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ISM

SUBMARINE DISMANTLING PROJECT

Operational Analysis Supporting Paper (OASP)

- 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 redacted 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

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Issue	Date	Details of Amendment	DCCF
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0.2	3 Aug 11	Draft following internal project review.	
0.3	23 Aug 11	Draft following review by the project team, D Scrutiny and DASA/DESA.	
0.4	26 Aug 11	Updated following comments from project team.	
0.5	2 Sep 11	Draft following review, and including a revised Section 3, expanded Section 7 and Executive Summary.	
0.6	9 Sep 11	Updated following comments from senior MOD stakeholders.	
0.7	16 Sep 11	Updated following comments from project team.	
0.8	23 Sep 11	Updated following comments from project team.	
1.0	21 Oct 11	Updated following comments from project team.	
1.0a	21 Oct 11	Public release version with commercially sensitive cost data presented as ratios or redacted. Other classified data is also redacted.	

Distribution

SDP Project Board
SDP Virtual Team (MOD and Customer Friend Members only)
SDP Scrutiny Meeting Members

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Executive Summary

Single Statement of User Need (SSUN)

The Submarine Dismantling Project (SDP) exists:

"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 MODs 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."

Context

At the end of the current Assessment Phase, the project will submit its Main Gate Business Case (MGBC) in order to proceed to its Demonstration Phase. This MBGC will be underpinned by an Operational Analysis Supporting Paper (OASP). Before this however, the project is undertaking a public consultation and so this version of the OASP represents a summary of the project's current assessment of the options and proposals for the most cost-effective approach to the project. The project has also undertaken a Strategic Environmental Assessment (SEA) to assess the likely significant environmental effects of SDP activities and options and this has informed the assessment of the options.

Background

When a nuclear powered submarine leaves service with the Royal Navy, the nuclear fuel is removed for long-term storage at the Nuclear Decommissioning Authority (NDA) site at Sellafield. The remaining radioactive material is contained securely in the reactor compartment and remains in the submarine, which is stored safely afloat.

Although this has proved to be an acceptable arrangement for over 20 years, it does not fulfil Government and MOD's nuclear decommissioning policy which requires that nuclear decommissioning activities should be carried out as soon as reasonably practicable. Further, the capacity to store further submarines will be reached by 2020 and there are no existing berthing facilities suitable for the Vanguard Class submarines when they leave service. These issues underline the need for a long-term solution for submarine dismantling.

The project scope includes past and current classes of Royal Navy nuclear submarines, 27 in all. It does not include dismantling of Astute class or Successor submarines although the project is required, where possible, to retain flexibility for future classes. The project includes:

- The interim storage on land of the resultant ILW pending the availability of the UKs proposed Geological Storage Facility (GDF). The proposed GDF is assumed to be available for disposal of SDP ILW sometime after 2040.

- The dismantling of all parts of the submarines, including the non-radiological fore and aft sections which form the bulk of the vessels, at a conventional UK ship recycling facility. As much material as possible will be recycled.

- The eventual decommissioning of the dismantling and ILW storage facilities themselves.

Option Set

SDP has a large number of potential solutions, which have been formed into 9 options with a number of variants, 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.

The end point for all of the options is to have ILW in a form ready for final disposal in the UKs proposed GDF. The one exception to this is the Do Minimum option, which assumes *indefinite* afloat storage and therefore does not have the same end point as the other options. The table below summarises the options:

Option	Variants
0: Do Minimum	None
1: Reactor Compartment (RC) separation with interim storage at point of waste generation	Three variants for each: dismantling site at Devonport Dockyard (D), Rosyth Dockyard (R) and both (B)
2: Reactor Pressure Vessel (RPV) removal with interim storage at point of waste generation	
3: RPV removal with interim storage at a remote[1] commercial site	
4: RPV removal with interim storage at a remote MOD site	
5: RPV removal and size reduction with interim storage at point of waste generation	
6: RPV removal and size reduction with interim storage at a remote commercial site	
7: RPV removal and size with interim storage at a remote MOD site	
8: RPV removal and size reduction with interim storage at NDA site(s)	

Approach to Decision Making

The process used to assess SDP options is explained in *'SDP - Our Approach to Decision Making'* . Assessment of the options has been conducted in line with official MOD guidance and has involved the separate analysis of:

- **Operational Effectiveness (OE)**; 'how well' options meet the User Requirements as defined in the User Requirements Document (URD).
- **Whole Life Cost (WLC)** of the options through Investment Appraisal (IA)
- **Other Contributory Factors (OCF)** which are not measurable but may have a significant impact on the project.

[1] 'Remote' means a site remote from the location where dismantling occurs (the point of waste generation) which would mean that ILW would need to be transported between sites.

Operational Effectiveness

The OE of each option has been analysed using Multi-Criteria Decision Analysis (MCDA), allowing the overarching requirement to be broken down into a structured hierarchy against which experts could judge how well each option met the SDP requirements. The MCDA model was developed and populated using the outputs of three two-day workshops attended by a range of subject matter experts. The model included criteria covering compliance with policy, impact on maritime operations, health and safety and environmental impact. The OE of each option was represented by a score between 0 and 9.

Investment Appraisal

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 options. It is informed by a WLC model that has the functionality to present the cost of the options together with risk and uncertainty. The IA has focused on the measurable costs, including those needed to meet minimum legal requirements for health and safety and environmental compliance.

The WLC Model can present costs in terms of outturn, Net Present Value (NPV) or constant costs. Within the IA, NPV is the preferred form of analysis as it takes account of the time value of money and is used to appraise options over long periods of time

Other Contributory Factors

At this stage OCF that may have a bearing on the project options have been identified, but a more comprehensive and conclusive assessment of OCF will be delayed until responses from public consultation are available.

Results

The OE and IA results have been combined in a Combined Operational Effectiveness Investment Appraisal (COEIA) which is represented in Figure A below. This presents the median data values for all options but with groupings of the technical approaches identified by different colours. The lines on Figure A separate the options into three groups:

- Options with dismantling at Devonport or both sites.
- Options with dismantling at Rosyth.
- Do Minimum.

This shows that, by median value, the Devonport and Dual Site Options cost less than those at Rosyth, although the error margins would need to be reduced before these findings could be taken as conclusive.

Figure A also shows a trend for options with higher effectiveness to have lower WLC which is explained by the fact that lower WLC is associated with less complicated operations and a smaller amount of capital investment in plant.

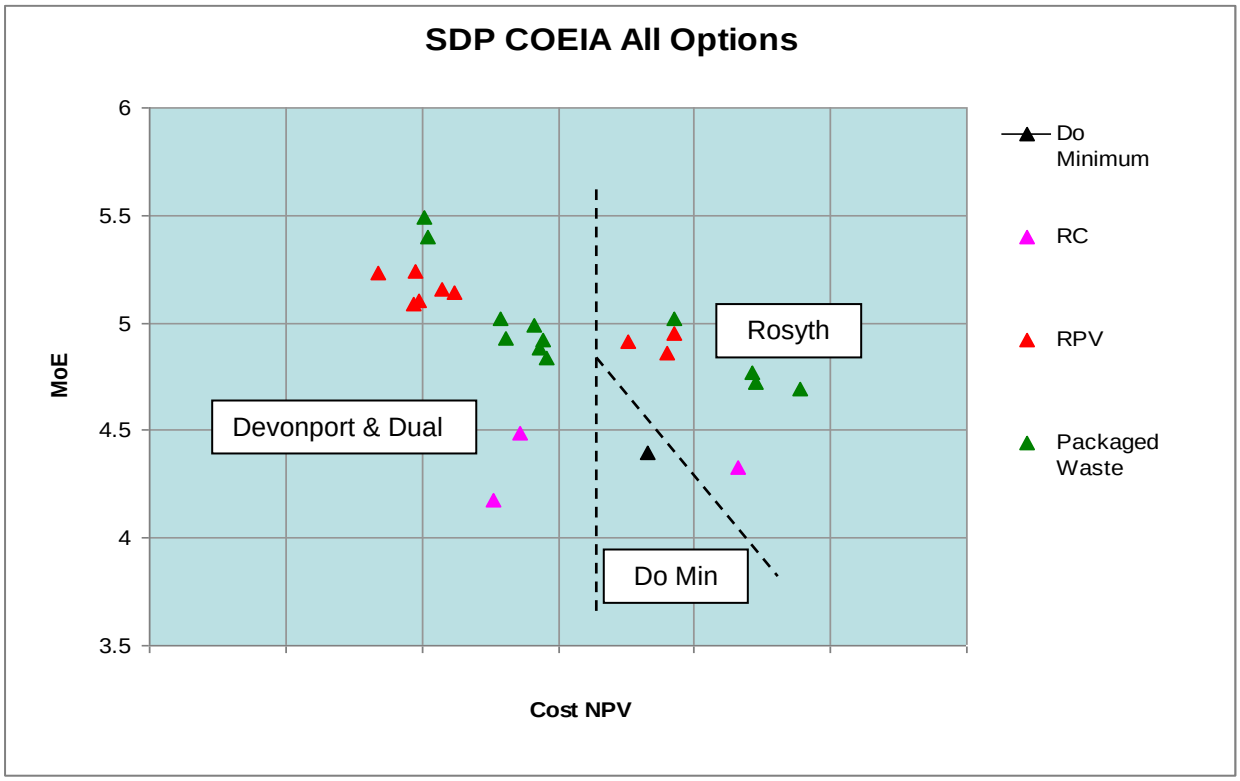

Figure A - The Cost-Effectiveness of SDP Options (Median Values)

The Figure below shows the 8 best-performing options and Options 1D (the best RC option) and 0 (Do Minimum) as comparators.

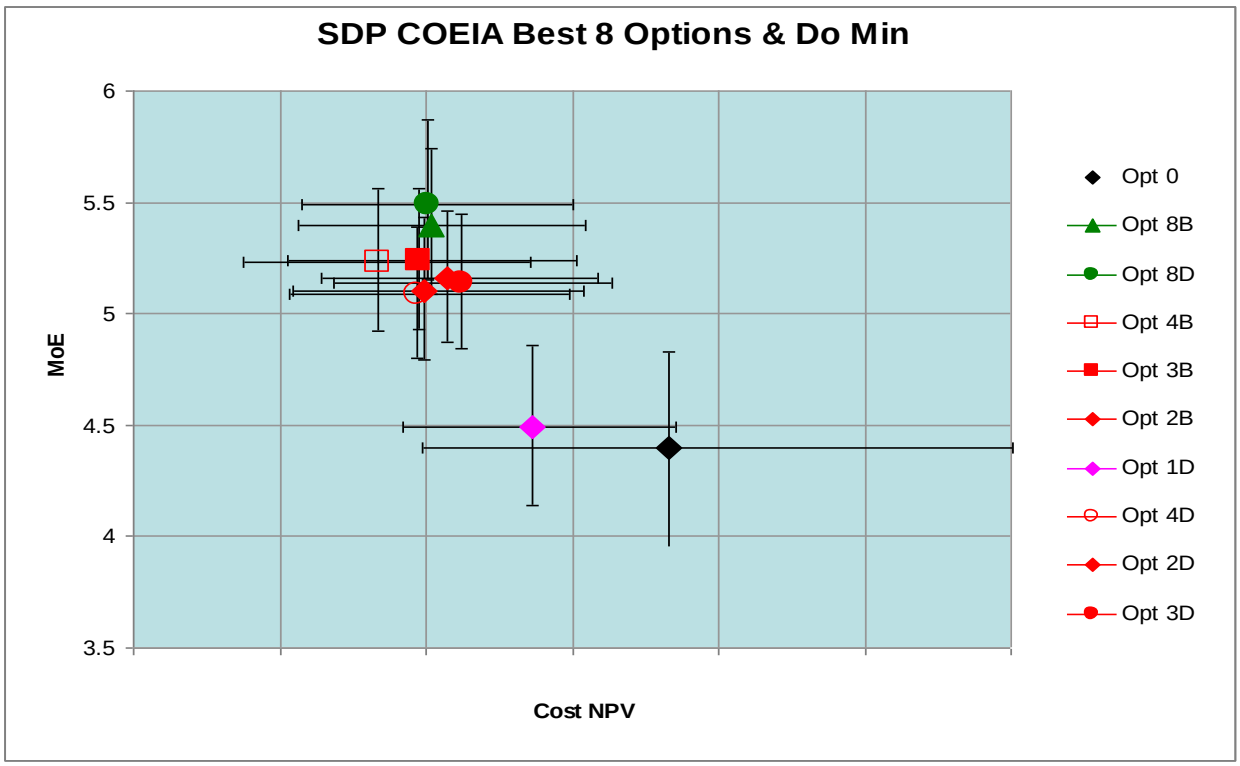

Figure B - The Cost Effectiveness of the Highest Scoring & Lowest WLC SDP Options

These best-performing options, as shown in Figure B, are in no particular order:

- Options 8B and 8D (Packaged Waste with storage at a NDA site; dismantling at dual sites and Devonport).
- Options 4B and 4D (RPV removal with storage at a commercial site; dismantling at dual sites and Devonport).
- Option 3B and 3D (RPV removal with storage at a MOD site, dismantling at dual sites and Devonport).
- Option 2B and 2D (RPV removal with storage at point of waste generation, dismantling at dual sites and Devonport).

The COEIA has not identified a single option which provides a demonstrably more cost-effective solution to SDP than the others. Nor does it provide a basis to robustly discount any of the Options (except 'Do Minimum' which is already discounted). Further work will therefore be required in order to arrive at clear recommendations and this will involve testing assumptions and opportunities, refining cost estimates and reviewing the whole assessment in the light of public consultation responses. Nonetheless, for purposes of making proposals in consultation, it is possible to propose tentative groupings and rankings of the cost-effectiveness of the options based on analysis to date. These groupings are shown in Table A (below).

Rank	Options	Summary
1st RANK (greatest potential)	Options: 8D/8B (Packaged Waste with NDA storage) & 2D/2B; 3D/3B; 4D/4B (RPV removal).	The majority of these options have an effectiveness which is higher by a statistically significant margin than Options 1 and 0. The RPV options (2 to 4) offer the greatest potential to take advantage of future opportunities which may deliver significant WLC savings). These 8 options have both the highest 8 median OE values and the lowest 8 median WLC values.
2nd RANK	Options: 5D/5B; 6D/6B; 7D/7B (Packaged Waste)	These options do not perform as well as those in the first rank, as they all have lower median effectiveness values and higher median WLC values than Options 2 to 4 and 8 (D and B variants). They foreclose on future opportunities and do not offer the policy benefits of NDA storage.
3rd RANK	Rosyth Variants 2R, 3R, 4R, 5R, 6R, 7R, 8R (RPV and Packaged Waste)	The Rosyth (R) variants all have lower effectiveness than their equivalent Devonport (D) or Dual Site (B) equivalents, with the single exception of 1B, which performs less effectively than 1R. The median WLC of all the Rosyth options are all higher than the median WLC of the Devonport and Dual Site options. These variants are less effective due to moving submarines to Rosyth with the attendant impacts on the maritime enterprise resulting from use of the dockyard facilities.
4th RANK (least potential)	Options 1D, 1B & 1R (RC Separation)	These options have an effectiveness which is less than that of the highest ranking options by a statistically significant margin. The impact on the maritime enterprise and the potential for failure to meet policy objectives on nuclear decommissioning in the future makes these options only marginally viable.
5th RANK (comparator)	0 (Do Minimum)	These options have an effectiveness which is less than that of the highest ranking options by a statistically significant margin. It is only a comparator has a different end point to all of the other options: he submarines remain in afloat storage indefinitely.

Table A - Tentative Ranking of SDP Options

Figure C shows a grid of all the options and their variants with the colour coding from Table A applied.

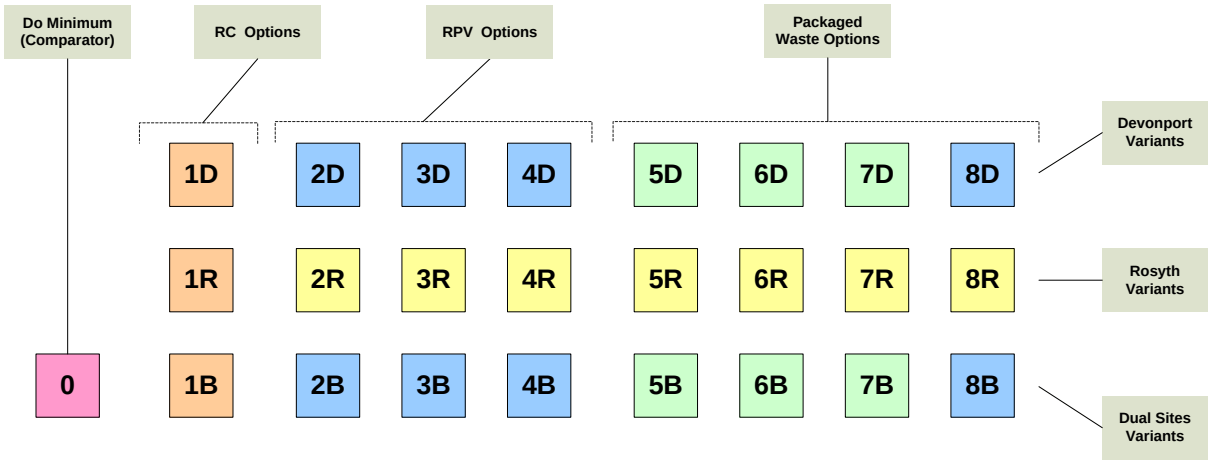

Figure C - Current standing of SDP Options based on analysis to date

Conclusions

In addition to the proposed rankings above, the following key conclusions emerge from the analysis:

- The environmental criteria were not found to discriminate significantly between the options in terms of OE, which demonstrates that they all have a similar level of environmental impact.
- The Health and Safety (H&S) criteria were also not found to discriminate significantly between the options in terms of OE. This is mainly because the assessment found that all options would be able to achieve the legally required standards.
- Options involving ILW storage at the point of waste generation showed no net advantages over other storage categories in terms of either OE or WLC.

Proposed Option

Whilst understanding that none of the options has emerged as a 'clear winner' there is value in proposing an option as the leading candidate around which public consultation can be focused. The proposed option is **RPV removal and storage with initial dismantling at both Devonport and Rosyth Dockyards.** At this stage, no site is proposed for ILW storage but the proposed way forwards involves working jointly with NDA to arrive at a decision on whether to use NDA storage facilities or to develop a new SDP storage facility.

RPV removal preserves the opportunity for disposal to the proposed GDF without the need for size reduction, which could reduce WLC significantly. More generally it retains the ability to take advantage of future opportunities by delaying size reduction until later.

Initial dismantling at both Devonport and Rosyth Dockyards provides latitude to optimise liabilities at both sites (earliest exit from Rosyth whilst avoiding congestion in Devonport). This option also avoids the need to transport submarines before the radioactive materials are

removed.

There has been found to be no net advantage in effectiveness or WLC to storage at point of waste generation compared to storage at a remote location, so if a new build store for SDP were selected as the best option, the site selection process would consider suitable nuclear sites owned by MOD and industry (if commercial site owners chose to bid). Such a process would require further stakeholder engagement and environmental assessment.

Responses from public consultation and other further assessment will be used to refine the analysis to arrive at recommendations for the SDP MGBC.

1. Introduction

1.1. Aim

1.1.1. The aim of the Submarine Dismantling Project (SDP) is to deliver a safe, secure, environmentally responsible, timely and cost-effective solution for the dismantling of 27 of the UK's defueled nuclear powered submarines.

1.1.2. At the end of its Assessment Phase, SDP must submit recommendations in its Main Gate Business Case (MGBC) to the Investment Appraisals Committee (IAC) on options for:

- The technical approach for removing radioactive materials from submarines (the 'initial dismantling' activity);
- The site(s) to be used for the initial dismantling activity;
- The type of site to be used for interim storage of Intermediate Level Waste (ILW) that is awaiting disposal in the UK's proposed Geological Disposal Facility (GDF).

1.1.3. Before developing its recommendations, the project is committed to public consultation on these options and its proposals to progress the project. The current assessment of these options is set out in this Operational Analysis Supporting Paper (OASP) which summarises the currently available evidence and underpins proposals for the most cost-effective approach to meeting the aims of the project.

1.1.4. The OASP includes a Combined Operational Effectiveness and Investment Appraisal (COEIA) and initial scoping of Other Contributory Factors (OCF), linked to the SDP User Requirements Document[2] (URD) and Benefits Report[3]. The Operational Effectiveness (OE) analysis and Investment Appraisal (IA), which underpin the COEIA, have been conducted following MOD guidance and have been subject to internal MOD scrutiny by D Scrutiny and DASA/DESA. The process used to assess SDP options is explained in *'SDP - Our Approach to Decision Making'*.

1.1.5. Figure 1 shows the hierarchy of key SDP decision making documents and how they support proposals for public consultation.

1.2. Strategic Environmental Assessment and Public Consultation

1.2.1. The project is undertaking a Strategic Environmental Assessment (SEA) in accordance with the relevant legislation[4] to assess the likely significant environmental effects of SDP activities and options, with key findings incorporated into the IA, OE and OCF analyses. Public consultation (to be called the 'Submarine Dismantling Consultation') starts on 28 October 2011 and will seek the public's views on the project's proposals and the underpinning assessment of the options. The consultation will also seek the public's views on the environmental assessment

[2] SDP User Requirements Document, v5.0, dated October 2011.
[3] SDP Benefits Report, v1.1, dated October 2011
[4] Strategic Environmental Assessment Directive, 2001/42/EC

of the options and project activities generally (described in the SEA Environmental Report and its Non-Technical Summary). The consultation will be at a local and national level with local events focussed around the candidate initial dismantling sites.

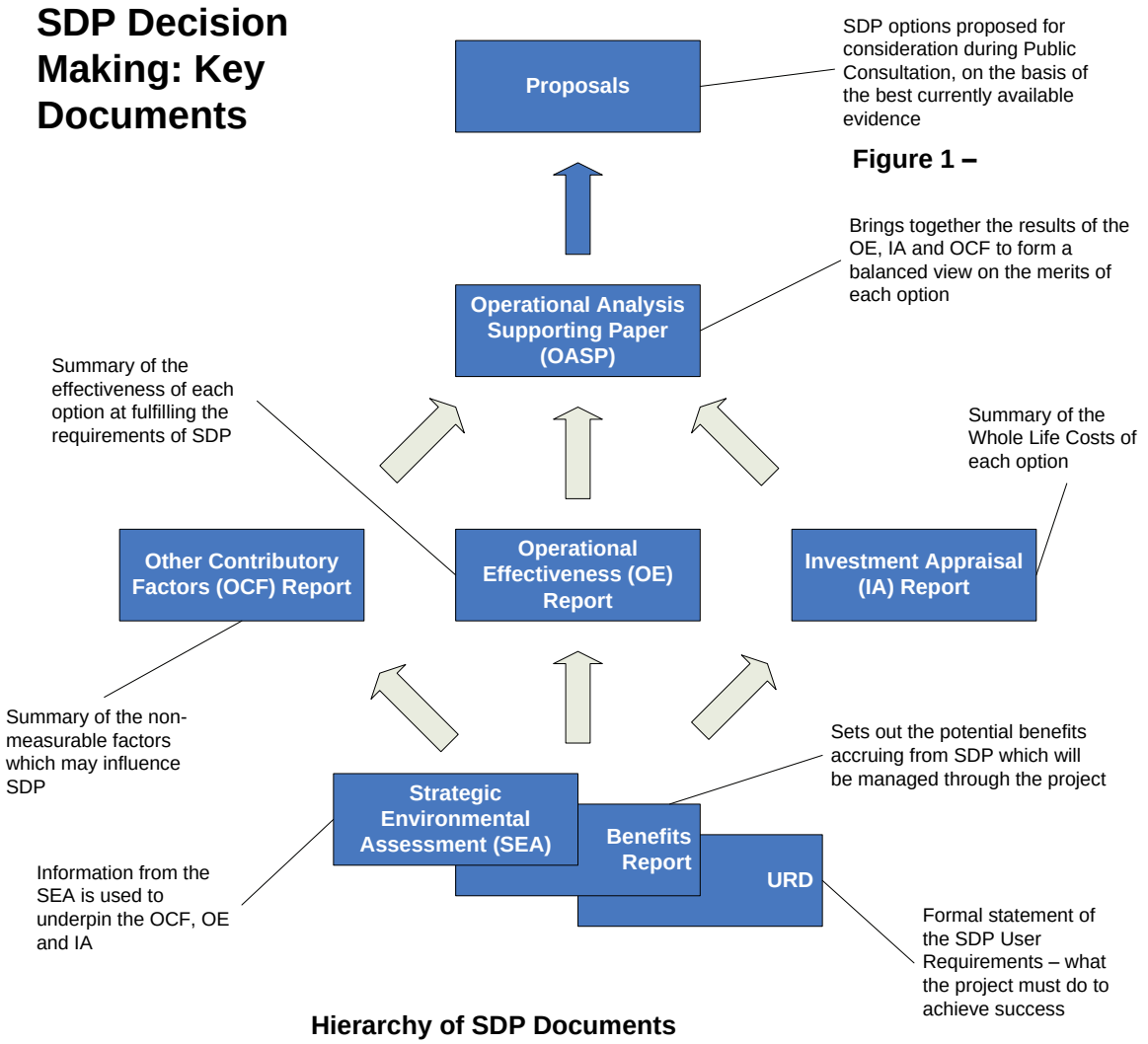

Figure 1 – Hierarchy of SDP Documents

1.2.2. This interim version of the OASP has being delivered to support consultation, and provides the rationale for *proposed* (as opposed to *recommended*) options for consideration. After public consultation, the OASP will be revised and updated to form recommendations for the project's MGBC as follows:

- The COEIA, and underpinning OE and IA, will be revised where sound technical concerns have been raised regarding the analysis, assumptions or input data.
- The COEIA will also be revised where further work is required to test underpinning assumptions or the feasibility of key opportunities, which may lead to the generation of new or revised options.

- The OCF will be assessed on the basis of findings from consultation to determine what bearing OCF have on the options.

- The SEA (and its inputs to the OE, IA and OCF) will be updated on the same basis, if necessary.

1.2.3. Such revision will require formal agreement from the SDP team and an audit trail to data underpinning any technical concerns arising from consultation. SDP is following the HM Government Code of Practice[5] for consultation, which stresses the need to consult at a time when there is still potential to influence the policy outcome, to analyse consultation responses carefully and to provide clear feedback to participants.

1.3. Document Structure

1.3.1. The OASP has been structured as follows:

- Section 2 describes the scope, scale and timescales of the project and sets out the Key User Requirements (KURs).

- Section 3 describes the benefits arising from the project, their provenance and how they will be managed.

- Section 4 describes the set of options and variants which have been put forward for the project, including the 'Do Minimum' comparator.

- Section 5 summarises the results of the Operational effectiveness (OE) analysis.

- Section 6 summarises the results of the Investment Appraisal (IA).

- Section 7 presents the Combined Operational Effectiveness and Investment Appraisal (COEIA) results.

- Section 8 describes the Other contributory Factors (OCF).

- Section 9 provides a summary of findings.

- Annex A contains a list of abbreviations.

- Annex B provides definitions for key concepts and terms in the OASP.

- Annex C provides references.

- Annex D lists the benefits accruing from SDP

- Annex E provides a list of key assumptions.

- Annex F provides a table of detailed results from the OE.

[5] www.bis.gov.uk/policies/better-regulation/consultation-guidance

- Annex G provides a table of the detailed results from the IA.

2. Project Scope and Scale

2.1. Single Statement of User Need (SSUN)

2.1.1. "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 MODs 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."

2.2. Background

2.2.1. When a nuclear powered submarine leaves service with the Royal Navy, it undertakes a process known as De-fuel, De-equip and Lay-Up Preparation (DDLP)[6]. This is conducted as soon as practicable, but is dependent on the availability of suitable docks and facilities. The reactor is defuelled and the fuel is removed for long-term storage at the Nuclear Decommissioning Authority (NDA) site at Sellafield. The remaining radioactive material (mainly irradiated steel, classed as ILW is contained securely in the reactor compartment and remains in the submarine, which is stored safely afloat. The 17 nuclear powered submarines which have left naval service are stored safely afloat, with 7 at Rosyth Dockyard and 10 at Devonport Dockyard. To date, 6 of the 17 await defuelling.

2.2.2. The primary reasons for undertaking SDP are as follows:

- Although afloat storage has proved to be a very safe arrangement for over 20 years, it does not fulfil Government[7] and MODs[8] nuclear decommissioning policy which requires that nuclear decommissioning activities should be carried out as soon as reasonably practicable.

- The capacity to store further submarines will be reached by 2020 and there are no existing berthing facilities suitable for the Vanguard Class submarines when they leave service. The cost of developing a new berthing facility has been estimated at [redacted] and has been included in the WLC model for the Do Minimum option, which assumes continued afloat storage.

- The cost of maintaining out-of-service submarines is increasing as they age and increase in number. These increasing costs have been included in the WLC model for the Do Minimum option.

- The ability to deliver savings by reducing the overall footprint required to support out-of-service submarines, which enables the efficient use of sites and facilities to support in-service submarines.

[6] Devonport Dockyard is the only nuclear licensed site in the UK planned to undertake this activity in the future.
[7] The Decommissioning of the UK Nuclear Industry's Facilities – Amendment to Command 2919, DTI Paper, Sep 04.
[8] "MOD policy for decommissioning and the disposal of radioactive waste and residual nuclear material arising from the nuclear programme", issued 9 Oct 07.

- Concerns have been expressed by the public (in earlier consultations), regularly in the local press and in Parliament about the duration of afloat storage and the need for progress in developing a solution.

- The lack of a proven solution for submarine dismantling is recognised as a risk within the business cases for future submarine classes and to the sustainability of the submarine programme as a whole.

2.2.3. These issues underline the need for a long-term solution for submarine dismantling which includes arrangements for interim land storage of the ILW arising and achieves the best value for the recyclable materials from the submarines[9].

2.3. Scope

2.3.1. The project scope includes past and current classes of Royal Navy nuclear submarines, 27 in all. Whilst the current project scope does not include dismantling of Astute class or Successor submarines, the project is required, where possible, to retain flexibility for future classes; namely to preserve options for adapting or life-extending dismantling facilities should this be required in the future. The project includes:

- The initial dismantling of the submarine in a nuclear licensed facility to remove ILW and all radioactive contamination.

- The interim storage on land of the resultant ILW until at least 2040, pending the availability of the proposed GDF. As the proposed GDF may not be available to receive SDP ILW until sometime after 2040, there is a requirement for any new ILW storage facilities to be designed to last up to 100 years, as recommended in the Committee on Radioactive Waste Management (CoRWM) report [10,11].

- The breaking and final dismantling of the submarine, once free of all radioactivity, at a conventional ship recycling facility. In this regard as much material as possible will be recycled.

- Transportation of submarines and radioactive waste, as required, between facilities undertaking the above activities.

- The eventual decommissioning of the dismantling and ILW storage facilities themselves.

2.3.2. MOD recognises the public interest in these activities and has committed to public consultation before major decisions are made, and to openness and transparency in the decision making process.

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[9] The scrap value per submarine has been estimated by the DSA to be between [redacted] and [redacted] (net) per submarine, after transport and dismantling costs have been removed.
[10] Managing our Radioactive Waste Safely, CoRWMs recommendations to Government, 31 July 2006, available at http://corwm.decc.gov.uk
[11] Response to the Report and Recommendations from the Committee on Radioactive Waste Management (CoRWM), By the UK Government and he devolved administrations, 25 October 2006. http://www.corwm.org.uk/Pages/Lnk_pages/key_issues.aspx

2.3.3. The project has been divided into a number of Phases and Gates in accordance with the principles of the CADMID cycle[12] and the project passed Initial Gate in 2002. The current dates corresponding to each stage and milestone of the project are maintained in the Project Management Plan[13] (PMP).

2.4. Capability Stakeholders & Customer

2.4.1. The Defence Nuclear Executive Board (DNEB) sets nuclear decommissioning policy for the Department. Head of Deterrent & Underwater Capability (DUWC) is the Sponsor and Senior Responsible Owner (SRO).

2.4.2. Owing to the nature of the project, stakeholders are many, have varied remits, and include:

- Internal MOD stakeholders.
- Other Government Departments (OGDs) including the Department of Energy and Climate Change (DECC) and the Department of the Environment Food and Rural Affairs (DEFRA).
- Devolved Administrations (the Scottish Government, Welsh Government and Northern Ireland Assembly).
- NDA.
- Regulatory Authorities and Agencies and Statutory Bodies.
- Local Government.
- Non Governmental Organisations (NGOs) and Community Based Organisations (CBOs).
- The general public and local communities.

2.4.3. A full list of stakeholders is presented in the PMP.

[12] See Annex B Definitions.
[13] SDP Project Management Plan, ISM, Issue 9.0, dated August 2011.

3. Benefits

3.1. Provenance

3.1.1. A workshop attended by a range of MOD stakeholders and an SDP Advisory Group observer was held on 2 November 2010 to capture SDP benefits and disadvantages. The results of this workshop are described in the SDP Benefits Report[14], and the results of the workshop have been used to generate a set of 11 high level benefits, which will be monitored by SDP to ensure that the project delivers a successful outcome. The profiles, which include metrics, baseline performance, target performance and suggested means of collection, are currently in draft form and will mature in time for MGBC, at which time a detailed plan for their implementation will also be complete.

3.1.2. SDP has a long planned duration as it is assumed that the 27 submarines which are in scope will be dismantled at a rate of one per year[15]. Benefits are usually realised after the conclusion of a relatively short-lived project but in the case of SDP, benefits will be accrued throughout the project lifetime and will be monitored on that basis.

3.1.3. Benefits accruing from SDP will be owned by the Project Sponsor, Cap DUW, and managed by ISM on behalf of D Submarines. In some cases, indirect benefits will accrue to other parts of MOD or external stakeholders, but they too will be managed by ISM. Close liaison with the MCP and industry suppliers to the submarine enterprise will be required.

3.2. Description of Benefits

3.2.1. Annex D identifies the benefits arising from SDP and their relationship to requirements within the URD or, in the case of some indirect benefits to external stakeholders, OCFs. It also includes the potential business metrics, the type of measurement to be used to gauge quantifiable components of performance. The type of benefits are defined as follows:

- Operational *and/or* Financial.
- Direct (an outcome of successfully meeting the user requirements set out in the URD) *or* Indirect (a favourable side-effect arising from programme success).

3.2.2. The benefits are:

- Improved Public Confidence
- Positive Socio-Economic Impact
- Wider Economic Benefit to MOD

[14] SDP Benefits Report, v1.1, dated October 2011.
[15] This assumption will be tested and an understanding of the impact of different dismantling rates developed after public consultation but before MGBC submission.

- Minimisation of Costs Associated with Submarine Liability
- Sustainable, Safe Removal and Disposal of Non-hazardous Waste
- Sustainable, Safe Removal and Disposal of Hazardous Waste
- Sustainable, Safe Removal and Disposal of LLW/VLLW
- Bounded and Managed ILW
- Avoidance of Operational Impact
- Maintenance of UK Industrial Capacity
- Mitigation of Environmental Impact

4. Option Set

4.1. Summary of Options

4.1.1. SDP has a large number of potential solutions, which have been formed into 9 options with a number of variants, 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.

4.1.2. Each option and variant also includes the re-use, recycling or disposal of non-radioactive components and transport of submarines and their waste. The options are described in Section 4.3 after a discussion of their derivation.

4.2. Derivation of Option Set

4.2.1. Technical Approach

4.2.2. A number of 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. The options are:

- 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.

4.2.3. Initial Dismantling Site(s)

4.2.4. Three generic types of sites were assessed for their suitability for SDP.

- Greenfield sites: sites that are undeveloped (or have reverted to a ‘natural’ state) and with no existing Authorisation or License for nuclear work.
- Brownfield sites: sites that are already developed but do not have an existing Authorisation or Licence for nuclear work.
- Existing authorised / licensed sites: sites that are already developed and have an existing Authorisation or Licence for nuclear work.

4.2.5. Initial screening work concluded, on value for money grounds, that Greenfield and

Brownfield sites will only be considered further if no suitable existing licensed/authorised site is available. The Greenfield and Brownfield site options are, therefore, not entirely discounted from further consideration (and have been assessed within the SEA) but were excluded from the long list of site options, which comprised the list of all existing nuclear authorised and licensed sites in the UK[16] .

4.2.6. This long list of sites was screened to assess their suitability for initial dismantling. against a pre-defined set of mandatory threshold criteria[17], based on Measures of Effectiveness (MoE) recorded in the URD. The remaining shortlisted options were:

- Devonport Dockyard;
- Rosyth Dockyard;
- Both Devonport and Rosyth Dockyards.

4.2.7. The dual site option utilises both of the identified sites for submarine dismantling but, as duplication of all facilities would be prohibitively expensive[18], only one size reduction facility is assumed. It has been assumed that 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).

4.2.8. Generic ILW Storage Site(s)

4.2.9. The same three generic types of sites were assessed for their suitability for interim ILW storage: Greenfield sites; Brownfield sites; and existing authorised / licensed sites. It was concluded that Greenfield and Brownfield sites will only be considered further if no suitable existing licensed / authorised site is available[18].

4.2.10. At this stage, it has not been possible to screen the long-list of existing nuclear licensed/authorised sites because of the different contexts and developing strategies affecting different types of site. For example, NDA is in the process of exploring opportunities to share its current and planned storage facilities to improve value for money and reduce environmental impact of new store build. Such a development in the NDA's strategy would be an important consideration in any site screening exercise. Commercial sites, meanwhile, would need to be screened through a commercial process inviting expressions of interest from site owners. As an intermediate step, therefore, four possible types of ILW storage site have been identified and assessed at a generic level:

- *Sites at the point of waste generation* (i.e. 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

[16] A register of nuclear licensed sites in the UK is available on the Health & Safety Executive web site at http://www.hse.gov.uk/nuclear/licensees/pubregister.pdf.
[17] SDP Site Criteria & Screening Paper, Issue 2.1 dated May 2011. Available at www.mod.uk/submarinedismantling
[18] The cost of a single size reduction facility has been estimated at around [redacted]. The cost of a single facility is thus expected to provide significant savings over the cost of two facilities, even when additional costs are taken into account such as the movement of RPVs between sites.

Packaged Waste being transported to one of the two sites after initial dismantling, for interim storage[19].

- *Commercial sites remote from the point of waste generation*. 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.

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

- *NDA site(s)* – all remote from the point of waste generation. It may be possible for MOD to use NDA storage facilities for storage of ILW arising from SDP.

4.2.11. 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[20] 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.

4.3. Option Set

4.3.1. The options are described fully in the SDP Options Report[21] and summarised in Table 1.

Option	Variants
Option 0: Do Minimum	None
Option 1: Reactor Compartment (RC) separation with interim storage at point of waste generation[22] and at a later date size reduction of ILW before transfer to the proposed GDF	Three variants for each: dismantling site at Devonport Dockyard (D), Rosyth Dockyard (R) and Both (B)
Option 2: Reactor Pressure Vessel (RPV) removal with interim storage at point of waste generation and at a later date size reduction of ILW before transfer to the proposed GDF	

[19] 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.
[20] For economic reasons, the project has assumed that no transport of RCs would be undertaken except in Option 1B which includes transport of RCs 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. The additional cost of remote storage of RCs has been estimated as [redacted].
[21] SDP Options Report, v1.0, dated February 2011.
[22] Devonport (D), Rosyth (R) or Both (B).

Option	Variants
Option 3: RPV removal with interim storage at a remote[23] commercial site and at a later date size reduction of ILW before transfer to the proposed GDF	
Option 4: RPV removal with interim storage at a remote MOD site and at a later date size reduction of ILW before transfer to the proposed GDF	
Option 5: RPV removal and size reduction to form Packaged Waste with interim storage at point of waste generation	
Option 6: RPV removal and size reduction to form Packaged Waste with interim storage at a remote commercial site	
Option 7: RPV removal and size reduction to form Packaged Waste with interim storage at a remote MOD site	
Option 8: RPV removal and size reduction to form Packaged Waste with interim storage at NDA site(s)	

Table 1 - SDP Options

4.3.2. It should be emphasised that *all* Options (except Do Minimum) conclude with the ILW in the form of Packaged Waste ready for disposal in the proposed GDF. The key difference is that Options 5 to 8 assume that size reduction happens shortly after initial dismantling, with ILW being placed in interim storage as Packaged Waste; whereas Options 1 to 4 assume that the RCs or RPVs are put in interim storage with size reduction conducted only when the proposed GDF is ready.

4.3.3. As noted above, Do Minimum (Option 0) represents a continuation of afloat storage of redundant submarines but identifies and implements the lowest incremental activities that can meet all mandatory requirements. This option is a comparator for analytical purposes and does *not* have the same end point as the technical options described above (i.e. final disposal in the proposed GDF).

4.3.4. Figure 2 provides a graphical summary of the Options.

[23] 'Remote' means a site remote from the location where initial dismantling occurs (ie. remote from the point of waste generation) meaning that off-site transportation of ILW would be required.

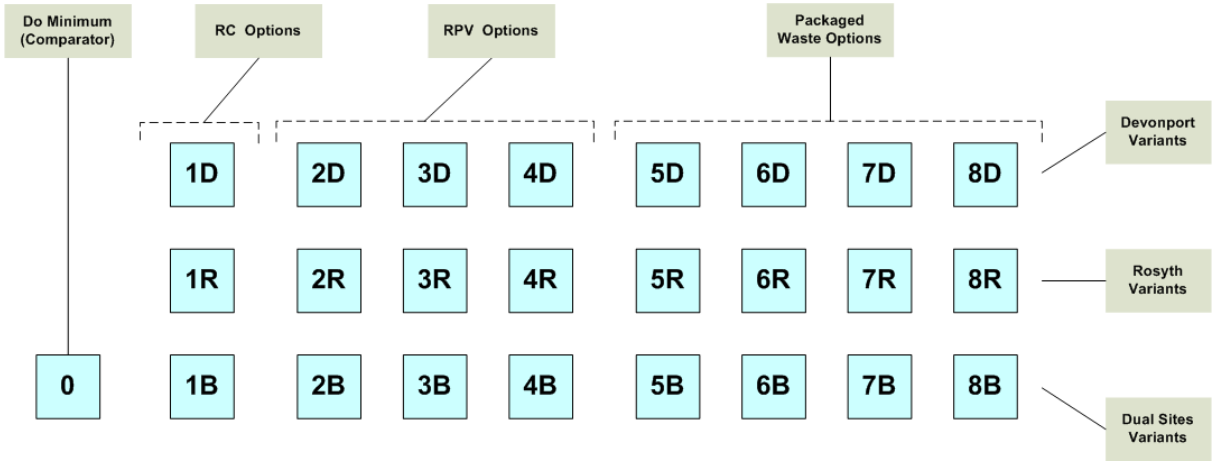

Figure 2 - Graphical Representation of Options

5. OE Analysis

5.1. Method of Analysis

5.1.1. SDP aims to develop a solution to deal with dismantling, recycling and disposal of existing assets rather than with developing a new military capability. Operational Effectiveness has therefore been assessed on the basis of 'how well' the different approaches to dismantling, storage and disposal meet the User Requirements as defined in the URD. The full results of the OE and a more detailed explanation of the process used to generate results is contained in the OE Report[24].

5.1.2. The ability of each option to meet the URD has been analysed using Multi-Criteria Decision Analysis (MCDA). This approach was adopted because it allowed the overarching requirement to be broken down into a structured hierarchy against which Subject Matter Experts (SMEs) could judge how well each option met the SDP requirements. The MCDA model was developed and populated using the outputs of three two-day workshops attended by a range of SMEs from the MOD, OGDs and industry:

- **Criteria Workshop:** MCDA criteria were developed from the MoE against each user requirement, with scoring scales between the threshold values (the minimum required level of performance) and objective values (the maximum level of performance above which no further benefit is accrued). The panel of SMEs agreed a set of 20 MCDA criteria based on the draft criteria proposed to them at the workshop.

- **Weighting Workshop:** each member of the panel attending provided a weight for each MCDA criteria and group of criteria based upon their significance towards meeting the SDP requirements. The weighting scale was from 0 to 10.

- **Scoring Workshop:** each member of the panel scored each option and variant against the MCDA criteria. The scoring scale was from 0 to 9.

5.1.3. D Scrutiny attended each of the workshops, as did representatives of the SDP Advisory Group (AG). Regulators, including the Environment Agency (EA) and Office of Nuclear Regulation (ONR), also attended the first criteria workshop. Whole Life Cost (WLC) was explicitly excluded from discussion at the workshops, as were non-quantifiable issues such as socio-economic impact or political factors, except where necessary to ensure that these issues were being addressed consistently elsewhere in IA or OCF analyses.

5.2. Derivation of MCDA Structure

5.2.1. The structure of the MCDA Model is shown in Figure 3. The criteria (at the lowest level of the structure) influence the operational benefits achieved in the levels above, as indicated by the arrows linking the criteria. In the MCDA model, each linkage has a weight assigned to it, indicating its relative importance. The workshop then scored each option against each criterion, with the overall effectiveness of each option determined by multiplying each score by each weight and summing the

[24] SDP OE Report, Issue 1.0 dated October 2011

results.

5.2.2. The different coloured boxes in the MCDA model shown below (Figure 3) identify the four main groups of criteria:

- Blue: Reduction in Impact to Government and MOD – Policy **(POL).**
- Yellow: Reduction of impact to Operations **(OP).**
- Purple: Minimisation of Health and Safety **(H&S)** Risk
- Green: Reduction of Environmental **(ENV)** Impact.

5.2.3. The MCDA model captured the effects of variability in scores and weights captured in the workshops using Monte Carlo simulation which sampled from the across the range of weight and score data to generate a distribution of effectiveness for each option[25]. This allowed 10%, 50% and 90% values to be generated for each option, with the range 10% to 90% providing error bars measuring confidence around the median of 50%. The model and input data was subject to Verification and Validation (V&V) by the project's team of industry experts[26].

5.2.4. The Strategic Environmental Assessment (SEA) being undertaken by SDP informed the definition and scoring of the Environmental group of 6 specific criteria (listed in Table 2). The SEA also informed the development of OCF to ensure that coherence was established between the decision making process outlined in this OASP and findings from the SEA.

[25] This operated by generating histograms for each set of weights (for the 20 criteria) and for each set of scores (for the 25 options scored against the 20 criteria, amounting to 500 in all), and then sampling randomly from the combinations 10,000 times. This generates a distribution of results for each option.
[26] Nuvia Review of SDP MCDA Monte-Carlo Model and Associated Data Checking, dated 30 June 2011.

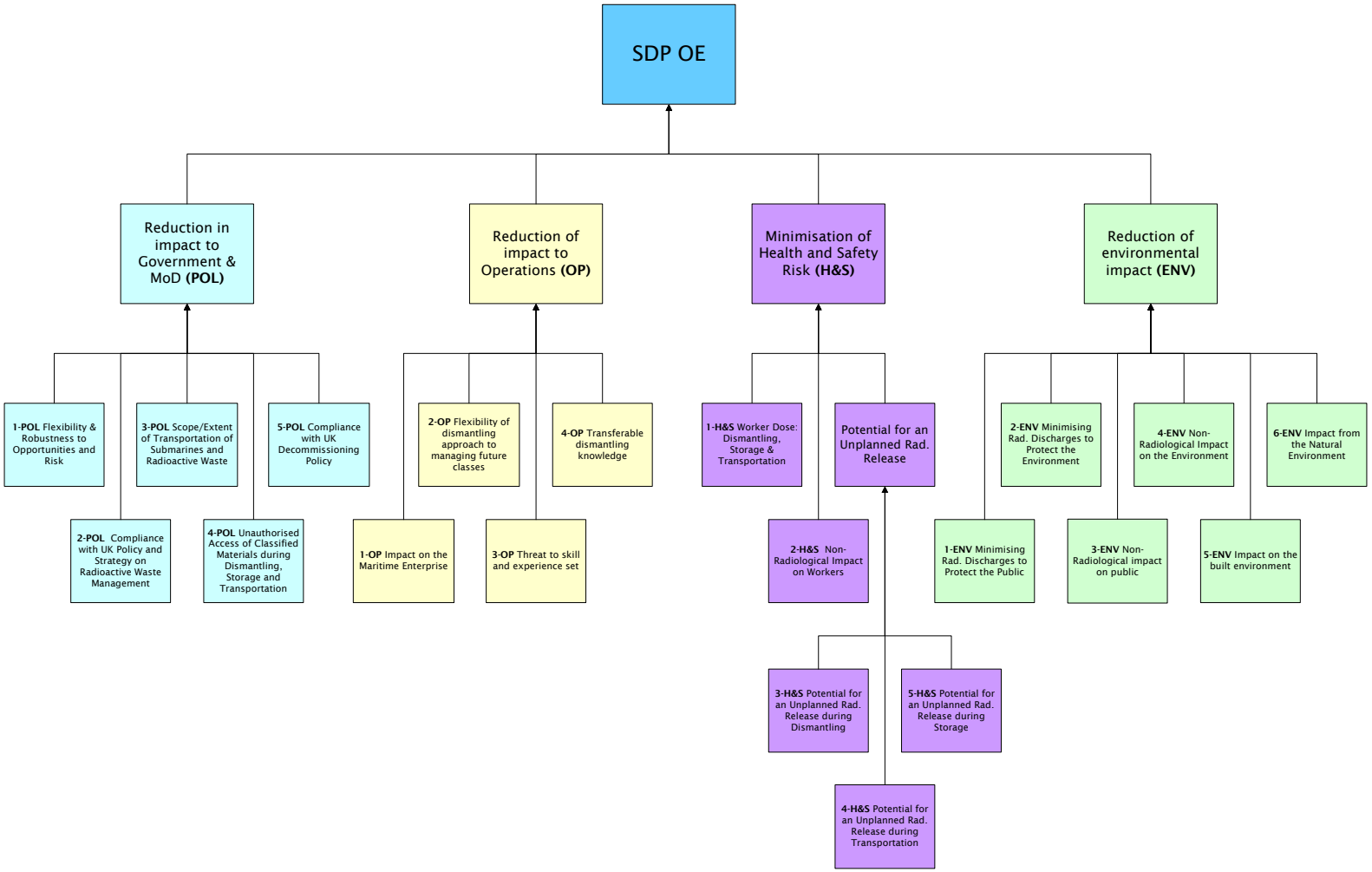

Figure 3 - MCDA Model

5.3. Criteria and Weights

5.3.1. Table 2 shows the criteria derived and agreed in the Criteria Workshop and weighted[27] in the Weighting Workshop. The MCDA model structure was built in three levels below the overall OE. The weights assigned to the linkages between the levels of the model have also been included in the table. The results, including detailed notes of deliberations at the Workshops, are included in the OE Report.

Category Weight	Category	Criterion Title		Criterion Weight
25.2%	Reduction in Impact to Government and MOD (POL)	1-POL: Flexibility and Robustness to Opportunities and Risk		**4.8%**
		2-POL: Compliance with UK Policy and Strategy on Radioactive Waste Management		**4.1%**
		3-POL: Scope/Extent of Transportation of Submarines and Radioactive Waste		**4.3%**
		4-POL: Unauthorised Access to Classified Materials during Dismantling, Storage and Transportation.		**6.6%**
		5-POL: Compliance with UK Decommissioning Policy		**5.3%**
32.2%	Reduction of impact to Operations (OP)	1-OP: Impact on the Maritime Enterprise and Wider MOD Operations		**12.2%**
		2-OP: Flexibility of Dismantling Approach to Managing Future Classes		**7.1%**
		3-OP: Threat to Skill and Experience set		**8.3%**
		4-OP: Transferable Dismantling Knowledge		**4.6%**
17.4%	Minimisation of Health and Safety Risk (H&S)	1-H&S: Worker Dose: Dismantling, Storage and Transportation		**0.0% (see below)**
		2-H&S: Non-Radiological Impact on Workers		**8.3%**
		U-H&S Potential for an Unplanned Radiological Release **(9.1%)**	3-H&S: Potential for an Unplanned Radiological Release during Dismantling	**3.2%**
			4-H&S: Potential for an Unplanned Radiological Release during Storage	**2.5%**
			5-H&S: Potential for an Unplanned Radiological Release during Transportation	**3.4%**
25.2%	Reduction of Environmental Impact (ENV)	1-ENV: Radiological Discharges to the Public		**5.2%**
		2-ENV: Radiological Discharges to the Environment		**4.5%**
		3-ENV: Non-Radiological Impact on the Public		**4.5%**
		4-ENV: Non-radiological Impact on the Environment		**4.3%**
		5-ENV: Impact on the Built Environment		**3.3%**
		6-ENV: Impact from the Natural Environment		**3.4%**

Table 2 - Summary of SDP Criteria and Weights

5.3.2. One of the criteria, 1-H&S *Worker Dose: Dismantling, Storage and Transportation*, was weighted and scored but, under advice from DASA/DESA, was instead

[27] In the table the weightings given are mean values derived from the MCDA model, which sampled from the weights and scores provided.

addressed as part of the IA to be consistent with the NDA's approach[28]. It has therefore been weighted as zero[29]. The qualitative discussions regarding the dose for each option are included in the OE Report, but the quantitative differences are considered in financial terms in the IA[30].

5.4. OE Results

The data captured at the Scoring and Weighting Workshops were entered into the MCDA model and overall OE scores generated. Figure 4 shows the results from the MCDA model, following 10,000 runs, and shows the 10th, 50th and 90th percentile values. Table F-1 in Annex F provides a table showing all the values from which the figure was derived. Note that the scale extends from 3.5 to 6; the full range of potential scores is from 0 to 9.

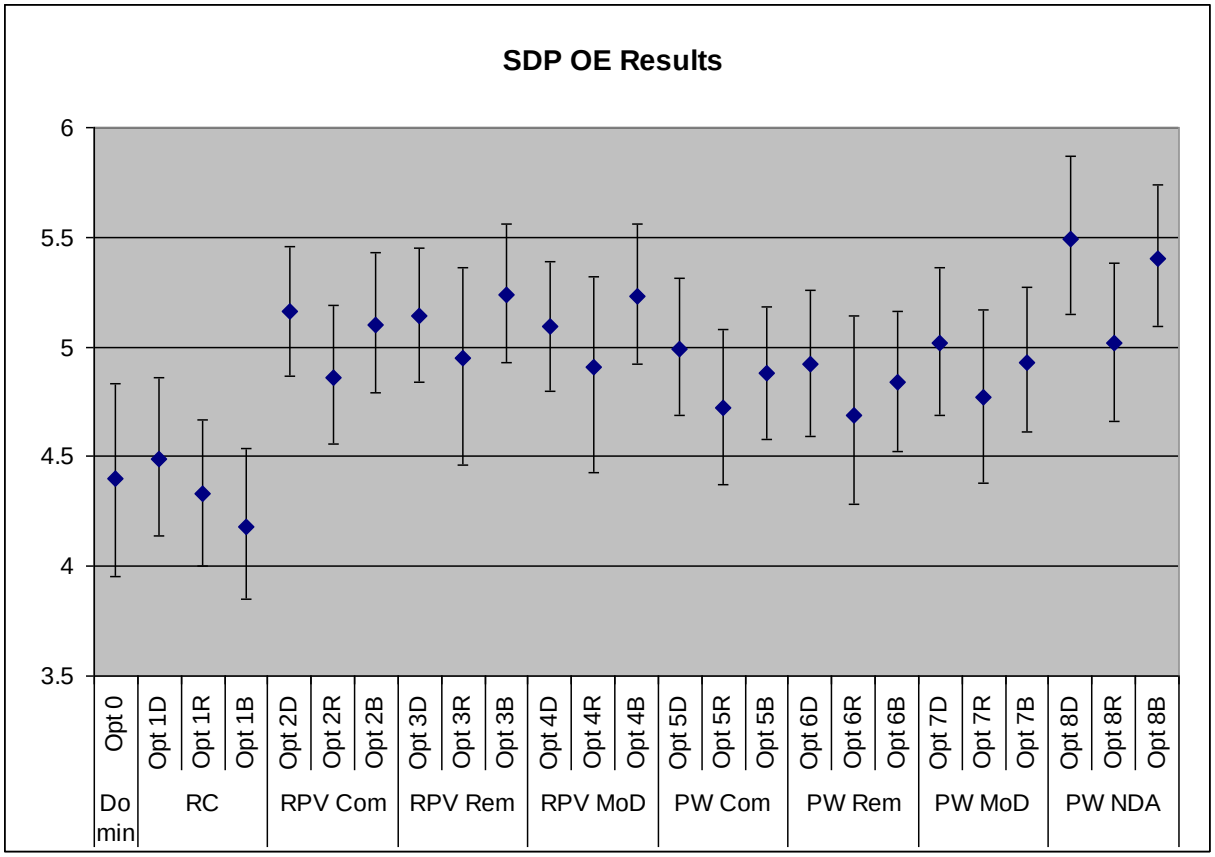

Figure 4 - OE Plot (OE scores on X-axis with error bars show 10%, 50% and 90% values)

[28] 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

[29] A sensitivity analysis was conducted by including the weight provided to 1-H&S during the OE; the effects were negligible as the scores for 1-H&S were very close across all options. The OE Report contains details of the sensitivity analysis.

[30] A sensitivity analysis was also conducted by setting all the H&S criteria to zero, to reflect a view that all of these factors should instead be considered in the IA. In this case the top eight (by median OE value) ranked options remain the same, with the top four being identically ranked and only three changing rankings within the top eight. Overall, only seven options change rank by more than one place, and the largest change is five ranks. Given the closeness of the OE results, this analysis demonstrates that the H&S criteria do not significantly influence the ranking of the results.

5.5. Interpretation of MCDA Results

5.5.1. Overall

5.5.2. Key points on the scoring scale were assigned a specific and tangible meaning[31]. A score of 1 corresponded to meeting a threshold value and 9 to an objective value. The resulting overall OE scores are, therefore, related to the threshold and objective measures of effectiveness specified in the URD but are quantified by variability bounds consistent with the spread of weights and scores captured at the workshop.

5.5.3. In the interpretation which follows, these terms have been used:

- **Statistically significant**; where the 10% value for one option exceeds the 90% value of another, their separation is considered statistically significant as there is less than a 1% chance of the lower scored option achieving a OE score greater than the higher scored option.

- **Trend or Clustering**; where there is a noticeable grouping or other arrangement of options, whilst understanding that they are not necessarily statistically significant.

5.5.4. Non-compliant Scores

5.5.5. Seventeen criteria out of 20 had threshold values (set at 1), a score below which options scoring 0 would be deemed as failing to meet the requirements in the URD. For all of these17 criteria, no options were scored zero by all members of the expert panels, but the following received some individual scores of 0:

- Option 0 (Do Minimum): received a single score of 0 for 1-OP *Impact on the Maritime Enterprise and Wider MOD Operations* (although the panel gave this a low mean score of 1.1). The main reason for the low scores was because of the significant impact to dockyard and naval base operations which would result from storing 27 submarines afloat, in terms of the operational impact of constructing new berthing facilities and associated infrastructure.

- Option 0 (Do Minimum) received two scores of 0 for 5-POL *Compliance with UK Decommissioning Policy* (with a mean score of 2.9). The main reason for the low scores was because UK Government policy states that decommissioning operations should be carried out as soon as reasonably practicable, whereas Option 0 does not progress decommissioning.

- Option 1R (RC interim storage at Rosyth): received a single 0 for 1-OP *Impact on the Maritime Enterprise and Wider MOD Operations* (with a low mean score of 1.2). The main reason for the low scores was because the footprint of the RC interim store was comparatively very large (ca.11,600 m^2) and locating such a store at Rosyth would have an adverse effect on the ability to decommission or re-develop Rosyth, which in turn could have a negative impact on the maritime enterprise.

5.5.6. The lack of consensus on these scores means that it is unreasonable to regard the

[31] These were written down for reference on the scoring sheets provided at the Scoring Workshop.

associated options as non-compliant, although they are indicative of potential difficulties that have yet to be quantified. This is particularly true for the scores for 1-OP *Impact on the Maritime Enterprise and Wider MOD Operations* where the average values are very low for both options discussed above.

5.5.7. It is also important to place Option 0 in context: it represents a comparator with a different end state to all the other options (the submarines are afloat, intact and continue to be a liability, rather than being made ready for disposal in the proposed GDF). During indefinite afloat storage, periodic inspections of the submarine hull would need to be carried out and relevant measures undertaken to prevent or limit hull corrosion. The same regulatory regime would continue to apply and conformance with authorisation conditions would still be mandatory.

5.5.8. Range of Results

5.5.9. Figure 5 shows that the median overall OE scores for the options range from 4.18 for Option 1B to 5.49 for Option 8D. The lowest 10% value is 3.85 for Option 1B and the highest 90% value is 5.87 for Option 1D. These results are not widely separated compared to the scale of 0 to 9, and it is important to place them in context, by examining the contribution of each group of MCDA criteria to the overall results.

5.5.10. The greatest contribution to the difference between options comes from criteria in the Operations (OP) group, with the largest single contribution from the impact on the maritime enterprise (1-OP). The second greatest contribution came from the weighted scores for the Policy (POL) group. In contrast there is little difference in the weighted scores ascribed to options for the Environmental (ENV) and Health & Safety (H&S) criteria, reflecting the view of the expert panels that these criteria should be scored for how well they meet the requirement *after* legal minimum requirements have already been met and that all options would be able to achieve the legal minima. The reason for weighting these criteria in this way is that compliance with the legal minima is already represented in the IA as a cost.

5.5.11. Identification of Statistically Significant Results

5.5.12. Analysis of the OE results has shown that Options 2D, 3B, 4B, 8D and 8B are separated by a statistically significant margin from Options 0 and 1, as shown in Figure 5. In addition Option 3D is separated by a statistically significant margin from Option 0.

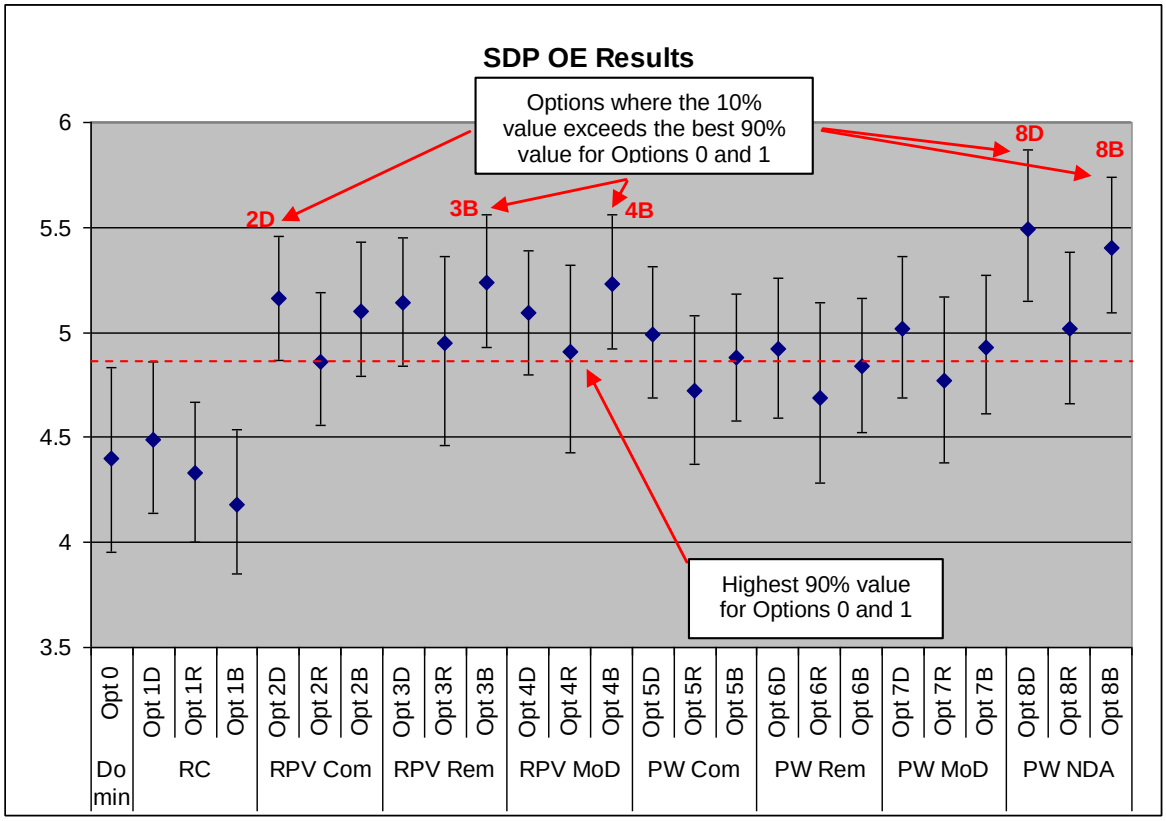

Figure 5 - Identification of Statistically Significant Options

5.5.13. The overall performance of Option 0 was comparatively weak compared to most of the other options. Option 0 performed very well on Health and Safety, well on environmental issues, poorly on policy issues and very poorly on operational issues.

5.5.14. In spite of the fact that other countries have adopted Option 1 (RC separation and storage), its overall performance when assessed in the UK context was comparatively weak compared to most of the other options and the three variants performed poorly in all areas.

5.5.15. This means that Options 1 (RC separation) and 0 (Do Minimum) offer effectiveness which is significantly less than the best performing variants of Options 2 to 4 (RPV) and 8 (Packaged Waste with storage at NDA sites(s)). No other options or variants are separated by a statistically significant degree, but this result indicates that Options 0 and 1 should be regarded as least compliant with the project requirements.

5.5.16. It is important to also note that Option 0 is a comparator with a different end point. At the conclusion of all the other 'Do Something' Options waste will be packaged in a form ready to enter the proposed GDF. With Option 0, the 27 submarines remain stored afloat, with WLC for their maintenance continuing to increase annually for an indefinite period into the future.

5.5.17. Discussion of Trends and Grouping

5.5.18. The closeness of the effectiveness scores means that it is difficult to separate Options 2 to 8. The overall performance of Options 2-4 was comparatively strong; they scored strongly against policy and operational criteria and slightly weaker against health and safety and environmental criteria. The overall performance of Options 5-8 was also comparatively strong and they scored strongly on environmental, policy and operational issues and somewhat weaker on health and safety issues.

5.5.19. It is valuable, however, to identify trends and clustering which may be used to inform proposals and future recommendations:

- For each particular option, the Rosyth variant (with the sole exception of Option 1) scores less well than the equivalent Devonport variant, forming a consistent pattern across Options 2 to 8. One reason for this relates to the comparative scoring of the Rosyth and Devonport variants against the 1-OP criterion, which was a particularly important criterion (and therefore highly weighted). Siting a large footprint interim RC store at either site could have a negative impact on the maritime enterprise and wider MOD operations. In the panel's assessment, however, this impact was slightly greater for Rosyth than for Devonport.

- For each particular option the Dual Site variant (with the exception of Option 1) scores better on operational issues than the equivalent Devonport variants, forming a consistent pattern across Options 2 to 8. The main reason for this is the increased flexibility of dismantling on more than one site. Also, dual site dismantling would reduce or negate the need for transportation of submarines between sites.

- Storage at a NDA site scored higher than the other packaged waste storage options, and was attractive for a number of reasons. These included taking advantage of industry best practise and avoiding the need to build (and decommission) stores, which would reduce impact on the maritime enterprise and on the environment.

5.6. Assessment of Options 2-8

5.6.1. Discussion of Options with Statistically Significant Separation

5.6.2. Figure 5 illustrates the comparatively poor performance of Options 0 and 1, compared to Options 2-8. In particular Options 2D, 3B, 4B, 8D and 8B scored higher than Options 0 and 1 by a statistically significant margin:

- Option 2D includes dismantling at Devonport Dockyard and interim storage of the RPV at Devonport. One of the key reasons why this option performs well is that interim storage of a RPV does not foreclose future opportunities (such as disposal of a whole RPV to the proposed GDF).

- Option 3B includes dismantling at Devonport and Rosyth Dockyards and interim storage of the RPV at a remote commercial site. This option performs particularly well because of reduced impact on maritime operations and the likelihood that new skills and experience would be acquired during removal of

the RPV. In contrast, it was judged to have a slightly higher security risk as the RPVs would be stored at a commercial site but not shape destroyed.

- Option 4B involves dismantling at Devonport and Rosyth Dockyards and interim storage of RPVs at a remote MOD site. It performed similarly to Option 3B, albeit with slightly lower security risk because RPVs would be stored at a MOD site.

- Option 8D includes dismantling and size reduction at Devonport Dockyard and interim storage of packaged waste at a NDA site. This option performed well because size reduction and packaging would provide novel and transferable skills. In addition, although it forecloses future opportunities (such as disposal of a whole RPV at the proposed GDF) it was considered attractive due to the potential benefits of using NDA facilities (see 5.5.19 above).

- Option 8B includes dismantling and size reduction at Devonport and Rosyth Dockyards and interim storage of packaged waste at an approved NDA site. This option performed similarly to Option 8D although there were more transport movements required which reduced the score somewhat.

5.6.3. Comparisons between Options 2-4 and Options 5-8

5.6.4. Options 2-4 and Options 5-8 offer similar technical solutions, differentiated only by the timing of some of the key operations. Under Options 2-4, the separated RPV will first of all be put into interim storage, then (once the proposed GDF is available) it will be size reduced and transported as packaged waste for disposal. Under Options 5-8, the separated RPV will first of all be size reduced, then put into interim storage followed by transportation of waste packages to the proposed GDF. Options 2-4 and Options 5-8 had similar scores under many of the criteria, but the key differentiators are:

- Options 2-4 performed better in policy terms because they keep future opportunities open and benefit from radioactive decay within the RPV. In contrast, early size reduction under Options 5-8 forecloses future opportunities and the facilities and processes required are more technically challenging.

- Options 5-8 scored better in terms of risk of unauthorised access because size reduction under Options 5-8 involves partial shape destruction of materials whereas Options 2-4 include storage of an intact RPV.

- Options 2-4 scored better than Options 5-8 because the storage of RPVs would allow time to develop the skills required to size reduce them. Moreover, early size reduction, under Options 5-8 would result in a reduced demand for SQEP over time, which was seen as having a negative impact.

- Options 5-8 performed better than Options 2-4 because of the transferable value of skills acquired from earlier RPV size reduction.

5.6.5. Caution must be exercised, however, in attempting to differentiate too strongly between Options 2-4 and Options 5-8, since the differences are not statistically significant. These differences may, however, help to frame the arguments for selecting proposed options.

5.7. OE Conclusions

5.7.1. Considering the OE *alone*, the following conclusions emerge:

- The comparator Option 0 (Do Minimum) has statistically significant lower effectiveness than the highest performing options with a RPV or Packaged Waste approach (ie Options 8D, 8B, 3B, 4B, 2D and 3D).

- Option 1 (RC) has statistically significant lower effectiveness than the highest performing options with a RPV or Packaged Waste approach (ie Options 8D, 8B, 3B, 4B and 2D).

- Those variants with dismantling at Rosyth demonstrate consistently less effectiveness than their equivalent variants at Devonport and for dual site dismantling - with the single exception of Option 1 (RC). In all other cases the Rosyth variant has the lowest OE score of the three variants for each option, although not by a statistically significant margin.

- The different types of ILW storage are not separated by a statistically significant margin, including those with storage at point of waste generation. The options involving storage of Packaged Waste at NDA site(s) have the highest effectiveness, albeit not by a statistically significant margin.

6. IA Results

6.1. 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[32] 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

6.2. Specialist Advice

6.2.1. 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.

6.3. Assumptions

6.3.1. Key financial assumptions used in the IA are described at Annex E. These assumptions could change following public consultation but provide a common reference to assess the through life cost of dismantling.

6.4. Qualitative Financial Impact

6.4.1. The IA has focused on the measurable costs these costs include those needed to meet the minimum legislative requirement. Qualitative financial arguments are discussed in the OCF analysis reported at Section 8. They provide additional analysis excluded from the IA because of the challenge in measuring them or the sensitive nature of obtaining costs.

6.5. Consideration of Worker Dose

6.5.1. 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[33].

6.5.2. 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.

[32] See Annex C for a full description of the 25 options considered for Public Consultation
[33] 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

6.5.3. The cost that is calculated for residual dose is included in the analysis alongside all other directly measurable costs. The cost calculations can be found in the full Investment Appraisal report.

6.6. Financial Analysis

6.6.1. The financial analysis was extracted from the SDP WLC Model. This underwent initial V&V[34] assurance from CAAS[35], challenge from the CAAS Estimating Assurance Team and review by the MODs internal scrutiny team and. Following the V&V CAAS have been invited to quarterly briefings outlining the development of the WLC Model.

6.7. Whole Life Cost Model

6.7.1. 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.

6.7.2. 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.

[34] Validation and Verification – Validation aims to determine that the data used to populate the model is valid in that it has a sound basis of estimate that can be supported. Verification is the process of checking that a model is consistent with its specification and is free from material errors (mathematical or logical).
[35] CAAS – Cost Assurance and Analysis Service an internal team within the MOD that provides review and challenge to the process of modelling across the MOD

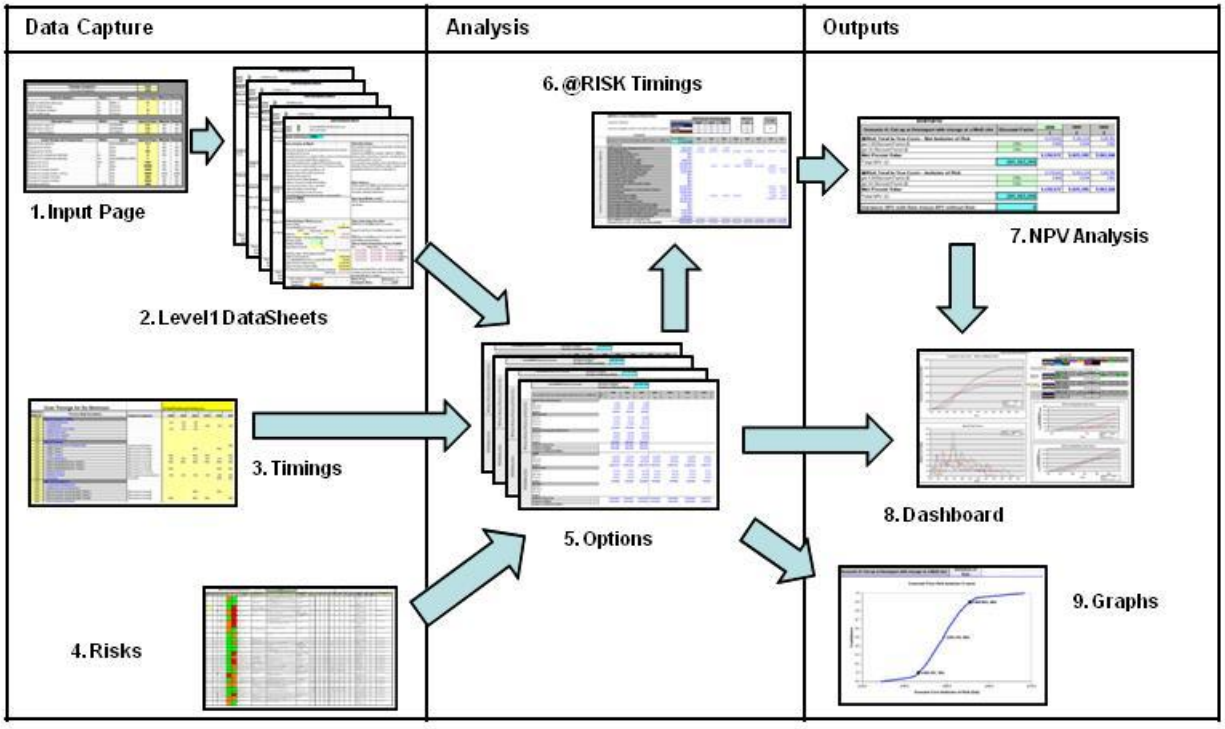

Figure 6 - WLC Model

6.8.1. 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.

6.8.2. 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.

6.8.3. All of the cost drivers feed into the overall cost of dismantling. Monte Carlo Analysis is run on the whole life cost model which conducts thousands of combinations of all the different cost drivers, 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. Of most interest is the 50% output. This is the value for which 50% of circumstances the cost will be less than and 50% the cost will be higher than.

6.9. Treatment of Risk

6.9.1. In addition to uncertainty, 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 WLC Model has an internal risk register compatible with the SDP Risk Register. The SDP Risk Register is updated on a regular basis with input from the risk owners. Some risks 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.

6.10. Results

6.10.1.

Rank	Option	Delta
1	Option 4B – *Dual Site, RPV with MOD Storage*	Most Economic
2	Option 4D – *Devonport Dockyard, RPV with MOD Storage*	+ 3.07%
3	Option 3B – *Dual Site, RPV with Commercial Storage*	+ 3.23%
4	Option 2B – *Dual Site, RPV with PoG Storage*	+ 3.53%
5	Option 8D – *Devonport Dockyard, Packaged Waste with NDA storage*	+ 3.92%

6.10.2. Table 3 shows the 5 lowest cost options, by NPV. Table G-1 in Annex G provides a table showing all the options and their WLC values.

Rank	Option	Delta
1	Option 4B – *Dual Site, RPV with MOD Storage*	Most Economic
2	Option 4D – *Devonport Dockyard, RPV with MOD Storage*	+ 3.07%
3	Option 3B – *Dual Site, RPV with Commercial Storage*	+ 3.23%
4	Option 2B – *Dual Site, RPV with PoG Storage*	+ 3.53%
5	Option 8D – *Devonport Dockyard, Packaged Waste with NDA storage*	+ 3.92%

Table 3 - Top 5 Options ranked financially

6.10.3.

Rank	Option	Delta
1	Option 4B – *Dual Site, RPV with MOD Storage*	Most Economic
2	Option 4D – *Devonport Dockyard, RPV with MOD Storage*	+ 3.07%
3	Option 3B – *Dual Site, RPV with Commercial Storage*	+ 3.23%
4	Option 2B – *Dual Site, RPV with PoG Storage*	+ 3.53%
5	Option 8D – *Devonport Dockyard, Packaged Waste with NDA storage*	+ 3.92%

6.10.4. Table 3 shows that Option 4B is the integrated option with the lowest cost option at 50 percentile value[36] primarily due to:

- Delay to spend on RPV size reduction; and
- That Dual Site dismantling negates the need for submarine towing.

6.10.5. 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.

6.10.6. 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.

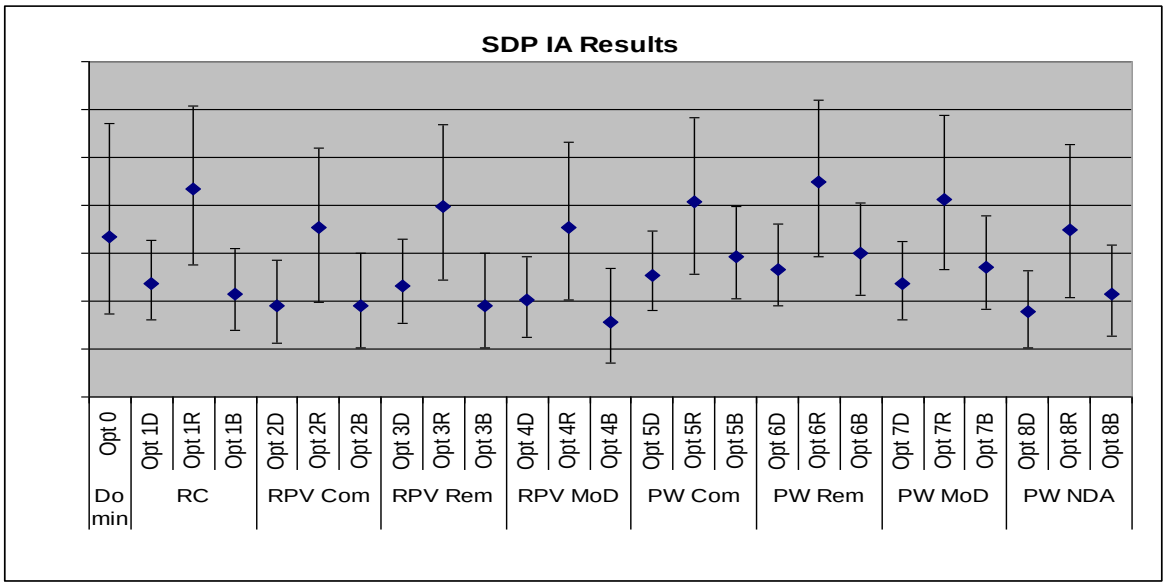

Figure 6 – Plot of options

6.10.7. 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 shown above in Figure 6 the difference between these options is relatively small; the reason for this clustering of options is due the commonality of the technical process employed in each option, i.e. all options have the same end point of the proposed GDF compliant packaged waste. With a very similar technical process and similar capital investment required, the options that offer best VFM are those that minimise expenditure in the early years and delay the bigger spend (the RPV size reduction) to the later years. The Rosyth options are more expensive option 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. These are

[36] The 50 percentile (median) value is the value that has a 50% probability of being exceeded and a 50% probability of being undershot and is sometimes referred to as the 50% confidence value.

typically 24-36% more expensive than the cheapest option.

6.10.8. The RC options are not amongst the cheapest options and typically add between 10% and 31% of cost when compared to the cheapest option.

6.11. Opportunities and Sensitivity

6.11.1. Opportunities are events that might occur and, if realised through specific actions, would benefit the project outcome in terms of performance, schedule or cost. The SDP opportunities were reviewed as part of a separate sensitivity analysis with reference to; whole RPV disposal and changes in the cost of future RPV size reduction.

6.12. Whole RPV Disposal

6.12.1. 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. Earlier work suggested that RPVs would be either to big or too heavy to be accepted whole for proposed GDF disposal.

6.12.2. There is an opportunity that, by the time the proposed GDF design is finalised, this assumption will change and that it will be able to accept whole RPVs for disposal without the need for size reduction.

6.12.3. 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 the RPV removal and RC separation options.

6.12.4. Table 4 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%

Table 4 - Top 5 Options ranked Financially: whole RPV disposal

6.12.5. 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 presents a significant opportunity that would further enhance the relative attractiveness of the RPV removal options and, albeit to a lesser extent, the RC separation options.

6.13. Sensitivity to Changes in the Future Cost of RPV Size Reduction

6.13.1. There is a significant chance that both the requirements of the RPV size reduction facility and the size reduction process may alter over the long-term[37]. 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.

6.13.2. 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.

6.13.3. 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 are difficult to predict so a relatively large proportional change has been modelled.

6.14. Decrease in the Future Cost of RPV Size Reduction

6.14.1.

#	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 %

6.14.2. Table 5 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 %

[37] 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.

3	3B	+ 4.1%	- 6.1 %
4	2B	+ 4.2%	- 6.3 %
5	2D	+ 6.0%	- 6.4 %

Table 5 - Top 5 Options ranked financially: RPV Size reduction facility (reduced by 50%)

6.14.3.

#	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 %

6.14.4. Table 5 shows that a 50% reduction in the future cost of size reduction results in a reduction in the NPV of the RPV and RC storage options of approximately 6.5%. For Options with whole RPV disposal opportunities all of the top five options have now become RPV storage options.

6.15. Increase in the Future Cost of RPV Size Reduction

6.15.1. There is the potential for the cost of size reduction to increase in the future, but this is considered to be less likely since the RPV radioactivity levels will drop over time.

6.15.2. Table 6 shows the impact of a 50% increase in the cost of size reduction:

#	Option	Delta between options	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 %

Table 6 - Top 5 Options ranked financially: RPV Size reduction facility (increased by 50%)

6.15.3. Table 6 shows that an increase in the future cost of the RPV size reduction facility and the cost of the process by 50% adds approximately 6.5% of cost to the RPV and RC options. This increase is enough to change the rankings of the lowest cost

options with the cheapest now becoming the packaged waste options which are expected to benefit through use of NDA storage facilities.

6.15.4. Overall the sensitivity analysis shows that a decrease in the cost of RPV size reduction will make the RPV storage options even more attractive than they already are relative to packaged waste. An increase in the cost of future size reduction could make packaged waste more attractive than RPV storage, however the cost of the RPV size reduction facility and consequent processing of ILW would have to rise by approximately **29%** for packaged waste to be cheaper than RPV storage and then only for packaged waste options which use NDA storage facilities.

6.15.5. The assessment of cost and technical feasibility for options involving NDA storage 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 storage facilities will be best value for money or deliverable within the timescales required by the project. None of the RPV storage options include the use of NDA storage facilities (although the feasibility of doing so is under investigation) and the other packaged waste technical options are still less financially attractive than comparable RPV storage options.

6.15.6. Future changes to the process, technology and regulation of RPV size reduction could thus have an impact on the cost of the project but are unlikely to significantly alter the relative attractiveness of RPV storage over packaged waste.

6.16. Summary Findings

6.16.1. The Investment Appraisal does not indicate a clear preferred option but highlights the need to undertake a 'Do Something' Option.

6.16.2. The assessment of cost (KUR 1.1.1.) indicates that the RPV 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 attached to all options and so, as stated above, it is not possible at this point to clearly indicate a strong preference for RPV storage over packaged waste.

6.16.3. 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.

6.16.4. Early cost modelling work indicates that Option 8D, ILW storage using NDA storage facilities may be preferable to a MOD bespoke storage solution (KUR 2.6.3) as it has the potential to avoid or reduce ILW storage costs[38].

6.16.5. The RPV storage options are further supported by potential opportunities that could lead to further reductions in the cost of the project. These opportunities include whole RPV disposal and a reduction in the future cost of RPV size reduction. If

[38] 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 2012.

these opportunities are realised, the VFM attractiveness of the RPV options are even greater with reductions of 11% and 6.5% respectively.

7. COEIA Results

7.1. Objective

7.1.1. To combine the results of the OE and IA reported above and develop an understanding of the cost-effectiveness of the SDP options. Central to this is the presentation of a number of COEIA plots which map the OE results (y-axis) against the IA results (x-axis).

7.1.2. On a COEIA plot an option is best when it lies in the top left hand corner of the plot, exhibiting high effectiveness and low WLC. An option is worst when it lies in the bottom right hand corner of the plot, exhibiting low effectiveness and high WLC.

7.2. COEIA Plots

7.2.1. Due to the number of SDP options and variants – 25 in total, these have been presented separately for Devonport, Rosyth and both combined. Each figure shows the OE results on the y-axis and IA results (NPV) on the x-axis. It is important to note that the origin is not shown on the figures and that the OE scale is from 3.5 and 6.0 and the IA scale is hidden due to commercial sensitivity. The three figures are:

- Dismantling at Devonport (variants D) and Option 0 (Do Minimum) – Figure 7.
- Dismantling at Rosyth (variants R) and Option 0 (Do Minimum) – Figure 8.
- Dual site dismantling (variants B) and Option 0 (Do Minimum) – Figure 9.

7.2.2. In all three figures the different technical approaches to dismantling are shown in different colours:

- Option 0 (Do Minimum) is black.
- Option1 (RC) is pink.
- Options 2 to 4 (RPV) are red.
- Options 5 to 8 (Packaged Waste) are green.

7.2.3. The different classes of interim storage sites are shown as different shapes:

- Point of waste generation are diamonds.
- Remote commercial storage as solid squares.
- Remote storage at MOD sites as open squares.
- NDA storage as triangles.

7.2.4. In all cases the shapes represent the median values of operational effectiveness and WLC, with error bars extending from 10% to 90%.

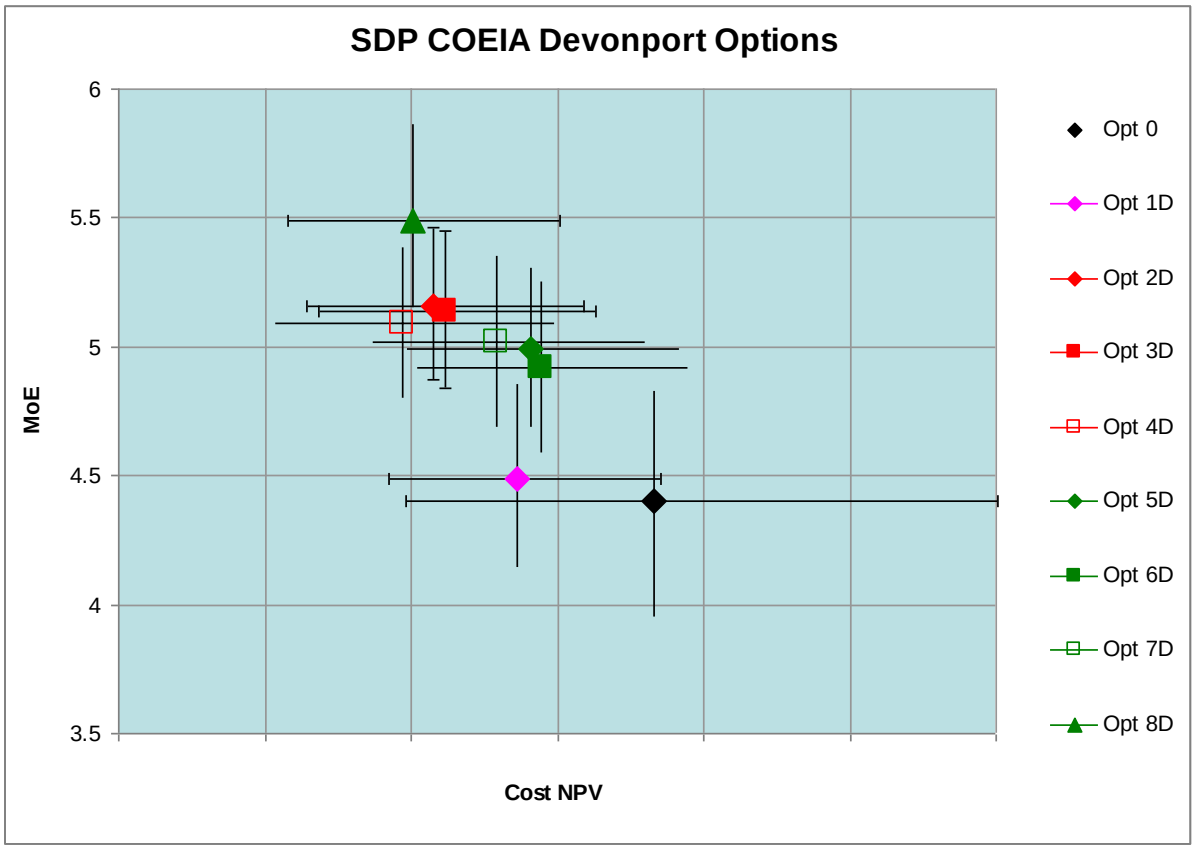

Figure 7 - COEIA Plot: Devonport Variants

7.2.5. Figure 7 shows that Options 2D (RPV removal with storage at point of waste generation), 8D (Packaged Waste with storage at a NDA site) and 3D (Packaged Waste with storage at a remote commercial site) have effectiveness values which are higher by a statistically significant margin than Option 0 (Do Nothing). Options 2D and 8D also have effectiveness values which are higher by a statistically significant margin than Option 1 (RC). There is no such differentiation in WLC, although it is noticeable that for the median values, *all* the Do Something options have lower WLC and higher OE than Do Minimum.

7.2.6. On the basis of Options 2D, 8D and 3D have been identified as being the most cost-effective Devonport based options and would be recommended to be taken forward for further comparison with other siting Options.

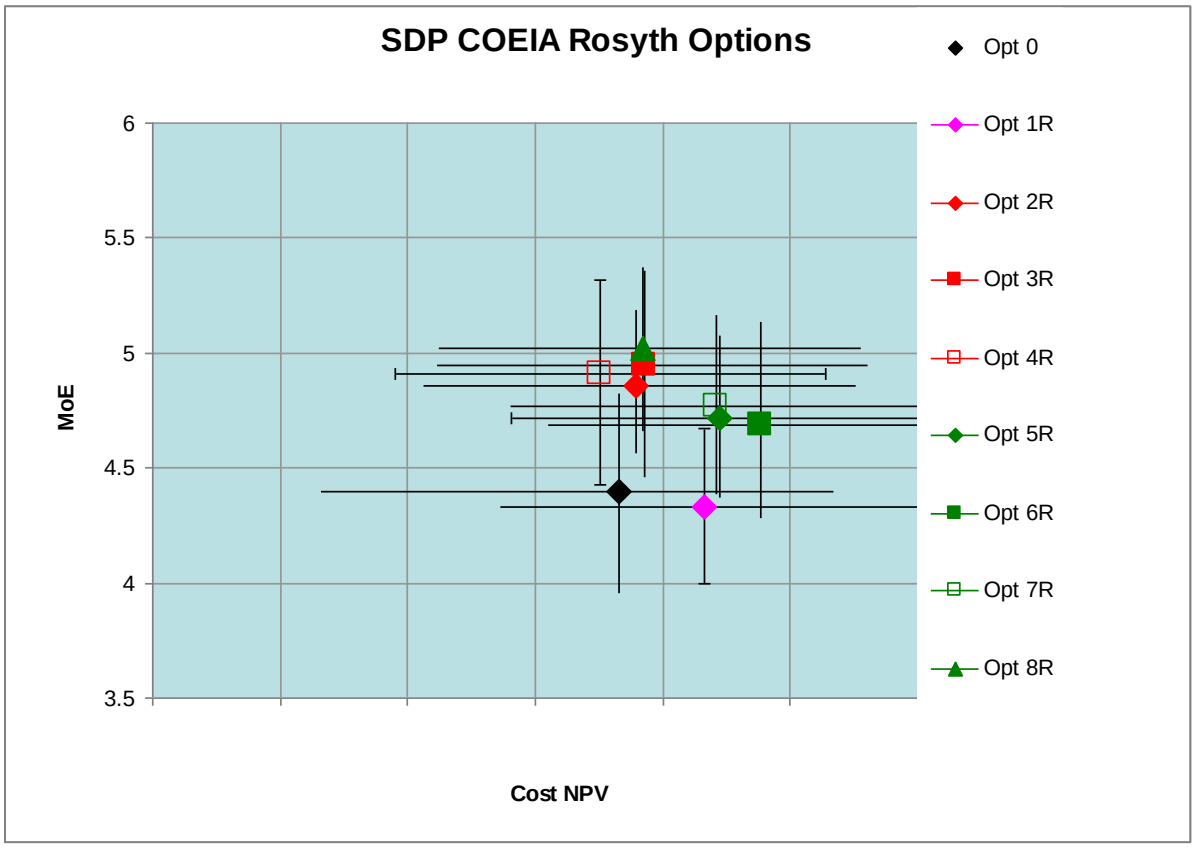

Figure 8 COEIA Plot: Rosyth Variants

7.2.7. Figure 8 shows that there is no differentiation in either OE or WLC for the Rosyth variants. Consideration of the 50% value (i.e. median value) for both OE and WLC shows that all the 'Do Something' options have higher WLC and higher OE than the Do Minimum, with the exception of Option 1R (RC) which has lower OE, and Option 4R (RPV storage at a remote MOD site) which has lower WLC.

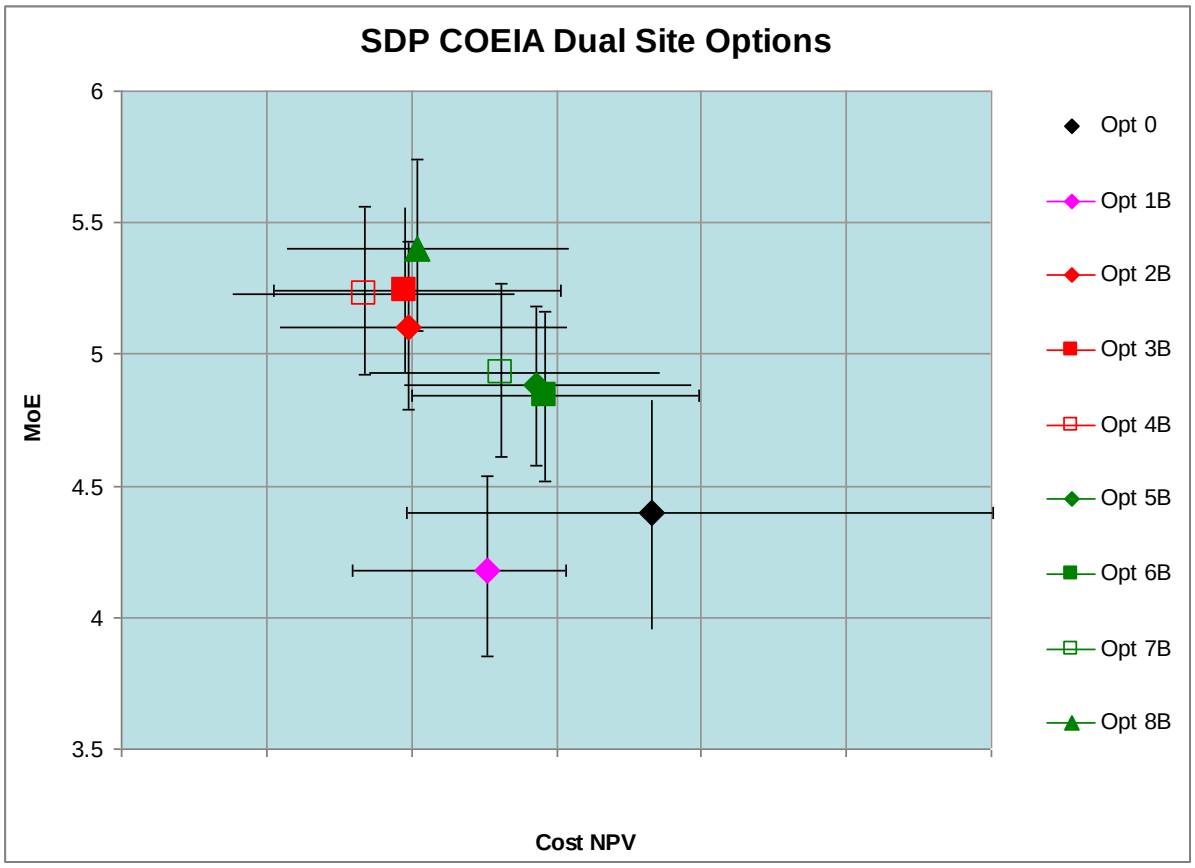

Figure 9 - COEIA Plot: Dual Site Dismantling Variants

7.2.8. Figure 9 shows that Options 3B (RPV removal with remote storage at commercial site), 4B (RPV removal with remote storage at MOD site) and 8B (Packaged Waste with storage at a NDA site) have effectiveness values which are higher by a statistically significant margin than Option 0 (Do Nothing). All the Do Something options excluding 6B (Packaged Waste with remote storage at a commercial site) have values which are higher by a statistically significant margin than Option 1B (RC). There is no such differentiation in WLC, although it is noticeable that for the median values, *all* the Do Something options have lower WLC and higher OE than Option 0 (Do Minimum), except for Option 1B (RC).

7.2.9. On the basis of Figure 9, Options 3B, 4B and 8B have been identified as being the most cost-effective dual site options and would be recommended to be taken forward for further comparison with other siting Options.

7.3. Identification of Most Cost-effective Options

7.3.1. The 8 options which score highest in terms of median OE and the 8 options which score lowest in terms of median WLC are precisely the same, although their rankings vary (see Annexes F and G for details). These are Options 8D, 8B, 4D, 4B, 3D, 3B, 2D and 2B, which are plotted on Figure 10 also plots Option 1D (the most effective RC option) and Option 0 (Do Minimum).

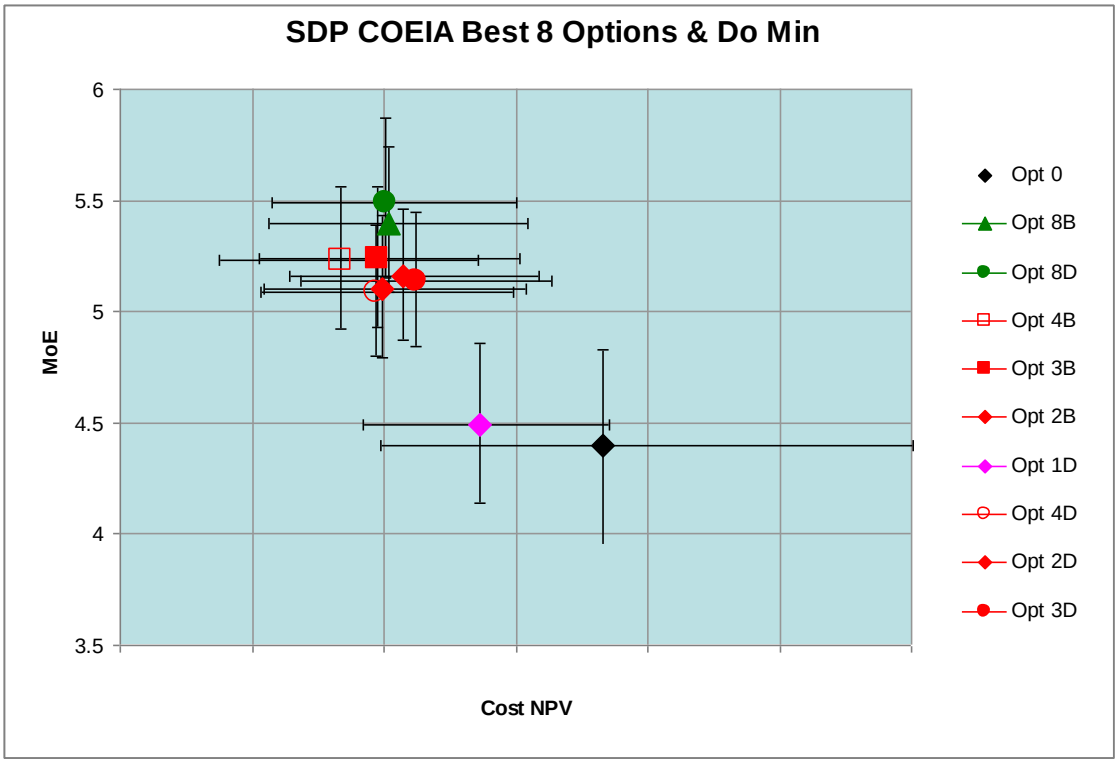

Figure 10 - COEIA Plot: Best 8 Options with Comparators (1D and 0)

7.3.2. Figure 10 shows that all of the Options (except Options 2B, 3D and 4D) are significantly more effective than both the Do Minimum (Option 0) and Option 1D. It can also be seen that all of the Options have lower median NPV values than Do Minimum, although none of the cost differences are statistically significant.

7.3.3. Plot of Median Values below presents the median data values for all Options but with groupings of the dismantling sites identified. This shows that, in general, Devonport and dual site Options tend to cost less than those at Rosyth. Again, this must be caveated by the fact that there is actually a high degree of overlap between 10% and 90% values (not shown here), although it does illustrate the clustering in the options.

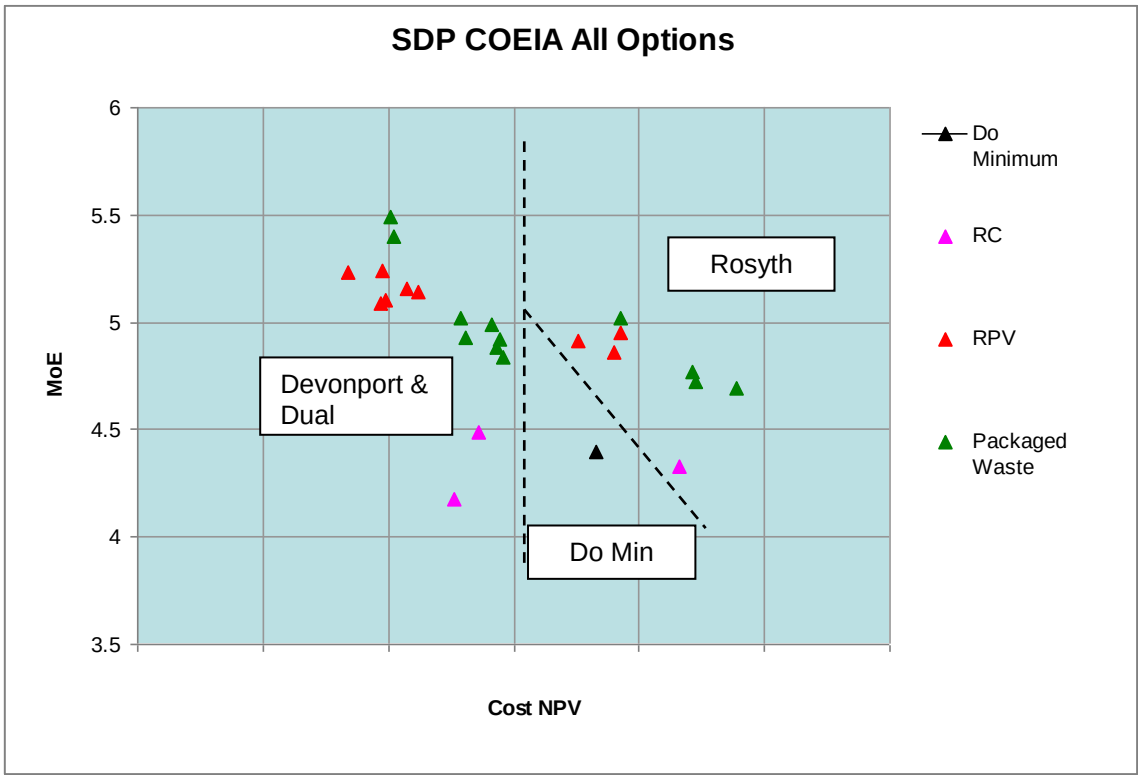

Figure 11 - COEIA Plot: Median Values for all Options (with Groupings)

7.3.4. Figure 11 shows a trend for options with higher effectiveness to have lower WLC (the eight options with lowest median WLC also have the highest median effectiveness). This trend is explained by the fact that lower WLC is associated with less complicated operations and a smaller amount of capital investment in plant. Broadly, less activity and less plant also means a lower impact on the environment and operations, thereby delivering higher effectiveness. It should be re-stated that all Options except for Option 0 do eventually lead to the same end-point - that is final storage in the proposed GDF.

7.4. Opportunity: Whole RPV Disposal to the Proposed GDF

7.4.1. As discussed in Section 6.10, whole RPV disposal to the proposed GDF could deliver savings of approximately 11%. Figure 12 is a speculative plot which shows the effect of these potential savings on the highest performing Options (those which have either the highest six OE scores and/or lowest WLC scores). There has been no amending of the OE scores in this plot. (The OE impact of whole RPV disposal has not been tested.)

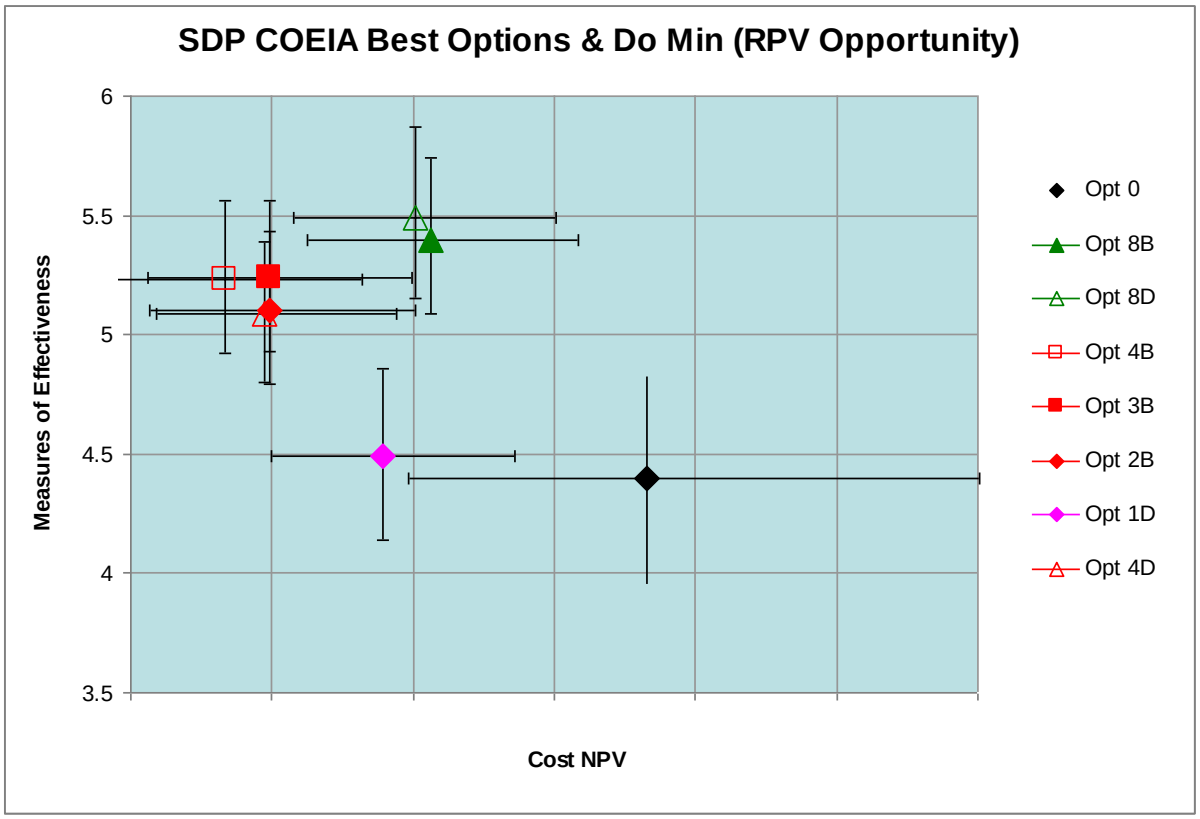

Figure 12 - COEIA Plot: Best Performing Options assuming Whole RPV Storage

7.4.2. In summary, if whole RPV disposal to GDF could be delivered, then:

- There is less clustering of the COEIA plot if the Whole RPV disposal opportunity is realised.
- All RPV and RC storage options become more attractive financially.
- Options 3B, 4B and 4D are now separated by a statistically significant margin from Option 0 in WLC terms.

7.4.3. It is not possible to re-assess effectiveness without repeating the workshops substantially, although it could be assumed that the reduction in required size-reduction activities would have a positive impact on the scores.

7.5. Discussion

7.5.1. The similarity in the options for both OE and WLC can be explained by the fact that all of them, with the exception of Option 0 (Do Minimum), represent the same end-to-end process of initial dismantling and final size reduction leading to disposal in the proposed GDF. The most significant/largest variable is the timing of interim ILW storage and the specific means of, and location for, dismantling, but the fundamental process is the same, leading to similar effectiveness and WLC.

7.5.2. Although the bulk of the options are grouped closely, there is a significant difference in OE between some of the RPV and Packaged Waste options (2D, 3B, 4B, 8D and 8B) and Option 0 and 1. This reflects the MCDA analysis which demonstrated that

the Do Minimum and RC options have a greater operational impact and are not as effective as meeting policy as Options 2 to 8.

7.5.3. Caution must be applied when looking at median values alone, but there is a clear trend when looking at dismantling sites: *all* the median values for WLC for Rosyth (excepting, narrowly, 4R) are more costly than the Do Minimum, while *all* the median values for WLC for Devonport and dual site dismantling are less costly than the Do Minimum. This reflects the higher costs associated with retaining a presence at Rosyth over the timescales of SDP; in dual site dismantling Options, only the initial stage of RPV removal is conducted at the dockyard, enabling operations there to conclude earlier.

7.5.4. The Packaged Waste options with NDA storage facilities perform best of all in OE due to greater adherence to policy and less impact operationally by removing storage from MOD sites. Their WLC is not, however, significantly less than the RPV options and, if the opportunities considered in Section 6 were to be realised, the latter would be significantly less without significantly impacting OE, as demonstrated in Figure 12. More generally, the median WLC of the RPV options is lowest, illustrating that the delay of RPV size-reduction is preferable to immediate dismantling.

7.5.5. The different types of storage site, including storage at point of waste generation, do not demonstrate significantly different OE or WLC, because the amount of ILW being transported is not large, and the storage requirements are the same regardless of where the store is sited. The only exception to this is storage at a NDA site, when a new store does not need to be built, although these savings are outweighed by other costs.

7.6. Summary of Findings

7.6.1. The COEIA has not identified a single option which provides a demonstrably more cost-effective solution to SDP than the other options. Although some options are separated by a statistically significant margin, the assessment to date remains inconclusive. The considerable overlaps in the assessment of effectiveness and WLC for most of the options reflect the common activities and common end points across the options. Further work will therefore be required in order to arrive at clear recommendations and this will involve testing assumptions and opportunities, refining cost estimates and reviewing the whole assessment in the light of public consultation responses.

7.6.2. For the purposes of consultation, however, it is possible to propose tentative rankings of the cost-effectiveness of the options based on analysis to date. Table 7 shows the options grouped and ranked into five levels from ‘highest potential’ to ‘lowest potential’. The ranks are coloured for the purposes of illustration (using a modified traffic light schema from Blue (highest) to Red (lowest)) according to their acceptability.

7.6.3. Recommendations to be presented at MGBC will need to have significantly reduced uncertainty in the assessment of the options but the rankings above provide an indication of how the project team considers the current standing of the options based on analysis to date.

Rank	Options	Description
1st RANK	Options: 8D/8B (Packaged Waste with NDA storage) & 2D/2B; 3D/3B; 4D/4B (RPV removal).	The majority of these options (2D, 3B, 4B, 8D and 8B) have an effectiveness which is higher by a statistically significant margin[39] than Options 1 and 0. The other options (2B, 3D and 4D) have effectiveness values which are very close to these leading options[40]. In addition, the median WLC of all these eight options exceed the median WLC of all of options 5, 6 and 7 (D and B variants). Finally, these 8 options have both the highest 8 median OE values and the lowest 8 median WLC values. Qualitatively, the RPV options (2 to 4) offer the greatest potential to take advantage of future opportunities which may deliver significant WLC savings. In addition, the NDA storage options offer considerable advantages in terms of coherence with National strategy and policy.
2nd RANK	Options: 5D/5B; 6D/6B; 7D/7B (Packaged Waste)	These options do not perform as well as those in the first rank, as they all have lower median effectiveness values and higher median WLC values than Options 2 to 4 and 8 (D and B variants). Qualitatively, these options foreclose on future opportunities and do not offer the policy benefits that the MCDA associated with NDA storage. They nonetheless remain viable options with effectiveness and WLC values not dissimilar to those in the first category
3rd RANK	Rosyth Variants 2R, 3R, 4R, 5R, 6R, 7R, 8R (RPV and Packaged Waste)	The Rosyth (R) variants all have lower effectiveness than their equivalent Devonport (D) or Dual Site (B) equivalents, with the single exception of 1B, which performs less effectively than 1R. In addition the median WLC of all the Rosyth options are all higher than the median WLC of the Devonport and Dual Site options Qualitatively, these variants are less effective due to moving submarines to Rosyth with the attendant impacts on the maritime enterprise resulting from use of the dockyard facilities. Although they are viable options there are significant obstacles to their implementation which will have to be overcome for them to go forward.
4th RANK	Options 1D, 1B & 1R (RC Separation)	These options have an effectiveness which is less than that of the highest ranking options by a statistically significant margin. The impact on the maritime enterprise and the potential for failure to meet policy objectives on nuclear decommissioning in the future makes these options only marginally viable.
5th RANK	0 (Do Minimum)	These options have an effectiveness which is less than that of the highest ranking options by a statistically significant margin. Do Minimum is only a comparator has a different end point to all of the other options: he submarines remain in afloat storage indefinitely.

Table 7 - Ranked & Grouped Categorisation of Options

7.6.4. Figure 13 shows a grid of all the options and their variants with the colour coding

[39] As noted above, this has been defined as when the 90% effectiveness level of one option is less than the 10% effectiveness level of another option. This gives a 1% probability of the lower option delivering a higher effectiveness than the higher option.
[40] Statistically, the 20% effectiveness value of these higher options exceeds the 90% effectiveness value of the lower options. This gives a 4% probability of the lower option delivering a higher effectiveness than the higher option.

applied.

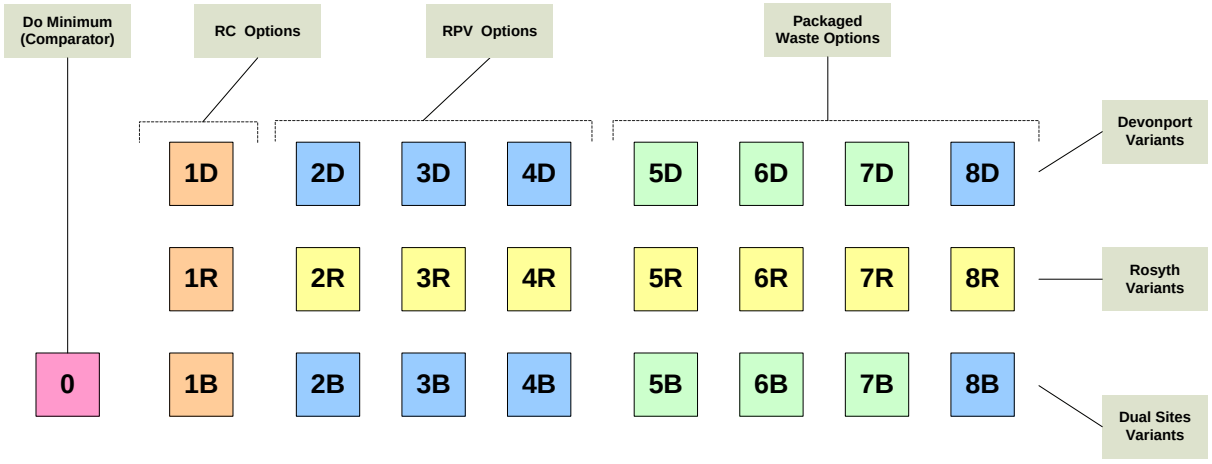

Figure 13 - Current standing of SDP Options based on analysis to date

8. Other Contributory Factors

8.1. Context

8.1.1. This Section summarises SDP OCF described more fully in the OCF Report[41], which is based on the results of a workshop held on 22 June 2011. The workshop aimed to identify OCFs that may have an effect on the project options but to defer more comprehensive and conclusive assessments until responses from public consultation are available. OCF have not, therefore, contributed to the development of proposed options as set out within this OASP but will contribute to the development of recommended options for the MGBC that follows after public consultation.

8.2. Public Confidence (OCF-01)

8.2.1. This OCF covers the potential impact of public confidence on SDP including both positive and negative issues and perceptions. Some options may inspire more public confidence than others.

8.3. Socio-Economic Impacts (OCF-02)

8.3.1. The WLC model being used in the IA does not include the financial benefit or disadvantage to the local communities, and this OCF covers the potential socio-economic impact of different SDP options on local communities. The SEA considers, at a high level, the potential for any significant socio-economic effects.

8.4. Political and Policy Frameworks (OCF-03)

8.4.1. Potential political impacts are not considered in the COEIA although the alignment of SDP options with specific policies on decommissioning and radioactive waste management is considered within the OE. Political factors may, however, have a significant bearing on SDP where they might impact on the project either at national or at local level.

8.5. Implications of/on other local projects (OCF-04)

8.5.1. This OCF considers the possible implications for SDP (and visa versa) of any other planned or proposed non-MOD developments in the vicinity of the candidate initial dismantling sites. The combined environmental implications of other planned local projects have been assessed by the SEA.

8.6. Impact of/on other UK Radioactive Management Initiatives (OCF-05)

8.6.1. This OCF covers the interactions between SDP and other radioactive waste management initiatives across government and the nuclear industry. Until now, the general practise of the civil nuclear sector has been to keep ILW at its site of origin pending disposal in the proposed GDF. However, building on the findings reported within the 2009 UK Radioactive Higher Activity Waste Storage Review, for some of the inventory the NDA is exploring opportunities to share current and planned storage. This could have a bearing on SDP ILW storage options. In addition, new

[41] SDP OCF Report, v0.4, July 2011

LLW / VLLW disposal routes are opening up, and the industry is considering alternative options for managing waste that is near class boundaries (eg. between ILW and LLW).

8.7. Commercial Considerations (OCF-06)

8.7.1. This OCF recognises that commercial negotiations, at a future date, will be required with site owners and operators and that site owners and operators have a wider set of influences acting upon them. A refusal to consider an option by a potential contractor could, in some cases, rule it out of contention although constructive engagement will help to mitigate this risk.

9. Conclusions

9.1. Ranking of Options

9.1.1. The COEIA has not identified a single option which provides a demonstrably more cost-effective solution to SDP than the other options, nor has it identified options that should be discounted at this stage (except for the Do Minimum option which is a comparator only). Further work will be required in order to arrive at clear recommendations, including an assessment of responses from public consultation. It is possible, however, to rank the Options in terms of their potential:

- First Rank **(Greatest Potential)**: Packaged Waste with NDA storage (Options 8D/8B) or RPV Removal (Options 2D/2B, 3D/3B and 4D/4B) with dismantling at Devonport or both sites.
- Second Rank: Packaged Waste with dismantling at Devonport or both sites (Options 5D/5B, 6D/6B and 7D/7B).
- Third Rank: Dismantling at Rosyth (2R to 8R).
- Fourth Rank **(Least Potential)**: RC Separation (Options 1D, 1R and 1B).
- Fifth Rank **(Comparator)**: Do Minimum (Option 0).

9.1.2. It is recommended that further analysis should be focused on the options with the greatest potential.

9.2. Further Conclusions

9.2.1. In addition to the ranking above, the following key conclusions emerge from the analysis:

- The environmental criteria, which were derived from the SEA) were not found to discriminate significantly between the options in terms of OE, although RC separation and storage is associated with potentially problematic issues at Devonport (Options 1D and 1B). This demonstrates that all of the options have a similar level of environmental impact.
- The Health and Safety (H&S) criteria were also not found to discriminate significantly between the options, demonstrating that all of the options offer a similar level of safety over and above the legal requirements to which SDP must adhere.
- Options involving ILW storage at the point of waste generation showed no net advantages over other storage categories in terms of either OE or WLC. This was because transport impacts (for storage at remote sites) were balanced by operational impacts (for storage at the point of waste generation.

9.3. Proposed Option

9.3.1. Whilst understanding that none of the options has emerged as a ‘clear winner’ there is value in proposing an option as the leading candidate around which public consultation can be focused. The proposed option is **RPV removal and storage**

with initial dismantling at both Devonport and Rosyth Dockyards. At this stage, no site is proposed for ILW storage but the proposed way forwards involves working jointly with NDA to arrive at a decision on whether to use NDA storage facilities or to develop a new SDP storage facility.

9.3.2. RPV removal preserves the opportunity for whole RPV disposal to the proposed GDF, which could reduce WLC significantly. More generally it retains the ability to take advantage of future opportunities by delaying size reduction until later. Its relative attractiveness could, however, change if the WLC of Packaged Waste storage can be assessed more accurately. In addition, public consultation responses may shape decision making.

9.3.3. Initial dismantling at both Devonport and Rosyth Dockyards provides the best opportunity for the optimal dismantling of submarines at both dockyards, to maximise the re-use of plant, flexibility of resources and expertise. This provides latitude to optimise liabilities at both sites (earliest exit from Rosyth whilst avoiding congestion in Devonport), but may change once more accurate submarine transportation costs have been determined and once responses from public consultation have been considered.

9.3.4. The COEIA found no net advantage to storage at point of waste generation compared to storage at a remote location suggesting that the MOD and commercial site options (which would require construction of new facilities) can be grouped for comparison with the NDA option (which would use existing or planned NDA storage facilities). MOD and NDA are undertaking a joint assessment of the WLC of using NDA facilities for storage of Packaged Waste and the feasibility and WLC of using NDA facilities for storage of RPVs.

A Annex A: Abbreviations

Abbreviation	Meaning
AG	Advisory Group
BC	Business Case
CAAS	Cost Assurance Advisory Services
CADMIT	Project life-cycle: Concept, Assessment, Design, Manufacture, In-Service, Termination
CBO	Community Based Organisation
CDAL	Cost Data Assumptions List
COEIA	Combined Operational Effectiveness and Investment Appraisal
CoRWM	Committee on Radioactive Waste management
DDLP	De-fuel, De-equip and Lay-Up Preparation
DECC	Department of Energy and Climate Change
DEFRA	Department of the Environment, Food and Rural Affairs
DE&S	Defence Equipment and Support
DNEB	Defence Nuclear Executive Board
DUWC	Deterrent and Underwater Warfare Capability
EA	Environment Agency
GDF	Geological Disposal Facility
HMNB	Her Majesty's Naval Base
IA	Investment Appraisal
IAC	Investment Approvals Committee
IGBC	Initial Gate Business Case
ILW	Intermediate Level Waste
ISD	In Service Date
ISM	In Service Submarines
KUR	Key User requirement
MCDA	Multi Criteria Decision Analysis
MCP	Maritime Change Programme
MDAL	Master Data Assumptions List
MG	Main Gate
MGBC	Main Gate Business Case
MOD	Ministry of Defence
MoE	Measure of Effectiveness
NGO	Non Governmental Organisation
NDA	Nuclear Decommissioning Authority
NPV	Net Present Value

Abbreviation	Meaning
OASP	Operational Analysis Supporting Paper
OCF	Other Contributory Factors
OE	Operational Effectiveness
OGD	Other Government Department
ONR	Office of Nuclear Regulation
PMP	Project Management Plan
RAG	Red Amber Green
RC	Reactor Compartment
RPV	Reactor Pressure Vessel
SDP	Submarine Dismantling Project
SEA	Strategic Environmental Assessment
SME	Subject Matter Expert
SRO	Senior Responsible Owner
SSUN	Single Statement of User Need
URD	User Requirement Document
V&V	Validation & Verification
WLC	Whole Life Cost

B Annex B: Definitions

Term	Definition
CADMID	Concept, Assessment, Demonstration, Manufacture, In-Service and Disposal. 'Manufacture' in the case of SDP relates to the development of facilities whilst 'Disposal' relates to the decommissioning of facilities at the end of the project.
COEIA	"Combined Operational Effectiveness Investment Appraisal (COEIA) is a formal comparison of acquisition options on a cost versus effectiveness basis to satisfy a User Requirement. "[The COEIA is necessary because]….the Investment Appraisal Committee (IAC) demand that Business Cases are founded on fundamental principles of cost effectiveness analysis enabling evidence based cost versus performance trade-offs within the option down-select process."[42]
IA	"Investment Appraisal (IA) is a method of gathering information in a structured format, to enable decisions to be made as to which of a number of options to meet a specific requirement offers the best value for money."[43]
MCDA	Multi-Criteria Decision Analysis (MCDA) provides decision makers with the means to evaluate different options when faced with numerous and potentially conflicting desired outcomes. In the case of SDP a MCDA model was built with 20 criteria arranged into a hierarchical tree. A panel of SMEs was used to weight the relative importance of each set of criteria or group of criteria. Each option was then scored against each criteria and an overall value for effectiveness derived from the weights and scores. The results, although largely subjective, are based on expert judgement and were subject to moderation through the process of debate and the recording of the SME views, scores and weights at the three workshops used to shape the MCDA model. It is usual for panels of different SME panels to weight and score a MCDA model but the relatively small community of experts familiar with submarine decommissioning meant that, having established that D Scrutiny were satisfied with the approach, a broadly common panel of SMEs were used in both the workshops.
MoE	"Measures of Effectiveness (MoE)….should be directly related to high level operational or business objectives rather than lower level measures of technical performance. It is convention for the MoE to be defined as a numerical quantity that increases with improved effectiveness. MoEs should reflect effectiveness in achievement of operational/business objectives as directly as possible."[44]
NPV	Net Present Value - this discounts current money values by a HM Treasury agreed weight and is used across investment appraisals to fairly assess options with different spend profiles.
OASP	"The Operational Analysis Supporting Paper (OASP) …..offers a well proven structured approach to planning, preparation and presentation of essential foundation evidence on which to construct the Business Case."[45]

[42] Taken from the Acquisition Operating Framework (AOF), Through Life Capability Management, Version 1.1.4, March 2010.
[43] Taken from JSP507, MOD Guide to Investment Appraisal and Evaluation, Version 3.0, dated December 2006.
[44] Taken from Foundations for the Business Case – Operational Analysis, DG(S&A), 2003.
[45] Taken from Foundations for the Business Case – Operational Analysis, DG(S&A), 2003.

Term	Definition
OCF	"Other Contributory Factors (OCF) are those aspects that may have significant influence on procurement decisions but cannot be taken into account within quantitative BoI, Scaling and COEIA analysis such as human factors assessment [or] political, environmental, sociological, technological and environmental aspects."
OE	"[Operational Effectiveness (OE)].....adopts a combination of methods in assessment of operational and business capability embracing: • Quantitative approaches via mathematical modelling of physical system behaviour within context of representative operational or business situations. • Qualitative approaches exploiting judgement of military and technology subject matter experts drawing on operational evidence and technology application opportunities…"[46]
Option	"Depending on context, either – one possible solution, in competition with other mutually exclusive solutions, or – a possible variation within a solution, to be judged on its merits relative to the basic solution and other options."[47]
Outturn	Outturn – is the term given to financial profiles that include the impact of annual inflation and it is used to review affordability.
Proposed Option	The option for SDP, intended for presentation during public consultation. The proposed option will be defined through the COEIA and offer best value for money compared to alternative options. The proposed option may change, or be subject to refinement, on the basis of public consultation.
URD	"The User Requirements Document (URD) is a structured definition of the MODs through-life need for a bounded capability which is managed throughout the life of the capability."[48]
WLC	Whole Life Cost is a term that is used in financial modelling to affirm that scenarios or options considered include all the costs from a project from its beginning to end commonly referred to as 'cradle to grave'.

[46] Taken from Foundations for the Business Case – Operational Analysis, DG(S&A), 2003. The definition is actually for Operational Analysis (OA) but it provides a good description of Operational Effectiveness.
[47] Taken from the Acquisition Operating Framework (AOF), Requirements and Acceptance, Version 1.1.4, March 2010. Taken ultimately from the APM Body of Knowledge, 5th Edition, ISO 15288.
[48] Taken from the Acquisition Operating Framework (AOF), Requirements and Acceptance, Version 1.1.4, March 2010.

C Annex C: References

Title	Originator	Reference/ Version	Date
SDP Benefits Report	ISM	Issue V1.0	2 Feb 11
SDP Integrated Options Report	ISM	Issue V1.0	18 Feb 11
SDP Investment Appraisal (IA)	ISM	Issue 1	20 July 11
SDP Operational Effectiveness (OE) Report	ISM	Issue 0.3	14 Jul 11
SDP Other Contributory Factors (OCF) Report	ISM	Issue 0.4	14 Jul 11
Our Approach to Decision Making	ISM	Issue 1.1	18 Aug 11
SDP Project Management Plan (PMP)	ISM	Issue V9.0	Aug 11
SDP User Requirements Document	ISM	Issue V4.0	Feb 11
Strategic Environmental Assessment (SEA): Final Scoping Report	ENTEC	V3.0 (Reg. No. 25271)	21 Mar 11
Review of SDP MCDA Monte-Carlo Model and Associated Data Checking	Nuvia	Issue V1.0	30 June 11

D Annex D: SDP Benefits

Benefit	Type	Short Description	Potential Metrics	Link to KUR or OCF
Improved Public Confidence (SDP-BEN-01)	Operational, direct	SDP provides the opportunity to engage with the public and build greater understanding about the submarine enterprise and nuclear safety. SDP will provide confidence to the decision to conduct dismantling and demonstrate a commitment to reducing intergenerational equity.	1) Public attitudes towards SDP in the form of responses to questionnaires directed at the local communities associated with potential (and later actual) dismantling and ILW storage locations. 2) Progress against SDP schedule in terms of unanticipated delays to planning permission or other activities brought about by adverse public opinion. 3) Performance against SDP risks in terms of the level of successful risk mitigation or reduction achieved by the project.	UR5.2.1 The user requires that SDP inspires public confidence and thereby upholds the MODs reputation as a responsible nuclear operator.
Positive Socio-Economic Impact (SDP-BEN-02)	Operational & financial, indirect	SDP will deliver a positive socio-economic effect on communities local to dismantling (primarily) and ILW Storage (less significantly) such as by delivering net increased direct and indirect employment[49], and by mitigating any negative perception of its activities through engagement with the local population.	Inferred economic impact through the analysis of direct employment resulting from SDP activities and estimates of indirect impacts on employment and other economic activities (in £ terms).	OCF-02 Socio-economic Impacts

[49] The SEA provides estimates for the number of jobs created as a result of the different SDP options, which will form the basis of any measure of socio-economic impact.

Benefit	Type	Short Description	Potential Metrics	Link to KUR or OCF
Wider Economic Benefit to MOD (SDP-BEN-03)	Financial, indirect	SDP can deliver economic benefits to the MOD beyond the direct impact of financial savings associated with submarine dismantling (compared to afloat storage). These may take the form of sharing infrastructure with other maritime projects, realising the sale of land or other assets and/or achieving contract savings by balancing dockyard activities.	Economic impact on the MOD (in £ terms).	OCF-02 Socio-economic Impacts UR1.1.1 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.
Minimisation of Costs Associated with Submarine Liability (SDP-BEN-04)	Financial, direct	Indefinite afloat storage will become increasingly costly as the number and age of out of service submarines increases. SDP can deliver WLC savings across the lifetime of the project, although not necessarily early in the project lifetime. Savings will also include the financial revenues achieved through recycling material.	Economic impact on the MOD (in £ terms).	UR1.1.1 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.
Sustainable, Safe Removal and Disposal of Non-hazardous Waste (SDP-BEN-05)	Operational, direct	SDP will ensure that all non-hazardous waste streams arising from submarine dismantling are managed in accordance with security and safety regulation, legislation, policy and strategy. This benefit is associated with the successful removal of MODs liability for non-hazardous waste.	Management of non-hazardous waste without unanticipated incident or delay.	UR1.1.1 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.
Sustainable, Safe Removal and Disposal of Hazardous Waste (SDP-BEN-06)	Operational, direct	SDP will ensure that all hazardous waste streams arising from submarine dismantling are managed in accordance with security and safety regulation, legislation, policy and strategy. This benefit is associated with the successful removal of MODs liability for hazardous waste.	Management of hazardous waste without unanticipated incident or delay.	UR1.1.1 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.

Benefit	Type	Short Description	Potential Metrics	Link to KUR or OCF
Sustainable, Safe Removal and Disposal of LLW/VLLW (SDP-BEN-07)	Operational, direct	SDP will ensure that all radiological waste streams arising from submarine dismantling are managed in accordance with security and safety regulation, legislation, policy and strategy. This benefit is associated with the successful removal of MODs liability for LLW/VLLW.	Management of LLW/VLLW without unanticipated incident or delay.	UR1.1.1 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.
Bounded and Managed ILW (SDP-BEN-08)	Operational, direct	SDP will ensure that all radiological waste streams arising from submarine dismantling are managed in accordance with security and safety regulation, legislation, policy and strategy. This benefit is associated with the successful removal of MODs liability for ILW and its preparation for eventual disposal in the proposed GDF.	Management of ILW without unanticipated incident or delay.	UR1.1.1 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. UR2.6.3 The user requires a means to store ILW from 27 defuelled nuclear submarines until a national disposal route is established.
Avoidance of Operational Impact (SDP-BEN-09)	Operational & financial, direct	Continued afloat storage has the potential to disrupt current operations as berthing space will become increasingly difficult to find as more submarines become redundant. The project is required, where possible, to retain flexibility for future classes; namely to preserve options for adapting or life-extending dismantling facilities should such a decision be taken in the future.	1) The available berthing space for afloat storage is not exceeded 2) The estimated cost (in £ terms) of enhancing the dismantling and ILW storage facilities to manage future classes.	UR3.4.1 The user requires that the capability is in service before the decommissioned submarine storage capacity is reached

Benefit	Type	Short Description	Potential Metrics	Link to KUR or OCF
Maintenance of UK Industrial Capacity (SDP-BEN-10)	Financial, indirect	SDP will support the partnership between the MOD and industry by maintaining contractual links with UK companies involved in the submarine enterprise, preserving nuclear skills and broadening the UK knowledge of dealing with the liability of out of service submarines.	Value of additional contracts placed with industry involved with the submarine enterprise (in £ terms).	UR1.1.1 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.
Mitigation of Environmental Impact (SDP-BEN-11)	Operational, direct	SDP must deliver minimal environmental impact and ensure that all activities meet legal and regulatory limits. In addition SDP will aim to meet MOD and Government policy and strategy guidelines, bearing in mind that there can be contradictions of ambiguities which must be reconciled.	Environmental impacts against statutory, legal, policy and strategy, measured in terms of exception (when there are issues to report).	UR1.1.1 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.

E Annex E: Key Assumptions

Overview

This Annex contains key assumptions which underpin SDP and the analysis within the OASP. It includes key technical and financial assumptions, and provides a brief on LUSM storage. For a full list of project assumptions, see the MDAL. Working assumptions are those which have been made to support the OE or other activities, and are differentiated from project assumptions.

Technical Assumptions

These working assumptions were made for the purposes of the options analysis and are not project assumptions:

- Where a new build facility is required, there will only be one ILW storage site. This applies to RCs, RPVs or Packaged Waste not stored at a NDA site. In the case of options to use NDA storage facilities for packaged waste, one or more sites may be used.

- There will only be one RPV Size Reduction Facility.

- The project has assumed that no transport of RCs would be undertaken, because preliminary analysis indicated that the transport costs would be considerable and there were seen to be significant risks associated with RC transport by sea. In order to fit with the other assumptions surrounding options, however, it has been assumed that Option 1B includes transport of RCs 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. The additional cost of remote storage of RCs has been estimated as significant.

- Another working assumption during the MCDA workshops was that in the case of Option 1B the RCs would be transported from Rosyth to Devonport. This was done as transportation in the other direction would make a difference to the scoring. Transport to Devonport would involve less RCs and qualitatively the scores for transport to Rosyth were considered by the workshop to be less favourable.

- A working assumption was made for Options 2, 3 and 4 (RPV), the Interim Storage Facility and the Size Reduction Facility will be on the same site. Transport of RPVs to a separate size reduction facility would be feasible and so this is a working assumption only that was adopted for purposes of options analysis and environmental impact assessment.

  - The corollary working assumption is that for Option 2B, (dual site RPV removal), RPVs from one site will need to be transported to an interim store on the other site (from either Devonport to Rosyth or Rosyth to Devonport). .

- For Options 5 to 8 (Packaged Waste), the Initial Dismantling Facility and the Size Reduction Facility will be on the same site. Again, transport of RPVs to a separate size reduction facility would be feasible and so this is a working

assumption only that was adopted for purposes of options analysis and environmental impact assessment.

Financial Assumptions

All assumptions used by the IA are contained in the SDP Master Data Assumptions List (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.
- The Demonstrator is expected to commence in [redacted] and In-service Date (ISD) in [redacted] across all options (also in the MDAL).
- The proposed GDF is expected to be available from 2040.
- One submarine is to be dismantled per year.
- ILW must be packaged into 3m³ boxes before it can enter the proposed GDF.
- The WLC includes full cost of ILW Storage and the costs of disposal in the proposed GDF, which are a fraction of the total cost.
- Costs include associated afloat storage costs (such as maintenance, berthing and potential infrastructure improvements).

LUSM Storage Summary

There are 7 submarines stored at Rosyth, all of which are defuelled:

- Churchill
- Dreadnought
- Swiftsure
- Revenge (SSBN)
- Resolution (SSBN)
- Repulse (SSBN)
- Renown (SSBN)

There are 10 submarines stored at Devonport:

- Warspite (defuelled)
- Valiant (defuelled)
- Conqueror (defuelled)
- Courageous (defuelled)
- Splendid (fuelled)
- Spartan (fuelled)
- Sovereign (fuelled)
- Superb (fuelled)
- Trafalgar (fuelled)
- Sceptre (fuelled)

No further submarines will be stored at Rosyth. All submarines coming out of service will in future be taken to Devonport for defuelling. The situation at Devonport is as follows:

- The 3 Basin Facility Safety Case (FSC130) allows 14 submarines to be stored of which 10 are permitted to be fuelled (this will be reached in FY 20/21) – which means the last two T-Class coming out of service cannot presently be stored in 3 Basin.

[redacted]

- V Class submarines cannot be stored in 3 basin – will have to be stored in 4 or 5 basin with infrastructure costs nearing [redacted] and berthing costs to Babcock (3 Basin is wholly owned by the MOD)

If the submarines at Rosyth were to be moved to Devonport:

- SSBNs will not fit in 3 Basin and will have to be stored elsewhere, if this has to be a non tidal basin, infrastructure costs could near [redacted].
- If SSNs are moved to Devonport, 3 basin would reach the 14 submarine capacity in [redacted], and the 16 submarine capacity in [redacted].

F Annex F: OE Results

Ranked in terms of OE (high to low).

Rank	Option	10th%	50th%	90th%
1	8D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at an approved NDA site	5.15	5.49	5.87
2	8B: RPV removal & size reduction at Devonport & Rosyth to form Packaged Waste with interim storage at an approved NDA site	5.09	5.40	5.74
3	3B: RPV removal at Devonport & Rosyth with interim storage at remote commercial site	4.93	5.24	5.56
4	4B: RPV removal at Devonport & Rosyth with interim storage at remote MOD site	4.92	5.23	5.56
5	2D: RPV removal at Devonport with interim storage at POWG	4.87	5.16	5.46
6	3D: RPV removal at Devonport with interim storage at remote commercial site	4.84	5.14	5.45
7	2B: RPV removal at Devonport & Rosyth with interim storage at POWG	4.79	5.10	5.43
8	4D: RPV removal at Devonport with interim storage at remote MOD site	4.80	5.09	5.39
9	7D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote MOD site	4.69	5.02	5.36
10	8R: RPV removal & size reduction at Rosyth to form Packaged Waste with interim storage at an approved NDA site	4.66	5.02	5.38
11	5D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at POWG	4.69	4.99	5.31
12	3R: RPV removal at Rosyth with interim storage at remote commercial site	4.46	4.95	5.36
13	7B: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote MOD site	4.61	4.93	5.27
14	6D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote commercial site	4.59	4.92	5.26
15	4R: RPV removal at Rosyth with interim storage at remote MOD site	4.43	4.91	5.32
16	5B: RPV removal & size reduction at Devonport & Rosyth to form Packaged Waste with interim storage at POWG	4.58	4.88	5.18
17	2R: RPV removal at Rosyth with interim storage at POWG	4.56	4.86	5.19
18	6B: RPV removal & size reduction at Devonport & Rosyth to form Packaged Waste with interim storage at remote commercial site	4.52	4.84	5.16
19	7R: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote MOD site	4.38	4.77	5.17
20	5R: RPV removal & size reduction at Rosyth to form Packaged Waste with interim storage at POWG	4.37	4.72	5.08
21	6R: RPV removal & size reduction at Rosyth to form Packaged Waste with interim storage at remote commercial site	4.28	4.69	5.14
22	1D: RC separation at Devonport with interim storage at point of waste generation (POWG)	4.14	4.49	4.86
23	0: Continued Afloat Support	3.95	4.40	4.83
24	1R: RC separation at Rosyth with interim storage at POWG	4.00	4.33	4.67
25	1B: RC separation at Devonport & Rosyth with interim storage at POWG	3.85	4.18	4.54

Table F-1: SDP Options Ranked by 50% Confidence OE Scores

G Annex G: IA Results

Ranked in terms of median WLC in £m (lowest to highest).

Rank	Option	10th% 50th% 90th%
1	4B: RPV removal at Devonport & Rosyth with interim storage at remote MOD site	Redacted Due To Commercial Sensitivity
2	4D: RPV removal at Devonport with interim storage at remote MOD site	
3	3B: RPV removal at Devonport & Rosyth with interim storage at remote commercial site	
4	2B: RPV removal at Devonport & Rosyth with interim storage at POWG	
5	8D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at an approved NDA site	
6	8B: RPV removal & size reduction at Devonport & Rosyth to form Packaged Waste with interim storage at an approved NDA site	
7	2D: RPV removal at Devonport with interim storage at POWG	
8	3D: RPV removal at Devonport with interim storage at remote commercial site	
9	1B: RC separation at Devonport & Rosyth with interim storage at POWG	
10	7D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote MOD site	
11	7B: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote MOD site	
12	1D: RC separation at Devonport with interim storage at point of waste generation (POWG)	
13	5D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at POWG	
14	5B: RPV removal & size reduction at Devonport & Rosyth to form Packaged Waste with interim storage at POWGk	
15	6D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote commercial site	
16	6B: RPV removal & size reduction at Devonport & Rosyth to form Packaged Waste with interim storage at remote commercial site	
17	4R: RPV removal at Rosyth with interim storage at remote MOD site	
18	0: Continued Afloat Support	
19	2R: RPV removal at Rosyth with interim storage at POWG	
20	8R: RPV removal & size reduction at Rosyth to form Packaged Waste with interim storage at an approved NDA site	
21	3R: RPV removal at Rosyth with interim storage at remote commercial site	
22	1R: RC separation at Rosyth with interim storage at POWG	
23	7R: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at remote MOD site	
24	5R: RPV removal & size reduction at Rosyth to form Packaged Waste with interim storage at POWG	
25	6R: RPV removal & size reduction at Rosyth to form Packaged Waste with interim storage at remote commercial site	

Table G-1: SDP Options Ranked by 50% Confidence OE Scores