[redacted]

ISM

SUBMARINE DISMANTLING PROJECT (SDP)

Investment Appraisal

- interim public release version to support the Submarine Dismantling Consultation

Issue 1.0a – October 2011

This document has been released as background information to support the Submarine Dismantling Consultation (28 Oct 2011 – 17 Feb 2012). This Issue 1.0a presents the same analysis as the protected Issue 1.0 but cost information, that is commercially sensitive, has been removed and / or presented as ratios rather than absolute costs.

In addition, this document has been redacted to protect:

- **Personal information;**
- **Information that is commercially sensitive; and**
- **Schedule estimates that have yet to be formally approved by MOD.**

For further information about the Submarine Dismantling Project, please visit: www.mod.uk/submarinedismantling

[redacted]

Document Information

Project Name:	Submarine Dismantling Project		
Document Title:	Investment Appraisal – Interim public release version to support the Submarine Dismantling Consultation		
Issue Status:	Issue 1.0a	**Reference:**	SUBIPT/420/1727
Produced By:	ISM Ash 1b Defence Equipment & Support MOD Abbey Wood Bristol BS34 8JH	**Level of Control:**	This document is controlled to Level 1/2/3/4 iaw SDP PMP Document Quality Management Procedure. At each level the Document must be approved and Authorised.

Document Authorisation

Owner:	[redacted], DES SM IS-ProjChng-DepHd	**Peer Reviewer**	[redacted], DES Fin, , DASA/DESA , DES SM IS-Fin-AsstHd
Author:	[redacted], DES-SM-IS-SDP-FIN-CON	**Committee Endorsement:**	N/A
Editorial Checker:	[redacted], DES-SM-IS-SDP-Con1	**Technical Checker:**	[redacted], DES SM IS-PSO4
Document Approver:	[redacted], DASA/DESA	**Approver's Signature:**	Signature reqd before distribution
Document Authoriser:	[redacted], DES SM IS-ProjChng-DepHd	**Authoriser's Signature:**	Signature reqd before distribution

Conditions of Use

SDP PMP Document Quality Management Procedure. Proposed amendments and comments should be directed to the Document Owner at the address above.

Amendment History

Issue	Date	Details of Amendment	DCCF
0.1	01 July 11	Draft Issue for initial discussions within SDP team	
0.2	20 July 11	Second iteration of the IA following incorporation of comments from DASA/DESA, DES-FIN and the wider SDP MOD team.	
0.3	28 July 11	Third iteration following input from ISM Finance and MOD Main Building Scrutiny	
0.4	31 August 11	Fourth iteration following alignment with updated OASP	
0.5	19 September 11	Updated to align with style Guidance and OASP	
0.6	26 September 11	Updated to include IA plot aligned with OE plot format	
0.7	10 October 11	Included description of consideration of worker dose	
1.0	21 October 11	Updated following review by project team	
1.0a	21 October 11	Public release version presenting the same information as protected Issue 1.0 but with cost information, that is commercially sensitive, removed and / or presented as ratios rather than absolute costs.	

Distribution

SDP Project Board
SDP Virtual Team
SDP Scrutiny Meeting Members
NDA

Table of Contents

1. Executive Summary

1.1 Background

This Investment Appraisal (IA) seeks to quantify the Whole Life Cost of the strategic options for the Submarine Dismantling Project (SDP). It supports the project's wider analysis of these options, the Combined Operational Effectiveness and Investment Appraisal (COEIA), which will inform the public consultation.

The IA will be revisited following consultation and further developed to inform the project's Main Gate Business Case (MGBC) submission to the MOD approval authorities.

1.2 Scope

The IA covers the costs of all stages of SDP activities from current planning phases to final decommissioning including direct and indirect costs to quantify the overall cost to MOD of the various options. There are 25 strategic options[1] which have been costed.

Actual cost estimates cannot be published in the public domain at this stage as they are commercially sensitive and retain a significant degree of uncertainty. Financial ranking of the options will be provided, however, to demonstrate the relative cost of the options.

1.3 Results

#	Option Code	Option Description	Delta
1	Option 4B	*Dual site - RPV removal - interim storage at MOD site*	Most Economic
2	Option 4D	*Devonport site - RPV removal - interim storage at MOD site*	+3.07%
3	Option 3B	*Dual site - RPV removal - interim storage at remote commercial site*	+3.23%
4	Option 2B	*Dual site - RPV removal - interim storage at Point of waste generation site*	+3.53%
5	Option 8D	*Devonport - RPV removal and size reduction to form packaged waste - interim storage using NDA storage facilities*	+3.92%

Figure 1 - Top 5 Options ranked at NPV (50%) including risk

Figure 1 shows that Option 4B is the integrated option with the lowest cost option at 50%[2] primarily due to:

- Delay to spend on Reactor Pressure Vessel (RPV) size reduction; and
- Dual Site negates the need for submarine towing

[1] See Annex C for a full description of the 25 options considered for Public Consultation
[2] 50% = the 50% confidence percentile. It is anticipated that SDP is 50% confident that costs will not exceed this amount.

Options 4D, 3B and 2B also feature in the top 5 ranking options due to the delay of spend on RPV size reduction. The cost of these options varies depending on the storage solution adopted.

The anomaly is Option 8D, despite a different technical approach it benefits from the possibility of avoiding ILW store build costs and reduced operation and final decommissioning costs through the use of NDA storage facilities. A joint assessment of the costs and benefits has yet to conclude but MOD's early estimates suggest that the potential savings may be significant.

The five lowest cost options show a slight bias towards a dual site initial dismantling option (Options with suffix B) due to the avoidance of submarine movement costs despite the potential requirement for additional facilities.

As Figure 2 demonstrates there is a high degree of clustering between the Devonport and Dual Site options. The Rosyth options are more expensive due to the 20 additional submarine moves that would be required over and above those for the Devonport options, risk of high nuclear overheads and reduced potential for site rationalisation.

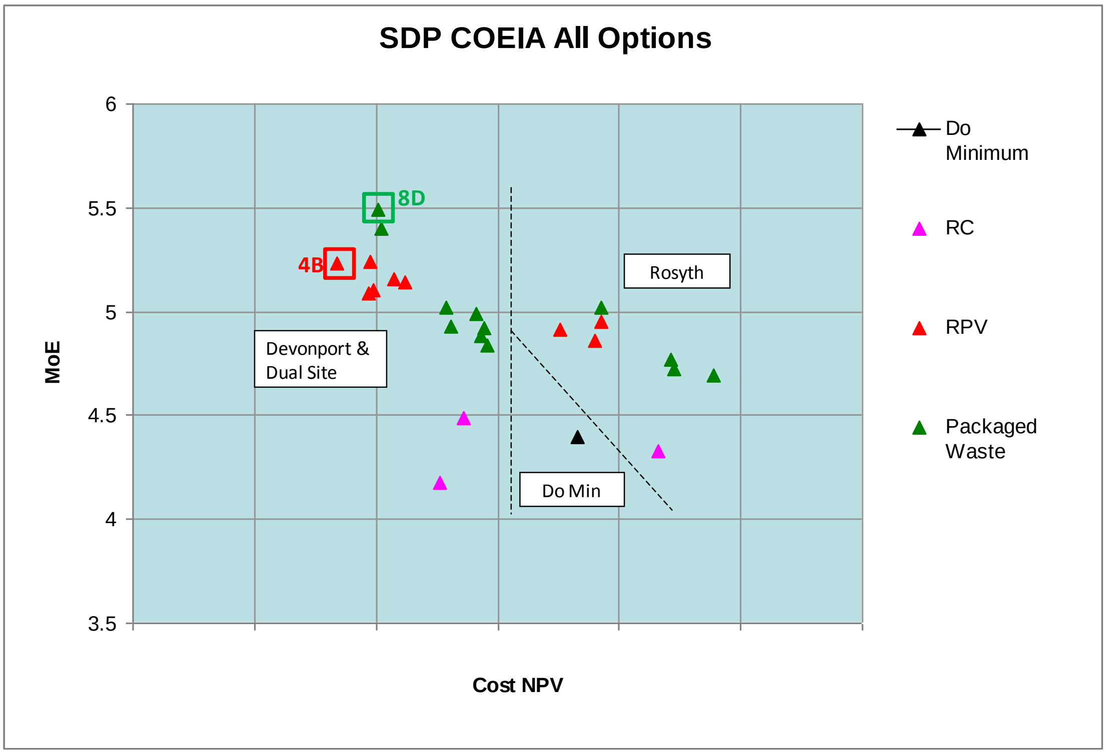


Figure 2 - NPV COEIA Plot – the clustering of 'Do Something' Options

1.4 Comparison of options against Key User Requirements

SDP has one Key User Requirement (KUR) relating to cost, as below:

Ref	User Requirement	4B	4D	3B	2B	8D
1.1.1	The user requires a solution which is as cost-effective as possible, minimising the costs of submarine dismantling and ILW storage without compromising safety, security, sustainability or regulatory compliance.	1st Most cost effective	2nd	3rd	4th	5th

Figure 4 - Top 5 Options assessed against relevant KUR

1.5 Conclusions

The financial analysis does not indicate a clear preferred option but highlights the need to undertake a 'Do Something' option, over the 'Do Minimum' option of continued afloat support.

The assessment of cost (KUR 1.1.1.) indicates that the RPV removal and storage Options 4D, 3B, 2B and 4B are the least costly when considering the 50% NPV of each option, illustrating that the delay of RPV size reduction is somewhat preferable to immediate dismantling. There is a degree of overlap of the options when considering the wider uncertainty bounds of the options and so as stated above it is not possible at this point to clearly indicate a strong preference for RPV removal storage over RPV removal, size reduction to form packaged waste.

The assessment of cost demonstrates that initial dismantling should be undertaken at Devonport or Dual Site, with Dual Site marginally more attractive as the costs of additional facilities for RPV removal are slightly less than the cost of preparing and transporting the submarines between dismantling sites. Initial dismantling at Rosyth is negatively differentiated financially as are the RC options.

The early assessment of cost indicates that Option 8D, ILW storage using NDA storage facilities is preferable to a MOD bespoke storage solution as this has the potential to avoid/reduce ILW storage costs[3].

The RPV removal and storage options are further supported by potential opportunities that could lead to further reductions in the cost of the project; whole RPV disposal and a reduction in the future cost of RPV size reduction. If these opportunities are realised the VFM attractiveness of the RPV removal and storage options are even greater with reductions of 11% and 6.5% respectively.

[3] This is based on early qualitative findings based on high level discussions with the NDA, A joint MOD/NDA IA is currently in process this explores the economic business case of a joint MOD/NDA storage solution and is expected to report its results in [redacted].

2. Requirement

2.1. Outline

2.1.1. The SDP Single Statement of User Need is: “To dismantle, cost effectively, 27 defuelled nuclear submarines by 2050, without exceeding the submarine storage capacity, in a safe, secure, and sustainable manner which upholds MOD’s reputation as a responsible nuclear operator; stores Intermediate Level Waste (ILW) until a national disposal route is available; disposes of all other radioactive, hazardous and non-hazardous waste in accordance with legislation and minimises impact upon military capability.”

2.1.2. The project includes the interim storage on land of the resultant long-lived ILW the proposed GDF will be available to SDP sometime after 2040. Key User Requirements refer to Annex B.

2.2. Options in Scope

2.2.1. There are 25 options in scope for the public consultation. Effectively there are three technical approaches, up to four ILW storage options and each option can be dismantled at; Devonport (D), Rosyth (R) or a combination of Both (B). For a more detailed description of the options refer to Annex C.

OPTION			
Ref	**Description**	**Ref**	**Description**
0	Do Minimum Option - continued afloat support	5D	RPV removal and size reduction at Devonport to form Packaged Waste with interim storage PoG site:
1D	RC Separation at Devonport with interim storage at point of waste generation (PoG)	5R	RPV removal and size reduction at Rosyth to form Packaged Waste with interim storage PoG site:
1R	RC Separation at Rosyth with interim storage at PoG	5B	RPV removal and size reduction at Both Sites to form Packaged Waste with interim storage PoG site:
1B	RC Separation at Both Sites with interim storage at PoG	6D	RPV removal and size reduction at Devonport to form Packaged Waste with interim storage at remote commercial site:
2D	RPV Removal at Devonport with interim storage at PoG	6R	RPV removal and size reduction at Rosyth to form Packaged Waste with interim storage at remote commercial site
2R	RPV Removal at Rosyth with interim storage at PoG	6B	RPV removal and size reduction at Both Sites to form Packaged Waste with interim storage at remote commercial site:
2B	RPV Removal at Both Sites with interim storage at PoG	7D	RPV removal and size reduction at Devonport to form Packaged Waste with interim storage at MOD site:
3D	RPV removal at Devonport with interim storage at remote commercial site	7R	RPV removal and size reduction at Rosyth to form Packaged Waste with interim storage at MOD site
3R	RPV removal at Rosyth with interim storage at remote commercial site	7B	RPV removal and size reduction at Both Sites to form Packaged Waste with interim storage at MOD site:
3B	RPV removal at Both Sites with interim storage at remote commercial site	8D	RPV removal and size reduction at Devonport to form Packaged Waste with interim storage at an approved NDA site:
4D	RPV removal at Devonport with interim storage at remote MOD site	8R	RPV removal and size reduction at Rosyth to form Packaged Waste with interim storage at an approved NDA site
4R	RPV removal at Rosyth with interim storage at remote MOD site	8B	RPV removal and size reduction at Both Sites to form Packaged Waste with interim storage at an approved NDA site:
4B	RPV removal with at Both Sites with interim storage at remote MOD site		

Figure 5 - The 25 Options in scope

Note that under current MDAL assumptions all ILW must be reduced to 3m³ boxes in order to be GDF compliant. Options 1-4 will require size reduction once the proposed GDF will be available to SDP sometime after 2040”.

3. Methodology

3.1. Specialist Advice

3.1.1. The IA has used specialist advice from; ISM Financial Controller, SDP Risk Manager and industry experts including those involved in civil nuclear decommissioning. In addition Cost Assurance Advisory Services (CAAS), DASA/DESA, DES-FIN have been consulted and their advice sought. CAAS undertook a V&V exercise on the WLC Model this independent financial analysis provided assurance on the underlying financial data and the functionality of the WLC Model. The ISM Financial Controller has challenged and advised on contextualising the finance issues. The SDP Risk Manager has coordinated and supported the integration of risks and the application of uncertainty. The underpinning financial data has been collated from industry experts and comparative estimates.

3.2. Assumptions

3.2.1. The IA is consistent with the SDP MDAL but specific financial assumptions are:

- All Costs are in pounds sterling (£);
- NPV discounts constant prices at the HM Treasury approved rate of 3.5% for 1-30 years then 3% thereafter;
- Year 0 is FY11/12 therefore any costs incurred prior to April 2011 have been treated as sunk cost and excluded from this analysis;
- Inflation is at the planning round approved rate of 2.5% per annum;
- Costs provided to support the options are based on the best available knowledge of the cost author;
- The Demonstrator is expected to commence 2016 and In-service Date (ISD) 2019 across all options;
- The proposed GDF will be available to SDP sometime after 2040
- A drumbeat of one submarine to be dismantled per year;
- ILW must be packaged into $3m^3$ boxes before it can enter the proposed GDF;
- The WLC include full cost of ILW Storage and proposed GDF disposal; which are a fraction of the total proposed GDF cost; and
- Costs include associated afloat storage costs (such as maintenance, berthing and potential infrastructure improvements).

3.2.2. These assumptions could change following the public consultation, SEA and MGBC but provide a common reference to assess the through life cost of dismantling.

3.3. Qualitative Financial Impact

3.3.1. The IA has focused on the measurable costs, these costs include those needed to meet the minimum legislative requirement and benefits beyond this are excluded. These are covered in the OE Analysis report[4] and Other Contributing Factors Paper[5.] They provide additional analysis excluded from the IA because of the challenge in measuring them or the sensitive nature of obtaining costs.

3.4. Consideration of Worker Dose

3.4.1. Following advice from DASA/DESA, the differences in worker dose across the options are addressed within the IA following the same practice as the NDA[6].

3.4.2. The approach to worker dose within investment appraisals involves calculation of the residual worker dose, in manSv, that is estimated for each of the options. This is the worker dose that is estimated to be incurred after steps have been taken to limit exposure to as low as reasonably practicable. The resulting dose is multiplied by a value of £/manSv that is based on studies conducted by the National Radiological Protection Board (NRPB), now part of the Health Protection Agency.

3.4.3. The cost that is calculated for residual dose is included in the analysis alongside all other directly measurable costs and is summarised in Appendix F.

---

[4] Operational Effectiveness Report, Issue 0.3
[5] Other Contributory Factors Report, Issue 0.4
[6] NDA Guidance for the Production of Business Cases, Doc No EGG 08, Rev 6, November 2009. Available at: http://www.nda.gov.uk/documents/upload/EGG08-NDA-guidance-for-the-production-of-business-cases-Rev7.pdf

4. Financial Analysis:

4.1.1. The financial analysis was extracted from the SDP WLC Model. This underwent initial Verification & Validation (V&V)[7] assurance from CAAS, challenge from the CAAS Estimating Assurance Team and review by the MOD's internal scrutiny. Following the V&V CAAS have been invited to quarterly briefings outlining the development of the WLC Model.

4.1.2. The WLC Model contains a cost data assumptions list (CDAL) and data sheets. Costs model input data and assumptions was collected from industry, MOD SMEs, customer friend and third party sources as well as aligned with the project MDAL. The data makes up the key cost drivers of each option. The timing sheets allocate when the costs will occur, and is consistent with the MDAL and SDP Schedule. The other input is the SDP risk register. The WLC Model has the functionality to present the costed options with and without risk.

4.1.3. The analysis uses the @RISK software, the result of which creates a 10%, 50% and 90% confidence range. This can be output as outturn, Net Present Value (NPV) or constant costs. The preferred analysis by the MOD is NPV as this takes account of the time value of money and is fairer way to appraise options over long periods of time. NPV uses the HM Treasury approved 3.5% discount rate.[8]

Rank	Option	Delta
1	Option 4B – *Dual Site, RPV removal with interim storage at MOD site*	Most Economic
2	Option 3B – *Dual Site, RPV removal with interim storage at remote commercial site*	+3.68%
3	Option 2B – *Dual Site, RPV removal with interim storage at Point of waste generation site*	+3.68%
4	Option 4D – *Devonport Site, RPV removal with interim storage at MOD site*	+4.95%
5	Option 8D – *Devonport, RPV removal and size reduction to form packaged waste with interim storage using NDA storage facilities*	+5.15%

Figure 6- Top 5 Options ranked at NPV (50%) excluding risk

4.1.4. Under NPV the RPV removal and storage options represent better VFM than other technical options. These options are most attractive for the following reasons:

- The large scale capital investment for an RPV size reduction facility is delayed until the point when the proposed GDF is assumed to be available to accept MOD waste. The cost is thus heavily discounted;
- The dismantling operations are spread over a longer period with de-planting undertaken early and size-reduction later; and
- The bespoke RPV store build and operations costs are comparable to a packaged waste store and both are more affordable than an RC store.

[7] 20100920-SDP_Final_Report _PC
[8] See HM Treasury Greenbook and JSP507. 3.5% discount rate is applied to years 1-30, 31 years + the discount rate is adjusted to 3.0%

4.1.5. Rosyth options offer the least VFM even excluding the financial risks of staying in Rosyth post 2020. The main reason is the requirement to move 20 submarines to Rosyth as a Rosyth option requires the movement of all existing Devonport Laid Up Submarines (LUSMs) and all current at sea submarines require defuelling and decommissioning at Devonport before initial dismantling at Rosyth. There are a number of costs required for submarine movement to be undertaken in a safe and secure way.

5. Risk and Uncertainty

6.1 Treatment of Uncertainty

5.1.1. The whole life cost of each option is built up from a number of cost drivers. Each cost driver is expressed as a three point estimate with a minimum, maximum and most likely cost. This range between the minimum and maximum costs is known as an 'uncertainty band' and is applied to all of the costed activities expected to be undertaken as part of SDP. The extent of the uncertainty varies by cost driver and is dependant upon a number of factors such as the amount of historical cost data available for similar activities and the level of detail for which the cost driver is broken down to.

5.1.2. A range of information sources have been consulted to develop the minimum, most likely and maximum values for each cost driver including internal MOD staff, quoted figures, contracted rates, actual costs for similar activities and independent industry sources. The sources and rationale for the information has been recorded and documented within the WLC Model as part of a robust audit trial. The cost data input sheet also includes reference to any considerations, associated risks, the date when the data was obtained and a self assessment (i.e. a Red/Amber/Green (RAG) status) on the quality of financial data.

5.1.3. All of the cost drivers feed into the overall cost of dismantling. To obtain an output Monte Carlo Analysis is run on the whole life cost model using @Risk software[9]. Using @Risk 10,000 combinations of all the different cost drivers are quickly conducted, each time taking a random value for each cost driver within the uncertainty band. The output is a range of values for the total cost of the project giving a 10%, 50% and 90% confidence range.

5.2. Treatment of Risk

5.2.1. The SDP Risk Register is used to inform the WLC Model, data from the SDP risk register has been assessed with the SDP risk manager and all relevant risks with a cost impact have been added to the analysis. The SDP Risk Register is managed by the SDP Risk manager and is updated on a regular basis with input from the risk owners. The WLC Model has an internal risk register compatible with the SDP Risk Register. In addition the WLC Model includes commercially sensitive risks. Figure 7 identifies the top five risks from the WLC Model. These risks are shown post mitigation, illustrate the probability of occurrence and include a 3 point estimate of cost. Some risks, including several of those in Figure 7 are common across more than one option. Where the impact or probability of a risk occurring varies for different options the variation is captured in the WLC Model risk log and applied separately to each option..

[9] @RISK is an excel add-in designed to run simulations where there is uncertainty and risk attached to options analysis.. @RISK enables rapid simulation of complex models with many inputs and provides a standard output that can be compared against other options. It is recognised and approved by CAAS

Risk Ref	Risk Description	Impacts Options	Probability	Cost £m		
				Min	ML	Max
SR92	Judicial Review due to inconsistencies in process, failure to provide sufficient consultation or information for consultation or legal challenge by NGOs.	All Options	50%	**Costed Risks have been redacted due to commercial sensitivity**		
049	That transport of the RPV is delayed due to the unavailability of suitable transportation or unavailability of a store, delaying the commencement of storage and incurring additional cost of building a temporary buffer facility.	Options 3-4	40%			
P37200	That the submarine radiological contamination survey identifies significant unexpected contamination external to the RC resulting in inability to conduct designed dismantling process and requirement to alter work package to conduct breaking on-site at nuclear rates.	Options 1-8 all variants	10%			
056	That indefinite storage becomes necessary because the proposed GDF is not available for ILW disposal. Should this risk occur, use of the RC store is extended incurring additional operational, inspection and maintenance costs.	Options 1-8 all variants but to different degrees	50%			
101	The effort and expense in returning the submarine to a transportable state is extensive - it requires a SADP type overhaul.	Options 1-8 all variants	30%			

Figure 7 – Top 5 Risks to the project

Opt No.	Description	Analysis – Amount of risk added to each option
0	Continued Afloat Support	11.7%
1	RC Separation with interim storage at point of waste generation (PoWG): Variant 1D: Devonport. Variant 1R: Rosyth: Variant 1B: Devonport & Rosyth.	 16.9% 22.2% 18.4%
2	RPV Removal with interim storage at PoWG: Variant 2D: Devonport. Variant 2R: Rosyth. Variant 2B: Devonport & Rosyth.	 20.8% 28.9% 22.6%
3	RPV removal with interim storage at a remote commercial site: Variant 3D: Devonport. Variant 3R: Rosyth. Variant 3B: Devonport & Rosyth.	 20.1% 27.7% 22.2%
4	RPV removal with interim storage at a remote MOD site: Variant 4D: Devonport.	 20.6%

	Variant 4R: Rosyth. Variant 4B: Devonport & Rosyth.	27.9% 22.8%
5	RPV removal and size reduction to form Packaged Waste with interim storage PoWG: Variant 5D: Devonport. Variant 5R: Rosyth. Variant 5B: Devonport & Rosyth.	 17.3% 25.5% 21.1%
6	RPV removal and size reduction to form Packaged Waste with interim storage at a remote commercial site: Variant 6D: Devonport. Variant 6R: Rosyth. Variant 6B: Devonport & Rosyth.	 18.2% 18.2% 25.1%
7	RPV removal and size reduction to form Packaged Waste with interim storage at remote MOD site: Variant 7D: Devonport. Variant 7R: Rosyth. Variant 7B: Devonport & Rosyth.	 18.1% 24.8% 20.7%
8	RPV removal and size reduction to form Packaged Waste with interim storage using NDA storage facilities: Variant 8D: Devonport. Variant 8R: Rosyth. Variant 8B: Devonport & Rosyth	 18.8% 25.8% 21.6%

Figure 8 – Impact of Risks on Options viewed at NPV

5.2.2. Figure 8 illustrates that risk can add a significant amount to the cost of the option but ultimately it does not impact the financial ranking of the options. This is because the main risks are common across all options, although exacerbated in some more than others. The risk difference is more pronounced in the technical approach and the initial dismantling sites. It is unsurprising that storage site is not a significant factor as these are generic.

5.2.3. The Rosyth options are riskier due to SDP being the only significant MOD presence (from 2020) and the risk of incurring the full overhead and site rationalisation impacting Babcock's 2020 vision for Rosyth[10].

[10] [redacted]

6. Optimism Bias

Optimism Bias was undertaken as a separate exercise and has been used to test the application of risk and uncertainty applied. It used the public sector approved Mott McDonald (MMD) Optimism Bias Estimator.

6.1. Methodology Used.

6.1.1. Cost breakdowns of all facilities in terms of MMD "Project Types" were prepared. The decision to analyse facilities instead of options was taken due to the use of common facilities across options and the application of Optimism Bias to capital expenditure. A one day workshop with appropriate SMEs was used to analyse each facility, prioritising discussion in terms of highly weighted criteria from the relevant project types, as well as criteria that would differentiate between facilities. Participants were asked to assess the mitigation currently in place, taking into account current risks captured and current cost accuracy.

6.2. Optimism Bias Summary Outputs

6.2.1. Optimism bias indicated that most of the current estimated costs of capital facilities are within the expected risk/uncertainty boundaries. However, it suggested that two of the facilities may require an increase in the level of uncertainty/risks associated with them so will require further analysis.

6.3. Optimism Bias Further Work

6.3.1. Babcock are supporting the development of the detailed costing of the RPV size reduction facility with a separate independent review. The cost increase of a size reduction facility has been addressed in the sensitivity analysis section. MOD SMEs are providing a more detailed design of the RC storage facility, recognising the risks involved of housing and moving such a heavy container. Work to date to understand optimism bias is described in the Optimism Bias Report[11].

[11] 20110721 SDP Optimism Bias Report version 0.1

7. Sensitivity Analysis

A separate sensitivity analysis was undertaken with reference to; Whole RPV disposals, the RPV size reduction facility and multi-stream dismantling. Due to the project's relative immaturity and the high level of clustering, the analysis has focused on variables that could change the ranking of options.

7.1. Whole RPV disposal

7.1.1. Currently it is a project assumption that RPVs will require size reduction into packaged waste in $3m^3$ boxes at some point in the project, either immediately prior to interim storage, for the packaged waste options or following interim storage for the RPV and RC storage options. The RPV is expected to be too big in its current form to 'fit' in the proposed GDF and the RC at circa 1,000 tonnes is far too large and heavy to be acceptable for GDF disposal.

7.1.2. There is an opportunity that by the time the proposed GDF is available to SDP that this project assumption changes and that it becomes possible to dispose of whole RPVs within the proposed GDF, without the need for further size reduction.

7.1.3. As the construction of an RPV size reduction facility and its operation is one of the largest areas of cost across all options this opportunity may have the potential to significantly reduce the cost of some of the options.

7.1.4. Figure 11 below shows how the whole life costs of the 5 lowest cost options vary following realisation of the whole RPV disposal opportunity:

#	Option	Delta between options	Delta between baseline option and opportunity
1	4B	Most Economic	**-11.6%**
2	4D	+3.7%	**-11.1%**
3	3B	+4.1%	**-10.9%**
4	2B	+4.1%	**-11.1%**
5	2D	+4.3%	**-12.5%**

Figure 11 – Impact of Direct RPV Disposal – top 5 options (NPV at 50% inclusive of risk)

7.1.5. The estimated impact of realising the whole RPV disposal opportunity is a reduction in the NPV of the RPV and RC storage options of approximately 11%. This changes the financial ranking of options with the top five options all now becoming RPV storage options. Where previously Option 8D, packaged waste storage using NDA storage facilities was amongst the top five there is now a clear distinction between RPV storage options and packaged waste options. This is thus a significant opportunity that further enhances the relative attractiveness of RPV storage

7.2. Sensitivity to changes in the future cost of RPV size reduction

7.2.1. There is a significant chance that both the RPV size reduction facility and the size reduction process may alter over the long-term[12]. This is due to several factors:

- The radioactivity of the RPV will have reduced in the intervening period;
- Changes in technology may provide a more efficient process of size reduction; and
- Regulatory changes may allow more flexibility or conversely impose more stringent requirements in the process of size reduction.

7.2.2. Major changes in the technology and process of size reduction and the regulatory environment may thus make size reduction significantly cheaper or more expensive. Sensitivity analysis was conducted to estimate the impact that changes would have on the NPV of all relevant options, namely those involving RPV or RC storage.

7.2.3. Sensitivity testing has looked at the effect on cost of the whole dismantling project of reducing and of increasing the cost of both the RPV size reduction facility and the cost of the process by 50%. The exact magnitude of changes over time is difficult to predict so a relatively large proportional change has been modelled.

7.3. Decrease in the future cost of RPV size reduction

7.3.1. Figure 12 below shows the impact of a 50% decrease in the cost of size reduction

#	Option	Delta between options	Delta between baseline option and opportunity
1	4B	Most economic	**-6.9%**
2	4D	+3.6%	**-6.5%**
3	3B	+4.1%	**-6.1%**
4	2B	+4.2%	**-6.3%**
5	2D	+6.0%	**-6.4%**

Figure 12 – Impact of 50% lower cost of future size-reduction – top options (NPV at 50% inclusive of risk)

7.3.2. A 50% reduction in the future cost of size-reduction results in a reduction in the NPV of the RPV removal and storage options of approximately 6.5%. As per the direct RPV disposal opportunity all the top five options are now RPV removal and storage options.

7.4. RPV size reduction facility – cost increase

7.4.1. There is the potential for the cost of RPV size-reduction facility to increase in the future (i.e. changes in legislation/policy) or that initial estimates of the capital cost were understated (see optimism bias section).

7.4.2. Figure 13 below shows the impact of a 50% increase in the cost of size reduction:

[12] Technology and the regulation of the nuclear industry move on over time and it is unlikely that the techniques in use now will remain the same in 30 or 40 years. Additionally the activity of the RPVs will change over time leading to potential variation in the way in which they would be cut during size reduction.

#	Option	Delta	Delta between baseline option and opportunity
1	8D	Most economic	**-**
2	8B	+0.3%	**-**
3	4B	+2.7%	**6.4**
4	4D	+6.5%	**6.6**
5	2B	+6.5%	**6.2**

Figure 13 – Impact of 50% higher cost of future size-reduction – top options (NPV at 50% inclusive of risk)

7.4.3. A 50% increase in the cost of RPV size-reduction causes an increase in the NPV of the RPV options of circa 6.5%. The two most attractive options are now 8D and 8B both packaged waste using NDA storage facilities[13]. The other packaged waste technical options are still less financially attractive than comparable RPV removal and storage options.

7.4.4. Overall a 50% change in the future cost of the RPV size-reduction facility and associated processing has a 6-7% impact on the overall NPV of the project. The cost of the RPV size reduction facility and consequent processing would have to rise **29.3%** for option 8D to be provide better VFM that option 4B. Changes in the level of requirement and process over time could impact on the cost of the project but are unlikely to significantly alter the relative attractiveness of RPV removal and storage over packaged waste.

7.5. Multi-stream dismantling

7.5.1. All options assume a Demonstrator start-date of 2016/17 and a dismantling rate of one submarine per year. If dismantling happened concurrently it could bring forward the demonstrator by two years. This opportunity is only realisable for RPV removal and storage options due to the time required to plan and build either a RPV size reduction facility or an RC storage pad.

#	Option	Delta	Delta between baseline option and opportunity
1	4B	Most Economic	**-1.0%**
2	2B	+3.72%	**-0.8%**
3	3B	+3.75%	**-0.4%**
4	4D	+4.51%	**-**
5	8D	+4.91%	**-**

Figure 14 – Impact of multi-stream dismantling – top options (NPV at 50% inclusive of risk)

[13] The assessment of cost and technical feasibility for options involving NDA facilities is still being developed with NDA and has yet to be formalised in a mutually agreed business case. So there is no certainty that the options to use NDA facilities will be best value for money or deliverable within the timescales required by the project

7.5.2. The impact of multi-stream dismantling on the dual-site options **is minimal** as the increased benefits in reducing the long-term afloat storage costs and commitments within Rosyth are offset by the increased to NPV caused by bringing a greater proportion of costs earlier in the project.

7.5.3. In addition there are likely to be major operational factors which will have a greater impact on the decision, such as the availability of workforce and materials and the throughput limitations of the mature process design.

7.6. Worker Dose

7.6.1. The cost attributed to residual worker dose (following the method described at 3.4) was found to be immaterial to the overall cost of each option and comprised less than [redacted] of the overall cost of each option.

7.6.2. The cost of residual worker dose is very low because the cost of facilities and operational processes required to reduce it to a level that is as low as reasonably practicable has already been accounted for in the estimates for each option.

7.6.3. Due to the very low level of cost associated with the worker dose the options are not differentiated by differences in residual worker dose, nor are they sensitive to changes in worker dose.

7.7. Conclusion on Option 4B compare to Option 8B

7.7.1. Further sensitivity analysis focused on what would need to happen for Option 8D (Devonport, Packaged Waste Reduction and using NDA storage facilities) to outperform Option 4B (Dual Site, RPV removal and MOD bespoke storage).

7.7.2. The cost of an RPV store would need to be **71%** more expensive than current PW store estimates. The cost of RPV storage would need to be **100%** more expensive than current PW storage estimates.

7.7.3. The cost of an RPV packaging facility would need to be **142%** more expensive than currently estimated and the cost of packaging and preparing an RPV for transport is **142%** more expensive than currently estimated.

7.7.4. The cost of the RPV size reduction facility and consequent processing would have to rise **29.3%** for option 8D to be provide better VFM that option 4B.

7.7.5. Annex E contains the tables to support this analysis.

8. IA Conclusions

8.1.1. This IA concludes that all options are considered as part of the public consultation. At NPV (KUR 1.1.1.) the options are clustered with small deltas between them. Against this context the RPV removal and storage and RPV removal and size reduction to form package waste solutions; Option 4B, 4D, 3B, 2B and 8D provide the best VFM. Option 8D requires further investigation especially the prospect of the NDA taking a whole RPV as packaged waste. The Rosyth options do not provide VFM in comparison with options involving Devonport or Dual Site. The RC options 1D, 1R and 1B are negatively differentiated and do not meet VFM objectives.

8.1.2. The IA is only a VFM view point on the current available data and other factors from the OE and OCF can legitimately be used to determine which option is selected as all of these (within the uncertainty of the work) represent a VFM solution.

8.1.3. All the cost forecasts in this IA have been produced using the best information available at the time of the assessment and to a level applicable in the time allowed. These costs are by nature subject to change with time and should be used with care. If there are any changes to the requirement or additional information becomes available, the IA should be reviewed. No costs from this IA should be quoted outside the context of the task for which they have been prepared.

8.2. Project Evaluation

8.2.1. The IA has been produced with input from the scrutiny community and the WLC Model that is the source of the data was verified and validated by CAAS. This level of challenge and dialogue is set to continue.

8.2.2. Following the public consultation the IA will be refreshed. There maybe an opportunity to refine the options as a result of this. In the interim costs will continue be collected, assimilated and challenged. Regular briefings have been scheduled with CAAS, DASA/DESA and DES FIN with a view to refining the costs focussing on the affordability and risks for IAC in [redacted] and MGBC in [redacted].

Annex A: Abbreviations

Abbreviation	Meaning
CAAS	**Cost Assurance Advisory Services**
CAPEX	**Capital Expenditure**
COA	**Concept of Analysis**
COEIA	**Combined Operational Effectiveness and Investment Appraisal**
Confidence Level	The output of a Monte Carlo Simulation is to provide 10:50:90 confidence levels. This enables the user to see at what cost we are 10% likely to be under, 50% likely to be under and so on.
DISM	**Department of In service Submarines**
GDF	**Geological Disposal Facility**
HMNB	**Her Majesty's Naval Base**
HMT	**Her Majesty's Treasury**
IA	**Investment Appraisal**
IAC	**Investment Appraisal Committee**
ILW	**Intermediate Level Waste**
ISM	**In Service Submarines**
JSP	**Joint Service Publication**
KUR	**Key User Requirement**
LLW	**Low Level Waste**
LLWR	**Low Level Waste Repository**
LUSM	**Laid Up Submarines**
MDAL	**Master Data and Assumptions List**
MGBC	**Main Gate Business Case**
MMD	**Mott McDonald (Optimism Bias Tool)**
MOD	**Ministry of Defence**
Monte Carlo	**Monte Carlo** simulation is a problem solving technique used to approximate the probability of certain outcomes by running multiple trial runs, called simulations, using random variables
MPOS	**MOD's Proposed Option Study**
NDA	**Nuclear Decommissioning Authority**
NPV	**Net Present Value** – this discounts current money values by a HM Treasury agreed wait and is used to fairly appraise options with different spend profiles.
OASP	**Operational Analysis Supporting Paper**
OB	**Optimism Bias -** is the demonstrated systematic tendency for people to be overly optimistic about the outcome of planned actions. This includes over-estimating the likelihood of positive events and under-estimating the likelihood of negative events.
OCF	**Other Contributory Factors**

Abbreviation	Meaning
OE	**Operational Effectiveness**
OGD	**Other Government Department**
PE	**Project Evaluation**
PoWG	**Point of Waste Generation**
PR11	**Planning Round 11**
PW	**Packaged Waste**
RC	**Reactor Compartment**
RPV	**Reactor Pressure Vessel**
SADP	**Submarine Advanced Docking Period**
SDP	**Submarine Dismantling Project**
SEA	**Strategic Environmental Assessment**
SSBN	**Ballistic Missile Submarine – Nuclear**
SSN	**Attack Submarine – Nuclear**
SQEP	**Suitability Qualified Experienced Personnel**
V-Class	**Vanguard Class Submarines**
VFM	**Value for Money**
WLC	**Whole Life Cost**

Annex B: Key User Requirements

The Key User Requirements from the User Requirement Document, February 2011 are shown below:

Ref	User Requirement	Justification
1.1.1	The user requires a solution which is as cost-effective as possible, minimising the costs of submarine dismantling and ILW storage without compromising safety, security, sustainability or regulatory compliance.	To minimise the cost of dismantling and ILW storage whilst delivering an effective solution.
2.6.3	The user requires a means to store Intermediate Level Waste (ILW) from 27 defuelled nuclear submarines until a national disposal route is established.	To carry out Government and MOD nuclear decommissioning policy, with the long term aim of disposal of ILW.
3.4.1	The user requires that the capability is in service before the redundant submarine storage capacity is reached. To achieve this IOC must be accomplished by [redacted] and FOC by [redacted]	Storage in 3 basin, in Devonport, is limited and storage elsewhere is likely to impact operation of the dockyard or naval base. Therefore SDP should be operational before the current storage capacity is reached.
5.2.1	The user requires that SDP inspires public confidence and thereby upholds the MOD's reputation as a responsible nuclear operator.	To fulfil Ministerial commitments in response to previous public consultations, and commitments to undertaking further public consultation before major decisions are made.[14]

[14] S of S announcement, May 2000, and Min(DP) response to the recommendations of Consultation on ISOLUS Outline Proposals (CIOP), Feb 05.

Annex C: Detailed Background to the Options

SDP has 25 potential solutions, which have been developed from combinations of the following:

- **Technical Approaches** to the initial dismantling of submarines.
- **Initial Dismantling Site(s)**.
- **Generic ILW Storage Site(s)** for ILW arising from initial dismantling.

Each option and variant also includes the re-use, recycling or disposal of non-radioactive components and transport of submarines and their waste.

Derivation of Option Set

Technical Approach

Extensive technical and environmental assessments have been carried out to develop a more detailed understanding of the available options, leading to the shortlist of three alternatives for removing the radioactive waste from the submarines.

- Separate and store the whole Reactor Compartment (RC): the whole RC is separated from the front and rear sections of the submarine and stored whole, leaving the hull of the submarine in two halves.
- Remove and store the Reactor Pressure Vessel (RPV): the RPV and other radioactive materials are removed from the submarine, leaving the submarine intact.
- Remove and size reduce the Reactor Pressure Vessel for storage as Packaged Waste: the RPV and other radioactive waste is removed and then cut into smaller pieces and packaged into boxes for storage. The submarine is left intact.

Initial Dismantling Site(s)

- Devonport Dockyard;
- Rosyth Dockyard;
- Both Devonport and Rosyth Dockyards. (Dual Site)

The dual site option utilises both of the identified sites for submarine dismantling but, as duplication of all facilities would be prohibitively expensive[15], only one size reduction facility is assumed. This facility will be located at one of the initial dismantling sites (for the storage as Packaged Waste options) or at the ILW storage site (for the storage as RPV and RC options).

[15] The cost of a single dismantling facility has been estimated to be a multi-million pound investment. The cost of two facilities, even taking account of the costs of RPV movement, has been estimated to be approximately 50%+ than a single facility.

Generic ILW Storage Site(s)

At this stage, it has not been possible to screen the long-list of existing nuclear Licensed/Authorised sites because of the different governance arrangements and strategies for sites under differing ownership. As an intermediate step, 4 possible categories of candidate sites for storage of ILW have therefore been identified and assessed at a generic level:

- Storage at point of waste generation (Devonport Dockyard / HM Naval Base Devonport and / or Rosyth Dockyard). For the dual site dismantling option, storage at the point of waste generation would mean RCs, RPVs or Packaged Waste being transported to one of the two sites after initial dismantling, for interim storage[16].

- Storage at remote commercial site. This category could include both Rosyth Dockyard and Devonport Dockyard if dismantling were conducted at the other site, but also any existing licensed sites where the owner wished to bid for provision of a storage service to MOD.

- Storage at remote MOD site. This category includes all the nuclear licensed or authorised sites owned by MOD that are remote from the point of waste generation.

- Storage at NDA site(s) - It may be possible for ILW arising from SDP to be stored using NDA facilities. These are all remote from the point of waste generation.

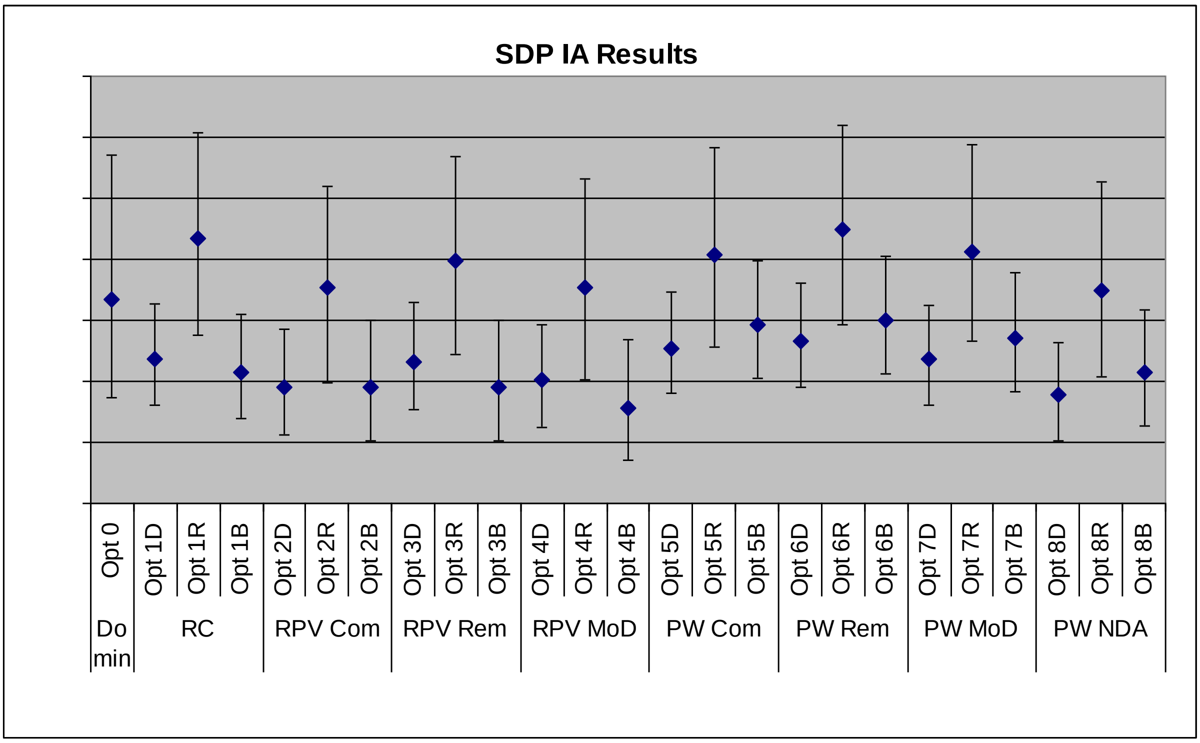
The costs associated with transport and dockside handling facilities to move all 27 RCs, render their storage at a remote site, including NDA sites, as uneconomic and this has not, therefore, been assessed as an option[17] although it remains as an opportunity to be reviewed as estimates are refined and assumptions are tested. Storage of RPVs at an NDA site has also not been assessed as an option because its feasibility has yet to be proven through joint studies with NDA.

[16] Cost modelling has indicated that, due to the relatively low number of waste packages, the cost of waste movement is preferable to the cost of building additional storage facilities. The building of two stores results in significant upfront capital costs but also creates a legacy in terms of operation and decommissioning making it uneconomic to develop two stores at two locations.

[17] For economic reasons, the project has assumed that no transport of RCs would be undertaken except in Option 1B which includes transport of RC's from one site where initial dismantling has been conducted to the other initial dismantling site where they would be stored. Option 1B has been configured in this way because the costs, risks and operational legacy associated with two stores are judged to outweigh those of transporting RCs.

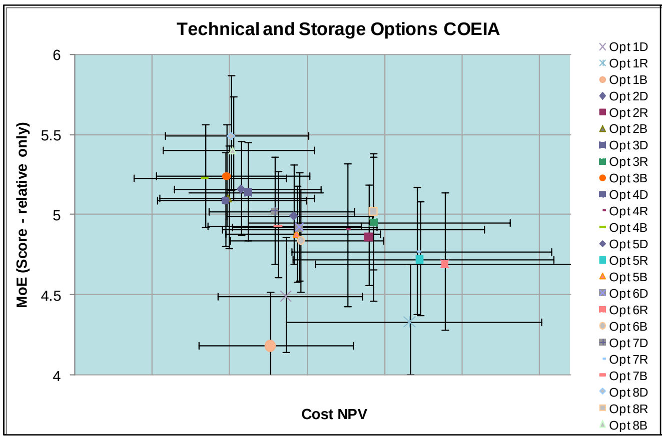
Annex D: Additional Graphs

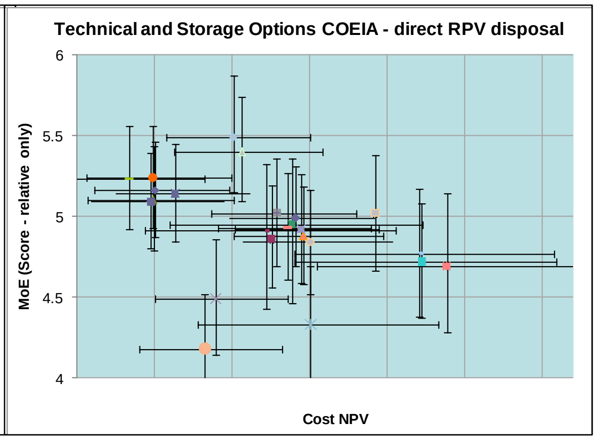
IA plot showing NPV costs of all options



At NPV there is a higher degree of clustering and the RPV options are the most attractive financially.

COEIA Plot showing impact of Sensitivity on whole RPV disposal (compared to as-is)





If the RPV Whole Disposal opportunity becomes realisable it has the potential to provide an increased value for money argument for the MOD and would provide some clear differentiation between options as illustrated by COEIA plots above.

The impact of this specific opportunity on effectiveness is not calculated as it would require a re-run of the effectiveness workshops. However, the overall potential for opportunities on each option was considered through the OE criteria Flexibility and Robustness to Opportunities and Risk.

Annex E: Additional Sensitivity Analysis

Increase Cost of an RPV Store Build

The cost of the RPV store in relation to the PW store may influence the relative value-for-money of the different options, at present the RPV and PW store costs are modelled very similar due to immature design and similar space requirements

Table below shows the modelled increase in cost of RPV store capital build by 50%

#	Option	Delta	Delta between baseline option and opportunity
1	4B	Most Economic	**+2.8&**
2	8D	+1.03%	**-**
3	8B	+1.30%	**-**
4	4D	+2.62%	**+2.4%**
5	2B	+3.41%	**+2.7%**

Key Findings

- Negatively impacts RPV storage options by approximately 2.5%
- Using NDA storage facilities the PW options become slightly more attractive but the RPV removal and storage option is still favourable
- For Option 8D to be more attractive than Option 4B the cost of an RPV store must increase by **71%**

Increase Cost of an RPV Store Operation

The cost of operating the RPV store in relation to the PW store may influence the relative value-for-money of the different options, at present the RPV and PW store operation costs are modelled very similar due to immature design and similar space requirements that is expected.

Table below shows the modelled increase in cost of RPV store operation by 50%

#	Option	Delta	Delta between baseline option and opportunity
1	4B	Most Economic	**+2.1&**
2	8D	+1.74%	**-**
3	8B	+2.01%	**-**
4	4D	+2.82%	**+1.9%**
5	3B	+4.76%	**+3.7%**

Key Findings

- negatively impacts RPV storage options by approximately +1.9-3.7%
- Using NDA storage facilities the PW options become slightly more attractive **–** but RPV removal and storage is still the most economic option
- For Option 8D to provide better VFM than Option 4B the cost of RPV store operation would need to increase by **100%.**

Increase cost of RPV packaging facility build

The cost of the RPV packaging facility (or infrastructure to allow packaging) is a distinct requirement for all RPV storage scenarios, the actual cost of this facility may impact the relative value-for-money of the different dismantling process options

The table below shows the modelled **increase** in cost of RPV packaging facility capital build by **50%**

#	Option	Delta	Delta between baseline option and opportunity
1	4B	Most Economic	**+1.8%**
2	8D	+2.11%	**-**
3	4D	+2.40%	**+1.1%**
4	8B	+2.92%	**+0.5%**
5	3B	+3.40%	**+1.9%**

Key Findings

- Negatively impacts RPV removal and storage options by 1-2% depending on site of packaging facility and dual-site packaged waste option by approximately 0.5%
- PW options that plan to use NDA storage facilities become slightly more attractive but the RPV removal and storage option is still favourable
- For Option 8D to provide better VFM than Option 4B the cost of the RPV packaging facility would need to increase by **142%.**

Increase cost of RPV packaging and preparing for transport

The cost of conducting the process of RPV packaging in a bespoke facility is a distinct requirement for all RPV removal and storage options, the actual cost of this process may impact the relative value-for-money of the different dismantling process options

The table below shows the modelled increase in cost of RPV packaging process operation by 50%

#	Option	Delta	Delta between baseline option and opportunity

1	4B	Most Economic	**+2.0%**
2	8D	+1.83%	**-**
3	4D	+2.35%	**+1.3%**
4	8B	+2.69%	**+0.6%**
5	2B	+3.39%	**+1.9%**

Key Findings

- Negatively impacts RPV storage options by +1-2% depending on site of packaging facility.
- Packaged Waste options using NDA storage facilities become slightly more attractive but the RPV removal and storage option is still favourable
- For Option 8D to provide better VFM than Option 4B the cost of the RPV packaging and preparation for transport facility would need to increase by **142%.**

Annex F: Worker Dose Calculations

The values attributed to worker dose within the IA were in-line with NDA practice and based on the valuation used within the NDA's guidance for the production of business cases.

The following table outlines the values framework and metric for worker dose:

Individual Annual Dose	Valuation
< 5 mSv/year	£50k/manSv
> 10 mSv/yr	£100k/manSv Intermediate doses are scaled

The following table shows the best estimate of dose attributable to each of the technical options and the corresponding value attributable to dose that is used within the IA, based on the valuation outline above.

Technical Option	Best estimate of individual annual dose	Best estimate of total dose per boat	Value attributed to dose (£) (per boat)	Value attributed to dose (£) (WLC over 27 boats)
RC separation	< 1mSv/year	9 man mSv in total	£450	£12,150
RPV removal	< 1mSv/year	~50 man mSv in total	~ £2,500	~ £67,500
Packaged Waste	< 1mSv/year	~50 man mSv in total	~ £2,500	~ £67,500

It should be noted that the valuation framework results in low cost values as the estimated worker dose is that which would be incurred following steps taken to reduce it to a level that is as low as reasonably practicable. The significant cost is that incurred in the facilities and processes that are designed to reduce the dose to workers to that level.