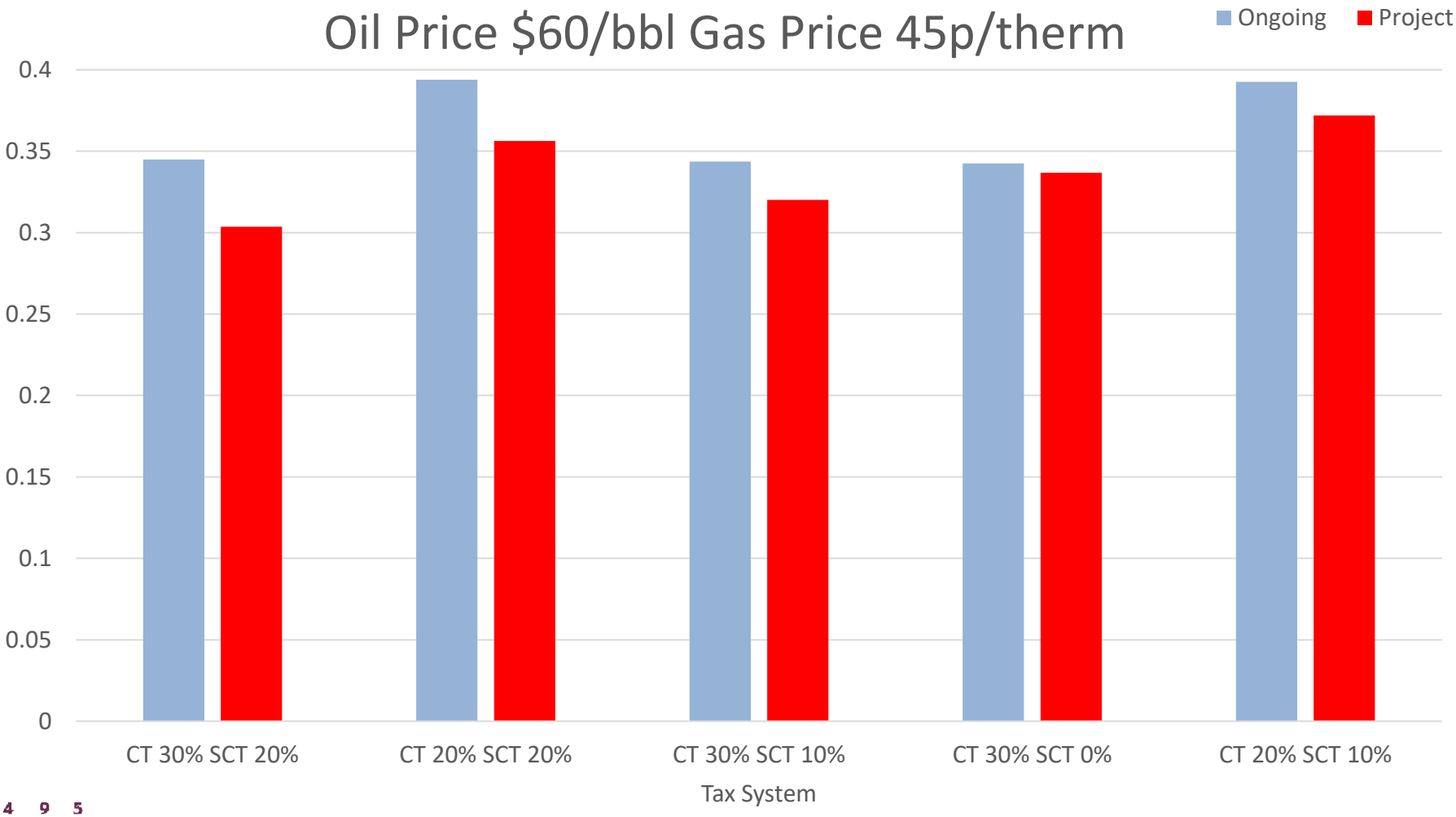
# CNS Oil 10 Mboe
# Real Post-tax NPV @ 10% / Real Devex @ 10%
# Oil Price $60/bbl Gas Price 45p/therm

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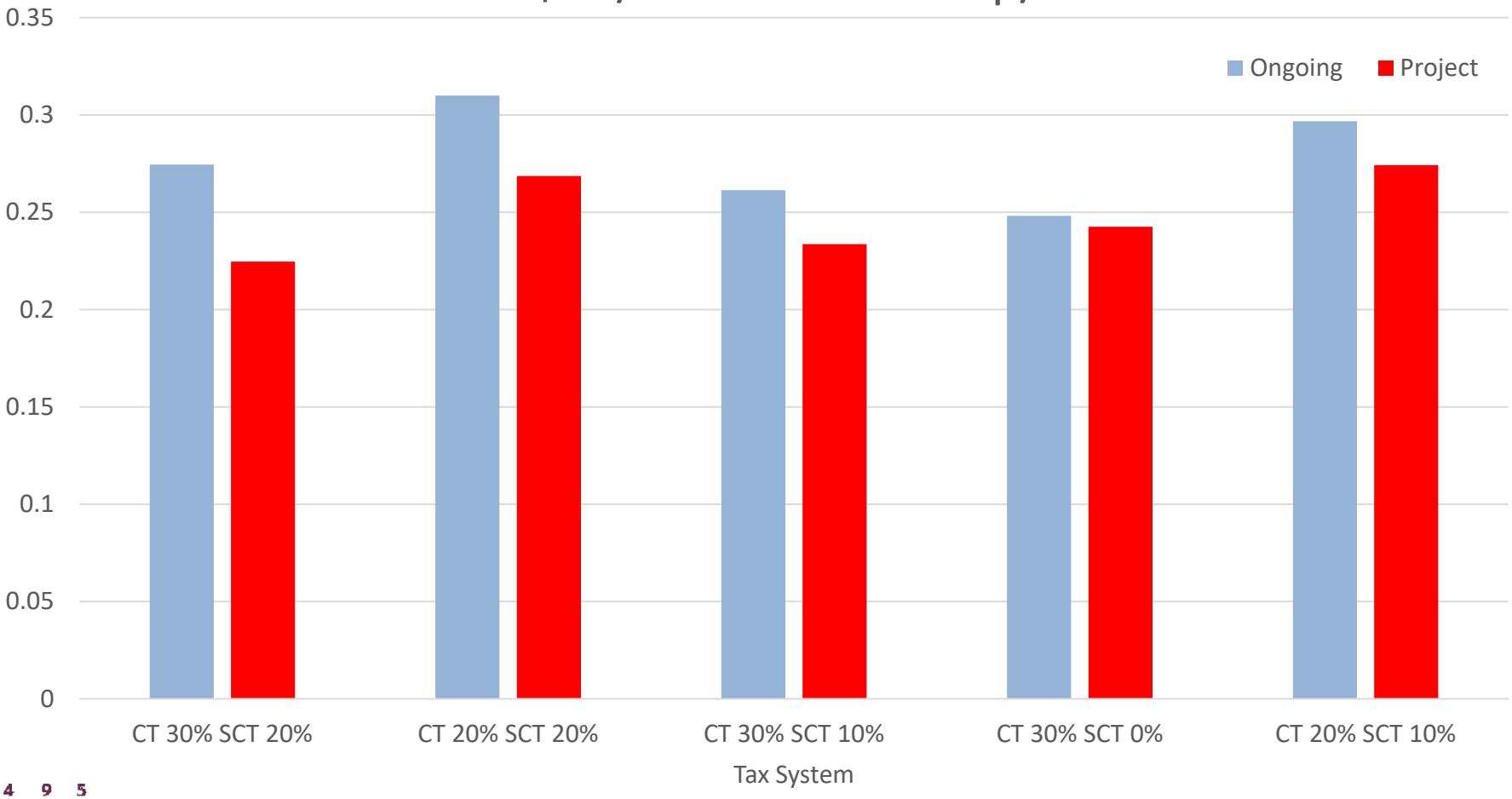
# CNS Oil 20 Mboe
# Real Post-tax NPV @ 10% / Real Devex @ 10%
# Oil Price $50/bbl Gas Price 40p/therm

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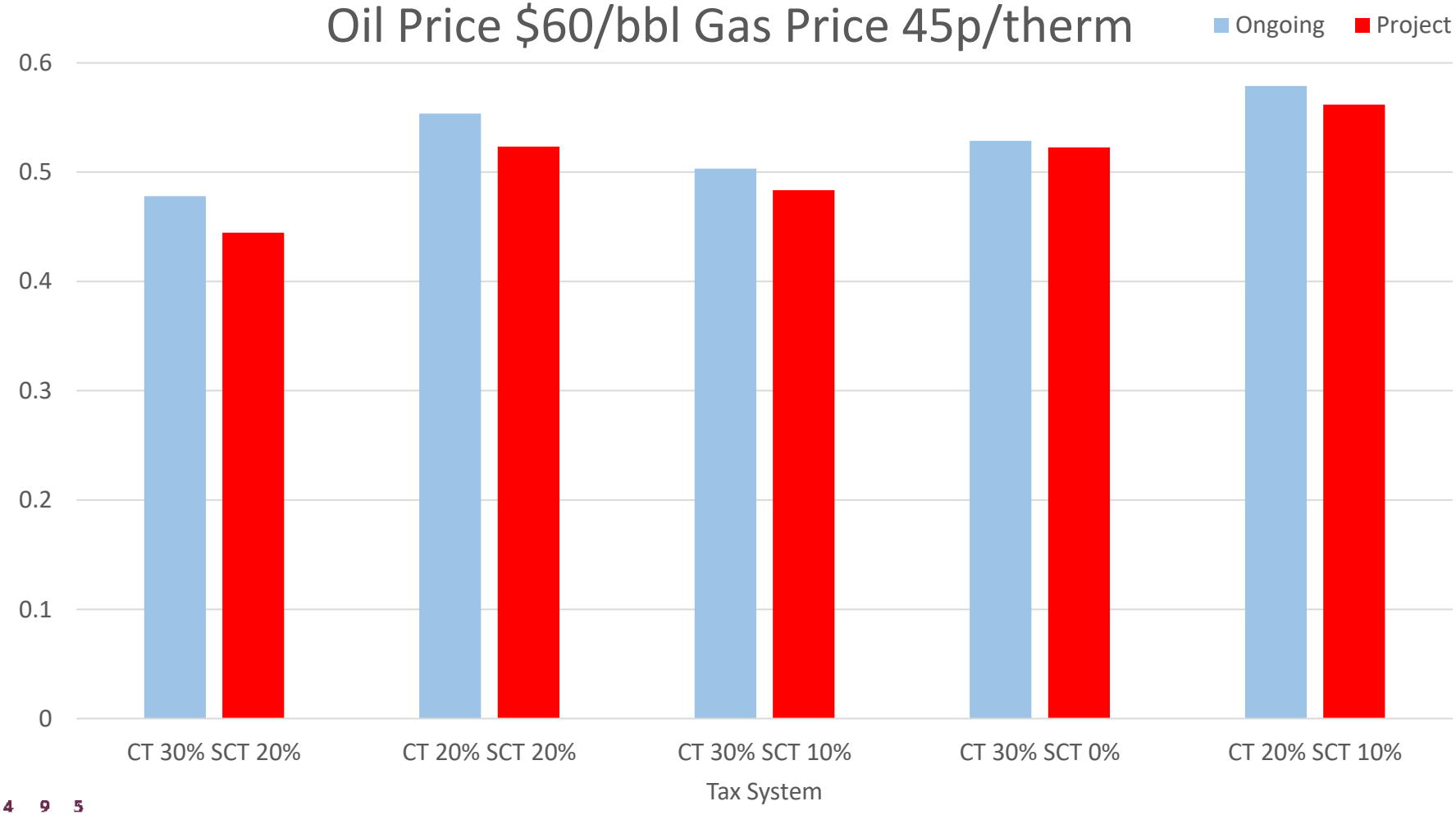
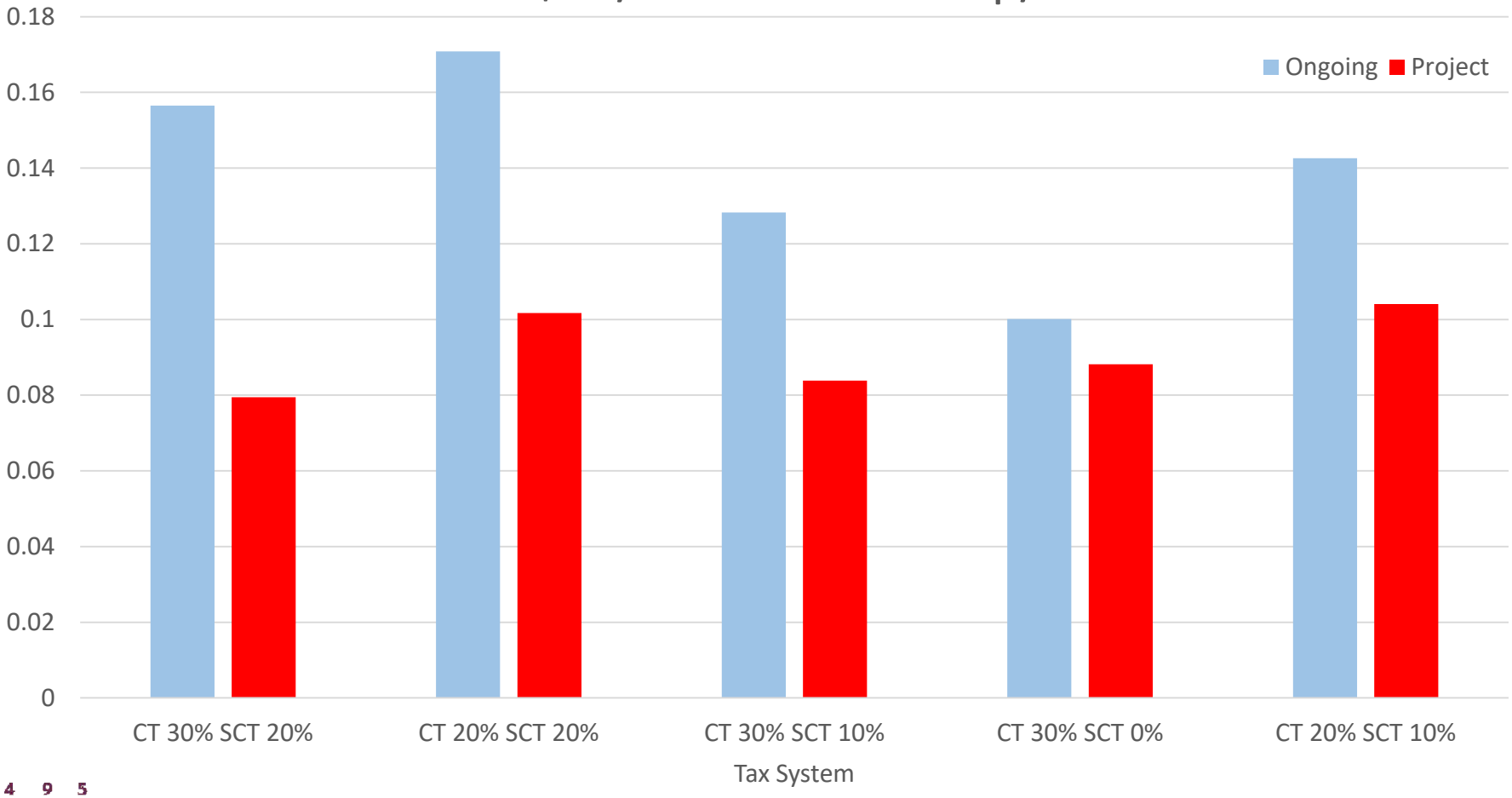
# CNS Oil 20 Mboe
# Real Post-tax NPV @ 10% / Real Devex @ 10%
# Oil Price $60/bbl Gas Price 45p/therm



# WoS Oil 100 Mboe
# Real Post-tax NPV @ 10% / Real Devex @ 10%
# Oil Price $50/bbl Gas Price 40p/therm

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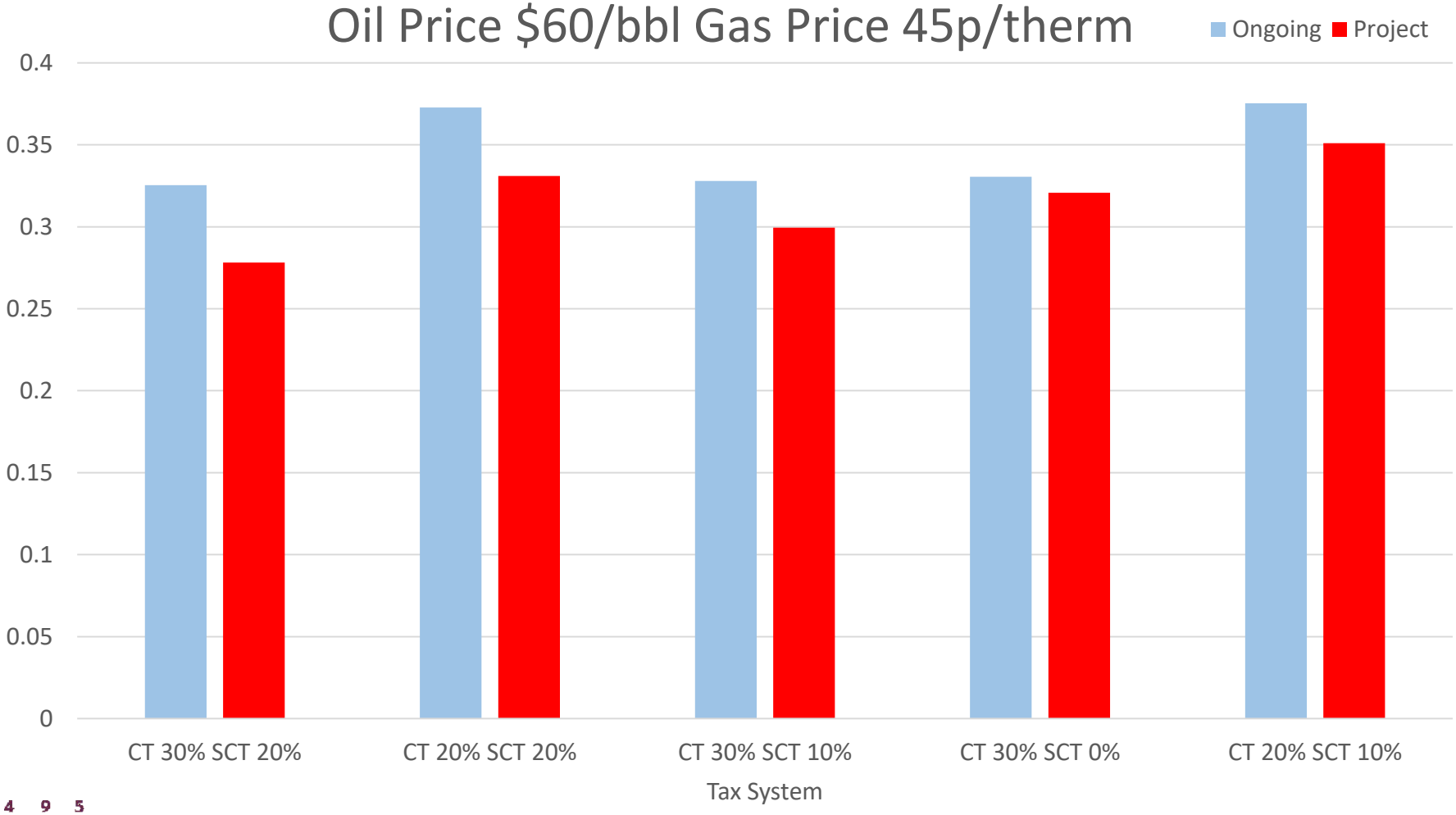
# WoS Oil 100 Mboe
## Real Post-tax NPV @ 10% / Real Devex @ 10%
## Oil Price $60/bbl Gas Price 45p/therm

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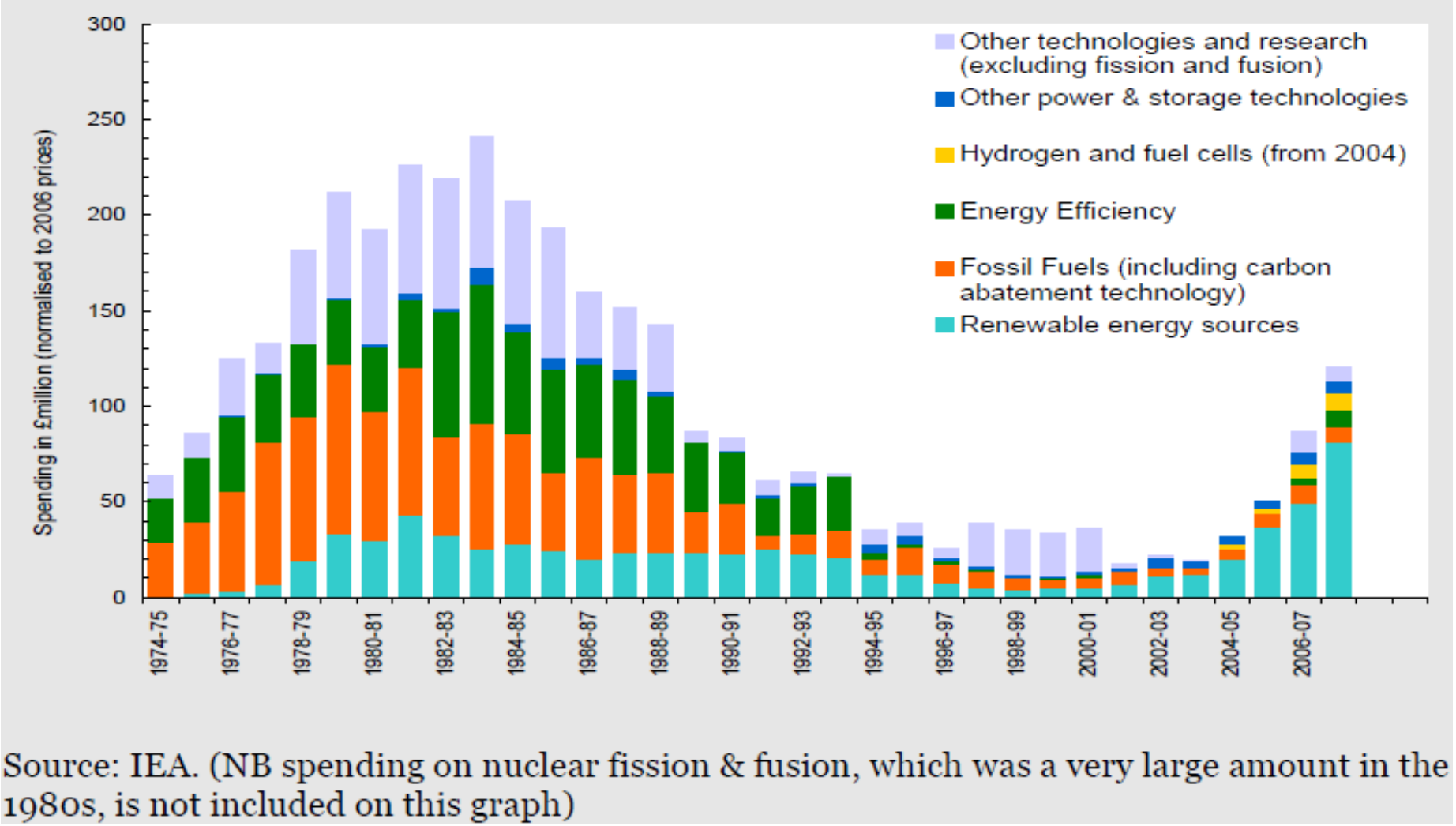
# Further Tax Incentives

1. Reducing the rate of CT would help cash flows from existing operations and incentivise new investments. State Aids issue a problem.
2. To encourage EOR projects consideration should be given to allowing the IA for SC to apply to purchases of raw materials such as polymers, miscible gas and $CO_2$.

# UK energy R&D spending 1974-2007




Source: IEA. (NB spending on nuclear fission & fusion, which was a very large amount in the 1980s, is not included on this graph)

Secondary source: M. Wicks (2009)

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# Reinforcing MER Strategy

1. To reduce potential conflict between competition laws and collaboration CMA and DECC/OGA could produce Guidance Notes on what collaborative arrangements are consistent with competition laws and what are inconsistent.
2. OGA to be very proactive with respect to encouraging enhancement of asset integrity. Short term gains can be very large.

# Reinforcing MER Strategy

3. Optimising the use of infrastructure may require further consideration to be given to terms of access including tariffs.
4. Given the very serious capital rationing problem consideration should be given to Government loan guarantees.
5. Emphasis could be more geared to Maximisation of Total Value Added where role of supply chain is given more prominence.