DEPARTMENT OF ENERGY & CLIMATE CHANGE

Consultation on a Methodology to Determine a Fixed Unit Price for Waste Disposal and Updated Cost Estimates for Nuclear Decommissioning, Waste Management and Waste Disposal

March 2010

Contents

Chapter 1: Introduction

Executive Summary

Aim of the consultation

1.1 This consultation follows the publication of three pre-consultation discussion papers during autumn 2008 and spring 2009 on specific issues relating to the Government's policy to set a Fixed Unit Price for the disposal of intermediate level waste (ILW) and spent fuel from new nuclear power stations[1]. These papers informed discussions with stakeholders during the pre-consultation in order to refine the proposed Fixed Unit Price methodology for this consultation.

1.2 The consultation document aims to inform stakeholders and the wider public of:

- Changes to the Government's policy framework for setting a Fixed Unit Price as a result of feedback from stakeholders received during the pre-consultation.
- The main stages of the proposed methodology to determine a Fixed Unit Price and worked examples of how it would be calculated using this methodology.
- The Government's updated estimates of the costs for decommissioning, waste management and waste disposal.

1.3 We are seeking responses to the questions contained in the consultation document (for full list see page 10). The responses will assist the Government in developing a finalised approach on the issues covered by the consultation. The finalised approach on a methodology for the Fixed Unit Price will provide clarity on how a Fixed Unit Price will be determined for a prospective operator of a new nuclear power station.

Proposed changes as a result of the pre-consultation process

1.4 The Government proposes changes to two elements of the policy framework for setting a Fixed Unit Price as result of the pre-consultation process.

1.5 The first proposed change to the Government's policy framework relates to when a Fixed Unit Price should be set. The Government proposes to offer prospective operators the option to defer the setting of their Fixed Unit Price, provided they can assure the Secretary of State that in the interim they will make prudent provision in their Funded Decommissioning Programme (FDP) for waste disposal costs and will be capable of meeting in full their waste disposal liabilities even in the event of subsequent escalation in costs.

1.6 In order to obtain this assurance the Government would:

- Limit the duration of the deferral by specifying a maximum "Deferral Period" at the end of which the Fixed Unit Price will be set.
- For the interim period, provide the prospective operator with an "expected Fixed Unit Price" (eFUP) to enable it to make prudent provision.

[1] These three discussion papers are available at: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/new/waste_costs/ waste_costs.aspx

1.7 The eFUP will be the Government's best estimate of the level of the Fixed Unit Price at the time it is eventually set. The Fixed Unit Price set at the end of the Deferral Period is expected to be based on much more accurate cost estimates than those currently available. This means that at the time an operator's FDP is first approved, the eFUP provided by the Government is likely to include a smaller risk premium and therefore be lower than a Fixed Unit Price offered at that time. This is because in opting for an eFUP the operator is accepting more risk and the Government is taking less risk. The level of the eFUP will be regularly reviewed during the Deferral Period and is likely to be revised from time to time.

1.8 This consultation document sets out worked examples for how a Fixed Unit Price and an eFUP would be determined based on the Government's proposed methodology. It also sets out a worked example of how the Fixed Unit Price and eFUP for spent fuel would be converted into p/kWh. These build on the worked examples set out in Discussion Paper 3.

1.9 The second proposed change to the Government's policy framework relates to the Schedule for when title to and liability for an operator's waste should transfer to the Government. The Government published a consultation document in February 2008 (referred to in this document as the "FDP Guidance consultation document") which said that the Schedule was expected to be aligned to estimates for availability of disposal facilities[2]. However, if the Schedule were set in relation to current estimates of the availability of a Geological Disposal Facility (GDF) the operator would be responsible for the onsite interim storage of their waste for several decades after revenues from that nuclear power station have ceased, and potentially for many years after it has been otherwise decommissioned.

1.10 The pre-consultation process highlighted that this scenario presents a risk to both the operator and the Government. The Government considers that it is better placed than an operator to manage the risk and proposes that the transfer of title and liability be brought forward (Early Transfer) and the Transfer Date be aligned with the operator's decommissioning timetable. However it remains the Government's policy that operators will meet their full share of waste management costs. The Government would therefore need to be compensated for the waste management costs that it would incur from Early Transfer.

1.11 The Government proposes to recover these additional costs through its existing requirement for an operator to estimate all waste management costs in their FDP and to make provision for these costs in their independent Fund. This would ensure that there were sufficient monies to pay for waste management costs arising after the Transfer Date. These monies would transfer to the Government as a lump sum final payment at the same time as title to and liability for the waste is transferred. The Government will provide the operator with an "Assumed Disposal Date" (in addition to the Transfer Date) so that the operator knows the expected time period over which the Government will be responsible for maintaining their waste in interim storage prior to disposal.

1.12 Under the proposal for Early Transfer, the Fixed Unit Price will be paid many years before the Assumed Disposal Date. It is therefore necessary to adjust the payment made by the operator to reflect this early payment and this will be done through the application of an appropriate discount rate to the Fixed Unit Price to reflect this time difference. This discount rate will be determined nearer to the Transfer Date and set in relation to the rates of returns available at that time on long-term investments.

[2] Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations. Paragraph 2.15. Available at: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/new/waste_costs/waste_costs.aspx

The proposed methodology to determine a Fixed Unit Price

1.13 The consultation document sets out the proposed methodology to determine a Fixed Unit Price. This methodology will also be applied to determine the level of the eFUP.

1.14 The methodology to determine a Fixed Unit Price will use estimates of waste disposal costs derived from the NDA's "Parametric Cost Model". NDA, at the request of DECC, has developed a range of scenarios for geological disposal and these have been used in the Parametric Cost Model to identify the cost impact of these scenarios.

1.15 These estimates will then need to be adjusted to take account of risk and uncertainty. Three distinct sets of risks have been identified:

- Risks arising because we do not yet have a site for a GDF and therefore the geological environment in which a GDF will be built is uncertain. To accommodate this risk, the methodology to determine a Fixed Unit Price considers a variety of geological scenarios and their associated costs and uses Monte Carlo methods in order to determine a distribution of estimated disposal costs.
- Risks relating to the possibility that the Parametric Cost Model does not correctly calculate the costs of a specific disposal scenario. These risks have been defined as "In-Model Risks" and the cost estimates need to be adjusted for these risks. At present this will take the form of an "Optimism Bias" adjustment, though in future it may be possible to address this issue through a comprehensive assessment of the level of uncertainty in estimated costs.
- Risks relating to wider uncertainties, defined as "Out-of-Model Risks". This will take the form of a "Contingency Allowance", calculated through an exercise to identify a set of risks, together with an assessment of the consequence and probability of each risk occurring.

1.16 The Government considers that an operator's full share of waste management costs should include a contribution toward the fixed costs of building a GDF that will take both legacy and new build wastes. The contribution will be related to the use the operator is expected to make of a GDF and will be estimated by its share of the expected total variable costs of a GDF. The cost estimates used in the methodology to determine a Fixed Unit Price will assume the co-disposal of legacy and new build waste. However the proposed methodology retains the flexibility to revise this assumption at a later date if there were reasons to consider that there was a significant risk that a second GDF might be needed in order to accommodate all the waste from new nuclear power stations.

1.17 The fixed costs of a GDF will be incurred many years before the emplacement of new wastes in a GDF because it is currently assumed that emplacement of legacy wastes will take priority. The issue of "late payment" of the contribution to the fixed costs of a GDF was considered in the pre-consultation discussion papers. Having considered this issue, the Government proposes that the element of the Fixed Unit Price relating to the contribution to the fixed costs of a GDF should be subject to a "financing charge", based on the approach that might be taken in the theoretical case that the Government were constructing a GDF to a timescale driven by the needs only of new build operators.

1.18 It is important to note that when an operator of a new nuclear power station requests a Fixed Unit Price, its level will be determined by the Secretary of State, having regard to the cost estimates derived from the cost modelling process.

1.19 If an operator opts to defer the setting of its Fixed Unit Price, the basis on which its Fixed Unit Price will be determined will be set out in an agreement between the Secretary of State and the operator that will be agreed alongside the operator's FDP.

1.20 When a Fixed Unit Price or an eFUP is set, its value will be indexed for inflation.

Deciding the "unit" for the Fixed Unit Price

1.21 The purpose of setting a fixed price per unit of ILW or spent fuel for disposal is to ensure that the amount an operator pays is relative to the amount of waste or spent fuel they produce. It is therefore important to be clear about the units to be used for the Fixed Unit Price for ILW.

1.22 For ILW it is considered sufficient to use a simple volume measure. The UK Radioactive Waste Inventory measures the volume of existing ILW in cubic metres of packaged volume and it is proposed that the same unit be used for the Fixed Unit Price for ILW.

1.23 A Fixed Unit Price for spent fuel will need to take into account more detailed considerations around its disposal route and the impact of various assumptions around, for example, fuel burn-up and heat load. It will be important that the unit for spent fuel reflects the costs of disposal. There are a number of units that could be used for setting a Fixed Unit Price for spent fuel, based on output or quantity of spent fuel. It is proposed that the Fixed Unit Price for spent fuel be levied in terms of pence per kilowatt electricity generated (p/kWh(e)). The best alternative option is considered to be a quantity-based unit such as tonnes of uranium (tU).

Worked examples

1.24 Chapter 4 of this consultation document sets out worked examples for how the Fixed Unit Price would be calculated using the proposed methodology and the estimated waste disposal liability that would imply for a generic PWR.

1.25 The Fixed Unit Price and eFUP figures provided for the purpose of illustration are based on an Assumed Disposal Date of 2130 and a Transfer Date of 2080. The price payable on the Transfer Date is calculated on the basis of a real annual discount rate of 2.2%.

Table 1: illustrative values for the Fixed Unit Price, eFUP and total estimated waste disposal liability, as calculated in the worked examples in Chapter 4

	Fixed Unit Price		eFUP	
	On Assumed Disposal Date (2130)	On Transfer Date (2080)	On Assumed Disposal Date (2130)	On Transfer Date (2080)
Spent fuel: per canister (£k)	1645 – 2014	554 – 679	1082	365
p/kWh	0.194 – 0.238	0.065 – 0.080	0.128	0.043
ILW per m^3 (£k)	32.0 – 48.4	10.8 – 16.3	25.3	8.5
Waste disposal liability (£m)	887 – 1104	299 – 372	592	199

Updated estimates of the costs for decommissioning, waste management and waste disposal

1.26 The consultation document provides updated estimates of the costs for decommissioning, waste management and waste disposal. It explains how these updated estimates have been developed, and compares the figures with the Government's previous estimates set out in the 2007 Nuclear Consultation[3]. It also explains that it is important to be cautious in estimating total costs as there are considerable uncertainties in a number of areas.

1.27 Operators of new nuclear power stations will be expected to calculate their own estimates of these costs. However, the Government's methodology to determine the cost estimates provides operators with an example of how they might calculate their own cost estimates, as well as ensuring that the Government and the Nuclear Liabilities Financing Assurance Board (NLFAB) have a benchmark against which to assess the estimates produced by the operators.

1.28 In order to produce a generic estimate of the costs for decommissioning and waste management, a series of assumptions have been made, drawing on the Base Case set out in the FDP Guidance consultation document. Based on these assumptions and taking the considerable uncertainties into account, for a generic PWR reactor with a capacity of 1.35GW, operating for 40 years, decommissioning and waste management costs are estimated to be in the range £800 – £1800m. This compares to the estimate of £636m given in the 2007 Nuclear Consultation. The increase in the updated estimate is because the 2007 estimate is considered to have excluded important categories of waste management costs that will need to be met from an operator's independent Fund.

1.29 Based on the worked examples set out in Chapter 4, illustrative figures are also provided for the costs of waste disposal for a generic PWR. On the basis of setting a Fixed Unit Price, an operator's total waste disposal liability on the Assumed Disposal Date is estimated to be in the range £887 – 1104m, which translates to a payment on the Transfer Date in the range £299 – 372m. On the basis of setting an eFUP, an operator's total waste disposal liability on the Assumed Disposal Date is estimated to be £597m, which translates to a payment on the Transfer Date of £199m. These compare to an estimate of £276m given in the 2007 Nuclear Consultation. The reason for the increase in the updated estimate is that the 2007 estimate predated the detailed analysis set out in Chapters 3 and 4 of this consultation document, and important assumptions that underpinned the previous estimates in 2007 have since been revised.

1.30 Finally, the consultation document shows how the updated cost estimates might translate into a "levelised cost", i.e. a cost per unit of electricity generated. This calculation depends on the assumptions made around the investment performance of the operator's independent Fund and, given the long timescales involved, even small variations in assumed fund performance can have a very large impact on the estimated level of payments into the Fund. It will be for the operator to propose an investment strategy for their Fund, and this will be approved by the Secretary of State as part of the FDP approval process.

1.31 Therefore the example figures provided in this consultation document are for illustrative purposes only. The operator will be responsible for making good any shortfall or risk of shortfall in the accumulated monies held by their independent Fund, in order to ensure that the Fund is sufficient to meet their waste and decommissioning liabilities.

[3] The Future of Nuclear Power. The Role of Nuclear Power in a Low Carbon UK Economy http://www.berr.gov.uk/files/file39197.pdf

Table 2: illustrative values for an operator's waste disposal costs expressed in £/MWh[4]

	Target fund value in 2080 (£m)	Levelised cost (£/MWh)
Fixed Unit Price	299 – 372	0.26 – 0.71
eFUP	199	0.18 – 0.38

Table 3: illustrative values for an operator's decommissioning and waste management costs expressed in £/MWh

	Total cost estimate (£m)	Levelised cost (£/MWh)
Decommissioning and waste management costs	800 – 1800	0.59 – 2.65

Responding to the consultation

1.32 We want to hear from members of the public, industry, financial and other institutions that may be involved in the financing of new nuclear power stations, non-governmental organisations and any other organisation or body with an interest.

1.33 When responding please state whether you are responding as an individual or representing the views of an organisation. If you are responding on behalf of an organisation, please make it clear who the organisation represents and, where applicable, how you assembled the views of members.

How to respond

1.34 A response form is included at Annex F.

1.35 The closing date for responses is **18 June 2010**. Email responses are preferred. Please send your response to the consultation mailbox: decomguidance@decc.gsi.gov.uk

1.36 Alternatively, please send hard copy responses by post to:

Fixed Unit Price methodology and updated cost estimates consultation
Office for Nuclear Development
Department of Energy and Climate Change
Area 3D
3 Whitehall Place
London
SW1A 2AW

[4] It should be noted that although both Table 1 and Table 2 show waste disposal costs expressed in the form of money per unit output, there are important differences between them. It is to help make this distinction clear that Table 1, and Section 4.4, use the unit p/kWh while Table 2, and Section 5.5, use the unit £/MWh:

- The p/kWh figures in Table 1 are an illustration of a Fixed Unit Price for spent fuel. Hence these figures do not depend on any fund growth assumptions. They also exclude costs of ILW disposal.
- The £/MWh figures in Table 2 are a "levelised cost" estimate, covering the disposal of both spent fuel and ILW. These figures depend heavily on the assumed rate of fund growth and would be subject to change depending on actual fund performance, to ensure that there were sufficient monies in an operator's Fund to meet the waste disposal liability.

Additional copies

1.37 You may make copies of this document without seeking permission. An electronic version can be downloaded from DECC's website at: http://www.decc.gov.uk/en/content/cms/consultations/nuc_waste_cost/nuc_waste_cost.aspx

1.38 Further hard copies of the consultation document may be obtained from:

Publications Orderline, ADMAIL, 528, London SW1W 8YT
Tel: 0845-015 0010
Fax: 0845-015 0020
Minicom: 0845-015 0030

Confidentiality and data protection

1.39 Your response may be made public by the Government. If you do not want all or part of your response or name made public, please identify the information which you do not wish to be disclosed. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded as binding on the Department.

1.40 You should be aware that information provided in response to the consultation, including personal information, may be subject to publication or disclosure in access to information regimes (primarily the Freedom of Information Act 2000 (FOIA), the Data Protection Act 1998 (DPA) and the Environmental Information Regulations 2004 (EIR)).

1.41 If you want information that you have provided to be treated as confidential, please be aware that, under the FOIA, there is a statutory Code of Practice with which public authorities must comply and which deals with, amongst other things, obligations of confidence.

1.42 In view of this, it would be helpful if you could explain to us why you regard the information you have provided as confidential. If we receive a request for disclosure of the information we will take full account of your explanation, but we cannot give an assurance that confidentiality can be maintained in all circumstances.

1.43 The Department will process your personal data in accordance with the DPA and in the majority of circumstances this will mean that your personal data will not be disclosed to third parties.

Help with queries

1.44 A copy of the consultation code of practice criteria is set out at Annex G.

1.45 Please direct any queries about the consultation to our consultation mailbox: decomguidance@decc.gsi.gov.uk or in writing to the address given in paragraph 1.36 above.

1.46 If you have any comments or complaints about the way the consultation has been conducted (as opposed to comments about the issues which are the subject of the consultation), these should be sent to the DECC Consultation Co-ordinator:

DECC Consultation Co-ordinator
3 Whitehall Place
London
SW1A 2AW
Email: consultation.coordinator@decc.gsi.gov.uk

Next steps

1.47 The finalised approach on the issues covered by the consultation will be issued alongside the finalised FDP guidance, which we expect to publish later in 2010. Responses to the consultation will be taken into account when developing both documents.

Complete list of consultation questions

1.48 This consultation focuses on the consultation questions listed below. When considering responses to this consultation, the Government will give greater weight to responses that are based on argument and evidence, rather than simple expressions of support or opposition.

1.49 When answering these questions please explain and give reasons for your answers.

Chapter 3: The methodology to determine a Fixed Unit Price	
1	Do you agree or disagree that prospective operators of new nuclear power stations should be given the option to defer the setting of their Fixed Unit Price? If so, do you agree that this deferral should be limited to 10 years after the nuclear power station has commenced operation? Do you have any comments on the way the Government proposes to determine an expected Fixed Unit Price as the basis for an operator's interim provision in the event that they choose to defer the setting of their Fixed Unit Price?
2	Do you agree or disagree with the proposal that the Schedule for the Government to take title to and liability for an operator's waste should be set in relation to the predicted end of the decommissioning of the nuclear power station? Do you have any comments on the way the Government proposes to recoup the additional costs it will incur in this case?
3	Do you agree or disagree that the proposed methodology to determine a Fixed Unit Price strikes the right balance in protecting the taxpayer, by taking a prudent and conservative approach to cost estimation, while facilitating new nuclear build by providing certainty to operators? What are your reasons?
4	Do you agree or disagree with the proposed approach to determining an operator's contribution to the fixed costs of constructing a Geological Disposal Facility? What are your reasons?
5	Do you agree or disagree with the proposal that the units to be used for the Fixed Unit Price are pence per kWh for spent fuel and cubic metres of packaged volume for intermediate level waste? What are your reasons?
Chapter 5: Updated estimates of the costs for decommissioning, waste management and waste disposal	
6	Do the updated cost estimates represent a credible range of estimates of the likely costs for decommissioning, waste management and waste disposal for a new nuclear power station?

Chapter 2: Background

2.1 This section sets out the background to the proposals in this consultation. It is provided here for information only.

The White Paper on Nuclear Power

2.2 The White Paper on Nuclear Power[5] published in January 2008 set out the Government's formal response to the consultation on the future of nuclear power. The Nuclear White Paper stated that:

"The Government believes it is in the public interest that new nuclear power stations should have a role to play in this country's future energy mix alongside other low-carbon sources; that it would be in the public interest to allow energy companies the option of investing in new nuclear power stations; and that the Government should take active steps to open up the way to the construction of new nuclear power stations. It will be for energy companies to fund, develop and build new nuclear power stations in the UK, including meeting the full costs of decommissioning and their full share of waste management costs."

2.3. The Government also confirmed its commitment to put in place legislative arrangements to ensure that operators of new nuclear power stations have secure financing arrangements in place to meet the full costs of decommissioning and their full share of waste management costs.

The Energy Act 2008

2.4 This policy is being implemented through a framework created by the Energy Act 2008[6]. The Act requires operators of new nuclear power stations to have a Funded Decommissioning Programme (FDP) approved by the Secretary of State, in place before construction of a new nuclear power station begins and to comply with this programme thereafter.

2.5 Running in conjunction with this consultation is a consultation on the draft regulations for financing of nuclear decommissioning and waste handling, derived from the Energy Act 2008.[7]

Nuclear Liabilities Financing Assurance Board (NLFAB)

2.6 In the Nuclear White Paper, the Government announced its intention to create a new independent advisory body, the Nuclear Liabilities Financing Assurance Board (NLFAB). This board will provide impartial scrutiny and advice on the suitability of the FDPs submitted by operators of new nuclear power stations.

2.7 The NLFAB will advise the Secretary of State on the financial arrangements within the programme. Once the programme is approved, the NLFAB will also provide advice to the

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5 Meeting the Energy Challenge, A White Paper on Nuclear Power. Available at: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/white_paper_08/white_paper_08.aspx

6 Energy Act 2008 www.opsi.gov.uk/acts/acts2008/pdf/ukpga_20080032_en.pdf

7 The Energy Act 2008 – Consultation on The Financing of Nuclear Decommissioning and Waste Handling Regulations 2010. URN 10D/574. http://www.decc.gov.uk/en/content/cms/consultations/nuc_dec_fin/nuc_dec_fin.aspx

Secretary of State on the regular reviews and ongoing scrutiny of financial arrangements. The Board consists of experts from relevant fields[8] and was appointed in March 2009.

Funded Decommissioning Programme Guidance

2.8 The FDP Guidance consultation document published in February 2008 set out two sets of draft guidance on what an approvable FDP should contain[9]. The finalised guidance is expected to be published later in 2010 and will assist operators in understanding their obligations under the Energy Act, and what is required for an approvable FDP.

2.9 The first set of guidance (Decommissioning and Waste Management Plan (DWMP) guidance) will assist operators in setting out and costing the steps involved in decommissioning a new nuclear power station and managing and disposing of hazardous waste and spent fuel in a way which the Secretary of State may approve. The guidance will include a Base Case, which will set out a realistic and prudent way to estimate the potential costs for decommissioning and waste management.

2.9.1 The second set of guidance (Funding Arrangements Plan (FAP) guidance) will assist operators in setting out acceptable financing proposals to meet the costs identified. It will set out the guiding principles by which the Government would expect to assess the funding proposals submitted by operators as part of their FDP for approval under the provisions in the Energy Act.

2.9.2 A total of 43 formal written responses to the FDP Guidance Consultation were received and the Government Response was published in September 2008[10].

The policy to set a Fixed Unit Price

2.10 The FDP Guidance consultation document also included background information on the Government's policy to set a Fixed Unit Price for operators of new nuclear power stations for disposal of their intermediate level waste (ILW) and spent fuel and a schedule for the Government to take title to and liability for these materials.

2.11 The Fixed Unit Price will be set at a level over and above expected costs and will include a significant risk premium. This risk premium should help to ensure that the operator bears the risks around uncertainty in waste costs and will provide the taxpayer with material protection against the eventuality that the actual costs of geological disposal exceed the projected costs.

2.12 Should the actual costs of providing the waste disposal service prove lower than expected, these lower costs will not be passed on to the operator who would have gained from the certainty of a Fixed Unit Price and would not have been exposed to the risk of price escalation.

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8 The members of the NLFAB are listed at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/new/waste_costs/nlfab/nlfab.aspx

9 Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations. Available at: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/new/waste_costs/waste_costs.aspx

10 The Government Response to the Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations. Available at: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/new/waste_costs/waste_costs.aspx

2.13 The Fixed Unit Price for the disposal of ILW and spent fuel will be based on an estimate of the costs of disposing these materials in a Geological Disposal Facility (GDF). This costing will include:

- an estimate of the costs of disposing of ILW and spent fuel in a GDF;
- a significant risk premium to cover the risk that the eventual costs of building a GDF are higher than estimated, and the risk that the GDF is not available when required by the agreed Schedule for the Government to take title to and liability for these materials.

2.14 The methodology to determine a Fixed Unit Price will use the NDA's latest estimates of waste disposal costs for ILW and spent fuel. The NDA has developed a "Parametric Cost Model" to enable the costs of a GDF for higher activity wastes to be estimated despite the current level of uncertainty. A description of how the Government will use the NDA's Parametric Cost Model to determine the appropriate level for the Fixed Unit Price is provided in Section 3.3 of this document.

2.15 The Nuclear White Paper set out that new nuclear power stations should proceed on the basis that spent fuel will not be reprocessed. Thus the methodology to determine a Fixed Unit Price assumes that a once-through fuel cycle and that spent fuel will be disposed of after it has been used. However in accepting a Fixed Unit Price an operator would not be irrevocably committed to the disposal of its spent fuel in a GDF being constructed by the Government, if technological or other developments made an alternative approach more economically attractive. The agreement between the Government and the operator setting out the terms on which the Government will take title to and liability for the operator's waste would cover issues such as the abort or termination costs that would be payable by the operator if it later chose not to use the Government waste disposal service.

Pre-consultation discussion papers on specific issues relating to the Fixed Unit Price

2.16 In response to the level of interest shown by stakeholders during the 2008 FDP Guidance Consultation on the policy to set a Fixed Unit Price, the Government Response set out plans to produce a series of three discussion papers[11] and to hold a formal public consultation on the issues covered by the papers.

2.17 Each of the discussion papers addressed specific issues relating to the methodology to determine a Fixed Unit Price for the disposal of ILW and spent fuel from new nuclear power stations:

- The first paper in this series, issued in October 2008, was on a methodology to determine how the fixed costs of building a GDF should be apportioned to and shared between operators of new nuclear power stations.
- The second paper in this series, issued in January 2009 discussed a methodology to determine a Fixed Unit Price.
- The third paper, issued in May 2009 set out a worked example to illustrate issues around a methodology to determine a Fixed Unit Price.

[11] These three discussion papers are available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/new/waste_costs/waste_costs.aspx

2.18 Chapter 3 of this document sets out the Government's proposed methodology to determine a Fixed Unit Price. This methodology takes into account the feedback that has been received during the pre-consultation. The worked example in Section 4.2 of this document is a revised and updated version of the worked example in Discussion Paper 3.

Updated estimates of the costs for decommissioning, waste management and waste disposal

2.19 The FDP Guidance consultation document said that the Government would develop updated estimates of the costs for decommissioning, waste management and waste disposal and included a draft methodology for estimating these costs. The methodology published in the FDP Guidance consultation document has been used to develop updated estimates of these costs and these updated estimates are set out in Chapter 5 of this document. The chapter also compares the updated cost estimates with the Government's previous estimates, that were published in the "Consultation on the Future of Nuclear Power" issued in May 2007[12].

2.20 Operators of new nuclear power stations will be expected to calculate their own estimates of these costs. However, the Government's methodology to determine the cost estimates provides operators with an example of how they might calculate their own cost estimates, as well as ensuring that the Government, the NLFAB and those responsible for managing operators' Funds have a benchmark against which to assess the estimates produced by the operators.

The Government policy on geological disposal

2.21 In the White Paper on Nuclear Power the Government set out its conclusion on waste and decommissioning:

"Having reviewed the arguments and evidence put forward, the Government believes that it is technically possible to dispose of new higher-activity radioactive waste in a geological disposal facility and that this would be a viable solution and the right approach for managing waste from any new nuclear power stations. The Government considers that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities and that this should be explored through the Managing Radioactive Waste Safely programme. The Government considers that waste can and should be stored in safe and secure interim storage facilities until a geological facility becomes available."

2.22 On 12 June 2008, the Government published the White Paper "Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal"[13]. The White Paper set out the framework for managing higher activity radioactive waste in the long-term through geological disposal, coupled with safe and secure interim storage and ongoing research and development to support its optimised implementation. The Managing Radioactive Waste Safely (MRWS) White Paper set out the Government's view that geological disposal and an approach based on voluntarism and partnership as a means of siting of a GDF is the right way forward.

[12] The Future of Nuclear Power. The Role of Nuclear Power in a Low Carbon UK Economy. http://www.berr.gov.uk/files/file39197.pdf

[13] MRWS White Paper, available at http://mrws.decc.gov.uk/

2.23 The MWRS White Paper gave the following explanation of what is meant by "geological disposal":

"Geological disposal involves isolating radioactive waste deep inside a suitable rock formation to ensure that no harmful quantities of radioactivity ever reach the surface environment. It is a multi-barrier approach, based on placing wastes deep underground, protected from disruption by man-made or natural events. Geological disposal is internationally recognised as the preferred approach for the long-term management of higher activity radioactive waste."

2.24 The Government has given responsibility for planning and implementing geological disposal to the NDA, so as to enable the NDA to take an integrated view across the waste management chain, with both long and short-term issues addressed in planning and strategy development. Since then NDA's Radioactive Waste Management Directorate (RWMD) has been established, which will develop into an effective delivery organisation to implement geological disposal.

Chapter 3: The methodology to determine a Fixed Unit Price

3.1 Introduction

3.1.1 The Fixed Unit Price will provide certainty to operators of new nuclear power stations on the costs of disposing of the ILW and spent fuel they will generate. In return for this certainty the Government will set the Fixed Unit Price at a level that helps ensure that the operator bears the risks around uncertainty in waste disposal costs and provides the taxpayer with material protection.

3.1.2 The Fixed Unit Price the Government will set for an operator will reflect the most up to date estimates of costs available at the date when the price is set and the level of certainty the Government has on those costs. The Fixed Unit Price will be set at a level over and above expected costs and will include a significant risk premium.

3.1.3 This chapter describes the issues that have been considered in devising the methodology to determine a Fixed Unit Price. In particular, this chapter sets out how the Government proposes to estimate the costs of waste disposal, the main uncertainties around those cost estimates and how those uncertainties are handled in the methodology.

3.1.4 Chapter 4 provides worked examples to illustrate the possible values for a Fixed Unit Price implied by this methodology. It should be noted that all calculations in this consultation are in "real" money, i.e. they disregard inflation. All money values in the worked examples in Chapter 4 are expressed in constant September 2008 money and are undiscounted except where indicated. When a Fixed Unit Price is set, its value will be indexed for inflation. When an operator sets out the investment strategy for its independent Fund, the Fund will be expected to recognise and address the risks associated with its investment strategy, including inflation risk[14].

3.1.5 Ahead of this consultation the Government issued three pre-consultation discussion papers during autumn 2008 and spring 2009 on issues relating to a methodology to determine a Fixed Unit Price[15]. In particular, Discussion Paper 3 set out a worked example for how a Fixed Unit Price might be calculated. Much of the proposed policy set out in this consultation builds on the analysis in those discussion papers and subsequent discussions with stakeholders. There were several issues that arose in the course of discussions with stakeholders during the pre-consultation process. This chapter discusses two of these issues in detail and sets out changes to the Government's approach that have resulted from the pre-consultation process.

[14] FDP Guidance consultation document, page 102.

[15] These discussion papers are available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/new/waste_costs/waste_costs.aspx

3.2 Issues arising from the pre-consultation process

3.2.1 The purpose of the pre-consultation discussion papers was to provide stakeholders with the opportunity to feed in views as the Government's policy developed. The feedback received on these papers has caused the Government to propose changes to two elements of the policy framework for setting a Fixed Unit Price that was set out in February 2008 in the FDP Guidance consultation document. These relate to:

- when the Fixed Unit Price should be set;
- when title to and liability for an operator's waste should transfer to the Government.

When the Fixed Unit Price should be set

Consultation Question 1:

Do you agree or disagree that prospective operators of new nuclear power stations should be given the option to defer the setting of their Fixed Unit Price? If so, do you agree that this deferral should be limited to 10 years after the nulear power station has commenced operation? Do you have any comments on the way the Government proposes to determine an expected Fixed Unit Price as the basis for an operator's interim provision in the event that they choose to defer the setting of their Fixed Unit Price?

3.2.2 The FDP Guidance consultation document said "we anticipate that operators will request that the Government provide them with a Fixed Unit Price at the time they seek approval for their Funded Decommissioning Programme"[16]. Prospective operators will be required to have their FDP agreed by the Secretary of State before commencing construction of their new nuclear power station. Therefore the pre-consultation discussion papers assumed that an operator's Fixed Unit Price would be set at the time the operator's FDP is agreed, that is before construction commenced.

3.2.3 The pre-consultation discussion papers set out the key uncertainties that the Government has identified in the estimate of waste disposal costs; the most significant is that a site has not yet been selected for a GDF. This means that it is difficult to estimate accurately the costs of waste disposal as the geological environment and final disposal concepts are not yet known. Furthermore it is expected to be some years before a site is identified and hence costs can be more accurately estimated.

3.2.4 As the level of uncertainty over costs is currently high, a Fixed Unit Price set in relation to current cost estimates would include a very substantial risk premium to reflect this uncertainty and provide material protection to the taxpayer from the risk of future cost escalation.

3.2.5 The FDP Guidance consultation document said "energy companies have indicated that they would be prepared to pay a significant risk premium over and above the expected cost of disposing of waste and spent fuel, in return for having the certainty of a Fixed Unit Price"[17]. However, given that investment in new nuclear in the UK will be private sector led and evaluated on a purely economic basis, it is possible that a prospective operator may evaluate the benefit from fixing the unit price at the outset to be outweighed by this very substantial risk premium.

[16] FDP Guidance consultation document paragraph 2.13

[17] FDP Guidance consultation document paragraph 2.9

3.2.6 In this case, a prospective operator might request that the setting of their Fixed Unit Price be deferred until a later date. This would be on the expectation that over time greater certainty over waste disposal costs would be reflected in a smaller risk premium and a lower Fixed Unit Price. It should be noted however that in seeking a deferral the operator would be accepting the risk that a Fixed Unit Price set at a later date could be higher than the price on offer at the outset, if estimated costs escalate sufficiently in the intervening period.

3.2.7 **Having considered this issue the Government proposes to offer a prospective operator two options: a Fixed Unit Price set at the time their FDP is first agreed; or, to defer the setting of their Fixed Unit Price for a defined period. In order to exercise the option to defer, the Secretary of State would need to be assured that in the interim the operator will make prudent provision in their FDP for waste disposal costs and will be capable of meeting in full its waste disposal liabilities even in the event of subsequent escalation in costs.**

3.2.8 In order to obtain this assurance the Government would:

- Limit the duration of the deferral by specifying a maximum "Deferral Period" at the end of which the Fixed Unit Price will be set.
- For the interim period, provide the prospective operator with an "expected Fixed Unit Price" (eFUP) to enable it to make prudent provision.

Setting an expected Fixed Unit Price (eFUP)

3.2.9 If an operator opts to defer the setting of their Fixed Unit Price, the Government will provide them with an eFUP. This will be the Government's best estimate of the level of the Fixed Unit Price at the time it is eventually set, i.e. at the end of the Deferral Period.

3.2.10 The Government will use the same methodology to determine a Fixed Unit Price whether it is set alongside the approval of an operator's FDP or whether it is set at the end of a Deferral Period. Therefore an eFUP will also be determined using the same methodology. The Fixed Unit Price and the eFUP will be based on estimated disposal costs and will include a risk premium to reflect the level of uncertainty in those cost estimates. The key difference is that:

- a Fixed Unit Price will include a risk premium that reflects the level of certainty over waste disposal costs at the time the price is set;
- an eFUP will include a risk premium that reflects the Government's best estimate of the level of certainty there will be over waste disposal costs at the end of the Deferral Period.

3.2.11 At present the level of uncertainty in the estimate of disposal costs is high and so the risk premium that will be required by the Government in order to set a Fixed Unit Price will be similarly high. Over time, and as progress is made in the implementation of geological disposal, the level of uncertainty is expected to reduce. Indeed the objective of deferring the setting of a Fixed Unit Price is to allow much of this uncertainty to be resolved and it is expected that a Fixed Unit Price set at the end of the Deferral Period will be based on much more accurate cost estimates than those currently available.

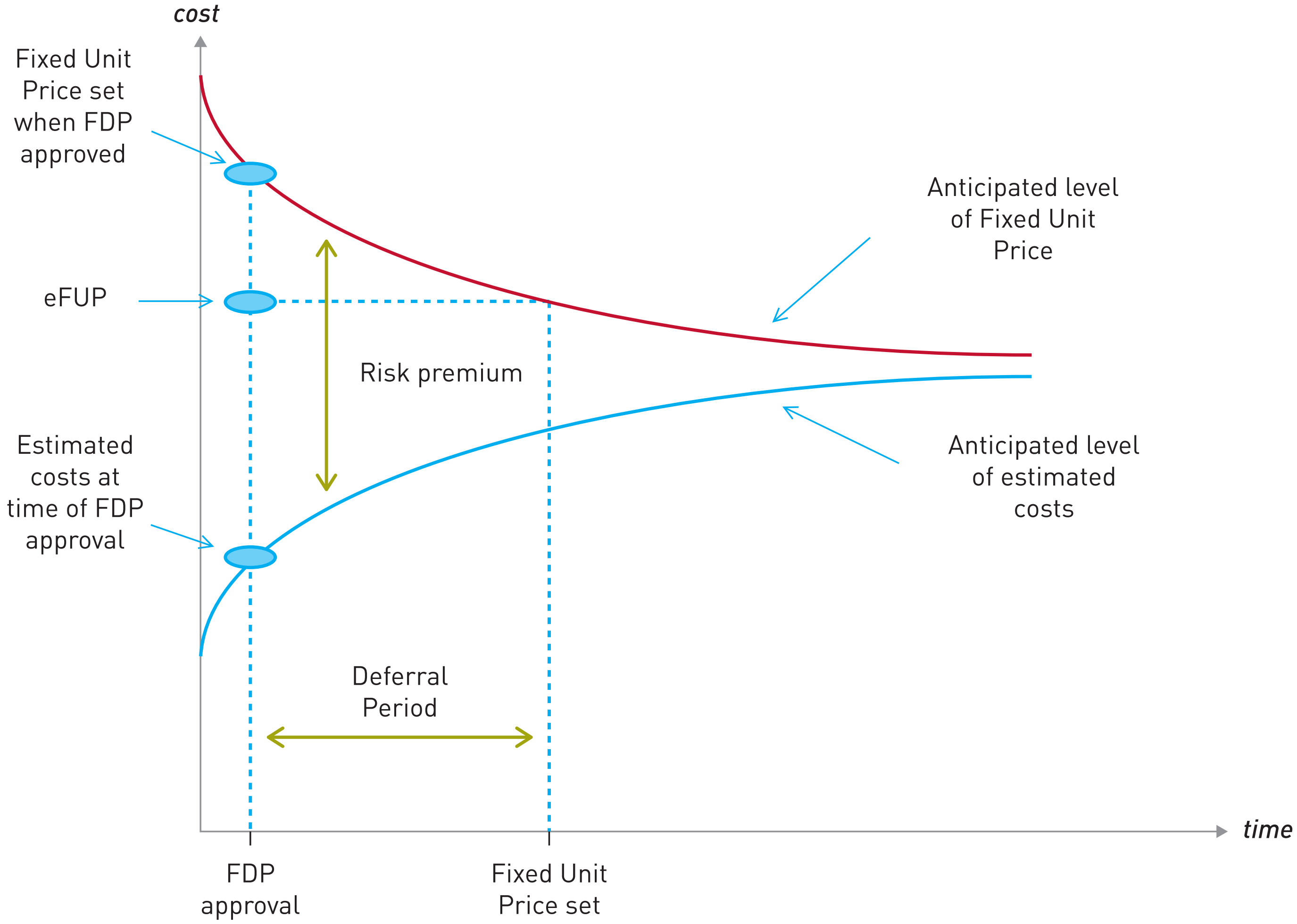
3.2.12 This means that at the time an operator's FDP is first approved, the eFUP provided by the Government is likely to include a smaller risk premium than a Fixed Unit Price offered at that time and therefore the eFUP will be lower than the Fixed Unit Price.

This is because in opting for an eFUP, which is subject to change over time, rather than a Fixed Unit Price, which by definition cannot be revised, the operator is accepting more risk and the Government is taking less risk.

3.2.13 The level of the eFUP will be regularly reviewed during the Deferral Period and is likely to be revised from time to time. The eFUP might be revised upwards in the event of changes either to estimates of waste disposal costs or to estimates of the risk premium that will be required at the end of the Deferral Period. For example if progress towards a GDF is slower than currently anticipated the Government might need to revise upwards the level of the risk premium included in the eFUP.

3.2.14 Figure 1 illustrates this proposal. It shows that a Fixed Unit Price set at the time an operator's FDP is first approved will include a large risk premium over estimated costs. This is due to the high level of uncertainty around those costs. Over time, it is expected that estimated costs will increase, but that the risk premium required will reduce as there is greater certainty over those cost estimates. The eFUP represents the anticipated level of the Fixed Unit Price at the end of the Deferral Period.

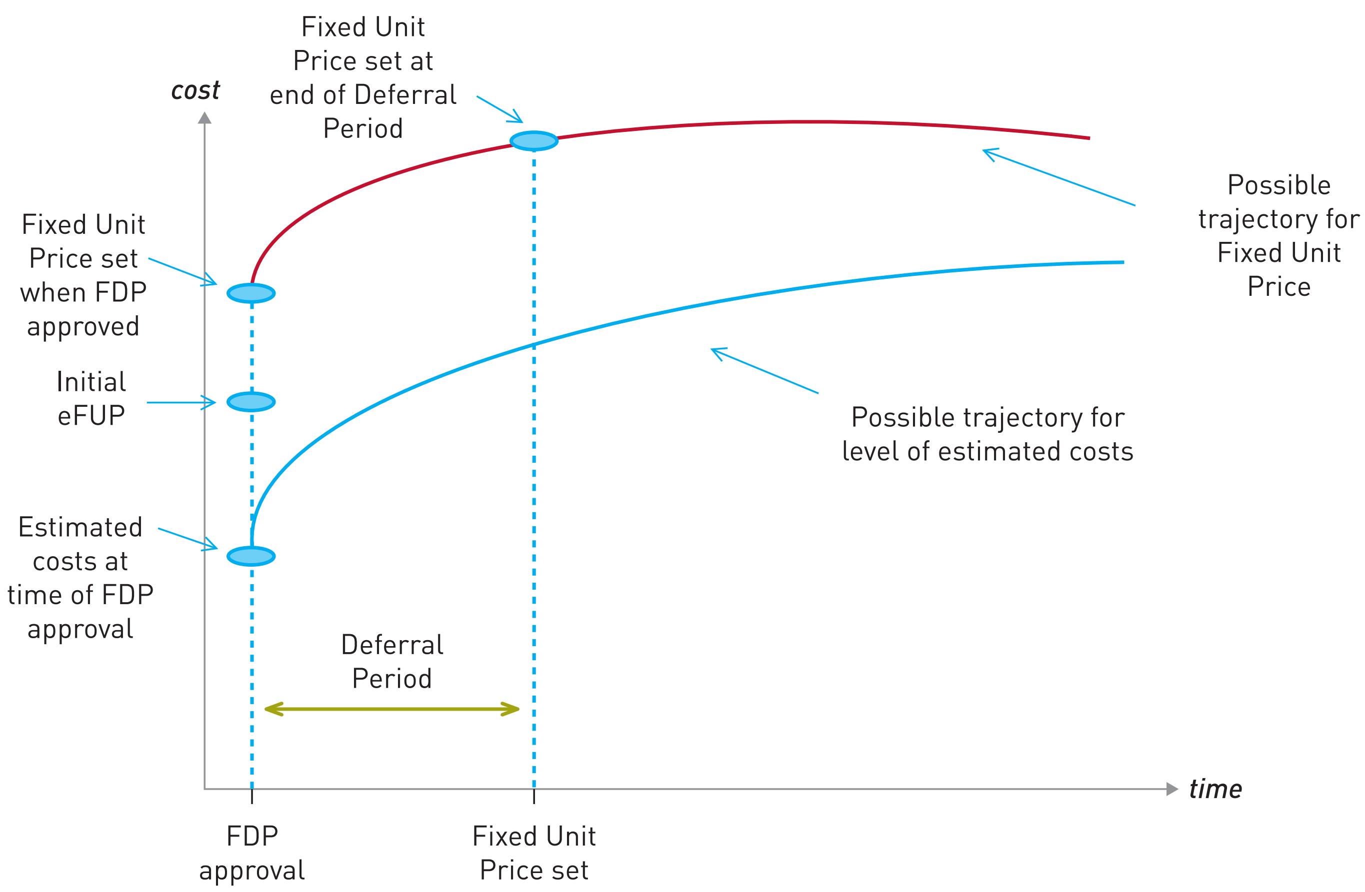
Figure 1: illustration of the expected impact of deferring the setting of a Fixed Unit Price



3.2.15 It is considered likely that over time estimates of disposal costs will rise, but greater certainty over those estimates will cause the risk premium to fall. Figure 1 reflects the expectation that, as progress in made towards implementation of a GDF, the reduction in the risk premium will more than offset any increase in estimated costs, and hence the level of the Fixed Unit Price will fall over time.

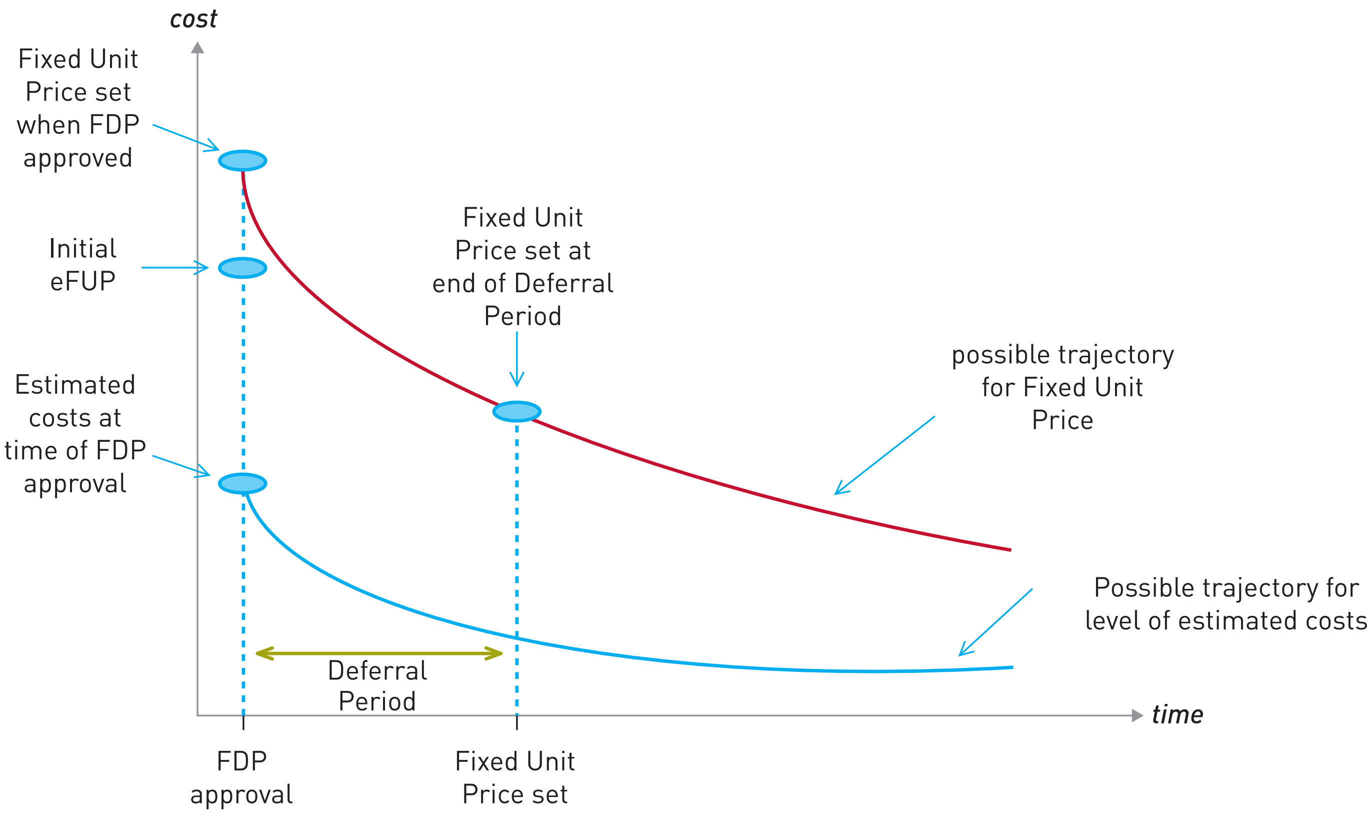
3.2.16 It is of course possible that cost estimates might increase more rapidly, or the risk premium reduce more slowly, than assumed in Figure 1 in which case the eFUP might increase over time and the Fixed Unit Price set at the end of the Deferral Period could be higher than that offered at the outset. This more pessimistic scenario is illustrated in Figure 2.

Figure 2: alternative illustration of the expected impact of deferring the setting of a Fixed Unit Price (pessimistic scenario)



3.2.17 It is also possible that the level of estimated costs might fall over time, or the risk premium could be reduced more quickly than assumed in Figure 1. In this case the level of the eFUP would fall over time and the Fixed Unit Price set at the end of the Deferral Period could substantially be lower than that offered at the outset. This more optimistic scenario is illustrated in Figure 3.

Figure 3: alternative illustration of the expected impact of deferring the setting of a Fixed Unit Price (optimistic scenario)



3.2.18 Section 4.3 of this document provides a worked example of how an eFUP would be calculated in the event that an operator opted to defer the setting of its Fixed Unit Price.

Limiting the duration of the Deferral Period

3.2.19 The total cost of disposing of the waste from a new nuclear power station will not be certain until many years after the end of electricity generation at the station and after revenues have ceased. However if an operator's waste disposal liability remained uncertain beyond the end of generation, there would be a risk that the operator could not fund its liabilities in the event of subsequent escalation in waste disposal costs. Therefore to protect the taxpayer the Government will specify the maximum length of the "Deferral Period", which will come to an end during the operational life of the station. This will ensure that the price that an operator will pay for the disposal of its waste is clearly defined at a level which provides material protection to the taxpayer from future cost escalation, and the operator will be required to make prudent provision to meet their liability.

3.2.20 As discussed above, an eFUP, which an operator would use as the basis of their prudent provision during the Deferral Period, could be revised upward over time. The operator would be accepting the risk that the Fixed Unit Price that the Government will set at the end of the Deferral Period could be higher than the eFUP previously provided by the Government. In this case the operator would be required to increase payments into their fund to ensure there were sufficient monies to meet their liabilities. The size of this increase in fund contributions would depend on the scale of the increase in estimated liabilities and on the remaining period over which additional contributions were to be made.

3.2.21 To avoid the risk that there are insufficient years of operation to make up any shortfall in the operator's fund it is proposed to limit the length of the Deferral Period to no more than 10 years after the nuclear power station begins to generate electricity.

When title to and liability for an operator's waste should transfer to the Government

Consultation Question 2:

Do you agree or disagree with the proposal that the Schedule for the Government to take title to and liability for an operator's waste should be set in relation to the predicted end of the decommissioning of the nuclear power station? Do you have any comments on the way the Government proposes to recoup the additional costs it will incur in this case?

3.2.22 Alongside the Fixed Unit Price, a schedule will be agreed for the Government to take title to and liability for an operator's waste (the Schedule). The FDP Guidance consultation document said that the Government expected the Schedule to be aligned to estimates for availability of disposal facilities[18].

3.2.23 The Government has not set a fixed delivery timetable for the implementation of geological disposal, but the NDA's planning assumption is that a UK facility could be operational by about 2040, with all legacy wastes emplaced by about 2130[19] (for the inventory of legacy wastes set out in Annex D). It is currently anticipated that emplacement of new build wastes would begin once the emplacement of legacy wastes is complete (though it might be possible to dispose of new build ILW somewhat earlier).

3.2.24 The first new nuclear power stations are expected to be operational from around 2018 and the Base Case assumption is for a reactor life of 40 years. In this case, if a GDF is not able to take the spent fuel from a new nuclear power station until 2130 this implies around 70 years of interim storage after the end of the nuclear power station's operating life[20]. Therefore if the Schedule were set in relation to estimates of the availability of a GDF the operator would be responsible for the onsite interim storage of their waste for several decades after revenues from that power station have ceased, and potentially for many years after the nuclear power station has been otherwise decommissioned.

3.2.25 The pre-consultation process has highlighted that this scenario presents a risk to both the operator and the Government. The risk to the operator is that it might face additional costs over an extended period during which the station is not generating revenues to meet those costs. The consequent risk to the Government is that the operator might prove unable to meet all the additional costs over this period and they would fall to the taxpayer.

[18] FDP Guidance consultation document paragraph 2.15

[19] Consultation on draft National Policy Statements for Energy Infrastructure page 148 http://data.energynpsconsultation.decc.gov.uk/documents/condoc.pdf

[20] It should also be noted that the assessments of the disposability of spent fuel from new nuclear power stations carried out by NDA as part of the Generic Design Assessment process included the finding that if spent fuel is produced at the highest burn-up considered (which is 65 GWd/tU) spent fuel cooling might be required for a period of up to 100 years before disposal. One of the characteristics of increased burn-up fuel is that the inventory of long-lived radionuclides in the fuel increases and, as a consequence, the spent fuel is thermally hot. Therefore higher burn-up spent fuel will in general require longer periods of interim storage. However NDA's finding is based on a number of conservative assumptions and there are several factors that may shorten the actual storage period that is likely to be required for spent fuel from new nuclear power stations. This issue is discussed in "The Arrangements for the management and disposal of waste from new nuclear power stations: a summary of evidence" pages 13-14 http://data.energynpsconsultation.decc.gov.uk/documents/wasteassessment.pdf

3.2.26 **The Government considers that over such very long timescales it is better placed than an operator to manage cost risks. Hence to ensure that risks lie where they are most effectively managed it is proposed that the transfer to the Government of title and liability be brought forward (Early Transfer) and the Transfer Date be aligned with the operator's decommissioning timetable, rather than to an estimate of the availability of a GDF.**

Recovery of additional costs to the Government

3.2.27 Under Early Transfer, the Government would become responsible for the operator's waste many years ahead of disposal. However it remains the Government's policy that operators will meet their full share of waste management costs. Government would therefore need to be compensated for incurring the following waste management costs:

- the interim storage of the waste pending disposal;
- the costs of transporting the waste from the site of the nuclear power station to a GDF (in line with the Base Case assumption of onsite interim storage);
- the cost of encapsulating spent fuel for disposal (in line with the Base Case assumption that encapsulation of spent fuel is expected to take place immediately prior to disposal)[21].

3.2.28 One approach would be for the Government to expand the scope of the Fixed Unit Price to cover these costs. This would require the Government to estimate these costs, together with their attendant level of uncertainty. However this uncertainty is considerable, particularly around the costs of encapsulation, and hence the additional risk premium would be large.

3.2.29 **Therefore the Government does not propose to expand the scope of the Fixed Unit Price beyond the estimated cost of geological disposal.**

3.2.30 Instead the Government proposes to recover these additional costs outside the Fixed Unit Price framework. An operator is required in its FDP to estimate waste management costs. These estimates must be independently verified, periodically reviewed and agreed by the Secretary of State. The Government's view is that Early Transfer need not affect these arrangements. The operator will continue to be required in its FDP to estimate all waste management costs up to the point that waste is delivered to a GDF for final disposal and to make provision for these costs in their independent Fund. This would ensure that there were sufficient monies to pay all of these costs, including those waste management costs arising after the Transfer Date.

3.2.31 These monies would transfer to the Government as a lump sum payment at the same time as title to and liability for the waste is transferred. This lump sum would be a full and final payment for all remaining waste management costs (including the decommissioning of interim stores if necessary). The level of this lump sum would not be set at the outset but instead would be estimated in the operator's FDP and regularly reviewed. It is anticipated that the final level of this lump sum payment would be fixed shortly before the Transfer Date.

[21] It should be noted that this does not imply that the Government would commit to the provision of encapsulation facilities for the spent fuel from new nuclear power stations. The Government's view remains that the operator should be responsible for ensuring the encapsulation of its spent fuel and would expect the operator in its FDP to demonstrate credible plans for the encapsulation of its spent fuel and prudent provision for the costs. If Early Transfer means that the Government is ultimately responsible for carrying out encapsulation, the operator's plans and financial provision would transfer to the Government alongside the spent fuel.

3.2.32 At present there is uncertainty over these waste management costs but this should reduce over time. By the Transfer Date (assumed for the purpose of illustration to be around 2080 in the worked examples set out in this consultation) it should be possible to estimate these costs with a much higher degree of confidence. Notwithstanding this, under this approach the Government would expect the operator's provision to be based on a conservative, evidence-based, estimate of the waste management costs, and would expect the lump sum payment to include a commensurate risk premium to protect the taxpayer in the event that the waste management costs are higher than estimated.

3.2.33 In order for the operator to estimate and make prudent provision in their FDP for the waste management costs the operator will need to know the expected time period over which the Government will be responsible for maintaining their waste in interim storage prior to disposal.

3.2.34 **Therefore the Government will also provide an operator with an "Assumed Disposal Date," to enable the operator to make prudent provision for waste management costs.**

3.2.35 In the event that geological disposal facilities were not available at the Assumed Disposal Date, the Government would bear the cost of continued interim storage. Therefore the calculation of the risk premium included in the Fixed Unit Price would need to take account of this uncertainty[22].

Impact of Early Transfer on the Fixed Unit Price

3.2.36 The Fixed Unit Price will be the price applicable at the Assumed Disposal Date. However under Early Transfer, the Fixed Unit Price will be paid many years before the Assumed Disposal Date.

3.2.37 As a general principle the Government considers it necessary for the payment made by an operator in relation to the Fixed Unit Price to reflect the "time value of money", i.e. that the value of money is affected by when it is paid, based on the principle that a sum of money paid today is more valuable than the certainty of receiving the same sum at a later date. It is therefore necessary to adjust the payment made by the operator to reflect this early payment. This will be done through the application of an appropriate discount rate to the Fixed Unit Price to reflect this time difference.

3.2.38 This discount rate will not be fixed alongside the Fixed Unit Price. Rather, it will be determined nearer the Transfer Date and set in relation to the rates of returns at that time on long-term investments in Government securities and similar assets. The Government will provide the operator with an estimated long-term discount rate, to enable prudent provision to be made. The worked examples in Chapter 4 apply a real discount rate of 2.2% per annum, as this is consistent with the long-term discount rate applied to legacy liabilities in the NDA's Annual Report and Accounts.

3.2.39 The reason for setting the Fixed Unit Price in relation to the Assumed Disposal Date, and then discounting that price to determine the price that an operator would pay on the Transfer Date, is in order for the methodology to be able to accommodate a change in the Transfer Date without requiring the Fixed Unit Price to be recalculated.

3.2.40 This is because it is considered possible that an operator might seek a new Transfer

[22] The probability and consequence of this risk is considered in the illustrative Contingency Allowance calculation in Annex C. This risk is considered as Risk B2.

Date in the event of a significant change in their decommissioning timetable. For example if the life of the nuclear power station were extended beyond that assumed at the time the Fixed Unit Price were set it is likely that this would have a knock-on effect on the timing of the end of decommissioning. In this event the Government would expect to consider a change to the Transfer Date. In contrast, once the Assumed Disposal Date is set this is not expected to be subject to change.

3.2.41 **In summary, it is proposed that:**

- **the Fixed Unit Price should be the price that would be applicable at the Assumed Disposal Date;**
- **if, as is currently anticipated, the Transfer Date is earlier than the Assumed Disposal Date, the Fixed Unit Price will be discounted appropriately.**

Setting the Transfer Date in the case where an operator opts for a deferred Fixed Unit Price

3.2.42 If an operator opts to defer the setting of their Fixed Unit Price it is expected that the setting of the Transfer Date and Assumed Disposal Date will also be deferred.

3.2.43 Therefore, alongside an eFUP the Government will also provide the operator with an "expected Transfer Date" and an "expected Disposal Date" to enable the operator to make prudent provision for waste management costs in their FDP.

3.3 Description of the proposed methodology

Consultation Question 3:

Do you agree or disagree that the proposed methodology to determine a Fixed Unit Price strikes the right balance in protecting the taxpayer, by taking a prudent and conservative approach to cost estimation, while facilitating new nuclear build by providing certainty to operators? What are your reasons?

3.3.1 This section sets out the main stages of the proposed methodology to determine an operator's Fixed Unit Price. It covers:

- the way in which waste disposal costs will be estimated;
- how those estimates will be adjusted for uncertainty;
- how an operator's share of the fixed costs of a GDF will be determined;
- how a Fixed Unit Price will be set.

3.3.2 The Government will offer an operator a Fixed Unit Price alongside the approval of its FDP and in this case the Fixed Unit Price would be determined in accordance with this methodology. Section 4.2 sets out a worked example for how a Fixed Unit Price would be determined.

3.3.3 If an operator opts to defer the setting of their Fixed Unit Price, the Government will provide the operator with an eFUP, based on the Government's best estimate of the Fixed Unit Price that would be set at the end of the Deferral Period. This eFUP will also be determined using the methodology set out here but, for the reasons given above, the assumptions made around risk and uncertainty would be different. Section 4.3 sets out a worked example for how an eFUP would be determined.

Estimating waste disposal costs

3.3.4 The starting point for the methodology is to establish the most up to date estimates of disposal costs for ILW and spent fuel in a GDF. However the cost of a GDF is uncertain. It is influenced by many different factors, including the inventory of waste, timings of waste arisings, the geology at the site in question and the detailed design of a GDF.

3.3.5 The methodology to determine a Fixed Unit Price will use the NDA's latest estimates of waste disposal costs for ILW and spent fuel. The NDA has developed a "Parametric Cost Model" to enable the costs of a GDF for higher activity wastes to be estimated despite the current level of uncertainty.

3.3.6 The Parametric Cost Model generates updated cost estimates for geological disposal. It allows the key parameters that impact on the construction and operating costs of a GDF in the UK to be varied. The Parametric Cost Model uses as its basis the detailed cost estimate that underpins the NDA's current best estimate included in its 2007/08 Annual Report and Accounts. Annex A provides more detail on the Parametric Cost Model and the way it used in this methodology.

3.3.7 NDA, at the request of DECC, has developed a range of scenarios for geological disposal which differ – for example in geology or inventory – from the scenario used to develop NDA's current best estimate, and these have been used in the Parametric Cost Model to identify the cost impact of these scenarios.

3.3.8 These figures have been used for the worked examples set out in Sections 4.2 and 4.3, and are detailed in Annex A. These scenarios will continue to be refined over time. The estimates for each scenario are derived from the Parametric Cost Model, which is also subject to review and refinement in the future. Hence the costs estimates set out in Annex A and used in the worked example should be considered illustrative.

3.3.9 In addition, the methodology to determine a Fixed Unit Price assigns a probability to each scenario to enable a distribution of estimated waste disposal costs to be derived. For simplicity, in the worked examples in this consultation each scenario has been considered equally probable. However this assumption will change over time.

Summary

Each time the Government seeks to calculate a Fixed Unit Price or an eFUP, DECC, in collaboration with NDA, will undertake an exercise to determine GDF scenarios, estimate the costs of those scenarios and consider the probability of those scenarios, using the most up-to-date information from NDA. These will enable a distribution of estimated costs to be derived, which will be the starting point for the methodology to determine a Fixed Unit Price.

Handling uncertainty in cost estimates

3.3.10 Three distinct sets of risks arise from the use of the Parametric Cost Model to estimate waste disposal costs for new build ILW and spent fuel. These risks need to be taken into account in the methodology, in order to adjust for uncertainty in current estimated costs.

3.3.11 The first set of risks arises because we do not yet have a site for a GDF. Therefore the geological environment in which a GDF will be built is uncertain. Geology has a significant cost impact, therefore to accommodate this risk the Fixed Unit Price methodology considers a variety of geological scenarios and their associated costs. The methodology then uses Monte Carlo methods[23] in order to determine a distribution of estimated disposal costs.

3.3.12 The second set of risks relate to the possibility that the Parametric Cost Model does not correctly calculate the costs of a specific disposal scenario. This includes such things as the consequences of delays, the possibility that costs for the assumed activities and their duration, scope and timing may be different in practice, or that some activities, and their associated costs, have not been included in the Parametric Cost Model's estimate. These have been defined as "In-Model Risks" and the cost estimates need to be adjusted for these risks. At present these are handled through an "Optimism Bias" adjustment. This is discussed in more detail below.

3.3.13 The third set of risks relate to wider uncertainties. In the absence of a site for a GDF, NDA has made a number of assumptions when using the Parametric Cost Model to estimate waste disposal costs, for example the NDA's estimates are based on an assumed disposal concept (which for spent fuel is the Swedish KBS-3 concept). In addition, DECC has made some further assumptions in order to use Parametric Cost Model data to estimate the costs of disposing of new build wastes. For example it is assumed that no additional fixed costs are incurred as a result of including new build wastes in a GDF designed and built for the disposal of legacy wastes.

3.3.14 If any of these assumptions do not occur in practice then the accuracy of the Parametric Cost Model output used in the Fixed Unit Price methodology is likely to be affected. These have been defined as "Out-Of-Model Risks" and are handled in the methodology by a Contingency Allowance. This is discussed in more detail below, and a worked example of the calculation of a Contingency Allowance is set out in Annex C.

Table 4: a summary of the handling of In-Model and Out-of-Model risks in the methodology

Type of uncertainty	Handling	Examples
In-Model Risks	Optimism Bias adjustment	• Uncertainties in engineering costs. • Costs excluded from Parametric Cost Model.
Out-of-Model Risks	Contingency Allowance	• Different disposal concept adopted. • That a GDF cannot operate optimally during emplacement of new build wastes.

[23] Monte Carlo simulation is a mathematical technique which can be used to allow for risk and uncertainty in quantitative analysis and decision making. See Annex B for a description of how Monte Carlo methods have been used in this methodology.

Adjusting for In-Model Risks

3.3.15 One rigorous approach to managing risk and uncertainty is to construct a comprehensive risk register to assess the probability and consequence of each event, and to construct an overall risk estimate by combining individual values. Such an approach is often adopted to create a probability-linked total cost estimate. This technique is used in engineering projects where most or all of the inputs to the total costs are known and when there is good historic evidence on cost variability. Such a comprehensive assessment has not yet been completed for the GDF implementation programme and the scenarios identified for this methodology, and at this stage we do not think it feasible to undertake such an exercise for the purposes of setting a Fixed Unit Price.

3.3.16 An alternative approach is to use the methodology set out in HM Treasury "Green Book" guidance[24], which is designed to be used in circumstances such as these where a comprehensive assessment of risk is not possible. This allows estimated project costs to be adjusted for "Optimism Bias," which is defined in the Green Book as the "demonstrated, systematic, tendency for project appraisers to be overly optimistic." The Green Book offers guidance on possible optimism bias factors, based on an analysis of historic public sector project cost out-turns versus their original cost estimates.

3.3.17 **Therefore in order to reflect In-Model Risks, the Fixed Unit Price methodology will adjust the cost estimates derived from the Parametric Cost Model for Optimism Bias.**

3.3.18 When a Fixed Unit Price or eFUP is requested the Government will undertake an exercise to determine the appropriate level of the Optimism Bias adjustment, taking into account Treasury guidance.

3.3.19 The derivation of the appropriate level for the Optimism Bias adjustment, following Green Book guidance, has not been carried out for this consultation. For the worked examples we have used a figure drawn from Treasury guidance to illustrate the impact of the Optimism Bias adjustment. In Green Book terms, a GDF can be categorised as a "non-standard civil engineering project" with a "recommended adjustment range" of 6-66%. In the early stages of a project Green Book advice is always to start with the upper bound. Therefore the worked examples use 66% as an illustrative Optimism Bias adjustment.

3.3.20 During the pre-consultation process concerns were expressed that having two risk allowances – the Optimism Bias adjustment and the Contingency Allowance – meant that double counting of risks was possible. In particular, it was suggested that some of the wider uncertainties that are defined here as Out-of-Model Risks (such as changes to the design and scope of the project) should be regarded as falling within the scope of an Optimism Bias adjustment, and that therefore a separate Contingency Allowance is not needed.

[24] The Green Book is an HM Treasury publication that presents the techniques and issues that should be considered when carrying out assessments of new policies, programmes and projects. The HM Treasury Supplementary Green Book Guidance on Optimism Bias is available at http://www.hm-treasury.gov.uk/data_greenbook_supguidance.htm

3.3.21 The potential for double counting is recognised. Set out below are the main In-Model Risks expected to be taken into account in determining the level of the Optimism Bias adjustment. These are:

- Uncertainties in estimating engineering costs. This is essentially standard engineering contingency.
- Costs excluded from the Parametric Cost Model, such as the provision of a community benefits package and the need to maintain institutional control for the facility post-closure.

3.3.22 Without more detailed analysis it is not possible to conclude whether these In-Model Risks taken together are sufficient to merit the 66% Optimism Bias adjustment used in the worked examples in Chapter 4 for the purpose of illustration. It is possible that 66% is too high, but equally it is possible that it is too low. This requires further analysis, and the Government does not propose to commission this work until a prospective operator requests a Fixed Unit Price or an eFUP.

3.3.23 However it is reiterated that the figure of 66% is merely illustrative for the purposes of producing a worked example. It should not be assumed that this is the figure that will be used when a Fixed Unit Price or an eFUP is provided to an operator.

3.3.24 In the event that an operator opts to defer the setting of a Fixed Unit Price, the way In-Model Risks are handled is expected to change over time, depending on progress in the implementation of geological disposal. Based on NDA's current planning assumptions, it is expected that by the end of the Deferral Period it should be possible to produce a comprehensive project cost estimate based on a final disposal concept and specific site. If this is the case then the Fixed Unit Price set at the end of the Deferral Period could take account of In-Model Risks through a comprehensive assessment of the level of uncertainty in estimated costs, consistent with Green Book principles, rather than through an Optimism Bias adjustment.

Summary

When a Fixed Unit Price or an eFUP is requested by a prospective operator, estimated costs will be adjusted for "In-Model Risks". At present this will take the form of an "Optimism Bias" adjustment, though in future it may be possible to address this issue through a comprehensive assessment of the level of uncertainty in estimated costs.

When a price is first requested by a prospective operator the Government will undertake an exercise to determine the appropriate level of the Optimism Bias adjustment in this case, taking into account Treasury guidance.

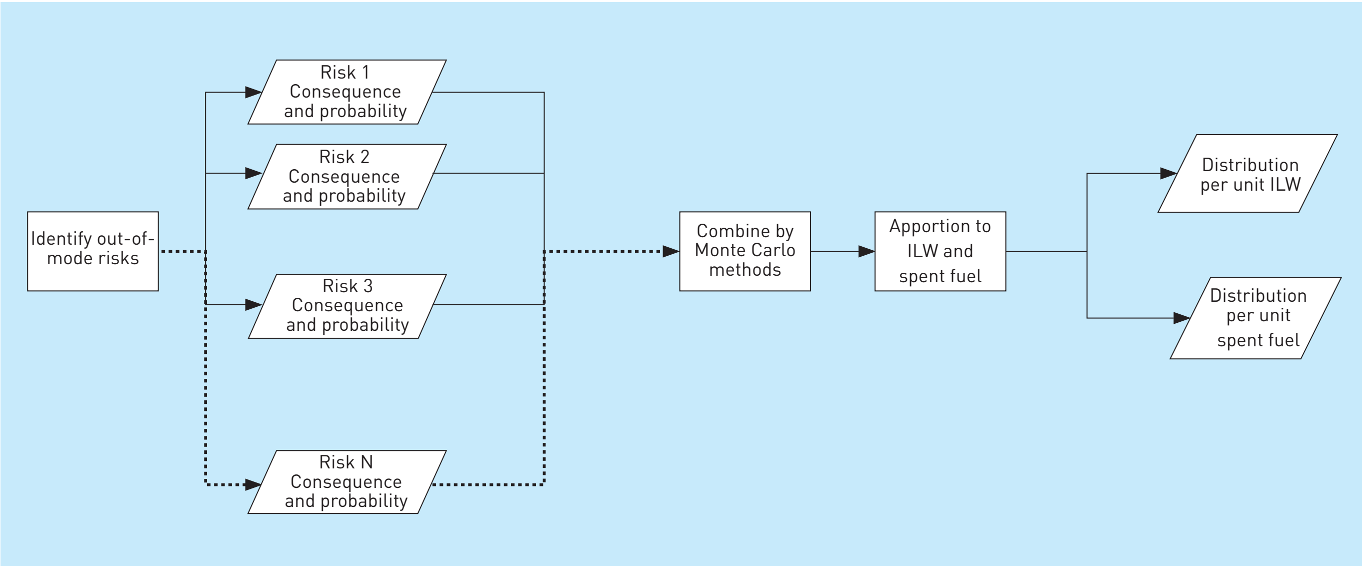
Adjusting for Out-of-Model Risks

3.3.25 The methodology to determine a Fixed Unit Price takes account of Out-of-Model Risks through the inclusion of a Contingency Allowance.

3.3.26 The calculation of the Contingency Allowance is inherently difficult. The approach taken in this methodology is illustrated in Figure 4. A set of risks is identified, together with an assessment of the consequence and probability of each risk occurring. These assessments are then combined by Monte Carlo methods to determine a distribution for the Contingency Allowance. This distribution is then combined with the distribution derived earlier in the methodology for waste disposal costs, to produce a risk-adjusted distribution for total waste disposal costs.

3.3.27 Annex C has a worked example of how a Contingency Allowance would be calculated. The figures in Annex C are illustrative, and it is proposed that an exercise similar to that shown in Annex C would be carried out using latest available information each time an operator requested a Fixed Unit Price.

Figure 4: illustration of how a Contingency Allowance will be derived



3.3.28 The analysis in Annex C identifies six Out-of-Model Risks to be considered and these are within two broad groups:

(A) Risks related to the possibility that the fundamental assumptions underpinning the Parametric Cost Model's estimation of waste disposal costs do not correspond to the final outcome:

A1: Risk that the KBS-3 disposal concept (for HLW/spent fuel) and immobilisation in grout disposal concept (for ILW/LLW) are not adopted.

A2: Risk that it is not possible to build a single GDF for the disposal of both HLW/spent fuel and ILW/LLW ("co-location").

A3: Risk that a GDF is not closed immediately after last waste emplacement.

(B) Risks related to the possibility that the assumptions made in applying the Parametric Cost Model to the estimation of new build waste disposal costs do not correspond to the final outcome:

B1: Risk that emplacing new build wastes in the same GDF as legacy wastes leads to additional fixed costs.

B2: Risk that an inaccurate date is set for the start of new build waste emplacement.

B3: Risk that a GDF cannot operate optimally during emplacement of new build spent fuel.

3.3.29 Annex C discusses these six out-of-model risks, including their estimated consequences and probability, and concludes that the Contingency Allowance in the worked example should not include a specific element relating to two of them (B1 and B2). Annex C then explains how a distribution is determined for each of the other four risks. These distributions have then been combined by Monte Carlo methods to produce an overall Contingency Allowance.

3.3.30 Section 3.2 sets out the proposal that an operator be given the option to defer the setting of their Fixed Unit Price for a specified Deferral Period. The purpose of deferring the setting of a Fixed Unit Price is to provide time for the level of uncertainty to be reduced.

3.3.31 The worked examples and illustrative figures in this consultation are on the basis of a new nuclear power station that begins generating electricity in 2020. Therefore if the operator of this nuclear power station took the option to defer setting their Fixed Unit Price and a Deferral Period of 10 years was set (as proposed in Section 3.2), this would mean the operator's Fixed Unit Price would be set in 2030.

3.3.32 NDA's current planning assumption is that a site for a GDF will be identified by 2025. In this case, by 2030 a detailed site-specific and design-specific cost estimate would be available. Hence some of the risks currently identified as Out-of-Model might have crystallised and been incorporated into the detailed cost estimate, while others might no longer be relevant and would be disregarded.

3.3.33 **In this case it may be possible to conclude that there were no Out-of-Model Risks and therefore no need for a Contingency Allowance. This is the basis on which the worked example for an eFUP has been calculated in Section 4.3.**

3.3.34 However the Fixed Unit Price set at the end of the Deferral Period will reflect the actual level of uncertainty over estimated costs at that time. In the event that progress in the implementation of geological disposal were slower than NDA's current planning assumption, so that for example a site for a GDF were not identified by the end of the Deferral Period, then the Fixed Unit Price would include a Contingency Allowance.

Summary

When a Fixed Unit Price or an eFUP is requested, consideration will be given to whether estimated costs should be adjusted for Out-of-Model Risks. If required, this will take the form of a "Contingency Allowance", calculated through an exercise to identify a set of risks, together with an assessment of the consequence and probability of each risk occurring.

Determining an operator's share of the fixed costs of a GDF

Consultation Question 4:

Do you agree or disagree with the proposed approach to determining an operator's contribution to the fixed costs of constructing a Geological Disposal Facility? What are your reasons?

3.3.35 The Government is using the estimated costs of geological disposal as the cost base for determining a Fixed Unit Price. There are two different categories of cost considered:

- **Fixed costs,** such as the construction of the surface facilities, access shafts and the access drift. These costs are largely unrelated to the volume of waste being emplaced.
- **Variable costs,** such as the construction of underground deposition tunnels for spent fuel, and underground disposal vaults for ILW. These costs vary with the volume of waste being emplaced.

3.3.36 The Government considers that a new build operator's full share of waste management costs should include a contribution towards the fixed costs of building a GDF that will take both legacy and new build wastes. This contribution will be calculated as part of the methodology to determine a Fixed Unit Price.

3.3.37 **The Government's view is that a new build operator's share of the fixed costs of a GDF should be calculated in proportion to its share of estimated total variable costs.**

3.3.38 This is because the Government's view is that an operator's contribution to the fixed costs of a GDF should be in proportion to the use it makes of the GDF's capacity. The best way of measuring this is considered to be through estimates of its share of total variable cost, as this takes into account both the quantity and the nature of the wastes emplaced.

3.3.39 Hence the share of the fixed costs of a GDF to be allocated to a single new nuclear power station is V_N/V_T, where:

- V_N is the estimated variable cost of disposing of the ILW and spent fuel from one new nuclear power station in a GDF; and
- V_T is the estimated total variable cost of a GDF, incorporating the disposal of both legacy wastes and new build wastes.

3.3.40 The methodology provides an estimate of the variable cost per unit of spent fuel and ILW. The total variable cost for a single new nuclear power station (V_N) can be calculated with reference to an assumed inventory and the inventory that has been assumed in this consultation for a generic PWR is set out in Annex D.

3.3.41 However further assumptions are required to calculate the estimated total variable cost of a GDF (V_T). Firstly an estimate of the inventory of legacy wastes to be emplaced in a GDF is required, and the inventory that has been assumed for the worked examples is also set out in Annex D.

3.3.42 In addition, an estimate of the total inventory of new build wastes to be emplaced in a GDF is required, which requires an assumption around how many new nuclear power stations will be built. This is uncertain, as it will be for energy companies to build new nuclear power stations.

3.3.43 Under an assumption of the co-disposal of legacy and new build wastes in a single GDF, the share of GDF fixed costs per unit of new build waste (and hence per new nuclear power station) falls gradually as the size of the new build fleet increases. This is because the level of the fixed costs is not affected by the volume of waste to be emplaced, and hence as the fleet size increases each unit's contribution to the fixed costs of the GDF reduces, as the total is spread more widely.

3.3.44 However as the size of the new build fleet increases, the share of the fixed costs of a GDF borne by new build as a whole increases. This is because the proportion of the total inventory of waste for disposal that is attributable to nuclear new build increases.

3.3.45 In light of the finding that unit costs fall gradually as the size of the new build fleet increases, the determination of a Fixed Unit Price using this methodology will be based on a conservative estimate of the likely size of the new build fleet.

3.3.46 There is a further consideration. The Government considers that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities. However the FDP Guidance consultation document acknowledged that the size of the new build programme, and the specification of the site chosen for a GDF, will have an impact on the feasibility of co-disposal. In the event that a second GDF were needed as a result of the new build programme becoming very large, this would imply a significantly greater total cost, although such cost would be spread over a larger nuclear programme.

3.3.47 In the theoretical scenario of there being a dedicated GDF for new build ILW and spent fuel, unit costs are likely to be higher, especially where the new build fleet is small, as the total fixed costs of a GDF would be spread solely across the new build fleet and not shared with legacy wastes.

3.3.48 Discussion Paper 2 considered the impact of uncertainty over the size of the new build fleet on the modelling of waste disposal costs and the consequent risk that a second GDF might be needed in the event that the new build fleet is large[25]. The paper identified two broad approaches:

- An approach in which the methodology to determine a Fixed Unit Price is based on a presumption of the co-disposal of legacy and new build waste, but retains the flexibility to revise this at a later date for subsequent reactors if there were reasons to consider that there was a significant risk that a second GDF might be needed – this was termed "Option A".
- An approach in which the methodology makes an estimation of the risk that a second GDF might be needed and factors this in from the outset, deriving a probabilised unit cost distribution – this was termed "Option B".

[25] Discussion Paper 2 section 3.3.

3.3.49 Having considered this issue in the pre-consultation process, the Government's view is that Option A should be used for the calculation of the Fixed Unit Price, as it is consistent with the Government's view that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities.

3.3.50 The flexibility contained within this approach would be reinforced in the event that an operator took the option to defer the setting of its Fixed Unit Price. If during the Deferral Period the Government's view changed and it was concluded that a second GDF might be needed then this could be expected to change the estimated costs of waste disposal, which would feed through into the Fixed Unit Price set at the end of the Deferral Period. This is a risk that the operator would be accepting in opting to defer the setting of its Fixed Unit Price.

Summary

The Fixed Unit Price will include a contribution to the fixed costs of a GDF. An operator's share of the fixed costs of a GDF will be related to the use it is expected to make of a GDF. This will be estimated by its share of the expected variable costs of a GDF.

The cost estimates used in the methodology to determine a Fixed Unit Price will assume the co-disposal of legacy and new build waste. However the methodology retains the flexibility to revise this assumption at a later date if there were reasons to consider that there was a significant risk that a second GDF might be needed in order to accommodate all the waste from new nuclear power stations.

Adjusting the fixed contribution to take account of the "time value of money"

3.3.51 As set out in Section 3.2, as a general principle the Government considers it necessary for the payment made by an operator in relation to the Fixed Unit Price to reflect the "time value of money", i.e. that the value of money is affected by when it is paid, based on the principle that a sum of money paid today is more valuable than the certainty of receiving the same sum at a later date.

3.3.52 The Fixed Unit Price includes a component relating to the variable costs of waste disposal and a contribution to the fixed costs of a GDF. The variable costs are assumed to be incurred immediately before emplacement. This is because it is expected that underground tunnels and vaults will only be excavated in response to demand. In contrast, the fixed costs of a GDF will be incurred many years before the emplacement of new build wastes in a GDF because it is currently assumed emplacement of legacy wastes will take priority.

3.3.53 The issue of the "late payment" of the contribution to the fixed costs of a GDF was considered in Discussion Paper 3[26]. This considered whether a "financing charge" should be added to reflect this timing difference and a number of possible approaches were considered.

[26] Discussion Paper 3 pages 30-32.

3.3.54 At one end of the spectrum it could be argued that the GDF's fixed costs should be considered "sunk costs" because they would be incurred in full anyway, in view of the need to accommodate legacy wastes. Therefore from an economic efficiency perspective it could be argued that the right approach would be to require a new build operator to pay only the **marginal costs** of waste disposal, i.e. without any contribution to the fixed costs. On this basis there would be no contribution to capital costs and accordingly no financing charge. Against this it could be argued that in the interests of "fairness", a new build operator should make some contribution to the fixed costs. Indeed as set out in the FDP Guidance consultation document and again here, the Government considers that the Fixed Unit Price should include a contribution to the fixed costs of a GDF[27].

3.3.55 At the other end of the spectrum lies a **"deferred payment"** approach. This would treat a GDF as a project in which all fixed costs were being shared by legacy and new build (but on the timescales currently envisaged, i.e. in order to enable the disposal of legacy wastes in advance of the disposal of new build waste). In this case it could be argued that a new build operator's contribution to the fixed costs should be paid as and when those costs were incurred and in the event that payment was not made until later, interest would be charged (reflecting the cost to Government of financing the project) during the intervening period. However this approach, if applied in full, would appear to place an unfair burden on new build operators, as they would be required to pay towards the fixed costs of a GDF many decades ahead of need. This approach does also disregard the fact that the MRWS programme envisages that a GDF will be built to manage the existing inventory of legacy and committed waste, regardless of whether or not there are any new nuclear power stations.

3.3.56 There are a number of intermediate approaches, which include a contribution to the fixed costs of a GDF in the Fixed Unit Price, but which would not require a new build operator to pay that contribution ahead of need and in which interest on the full period from incurring the fixed costs to the payment of the fixed price would not be made.

3.3.57 One approach would be to argue that there should be **no financing charge** applied to the share of the fixed costs included in the Fixed Unit Price. The rationale for this approach would be that these costs are not being incurred on behalf of the new build operator (as they are costs that the Government will incur anyway) and the availability of space in a GDF and a filling schedule for new build wastes will be heavily influenced by legacy waste disposal issues.

3.3.58 Another intermediate approach might be to apply a financing charge on the share of fixed costs included in the Fixed Unit Price, based on the approach that might be taken in the theoretical case that the Government were constructing a GDF to a timescale driven by the needs of new build operators. In this case a GDF would be built many decades later, as it would not need to be ready until the waste from new build operators was ready for disposal. This was described in Discussion Paper 3 as the **"virtual GDF"** approach. It assumes that under this scenario the theoretical GDF would follow the existing GDF cost profile, but with all fixed costs incurred later so that it would open at the point that new build wastes were due for disposal, with interest charges applied to a new build operator's contribution to the fixed costs on this basis. In other words, rather than applying the interest charge for many decades, it would only be applied for the few years between construction and first emplacement (when the fixed price would be paid).

[27] FDP Guidance consultation document, paragraph 2.33.

3.3.59 The figures in the worked example in Discussion Paper 3 were calculated on the basis of the "virtual GDF" approach, as this seemed to strike a reasonable balance between economic efficiency and the broader consideration of ensuring fairness in the allocation of the fixed costs of a GDF.

3.3.60 Having considered this question further during the pre-consultation process, the Government has concluded that a financing charge should be applied, based on the "virtual GDF" approach, i.e. the approach that might be taken in the theoretical case that the Government were constructing a GDF to a timescale driven by the needs of new build operators.

Summary

The element of the Fixed Unit Price relating to the contribution to the fixed costs of a GDF should be subject to a "financing charge" based on the approach that might be taken in the theoretical case that the Government were constructing a GDF to a timescale driven by the needs of new build operators.

Setting the price

3.3.61 It is important to note that when an operator of a new nuclear power station requests a Fixed Unit Price, its level will be determined by the Secretary of State. Therefore it is proposed that the methodology to determine a Fixed Unit Price will consist of two main parts:

- a cost modelling process, to derive estimates of the costs of waste disposal, taking into account the level of uncertainty around the estimation of those costs;
- determination of the Fixed Unit Price by the Secretary of State, in which he would have regard to the cost estimates derived from this modelling.

3.3.62 In assessing the level at which to set the Fixed Unit Price the Secretary of State will consider whether in his view the figure resulting from the methodology to determine a Fixed Unit Price provides sufficient protection for the taxpayer. For example this might include consideration of whether the cost modelling has taken sufficient account of the need for protection against the risk of cost escalation and other uncertainties. In the event that the Secretary of State set a price outside the range indicated by this cost modelling he would expect to explain his reasons.

3.3.63 In the event that an operator took the option to defer the setting of its Fixed Unit Price, it is expected that they would want an assurance from the Government on how their Fixed Unit Price would eventually be set. It is anticipated that this will be set out in an agreement between the operator and the Secretary of State that would be agreed alongside the Secretary of State's approval of the operator's FDP.

3.3.64 In this agreement the Government would expect to commit to a transparent application of this methodology throughout the process: from the setting of the eFUP, through each Quinquennial Review until the end of the Deferral Period, at which point a Fixed Unit Price would be set. This is expected to include provisions for transparency and independent scrutiny of the Government's cost estimates, analogous to the third party verification that an operator will be required to obtain in relation to the cost estimates in their FDPs.

3.3.65 As stated above, it should be noted that the Fixed Unit Price, and the eFUP, will of course be indexed for inflation.

Summary

When a prospective operator of a new nuclear power station requests a Fixed Unit Price, its level will be determined by the Secretary of State, having regard to the cost estimates derived from this modelling.

If an operator opts to defer the setting of its Fixed Unit Price, the basis on which their Fixed Unit Price will be determined will be set out in an agreement between the Secretary of State and the operator that will be agreed alongside the operator's FDP.

Adjusting the level of the Fixed Unit Price to reflect Early Transfer

3.3.66 The Fixed Unit Price will be the price applicable on the Assumed Disposal Date. As set out in Section 3.2 above, under Early Transfer, the Fixed Unit Price will be paid many years before the Assumed Disposal Date. It is therefore considered necessary to adjust the payment made by the operator to reflect this early payment. This will be done through the application of an appropriate discount rate to the Fixed Unit Price to reflect this time difference.

3.3.67 This discount rate will not be fixed at the same time as the Fixed Unit Price is set. Rather it will be determined nearer the Transfer Date and set in relation to the rates of returns at that time on long-term investments in Government securities and similar assets. The Government will provide the operator with an estimated long-term discount rate, to enable prudent provision to be made. The worked examples in Chapter 4 for the purpose of illustration apply a discount rate of 2.2% per annum, as this is consistent with the long-term discount rate applied to legacy liabilities in the NDA's Annual Report and Accounts.

Summary

The Fixed Unit Price will be the price applicable on the Assumed Disposal Date. If, as currently anticipated, the Transfer Date is earlier than the Assumed Disposal Date, the Fixed Unit Price will be discounted at an appropriate rate.

3.4 Deciding the "unit" for the Fixed Unit Price

Consultation Question 5:

Do you agree or disagree with the proposal that the units to be used for the Fixed Unit Price are pence per kWh for spent fuel and cubic metres of packaged volume for intermediate level waste? What are your reasons?

3.4.1 The purpose of setting a fixed price per unit of ILW or spent fuel for disposal is to ensure that the amount that an operator pays is relative to the amount of waste or spent fuel they produce. It is therefore important to be clear about the units to be used for setting a Fixed Unit Price.

Intermediate Level Waste

3.4.2 For ILW it is considered sufficient to use a simple volume measure. The UK Radioactive Waste Inventory measures the volume of existing ILW in cubic metres of packaged volume and it is proposed that the same unit be used for the Fixed Unit Price.

Spent fuel

3.4.3 The unit to be used for the Fixed Unit Price for spent fuel will need to take into account more detailed considerations around its disposal route and the impact of various assumptions around, for example, fuel burn-up and heat load. It will be important that the unit for spent fuel reflects the costs of disposal.

3.4.4 The MRWS White Paper said the following on the disposal of spent fuel[28]:

Because they generate heat, HLW and spent fuel (if classified as waste for disposal) require different disposal structures and layouts from ILW, LLW and other non-heat generating radioactive materials. There are a number of ways in which HLW and spent fuel could be packaged and contained, and research in this area is likely to present alternative models over the coming years. For example, one method that is planned to be used in Sweden and Finland, and could potentially be applicable in the UK to stocks of HLW and spent fuel, is based on sealing the waste in copper canisters with a cast iron internal frame for strength. These canisters are placed in individual deposition holes drilled in the floor of deposition tunnels and surrounded by bentonite clay, which expands on contact with water and so seals the space around the canister. Under appropriate conditions copper is extremely resistant to corrosion, and in a suitable geo-chemical environment such as this the canisters can be expected to maintain their integrity for hundreds of thousands of years. Following waste emplacement, the deposition tunnels would be backfilled and sealed[29].

3.4.5 The NDA's Parametric Cost Model assumes the KBS-3 copper canister disposal concept (i.e. the method described above for use in Finland and Sweden) and estimates costs on a per canister basis. Hence at present this is the basis on which unit costs of waste disposal are estimated. However, converting the amount of spent fuel generated by a

[28] MRWS White Paper page 71. Available at: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/radioactivity/waste/waste/management/management.aspx

[29] The MRWS White Paper also considered high level waste (HLW) as there is a substantial HLW element to the existing waste inventory. The Base Case assumption for new build is that there will be no reprocessing of uranium fuel and spent fuel will be disposed of after it has been used. Under this assumption, there will be no HLW from new nuclear power stations.

new nuclear station to a number of canisters requires an understanding of the capacity of a single canister. This capacity will be dependent upon a number of issues, notably the heat released by material in the canister – this is a key parameter for safe disposal.

3.4.6 In addition, although the KBS-3 copper canister is the assumed disposal route at this stage, it has not been confirmed that this will be the disposal route finally adopted for a GDF. This uncertainty means that the canister is not considered an appropriate unit for the Fixed Unit Price for spent fuel.

3.4.7 There are a number of alternative units that could be used for setting a Fixed Unit Price for spent fuel, which are less liable than the canister to change over time. These fall broadly into three categories, as outlined below.

3.4.8 **Quantity-based units**: such as tonnes of uranium (tU) or spent fuel assemblies. These units directly describe the spent fuel to be disposed of and it is straightforward to translate a quantity-based unit into a disposal concept such as the current copper canister assumption (the present maximum canister size is designed to take four PWR fuel assemblies, with a weight of just over two tonnes in total). However a simple quantity-based unit offers no link to the heat loading of the canister, as the heat generated by a quantity of spent fuel will depend upon its initial composition, total burn-up and conditions of irradiation and also on the duration of interim storage prior to disposal in a GDF. Hence it might need to be accompanied by parameters describing the heat output and other characteristics of the fuel. These parameters would need to be set with reference to an assumption of the likely disposal route.

3.4.9 **Output-based units**: for example a price in pence per kilowatt hour (p/kWh). An output-based unit would be very simple to measure, though there would need to be a calculation of how output translated into a quantity of spent fuel for the calculation of disposal costs, which would again need to be made with reference to a disposal concept. However there is in general a relationship between the power output of fuel and its characteristics after irradiation. For example, higher burn-up, which is a consequence of generating increased amounts of energy from a given amount of fuel, implies greater heat output from the spent fuel and thus potentially greater disposal costs.

3.4.10 **Activity-based units**: for example adopting the Becquerel (Bq) as a unit for costing disposal. The level of activity is one of the key characteristics of the spent fuel that influences its costs of disposal, for example higher burn up would imply a higher Bq level. However, as noted above, a key constraint is heat output, and the relationship between the activity of the material in Bq and the heat output of the spent fuel is complex, hence an activity-based unit might entail some complex calculations to produce estimated disposal costs.

3.4.11 Whichever unit is chosen, a unit cost of disposal can only be estimated with reference to an assumed disposal route, which at present is the copper canister described above. This means that in all cases there is a risk that a change to the disposal route might imply a change in the estimated costs of disposal after the Fixed Unit Price has been set.

3.4.12 In considering which unit should be used for the Fixed Unit Price for spent fuel, the Government has looked for a unit that is simple to express and measure, resilient to possible future changes in the disposal concept and which has a clear relationship with the costs of disposal.

3.4.13 **Having considered this question, the Government proposes that the Fixed Unit Price for spent fuel should be levied in terms of pence per kilowatt electricity generated (p/kWh(e)).**

3.4.14 Of the alternatives, the Government considers a quantity-based unit, such as tU, to be a more viable alternative than an activity-based unit, given the complexity of the latter.

3.4.15 Section 4.4 sets out how the illustrative values for a Fixed Unit Price and eFUP generated by the methodology, which are expressed in a price per canister, translate into a Fixed Unit Price or eFUP expressed in p/kWh(e).

Summary

The methodology to determine a Fixed Unit Price calculates disposal costs with reference to the units used in NDA's Parametric Cost Model, which are canisters of spent fuel and cubic metres of packaged ILW.

It is proposed that the Fixed Unit Price for ILW will be charged per cubic metre of packaged volume. For spent fuel it is proposed that the Fixed Unit Price will be charged in pence per kilowatt hour of electricity generated (p/kWh(e)).

Chapter 4: Worked examples

4.1 Introduction

4.1.1 This section has three worked examples, for the purpose of illustration, that follow the methodology set out in Chapter 3. These build on the worked example set out in Discussion Paper 3:

- Section 4.2 has a worked example of how a Fixed Unit Price would be calculated using this methodology;
- Section 4.3 has a worked example of how an eFUP would be calculated using this methodology;
- Section 4.4 has a worked example of how the Fixed Unit Price and eFUP for spent fuel would be converted to p/kWh.

4.1.2 It is important to note that when an operator of a new nuclear power station requests a Fixed Unit Price, its level will be set by the Secretary of State. Therefore the methodology to determine a Fixed Unit Price will consist of two main parts:

- a cost modelling process, to derive estimates of the costs of waste disposal, taking into account the level of uncertainty around the estimation of those costs;
- determination of the Fixed Unit Price by the Secretary of State, in which he would have regard to the cost estimates derived from this modelling.

4.1.3 This chapter focuses primarily on the cost modelling element of the methodology. There is a step-by-step description of the methodology, together with a discussion of the data and assumptions that have been used to calculate the worked examples. The purpose of the worked examples is to illustrate the methodology. The numbers given here are illustrative and should not be taken as representing the level of the Fixed Unit Price or eFUP that will actually be set for an operator of a new nuclear power station.

4.1.4 The worked example in Section 4.2 calculates illustrative values for the Fixed Unit Price. It divides the methodology into a series of stages and then breaks each stage down into a number of steps in order to demonstrate how it has been calculated. The worked example in Section 4.3 follows the same process, but applies different assumptions at certain steps to calculate an illustrative eFUP. The stages in the calculation of the worked examples are as follows:

- determine GDF scenarios and respective probabilities;
- derive an estimate of variable costs per unit of ILW and spent fuel and adjust for In-Model Risks through an Optimism Bias adjustment;
- calculate an operator's share of the fixed costs of a GDF per unit of ILW and spent fuel and adjust for In-Model Risks through an Optimism Bias adjustment;
- develop an overall distribution for estimated unit costs and adjust for Out-of-Model Risks through a Contingency Allowance;
- derive a Fixed Unit Price and estimated total waste disposal liability.

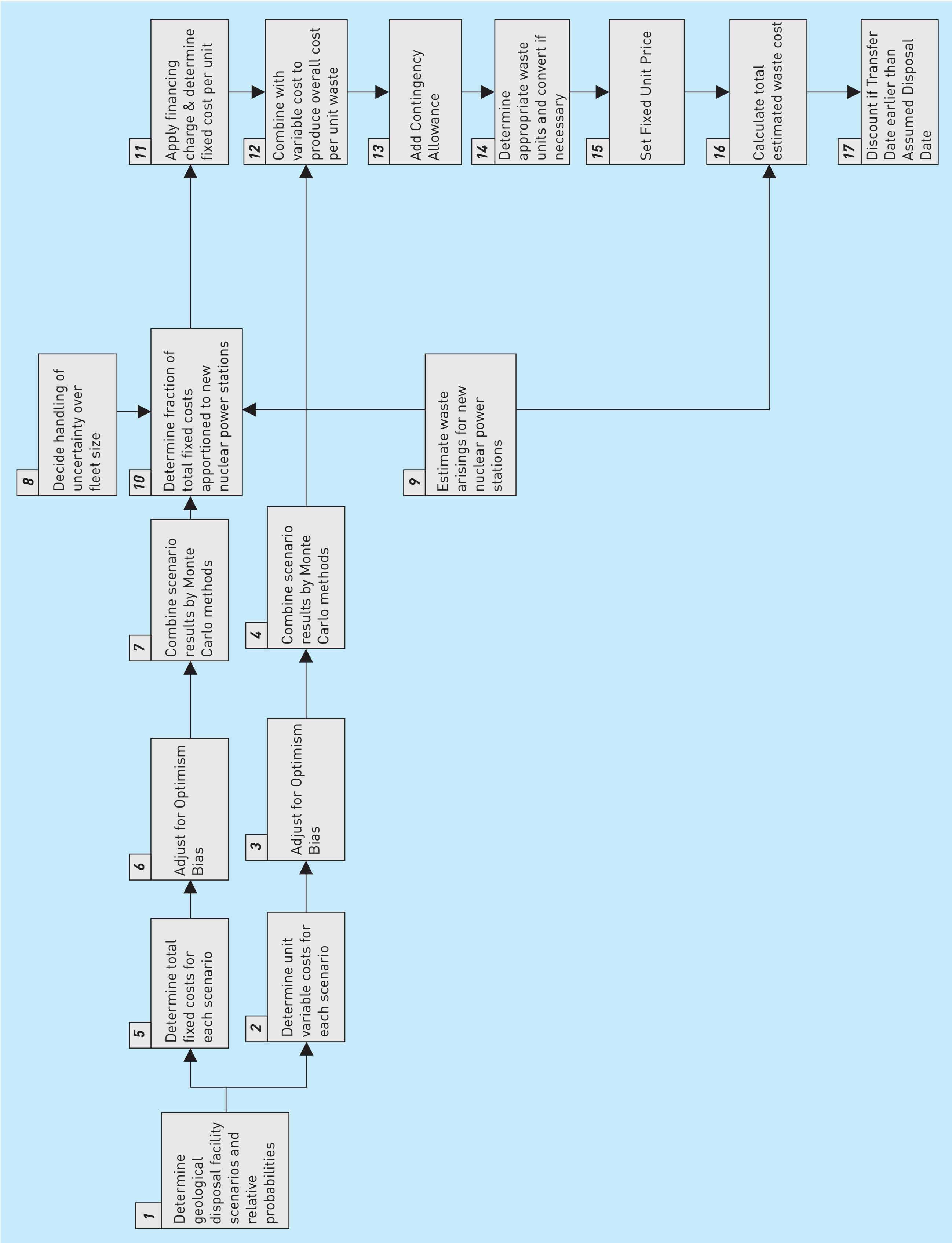
4.1.5 In the worked example in Section 4.2, for each stage there is firstly a description of each of the steps that will be taken in the proposed methodology, with a description of what has been done to generate the worked example. Secondly there is a short table summarising each step of the methodology, setting out the rationale behind the data and other assumptions that have been used in the worked example. Finally there is a step-by-step calculation of the worked example itself.

4.1.6 In order to illustrate the methodology, there is a flow chart at Figure 5. Each step in the flow chart is numbered and those steps are referenced in the worked examples. There are 17 steps in total.

4.1.7 The worked example in Discussion Paper 3 had some additional steps at the end, which translated the estimated total waste disposal liability into an indicative annual payment into the operator's independent Fund. This illustrative calculation is now set out in Section 5.5 of this consultation document.

4.1.8 It should be noted that all calculations in this consultation are in "real" money, i.e. they disregard inflation. All money values in these worked examples are expressed in constant September 2008 money and are undiscounted except where indicated. When a Fixed Unit Price or an eFUP is set, its value will be indexed for inflation.

Figure 5: flow chart showing how the worked examples have been calculated



4.2 A worked example of how a Fixed Unit Price would be calculated using this methodology

Determine GDF scenarios and respective probabilities

4.2.1 As discussed in Section 3.3, the Parametric Cost Model devised by NDA will be used to provide estimates of the costs of waste disposal in a GDF. When the Government models waste disposal costs in order to set a Fixed Unit Price, a number of scenarios will be considered, varying the main factors that impact on cost, such as geology, GDF layout, depth and waste inventory, and the probability of each of these scenarios will also be considered (**Step 1**).

4.2.2 An exercise to determine GDF scenarios, estimate the costs of those scenarios and consider the probability of those scenarios will need to be undertaken each time a potential new nuclear operator requests a Fixed Unit Price. For this worked example nine scenarios have been used. These are listed in Annex A. For simplicity, in this worked example it is assumed that all the scenarios are equally probable.

4.2.3 The estimates for each scenario are derived from the Parametric Cost Model, which is subject to review and refinement in the future. Hence the cost estimates and assumed probabilities given here are illustrative and subject to change.

Derive an estimate of variable costs per unit

4.2.4 For each scenario the Parametric Cost Model has provided an estimate for variable waste disposal costs per unit of ILW and spent fuel (**Step 2**). The Parametric Cost Model uses the copper canister as the unit for estimating the costs of spent fuel disposal and packaged volume in cubic metres (m^3) for estimating the costs of ILW disposal. Therefore these are the units used in the worked example. However, as is discussed in Section 3.4, the cost estimates derived from this methodology can be converted into alternative units for charging purposes.

4.2.5 As described in Section 3.3, the cost estimates derived from the Parametric Cost Model might need to be adjusted for both In-Model and Out-of-Model Risks. This worked example assumes that both of these adjustments are needed. In-Model Risks are addressed here by adjusting the estimates of unit variable cost for each scenario for "Optimism Bias," which is defined as the "demonstrated, systematic tendency for project appraisers to be overly optimistic" (**Step 3**). Out-of-Model Risks are addressed in Step 13 below.

4.2.6 The level of the Optimism Bias adjustment in this worked example has been set at the upper end of the range recommended in Treasury's Green Book Guidance. However this figure is illustrative and, as set out in Section 3.3, when a prospective operator requests a Fixed Unit Price the Government will consider the appropriate level of the Optimism Bias adjustment, taking into account Treasury guidance.

4.2.7 The adjusted estimates for each scenario and are then combined by Monte Carlo methods, using the probability for each scenario assigned in Step 1, to produce a distribution for estimated unit variable costs (**Step 4**).

Approach to be taken when setting a Fixed Unit Price	Assumption for worked example
Steps 1-2: An exercise to determine GDF scenarios, estimate the costs of those scenarios and consider the probability of those scenarios will need to be undertaken each time a prospective new nuclear operator requests a Fixed Unit Price.	DECC has asked NDA to provide base cost estimates for a number of scenarios from the Parametric Cost Model. Nine of these scenarios were used to generate the figures in this worked example. These scenarios seek to establish the cost impact of varying the assumed waste inventory, geology, depth and GDF layout. See Annex A for more on these scenarios. The key driver of cost variability is the geological environment assumed, and in this case all geological environments have been assumed equally likely. This is a reasonable assumption as the location of a GDF is not yet known.
Step 3: When a Fixed Unit Price is requested the Government will undertake an exercise to determine the appropriate level of adjustment for In-Model Risks. At present, this will be in the form of an Optimism Bias adjustment, calculated in line with Treasury guidance.	The level of the Optimism Bias adjustment in this worked example is 66%. In Green Book terms, a GDF can be categorised as a "non-standard civil engineering project" with a "recommended adjustment range" of 6-66%. In the early stages of a project Green Book advice is always to start with the upper bound.
Step 4: No assumptions required. See Annex B of this document for a brief description of how Monte Carlo calculations are produced in the methodology.	

Fixed Unit Price Worked Example

(NB all figures in this worked example are in constant September 2008 money and are undiscounted)

Step 1

Nine scenarios have been used for this worked example. They are set out in Annex A.

Step 2

For the nine scenarios listed in Annex A, the Parametric Cost Model's estimates are:

- spent fuel unit variable disposal cost in the range £398.3-601.4k per canister;
- ILW unit variable disposal cost in the range £9.17-12.29k per m^3.

Step 3

Applying the 66% Optimism Bias adjustment to these figures gives:

- Spent fuel unit variable cost in the range £661.1-998.3k per canister;
- ILW unit variable cost in the range £15.2-20.4k per m^3.

Fixed Unit Price Worked Example (continued)

Step 4

Combining the appropriate values for each scenario by Monte Carlo methods gives:

- Spent fuel unit variable disposal cost distribution with a minimum of £661.1k, a P_{50} of £712.6k and a maximum of £998.3k[30];
- ILW unit variable disposal cost distribution with a minimum of £15.2 k, a P_{50} of £15.9k and a maximum of £20.4k.

Calculate an operator's share of the fixed costs of a GDF per unit of ILW or spent fuel

4.2.8 For each scenario the Parametric Cost Model also provides an estimate for the total fixed costs of a GDF (**Step 5**). These estimates are also considered to be subject to In-Model Risks, and therefore are adjusted for Optimism Bias (**Step 6**). They are then combined by Monte Carlo methods[31] to produce a distribution for estimated total fixed costs (**Step 7**).

4.2.9 As set out in Section 3.3, a new build operator's share of the fixed costs of a GDF is allocated in proportion to its share of estimated total variable costs. Hence the share of the fixed costs of a GDF to be allocated to a single new nuclear power station is V_N/V_T, where:

- V_N is the estimated variable cost of disposing of the ILW and spent fuel from one new nuclear power station in a GDF; and
- V_T is the estimated total variable cost of a GDF, incorporating the disposal of both legacy and new build wastes.

4.2.10 For this calculation we need to estimate both the operator's total variable costs (V_N) and also the total variable costs for a GDF as a whole (V_T). These figures are derived by multiplying the unit cost distributions from Step 4 with estimates of the relevant waste inventories.

4.2.11 To estimate the total waste inventory for a GDF, we need to decide how to handle the uncertainty around the size of the new build fleet, and in particular whether the co-disposal of legacy wastes and new build wastes might not be feasible in the event that the new nuclear fleet is very large (**Step 8**). As set out in Section 3.3, the methodology to determine a Fixed Unit Price will assume the co-disposal of legacy and new build waste, but retain the flexibility to revise this at a later date for subsequent reactors if there were reasons to consider that there was a significant risk that a second GDF might be needed.

4.2.12 The calculation of an overall waste inventory requires an estimate of the legacy waste inventory and an estimate of the waste inventory from a typical new nuclear power station (**Step 9**). Annex D sets out how the assumed waste inventories used in these worked examples have been derived. For this worked example, it has been conservatively estimated that the new build fleet will consist of four reactors.

[30] In order to give an indication of the characteristics of the cost distributions generated in this worked example, in most cases we give the minimum, maximum and "P_{50}" values, where P_{50} is the 50th centile point on the distribution.

[31] Although the Monte Carlo analyses of fixed and variable costs have been run separately in Steps 4 and 7, they have been drawn from scenarios that are consistent with each other to ensure that any potential correlation effects are correctly accommodated.

4.2.13 Once a total waste inventory has been determined, it can be combined with the unit variable cost estimates from Step 4 to calculate total variable costs (V_T) and a new build operator's share of those costs (V_N/V_T). This fraction is then applied to the distribution of GDF fixed costs from Step 7 to give a distribution for a new build operator's contribution to a GDF's fixed costs (**Step 10**).

4.2.14 As discussed in Section 3.3, in order to reflect the time value of money, a financing charge is added to the distribution of a new build operator's contribution to GDF fixed costs at this stage. This adjusted distribution is then divided by the new build operator's waste inventory derived in Step 9 to give a distribution for the share of fixed costs per unit of ILW or spent fuel (**Step 11**).

Approach to be taken when setting a Fixed Unit Price	Assumption for worked example
Step 5-7: as for Steps 1-4.	See Steps 1-4.
Step 8: The cost modelling will assume the co-disposal of legacy and new build waste. It will also make a conservative estimate of the likely size of the new build fleet. As discussed in Section 3.3 unit costs fall gradually as the size of the new build fleet rises. Therefore a conservative estimate of the size of the new build fleet size is a cautious assumption.	As for the proposed methodology. The worked example assumes a fleet of four new reactors.
Step 9: An estimated legacy waste inventory will be estimated based on latest figures from NDA. A predicted waste inventory for a new nuclear power station will be estimated in light of the specific characteristics of the station under consideration.	The estimated legacy waste inventory used in the worked example is: • 10,659 canisters of HLW/spent fuel; • 390,000m^3 of ILW. A predicted waste inventory for a generic 1.35GW PWR is used: • 500 canisters of spent fuel (i.e. 2000 fuel bundles, 1030 tU[32]); • 2000 m^3 of ILW. Annex D sets out how the waste inventories used in these worked examples have been derived.
Step 10: A new build operator's share of the fixed costs of a GDF will be allocated in proportion to its share of variable costs.	As for the methodology.

[32] The copper canister has a capacity of four PWR spent fuel bundles, or 2.06 tU.

Approach to be taken when setting a Fixed Unit Price	Assumption for worked example
Step 11: The financing charge will be applied on the basis of the "virtual GDF" approach. An interest rate consistent with Treasury guidance will be applied, and the indicative GDF spend profile will be based on NDA's most up-to-date cost estimates. The distribution for the fixed contribution is then divided by the assumed waste inventory from Step 9 to produce a fixed cost contribution per unit.	The financing charge has been calculated using a real interest rate of 2.2% and an indicative GDF spend profile based on latest cost estimates[33]. The effect of this approach is to uplift the value of the new build operator's contribution to the fixed costs of a GDF by around 38% compared to the case with no financing charge.

Fixed Unit Price Worked Example (continued)

Step 5

For the nine scenarios considered in this worked example, and described in Annex A, the Parametric Cost Model estimates the total fixed costs of a GDF to be in the range £4401-5015m.

Step 6

Applying the 66% Optimism Bias adjustment to these figures gives an estimate of the total fixed costs of a GDF in the range £7306-8325m.

Step 7

Combining the values for each scenario by Monte Carlo methods gives a distribution for total fixed costs with a minimum of £7306m, a P_{50} of £7317m and a maximum of £8325m.

Step 8

This worked example assumes the co-disposal of legacy and new build waste in a single GDF and assumes a new build fleet of four new reactors.

Step 9

The estimated legacy waste inventory is:

- Spent fuel/HLW inventory of 10659 canisters;
- ILW inventory of 390,000 m^3.

The estimated waste inventory for a single new nuclear power station is:

- Spent fuel inventory of 500 canisters;
- ILW inventory of 2000 m^3.

[33] There is an expenditure profile on page 36 of the NDA 2007/08 Annual Report and Accounts http://www.nda.gov.uk/documents/upload/Annual-Report-and-Accounts-2007-2008.pdf.

Fixed Unit Price Worked Example (continued)

Step 10

For the scenarios considered in Step 1:

- Total legacy variable costs (combining the unit variable costs from Step 4 with the inventory from Step 9) are estimated to be in the range £12975-18597m;
- V_N – total variable costs for a new build operator (combining the unit variable costs from Step 4 with the inventory from Step 9) – is in the range £361-540m (of which around 92% are related to spent fuel);
- V_T – total variable costs (variable costs for legacy plus the variable costs for four new build reactors) – is in the range £14419–20757m.

Therefore V_N/V_T – the new build operator's share of total fixed costs – is in the range 2.5–2.6%.

Applying this to the distribution for fixed costs determined in Step 7 gives a distribution for a new build operator's share of total fixed costs with a minimum of £180.3m, a P_{50} of £185.1m and a maximum of £220.3m.

Step 11

Adding in the financing charge uplift of 38% gives an adjusted distribution with a minimum of £248.9m, a P_{50} of £255.4m and a maximum of £303.8m.

Allocating these costs to spent fuel and ILW in proportion to their share of variable costs, and dividing by the inventory from Step 9 gives:

- for spent fuel a distribution for fixed costs per canister with a minimum of £453.8k, a P_{50} of £468.9k and a maximum of £564.0k;
- for ILW a distribution for fixed costs per m^3 with a minimum of £10.3k, a P_{50} of £10.7k and a maximum of £11.3k.

Develop an overall distribution for estimated unit costs

4.2.15 Combining the distribution for variable costs per unit from Step 4 and the distribution for fixed costs per unit from Step 11 gives an overall distribution for estimated unit costs (**Step 12**).

4.2.16 These figures will be calculated on the basis of estimates produced by the Parametric Cost Model. As explained in Section 3.3, in addition to the In-Model Risks there is a second set of uncertainties – costs and wider project risks – that fall outside the scope of the Parametric Cost Model. Hence this worked example has a further "Contingency Allowance" to allow for these Out-of-Model Risks.

4.2.17 The way in which a Contingency Allowance will be calculated is described in Section 3.3. Annex C sets out how the values for the Contingency Allowance used in this worked example have been calculated.

4.2.18 The Contingency Allowance is in the form of a distribution rather than a single value and is combined using Monte Carlo methods with the cost distribution derived under Step 12 to give a final cost distribution (**Step 13**).

Approach to be taken when setting a Fixed Unit Price	Assumption for worked example
Step 12: No assumptions involved.	N/A
Step 13: The way in which a Contingency Allowance will be calculated is described in Section 3.3.	The derivation of the Contingency Allowance for this worked example is set out at Annex C. The Contingency Allowance for the worked example is based on the following distributions: • For spent fuel, a minimum of £-133.3k, P_{50} of £99.3k and maximum of £704.9k; • For ILW, a minimum of £-3.0k, P_{50} of £0.3k and a maximum of £19.5k.

Fixed Unit Price Worked Example (continued)

Step 12

Combining the distributions from Step 4 and Step 11 gives the following distributions for overall unit costs:

- Spent fuel per canister cost distribution with a minimum of £1115.2k, a P_{50} of £1181.8k and a maximum of £1554.6k;
- ILW per m^3 unit cost distribution with a minimum of £25.7k, a P_{50} of £26.7k and a maximum of £31.8k

Step 13

The adjustment for Out-of-Model Risks is based on the following distributions:

- For spent fuel, a minimum of £-133.3k, P_{50} of £99.3k and maximum of £704.9k;
- For ILW, a minimum of £-3.0k, P_{50} of £0.3k and a maximum of £19.5k.

Combining the Contingency Allowance distributions with those derived in Step 12, using Monte Carlo techniques, gives a final cost distribution as follows:

- For spent fuel, a minimum of £1023.0k, P_{50} of £1320.2k and maximum of £2253.3k;
- For ILW, a minimum of £23.4k, P_{50} of £27.7k and a maximum of £50.9k.

Derive a Fixed Unit Price and estimated total waste disposal liability

4.2.19 The cost estimates are expressed in the units used by the Parametric Cost Model to calculate costs, i.e. copper canisters for spent fuel and m^3 for ILW. The distribution of costs derived in Step 13 can be converted into a number of possible alternative units (**Step 14**). For the reasons given in Section 3.4, it is proposed that the Fixed Unit Price for spent fuel will be set in p/kWh(e) rather than canisters. However for simplicity, this worked example retains the units used by the Parametric Cost Model. Section 4.4 sets out how the illustrative spent fuel prices derived here convert in p/kWh(e).

4.2.20 The Secretary of State will then set the Fixed Unit Price, having regarded to the risk adjusted cost distribution derived in this methodology (**Step 15**). In setting the price he will consider whether in his view the figure derived from the methodology to determine a Fixed Unit Price provides appropriate protection for the taxpayer. For example this might include consideration of whether the cost modelling has taken sufficient account of the need for protection against the risk of cost escalation and other uncertainties.

4.2.21 All values in this worked example are in constant September 2008 money values. However once a Fixed Unit Price has been set it will be indexed for inflation.

4.2.22 For this worked example, four possible Fixed Unit Prices are considered, each equating to a point on the cost distribution derived at Step 13. Once a Fixed Unit Price has been set, an estimated total waste disposal liability for a new build operator can be calculated (**Step 16**), by combining the Fixed Unit Price with the operator's estimated waste inventory derived in Step 9.

4.2.23 The Fixed Unit Price derived in this methodology is the price that would be charged at the Assumed Disposal Date, which in this worked example is 2130. The Transfer Date in this worked example is 2080. Therefore the Fixed Unit Price is discounted to reflect the timing difference (**Step 17**). In this worked example a discount rate of 2.2% per annum has been used, in line with NDA's long-term discount rate.

Approach to be taken when setting a Fixed Unit Price	Assumption for worked example
Step 14: The Fixed Unit Price for spent fuel will be converted from canisters into a price in p/kWh.	The units in the worked example are the copper canister for spent fuel and m^3 for ILW. These have been chosen for simplicity, as they are the units used in the Parametric Cost Model.
Step 15: When an operator of a new nuclear power station requests a Fixed Unit Price its level will be determined by the Secretary of State. He will consider whether in his view the figure resulting from the methodology to determine a Fixed Unit Price provides sufficient protection for the taxpayer. Once set the Fixed Unit Price will be indexed for inflation.	The worked example has four different illustrative values for the Fixed Unit Price. These prices are equivalent to the 80th, 90th, 95th and 99th centiles from the risk adjusted cost distribution derived in Step 13. The figures in this worked example are in "real" money, i.e. they disregard inflation. All money values in the worked examples are expressed in constant September 2008 money and are undiscounted except where indicated.
Step 16: The total waste liability can be estimated by combining the Fixed Unit Price derived in Step 15 with the expected waste inventory from Step 9.	As for the proposed methodology.
Step 17: A value for the Fixed Unit Price and the total estimated total waste disposal liability on the Transfer Date will be calculated by the application of an appropriate discount rate for the period between the Transfer Date and the Assumed Disposal Date.	This worked example assumed a Transfer Date of 2080 and an Assumed Disposal Date of 2130. The discount rate applied is 2.2%.

Fixed Unit Price Worked Example (continued)

Step 14

There is no conversion of units in this worked example. However see Section 4.4 to see how this conversion will work for spent fuel.

Step 15

For this worked example four risk adjusted unit cost estimates at different confidence levels have been taken from the distributions derived in Step 13:

	P_{80} (£k)	P_{90} (£k)	P_{95} (£k)	P_{99} (£k)
Spent fuel (per canister)	1645	1737	1822	2014
ILW (per m^3)	32.0	35.1	40.8	48.4

Step 16

If we treat these risk adjusted unit cost estimates as possible values for the Fixed Unit Price it is possible to determine values for the estimated waste disposal liability in each case, by multiplying these prices by the waste inventory for a typical new nuclear power station from Step 9:

Estimated waste disposal liability value in 2130	P_{80} (£m)	P_{90} (£m)	P_{95} (£m)	P_{99} (£m)
	887	939	993	1104

Step 17

Discounting the figures from Step 15 at 2.2% pa for the period between 2080 and 2130 gives illustrative values for the Fixed Unit Price at the Transfer Date:

Discounted figures	P_{80} (£k)	P_{90} (£k)	P_{95} (£k)	P_{99} (£k)
Spent fuel (per canister)	554	585	614	679
ILW (per m^3)	10.8	11.8	13.7	16.3

Discounting the figures from Step 16 at 2.2% pa for the period between 2080 and 2130 gives illustrative values for the target fund value at the Transfer Date.

Target fund value in 2080	P_{80} (£m)	P_{90} (£m)	P_{95} (£m)	P_{99} (£m)
	299	316	334	372

4.3 A worked example of how an eFUP would be calculated using this methodology

4.3.1 As discussed in Section 3.2, it is proposed that prospective operators of new nuclear power stations be given the option to defer the setting of a Fixed Unit Price for the disposal of their ILW and spent fuel. If an operator opts to defer, the Government will provide the operator with an eFUP, in order to enable them to make prudent provision for waste disposal costs in the period before their Fixed Unit Price is set.

4.3.2 The level of the eFUP would be the Government's best estimate of level of the Fixed Unit Price at the time it is eventually set, i.e. at the end of the Deferral Period. This section sets out a worked example for how an eFUP will be determined using this methodology. The key difference between the calculation of a Fixed Unit Price in the worked example in Section 4.2 and the calculation of an eFUP in this worked example is that:

- a Fixed Unit Price will include a risk premium that reflects the level of certainty over waste disposal costs at the time the price is set;
- an eFUP will include a risk premium based on the best estimate of the level of certainty there will be over waste disposal costs at the end of the Deferral Period.

4.3.3 Much of the analysis and many of the assumptions set out in Section 4.2 also apply in this worked example and are not repeated. This section on a worked example for the calculation of an eFUP additionally assumes that a new nuclear power station starting generation of electricity in 2020 has a Deferral Period of 10 years after start of generation, therefore its Fixed Unit Price would be set in 2030.

4.3.4 This means that the eFUP is the Government's best estimate of the Fixed Unit Price it would expect to set in 2030. In order to calculate this, it is necessary to estimate the level of uncertainty that there will be over waste disposal costs in 2030.

4.3.5 The NDA's current planning assumptions are for construction of a GDF to begin in 2025 and first waste emplacement to begin in 2040. In these circumstances, many of the uncertainties considered in the worked example in Section 4.2 would not apply when estimating disposal costs in 2030, for example there would be much less uncertainty over the geological environment. Similarly, many of the wider project uncertainties, defined in the methodology as Out-of-Model Risks, would no longer apply, and those that did apply could be incorporated into an assessment of project risk (i.e. they would become In-Model Risks), as the project will be much more closely defined and being implemented.

4.3.6 Therefore the illustrative eFUP derived in this worked example includes a smaller risk premium than the illustrative values for the Fixed Unit Price derived in Section 4.2. However in opting for an eFUP, which is subject to change over time, rather than a Fixed Unit Price, which by definition cannot be revised, the operator is accepting more risk and the Government is taking less risk.

4.3.7 The eFUP will be regularly reviewed during the Deferral Period and is likely to be revised from time to time. The eFUP might be revised upwards in the event of changes either to estimates of waste disposal costs or to estimates of the risk premium that will be required at the end of the Deferral Period. For example if progress towards a GDF is slower than currently anticipated the Government might need to revise upwards the level of the risk premium included in the eFUP.

4.3.8 This section follows the same structure as Section 4.2. It divides the methodology into the same series of stages and steps in order to demonstrate how it has been calculated. Therefore the flow chart shown at Figure 5 is also an illustration of how this worked example was derived. The differences between the two worked examples relate to differences in the handling of uncertainty in cost estimates.

Determine GDF scenarios and respective probabilities

4.3.9 As in the worked example in Section 4.2, the Parametric Cost Model devised by NDA has been used to provide the estimates of the costs of waste disposal in a GDF through an exercise to determine GDF scenarios, estimate the costs of those scenarios and consider the probability of those scenarios (**Step 1**).

4.3.10 However in estimating the level of a Fixed Unit Price set in 2030 it is necessary to consider which of these scenarios is expected to be applicable in 2030. It is currently expected that by 2030 the site of a GDF will be known, so there will no longer be any uncertainty over the geological environment in which the facility will be built. This worked example assumes the geological environment assumed in NDA's base case, which is higher strength rocks.

4.3.11 There may be some residual uncertainty, for example over the categories of materials to be emplaced in the GDF and over whether or not a restricted footprint (where material is disposed of in several layers at different depths underground) might be necessary for the emplacement of waste. However the cost impact of these remaining uncertainties is small compared to the uncertainty over geology.

4.3.12 Therefore this worked example considers scenarios 1, 2 and 3 from Annex A and assumes all three scenarios are equally likely.

Derive an estimate of variable costs per unit

4.3.13 As in the worked example in Section 4.2, for each scenario the Parametric Cost Model has provided an estimate for variable waste disposal costs per unit of ILW and spent fuel (**Step 2**).

4.3.14 Some adjustment is needed to these estimates to reflect the level of uncertainty around them. With regard to In-Model Risks, at present this takes the form of an Optimism Bias adjustment (**Step 3**). As in Section 4.2, the level of the Optimism Bias adjustment in the worked example has been set at the upper end of the range recommended in Treasury's Green Book Guidance.

4.3.15 However the way In-Model Risks are handled in the setting of an eFUP is expected to change over time, depending on progress in the implementation of geological disposal. Based on NDA's current planning assumptions, it is expected that by the end of the Deferral Period it should be possible to produce a comprehensive project cost estimate based on a final disposal concept and specific site. Therefore at one of the regular reviews of the level of the eFUP that will take place during the Deferral Period it is expected that the Optimism Bias adjustment in this methodology would be replaced by an adjustment for In-Model risks that reflected a comprehensive assessment of the level of uncertainty in estimated costs, consistent with Green Book principles.

4.3.16 The adjusted estimates for each scenario are then combined by Monte Carlo methods, using the probability for each scenario assigned in Step 1, to produce a distribution for estimated unit variable costs (**Step 4**). However in this worked example only three scenarios are considered and the variability in costs across these scenarios is small. This is because the main driver of variability in estimated cost for each scenario is the assumed geological environment and, for the reasons given above, the eFUP derived here assumes that the geological environment will be known at the end of the Deferral Period.

eFUP Worked Example

(NB all figures in this worked example are in constant September 2008 money and are undiscounted)

Step 1

Three scenarios have been used for this worked example. They are scenarios 1-3 in Annex A.

Step 2

For the three scenarios considered here, the Parametric Cost Model's estimates are:

- spent fuel unit variable disposal cost in the range £398.3-407.8k per canister;
- ILW unit variable disposal cost in the range £9.17-9.55k per m^3.

Step 3

Applying the 66% Optimism Bias adjustment to these figures gives:

- Spent fuel unit variable cost in the range £661.1-677.0k per canister;
- ILW unit variable cost in the range £15.2-15.9k per m^3.

Step 4

Combining the appropriate values for each scenario by Monte Carlo methods gives:

- Spent fuel unit variable disposal cost distribution with a minimum of £661.1k, a P_{50} of £661.1k and a maximum of £677.0k;
- ILW unit variable disposal cost distribution with a minimum of £15.2 k, a P_{50} of £15.2k and a maximum of £15.9k.

Calculate an operator's share of the fixed costs of a GDF per unit of ILW or spent fuel

4.3.17 As in the worked example in Section 4.2, for each scenario the Parametric Cost Model has also been used to obtain an estimate for the total fixed costs of a GDF (**Step 5**). As in Section 4.2 these estimates are adjusted for Optimism Bias (**Step 6**), and then combined by Monte Carlo methods to produce a distribution for estimated total fixed costs (**Step 7**). However as discussed above in relation to variable costs, the way In-Model Risks are handled in the setting of an eFUP is expected to change over time and it is expected that by the end of the Deferral Period it should be possible to produce a comprehensive assessment of the uncertainty in estimated costs.

4.3.18 For the three scenarios considered in this worked example the Parametric Cost Model's estimate for fixed costs is the same (as each scenario assumes the same geological environment). This means that combining the values for each scenario by Monte Carlo methods gives a single value.

4.3.19 The methodology to determine a Fixed Unit Price will assume the co-disposal of legacy and new build waste, but retain the flexibility to revise this at a later date for subsequent reactors if there were reasons to consider that there was a significant risk that a second GDF might be needed. Hence this worked example assumes the co-disposal of legacy and new build waste (**Step 8**). However in setting the assumed size of the new build fleet and therefore the expected volume of new build wastes, it is necessary to estimate the likely size of the fleet at the end of the Deferral Period. For this worked example, it has been estimated that the new build fleet will consist of 10 reactors.

4.3.20 A new build operator's share of the fixed costs in this worked example is calculated in the same way as in the worked example in Section 4.2 (**Steps 9 – 11**). This includes a financing charge, added to the fixed cost contribution to reflect the period between the costs being incurred and the Assumed Disposal Date.

eFUP Worked Example (continued)

Step 5

For the three scenarios considered in this worked example the Parametric Cost Model estimates the total fixed costs of a GDF as £4401m.

Step 6

Applying the 66% optimism bias adjustment to this figure gives an estimate of the total fixed costs of a GDF as £7306m.

Step 7

There is no variation between the estimated fixed costs for these scenarios, so combining the values for each scenario by Monte Carlo methods gives a single value of £7306m.

Step 8

This worked example assumes the co-disposal of legacy and new build waste in a single GDF and assumes a new build fleet of ten new reactors.

Step 9

The estimated waste inventory for a single new nuclear power station is:

- Spent fuel inventory of 500 canisters;
- ILW inventory of 2000 m^3.

The estimated legacy waste inventory is:

- Spent fuel/HLW inventory of 10659 canisters;
- ILW inventory of 390,000 m^3.

Step 10

For the scenarios considered in Step 1:

- Total legacy variable costs (combining the unit variable costs from Step 4 with the inventory from Step 9) are estimated to be in the range £12975-13416m;
- V_N – total variable costs for a new build operator (combining the unit variable costs from Step 4 with the inventory from Step 9) – is in the range £361-370m (of which around 92% are related to spent fuel);
- V_T – total variable costs (legacy variable costs plus the variable costs for four new build reactors) – is in the range £16584–17120m.

Therefore V_N/V_T – the new build operator's share of total fixed costs – is around 2.2%.

Applying this to the distribution determined in Step 7 gives a distribution for a new build operator's share of GDF fixed costs with a minimum of £157.0m, a P_{50} of £158.9m and a maximum of £160.0m.

Step 11

Adding in the financing charge uplift of 38% gives an adjusted distribution with a minimum of £216.7m, a P_{50} of £219.3m and a maximum of £220.9m.

Allocating these costs to spent fuel and ILW in proportion to their share of variable costs, and dividing by the inventory from Step 9 gives:

- for spent fuel a distribution for fixed costs per canister with a minimum of £395.5k, a P_{50} of £401.7k and a maximum of £405.3k;
- for ILW a distribution for fixed costs per m^3 with a minimum of £9.1k, a P_{50} of £9.2k and a maximum of £9.5k.

Develop an overall distribution for estimated unit costs

4.3.21 As in the worked example in Section 4.2, the distribution for variable costs per unit from Step 4 and the distribution for fixed costs per unit from Step 11 are combined to give an overall distribution for estimated unit costs (**Step 12**).

4.3.22 This worked example assumes that progress on the implementation of geological disposal is in line with NDA's current planning assumptions, i.e. for construction of a GDF to begin in 2025. This means that at the end of the Deferral Period in 2030 many of the wider uncertainties, defined in the methodology as Out-of-Model Risks, would no longer apply, and those that did apply could be incorporated into the model (i.e. they would become In-Model Risks) as the project will be much more closely defined and being implemented. Therefore in this worked example it is not considered necessary to apply a further Contingency Allowance to allow for Out-of-Model Risks (**Step 13**).

4.3.23 This means that the final cost distribution is the same as that derived in Step 12.

eFUP Worked Example (continued)

Step 12

Combining the distributions from Step 4 and Step 11 gives the following distributions for overall unit costs:

- Spent fuel per canister cost distribution with a minimum of £1056.6k, a P_{50} of £1062.8k and a maximum of £1082.3k;
- ILW per m^3 unit cost distribution with a minimum of £24.3k, a P_{50} of £24.5k and a maximum of £25.3k.

Step 13

There is no Contingency Allowance in this worked example. Therefore the final cost distribution is that derived in Step 12.

Derive an eFUP and estimated total waste disposal liability

4.3.24 As in Section 4.2, for simplicity this worked example retains the units used by the Parametric Cost Model (**Step 14**).

4.3.25 The Secretary of State will then set the level of the eFUP, having regarded to the risk adjusted cost distribution derived in this methodology (**Step 15**). As with Section 4.2, all values in this worked example are in constant September 2008 money values. However once an eFUP has been set it will be indexed for inflation.

4.3.26 As set out in Section 3.3 it is expected that an operator would want an assurance from the Government on how their Fixed Unit Price would eventually be set. It is anticipated that this will be set out in an agreement between the operator and the Secretary of State that would be agreed alongside the Secretary of State's approval of the operator's FDP.

4.3.27 As for the worked example in Section 4.2, four possible eFUPs are considered, each equating to a point on the cost distribution derived at Step 13. However due to the way the distribution has been derived, based on three scenarios all relating to a single geological environment, the value of the illustrative price is the same for all the centiles considered.

4.3.28 Once an eFUP has been established, an estimated total waste disposal liability for a new build operator can be calculated in the same way as in Section 4.2, and then discounted to reflect the timing difference between the Transfer Date and the Assumed Disposal Date (**Step 16-17**).

eFUP Worked Example (continued)

Step 14

There is no conversion of units in this worked example. However see Section 4.4 to see how this conversion will work for spent fuel.

Step 15

For this worked example four risk adjusted unit cost estimates at different confidence levels have been taken from the distributions derived in Step 13. Due to the way the distribution has been derived, based on three scenarios, the value of the illustrative price is the same for all the centiles considered.

	P_{80} (£k)	P_{90} (£k)	P_{95} (£k)	P_{99} (£k)
Spent fuel (per canister)	1082	1082	1082	1082
ILW (per m^3)	25.3	25.3	25.3	25.3

Step 16

If we treat these risk adjusted unit cost estimates as possible values for the eFUP it is possible to determine a value for the estimated waste disposal liability in this case, by multiplying these prices by the waste inventory for a typical new nuclear power station from Step 9:

Estimated waste disposal liability value (£m)	592

Step 17

Discounting the figures from Step 15 at 2.2% pa for the period between 2080 and 2130 gives illustrative values for the Fixed Unit Price at the Transfer Date:

Discounted figures	P_{80} (£k)	P_{90} (£k)	P_{95} (£k)	P_{99} (£k)
Spent fuel (per canister)	365	365	365	365
ILW (per m^3)	8.5	8.5	8.5	8.5

Discounting the figures from Step 16 at 2.2% for the period between 2080 and 2130 gives illustrative values for the target fund value at the Transfer Date:

Target fund value in 2080 (£m)	199

4.4 A worked example of how the Fixed Unit Price for spent fuel would be converted to p/kWh

4.4.1 As discussed in Section 3.4, it is proposed that the Fixed Unit Price for spent fuel be set in p/kWh. This section considers how the illustrative values for a Fixed Unit Price or an eFUP for spent fuel derived at Step 15 of the worked examples in this chapter convert into p/kWh. This section also sets out how the discounted values for the Fixed Unit Price or eFUP derived at Step 17 of the worked examples convert in p/kWh.

4.4.2 The illustrative values for the Fixed Unit Price or eFUP for a canister of spent fuel can be converted into p/kWh as follows. A total estimated waste disposal liability for spent fuel is calculated by multiplying the values for the Fixed Unit Price or eFUP per canister (from Step 15) with the estimated spent fuel inventory in canisters (from Step 9). (NB this total is slightly smaller than the total waste disposal liability calculated at Step 16, as this calculation relates only to spent fuel). This total is then divided by the estimated output of the new nuclear power station to give a value in p/kWh. For this exercise the total output has been estimated at 10,600GWh/year, or 424,000GWh over the 40 year life of the station[34].

4.4.3 It should be noted that, as with all figures in this chapter, the numbers here are in constant September 2008 money and are undiscounted. However the Fixed Unit Price and eFUP, regardless of the "unit", will be indexed with inflation.

4.4.4 Tables 5 and 6 show how the figures from Step 15 of the methodology convert in p/kWh, i.e. these are the prices applicable at the Assumed Disposal Date, which in the worked examples is 2130.

[34] This is an estimate based on a generic 1.35GW(e) PWR with a load factor of 90%.

Table 5: illustrative values applicable at the Assumed Disposal Date for a Fixed Unit Price for spent fuel expressed in p/kWh

	P_{80}	P_{90}	P_{95}	P_{99}
Illustrative Fixed Unit Price per canister from Step 15, Section 4.2 (£k)	1645	1737	1822	2014
Equivalent in p/kWh	0.194	0.205	0.215	0.238

Table 6: illustrative values applicable at the Assumed Disposal Date for an eFUP for spent fuel expressed in p/kWh

Illustrative eFUP per canister from Step 15 Section 4.3 (£k)	1082
Equivalent in p/kWh	0.128

4.4.5 Tables 7 and 8 show how the figures from Step 17 of the methodology convert in p/kWh, i.e. these are the discounted prices applicable at the Transfer Date, which in the worked examples is 2080.

Table 7: illustrative values applicable at the Transfer Date for a Fixed Unit Price for spent fuel expressed in p/kWh

	P_{80}	P_{90}	P_{95}	P_{99}
Illustrative Fixed Unit Price per canister from Step 17, Section 4.2 (£k)	554	585	614	679
Equivalent in p/kWh	0.065	0.069	0.072	0.080

Table 8: illustrative values applicable at the Transfer Date for an eFUP for spent fuel expressed in p/kWh

Illustrative eFUP per canister from Step 17 Section 4.3 (£k)	365
Equivalent in p/kWh	0.043

Comparing the figures here with the figures in Section 5.5

4.4.6 Section 5.5 provides an illustration of how the updated cost estimates set out in Chapter 5 might translate into annual payments into the operator's independent Fund, expressed as a cost per unit electricity generated (£/MWh).

4.4.7 It is important to note that although both the figures here and those figures given in Section 5.5 are expressed in the form of money per unit output, there are important differences between them. It is to help with this distinction that Section 5.5 uses the unit £/MWh, whereas this section uses the unit p/kWh[35].

[35] As there are 100 pence in a pound and 1000kW in a MW, £1/MWh equals 100p per 1000kWh, i.e. 0.1p/kWh.

4.4.8 This is because the figures calculated in Section 5.5 are a "levelised cost" estimate - an estimate of how much money an operator would need to pay into their independent Fund at the time of generation in order to meet their waste disposal liability at the time of waste transfer. That figure depends heavily on the assumed rate of fund growth and would be subject to change depending on actual fund performance, to ensure that there were sufficient monies in the Fund to meet the waste disposal liability.

4.4.9 In contrast the p/kWh figures derived in this section are an illustration of a Fixed Unit Price expressed as a value per unit of output. Hence it does not depend on any fund growth assumptions – the operator would be responsible for ensuring that their independent Fund had sufficient monies to pay this price per unit at the Transfer Date (subject to discounting at the appropriate rate as set out in Section 3.2), regardless of the performance of the Fund.

Chapter 5: Updated estimates of the costs for decommissioning, waste management and waste disposal

5.1 Introduction

5.1.1 The FDP Guidance consultation document said that the Government would develop updated estimates of the costs of decommissioning, waste management and waste disposal and included a draft methodology for estimating these costs. An operator of a new nuclear power station will be expected to calculate their own estimates of these costs, which will differ from those produced by the Government, as they will be specific to the reactor design, site and other operational decisions of the operator, rather than generic. However, the Government's methodology to determine cost estimates provides the operator with an example of how they might calculate their own estimates, as well as ensuring that the Government, the NLFAB and those responsible for managing operators' Funds have a benchmark against which to assess the estimates produced by the operator.

5.1.2 The methodology published in the FDP Guidance consultation document has been used to develop updated estimates of the costs of decommissioning, waste management and waste disposal and these updated estimates are published in this chapter. The chapter also explains how these updated estimates have been developed, and compares them with the Government's previous estimates, that were published in the "Consultation on the Future of Nuclear Power"[36] issued in May 2007.

5.1.3 It is important to be cautious in estimating total costs as there are considerable uncertainties in a number of areas. Also the time frame under consideration is very long, hence even modest changes in certain assumptions can mean substantial changes to cost estimates.

5.1.4 The FDP Guidance consultation document explained that the Government would develop a cost model, which it would use as a tool to assist it with the estimation of costs. A DECC cost model has now been developed and has been used to produce some of the updated cost estimates set out in this chapter. We do not intend to publish the model as it has been developed by the Government as a tool for its own internal use and some of the data inputs are based on commercially sensitive information provided in confidence. However this chapter sets out the key elements of the analysis that underpins the DECC model.

Consultation Question 6:

Do the updated cost estimates represent a credible range of estimates of the likely costs for decommissioning, waste management and waste disposal for a new nuclear power station?

[36] The Future of Nuclear Power. The Role of Nuclear Power in a Low Carbon UK Economy. http://www.berr.gov.uk/files/file39197.pdf

5.2 Categories of costs under consideration

5.2.1 Table 6 in the FDP Guidance consultation document[37] shows which costs will be expected to be discharged from an operator's independent Fund and which would be expected to be met from operational expenditure. This chapter is concerned solely with costs which will be met from the Fund and these costs can be divided into two categories:

- **Decommissioning and waste management costs.** This includes decommissioning engineering costs, i.e. those costs associated with demolishing the power station and remediation of the site, and those costs relating to the storage, packaging and transport of spent fuel, ILW and LLW.
- **Waste disposal costs.** Those costs relating to the disposal of ILW and spent fuel in a GDF and covered by the Fixed Unit Price.

5.2.2 Updated cost estimates for these two categories are provided in this chapter. The estimates and the underpinning analysis are intended to provide the Government and the NLFAB with a benchmark against which to assess the estimates produced by operators. The Government does not intend to publish details of all of its underpinning analysis and assumptions. This is because some of the data used has been provided on a confidential basis. It is also because the Government expects operators to develop their own cost estimates and will subject those estimates to close scrutiny. It considers the publication of the Government's own detailed estimates in advance as having the potential to reduce the effectiveness of that scrutiny.

5.2.3 An operator will be required to ensure that there are sufficient monies in their independent Fund to meet the costs identified. They will need to ensure that there is transparency between and separate reporting of the two sets of liabilities, those which arise in relation to decommissioning and waste management on the one hand and waste disposal on the other, as well as in the monies accumulated to meet the costs of each.

5.3 Decommissioning and waste management costs

Decommissioning engineering costs

5.3.1 An operator of a new nuclear power station will be required to produce an estimate of decommissioning engineering costs. This is expected to include components such as:

- decontamination and dismantling;
- winding down of the workforce;
- operation of fuel ponds after station operation;
- the management of non-radioactive hazardous decommissioning wastes;
- all other costs associated with the operating of the site after the end of its generating life. These costs are not necessarily limited to those associated with maintaining the infrastructure.

[37] FDP Guidance consultation document page 71.

5.3.2 It is difficult to produce a generic estimate for the cost of decommissioning a new nuclear power station. Although there is a considerable body of data on the actual and estimated costs of decommissioning, the figures are very widely spread and are not necessarily directly applicable to decommissioning of the reactor designs currently being considered by prospective new build operators.

5.3.3 A number of different factors impact upon estimates of decommissioning costs. In particular:

- the period assumed for the start and duration of decommissioning;
- the reactor design;
- the scope of activities covered by the definition of decommissioning activities, (in particular the extent to which costs relating to the management and disposal of radioactive wastes are included);
- the choice of decommissioning strategy adopted by the operator;
- the regulatory regime (when considering data from different countries).

5.3.4 In addition to which, the range of available UK and international data need to be adjusted for the effect of time and/or currency variations.

Radioactive waste management costs

5.3.5 An operator of a new nuclear power station will also be required to produce estimates of the costs relating to the management of spent fuel, ILW and LLW. This is expected to include the following components:

Spent fuel

- The costs of keeping the spent fuel in safe and secure interim storage in line with regulatory requirements until it can be disposed of in a GDF.
- The costs of encapsulating the spent fuel for disposal.
- The costs of transporting the spent fuel from the interim store to a GDF.

ILW

- The cost of keeping the ILW in safe and secure interim storage in line with regulatory requirements until it can be disposed of in a GDF.
- The conditioning (including packaging) of decommissioning ILW (it is assumed that operational ILW will be packaged as it arises and that the cost of this will be met from operational expenditure).
- The cost of transporting the operational and decommissioning ILW waste from the interim store to a GDF.

LLW

- The cost of packaging of LLW waste from decommissioning.
- The cost of transporting the decommissioning LLW for disposal in LLW disposal facilities.

5.3.6 There are three sets of considerations when estimating waste management costs:

- **The volumes of waste to be managed**. Waste management costs are, unlike decommissioning costs, broadly proportionate to the quantity of waste generated. The FDP Guidance consultation document set out the Base Case assumption of a reactor life of 40 years, hence this is the basis on which waste management costs have been estimated. If the reactor were to have a longer or shorter life than 40 years then the total waste management cost estimate would need to change accordingly.
- **The steps to be taken to manage the waste**. For example, the technology used for interim storage, the duration of that storage, and whether storage and packaging takes place on the site of the nuclear power station or at a regional or central location.
- **The cost of each separate waste management activity.** It is possible to estimate the cost of some of these activities with a high degree of confidence, because these activities are being undertaken for existing wastes, for example costs relating to the management and disposal of LLW and the transport of spent fuel. For other activities there is much more uncertainty over costs as current data is not available, for example for the costs of encapsulating spent fuel for disposal.

Estimate of costs in the 2007 Nuclear Consultation

5.3.7 Analysis undertaken for the 2006 Energy Review included an exercise to estimate decommissioning costs for a new nuclear power station. This was the basis of the estimate published in the 2007 Nuclear Consultation which estimated the costs of decommissioning a new nuclear power station at £636m (2006 money values). This was based on estimates from reactor vendors and a review of other data.

5.3.8 The 2007 Nuclear Consultation did not identify waste management as a separate category of costs within the overall decommissioning cost estimate. However some aspects of waste management costs will have been included within the scope of the source data on which the decommissioning estimate was based.

5.3.9 In order to produce a generic estimate of decommissioning costs, the exercise undertaken for the 2006 Energy Review sought to estimate costs in terms of cost per GW installed capacity. In response to this exercise, high level estimates were provided by Areva on the cost for decommissioning an EPR reactor, and by Westinghouse on the cost for decommissioning an AP1000 reactor. These are the reactor designs currently going through the Generic Design Assessment (GDA) process[38].

5.3.10 The high level estimates obtained from Areva and Westinghouse were then adjusted to take account of differences in scope. No determination was made of the different levels of conservatism or contingency included in the estimates. This resulted in a base estimate of the cost of decommissioning of an EPR reactor in the range £255-345m per GW, and an estimate of the cost for decommissioning an AP1000 reactor in the range £340-£360m per GW.

[38] Through the GDA process the nuclear regulators are assessing the safety, security and environmental impact of power station designs, including the quantities and types of waste that are likely to arise, their suitability for storage, transport and their disposability. More information about GDA is available at the HSE's new nuclear power stations website http://www.hse.gov.uk/newreactors/index.htm

5.3.11 A review of actual data from decommissioning reactors (of earlier generations) was also undertaken. Few large scale commercial PWR reactors have reached advanced stages of decommissioning, however there are examples in the US where work is substantially complete, and decommissioning has been completed to NRC satisfaction. Two key examples are Maine Yankee (a 900MW PWR) and Trojan (a 1,155MW PWR).

5.3.12 In both cases the nuclear facilities have been dismantled, but other structures remain, and in the case of Maine Yankee, certain wastes remain on site in a packaged form in newly engineered facilities as a consequence of the unavailability of Yucca Mountain. The disclosed costs given for the decommissioning of Maine Yankee were US$440m (2001 money value) which was updated to give an estimate of £360m per GW (2006 money value). The disclosed costs for the decommissioning of Trojan were US$300m (1997 money value) which was updated to give an estimate of £220m per GW (2006 money value).

5.3.13 Finally, a review was undertaken of the studies in the public domain, which assessed the level of provisioning for decommissioning costs made by European utilities operating PWRs. The studies that were considered are listed in Annex E.

5.3.14 The analysis found that there was a lack of specificity or disclosure of many of the key assumptions and hence it was considered critical to treat with caution the single value estimates stated by a number of the sources.

5.3.15 It was concluded that the available data sources pointed to a central estimate for the decommissioning of a PWR in the range of £250m - £350m per GW (2006 money value). However, it was considered that these data sources were unlikely to include much provision for contingency, and consequently it was felt that a prudent assumption was to increase the range by a factor of 1.2 to reflect that contingency. This gave rise to an estimate for decommissioning costs in the range between £300m and £420m per GW.

5.3.16 On the basis of the analysis summarised above, the 2007 Nuclear Consultation gave a best estimate of £400m per GW for decommissioning a new nuclear power station. This figure was then applied to a PWR with an installed capacity of 1.59GW to give the estimate of £636m published in the Nuclear Consultation.

Updating this estimate

5.3.17 Since the publication of the estimate for decommissioning costs in the 2007 Nuclear Consultation, the Government has carried out further analysis in order to produce an updated cost estimate. This analysis involved undertaking a review of available data on decommissioning costs obtained from a variety of sources including continuation of direct contact with reactor vendors. We also undertook a further review of third party studies in the public domain published since the Nuclear Consultation; and international studies strategically aligned with the Base Case assumption of prompt decommissioning. The further studies that were considered are also listed in Annex E.

5.3.18 This further analysis has identified a number of factors indicating that the 2007 estimate might overstate actual decommissioning and waste management costs, and a number of factors that suggest that it might understate actual costs.

5.3.19 Factors that suggest that the 2007 estimate could be unnecessarily high and might need to be revised downwards include:

- The analysis of publicly available data has found that £350-420m per GW is at the high end of the estimates in the public domain of actual and forecast PWR decommissioning costs.
- The requirement for an operator to produce a decommissioning plan before construction of a new nuclear power station begins, and then to review and update this plan throughout operation, should provide opportunities for more efficient and cost effective decommissioning than has been possible with previous generations of nuclear power stations.

5.3.20 Factors that suggest that the 2007 figure could be low and might need to be revised upwards include:

- Estimates of nuclear construction and decommissioning costs, for example estimates of the costs of constructing the new EPRs in Finland and France, have risen substantially. In the absence of detailed cost estimates, some high level estimates of the costs of decommissioning are calculated as a percentage of construction costs, hence escalation of construction costs might be expected to feed through to higher decommissioning costs.
- The scope of the costs covered by the 2007 estimate did not include all the aspects of waste management currently anticipated for new nuclear power stations in the UK. In particular the source data on which it was based will not have taken account of the requirement for an extended period of interim storage for spent fuel and ILW prior to disposal in a GDF, nor the costs of encapsulation of spent fuel for disposal.

5.3.21 **This further analysis has reinforced the extent to which there is uncertainty over the likely costs of decommissioning a new nuclear power station, and that caution is needed in making a generic cost estimate. However on balance, the 2007 estimate is considered an under-estimate, as it excluded important categories of costs that will need to be met from an operator's independent Fund.**

5.3.22 In order to produce generic estimates of decommissioning and waste management costs, a series of assumptions have been made, drawing on the Base Case set out in the FDP Guidance consultation document. When setting out their estimate for decommissioning and waste management costs in their FDP, an operator will be expected to set out the assumptions that have been made and to justify any variations from the Base Case.

5.3.23 The estimates given here relate solely to decommissioning and waste management costs incurred after the end of electricity generation. However it should be noted that the Energy Act 2008 includes provisions that enable the Secretary of State to designate certain steps by way of waste management and disposal, which are undertaken during the generating lifetime of the station, as "designated technical matters". The Energy Act requires the FDP to contain estimates of the costs likely to be incurred in connection with the designated technical matters[39].

[39] FDP Guidance consultation document Section 4.1

5.3.24 The estimates here are for a generic PWR and are based on a series of assumptions. Hence there is considerable uncertainty over costs, which is reflected in the range of estimated costs set out here. A prospective operator of a new nuclear power station should be able to estimate their decommissioning and waste management costs within a narrower range as some of the generic assumptions made in this exercise can be refined in the light of a specific proposal from an operator. The operator will also be expected to set out their operating strategy in their FDP and explain how their cost estimates have been derived. This will include setting out clearly their decommissioning strategy, the way in which they expect to manage their waste and the anticipated volumes of waste that the nuclear power station is expected to produce. However some uncertainty will remain and an operator will be expected to take this uncertainty into account when producing their own estimates of waste disposal costs and making prudent provision for these costs in their FDP.

5.3.25 The main assumptions that have been made for the purpose of producing a cost estimate for decommissioning and waste management for a generic PWR are in line with the Base Case and with the assumptions made for the worked examples in Chapter 4, namely:

- That the new nuclear power station has a life of 40 years. It is assumed to begin operation in 2020 and to cease generation in 2060.
- That decommissioning begins immediately at the end of generation (i.e. there is no "care and maintenance" period) and decommissioning is assumed to be completed in 2080.
- ILW and spent fuel is assumed to be kept in interim storage on the site of the new nuclear power station until it can be transferred to a GDF for disposal.
- ILW will be packaged as it arises, but spent fuel will be kept in interim storage and encapsulated immediately prior to transfer to a GDF. In the absence of proposals for centralised packaging facilities, it is assumed that encapsulation of spent fuel and packaging of ILW are also carried out on-site.
- That the dates for the geological disposal of ILW and spent fuel are those set out in Chapter 3, i.e. it is assumed that waste disposal will take place in around 2130[40].
- The assumed waste volumes are in line with those set out in Annex D.

5.3.26 **Taking these factors into account, for a generic PWR reactor with a capacity of 1.35GW, operating in accordance with these assumptions, decommissioning and waste management costs are estimated to be in the range £800 – £1800m.**

[40] Chapter 3 sets out the revised proposal that the schedule for the transfer of title to and liability for an operator's waste should be aligned with the operator's decommissioning timetable. On the basis of the assumptions set out above, this means the Transfer Date would be 2080. However, and as set out in Chapter 3, the operator will still be expected to estimate waste management costs beyond the date of transfer up to the Assumed Disposal Date and make prudent provision for these costs. The monies set aside in the operator's independent Fund for these costs would then transfer to the Government at the point of transfer, as a full and final payment from the operator.

5.3.27 Varying the assumptions set out above will have a significant effect on estimated costs. For example, assuming a reactor life of 60 years, which is the design lifetime estimated by the reactor vendors, would mean proportionately larger waste volumes and thus increased packaging and transport costs.

5.3.28 In addition, the assumptions of onsite storage until the point of disposal and onsite encapsulation of spent fuel are considered conservative. In the event that regional or central facilities were available for either storage or encapsulation that should lead to significant reductions in waste management costs.

5.3.29 It is important to note that these are estimates for a generic PWR and based on a set of assumptions. An operator's estimate will differ from these estimates and it will be for the operator to demonstrate that their cost estimates are credible and robust and to set out the basis on which their estimates have been derived.

5.4 Waste disposal costs

5.4.1 Chapter 3 sets out the proposed methodology to determine a Fixed Unit Price and Chapter 4 has worked examples that give illustrative values for a Fixed Unit Price and eFUP, and estimates how these prices would translate into an operator's total waste disposal liability. This section explains how the estimates derived in Chapter 4 compare with the estimates for waste disposal costs given in the 2007 Nuclear Consultation.

Estimate of waste disposal costs in the 2007 Nuclear Consultation

5.4.2 The Nuclear Consultation noted that:

"It is difficult to accurately state the additional costs of new build waste on the costs of geological disposal at this stage. As discussed (in chapter thirteen) further work will be undertaken to establish the costs, and the range of likely uncertainty, as clearly as possible. This will take place alongside work to settle the financing arrangements to cover the cost of waste management, and before new build is allowed to take place. At this stage we simply note that the 2003 cost estimates prepared by Nirex indicated that a new build programme of this size would add a little over £2bn (undiscounted) to an overall geological disposal project costing approximately £10bn (undiscounted)"[41].

5.4.3 In the absence of detailed work on cost estimates, a series of assumptions were made to derive an estimate of the costs of waste disposal for a new nuclear power station of £276m (2006 money value). This was based on three assumptions in particular:

- That a GDF built to dispose of legacy waste could cost £25bn. This was considered a very conservative estimate and predates the detailed work by NDA described in Annex A.
- That the variable costs of the GDF would be £17.5bn, or 70% of the total, and the price paid by new build operators would relate solely to the additional variable costs incurred as a result of the disposal of new build wastes in a GDF.
- That, based on a CoRWM estimate that a 10GW new build programme would add 10% to the volumes of waste for disposal, a 10GW new build fleet would add 10% to the variable costs of a GDF, i.e. £1.75bn.

[41] The Future of Nuclear Power page 135

5.4.4 It was on this basis that the waste disposal cost for a 1.59GW new nuclear power station was estimated to be £276m.

Updating this estimate

5.4.5 The Nuclear Consultation's estimate of waste disposal costs predates the detailed analysis set out in Chapters 3 and 4, and there are two key areas where the assumptions on which the 2007 figures were based now need to be updated:

- The 2007 figures assumed that new build operators would not contribute to the fixed costs of a GDF. This was an assumption for cost modelling purposes and the Government has since stated that an operator's full share of waste disposal costs should include a contribution to the fixed costs of a GDF.
- In the absence of more detailed analysis, the 2007 figures did not take account of the very significant differences between the variable costs of disposing of HLW/spent fuel on the one hand and ILW on the other. A 10GW new build programme is estimated to add less than 10% to the total volume of ILW for disposal[42]. However a 10GW programme is estimated to increase the total inventory (waste from existing and new nuclear power stations) of HLW/spent fuel for disposal by 50-55%[43]. Spent fuel is substantially more expensive to dispose of than ILW, therefore the assumptions that underpinned the 2007 figures underestimated the variable costs of disposing of the spent fuel and ILW from a 10GW programme in a GDF.

5.4.6 Chapter 4 includes some illustrative figures for the costs of waste disposal for a generic 1.35GW PWR operating for 40 years:

- On the basis of a Fixed Unit Price as derived in Section 4.2, a total waste disposal liability on the Assumed Disposal Date of £887 – 1104m, which translates to a payment on the Transfer Date in the range £299 – 372m.
- On the basis of an eFUP as derived in Section 4.3, a total waste disposal liability on the Assumed Disposal Date of £592m, which translates to a payment on the Transfer Date of £199m.

5.5 Translating the updated cost estimates into an indicative annual payment into an operator's independent Fund

5.5.1 This section provides an illustration of how the updated cost estimates set out here might translate into annual payments into an operator's independent Fund, expressed as a cost per unit of electricity generated (£/MWh).

5.5.2 These figures are for illustrative purposes only. The operator will be responsible for making good any shortfall or risk of shortfall in the accumulated monies held by their independent Fund, in order to ensure that the Fund is sufficient to meet their waste and decommissioning liabilities. The NLFAB will advise the Secretary of State on the financial arrangements that an operator submits for approval and will provide advice to the Secretary of State on the regular reviews and ongoing scrutiny of funding arrangements.

[42] The arrangements for the management and disposal of waste from new nuclear power stations: a summary of evidence page 32, http://data.energynpsconsultation.decc.gov.uk/documents/wasteassessment.pdf

[43] The arrangements for the management and disposal of waste from new nuclear power stations: a summary of evidence page 7

5.5.3 An operator will be required to ensure that there are sufficient monies in their independent Fund to meet the costs identified. They will need to ensure that there is transparency between, and separate reporting of the two sets of liabilities which arise in relation to decommissioning and waste management on the one hand and waste disposal on the other, as well as in the monies accumulated to meet the costs of each.

5.5.4 The monies in the Fund will be accumulated through a combination of payments by the operator and growth of investments. Therefore in order to estimate the level of payments that will be required by an operator it is necessary to estimate not only costs, but also the impact of the investment performance of the Fund over its lifetime.

5.5.5 The performance of an operator's independent Fund will depend on a number of factors, including the Fund's investment strategy and the performance of the economy over time. It is impossible to project fund performance over the very long timescales involved here. Moreover, given the long timeframes involved, even small variations in assumed fund performance can have a very large impact on the estimated level of payments into the Fund. It will be for the operator to propose an investment strategy for their Fund, and this will be approved by the Secretary of State as part of the FDP approval process.

5.5.6 It is considered likely that the investment strategy of an operator's independent Fund will change after the end of generation. During the operational life of the plant a Fund might pursue a relatively aggressive investment strategy aiming to maximise fund growth, in the knowledge that in the event of poor investment returns, the power station would be generating revenues from which any shortfall in the Fund could be made up. In contrast, after end of generation it is likely that a more cautious investment strategy will be pursued while the Fund is drawn down to pay decommissioning, waste management and waste disposal costs. This is because, in the absence of revenues from the nuclear power station, it is likely to be more difficult for an operator to make up any shortfall.

5.5.7 For the purposes of illustration, the figures in this section assume different investment strategies during and after generation. Three possible real annual growth rates are considered for the Fund during generation: 3.5%, 2.2% and 1%. Two, more conservative, real annual growth rates are considered for the Fund after end of generation; 1% or 0% (a 0% real annual growth rate would mean that the Fund grows only in line with inflation)[44].

5.5.8 As set out above, it should be noted that all calculations in this consultation are in "real" money, i.e. they disregard inflation. All money values in the worked examples in Chapter 4 are expressed in constant September 2008 money and are undiscounted except where indicated. When a Fixed Unit Price or an eFUP is set, its value will be indexed for inflation. When an operator sets out the investment strategy for its independent Fund, the Fund will be expected to recognise and address the risks associated with its investment strategy, including inflation risk.

Waste disposal costs

5.5.9 Using the illustrative waste disposal liabilities derived in the worked examples in Sections 4.2 and 4.3, which are based on a series of assumptions, it is estimated that

[44] It should be noted that the assumptions used here are different from those used in Discussion Paper 3, which included similar calculation to those given here for waste disposal costs, but which assumed uniform real fund growth over the lifetime of the Fund.

a generic PWR would have the following waste disposal liabilities on the assumed Transfer Date of 2080:

- On the basis of a Fixed Unit Price as derived in Section 4.2, a total waste disposal liability in the range £299 – 372m;
- On the basis of an eFUP as derived in Section 4.3, an expected waste disposal liability of £199m.

5.5.10 Table 9 translates these figures into an illustrative annual fund payment, calculated as a figure per MWh (using the same output assumption as in Section 4.4, i.e. output of 10,600GWh(e) per year).

Table 9: illustrative annual fund payment to cover waste disposal costs, expressed as a figure per MWh

Fund growth assumption		**Annual fund payment in £/MWh**	
During generation *(2020-2059)*	***After end of generation*** *(2060-2079)*	***Fixed Unit Price*** *(target fund value £299m – £372m)*	***eFUP*** *(target fund value £199m)*
3.5%	1%	0.26 – 0.33	0.18
2.2%	1%	0.36 – 0.45	0.24
1%	1%	0.47 – 0.58	0.31
3.5%	0%	0.32 – 0.40	0.22
2.2%	0%	0.44 – 0.54	0.29
1%	0%	0.57 – 0.71	0.38

5.5.11 It is important to note that although both the figures here and those figures given in Section 4.4 are expressed in the form of money per unit output, there are important differences between them. It is to help with this distinction clear this section uses the unit £/MWh, whereas Section 4.4 uses the unit p/kWh.

5.5.12 This is because the figures calculated in this section are a "levelised cost" estimate - an estimate of how much money an operator would need to pay into their independent Fund at the time of generation in order to meet their waste disposal liability at the time of waste transfer. That figure depends heavily on the assumed rate of fund growth and would be subject to change depending on actual fund performance, to ensure that there were sufficient monies in the Fund to meet the waste disposal liability.

5.5.13 In contrast the p/kWh figures derived in Section 4.4 are an illustration of a Fixed Unit Price for spent fuel expressed as a value per unit of output. Hence it does not depend on any fund growth assumptions – the operator would be responsible for ensuring that their independent Fund had sufficient monies to pay this price per unit at the Transfer Date (subject to discounting at the appropriate rate as set out in Section 3.2), regardless of the performance of the Fund.

Decommissioning and waste management costs

5.5.14 As set out in Section 5.3, decommissioning and waste management costs for a generic PWR are estimated to be within the range £800 – £1800m.

5.5.15 Under Early Transfer some of these costs will be incurred during the period between the end of generation and the Transfer Date, and some costs will be incurred between the Transfer Date and the Assumed Disposal Date. Up to the Transfer Date the operator will be directly responsible for decommissioning their nuclear power station and managing the waste. After the Transfer Date, the Government will be responsible for managing the waste pending disposal (it is assumed that decommissioning will be complete by the Transfer Date, except for the decommissioning of the interim storage facilities, which cannot be done until the waste materials have been removed from the site.)

5.5.16 As set out in Section 3.2, at the Transfer Date the operator will pay a lump sum to the Government in full and final payment for all remaining waste management costs (including the decommissioning of interim stores if necessary). This lump sum will be estimated in the operator's FDP approved by the Secretary of State and regularly reviewed to ensure it is sufficient to cover costs.

5.5.17 This lump sum will cover costs to be incurred by the Government over a long period (50 years on the assumptions used in worked examples here). In line with the approach set out in Section 4.2, as a general principle the Government considers it necessary for the payment made by an operator to reflect the "time value of money", i.e. that the value of money is affected by when it is paid, based on the principle that a sum of money paid today is more valuable than the certainty of receiving the same sum at a later date.

5.5.18 It is therefore considered necessary to adjust the payment made by the operator to reflect the time value of money. This will be done through the application of discounting to future costs covered by the lump sum. The discount rate will not be fixed at the outset. Rather it will be determined nearer the Transfer Date and set in relation to the rates of returns at that time on long-term investments in Government securities and similar assets. In the meantime the Government will provide the operator with an estimated long-term discount rate, to enable prudent provision to be made. The calculations in this section apply a discount rate of 2.2% per annum, as this is consistent with the long-term discount rate applied to legacy liabilities in the NDA's Annual Report and Accounts.

5.5.19 In order to estimate how much an operator will need in its independent Fund in order to meet these obligations it is necessary to estimate the profile of expenditure on waste and decommissioning costs. A simplified cost profile has been applied as set out in Table 10. It splits the period over which these costs are incurred into three periods:

- Period A (2060-2079): the decommissioning of the nuclear power station, during which the majority of costs are assumed to be incurred.
- Period B (2080-2124): a period of limited annual costs relating to the maintenance of the wastes in safe and secure interim storage.
- Period C (2125-2129): during this period there will be substantial expenditure covering the encapsulation of spent fuel for disposal, transporting the spent fuel and ILW to a GDF and the decommissioning of the interim stores.

Table 10: simplified cost profile for waste and decommissioning costs

Time period	Assumed Dates	Spend per annum (% of total)	Spend over the period (% of total)
A	2060-2079	2.8%	56%
B	2080-2124	0.4%	18%
C	2125-2129	5.2%	26%

5.5.20 This assumed cost profile can then be combined with the updated cost estimate for decommissioning and waste management of £800-1800m, the fund growth and discounting assumptions set out above and the output assumption of 10,600GWh(e) per year to derive the illustrative annual fund payments in £/MWh, as set out in Table 11.

Table 11: illustrative annual fund payment to cover Decommissioning and Waste Management costs, expressed as a figure per MWh

Fund growth assumption		Annual fund payment in £/MWh for decommissioning and waste management costs *(total cost estimate £800m – £1800m)*
During generation *(2020-2059)*	***After end of generation*** *(2060-2079)*	
3.5%	1%	0.59 – 1.33
2.2%	1%	0.80 – 1.80
1%	1%	1.04 – 2.35
3.5%	0%	0.66 – 1.49
2.2%	0%	0.90 – 2.03
1%	0%	1.18 – 2.65

Annex A: Data from NDA's Parametric Cost Model used in the worked examples in Chapter 4

1. The NDA has developed a Parametric Cost Model to generate updated estimates of the costs of geological disposal. It allows the key parameters that impact on the construction and operating costs of a GDF in the UK to be varied.

2. The Parametric Cost Model uses as its basis the detailed cost estimate that underpins the NDA's current best estimate included in its 2007/08 Annual Report and Accounts. The detailed cost estimate resulted from a rigorous process in 2007/08 that included bottom up estimates with costs and prices included from tender information, quotations, relevant industry data and current salary levels.

3. The output from the Parametric Cost Model results from a series of assumptions being selected and, as a consequence, the cost estimates it produces depend on the assumptions used. A range of parameters can be varied, to examine the cost impact from changing the parameters. For example, the Parametric Cost Model can vary parameters such as rock type, depth and waste inventories, to reflect their impact on costs. The Parametric Cost Model can also estimate the cost for disposing of a specified amount of ILW and spent fuel in a GDF.

4. In order to enable waste disposal costs for ILW and spent fuel from new nuclear power stations to be estimated, NDA, at the request of DECC, has developed a range of scenarios for geological disposal which differ – for example in geology or inventory – from the scenario used to develop NDA's current best estimate, and these have been used in the Parametric Cost Model to identify the cost impact of these scenarios.

5. The nine scenarios that have been used in the development of this paper are listed in Table 12, together with a "base scenario", from which the other estimates are derived.

6. As stated in the NDA's Annual Report and Accounts 2007/08, the current best estimate within the range of potential costs for a GDF is £12.2 billion undiscounted. This figure covers both the fixed costs of a GDF and the variable costs of the disposal of legacy waste, which is all known waste that currently exists and waste arising from current facilities and therefore does not include any provision for new build waste or a number of other potential wastes.

Table 12: the scenarios and their cost implications

Scenario	Geology/depth	Legacy wastes?	Legacy U and Pu?	New build wastes?	Restricted footprint?	Variable cost		Fixed costs
						Canister of spent fuel (£k)	m^3 ILW (£k)	£m
Base	Strong rock 650m	Yes	No	No	No	398.3	8.99	4,401
1	Strong rock 650m	Yes	No	Yes	No	398.3	9.55	4,401
2	Strong rock 650m	Yes	Yes	Yes	No	398.3	9.17	4,401
3	Strong rock 650m	Yes	Yes	Yes	Yes	407.8	9.17	4,401
4	Evaporite 650m	Yes	No	Yes	No	429.3	9.95	4,408
5	Evaporite 650m	Yes	Yes	Yes	No	429.3	9.56	4,408
6	Evaporite 650m	Yes	Yes	Yes	Yes	438.9	9.56	4,408
7	Low strength 500m	Yes	No	Yes	No	596.6	11.54	5,015
8	Low strength 500m	Yes	Yes	Yes	No	596.6	12.29	5,015
9	Low strength 500m	Yes	Yes	Yes	Yes	601.4	12.29	5,015

7. The £12.2bn figure represents an estimate based on a given set of assumptions (equivalent to the "base scenario" in Table 12). The exact cost of a GDF will be influenced by many different factors, including the inventory of waste, the geology of the site in question and the design of a GDF. The fact that different values for the estimate costs of a GDF can be derived from this paper does not imply that the figure in the NDA Annual Report and Accounts is wrong – they are the result of variations to the parameters used to estimate costs in the Parametric Cost Model to model scenarios requested by DECC.

8. The purpose of the worked examples in Chapter 4 is to derive estimates of the possible costs of waste disposal that can be used for the purposes of determining a Fixed Unit Price which, once set, will not be capable of being amended. Therefore the estimates derived here are necessarily conservative, aiming to make allowance for a range of uncertainties and risks that costs may escalate in future years. Therefore it is reasonable that the estimates for the costs of a GDF used in the worked examples are significantly higher than the provision for the costs of a GDF in the NDA's Annual Report and Accounts 2007/08.

Annex B: A note on how Monte Carlo calculations have been produced for this consultation

1. Monte Carlo simulation is a mathematical technique that can be used to allow for risk and uncertainty in quantitative analysis and decision making. It is suitable for use in this modelling work because some of the input information takes the form of a distribution of values and hence the output will also be in the form of a distribution. In Monte Carlo methods the calculation is undertaken a large number of times. In each iteration, single values for each of the input data are sampled from the appropriate distributions and used to calculate a single value for the result. Over a large number of iterations, the distribution for the results of the calculation is generated.

2. In the worked examples in Chapter 4, we have generally calculated distributions over 10,000 iterations, but, to ensure accuracy, we might perform a larger number of iterations when conducting calculations to assist in the setting of a Fixed Unit Price.

3. Distributions of input data are involved at three Steps in the worked examples – Steps 4, 7 and 13. For the calculations in Step 4 and Step 7, the two distributions from which values are drawn relate to the costs of waste disposal for each scenario and the relative probabilities of each scenario. The costs are set out in Table 12 and for the worked examples in Chapter 4 all scenarios are considered equally probable. For the calculations at Step 13 a distribution for estimated unit costs that has been derived earlier in the methodology is combined with a distribution for a Contingency Allowance.

Annex C: The derivation of the Contingency Allowance for the worked example in Section 4.2

1. This Annex describes the six risks that have been considered when deriving the Contingency Allowance for inclusion in the worked example in Section 4.2.

2. It should be noted that this calculation is also a worked example. This is not necessarily a definitive list of the risks that will be taken into account when determining a Contingency Allowance for the purposes of setting a Fixed Unit Price. It is anticipated that an exercise to determine a Contingency Allowance will be carried out, following a process similar to this one, each time an operator requests a Fixed Unit Price.

A. Risks related to the possibility that the fundamental assumptions underpinning the Parametric Cost Model's estimation of waste disposal costs do not correspond to the final outcome

3. Like all cost models, the Parametric Cost Model is based on a number of underlying assumptions. This group of risks considers the possibility that some of the key assumptions do not reflect what actually happens when a GDF is built and operated. Three key assumptions have been identified and taken into account in the calculation of the Contingency Allowance.

4. It should be noted that the risks around these assumptions apply equally to estimates of disposal costs for new build and legacy material. Hence a new build operator's share of the allowance for these risks is determined in line with the apportionment of fixed costs.

A1: Risk that the KBS-3 disposal concept (for HLW/spent fuel) and immobilisation in grout disposal concept (for ILW/LLW) are not adopted

Description of the risk

5. The Parametric Cost Model assumes that a GDF will be built according to the KBS-3 concept for HLW/spent fuel disposal and the immobilisation in grout concept for ILW/LLW disposal. The choice of disposal concept fundamentally affects GDF design and therefore cost and the Parametric Cost Model's assumptions are subject to change. The Committee on Radioactive Waste Management (CORWM) for example has noted that there are a number of possible disposal concepts and has recommended that NDA avoid giving the impression that it prefers one concept or design[45].

6. It should be noted that this risk relates only to scenarios where a *fundamentally* different disposal concept is adopted. Smaller design modifications, such as those that might be implemented in response to specific operational issues at the site of a GDF, would be regarded as project uncertainties, and thus would be an In-Model Risk.

[45] CoRWM report on geological disposal, e.g. paragraph 12.54, at: http://www.corwm.org.uk/Pages/Current%20Publications/2550%20CoRWM%20Report%20on%20Geological%20Disposal%20Final%2031%20July%2009.pdf

Consequence

7. It is difficult to estimate the cost impact of applying a different disposal concept. It is not necessarily the case that this would increase costs. Indeed, a key driver for the adoption of a different disposal concept might be to reduce expected costs.

8. NDA has carried out some limited, high-level analysis of the cost impact of adopting different disposal concepts for the disposal of spent fuel. It has considered 10 alternative concepts[46] and examined their potential cost impact by flexing those parameters of the Parametric Cost Model that are expected to be affected. In taking account of different disposal concepts the Parametric Cost Model only flexes the construction costs associated with the excavation size and underground layout and does not alter the cost of the emplacement equipment or backfill material. On the basis of this exercise they found that the changes in disposal concept that they examined implied a relatively modest variation in cost. Some concepts were found to imply higher costs than the KBS-3 concept assumed in the Parametric Cost Model, while others implied lower costs.

9. In order to quantify the consequence of this risk, this exercise has drawn on NDA's work but recognises that it was a limited, high level analysis. Therefore a pragmatic approach has been adopted, in which this risk is allowed for through a 3-point estimate, derived on the basis of a proportion of estimated costs. This distribution assumes that the range of possible consequences for this risk is to vary costs by +/-10%, with the most likely outcome being disposal costs at the level predicted by the Parametric Cost Model (i.e. a triangular distribution with a minimum of -10%, mode of 0% and maximum of +10% of estimated costs).

10. Although the analysis from NDA on the cost impact of adopting different disposal concepts has been focussed on spent fuel, the same distribution is also used in this exercise to estimate the consequence of this risk for the cost of disposing of ILW.

11. The cost estimate to which this uncertainty is applied is derived earlier in the methodology to determine a Fixed Unit Price. These figures are obtained from Step 12 of methodology, which is where the estimated costs from the Parametric Cost Model for each scenario have been uplifted for Optimism Bias and then combined by Monte Carlo methods to produce a distribution.

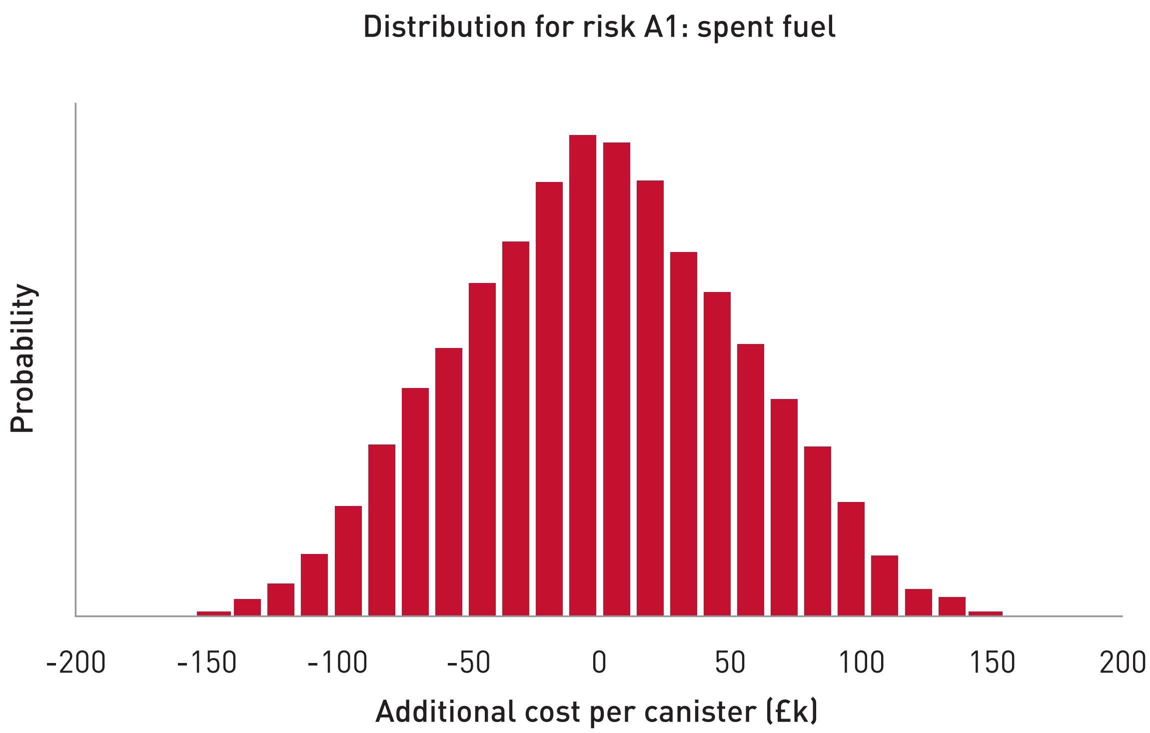
12. In this exercise, the figures have been drawn from Step 12 of the worked example in Section 4.2, which has the following distributions for overall unit costs:

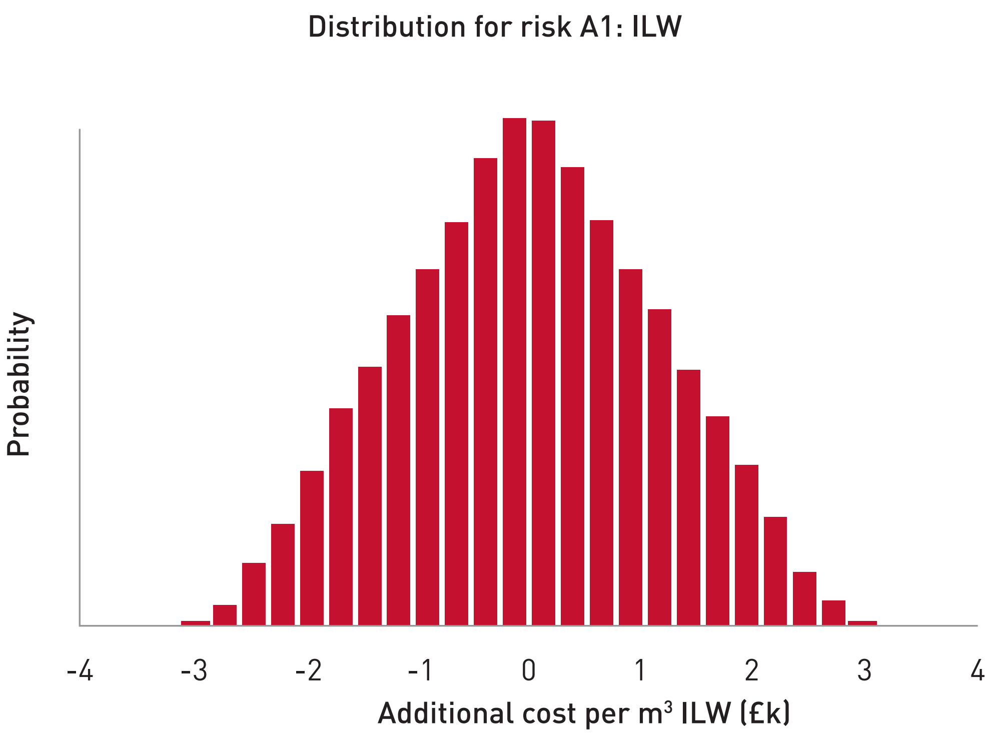
- Spent fuel per canister cost distribution with a minimum of £1115.2k, a P_{50} of £1181.8k and a maximum of £1554.6k;
- ILW per m^3 unit cost distribution with a minimum of £25.7k, a P_{50} of £26.7k and a maximum of £31.8k.

13. Hence to derive a distribution for the cost implications of this risk, these cost distributions are combined by Monte Carlo methods with the triangular distribution from paragraph 9 above. This gives the following distributions:

[46] The ten concepts considered are drawn from the paper "Geological Disposal Options for High-Level Waste and Spent Fuel." This paper examined a total of 12 different concepts, of which two ("hydraulic cage" and "very deep boreholes") were excluded on the basis that there was no estimate the likely costs of adopting these concepts. http://www.nda.gov.uk/loader.cfm?csModule=security/getfile&pageid=20941

- cost per canister of spent fuel with a minimum of £-152.7k, a mean of £0.1k and a maximum of £151.0k
- cost per m^3 of ILW with a minimum of £-3.1k, a mean of £0k and a maximum of £3.1k.





A2: Risk that it is not possible to build a single GDF for the disposal of both HLW/spent fuel and ILW/LLW ("co-location")

Description of the risk

14. The MRWS White Paper said that it would be possible to build more than one GDF, for example one for ILW/LLW and one for HLW/spent fuel, and that this could be necessary if the geology at potential sites was not suitable for a "co-located" GDF. However the MRWS White Paper also said that "the Government sees no case for having separate facilities if one facility can be developed to provide suitable, safe containment for the Baseline Inventory"[47].

15. However this will remain uncertain until a safety case can be made for a co-located facility at a specified site. This is another issue discussed in CoRWM's recent report on geological disposal[48].

16. It should be note that this risk is different to the risk that a second GDF might be needed due to the volume of waste for disposal in the case that the new build fleet is very large. The way that risk is handled in this methodology is set out in Section 3.3.

Consequence

17. If co-location is not possible, two GDFs would have to be built, with two sets of fixed costs. It is possible that a simple doubling of the fixed cost estimate from the Parametric Cost Model might overstate total cost in this scenario, as the cost of each GDF in this scenario might be somewhat lower than the cost of a single GDF for all wastes. NDA has estimated the cost of two separate GDFs for ILW/LLW and HLW/spent fuel using the Parametric Cost Model and found that the reduction in the fixed cost is very small (in the order of 1-2%). There may however also be some reduction in costs in building a second GDF as a result of learning from experience.

18. Therefore it has been assumed for this exercise that the cost impact of not being able to implement co-location would be that two GDFs would be built, each of them having fixed costs of 95% of a co-located GDF. The costs of both GDFs must be shared between new build and legacy material. As each GDF now only contains a single category of waste we can apportion fixed costs between legacy and new build simply on the basis of quantity.

19. The worked examples in Chapter 4 include assumptions on both the legacy inventory and the assumed inventory of spent fuel from a new nuclear power station. The derivation of these assumptions is set out in Annex D. On the basis of those assumptions:

    - A new build operator's share of the fixed costs of a dedicated HLW/spent fuel GDF would be 4% (based on a generic spent fuel inventory of 500 disposal canisters, an assumed new build fleet of four reactors and an estimated legacy inventory of 10,659 canisters).
    - A new build operator's share of the fixed costs of a dedicated LLW/ILW GDF would be 0.5% (based on a generic ILW inventory of 2,000m^3, an assumed new build fleet of four reactors and an estimated legacy inventory of 390,000m^3).

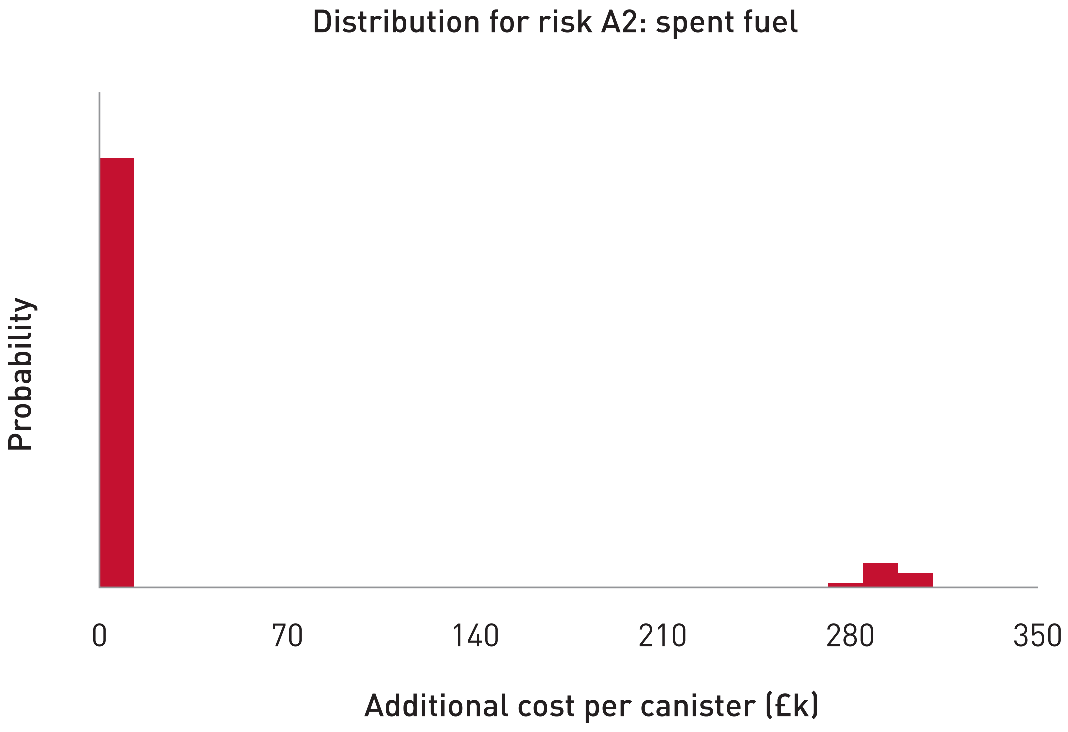
[47] MRWS White Paper page 29

[48] CORWM report on geological disposal see paragraphs 12.30-12.39

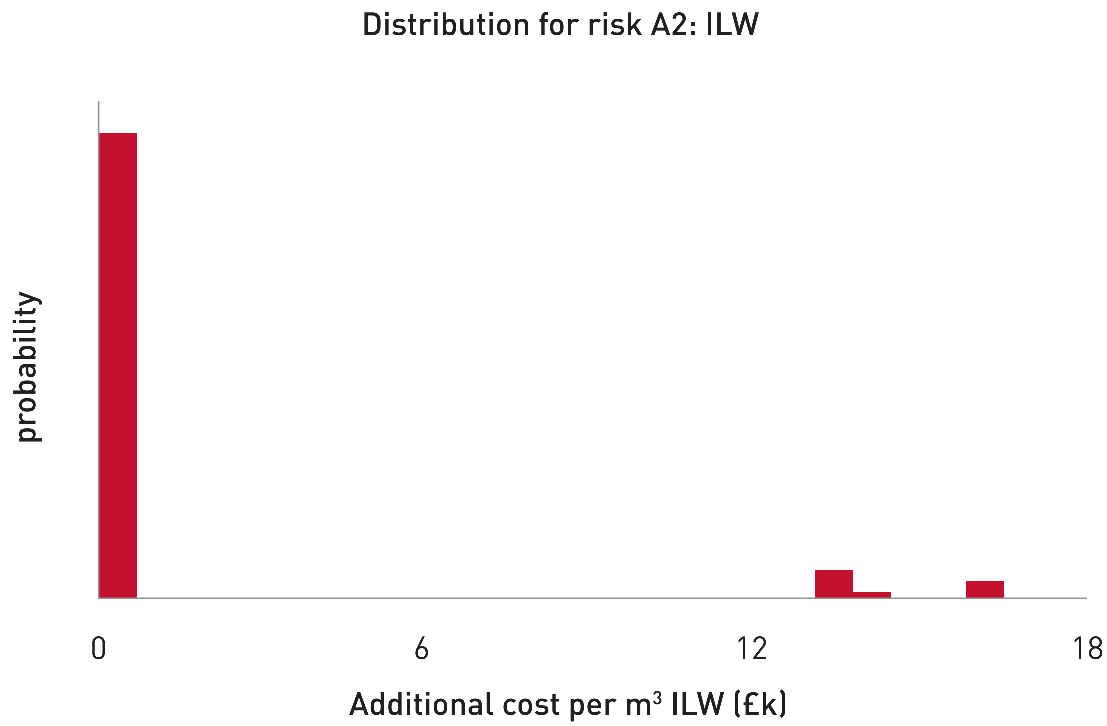
20. This contribution to the fixed costs can then be apportioned on a per unit basis and the additional cost that would result can be calculated. The consequence of this risk, per unit of spent fuel or ILW, is therefore the fixed cost contribution per unit based on a two dedicated GDFs, less the cost per unit based on a co-located GDF. It should be noted that this is not a single number, as the estimate of costs per unit is in both cases a distribution (because it has been derived through combining by Monte Carlo methods the cost estimates for each disposal scenario).

21. In the absence of any information that permits an accurate estimate of the probability of this scenario, in this exercise a probability of 10% has been assigned to this risk. However this risk is different in kind from A1. This is a discrete event that is assumed to occur 10% of the time. Therefore the distributions associated with the risk for spent fuel and ILW each have simply two discrete values: the additional cost as calculated above, or zero. These distributions do not, in any meaningful sense, have a mean, as can be seen from the charts shown below[49]. This gives the following distributions:

- cost per canister of spent fuel with a minimum of £0 and a maximum of £311.4k.
- cost per m^3 of ILW with a minimum of £0 and a maximum of £16.5k.



[49] It can be seen from the charts that there are three distinct values at the right hand side. This is because there is uncertainty over the fixed costs of a GDF and this depends in particular on the geological environment in which it is constructed. A GDF built in low strength rock would have higher fixed costs than a GDF built in strong rock or evaporites, and thus the cost impact of this risk varies according to the geology assumed.



A3: Risk that the GDF is not closed immediately after last waste emplacement

Description of the risk

22. This subject was also discussed in the MRWS White Paper, which said that "closure at the earliest opportunity once facility waste operations cease provides greater safety, greater security from terrorist attack, and minimises the burdens of cost, effort and worker radiation dose transferred to future generations". However it also said that "Government's view is that the decision about whether or not to keep a geological disposal facility (or vaults within it) open once facility waste operations cease can be made at a later date"[50].

23. There are two reasons in particular why immediate closure might not be adopted:

(i) to allow for the possible retrieval of waste materials (perhaps due to concern over the performance of a GDF);

(ii) a care and maintenance period, perhaps whilst the performance of the facility is subject to extended monitoring.

Consequence

(i) Possible retrieval of waste

24. In the case of waste from new nuclear power stations, no disposal is envisaged until a GDF has been open for a substantial period of time (on the basis of NDA's current planning assumptions set out in Section 3.2, this could be 90 years). This should be a sufficient time period for any substantial problems to be identified. Only in the absence of such problems would emplacement of new build wastes take place. If such problems were encountered there might be a delay in the final disposal of new build wastes, hence requiring an extension to the period of interim storage, but this risk is covered by Risk B2 below.

[50] MRWS White Paper page 28

25. Therefore we do not consider that there should be an element of the Contingency Allowance relating to possible retrieval costs.

(ii) Care and maintenance period

26. The current assumption is that a GDF will be backfilled as soon as possible, but it is not inconceivable that circumstances may require backfilling to be deferred. Maintaining an open facility will incur care and maintenance costs.

27. It is assumed that a care and maintenance period would only be adopted in order to able to confirm that the GDF is performing as expected. As indicated in the above discussion around possible retrieval of waste, it is assumed that the longer a GDF operates without problems being identified, the less likely it is that problems will subsequently arise necessitating either long term monitoring or retrieval.

28. One of the factors that will determine the operational life of a GDF is the volume of new build wastes to be disposed of within it. Therefore the materiality of this risk varies with the size of the new build fleet. The larger the new build fleet, the longer the operational life of a GDF and therefore the less likely it is considered to be that a care and maintenance period would be required between last waste emplacement and final closure.

29. The worked example in Section 4.2 assumes a fleet of four new nuclear reactors, as this is considered a conservative assumption for the purposes of calculating a Fixed Unit Price. In this case it is considered necessary to take account of the risk that a care and maintenance period might be needed.

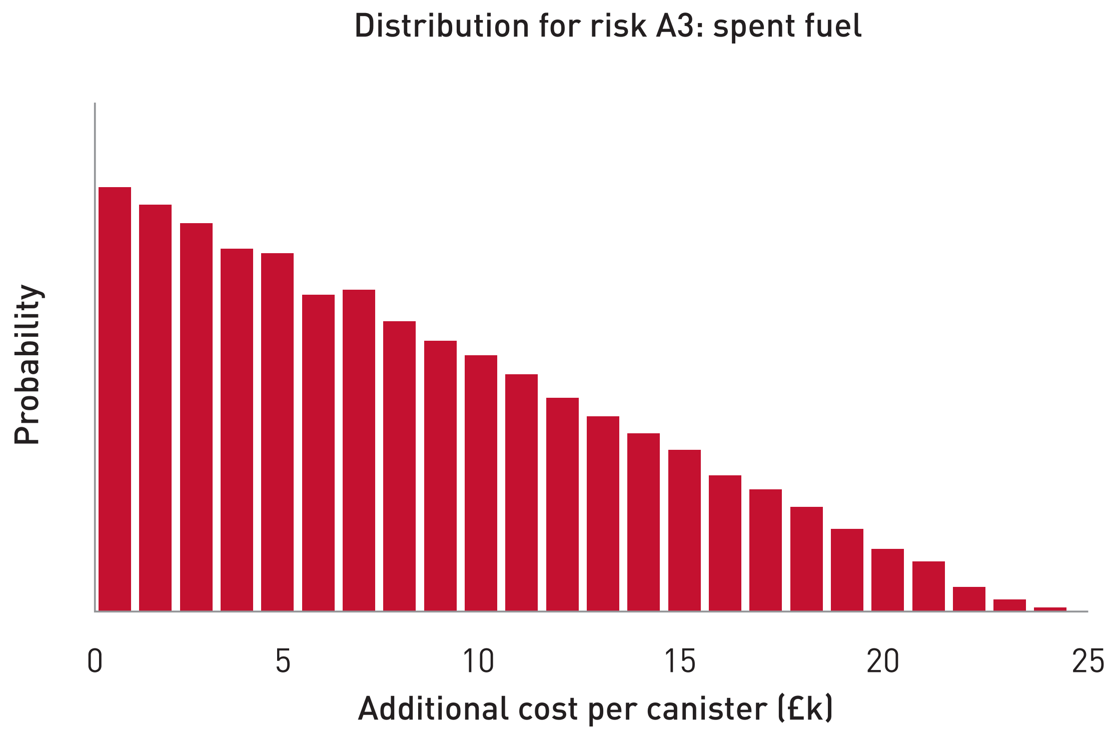
30. Using the Parametric Cost Model, NDA has estimated the cost impact of a 50 year care and maintenance period. It estimated that the costs would be of the order of £10m per year. Beyond this point costs are likely to escalate because of the need for major refurbishments. In deriving an allowance for this it is assumed that care and maintenance beyond 50 years is unnecessary. This period should have been sufficient to demonstrate satisfactory performance.

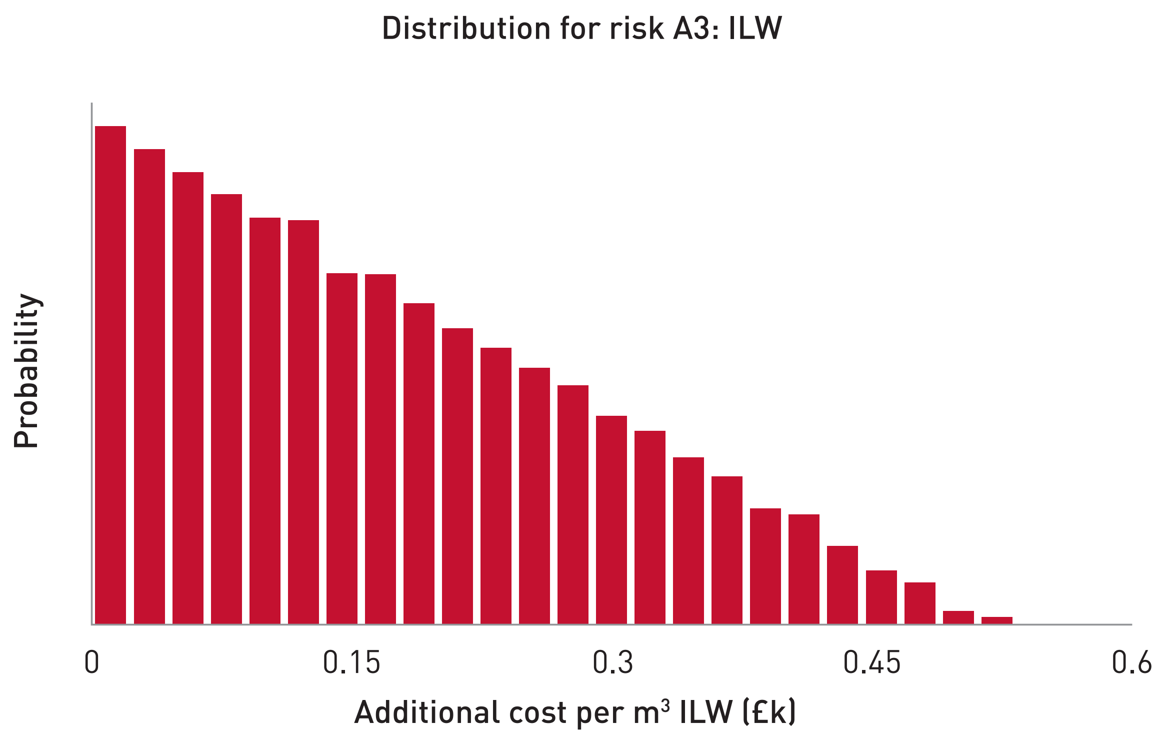
31. If costs are apportioned in the same way as the fixed costs of a GDF are apportioned in this methodology (i.e. in proportion to share of total variable costs) the estimated annual cost of £10m over 50 years translates to a total additional cost of £24.0k per canister of new build spent fuel and £0.5k per m^3 of ILW.

32. In order to derive a distribution of estimated costs for this exercise it is assumed that the minimum and the mode coincide at zero years – this is chosen to reflect the fact that monitoring the facility through its operational life might provide sufficient confidence that its performance is satisfactory to permit backfilling. The maximum duration is taken to be 50 years in accordance with the argument above.

33. This gives the following distributions for this risk:

- cost per canister of spent fuel with a minimum of £0k, mean of £7.8k and a maximum of £24.0k;
- cost per m^3 of ILW with a minimum of £0k, mean of £0.2k and a maximum of £0.5k.


Distribution for risk A3: spent fuel
Probability
0
5
10
15
20
25
Additional cost per canister (£k)


Distribution for risk A3: ILW
Probability
0
0.15
0.3
0.45
0.6
Additional cost per m3 ILW (£k)

B. Risks related to the possibility that the assumptions made in applying the Parametric Cost Model to the estimation of new build disposal costs do not correspond to the final outcome

34. A number of assumptions have been made in order to use the Parametric Cost Model to estimate the costs of disposing of new build ILW and spent fuel in a GDF. This group of risks considers the consequences if some or all of these assumptions do not correspond to the actual outcome when new build waste is emplaced in a GDF.

35. It should be noted that, in contrast to the risks in Group A, these risks apply solely to the estimation of waste disposal costs for new build. Hence the contingencies identified here are to be borne by new build alone and not shared with legacy.

B1: Risk that emplacing new build wastes in the same GDF as legacy leads to additional fixed costs

Description of the risk

36. The methodology to determine a Fixed Unit Price, set out in Section 3.3, assumes that the emplacement of new build wastes in a GDF, which has been designed and built for the disposal of legacy wastes, does not entail any additional fixed costs. However there are a number of scenarios in which the addition of new build wastes to the existing inventory of waste materials for disposal might lead to additional fixed costs:

   (i) There is a risk that, as a result of the lifetime of a GDF being extended significantly to accommodate new build wastes, some of the shared facilities might need replacement or refurbishment, over and above the routine maintenance factored into the Parametric Cost Model's cost estimates.

   (ii) It is possible that the design of a GDF might be amended to reflect the larger inventory implied by the inclusion of new build wastes. These changes might be to increase either GDF throughput or GDF lifetime, and might imply greater fixed costs.

   (iii) There is a risk that, as a result of the new build fleet being large, the total waste inventory might lead to a second GDF being required.

Consequence

37. The materiality of these risks depends on the size of the new build fleet. If there is only a small number of new nuclear power stations then these risks are considered negligible, however they become significant in the event the new build fleet is large.

38. However as the new build fleet grows larger so does the contribution made by new build operators to GDF fixed costs through the Fixed Unit Price. For example, the calculations in the worked example in Section 4.2 show that a considerable proportion of the Fixed Unit Price is calculated with reference to the contribution to GDF fixed costs and each new reactor would be contributing a substantial amount towards GDF fixed costs. It seems a reasonable assumption that any additional costs that result from scenarios (i) or (ii) will be more than offset by the additional funds provided by new build operators to pay towards the fixed costs of a GDF.

39. This is not necessarily the case for scenario (iii) but, as set out in Section 3.3, the Fixed Unit Price will be set on the basis of the co-disposal of legacy and new build wastes (however the methodology retains the flexibility to revise this assumption at a later date if needed).

40. Therefore it is not proposed to include an element relating to risk B1 in the Contingency Allowance.

B2: Risk that an inaccurate date is set for the start of new build waste emplacement

Description of the risk

41. As set out in Section 3.2, in order for the operator to estimate and make prudent provision in their FDP for waste management costs the operator will need to know the expected time period over which they must make prudent provision for interim storage costs. Therefore the Government will provide the operator with an "Assumed Disposal Date." In the event that geological disposal facilities were not available at the Assumed Disposal Date, the Government would bear the cost of continued interim storage.

42. The NDA's current planning assumptions are that a GDF will be operational in 2040, legacy spent fuel/HLW disposal is estimated to begin in 2075 and be completed by around 2130 for the assumed inventory set out in Annex D. At this point it is expected that the disposal of new build spent fuel would begin (it is possible that the disposal of new build ILW could begin earlier). However these dates are based on assumptions (for example around the duration of site selection and construction, and on the rate of waste emplacement in a GDF once it is operational) and are subject to considerable uncertainty.

Consequence

43. If disposal facilities are not available on the Assumed Disposal Date, the Government will face additional interim storage costs and, in the event that disposal is delayed substantially, there might also be costs relating to the rebuilding of interim stores and repackaging of wastes.

44. However a delay to the disposal of new build wastes implies that the expenditure on the variable costs associated with disposing of those wastes would also be delayed. This would serve to reduce the "real value" of those costs to the Government at the Assumed Disposal Date, due the effect of discounting.

45. As an example, take the case where at the Assumed Disposal Date the Government expects the variable cost of disposing of a canister of spent fuel to be £1m. If disposal is delayed, then the "present value" of the liability the Government faces is reduced. At a discount rate of 2.2% (which is the required discount rate for NDA's liabilities), for each year of delay the present value of the Government's liability for disposing of the canister would be reduced by £22k.

46. This is likely to be substantially higher than the additional costs being incurred in this case; the current estimate of maintaining an interim store for a year is in the region of perhaps £4-6k per canister per year. In the event of an extended delay it seems a reasonable assumption that the cumulative impact of discounting on disposal costs would more than offset the additional costs around refurbishment of interim stores and possible repackaging.

47. Therefore, although there would be extra costs to the Government resulting from an extended period of interim storage prior to final disposal, it is expected that the monies provided by the Fixed Unit Price should be sufficient to meet these additional costs without the need to include an extra element in the Contingency Allowance specifically to address Risk B2.

B3: Risk that the GDF cannot operate optimally during emplacement of new build spent fuel

Description of the risk

48. The estimation of the variable costs of disposal for spent fuel from new nuclear power stations relies on two key assumptions around the operation of a GDF:

- that each disposal canister is filled to its maximum capacity of four fuel assemblies;
- that a GDF is able to emplace the disposal canisters at the same rate (200 per year) that has been assumed for the disposal of legacy wastes.

49. It is on this basis that it is assumed that the spent fuel inventory used in the worked examples in Chapter 4, which is 2000 fuel assemblies (based on a generic 1.35 GW PWR operating for 40 years), is translated to 500 disposal canisters, and disposal of this inventory is assumed to take two and a half years.

50. However this assumes that all the new build spent fuel is ready for disposal at the allotted time. The assessments of the disposability of new build spent fuel carried out as part of the Generic Design Assessment have found that if all new build spent fuel were to be subject to the maximum burn-up considered, which is 65GWd/tU, then the spent fuel might need around 100 years of cooling in interim storage before it could be disposed of in a GDF (assuming the KBS-3 copper canister, subject to the current assumed surface temperature constraint and filled with the maximum four spent fuel bundles)[51].

51. As set out above, the current best estimate of when spent fuel from a new nuclear power station can begin to be emplaced in a GDF is 2130. For a reactor that starts operating in 2020 and operates for 40 years this means its spent fuel will be due for disposal 70 years after end of generation. In this case the reactor's total spent fuel inventory would have been subject to an average of 90 years cooling, and the fuel discharged at end of generation would have been cooled for 70 years at the point of disposal, whereas that produced at the start of generation would already have been cooled for 110 years.

Consequence

52. This risk is related to the heat output of the disposal canister at the point of disposal, so applies only to spent fuel and not to ILW.

53. The finding in NDA's disposability assessments is based on some very conservative assumptions. In particular it assumes that all bundles are subject to the maximum burn up, whereas in practice there will be some variation in burn up across the inventory of spent fuel from a new nuclear power station, and the average burn up will be lower than the maximum possible. This would reduce the cooling time required – and as an example NDA also calculated that for spent fuel with an average burn up of 50GWd/tU, a cooling period of around 75 years would be required. There is also mitigating action that could be taken to reduce the heat load of a given spent fuel canister, such as mixing hotter and cooler fuel bundles in each canister.

[51] The Summary Disposability Assessment for the AP-1000 page 5.
http://www.nda.gov.uk/documents/upload/TN-17548-Generic-Design-Assessment-Summary-of-DA-for-Wastes-and-SF-arising-from-Operation-of-APPWR-October-2009.pdf.
Summary Disposability Assessment for the EPR page 6.
http://www.nda.gov.uk/documents/upload/TN-17548-Generic-Design-Assessment-Summary-of-Disposability-Assessment-for-Wastes-and-Spent-Fuel-arising-from-Operation-of-the-EPWR.pdf

54. However the Contingency Allowance should consider the risk that at the scheduled point of disposal some of a new build operator's spent fuel is too "hot" for disposal in accordance with the assumptions made in the methodology to determine a Fixed Unit Price. In this case the GDF operator would have the choice either of delaying disposal to allow further cooling in interim storage, or putting fewer bundles in each canister to allow disposal to continue as scheduled.

55. This worked example assumes that the GDF operator would prefer to continue with disposal at the maximum throughput rate, rather than to reduce throughput or put the GDF into care and maintenance while the spent fuel was subject to further cooling. This would entail filling some canisters with fewer than the maximum four bundles, and therefore more canisters would be required. It has been calculated that on the basis of NDA's findings that around 20% more canisters might be needed in this case[52], which translates to an uplift of 20% in the total unit cost calculated in the methodology to determine a Fixed Unit Price.

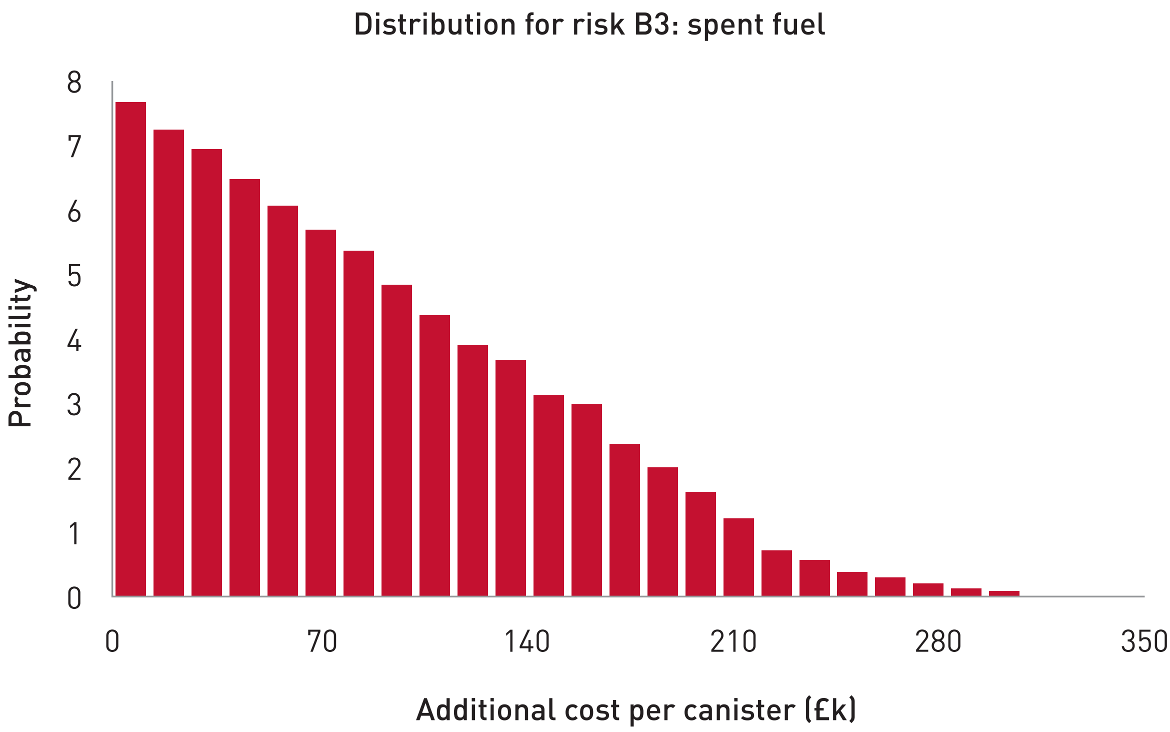
56. Therefore for this risk, the worst case is a 20% uplift in unit cost. For this exercise it is assumed that the minimum cost and the mode coincide at zero – this is chosen to reflect the fact that the NDA finding that 100 years cooling might be required is based on some very conservative assumptions.

57. As with other risks in this exercise the cost estimate to which this uncertainty is applied is derived from Step 12 in the worked example in Section 4.2, which has a distribution for the costs per canister of spent fuel with a minimum of £1115.2k, a P_{50} of £1181.8k and a maximum of £1554.6k.

58. This gives the following distribution for this risk:

- cost per canister of spent fuel with a minimum of £0k, mean of £85.8k and a maximum of £305.6k.

[52] This calculation is based on the assumption that not all fuel bundles will have reached 65 GWd/tU burn up. In particular, some fuel from the first and last discharges will have been subject to burn-up substantially lower than the others. It is assumed that therefore one of these bundles could be disposed of in a canister containing three bundles of higher burn up fuel. Therefore some canisters would still be disposable while holding four bundles.



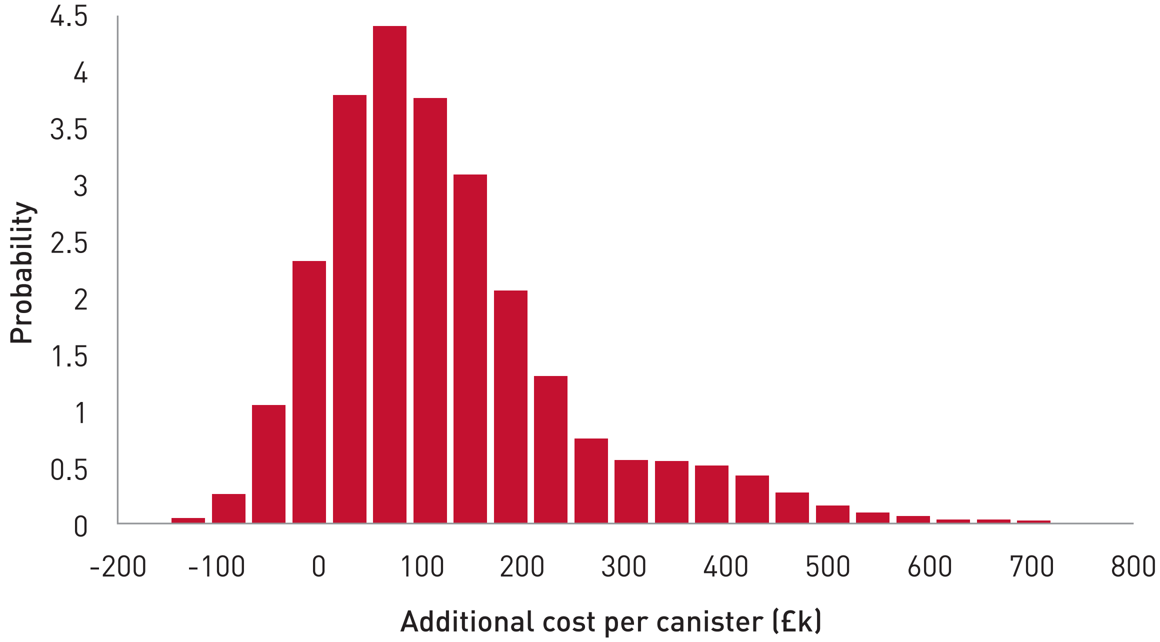
Overall contingency distributions

59. These are derived by combining the various distributions derived above by Monte Carlo methods to give a single distribution. For this worked example this gives the following distributions for the Contingency Allowance:

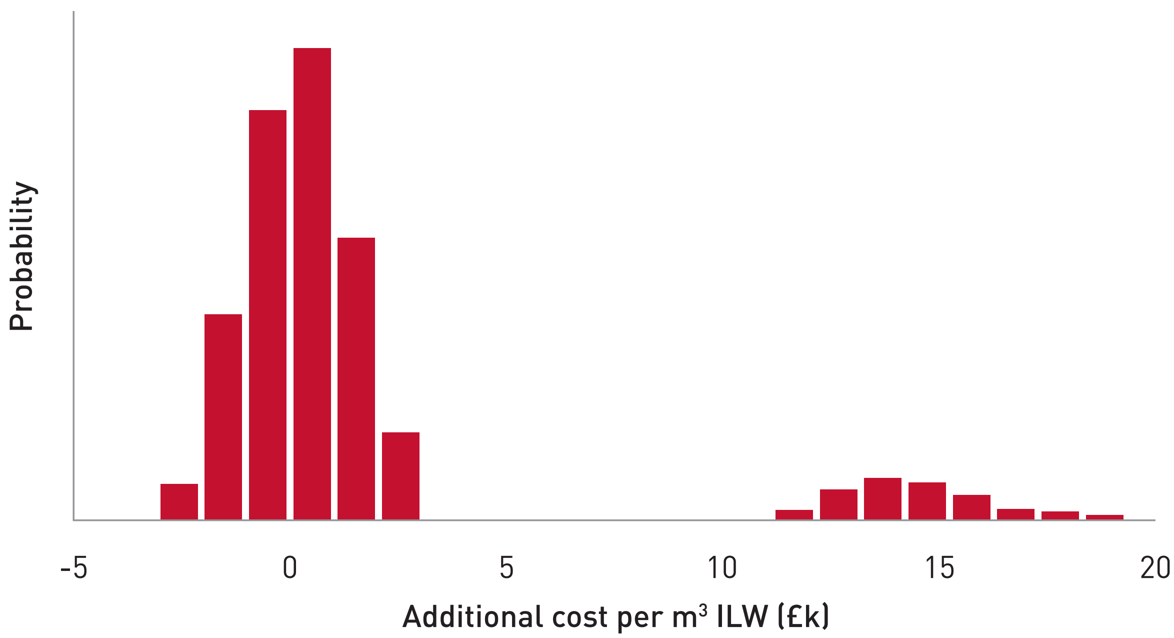
- cost per canister of spent fuel with a minimum of £-133.3k, P_{50} of £99.3k and maximum of £704.9k;
- cost per m^3 of ILW with a minimum of £-3.0k, P_{50} of £0.3k and a maximum of £19.5k.[53]

[53] It can be seen that the distribution for ILW is "bi-modal", i.e. it has two distinct peaks. This is because of the effect of risk A2, which is bi-modal and is the largest element in the overall ILW contingency distribution. The distribution for spent fuel is not bi-modal. This is because although risk A2 is also important for spent fuel, risk B3, which does not apply to ILW, is comparable in scale and has a "smoothing" effect on the overall spent fuel distribution.

Distribution for Contingency Allowance: spent fuel



Distribution for Contingency Allowance: ILW



Annex D: Derivation of the waste inventories used for the calculations in this consultation

Legacy inventories

1. The inventory assumed in the worked examples in this consultation is the scenario that underpins the estimate in NDA's 2007/08 Annual Report and Accounts. This inventory was based on that given in the 2007 Consultation "Managing Radioactive Waste Safely"[54] and is set out in Table 13 below.

Table 13: summary of legacy inventory assumed in the worked examples in Chapter 4

Waste/material	Inventory Packaged Volume (m^3)	Inventory (tonnes)	Number of disposal units/canisters
LLW	37,200		
ILW	353,000		
Sub-total (LLW/ILW)	**390,200**		
HLW	1,290		3,291
PWR Spent Fuel		1,200	572
AGR Spent Fuel		7,000[55]	6,796
Sub-total (HLW/spent fuel)			**10,659**

2. This inventory is subject to change over time. For example the inventory set out in the 2008 MRWS White Paper was slightly different to that given above. In the future, there are other materials – Plutonium, Highly Enriched Uranium and Depleted Uranium – which might require disposal in a GDF. If these materials were included in the inventory for disposal that would significantly increase volumes and the total cost of disposing of legacy wastes.

New build inventories

3. These are derived from the inventories set out in the Disposability Assessment reports on the EPR and AP-1000 designs produced by NDA as part of the Generic Design Assessment (GDA) process. On the basis of these inventories an assumed inventory for a generic PWR operating for 40 years has been derived. This section summarises how these generic inventories of waste have been calculated.

[54] Managing Radioactive Waste Safely: a framework for implementing geological disposal" June 2007 page 12. http://mrws.decc.gov.uk/en/mrws/cms/Home/What_is_the_Go/What_is_the_Go.aspx.

[55] The inventory given in the 2007 MRWS Consultation was based on 3,500 canisters of AGR spent fuel, but this value was considered to be a more appropriate figure when this exercise was undertaken by NDA.

EPR

4. The EPR has a rated thermal power of 4500MW and an electrical power output of approximately 1600-1660MW(e) depending on site-specific factors. For this exercise the electrical power output of an EPR is assumed to be 1630MW(e).

5. Spent fuel arisings: the GDA Disposability Assessment for the EPR assumes that over a 60 year operating life an EPR would generate 3600 spent fuel assemblies, i.e. 900 disposal canisters. This equates to an average of 60 assemblies a year, or 36.8 assemblies per GW per year.

6. ILW arisings: the GDA Disposability Assessment for the EPR assumes that over a 60 year operating life an EPR would generate:
   - 1647-3201m^3 packaged operational ILW[56], which equates to 37.5-53.4m^3 per year.
   - 449.3m^3 decommissioning ILW.

AP-1000

7. The AP-1000 has a rated thermal power of 3400MW and an electrical power output of 1117-1154MW(e) depending on site-specific factors. For this exercise the electrical power output of an AP-1000 is assumed to be 1135MW(e).

8. Spent fuel arisings: the GDA Disposability Assessment for the AP-1000 assumes that over a 60 year operating life an AP-1000 would generate 2560 spent fuel assemblies, i.e. 640 disposal canisters. This equates on average 42.7 assemblies a year, or 37.6 assemblies per GW per year.

9. ILW arisings: the GDA Disposability Assessment for the AP-1000 assumes that over a 60 year operating life an AP-1000 would generate:
   - 3237.8m^3 packaged operational ILW, which equates to 54m^3 per year.
   - 212.1m^3 decommissioning ILW.

Generic PWR

10. We have assumed a generic PWR with an electrical power output of 1.35GW(e) operating for 40 years.

11. Spent fuel arisings: we have assumed that this generic PWR produces 37 assemblies per GW per year, which equates to 50 assemblies per year, i.e. 2000 assemblies, or 500 canisters, over a 40 year operating life.

12. ILW arisings: we have assumed that this generic PWR produces 40m^3 of operational ILW per year, which equates to 1600m^3 over a 40 year operating life. We have further assumed that the generic PWR produces 400m^3 of decommissioning ILW. This gives a total of 2000m^3 of packaged ILW for disposal.

[56] The Disposability Assessment included a reference case, which calculated an operational ILW volume of 3201m^3 and two variant cases. Variant 1 calculated an operational ILW volume of 1647m^3, Variant 2 calculated an operational ILW volume of 2285m^3.

Annex E: Estimated costs of reactor decommissioning from third party academic or research studies

Studies considered as part of analysis undertaken for the 2006 Energy Review

Source	Reactor type	Cost estimate	Comment	2006 money value cost estimate
Nuclear Energy Agency/Organisation for Economic Co-operation and Development 2003[1]	PWRs – range of countries	Average $320m/GW, with range of $200m – $400m for larger reactors	Expressed in July 2001 money values, reflecting 19 reference PWR reactors	£220m/GW average, with range of £135m – £270m
Dominion Energy for US Department of Energy 2004[2]	4 designs, including AP1000	$416m for 1,150MW unit	Quoted as 2003 money values, does not include full demolition, but achieves de-licensing in US	£250m/GW (though likely to be higher for total demolition)
Bayliss and Langley[3]	Average PWR – USA	$368m	1998 money values to licence termination. NEI study of 60 PWRs from 500MW to 1,095MW, with and without full disposal and site remediation	£265m (assuming average size of 750MW)
	Average BWR – USA	$420m	1998 money values to licence termination NEI study of 30 BWRs from 540MW to 1,140MW, with and without full disposal and site remediation	£300m (assuming average size of 800MW)

Source	Reactor type	Cost estimate	Comment	2006 money value cost estimate
Bayliss and Langley[3] (cont...)	Various reactors	€275m – €600m	1997 – 2000 UNIPEDE study, covering 12 countries (10 in Europe), assumed 1998 money values	£230m – £500m (no reference MW)
Morgan Stanley research[4]	European fleet	€260m – €800m per GW installed	Based on disclosed provisions of E.On, RWE, Electrabel, Fortum and CEZ, generally 2004 money values	£190m/GW – £590m/GW
	PWR	€110m – €1.1bn per GW installed	Based on data from 21 sites. Average of €396m, in 2001 money values	£311m/GW (average)

Notes to above table

1. "Decommissioning Nuclear Power Plants: Policies, Strategies and Costs". Available at: http://www.oecdbookshop.org

2. Report for US Department of Energy by Dominion Energy Inc., Bechtel Power Corporation, TLG Inc. and MPR Associates. "Study of Construction Technologies and Schedules, O&M Staffing and Cost, Decommissioning Costs and Funding Requirements for Advanced Reactor Designs." http://www.ne.doe.gov/np2010/reports/1DominionStudy52704.pdf

3. Bayliss and Langley data extracted from their book "Nuclear Decommissioning, Waste Management and Environmental Site Remediation". Oxford: Elsevier, 2003. Available at: http://www.elsevier.com/wps/find/bookdescription.cws_home/680930/description#description

4. Morgan Stanley "Nuclear Prospects". September 2005

Further studies considered in 2009 as part of the work to develop updated cost estimates

Source	Reactor type	Cost estimate	Comment	2009 money value cost estimate
International Atomic Energy Association 2005[1]	PWR	€150m/GW – €750m/GW	Expressed in 2005 money values	£140m/GW - £560m/GW
Nuclear Energy Agency 2008[2]	PWR	$320m/GW	Average estimate per reactor expressed in 2001 money values	£270m/GW
	BWR	$420m/GW		£350m/GW
County Report Sweden 2007[3]	PWR	€100m/GW	Expressed in 2004 money values	£97m/GW
	BWR	€130m/GW		£126m/GW

Notes to above table

1 "Financial Aspects of Decommissioning: Report by an Expert Group". http://www-pub.iaea.org/MTCD/publications/PDF/te_1476_web.pdf

2 "Nuclear Energy Agency: Nuclear Energy Outlook 2008". NEA No 6348. Available at: http://www.oecdbookshop.org

3 Country Report Sweden on behalf of the European Commission Directorate-General Energy and Transport "Comparison among different decommissioning funds methodologies for nuclear installations" http://www.wupperinst.org/uploads/tx_wiprojekt/EUDecommFunds_SE.pdf

Annex F: Response form for the consultation document

You may respond to this consultation by email or by post.

Respondent Details	
Name:	
Organisation:	
Address:	
Town/ City:	
County/ Postcode:	
Telephone:	
E-mail:	
Fax:	

Please return by 18th June 2010 to:
Fixed Unit Price methodology and updated cost estimates consultation Office for Nuclear Development Department of Energy and Climate Change Area 3D 3 Whitehall Place London SW1A 2AW You can also submit this form by email: decomguidance@decc.gsi.gov.uk

Tick this box if you are requesting non-disclosure of your response. ☐

No.	Question
Chapter 3: The methodology to determine a Fixed Unit Price	
1	Do you agree or disagree that prospective operators of new nuclear power stations should be given the option to defer the setting of their Fixed Unit Price? If so, do you agree that this deferral should be limited to 10 years after the nuclear power station has commenced operation? Do you have any comments on the way the Government proposes to determine an expected Fixed Unit Price as the basis for an operator's interim provision in the event that they choose to defer the setting of their Fixed Unit Price?
Response	
2	Do you agree or disagree with the proposal that the Schedule for the Government to take title to and liability for an operator's waste should be set in relation to the predicted end of the decommissioning of the nuclear power station? Do you have any comments on the way the Government proposes to recoup the additional costs it will incur in this case?
Response	
3	Do you agree or disagree that the proposed methodology to determine a Fixed Unit Price strikes the right balance in protecting the taxpayer, by taking a prudent and conservative approach to cost estimation, while facilitating new nuclear build by providing certainty to operators? What are your reasons?
Response	
4	Do you agree or disagree with the proposed approach to determining an operator's contribution to the fixed costs of constructing a Geological Disposal Facility? What are your reasons?
Response	

No.	Question
5	Do you agree or disagree with the proposal that the units to be used for the Fixed Unit Price are pence per kWh for spent fuel and cubic metres of packaged volume for intermediate level waste? What are your reasons?
Response	
Chapter 5: Updated estimates of the costs for decommissioning, waste management and waste disposal	
6	Do the updated cost estimates represent a credible range of estimates of the likely costs for decommissioning, waste management and waste disposal for a new nuclear power station?
Response	

Please select the category below which best describes who you are responding on behalf of.

	Business representative organisation/trade body
	Central Government
	Charity or social enterprise
	Individual
	Large business (over 250 staff)
	Legal representative
	Local Government
	Medium business (50 to 250 staff)
	Micro business (up to 9 staff)
	Small business (10 to 49 staff)
	Trade union or staff association
	Other (please describe):

Thank you for taking the time to let us have your views. The Government does not intend to acknowledge receipt of individual responses unless you tick the box. ☐

Annex G: The Consultation Code of Practice Criteria

The seven consultation criteria

Criterion 1 **When to consult**

Formal consultation should take place at a stage when there is scope to influence the policy outcome.

Criterion 2 **Duration of consultation**

Consultation should normally last for at least 12 weeks with consideration given to longer timescales when feasible and sensible.

Criterion 3 **Clarity of scope and impact**

Consultation documents should be clear about the consultation process, what is being proposed, the scope to influence and the expected costs and benefits of the proposals.

Criterion 4 **Accessibility of consultation exercises**

Consultation exercises should be designed to be accessible to, and clearly targeted at, those people the exercise is intended to reach.

Criterion 5 **The burden of consultation**

Keeping the burden of consultation to a minimum is essential if consultations are to be effective and if consultees' buy-in to the process is to be obtained.

Criterion 6 **Responsiveness of consultation exercises**

Consultation responses should be analysed carefully and clear feedback should be provided to participants following the consultation.

Criterion 7 **Capacity to consult**

Officials running consultations should seek guidance on how to run an effective consultation exercise and share what they have learned from the experience.

The code of practice can be accessed at www.berr.gov.uk/files/file47158.pdf

Annex H: Glossary

Assumed Disposal Date – means the date that the operator is entitled to assume in their FDP for the disposal of their ILW and spent fuel in a GDF. The Government will provide the operator with an Assumed Disposal Date when it sets a Fixed Unit Price. In the event that geological disposal facilities were not available at the Assumed Disposal Date, the Government would bear the cost of continued interim storage.

Base Case – means the steps set out in the FDP Guidance consultation document for waste management, disposal and decommissioning that the Government considers should be included in and costed as part of the DWMP that operators will need to submit to the Secretary of State for approval.

Co-disposal – means disposal of new build wastes in the same GDF as legacy wastes.

Co-location – means disposal of HLW/spent fuel and ILW/LLW in a combined GDF in which there are separate parts of the facility for the various types of waste.

Committed waste – radioactive waste that will arise in future from the operation or decommissioning of existing nuclear facilities.

Committee on Radioactive Waste Management (CoRWM) – CoRWM provide independent scrutiny and advice to UK Government and devolved administration Ministers on the long-term radioactive waste management programme, including storage and disposal.

Conditioning – means any process used to prepare waste for long-term storage and/or disposal.

Contingency Allowance – the element of the methodology to determine a Fixed Unit Price that takes account of "Out-of-Model" risks.

Decommissioning –

(a) Decommissioning begins when the reactor is shut down with no intention of further use for the purpose of generating electricity.

(b) Decommissioning means dismantling the station and remediating the site including waste management but not including waste disposal to a condition agreed with the regulators and the planning authority.

(c) Decommissioning ends when all station buildings and facilities have been removed and the site has been returned to an end state which has been agreed with the regulators and the planning authority.

Decommissioning and Waste Management Plan (DWMP) – means the part of the FDP which sets out and costs the steps involved in decommissioning a new nuclear power station and managing and disposing of hazardous waste and spent fuel in a way which the Secretary of State may approve.

Decommissioning liabilities – means the liabilities which arise in relation to decommissioning which include the waste management liabilities but exclude the waste disposal liabilities.

Deferral Period – means the specified period for which the setting of an operator's Fixed Unit Price would be deferred. The consultation proposes that this deferral should be limited to 10 years after the nuclear power station has commenced operation.

Early Transfer – means title and liability for an operator's waste transferring to the Government earlier than in relation to estimates of the availability of a GDF. The consultation proposes that the Schedule for the Government to take title to and liability for an operator's waste should be set in relation to the predicted end of the decommissioning of the nuclear power station.

Encapsulation – means a process in which radioactive waste is physically enclosed in a material with the aim of preventing radionuclides from escaping. In this consultation document it specifically refers to the packaging of spent fuel for disposal in a GDF.

Expected Fixed Unit Price (eFUP) – the basis for an operator's interim provision in the event that they choose to defer the setting of their Fixed Unit Price. This will be the Government's best estimate of the level of the Fixed Unit Price at the time it is eventually set, i.e. at the end of the Deferral Period.

Financing charge – an uplift applied to the element of the Fixed Unit Price that relates to the contribution to the fixed costs of a GDF. It reflects the time difference between those costs being incurred and the payment being made. It is proposed that the financing charge be calculated on the basis of the approach that might be taken in the theoretical case that the Government were constructing a GDF to a timescale driven by the needs of new build operators.

Fixed Unit Price – the Government's policy is to set a fixed price for operators of new nuclear power stations for disposal of their intermediate level waste and spent fuel, and a schedule for the Government to take title to and liability for these materials.

Fund – means a trust or other vehicle constituted for the purpose of accumulating, managing and investing monies obtained from the operator for the purpose of the Objective and includes, as the context permits or requires, any person which is a member of, or is responsible for the management of that entity.

Funded Decommissioning Programme (FDP) – means the programme that any operator of a new nuclear power station will need to have approved by the Secretary of State before construction begins and to comply with thereafter.

Funding Arrangements Plan (FAP) – means the part of the FDP which sets out the operator's detailed plans for one or more Funds to deliver sufficient monies to meet its decommissioning, waste management and waste disposal liabilities identified in the operator's DWMP.

Generating lifetime – means the period beginning with the date on which the power station first generates electricity and ending with the date on which the reactor is shut down with no intention of further use for the purpose of generating electricity.

Generic Design Assessment – the generic assessment being undertaken by the Health and Safety Executive and the Environment Agency of the suitability of new reactor designs for use in the UK.

Geological Disposal Facility (GDF) – a long-term management option involving the emplacement of radioactive waste in an engineered underground facility or repository, where the geology (rock structure) provides a barrier against the escape of radioactivity and there is no intention to retrieve the waste once the facility is closed.

Hazardous waste – has the meaning given by section 37 of the Energy Act 2004.

Higher activity waste – includes the following categories of radioactive waste: high level waste (HLW), intermediate level waste (ILW) and a small fraction of low level waste (LLW) with a concentration of specific radionuclides. In relation to new nuclear power stations, higher activity waste is expected to be ILW and spent fuel.

High Level Waste (HLW) – radioactive wastes in which the temperature may rise significantly as a result of their radioactivity, so this factor has to be taken into account in the design of storage or disposal facilities.

Independent Fund – means a Fund which complies with the principle of independence set out in the FDP Guidance consultation document[57].

In-Model Risks – risks relating to the possibility that the NDA's Parametric Cost Model does not correctly calculate the costs of a specific disposal scenario.

Interim storage – means storage of radioactive waste prior to implementing a final management step, such as geological disposal.

Intermediate level waste (ILW) – means radioactive wastes exceeding the upper activity boundaries for LLW but which do not need heat to be taken into account in the design of storage or disposal facilities.

Legacy waste – means radioactive waste which already exists or whose arising is committed in future by the operation of an existing nuclear power plant.

Low level waste (LLW) – radioactive waste having a radioactive content not exceeding four gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta/gamma activity.

Managing Radioactive Waste Safely (MRWS) – a phrase covering the whole process of public consultation, work by CoRWM, and subsequent actions by the Government, to identify and implement the option, or combination of options, for the long term management of the UK's higher activity radioactive waste.

Monte Carlo simulation – a mathematical technique, used in the methodology to determine a Fixed Unit Price, which can be used to allow for risk and uncertainty in quantitative analysis and decision making.

Nuclear Decommissioning Authority (NDA) – a non-departmental public body, established under the Energy Act 2004, responsible for the decommissioning and clean-up of the UK's civil public sector nuclear sites. The NDA's sponsoring Government department is the Department for Energy and Climate Change (DECC); for some aspects of its functions in Scotland it is responsible to Scottish Ministers. The NDA is the implementing organisation, responsible for planning and delivering a GDF.

[57] FDP Guidance consultation document paragraph 5.2.6

Nuclear Liabilities Financing Assurance Board (NLFAB) – the independent advisory body who will provide impartial scrutiny and advice to the Secretary of State on the suitability of FDPs submitted by operators of new nuclear power stations.

Operator – the legal person who holds a licence under the Nuclear Installations Act 1965 in relation to the site to which the programme relates, or who has applied for such a licence in relation to such a site.

Optimism Bias – defined in HM Treasury "Green Book" guidance[58] as the "demonstrated, systematic, tendency for project appraisers to be overly optimistic.

Out-of-Model Risks – risks arising from the assumptions that NDA has used when using the Parametric Cost Model to estimate waste disposal costs and the further assumptions that DECC has made in order to use Parametric Cost Model data to estimate the costs of disposing of new build wastes.

Packaging – means placing waste into a container for long-term storage and/or disposal.

Parametric Cost Model – a model developed by NDA to generate updated estimates of the costs of geological disposal. The Parametric Cost Model has been used by DECC to estimate the costs of disposing of new build ILW and spent fuel in a GDF.

Pressurised water reactor (PWR) – means a nuclear reactor in which water is used as the coolant and moderator.

Radioactive waste – has the meaning set out in Section 2 of the Radioactive Substances Act 1993.

Radioactive Waste Management Directorate (RWMD) – a directorate of NDA. It is envisaged that RWMD will evolve under the NDA into the 'NDA's delivery organisation' for the GDF.

Safety Case – means the complete set of arguments that demonstrates that a nuclear facility or operation is or, if particular actions are taken, will be safe.

Schedule – means the date for when title to and liability for an operator's waste should transfer to the Government. The consultation proposes that the Schedule be brought forward (Early Transfer) and the Transfer Date be aligned with the operator's decommissioning timetable.

Spent fuel – means fuel that has been used in a nuclear reactor and for which there is no further use as fuel.

Target fund value – means the value or sum which the Fund is required to achieve under the terms of the approved FDP.

Time value of money – the principle that the value of money is affected by when it is paid, based on the principle that a sum of money paid today is more valuable than the certainty of receiving the same amount of money at some time in the future.

[58] The Green Book is an HM Treasury publication that presents the techniques and issues that should be considered when carrying out assessments of new policies, programmes and projects.

Transfer Date – means the date upon which title to and liability for an operator's waste will transfer to the Government.

Transport costs – the cost of transporting waste from the new nuclear power station to another location, such as a GDF.

Uranium – means a heavy, naturally occurring and weakly radioactive element, commercially extracted from uranium ores. By nuclear fission (the nucleus splitting into two or more nuclei and releasing energy) it is used as a fuel in nuclear reactors to generate heat.

Virtual GDF – means the approach to the financing charge that might be taken in the theoretical case that the Government were constructing a GDF to a timescale driven by the needs of new build operators.

Voluntarism – means an approach in which communities "express an interest" in participating in the process that would ultimately provide the site for a GDF. Initially a community would be expressing an interest in finding out more about what hosting such a facility would involve. In the latter stages, there would be more detailed discussion of plans and potential impacts.

Waste disposal liabilities – means the liability to pay the sum charged to the operator by the Government in connection with an approved FDP in relation to the disposal by the Government of higher activity waste produced on the relevant site.

Waste management – means:

(a) treating, storing and transporting higher activity waste pending disposal pursuant to the schedule agreed with the Government;

(b) treating, storing, transporting and disposing of low level waste;

(c) treating, storing, transporting and disposing of non-radioactive hazardous waste; and

(d) planning undertaken during the generating life of the station or subsequently which is necessary in order to carry out decommissioning.

Waste management liabilities – means the cost of carrying out waste management insofar as the cost of those activities is required to be met from the Fund[59].

[59] Table 6 on page 71 of the FDP Guidance consultation document sets out more information about the activities which the Secretary of State would expect to be paid for by the Fund.

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