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The Economics of Enhanced Oil Recovery (EOR) in the UKCS and the Tax Review

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Research in North Sea Economics has been conducted in the Economics Department since 1973. The present and likely future effects of oil and gas developments on the Scottish economy formed the subject of a long term study undertaken for the Scottish Office. The final report of this study, The Economic Impact of North Sea Oil on Scotland, was published by HMSO in 1978. In more recent years further work has been done on the impact of oil on local economies and on the barriers to entry and characteristics of the supply companies in the offshore oil industry.

The second and longer lasting theme of research has been an analysis of licensing and fiscal regimes applied to petroleum exploitation. Work in this field was initially financed by a major firm of accountants, by British Petroleum, and subsequently by the Shell Grants Committee. Much of this work has involved analysis of fiscal systems in other oil producing countries including Australia, Canada, the United States, Indonesia, Egypt, Nigeria and Malaysia. Because of the continuing interest in the UK fiscal system many papers have been produced on the effects of this regime.

From 1985 to 1987 the Economic and Social Science Research Council financed research on the relationship between oil companies and Governments in the UK, Norway, Denmark and The Netherlands. A main part of this work involved the construction of Monte Carlo simulation models which have been employed to measure the extents to which fiscal systems share in exploration and development risks.

Over the last few years the research has examined the many evolving economic issues generally relating to petroleum investment and related fiscal and regulatory matters. Subjects researched include the economics of incremental investments in mature oil fields, economic aspects of the CRINE initiative, economics of gas developments and contracts in the new market situation, economic and tax aspects of tariffing, economics of infrastructure cost sharing, the effects of comparative petroleum fiscal systems on incentives to develop fields and undertake new exploration, the oil price responsiveness of the UK petroleum tax system, and the economics of decommissioning, mothballing and re-use of facilities. This work has been financed by a group of oil companies and Scottish Enterprise, Energy. The work on CO2 Capture, EOR and storage was financed by a grant from the Natural Environmental Research Council (NERC) in the period 2005 – 2008.

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c) Full Cycle Returns to Exploration in the UKCS
d) Economics of CO_2 EOR Cluster Developments in the Central North Sea/ Outer Moray Firth

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The Economics of Enhanced Oil Recovery (EOR) in the UKCS and the Tax Review

Professor Alexander G. Kemp
And
Linda Stephen

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The Economics of Enhanced Oil Recovery (EOR) in the UKCS and the Tax Review

Professor Alexander G. Kemp and Linda Stephen

1. Background and Context

In a mature petroleum province such as the UK Continental Shelf (UKCS) the attainment of maximum economic recovery should clearly be regarded as a priority. This is the overriding theme of the Wood Review. In pursuit of this there is an obvious role for tertiary recovery or enhanced oil recovery (EOR) schemes. Currently the oil recovery factor in the UKCS is believed to be around 45% though comprehensive evidence is rather elusive. EOR schemes have been common in onshore situation in North America for many years but much less common in offshore situations. The costs of implementing EOR schemes are clearly much higher in the offshore environment, and this, rather than knowledge of the technology, has been the main inhibiting factor. The inherent risks of the schemes are also a main consideration.

The current Tax Review provides an important opportunity to consider the incentives which are appropriate for EOR schemes. In the USA where tertiary recovery schemes are common the challenging economic environment is recognised through the provision of special tax incentives restricted to genuine EOR schemes. Currently in the UKCS the Brownfield (BF) Allowance against Supplementary Charge (SC) is available for EOR schemes (except CO_2 EOR). Whether it is appropriate for genuine EOR schemes (as opposed to other incremental projects) is investigated in this paper. The study examines the economics of schemes relating to Low Salinity Waterflood, Polymer Flood (risked and unrisked), and Miscible Gas Injection. CO_2 EOR schemes are the subject of a separate paper.

2. Key Features of the EOR Schemes

(a) Low Salinity Projects

From the economic perspective a Low Salinity project involves a substantial initial investment followed by a modest annual production spread over a very long time period. The result is that the project payback period is also very long. In absolute terms the extra operating costs are substantial, particularly in terms of requirements for manpower and beds offshore. Key risks of the projects relate to (1) the effectiveness of the waterflood technology in enhancing oil production, (2) the commissioning of the low salinity kit, (3) the additional complexity of managing the reservoir, and (4) the extra problems regarding well integrity. A further feature relates to the extra weight on the platform from the low salinity kit which reduces the flexibility of other activities on the platform.

In the present study a project involving potential EOR of 42 mmbbls was examined. The development cost was estimated at £338 million at 2014 prices. The development costs per barrel are around $13.3 again at 2014 prices. Lifetime operating costs are estimated at around £100 million and operating costs per barrel at just under $4. The precise figure for unit costs depend on the economic cut off which in turn depends on the oil price.

(b) Polymer Flood Schemes

Key characteristics of polymer flood schemes from an economic perspective are (1) high initial investment, including costs of modifying the FPSO/platform to equip it for receipt of polymers, and (2) the costs of building the EOR storage facilities. Operating costs are very high because of the need to purchase large amounts of polymer over a long period. The costs of polymers may well constitute 80%-90% of total operating costs. The EOR production will generally be at modest levels but over a very long time period. The result is that the payback period will also be very long.

There are several major risks surrounding investment in chemical EOR projects. A key one relates to the extent of degradation of the polymer in the reservoir. There can be degradation of polymer in the chokes such that the full viscosity is not obtained at the other side of the choke. This highlights the importance of the choice of detailed technologies relating to choke solution, inversion mixer design, and shear resistant polymer solution. In the present study two cases have been modelled, labelled risked and unrisked. The risked case shows a low production outcome reflecting the situation where the risks are not mitigated. The unrisked case reflects the upside outcome if the risks did not materialise. Other project risks relate to the availability of polymers over a long period. Optimally at least 90% availability is needed. Availability in practice also depends upon suitable long term supply contracts.

In the modelling of the risked case the potential EOR (including sales gas) was around 17.5 mmboe, depending on the economic cut-off. The development cost was estimated at £116 million at 2014 prices. The unit development cost was estimated at $10.67 per boe. Lifetime operating costs were estimated at £454 million at 2014 prices and unit operating cost at $41.9 per boe. In the unrisked case the potential

EOR was estimated at 38.3 mmboe. The total development cost was estimated at £156 million at 2014 prices, and the total lifetime operating cost at £529 million. The development cost per boe was estimated at $6.7 and the operating cost $22.7 per boe.

(c) Miscible Gas Injection

Key features of Miscible Gas EOR schemes include substantial investment costs and very large operating costs, due principally to the need to purchase substantial quantities of gas over a long period. The degree of security attached to long term gas supplies and their price constitute the most important risks. There is likely to be a long payback period with the production profile being at modest levels over a long period. There should be enhanced production of NGLs, but substantial risks relate to the extent of this. The risk relating to the EOR itself is comparatively low.

In the modelling undertaken in this paper the potential EOR is around 53.3 mmboe depending on the economic cut-off. This includes a worthwhile volume of NGLs. The total development costs were estimated at £503.5 million at 2014 prices. Lifetime operating costs including purchase of gas were estimated at £1,492 million, again at 2014 prices. The development costs per boe were estimated at $15.5 and operating costs at $46 per boe.

3. Modelling Procedures and Assumptions

The modelling procedures assume that the EOR projects are undertaken on host or mother fields where, at the time of the investment in the EOR scheme, the licensee is in a full tax-paying position. He is assumed to be subject to corporation tax (CT) and Supplementary Charge (SC) but not

Petroleum Revenue Tax (PRT). The current Brownfield (BF) Allowance against SC is in place, and applies to the projects where they qualify. To qualify the incremental capital costs have to exceed £60 per tonne of incremental reserves. The allowance increases linearly to a maximum of £50 per tonne when capital costs reach £80 per tonne of incremental reserves. The allowance is spread over 5 years. The maximum total allowance is £250 million in non-PRT fields (and £500 million in PRT fields).

Various experiments were undertaken to measure the impact of other taxation arrangements. Thus the effects of the BF allowance at a maximum rate of £75 per tonne without overall caps were examined. Given the importance of operating costs the effects of the BF allowance applied to capital plus operating costs (TC) was also examined with the size of the allowance being kept to maxima of £50 and £75 per tonne in the experiments.

Further experiments were conducted with the BF allowance being replaced by an investment uplift allowance, restricted to the incremental revenues from the EOR projects. Rates of 50%, 62.5% and 75% were examined. Further experiments extended the eligibility of the uplift allowance to investment plus operating costs (TC). Again rates of 50%, 62.5% and 75% were employed.

Yet further experiments were conducted on the effects of removing SC from the tertiary recovery schemes. To enhance understanding of the overall project economics, sensitivity analysis was undertaken to measure the effects of increases in production of 20%, decreases in investment costs by 20%, and decreases in operating costs of 20%.

Given the relatively modest returns on all the projects the results emphasise the pre-tax and post-tax NPVs at different real rates of discount, namely 0%, 5%, 10% and 15%.

The oil prices used in the modelling are $90 per barrel in real terms and for gas 58 pence per therm in real terms. A sensitivity analysis with prices of $110 per barrel and 58 pence per therm was also undertaken.

4. Results

In Charts 1-4 the NPVs are shown with the $90, 58 pence price scenarios for the 4 projects showing pre-tax and post-tax values with the present BF allowance at £50 per tonne, and an increased maximum allowance at £75 per tonne, based on investment costs per tonne of EOR. These charts also show the results of modelling when the BF allowance is based on capital plus operating costs (TC). In Chart 1 it is seen that the NPVs of the Low Salinity Waterflood project at 10% real discount rate under all the schemes are very low. The pre-tax NPV is negative at this discount rate. The NPV/I ratios are also negative before tax. The value of +0.3 is commonly employed as an investment hurdle. At 5% discount rate the NPVs are generally healthy. The NPV/I ratios are also well in excess of 0.3, being 0.45 under the current tax system. The BF allowance at £75 per tonne based on TC gives the highest post-tax return. The NPV at 10% is £39 million and the NPV/I ratio is 0.13. Overall the project offers very modest returns at the likely weighted average cost of capital (WACC) of the investor in relation to the investment cost of around £338 million.

Chart 1

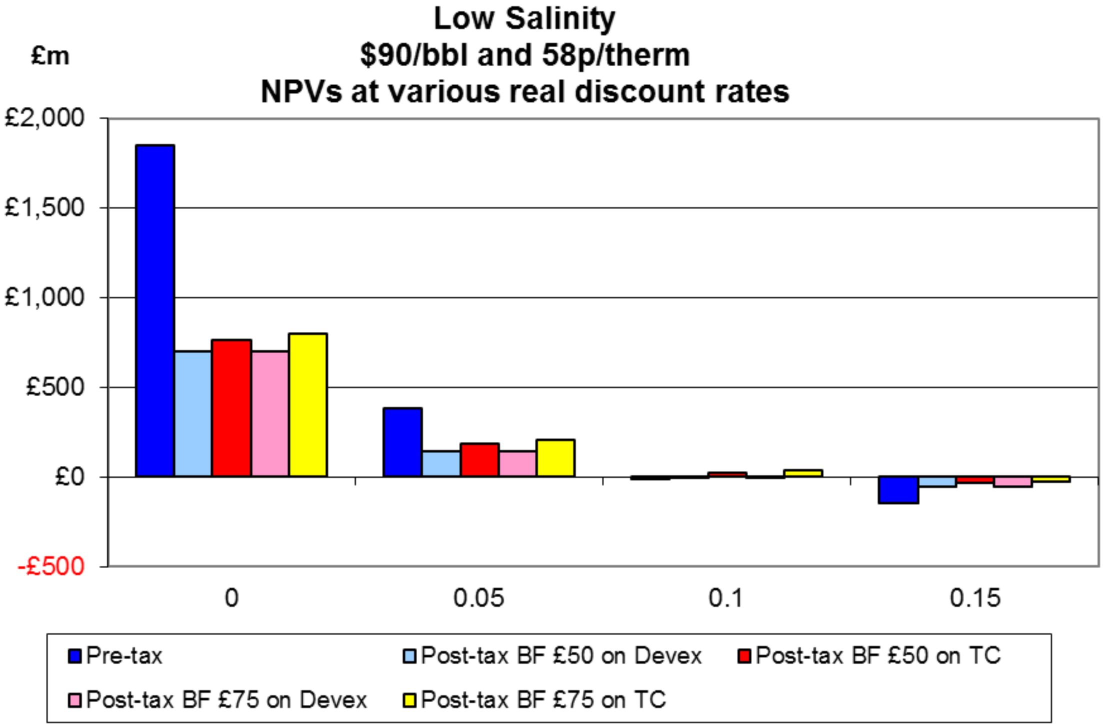
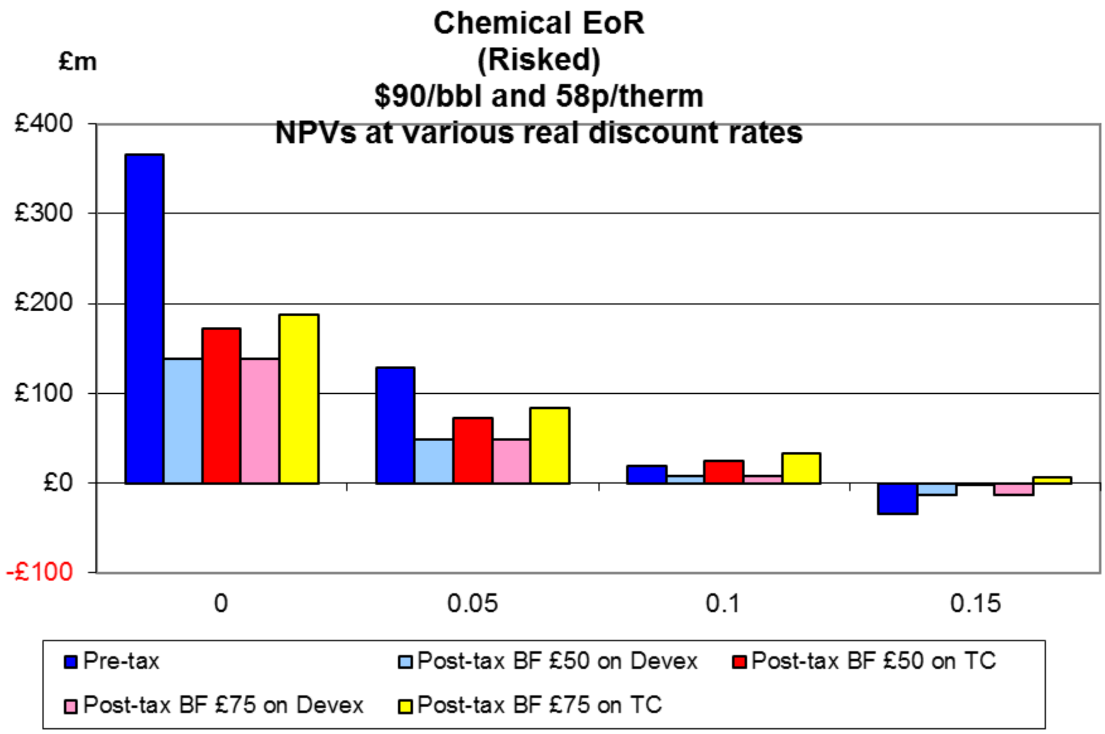


Chart 2



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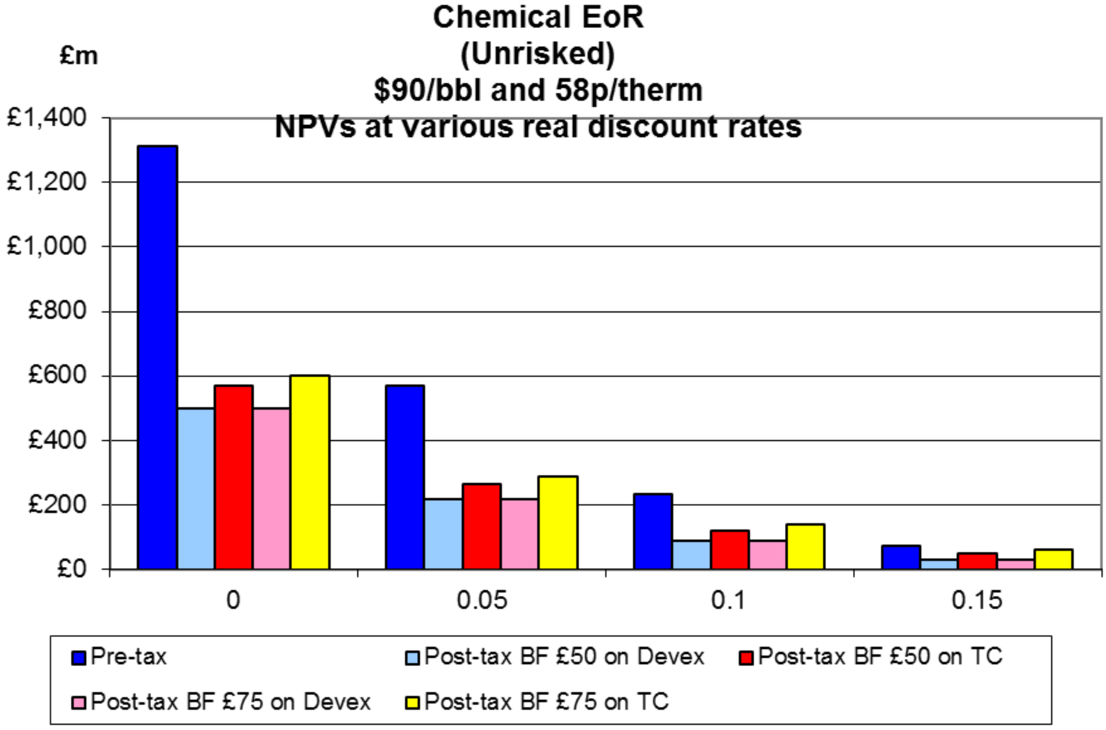

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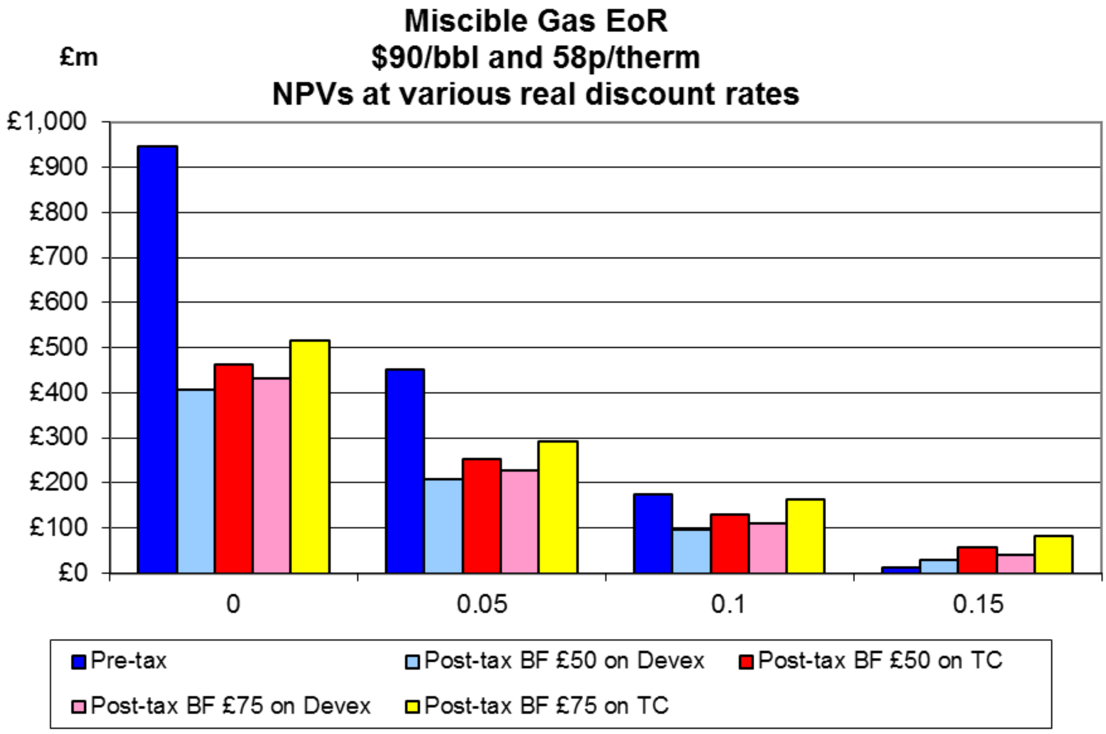


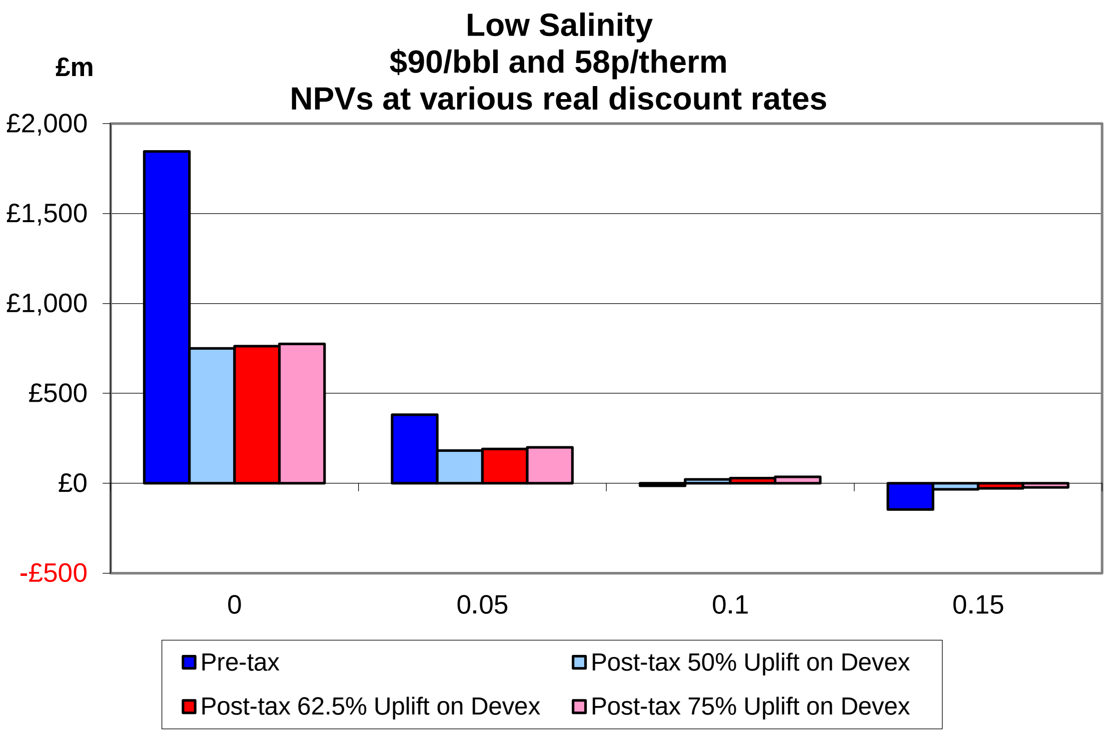
In Chart 2 the results are shown for the risked Polymer Flood project. As measured by the size of the NPV this is a marginal project. The IRR does exceed 10% under all the schemes examined, but the scales of the returns are very modest. The NPV at 10% under the current tax system is only £7.4 million and the NPV/I ratio is .07. The pre-tax NPV/I ratio is 0.19. Again, the BF allowance at £75 per tonne based on TC is the most effective of the tax schemes examined. The NPV/I ratio at 10% discount rate becomes 0.32 which exceeds the pre-tax ratio. But at 5% discount rate pre-tax returns are well in excess of post-tax values. At 5% real discount rate the NPV/I ratios all comfortably exceed 0.3. With this project there is a very big difference in the size of the post-tax NPVs when the allowance is based on TC compared to investment cost only, reflecting the large costs involved in purchasing the polymers. With BF allowance of £75 per tonne based on investment costs the post-tax NPV at 10% is £7.4 million but if the allowance were based on TC the NPV becomes £33 million.

In Chart 3 the pre-tax and post-tax returns are shown for the unrisked Polymer Flood project. These are substantially more attractive compared to the risked case. The NPVs at 15% are positive both before and after tax. At 10% discount rate the post-tax NPV under the present tax system is £89 million. The NPV/I ratios comfortably exceed the hurdle of 0.3. With the present tax system it is 0.69. Again, the BF allowance at £75 per tonne based on TC is the most powerful incentive scheme. The NPV/I ratio at 10% is then 1.06.

In Chart 4 the returns to the Miscible Gas project are shown. With all tax permutations the NPVs at 15% discount rate are positive. At 10% discount rate the pre-tax NPV/I ratio is 0.41, but, after the present tax, it is 0.22. With the BF allowance of £50 per tonne based on TC it becomes 0.3. With the BF allowance of £75 per tonne based on investment costs the ratio is 0.26. When it is based on TC the ratio becomes 0.38.

In Charts 5-8 inclusive the results of introducing an investment uplift allowance with rates of 50%, 62.5% and 75% are shown. In Chart 5 the results for the Low Salinity project indicate very small post-tax NPVs at 10% discount rate. The NPV/I ratios are all far below 0.3. It will be recalled that this project had a negative pre-tax NPV at 10% real discount rate. At 5% real discount rates the NPV/I ratios all exceed 0.3. But this discount rate is below the WACC for investors. In all cases post-tax NPVs increase to a modest extent the higher the size of the uplift.

Chart 5



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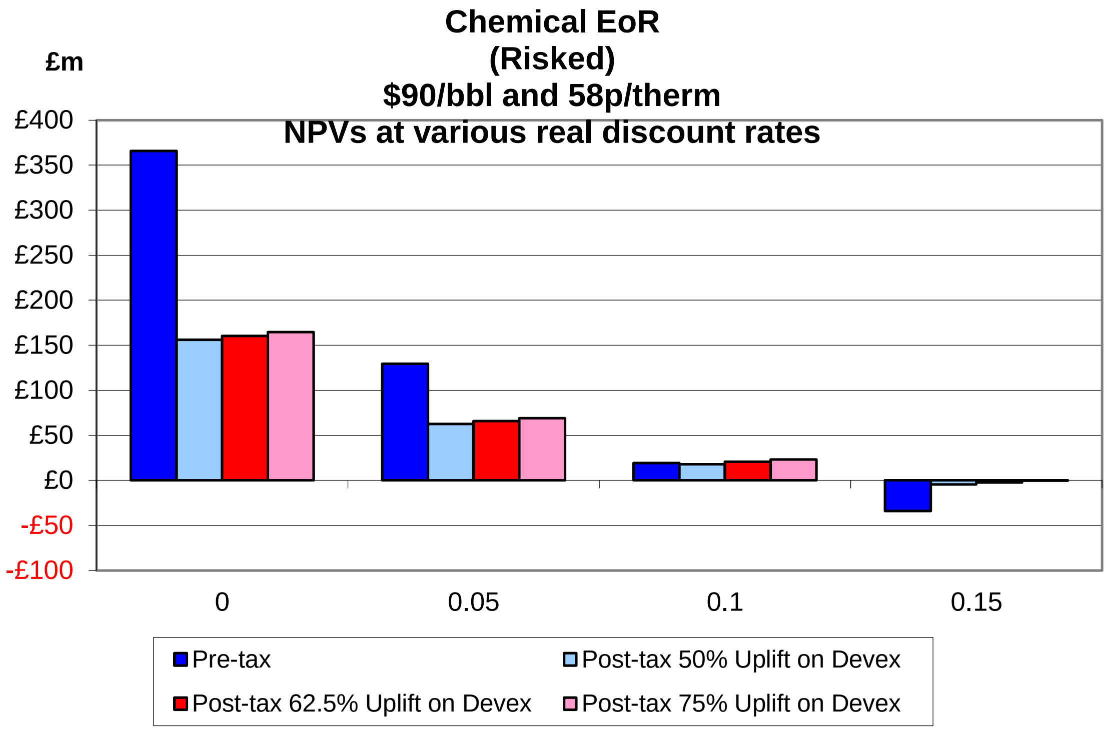

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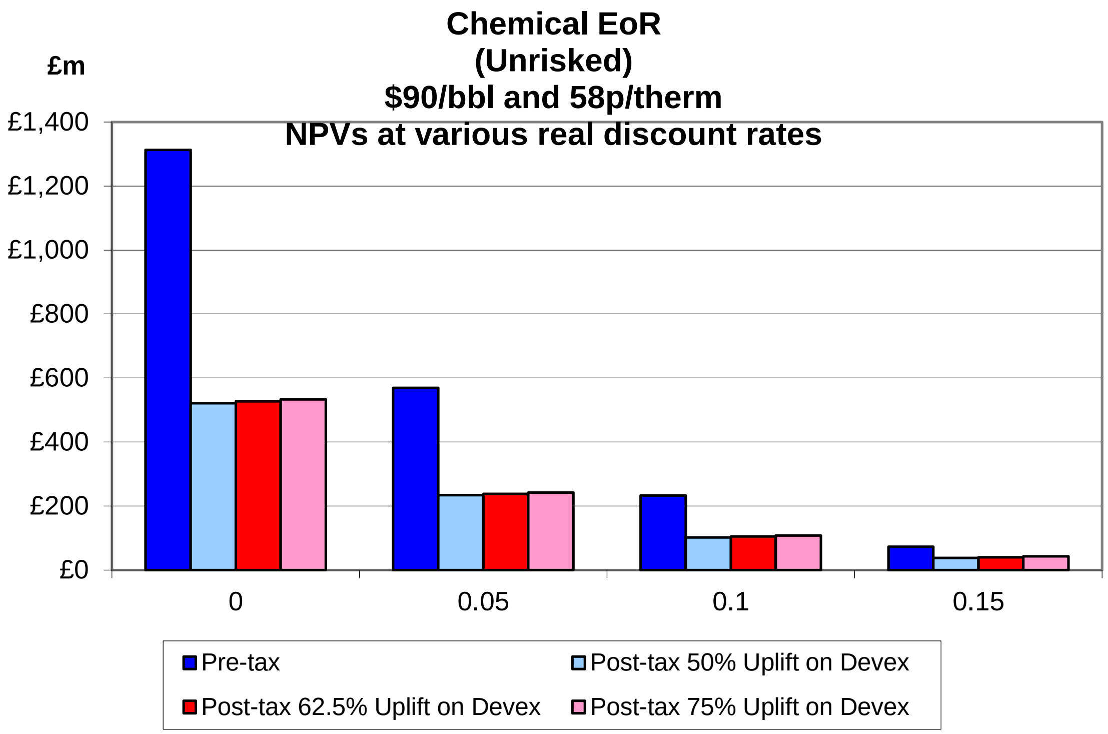

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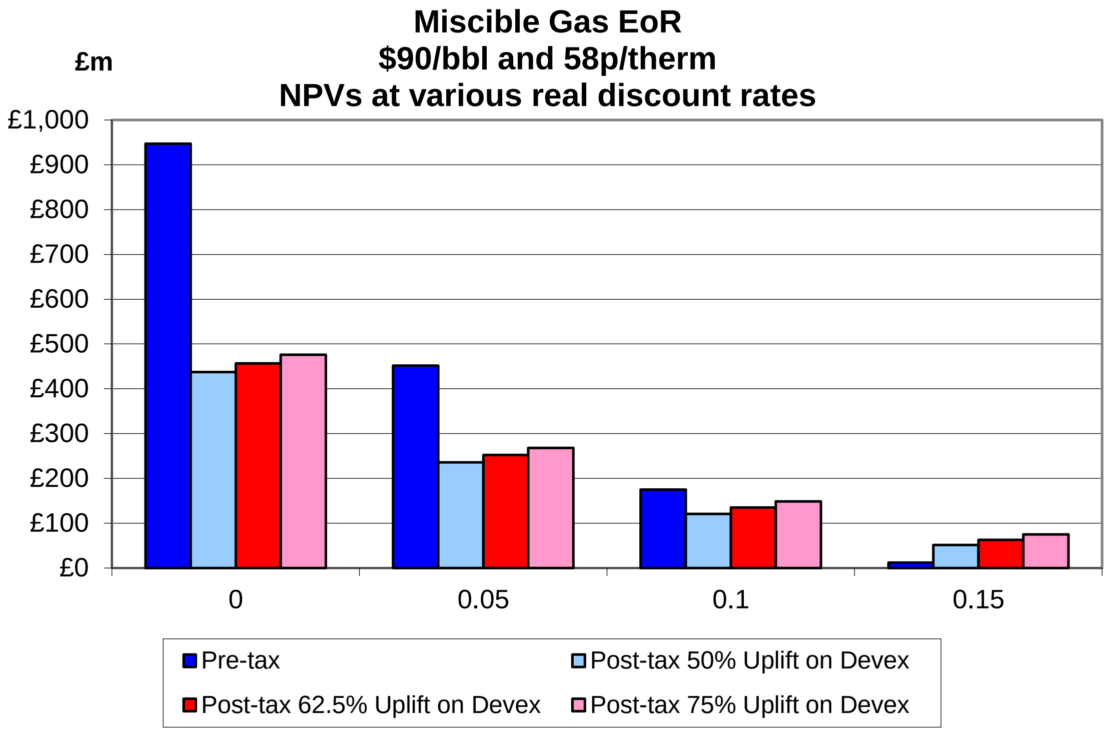


In Chart 6 the returns to the risked Polymer Flood project are shown. At 10% discount rate the NPVs are all positive, but the NPV/I ratios are below 0.3 in all cases, being 0.18 with 50% uplift, 0.2 with 62.5% rate and 0.23 with 75% rate. At 5% real discount rate the NPV/I ratios comfortably exceed 0.3 in all cases, being 0.58 at 50% uplift rate. Again the size of the NPV increases modestly the greater the size of the uplift.

In Chart 7 the returns to the unrisked Polymer Flood project are shown. At 10% discount rate the NPVs are all significantly positive. The NPV/I ratios are also well in excess of 0.3 in all cases. At 50% uplift the ratio is 0.79, at 62.5% it is 0.81, and at 75% it is 0.84. The returns increase to a modest extent the higher the uplift allowance.

In Chart 8 the returns to the Miscible Gas project are shown. At 10% discount rate the NPVs are all substantially positive. The NPV/I ratio is

0.4 before tax, but after tax with 50% uplift it is 0.28. At 62.5% uplift the ratio is 0.31, and at 75% rate it is 0.35. At 5% real discount rate the NPVs are all very substantially positive and the NPV/I ratios are all well in excess of 0.3.

In Charts 9-12 the results are shown when the uplift allowance applies to capital and operating costs (TC). In Chart 9 where the returns to the Low Salinity project are shown, it is seen that at 10% discount rate the NPVs after tax are modestly positive though the pre-tax value is negative. The NPV/I ratios are all far below 0.3, being 0.08 at 50% uplift and 0.13 at 75% rate. The project is not commercially viable in this scenario. At 5% real discount rate the NPVs are significantly positive and the NPV/I ratios greatly exceed 0.3, being 1.2 before tax and 1.0 with 50% uplift on TC. With respect to the effects of the different rates of uplift it is seen that the NPVs increase modestly in relation to the rate of uplift. A comparison with Chart 5 indicates that there is little difference in the size of the NPVs with the uplift based on TC compared to investment cost only. This is because the incremental operating costs per boe on this project are very low.

Chart 9

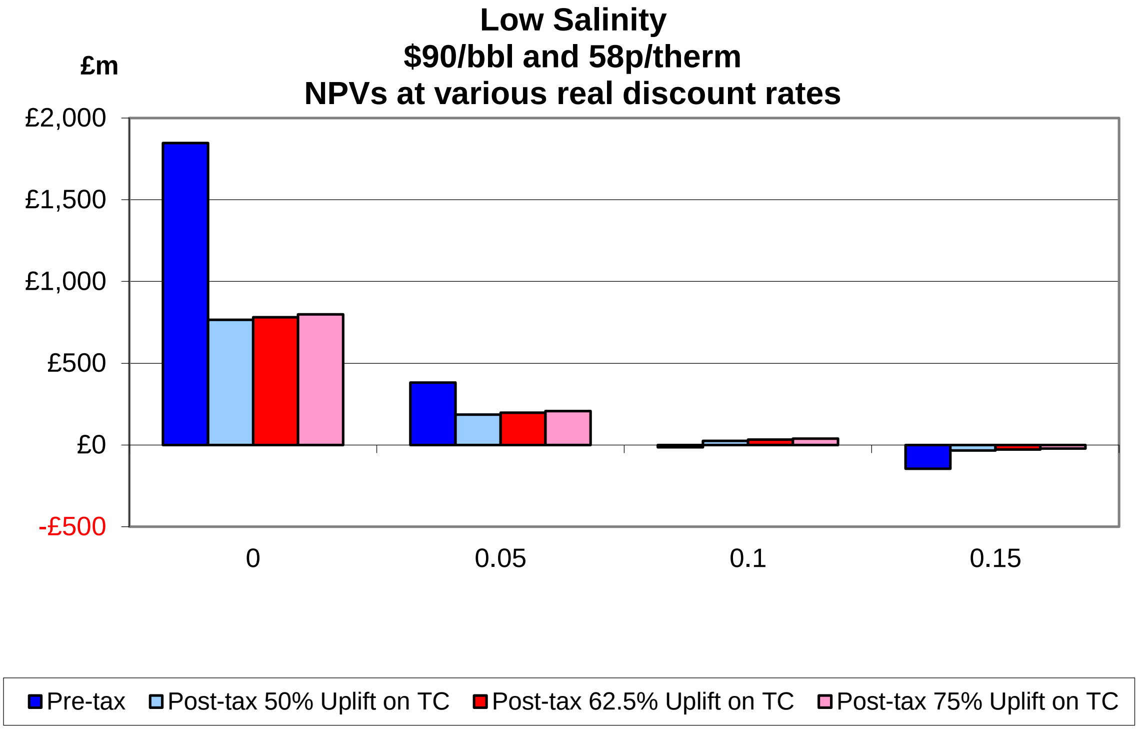


Chart 10

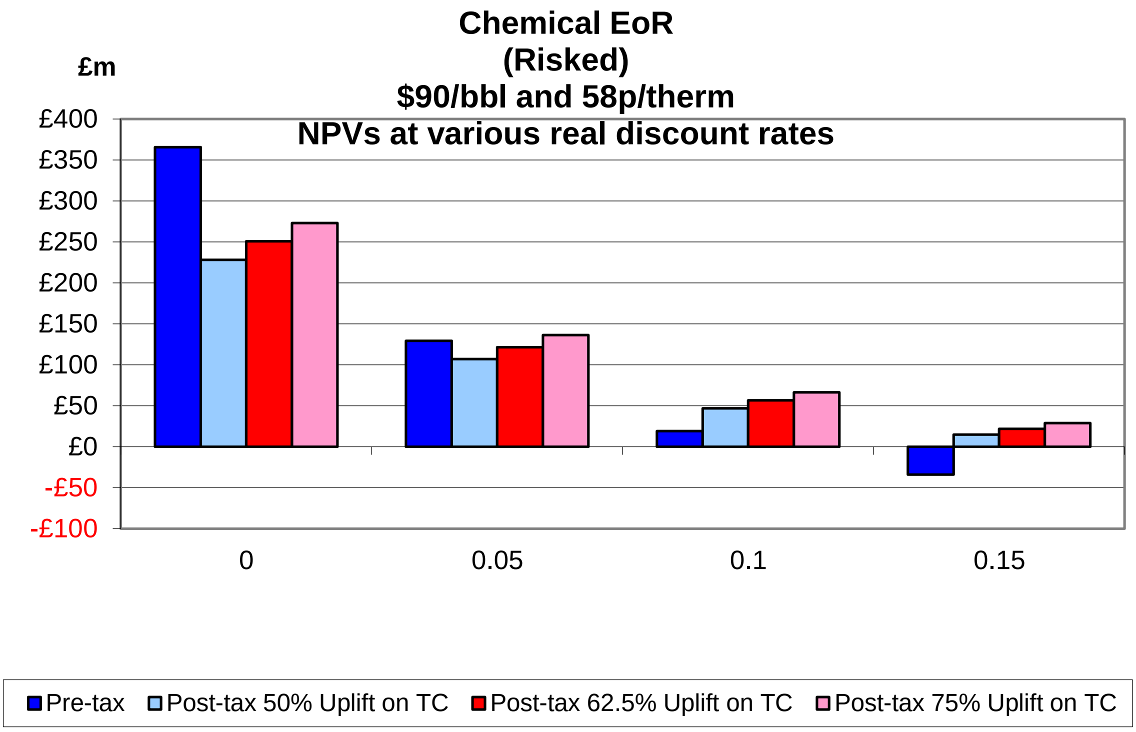
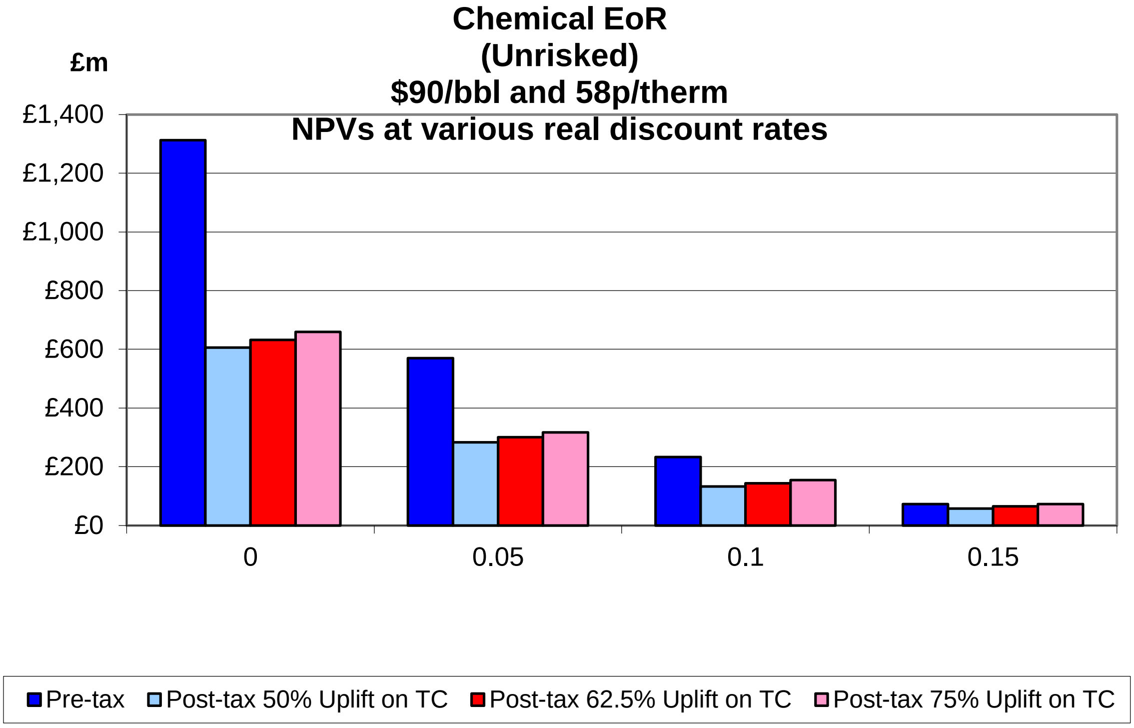


Chart 11



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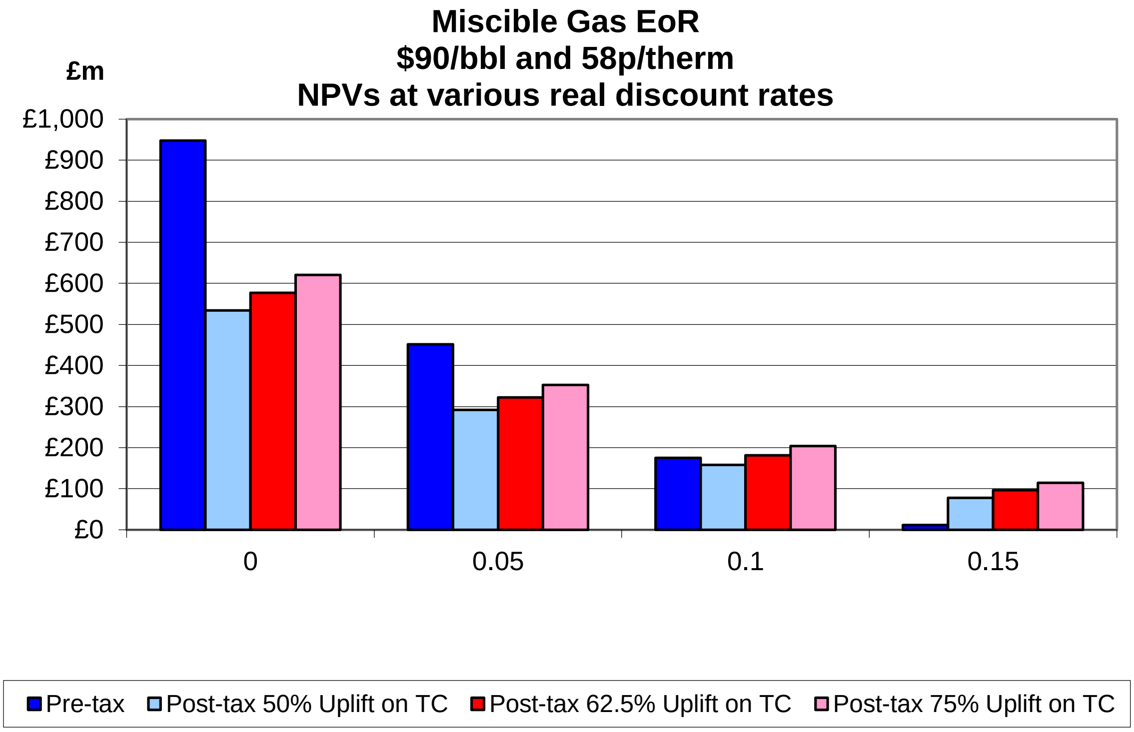


The position is quite different on the risked Polymer Flood project the results for which are shown in Chart 10. At 10% real discount rate the post-tax NPVs are significantly positive. The NPV/I ratios comfortably exceed 0.3, even at the uplift rate of 50% where it is 0.46. The inclusion of operating costs in the allowance makes a big difference to its effectiveness. When the allowance was based on investment costs only (see Chart 6), at 10% discount rate the NPV/I ratio at 50% uplift was only 0.18 and at 75% uplift it was 0.23.

In Chart 11 the results are shown for the unrisked Polymer Flood scheme. At 10% discount rate the NPVs are all substantially positive. The NPV/I ratios all exceed 0.3 by substantial margins even with the uplift at 50% where the ratio is 1.03.

In Chart 12 the results for the Miscible Gas project are shown. At 10% real discount rate the NPVs are all substantially positive. The NPV/I ratio with 50% uplift is 0.36 and with 75% uplift it is 0.476. When the uplift allowance was based on investment costs only (Chart 8) the NPV/I ratio was 0.28 with uplift at 50% and 0.346 at 75% uplift. Thus the allowance based on TC further incentivises the development of this project.

In Charts 13-16 the results of removing SC from the EOR schemes are shown. To enhance understanding of the underlying economics of the projects the results are also shown for (a) production increase of 20%, (b) decrease in development costs of 20%, and (c) decrease in operating costs of 20%.

Chart 13

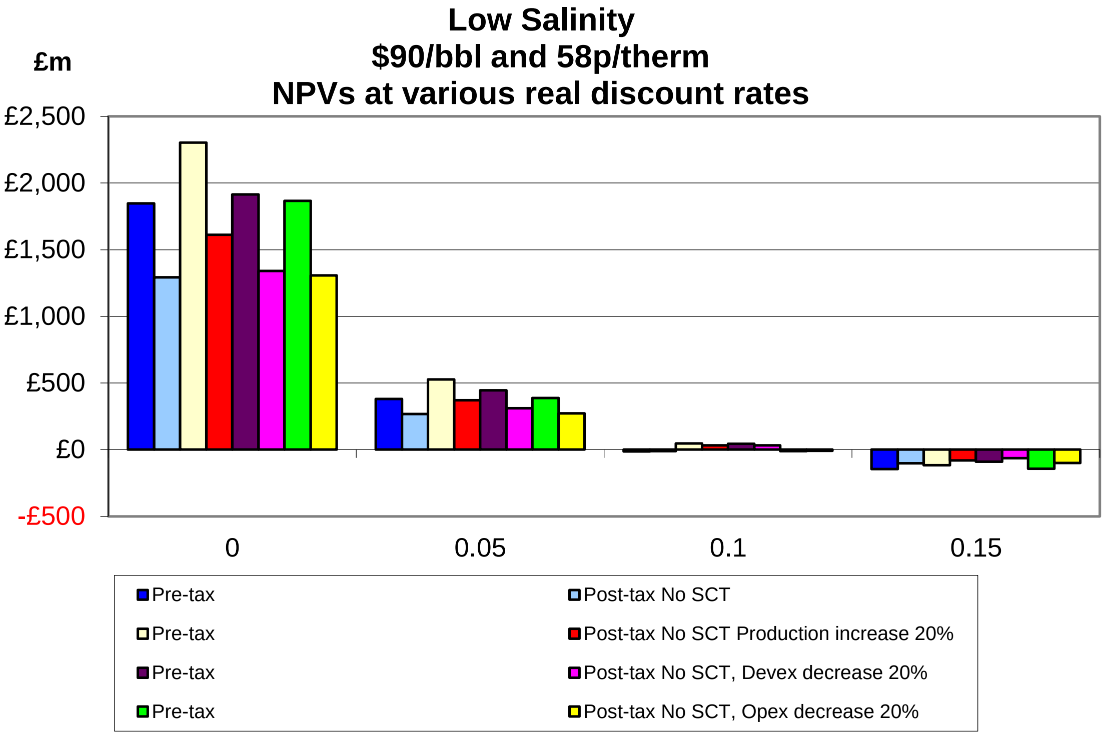
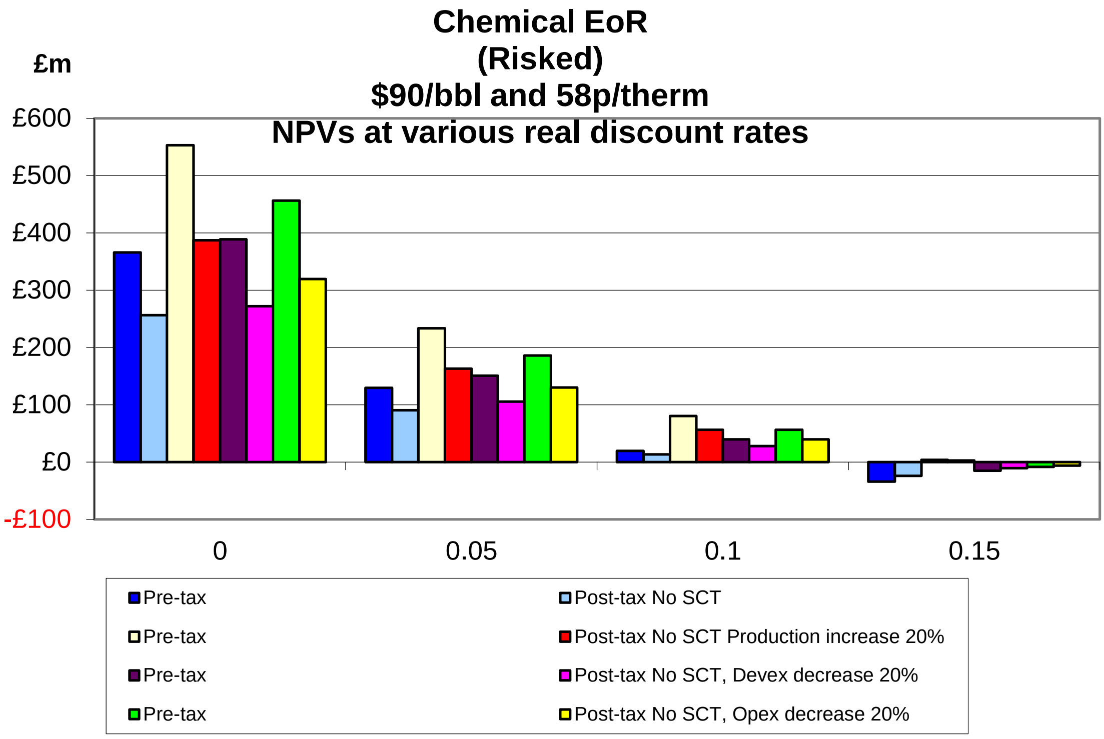


Chart 14



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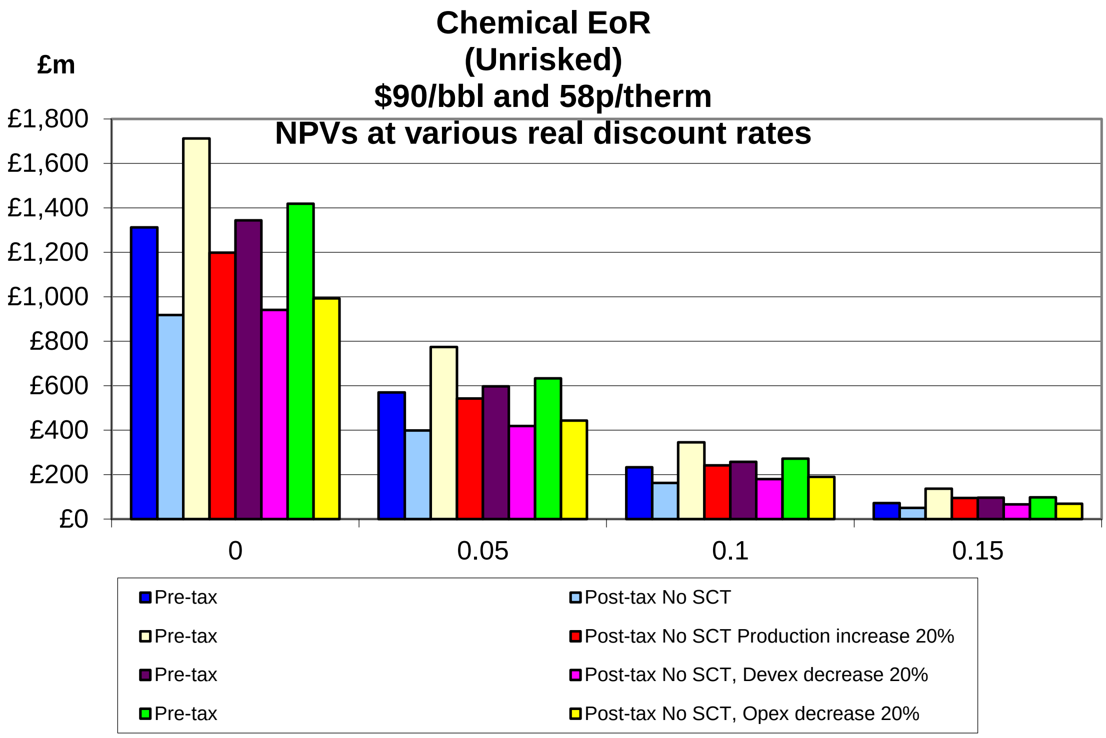
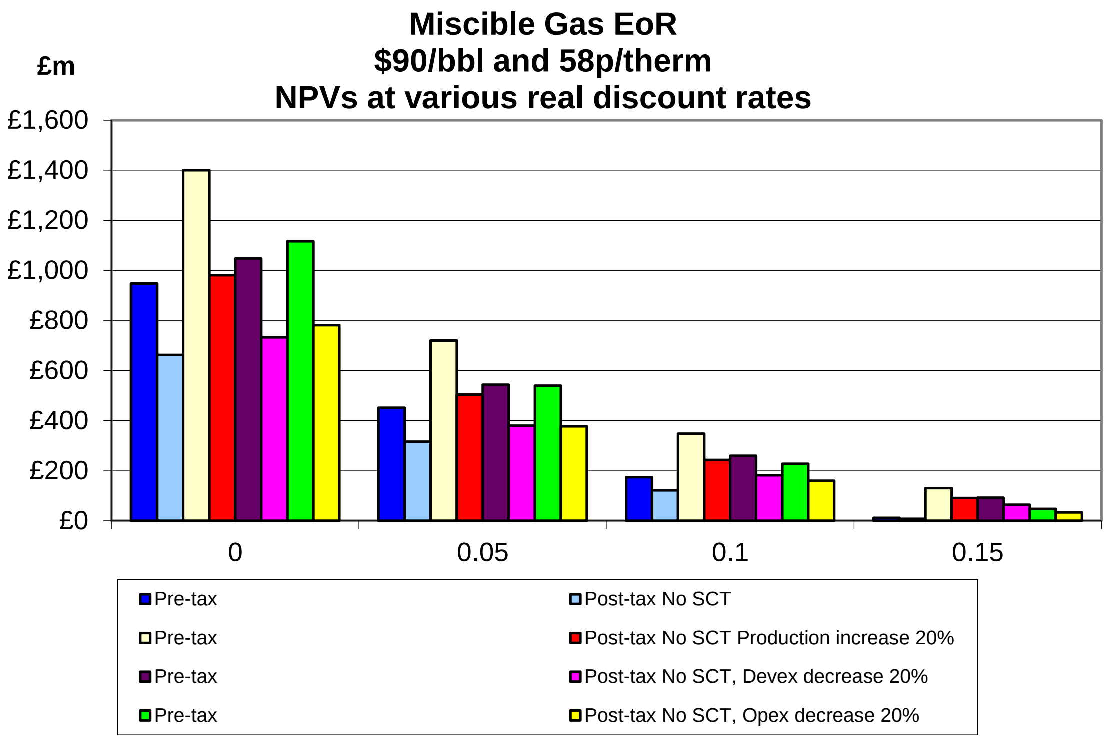


Chart 16



In Chart 13 the results for the Low Salinity scheme indicate that at 10% real discount rate the project has either a negative NPV or a very low positive value under all the permutations. The NPV/I ratios are far below the 0.3 hurdle. At 5% real discount rate the NPVs are positive under all the scenarios, and the NPV/I ratios substantially exceed 0.3. With no SC but no other change the project has an NPV/I ratio of 0.85. In this scenario the return is higher compared to the effects of the other incentive schemes discussed above. To enhance the returns it is also seen that a production increase of 20% has a stronger effect than a reduction of 20% in the investment costs. The effect is even stronger compared to a reduction in operating costs of 20%.

In Chart 14 the returns are shown for the risked Polymer Flood scheme. At 10% discount the removal of SC produces a small positive NPV. But the NPV/I ratio is only 0.13. At 5% real discount rate the post-tax NPV is positive to the extent that the NPV/I ratio becomes 0.84.

If production were increased by 20% there is a substantial positive effect on returns. At 10% real discount rate the post-tax NPV is £56 million and the NPV/I ratio is 0.56. If investment costs decreased by 20% the resulting pre-tax NPV/I ratio comfortably exceeds 0.3 and the post-tax ratio becomes 0.34. If operating costs were decreased by 20% the post-tax NPV just exceeds that obtained with 20% reduction in investment costs, but it remains less than the NPV from a 20% production increase.

In Chart 15 the results are shown for the unrisked Polymer Flood scheme. At 10% discount rate the post-tax NPV with no other changes is significantly positive and the NPV/I ratio becomes 1.27. It is also seen that a 20% increase in production is the most effective means to enhance the NPV. A decrease in operating costs of 20% is rather more effective than a decrease in investment costs of 20%, reflecting the importance of the polymer costs to the overall project.

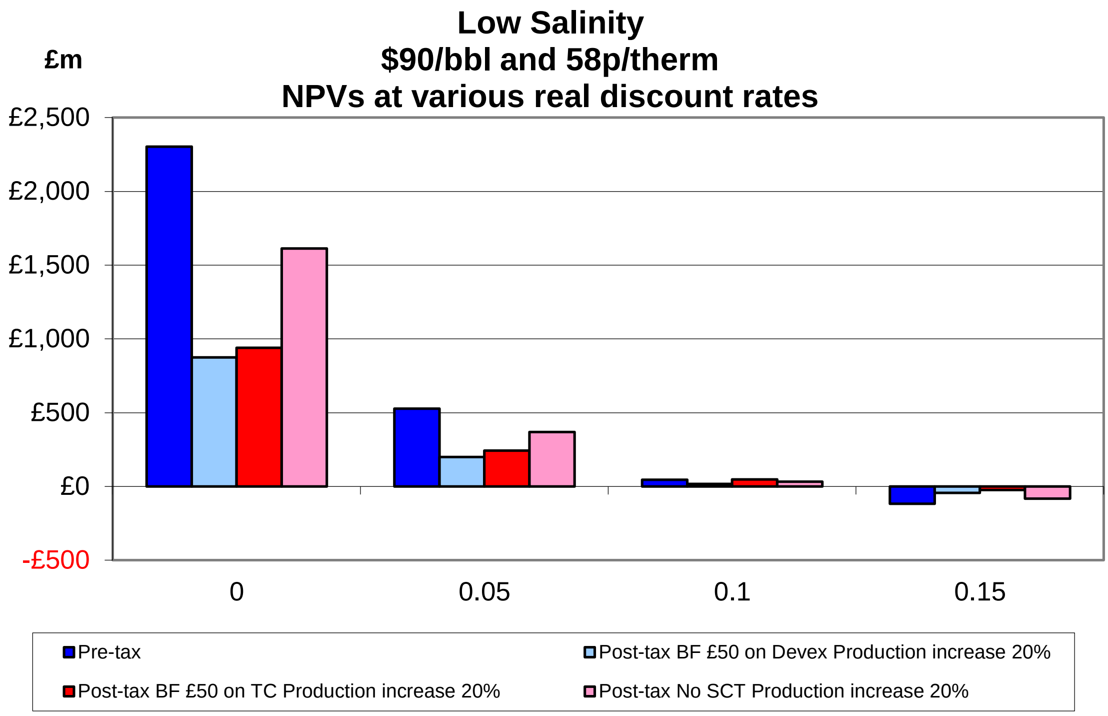
In Chart 16 the results are shown for the Miscible Gas project. At 10% discount rate the NPVs are generally significantly positive. The NPV/I ratio without SC but with no other changes is 0.29. If other favourable changes can be made to production, investment costs or operating costs the NPV/I ratio comfortably exceeds the 0.3 hurdle. As with the other projects increasing production by 20% has a much stronger effect on the NPV compared to reductions in investment or operating costs by a similar proportion. With a production increase of 20% the NPV/I ratio becomes 0.57.

To further enhance understanding of the economics of the projects with different tax incentives in Chart 17-20 the returns to the projects are shown with production increases of 20% along with (a) BF allowance of £50 per tonne based on investment costs, (b) BF allowance of £50 based on TC, and (c) no SC. In Chart 17 it is seen that, at the 10% discount rate, the NPVs for the Low Salinity project are all positive, but the values are so small that the NPV/I ratios are all well below 0.3. At 5% real discount rate all the post-tax NPV/I ratios are considerably above 0.3. The largest post-tax NPV comes when there is no SC.

In Chart 18 the returns on the risked Polymer Flood scheme are shown. At 10% real discount rate the NPVs are all positive. The pre-tax NPV/I ratio is very considerably in excess of 0.3, but the post-tax value with the present BF allowance is just on 0.3. However, with the BF allowance at

£50 per tonne based on TC the ratio becomes 0.47, and when there is no SC the hurdle is also substantially exceeded.

Chart 17



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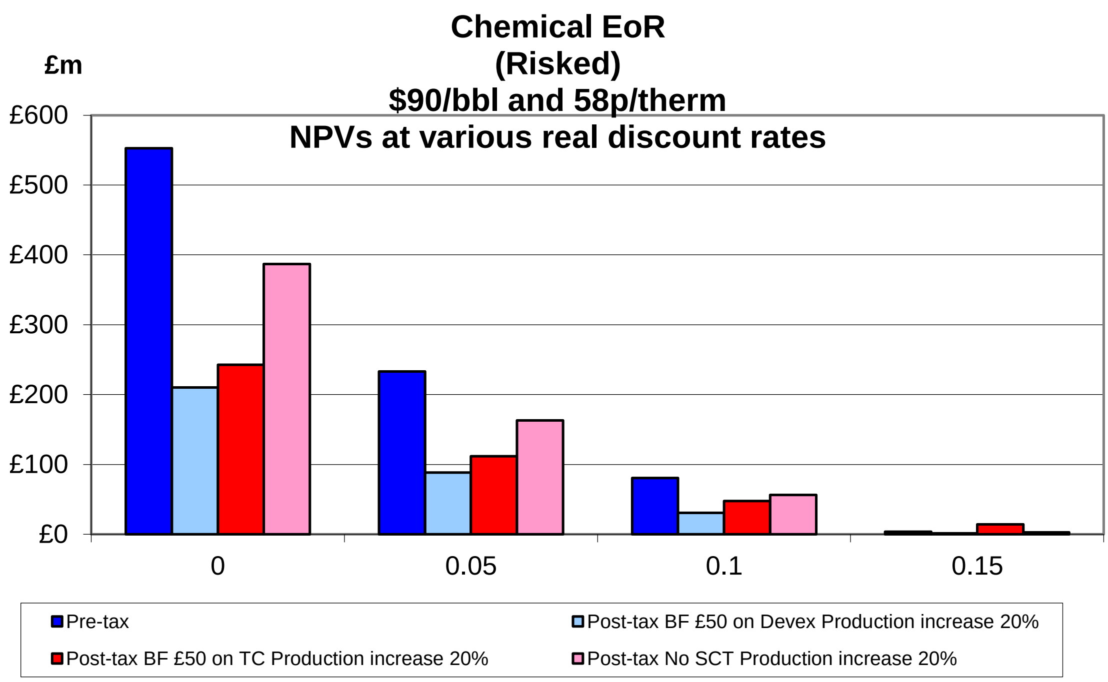

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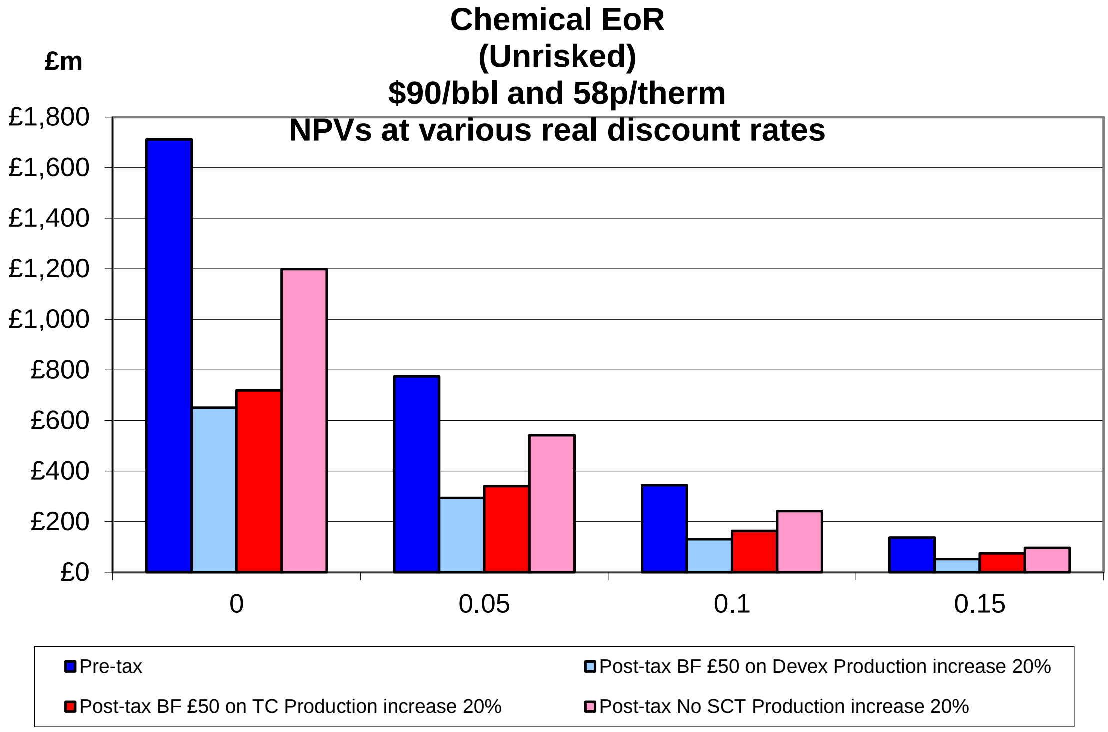

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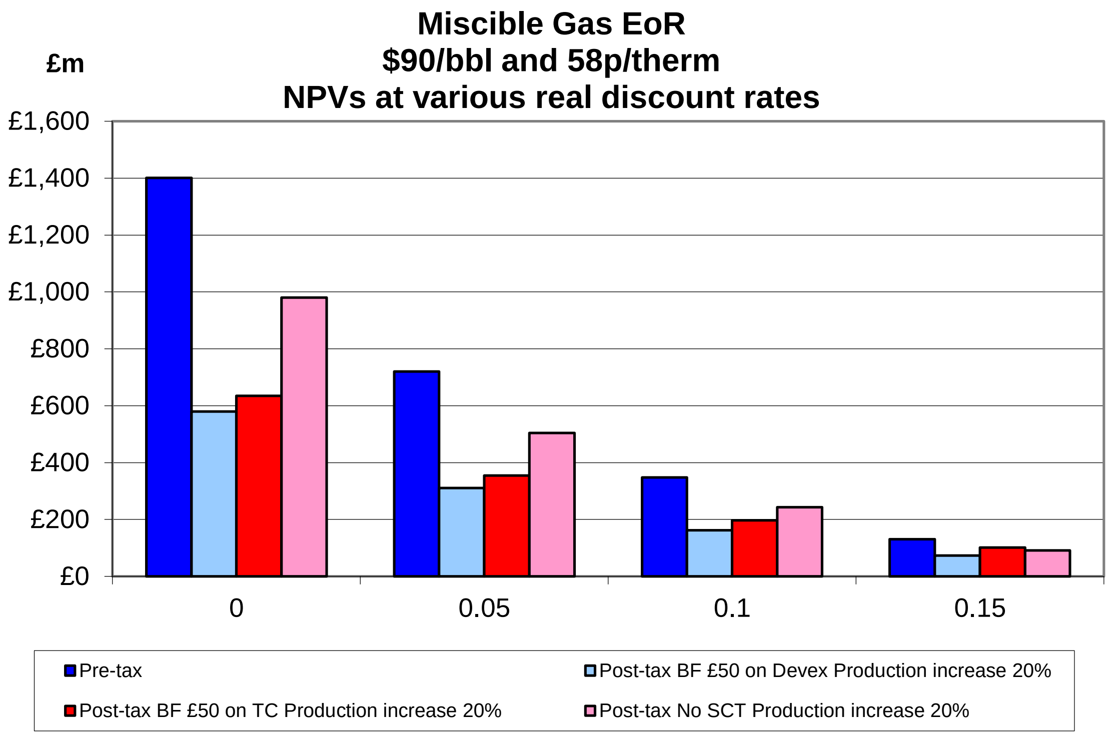
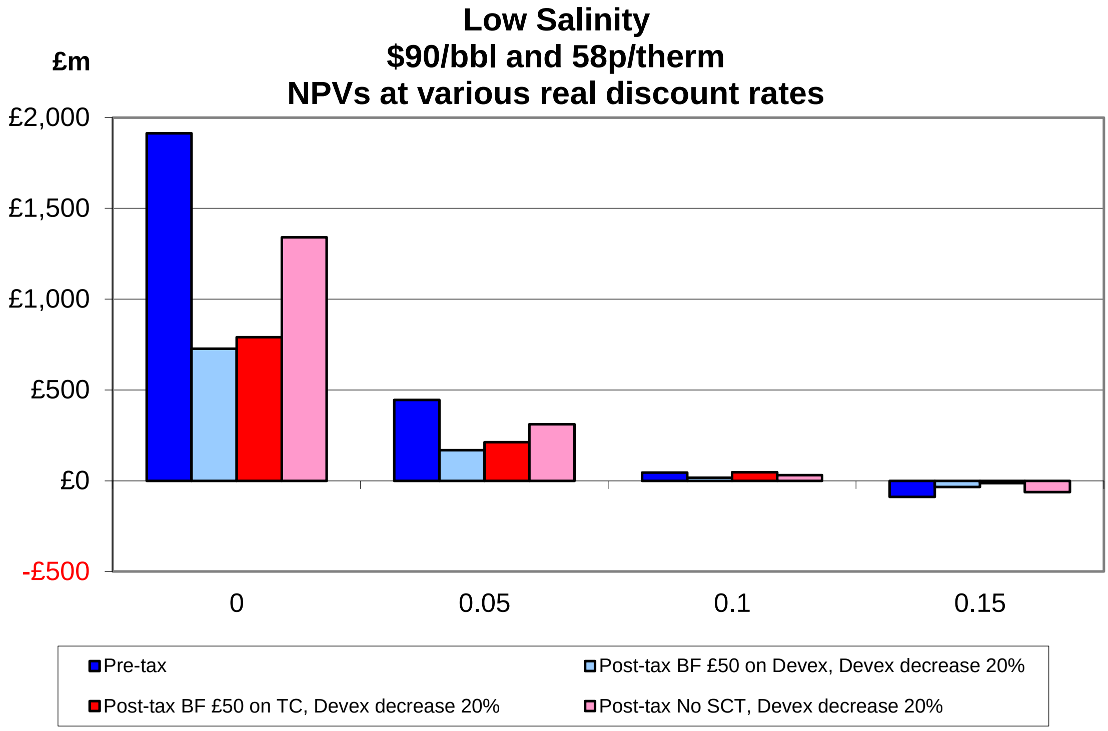


In Chart 19 the results are shown for the unrisked Polymer Flood scheme. At 10% discount rate all the NPVs are significantly positive. The NPV/I ratios exceed the 0.3 hurdle by very large margins in all cases.

In Chart 20 the returns to the Miscible Gas scheme are shown. At 10% discount rate the NPVs are all significantly positive. The post-tax NPV/I ratio is 0.38 with the present tax system. If the BF allowance at £50 per tonne were based on TC the NPV/I ratio becomes 0.46, and if there were no SC the ratio is even higher.

In Charts 21-24 the results are shown with a decrease in investment costs of 20% with (a) current BF allowance of £50 per tonne, (b) BF of £50 per tonne based on TC, and (c) no SC. For the Low Salinity project, in Chart 21 it is seen that, with the 10% discount rate, the NPVs are positive, but the NPV/I ratio is 0.07 with the allowance based on investment costs, and 0.16 when the allowance is based on TC. At 5% real discount rate the NPV/I ratios exceed 0.3 under all the schemes. The returns are clearly higher in the scheme with no SC.

Chart 21



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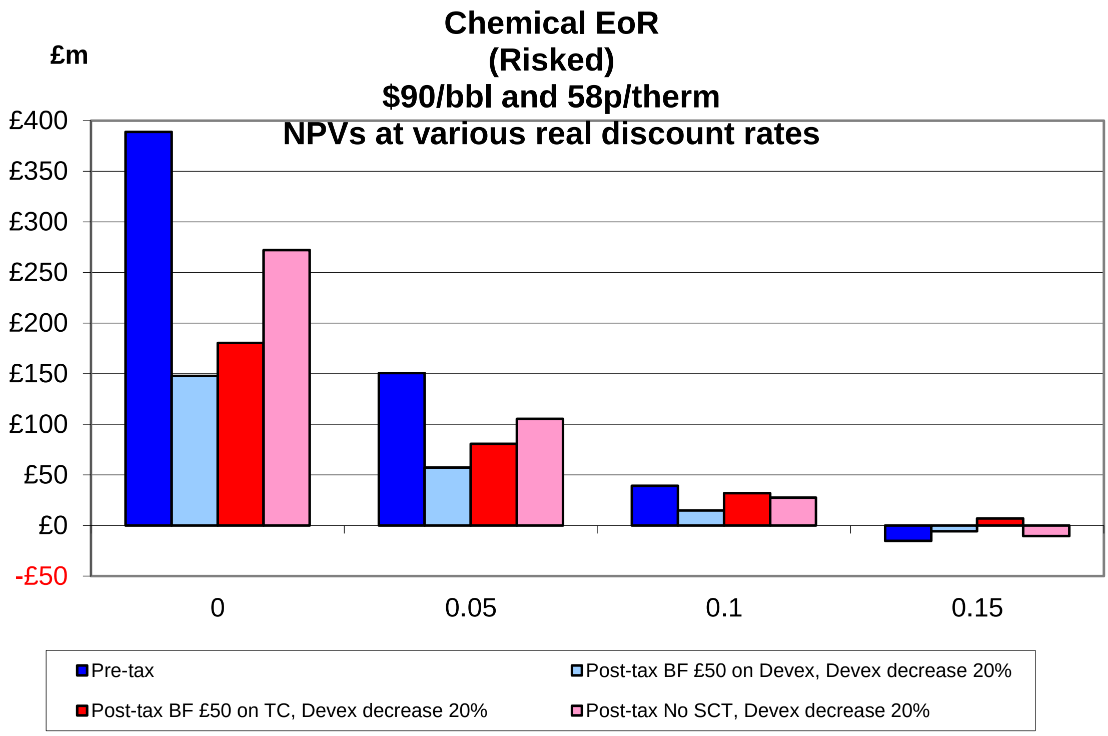

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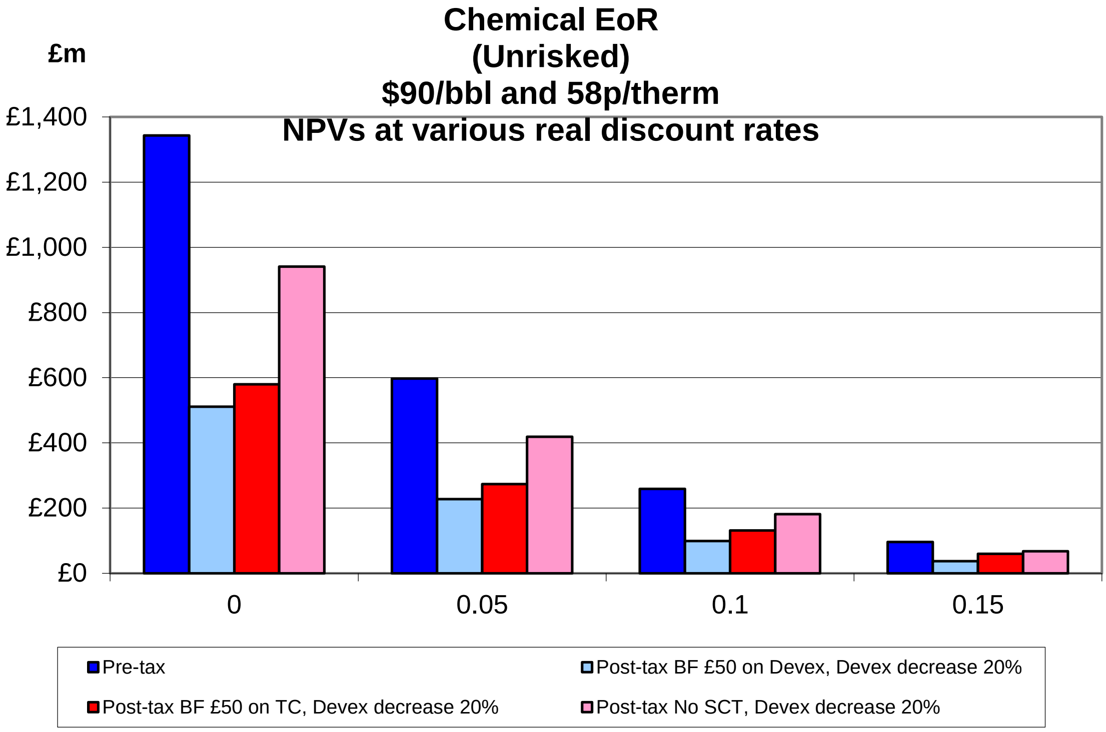

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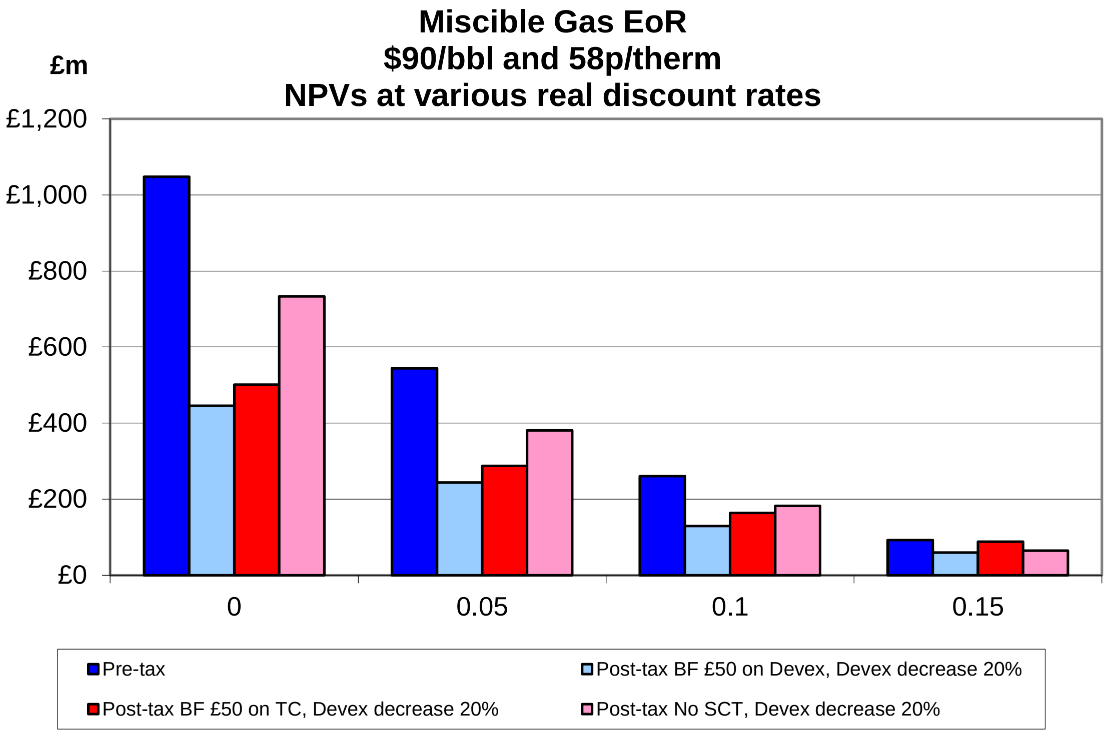


In Chart 22 the returns to the risked Polymer Flood scheme are shown. At 10% discount rate the NPVs are all positive. But with the present tax system the NPV/I ratio is only 0.186. When the BF allowance at £50 per tonne is based on TC the NPV/I ratio becomes 0.46.

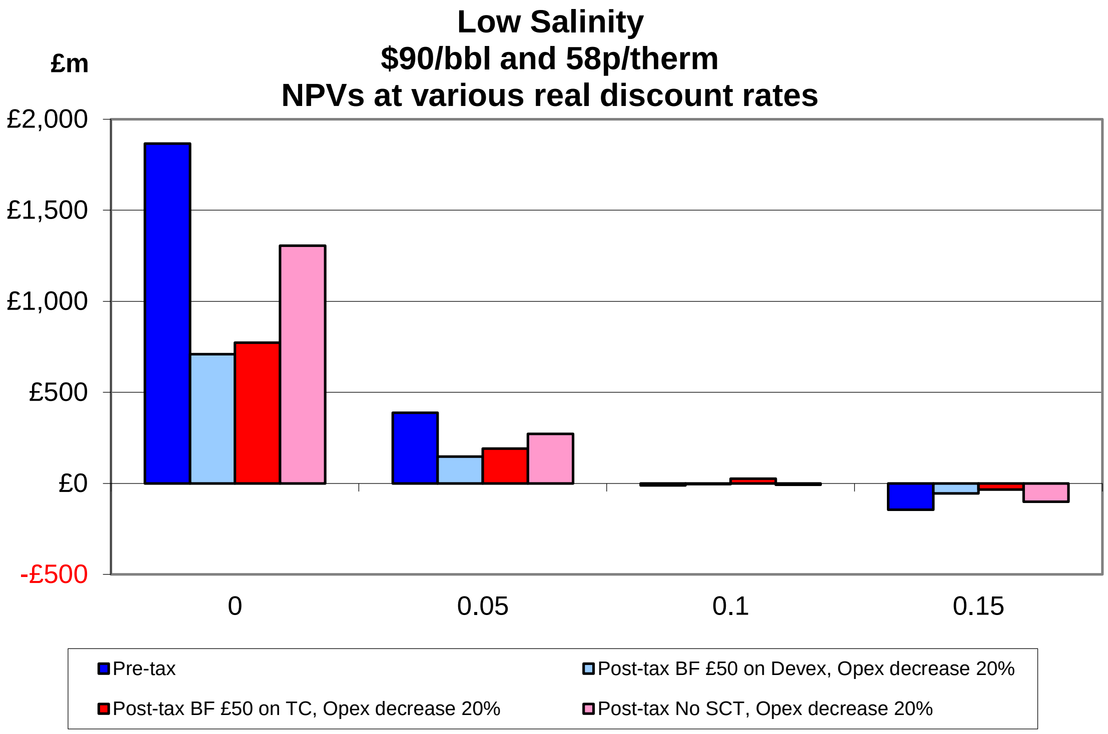
In Chart 23 the returns are shown to the unrisked Polymer Flood project. The NPVs are all positive at 10% real discount rate, and the NPV/I ratios are all well in excess of the hurdle of 0.3. The highest post-tax returns are achieved with the case of no SC.

In Chart 24 the returns are shown for the Miscible Gas project. At 10% discount rate the NPVs are all significantly positive. But the post-tax NPV/I ratio with the current tax system is 0.37. With the BF allowance at £50 per tonne based on TC the ratio is 0.46. With no SC the hurdle is clearly exceeded.

In Charts 25-28 the returns are shown with the operating costs decreased by 20% under (a) the present tax system, (b) the BF allowance at £50 per tonne based on TC, and (c) no SC. In Chart 25 the returns are shown for the Low Salinity project. The NPV/I ratios at 10% are far below the 0.3 hurdle. It is seen that the NPVs at 10% discount rate are either negative or very slightly positive. At 5% real discount rate the NPVs are all positive. With the present tax system the NPV/I ratio is 0.46.

In Chart 26 the returns to the risked Polymer Flood project are shown. At 10% real discount rate the NPVs are all positive. The NPV/I hurdle of 0.3 is passed before tax but with the present tax system the ratio is 0.21. With the BF allowance of £50 per tonne based on TC the ratio is 0.38. With no SC the ratio is 0.39.

Chart 25



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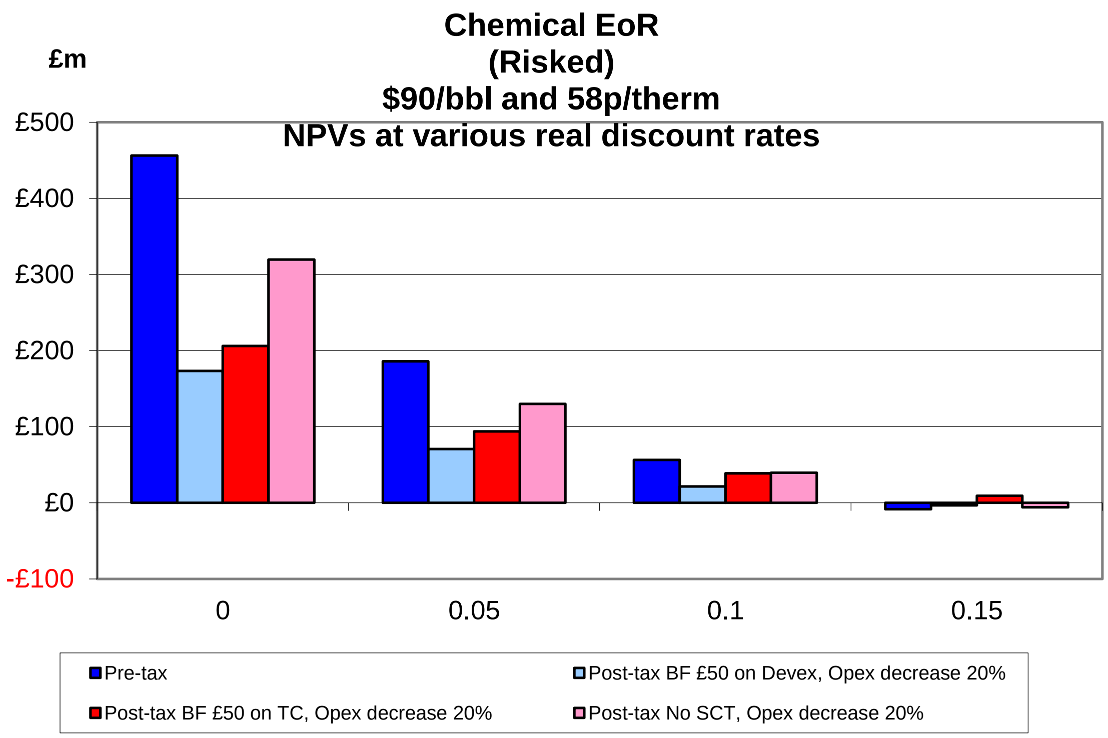

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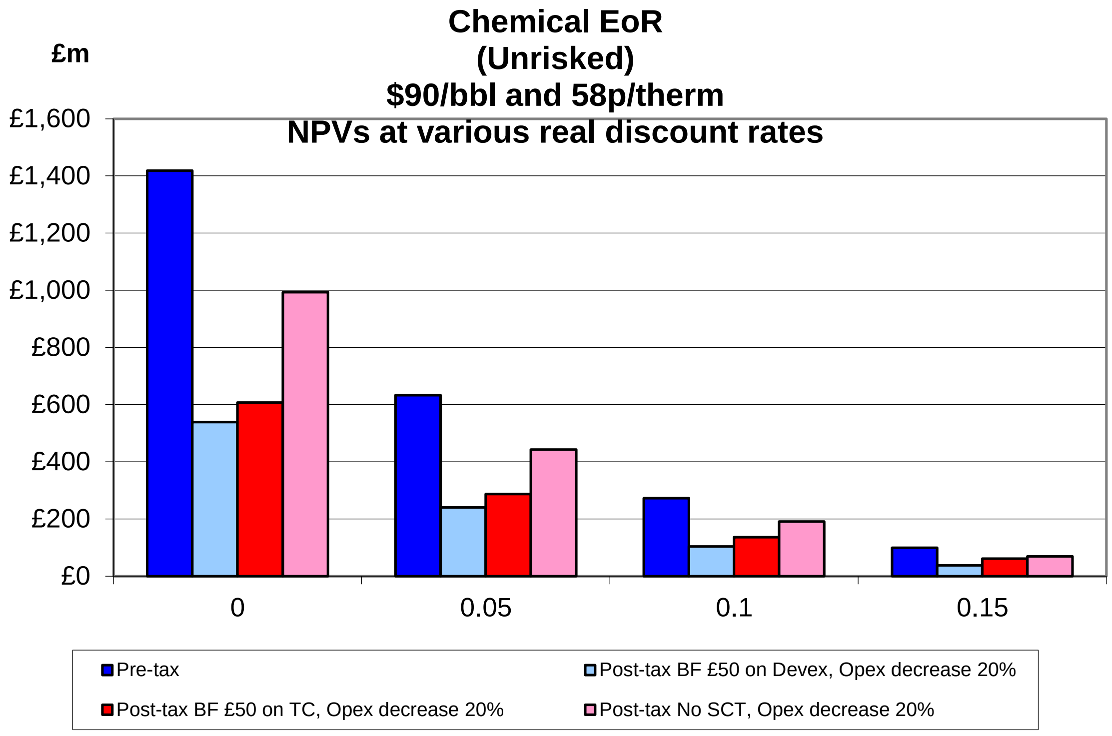

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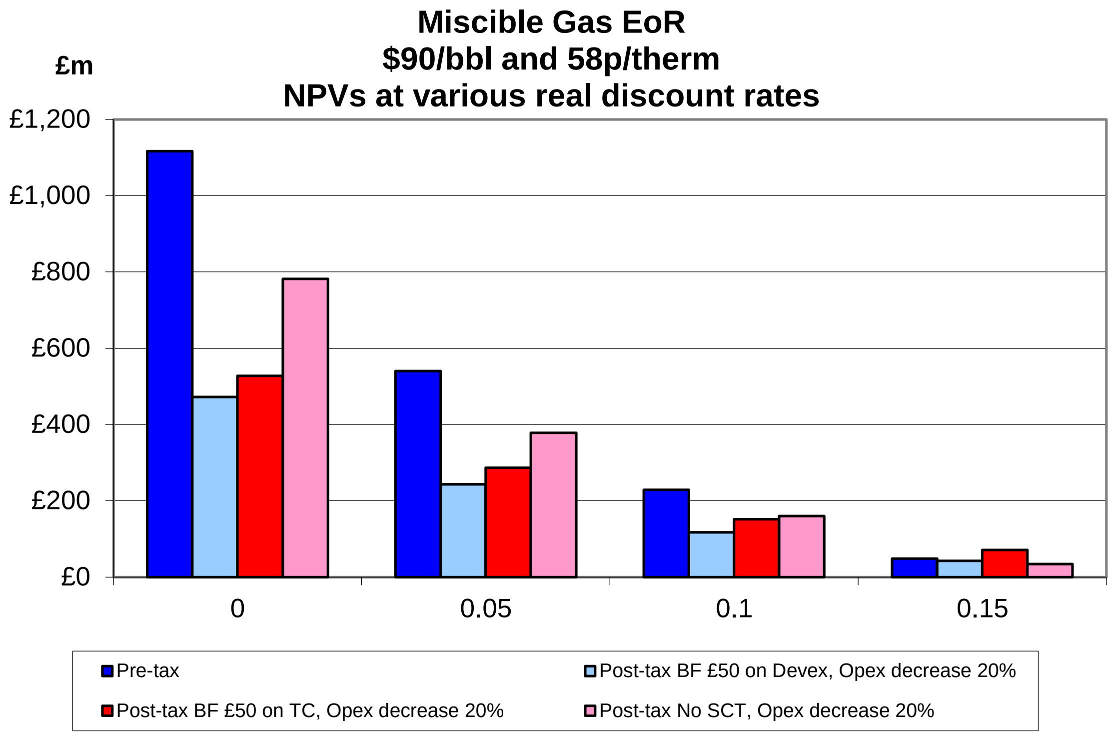


In Chart 27 the returns to the unrisked Polymer Flood project are shown. At 10% discount rate all the NPVs are significantly positive. The pre-tax NPV/I ratio is far above the 0.3 hurdle, and after the imposition of the present tax system it is 0.8. The highest post-tax returns are achieved with the removal of SC where the NPV/I ratio at 10% is 1.49.

In Chart 28 the results are shown for the Miscible Gas project. At 10% real discount rate all the NPVs are positive. The pre-tax NPV/I ratio clearly passes the 0.3 hurdle, but, under the present tax system, the post-tax ratio at 10% is 0.27. With BF allowance of £50 per tonne based on TC the hurdle is passed with a ratio of 0.35. With no SC the ratio at 10% is 0.37.

5. <u>Oil Price Sensitivity</u>

The effects of all the scenarios on the returns to the four projects were also evaluated at an oil price of $110 in real terms. The full set of results is reported in the Appendix. Significant differences and implications for the returns to the projects are summarised below.

(a) With respect to the Low Salinity project the pre-tax returns failed the NPV/I at 10% hurdle at both $90 and $110 prices. In the latter case the ratio is 0.176. At 5% discount rate the pre-tax returns at $90 were sufficient to meet the NPV/I > 0.3 hurdle. Under the existing tax system at 10% discount rate the project failed the NPV/I > 0.3 hurdle at both $90 and $110 prices. In the latter case the ratio is 0.067. At 5% real discount rate the project passes the NPV/I > 0.3 hurdle at the $90 price and so at the $110 one. With the investment uplift schemes the project failed the NPV/I > 0.3 hurdle at both $110 and $90 prices at 10% discount rate. At 5% discount rate the hurdle was passed at

$90 prices and so at $110. With uplift based on TC the project fails the hurdle at $110 as well as at $90 at 10% discount rate. The NPV/I ratio is 0.13 at $110. With no SC the project again fails the hurdle of NPV/I > 0.3 at 10% discount rate at $110 as well as at $90. At 5% discount rate without SC the project passes the hurdle at $90 as well as at $110. With respect to the effects of variations in production, investment costs, and operating costs there is generally little difference across the two price scenarios regarding whether or not the project passes the post-tax investment hurdle.

(b) With respect to the risked Polymer Flood scheme, at $110 price at 10% discount rate the project has a pre-tax NPV/I ratio of 0.82 and a post-tax one of 0.31 with the present tax system. At $90 price the post-tax ratio was only 0.07. At 5% real discount rate the project passes the pre-tax hurdle at $90. With BF allowance at £75 per tonne based on TC the project clearly passes the investment hurdle at 10% discount rate at $110 with a ratio of 0.56. At the $90 price the ratio is 0.32. With the investment uplift schemes at 10% discount rate the project fails the NPV/I test at $90 even with uplift at 75%, but passes the hurdle at $110. Even with the uplift at 50% the NPV/I ratio is 0.41. When the uplift is based on TC the project passes the hurdle at $90 as well as $110, even with the uplift at 50%. When SC is removed from the EOR projects at 10% discount rate it fails the investment hurdle at $90, but clearly passes it at the $110 price. When production is increased by 20% at 10% discount rate the project passes the hurdle at $90 under the present tax system. Similarly, when investment costs are reduced by 20% at 10% discount rate the project passed the investment hurdle at $90 under the present tax system. When operating costs are reduced by 20% at 10% discount rate the project also passes the investment hurdle under the current tax system at $90 price.

(c) The unrisked Polymer Flood scheme was found to pass all the investment hurdles at $90 as well as $110 at 10% real discount rates.

(d) With respect to the Miscible Gas scheme it was found that the project clearly passed the pre-tax investment hurdle at 10% real discount rate at $90 as well as $110. But on an after-tax basis the project failed the hurdle at 10% discount rate under the present tax system at $90 price (ratio of 0.22), but passed the hurdle at $110 price (ratio of 0.39). A larger BF allowance (£75 per tonne based on TC per tonne of EOR) was needed to enable the hurdle to be passed at the $90 price. If the investment uplift were introduced it was found that at 50% rate the project failed the investment hurdle at $90 (ratio of 0.18), but passed it at $110 (ratio of 0.45). At the $90 price an investment uplift of 75% was needed to pass the hurdle. When the uplift was based on TC the project passed the hurdle under the $90 price with a 50% rate (ratio of 0.37). If SC were removed from EOR projects the Miscible Gas project just fails the hurdle at 10% discount rate and $90 price (ratio of 0.29), but passes it at the $110 price (ratio of 0.6). If production were to increase by 20% the project passes the hurdle at 10% discount rate at $90 as well as $110 under the present tax system. The same finding applies to reductions in investment costs of 20%. With reductions in operating costs of 20% the investment hurdle is not reached at 10% discount rate at the $90 price (ratio is 0.27), but is comfortably passed at $110 price (ratio is 0.45).

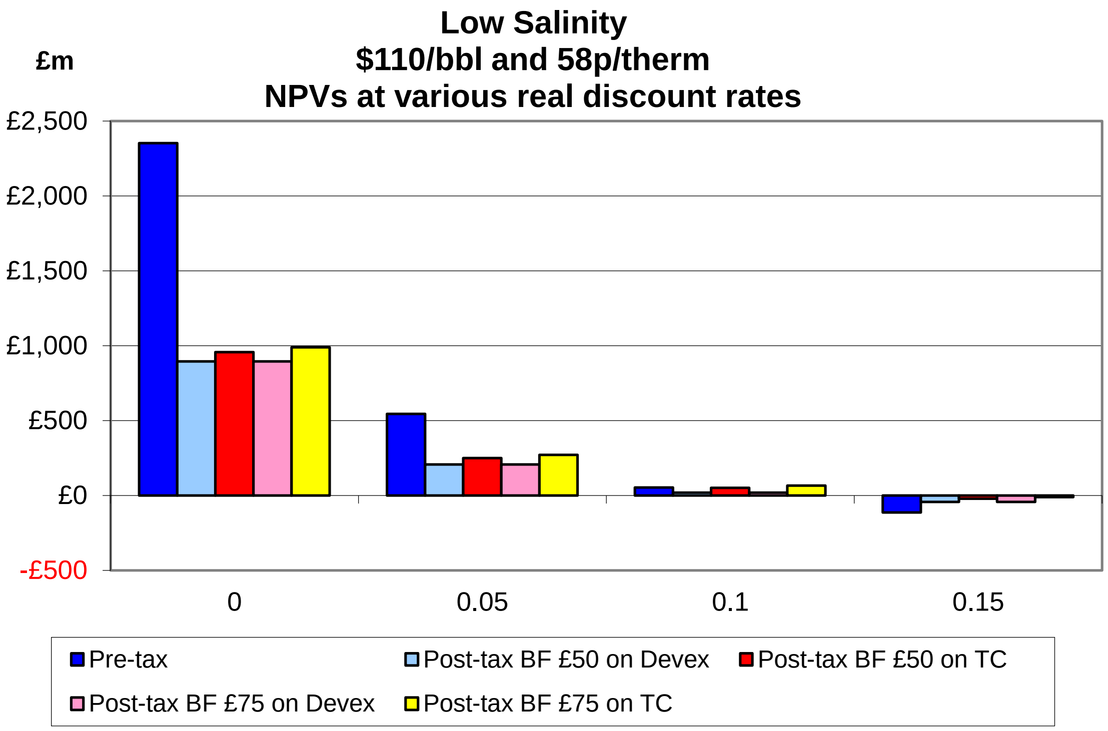
6. Conclusions

In this study the economics of several EOR projects in the UKCS have been examined in detail in the context of the Tax Review. The findings indicate that currently the project investment economics are quite challenging. At oil prices and hurdle rates likely to be employed by investors the returns are generally modest. The efficiency of several types and rates of further tax incentives was examined. An uplift allowance for SC related to investment and operating costs (TC) was found to produce incentives which performed reasonably efficiently. The provision of an uplift relating to operating costs is unusual, but, given the very high costs involved in purchasing polymers and gas for schemes which are promising in the context of the UKCS there is a case for an uplift relating to these product requirements. They are akin to capital expenditures when a wider view of their purpose is considered. Even a partial allowance for these costs would be reasonably effective.

The more radical approach of removing SC from EOR projects was also considered. In many circumstances this operated reasonably efficiently. But in rather more cases the uplift mechanism produced a more effective solution.

Appendix

Chart A1



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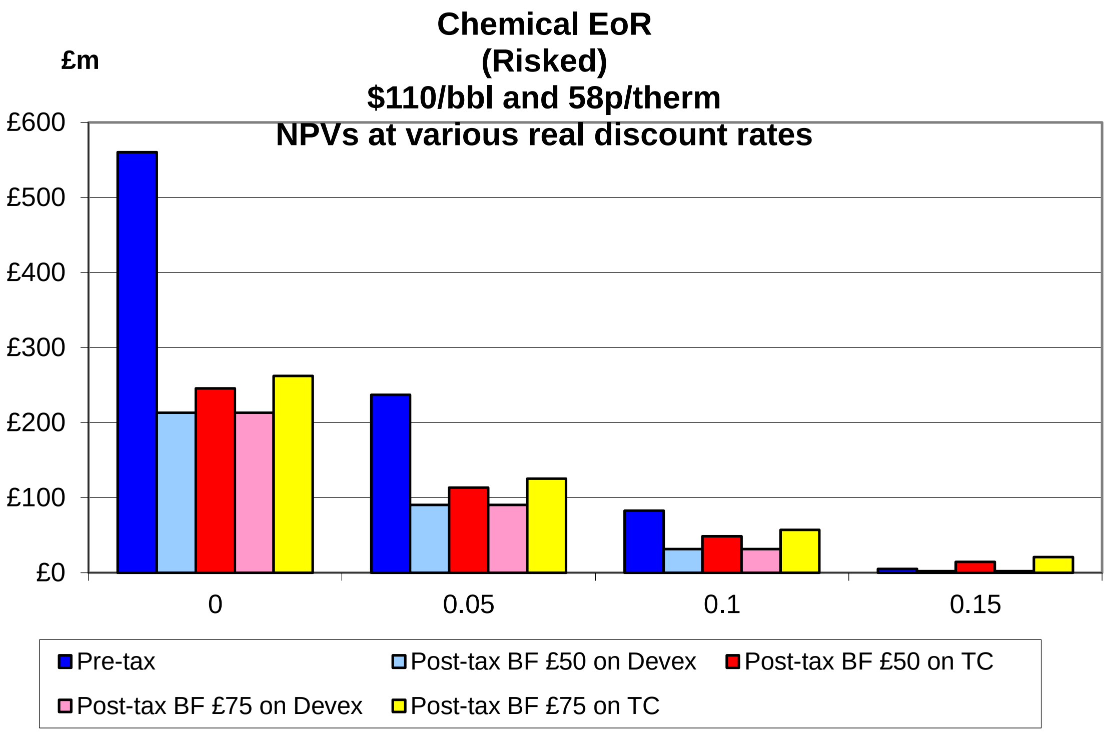

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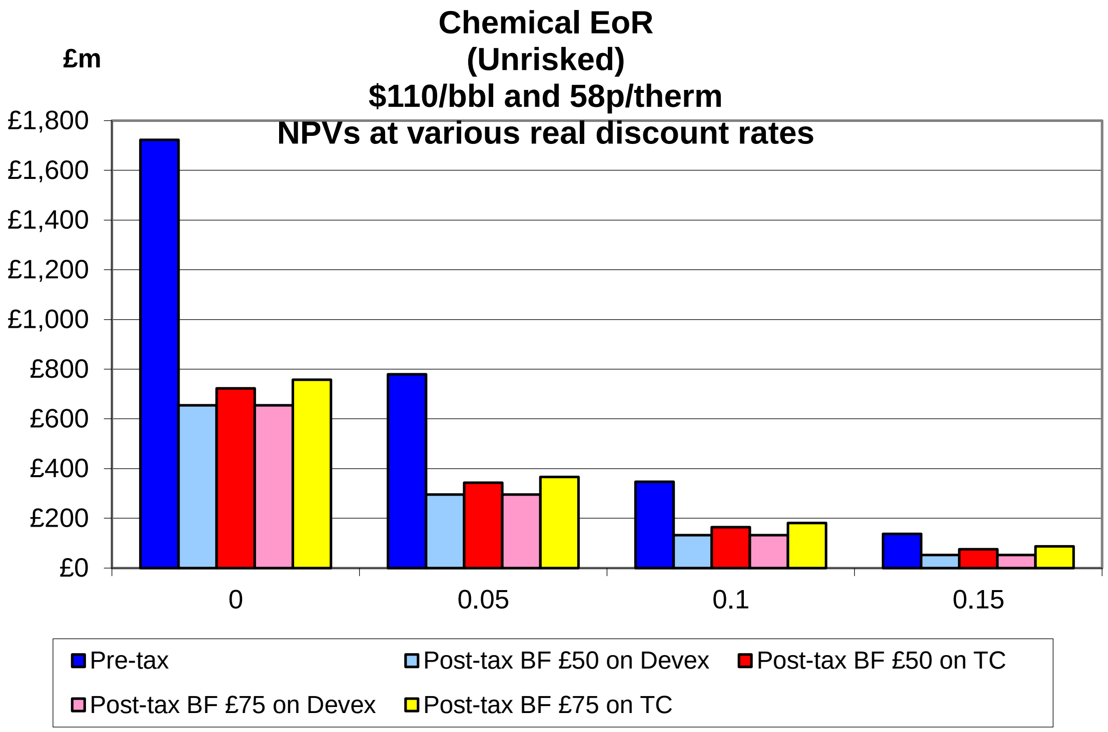

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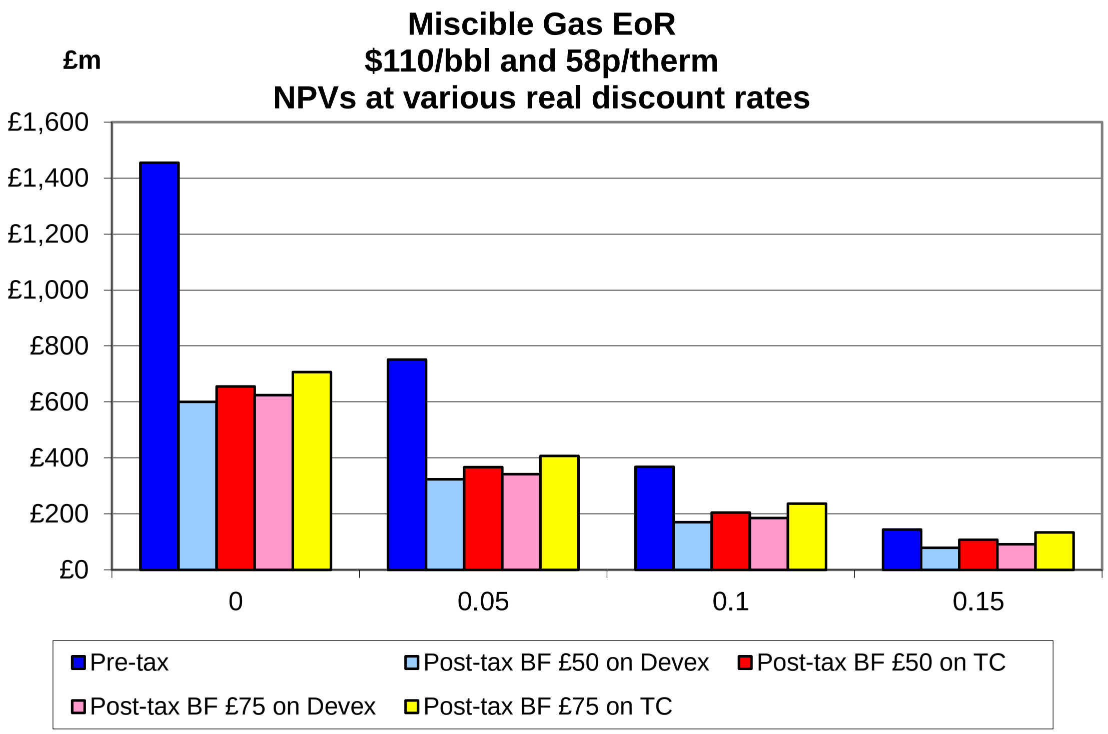

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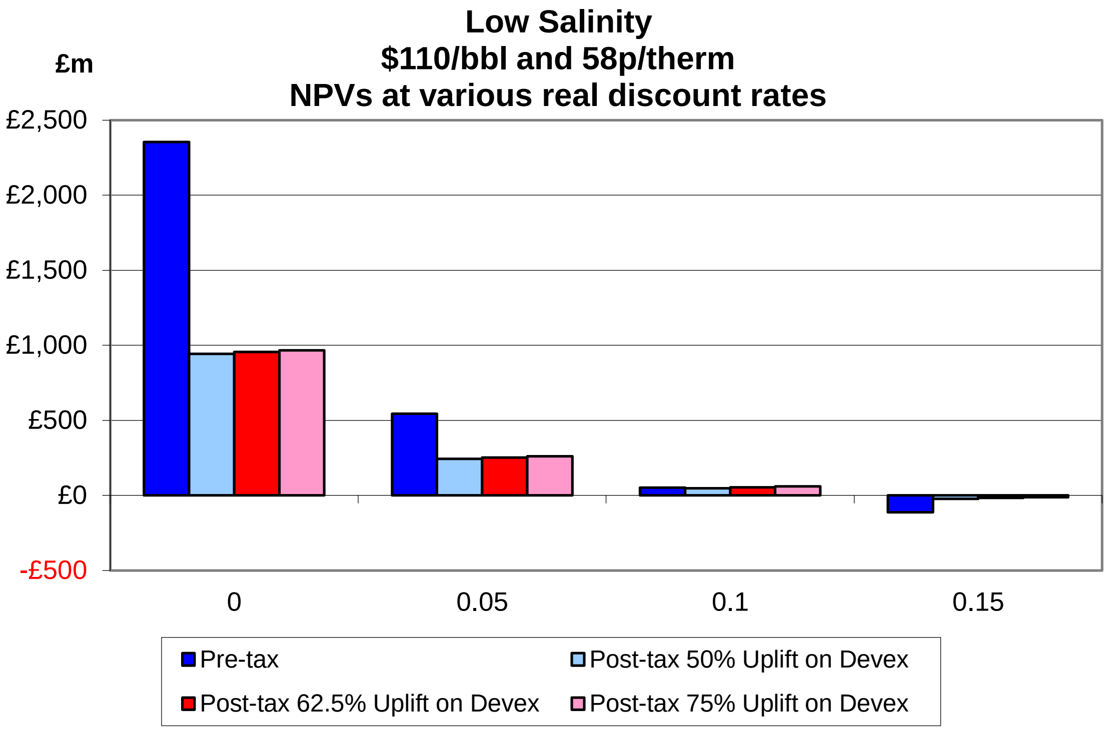

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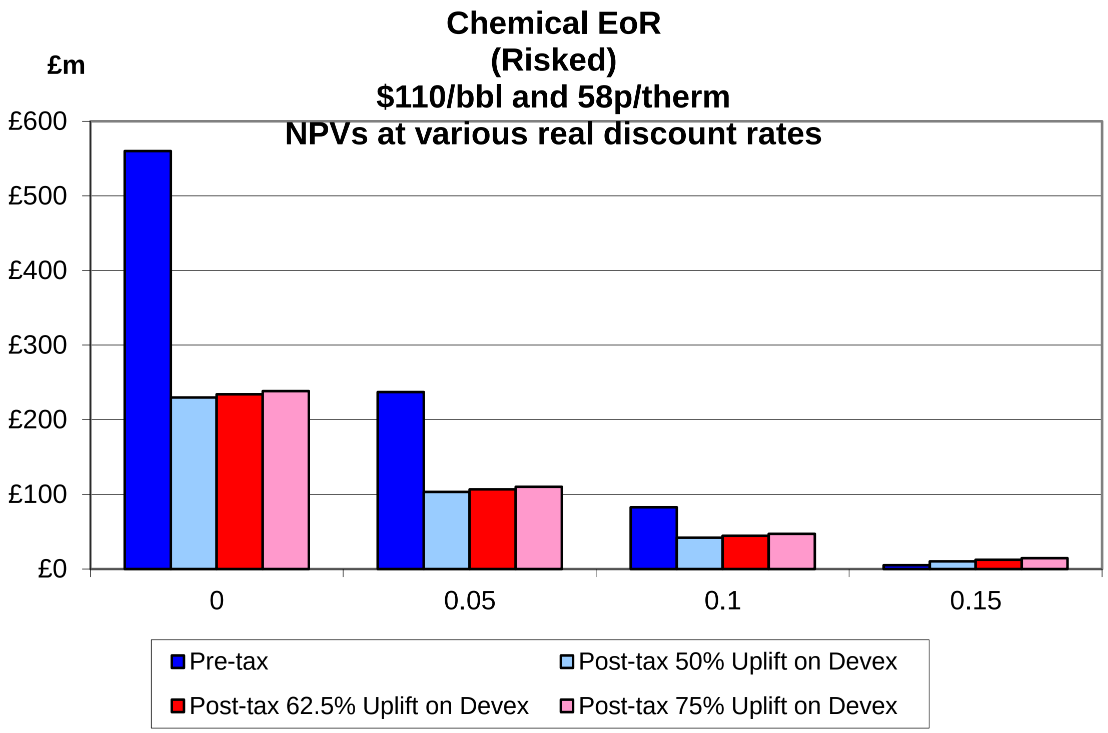

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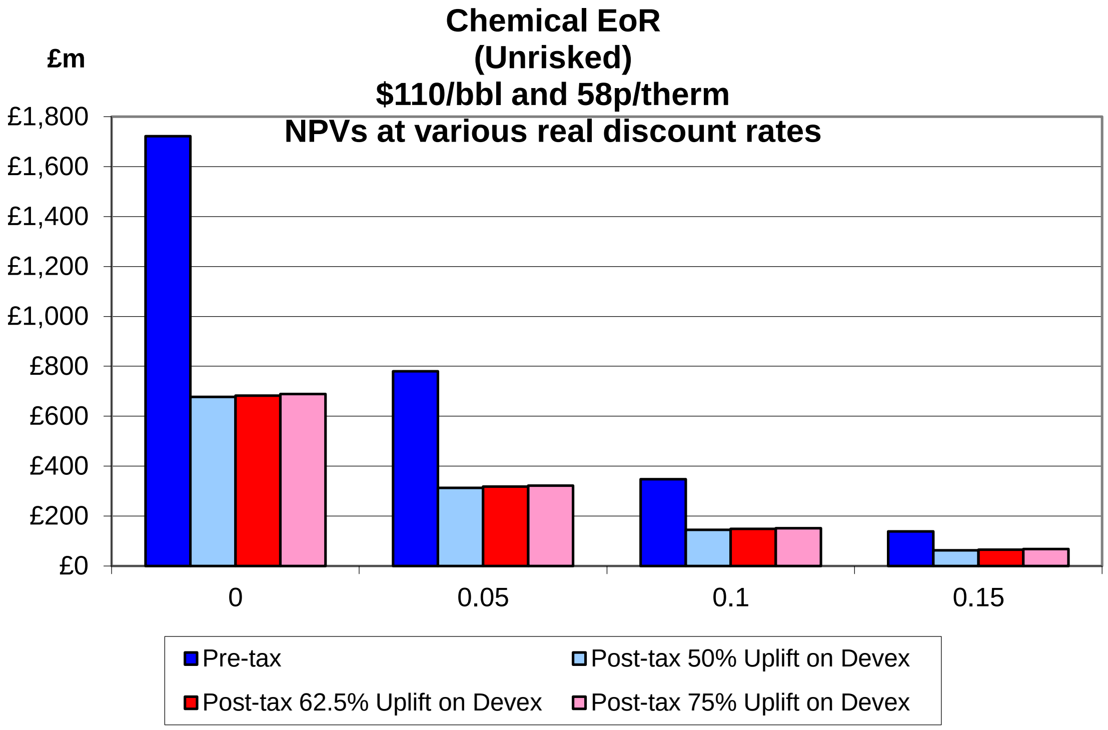

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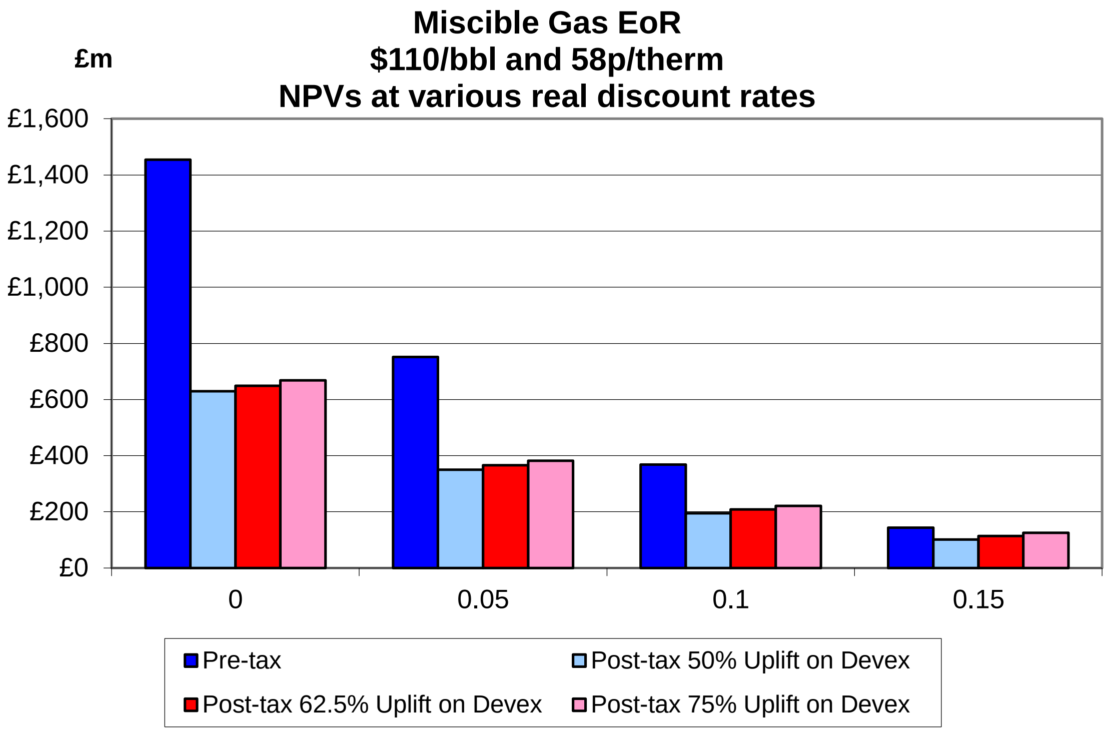

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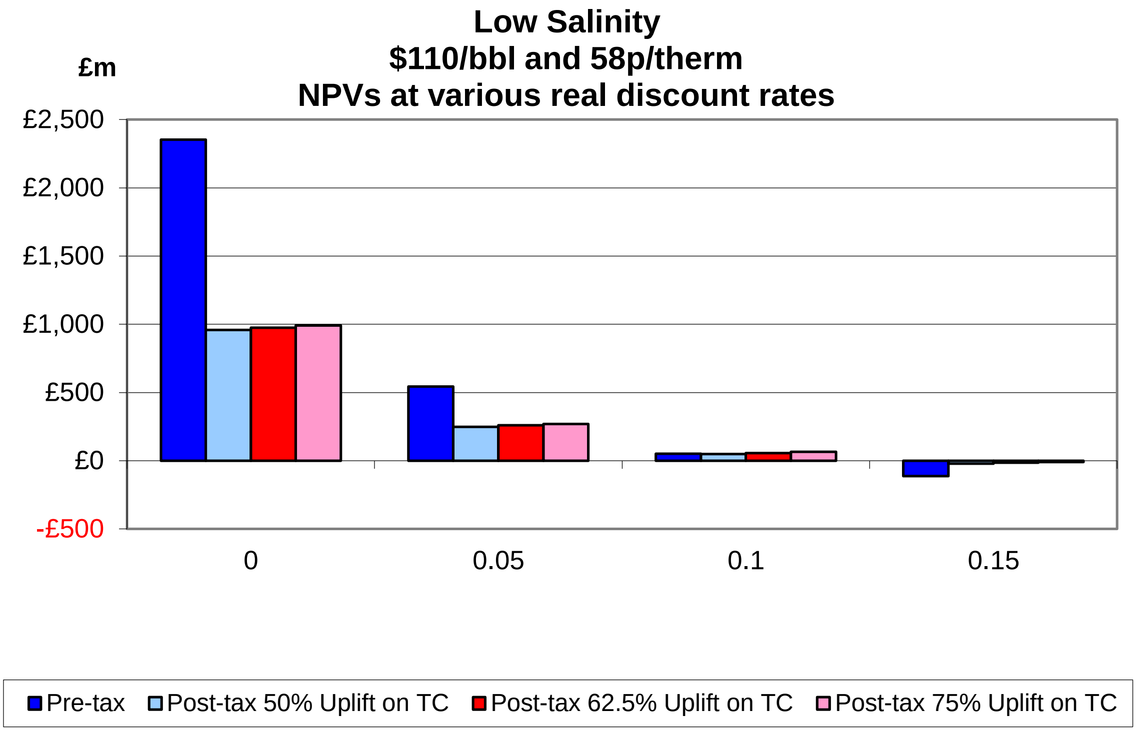

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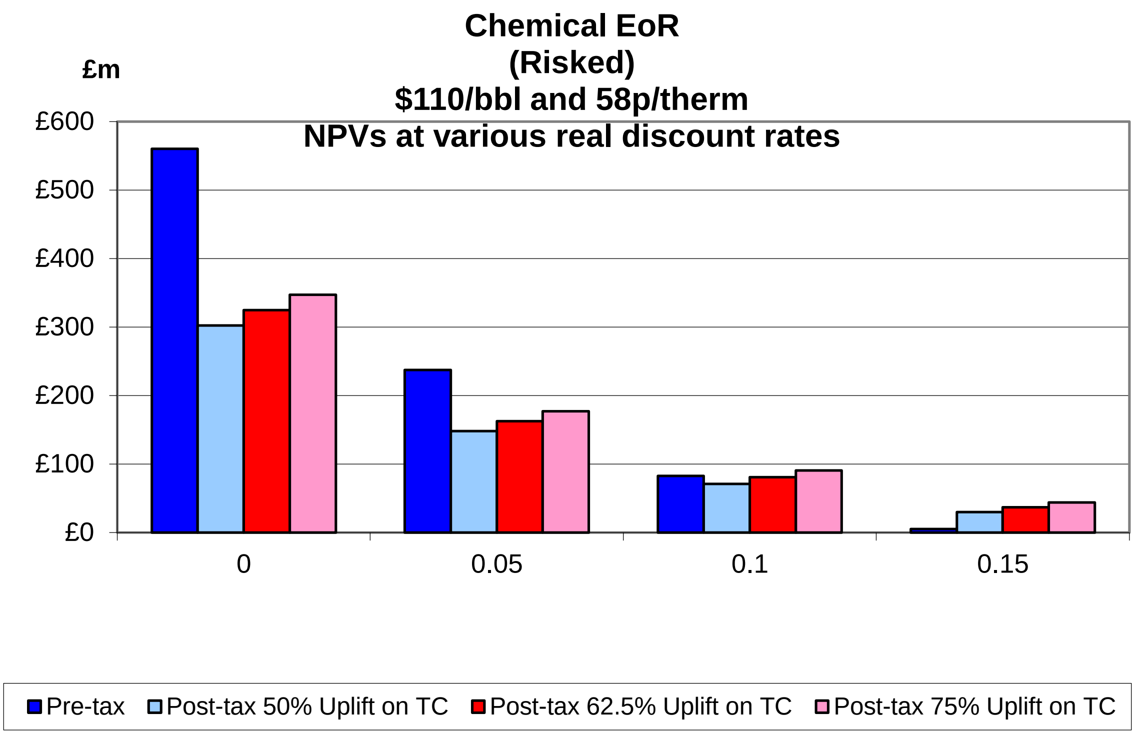

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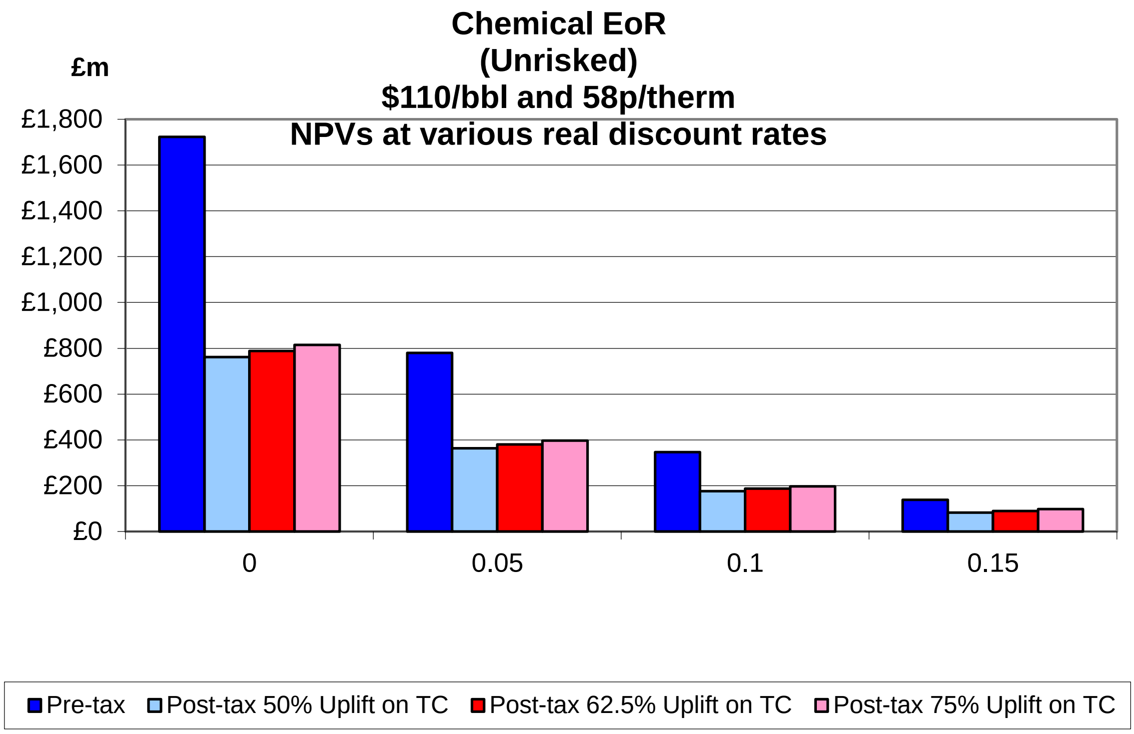

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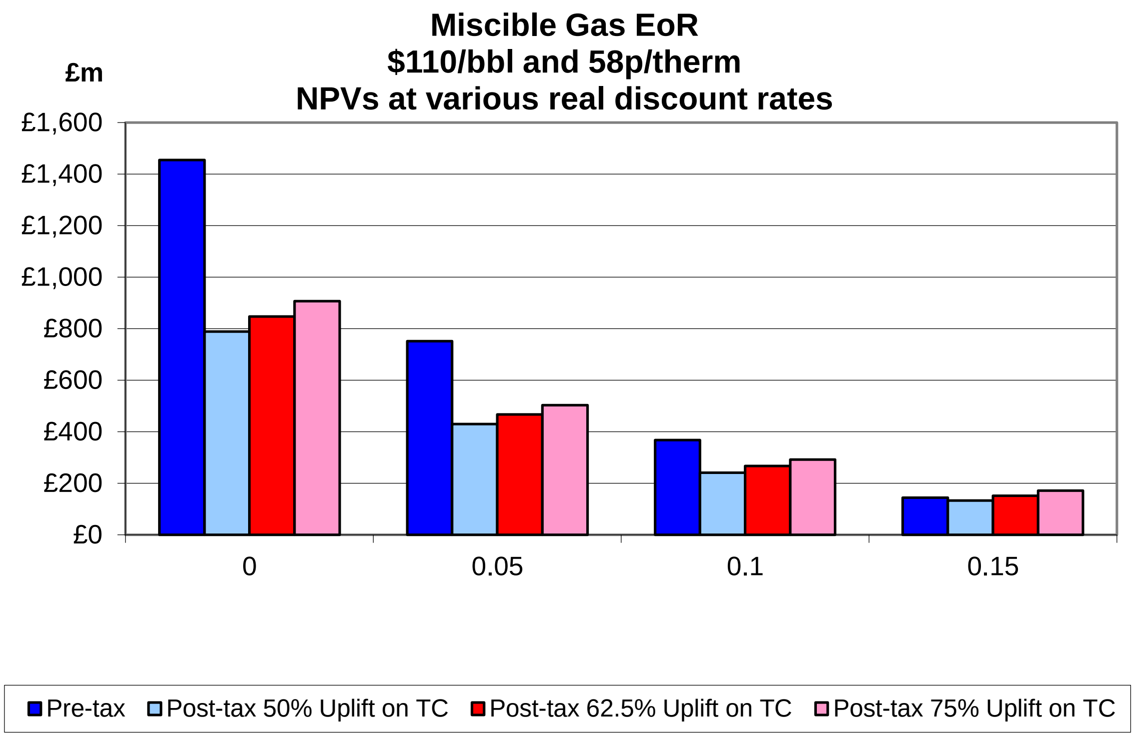

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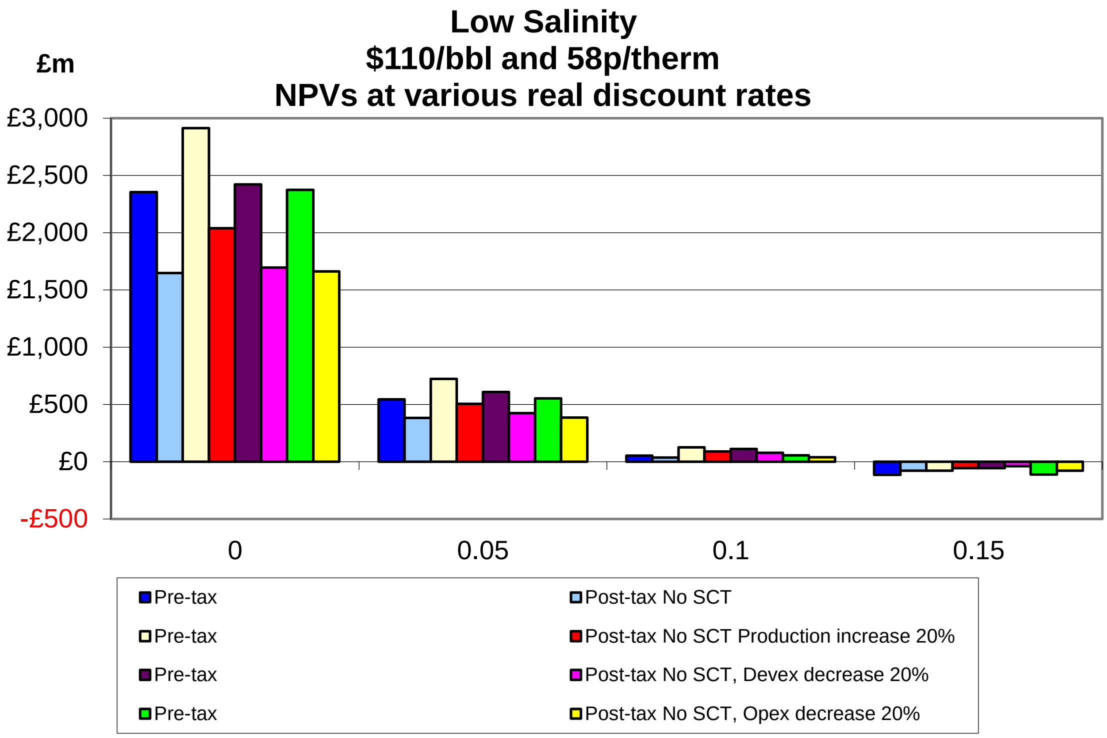

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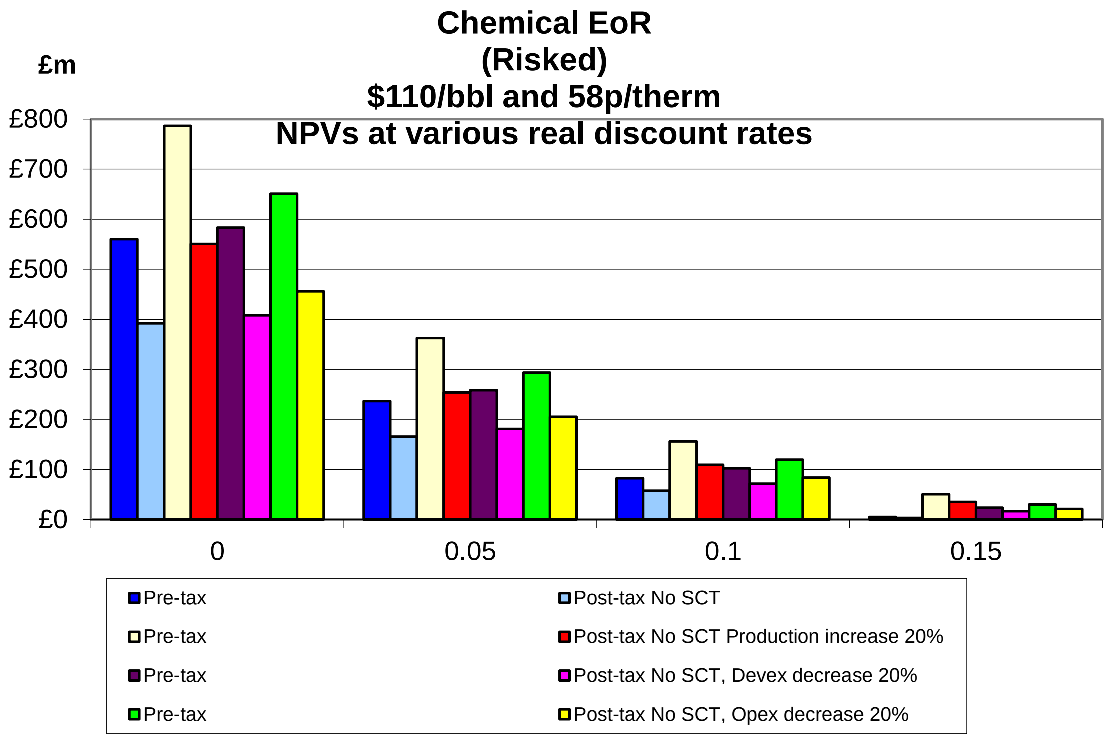

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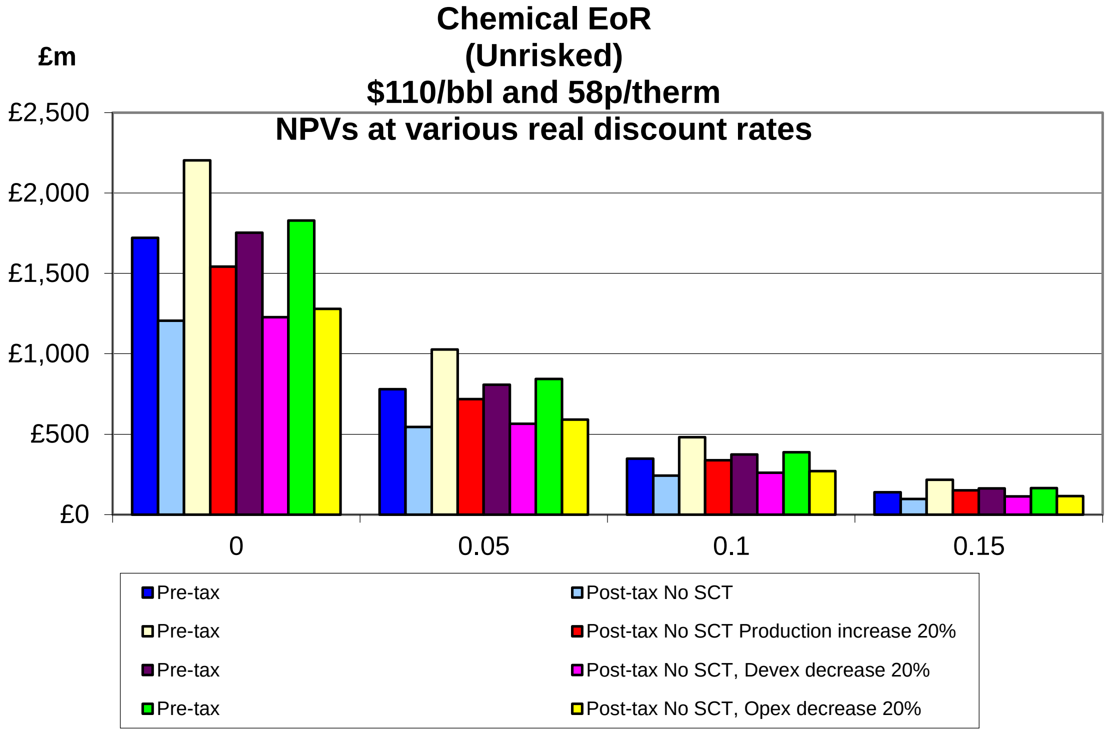

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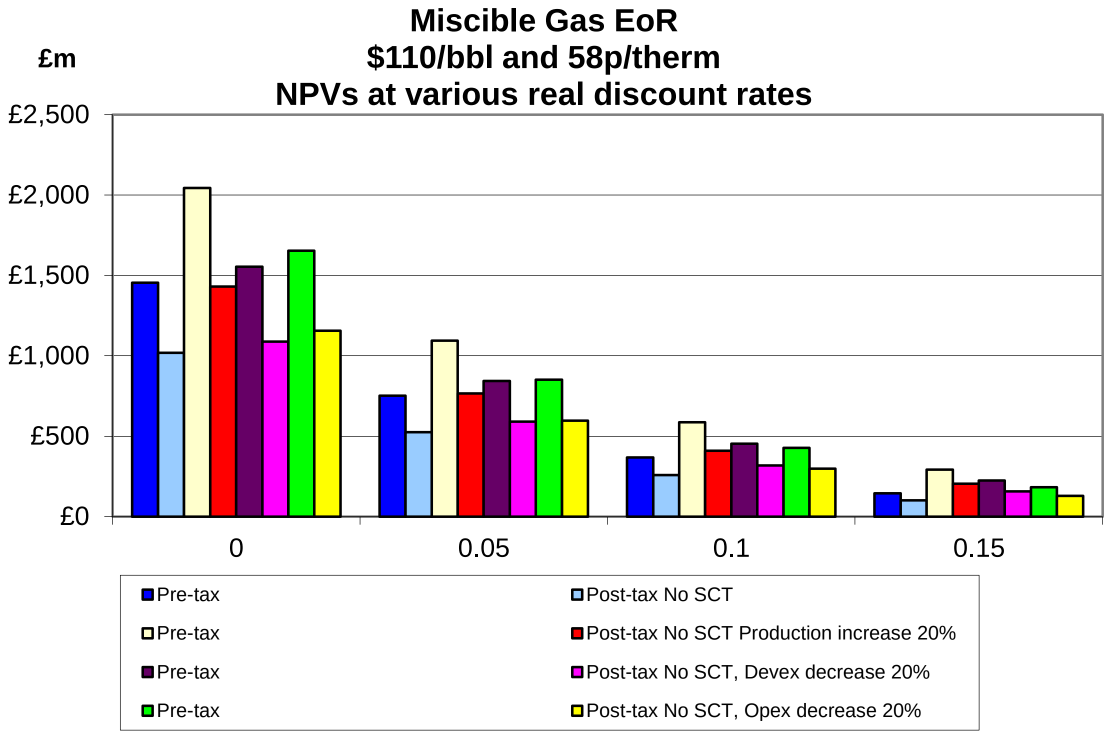

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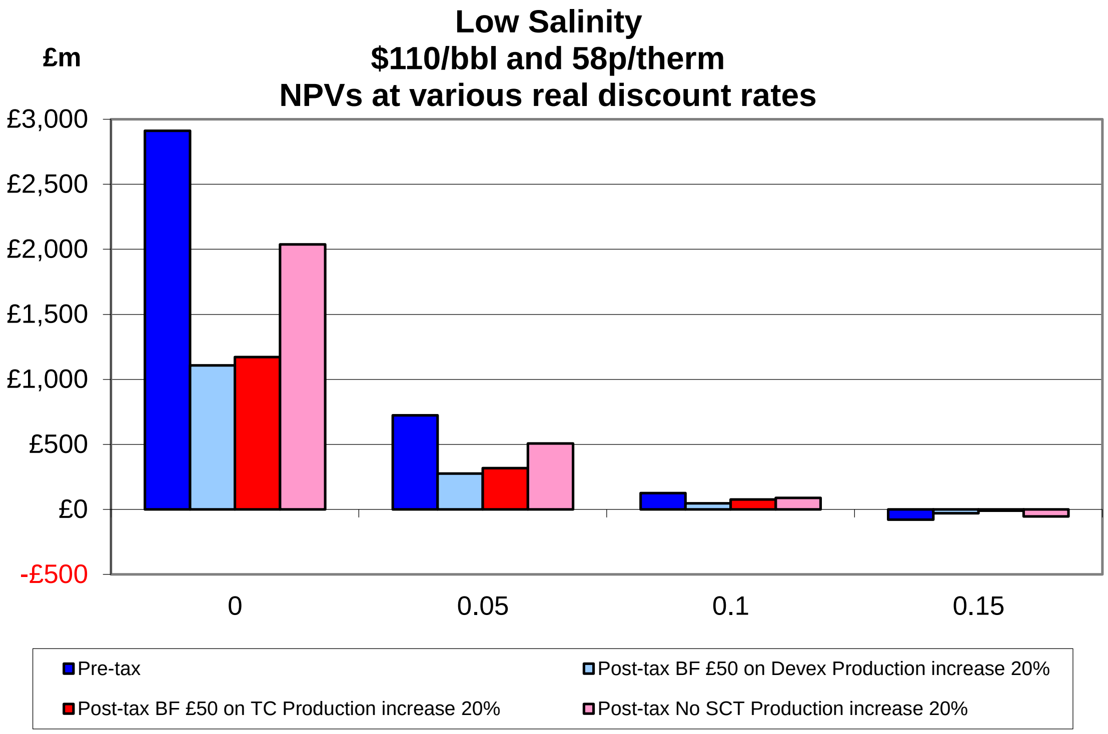

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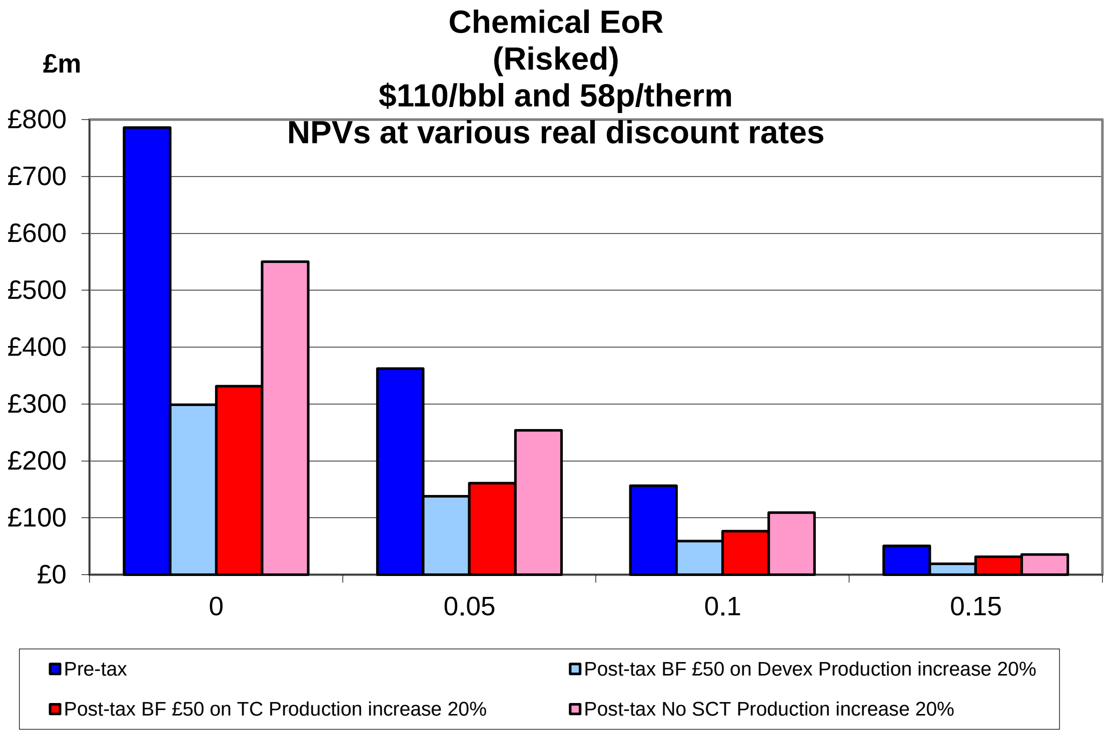

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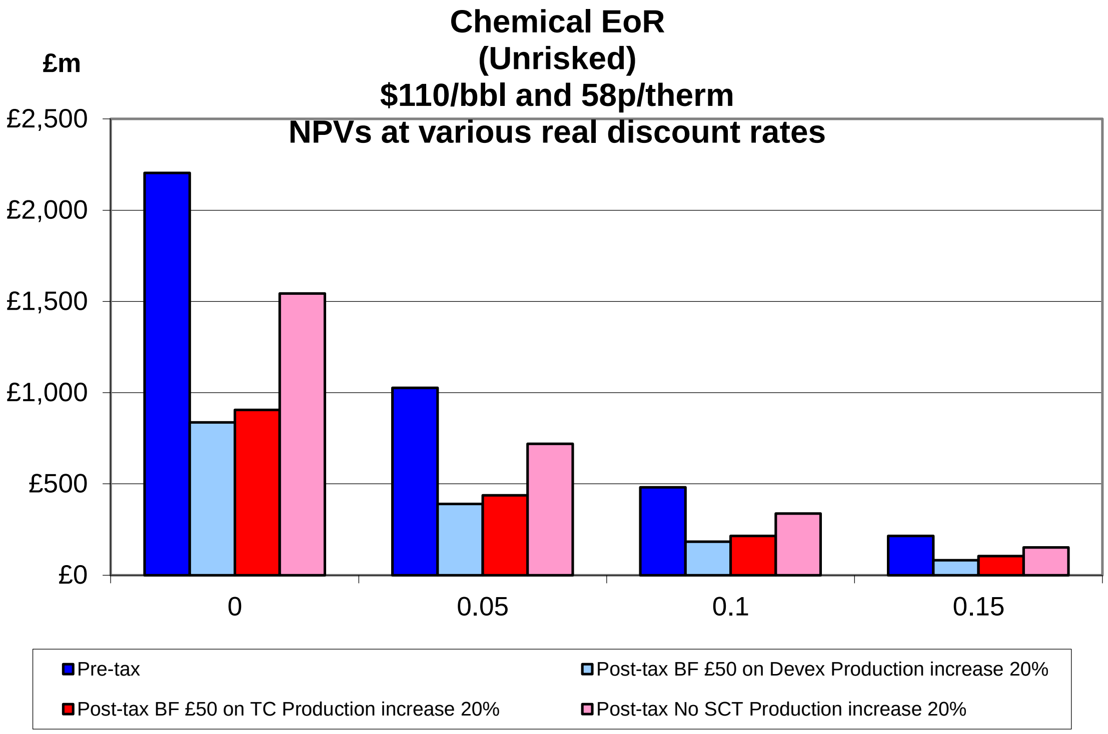

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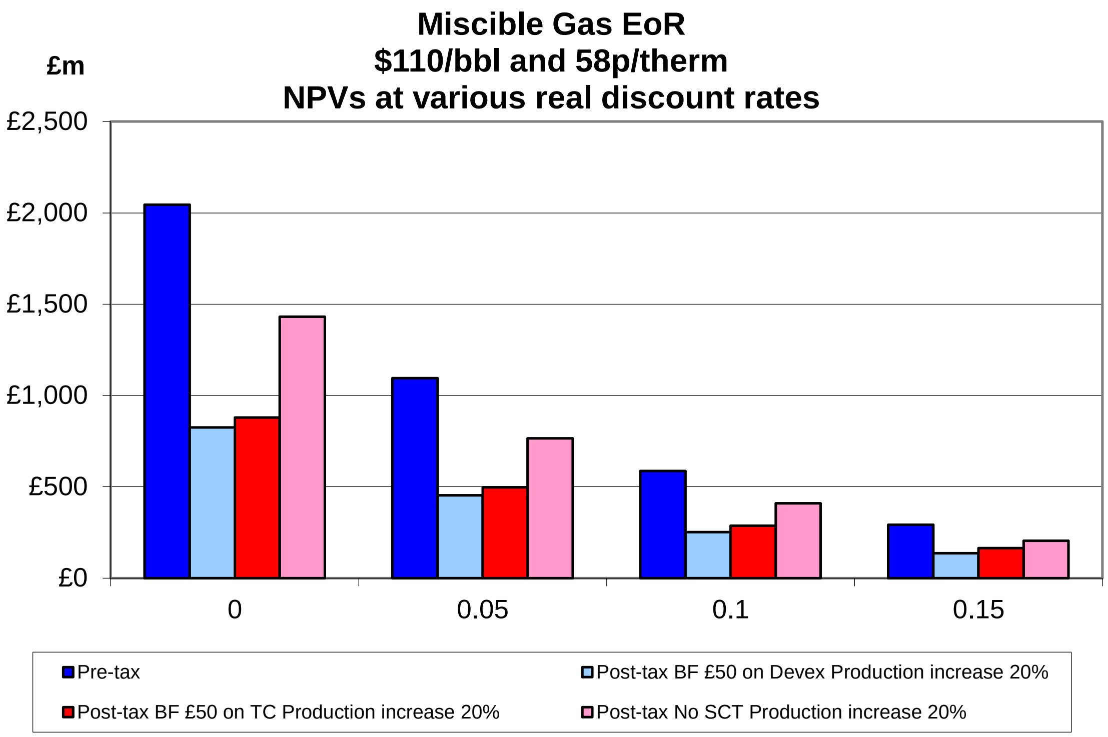

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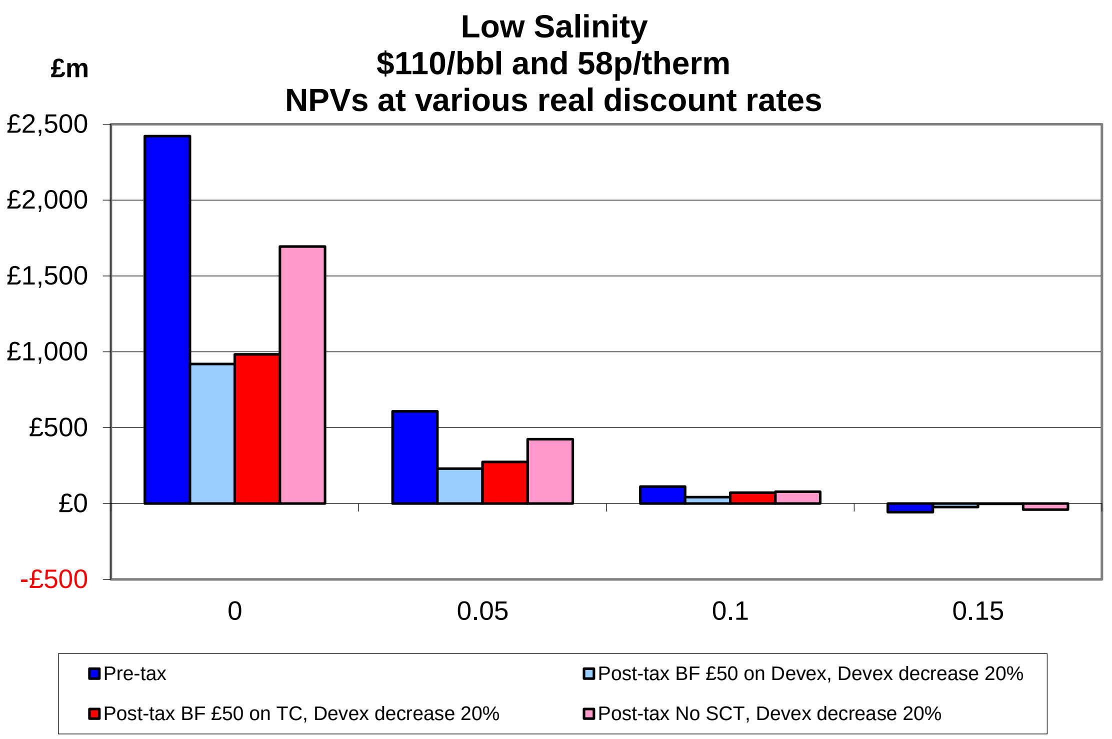

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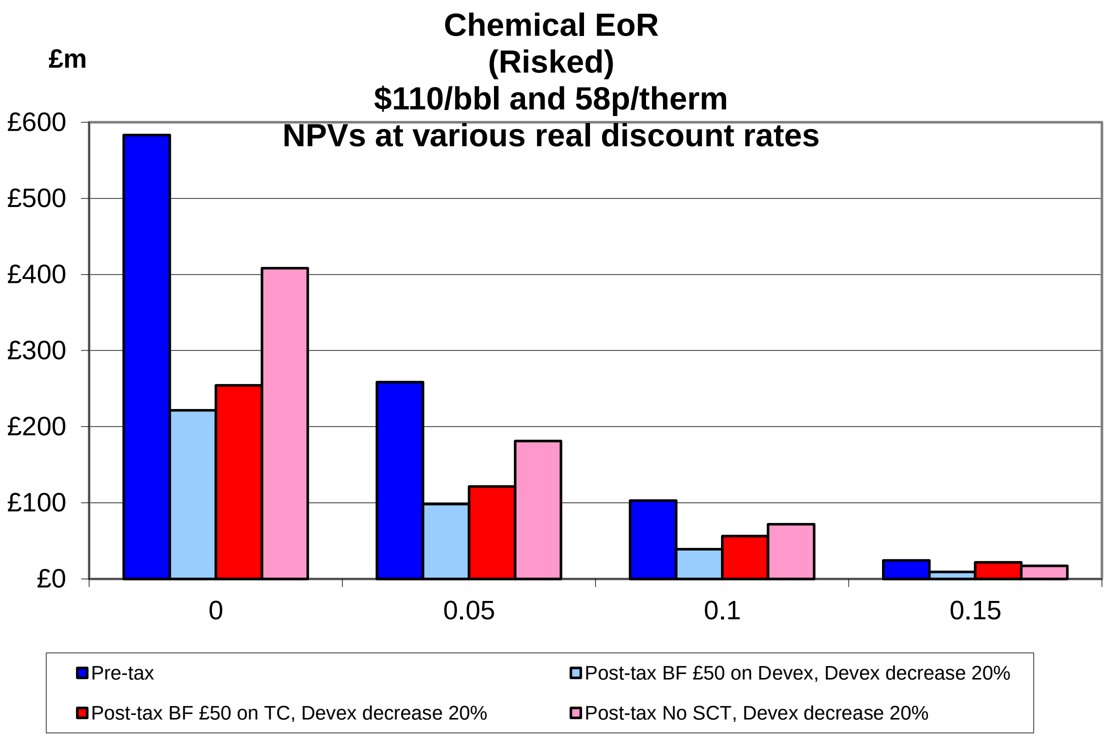

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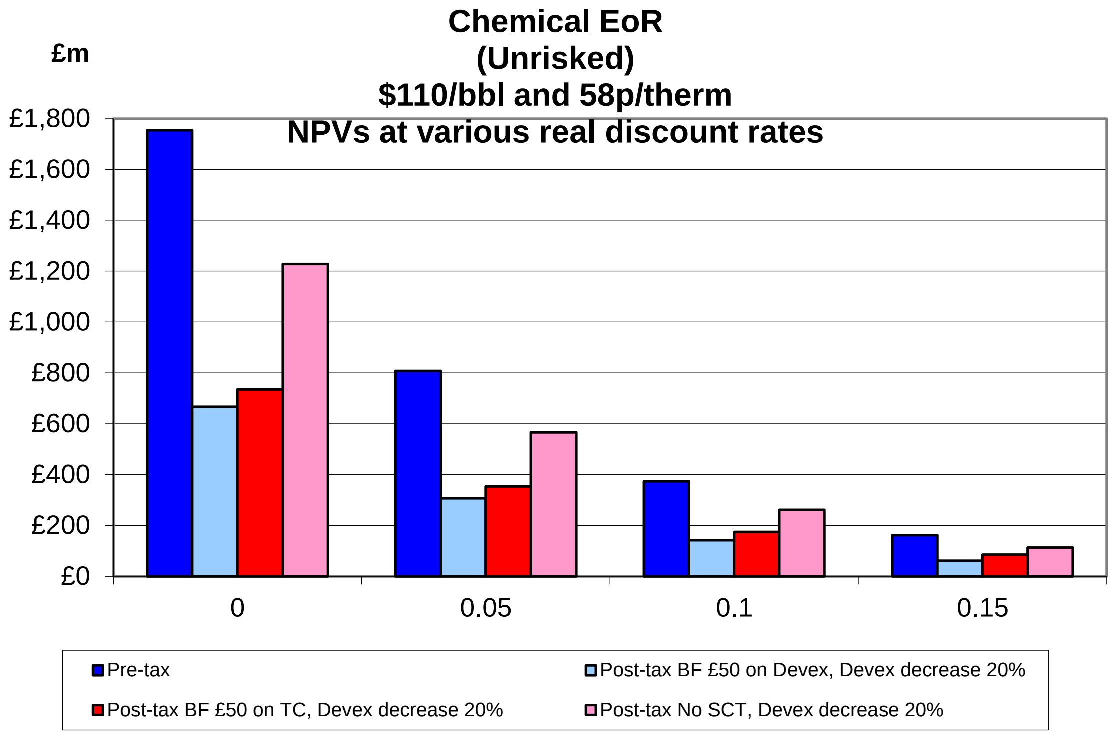

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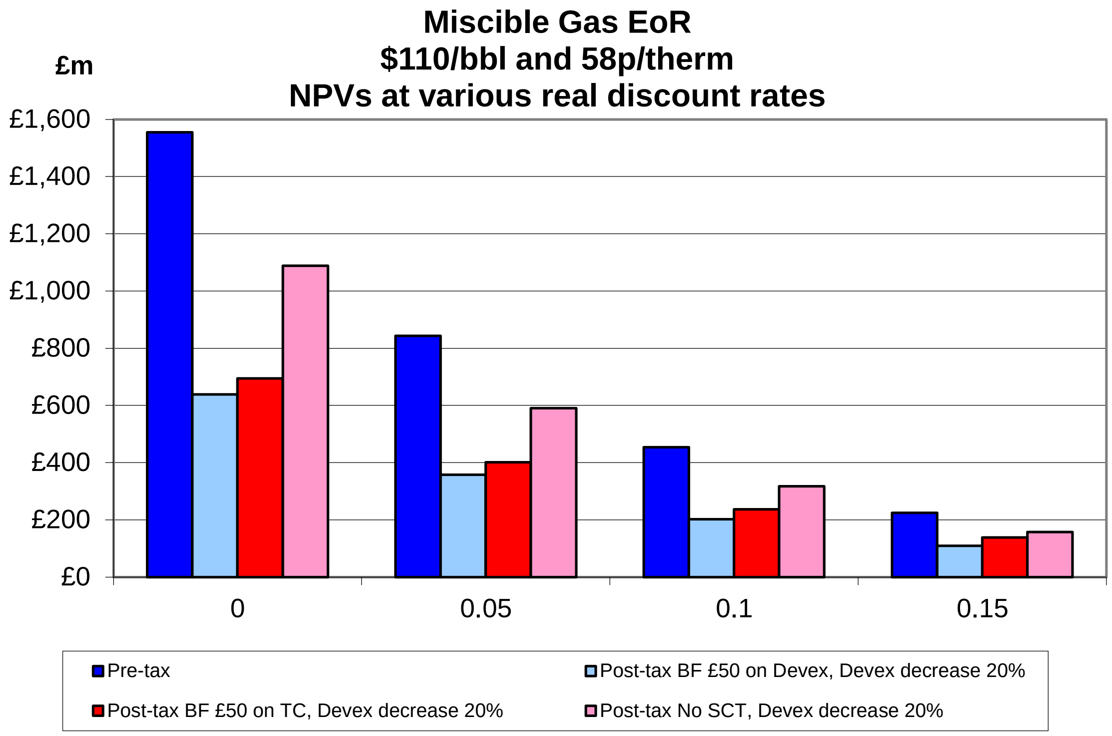

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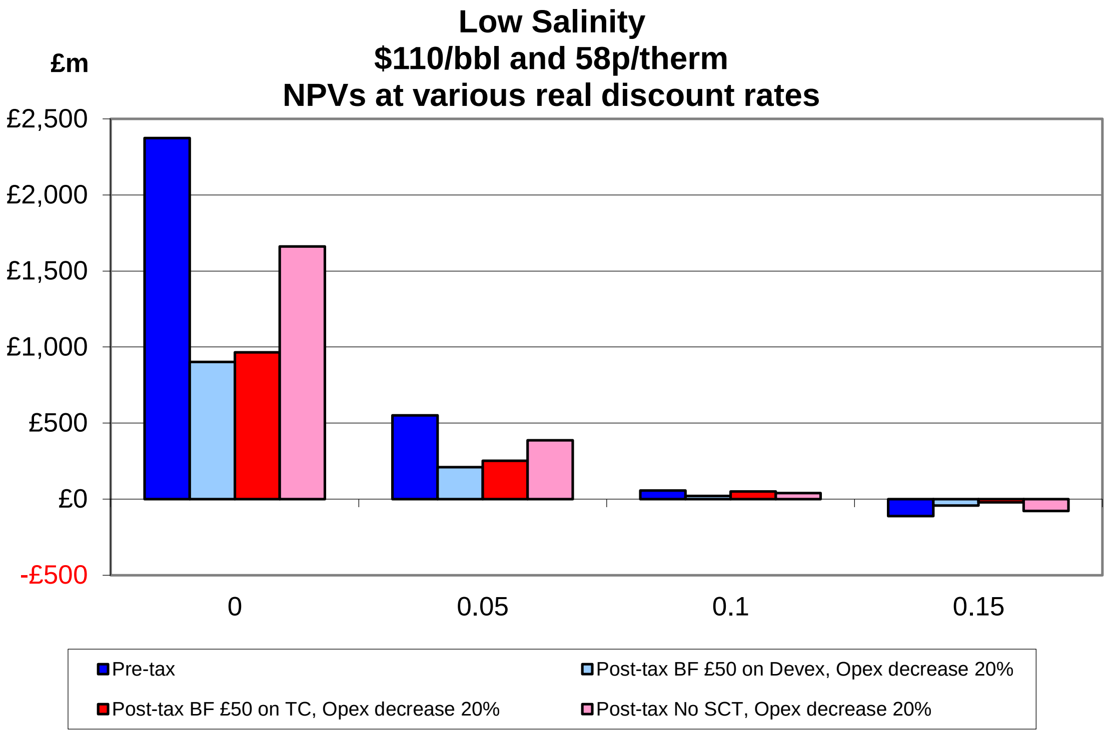

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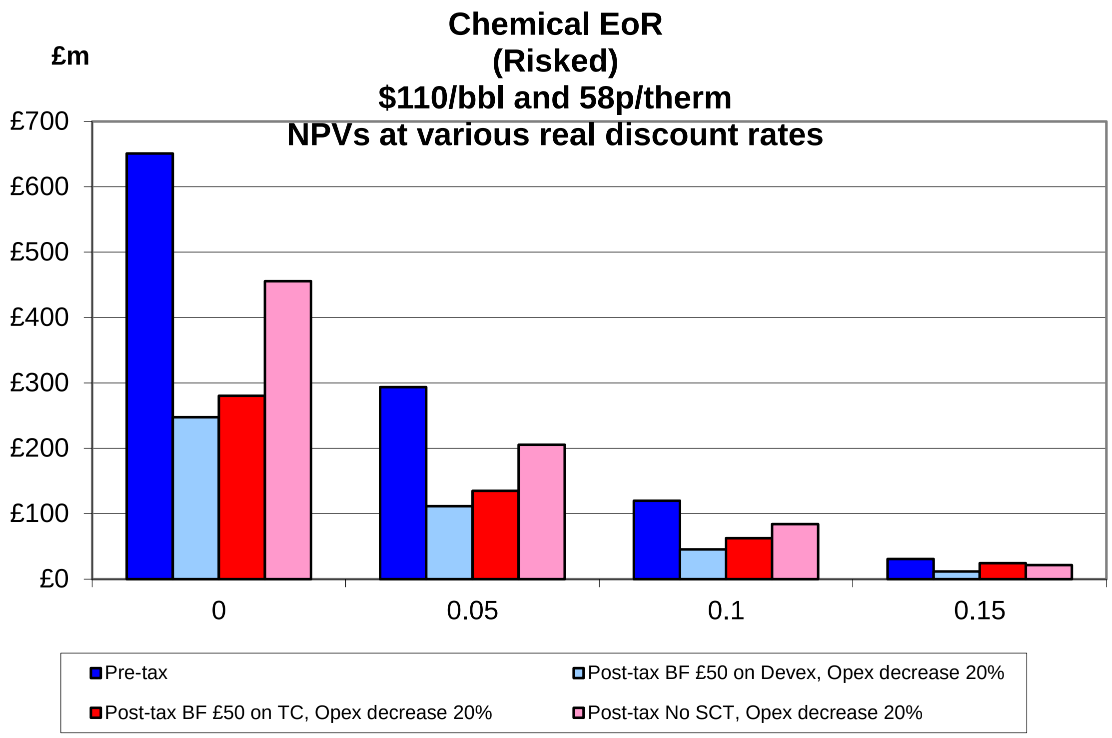

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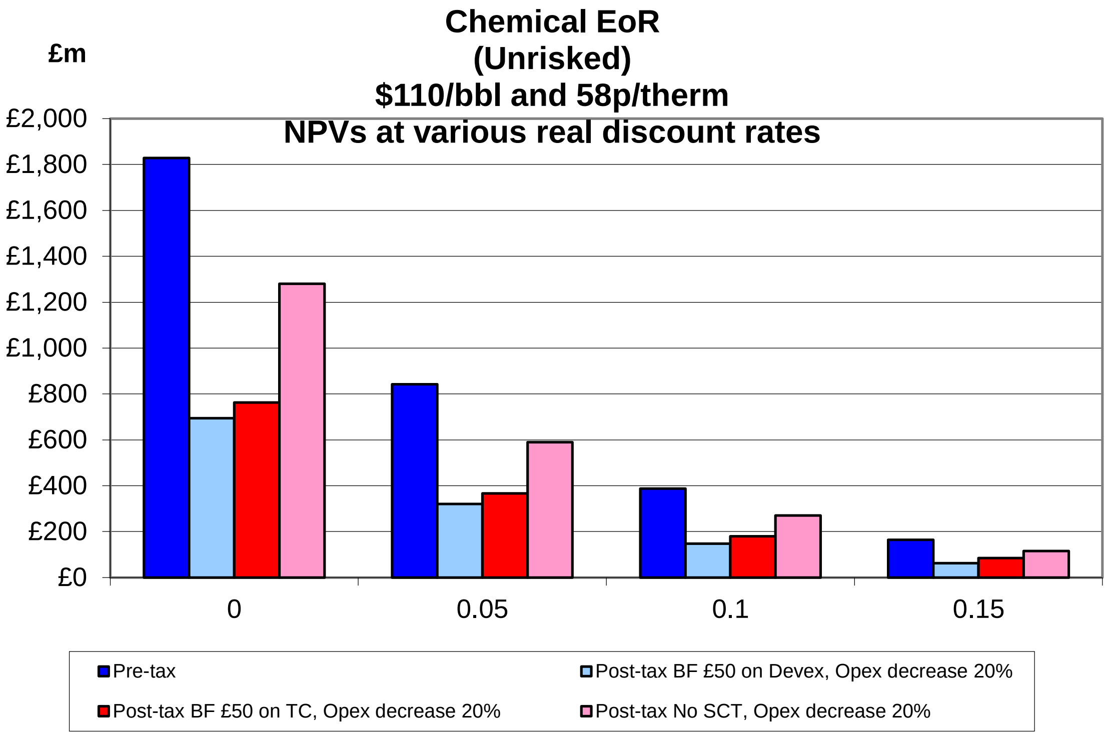

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