

# NUCLEAR POWER GENERATION COST BENEFIT ANALYSIS

## Main messages

This note attempts to provide answers to the following questions:

- What is the scope for new nuclear power generation given the existing generation capacity stock and its likely evolution?
- What are the costs and benefits associated with nuclear relative to a do nothing case where new investment in electricity generation is likely to flow to gas fired plant?

The answers to these questions may be summarised as follows:

- Should the private sector take commercial decisions to invest in new nuclear, the economic analysis suggests that there is scope for adding a relatively small amount of new nuclear capacity in the period to 2025.
  - Nuclear new build could be added to replace existing nuclear plants scheduled for closure; the bulk of the existing fleet will have reached the end of its design life by 2025.
  - In addition, new nuclear capacity might be added to meet demand growth. This would require switching current gas fired baseload plant to operation as mid-merit or peaking plant.
  - It is likely that the first new nuclear plant could be added by around 2021, if not before, assuming an eight year pre-development period (for pre licensing, public enquiry, licensing, etc.) starting in 2007, and six years construction.
- Investment in new nuclear capacity can be justified economically in some – but not all - the states of the world considered in this analysis.
  - Adding new nuclear capacity could help to reduce forecast carbon emissions, and to reduce the level of forecast gas consumption / imports.
  - Within power generation, new nuclear appears to be a cost effective means for meeting carbon emissions reduction targets. Adding new nuclear capacity would not preclude investment in other forms of low carbon generation.
  - Investment in nuclear new build would result in carbon abatement cost savings sufficient to offset the nuclear cost penalty relative to gas fired plant in a central gas price scenario.
  - Adding new nuclear plant would also partially mitigate risks associated with dependence on imported gas. In particular, costs associated with insuring against the risk of fuel supply interruption (e.g. through adding gas storage capacity) could be reduced as nuclear plant is added. Investment in new nuclear capacity would also provide a hedge against the risk of high gas prices.
  - Nuclear investment is not justified at the higher end of the range of costs, or in a low gas price world, or in a central gas price world where there is no carbon price.
- Keeping the door open for investment in new nuclear capacity would seem to be a low risk option from an economic point of view.

- The risk of high nuclear costs could be limited through design of the regulatory framework (e.g. through pre licensing of plant designs, and other rationalising of the planning process).
- If carbon reduction continues to be a Government objective, it is likely that the carbon price will be sufficiently high to justify nuclear investment, except in a low gas price world.
- The Government may want to attach more weight to the benefits of adding nuclear capacity in a high gas price world rather than costs in a low gas price world.
- The resource cost in keeping the door open to new projects is limited. Financial liability for the Government would be limited under the assumption that any projects will be delivered on a commercial basis.

## **Executive Summary**

*The analysis is economic rather than financial, and covers the range of costs and benefits. It does not attempt to monetise expected accident costs, although these would not be sufficiently large to change the results of the analysis.*

The approach in this analysis is to attempt to look at the range of costs and benefits associated with investment in new nuclear generation capacity. In theory, if the benefits exceed costs, it would be a good idea for the Government to enable (if not necessarily directly support) new nuclear build. If the costs exceed the benefits, then such a policy would, in theory, not be justified.

The analysis is economic rather than financial and, as such, cannot be used as a basis for determining likely commercial appetite for bringing forward nuclear projects. It would be for the private sector to conduct financial analysis as part of project due diligence and to bring forward projects accordingly. The aim of this analysis is to determine whether there is potential benefit in keeping the door open for such projects.

Costs and benefits have been accounted for as fully as possible. The analysis considers resource costs associated with nuclear plant relative to alternatives of gas fired generation and other technologies. It includes valuation of environmental benefits (there are carbon emission reductions to be gained from adding nuclear rather than gas fired capacity) and security of supply benefits (nuclear power is subject to lower probabilities of fuel supply interruption than gas fired generation).

A proviso is necessary: the analysis does not attempt to monetise all costs and benefits. Specifically, a monetary value associated with potential accidents is not estimated. Evidence suggests that the likelihood of such accidents is negligible, particularly in the UK context.<sup>1</sup> Though accident risk should not be dismissed, the

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<sup>1</sup> The literature suggests a range for the probability of major accidents (core meltdown plus containment failure) from  $2 \times 10^{-6}$  in France, to  $4 \times 10^{-9}$  in the UK. The associated expected cost is estimated to be of the order £0.03 / MWh to £0.30 / MWh depending on assumptions about discount rates and the value of life; using the figure at the top end of this range would not change the results of the cost benefit analysis. Introducing risk aversion, the results of the cost benefit analysis in the central case (defined in Section 3 below) would be robust for a risk aversion factor of 20 at the highest

assumption is that this can be managed through design of regulatory and corporate governance arrangements for the nuclear industry.<sup>2</sup>

*The analysis identifies scope for replacing existing capacity by adding 6 GW of new nuclear capacity by 2025 in the base case. This is purely illustrative for the purposes of this cost benefit analysis; investment decisions rest with the private sector.*

Existing nuclear power stations with 3.5GW of capacity are scheduled to close between 2018 and 2025. This figure rises to 6GW if some of the plant due to close in the period before 2018 has life extension such that it closes between 2018-2025. There is scope to replace this 6GW of retiring plant with new nuclear capacity over the same period. This is illustrative for the purposes of the cost benefit analysis. The analysis does not attempt to judge how many (if any) new nuclear power stations should be built over a certain period; it will be for the private sector to make these commercial decisions.

New nuclear capacity might also be added to meet demand growth. It is important to recognise here that it is unlikely to be economic to operate nuclear plant as non-baseload. Given this constraint, adding nuclear capacity to meet demand growth would require existing gas fired plants switching from baseload to mid merit / peaking operation. Actually this might be attractive from an economic point of view as it is likely that the thermal efficiency of existing gas fired plants will decline with age, something which would favour operation at lower load factors. There would be scope for adding *up to* 8 GW of new nuclear capacity to meet demand growth in the period 2018-2025.

The base case assumption in the analysis is that the first new nuclear plant could be added from 2021, with subsequent plants added at twelve to eighteen month intervals. This assumption allows for a pre-development of eight years starting in 2007, and a construction period of six years. It reflects the possibility that there may be a resource constraint, both as regards capacity of the UK construction industry, and as regards the ability / willingness of investors to add nuclear new build in the UK given demand for new nuclear capacity in other markets (e.g. China, India). Under this base case assumption, around 6 GW of new capacity could be added before 2025; the resulting stock of total nuclear capacity would not exceed the current level. This base case assumption reflects the potential for new nuclear capacity before 2025; this is illustrative, and it will be for the market to make investment decisions.

*A range of nuclear costs based on studies, market data and projects under development / implementation is considered. Alternative assumptions on nuclear generation costs are considered in the context of alternative scenarios for gas and carbon prices.*

The analysis highlights considerable uncertainty surrounding economic appraisal of possible nuclear investments. This stems from various sources, including uncertainty as regards nuclear construction costs and gas prices.

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estimated value for the expected accident cost. For a summary of the relevant literature, see “Externalities of Energy (ExternE), Methodology 2005 Update”, European Commission.

<sup>2</sup> This assumption is similar to the position of the Sustainable Development Commission, see “The role of nuclear power in a low carbon economy”, SDC position paper, March 2006.

The approach is to model uncertainty and to show the extent of economic viability under a range of scenarios, particularly more pessimistic scenarios for nuclear (high nuclear construction costs, low gas prices, low carbon prices). The range of scenarios covers the range of cost estimates provided in various studies of nuclear generation, and the range of the DTI's fossil fuel price forecasts.

The central case cost of new nuclear power generation is assumed to be around £38 / MWh. The main cost drivers are construction and financing costs, giving an assumed capital cost of £25 / MWh; this is significantly higher than the capital cost for the project currently under implementation to add a new nuclear plant in Finland. Other categories of cost are small in comparison: fuel costs are around £4 / MWh, and Operation and Maintenance costs are roughly £8 / MWh. Back end costs (decommissioning and waste management), whilst potentially of a large order of magnitude far into the future, would need only a relatively small annual contribution over time to ensure that the required amount is available. No decisions have been taken on the specific mechanism required.

The central gas price scenario models a world where the current market situation prevails, and the gas price remains linked to the oil price. Whereas the gas price has been around 20 pence / therm on average over the last decade, the average price in 2005 was 42 pence / therm. Going forward the central gas price remains high by historical standards, based on an assumed oil price of \$40 / bbl. The high gas price scenario models a world where the oil price remains around \$70 / bbl. The low gas price scenario models a world where there is increased competition in the gas market, resulting in decoupling of the gas price from the oil price, and a falling of the gas price towards marginal cost.

Regarding carbon prices, the range covered in the analysis models worlds where: there is no commitment to carbon reduction (then the carbon price is Eur 0 / tonne); there is some commitment, but carbon reduction targets are such that abatement costs remain low (Eur 15 (£10) / tonne of CO<sub>2</sub>); there is ongoing commitment to carbon reduction, resulting in a carbon price in line with the first quarter 2006 UK market price (Eur 25 [£ 17] / tonne of CO<sub>2</sub>); there is ongoing commitment to carbon reduction, with tightening targets resulting in increased abatement costs (Eur 36 [£ 25] / tonne of CO<sub>2</sub>).

*Nuclear generation has a small cost penalty relative to gas fired generation in the central case.*

Gas fired generation has a narrow cost advantage over new nuclear generation in the central gas price scenario, and this advantage becomes greater as the gas price falls and / or the nuclear cost increases. Nuclear generation has a cost advantage in a high gas price scenario and in a low nuclear cost scenario.

*Carbon emissions reductions are significant relative to gas fired plant*

The annual carbon emissions reduction from investing in a GW of nuclear plant is approximately 2.5 million tonnes of CO<sub>2</sub> (700,000 tonnes of carbon) / GW compared to investment in gas fired plant, and after allowing for emissions from construction of

nuclear plant and mining / processing uranium (“lifecycle emissions”); a programme to add 6 GW of new nuclear capacity would reduce annual emissions by around 15 million tonnes of CO<sub>2</sub> (4 million tonnes of carbon). Valuing emissions savings at a CO<sub>2</sub> price of Eur 36 [£25] / tonne gives a present value benefit of around £1.4 billion / GW over forty years from nuclear new build.

As regards contribution to meeting target emissions, nuclear generation is cost effective when compared with other forms of low carbon generation. Given the need for capacity both before and during the period when new nuclear capacity could be added to the system, and constraints as regards the speed with which a new nuclear programme could be implemented, investment in new nuclear capacity would not preclude investment in other forms of low carbon generation.

*Security of supply benefits are a smaller order of magnitude than environmental benefits.*

Investment in new nuclear capacity would reduce the level of total gas consumption and gas imports in 2025. For illustrative purposes, a programme to add 6 GW of new nuclear capacity by 2025 would reduce total forecast gas consumption in 2025 by around 7%.

In a world where gas fired plant is added to the power system rather than nuclear plant, this increases vulnerability in the event of a gas supply interruption. Given this vulnerability, the economic option would be to back up gas fired plants with oil distillate switching capability. In the event of a gas supply interruption, gas fired plants would then be able to continue operating by burning oil distillate rather than gas.

If nuclear plant is added rather than gas fired plant, there is no longer the need to maintain back up capability. One benefit of nuclear generation can then be seen as the avoided cost of this capability, estimated to be of the order £100 million / GW. In a more unstable world subject to the possibility of repeated / prolonged fuel supply interruptions, new nuclear generation can be viewed as a hedge either against high gas prices, or high costs of ongoing electricity generation using oil.

*Welfare balance is positive in central / high gas price, central / low nuclear cost worlds, and negative in low gas price / high nuclear cost worlds.*

The welfare balance associated with nuclear new build relative to a do nothing scenario where gas fired plant is added to the power system is the sum of environmental and security of supply benefits net of any nuclear cost penalties. Welfare balances under alternative scenarios are presented in the summary table below.

The table shows that, even at the high end of carbon prices, the net benefit of nuclear generation is negative at low gas prices or high nuclear costs. In a low gas price scenario, a CO<sub>2</sub> price of Eur 54 [£37] / tonne is required to justify new nuclear generation. In a high nuclear cost scenario, a CO<sub>2</sub> price of just above Eur 36 [£25] / tonne is required in order that the net benefit of new nuclear generation is positive.

Table: nuclear generation welfare balance under alternative gas price, carbon price and nuclear cost scenarios, NPV over forty years, £ million / GW

Carbon price (Eur / tCO <sub>2</sub> )	Low gas price	Central gas, high nuclear	Central gas price	Central gas, low nuclear	High gas price
0	-2100	-1400	-400	<b>900</b>	<b>1400</b>
15	-1500	-900	<b>200</b>	<b>1400</b>	<b>2000</b>
25	-1100	-500	<b>600</b>	<b>1800</b>	<b>2400</b>
36	-700	0	<b>1000</b>	<b>2300</b>	<b>2800</b>

Welfare balance is positive in the central gas price world for a CO<sub>2</sub> price above Eur 10 [£7] / tonne, and in high gas price / low nuclear cost worlds across the range of carbon prices (including a zero carbon price). Under the central gas price and a CO<sub>2</sub> price of Eur 36 [£25] / tonne, the NPV benefit over forty years associated with adding 6 GW of new nuclear to replace the existing capacity would be of the order £6 billion.

*Nuclear generation is likely to be justified in a world where there is continued commitment to carbon emissions reduction and gas prices are at or above 37 pence / therm.*

The economic case against nuclear arises if the probability of low gas prices / high nuclear costs is significantly higher than the probability attached to other scenarios, and / or the CO<sub>2</sub> price is significantly less than the Eur 36 [£25] / tonne value assumed in the analysis.

In the central gas price scenario, nuclear generation is economically justified unless commitment to emissions reduction falls away, in which case the relevant carbon price may become zero. As far as some commitment remains, net benefits associated with nuclear investment are likely to be positive, largely reflecting the environmental benefits of this option.

This continues to be true as nuclear costs increase beyond the range given in the various studies of nuclear generation. In the central gas price scenario, and valuing environmental benefits at a CO<sub>2</sub> price of Eur 36 [£25] / tonne, the economics of nuclear generation remain robust for a nuclear generation cost up to £43.50 / MWh. This is well above the forecast cost of power generation from the Finnish nuclear project currently under construction, by a margin that far exceeds any historical cost overruns associated with nuclear projects (e.g. Sizewell B).

*Economic risks associated with keeping the nuclear door open would appear to be limited*

In summary, the economics of nuclear depend critically on assumptions made about future gas and carbon prices, and nuclear costs. On some sets of assumptions, the nuclear case is positive; in others, negative, so a judgement has to be made about the relative weight to be given to the various scenarios.

In making such a judgement, it is important to note that probabilities associated with many of the various states of the world are endogenous rather than exogenous, and depend on policy decisions. This is true of the carbon price, which will depend on whether the UK remains committed to its goal of long term carbon reduction. To the extent that commitment *does* remain, then higher carbon price scenarios should be given more weight. It is true also for nuclear costs, where policy to improve the planning process would reduce the likelihood of a high nuclear cost scenario ensuing. Regarding gas prices, the weight to be attached to the high gas price scenario is again a policy decision. Where the Government is averse to the risk of high gas prices, other things equal, more weight should be attached to this scenario.

Within these likely scenarios nuclear generation yields positive net economic benefits. An additional factor in support of this argument is that the likelihood of low nuclear costs would increase for a programme of new build as opposed to a one off plant addition; the analysis of the forecast UK capacity balance suggests that there would be scope for a programme.

The resource cost of taking facilitative measures for new nuclear build would be limited initially to work required for improving the planning process, and for elaborating details of waste and decommissioning arrangements. The likelihood is that commercial projects would only be forthcoming in a world where the supporting policy framework as described above is in place, in which case expected economic benefits would be positive.

## 1. Introduction

The approach in this analysis is to attempt to look at the range of costs and benefits associated with investment in new nuclear generation capacity. In theory, if the benefits exceed costs, it would be a good idea for the Government to enable (if not necessarily directly support) new nuclear build. If the costs exceed the benefits, then such a policy would, in theory, not be justified.

Costs and benefits have been accounted for as fully as possible. The analysis considers resource costs associated with nuclear plant relative to alternatives of gas fired generation and other technologies. It includes valuation of environmental benefits (there are carbon emission reductions to be gained from adding nuclear rather than gas fired capacity) and security of supply benefits (nuclear power is subject to lower probabilities of fuel supply interruption than gas fired generation).

The analysis attempts to provide answers to the following questions:

- What is the scope for new nuclear power generation given the existing generation capacity stock and its likely evolution?
- What is the net economic benefit associated with nuclear relative to a do nothing case where new investment in electricity generation is likely to flow to gas fired plant?

These questions are answered within the following structure:

- Section 2 assesses the need for new generation capacity given the current and evolving capacity stock. The discussion here emphasises the fact that new nuclear capacity could only be added in the medium / long term given the substantial lead time for projects; this places a constraint on the timing / magnitude of any future nuclear programme. Of course, it will be for the private sector to make commercial decisions on if or when to invest.
- Section 3 contains a discussion of nuclear costs, and a comparison of nuclear costs with those of gas fired power generation. The analysis recognises the need to allow for the considerable uncertainty associated with nuclear costs and other variables, and the need for a cautious approach to modelling nuclear costs.
- Section 4 considers various perspectives on environmental benefits of nuclear investment. Cost effectiveness of new nuclear generation as regards carbon reduction is compared to cost effectiveness of other forms of low carbon generation. Nuclear carbon reduction is valued at various carbon prices / abatement costs and at the *Social Cost of Carbon*.
- Section 5 estimates security of supply benefits of adding new nuclear capacity. These are modelled as reduced costs of insuring against fuel supply interruption (e.g. costs of adding extra gas storage capacity) that would otherwise be added in a world where investment flows to gas fired rather than nuclear generation.
- Section 6 provides welfare balances – monetised environmental and security of supply benefits net of cost penalties – for nuclear investment under a range of scenarios modelling alternative nuclear costs, gas prices and carbon prices.

## 2. There is a relatively small need for new capacity between 2018-2025

*The economic analysis suggests that new investment should only take place when there is a need for capacity: to replace existing capacity upon retirement and to meet demand growth.*

In general, there are two contingencies where it would be economic to add new capacity:

- When existing capacity is retired. Assuming that there is capacity balance prior to retirement, failure to replace existing plant upon retirement would lead to capacity imbalance.
- As demand grows, there is a need for investment in new generation in order to maintain capacity balance.

The assumption in this analysis is that investment in nuclear plant is only considered when there is a need for new generation capacity. Investment in nuclear power when there is no need for capacity would incur excessive cost and could not be justified economically. It will of course be for the market to make commercial investment decisions.

From a financial perspective, unnecessary investment in new capacity would displace existing plant, leaving investors unable to recoup their investment. The upper bound on displaced investment would reflect the capital cost of gas fired plant, of the order £450 million / GW. In practice this could be lower, to the extent that existing plant would be partially depreciated by the time new nuclear capacity could be added.

*The timeframe for possible nuclear investment: 2018 and beyond.*

Given the long lead-time for nuclear projects, it is realistic that new nuclear plant could come on line only after 2018 at the earliest. This assumes (for the illustrative purposes of this cost benefit analysis) an aggressive schedule based on a six year pre-development period starting in 2007 followed by a five year construction period.

The *base case* assumption in the analysis is that the first new nuclear plant could be added from 2021, with subsequent plants added at twelve to eighteen month intervals, resulting in around 6 GW of new build by 2025.<sup>3</sup> This assumption allows for an eight year pre-development period starting in 2007 followed by a six year construction period. It reflects the possibility that there may be a resource constraint, both as regards capacity of the UK construction industry, and as regards the ability / willingness of investors to add nuclear new build in the UK given demand in other markets (e.g. China, India). This base case assumption reflects the potential for new nuclear capacity before 2025; this is illustrative, and it will be for the market to make investment decisions.

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<sup>3</sup> Capacity of new nuclear plants that might be added in the UK context varies from around 1-1.6 GW; the number of plants comprising a 6 GW programme would vary according to type of plant.

*Adding up to 3.6 GW of new capacity between 2018-2025 would replace existing nuclear plant scheduled for retirement during this period, and more as the life of plant due to retire before 2018 is extended*

Planned plant retirement is summarised in Table 1.<sup>4</sup> The table shows that there is 3.6 GW of existing nuclear capacity scheduled for retirement during the period 2018-2025. Of this, 2.5 GW could potentially be replaced by new nuclear capacity under the base case assumption, and 3.6 GW under the more aggressive schedule above.

This figure rises to 5 GW in the base case as life of existing plants is extended by nine years (i.e. so that plant scheduled to retire before 2021 actually retires in the period 2021-2025). Under the more aggressive scenario, there would be scope for replacing 6 GW of existing plant following nine year life extension. Life extension is likely to be economic given the low nuclear marginal generation cost relative to the electricity price. It is important to note, however, that life extensions have not yet been granted, and that the safety case will be key in any decision as to whether to grant life extensions going forward.

*Existing coal fired plant is scheduled to retire before nuclear could come on line.*

The table shows that 8.3 GW of coal fired plant is due to retire by 2016. This is the plant that has opted out of retrofitting equipment for control of sulphur dioxide emissions required under the EU's Large Combustion Plant Directive (LCPD). 2016 is actually the latest date that this plant can be retired, and it is likely in practice that retirement will occur early. It is unlikely, therefore, that this plant could be replaced by nuclear plant. There is the possibility that opted out plant could be exempted from the LCPD at a later stage, but this is not the current expectation, and decisions about whether to add new capacity should not assume such an exemption.

Table 1: retirement of existing coal fired and nuclear plant in the period 2015-2025, total GW, as scheduled and with life extension

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Coal plant retirement		8.3									
Nuclear plant retirement at planned closure				1.1					2.5		
Nuclear plant		2.4				1.1					2.5

<sup>4</sup> Underpinning the table is the following schedule for closure: Oldbury (2008), Wylfa (2010), Hinkley Point B (2011), Hutton B (2011), Hartlepool (2014), Heysham 1 (2014), Dungeness B (2018), Heysham 2 (2023), Torness (2023).

retirement with two year extension											
Nuclear plant retirement with five year extension		2.4			2.4					1.1	
Nuclear plant retirement with seven year extension			0.98		2.4		2.4				
Nuclear plant retirement with nine year extension					0.98		2.4		2.4		

*Opted in coal fired plant will continue to operate beyond 2025.*

Around 20 GW of existing coal plant has opted in to the LCPD. Given that this plant is largely over thirty-five years old, and given the cost of investments for compliance with the LPCD, it is unlikely that these would proceed without investments in rehabilitation and life extension. Assuming that the life of opted in plant is extended, this would be unlikely to retire during the period under consideration, and there would seem to be limited scope for replacement of opted in plant by new nuclear plant. The same is true for existing gas fired plant, the bulk of which was commissioned in the 1990s with at least forty year life.

*The economic analysis suggests that there may be scope for adding nuclear capacity to meet demand growth.*

One other option would be that nuclear plant is added to accommodate demand growth. Whilst new capacity need only be added to meet *peak* demand growth, and noting that it is unlikely to be economic to operate nuclear plant as non-baseload, it would be feasible to add nuclear plant and to switch existing gas fired plant from baseload to peak operation. This option may be attractive from an economic point of view as the thermal efficiency of existing gas fired plant declines with age.

Taking the UEP demand forecast as a starting point, the assumption is of annual demand growth around 1%.<sup>5</sup> This places an upper bound of 1% on the need for annual

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<sup>5</sup> See “UK energy and CO2 emissions projections, updated projections to 2020”, Department of Trade and Industry, February 2006.

incremental capacity, translating to around 0.6 GW / year. Actually less new capacity would be required to meet this level of demand growth if energy efficiency measures are being undertaken, in which case peak demand might grow less than energy demand.

It is important to recognise that nuclear plants which might be added in the UK context typically have capacity greater than 0.6 GW (from 1 GW to 1.6 GW), and are therefore larger than required to meet demand growth.<sup>6</sup> This does not necessarily undermine the economic case for nuclear investment (the economic case is discussed in detail below). It does, however, suggest that adding nuclear plant could lead to a reduction in the system reserve margin. For example, if it is known that nuclear plant will come on line in 2021, the incentive may be to invest less in the period before 2021 than would otherwise be the case if demand growth were to be accommodated through addition of smaller gas fired plant.

To the extent that tightening of the reserve margin would lead to small power price impacts, these would be muted in a scenario with higher demand growth. Under a more aggressive assumption of 1.5% annual demand growth – providing an upper bound on the amount of nuclear investment to meet demand growth - this would create annual demand for new capacity of the order 1 GW, summing to 5 GW of new capacity required from the base year (2021), and 8 MW from 2018.

*In summary, the economic analysis suggests that there would be scope for adding at least 6 GW of new nuclear capacity over the period 2021-2025, and there would be need for up to 14 GW of new capacity (nuclear or other) over the period 2018-2025. This is illustrative, for the purposes of this cost benefit analysis.*

To reiterate, the base case assumption is that the first nuclear plant could be added in 2021, and that subsequent plants could be added at twelve to eighteen month intervals after that time, resulting in possible nuclear new build of 6 GW by 2025. The discussion above suggests that from an economic point of view, there would be a need to add at least 6 GW of plant in the period 2021 – 2025. This is an economic analysis. It will be for the private sector to make commercial decisions on if or when to invest in new nuclear.

The base case assumption is therefore consistent with the forecast need for new capacity in the period 2021-2025; if 6 GW of new nuclear capacity were to be added, the resulting nuclear capital stock would not exceed the current level. For illustrative purposes, under a more aggressive schedule for adding the first and subsequent nuclear plants, there could be scope for nuclear contributing more to the required need for new capacity of up to 14 GW between 2018-2025 to replace existing capacity and to meet demand growth.

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<sup>6</sup> This does not preclude the possibility that smaller plants will become available in a time frame consistent with the period under consideration in this analysis .

### 3. The cost of new nuclear power generation

#### *Studies and market data on new nuclear costs*

*Nuclear costs are uncertain. This is reflected in a range of cost estimates in the literature, driven by variation in construction and financing costs. The average of the range is around £30 / MWh.*

There is considerable uncertainty as regards the forecast cost of new nuclear power generation. Cost data from detailed studies summarised in Table 2 shows that this applies to construction costs (ranging from £500-2,500 / kW), construction time (60-120 months), and cost of capital (5-10%).

It is these differences in capital costs that drive differences in levelised costs.<sup>7</sup> Though there is a range given for other cost components - fuel costs range from £1.50-7.00 / MWh, operating costs from £3.50-11.00 / MWh, and decommissioning costs £200-500 million – these have a small share in the net present value of total cost even at low discount rates.

It is important to note that some of the extremities for the ranges in the table are unlikely to be relevant for the UK context going forward. The most obvious example is Sizewell B, which may be seen as an outlier as regards capital costs. One contributing factor in this case related to the fact that Sizewell B was based on a new design. This was compounded by the fact that there were a number of costly design changes imposed by regulatory authorities during the construction process. In addition, the project sponsor for the Sizewell B project was a public sector company operating under a soft budget constraint; evidence suggests that cost inflation might be expected under these circumstances.

Going forward, it might be expected that costs for new reactor designs would fall after the first plant has been constructed; the cost premium in the case of Sizewell B would be diluted for a programme. Costly changes in safety standards during construction might be avoided through improvement of the regulatory framework and, in particular, through setting out detailed design standards prior to commencement of construction. Capital costs of more modern reactor designs are expected to be lower than those for Sizewell B, given that modern designs have a relatively small footprint and require less equipment.

Additional reasons provided by the Sustainable Development Commission<sup>8</sup> as regards why future costs are expected to be lower than those for Sizewell B include:

- Big-project management techniques have improved over the last fifteen years
- There is likely to be a more competitive, international process for letting a nuclear construction contract
- A consortium taking on a nuclear project would probably offer terms that are closer to a turnkey (fixed price) contract than the cost-plus contracts that were characteristic of past nuclear construction.

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<sup>7</sup> Levelised cost is defined as annuitised capital cost – including decommissioning - plus operating cost.

<sup>8</sup> See Sustainable Development Commission, *Ibid.*

- As a future nuclear project would be in the private rather than the public sector, there is likely to be a closer fit between risk and consequence: in other words, the prime contractors will have better incentives to control costs because they will suffer greater consequences in profit terms if they fail to do so.

In 2002 the Government's Performance and Innovation Unit reviewed Sizewell B together with the evidence on nuclear generation more generally, and suggested that likely levelised costs going forward would be in the range £22-38 / MWh, rather than the £60 / MWh cost of Sizewell B.

Table 2: summary of cost estimates for nuclear generation<sup>9</sup>

	Construction cost (£/kW)	Construction time (months)	Load factor (%)	Fuel cost (£/MWh)	O&M (£/MWh)	Decommissioning cost	Cost of capital (% real)	Levelised cost (£/MWh)
Sizewell B	2,250-3,000	86		7	11.5			60-
Rice University								50
Lappeenranta Univ.	1,300			2	5		5	16
Performance and Innovation Unit (2002)	<840						8-15	23.1-37.9
Scully Capital (2004)	500-800 (excludes owners and interest during construction [IDC] costs)	60	90	2.8	5.5	£260 million		20 – 23
MIT (2002)	1,111	60	75 - 85		8.3		11.5	37 – 44
Royal Academy of Engineers (2004)	1,150	60	85	4	4.5	Included in construction cost	7.5	23
Chicago University (2004)	555-1,000 (excludes IDC)	84	85	3	5.6	£195 million	12.5	29-39
Canadian Nuclear As	1,067	72		2.5	4.9	£3 / MWh	10	33
IEA/NEA (2005)	590 – 1,350	60-120	85	1.5-6.5	3.8-9		5-10	12-38
OXERA (2005 money values)	1,150-1,625		95	3	3.5	£500 million		Internal rate of return 8% - 11% at forecast market price
DGEMP (2003)	1,137	60					5 - 10	13.5-21.6
OECD (2003 money values)							10	25 – 33

<sup>9</sup> Sources: "The economics of nuclear power: analysis of recent studies", by Steve Thomas, July 2005; "Prospects for replacement nuclear in the UK", presentation by British Energy to the DTI.

Another example of data that is not relevant to the UK context going forward is the Rice University study, which relates to forecast costs in the Japanese context; relatively high forecast costs here may reflect relatively high costs of electricity and high costs more generally in Japan. Regarding the extremities of the range for the IEA studies, the low costs relate to Eastern Europe, and the high costs relate to Japan. Examples from Eastern Europe are not relevant to the UK context given differences in labour market conditions, possible exchange rate distortions, and different accounting standards used in formulating cost estimates.

Excluding Sizewell B and the Rice University study, the range of levelised costs in the table is £12.00-38.00 / MWh. Including Sizewell B and the Rice University studies increases the upper bound on the range to £60.00 / MWh, but has only a limited impact on the average, increasing this from £29 to £32 / MWh.

This average is close to the average of cost estimates that have emerged from the market in the context of the Energy Review, summarised in Table 3. The most detailed analysis here is that carried out by PB Power for the Royal Academy of Engineers, suggesting a range of new nuclear costs from £22-36 / MWh.<sup>10</sup> Other estimates tend to fall in this range, with the average of all estimates in the table equal to £30 / MWh.

Table 3: 2006 estimates of nuclear new build costs in the UK context<sup>11</sup>

Institution	New entry price (£/MWh)
Centrica	23 – 34
Deloitte	36
E.ON	24 – 40
HSBC	27
Ilex	24-45
KPMG	23
Lehmans	33
Morgan Stanley	28-32
PB Power	22-36
UBS	27
Average	30 (assuming midpoints for the above ranges)

*Estimated overnight construction cost for the Finnish Okiluoto project is around £1050 / kW. For a French programme, estimated overnight construction cost is around £900 / kW.*

The Finnish Olikiluoto project (herinafter the *TVO Project*) is probably the highest profile example of a nuclear new build project currently under implementation. This project is sponsored by a French – German consortium, with finance secured against long term power off-take agreements signed with large industrial consumers.

<sup>10</sup> See “Powering the nation: a review of the costs of generating electricity” by PB Power, March 2006.

<sup>11</sup> Sources: PB Power, *Ibid*; “Keeping the lights on: nuclear, renewables and climate change”, by the Environmental Audit Committee, March 2006; “2020 vision, the next generation, meeting UK power generation objectives in 2020 – a strategic insight”, by Deloitte, February 2006; “Nuclear: core of the matter”, Morgan Stanley Equity Research, September 2005; “Q Series: the future of nuclear”, UBS Investment Research, March 2005; and various presentations to the DTI.

Construction of the 1,600 MW European Pressurised Water Reactor (EPR) will be carried out under a turnkey (fixed price) contract.

Various cost estimates have been reported for new nuclear generation in the Finnish context, with levelised cost estimates ranging from £15-22 / MWh. The Finnish studies relate to PWR and BWR reactors rather than the EPR reactor currently under construction. French estimates for the levelised cost of an EPR reactor range from £13-21 / MWh. Forecast overnight construction costs for a French programme to add 10 reactors are around £900 / kW.<sup>12</sup> It is understood that the cost for the TVO Project is of the order Euro 3 billion, which translates to an overnight capital cost of around £1050 / kW.<sup>13</sup>

In May 2006 it was announced that a new EPR reactor will be added in Flamanville, France, with construction to start in 2007, and operation scheduled to commence in 2012. The cost quoted for this plant has been revised up from Euro 3 billion to Euro 3.3 billion in order to reflect recent increases in the price of steel.

The EPR is one candidate for addition in the UK context. Amongst other candidates is the AP1000, developed design developed by Westinghouse and approved by the US Nuclear Regulatory Commission in Autumn 2004; there are, however, currently no contracts in place for construction of AP 1000 reactors. American and Canadian LWR plants could also be added in the UK context, although again, these are at an early stage of development, and are yet to gain regulatory approval. The fact that designs are at least somewhat untested suggests that there must be a degree of uncertainty about what costs would be in the UK context if there were to be a new nuclear programme.

This stems in part from the possibility that much of the available data probably originates from the nuclear industry. One argument is that costs may have been underestimated, particularly at the pre-contract stage where the industry may be trying to win support for nuclear new build. For the project under implementation in Finland, it could be argued that the construction costs have either been underestimated, or that the contract price was discounted as part of a wider marketing strategy by the equipment vendor. It may also be argued that costs are sensitive to planning regimes, and that standards in the UK context may differ from those in other countries. Differences in labour market conditions between the UK and other countries might also lead to differences in forecast relative costs for the UK.

The level of uncertainty about costs is not, however, unbounded. Both new reactor designs are modifications of earlier designs, incorporating innovations to reduce costs

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<sup>12</sup> This data, together with data on the TVO Project is taken from “The role of nuclear power in a low carbon economy: the economics of nuclear power”, prepared by NERA for the Sustainable Development Commission in March 2006.

<sup>13</sup> This cost includes interest during construction (IDC) and fuel for the first operating cycle. In estimating the overnight cost, IDC at a rate of 2.6% over a five year construction period is subtracted from the total construction cost. This rate is believed to be the debt cost for at least some tranches (e.g. provided by export credit agencies) of the finance, see NERA, *Ibid*. To the extent that commercial banks providing debt for the project will charge more than 2.6%, the level of IDC subtracted from the total will be too low, and the estimated overnight construction cost too high. Fuel costs for the first operating cycle – assumed to be 18 months - are valued at a rate of £4 / MWh and subtracted from the total construction cost.

(simplified designs requiring less equipment, and increased size to exploit potential scale economies); the fact that new designs are *evolutionary* provides a reasonably sound basis for cost forecasts.

As regards planning, it is not clear that designs approved in western European and US countries should not be approved in the UK context. To the extent that approval would require modification, expected cost increases would be contained if modifications were agreed in the pre-development stage of project implementation, rather than during construction.

Wage convergence as a result of increased labour market integration in Europe suggests that cost estimates for other European countries are likely to be relevant in the UK context. This applies more given that continued convergence is likely to occur through the period to possible commencement of new nuclear plant construction.

On balance, the fact that there is cost uncertainty over nuclear new build construction costs does not preclude cost benefit analysis of this option. Rather, it suggests that the methodology should adequately reflect uncertainty. The assumption in this analysis is that, whilst there is a degree uncertainty associated with costs, a plausible range for forecast costs can be specified.

***The approach to modelling uncertainty: robustness of economics in pessimistic cases***

*The analysis covers a range of scenarios for nuclear costs, gas prices and carbon prices.*

One approach in a situation characterised by uncertainty would be to undertake Monte Carlo analysis of expected net benefits. In the situation under consideration, however, it would not be feasible to do a meaningful analysis of this type given the lack of information about underlying probability distributions, particularly as regards nuclear costs.

Given the constraints, the approach taken is to model a range of cases for alternative values of key variables. Probabilities are not assigned to the various scenarios: doing this would suggest a spurious degree of information about underlying probability distributions for key variables. It might also be inappropriate given that at least some probabilities would be *endogenous* rather than *exogenous*: nuclear costs would vary depending on the planning regime; carbon prices will depend on the Government's policy towards carbon reduction; the weight (as opposed to the probability) attached to a high gas price scenario will depend on the Government's attitude to risk (greater weight would be given as the Government is more risk averse to high gas prices).

Given the uncertainty, and the difficulties associated with attaching probabilities to alternative states of the world, the approach is to assess the extent to which the economics of nuclear power remain robust in pessimistic scenarios (e.g. can nuclear cost be justified in a high nuclear cost scenario on the basis of environmental or security of supply benefits?).

*The central case assumption on nuclear overnight construction cost adds a 20% premium to the Finnish project, and a 20-40% premium to French programme costs. Financing is assumed to be provided at market rates.*

The assumptions on nuclear cost draw on the various studies and market data cited above. The central case nuclear cost assumption reflects a 30% levelised cost premium on the average of the studies, and a 30% premium on the market data.

Regarding capital cost – this is the main driver of total cost – the assumption is of an overnight (i.e. excluding owner's cost and IDC) construction cost equal to £1,250 / kW. In comparison with the TVO Project, the central case construction cost adds a 20% premium to allow for:

- The possibility that costs of this project have been discounted as part of a wider marketing strategy.
- The possibility that costs have been underestimated.
- Potentially more onerous regulatory requirements in the UK as opposed to the Finnish context, notwithstanding arguments above that planning process design can reduce pre-development and construction costs.

The central case is regarded as being conservative, particularly because the cost for the TVO Project relates to one plant rather than a nuclear programme. Unit construction costs for a programme are estimated to be 25% or more lower than for the addition of one plant.<sup>14</sup> The differential reflects one off costs (e.g. finalising a design to meet national regulatory requirements) and possible scale / scope economies associated with programme build (e.g. through batch production of components). The central case assumption builds in a 40% premium relative to the French forecast overnight cost for a 10 GW programme.

In order to compare the central case assumption with the Flamanville project, a construction cost estimate is required for the latter. It is not, however, straightforward to unravel the Flamanville construction cost estimate from the total cost estimate. The total cost estimate for Flamanville excludes interest during construction, but includes *all* design costs associated with the EPR technology, and may include provision for the regulatory approval process, the public enquiry, the first fuel core, and significant expenditure on transmission network strengthening; all of these costs, which could amount to hundreds of millions of pounds, should be subtracted from the total cost to give an overnight construction cost against which to compare the central case assumption. Adjusting the Flamanville cost down by 25% to allow for design costs gives a construction cost that is 15% lower than the central case assumption.<sup>15</sup>

Two high cost sensitivities are included. One of these – the *central high* case – assumes that the overnight construction cost for the Flamanville project equals the total project cost. This is regarded as being high for the reasons above (the total cost

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<sup>14</sup> See NERA, *Ibid.*

<sup>15</sup> The Flamanville project will be sponsored by Electricite de France (EdF). EdF has stressed that the forecast cost for Flamanville is for one plant rather than a program. The cost adjustment used to move from a French plant to a program is 25%, much of this reflecting the difference in design costs for first and subsequent units. See “EdF to build Flamanville 3”, *Nucleonics Week*, May 2006.

actually includes other costs in addition to overnight costs, and relates to one plant rather than a programme).

The high nuclear cost sensitivity allows for a 30% construction cost over-run relative to the central case. This may be compared to the 35% difference between ordered and actual cost for Sizewell B. As noted above, it is not expected that a cost over-run of the order of magnitude associated with Sizewell B would be experienced in the future. In the UK context going forward, it is assumed that a sensitivity based on 30% above the central case would be adequate to capture possible cost overruns, particularly given that the central case assumption is conservative, and that a new build programme would probably cover more than one unit.

A low nuclear cost sensitivity is included in order to reflect the full range of cost estimates that come from the various studies and market data. Specifically, the low cost sensitivity reflects the possibility that nuclear new build in the UK may occur in the form of a programme, rather than through the addition of one plant (or one each of different technologies). The low cost sensitivity is based on an overnight construction cost estimate at the low end of the range (£900 / kW).

Financing costs assumed in the central case are chosen to reflect conditions in current UK financial markets rather than the low rates at which finance has been provided for the Finnish project. Lower nuclear costs than those assumed in the central case could then result from falling financing costs, particularly if one or more projects were to progress well, thus providing positive signals about project related risks.

### ***Comparing the cost of new nuclear generation with gas fired generation***

*The range of nuclear costs considered is £30 / MWh to £44 / MWh. The central assumption is a levelised cost of £37.50 / MWh.*

The analysis proceeds by comparing nuclear and gas fired generation costs. The assumption is that in a *do nothing* scenario, investment would probably flow to gas fired generation. This provides the benchmark against which to compare nuclear investment. The relative cost of nuclear may then be regarded as a cost / benefit, depending on whether nuclear is more / less expensive than gas fired plant.

The nuclear generation levelised cost in the central case is assumed to be £37.50 / MWh, based on detailed data summarised in Table 4. In addition to assumptions on overnight construction and financing costs (discussed above), the table shows that the central case assumption is conservative in the following respects:

- The pre development period is assumed to be longer than that for Sizewell B. The construction period is assumed to be between vendors' estimates and that for Sizewell B.
- Load factors and operational lives are assumed low relative to vendors' estimates.
- Waste recycling costs and decommissioning costs are high relative to vendors' estimates.

Table 4: central case assumptions on costs of nuclear new build generation<sup>16</sup>

Key Item	Assumption	Source / Comment
Pre development cost	£250 million	Environmental Audit Committee “Keeping the Lights on: Nuclear, Renewables & Climate Change”, March 2006.
Pre-development period	8 years	5 years to obtain technical and site licence with 3 years public enquiry. Note Sizewell B predevelopment period was 7 years.
Construction cost	£1,250/kW plus £560m IDC and £10/kW onsite waste storage every ten years over life	Equates to build cost of around £2.8 billion. This may be compared to the £2 billion cost for the Finnish Olkiluoto project
Construction period	6 years	Vendors’ estimates range from 5 – 5.5 years. Note Sizewell B construction period was 7 years.
Load Factor	80% rising to 85% after five years.	Vendors expect 90% plus.
Operational life	40 years	Vendors expect 60 year life.
O&M cost	£7.7/MWh (or £90m per annum)	This is within the range provided by the Sustainable Development Commission. Vendors expect O&M to be around £40m per annum
Fuel supply cost	£3.9/MWh	Based on a raw uranium price of \$40/lb, which with enrichment and fabrication costs as published by the Uranium Information Centre gives £2,200/ kg all in cost. PB Power notes that most studies assume a fuel cost of around £4/MWh.
Waste disposal cost	Fund size of £276 million at end of 40 years or £0.4/MWh	Assumes waste is stored in combined deep geological repository. This is forecast to cost £25 billion for legacy waste. Assumption is that a 10GW new build programme would add 10% to repository volume. Variable element of repository costs is assumed to be 70%. Fund growth assumed to be 2.5% real.
Decommissioning cost	Fund size of £636 million at end of 40 years or £0.7/MWh	Decommissioning cost assumed to be £400 million / GW. Vendors’ estimates of decommissioning costs are from £325 million / GW

<sup>16</sup> Cost assumptions are in 2006 prices throughout.

		for the EPR, and £400 million for the AP 1000. Fund growth assumed to be 2.5% real.
Cost of capital	10%	Post tax real Weighted Average Cost of Capital (WACC), used in a number of studies and widely accepted by industry.

The high nuclear cost sensitivity of £43.70 / MWh is chosen as the highest levelised cost for the range of sensitivities in Table 5. It covers, *inter alia*, the possibility of a 30% construction cost over-run relative to the central case / a financing cost of 12%. Though it does not cover the combination of these events (which would result in a levelised cost of the order £48 / MWh), this is not limiting, in the sense that £43 / MWh (i.e. the value for nuclear cost in the high case) is close to the switching value for the analysis (see the discussion of welfare balances in Section 6 below).

To reiterate, the high case may be regarded as representing an extreme given that the central case is conservative, and that cost overruns of the order 30%, whilst these have occurred in some cases historically, are less likely to occur going forward (as argued above, because the planning regime is expected to be improved, projects will be implemented under incentive based contracts, etc.).

The *central high* case assumes a levelised cost of £40.20 / MWh and covers various combinations from a range of cost sensitivities including increased pre development costs relative to the central case, longer pre development and construction periods, higher construction costs (£1,400 / kW), lower load factor and operating life, and higher fuel, decommissioning and waste disposal cost. For example, the central high case adds to the central case a premium equal to increased pre –development, fuel, decommissioning and waste disposal costs as summarised in Table 5.

Table 5: assumptions for high cost nuclear sensitivities

	Data	Levelised cost (£/MWh)
Base case		37.5
Predevelopment cost	£300 million (i.e. £50 million increase on base case)	37.9
Predevelopment period	12 month increase	37.6
Construction period	10 years	41.8
Operation period	30 years	38.9
Construction cost	£1400 / kW	40.2
Construction cost	£1600 / kW (i.e. 30% increase on base case)	43.7
Availability first five years	60%	38.5
Fuel cost	£2,500 / kg	38.1
Cost of capital	12%	42.1

Decommissioning cost	£950 million fund at the end of forty years (50% increase on base case)	37.8
Waste disposal cost	£320 million at the end of forty years (15% increase on base case)	37.6

The sensitivity value for low nuclear cost is assumed to be £30 / MWh, roughly corresponding to construction cost of £900 / kW – the French forecast cost for a programme of ten reactors – or a financing cost of 7%, or a combination of other factors (e.g. reduced predevelopment cost, O&M cost, fuel cost, etc.), see Table 6.

Table 6: assumptions for low cost nuclear sensitivities

	Data	Levelised cost (£/MWh)
Base case		37.5
Predevelopment cost	£100 million	36.2
Predevelopment period	12 months reduction	37.4
Operation period	60 years	36.4
Construction cost	£850 / kW	30
Availability first five years	90%	37.0
O&M cost	£35 / kW	34.6
Fuel cost	£1,300 / kg	35.9
Cost of capital	7%	30.9

*The analysis considers a range of gas prices from 21 pence / therm to 53 pence per therm. This translates to a range of levelised costs from £25 / MWh to £45 / MWh. The central case gas price is assumed to be 37 pence / therm, translating to a levelised cost of £35 / MWh.*

The central gas price is taken from the energy price scenarios being used more widely across the Energy Review. The central gas price scenario models a world where the current market situation prevails, and the gas price remains linked to the oil price. Whereas the gas price has been around 20 pence / therm on average over the last decade, the average price in 2005 was 42 pence / therm. Going forward the central gas price remains high by historical standards, based on an assumption that the oil price is \$40 / bbl.

Gas price sensitivities correspond to the low and high gas price scenarios being used in the Energy Review. The high gas price scenario models a world where the oil price continues to be around \$70 / bbl. The low gas price scenario models a world where there is increased competition in the gas market, resulting in decoupling of the gas price from the oil price, and a falling of the gas price towards marginal cost.

The central gas price is assumed to be 36.6 pence per therm. This translates to a levelised cost of £34.60 / MWh for gas fired generation under assumptions contained in Table 7. Gas fired generation technology is well tested in the UK context – the

large amount of new build in the 1990s was gas fired - and the assumptions in the table reflect market data.

The assumption that thermal efficiency is 53% requires an increase from the current average of 48% for the UK gas fired generation stock. It is reasonable to assume that thermal efficiency will increase to 53% by around 2020. It is optimistic, however, to assume that this will be sustained through plant life. The assumption on thermal efficiency may then be seen as conservative from the point of view of nuclear generation; for a lower level of thermal efficiency, gas fired generation cost would be higher.

The high gas price of 53 pence / therm translates to a levelised cost of £45.20 / MWh under other cost assumptions as per Table 7, and the low gas price of 21 pence / therm translates to a levelised cost of £24.50 / MWh on a similar basis.

Table 7: central case assumptions on generation cost for a CCGT

Key Item	Assumption
Pre development cost	Included in construction cost
Predevelopment period	3 years
Construction cost	£440/kW plus £23m IDC
Construction period	3 years
Load Factor	85%
Operational life	35 years
Thermal efficiency (HHV)	53%
O&M cost	£3/MWh (or £11m per annum)
Fuel supply cost	DTI gas central 36.6p/therm
Cost of capital	10%

*Gas fired plant has a cost advantage over nuclear in the central and low gas price cases. Nuclear plant has a cost advantage in the low nuclear cost and high gas price scenarios.*

The approach adopted is to compare levelised costs of gas fired and nuclear plant. Proceeding in this way incorporates commercial financing costs into the analysis, thus reflecting a commercial view of risks associated with power generation investments / the *opportunity cost* of capital.

Levelised costs of the two plant types are compared over the assumed operational life of a nuclear plant (40 years). Cost differentials between the two plant types are multiplied by annual output to give an annual nuclear cost penalty / cost advantage.

The cost penalty / advantage is regarded as a societal cost / benefit to be discounted at the Social Time Preference Rate (STPR). The analysis uses the UK Government discount rates of 3.5% for a period up to thirty years in the future, and 3% from thirty-one to seventy-five years.<sup>17</sup>

<sup>17</sup> See the “Treasury Green Book”, which can be accessed via the Treasury website ([www.hm-treasury.gov.uk](http://www.hm-treasury.gov.uk)), The 3.5% figure for the discount rate assumes a growth rate of 2%, and a pure time preference rate of 1.5%. Present values are estimated for base year - assumed to be 2021 – when nuclear generation could come on line.

The methodology of levelising costs at a rate based on commercial financing costs and discounting back cost penalties / advantages at the STPR is consistent with the approach used in the UK Government's Climate Change Programme Review (CCPR), which compares costs of alternative options for carbon reduction.<sup>18</sup>

Table 8 summarises cost penalties / advantages of nuclear generation in the various scenarios. The cost advantage of gas fired plant over nuclear plant in the central gas price case is obvious from inspection of the levelised costs of the two plant types. The annual cost advantage of gas fired plant is £21.8 million / GW (equal to 7,450 GWh annual output of a nuclear plant, multiplied by the levelised cost differential of just under £3 / MWh). The NPV of this amount over a forty year period discounted at 3 / 3.5 % depending on the year is £494.8 million / GW; on this basis a 6 GW nuclear programme would involve a cost penalty of the order £3 billion in the central case.

Gas fired generation has a cost advantage over forty years ranging from £1.5 billion / GW in the high nuclear cost sensitivity to £2.2 billion / GW in the low gas price sensitivity. Nuclear generation has a cost advantage ranging from NPV £800 million / GW in the low nuclear cost sensitivity to £1.3 billion / GW in the high gas price sensitivity.

Table 8: nuclear cost penalties / advantages in gas price and nuclear cost scenarios

	Levelised nuclear cost (£/MWh)	Levelised gas cost (£/MWh)	Annual cost penalty per nuclear plant (£ million / GW)*	Net present value over forty years (£ million / GW)
Central case	37.5	34.60	-21.8	-494.8
Low gas price sensitivity	37.5	24.50	-96.7	-2,193.5
High nuclear cost sensitivity	43.7	34.60	-68	-1,541.7
Central high nuclear cost sensitivity	40.2	34.60	-41.9	-950.7
Low nuclear cost sensitivity	30	34.60	34	771.7
High gas price sensitivity	37.5	45.20	57.3	1,298.5

\* A nuclear cost penalty is signified by a negative number, and a cost advantage by a positive number.

#### 4. Environmental benefits of nuclear power

*Carbon emissions reductions are significant relative to gas fired plant.*

The Sustainable Development Commission states that nuclear power may be regarded as a low carbon form of generation.<sup>19</sup>

<sup>18</sup> See "Greenhouse gas policy evaluation in Government departments", DEFRA, April 2006.

<sup>19</sup> See Sustainable Development Commission, *Ibid.*

Carbon reduction related to investment in new nuclear generation can be estimated relative to the counterfactual in this analysis where gas fired plant is added to the system. Then carbon reduction is equal to the level of emissions that would occur if gas fired plant were to be added rather than nuclear.

Gas fired emissions are a function of thermal efficiency, which was assumed to be 53% in the central case above. Similarly to the cost analysis, to the extent that 53% is optimistic, this will lead to the estimate of nuclear emissions reductions being conservative; gas fired emissions increase as the level of thermal efficiency falls.

The assumption of 53% thermal efficiency translates to an emissions factor of 0.35<sup>20</sup>, which can be multiplied by gas fired output to give the level of emissions.<sup>21</sup> In calculating output, and in keeping with central case analysis, a plant capacity of 1 GW and a load factor of 85% is assumed. Annual output of a 1 GW gas fired plant is then 7,450 GWh, with associated emissions of 2.6 million tonnes of CO<sub>2</sub> (710,000 tonnes of carbon); this is the annual carbon emissions reduction from adding 1 GW of nuclear plant. Adding 6 GW of nuclear plant would reduce annual CO<sub>2</sub> emissions by around 15 million tonnes (over 4 million tonnes of carbon).

*Nuclear lifecycle carbon emissions are small relative to emissions reductions.*

It is important to recognise that there are carbon emissions associated with the construction of nuclear power plants, and with the mining, transport and processing of uranium. These *lifecycle emissions* should be subtracted from the total emissions reduction above to give a net emissions reduction.

There are various studies on nuclear lifecycle emissions, providing a range for carbon dioxide emissions from 5 g / kWh to 20 g / kWh.<sup>22</sup> The approach in the current analysis is to take the average of the range. This is reasonable given that the high end of the range reflects an assumption that electricity inputs to the nuclear lifecycle are based on coal rather than gas fired generation; in the UK, the marginal plant going forward is likely to be gas fired, with relatively low emissions compared to coal.

Under an assumption that lifecycle emissions of carbon dioxide are 10 g / kWh, this gives annual lifecycle CO<sub>2</sub> emissions of 87,000 tonnes (25,000 tonnes of carbon). Subtracting this from the emissions reduction for nuclear above gives a net CO<sub>2</sub> emissions reduction of 2.52 million tonnes (685,000 tonnes of carbon) annually. This may actually underestimate emissions reductions given that there are lifecycle emissions associated with gas fired plant (e.g. associated with construction, gas flaring, etc.); it is not possible to allow for this given a lack of data on these categories of gas fired generation lifecycle emissions.

The above argument assumes that uranium continues to be available at current levels of quality. The Sustainable Development Commission argues that this assumption is valid subject to the proviso that the raw uranium price may have to increase

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<sup>20</sup> This figure is calculated using data from DEFRA's National Atmospheric Emissions Inventory.

<sup>21</sup> This emissions factor relates to CO<sub>2</sub> rather than carbon emissions.

<sup>22</sup> These are summarised on the website of the Uranium Information Centre ([www.uic.com.au](http://www.uic.com.au)).

significantly in order to bring new supplies forward.<sup>23</sup> The cost analysis in Section 3 above shows that a large increase in the price of raw uranium results in only a small increase in the levelised nuclear generation cost. This is because the raw uranium cost is only a small part of the total fuel cost, which in turn is only a small part of levelised cost.

*Nuclear generation is a cost effective means of reducing carbon emissions.*

Alternative forms of low carbon power generation may be compared in terms of cost effectiveness of carbon reduction. Cost effectiveness is defined as the present value of any cost penalty relative to the base case divided by lifetime carbon emissions reductions.

The cost penalty underpinning the cost effectiveness calculation is estimated according to the methodology in Section 3 above: levelised costs for low carbon generation technologies are compared with gas fired levelised generation costs; the difference in levelised costs is multiplied by annual output to give an annual cost penalty; the annual cost penalty is discounted at the social rate of time preference to give a present value cost penalty.

Levelised costs for low carbon generation technologies, presented in Table 9, are derived from a DTI financial model of power generation.<sup>24</sup> Levelised cost estimates draw on market data where this is available, most notably for onshore / offshore wind and marine technologies. The range of levelised cost for coal fired Carbon Capture and Storage (CCS) generation reflects the fact that this technology is at an early stage of development, and so there is a great deal of uncertainty over what related costs might actually be.

The table shows that the most effective form of low carbon generation may be to retrofit existing coal fired plant with CCS equipment; this could be an attractive option for coal fired plant that has opted out of the EU's LCPD (see Section 2 above), depending on the age and quality of opted out plant.

Regarding new capacity, nuclear is the most cost effective form of low carbon generation, followed by coal fired CCS, then onshore wind. Offshore wind and marine generation based on cost estimates for the Severn Barrier project are the least cost effective forms of low carbon generation. This ranking of technologies on the basis of cost effectiveness is largely consistent with the ranking in the DTI's *Carbon Abatement Technology Strategy*.<sup>25</sup>

Table 9: cost effectiveness of alternative low carbon generation technologies

	Levelised cost (£/MWh)	Net present value of cost penalty over forty years (£)	Cost effectiveness (£/tonne CO <sub>2</sub> )	Cost effectiveness (£/tonne carbon)

<sup>23</sup> See Sustainable Development Commission, *Ibid*.

<sup>24</sup> See "Overview of modelling of the relative electricity generating costs of different technologies", Department of Trade and Industry, July 2006.

<sup>25</sup> See "A strategy for developing carbon abatement technologies for fossil fuel use, carbon abatement technologies programme", Department of Trade and Industry, June 2005.

		million / GW)		
Nuclear	37.5	494.8	4.9	18
On shore wind	55	3,449.8	34.2	125.5
Off shore wind	83	8,203.3	81.4	298.5
Coal CCS retrofit	35.7- 44.5	190.8 – 1,676.8	1.9 – 16.6	7 - 60.9
Coal CCS new	40.8-49.3	1,052 – 2,487.3	10.4 – 24.7	38.1 – 90.6
Marine (Severn barrier)	67.8	5,611.2	55.7	204.2

Notwithstanding the cost advantage of nuclear generation, investing in nuclear new build would not preclude adding other forms of low carbon generation capacity to the system. This is the case for the period before new nuclear could be added (2018 at the earliest), during which low carbon generation capacity will continue to be added under the Renewables Obligation. It is also the case for the period when nuclear could be added; adding 6 GW of new nuclear capacity by 2025 would leave a need for up to 8 GW of additional capacity over the period 2018-2025 (see Section 2 above) which could in principle be met through investment in other forms of low carbon generation.

*Other low carbon technology costs are expected to fall – but nuclear should remain competitive.*

The cost advantage of nuclear power over coal fired CCS may be expected to decline over time as CCS technology is developed. It is important to note, however, that the lower end of the range for CCS costs is above the central case nuclear cost. It is possible also that nuclear costs would be lower than assumed in the central case, particularly over time. In these circumstances, it would seem reasonable to assume that nuclear generation will remain competitive with CCS over time.

The same applies for offshore wind: the current capital cost of around £1,600 / kW is expected to decline due to *learning* as more of the technology is deployed. Under an assumption that steel prices fall from current levels, that on top of this capital costs fall 70% by 2020, and that there is a 10% reduction in operating costs, this gives a levelised cost for offshore wind of £55 / MWh. Compared to the central nuclear case, offshore wind then has a cost penalty in excess of £3.5 billion / GW NPV over forty years, and does not compete with nuclear, even in a high nuclear cost scenario.

*The value of nuclear carbon emissions reductions is £1.4 billion / GW for a CO2 price of Eur 36 [£25] / tonne.*

Carbon emissions reductions can be monetised using a carbon price, which may be regarded as a proxy for marginal emissions abatement cost. If nuclear plant is added, abatement costs elsewhere in the economy are reduced to meet a given target for carbon reduction. The reduction in abatement cost may be regarded as a benefit associated with nuclear generation to be offset against any nuclear cost penalty.

This argument applies as long as commitment to carbon emissions reduction remains. If commitment were to fall away, there would be less onerous targets for carbon

emissions reduction, with lower related abatement costs. At the extreme, in a world where there is no commitment to carbon reduction and no abatement activity, there would be no abatement cost saving for nuclear generation.

In order to allow for uncertainty about future abatement costs, three carbon prices are used for valuing nuclear related potential carbon emissions reductions:

- the price prevailing in the UK in the first quarter 2006 (Eur 25 [£17] / tonne of CO<sub>2</sub>);
- a lower price (Eur 15 [£10] / tonne of CO<sub>2</sub>), reflecting a more relaxed policy towards carbon emissions reduction;
- a higher price (Eur 36 [£25] / tonne of CO<sub>2</sub>), reflecting a more aggressive approach to carbon emissions reductions.

The value of carbon emissions reductions, presented in Table 10, ranges from £570 million / GW to £1.4 billion / GW, in NPV over forty years.

Table 10: the value of carbon emissions reductions from nuclear generation

Carbon price (Eur / tCO <sub>2</sub> )	Annual benefit of carbon reduction (£ million / GW)	NPV of carbon reduction over forty years (£ million / GW)
15	25.2	571.5
25	42.8	971.5
36	61.9	1,402.7

*Carbon emissions reductions valued at the social cost of carbon range from £1.3 billion / GW to £3.2 billion / GW.*

An alternative to using carbon prices / abatement costs is to value emissions reductions at the *social cost of carbon*. The social cost of carbon is estimated as the marginal benefit of carbon emissions reduction in terms of mitigation of climate change and related adverse impacts. Using the social cost of carbon to value carbon emissions reductions assumes continued commitment to carbon reduction.

For the purposes of this analysis, DEFRA's estimates of the social cost of carbon are used. DEFRA provides low, central and high case estimates, starting at £18 / tCO<sub>2</sub> (low), £29 / tCO<sub>2</sub> (central), £51 / tCO<sub>2</sub> (high) in 2021 and increasing each year subsequently to £30 / tCO<sub>2</sub> (low), £41 / tCO<sub>2</sub> (central) and £63 / tCO<sub>2</sub> (high) in 2060.<sup>26</sup> The estimates include a wide range of assumptions on the science of climate change, and the economics of related impacts (e.g. the value of prevented fatalities due to carbon emissions reduction). On the basis of these assumptions, Table 13 shows that the present value of carbon reductions at the social cost of carbon over a forty year period ranges from £1.3 billion / GW to £3.2 billion / GW.

<sup>26</sup> The full series for the social cost of carbon are published on the DEFRA website ([www.defra.gov.uk](http://www.defra.gov.uk)).

Table 11: the value of carbon emissions reductions from nuclear generation

Social cost of carbon	Annual benefit of carbon reduction (£ million / GW)	NPV of carbon reduction over forty years (£ million / GW)
DEFRA low	44.6	1,291
DEFRA central	72.6	1,923.7
DEFRA high	128.3	3,188.9

## 5. Security of supply benefits of nuclear power

*Nuclear new build could lead to reductions in the level of UK total gas consumption.*

Adding nuclear plant could result in reduced energy unserved in the event of a major fuel supply interruption (e.g. due to cold weather, technical or political factors). One way to illustrate the order of magnitude of this benefit is to consider the level of reduction in gas consumption by the power sector as more nuclear plant is added. In the base case, where 6 GW of nuclear capacity is added by 2025, this would result in reduced forecast gas consumption of 7%.<sup>27</sup>

*Gas fired power stations may be subject to fuel supply interruption for technical and political reasons.*

In the context of the Energy Review, a consultancy study was undertaken to assess the magnitude of expected gas supply interruptions and associated costs.<sup>28</sup> This study is relevant in considering potential security of supply benefits related to nuclear power, equal to avoided costs due to gas supply interruption as nuclear plant is added. For example, if new nuclear capacity were to be added rather than gas fired plant, this would free up gas for consumption in other sectors (e.g. large industry) in the event of a supply shortage, thus reducing the economic impact of the shortage.

The study defines and assigns probabilities to various gas demand – supply scenarios:

- *Constrained*: high gas demand, low UK domestic supply, low import capacity, low storage capacity
- *Balanced*: central gas demand, central UK domestic supply, central import capacity, central storage capacity
- *Abundant*: low gas demand, high UK supply, high import capacity, high storage capacity

<sup>27</sup> The 2025 gas consumption forecast is derived from the 2020 forecast published in “UK energy and CO2 emissions projections, updated projections to 2020”, Department of Trade and Industry, February 2006. The 2020 forecast is increased by an amount equal to the forecast gas consumption by 6 GW of gas fired capacity. The percentage reduction in 2025 consumption due to investment in new nuclear capacity is the forecast gas consumption by 6 GW of gas fired plant relative to total forecast 2025 gas consumption.

<sup>28</sup> “Strategic storage and other options to ensure long term gas security”, prepared by ILEX Energy Consulting for the DTI, April 2006.

In addition, a set of technical / political events that could impact gas supply is defined: field outages; LNG terminal outages; pipe outages; storage facility outages. The methodology used is then to simulate the annual gas demand – supply balance under assumptions about probabilities associated with the technical / political events, and to estimate the level of expected energy unserved.

*Expected costs associated with fuel supply interruption over the period when nuclear plant could be added are of the order NPV £100 million / GW.*

The results of the simulation suggest that for the period beyond 2015 there is a 2% probability of a gas supply interruption equal in magnitude to gas demand from 3.5 GW of gas fired power generators; larger interruptions occur with lower – but non zero – probability. The study values a gas supply interruption at £11-12 / therm, based on analysis of value added data for gas consuming industrial consumers, and assuming that these consumers would bear the cost of any interruption. Applying this to the annual expected energy unserved gives an NPV for the expected *cost* of interruptions around £8.6 billion over thirty years.

The risk of gas supply interruptions could be mitigated through increasing the level of gas storage capacity; if an interruption were to occur, this could be offset by releasing stored gas. The study considers alternative forms of gas storage (depleted field, salt cavern, LNG) and concludes that distillate storage at gas fired power plants is the least cost means of mitigating against the risk of gas supply interruption.

The cost of providing oil distillate back up capacity is estimated to be around NPV £100 million / GW of capacity, or NPV £1 billion for 10 GW of back up, which would provide sufficient cover to almost fully mitigate the risk of fuel supply interruption. From an economic point of view, 10 GW back up should be added and gas supply interruptions avoided (because related benefits [£8.6 billion avoided economic impact of interruptions] exceed costs [£1 billion]).

In a world where nuclear rather than gas fired capacity is added, the need for back up declines, because nuclear does not need to switch fuels in the event of a gas supply interruption. Adding nuclear generation does not provide more or less security of supply than adding gas fired power generation with back up. Rather, the *security of supply* benefit associated with nuclear investment is the avoided cost of oil distillate back up for gas fired power generation (i.e. £100 million / GW).

This argument is consistent with a separate study carried out for the DTI by OXERA.<sup>29</sup> In this study, it is assumed that there is a 3% probability that 1 GW of gas fired plant could be off the system for a period of one year. Under this assumption it is estimated that adding 1 GW of nuclear plant would reduce the expected level of unserved energy by 28 MWh per year, valued at around £9 million.

It may be inferred from this study that if gas fired plant were to be added to the system, this should be backed up by oil distillate; the cost of back up is less than the

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<sup>29</sup> Summarised in “Advancing economics in business”, by OXERA, November 2005.

expected cost of unserved energy resulting from gas supply interruption. Similarly to the ILEX study, the benefit of nuclear generation can then be seen as the avoided cost of backing up gas fired power stations with oil distillate capacity.

*Security of supply benefits can support – but not make – the case for nuclear generation*

Security of supply benefits associated with nuclear generation are of too small an order of magnitude to *make* the case for nuclear generation. This can be illustrated by comparing the security of supply benefits with nuclear cost penalties ranging from £500 million / GW (in the central gas price scenario) to over £2.2 billion / GW (in the low gas price scenario).

Given that in none of these cases does the security of supply benefit offset the cost penalty – the difference between these two is large for the low gas price and high nuclear cost scenarios – nuclear generation cannot be justified on the grounds of security of supply alone. This should rather be regarded as only one benefit, to which other benefits of a higher order of magnitude should be added if the case for nuclear generation is to be made.

*Adding nuclear capacity may provide a hedge against high gas prices.*

It might be argued that the analysis above is *stylised*, in the sense that it relies on tightly defined outage events and related probabilities, and does not capture the full range of contingencies for fuel supply interruption. The analysis does not model, for example, a world where market power in the gas industry is highly concentrated, and where a dominant supplier might choose to interrupt gas supply to the UK market either repeatedly or on a long term basis.

In understanding the benefit of adding nuclear generation in this type of world, it is necessary to understand what would happen in a counterfactual where gas fired generation is added. The likely outcome would either be sustained high gas prices, or ongoing fuel switching contingent upon repeated / long term gas supply interruption, both of which would result in higher generation costs than under the central gas price scenario.

The security of supply benefit of new nuclear capacity may then be best understood in terms of a cost advantage relative to gas fired generation costs in a high gas price scenario – estimated in Section 3 above - rather than in terms of reduced energy unserved in the event of fuel supply interruptions.<sup>30</sup>

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<sup>30</sup> At an oil price of \$40 bbl, it becomes economic to switch fuel at a gas price around 50 pence / therm. To the extent that the oil price might be above \$40 bbl, the cost saving for nuclear in a world where there is ongoing fuel switching would be above that in the high gas price scenario above.

**6. From an economic perspective, total net benefits of nuclear power justify new nuclear playing a role in a carbon emissions reduction policy**

*Welfare balance is positive in central / high gas price, central / low nuclear cost worlds, and non zero carbon price worlds, and negative in low gas price / high nuclear cost worlds.*

The welfare balance associated with nuclear new build relative to a do nothing scenario where gas fired plant is added to the power system is the sum of security of supply and environmental benefits net of any nuclear cost penalties.

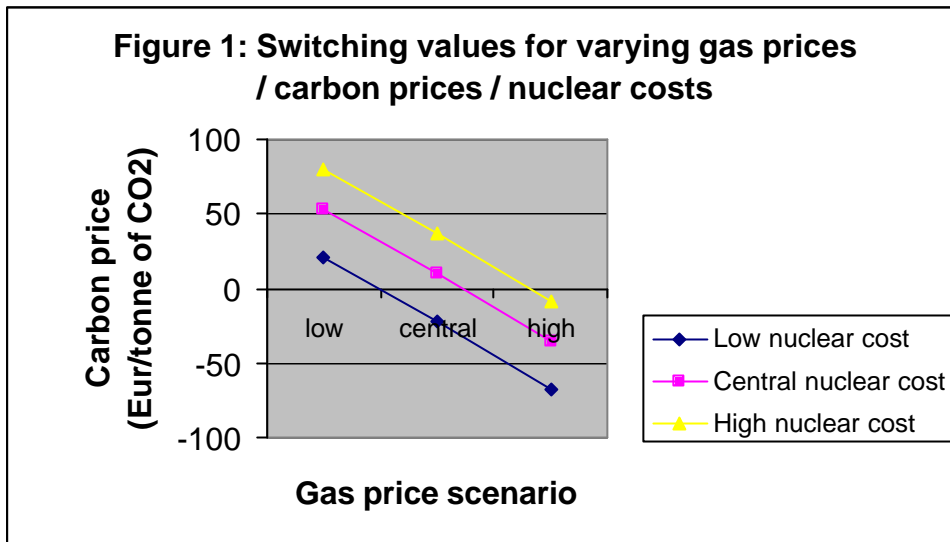
Table 14 shows welfare balances based on cost penalties, environmental benefits and security of supply benefits for the various scenarios in the cost benefit analysis. A negative number in the table should be interpreted as representing a net cost associated with nuclear generation, and a positive number as representing a net benefit.

Table 14: nuclear generation welfare balance under alternative gas price, carbon price and nuclear cost scenarios, NPV over forty years, £ million / GW

Carbon price (Eur / tCO <sub>2</sub> )	Low gas price	Central gas, high nuclear	Central gas price	Central gas, low nuclear	High gas price
0	-2100	-1400	-400	<b>900</b>	<b>1400</b>
15	-1500	-900	<b>200</b>	<b>1400</b>	<b>2000</b>
25	-1100	-500	<b>600</b>	<b>1800</b>	<b>2400</b>
36	-700	0	<b>1000</b>	<b>2300</b>	<b>2800</b>

The table shows that the net benefit of nuclear generation is negative at low gas prices / high nuclear costs across the range of CO<sub>2</sub> prices. Welfare balance is positive in the central gas price world depending on the CO<sub>2</sub> price, and in high gas price / low nuclear cost worlds across the range of CO<sub>2</sub> prices (including a zero CO<sub>2</sub> price). Under the central gas price and a CO<sub>2</sub> price of Eur 36 [£25] / tonne, the NPV benefit over forty years associated with adding 6 GW of nuclear capacity would be of the order £6 billion.

Switching values for the key variables are presented in Figure 1. The figure shows that the CO<sub>2</sub> price can fall to Eur 10 [£7] / tonne before the welfare balance is negative in a central gas price – central nuclear cost scenario. In a low gas price scenario, the CO<sub>2</sub> price must rise to Eur 54 [£37] / tonne in order for the nuclear welfare balance to be positive; this carbon price is within the range between DEFRA’s central and high case estimates of the social cost of carbon. In a high nuclear cost scenario, the CO<sub>2</sub> price must rise to just above Eur 36 [£25] / tonne, or the gas levelised cost must rise to £34.80 / MWh for a CO<sub>2</sub> price of Eur 36 [£25] / tonne, in order that the welfare balance is positive.



*Nuclear generation is likely to be justified in a world where there is continued commitment to carbon emissions reduction and gas prices are at or above 37 pence / therm*

The economic case against nuclear arises if the probability of low gas prices / high nuclear costs is significantly higher than the probability attached to other scenarios, and / or the CO<sub>2</sub> price is significantly less than the Eur 36 [£25] / tonne value assumed in the analysis.

In the central gas price scenario, nuclear generation is economically justified unless commitment to emissions reduction falls away, in which case the relevant carbon price may become zero. As far as some commitment remains, net benefits associated with nuclear investment are likely to be positive, largely reflecting the environmental benefits of this option.

This continues to be true as nuclear costs increase beyond the range given in the various studies of nuclear generation. In the central gas price scenario, and valuing environmental benefits at a CO<sub>2</sub> price of Eur 36 [£25] / tonne, the economics of nuclear generation remain robust for a nuclear generation cost up to £43.50 / MWh. This is well above the forecast cost of power generation from the Finnish nuclear project currently under construction, by a margin that far exceeds any historical cost overruns associated with nuclear projects (e.g. Sizewell B).

*Economic risks associated with keeping the nuclear door open would appear to be limited*

In summary, the economics of nuclear depend critically on assumptions made about future gas and carbon prices, and nuclear costs. On some sets of assumptions, the nuclear case is positive; in others, negative, so a judgement has to be made about the relative weight to be given to the various scenarios.

In making such a judgement, it is important to reiterate the argument in Section 3 above: many of the probabilities associated with the various states of the world considered in the analysis are endogenous rather than exogenous, and depend on policy decisions. This is true of the carbon price, which will depend on whether the UK remains committed to its goal of long term carbon reduction. To the extent that commitment does remain, then higher carbon price scenarios should be given more weight. It is true also for nuclear costs, where policy to improve the planning process would reduce the likelihood of a high nuclear cost scenario ensuing. Regarding gas prices, the weight to be attached to the high gas price scenario is again a policy decision. Where the Government is averse to the risk of high gas prices, other things equal, more weight should be attached to this scenario.

Within these likely scenarios nuclear generation yields positive net economic benefits. An additional factor in support of this argument is that the likelihood of low nuclear costs would increase for a programme of new build as opposed to a one off plant addition; the analysis of the forecast UK capacity balance suggests that there would be scope for a programme.

The resource cost of taking facilitative measures for new nuclear build would be limited initially to work required for improving the planning process, and for elaborating details of waste and decommissioning arrangements. The likelihood is that commercial projects would only be forthcoming in a world where the supporting policy framework as described above is in place, in which case expected economic benefits would be positive.