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The Effects of the European Emissions Trading Scheme (EU ETS) on Activity in the UK Continental Shelf (UKCS) and CO_2 Leakage

Professor Alexander G. Kemp and
Linda Stephen

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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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The Effects of the European Emissions Trading Scheme (EU ETS) on Activity in the UK Continental Shelf (UKCS) and CO_2 Leakage

Professor Alexander G. Kemp
and
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1. Introduction

The European Emissions Trading Scheme (EU ETS) applies not only to activities in the UK mainland but to the UK Continental Shelf (UKCS), and the changes to the arrangements from the start of Phase III in 2013 will have significant effects on the industry. From that date generators of electricity will have to purchase at auction CO_2 allowances necessary to cover all the emissions relating to power generation. Further, with respect to CO_2 emissions from other activities such as those relating to mechanical power and those emanating from gas flaring, the proposals are that free allowances are to be reduced linearly from 80% of the relevant allocation (i.e. excluding power generation) in 2013 to 0% in 2027.

From the viewpoint of the economic impact on investors in the UKCS the requirement to purchase CO_2 allowances is akin to a tax or an extra operating cost. This can lead to an acceleration of the timing of the date of cessation of production (COP). It could also result in fields which would otherwise be developed remaining undeveloped. There would be a loss of oil and gas production from the UKCS and a consequent need for further imports, quite possibly from countries where no attempts were being made to reduce CO_2 emissions. This raises the CO_2 leakage issue.

In this paper the effects of the arrangements proposed for Phase III of the EU ETS and beyond to 2040 are modelled under a variety of assumptions. The emphasis is on elucidating the likely effects on (1) direct costs to licensees, (2) (cumulative) production, (3) changes in overall operating costs, and (4) new field investment. The wide variety of plausible outcomes has necessitated the employment of a substantial number of scenarios to produce a worthwhile understanding of the likely effects and the key sensitivities determining the outcomes.

2. Methodology and Data

The projections of production and expenditures in the absence of Phase III of the EU ETS have been made through the use of financial simulation modelling, including the use of the Monte Carlo technique, informed by a large, recently-updated, field database validated by the relevant operators. The field database incorporates key, best estimate information on production, and investment, operating and decommissioning expenditures. These refer to over 320 sanctioned fields, 159 incremental projects relating to these fields, 29 probable fields, and 28 possible fields. These latter are as yet unsanctioned but are currently being examined for development. An additional database contains 251 fields defined as being in the category of technical reserves. Summary data on reserves (oil/gas) and block locations are available for these. They are not currently being examined for development by licensees.

Monte Carlo modelling was employed to estimate the possible numbers of new discoveries in the period to 2035. The modelling incorporated assumptions based on recent trends relating to exploration effort, success rates, sizes, and types (oil, gas, condensate) of discovery. A moving average of the behaviour of these variables over the past 5 years was calculated separately for 6 areas of the UKCS (Southern North Sea, (SNS), Central North Sea (CNS), Moray Firth (MF), Northern North Sea (NNS), West of Scotland (WOS), and Irish Sea (IS)), and the results employed for use in the Monte Carlo analysis. Because of the very limited data for WOS and IS over the period judgemental assumptions on success rates and average sizes of discoveries were made for the modelling.

It is postulated that the exploration effort depends substantially on a combination of (a) the expected success rate, (b) the likely size of discovery, and (c) oil/gas prices. In the present study 3 future oil/gas price scenarios were employed as follows:

Table 1

Future Oil and Gas Price Scenarios

	Oil Price (real) $/bbl	Gas Price (real) pence/therm
High	80	70
Medium	60	50
Low	45	30

The postulated numbers of annual exploration wells drilled for the whole of the UKCS are as follows for 2009, 2030, and 2035:

Table 2

Exploration Wells Drilled

	2010	2030	2035
High	38	30	28
Medium	32	25	23
Low	25	20	19

The annual numbers are modelled to decline in a broadly linear fashion over the period.

It is postulated that success rates depend substantially on a combination of (a) recent experience, and (b) size of the effort. It is further suggested that higher effort is associated with more discoveries but with lower success rates compared to reduced levels of effort. This reflects the view that low levels of effort will be concentrated on the lowest risk prospects, and thus that higher effort involves the acceptance of higher risk. For the UKCS as a whole 3 success rates were postulated as follows with the medium one reflecting the average over the past 5 years.

Table 3 **Success Rates for UKCS**	
Medium effort/Medium success rate	= 26%
High effort/Low success rate	= 24%
Low effort/High success rate	= 28%

It should be noted that success rates have varied considerably across sectors of the UKCS. Thus in the CNS and SNS the averages have exceeded 30% while in the other sectors they have been well below the average for the whole province. It is assumed that technological progress will maintain these success rates over the time period.

The mean sizes of discoveries made in the historic period for each of the 6 regions were calculated. They are shown in Table 4. It was then assumed that the mean size of discovery would decrease in line with recent historic experience. Such decline rates are quite modest.

Table 4 Mean Discovery Size MMboe	
SNS	**9**
CNS	**25**
NNS	**25**
MF	**20**
WoS	**81**
IS	**5**

For purposes of the Monte Carlo modelling of new discoveries the SD was set at 50% of the mean value. In line with historic experience the size distribution of discoveries was taken to be lognormal.

Using the above information the Monte Carlo technique was employed to project discoveries in the 6 regions to 2035. For the whole period the total numbers of discoveries for the whole of the UKCS were are follows:

Table 5 **Total Number of Discoveries to 2035**	
High effort/Low success rate	210
Medium Effort/Medium Success Rate	194
Low effort/High success rate	167

For each region the average development costs (per boe) of fields in the probable and possible categories were calculated. These reflect substantial cost inflation over the last few years. Investment costs per boe depend on several factors including not only the absolute costs in different operating conditions (such as water depth) but on the size of the fields. Thus in the SNS development costs were found to average nearly $14 per boe because of the small size of fields. In the CNS they averaged nearly $19/boe and in the NNS they averaged over $17/boe. Operating costs over the lifetime of the fields were also calculated. The averages were found to be $8.5/boe in the SNS, over $11/boe in the CNS and $12.4/boe in the NNS. Total lifetime field costs (including decommissioning but excluding E and A costs) were found to average over $23 per boe in the SNS, over $32 per boe in the CNS, and $31 per boe in the NNS.

Using these as the mean values the Monte Carlo technique was employed to calculate the development costs of new discoveries. A normal distribution with a SD = 20% of the mean value was employed. For new discoveries annual operating costs were modelled as a percentage of accumulated development costs. This percentage varied according to field size. It was taken to increase as the size of the field was reduced reflecting the presence of economies of scale in the exploitation costs. Thus the field lifetime costs in small fields could become very high on a per boe basis.

With respect to fields in the category of technical reserves it was recognised that many have remained undeveloped for a long time, and so the mean development costs in each of the basins was set at $5/boe higher than the mean for the new discoveries in that basin. Thus for the CNS the mean development costs are over $24/boe and in NNS over $22/boe. For purposes of Monte Carlo modelling a normal distribution of the recoverable reserves for each field with a SD = 50% of the mean was assumed. With respect to development costs the distribution was assumed to be normal with a SD = 20% of the mean value.

The annual numbers of new field developments were assumed to be constrained by the physical and financial capacity of the industry. This subject is currently very pertinent in the UKCS. The ceilings were assumed to be linked to the oil/gas price scenarios with maxima of 20, 17, and 13 respectively under the High, Medium, and Low Price Cases. These constraints do not apply to incremental projects which are additional to new field developments.

A noteworthy feature of the 159 incremental projects in the database validated by operators is the expectation that the great majority will be executed over the next 3 or 4 years. It is virtually certain that in the medium and longer-term many further incremental projects will be designed and executed. They are just not yet at the serious planning stage. Such projects can be expected to be linked not only to currently sanctioned fields, but also to those presently classified as in the categories of probable, possible, technical reserves, and future discoveries.

Accordingly, estimates were made of the potential extra incremental projects from all these sources. Examination of the numbers of such projects and their key characteristics (reserves and costs) being examined by operators over the past 5 years indicated a decline rate in the volumes. On the basis of this, and from a base of the information of the key characteristics of the projects in the database, it was felt that, with a decline rate reflecting historic experience, further portfolios of incremental projects could reasonably be expected. As noted above such future projects would be spread over all categories of host fields. Their sizes and costs reflect recent trends.

With respect to investment decision making and project screening criteria oil companies (even medium-sized and smaller ones) currently assess their opportunities in the UKCS in comparison to those available in other parts of the world. Capital is allocated on this basis with the UKCS having to compete for funds against the opportunities in other provinces. A problem with the growing maturity of the UKCS is the relatively small average field size and the high unit costs. Recent mean discovery sizes are shown in Table 4 but, given the lognormal distribution, the most likely sizes are below these averages. It follows that the materiality of returns, expressed in terms of net present values (NPVs), is quite low in relation to those in prospect in other provinces (such as offshore Angola, for example). Oil companies frequently rank investment projects according to the NPV/I ratio. Accordingly, this screening method has been adopted in the present study. Specifically, the numerator is the post-tax NPV at 10% discount rate in real terms and the denominator is pre-tax field investment at 10% discount rate in real terms. This differs from the textbook version which states that I should be in post-tax terms because the expenditures are tax deductible through allowances. Oil companies maintain that they allocate capital funds on a pre-tax basis, and this is employed here as the purpose is to reflect realistically the decision-making process. The development project goes ahead when the NPV/I ratio as defined above in real terms ≥ 0.3. The 10% real discount rate reflects the weighted average cost of capital to the investor. The modelling has been undertaken under the current tax system. This includes the field allowances introduced in the Finance Act 2009.

In the light of experience over the past few years some rephasing of the timing of the commencement dates of new field developments and incremental projects from those projected by operators was undertaken related to the probability that the project would go ahead. Where the operator indicated that a new field development had a probability ≥ 80% of going ahead the date was left unchanged. Where the probability ≥ 60% < 80% the commencement date was slipped by 1 year. Where the probability ≥ 40% < 60% the date was slipped by 2 years. Where the probability was ≥ 20% < 40% the date was slipped by 3 years, and where the probability was < 20% it was slipped by 4 years. If an incremental project had a probability of proceeding ≥ 50% the date was retained but where it was < 50% it was slipped by 1 year.

Within the above framework modelling and data assumptions were made to estimate the effects on activity of the proposed EU ETS arrangements from the start of Phase III onwards. Information on emissions is available from the series of EEMS publications, including those relating to both combustion and flaring at a facility level. Data on allocations of allowances to installations are available from the National Allocation Plans (including for Phases II and III). Unfortunately the data on both emissions and allocations relate to installations rather than fields. Accordingly, by inspection and using knowledge of any relationships discovered, fields were linked to installations where these were prevalent. Emissions and allowances relating to communal installations such as terminals were shared with the linked fields on a unit of production basis. This proved to be relatively straightforward with respect to sanctioned fields. With respect to incremental projects relating to sanctioned fields these were linked where justified by inspection, and the allowances arising from the presence of the incremental project were attributed to the host field. The effects of the EU ETS scheme were calculated on the combined host plus incremental project. This procedure also applies to future incremental projects.

From the data over the past few years it is clear that emissions do not follow production in a field. It was assumed in the present study that emissions would remain constant throughout the life of a field.

With respect to discovered but as yet undeveloped fields, namely those defined as "probable", "possible" and "technical reserves" a method was required to estimate their likely emissions. From the information available on emissions relating to existing sanctioned installations/fields and the allocations of allowances made to them, plus the information on the change in allowances allocated following the linking of a new project/field to an existing installation a pattern was discerned showing the relationship between average emissions and average peak production per day. On the basis of this relationship estimates were made of the emissions for the fields in the categories of "probable", "possible", and "technical reserves". It was decided not to attempt to make estimates for fields in the category of future discoveries because the areas of uncertainty were felt to be too great. (The initial modelling of future activity levels had to include new discoveries, however, to distinguish the numbers and phasing of fields in the category of technical reserves). The definition of the coverage of the study as far as CO_2 emissions is concerned is thus all sanctioned fields, all current and future incremental projects, and all currently discovered but undeveloped fields. Of course, only those which pass the investment hurdles discussed above in the absence of the Phase III arrangements are included in the base case against which the effects of the scheme are to be measured.

From inspection of the data on the composition of emissions there was found to be a wide range in the proportion emanating from electricity generation. It was also unclear how this would change through time. Accordingly, for purposes of illuminating the possible future impact of the Phase III proposals, it was decided to model the effect of 3 scenarios. The first is where full allowances are given to cover 80% of the total allocation in 2013, falling linearly to 0% in 2027. This would only be possible with zero electricity generation, and this scenario is primarily regarded as a case to compare with others where tougher obligations are imposed. For convenience it is termed here the "maximum allowance case". The second case is where 50% of the emissions relate to electricity generation and thus all the allowances required to cover the related emissions have to be bought at auction. Free allowances for the remaining 50% emissions are available to the extent of 80% in 2013 falling linearly to 0% in 2027. The third case is where all allowances have to be bought at auction from 2013 onwards. In all cases it is assumed that allowances will equal emissions and thus that penalties are avoided.

The imposition of obligations to purchase CO_2 allowances at auction has an effect akin to a tax. In this paper a systematic analysis is made of the consequences including the CO_2 leakage issue.[1] One basic issue is the incidence of the obligation to purchase CO_2 allowances. This will differ according to the ability of the organization on whom the obligation is placed to pass on the burden to others. In the case of electricity generation in the UK it is likely that in the electricity market itself UK generators will to a large extent pass on the burden to electricity consumers. Electricity is not widely traded internationally and in the case of the EU trade is likely to be among partner countries. Electricity prices are likely to increase following the start of Phase III to an extent determined by the price elasticities of demand and supply. In the North Sea, however, the situation is quite different. The oil market is a world one, and so increasingly is the gas market. When producers of North Sea oil and gas are faced with increased costs for electricity generation due to

[1] For an excellent general discussion of the CO_2 leakage issue see R. A. Ritz, CO_2 Leakage under Incomplete Environmental regulation: An Industry-Level Approach, Oxford Institute for Energy Studies, November 2009.

the obligation to purchase CO_2 allowances they cannot pass on the costs in higher oil and gas prices because in the world market there are plenty competing producers outside the EU ETS who are not faced with such increased costs. Thus the impact and incidence of the Phase III obligations will be on the North Sea producers. Similarly, when allowances have to be purchased for purposes other than electricity generation the producers on whom the burden is placed will not be able to pass on the cost to oil/gas consumers. The incidence will continue to be on the producers.

Within this conceptual framework the effects of the Phase 3 proposals were examined within the modelling framework described above. With respect to production there are 2 distinct effects. Purchases of allowances increase operating costs, and the result will be an acceleration of the timing of the economic limit of the field from the producer's viewpoint. The effect is akin to that of a royalty or production tax. The second effect is on the investment decision in new fields and/or incremental projects. The increased operating costs may render uneconomic the returns to a new investment. The modelling calculates the loss of the investment outlays and the reduced operating costs emanating from accelerated cessation of production (COP). The total field operating costs are, of course, greatly increased by the need to purchase CO_2 allowances. The model calculates these and the consequent net change in field lifetime operating costs after taking account of the reduction from the acceleration of the COP dates.

As background to the study the emissions from the UKCS for selected past years are summarized in Table 6.

Table 6 CO_2 Emissions from UKCS ($MtCO_2$)				
	2000	2002	2005	2008
Combustion	16.95	17.68	15.93	14.31
Flaring	5.45	5.30	5.08	5.73
TOTAL	**22.40**	**22.98**	**21.01**	**20.04**

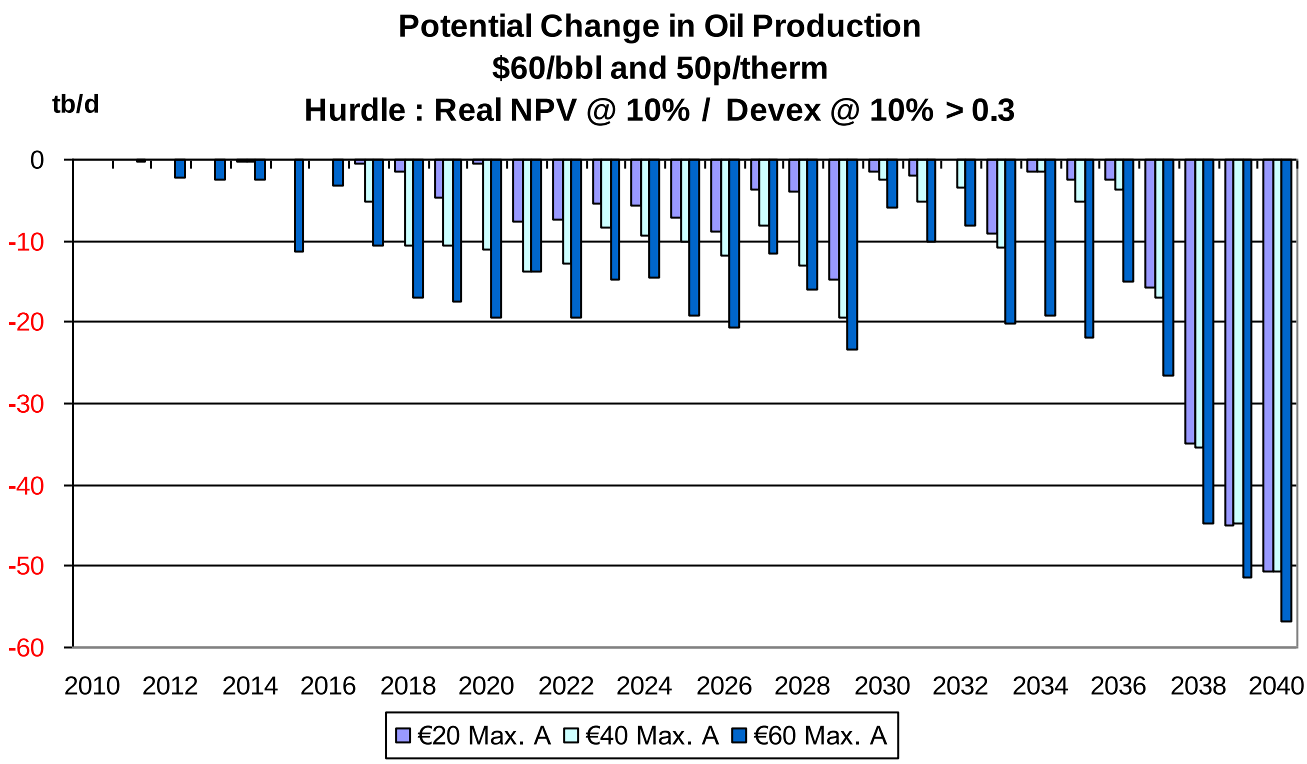
3. Results

The results are shown in relation to the sum of sanctioned fields, incremental projects (current and future), probable fields, possible fields, and technical reserves, which pass the economic hurdles.

a. Maximum Allowance

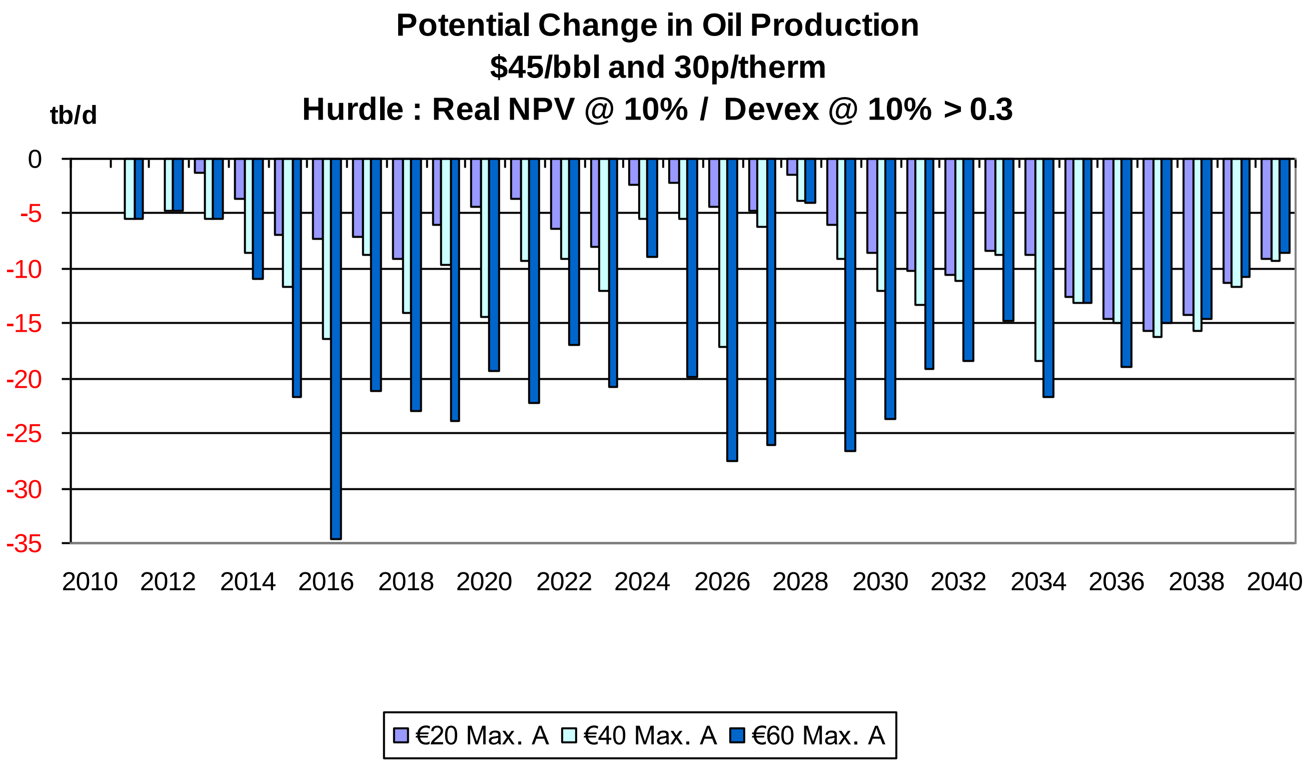
(i) Changes in Production

Chart 1



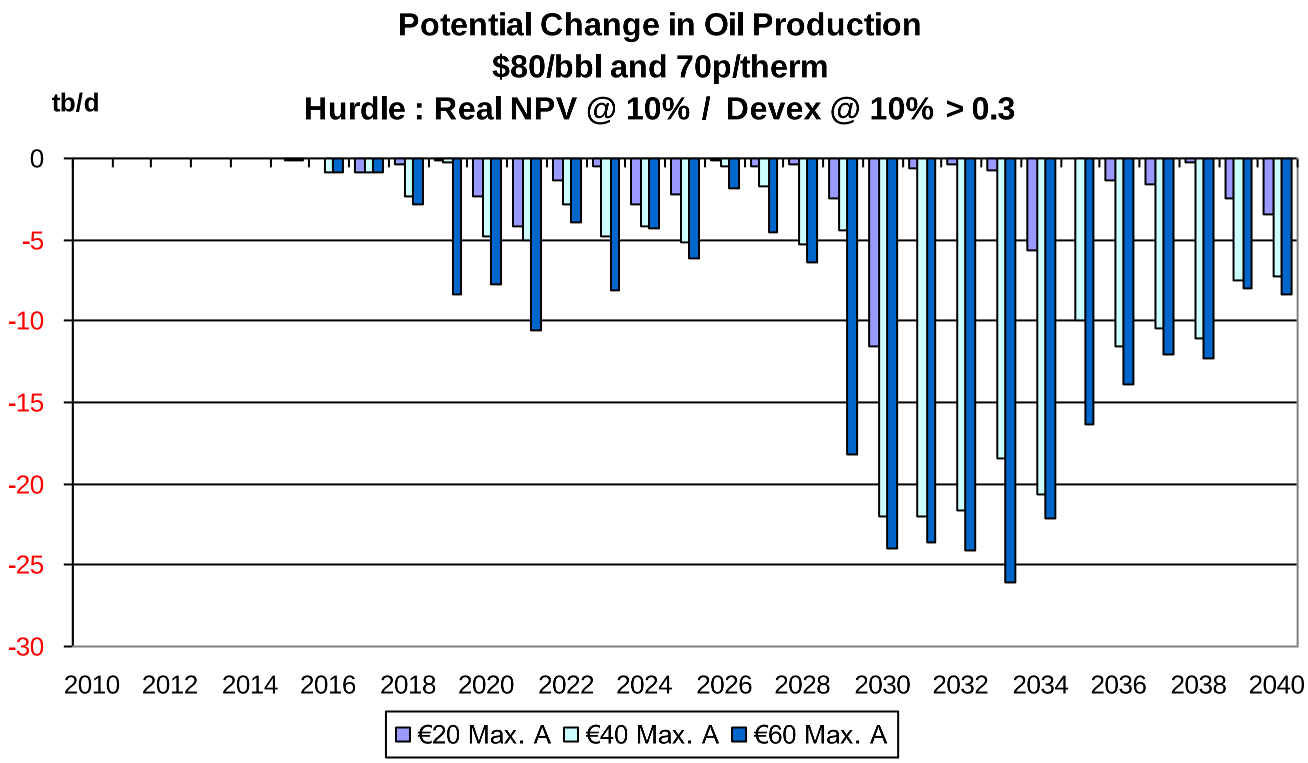
In Chart 1 it is see that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 9tb/d in 2026, 15tb/d in 2029 and 51tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 14tb/d in 2021, 19tb/d in 2029 and 51tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 19tb/d in 2020, 23tb/d in 2029 and 57tb/d in 2040.

Chart 2



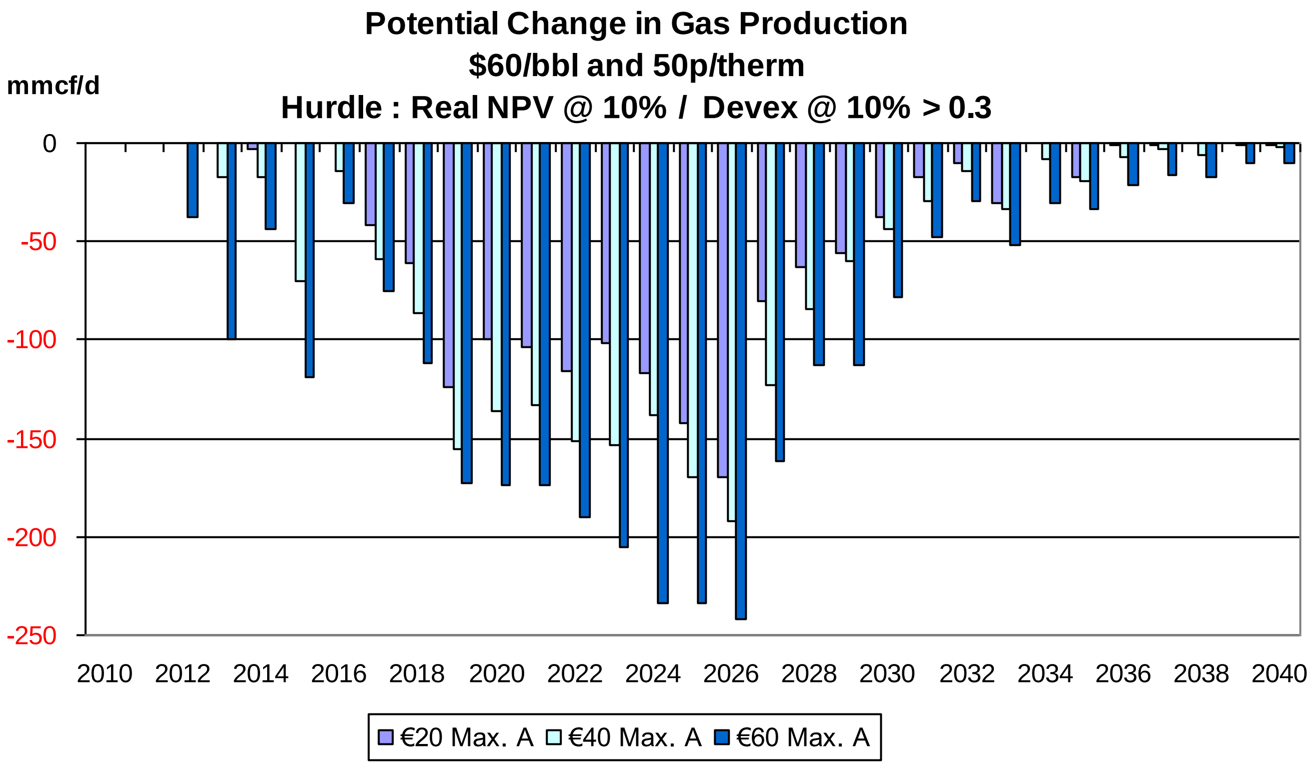
In Chart 2 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 9tb/d in 2018 and 2030, 15tb/d in 2036 and 9tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 15tb/d in 2018 and 2020, 17tb/d in 2026 and 9tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 35tb/d in 2016, 27tb/d in 2029 and 9tb/d in 2040.

Chart 3



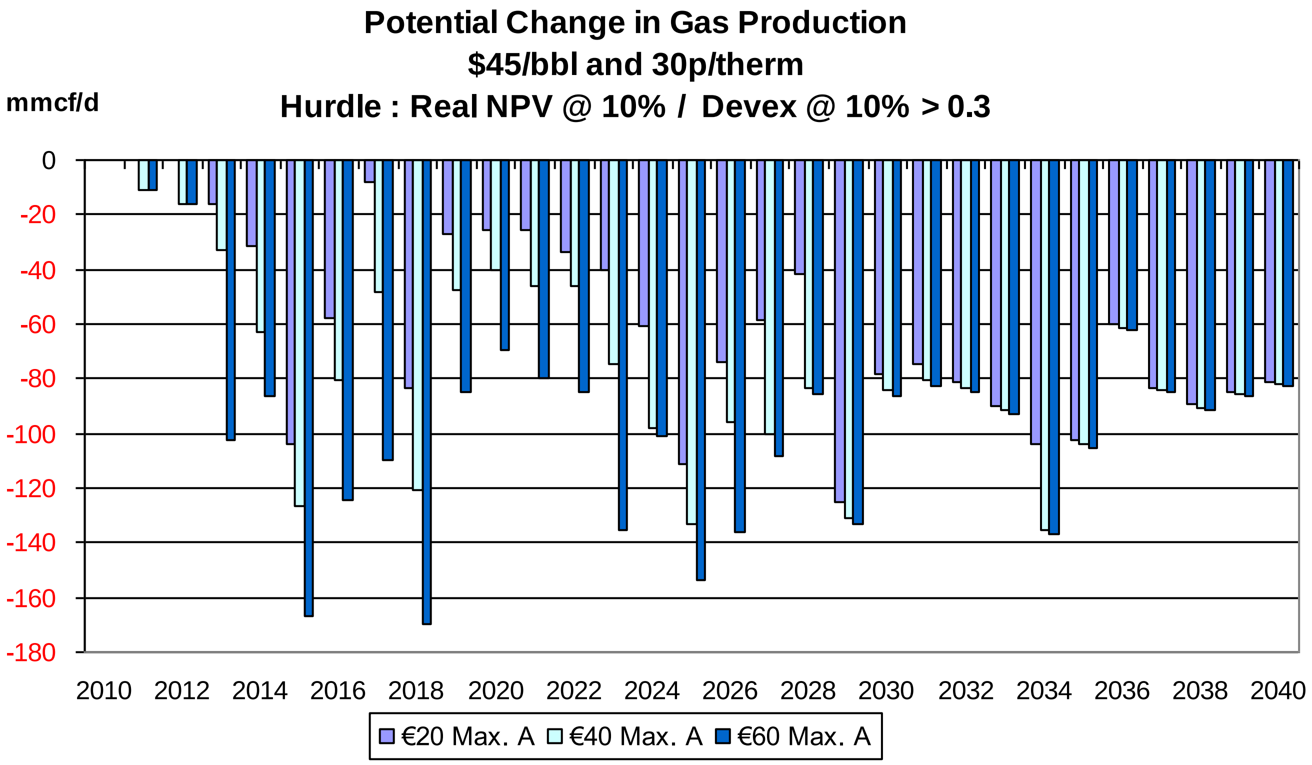
In Chart 3 at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 4tb/d in 2021, 12tb/d in 2030 and 3tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 5tb/d in 2020 and 2021, 22tb/d in 2030, 2031 and 2032 and 7tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 11tb/d in 2021, 26tb/d in 2033 and 8tb/d in 2040.

Chart 4



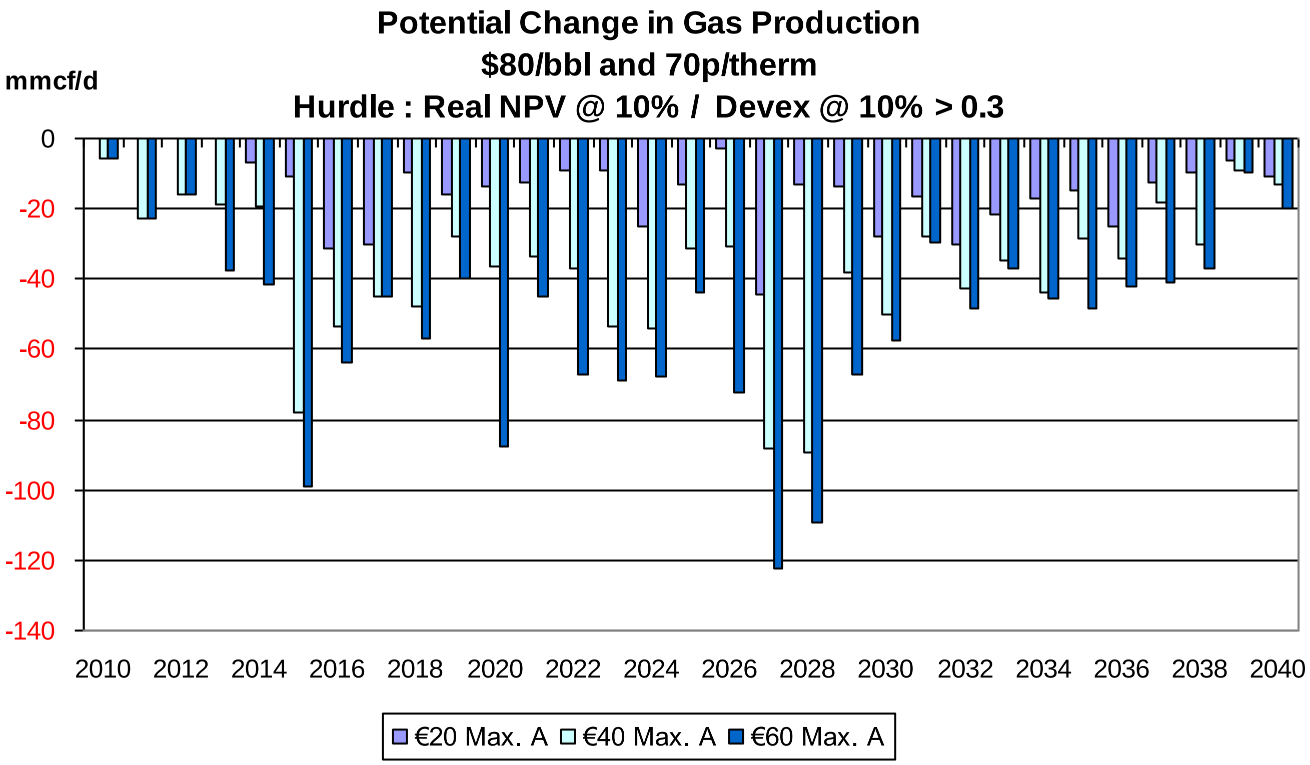
In Chart 4 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 124mmcf/d in 2019 and 170mmcf/d in 2026. With a CO_2 price of €40/t gas production could be reduced by 155mmcf/d in 2019 and 192mmcf/d in 2026. With a CO_2 price of €60/t gas production could be reduced by 173mmcf/d in 2019 and 242mmcf/d in 2026.

Chart 5



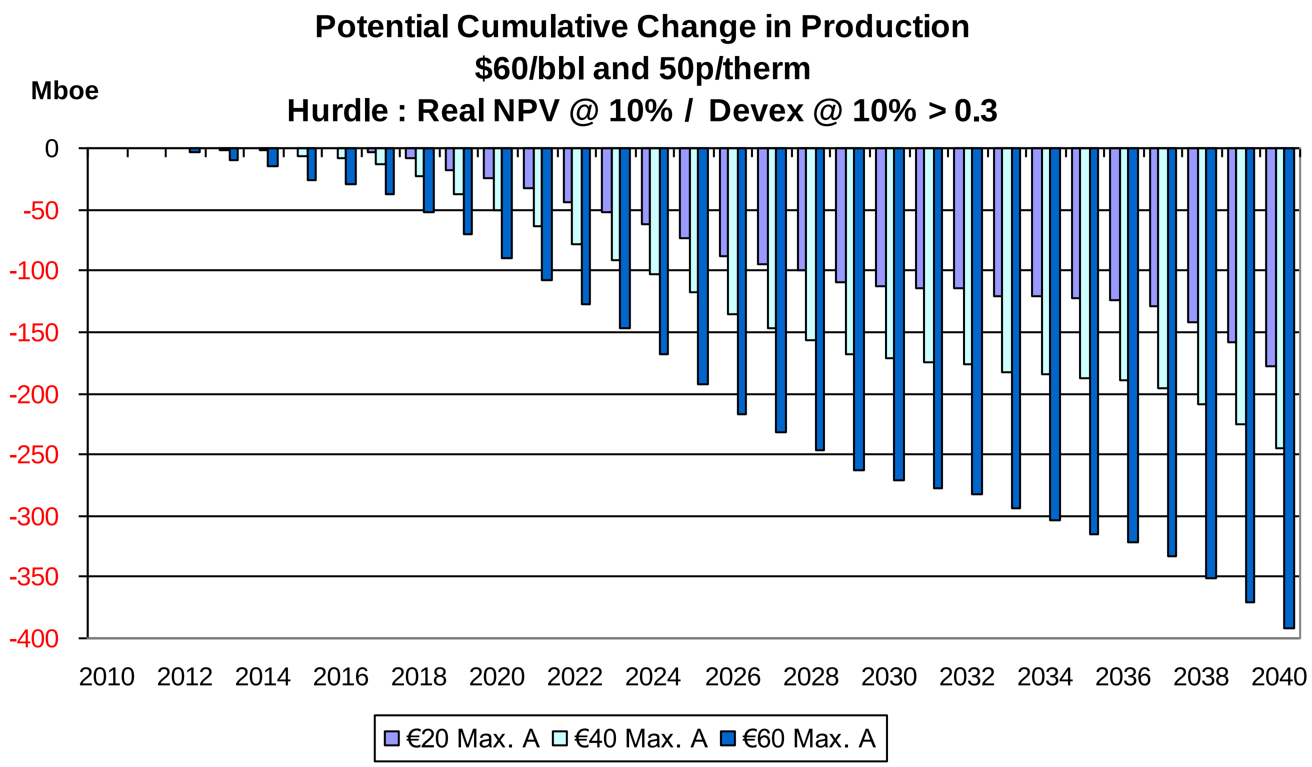
In Chart 5 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 104mmcf/d in 2015 and 111mmcf/d in 2025. With a CO_2 price of €40/t gas production could be reduced by 127mmcf/d in 2015 and 133mmcf/d in 2025. With a CO_2 price of €60/t gas production could be reduced by 170mmcf/d in 2018 and 154mmcf/d in 2025.

Chart 6



In Chart 6 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 16mmcf/d in 2019, 25mmcf/d in 2024 and 28mmcf/d in 2030. With a CO_2 price of €40/t gas production could be reduced by 53mmcf/d in 2023 and 89mmcf/d in 2028. With a CO_2 price of €60/t gas production could be reduced by 88mmcf/d in 2020 and 122mmcf/d in 2027.

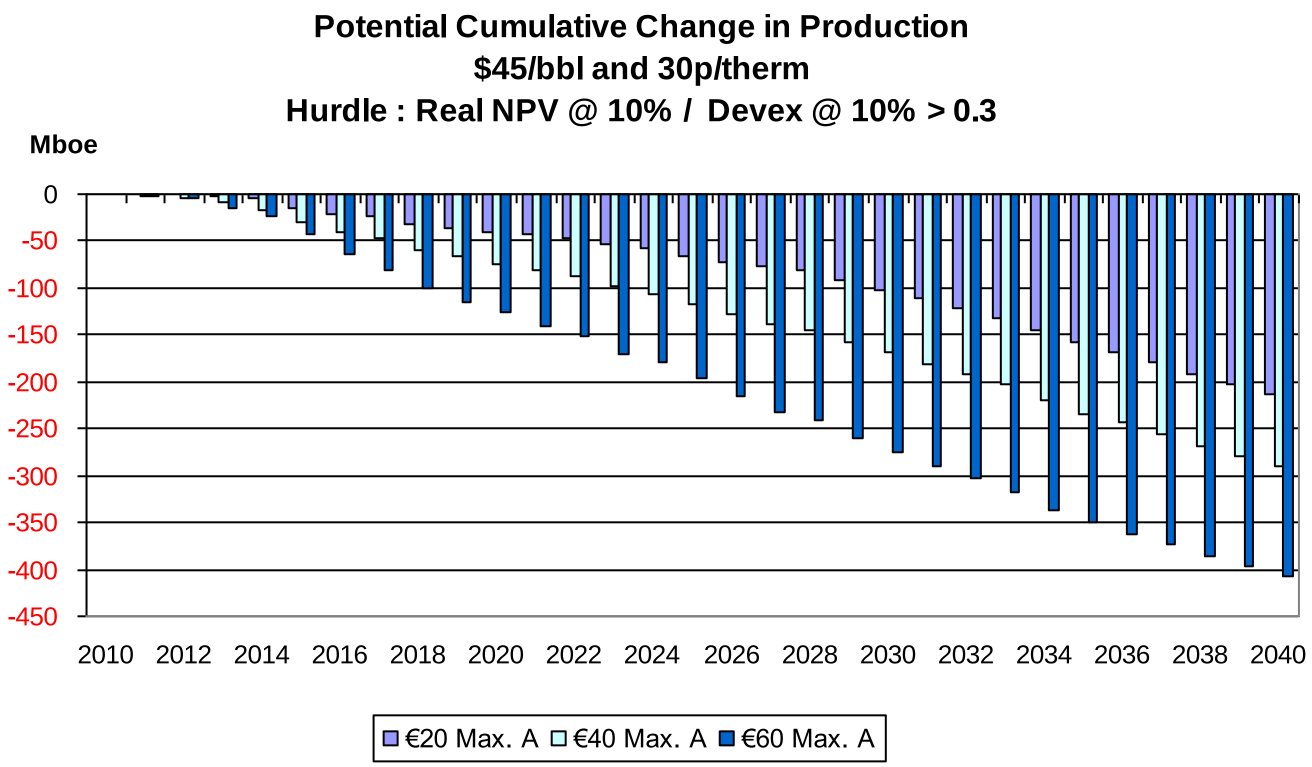
Chart 7



In Chart 7 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative hydrocarbon production could be reduced by 24 million barrels oil equivalent (mmboe) by 2020 (8mboe from the sanctioned fields and incremental investments and the rest from the technical reserves fields), 112mboe by 2030 (19mboe from sanctioned fields and incremental investments, 5mboe from the Probable fields, 2mboe from Possible fields and 86mboe from the technical reserves fields), and 177mboe by 2040 (26mboe from sanctioned fields and incremental investments, 5mboe from the Probable fields, 2mboe from Possible fields and 144mboe from the technical reserves fields). With a CO_2 price of €40/t cumulative hydrocarbon production could be reduced by 50mboe by 2020 (23mboe from sanctioned fields and incremental investments, 7mboe from the Probable fields, and

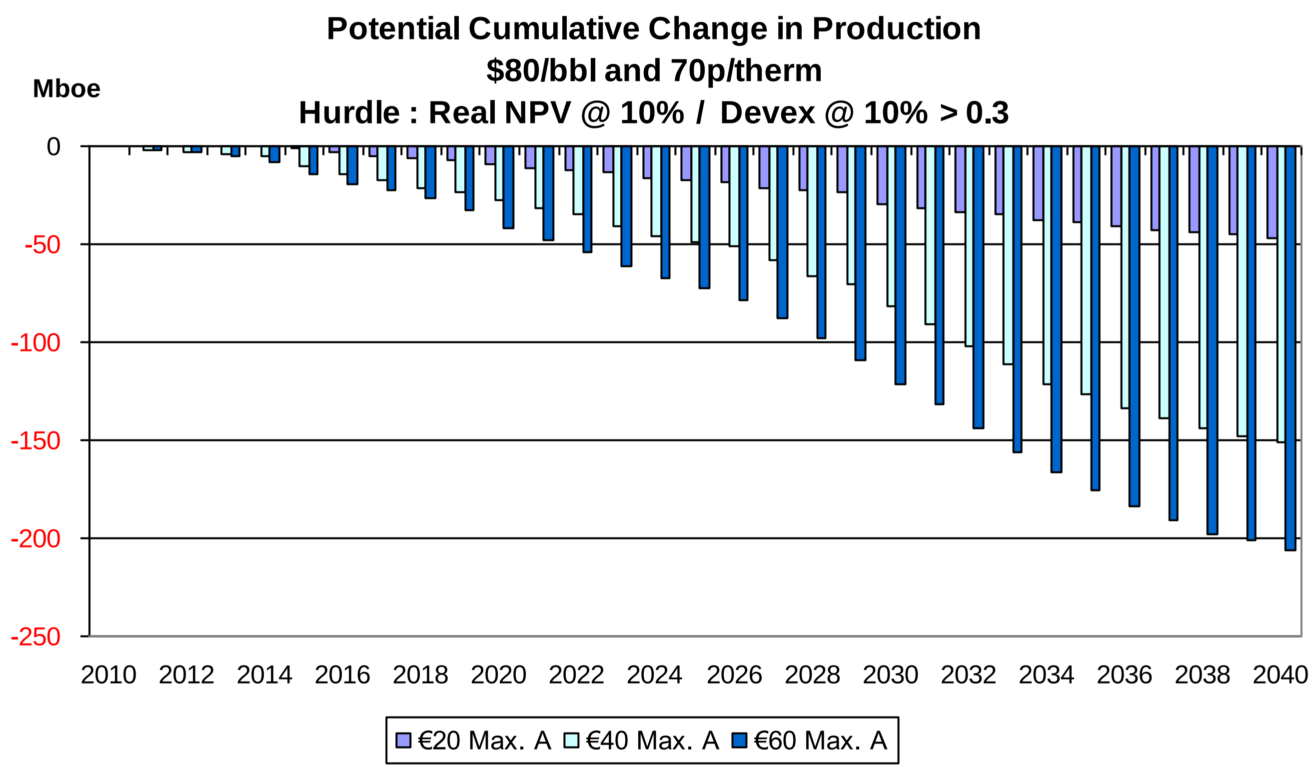
19mboe from the technical reserve fields), 171mboe by 2030 (51mboe from sanctioned fields and incremental investments, 16mboe from the Probable fields, 5mboe from Possible fields and 100mboe from the technical reserves fields), and 244mboe by 2040 (62mboe from sanctioned fields and incremental investments, 16mboe from the Probable fields, 5mboe from Possible fields and 161mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative production could be reduced by 90mboe by 2020 (52mboe from sanctioned fields and incremental investments, 13mboe from the Probable fields, 4mboe from Possible fields and 21mboe from the technical reserve fields), 271mboe by 2030 (117mboe from sanctioned fields and incremental investments, 26mboe from the Probable fields, 12mboe from Possible fields and 115mboe from the technical reserves fields), and 392mboe by 2040 (145mboe from sanctioned fields and incremental investments, 26mboe from the Probable fields, 12mboe from Possible fields and 210mboe from the technical reserves fields).

Chart 8



In Chart 8 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative hydrocarbon production could be reduced by 40mboe by 2020 (20mboe from sanctioned fields and incremental investments and 20mboe from Possible fields), 102mboe by 2030 (54mboe from sanctioned fields and incremental investments, 29mboe from Possible fields and 19mboe from the technical reserves fields), and 213mboe by 2040 (127mboe from sanctioned fields and incremental investments, 29mboe from Possible fields and 56mboe from the technical reserve fields). With a CO_2 price of €40/t cumulative production could be reduced by 75mboe by 2020 (48mboe from sanctioned fields and incremental investments and 27mboe from Possible fields), 169mboe by 2030 (110mboe from sanctioned fields and incremental investments, 39mboe from Possible fields, and 20mboe from the technical reserves fields) and 290mboe by 2040 (192mboe from sanctioned fields and incremental investments, 39mboe from Possible fields, and 58mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative production could be reduced by 127mboe by 2020 (77mboe from sanctioned fields and incremental investments, 36mboe from Possible fields and 14mboe from the technical reserves fields), 276mboe by 2030 (169mboe from sanctioned fields and incremental investments, 49mboe from Possible fields and 57mboe from the technical reserves fields) and 407mboe by 2040 (248mboe from sanctioned fields and incremental investments, 50mboe from Possible fields and 109mboe from the technical reserves fields).

Chart 9

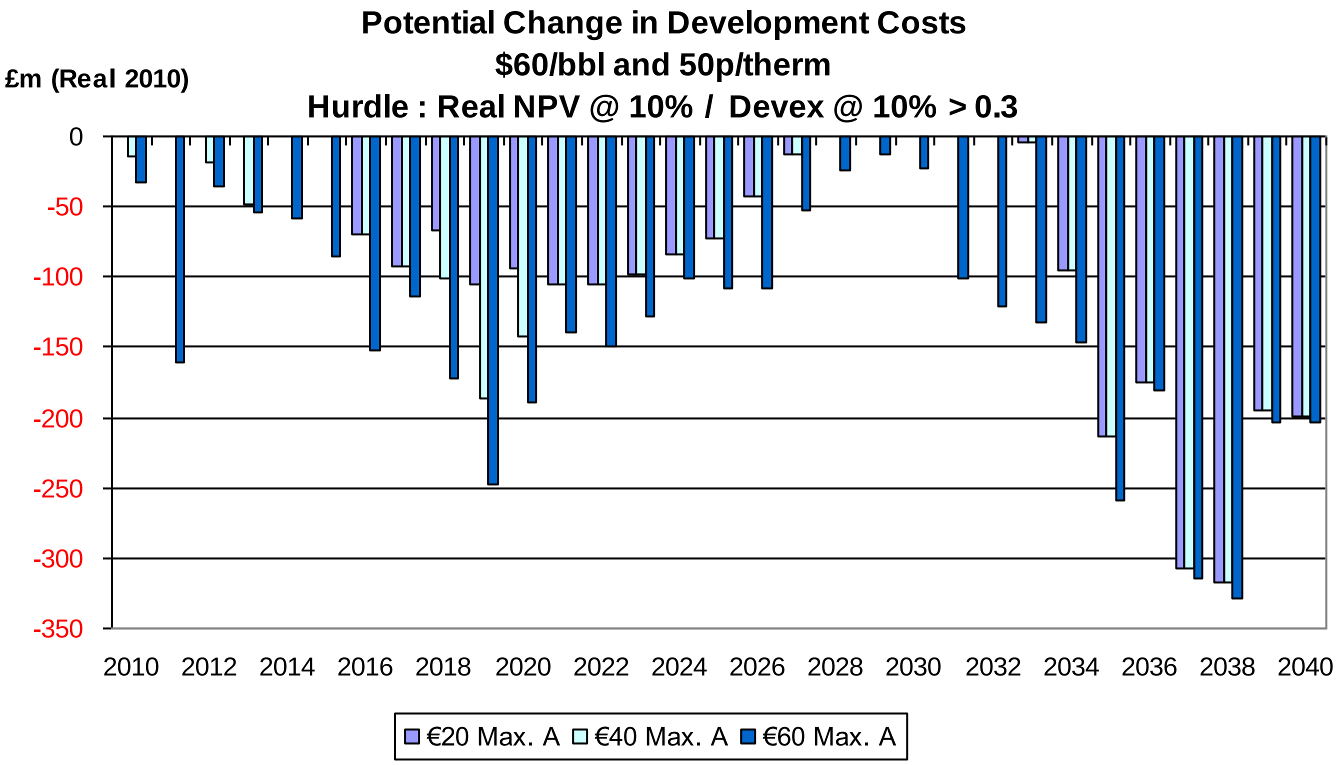


In Chart 9 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative hydrocarbon production could be reduced by 9mboe by 2020 (5mboe from sanctioned fields and incremental investments, and 4mboe from the technical reserves fields), 30mboe by 2030 (18mboe from sanctioned fields and incremental investments, 1mboe from the Probable fields, 4mboe from Possible fields and 7mboe from the technical reserves fields), and 47mboe by 2040 (24mboe from sanctioned fields and incremental investments, 1mboe from the Probable fields, 4mboe from Possible fields and 17mboe from the technical reserves fields). With a CO_2 price of €40/t cumulative hydrocarbon production could be reduced by 28mboe by 2020 (15mboe from sanctioned fields and incremental investments, 9mboe from the Probable fields and 4mboe from the technical reserve fields), 81mboe by 2030 (46mboe from sanctioned fields and incremental investments, 19mboe from the Probable fields, 5mboe from

Possible fields and 12mboe from the technical reserves fields), and 151mboe by 2040 (57mboe from sanctioned fields and incremental investments, 21mboe from the Probable fields, 5mboe from Possible fields and 67mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative hydrocarbon production could be reduced by 41mboe in 2020 (28mboe from sanctioned fields and incremental investments, 9mboe from the Probable fields and 4mboe from the technical reserves fields), 121mboe by 2030 (76mboe from sanctioned fields and incremental investments, 24mboe from the Probable fields, 7mboe from Possible fields and 15mboe from the technical reserves fields), and 206mboe by 2040 (98mboe from sanctioned fields and incremental investments, 26mboe from the Probable fields, 7mboe from Possible fields and 74mboe from the technical reserves fields).

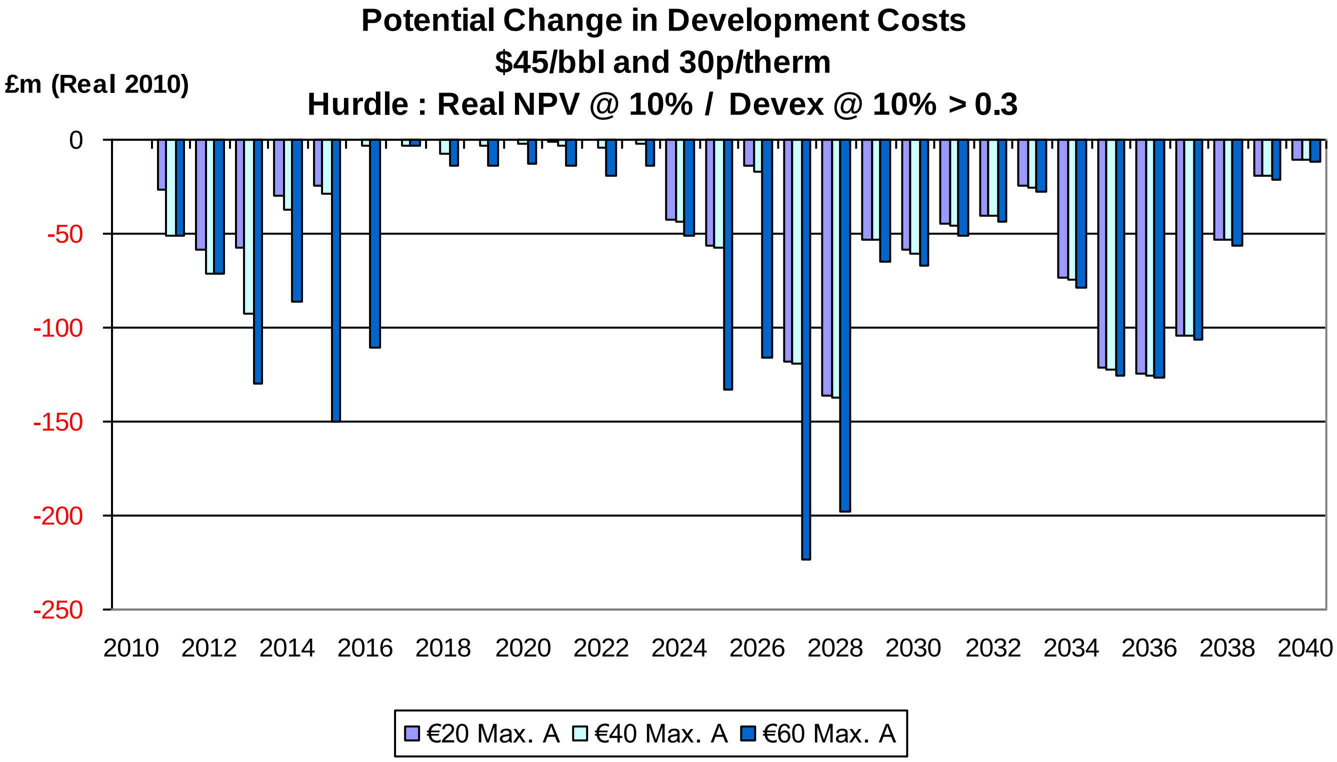
(ii) Changes in Development Expenditures

Chart 10



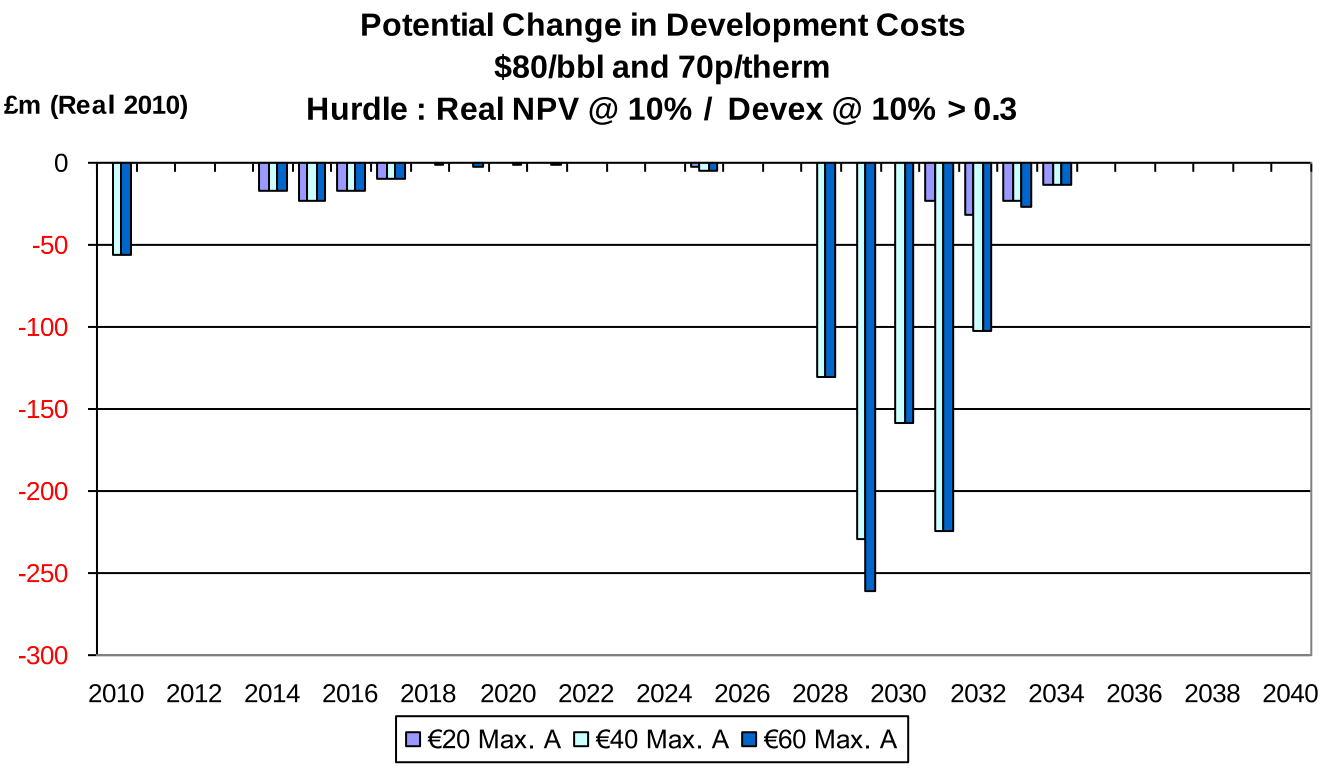
From Chart 10 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £427m by 2020, £950m by 2030 and £2,460m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £673m by 2020, £1,195m by 2030, and £2,705m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £1,302m by 2020, £2,149m by 2030, and £4,140m by 2040.

Chart 11



From Chart 11 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £197m by 2020, £675m by 2030, and £1,291m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £300m by 2020, £798m by 2030, and £1,419m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £642m by 2020, £1,541m by 2030, and £2,190m by 2040.

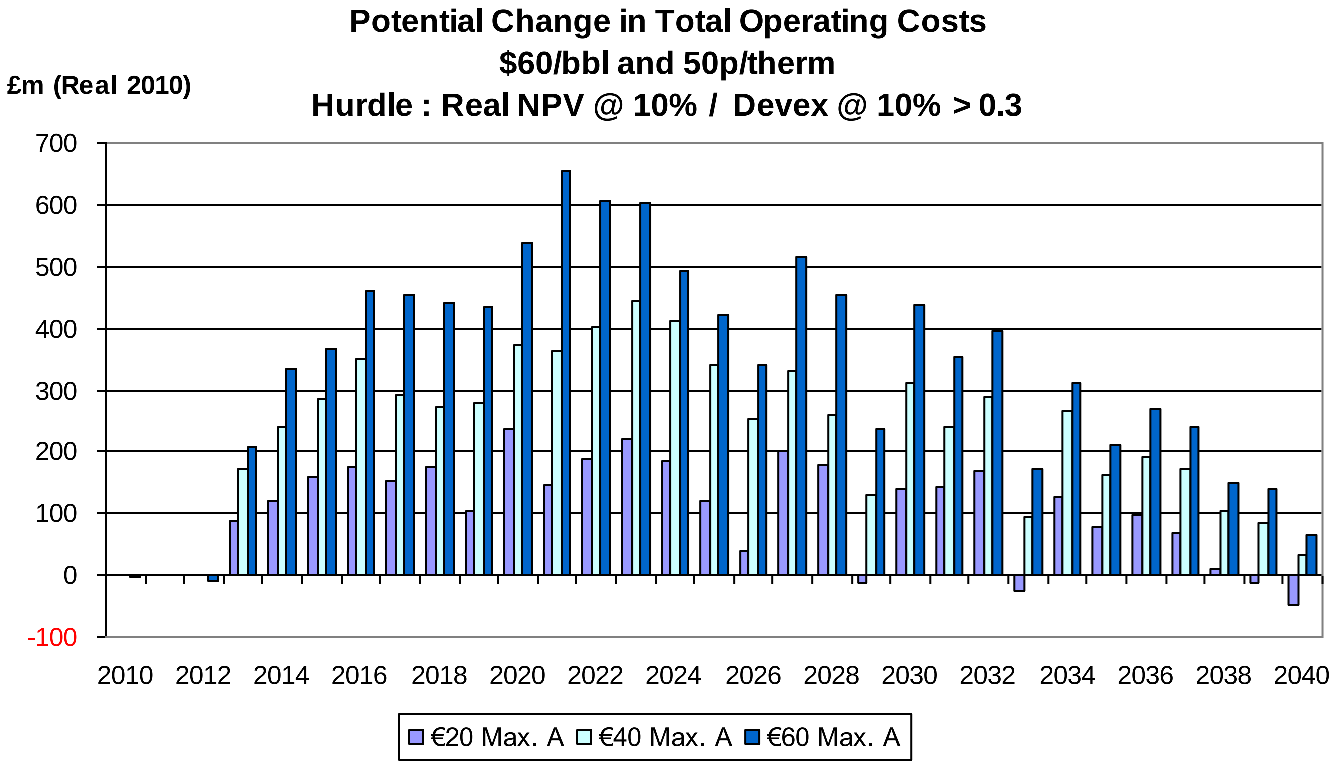
Chart 12



From Chart 12 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £67m by 2020, £70m by 2030, and £160m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £123m by 2020, £645m by 2030, and £1,008m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £128m by 2020, £683m by 2030, and £1,050m by 2040.

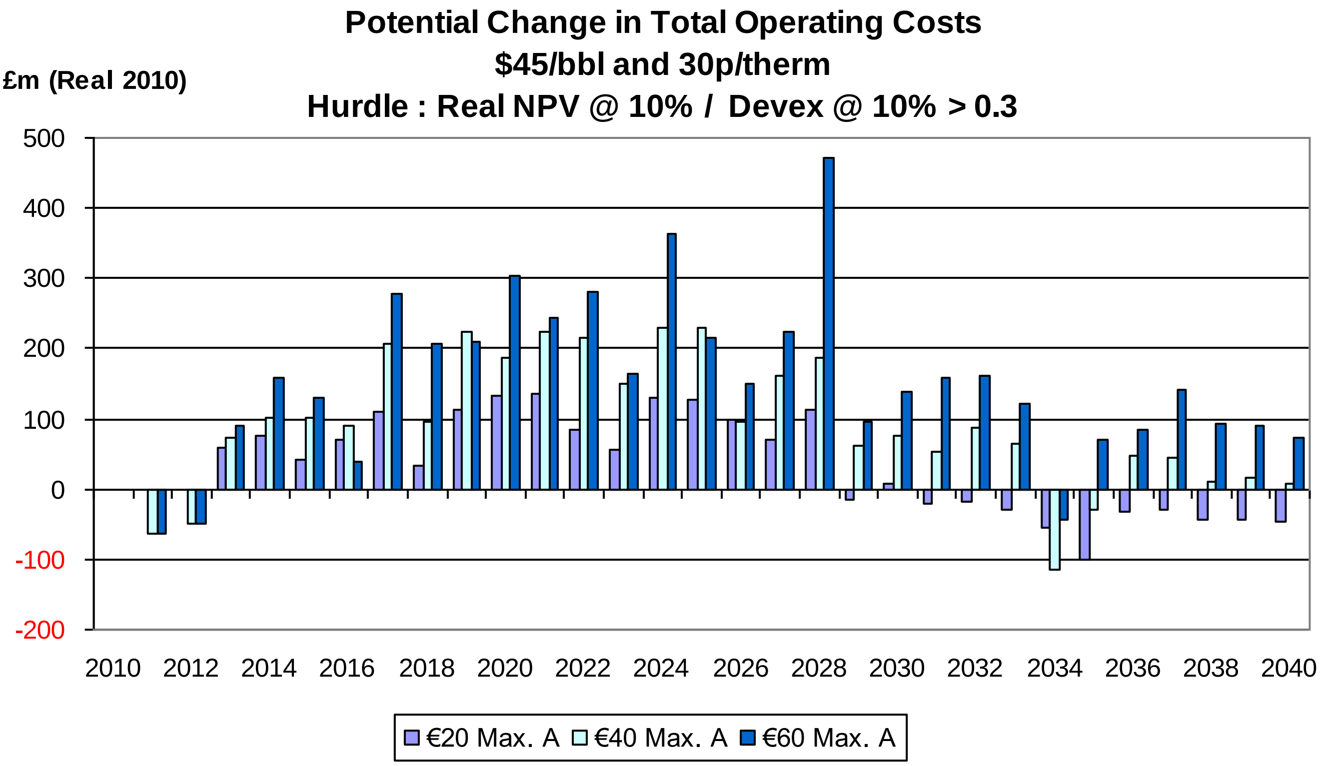
(iii) Changes in Total Operating Costs

Chart 13



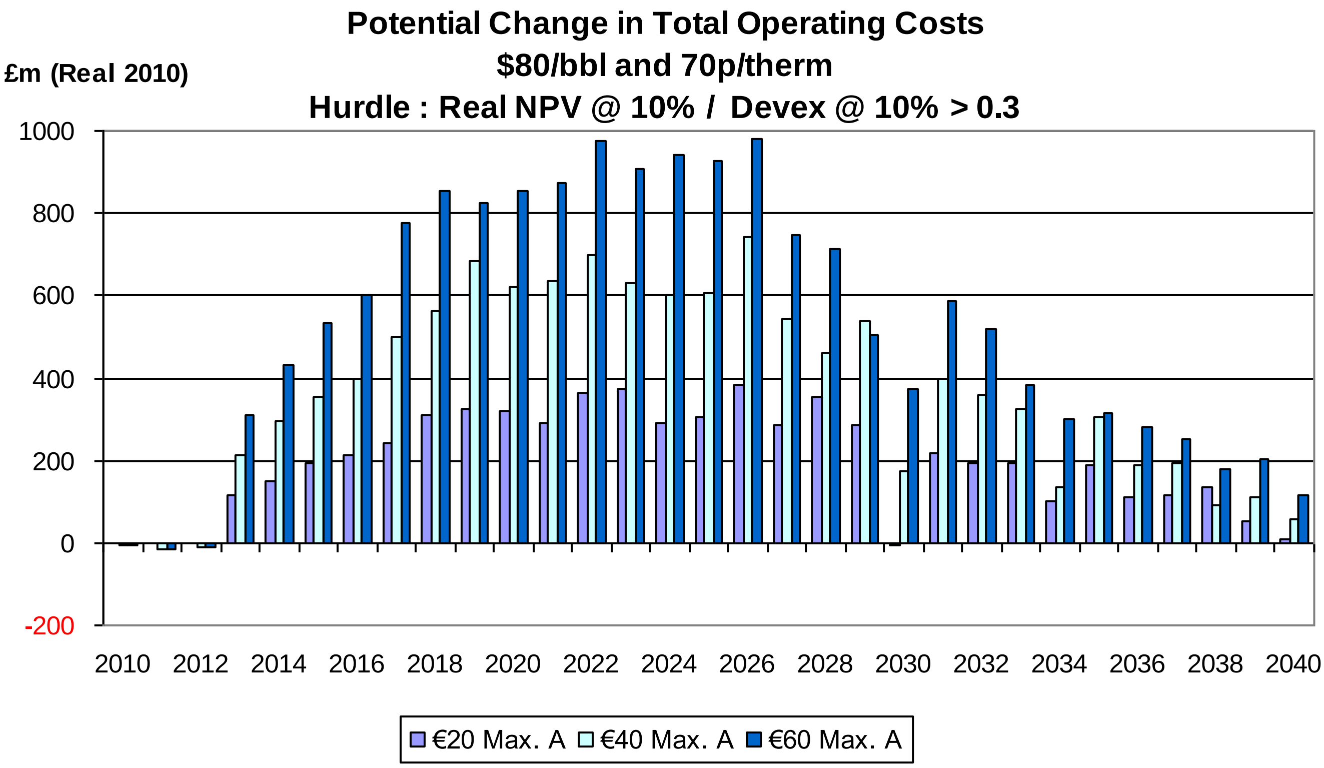
In this study the change in total operating costs is defined as the change in emissions costs minus the change in production operating costs. From Chart 13 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £236m in 2020. Cumulative spending on total operating costs could be increased by £1,213m by 2020, £2,624m by 2030, and £3,229m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £373m in 2020. Cumulative spending on total operating costs could be increased by £2,259m by 2020, £5,502m by 2030, and £7,141m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £538m in 2020. Cumulative spending on total operating costs could be increased by £3,226m by 2020, £7,986m by 2030, and £10,291m by 2040.

Chart 14



From Chart 14 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £134m in 2020. Cumulative spending on total operating costs could be increased by £637m by 2020, £1,446m by 2030, and £1,030m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £186m in 2020. Cumulative spending on total operating costs could be increased by £964m by 2020, £2,597m by 2030, and £2,778m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £302m in 2020. Cumulative spending on total operating costs could be increased by £1,297m by 2020, £3,647m by 2030, and £4,599m by 2040.

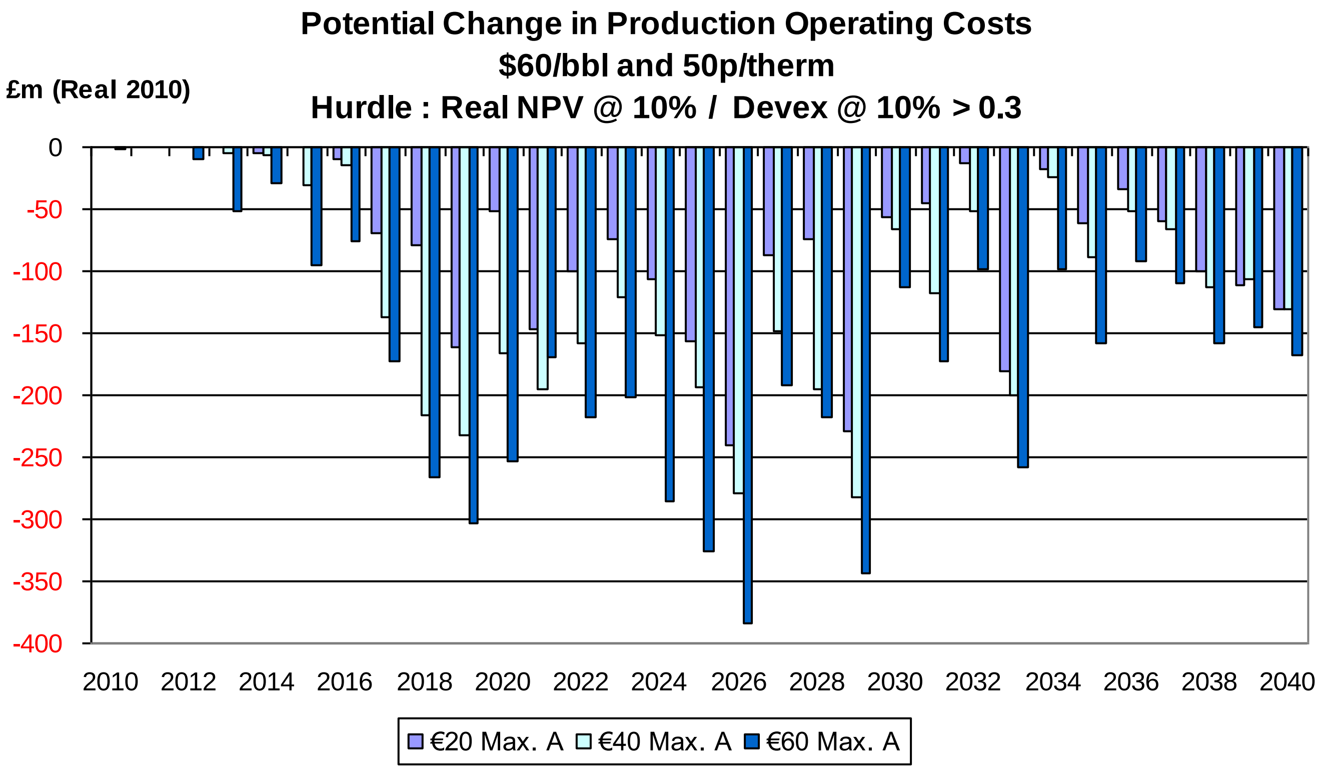
Chart 15



From Chart 15 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £318m in 2020. Cumulative spending on total operating costs could be increased by £1,866m by 2020, £4,792m by 2030, and £6,112m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £623m in 2020. Cumulative spending on total operating costs could be increased by £3,590m by 2020, £9,228m by 2030, and £11,393m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £854m in 2020. Cumulative spending on total operating costs could be increased by £5,150m by 2020, £13,096m by 2030, and £16,229m by 2040.

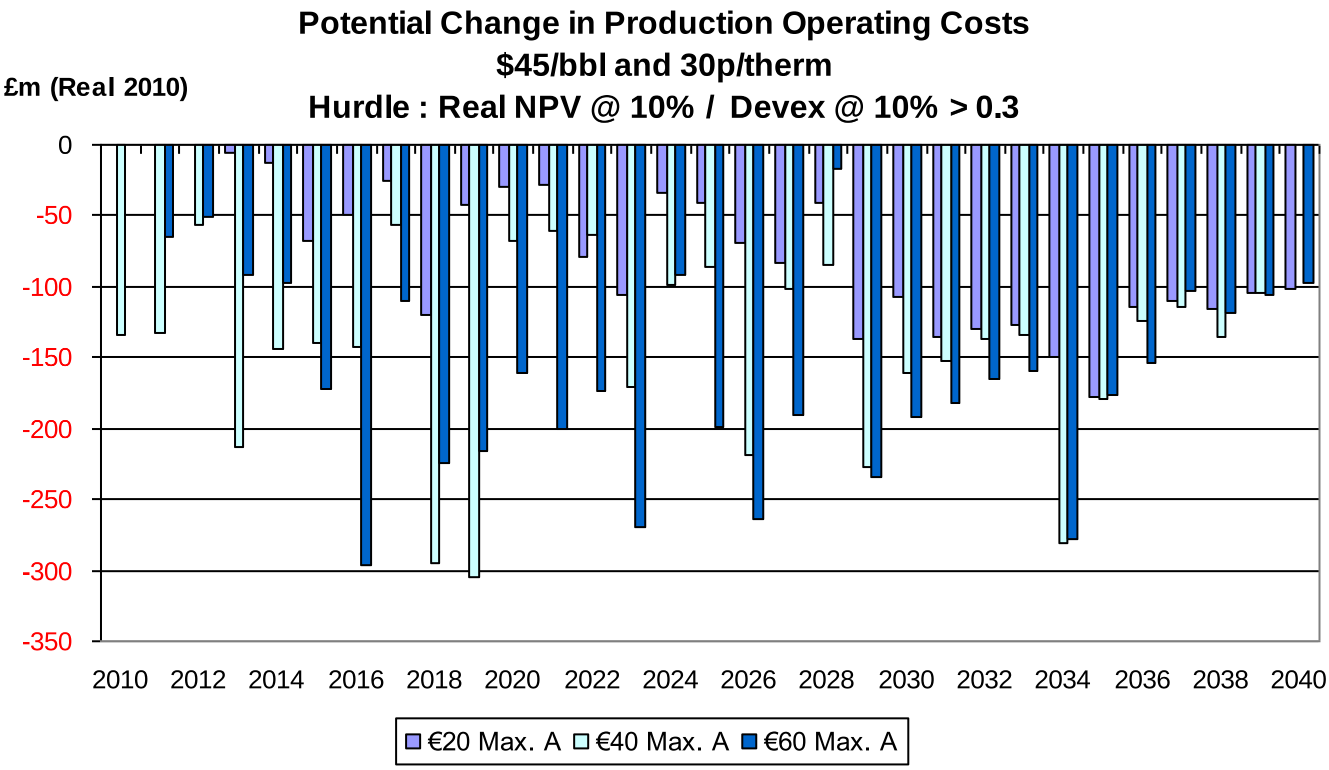
(iv)Changes in Production Operating Costs

Chart 16



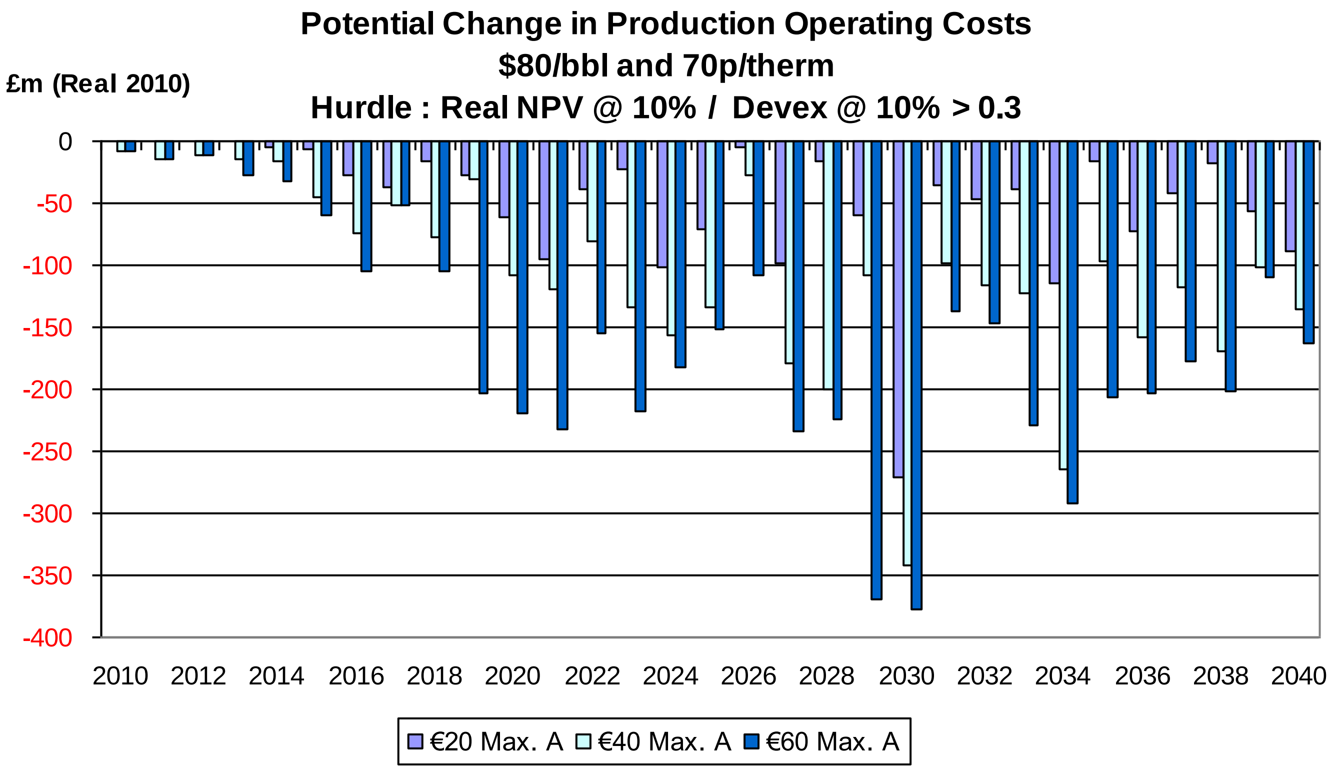
From Chart 16 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t <u>production</u> operating costs could be reduced by £161m in 2019. Cumulative spending on production operating costs could be reduced by £373m by 2020, £1,646m by 2030, and £2,397m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £232m in 2019. Cumulative spending on production operating costs could be reduced by £808m by 2020, £2,598m by 2030, and £3,549m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £304m in 2019. Cumulative spending on production operating costs could be reduced by £1,261m by 2020, £3,713m by 2030, and £5,172m by 2040.

Chart 17



From Chart 17 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £43m in 2019. Cumulative spending on production operating costs could be reduced by £354m by 2020, £1,078m by 2030, and £2,342m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £305m in 2019. Cumulative spending on production operating costs could be reduced by £1,689m by 2020, £2,960m by 2030, and £4,317m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £216m in 2019. Cumulative spending on production operating costs could be reduced by £1,484m by 2020, £3,317m by 2030, and £4,859m by 2040.

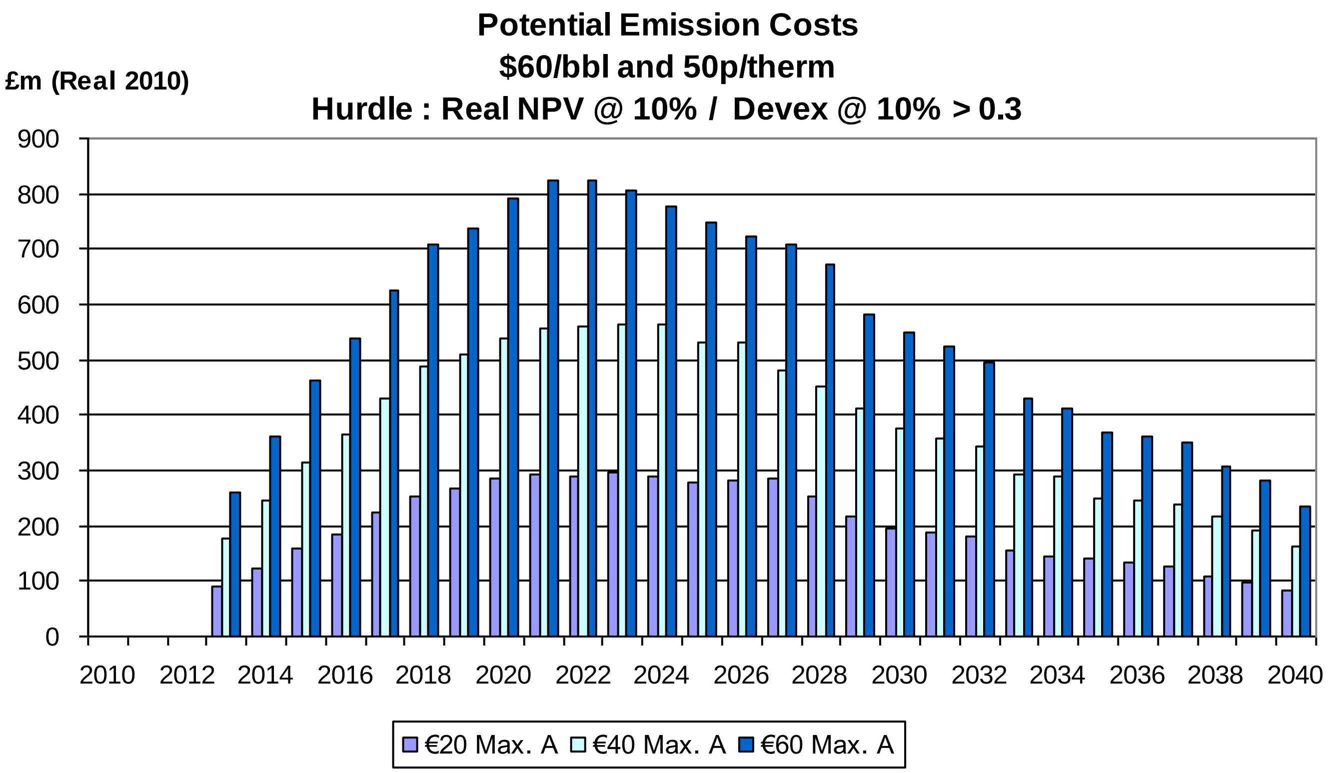
Chart 18



From Chart 18 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £61m in 2020. Cumulative spending on production operating costs could be reduced by £182m by 2020, £960m by 2030, and £1,487m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £108m in 2020. Cumulative spending on production operating costs could be reduced by £452m by 2020, £1,933m by 2030, and £3,313m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £219m in 2020. Cumulative spending on production operating costs could be reduced by £835m by 2020, £3,082m by 2030, and £4,951m by 2040.

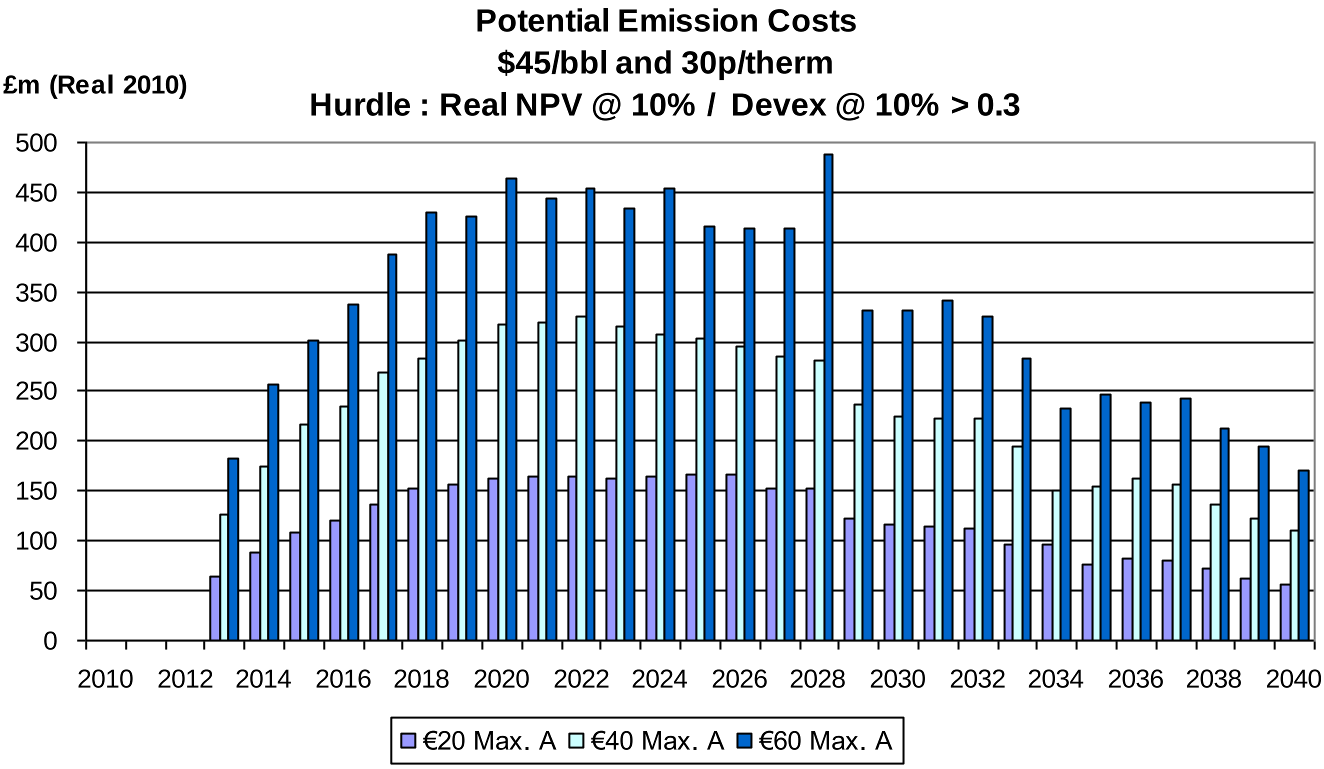
(v) Emission Costs

Chart 19



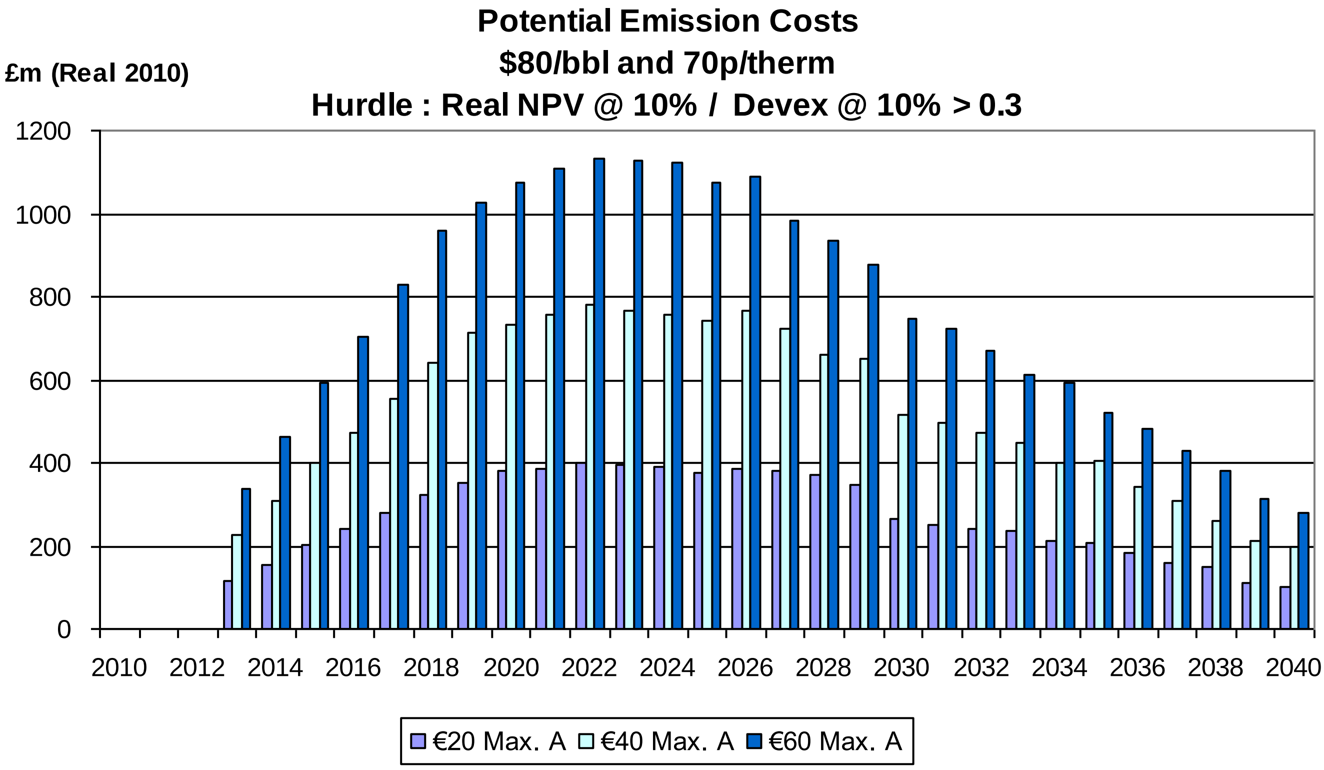
From Chart 19 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £287m in 2020. Cumulative spending on emissions could be £1,586m by 2020, £4,270m by 2030, and £5,626m by 2040. With a CO_2 price of €40/t emission costs could be £539m in 2020. Cumulative spending on emissions could be £3,068m by 2020, £8,100m by 2030, and £10,690m by 2040. With a CO_2 price of €60/t emission costs could be £792m in 2020. Cumulative spending on emissions could be £4,487m by 2020, £11,699m by 2030, and £15,463m by 2040.

Chart 20



From Chart 20 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £163m in 2020. Cumulative spending on emissions could be £991m by 2020, £2,524m by 2030, and £3,373m by 2040. With a CO_2 price of €40/t emission costs could be £317m in 2020. Cumulative spending on emissions could be £1,923m by 2020, £4,817m by 2030, and £6,451m by 2040. With a CO_2 price of €60/t emission costs could be £463m in 2020. Cumulative spending on emissions could be £2,782m by 2020, £6,964m by 2030, and £9,458m by 2040.

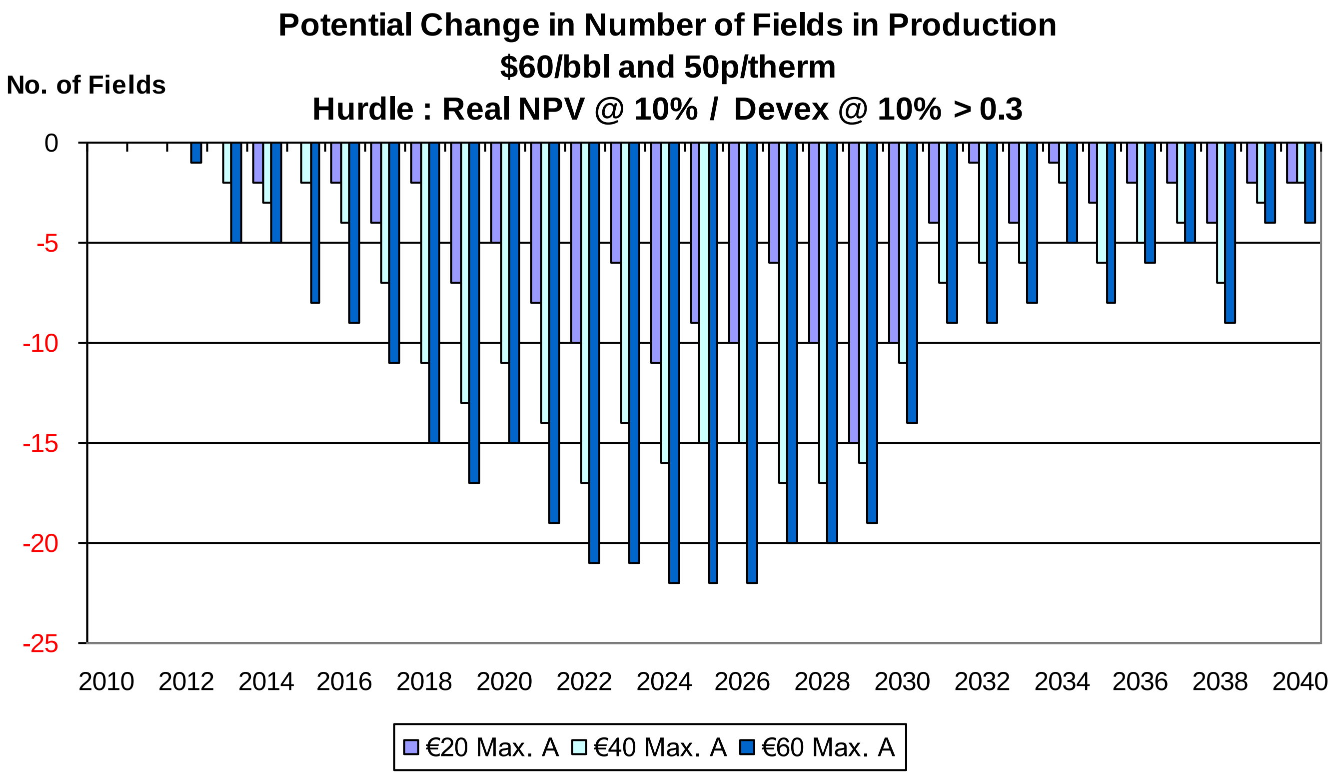
Chart 21



From Chart 21 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £379m in 2020. Cumulative spending on emissions could be £2,048m by 2020, £5,751m by 2030, and £7,600m by 2040. With a CO_2 price of €40/t emission costs could be £730m in 2020. Cumulative spending on emissions could be £4,042m by 2020, £11,161m by 2030, and £14,706m by 2040. With a CO_2 price of €60/t emission costs could be £1,073m in 2020. Cumulative spending on emissions could be £5,985m by 2020, £16,178m by 2030, and £21,180m by 2040.

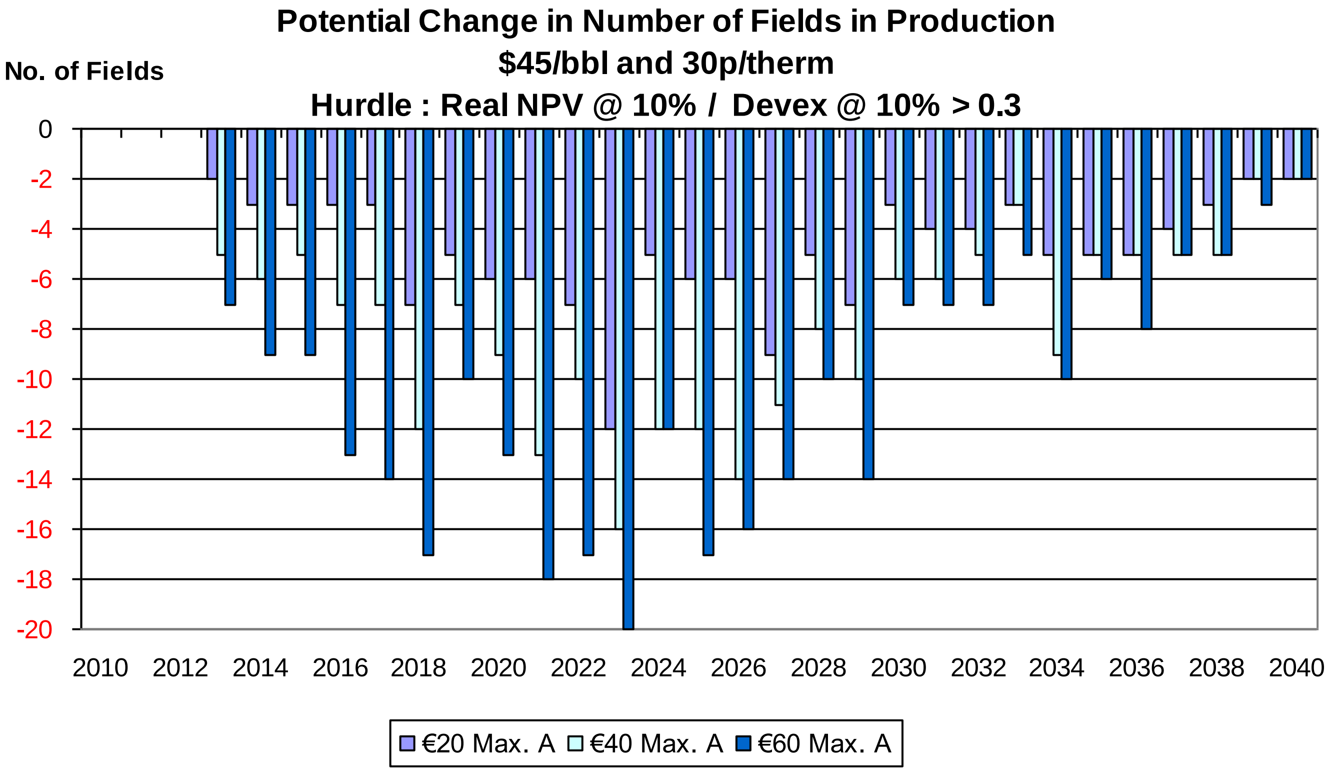
(vi)Changes in Numbers of Fields in Production

Chart 22



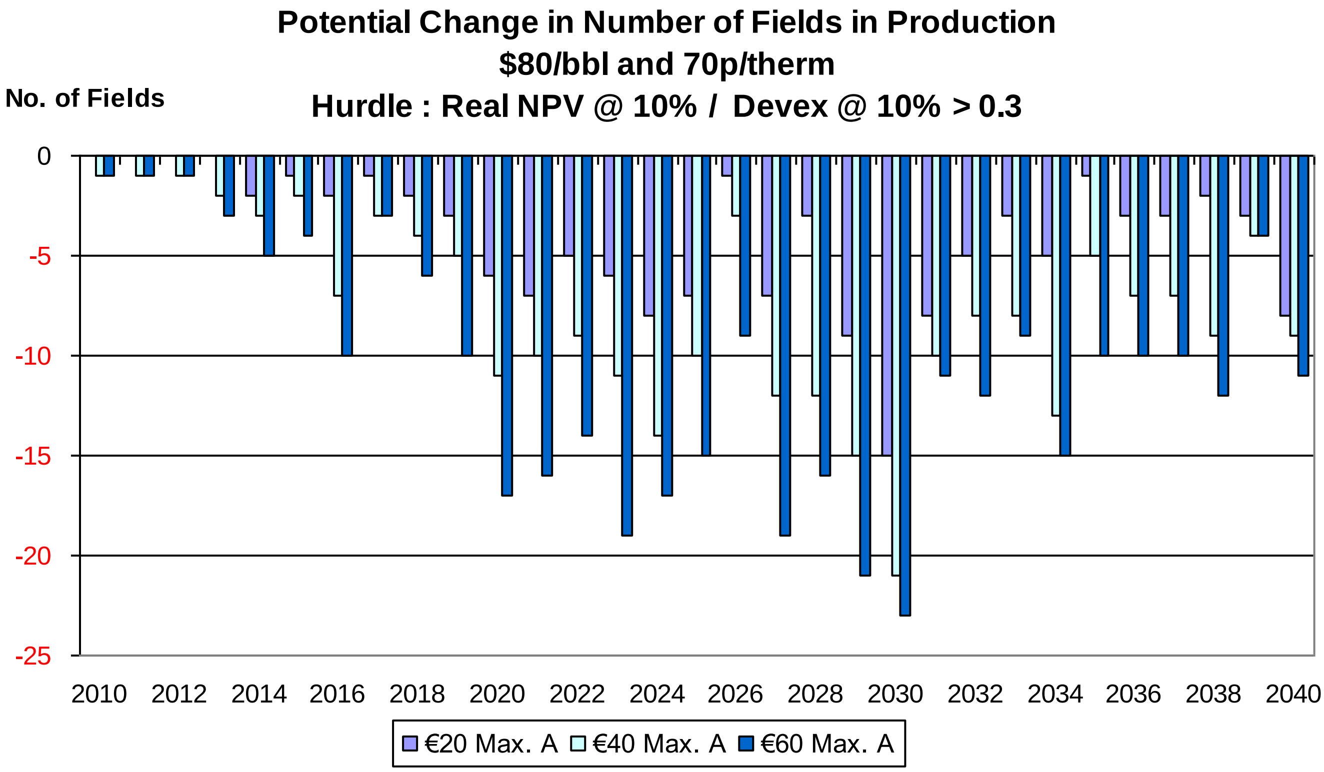
In this study the change in the number of fields in production reflects the reduction from both those rendered uneconomic by the EU ETS and those presently reaching their COP dates. From Chart 22 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 15 fewer fields in production in 2029. With a CO_2 price of €40/t there may be 17 fewer fields in production in 2022, 2027 and 2028. With a CO_2 price of €60/t there may be 22 fewer fields in production in 2024, 2025 and 2026.

Chart 23



From Chart 23 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 12 fewer fields in production in 2023 and 7 fewer 2029. With a CO_2 price of €40/t there may be 16 fewer fields in production in 2023. With a CO_2 price of €60/t there may be 20 fewer fields in production in 2023.

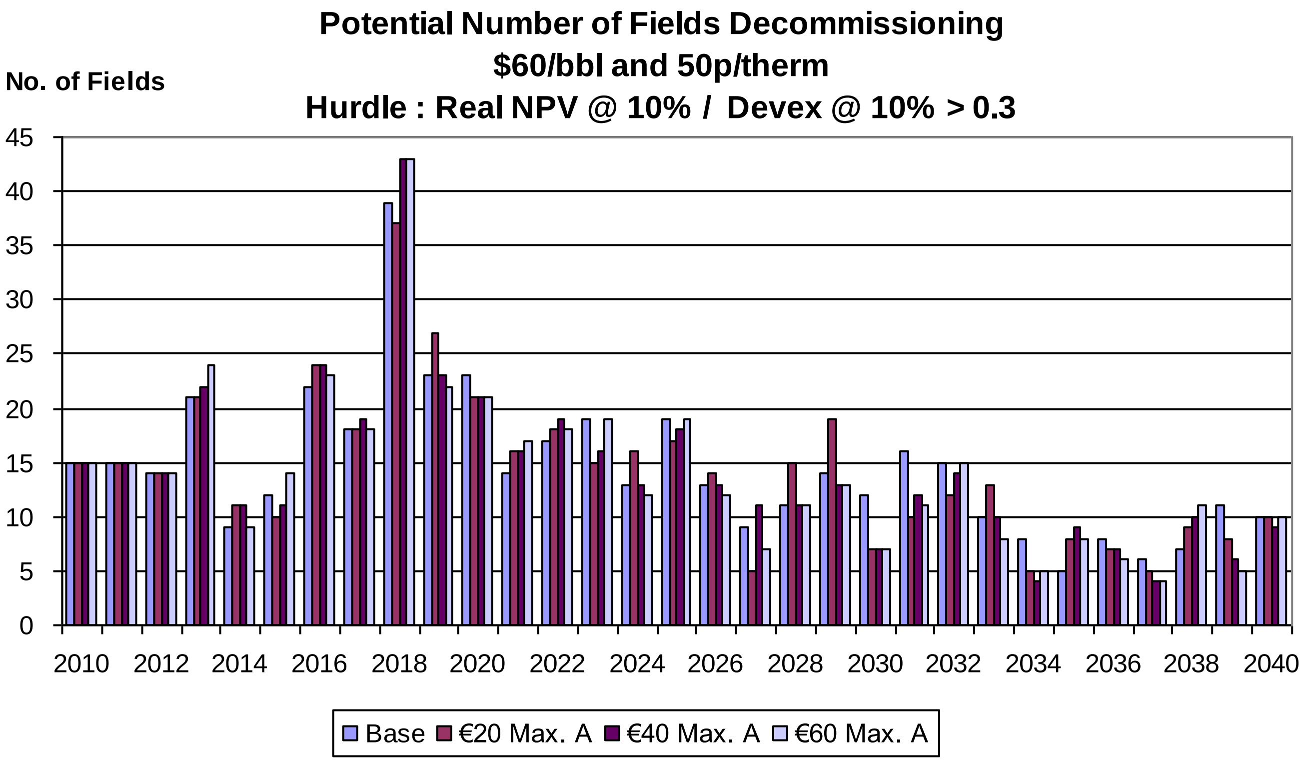
Chart 24



From Chart 24 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 8 fewer fields in production in 2024 and 15 fewer in 2030. With a CO_2 price of €40/t there may be 11 fewer fields in production in 2020 and 2023, and 21 fewer in 2030. With a CO_2 price of €60/t there may be 17 fewer fields in production in 2020, 19 fewer in 2023 and 2027, and 23 fewer in 2030.

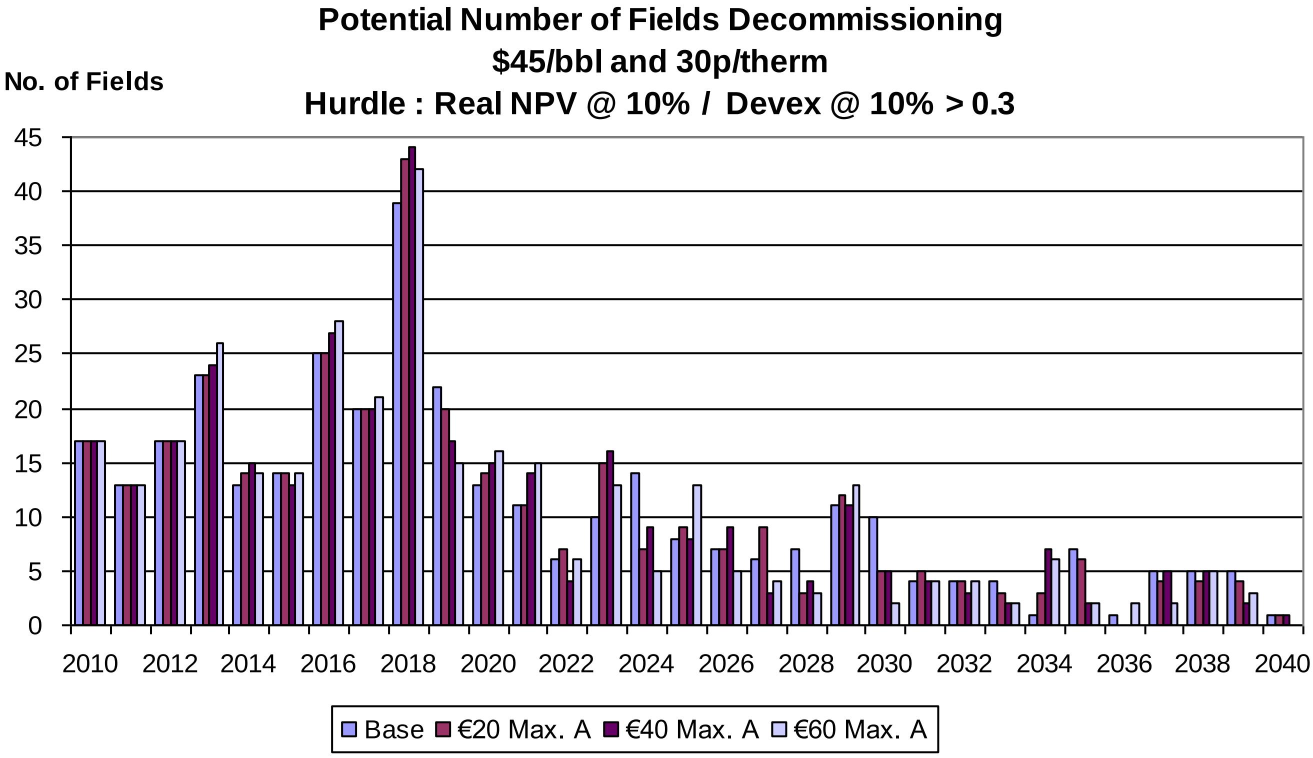
(vii) Numbers of Fields Decommissioning

Chart 25



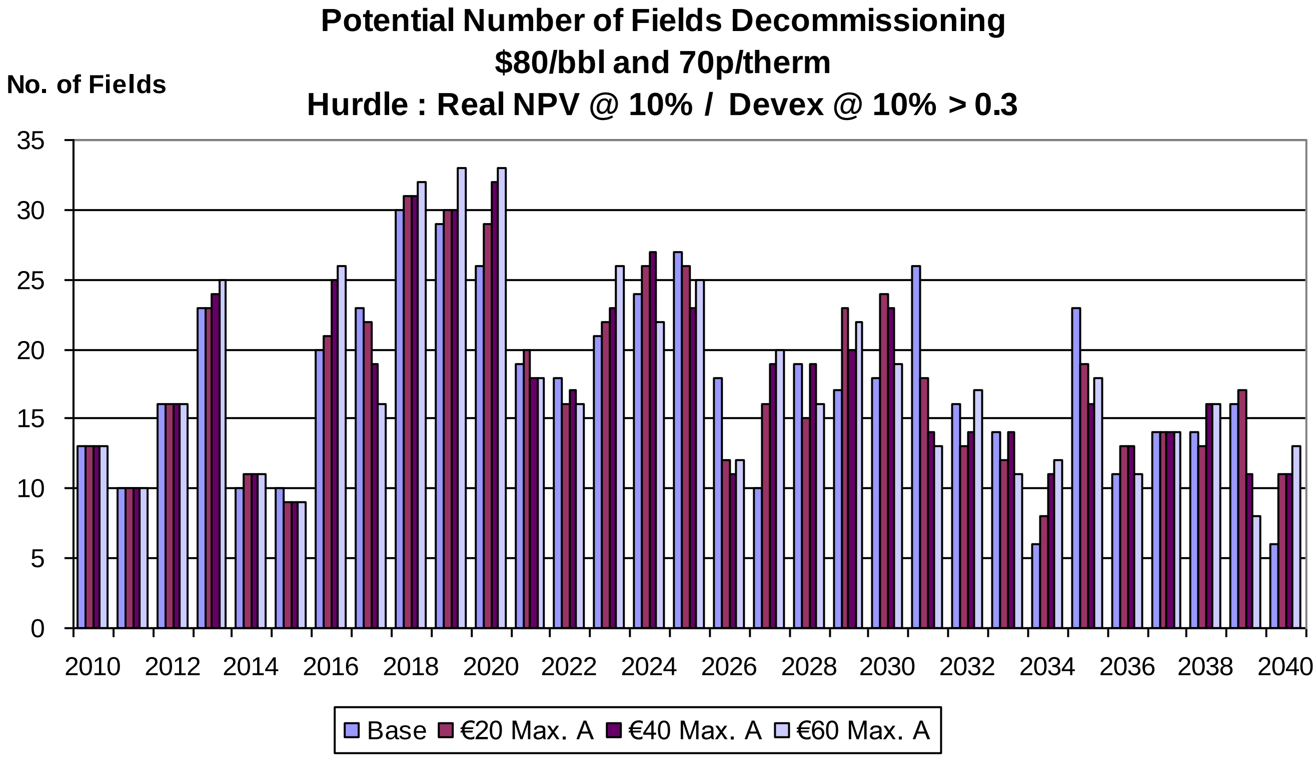
It follows from the above that the number of fields being decommissioned changes from the effects of Phase III of the EU ETS. From chart 25 it is seen that at the medium price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 2 extra fields which decommission in 2020 and 3 extra in 2030. However there are also 5 fewer fields in production in 2020, 10 fewer in 2030 and 2 fewer in 2040. With a CO_2 price of €40/t there may be 7 extra fields decommissioning in 2020 and 3 extra in 2030. However, there are also 11 fewer fields in production in 2020, 11 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €60/t there may be 7 extra fields decommissioning in 2020, and 1 extra in 2030. However there are 15 fewer fields in production in 2020, 14 fewer in 2030, and 4 fewer in 2040.

Chart 26



From Chart 26 it is seen that at the low price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 4 extra fields decommissioning in 2020. However, there are 6 fewer fields in production in 2020, 3 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €40/t there may be 6 extra fields decommissioning in 2020. However, there are 9 fewer fields in production in 2020, 6 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €60/t there may be 7 extra fields decommissioning in 2020. However, there are 13 fewer fields in production in 2020, 7 fewer in 2030, and 2 fewer in 2040.

Chart 27

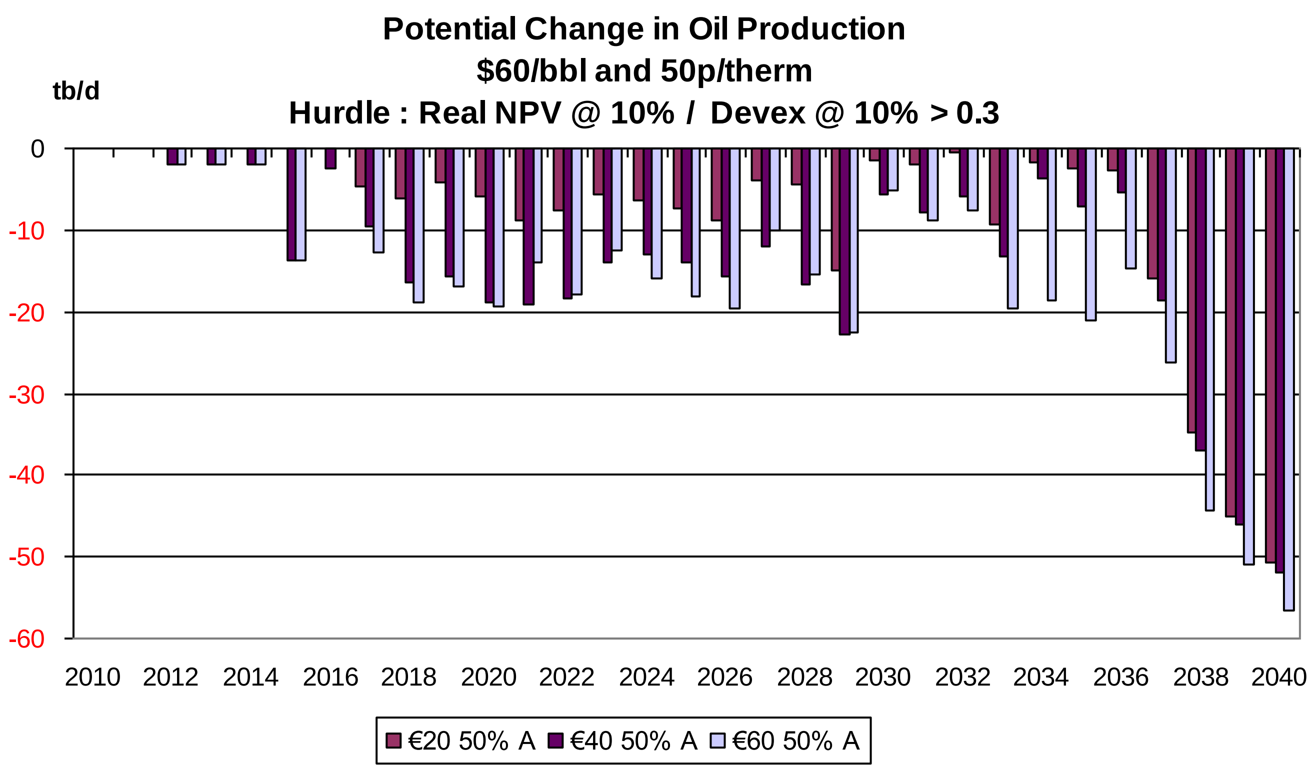


From Chart 27 it is seen that at the high price with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 5 extra fields decommissioning in 2020, 4 in 2030, and 6 in 2040. However, there are 6 fewer fields in production in 2020, 15 fewer in 2030 and 8 fewer in 2040. With a CO_2 price of €40/t there may be 10 extra fields decommissioning in 2020, 19 in 2030, and 7 in 2040. However, there are 11 fewer fields in production in 2020, 21 fewer in 2030, and 7 fewer in 2040. With a CO_2 price of €60/t there may be 14 extra fields decommissioning in 2020, 19 in 2030, and 6 in 2040. However, there are 17 fewer fields in production in 2020, 23 fewer in 2030, and 11 fewer in 2040.

b. Fifty Per Cent of Emissions from Electricity Generation

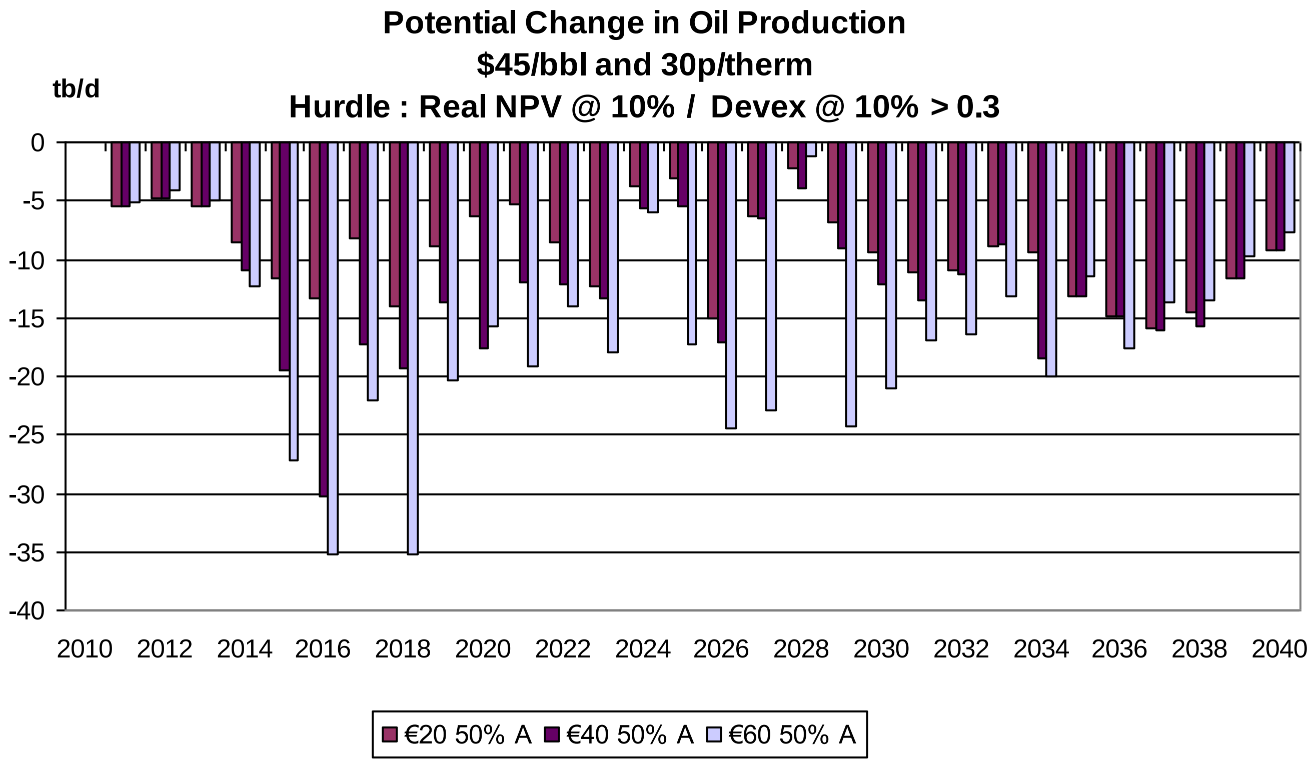
(i) Changes in Production

Chart 28



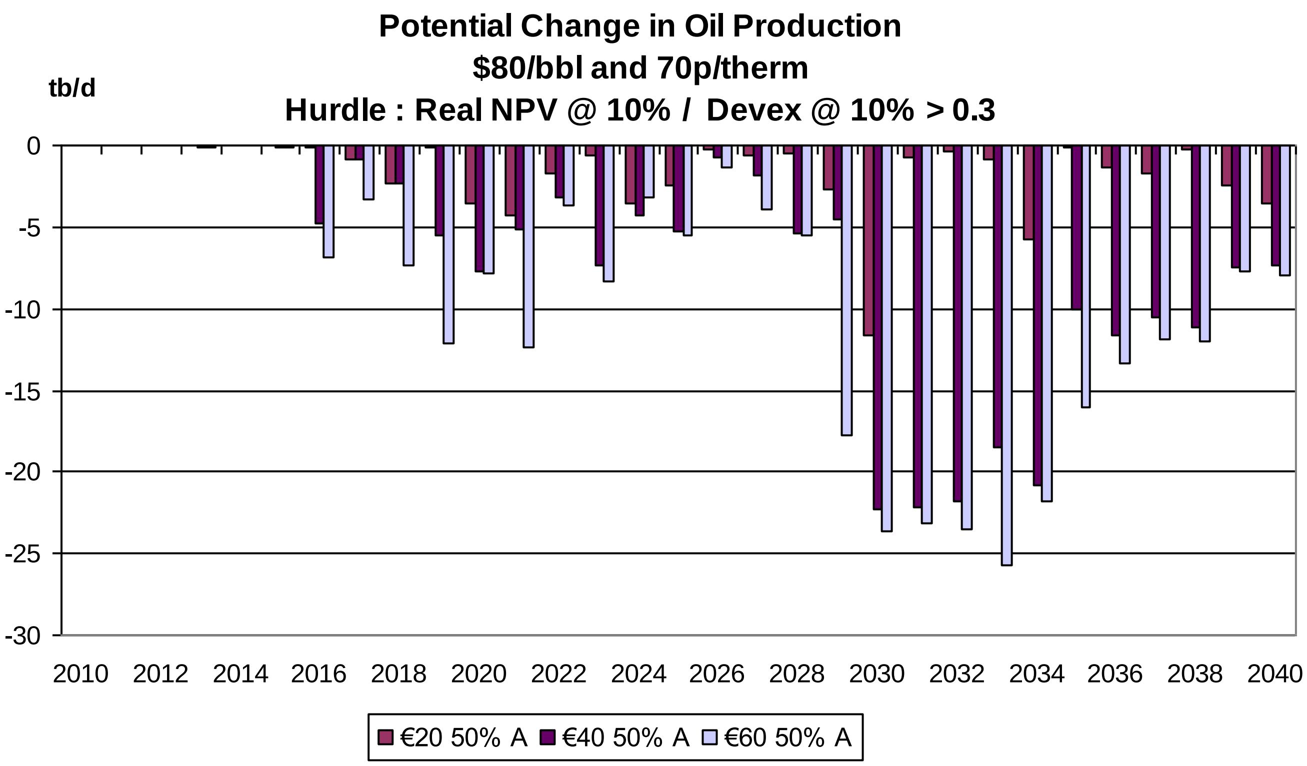
From Chart 28 it is seen that at the medium price, if 50% emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 9tb/d in 2026 15tb/d in 2029 and 51tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 19tb/d in 2020 and 2021, 23tb/d in 2029 and 52tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 19tb/d in 2020, 23tb/d in 2029, and 56tb/d in 2040.

Chart 29



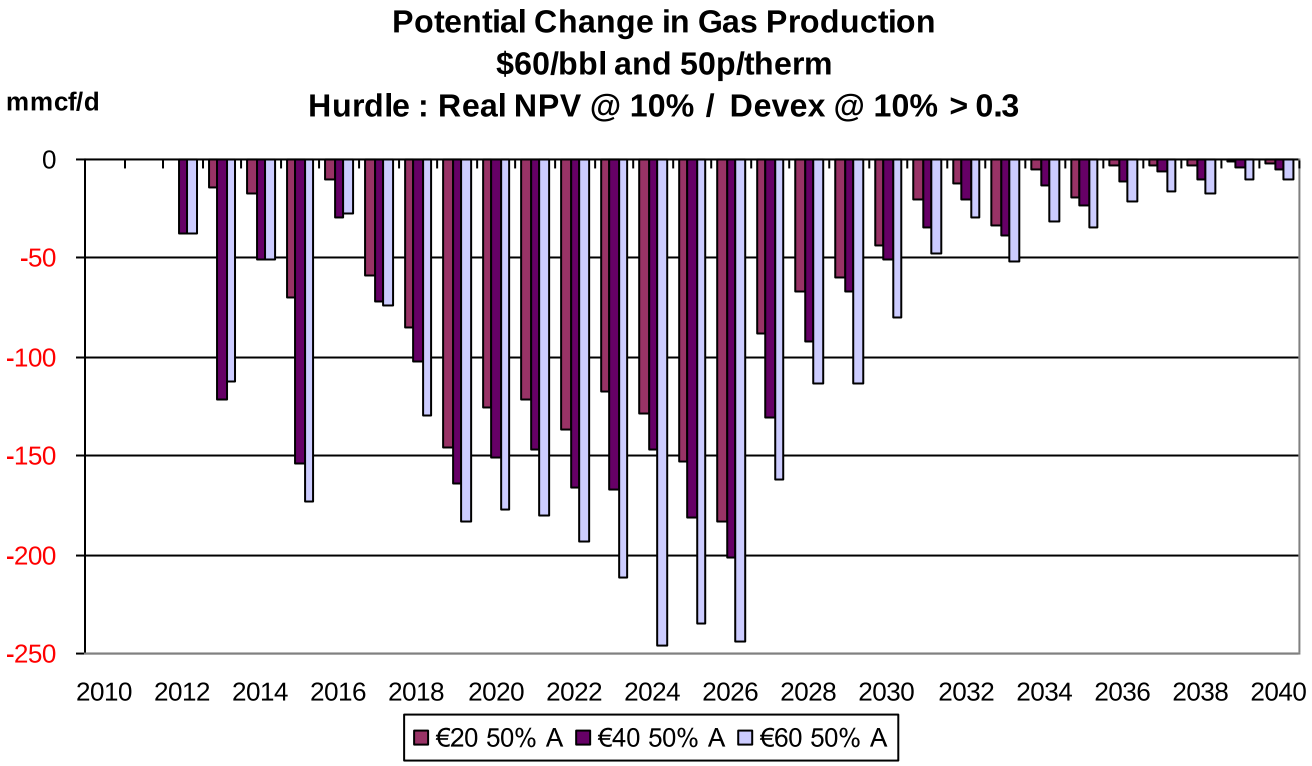
From Chart 29 it is seen that at the low price, if 50% emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 14tb/d in 2018, 11tb/d in 2031, and 9tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 30tb/d in 2016, 13tb/d in 2031, and 9tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 35tb/d in 2016 and 2018, 24tb/d in 2029, and 8tb/d in 2040.

Chart 30



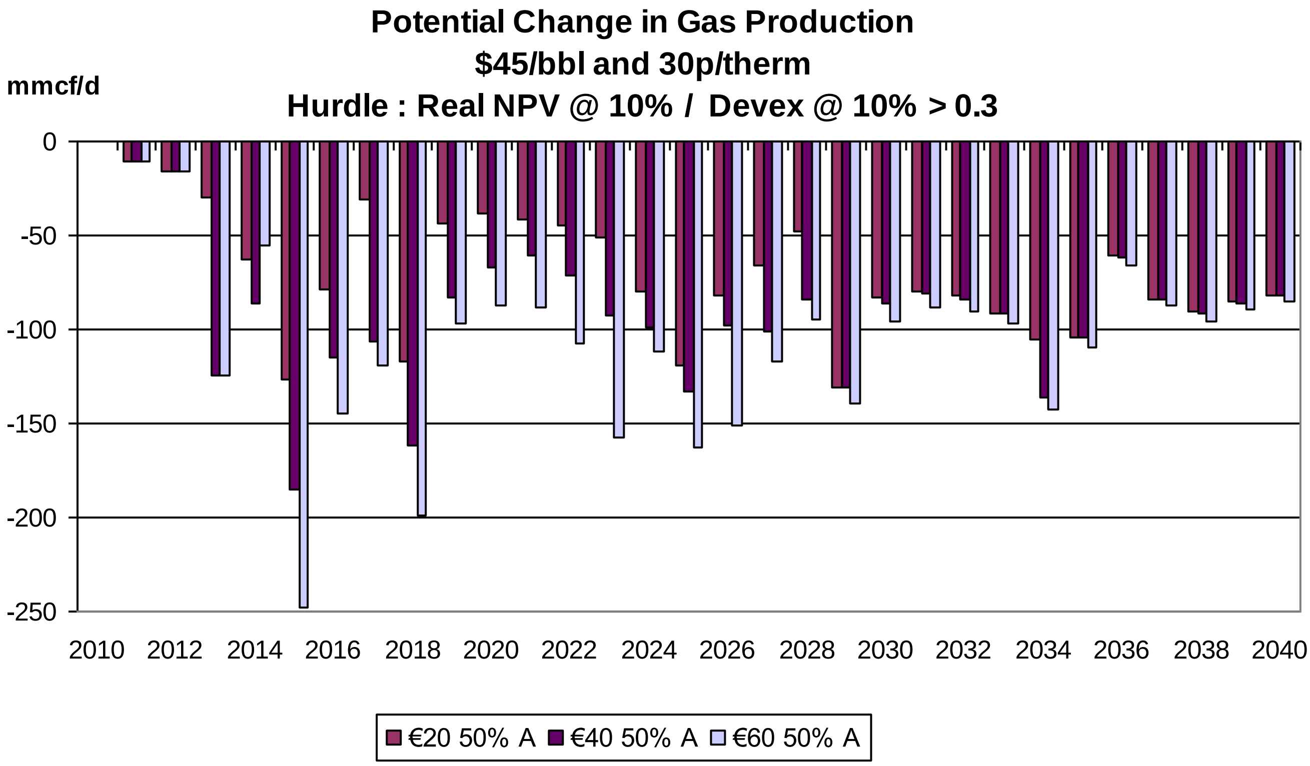
From Chart 30 it is seen that at the high price, if 50% emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 4tb/d in 2020 and 2021, 12tb/d in 2030, and 4tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 8tb/d in 2020, 22tb/d in 2030 and 2031, and 7tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 12tb/d in 2019 and 2021, 24tb/d in 2026, 26 in 2033, and 8tb/d in 2040.

Chart 31



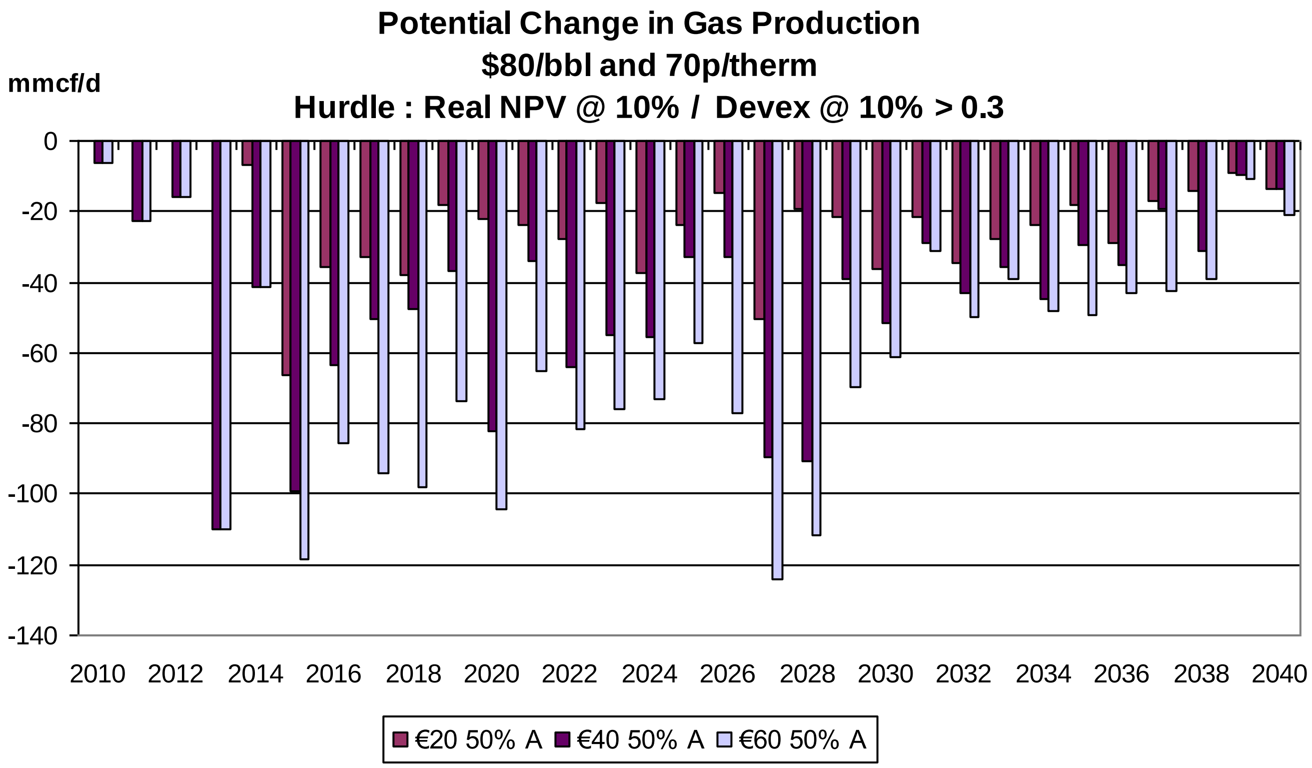
From Chart 31 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 146mmcf/d in 2019, and 183mmcf/d in 2026. With a CO_2 price of €40/t gas production could be reduced by 164mmcf/d in 2019, and 201mmcf/d in 2026. With a CO_2 price of €60/t gas production could be reduced by 183mmcf/d in 2019, and 244mmcf/d in 2026.

Chart 32



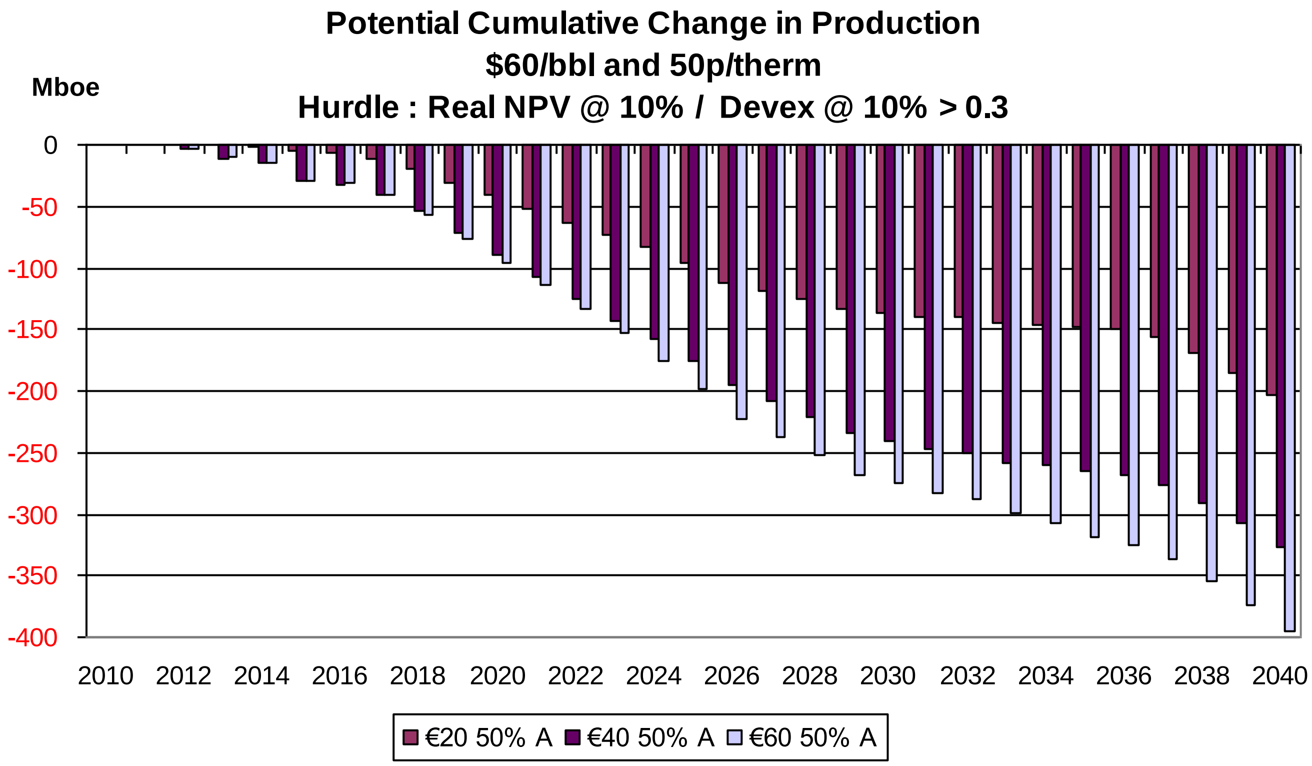
From Chart 32 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 127mmcf/d in 2015, and 131mmcf/d in 2029. With a CO_2 price of €40/t gas production could be reduced by 185mmcf/d in 2015, and 131mmcf/d in 2029. With a CO_2 price of €60/t gas production could be reduced by 248mmcf/d in 2015, and 139mmcf/d in 2029.

Chart 33



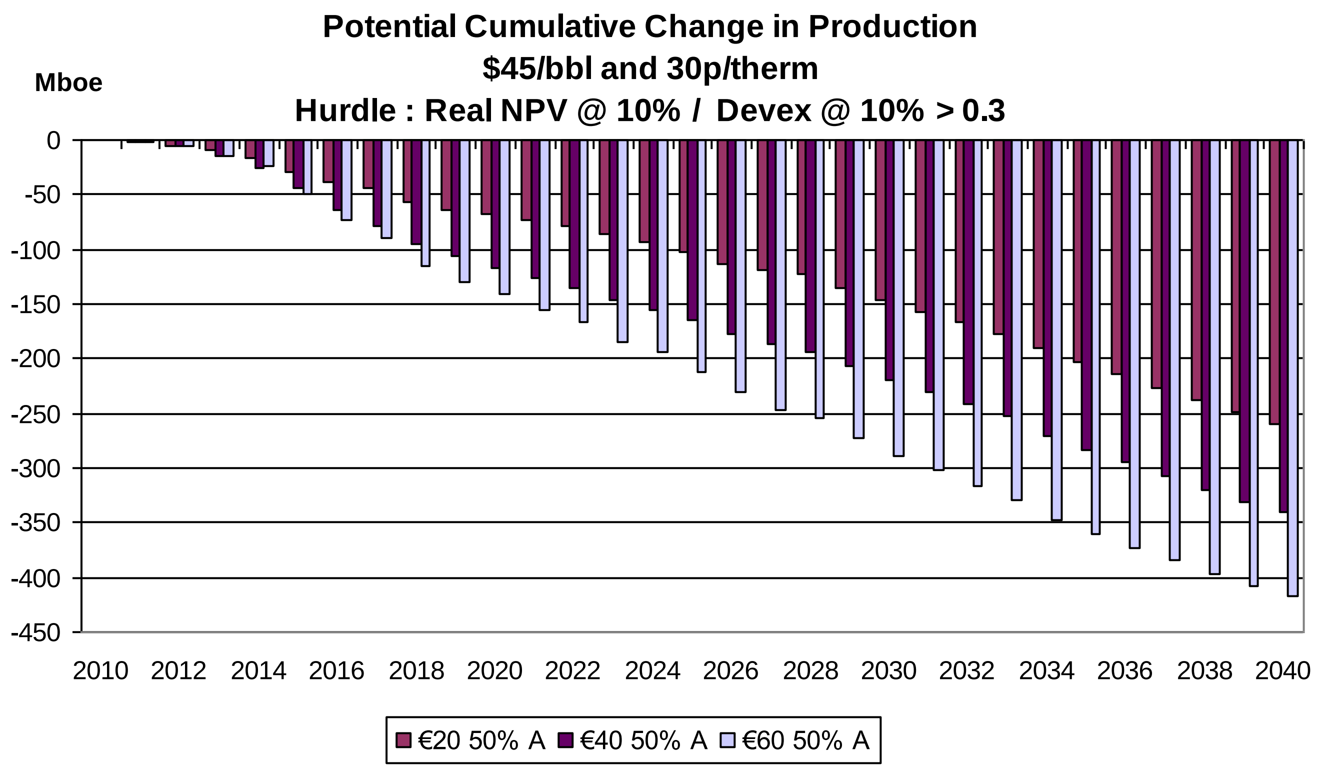
From Chart 33 it is seen that at the high price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 38mmcf/d in 2018 and 36mmcf/d in 2030. With a CO_2 price of €40/t gas production could be reduced by 82mmcf/d in 2020 and 52mmcf/d in 2030. With a CO_2 price of €60/t gas production could be reduced by 104mmcf/d in 2020 and 124mmcf/d in 2027.

Chart 34



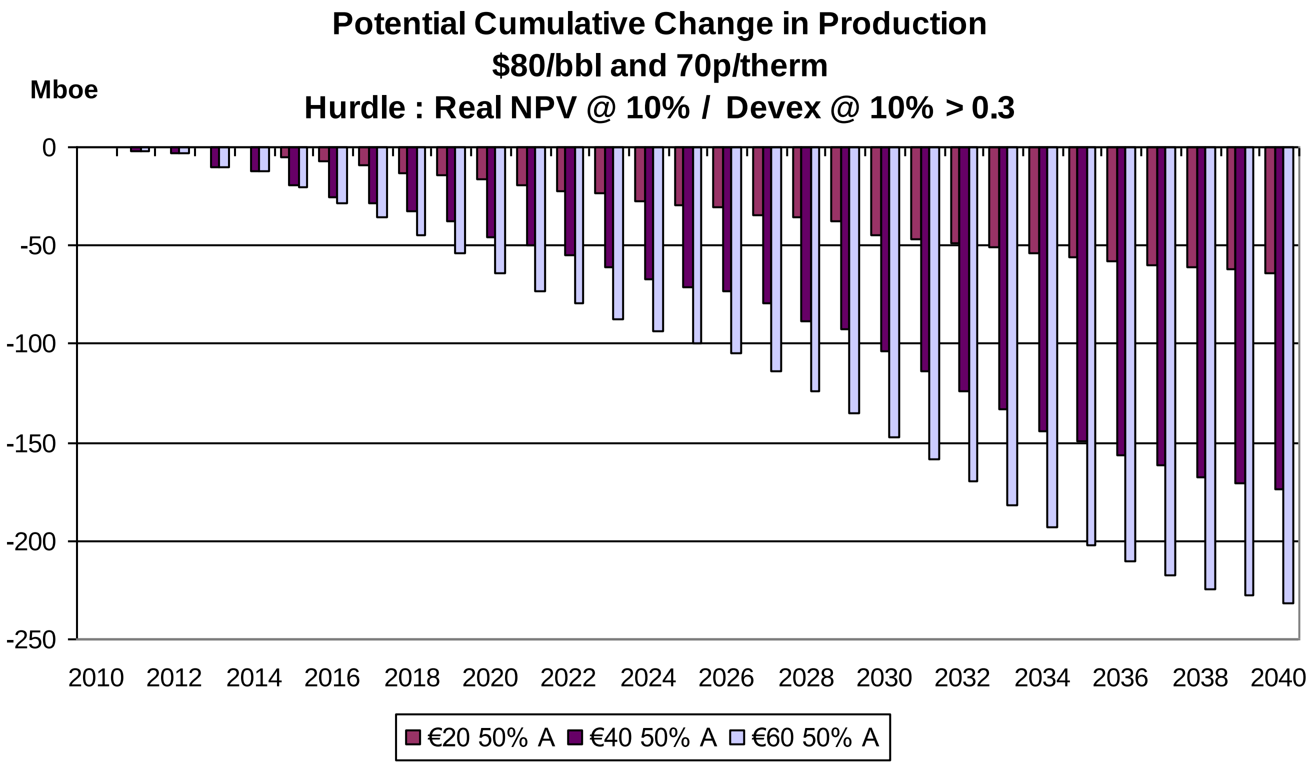
From Chart 34 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO2 cost of €20/t cumulative total hydrocarbon production could be reduced by 40mboe by 2020 (17mboe from sanctioned fields and incremental investments, 7mboe from the Probable fields and 16mboe from the technical reserves fields), 137mboe by 2030 (33mboe from sanctioned fields and incremental investments, 15mboe from the Probable fields, 2mboe from Possible fields and 86mboe from the technical reserves fields), and 204mboe by 2040 (42mboe from sanctioned fields and incremental investments, 15mboe from the Probable fields, 2mboe from Possible fields and 144mboe from the technical reserves fields. With a CO2 price of €40/t cumulative production could be reduced by 89mboe by 2020 (53mboe from sanctioned fields and incremental investments, 13mboe from the Probable fields, 4mboe from Possible fields and 19mboe from the technical reserves fields), 241mboe by 2030 (110mboe from sanctioned fields and incremental investments, 22mboe from the Probable fields, 9mboe from Possible fields and 100mboe from the technical reserves fields), and 328mboe by 2040 (135mboe from sanctioned fields and incremental investments, 22mboe from the Probable fields, 9mboe from Possible fields and 162mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative production could be reduced by 96mboe by 2020 (57mboe from sanctioned fields and incremental investments, 13mboe from the Probable fields, 4mboe from Possible fields and 21mboe from the technical reserves fields), 275mboe by 2030 (120mboe from sanctioned fields and incremental investments, 26mboe from the Probable fields, 13mboe from Possible fields and 116mboe from the technical reserves fields), and 395mboe by 2040 (146mboe from sanctioned fields and incremental investments, 26mboe from the Probable fields, 13mboe from Possible fields and 210mboe from the technical reserves fields).

Chart 35



From Chart 35 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative production could be reduced by 68mboe in 2020 (42mboe from sanctioned fields and incremental investments and 27mboe from Possible fields), 146mboe by 2030 (87mboe from sanctioned fields and incremental investments, 39mboe from Possible fields and 20mboe from the technical reserves fields), and 259mboe by 2040 (163mboe from sanctioned fields and incremental investments, 39mboe from Possible fields and 57mboe from the technical reserves fields). With a CO_2 price of €40/t cumulative production could be reduced by 117mboe in 2020 (68mboe from sanctioned fields and incremental investments, 36mboe from Possible fields and 14mboe from the technical reserves fields), 219mboe by 2030 (134mboe from sanctioned fields and incremental investments, 49mboe from Possible fields and 36mboe from the technical reserves fields), and 340mboe by 2040 (217mboe from sanctioned fields and incremental investments, 50mboe from Possible fields and 74mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative production could be reduced by 141mboe in 2020 (89mboe from sanctioned fields and incremental investments, 3mboe from the Probable fields, 36mboe from Possible fields and 14mboe from the technical reserves fields), 289mboe by 2030 (179mboe from sanctioned fields and incremental investments, 3mboe from the Probable fields, 49mboe from Possible fields and 57mboe from the technical reserves fields), and 417mboe by 2040 (255mboe from sanctioned fields and incremental investments, 3mboe from the Probable fields, 50mboe from Possible fields and 109mboe from the technical reserves fields).

Chart 36

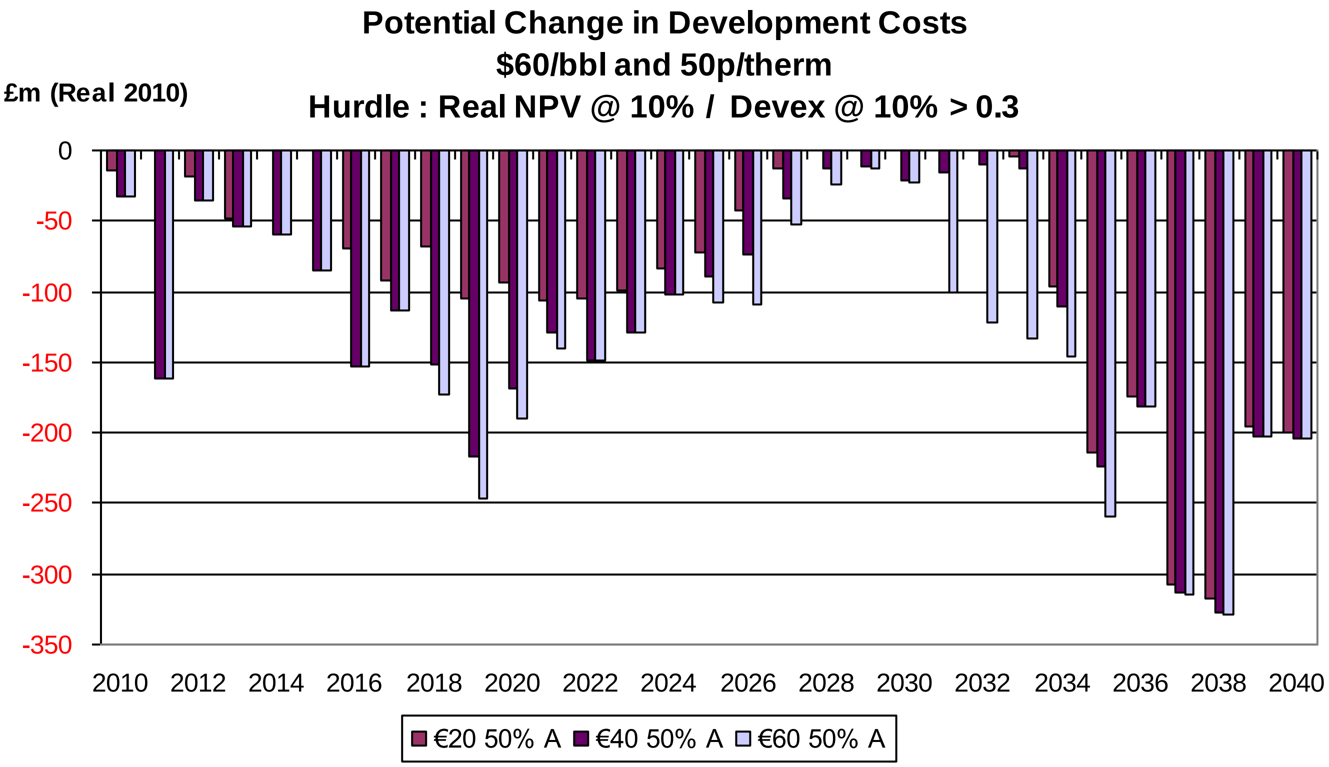


From Chart 36 it is seen that at the high price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative production could be reduced by 17mboe in 2020 (13mboe from sanctioned fields and incremental investment and 4mboe from the technical reserves fields), 45mboe by 2030 (33mboe from sanctioned fields and incremental investments, 1mboe from the Probable fields, 4mboe from Possible fields and 7mboe from the technical reserves fields), and 64mboe by 2040 (42mboe from sanctioned fields and incremental investments, 1mboe from the Probable fields, 4mboe from Possible fields and 17mboe from the technical reserve fields). With a CO_2 price of €40/t cumulative production could be reduced by 46mboe in 2020 (33mboe from sanctioned fields and incremental investments, 9mboe from the Probable fields and 4mboe from the technical reserves fields), 104mboe by 2030 (68mboe from sanctioned fields and incremental investments, 19mboe from the Probable fields, 5mboe from

Possible fields and 12mboe from the technical reserves fields) and 174mboe by 2040 (80mboe from sanctioned fields and incremental investments, 21mboe from the Probable fields, 6mboe from Possible fields and 67mboe from the technical reserve fields). With a CO_2 price of €60/t cumulative production could be reduced by 64mboe in 2020 (40mboe from sanctioned fields and incremental investments, 20mboe from the Probable fields and 4mboe from the technical reserves fields), 148mboe by 2030 (88mboe from sanctioned fields and incremental investments, 37mboe from the Probable fields, 7mboe from Possible fields and 15mboe from the technical reserves fields), and 232mboe by 2040 (110mboe from sanctioned fields and incremental investments, 39mboe from the Probable fields, 8mboe from Possible fields and 75mboe from the technical reserves fields).

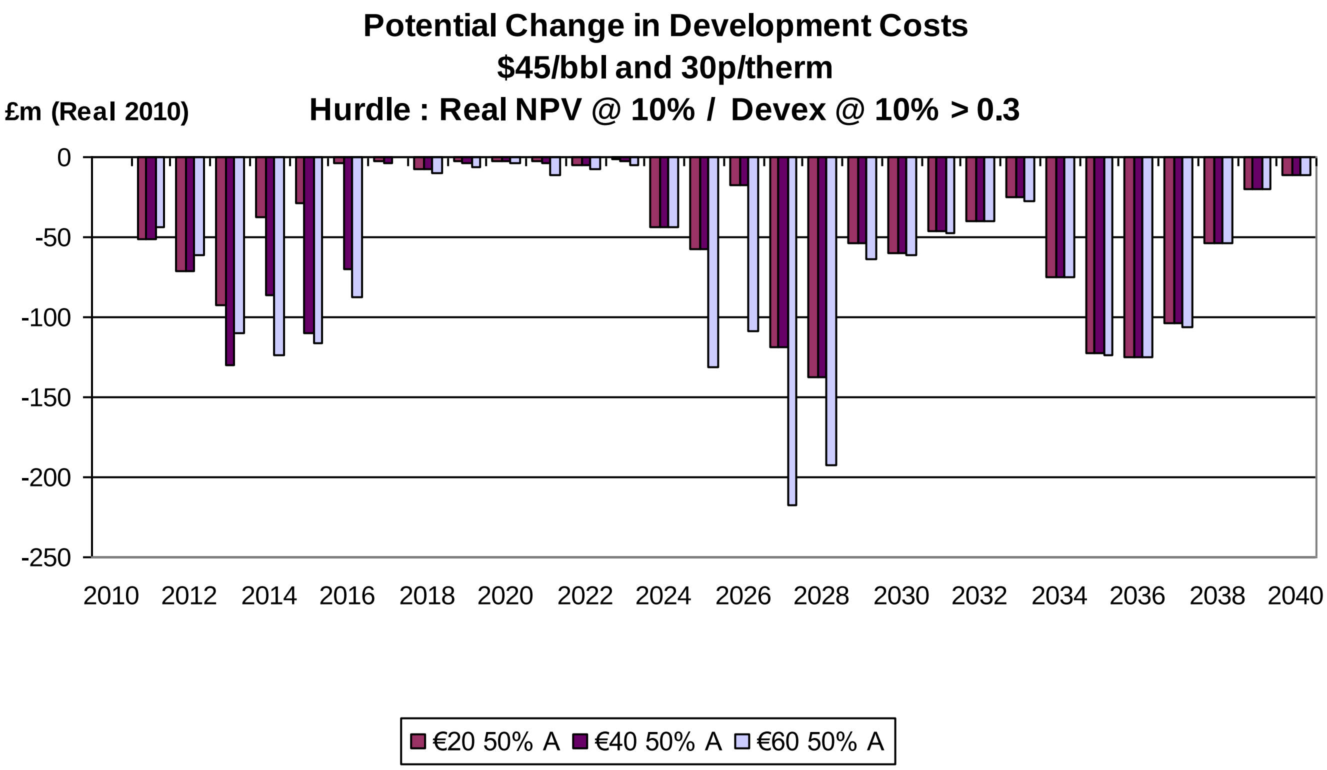
(ii) Changes in Development Expenditures

Chart 37



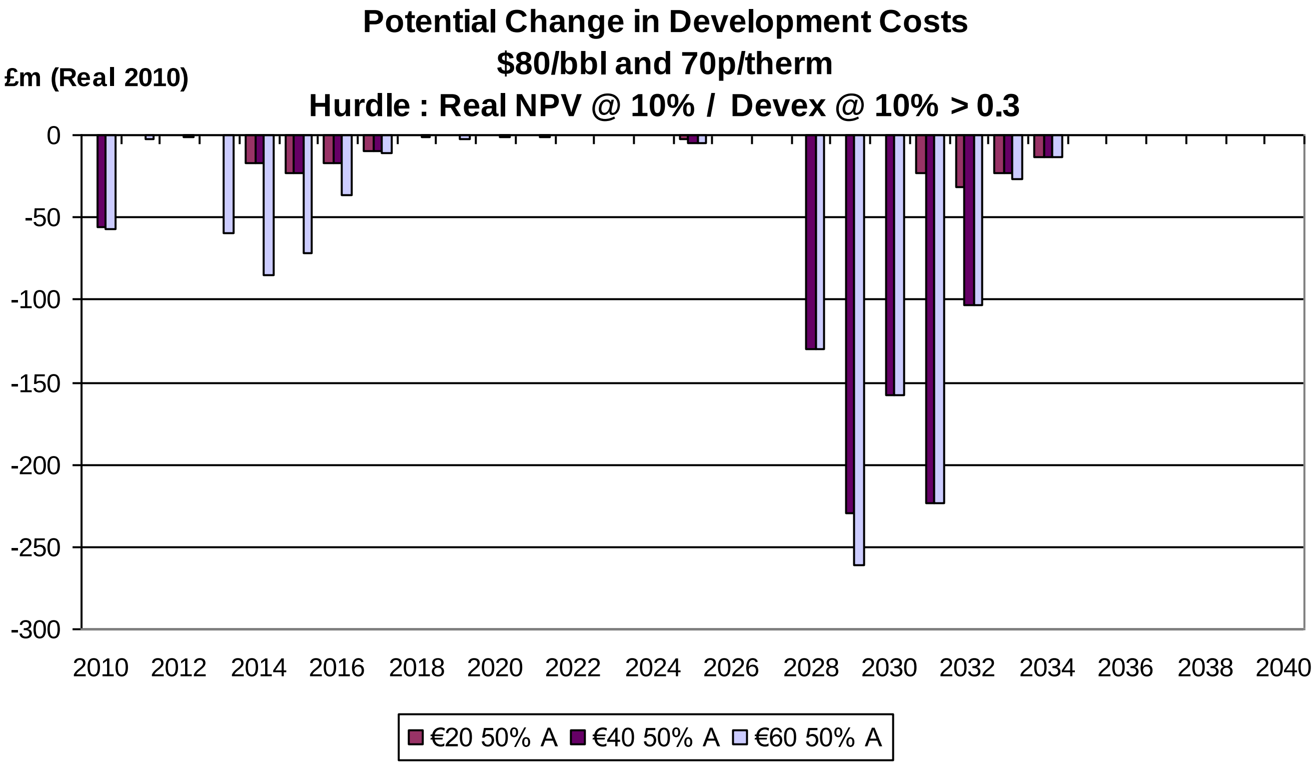
From Chart 37 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £509m by 2020, £1,032m by 2030, and £2,541m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £1,230m by 2020, £1,980m by 2030, and £3,579m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £1,302m by 2020 as with the Full allowance case, £2,150m by 2030, and £4,141m by 2040.

Chart 38



From Chart 38 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £300m by 2020, £798m by 2030, and £1,419m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £535m by 2020, £1,033m by 2030, and £1,655m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £552m by 2020, £1,396m by 2030, and £2,026m by 2040.

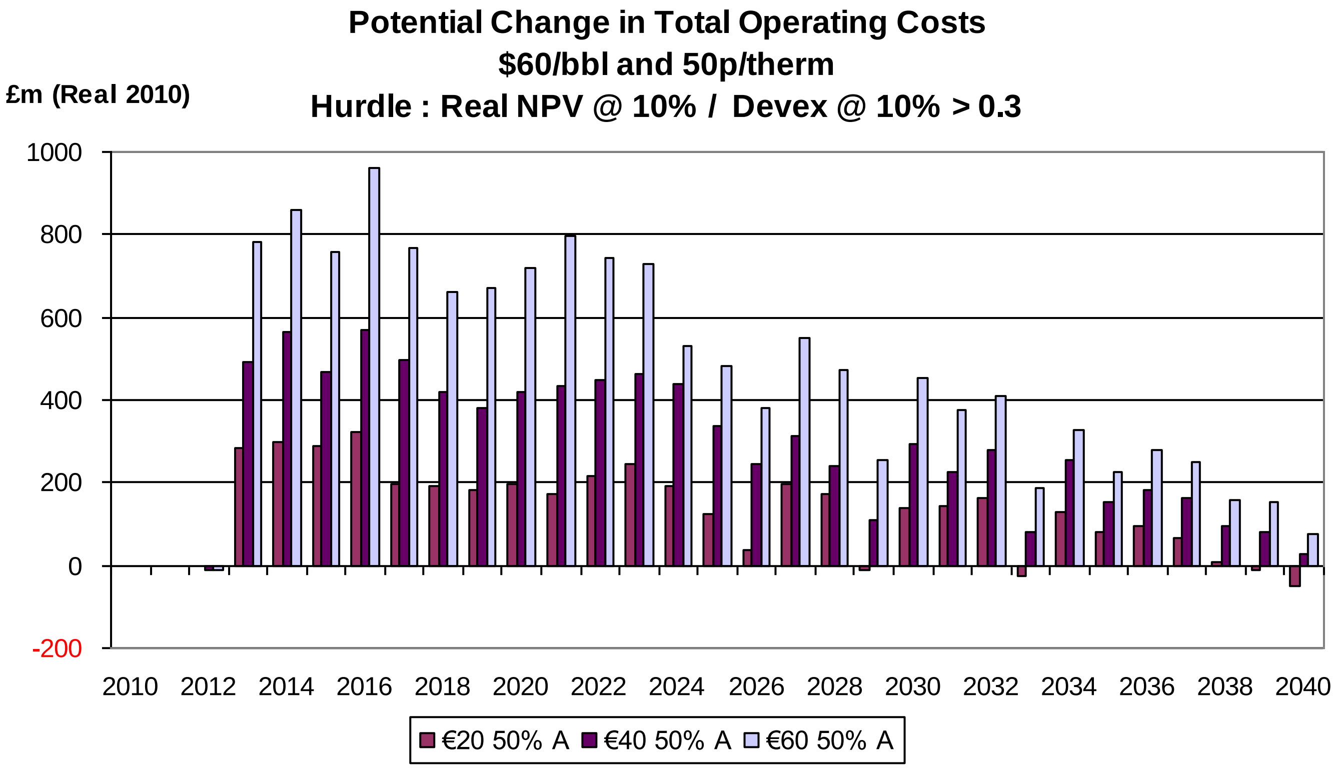
Chart 39



From Chart 39 it is seen that at the high price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £67m by 2020, £70m by 2030, and £160m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £123m by 2020, £645m by 2030, and £1,008m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £330m by 2020, £885m by 2030, and £1,252m by 2040.

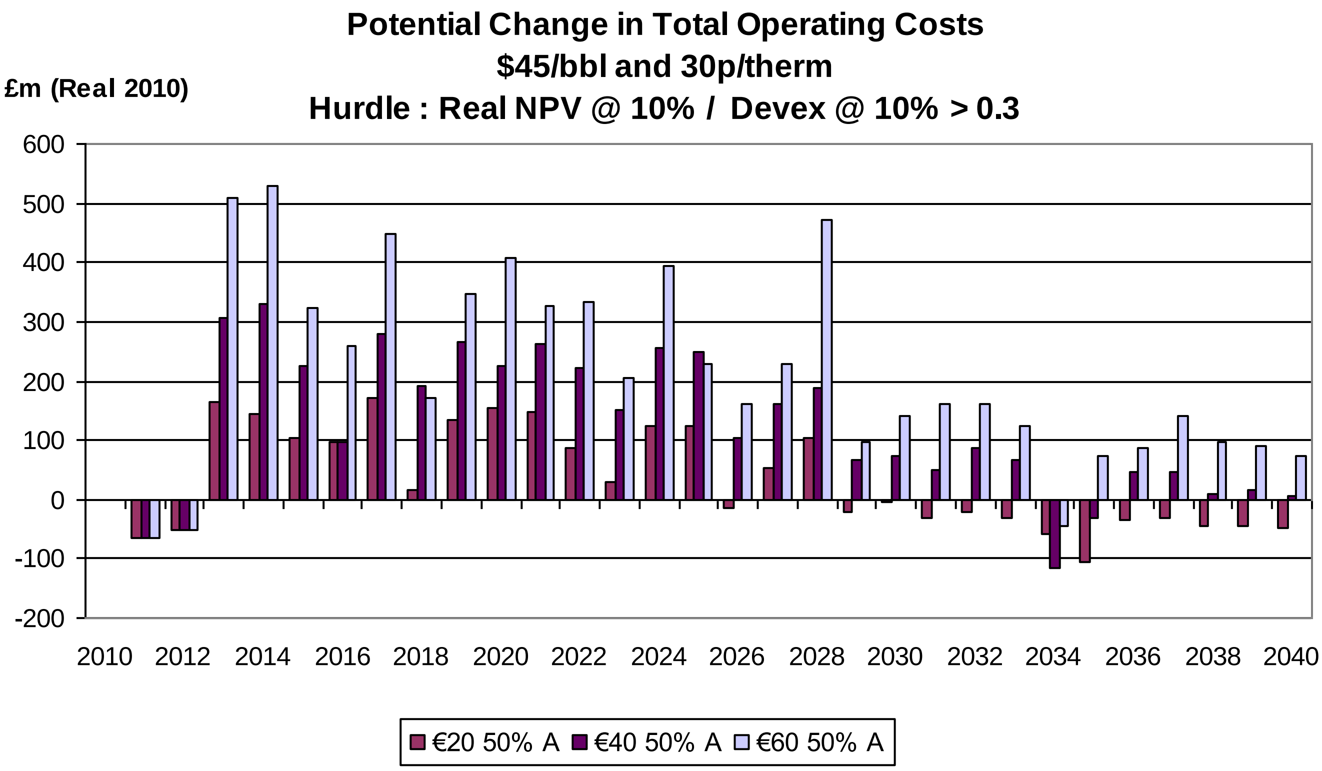
(iii) Changes in Total Operating Costs

Chart 40



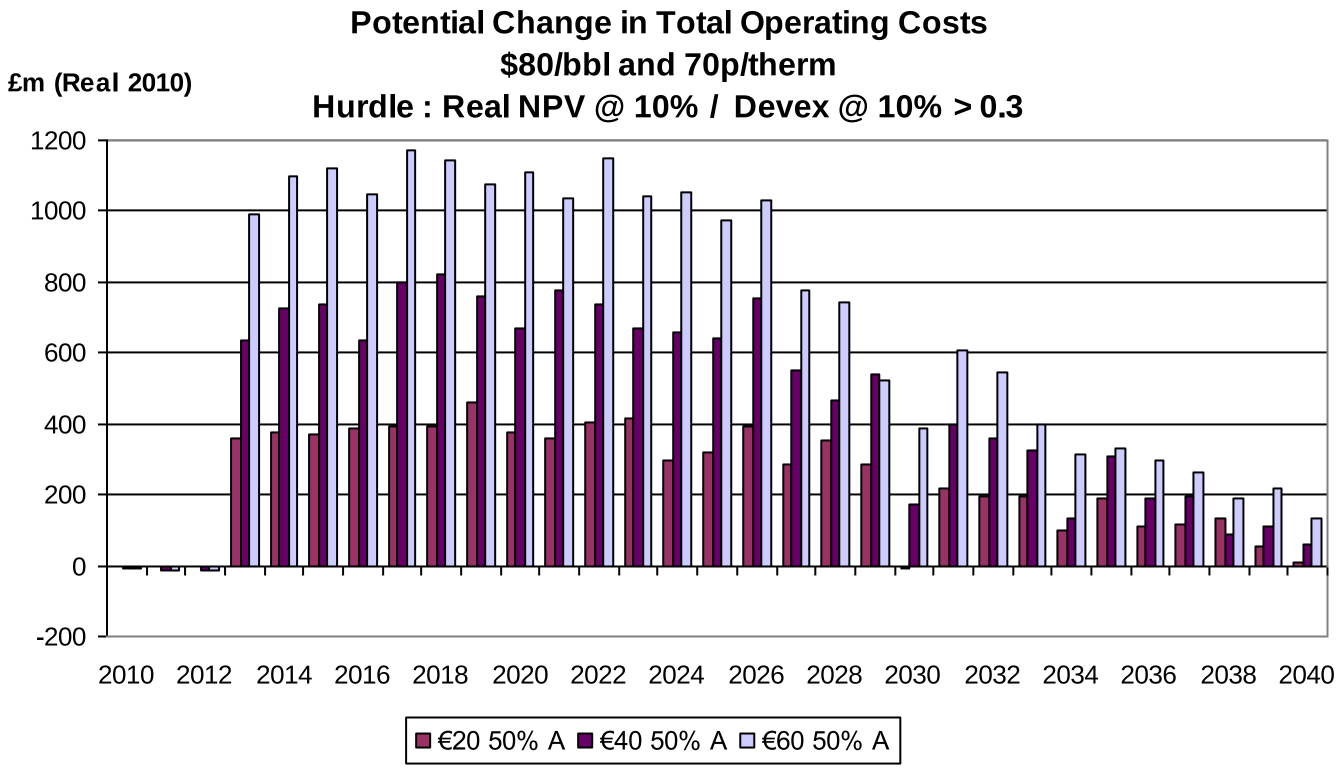
From Chart 40 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £199m in 2020. Cumulative spending on total operating costs could be increased by £1,966m by 2020, £3,450m by 2030, and £4,047m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £421m in 2020. Cumulative spending on total operating costs could be increased by £3,807m by 2020, £7,132m by 2030, and £8,678m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £719m in 2020. Cumulative spending on total operating costs could be increased by £6,167m by 2020, £11,567m by 2030, and £14,007m by 2040.

Chart 41



From Chart 41 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £154m in 2020. Cumulative spending on total operating costs could be increased by £866m by 2020, £1,502m by 2030, and £1,047m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £225m in 2020. Cumulative spending on total operating costs could be increased by £1,804m by 2020, £3,540m by 2030, and £3,727m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £409m in 2020. Cumulative spending on total operating costs could be increased by £2,882m by 2020, £5,467m by 2030, and £6,431m by 2040.

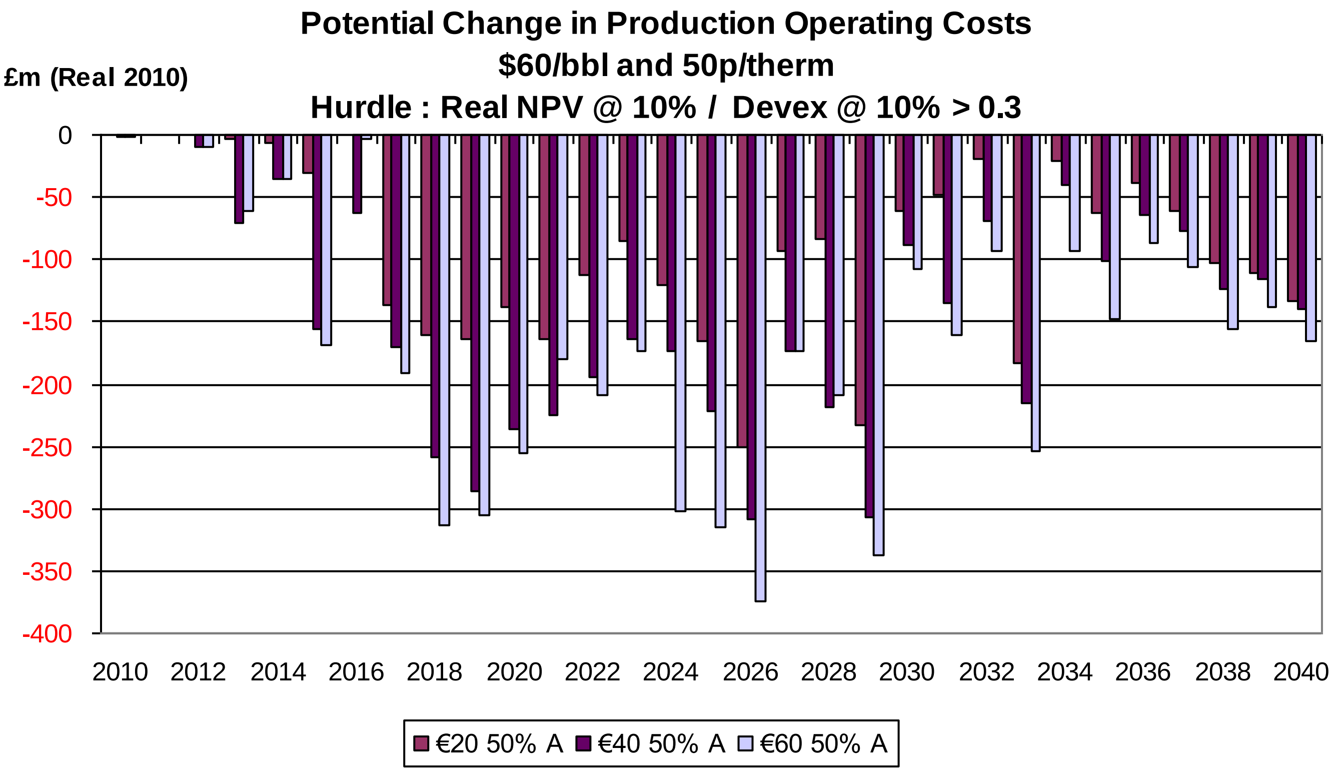
Chart 42



From Chart 42 it is seen that at the high price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £379m in 2020. Cumulative spending on total operating costs could be increased by £3,116m by 2020, £6,231m by 2030, and £7,557m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £672m in 2020. Cumulative spending on total operating costs could be increased by £5,756m by 2020, £11,719m by 2030, and £13,892m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £1,107m in 2020. Cumulative spending on total operating costs could be increased by £8,725m by 2020, £17,438m by 2030, and £20,724m by 2040.

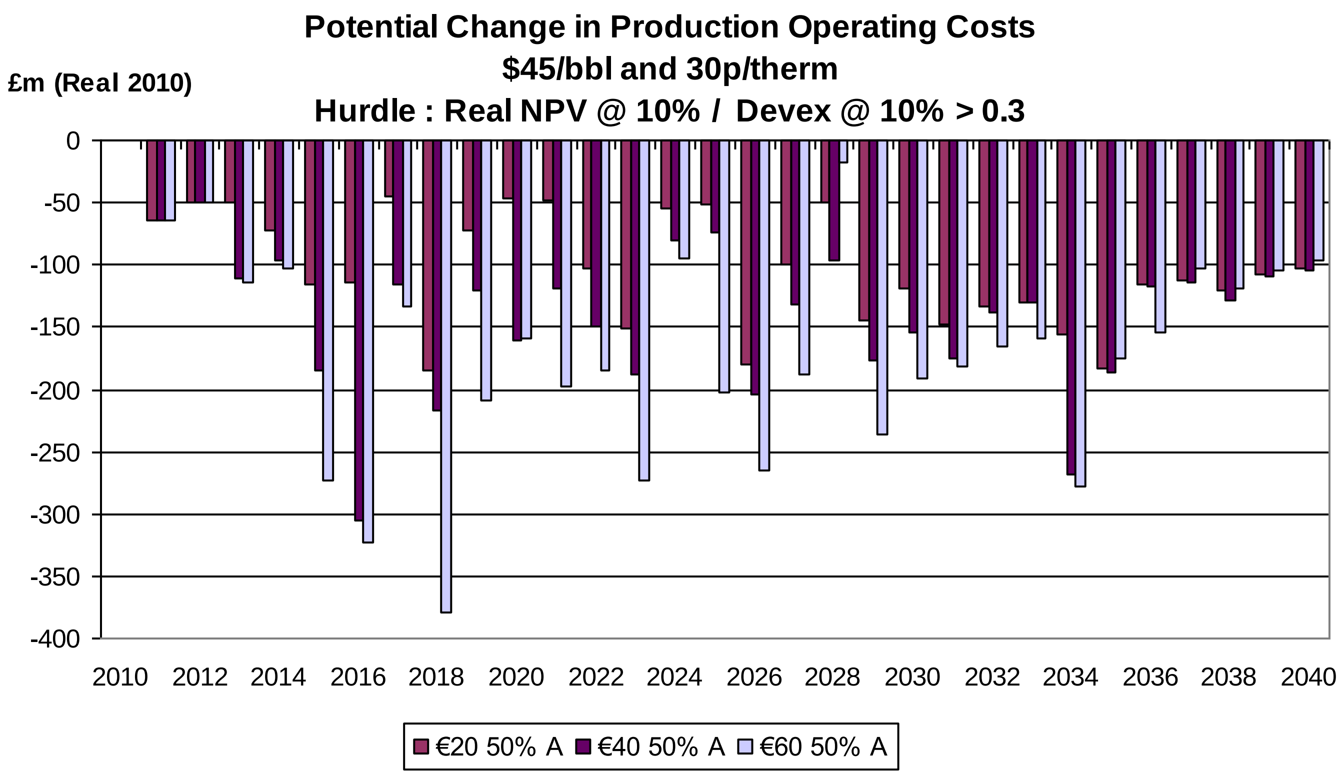
(iv)Changes in Production Operating Costs

Chart 43



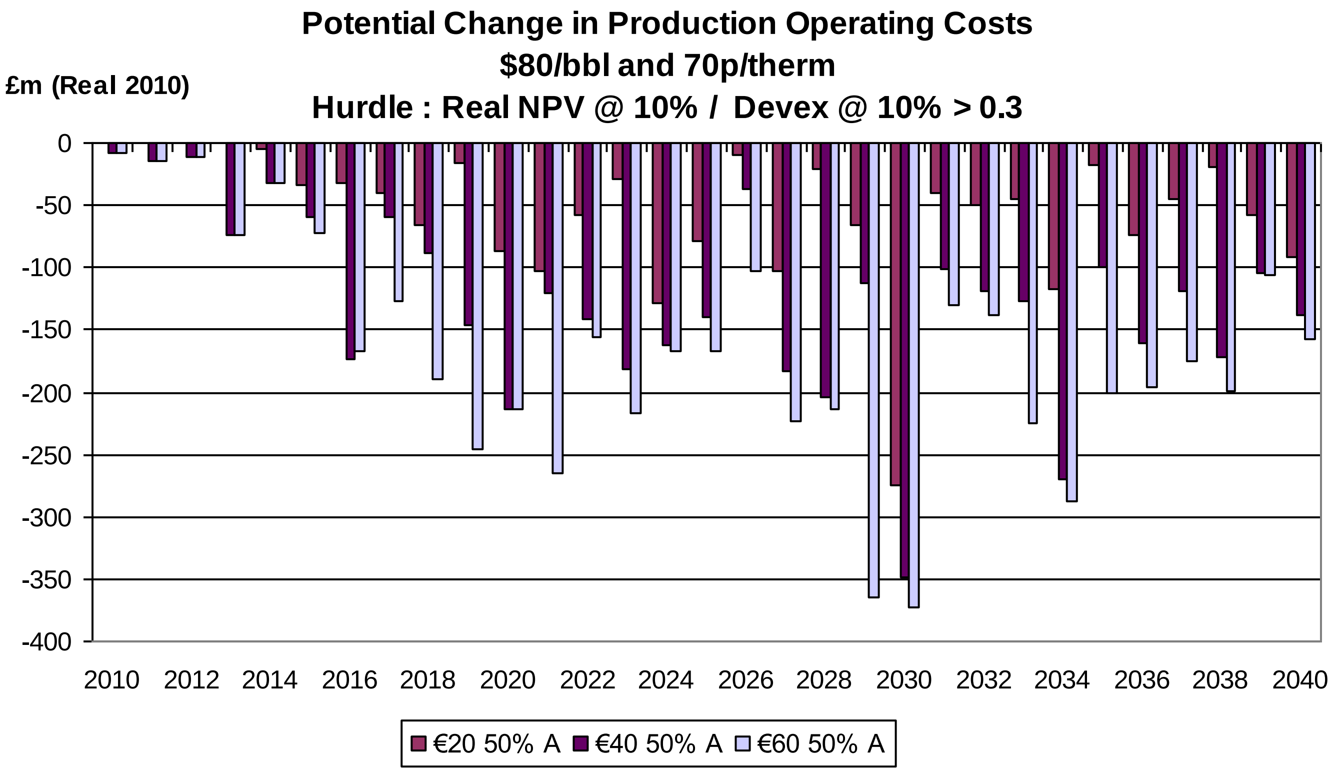
From Chart 43 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £164m in 2019. Cumulative spending on production operating costs could be reduced by £637m by 2020, £2,007m by 2030, and £2,786m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £286m in 2019. Cumulative spending on production operating costs could be reduced by £1,288m by 2020, £3,362m by 2030, and £4,442m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £305m in 2019. Cumulative spending on production operating costs could be reduced by £1,346m by 2020, £3,727m by 2030, and £5,128m by 2040.

Chart 44



From Chart 44 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £72m in 2019. Cumulative spending on production operating costs could be reduced by £812m by 2020, £1,813m by 2030, and £3,124m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £120m in 2019. Cumulative spending on production operating costs could be reduced by £1,620m by 2020, £3,115m by 2030, and £4,632m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £210m in 2019. Cumulative spending on production operating costs could be reduced by £1,807m by 2020, £3,657m by 2030, and £5,192m by 2040.

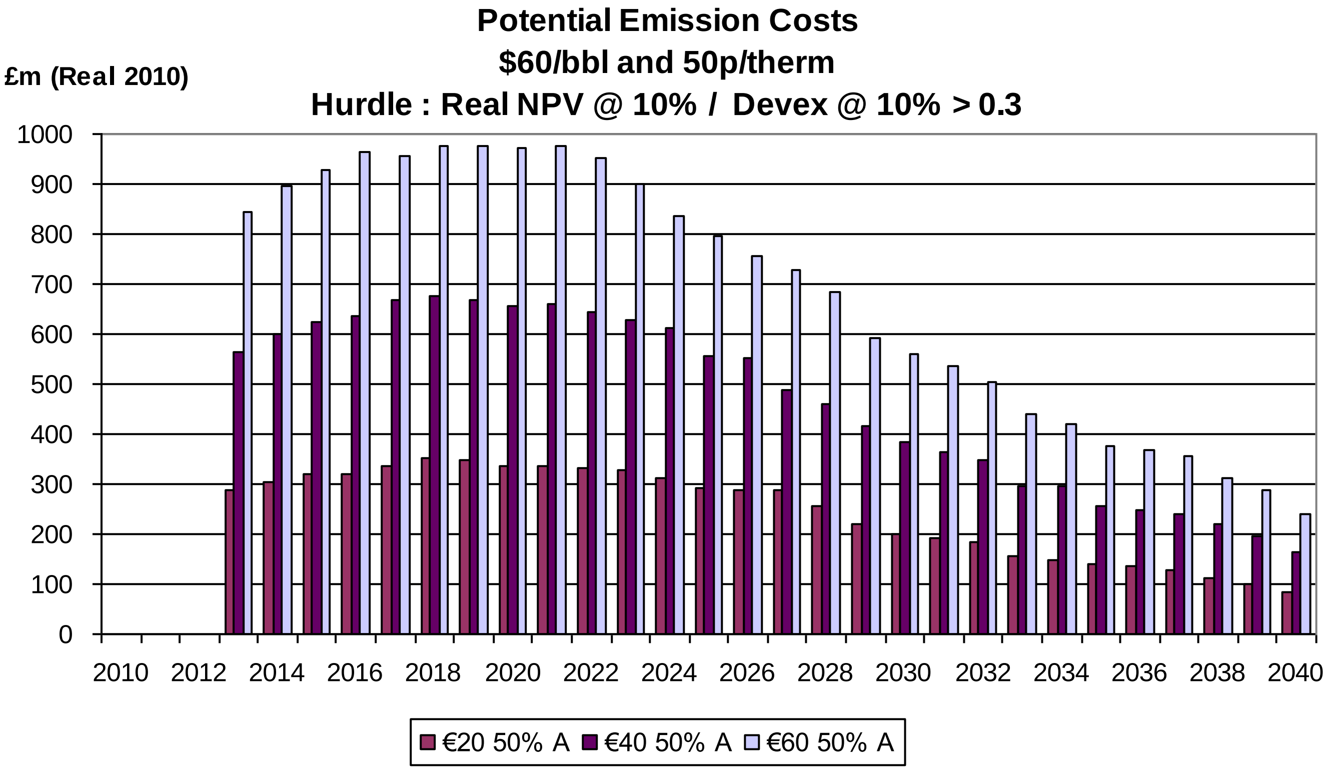
Chart 45



From Chart 45 it is seen that at the high price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £87m in 2020. Cumulative spending on production operating costs could be reduced by £281m by 2020, £1,150m by 2030, and £1,704m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £213m in 2020. Cumulative spending on production operating costs could be reduced by £882m by 2020, £2,517m by 2030, and £3,927m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £213m in 2020. Cumulative spending on production operating costs could be reduced by £1,156m by 2020, £3,402m by 2030, and £5,220m by 2040.

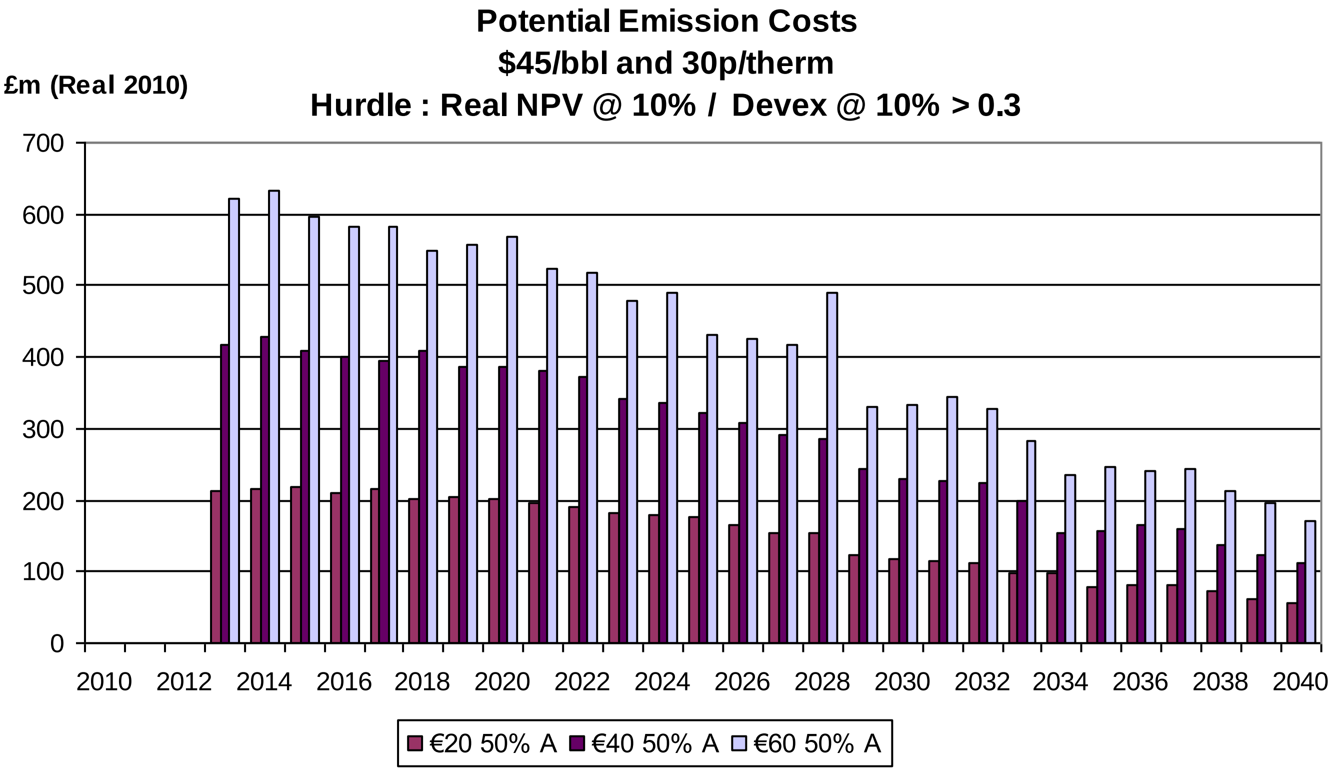
(v) Emission Costs

Chart 46



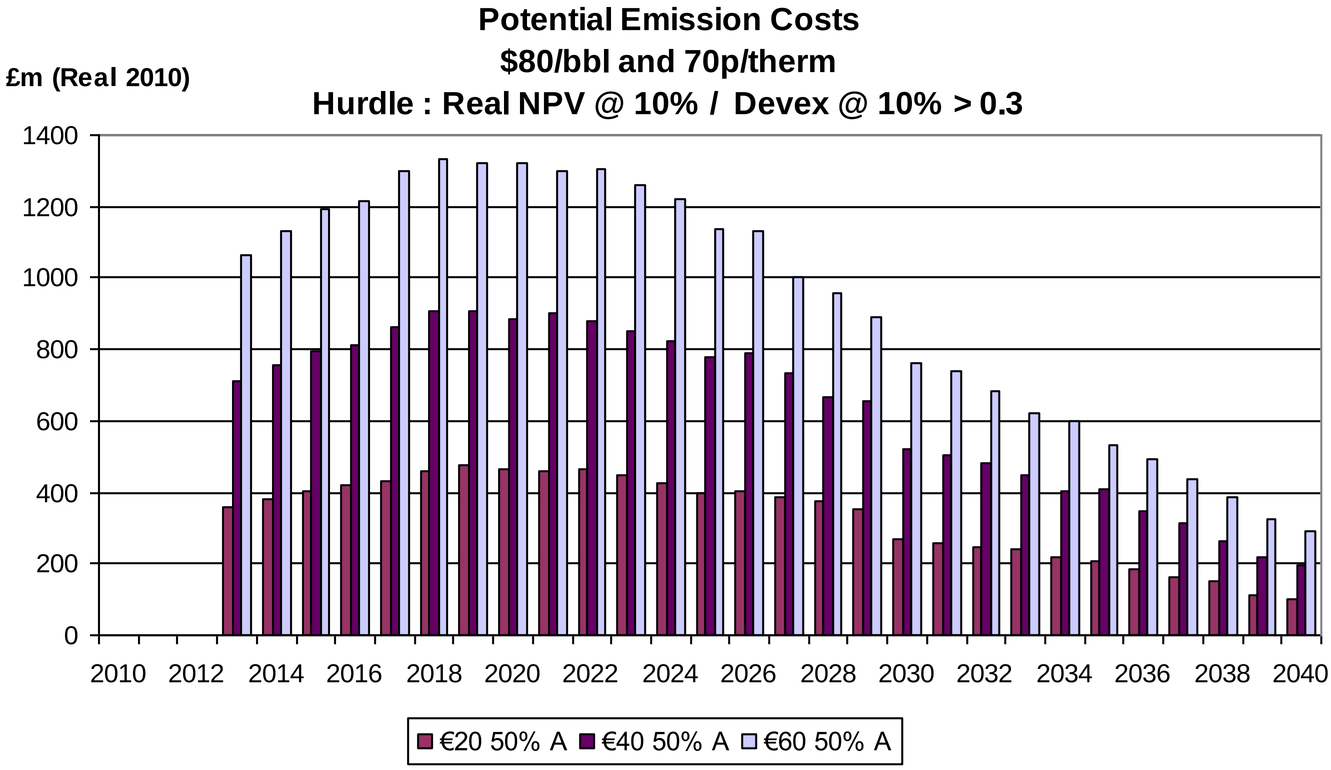
From Chart 46 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £337m in 2020. Cumulative spending on emissions could be £2,603m by 2020, £5,457m by 2030, and £6,832m by 2040. With a CO_2 price of €40/t emission costs could be £657m in 2020. Cumulative spending on emissions could be £5,095m by 2020, £10,495m by 2030, and £13,121m by 2040. With a CO_2 price of €60/t emission costs could be £974m in 2020. Cumulative spending on emissions could be £7,513m by 2020, £15,295m by 2030, and £19,135m by 2040.

Chart 47



From Chart 47 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £200m in 2020. Cumulative spending on emissions could be £1,678m by 2020, £3,315m by 2030 and £4,171m by 2040. With a CO_2 price of €40/t emission costs could be £386m in 2020. Cumulative spending on emissions could be £3,229m by 2020, £6,337m by 2030 and £7,994m by 2040. With a CO_2 price of €60/t emission costs could be £568m in 2020. Cumulative spending on emissions could be £4,689m by 2020, £9,124m by 2030 and £11,622m by 2040.

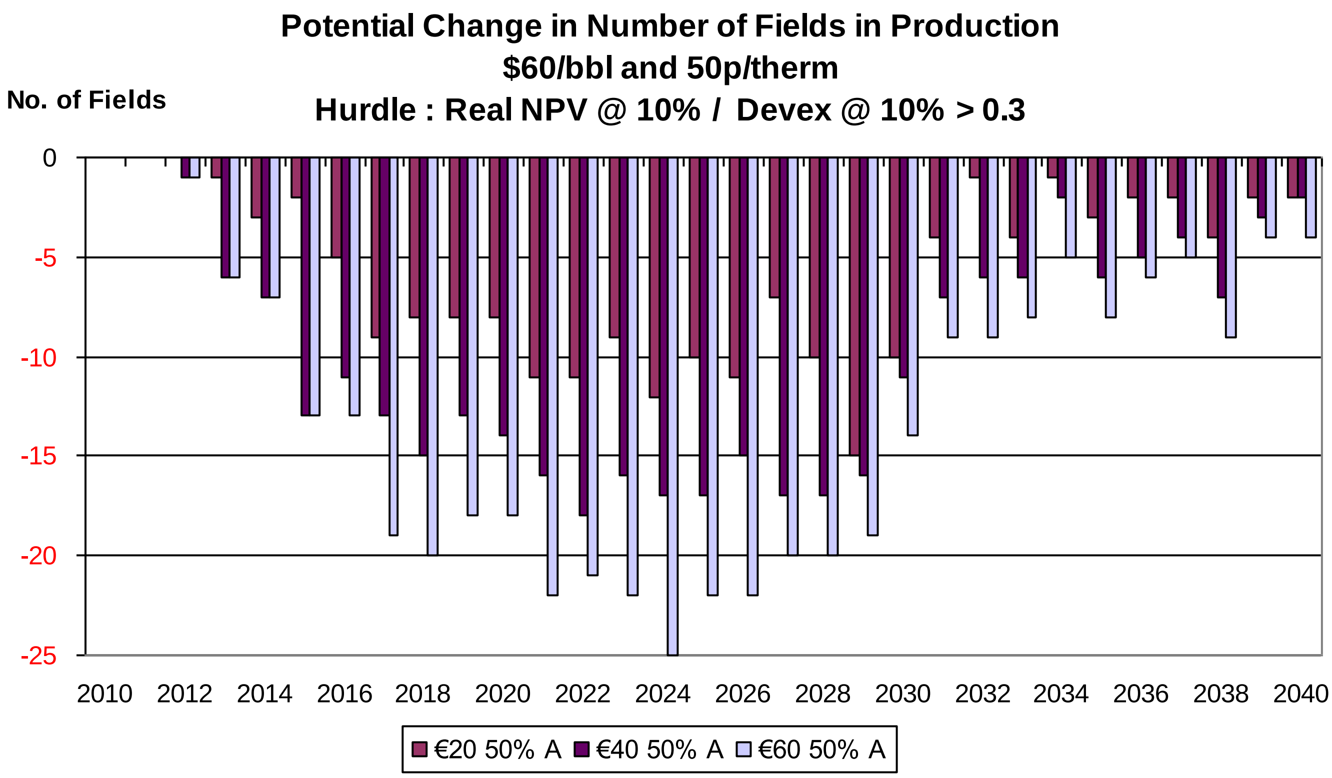
Chart 48



From Chart 48 it is seen that at the high price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £466m in 2020. Cumulative spending on emissions could be £3,397m by 2020, £7,382m by 2030, and £9,261m by 2040. With a CO_2 price of €40/t emission costs could be £886m in 2020. Cumulative spending on emissions could be £6,638m by 2020, £14,236m by 2030, and £17,819m by 2040. With a CO_2 price of €60/t emission costs could be £1,321m in 2020. Cumulative spending on emissions could be £9,880m by 2020, £20,841m by 2030, and £25,944m by 2040.

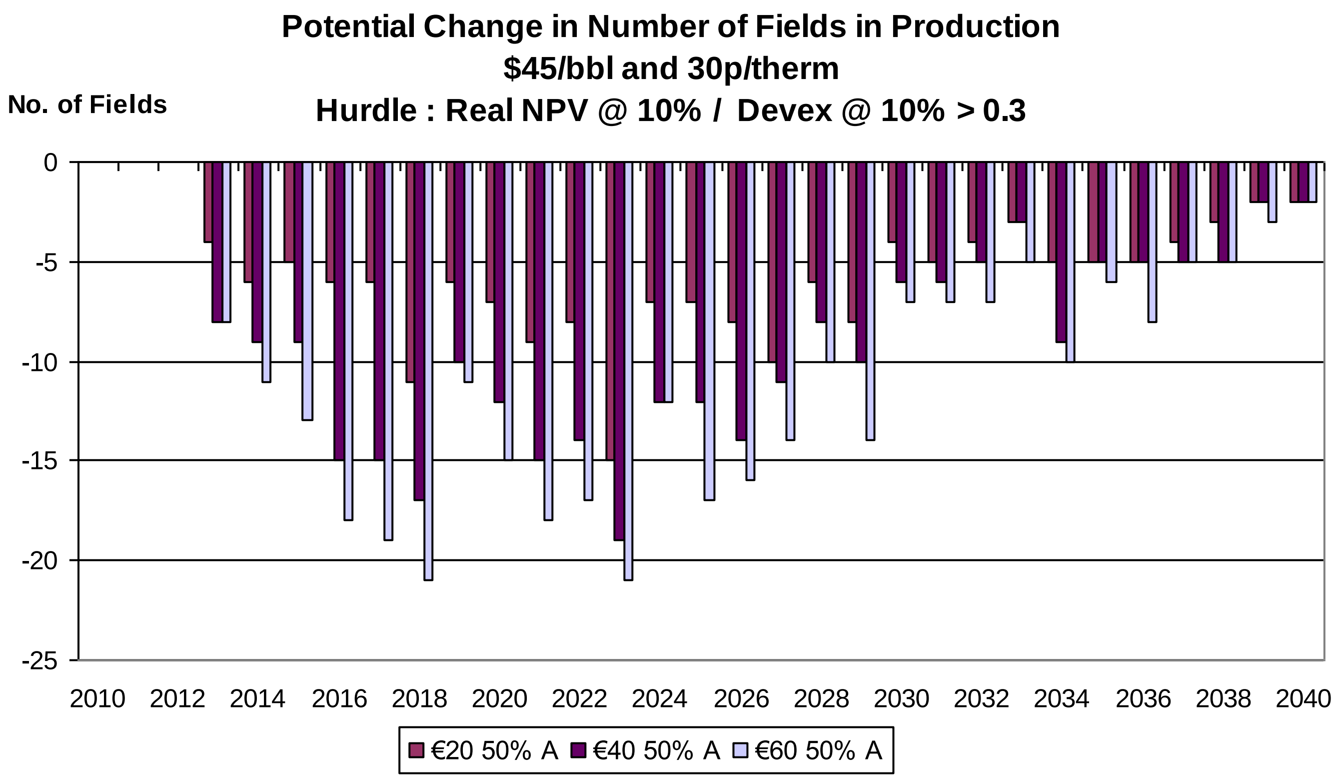
(vi)Changes in Numbers of Fields in Production

Chart 49



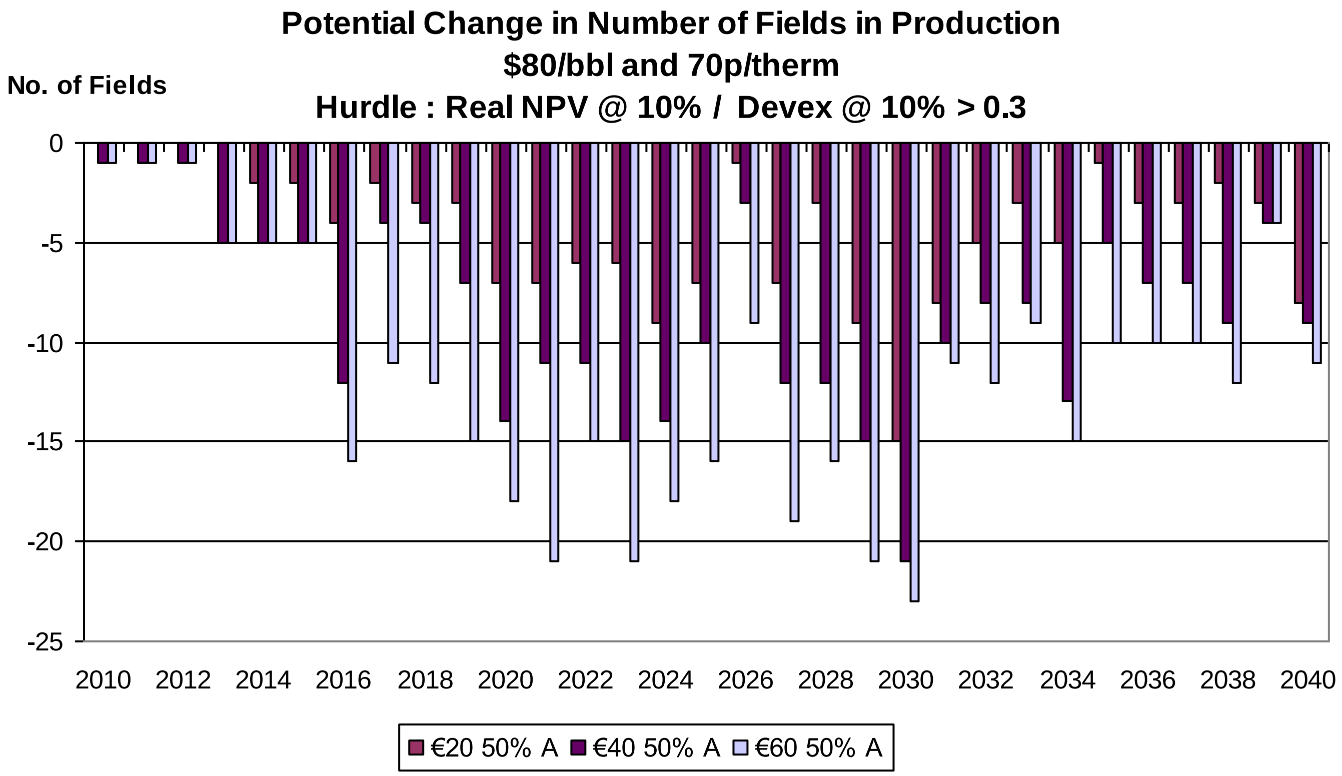
From Chart 49 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 15 fewer fields in production in 2029. With a CO_2 price of €40/t there may be 18 fewer fields in production in 2022. With a CO_2 price of €60/t there may be 25 fewer fields in production in 2024.

Chart 50



From Chart 50 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 15 fewer fields in production in 2023. With a CO_2 price of €40/t there may be 19 fewer fields in production in 2023. With a CO_2 price of €60/t there may be 18 fewer fields in production in 2021.

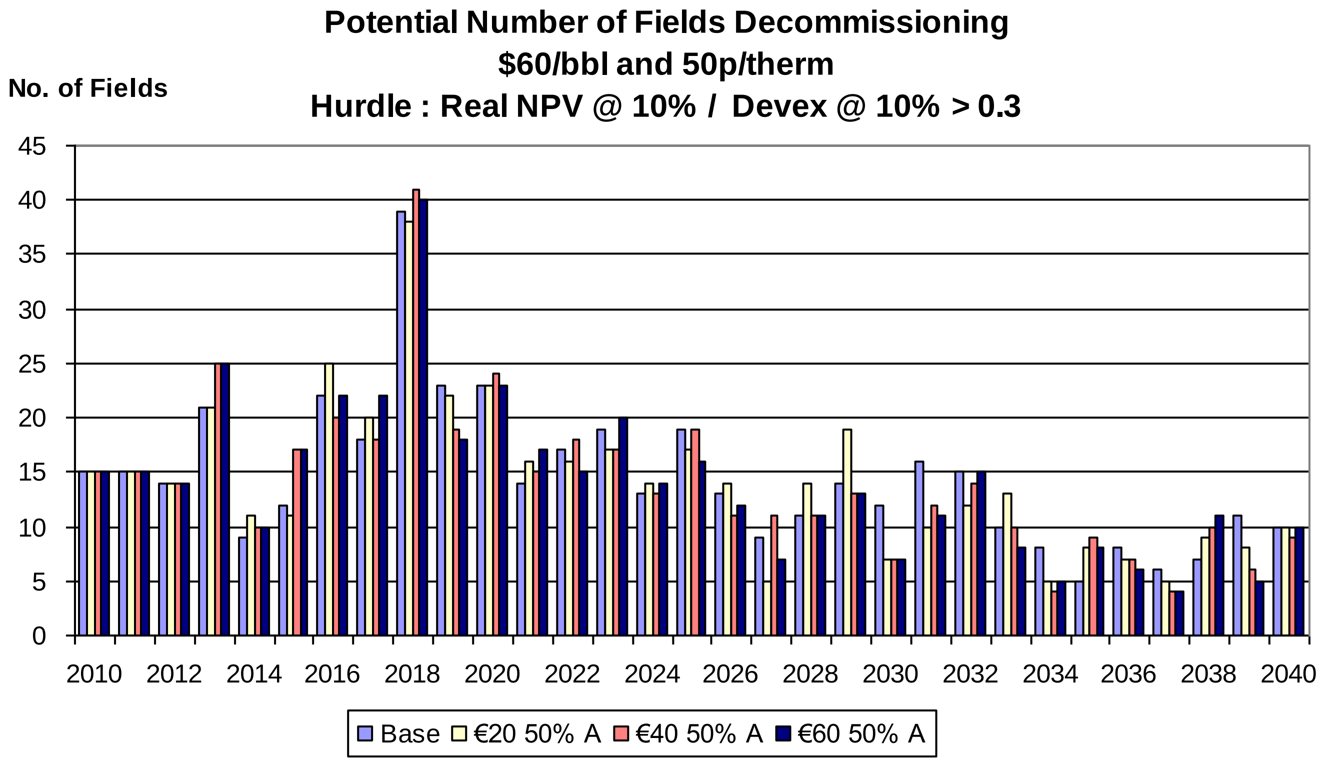
Chart 51



From Chart 51 it is seen that at the high price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 9 fewer fields in production in 2024 and 15 fewer in 2030. With a CO_2 price of €40/t there may be 14 fewer fields in production in 2020 and 21 fewer in 2030. With a CO_2 price of €60/t there may be 21 fewer fields in production in 2021 and 23 fewer in 2030.

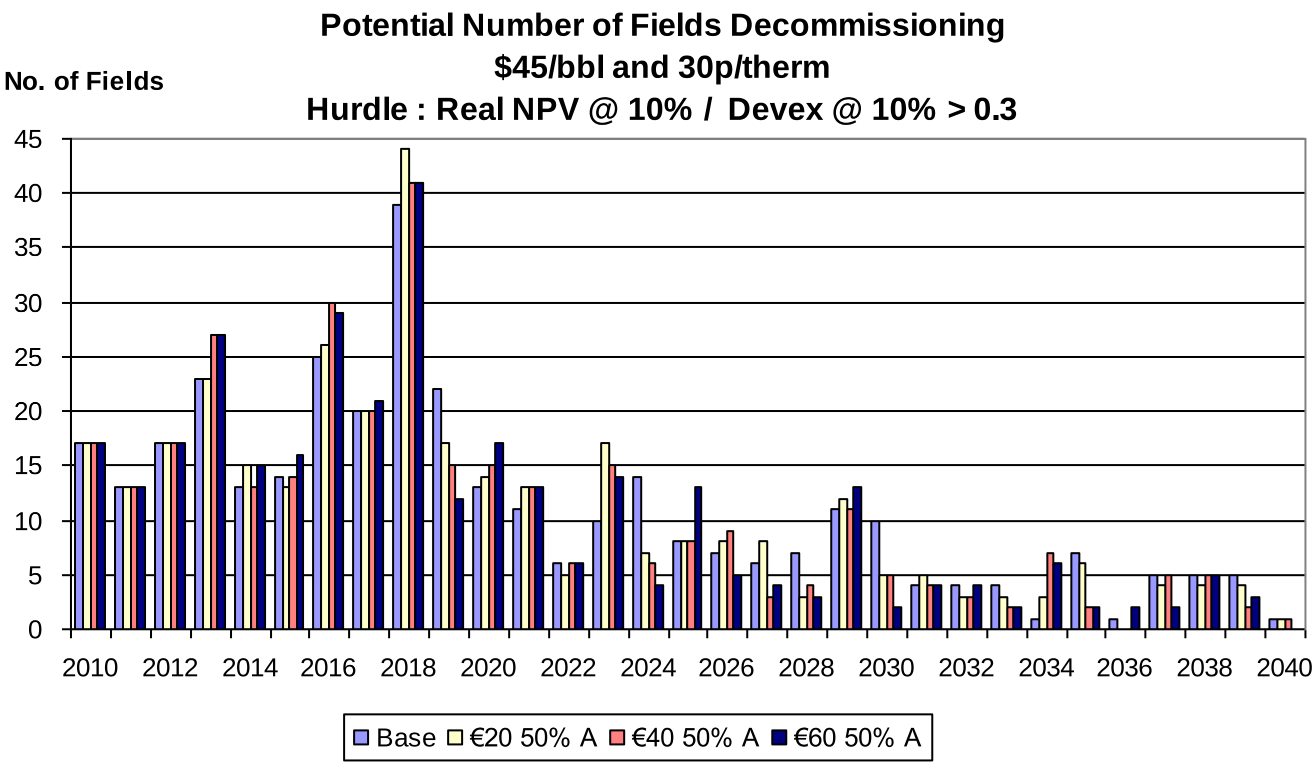
(vii) Numbers of Fields Decommissioning

Chart 52



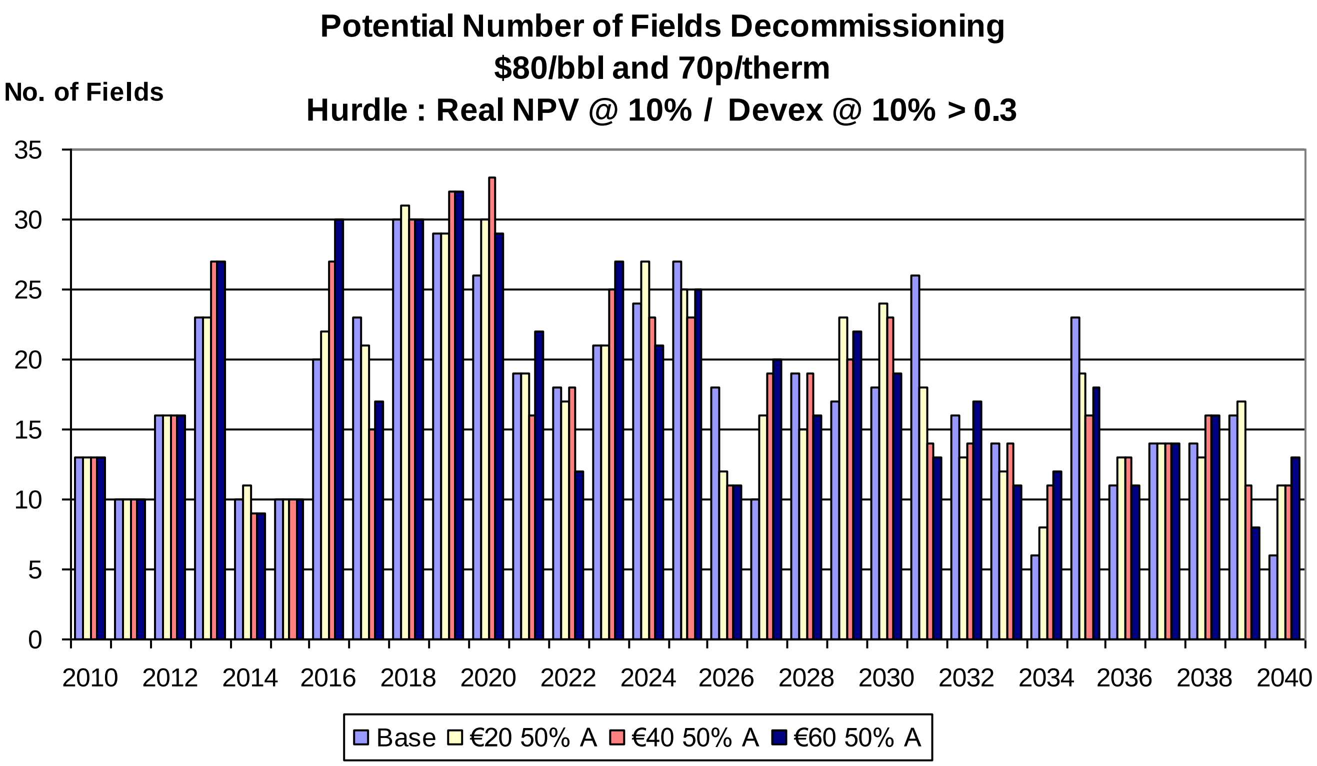
From Chart 52 it is seen that at the medium price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 4 extra fields which decommission in 2020 and 2 extra in 2030. However, there are also 8 fewer fields in production in 2020, 10 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €40/t there may be 7 extra fields decommissioning in 2020 and 1 extra in 2030. However, there are also 14 fewer fields in production in 2020, 11 fewer in 2030 and 2 fewer in 2040. With a CO_2 price of €60/t there may be 10 extra fields decommissioning in 2020 and 1 extra in 2030. However, there are also 18 fewer fields in production in 2020, 14 fewer in 2030, and 4 fewer in 2040.

Chart 53



From Chart 53 it is seen that at the low price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 3 extra fields decommissioning in 2020. However, there are 7 fewer fields in production in 2020, 4 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €40/t there may be 6 extra fields decommissioning in 2020. However, there are 12 fewer fields in production in 2020, 6 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €60/t there may be 9 extra fields decommissioning in 2020. However, there are 15 fewer fields in production in 2020, 7 fewer in 2030, and 2 fewer in 2040.

Chart 54

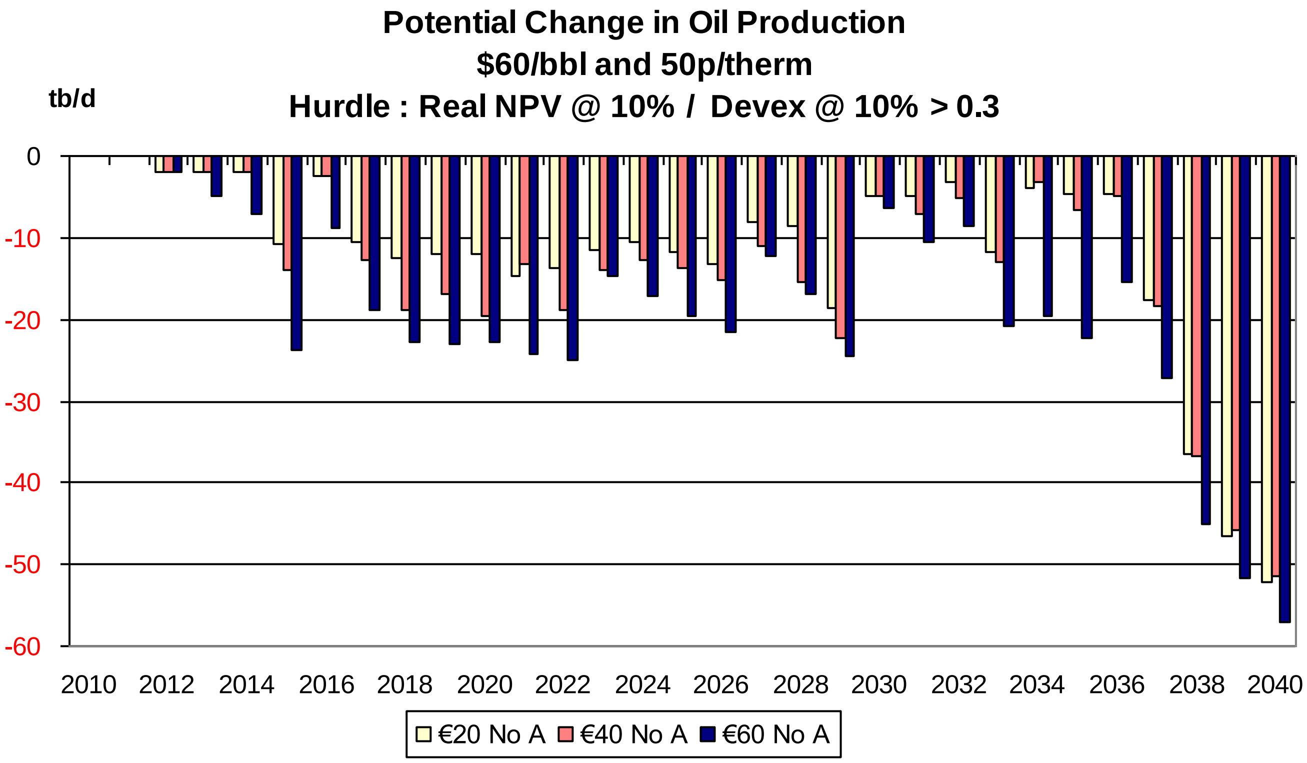


From Chart 54 it is seen that at the High price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 6 extra fields decommissioning in 2020, 14 extra in 2030 and 6 in 2040. However, there are 7 fewer fields in production in 2020, 15 fewer in 2030, and 8 fewer in 2040. With a CO_2 price of €40/t there may be 12 extra fields decommissioning in 2020, 18 extra in 2030 and 6 in 2040. However, there are 14 fewer fields in production in 2020, 21 fewer in 2030, and 9 fewer in 2040. With a CO_2 price of €60/t there may be 13 extra fields decommissioning in 2020, 17 extra in 2030 and 4 in 2040. However, there are 18 fewer fields in production in 2020, 23 fewer in 2030, and 11 fewer in 2040.

c. No Free Allowances

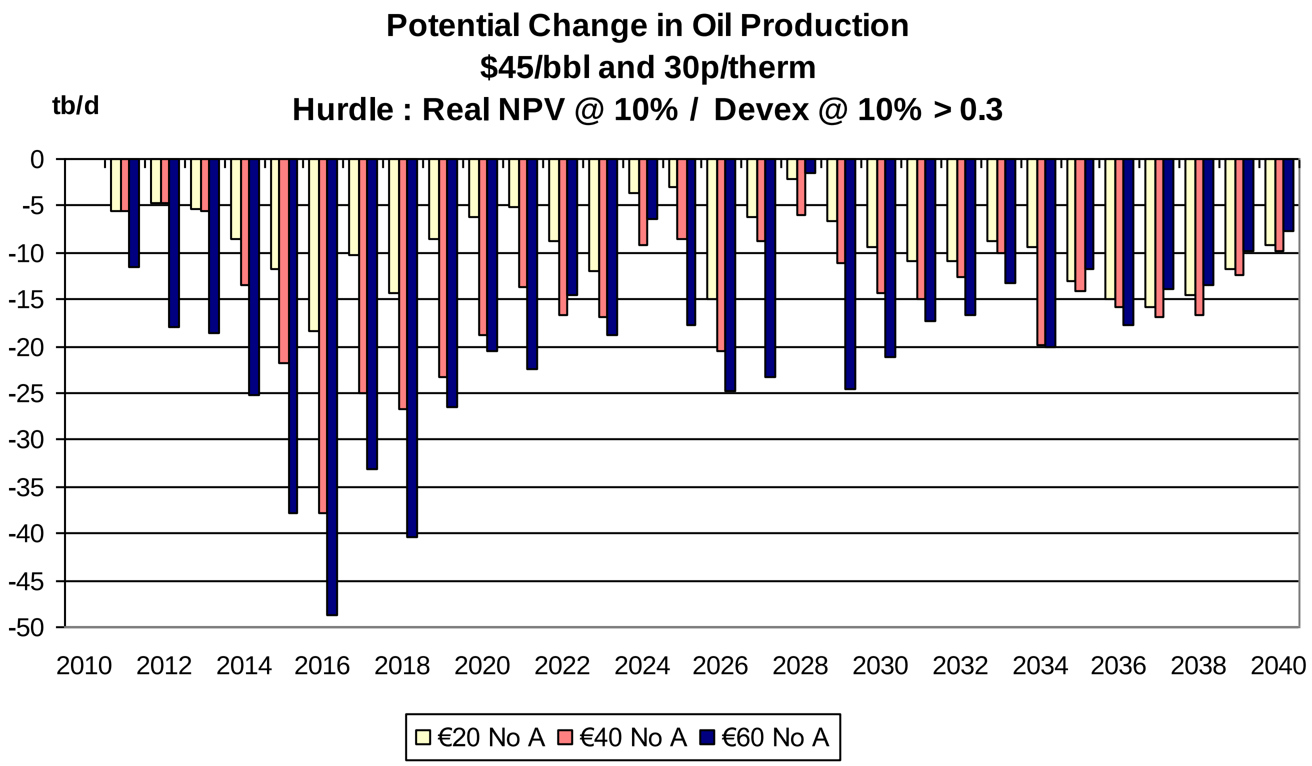
(i) Changes in Production

Chart 55



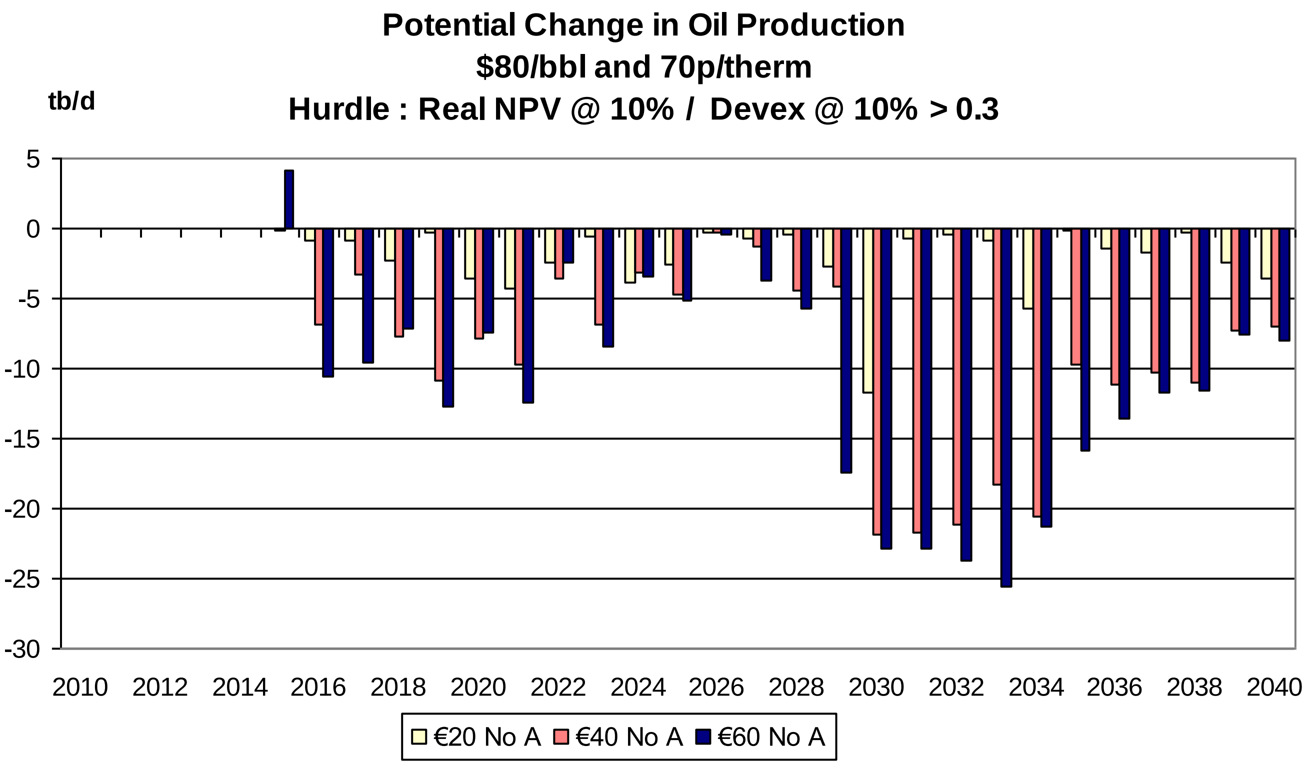
From Chart 55 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 13tb/d in 2026, 19tb/d in 2029, and 52tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 15tb/d in 2021, 19tb/d in 2029, and 52tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 23tb/d in 2020, 24tb/d in 2029, and 57tb/d in 2040.

Chart 56



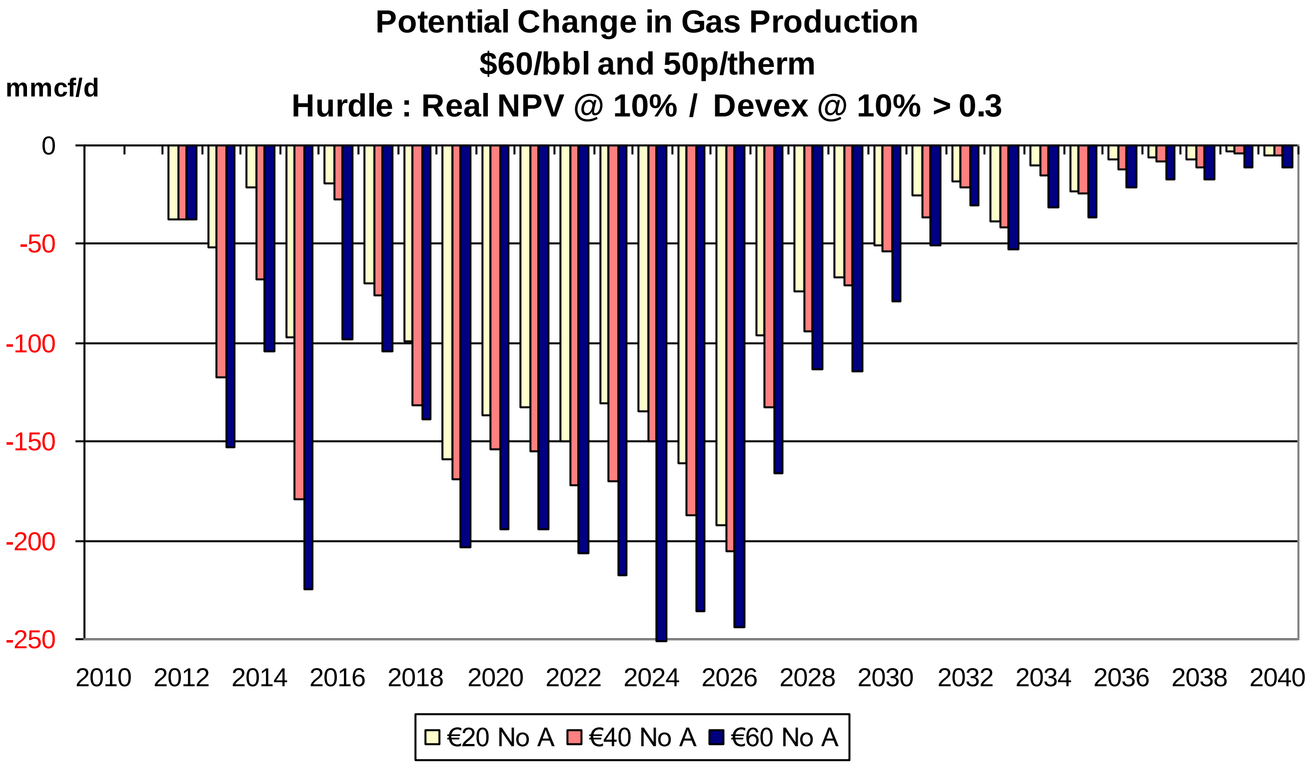
From Chart 56 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 18tb/d in 2016, 11tb/d in 2031, and 9tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 38tb/d in 2016, 14tb/d in 2030, and 10tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 49tb/d in 2016, 25tb/d in 2029, and 8tb/d in 2040.

Chart 57



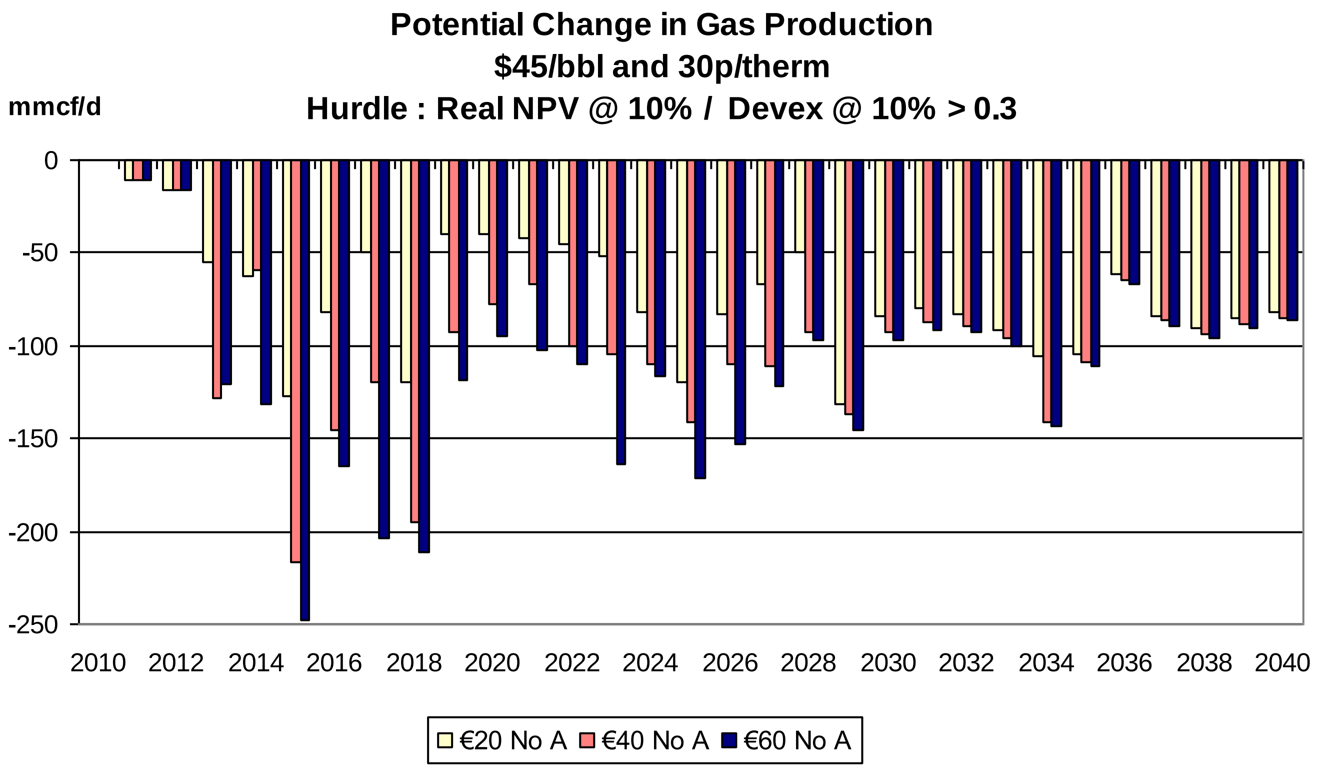
From Chart 57 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily oil production could be reduced by 12tb/d in 2030, and 4tb/d in 2040. With a CO_2 price of €40/t oil production could be reduced by 11tb/d in 2019, 122b/d in 2030, and 2031 and 7tb/d in 2040. With a CO_2 price of €60/t oil production could be reduced by 13tb/d in 2019, 23tb/d in 2030 and 2031, and 8tb/d in 2040.

Chart 58



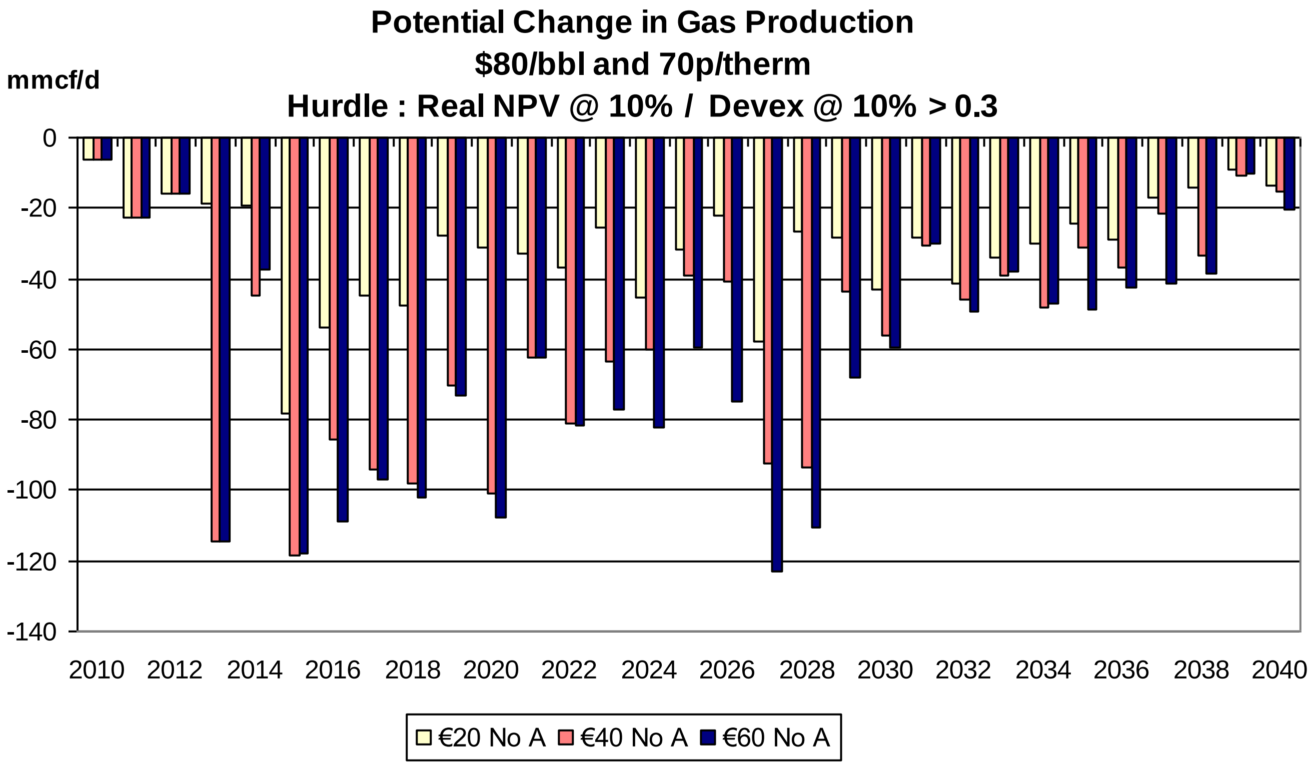
From Chart 58 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 159mmcf/d in 2019 and 192mmcf/d in 2026. With a CO_2 price of €40/t gas production could be reduced by 169mmcf/d in 2019 and 206mmcf/d in 2026. With a CO_2 price of €60/t gas production could be reduced by 1203mmcf/d in 2019 and 244mmcf/d in 2026.

Chart 59



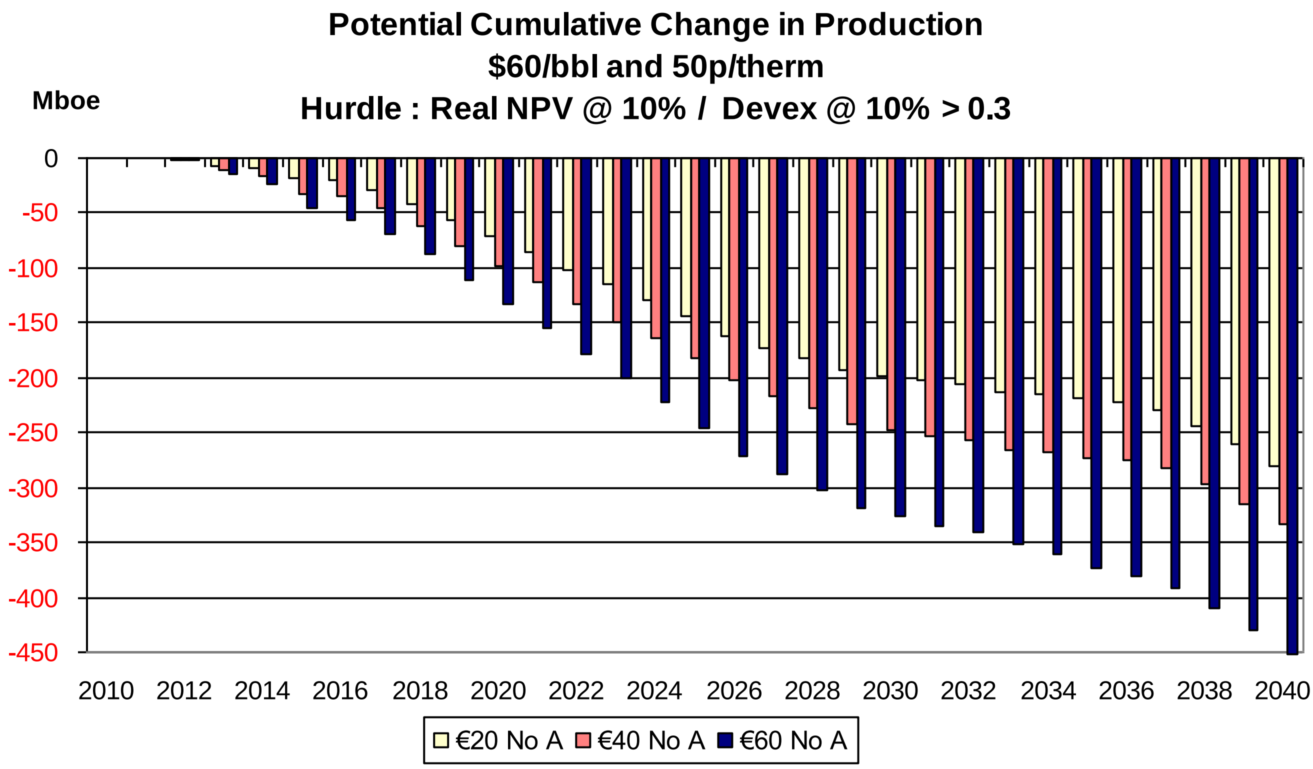
From Chart 59 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by 127mmcf/d in 2015, and 131mmcf/d in 2029. With a CO_2 price of €40/t gas production could be reduced by 216mmcf/d in 2015 and 137mmcf/d in 2029. With a CO_2 price of €60/t gas production could be reduced by 248mmcf/d in 2015, and 145mmcf/d in 2029.

Chart 60



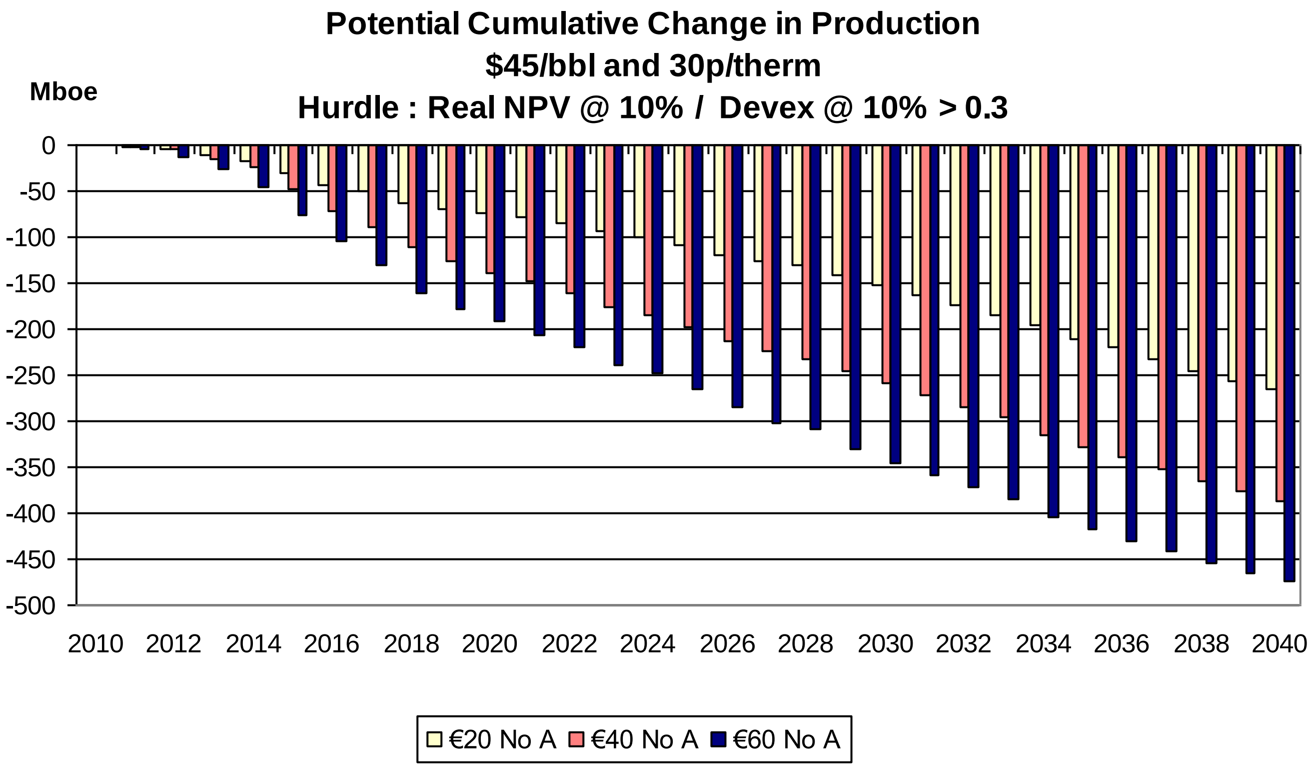
From Chart 60 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily gas production could be reduced by mmcf/d in 2022, and 43mmcf/d in 2030. With a CO_2 price of €40/t gas production could be reduced by 101mmcf/d in 2020, and 56mmcf/d in 2030. With a CO_2 price of €60/t gas production could be reduced by 108mmcf/d in 2020, and 123mmcf/d in 2027.

Chart 61



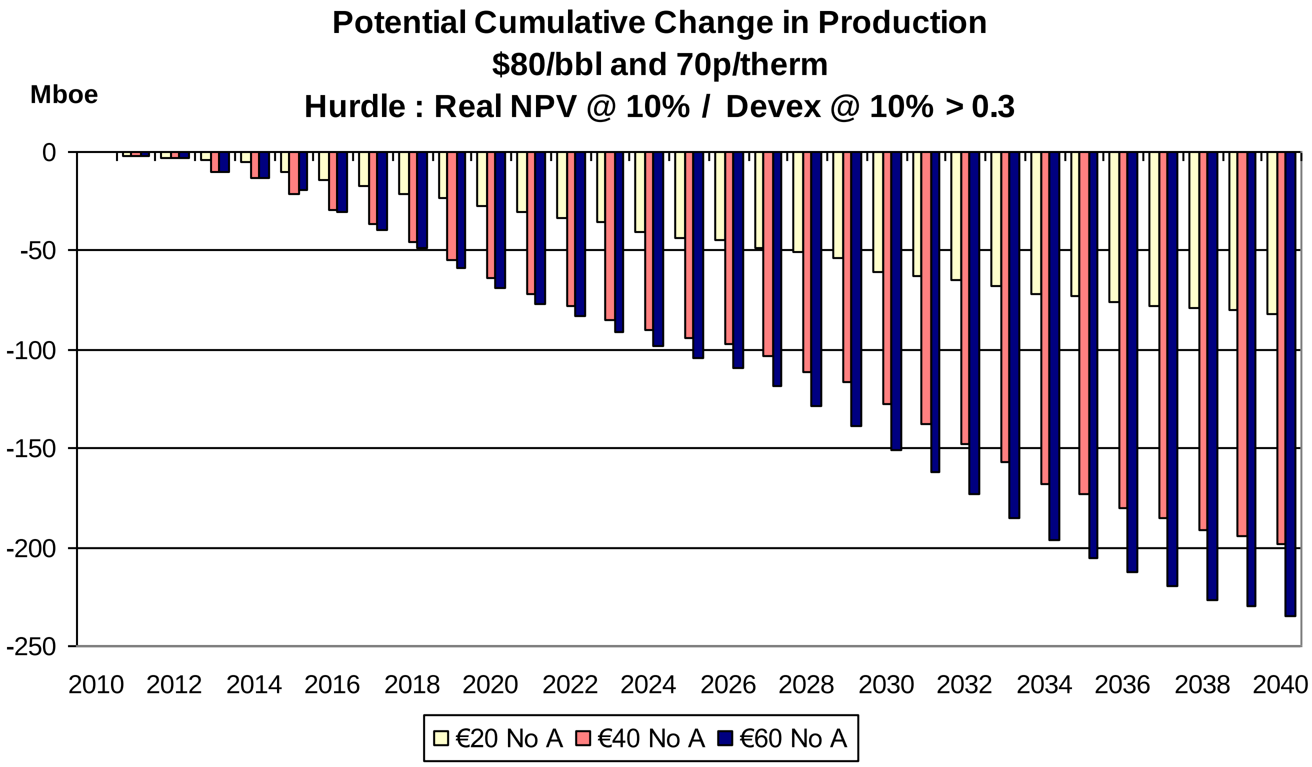
From Chart 61 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative total hydrocarbon production could be reduced by 71mboe in 2020 (38mboe from sanctioned fields and incremental investments, 13mboe from the Probable fields, 4mboe from Possible fields and 16mboe from the technical reserves fields), 199mboe by 2030 (85mboe from sanctioned fields and incremental investments, 21mboe from the Probable fields, 6mboe from Possible fields and 86mboe from the technical reserves fields), and 280mboe by 2040(109mboe from sanctioned fields and incremental investments, 21mboe from the Probable fields, 6mboe from Possible fields and 144mboe from the technical reserves fields). With a CO_2 price of €40/t cumulative production could be reduced by 97mboe in 2020 (61mboe from sanctioned fields and incremental investments, 13mboe from the Probable fields, 4mboe from Possible fields and 19mboe from the technical reserves fields), 248mboe by 2030 (117mboe from sanctioned fields and incremental investments, 22mboe from the Probable fields, 10mboe from Possible fields and 100mboe from the technical reserves fields), and 334mboe by 2040 (141mboe from sanctioned fields and incremental investments, 22mboe from the Probable fields, 10mboe from Possible fields and 162mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative production could be reduced by 133mboe in 2020 (70mboe from sanctioned fields and incremental investments, 13mboe from the Probable fields, 16mboe from Possible fields and 33mboe from the technical reserves fields), 327mboe by 2030 (146mboe from sanctioned fields and incremental investments, 26mboe from the Probable fields, 27mboe from Possible fields and 128mboe from the technical reserves fields), and 451mboe by 2040 (176mboe from sanctioned fields and incremental investments, 26mboe from the Probable fields, 27mboe from Possible fields and 222mboe from the technical reserves fields).

Chart 62



From Chart 62 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative hydrocarbon production could be reduced by 74mboe in 2020 (47mboe from sanctioned fields and incremental investments and 27mboe from Possible fields), 152mboe by 2030 (93mboe from sanctioned fields and incremental investments, 39mboe from Possible fields and 20mboe from the technical reserves fields), and 266mboe by 2040 (170mboe from sanctioned fields and incremental investments, 39mboe from Possible fields and 57mboe from the technical reserves fields). With a CO_2 price of €40/t cumulative production could be reduced by 139mboe in 2020 (90mboe from sanctioned fields and incremental investments, 36mboe from Possible fields and 14mboe from the technical reserves fields), 259mboe by 2030 (174mboe from sanctioned fields and incremental investments, 49mboe from Possible fields and 36mboe from the technical reserves fields), and 387mboe by 2040 (264mboe from sanctioned fields and incremental investments, 50mboe from Possible fields and 74mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative production could be reduced by 192mboe in 2020 (109mboe from sanctioned fields and incremental investments, 3mboe from the Probable fields, 36mboe from Possible fields and 43mboe from the technical reserves fields), 345mboe by 2030 (204mboe from sanctioned fields and incremental investments, 3mboe from the Probable fields, 49mboe from Possible fields and 88mboe from the technical reserves fields), and 474mboe by 2040 (282mboe from sanctioned fields and incremental investments, 3mboe from the Probable fields, 50mboe from Possible fields and 137mboe from the technical reserves fields).

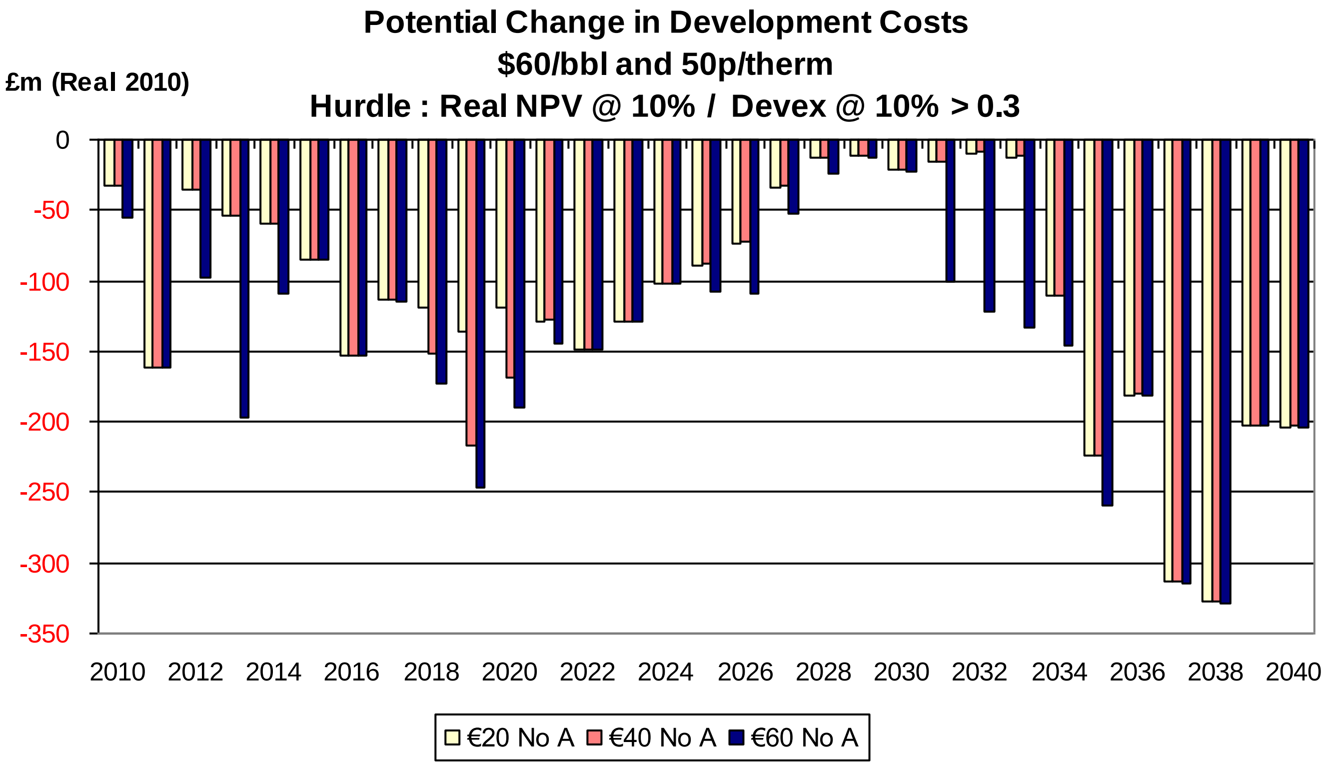
Chart 63



From Chart 63 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative production could be reduced by 27mboe in 2020 (14mboe from sanctioned fields and incremental investments, 9mboe from the Probable fields and 4mboe from the technical reserves fields), 60mboe by 2030 (35mboe from sanctioned fields and incremental investments, 15mboe from the Probable fields, 4mboe from Possible fields and 7mboe from the technical reserves fields), and 82mboe by 2040 (44mboe from sanctioned fields and incremental investments, 17mboe from the Probable fields, 4mboe from Possible fields and 17mboe from the technical reserves fields). With a CO_2 price of €40/t cumulative production could be reduced by 64mboe in 2020 (39mboe from sanctioned fields and incremental investments, 20mboe from the Probable fields and 4mboe from the technical reserves fields), 128mboe by 2030 (77mboe from sanctioned fields and incremental investments, 32mboe from the Probable fields, 5mboe from Possible fields and 13mboe from the technical reserves fields), and 198mboe by 2040 (90mboe from sanctioned fields and incremental investments, 34mboe from the Probable fields, 6mboe from Possible fields and 68mboe from the technical reserves fields). With a CO_2 price of €60/t cumulative production could be reduced by 68mboe in 2020 (43mboe from sanctioned fields and incremental investments, 20mboe from the Probable fields, 1mboe from Possible fields and 5mboe from the technical reserves fields), 151mboe by 2030 (90mboe from sanctioned fields and incremental investments, 37mboe from the Probable fields, 8mboe from Possible fields and 16mboe from the technical reserves fields), and 234mboe by 2040 (111mboe from sanctioned fields and incremental investments, 39mboe from the Probable fields, 8mboe from Possible fields and 76mboe from the technical reserves fields).

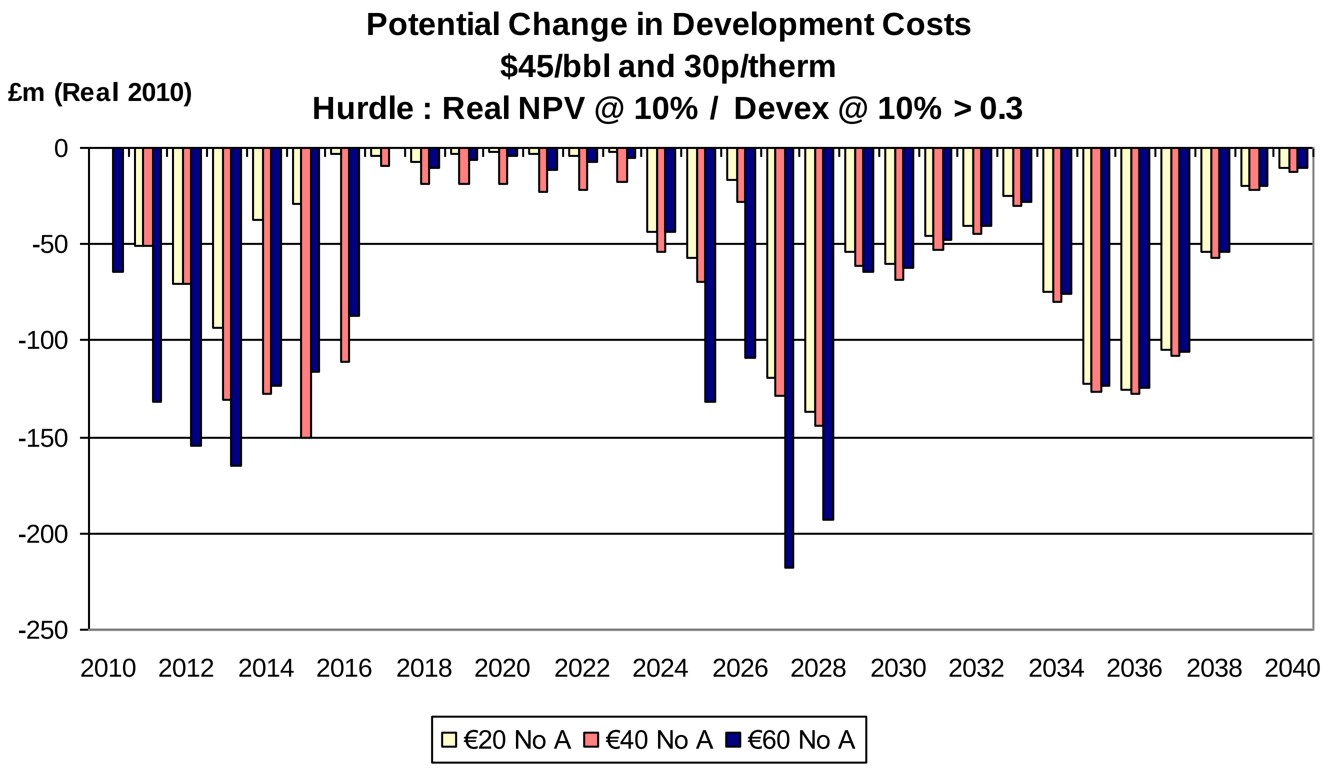
(ii) Changes in Development Expenditures

Chart 64



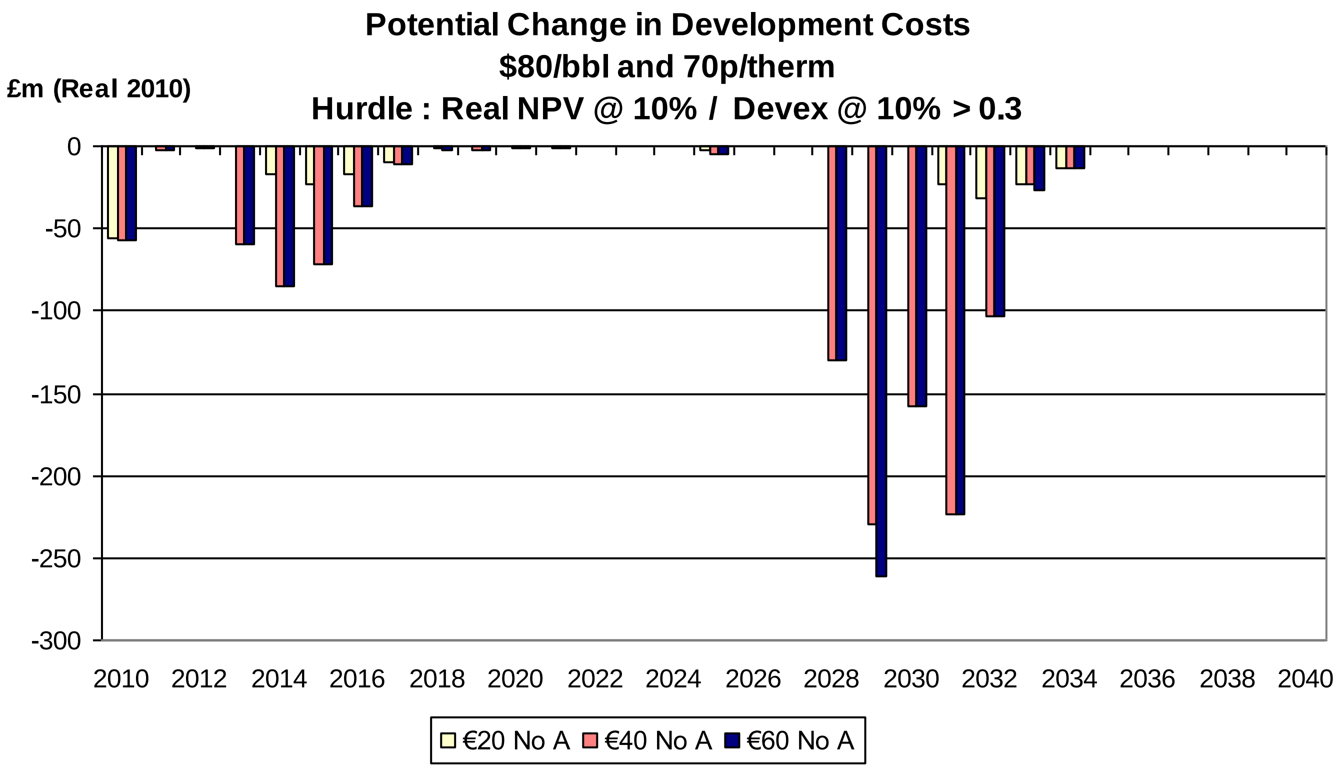
From Chart 64 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £1,067m by 2020, £1,816m by 2030, and £3,415m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £1,231m by 2020, £1,977m by 2030, and £3,574m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £1,582m by 2020, £2,436m by 2030, and £4,427m by 2040.

Chart 65



From Chart 65 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £301m by 2020, £798m by 2030, and £1,420m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £707m by 2020, £1,314m by 2030, and £1,986m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £861m by 2020, £1,706m by 2030, and £2,336m by 2040.

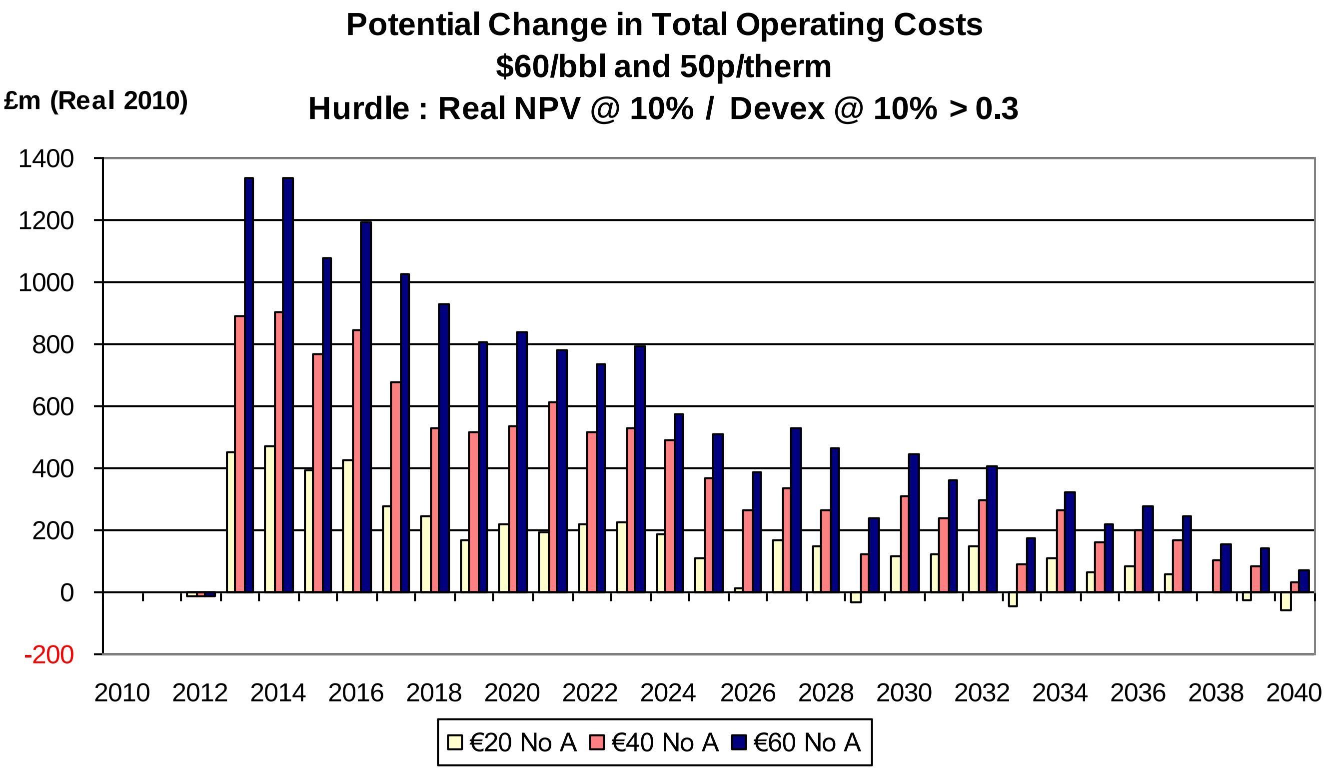
Chart 66



From Chart 66 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t cumulative spending on development could be reduced by £123m by 2020, £125m by 2030, and £216m by 2040. With a CO_2 price of €40/t cumulative spending on development could be reduced by £330m by 2020, £853m by 2030, and £1,216m by 2040. With a CO_2 price of €60/t cumulative spending on development could be reduced by £330m by 2020, £885m by 2030, and £1,252m by 2040.

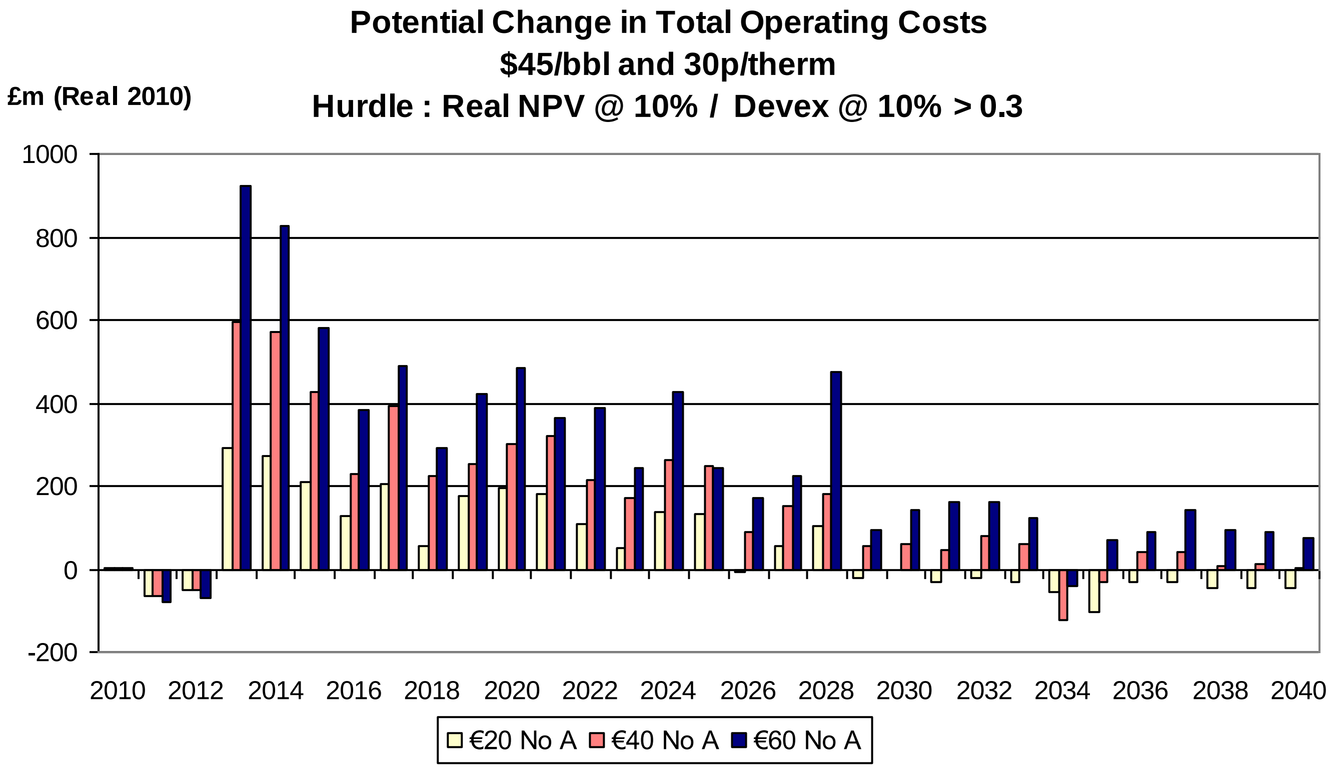
(iii) Changes in Total Operating Costs

Chart 67



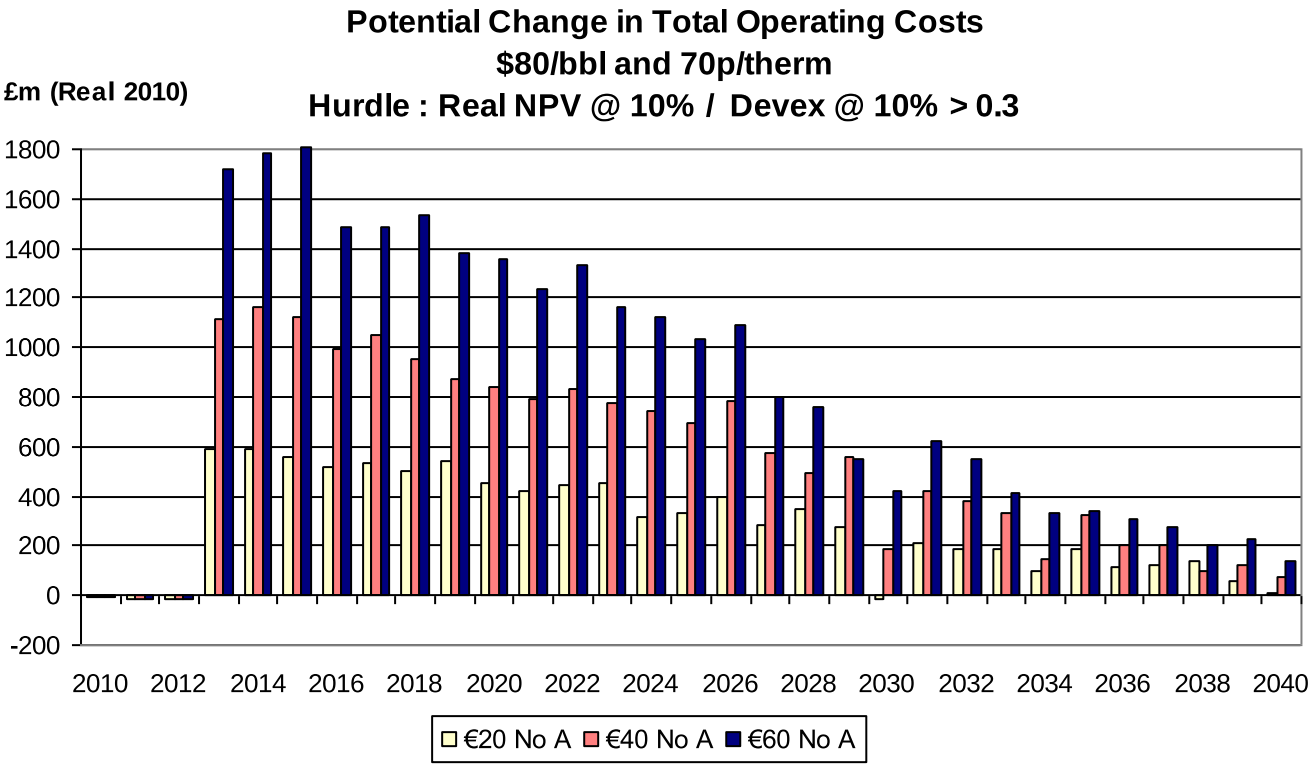
From Chart 67 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £220m in 2020. Cumulative spending on total operating costs could be increased by £2,638m by 2020, £3,980m by 2030, and £4,439m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £533m in 2020. Cumulative spending on total operating costs could be increased by £5,661m by 2020, £9,475m by 2030, and £11,122m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £837m in 2020. Cumulative spending on total operating costs could be increased by £8,528m by 2020, £13,989m by 2030, and £16,352m by 2040.

Chart 68



From Chart 68 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £193m in 2020. Cumulative spending on total operating costs could be increased by £1,422m by 2020, £2,170m by 2030, and £1,725m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £301m in 2020. Cumulative spending on total operating costs could be increased by £2,877m by 2020, £4,633m by 2030, and £4,769m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £482m in 2020. Cumulative spending on total operating costs could be increased by £4,253m by 2020, £7,030m by 2030, and £7,991m by 2040.

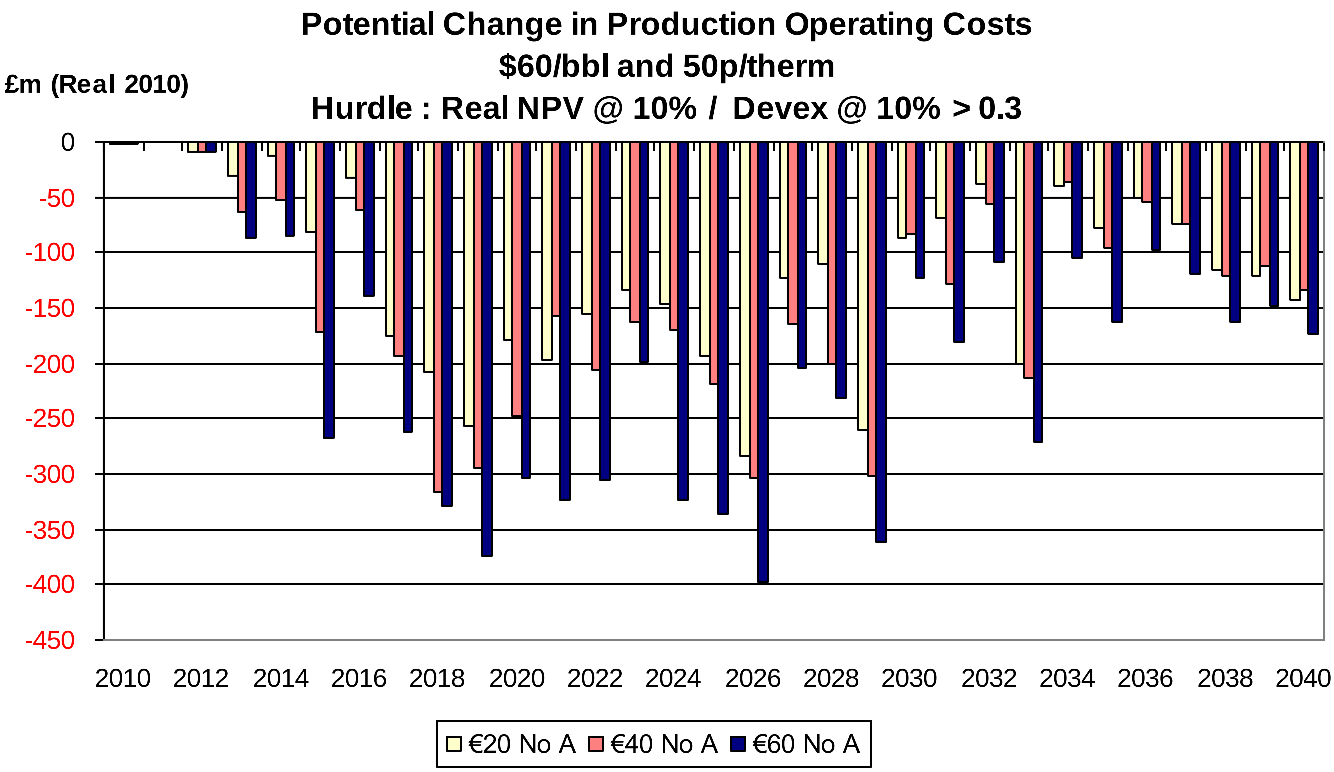
Chart 69



From Chart 69 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t total operating costs could be increased by £454m in 2020. Cumulative spending on total operating costs could be increased by £4,260m by 2020, £7,518m by 2030, and £8,822m by 2040. With a CO_2 price of €40/t total operating costs could be increased by £841m in 2020. Cumulative spending on total operating costs could be increased by £8,087m by 2020, £14,513m by 2030, and £16,808m by 2040. With a CO_2 price of €60/t total operating costs could be increased by £1,355m in 2020. Cumulative spending on total operating costs could be increased by £12,510m by 2020, £22,022m by 2030, and £25,438m by 2040.

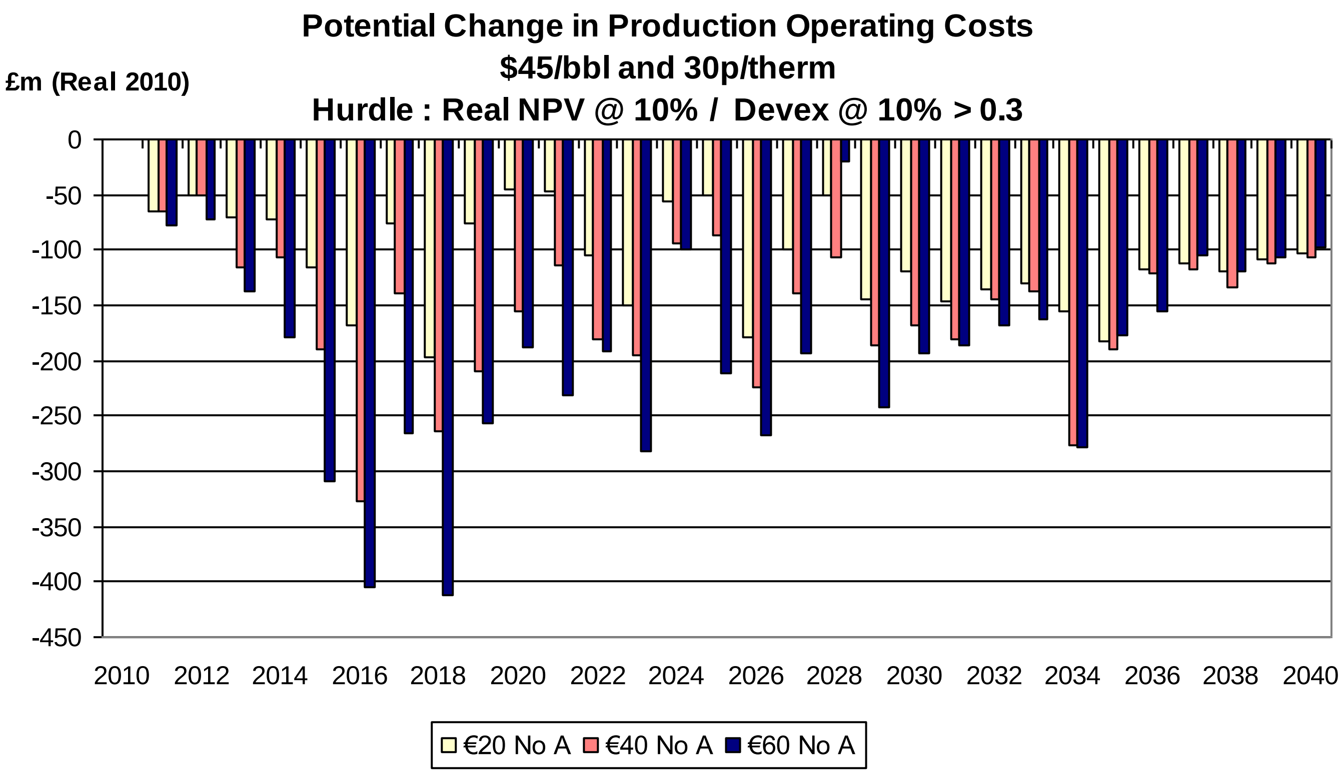
(iv)Changes in Production Operating Costs

Chart 70



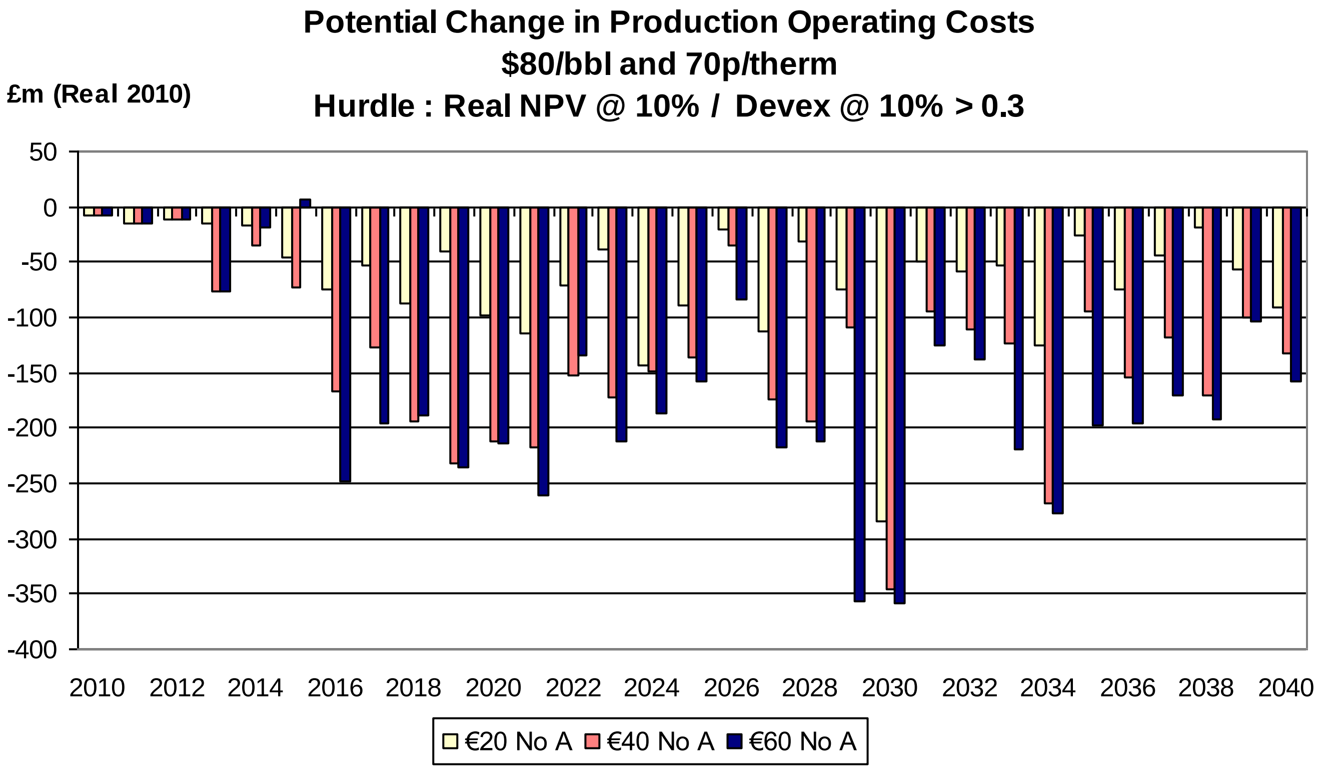
From Chart 70 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £257m in 2019. Cumulative spending on production operating costs could be reduced by £985m by 2020, £2,676m by 2030, and £3,605m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £294m in 2019. Cumulative spending on production operating costs could be reduced by £1,411m by 2020, £3,379m by 2030, and £4,405m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £375m in 2019. Cumulative spending on production operating costs could be reduced by £1,858m by 2020, £4,666m by 2030, and £6,193m by 2040.

Chart 71



From Chart 71 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £75m in 2019. Cumulative spending on production operating costs could be reduced by £933m by 2020, £1,936m by 2030, and £3,247m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £209m in 2019. Cumulative spending on production operating costs could be reduced by £1,425m by 2020, £2,798m by 2030, and £4,267m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £256m in 2019. Cumulative spending on production operating costs could be reduced by £2,299m by 2020, £4,231m by 2030, and £5,787m by 2040.

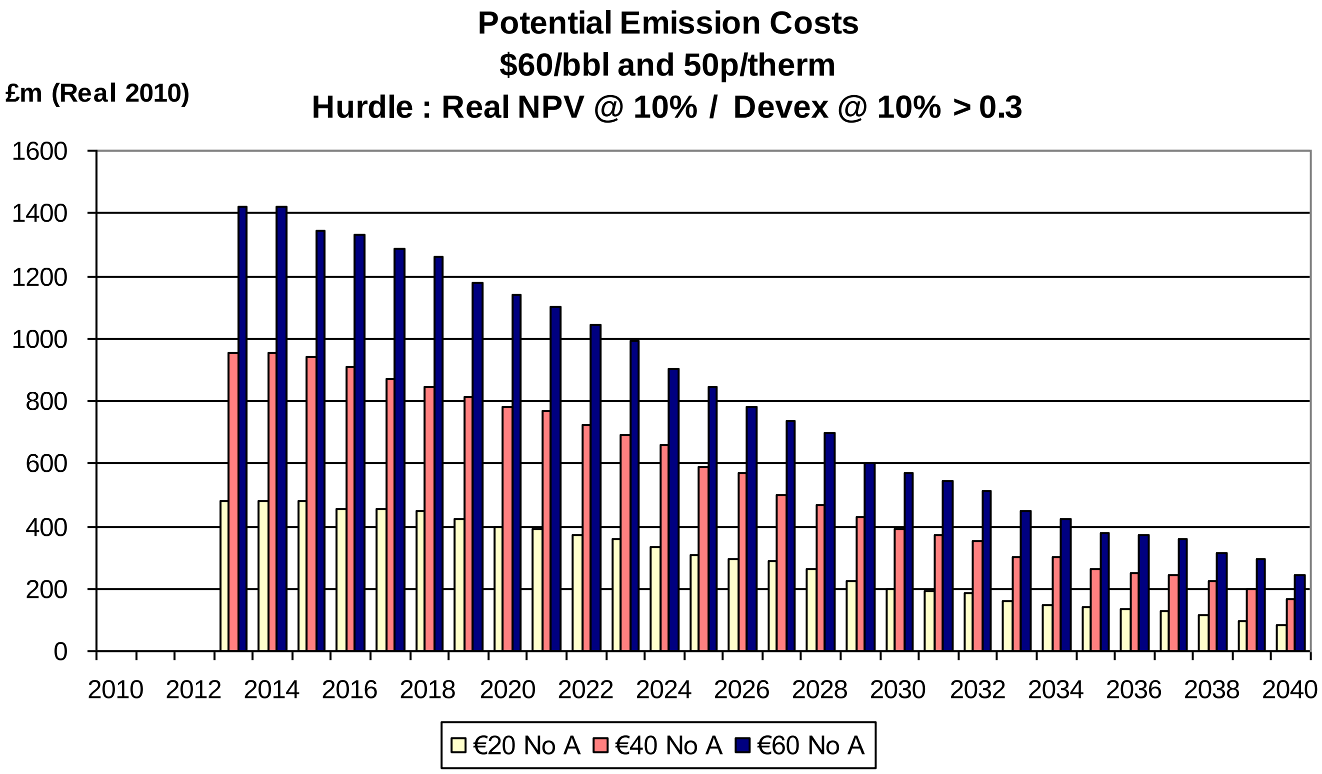
Chart 72



From Chart 72 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t production operating costs could be reduced by £98m in 2020. Cumulative spending on production operating costs could be reduced by £463m by 2020, £1,442m by 2030, and £2,042m by 2040. With a CO_2 price of €40/t production operating costs could be reduced by £212m in 2020. Cumulative spending on production operating costs could be reduced by £1,149m by 2020, £2,831m by 2030, and £4,196m by 2040. With a CO_2 price of €60/t production operating costs could be reduced by £213m in 2020. Cumulative spending on production operating costs could be reduced by £1,204m by 2020, £3,383m by 2030, and £5,159m by 2040.

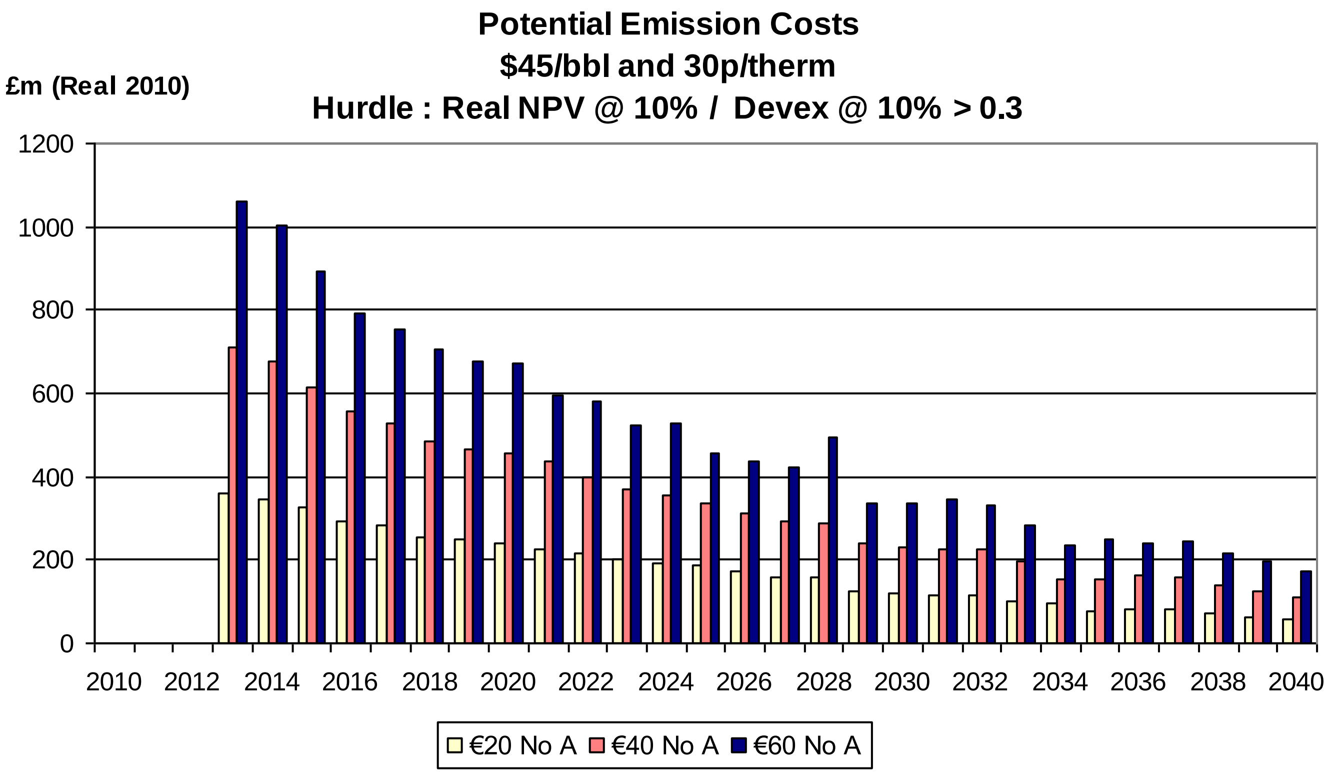
(v) Emission Costs

Chart 73



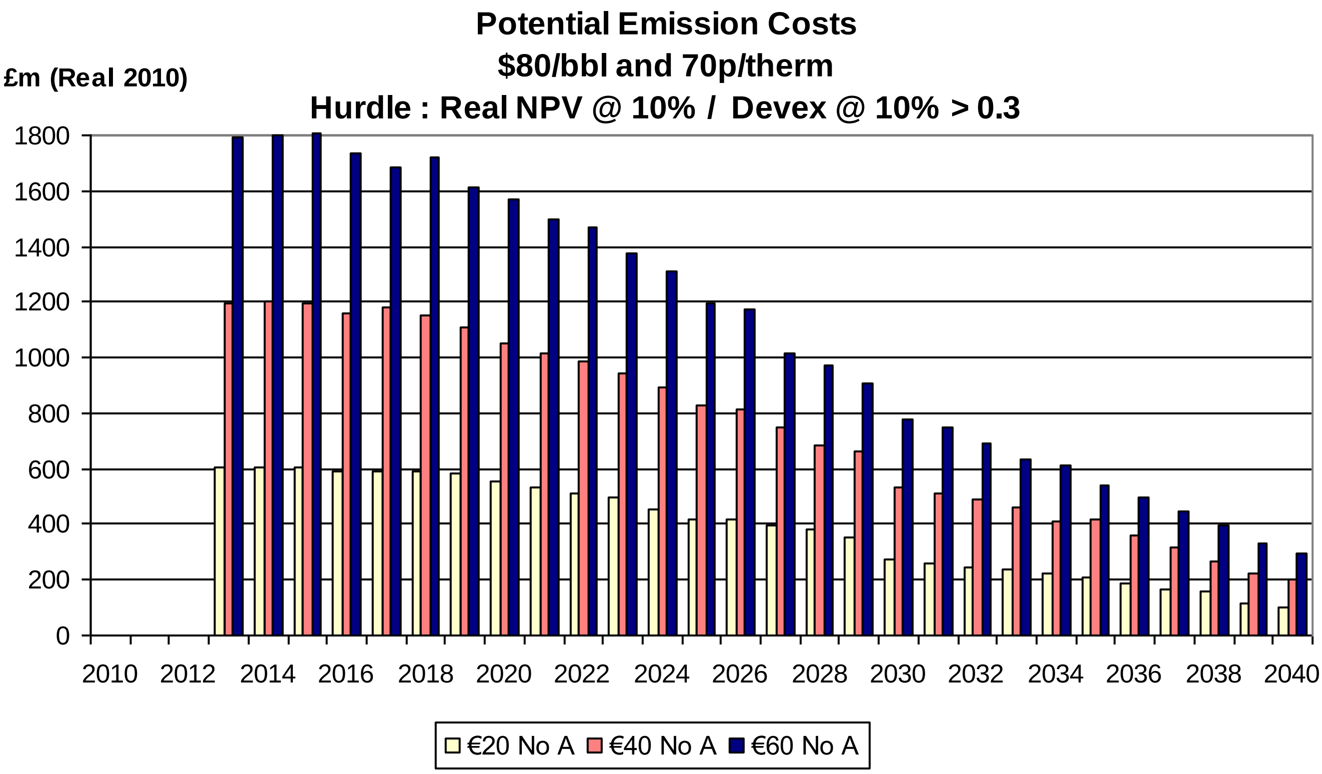
From Chart 73 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £398m in 2020. Cumulative spending on emissions could be £3,623m by 2020, £6,656m by 2030, and £8,043m by 2040. With a CO_2 price of €40/t emission costs could be £781m in 2020. Cumulative spending on emissions could be £7,072m by 2020, £12,854m by 2030, and £15,528m by 2040. With a CO_2 price of €60/t emission costs could be £1,141m in 2020. Cumulative spending on emissions could be £10,386m by 2020, £18,655m by 2030, and £22,545m by 2040.

Chart 74



From Chart 74 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £238m in 2020. Cumulative spending on emissions could be £2,355m by 2020, £4,106m by 2030, and £4,972m by 2040. With a CO_2 price of €40/t emission costs could be £456m in 2020. Cumulative spending on emissions could be £4,497m by 2020, £7,747m by 2030, and £9,401m by 2040. With a CO_2 price of €60/t emission costs could be £670m in 2020. Cumulative spending on emissions could be £6,552m by 2020, £11,261m by 2030, and £13,778m by 2040.

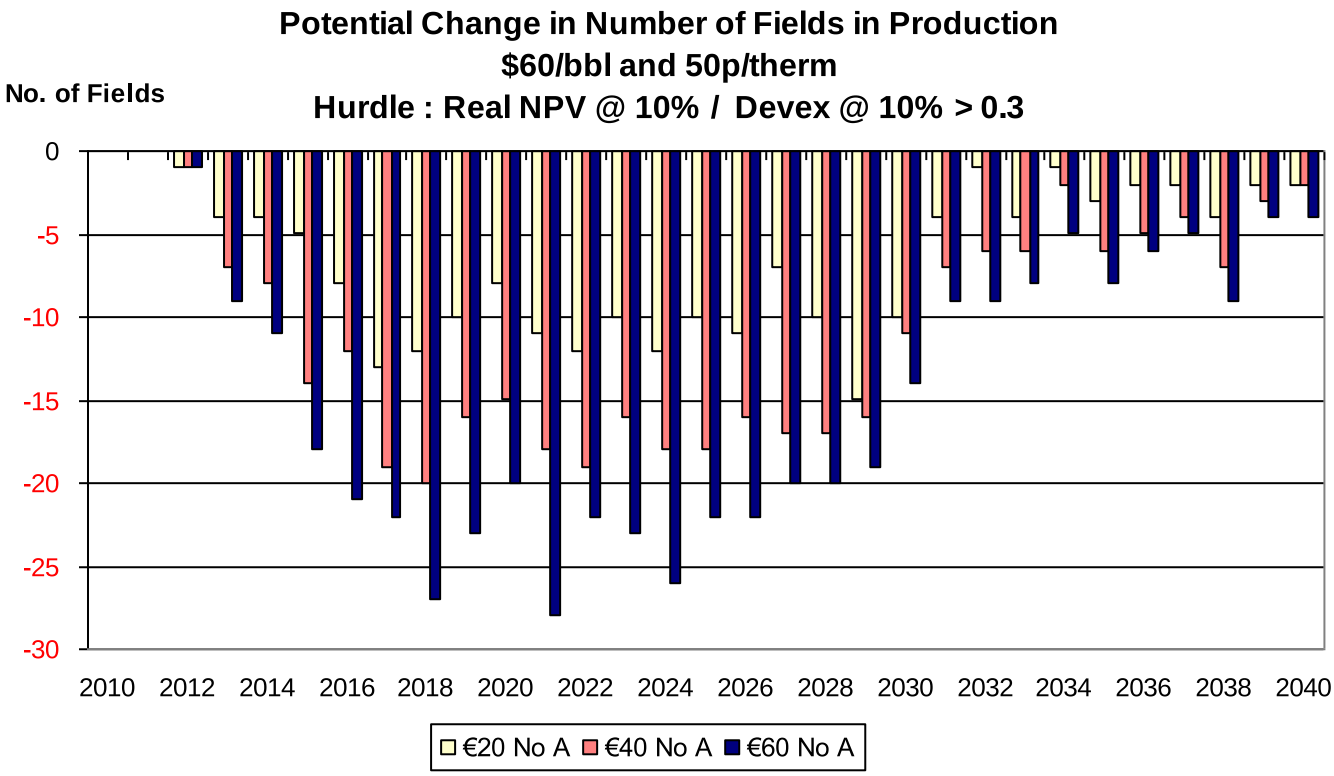
Chart 75



From Chart 75 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t potential emission costs could be £552m in 2020. Cumulative spending on emissions could be £4,723m by 2020, £8,960m by 2030, and £10,864m by 2040. With a CO_2 price of €40/t emission costs could be £1,053m in 2020. Cumulative spending on emissions could be £9,236m by 2020, £17,344m by 2030, and £21,004m by 2040. With a CO_2 price of €60/t emission costs could be £1,568m in 2020. Cumulative spending on emissions could be £13,714m by 2020, £25,406m by 2030, and £30,597m by 2040.

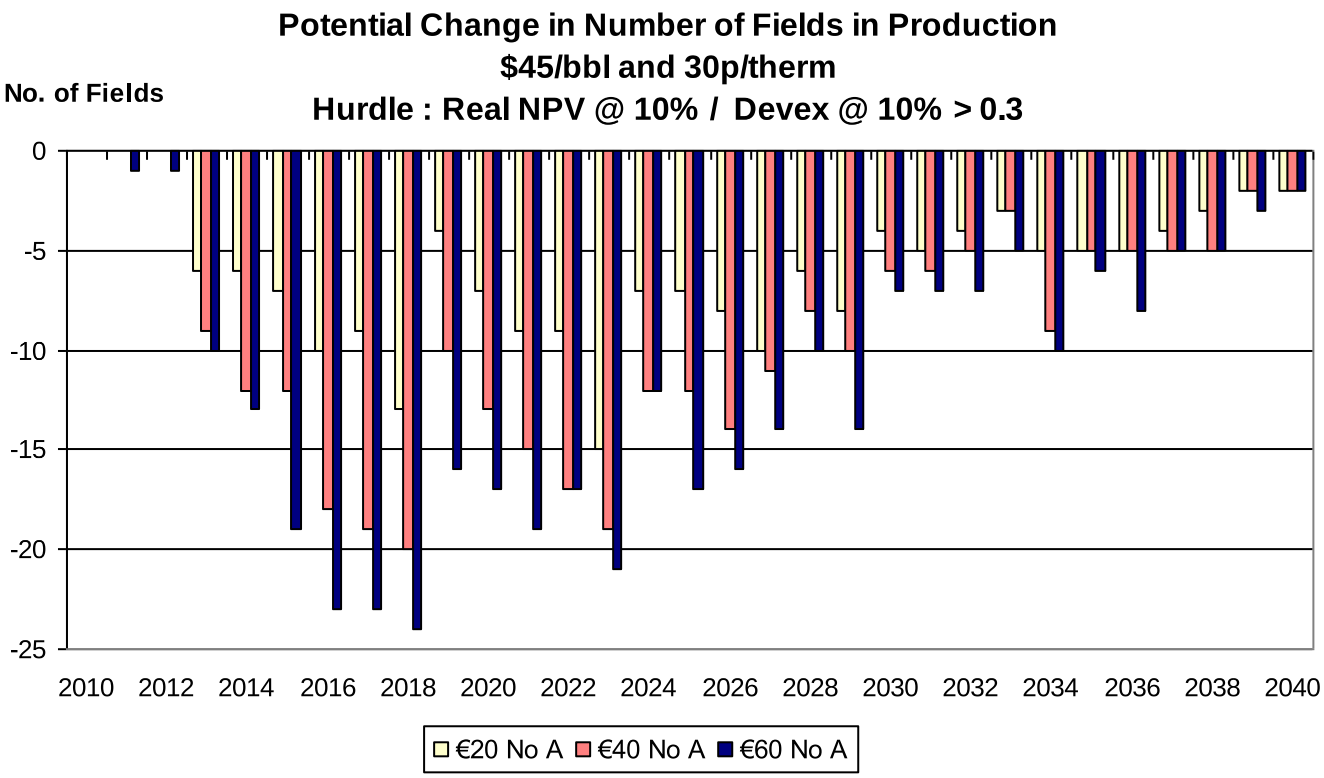
(vi)Changes in Numbers of Fields in Production

Chart 76



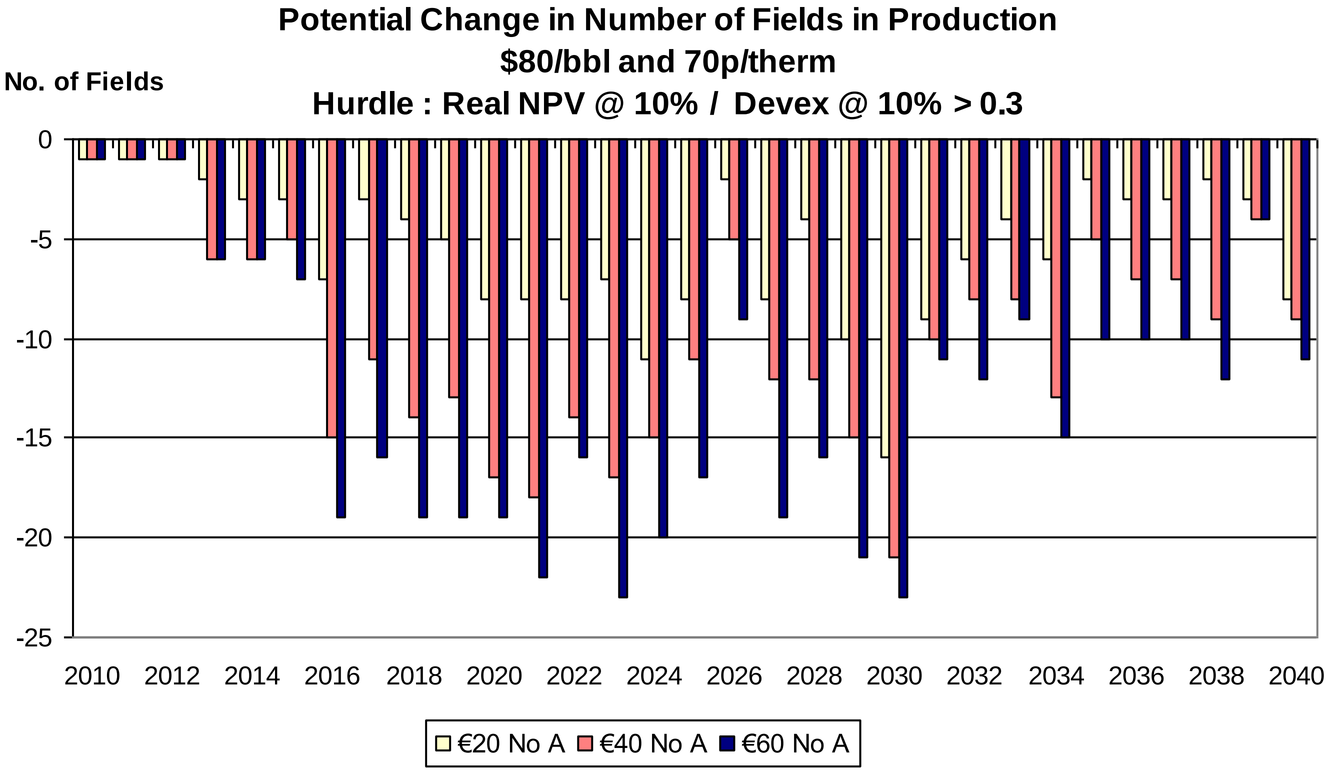
From Chart 76 it is seen that at the medium price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 15 fewer fields in production in 2029. With a CO_2 price of €40/t there may be 20 fewer fields in production in 2018. With a CO_2 price of €60/t there may be 28 fewer fields in production in 2021.

Chart 77



From Chart 77 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 15 fewer fields in production in 2023. With a CO_2 price of €40/t there may be 19 fewer fields in production in 2023. With a CO_2 price of €60/t there may be 21 fewer fields in production in 2023.

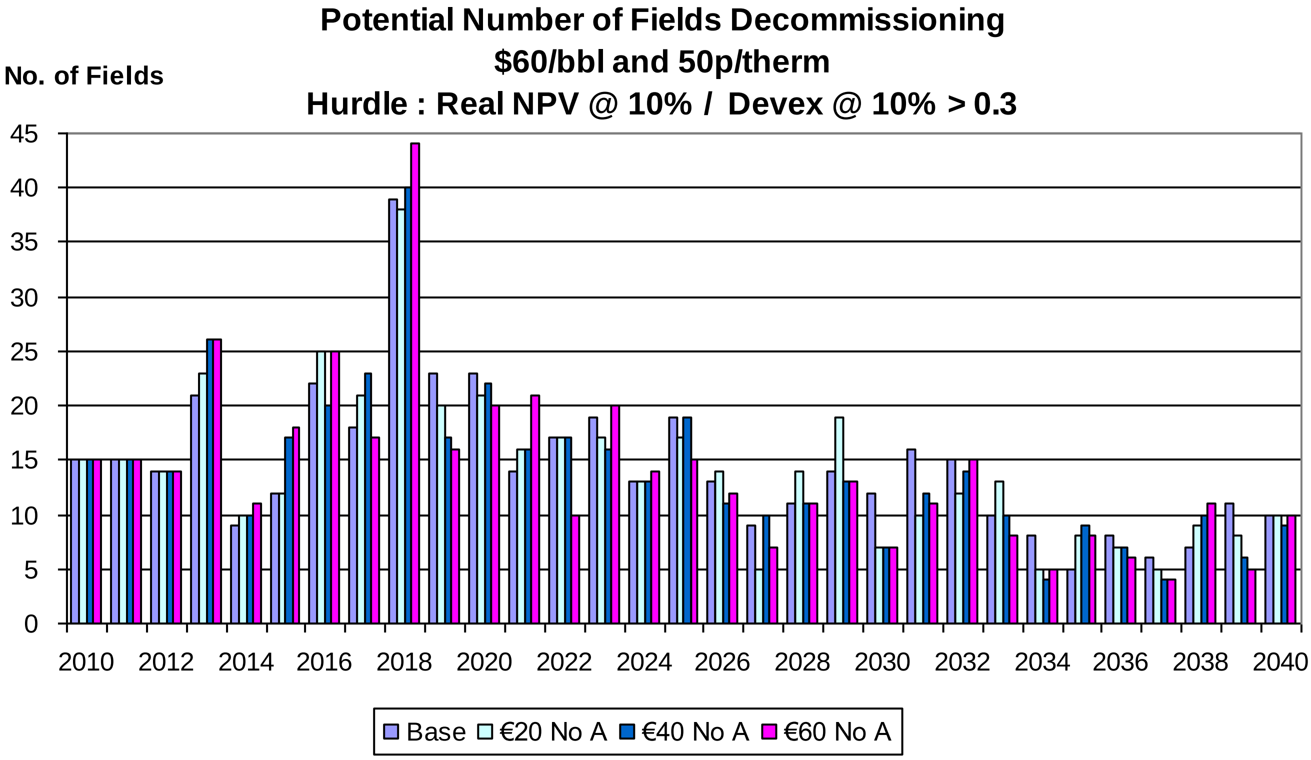
Chart 78



From Chart 78 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 11 fewer fields in production in 2024 and 16 fewer in 2030. With a CO_2 price of €40/t there may be 17 fewer fields in production in 2020 and 21 fewer in 2030. With a CO_2 price of €60/t there may be 22 fewer fields in production in 2021 and 23 fewer in 2023 and 2030.

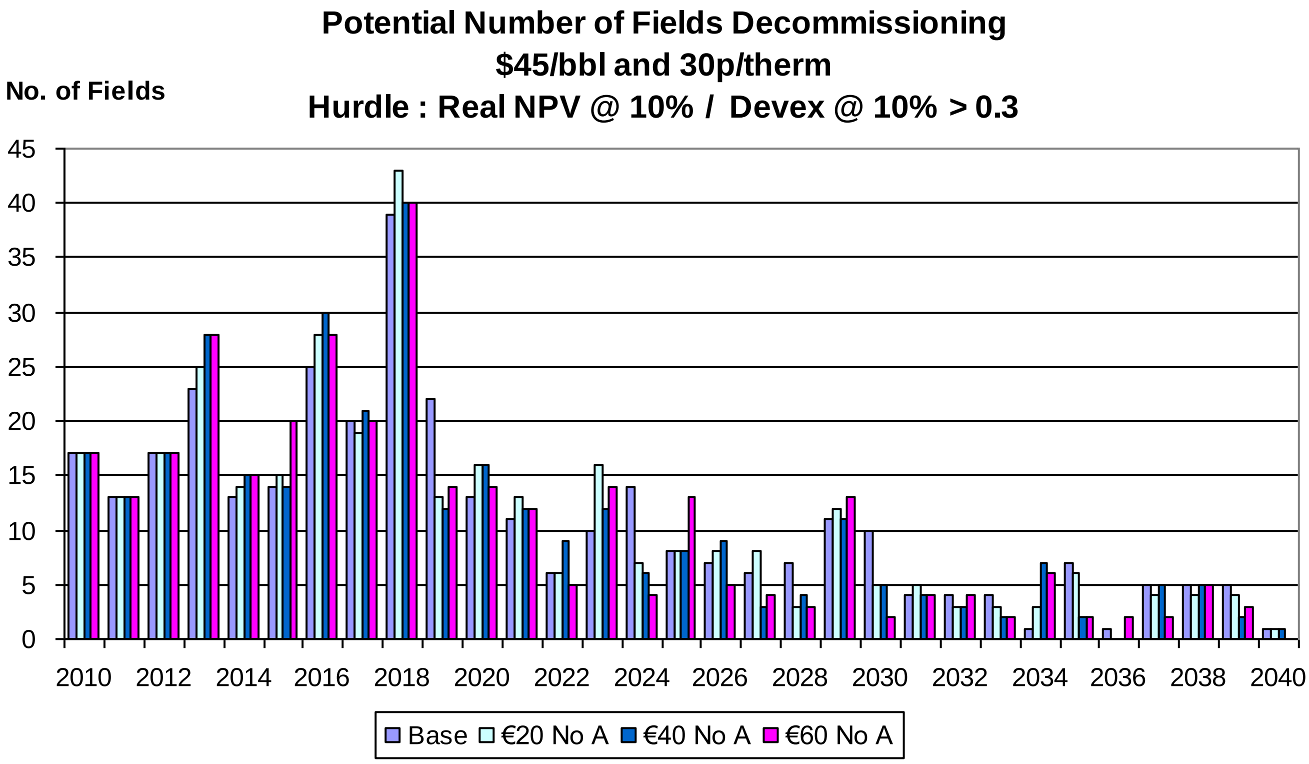
(vii) Numbers of Fields Decommissioning

Chart 79



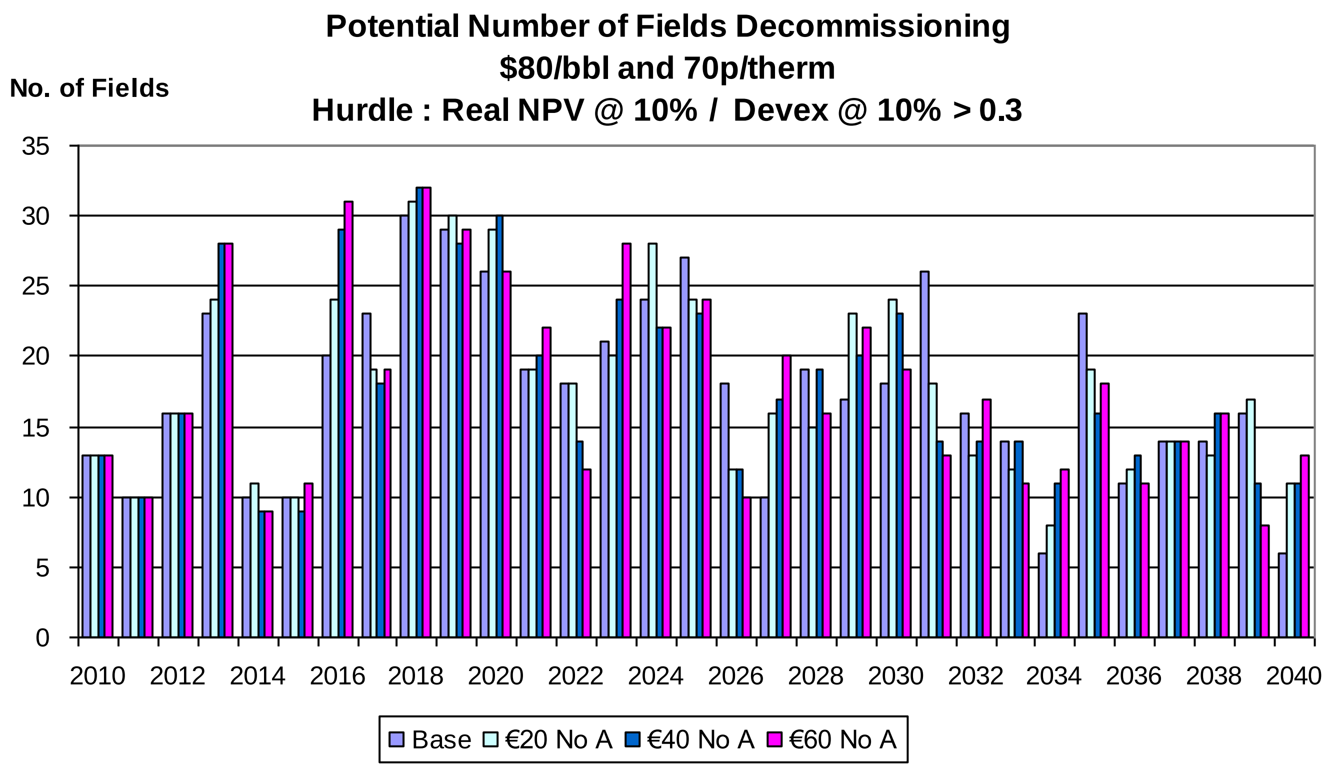
From Chart 79 it is seen that at the medium price with no free allwoances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 3 extra fields which may decommission in 2020 and 1 extra in 2030. However, there are also 8 fewer fields in production in 2020, 10 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €40/t there may be 8 extra fields decommissioning in 2020. However, there are also 15 fewer fields in production in 2020, 11 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €60/t there may be 10 extra fields decommissioning in 2020. However, there are also 20 fewer fields in production in 2020, 14 fewer in 2030, and 4 fewer in 2040.

Chart 80



From Chart 80 it is seen that at the low price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 4 extra fields which may decommission in 2020. However, there are also 7 fewer fields in production in 2020, 4 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €40/t there may be 7 extra fields decommissioning in 2020. However, there are also 13 fewer fields in production in 2020, 6 fewer in 2030, and 2 fewer in 2040. With a CO_2 price of €60/t there may be 10 extra fields decommissioning in 2020. However there are also 17 fewer fields in production in 2020, 7 fewer in 2030, and 2 fewer in 2040.

Chart 81



From Chart 81 it is seen that at the high price with no free allowances with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t there may be 7 extra fields which may decommission in 2020, 15 extra in 2030, and 6 in 2040. However, there are also 8 fewer fields in production in 2020, 16 fewer in 2030, and 8 fewer in 2040. With a CO_2 price of €40/t there may be 12 extra fields decommissioning in 2020, 15 in 2030 and 3 in 2040. However, there are also 17 fewer fields in production in 2020, 21 fewer in 2030, and 9 fewer in 2040. With a CO_2 price of €60/t there may be 14 extra fields decommissioning in 2020, 18 in 2030, and 5 extra in 2040. However, there are also 19 fewer fields in production in 2020, 23 fewer in 2030, and 11 fewer in 2040.

4. Summary and Conclusions

In this study the consequences of the proposals in Phase III of the EU ETS onwards to require licensees in the UKCS to purchase an increasing proportion of their CO_2 allowances have been examined. These effects depend on several factors which are subject to much uncertainty. Key direct uncertainties include (1) the size of total emissions, (2) the proportion of these emanating from electricity generation, (3) the extent of sharing the costs (directly or indirectly) between interconnected parties, and (4) the price of CO_2 allowances. The effects on activity in the UKCS also depend on several factors relating to the underlying economics of oil and gas exploitation including (1) oil/gas prices, (2) investment hurdle criteria employed by licensees in making investment decisions, and (3) the behavior of investment and operating costs.

Against this background it was decided that, in order to provide illumination on the prospects, a number of scenarios were constructed including 3 sets of oil and gas prices ($45 and 30 pence, $60 and 50 pence, and $80 and 70 pence), and 3 prices for CO_2 allowances (€20, €40, and €60 per tonne), and 3 cases of availability of free CO_2 allowances, namely (1) 80% of total requirements in 2013 falling linearly to 0% in 2027, (2) 80% of 50% of total requirements in 2013 falling to 0% in 2027 (50% of emissions from electricity generation), and (3) zero free allowances from 2013 onwards.

In the base case financial modelling included the fruits of future exploration. This is appropriate to determine possible activity levels in the longer term. The modelling procedure incorporating all future possible developments was also necessary to calculate both the numbers and timing of the development of discovered fields in the category of technical reserves.

For purposes of modelling the CO_2 emissions it was felt that, with respect to new discoveries, given all the uncertainties, the assumptions required were very extensive and it was decided to exclude these fields from the analysis of the Phase III obligations.

The outputs of the modelling emphasized (1) the loss of production from the UKCS resulting from the Phase III proposals through (a) accelerated cessation of production, and (b) non-development of fields which would otherwise have gone ahead, (2) reduction in field investment, (3) cost of purchase of CO_2 allowances, and (4) net increase in total operating costs (cost of purchase of CO_2 allowances minus production operating costs saved). The modelling also permitted the changes to the timing of the fields being decommissioned to be estimated.

With respect to the total loss of production from existing discoveries in the period to 2040 it was found that, in the case with maximum free CO_2 allowances, under the $60, 50 pence case there was a cumulative loss of 177 mmboe under the €20 CO_2 price, 244 mmboe under the €40 CO_2 price, and 392 mmboe under the €60 CO_2 price. Under the $45, 30 pence case the cumulative loss of production is 213 mmboe under the €20 CO_2 price, 290 mmboe at the €40 CO_2 price, and 407 mmboe at the €60 CO_2 price. Under the $80, 70 pence price case the cumulative loss of production is 47 mmboe under the €20 CO_2 price, 151 mmboe under the €40 CO_2 price, and 206 mmboe under the €60 CO_2 price. It is reiterated that these data exclude any loss of production attributable to the Phase III requirements relating to future discoveries. The loss of production is greatest under the $45, 30 pence price case because there are more marginal fields under this price scenario than with the others. (In this scenario many fields and projects are also sub-marginal even without the obligation to purchase CO_2 allowances). Under the high price case more fields/ projects can withstand the cost of purchasing allowances and still remain viable.

With respect to the loss of new field investment it was found that under the \$60, 50 pence case cumulative investment to 2040 would be reduced by £2.5 billion under the €20 CO_2 price, by £2.7 billion under the €40 CO_2 price and by £4.1 billion under the €60 CO_2 price. Under the \$45, 30 pence price scenario cumulative field investment is reduced by £1.3 billion under the €20 CO_2 price, by £1.4 billion under the €40 CO_2 price, and by £2.2 billion under the €60 CO_2 price. Under the \$80, 70 pence price case cumulative investment falls by £160 million under the €20 CO_2 price, £1 billion under the €40 CO_2 price and £1.1 billion under the €60 CO_2 price.

The total cumulative cost of purchasing CO_2 allowances under the \$60, 50 pence case was found to be £5.6 billion with €20 CO_2 price, £10.7 billion with €40 CO_2 price, and £15.5 billion with €60 CO_2 price. Under the \$45, 30 pence price case the cumulative costs of purchasing CO_2 allowances are £3.4 billion with €20 CO_2 price, £6.5 billion with €40 CO_2 price, and £9.5 billion with €60 CO_2 price. Under the \$80, 70 pence price scenario the costs of purchasing the allowances are £7.6 billion under the €20 CO_2 price, £14.7 billion with the €40 CO_2 price, and £21.1 billion with the €60 CO_2 price. The costs increase with oil/gas prices because more fields/ projects are viable at higher prices and the fields also have longer economic lives.

The change in total operating costs is the difference between the cost of purchasing allowances and the reduction in production operating costs. It was found that under the $60, 50 pence case cumulative total operating costs were increased by £3.2 billion under the €20 CO_2 price, by £7.1 billion under the €40 CO_2 price, and by £10.3 billion under the €60 CO_2 price. Under the $45, 30 pence case total operating costs increase by £1.0 billion under the €20 CO_2 price, by £2.8 billion under the €40 CO_2 price, and by £4.6 billion under the €60 CO_2 price. Under the $80, 70 pence case total operating costs increase by £6.1 billion under the €20 CO_2 price, by £11.4 billion under the €40 CO_2 price, and by £16.2 billion under the €60 CO_2 price.

The central case is where 50% of emissions are assumed to arise from electricity generation. Under the $60, 50 pence price case the cumulative loss of production to 2040 is 204 mmboe with €20 CO_2 price, 328 mmboe with €40 CO_2 price, and 395 mmboe with €60 CO_2 price. Under the $45, 30 pence case the cumulative loss of production is 259 mmboe under the €20 CO_2 price, 340 mmboe with the €40 CO_2 price, and 417 mmboe with the €60 CO_2 price. Under the $80, 70 pence case the cumulative loss of production is 64 mmboe under the €20 CO_2 price, 174 mmboe under the €40 CO_2 price, and 232 mmboe under the €60 CO_2 price.

With respect to new field investment it was found that under the $60, 50 pence case there would be a cumulative reduction of £2.5 billion under the €20 CO_2 price, £3.6 billion under the €40 CO_2 price, and £4.1 billion under the €60 CO_2 price. Under the $45, 30 pence scenario the reduction in investment amounts to £1.4 billion at the €20 CO_2 price, £1.7 billion at €40 CO_2 price, and £2.0 billion at the €60 CO_2 price. Under the $80, 70 pence price case the investment reduction is £160 million with the €20 CO_2 price, £1.0 billion at the €40 CO_2 price, and £1.3 billion at the €60 CO_2 price.

Under the scenario with 50% of emissions from electricity generation it was found that under the \$60, 50 pence case expenditure on purchasing allowances could cumulate to £6.8 billion with a CO_2 price of €20, £13.1 billion with a CO_2 price of €40, and £19.1 billion with a CO_2 price of €60. Under the \$45, 30 pence case total expenditure on CO_2 allowances could amount to £4.2 billion under the €20 price, £8 billion with €40 price, and £11.6 billion at €60 price. With the \$80, 70 pence price case total expenditure could be £9.3 billion at the €20 price, £17.8 billion at the €40 price, and £25.9 billion at the €60 price.

The resulting increase in total operating costs (cost of purchasing of CO_2 allowances less savings in production operating costs) at the \$60, 50 pence case is £4 billion under the €20 price, £8.7 billion under the €40 price, and £14 billion under the €60 price. Under the \$45, 30 pence case the increase in total operating costs is £1 billion at the €20 price, £3.7 billion at the €40 price, and £6.4 billion at the €60 price. Under the \$80, 70 pence case the increase in total operating costs is £7.6 billion at the €20 price, £13.9 billion a the €40 price, and £20.7 billion at the €60 price.

The third case considered was where all CO_2 allowances had to be purchased. Under the \$60, 50 pence case it was found that the loss of production was 280 mmboe under the €20 price, 334 mmboe under the €40 price and 451 mmboe under the €60 price. Under the \$45, 30 pence case the cumulative loss of production was found to be 266 mmboe under the €20 price, 387 mmboe at the €40 price, and 474 mmboe at the €60 price. Under the \$80, 70 pence case the loss of production was 82 mmboe at the €20 price, 198 mmboe at the €40 price, and 234 mmboe at the €60 price.

In this scenario under the \$60, 50 pence price case the loss of field investment was £3.4 billion at the €20 price, £3.6 billion at the €40 price, and £4.4 billion at the €60 price. With the \$45, 30 pence case the loss of investment was £1.4 billion at the €20 price, £2 billion at the €40 price, and £2.3 billion at the €60 price.

In this scenario total expenditure on purchasing CO_2 allowances at the \$60, 50 pence case would be £8 billion at the €20 price, £15.5 billion at the €40 price, and £22.5 billion at the €60 price. Under the \$45, 30 pence case the total cost of purchasing CO_2 allowances could be £5 billion at the €20 price, £9.4 billion at the €40 price, and £13.8 billion at the €60 price. Under the \$80, 70 pence price the costs of purchasing the allowances would be £10.9 billion under the €20 price, £21 billion under the €40 price, and £30.6 billion under the €60 price.

The resulting increases in total operating costs under the \$60, 50 price case were £4.4 billion with €20 price, £11.1 billion with €40 price, and £16.4 billion with €60 price. Under the \$45, 30 pence price the increase in total operating costs was £1.7 billion at €20 price, £4.8 billion at €40 price, and £8 billion at €60 price. Under the \$80, 70 pence case the increase in total operating costs is £8.8 billion at €20 price, £16.8 billion at €40 price, and £25.4 billion at €60 price.

The conclusions are that the introduction of the proposals under Phase III of the EU ETS will have noteworthy effects on activity in the UKCS, with a significant loss of production being the most obvious effect. It should be stressed that the results presented in this study do not indicate the full extent of the likely loss as they exclude the effects from future discoveries. It is to be expected that the loss of production from the UKCS will result in a corresponding replacement in production from countries where the EU ETS is not imposed. This produces the carbon leakage problem. The evidence produced in this study supports the claim that the carbon leakage problem in the UKCS will be significant under the present proposals.

Appendix 1

Potential Hydrocarbon Production

The charts below show aggregate prospective total hydrocarbon production in the UKCS from the fields/ projects in the categories of (1) sanctioned fields, (2) incremental projects both current and future, (3) probable fields, (4) possible fields, and (5) technical reserves. Thus future discoveries are excluded. The base case shows production in the absence of Phase III obligations.

Chart A.1

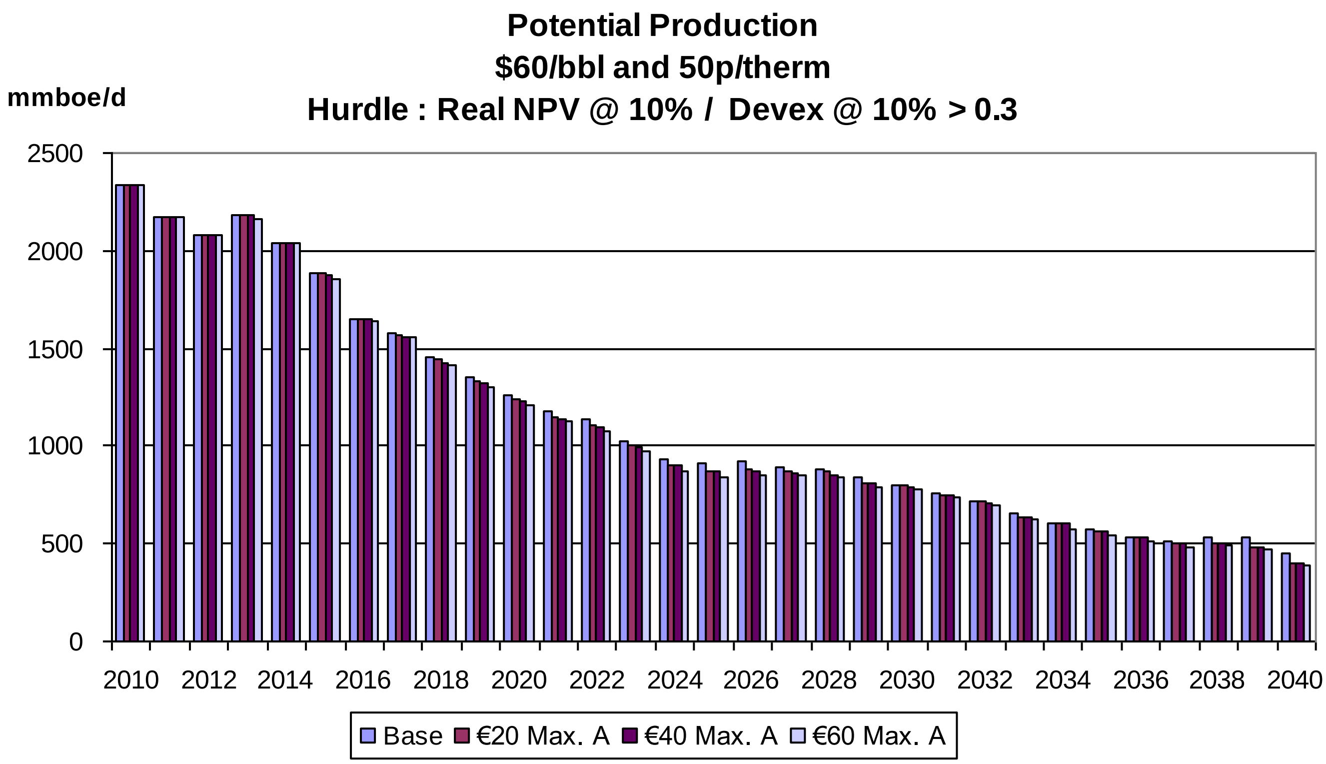
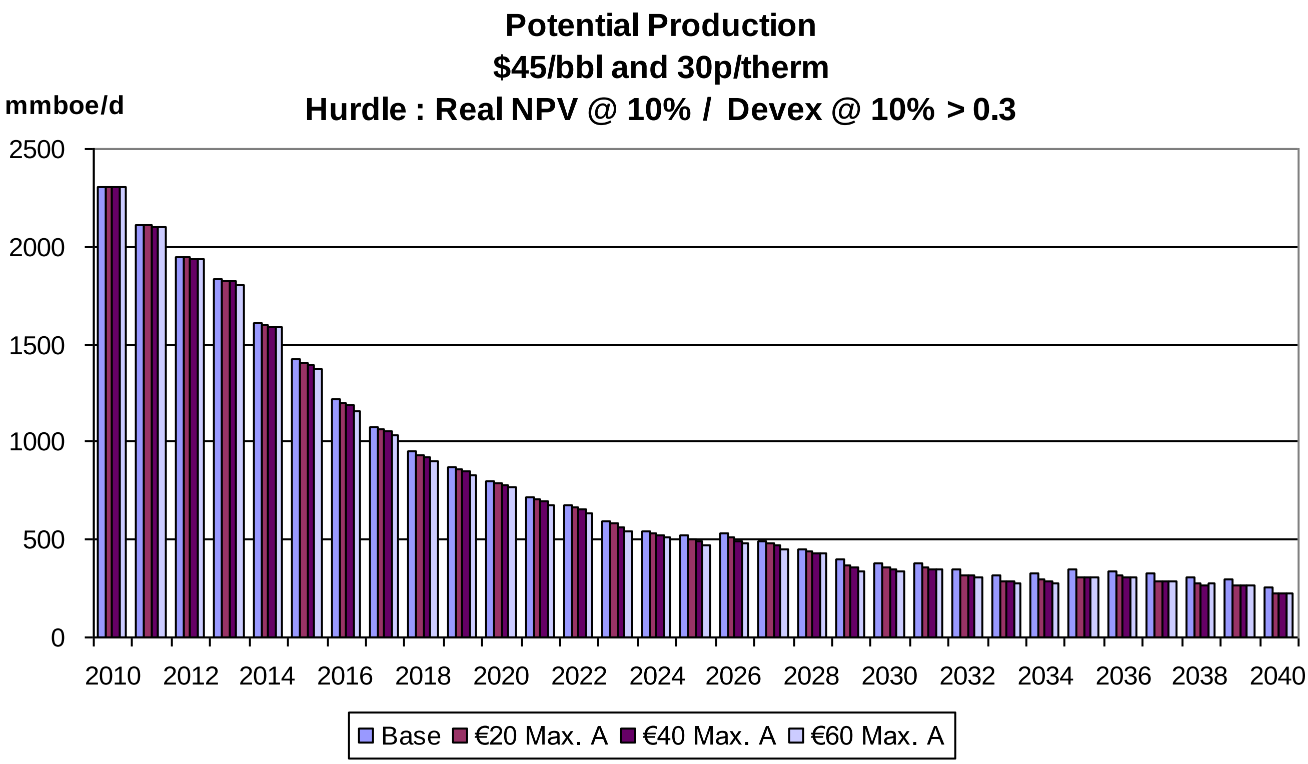


Chart A.1 shows hydrocarbon production before and after the imposition of Phase III of the EU ETS with maximum CO_2 allowance. At the $60, 50 pence price base production could be 1261mmboe/d in 2020, but with CO_2 costs of

€20 per tonne it could be 1243mmboe/d. Base production could be 804mmboe/d in 2030, but with CO_2 costs imposed it could be 796mmboe/d, and in 2040 base production could be 452mmboe/d but with CO_2 costs imposed it could be 402mmboe/d. With a CO_2 price of €40/t production could be 1876mmboe/d in 2015, 1225mmboe/d in 2020, 794mmboe/d in 2030 and 401mmboe/d in 2040. With a CO_2 price of €60/t production could be 1857mmboe/d in 2015, 1208mmboe/d in 2020, 783mmboe/d in 2030, and 393mmboe/d in 2040.

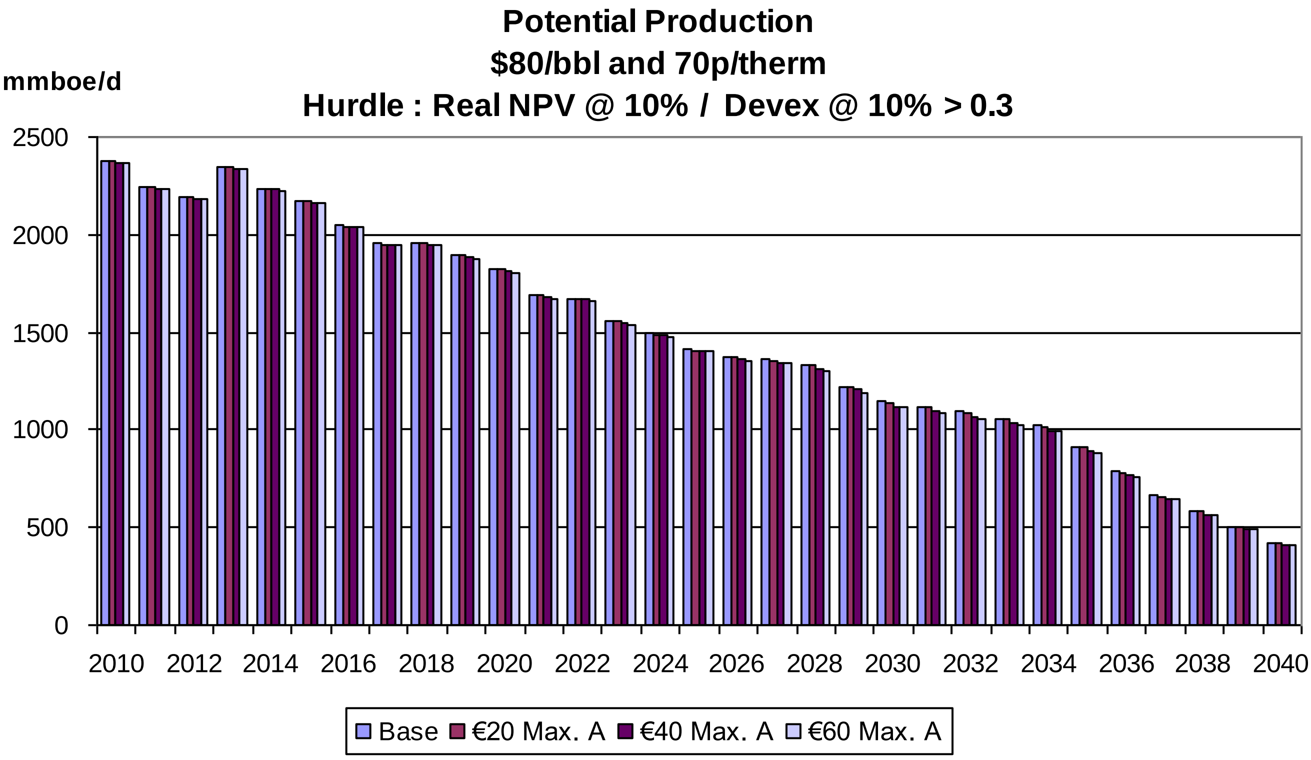
Chart A.2



At the $45, 30 pence price (Chart A.2), daily production could be 1427mmboe/d in 2015 with the base case. With EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 1402mmboe/d in 2015. Base production could be 798mmboe/d in 2020, but with CO_2 costs imposed it could be 789mmboe/d. Base production could be 383mmboe/d in

2030, but with CO_2 costs imposed it could be 357mmboe/d, and in 2040 base production could be 254mmboe/d, but with CO_2 costs imposed it could be 227mmboe/d. With a CO_2 price of €40/t production could be 1393mmboe/d in 2015, 776mmboe/d in 2020, 352mmboe/d in 2030 and 227mmboe/d in 2040. With a CO_2 price of €60/t production could be 1374mmboe/d in 2015, 765mmboe/d in 2020, 340mmboe/d in 2030, and 228mmboe/d in 2040.

Chart A.3



At the \$80, 70 pence price (Chart A.3), daily production could be 2174mmboe/d in 2015 with the base case. With EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 2170mmboe/d in 2015. Base production could be 1824mmboe/d in 2020, but with CO_2 costs imposed it could be 1819mmboe/d. Base production could be 1150mmboe/d in 2030, but with CO_2 costs imposed it could be 1133mmboe/d, and in 2040 base production could be 422mmboe/d, but with CO_2 costs imposed it could be

417mmboe/d. With a CO_2 price of €40/t production could be 2161mmboe/d in 2015, 1813mmboe/d in 2020, 1119mmboe/d in 2030, and 413mmboe/d in 2040. With a CO_2 price of €60/t production could be 2157mmboe/d in 2015, 1800mmboe/d in 2020, 1115mmboe/d in 2030, and 411mmboe/d in 2040.

Chart A.4

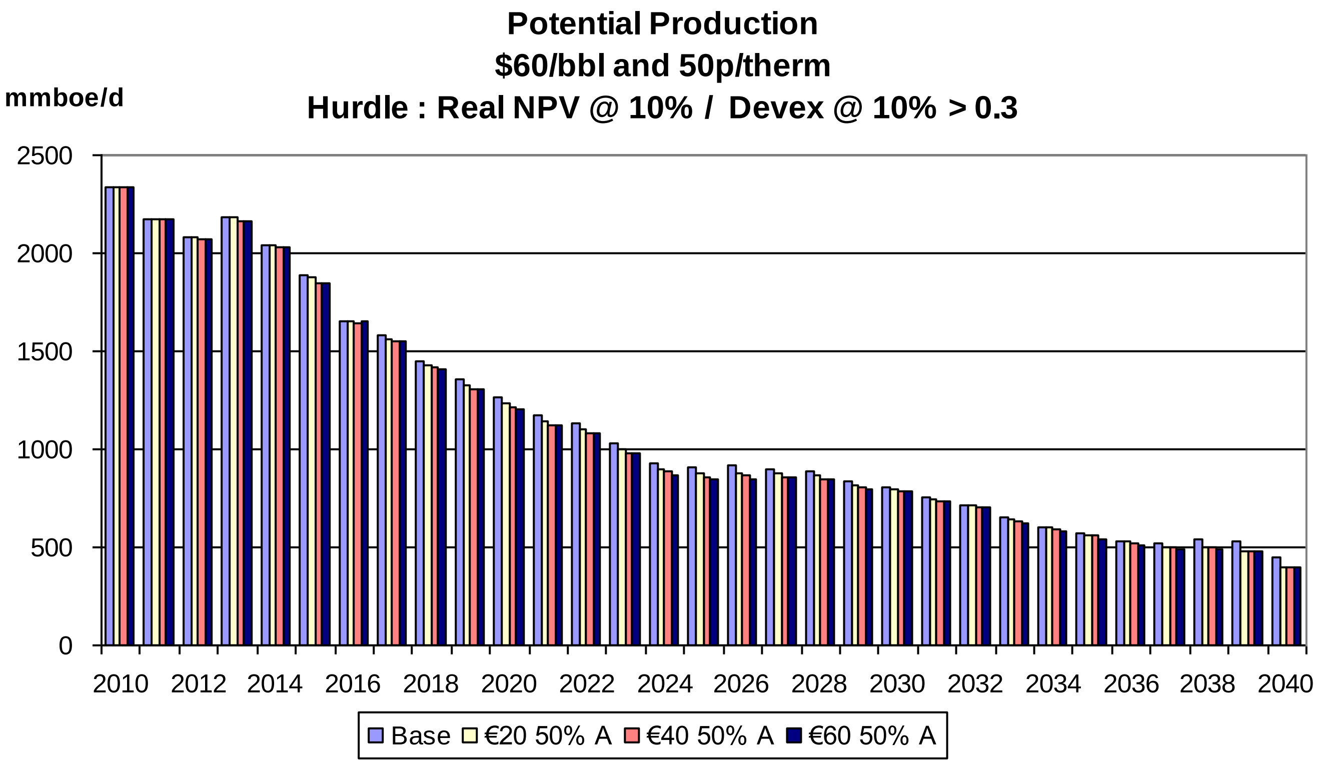
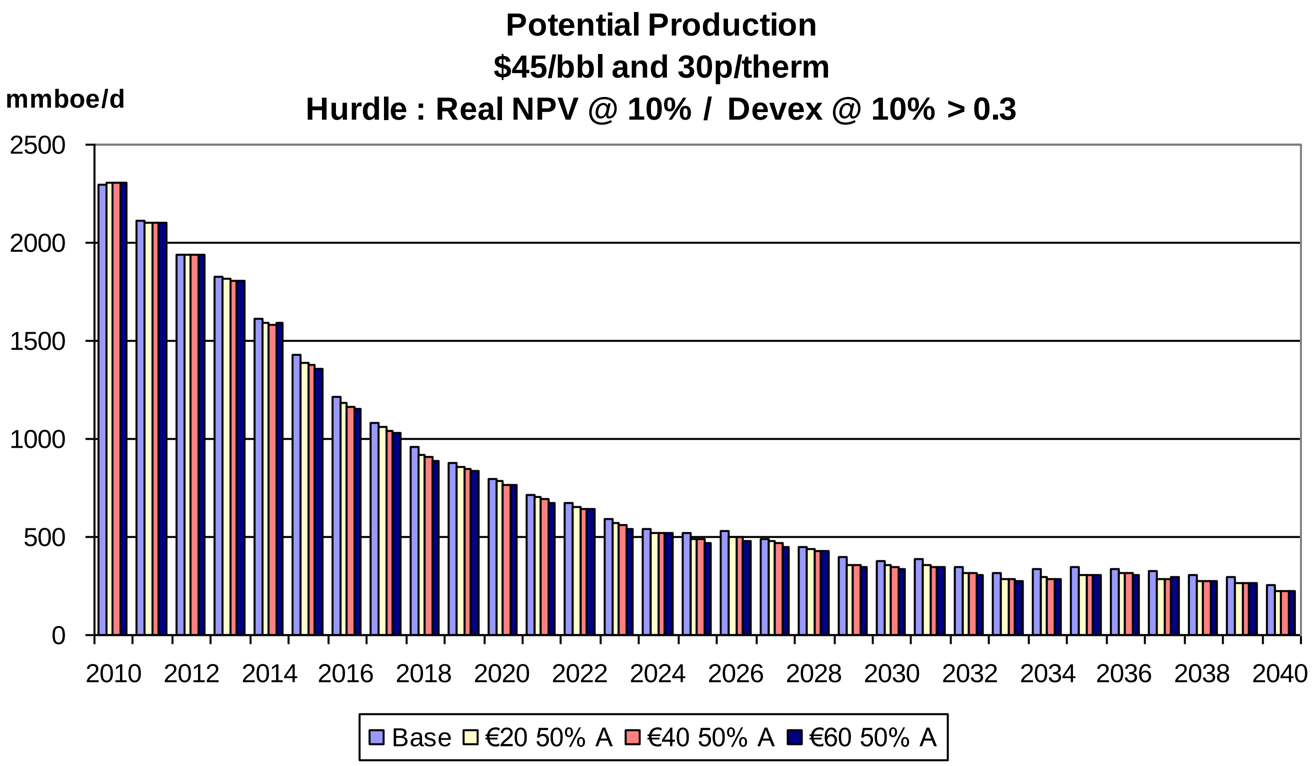


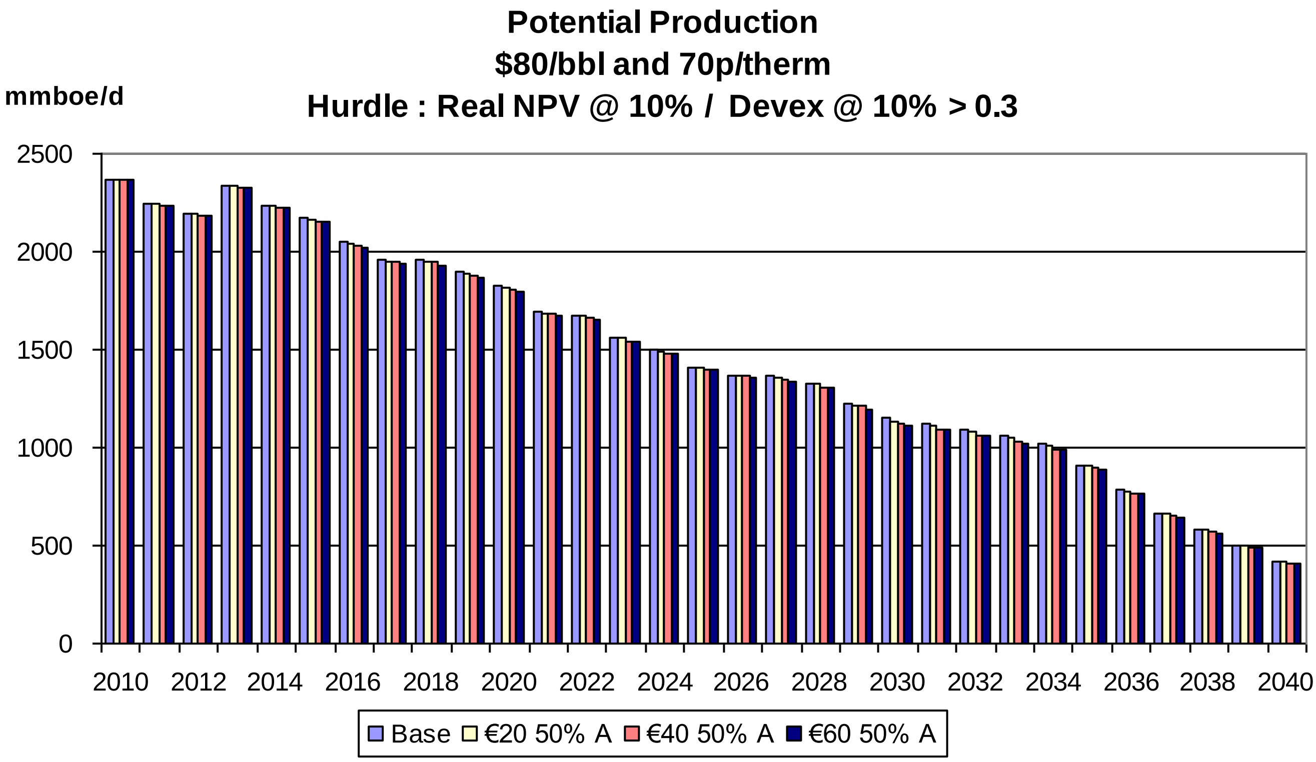
Chart A.4 shows production at $60, 50 pence before and after the imposition of Phase III obligations in the case where 50% of emissions arise from electricity generation. With EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 1876mmboe/d in 2015, 1232mmboe/d in 2020, 795mmboe/d in 2030, and 412mmboe/d in 2040. With a CO_2 price of €40/t production could be 1848mmboe/d in 2015, 1212mmboe/d in 2020, 788mmboe/d in 2030, and 399mmboe/d in 2040. With a CO_2 price of €60/t production could be 1845mmboe/d in 2015, 1207mmboe/d in 2020, 783mmboe/d in 2030, and 393mmboe/d in 2040.

Chart A.5



At the $45, 30 pence price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 1393mmboe/d in 2015, 785mmboe/d in 2020, 355mmboe/d in 2030, and 227mmboe/d in 2040. With a CO_2 price of €40/t production could be 1373mmboe/d in 2015, 768mmboe/d in 2020, 351mmboe/d in 2030, and 227mmboe/d in 2040. With a CO_2 price of €60/t production could be 1354mmboe/d in 2015, 766mmboe/d in 2020, 340mmboe/d in 2030, and 228mmboe/d in 2040.

Chart A.6



At the $80, 70 pence price, if 50% of emissions arise from electricity generation, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 2163mmboe/d in 2015, 1817mmboe/d in 2020, 1131mmboe/d in 2030, and 416mmboe/d in 2040. With a CO_2 price of €40/t production could be 2157mmboe/d in 2015, 1801mmboe/d in 2020, 1118mmboe/d in 2030, and 413mmboe/d in 2040. With a CO_2 price of €60/t production could be 2153mmboe/d in 2015, 1797mmboe/d in 2020, 1115mmboe/d in 2030, and 411mmboe/d in 2040.

Chart A.7

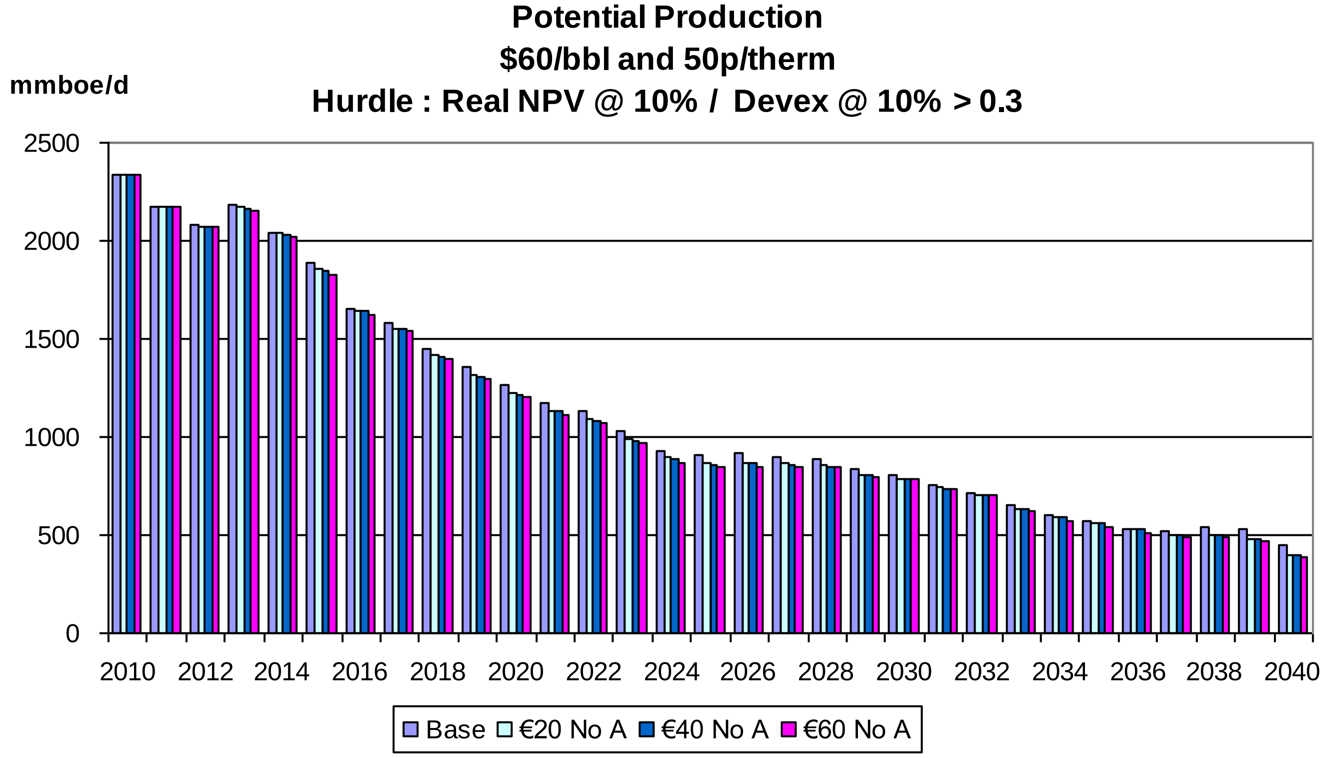
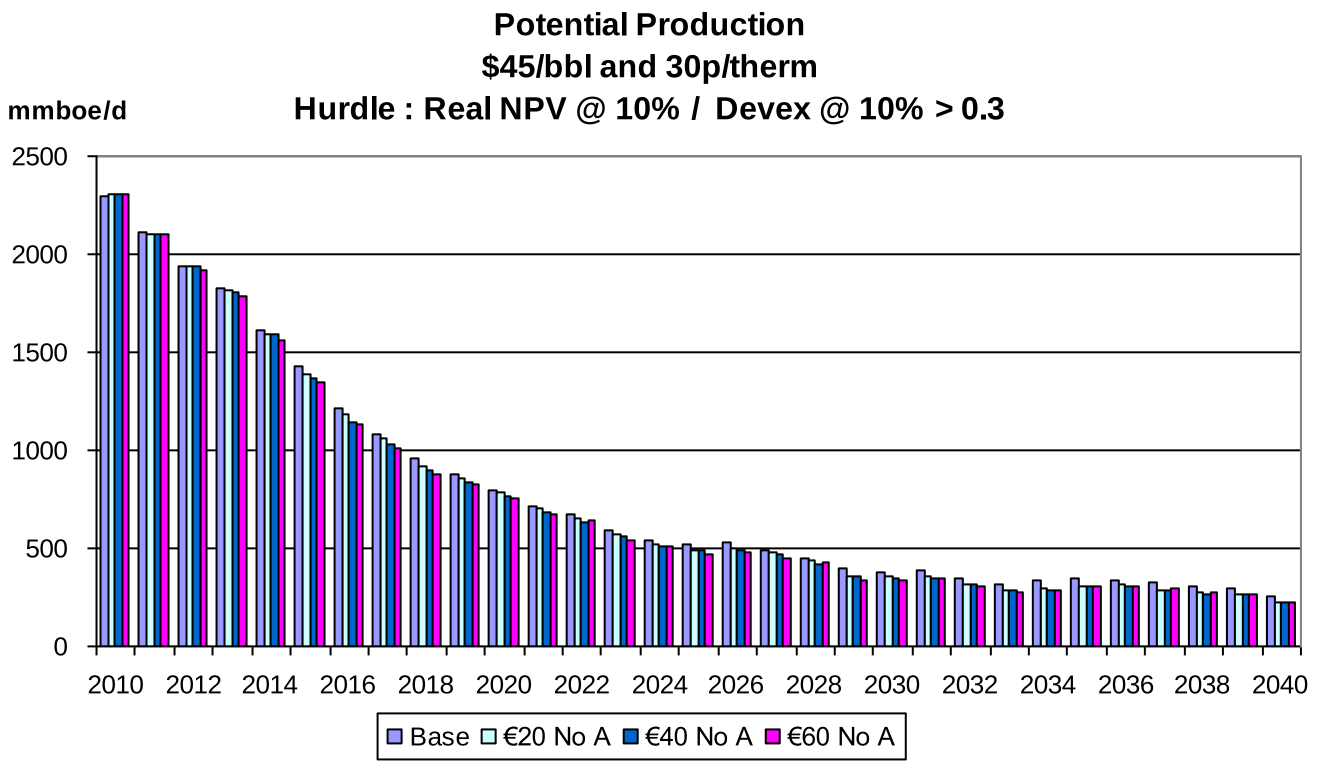


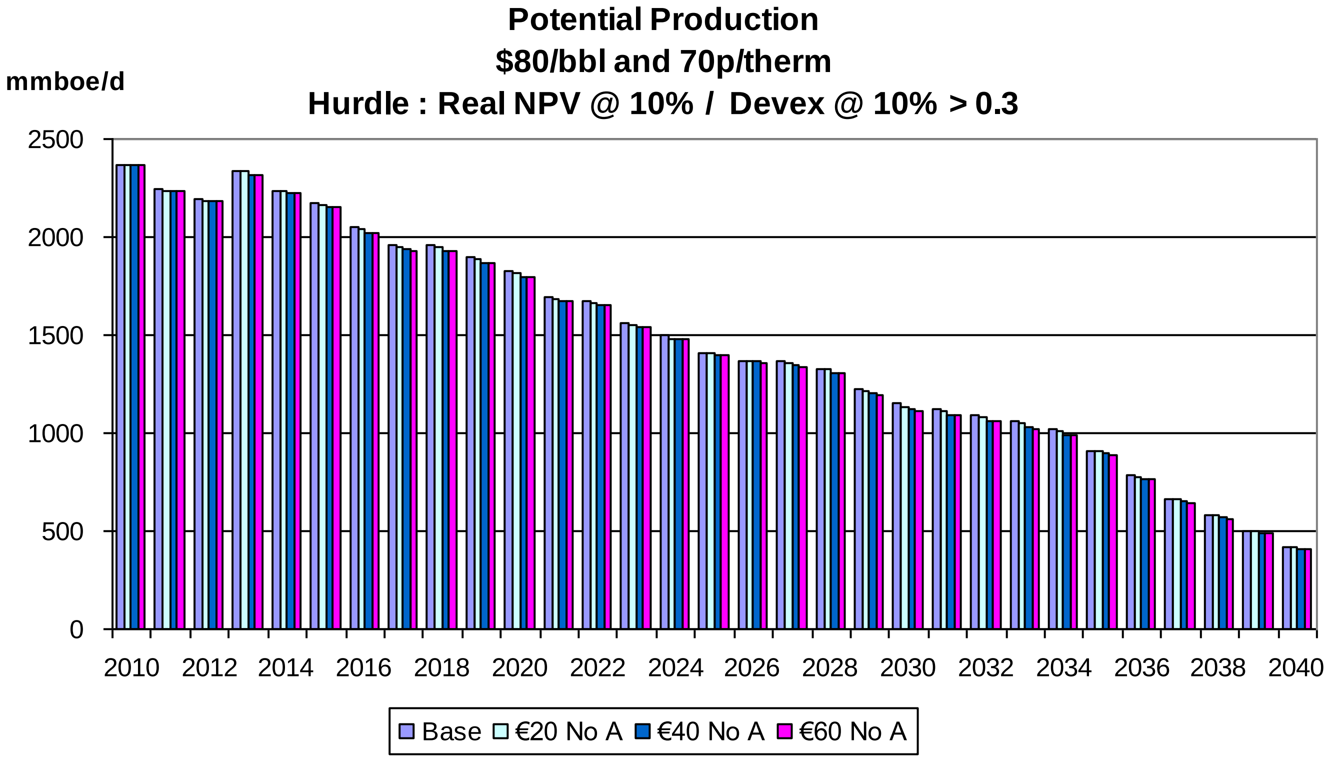
Chart A.7 shows production when no free allowances are available. At the \$60, 50 pence price, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 1861mmboe/d in 2015, 1222mmboe/d in 2020, 789mmboe/d in 2030, and 399mmboe/d in 2040. With a CO_2 price of €40/t production could be 1843mmboe/d in 2015, 1211mmboe/d in 2020, 788mmboe/d in 2030, and 399mmboe/d in 2040. With a CO_2 price of €60/t production could be 1824mmboe/d in 2015, 1201mmboe/d in 2020, 782mmboe/d in 2030, and 393mmboe/d in 2040.

Chart A.8



At the $45, 30 pence price, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 1393mmboe/d in 2015, 785mmboe/d in 2020, 355mmboe/d in 2030, and 227mmboe/d in 2040. With a CO_2 price of €40/t production could be 1365mmboe/d in 2015, 765mmboe/d in 2020, 348mmboe/d in 2030, and 226mmboe/d in 2040. With a CO_2 price of €60/t production could be 1344mmboe/d in 2015, 760mmboe/d in 2020, 340mmboe/d in 2030, and 228mmboe/d in 2040.

Chart A.9



At the $80, 70 pence price, with EU ETS costs imposed in Phase III and a CO_2 cost of €20/t daily production could be 2161mmboe/d in 2015, 1815mmboe/d in 2020, 1130mmboe/d in 2030, and 416mmboe/d in 2040. With a CO_2 price of €40/t production could be 2153mmboe/d in 2015, 1798mmboe/d in 2020, 1118mmboe/d in 2030, and 413mmboe/d in 2040. With a CO_2 price of €60/t production could be 2158mmboe/d in 2015, 1797mmboe/d in 2020, 1116mmboe/d in 2030, and 411mmboe/d in 2040.