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ISM

SUBMARINE DISMANTLING PROJECT

Operational Analysis Supporting Paper (OASP)

Issue 1.0 – October 2012

This document has been released as background information to support the MOD's Response to the Submarine Dismantling Consultation. This Issue 1.0 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.

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1.0	8 Oct 12	Formal release after final review and minor corrections and amendments to v0.4	[redacted]

Distribution

SDP Virtual Team
SDP Scrutiny Meeting Members

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Executive Summary

Aim

The aim of the Submarine Dismantling Project (SDP) is to deliver a safe, secure, environmentally responsible and cost-effective solution for dismantling 27 of the UK's decommissioned and defuelled nuclear submarines and for disposing of the waste generated. This includes storage of the Intermediate Level Waste (ILW) removed from the submarines, until the UK's planned Geological Disposal Facility (GDF) is available.

The project must uphold the MOD's reputation as a responsible nuclear operator throughout its activities. It is required to commence before submarine storage capacity is exceeded, in order to minimise any impact on military capability, and to complete by 2050.

Context

SDP is approaching the end of its Assessment Phase with the submission of its first Main Gate Business Case (MGBC1) to the Investment Approvals Committee (IAC), making recommendations on the key decisions that need to be taken in order to proceed to its Demonstration Phase. This Operational Analysis Supporting Paper (OASP) summarises the available evidence and recommends the most cost-effective approach to dismantling the submarines, including the technical approach to be adopted and where dismantling should be conducted.

SDP will subsequently seek further approval on which specific sites should be used to store ILW generated through dismantling, and to move beyond the Demonstrator Phase to dismantle the remaining 26 submarines. This decision point will constitute MGBC2 for SDP, which is scheduled for submission to the IAC in 2019.

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 of 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 berthing 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 in the 2020s. These issues underline the need for MOD to provide a long-term solution for submarine dismantling.

The project scope includes 27 Royal Navy nuclear submarines, including those currently in service, excepting the Astute class which is in the process of entering service[1]. Whilst the current project scope does not include dismantling of either the Astute class or the planned Successor submarines, the project is required, where possible, to retain flexibility for these

[1] SDP will dismantle the following classes of submarine (with the number of constituent submarines in brackets): Dreadnought (1), Valiant (2), Churchill (3), Swiftsure (6), Trafalgar (7), Resolution (4) and Vanguard (4). The latter two classes are SSBNs and all the others are SSNs.

and other future classes. The project includes:

- The interim storage on land of the resultant ILW pending the availability of the GDF which is assumed to be available sometime after 2040. The delivery of GDF is the responsibility of the Department for Energy & Climate Change (DECC).

- The dismantling of all non-radiological parts of the submarines at a conventional UK ship recycling facility. As much material as possible will be recycled, and all radiological and hazardous material will be disposed of safely (recognising that the ILW will be stored pending eventual disposal in the GDF).

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

Option Set

There are a large number of potential solutions to SDP, which have been formed into integrated options developed from combinations of the following:

- **Technical Approaches** to the initial dismantling of submarines.

- **Initial Dismantling Site(s).**

- **Generic type of 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 GDF, which is assumed to be packaged waste following the size reduction of the radiological parts of the submarine. This is termed 'interim storage' as the ILW will still need to be disposed in the 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 and does not deliver the intended project benefits[2]. Table A summarises the options which were selected for full analysis to support the submission of MGBC1[3]:

Category	Option identifier	Description
Indefinite afloat storage	0	Do Minimum **(Comparator only, which represents a continuation of the current approach)**
Options that separate the whole Reactor Compartment (RC) and store it at the	1R	RC separation at Rosyth, with interim storage at Point of Waste Generation (POWG) at Rosyth, and at a later date size reduction of ILW before transfer to the GDF. **(Operational Effectiveness (OE) and Other Contributory Factors (OCF) Comparator only)**[4]

[2] The Do Minimum option assumes that the MOD continue to store and maintain submarines in the same way as it does at present. Although this is a feasible option, the number of submarines stored will rise steadily and the maintenance required to keep them safe will also increase. This would impose an increased cost and operational burden on the MOD, and still not provide a true disposal route for the hulls.

[3] A wide range of alternative options have been discounted through a staged analysis and de-selection process which is described in more detail in the main body of this report,

[4] Those options with dismantling being conducted at Rosyth only are estimated to be much more expensive than Devonport only or dual site options. Public Consultation, however, resulted in a number of stakeholders expressing support for the RC options, and it was decided to keep Option 1R under consideration as an OE and OCF comparator.

Category	Option identifier	Description
dismantling site	1D	RC separation at Devonport, with interim storage at POWG at Devonport, and at a later date size reduction of ILW before transfer to the GDF
Options that remove and store the whole Reactor Pressure Vessel (RPV)	2D	RPV removal at Devonport, with interim storage at POWG at Devonport, and at a later date size reduction of ILW before transfer to the GDF
	3-4D[5]	RPV removal at Devonport, with interim storage at a remote MOD or commercial site and at a later date size reduction of ILW before transfer to the GDF
	2-4B	RPV removal at Devonport and Rosyth, with interim storage at one of the following: a remote MOD or commercial site, Devonport or Rosyth, and at a later date size reduction of ILW before transfer to the GDF
	9D[6]	RPV removal at Devonport with interim storage at NDA site(s), and at a later date size reduction of ILW before transfer to the GDF.
	9B	RPV removal at Devonport and Rosyth with interim storage at NDA site(s), and at a later date size reduction of ILW before transfer to the GDF
Options that remove the whole (RPV) and then reduce it in size to form packaged waste	5D	RPV removal and size reduction to form Packaged Waste with interim storage at POWG, all at Devonport
	6-7D	RPV removal and size reduction to form Packaged Waste at Devonport with interim storage at a remote MOD or commercial site
	5-7B	RPV removal and size reduction to form Packaged Waste at Devonport and Rosyth, with interim storage at one of the following: a remote MOD or commercial site, Devonport or Rosyth.
	8D	RPV removal and size reduction to form Packaged Waste at Devonport with interim storage at Nuclear Decommissioning Authority (NDA) site(s)
	8B	RPV removal and size reduction to form Packaged Waste at Devonport and Rosyth with interim storage at NDA site(s)

Table A SDP Integrated Options

Concept of Analysis

The process used to assess SDP options is explained in the endorsed Concept of Analysis[7] (CoA). Assessment of the options has been conducted in line with 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)[8].
- **Whole Life Cost (WLC)** of the options through Investment Appraisal (IA)

[5] This nomenclature reflects a grouping of previously separate options from earlier in the analysis process.
[6] Options 9D and 9B were added in 2012 when it was determined that it was feasible to store whole RPVs at NDA sites; hence the fact that the numbering system is not sequential .
[7] SDP Concept of Analysis, dated March 2011, Issue 1.1.
[8] SDP User Requirements Document, dated October 2011, v5.0.

- **Other Contributory Factors (OCF)** what is the significance of non-quantifiable factors which lie outside the remit of SDP or the MOD, on each SDP option.

This approach is entirely in keeping with MOD practice. Additionally, however, SDP undertook a process of formal Public Consultation during the second half of 2011. To inform this consultation, rigorous analysis was undertaken to deliver an Interim OASP[9], which contained a proposed (as opposed to recommended) option for public consideration. This OASP and supporting analysis has taken account, where appropriate, of findings from the SDP Public Consultation. It has also benefitted from a greater understanding of the options through technical studies which have reported since the Interim OASP was published in 2011.

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 populated using the outputs of a pair of two-day workshops attended by a range of subject matter experts. The model comprised criteria covering compliance with policy, impact on maritime operations, health and safety and environmental impact. The OE was an update of the 2011 analysis which informed the SDP Public Consultation.

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 can 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. The IA is also compliant with JSP 507[10].

Other Contributory Factors

The level of public and stakeholder interest in SDP, and the potential influence of key stakeholders over project delivery, means that the project must consider a wider range of OCFs than many MOD projects. Some of these OCFs have a major bearing on the MGBC decisions, and their analysis has provided a robust audit trail against challenge.

A set of top level OCFs was first derived and included for comment in the SDP Public Consultation Document[11]. These OCFs were then broken down into 20 more detailed factors for analysis. A workshop was held with subject matter experts and stakeholders to consider the results of this analysis and consultation feedback, and to identify those sub-factors that were 'potential deal breakers' or offered particular delivery or communications 'challenges' to SDP.

[9] SDP Interim OASP, Issue 1.0a, dated October 2011.
[10] JSP 507 - MOD Guide to Investment Appraisal and Evaluation, v5.0, April 2011.
[11] SDP Public Consultation Document, dated 28 October 2011.

Results

The OE and IA results have been combined in a Combined Operational Effectiveness Investment Appraisal (COEIA) shown in Figure A below. It shows each SDP integrated option as a point with the uncertainty around their OE and WLC values shown as error bars. The labels show the different technical approaches which might be used to dismantle the submarines: the Do Minimum (Do Min) option, RC separation, removal of the RPV and early size reduction to form Packaged Waste (PW).

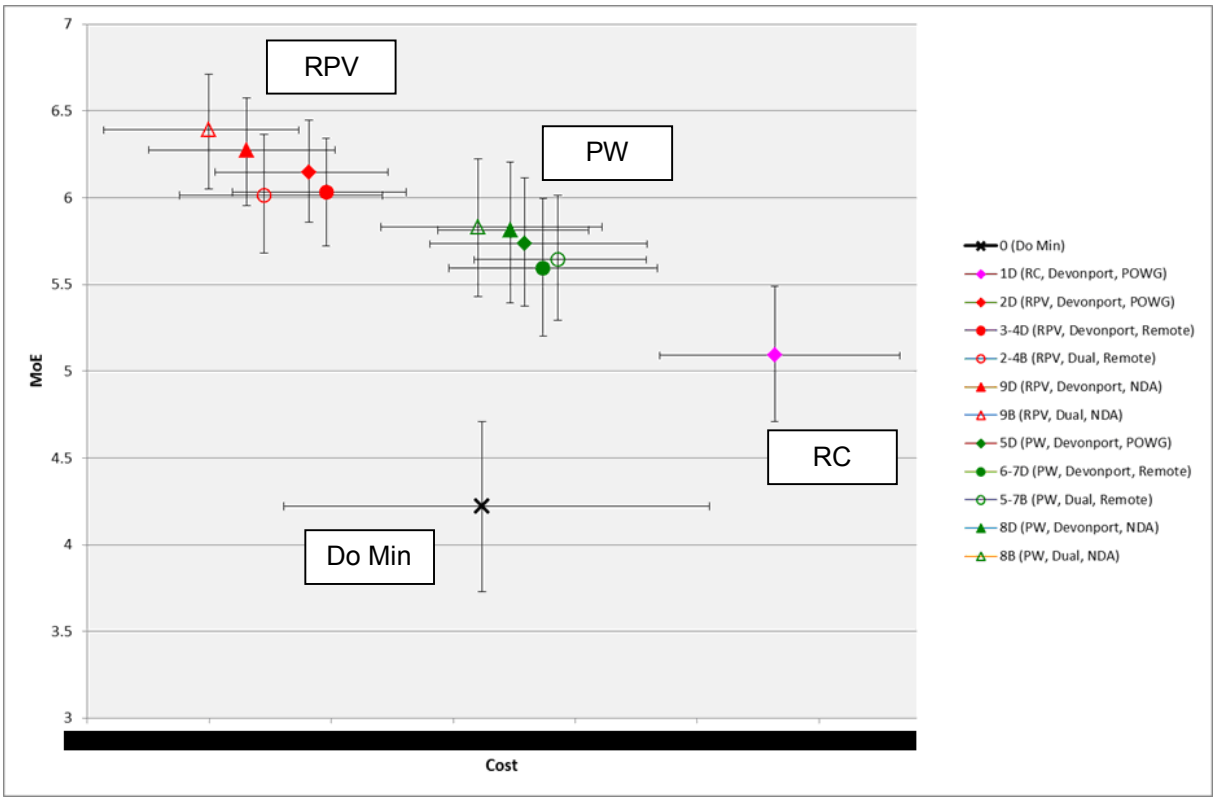

Figure A – SDP COEIA (Cost is NPV in £m)

Figure A shows a trend for options with higher effectiveness to have lower WLC which is explained by the fact that the lower cost represents less complicated operations and a smaller amount of capital investment, which results in associated time, operational and environmental benefits. It demonstrates that:

- Option 0 (Do Minimum) is significantly less effective that the Do Something options. Additionally, specific OE results indicate that is it not compliant with UK policy and poses an unacceptably high risk to maritime operations[12].
- Option 1D (RC) is significantly more costly than the other Do Something options.
- The Packaged Waste options are nearly all more costly than the RPV options (the exception is for Option 8B). Further, each pair of comparable options (such as 8B and 9B) are separated by a statistically significant cost margin.

[12] The Do Minimum option explicitly fails one of the SDP Key User Requirements, 3.4.1, "the user requires that the capability is in service before the decommissioned submarine storage capacity is reached."

The COEIA, therefore, demonstrates a clear preference for options involving RPV removal but does not identify 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 COEIA alone is inconclusive in respect of the sites for initial dismantling and ILW storage.

The OCF analysis does, however, provide evidence to help separate these RPV options. Perceptions of public risk, inter-generational equity and fairness and local political positions all favour dual site dismantling over Devonport-only dismantling. Given the closeness in WLC and OE between dual site and Devonport-only options, it is recommended that the former is selected to avoid potentially lengthy and/or costly delays arising from particular opposition to dismantling at Devonport only and the attendant movement of submarines.

In terms of generic ILW sites, a number of OCFs currently discriminate against those options with a *generic* POWG ILW storage relative to a *generic* remote storage location, but this does not mean that a *specific* POWG site will necessarily prove to be discriminated for or against relative to *specific* remote sites.[13] Importantly, potential host communities for storage remote from the POWG have not yet had a chance to make their input, and their insights and views may affect the decision making process for ILW storage sites. The situation with respect to other generic ILW storage site types is also complex, with different OCFs and stakeholder positions pointing to different and potentially contradictory solutions.

The judgement is, therefore, that neither the COEIA nor OCFs currently discriminate sufficiently between *generic* ILW storage site type options to make a decision. Furthermore, there are good reasons why a decision should not be made at this point. OCF analysis and feedback from key stakeholders does lead to a clear conclusion that SDP should consider all potential ILW storage sites, including NDA sites, on a 'level playing field', to avoid potential delays or cost when negotiating with local communities.

Recommended Option

The recommendation which emerges from this analysis is **RPV removal and storage with initial dismantling at both Devonport and Rosyth Dockyards**[14]. No specific site is currently proposed for ILW storage but it is recommended that this be decided through a transparent and consultative assessment which considers all credible site options, including NDA, MOD, Commercial and POWG sites. The recommended option set to be taken forward is, therefore, **Option 2-4 and/or 9B**.

This recommendation is supported firmly by the COEIA, which demonstrates that RPV removal is the most cost-effective approach to submarine dismantling. The OCF analysis, refines this further such that dual-site dismantling is recommended, but the decision on ILW storage needs to be based on a site specific assessment that considers all credible sites irrespective of whether they are NDA, MOD, commercial and/or POWG. This would require a transparent and consultative assessment that would follow MGBC1 announcements on the sites and methodology for initial dismantling.

[13] See the OCF Report, Issue 1.0, dated October 12.
[14] Initial dismantling refers to the removal of the RPVs from the hull. The remainder of the hulls would then be broken up using conventional ship recycling methods.

1. Introduction

1.1. Context

1.1.1. The aim of the Submarine Dismantling Project (SDP) is to deliver a safe, secure, environmentally responsible and cost-effective solution for dismantling 27 of the UK's decommissioned and defuelled nuclear submarines and for disposing of the waste generated. This includes storage of the Intermediate Level Waste (ILW) removed from the submarines, until the UK's planned Geological Disposal Facility (GDF) is available.

1.1.2. The project must uphold the MOD's reputation as a responsible nuclear operator throughout its activities. It is required to commence before submarine storage capacity is exceeded, in order to minimise any impact on military capability, and to complete by 2050.

1.1.3. SDP is approaching the end of its Assessment Phase with the submission of its first Main Gate Business Case (MGBC1) to the Investment Appraisal Committee (IAC), which will present recommendations on the key decisions that need to be taken in order to proceed to its Demonstration Phase. This Operational Analysis Supporting Paper (OASP) summarises the available evidence and recommends the most cost-effective approach to dismantling the submarines, including the technical approach to be adopted and where dismantling should be conducted.

1.1.4. SDP will subsequently seek further approval on which specific sites should be used to store ILW generated through dismantling, and to move beyond the Demonstrator Phase to dismantle the remaining 26 submarines. This decision point will constitute MGBC2 for SDP, which is scheduled for submission to the IAC in 2017.

1.2. SDP Decision Making Process

1.2.1. The decision making process leading up to MGBC is set out in the Concept of Analysis (CoA)[15] and SDP has prepared its recommendation to the IAC on the basis of three analyses:

- **Operational Effectiveness (OE)**: how effectively does each SDP option[16] meets the needs of the MOD set out in the User Requirements Document (URD)[17]? The OE analysis was conducted using Multi-Criteria Decision Analysis (MCDA) to capture expert judgement on the merits of the options under consideration to deliver SDP.

- **Investment Appraisal (IA)**: what is the Whole Life Cost (WLC) of each SDP option?

- **Other Contributory Factors (OCF)**: what is the significance of non-quantifiable factors, which lie outside the remit of SDP or the MOD, on each SDP option.

[15] SDP Concept of Analysis v1.1 dated March 2011.
[16] The SDP Integrated Options Report v1.0 dated February 2011 provides the baseline options developed in 2011, but the definitive set of options is described in the SDP Options De-selection Paper v1.0 dated May 2012.
[17] SDP URD v5.0 dated October 2011.

1.2.2. The results of the OE and IA have been brought together to form a Combined Operational Effectiveness and Investment Appraisal (COEIA), and reported alongside the findings of the OCF analysis, in this OASP.

1.2.3. This approach is entirely in keeping with MOD practice. Additionally, however, SDP undertook a process of formal public consultation on its options during the second half of 2011. To inform this consultation, rigorous analysis was undertaken to deliver an Interim OASP[18], which contained a proposed (as opposed to recommended) option for public consideration. This OASP and supporting analysis has taken account, where appropriate, of findings from public consultation. It has also benefitted from a greater understanding of the options through technical studies which have reported since the Interim OASP was published in 2011.

1.3. Decision Making Process

1.3.1. Figure 1 summarises the documents which underpin SDP decision making, their key features and inter-relationship.

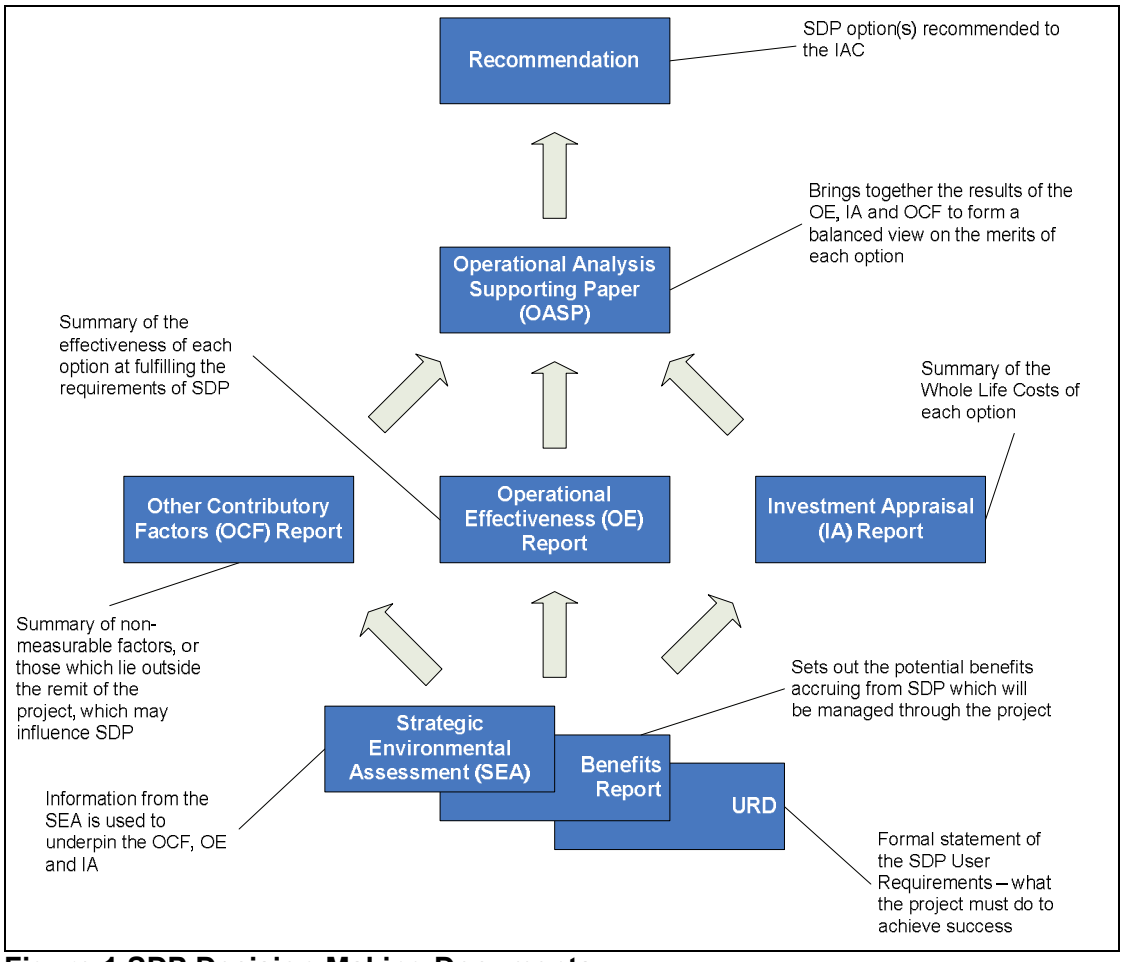

Figure 1 SDP Decision Making Documents

[18] SDP Interim OASP v1.0a dated October 2011.

1.4. Document Structure

1.4.1. The document is 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 which have been put forward for the project, including the 'Do Minimum' comparator.
- Section 5 summarises the results of the OE analysis.
- Section 6 summarises the results of the IA.
- Section 7 presents the COEIA results.
- Section 8 describes the OCF.
- Section 9 provides recommendations.
- 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.
- 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[19], in a safe, secure, and sustainable manner which upholds MODs reputation as a responsible nuclear operator; stores 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)[20]. 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 18 nuclear powered submarines which have already left naval service are stored safely afloat, with 7 at Rosyth Dockyard and 11 at Devonport Dockyard.

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 UK Government[21] and MODs[22] nuclear decommissioning policies, which requires that nuclear decommissioning activities should be carried out as soon as reasonably practicable.

- The current 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 maintaining the redundant submarines and conducting unplanned remedial work is increasing as they age. The rising costs of afloat storage have been included in the WLC model for the Do Minimum option.

- The ability to deliver significant savings by reducing the space required to support out-of-service submarines, which enables the efficient use of sites to support in-service submarines and other aspects of the maritime enterprise.

[19] See Annex C (Assumptions) for a description of the arrangements for Laid-up Submarine (LUSM) storage.
[20] Devonport Dockyard is the only nuclear licensed site in the UK planned to undertake this activity in the future.
[21] The Decommissioning of the UK Nuclear Industry's Facilities – Amendment to Command 2919, DTI Paper, Sep 04.
[22] "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[23]), regularly in the local and national 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 from the SDP and optimises the value for the recyclable materials from the submarines[24].

2.3. Scope

2.3.1. The project scope includes past and current classes of Royal Navy nuclear submarines, 27 in all, excepting the Astute class which is in the process of entering service[25]. While the current project scope does not include dismantling of Astute class or the planned Successor submarines, the project is required, where possible, to retain flexibility for these and other 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 GDF. As the 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 by the Committee on Radioactive Waste Management (CoRWM) report [26,27].

- The breaking and final recycling of the remainder of the submarine, once cleared of all radioactivity (to below regulatory limits), at a conventional ship recycling facility; as much material as possible will be recycled.

- The safe disposal of radioactive waste other than ILW (which will be safely stored until final disposal in the GDF), and hazardous waste.

- Transport of submarines and radioactive waste, as required, between facilities undertaking the above activities, and, eventually, to the GDF.

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[23] Two consultations were held, in 2001 and 2003 respectively, to provide early information to stakeholders and obtain feedback on issues of potential concern. For more information please see SDP Factsheet 1, History of the Project, which was produced for public consultation,

[24] The scrap value per submarine has been estimated by the Disposal Services Authority (DSA) to be between [redacted] and [redacted] (net) per submarine, after transport and dismantling costs have been removed.

[25] SDP will dismantle the following classes of submarine (with the number of constituent submarines in brackets): Dreadnought (1), Valiant (2), Churchill (3), Swiftsure (6), Trafalgar (7), Resolution (4) and Vanguard (4). The latter two classes are SSBNs and all the others are SSNs.

[26] Managing our Radioactive Waste Safely, CoRWMs recommendations to Government, 31/07/06, available at http://corwm.decc.gov.uk

[27] 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

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

2.3.2. The project has been divided into a number of Phases and Gates in accordance with the principles of the CADMID cycle[28] 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[29] (PMP). Broadly, however, and without prejudicing the PMP, Phase 2 (Assessment Phase) is planned to conclude in 2013 with MGBC1. Phase 3 (Demonstration Design & Approvals) is scheduled to take around 4 years to complete, and Phase 4 (Demonstrator Execution) a further 2, culminating in MGBC2. Phase 5 (Manufacture) is scheduled take around a year to complete, followed by an ISD at the end of the decade. Assuming a rate of dismantling one submarine a year, Phase 6 (In-Service) is scheduled to last until the second half of the 2040's.

2.3.3. This OASP supports MGBC1 and recommends the technical approach which should be adopted for dismantling, and where dismantling should be conducted. SDP will subsequently seek further approval on which specific sites should be used to store ILW generated through dismantling, and to move beyond the Demonstrator Phase to dismantle the remaining 26 submarines. This decision point will constitute MGBC2 for SDP, which is scheduled for submission to the IAC in 2019.

2.4. Public Consultation

2.4.1. The MOD recognises the public interest in SDP and has committed to public consultation before major decisions are made, and to openness and transparency throughout the decision making process.

2.4.2. The formal SDP Public Consultation period in advance of MGBC1 submission began on 28 October 2011 and closed on 17 February 2012[30]. The Consultation sought views on 3 key decisions about submarine dismantling:

- How the radioactive material would be removed from the submarines.
- Where removal of the radioactive material would be conducted.
- Which type of site would be used to store the radioactive waste awaiting disposal.

2.4.3. The consultation included 8 local exhibitions and 2 national workshops; 1200 people visited the events and 400 written responses were received[31]. The responses received were used to clarify the assumptions underpinning the OE analysis and to inform the OCF analysis, and have had a direct bearing on the recommendations put forward in this OASP.

2.5. Capability Stakeholders & Customer

2.5.1. The Defence Nuclear Executive Board (DNEB) sets nuclear decommissioning policy

[28] See Annex B Definitions.
[29] SDP Project Management Plan, ISM, Issue 11.0, dated May 12.
[30] See the SDP Consultation Document, dated 28 October 2011.
[31] See the SDP Post Consultation Report, dated July 2012.

for the Department. Head of Deterrent & Underwater Capability (DUWC) is the Sponsor and Senior Responsible Owner (SRO).

2.5.2. Owing to the nature of the project, there are many stakeholders with varied remits. A full list of stakeholders is presented in the PMP, but they include:

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

3. Benefits

3.1. Provenance

3.1.1. A workshop involving a range of MOD stakeholders and an Advisory Group[32] (AG) observer was held on 2 November 2010 to capture SDP benefits and impacts. The results of this workshop are described in the SDP Benefits Report[33]. They were 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 described in the SDP Benefits Realisation Plan[34].

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. Benefits are usually realised after the conclusion of a relatively short-lived project but in the case of SDP, they 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, DUWC, and managed by In-Service Submarines (ISM) on behalf of D Submarines. In some cases, indirect benefits will accrue to other parts of MOD or out to local communities, but they too will be managed by ISM. Close liaison with the Maritime Change Programme (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 (such as the financial benefit to the local community), 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.
- Minimisation of costs associated with submarine liability.

[32] The national SDP Advisory Group (AG) was set up in 2007 to offer independent constructive challenge and advice to the project team. Subgroups provide more detailed input on key issues as and when appropriate.
[33] SDP Benefits Report, v1.0, dated March 2011.
[34] SDP Benefits Realisation Plan, v0.3, dated December 2011. This Plan will be refined and updated in parallel with the submission of MGBC1.

- Sustainable, safe removal and disposal of non-hazardous waste.
- Sustainable, safe removal and disposal of hazardous Waste.
- Sustainable, safe removal and disposal of Low Level Waste (LLW)/Very Low Level Waste (VLLW).
- Bounded and managed ILW.
- Avoidance of operational impact.
- Maintenance of UK industrial capacity.
- Mitigation of environmental Impact.

3.2.3. The significance of the first of these benefits, increased public confidence, was underpinned by responses received from public consultation which "stressed the need for ongoing engagement with the public and for continued transparency throughout and beyond the decision making process."[35]

[35] SDP Post Consultation Report, dated July 2012.

4. Option Set

4.1. Derivation of Option Set

4.1.1. SDP has a large number of potential solutions, which have been formed into integrated options developed from combinations of the following:

- **Technical Approaches** to the initial dismantling of submarines.
- **Initial Dismantling Site(s)**.
- **Types of site for storage of Intermediate Level Waste (ILW)** arising from initial dismantling.

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

4.1.3. The option set taken forward for consideration in advance of the MGBC1 submission has been derived through a series of analysis and screening activities between 2010 and 2012[36]. The process included:

- Agreement, on the grounds of Value for Money (VfM), that greenfield and brownfield sites would only be considered for dismantling and/or ILW storage if an existing Licensed or Authorised site were not to be available.[37]
- Screening of a long list of candidate dismantling sites against agreed criteria, resulting in the identification of 3 candidate sites.[38]
- Development of a set of 25 integrated options for the analysis which informed the Interim OASP presented for public consultation.[39]
- Review of the option set in the light of new technical and WLC information, along with a more developed procurement strategy and a better understanding of stakeholder perspectives through public consultation. This led to the inclusion of 3 new options (which had moved from being project opportunities to becoming viable options) and then to the removal or grouping of 15 options.[40]

4.1.4. The result is an option set comprising 13 options, including a single Do Minimum comparator and 12 Do Something options, as described below.

[36] At each stage of the screening and analysis process, agreement was sought and reached with D Scrutiny and DASA/DESA.
[37] The VfM arguments against the use of greenfield and brownfield sites are summarised in the Proposed Site Criteria and Screening Paper v2.1, dated May 2011.
[38] The Measures of Effectiveness (MoE) used, and their derivation, is reported in the Proposed Site Criteria and Screening Paper v2.1, dated May 2011.
[39] As described in the Integrated Options Report, v1.0, dated February 2011.
[40] The SDP Options De-selection Paper, v1.0, May 2012, describes how the option set was reduced and grouped on the grounds of WLC and procurement strategy.

4.2. Components of the Option Set

4.2.1. Technical Approach

4.2.2. Extensive technical and environmental assessment led to a shortlist of 3 alternatives for removing the radioactive waste from the submarines.

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

4.2.3. During the development of options for MGBC1 submission, it was decided to represent all 3 technical approaches in the options analysis but to limit the number of RC options[41]. For all these approaches it is important to remember that all of them involve eventual dismantling of the RPV to form Packaged Waste, but that if the RC and RPV are stored, this occurs shortly before storage in the GDF. Further, all three of these technical approaches are concerned with initial dismantling to remove or separate the ILW. After this has been done the remainder of the hulls will be subjected to conventional ship recycling at a different site or sites.

4.2.4. Initial Dismantling Site(s)

4.2.5. The shortlisted initial dismantling site(s) are:

- Devonport Dockyard;
- Rosyth Dockyard;
- Both Devonport and Rosyth Dockyards (“dual site dismantling”).

4.2.6. The dual site option utilises both Devonport and Rosyth for initial submarine dismantling but, as duplication of all facilities would be prohibitively expensive[42], only one size reduction facility is assumed. This facility will be located at one of the initial dismantling sites for the Packaged Waste options. For the RC and RPV options, it would not be required until the GDF becomes available after 2040 at the

[41] The WLC model has demonstrated that RC options were generally uneconomic due to up front infrastructure costs. However, two RC options were considered further in order to adequately address public consultation responses.

[42] The cost of a single size reduction facility has been estimated to be [redacted]. The cost of two facilities, even taking account of the costs of RPV movement, has been estimated to be [redacted] more than a single facility.

earliest.[43]

4.2.7. During the Options De-selection Workshop it was decided to exclude the initial dismantling at Rosyth only option from further consideration except as a comparator.[44]

4.2.8. Generic ILW Storage Site(s)

4.2.9. At this stage, it has not been possible to assess the existing nuclear Licensed/ Authorised sites because of the different governance arrangements and strategies for sites under differing ownership. As an intermediate step, 4 possible categories of candidate sites for storage of ILW have, therefore, been identified:

- Storage at Point of Waste Generation (POWG) (Devonport Dockyard / HM Naval Base Devonport and / or Rosyth Dockyard). For the dual site dismantling option, storage at POWG would mean RCs[45], RPVs or Packaged Waste being transported to one of the two sites after initial dismantling, for interim storage.

- Storage at remote commercial site. This category could include both Rosyth Dockyard and Devonport Dockyard if dismantling were conducted at the other site, because such an arrangement would necessarily include transportation, It also includes any existing Licensed sites where the owner wished to bid for provision of a storage service to MOD.

- Storage at remote MOD site. This category includes all the Licensed or Authorised sites owned by MOD that are remote from POWG.

- Storage at NDA site(s). It may be possible for NDA storage facilities to store MOD waste.

4.2.10. Analysis subsequent to the publication of the Interim OASP concluded that the remote storage options (MOD and commercial) should be grouped as they could not be adequately differentiated without entering a commercial assessment. It was also agreed to group POWG options with remote options for those associated with dual site dismantling, because in practice dual site solutions always involve some transport of ILW due to the fact that only one ILW store will be built[46].

[43] A working assumption has been made for the RPV options: 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, however, be feasible and so this is only a working assumption for an activity that would not take place until 2040 at the earliest.
[44] IA work identified a very high relative WLC associated with the Rosyth only options, due to higher nuclear overheads and the preparation and transport by sea of a larger number of submarines to Rosyth. Consequently all those options with dismantling at Rosyth only were removed from consideration, with the exception of RC separation at Rosyth only, which was maintained as a comparator within the OE and OCF analyses.
[45] For economic reasons, it has been assumed that no transport of RCs would be undertaken.
[46] For the dual site options, storage at POWG assumes the construction of a single ILW store at either Devonport or Rosyth, necessitating the movement of RCs or RPVs from one site to the other so that, for purposes of transport, it becomes similar to a remote site.

4.3. Option Set

4.3.1. The options are summarised in Table 1. In the table, and throughout the remainder of the OASP, a consistent key has been used to identify the various options graphically, using the following schema. The different technical approaches are shown with different colours:

- Do Minimum (continued afloat storage) is black.
- RC options separation are pink.
- RPV removal options are red.
- Packaged Waste options are green.

4.3.2. The different types of interim storage sites are shown as different shapes:

- POWG options are diamonds.
- Remote storage options are circles.
- NDA storage options are triangles.

4.3.3. Finally, the dismantling sites are shown as different fills for the shapes:

- Devonport is shown as solid.
- Rosyth is shown as shaded.
- Dual site is shown as empty.

Category	Key	Option	Description
Indefinite afloat storage		0	Do Minimum **(Comparator only, which represents a continuation of the current approach)**
Options that separate the whole RC and store it at the dismantling site		1R	RC separation at Rosyth, with interim storage at Point of Waste Generation (POWG) at Rosyth, and at a later date size reduction of ILW before transfer to the GDF. **(Operational Effectiveness (OE) and Other Contributory Factors (OCF) Comparator only)**[47]
		1D	RC separation at Devonport, with interim storage at POWG at Devonport, and at a later date size reduction of ILW before transfer to the GDF
Options that remove the whole RPV		2D	RPV removal at Devonport, with interim storage at POWG at Devonport, and at a later date size reduction of ILW before transfer to the GDF

[47] Those options with dismantling being conducted at Rosyth only are estimated to be much more expensive than Devonport only or dual site options. Public Consultation, however, resulted in a number of stakeholders expressing support for the RC options, and it was decided to keep Option 1R under consideration as an OE and OCF comparator.

Category	Key	Option	Description
	●	3-4D[48]	RPV removal at Devonport, with interim storage at a remote MOD or commercial site and at a later date size reduction of ILW before transfer to the GDF
	○	2-4B	RPV removal at Devonport and Rosyth, with interim storage at one of the following: a remote MOD or commercial site, Devonport or Rosyth, and at a later date size reduction of ILW before transfer to the GDF
	▲	9D[49]	RPV removal at Devonport with interim storage at NDA site(s), and at a later date size reduction of ILW before transfer to the GDF.
	△	9B	RPV removal at Devonport and Rosyth with interim storage at NDA site(s), and at a later date size reduction of ILW before transfer to the GDF
Packaged Waste	◆	5D	RPV removal and size reduction to form Packaged Waste with interim storage at POWG, all at Devonport
	●	6-7D	RPV removal and size reduction to form Packaged Waste at Devonport with interim storage at a remote MOD or commercial site
	○	5-7B	RPV removal and size reduction to form Packaged Waste at Devonport and Rosyth, with interim storage at one of the following: a remote MOD or commercial site, Devonport or Rosyth.
	▲	8D	RPV removal and size reduction to form Packaged Waste at Devonport with interim storage at Nuclear Decommissioning Authority (NDA) site(s)
	△	8B	RPV removal and size reduction to form Packaged Waste at Devonport and Rosyth with interim storage at NDA site(s)

Table 1 SDP Options

4.3.4. 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 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 and 9 assume that the RCs or RPVs are stored intact in the interim with size reduction conducted only when the GDF is ready.

4.3.5. Do Minimum (Option 0), therefore, represents a continuation of afloat storage of redundant submarines but identifies and implements the lowest incremental activities that can meet all mandatory requirements. 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 and does not deliver the intended project benefits[50]. RC separation at Rosyth only (Option 1R) is a comparator for OE

[48] This nomenclature reflects a grouping of what were two separate options in the analysis for the Interim OASP. Option 3D was RPV removal at Devonport with ILW storage at a remote commercial site; and Option 4D was RPV removal at Devonport with ILW storage at a remote MOD site. Option 3-4D groups the two options. A similar nomenclature has been adopted for the other grouped options.
[49] Options 9D and 9B were added in 2012 when it was determined that it was feasible to store whole RPVs at NDA sites; hence the fact that the numbering system is out of order.
[50] The Do Minimum option assumes that the MOD continue to store and maintain submarines in the same way as it does at present. Although this is a feasible option, the number of submarines stored will rise steadily and the maintenance required to keep them safe will also increase. This would impose an increased cost and operational burden on the MOD, and still not provide a true disposal route for the hulls.

and OCF purposes, as the IA has demonstrated that the WLC of this option is prohibitively expensive. Nonetheless, it was retained as a comparator in the OE and OCF analyses in order to adequately address public consultation responses.

5. OE Analysis

5.1. OE Analysis Method

5.1.1. The SDP is concerned with developing a solution to dismantle, recycle and dispose 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 (URs) as defined in the URD[51]. The full results of the OE and a more detailed explanation of the process used to generate the results is contained in the OE Report[52].

5.1.2. The ability of each option to meet individual URs and, hence, deliver SDP benefits[53] has been analysed using MCDA. The relative ability of each option to fulfil the URs has been addressed by applying the judgement of a diverse group of Subject Matter Experts (SMEs) in a structured manner[54],[55]. The MCDA model which has been used for the analysis to support the MGBC1 submission has been developed through a series of activities between 2008 and 2012:

- The ISOLUS Technical Options Study (TOS)[56], which took place in 2008, involved a wide range of stakeholders and was formative in developing attributes analogous to MCDA criteria.
- The attributes applied in the TOS were reviewed in the development of criteria for the subsequent MOD Proposed Option Study (MPOS)[57],[58] which provided an indicative assessment of the technical options only.
- In November 2010 a benefits workshop, involving a range of MOD stakeholders and an AG observer, was held to identify benefits and underpin the SDP MCDA model[59].
- In 2011 a MCDA model was built on the basis of the benefits workshop; this included a two day criteria workshop with review by an expert panel.
- Following the criteria workshop, weighting and scoring was undertaken in two separate two day workshops. Weighting addressed the relative importance of criteria derived from URs to overall OE. Scoring addressed how well each option met the criteria.

[51] SDP User Requirements Document, Issue 5.0, October 2011.
[52] SDP OE Report, Issue 1.0, dated October 2012.
[53] The SDP benefits also included many financial factors which are covered by the IA, or by other factors which are covered by the analysis of OCF.
[54] As set out in the endorsed SDP Concept of Analysis (CoA), v1.1, March 2011.
[55] The URs have associated Measures of Effectiveness (MoE), with threshold values (the minimum required level of performance) and objective values (the maximum level of performance above which no further benefit is accrued). The relevant MoE's were used to generate a comprehensive list of MCDA criteria.
[56] Reported in SDP Technical Options Study, FNC 35114/35042R, dated June 2010.
[57] FNC Technical Note 36995/63406V, Selection of Criteria for MPOS Study, dated April 2010.
[58] SDP MOD Proposed Options Study (MPOS), FNC 36995/36702R Issue 1 dated August 2010.
[59] SDP Benefits Report, v1.0, dated March 2011.

- The MCDA model was applied to the 2011 options using the outputs of the weighting and scoring workshops to generate OE results to feed into the Interim OASP.

5.1.3. D Scrutiny and observers from the AG attended the workshops to develop the MCDA model, which has been used as the basis of the OE reported in this OASP to underpin the MGBC1 submission. The 2012 OE analysis process, which was an update[60] of the 2011 analysis process, centred on a pair of two day workshops attended by a range of SMEs from the MOD, OGDs and Industry:

- **Weights:** The links between the criteria in the MCDA model structure were weighted on a scale of 0 to 10 by a panel of Subject Matter Experts (SMEs), supported by technical informers. The weights across all criteria summed to unity.

- **Scores:** The 13 options were scored by SMEs against each of the 19 criteria. The scoring scale was from 0 to 9.

5.1.4. The MCDA model captured the range of SME views in the scores and weights from the workshops and, using a Monte Carlo simulation which sampled from across the range of weight and score data, a distribution of OE for each option[61] was generated. This allowed 10th, 50th and 90th percentile values to be generated for each option, with the range 10% to 90% providing uncertainty bounds around the median of 50%. The 90th percentile is the value at which only 10% of the weighted results score more highly; the 10th percentile the value at which only 10% of the weighted results score more poorly. The model and input data had been subject to Verification and Validation (V&V) by the project's team of industry experts in 2011[62].

5.1.5. WLC was explicitly excluded from consideration at the MCDA workshops, since the IA covers these, as were non-quantifiable factors, or potentially quantifiable factors which lie outside the remit of SDP or the MOD, such as socio-economic impact or political factors, which are covered in the OCF Report.

5.2. MCDA Model

5.2.1. Figure 2 shows the colour coded MCDA model structure[63]:

- 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

[60] The 2012 update took account of new technical information and the results of public consultation.
[61] This operated by generating histograms for each set of weights (for the criteria) and for each set of scores, and then sampling randomly from the combinations 10,000 times. This generates a distribution of results for each option.
[62] See "Review of SDP MCDA Monte-Carlo Model and Associated Data Checking", dated 30 June 2011, from Nuvia.
[63] The structure differs from the 2011 model only in that one Policy criteria (1-POL Flexibility and Robustness to Risk) was removed during the weighting workshop as it was considered to be covered by risk factors included in the IA.

- Green: Reduction of Environmental (ENV) Impact.

5.2.2. The Environmental criteria group included 6 specific criteria and scoring against these criteria was informed by results of the SDP Strategic Environmental Assessment (SEA)[64].

[64] See the SEA Non-Technical Summary, v2.0, dated October 2011, and in more detail the SEA Environmental Report, v1.0, dated October 2011.

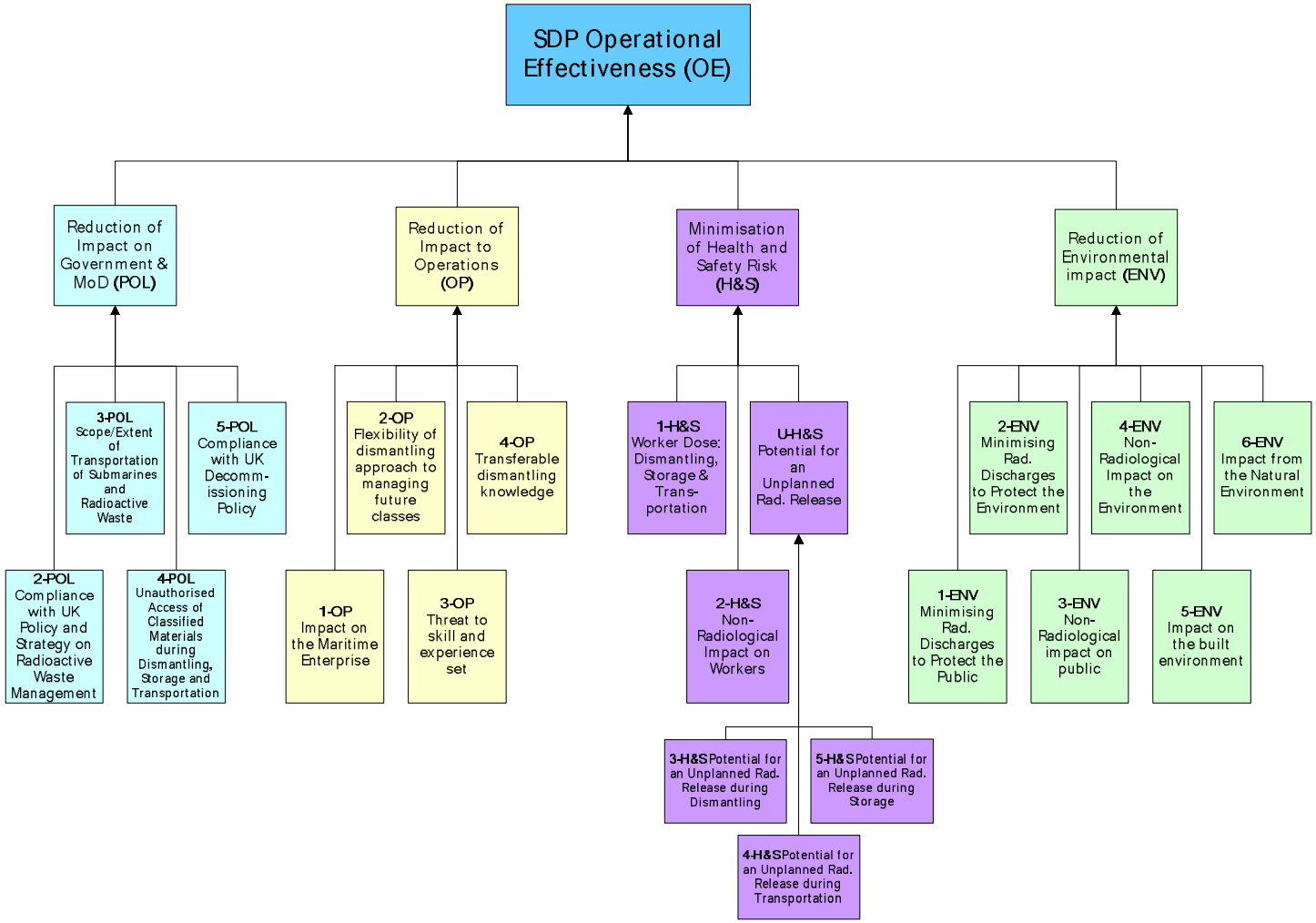

Figure 2 MCDA Model Structure

5.2.3. Table 2 shows the MCDA criteria and the median weights[65] assigned to the linkages between the various levels of the model.

Category Weight	Category	Criterion Title		Criterion Weight (to one decimal point)
22.1%	Reduction in Impact to Government and MOD (POL)	2-POL: Compliance with UK Policy and Strategy on Radioactive Waste Management		**5.9%**
		3-POL: Scope/Extent of Transportation of Submarines and Radioactive Waste		**3.5%**
		4-POL: Unauthorised Access to Classified Materials during Dismantling, Storage and Transportation.		**7.4%**
		5-POL: Compliance with UK Decommissioning Policy		**5.3%**
29.5%	Reduction of impact to Operations (OP)	1-OP: Impact on the Maritime Enterprise and Wider MOD Operations		**10.7%**
		2-OP[66]: Flexibility of Dismantling Approach to Managing Future Classes		**4.7%**
		3-OP: Threat to Skill and Experience Set		**8.5%**
		4-OP: Transferable Dismantling Knowledge		**5.6%**
26.0%	Minimisation of Health and Safety Risk (H&S)[67]	1-H&S: Worker Dose: Dismantling, Storage and Transportation		**7.3%**
		2-H&S: Non-Radiological Impact on Workers		**9.9%**
		U-H&S Potential for an Unplanned Radiological Release **(8.8%)**	3-H&S: Potential for an Unplanned Radiological Release during Dismantling	**2.9%**
			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%**
22.5%	Reduction of Environmental Impact (ENV)	1-ENV: Radiological Discharges to the Public		**5.2%**
		2-ENV: Radiological Discharges to the Environment		**4.1%**
		3-ENV: Non-radiological Impact on the Public		**3.6%**
		4-ENV: Non-radiological Impact on the Environment		**4.0%**
		5-ENV: Impact on the Built Environment		**3.2%**
		6-ENV: Impact from the Natural Environment		**2.4%**

Table 2 Summary of SDP Criteria and Weights

5.2.4. Figure 3 below shows the median weightings listed in the table above in graphical form.

[65] The weights recorded in the workshop were distributed according to the responses from individual SMEs; the weights in Table 2 are the median values of the responses.
[66] This criterion recognises that decisions taken now on SDP will set the context for decisions, to be taken at the appropriate point in the future, on dismantling of future classes of submarine. The dismantling of future classes (including Astute and later classes), however, remains outside the scope of SDP.
[67] These criteria are concerned primarily with the H&S of workers and employer responsibilities under the Health & Safety at Work Act.

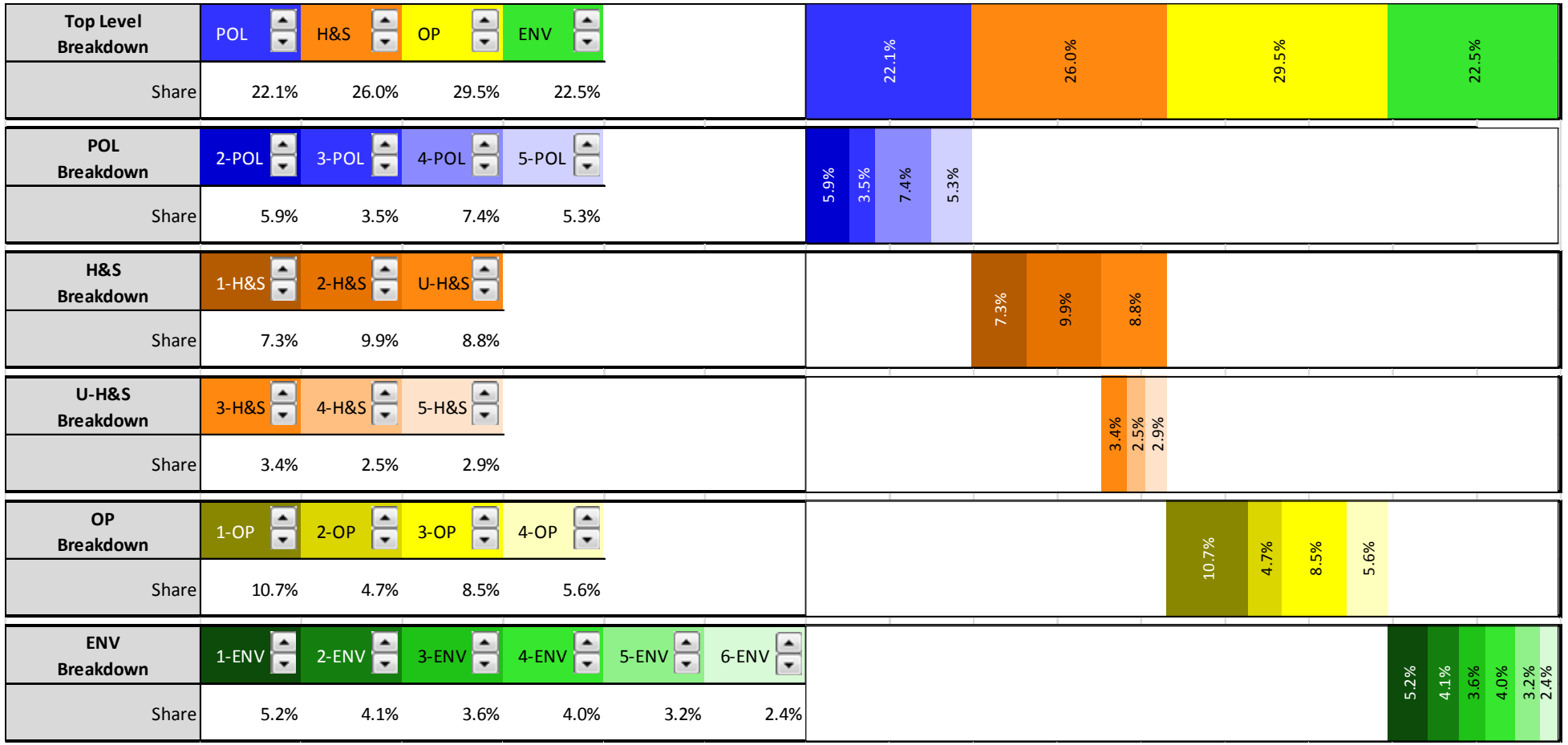

Figure 3 Graphical Representation of Median Weightings

5.3. OE Findings

5.3.1. The data captured at the 2012 Scoring and Weighting Workshops were entered into the MCDA model. Figure 4 shows the results from the MCDA model, following 10,000 runs, and shows the 10th, 50th and 90th percentile values. Note that the scale extends from 3 to 7; the full range of potential scores is from 0 to 10. Table F-1 in Annex F provides a table showing all the values from which the figure was derived.

Figure 4 OE Plot

5.4. Interpretation of OE Results

5.4.1. Overall

5.4.2. Key points on the scoring scale were assigned a specific and tangible meaning[68]. A score of 1 corresponded to meeting a threshold value and 9 to an objective value[69]. The resulting overall OE scores are, therefore, related to the threshold and objective measures of effectiveness specified in the URD and have uncertainty bounds that capture the spread of weights and scores at the workshop.

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

- Statistically significant separation; 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 of options, whilst recognising that it may not strictly be statistically significant.

[68] These were written down for reference on the scoring sheets provided at the Scoring Workshop.
[69] For example, take criterion 1-OP Impact on the Maritime Enterprise & Wider MOD Operations. A score of 1 indicates the greatest acceptable negative impact on the Maritime Enterprise and wider MOD Operations. A score of 9, in contrast, indicates a positive impact. The intermediate scores also have specific meanings, such as 7 meaning that the impact would be equivalent to the *current* level of impact of LUSMs. Finally, a score of 0 indicates an unacceptable negative impact on operations, equivalent to non-compliance with the requirements of the project.

5.4.4. Non-compliant Scores

5.4.5. Sixteen of the 19 criteria have threshold values which correspond to the minimum acceptable score, such that a score of zero means that an option is unacceptable, failing a SDP UR. For example, a score of zero for 2-POL *Compliance with Extant UK Policy & Strategy on Radioactive Waste Management* means 'unacceptable potential for non-compliance with UK policy and strategy'. Scores of zero were recorded by some or all delegates for the following criteria where zero indicates an unacceptable level of performance:

- Option 0 (Do Minimum): received 17 (out of 19) scores of 0 for 1-OP *Impact on the Maritime Enterprise and Wider MOD Operations*. The other two delegates recorded scores of 1, because of the significant impact to dockyard and naval base operations which would result from storing 27 submarines afloat, in terms of the impact of constructing new berthing facilities and associated infrastructure.

- Option 0 (Do Minimum) received 5 (out of 19) scores of 0 for 3-OP *Threat to Skill and Experience Set*. Other scores ranged from 1 to 5, with an overall mean of 1.8. The main reason for the low scores was that the lack of dismantling activity associated with continued afloat storage posed a significant threat to nuclear skills and experience.

- Option 0 (Do Minimum) received 14 (out of 19) scores of 0 for 2-POL *Compliance with Extant UK Policy & Strategy on Radioactive Waste Management*. The other scores recorded were three 1's, one 3 and one 9. The general view was that continued afloat storage was not in line with UK policy and strategy, although it is notable that one of the delegates dissented from this view and considered it to be in full compliance with extant policy, thereby scoring 9[70].

- Option 0 (Do Minimum) received 19 (out of 19) scores of 0 for 5-POL *Compliance with Extant UK Decommissioning Policy* because the 2004 Amendment to Command 2919 paper[71] states that decommissioning operations should be carried out as soon as reasonably practicable.

5.4.6. Option 0 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 GDF). The unanimous scores of 0 for 5-POL, and the preponderance of scores of 0 for 1-OP and 2-POL underline its status and indicate unambiguously that continued indefinite afloat storage is not a viable option.

5.4.7. Interpretation of Results

5.4.8. The median overall SDP OE scores for the options range from 4.26 for Option 0 to 6.44 for Option 9B. The lowest 10th percentile value is 3.77 for Option 0 and the highest 90th percentile value is 6.76 for Option 9B. These results indicate a reasonable degree of consensus, although the workshops included extensive and

[70] This disagreement reflected the view that as submarines stored afloat were not yet classified as waste, they could not be non-compliant with radioactive waste management policy. The majority of SMEs, however, treated the submarines as though they were (or would inevitably become) waste and were therefore non-compliant.
[71] The Decommissioning of the UK Nuclear Industry's Facilities – Amendment to Command 2919, DTA Paper, September 2004.

healthy debate with the mean standard deviation of scores across all options being only 0.8, and the mean standard deviation of weights being 1.4.

5.4.9. The one option which is differentiated from the others by a statistically significant margin is Option 0. The others are all relatively close in OE, reflecting the fact that they all have the same end state and involve the same fundamental process, except that size reduction is conducted at different times during the life cycle of the project.

5.4.10. The Do Something options exhibit the same trends:

- All the 50% confidence scores for the RPV options are higher than those of the Packaged Waste options, which in turn score higher than the RC options. This is largely because the RC options perform relatively poorly in terms of compliance with policy. They also score badly against several environmental criteria, and have a negative potential impact on operations due to the large physical footprint of the stores and RC handling arrangements. The differences between the scores for the RPV and Packaged Waste options are smaller but the higher RPV scores reflect greater flexibility to handle future submarine classes and deliver transferable dismantling knowledge. In addition the RPV options scored higher on some environmental criteria due to deferring or potentially avoiding size reduction.

- Within the RPV and Packaged Waste options, the 50% confidence scores for the NDA site options score are higher than any of others, with POWG having the lowest 50% confidence scores within each group. The NDA options score well in terms of delivering the least disruption to MOD operations by taking storage away from MOD sites, and also by delivering less environmental impact through sharing existing ILW storage facilities. In contrast the Devonport POWG sites are likely to create congestion around military activities. The POWG sites, however, generally scored better against transport criteria as they avoid the need to move ILW prior to GDF disposal.

- The 50% confidence scores for the dual site options are generally higher than their Devonport equivalents. In all cases, however, the differences are *not* statistically significant, and Option 3-4D scores marginally higher than Option 2-4B. The main distinguishing feature between the dual site and Devonport options are that the former are considered to create less disruption to operations.

- Option 1R, although it has a higher median OE score than Option 1D, is significantly less effective than the leading RPV options, 9B and 9D. Its median OE score is also lower than all the RPV and Packaged Waste median scores. In summary, although it cannot be ruled out in OE terms, it should not be considered further as it represents a comparator for the OE and OCF only.

5.4.11. Although these trends cannot differentiate between options in terms of statistically significant separation, they reveal consistent underlying patterns that identify the RPV options as frontrunners in terms of OE, and the NDA options within them to narrowly be considered the most effective.

5.5. Sensitivity Analysis

5.5.1. A number of sensitivity analyses were run on the baseline data:

- 1-H&S Worker Dose was removed, reflecting guidance from DASA DESA that it could be better to consider dose in terms of WLC.

- Each group of criteria - Policy (POL), Operations (OPS), Health & Safety (H&S) and Environmental (ENV) - was removed in turn to test the overall sensitivity of the results.

5.5.2. Table 4 shows the changes in ranking (of 50% confidence scores) arising from the analyses above. The shading shows where the rankings have changed. The exclusion of 1-H&S makes no change to the ranking, and the exclusion of H&S and ENV only changes one pair of rankings each. The removal of POL has a greater impact, although the RPV options remain the highest 5 ranking options. The removal of OPS is the only sensitivity analysis which changes the ranking of the top 2 options, although the overall pattern of ranks of options is not greatly changed.

Option	Baseline Ranking	No 1-H&S	No POL	No OPS	No H&S	No ENV
9B	1	1	1	2	1	1
9D	2	2	2	3	2	2
2D	3	3	5	1	3	3
3-4D	4	4	3	6	4	5
2-4B	5	5	4	5	5	4
8B	6	6	6/7	7	6	6
8D	7	7	6/7	8	7	7
5D	8	8	10	4	9	8
5-7B	9	9	11	9	8	9
6-7D	10	10	9	11	10	10
1R	11	11	8	13	11	11
1D	12	12	12	12	12	12
0	13	13	13	10	13	13

Table 3 Change in Options Ranking through Sensitivity Analysis

5.5.3. These analyses demonstrate that OPS and then POL have the greatest impact on the scores for the different options, but overall they demonstrate the robustness of the results, in that with only one exception (when OPS is removed), the top 5 ranked options remain the RPV options.

5.5.4. In order to better understand the extent to which differing perspectives might alter the outcome of the SDP OE analysis, the stakeholders within the AG were invited to provide their own views on the weights that should be applied to the criteria within the MCDA structure used for the OE analysis. The stakeholders were formed into groups according to the sectors in which they work, as follows:

- NGO/CBO;

- Local Authority;

- Industry;

- Regulatory / Consultancy.

5.5.5. Each group was asked to discuss and develop their own set of weights for the criteria in the 2011 MCDA model. Table 5 shows the changes in ranking (of 50% confidence scores) arising from the AG perspectives. The shading shows where the rankings have changed.

Option	Baseline Ranking	NGO/ CBO	Local Authority	Industry	Regulatory/ Consultancy
9B	1	2	1	1	2
9D	2	3	3	2	3
2D	3	1	2	3	1
3-4D	4	6	5	4	5
2-4B	5	5	4	5	4
8B	6	9	7	6	7
8D	7	10	8	7	8
5D	8	4	6	8	6
5-7B	9	7/8	9	9	9
6-7D	10	12/13	10	10	10
1R	11	12/13	11	11	12
1D	12	11	12	12	11
0	13	7/8	13	13	13

Table 4 Change in Options Ranking with AG Perspectives

5.5.6. The key observations from the sensitivity analyses were:

- The results from applying the Local Authority and Industry (especially) perspectives are very similar to the MOD baseline, with RPV remaining the best technical approach (as a group) and Option 9B as the front runner.
- The Regulators and the NGO/CBO perspectives compress the spread of results although RPV remains the best scoring technical approach (albeit by a narrower margin) and Option 9B the second best option after 2D.
- The OE score of the Do Minimum is increased due to a particularly high weighting being applied to H&S (specifically by the regulators and NGO/CBO groups), but it is the lowest scoring option in all perspectives except for the NGO/CBO group, where it lies in the centre of the rankings.

5.5.7. The different AG perspectives do not overturn the OE analysis, as they either confirm or compress the spread of the results, and do not put alternative options into the leading ranks of the options. Once again, these sensitivity analyses reflect the underlying robustness of the results.

5.6. Summary of OE Findings

5.6.1. The OE analysis has not identified clearly a single option as delivering the highest effectiveness but:

- Option 0 (Do Minimum) has been identified as being non-compliant with policy and presenting an unacceptable risk to the maritime enterprise, confirming its status as a non-viable comparator. In addition it is significantly less effective than the Do Something options.

- Option 1R, which was only included as an OE and OCF comparator, may be discounted from further consideration as it exhibits no advantage in OE over the other Do Something options, with a lower median score than all of them except for 1D.

- The RPV options, whilst not being statistically significantly differentiated from the Packaged Waste and RC at Rosyth options, all have 50% percentile scores in excess of the median scores presented by other options, and should, therefore, be considered preferentially.

- The Environmental and Health & Safety impact of each of the options are close and they do not act as significant differentiators. This is illustrated by the fact that the sensitivity analysis excluding 1-H&S, or excluding all H&S or ENV criteria, does not significantly alter the OE results.

- Of the three components which make up the integrated options, the technical approach provides the greatest differentiation between options. Furthermore, the results show clustering of the median values for each of the three approaches showing that the options within each approach are similar in terms of OE This further supports preferential consideration of the RPV options.[72]

- The different AG perspectives and the other sensitivity analyses, do not overturn the OE analysis, either confirming the results or reducing the spread between options, but do not significantly change the ranking of the options and of the highest ranked options in particular.

[72] The OE Report contains a full analysis of the different median scores for options and concludes that the most significant differentiator is technical approach, whereas the dismantling location and ILW site type are not as significant.

6. IA Results

6.1. Scope

The IA[73] covers the whole life costs of all stages of SDP activities from planning phases (post MGBC1) to final decommissioning to quantify the overall cost to MOD of the various 12 Options[74] and thus articulate the option which provides best value for money.

6.2. Specialist Advice

6.2.1. The IA has used specialist advice from: ISM Financial Controller, SDP Risk Manager, NDA Cost Engineers and industry experts. In addition Cost Assurance Advisory Services (CAAS), DASA/DESA, and DES-FIN FGA have been consulted and their advice sought. CAAS undertook a V&V exercise on the WLC Model and this independent financial analysis has provided assurance on the underlying financial data and the functionality of the WLC Model. The ISM Financial Controller has challenged and advised on capturing 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. The IA is consistent with 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 FY13/14, therefore, any costs incurred prior to April 2013 are treated as sunk cost and excluded from this analysis;
- VAT at 20% has been excluded from costs subject to the economic case;
- Inflation is at the planning round approved rate of 2.5% per annum;
- Costs provided to support the options are based on the best available knowledge of the project SMEs;
- The GDF will be available to SDP from 2040;
- One submarine to be dismantled per year after Planning Assumption Service Entry (PASE);

[73] See the SDP Investment Appraisal, Issue 1.0, dated October 2012, for full details.
[74] The process for selection of the Options from the set 25 at Public Consultation to the 12 (13 including Option 1R, which was retained as an OE and OCF comparator) was completed at the Option Down selection Workshop in March 2012. The outcome of this workshop is reported in the SDP De-Selection Paper, v1.0, dated May 2012.

- ILW must be packaged into 3m³ boxes before it can enter the GDF;
- The WLC includes the full cost of ILW Storage and GDF disposal; and
- Costs include associated afloat storage costs (such as maintenance, berthing and potential infrastructure improvements) as submarines wait dismantling.

6.3.2. These assumptions could change following the MGBC1 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 and benefits beyond this are excluded. These are covered in the OE and OCF analyses. They provide additional analysis excluded from the IA because of the challenge in measuring them or the qualitative nature of the costs.

6.5. Financial Analysis

6.5.1. The financial analysis was extracted from the SDP WLC Model. This underwent initial V&V[75] assurance from CAAS in September 2010. Following the initial V&V CAAS were invited to quarterly briefings outlining the development of the WLC Model leading to challenge from the CAAS Estimating Assurance Team and ongoing review by the MOD's internal scrutiny. A further V&V exercise was undertaken by CAAS in June-July 2012 with recommendations and amendments presented and implemented into the SDP WLC Model. A final V&V assurance from CAAS will be undertaken in September 2012 when no major challenges are expected to be presented.

6.6. Whole Life Cost Model

6.6.1. 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 suppliers and third party sources. All cost data was collected in alignment with the project MDAL. The data makes up the key cost drivers of each Option. The timing sheets within the WLC Model allocate when the costs will occur, and are consistent with the MDAL and SDP Master Schedule. Further cost input has been gathered from the SDP risk register, held within the separate Active Risk Manager (ARM) system and controlled by the project Risk Manager. The WLC Model has the functionality to present the costed options with and without risk.

6.6.2. The analysis uses the @RISK software which calculates a 10%, 50% and 90% confidence range of Option cost. This can be output as whole life outturn, Net Present Value (NPV) or constant costs, either at base costs only, with uncertainty added, or with risk and uncertainty. The preferred analysis by the MOD is NPV as this takes account of the time value of money and is fairer way to appraise options over long periods of time. NPV uses the HM Treasury approved 3.5% discount rate[76].

[75] 20100920-SDP_Final_Report _PC
[76] See HM Treasury Greenbook and JSP507. 3.5% discount rate is applied to years 1-30, 31 years + the discount rate is adjusted to 3.0%

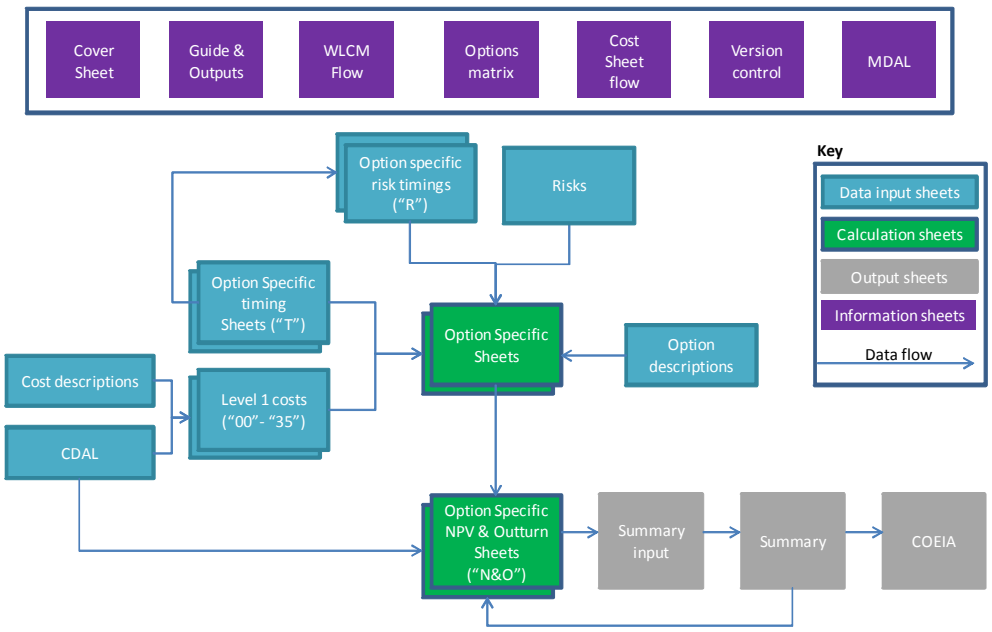

Figure 5 Schematic of WLC Model

6.7. Treatment of Uncertainty

6.7.1. The WLC 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 dependent upon a number of factors such as; historical cost data incurred on similar activities and the level of detail for which the cost driver is broken down to.

6.7.2. 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 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 an assessment (i.e. a Red/Amber/Green (RAG) status) on the quality of financial data.

6.7.3. All of the cost drivers feed into the overall cost of dismantling. To obtain an output Monte Carlo Analysis is run on the WLC Model using CAAS approved @Risk software[77], which can provide up to 10,000 combinations of all the different cost drivers which when conducted; it takes a random value for each cost driver within the uncertainty band. The output is a range of values for the total cost of the option giving a 10%, 50% and 90% confidence range.

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

6.8. Treatment of Risk

6.8.1. In addition to uncertainty, data from the SDP Risk Register is used to inform the WLC Model, data from the SDP Risk Register has been assessed with the SDP Risk Manager and all risks with a cost impact have been incorporated into the analysis. The SDP Risk Register is managed by the SDP Risk Manager and is updated on a regular basis with input from the risk owners. 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 timing sheets and applied separately to each Option.

6.8.2. CAAS have also undertaken a V&V exercise with the SDP Risk Manager and provided a number of recommendations which have been incorporated in the process.

6.9. Results

6.9.1. Table 5 shows the 5 lowest cost options, by NPV.[78]

Rank	Option	Ratios of Cost (%) (50%)
1	9B - RPV storage dismantling at Dual sites - storage at a NDA site	Most economic
2	9D - RPV storage dismantling at Devonport - storage at a NDA site	+ 2.98%
3	2-4B - RPV storage dismantling at Dual sites - storage at MOD	+ 4.37%
4	2D - RPV storage dismantling at Devonport - storage at POWG	+ 7.91%
5	3-4D RPV storage dismantling at Devonport - storage at MOD	+ 9.25%

Table 5 Top 5 Options ranked financially

6.9.2. Table 5 shows that Option 9B is the most economic option at 50%[79] primarily due to:

- Investment in minimal facilities to remove the RPV from the submarine;
- Delay to spend on RPV size reduction;
- The avoidance of towing seven submarines from Rosyth to Devonport;
- The RPV requiring a more economic unshielded store which is cheaper to design, build, commission and operate; and
- The potential for use of NDA storage for the RPV in either an existing store or part of their future plans;

[78] Table G-1 in Annex G provides a table showing all the options and their WLC values
[79] 50% = the 50% confidence percentile. It is anticipated that SDP is 50% confident that costs will not exceed this amount.

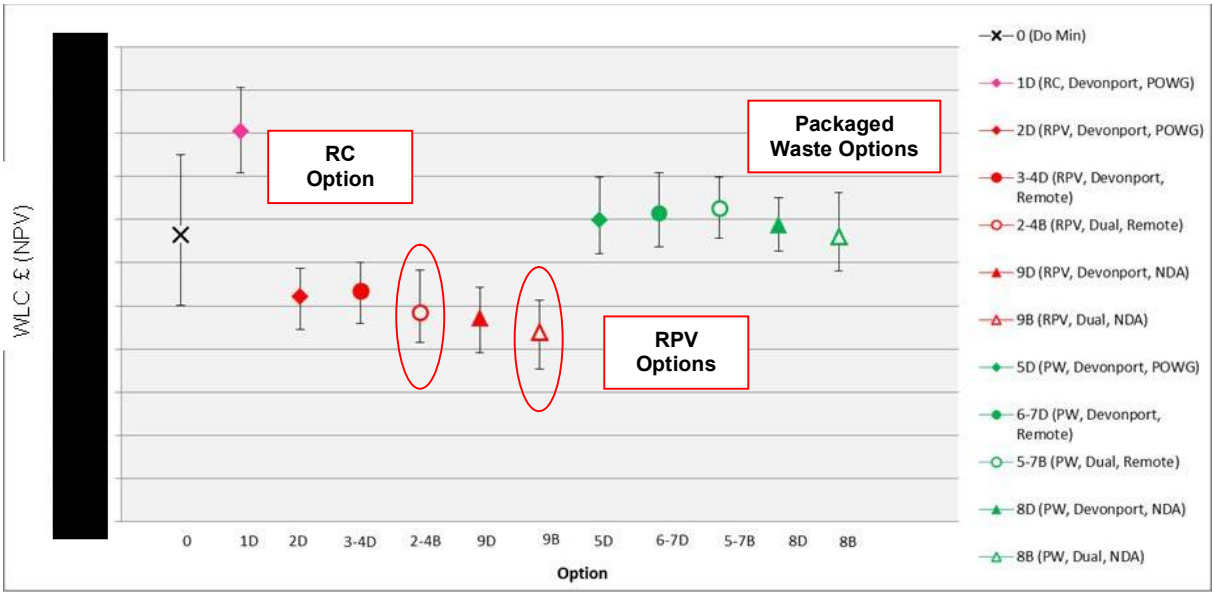

Figure 6 – Plot of options (WLC in £m)

6.9.3. Figure 6 shows the financial profile (10, 50 and 90% values) of the options and shows that there is significant separation between the types of technical option proposed. The top five ranked options are all RPV technical options, with the cheapest non-RPV technical option being Option 8B, and this is 21% more expensive than Option 9B.

6.9.4. Figure 6 illustrates a strong financial bias towards the RPV technical options (all in red), there is also a slight financial bias towards a dual site dismantling option due to the avoidance of submarine movement costs despite the potential requirement for the duplication of dismantling facilities. Equally there is a slight economic advantage to options involving storage using NDA facilities. These options provide some direct savings to MOD although these would need to be weighed against a site specific assessment of any risks created to NDA programmes. These wider risks to the NDA include negative impacts to the volunteerism approach to the GDF, disruption to the waste consolidation strategy and erosion of stakeholder capital. The impact of these risks if they were to be realised could significantly outweigh any economic advantage of a joint storage strategy.

6.10. Sensitivity analysis

6.10.1. Sensitivity analysis has been used to demonstrate the validity of cost differences between the options, particularly the technical approach. With a focus on the key cost drivers within each option, it has been possible to strengthen the evidence as to why selection of an RPV option is the recommended way forward.

6.11. Reactor Compartment

6.11.1. The RC technical option (1D) is 33% more expensive compared to the most economic option (9B) at 50% confidence. Table 6 below also illustrates the most optimistic 10% confidence level of Option 1D is more expensive by 10% to the most pessimistic 90% confidence level of the RPV technical Options 2-4B. To verify the provenance of the costs assumptions for the dock upgrade, the largest cost driver within RC option, the upgrade of the dock has been subjected to sensitivity analysis.

The dock upgrade represents 26% of the costs and is an exclusive requirement of the RC technical option.

6.11.2. The upgrade of the dock facility is estimated at 26% of the costs (constant cost). This cost has been generated through a site visit to the French 'Cachin' Dock in Cherbourg to understand the infrastructure required then assimilated to the closest British equivalent, the ship lift at Faslane[80]. The value of this upgrade has been reduced[81] at significant intervals to ascertain if it could impact the decision making:

WLC Differential Dual Site (9B) against Devonport Only (1D)		WLC Differential Dual Site (2-4B) against Devonport Only (1D)	
Dock upgrade (£m)	**NPV delta (£m)**	**Dock upgrade (£m)**	**NPV delta (£m)**

Table 6 Sensitivity Analysis on RC dock upgrade[82]

6.11.3. The sensitivity analysis shows that even if the RC option did not require such a significant dock upgrade it would still be more expensive than the RPV technical options. This is due to an additional set of operational activities to cut out the RC of c.7% of total cost and a more costly storage solution of c.2.5% of total cost.

6.11.4. The RC technical option is more expensive when compared to the RPV options. This is due to significant investment upfront to enable RC separation, a costlier storage solution and operational activities to separate the RC from the submarine. Furthermore, the RC option does not have the option of joining a national storage strategy with the NDA so any potential cost savings are omitted in the storage approach. This is due to both the location of the NDA sites and the economic challenge of moving the RC. The RC can only be moved by sea (due to its weight of c.1000 tonnes) which rules out NDA sites that do not have sea access, docks and heavy lifting equipment.[83]

6.12. Packaged Waste Options

6.12.1. The Packaged Waste technical option is 22% more expensive when compared to the most economic RPV option. There is a slight overlap at the 10% confidence level for 8B is matched by the 83% confidence level of Option 3-4D.

6.12.2. The Packaged Waste Options are more expensive than the RPV Options due to the greater shielded storage requirements of the ILW (the shielded store represents 5% of the financial commitment for Option 5-7B) and the design, commission and build

[80] Case Study Shiplift and 12 Berth had initial estimate in 1984 , whereas the apportionment of agreed settlement in 1993 was .This comparable example from Faslane illustrates that cost of large scale capital equipment tends to be underestimated. *(Blanked out due to commercial sensitivity of MoD costs. Originals reviewed by DASA/DESA)*.

[81] Reductions of this capital upgrade have been assessed because increases in cost would further increase the cost delta between the RC and RPV options.

[82] As per JSP507, sensitivity analysis is used to show how changes to assumptions affect NPV and options rankings. Due to commercial sensitivity this sensitivity analysis has been redacted however the range of variation within this sensitivity analysis has been deemed plausible and approved by DASA/DESA.

[83] Letter from NDA dated 22 October 2008 confirming that they do not docking facilities or suitable lifting equipment.

of the RPV size reduction facility for immediate size reduction.[84]

6.12.3. The sensitivity analysis has focused on the MOD variant solutions owing to the greater certainty of cost for this storage solution. The cost of the shielded store is currently estimated at 5% of total costs of 5-7B. This cost has been generated through a detailed study by Nuvia and compared to existing store builds by the NDA. The value of this has been reduced [85]at significant intervals.

WLC Differential Dual Site (2-4B) against 5-7B	
ILW Storage (£m)	**NPV delta (£m)**
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Table 7 Packaged Waste Storage Sensitivity Analysis[86]

6.12.4. The sensitivity analysis on the storage facility makes a minimal impact on the option's profile and even if reduced to zero it would not change the ranking. Furthermore, it was established that during the joint assessment with the NDA that the move away from shielded stores is currently being undertaken by the civil nuclear industry primarily due to the cost of build, operation and decommission of these stores.

6.12.5. To judge the impact of the size reduction facility it has been assumed that this facility will cost more in the future (i.e. through changes in legislation/policy and the complexity of the design). The requirement for immediate size reduction represents 15% of the financial commitment for Option 5-7B.This cost has been generated through a detailed study by Babcock[87] and compared to existing size reduction facilities at Sellafield. For the purpose of sensitivity analysis it has been assumed that the cost for the size reduction facility remains constant for the Packaged Waste option but is increased for the RPV options at significant intervals.

WLC Differential Dual Site (2-4B) against 5-7B			
Size reduction (£m)	**Cost increase**	**NPV in 2-4B**	**Delta NPV**
[redacted]	-	[redacted]	[redacted]
[redacted]	25%	[redacted]	[redacted]
[redacted]	50%	[redacted]	[redacted]
[redacted]	100%	[redacted]	[redacted]
[redacted]	200%	[redacted]	[redacted]

Table 8 Sensitivity Analysis on RPV Size reduction Facility[86]

6.12.6. There would need to be a substantial cost increase of +200% in the future for the Package Waste technical option to be preferred over the RPV option. The likelihood of this happening is very limited as it is more likely that the cost of the RPV size

[84] The current assumption is that same RPV size reduction facility is required for Package Waste and RPV options as currently the planned GDF requires 3m³ boxes.
[85] Sensitively analysis has focused on the reduction because an increase of cost in this facility would increase the cost delta between Packaged Waste and RPV options and thus make PW more unattractive.
[86] As per JSP507, sensitivity analysis is used to show how changes to assumptions affect NPV and options rankings. Due to commercial sensitivity this sensitivity analysis has been redacted however the range of variation within this sensitivity analysis has been deemed plausible and approved by DASA/DESA.
[87] Support to the cost benefit analysis team task 2.

reduction facility would actually reduce in terms of cost in the future or may not even be required. There is a significant chance that both the RPV size reduction facility and the size reduction process may alter over the long-term[88]. This would therefore reduce the level of investment in a size reduction facility. This is due to several factors:

- The radioactivity of the RPV will have decayed in the intervening period;
- Changes in technology may provide a more efficient process of size reduction;
- Commercial / national size reduction facilities may become available as other waste producers identify similar requirements to enable GDF disposal; and
- Regulatory changes may allow more flexibility or conversely impose more stringent requirements in the process of size reduction.

6.13. Whole RPV disposal

6.13.1. Based upon the current physical design of the GDF, it is assumed that RPVs will require size reduction into packaged waste in $3m^3$ boxes prior to disposal. However, whilst the GDF design continues to mature, there is an opportunity[89] that that it may become possible to dispose of whole RPVs without the need for further size reduction. This opportunity is being actively pursued by SDP in liaison with the NDA.

6.13.2. The Packaged Waste options are considerably more expensive when compared to the RPV options. This is due to the requirement of immediate dismantling and the investment in a size reduction facility. The challenge of designing, commissioning, building and testing such a facility should not be underestimated, as illustrated by the Sellafield Vitrification Plant.[90] The size reduction plant within this facility cost circa [redacted] and has encountered a number of issues in size-reduction.

6.13.3. In addition to the immediate build of a size reduction facility the packaged waste option would require the design, build and commission of a shielded ILW store. This adds additional expense and is no longer being followed by the civil nuclear industry who are focusing on the unshielded storage approach. It is, therefore, recommended on cost grounds that the Packaged Waste options are discounted.

6.14. RPV Options differentiators - Dual Site compared to Single Site

6.14.1. Within the remaining RPV options, the selection of the initial dismantling site(s) is a

[88] 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.
[89] Babcock compiled a letter of compliance to Radioactive Waste Management Directorate (RWMD) to ascertain the possibility of the planned GDF access being changed so as to support larger objectives. This question is also being asked by other Radioactive Waste Providers such as Magnox. However, a response is not due until November 2012.
[90] The Sellafield Vitrification plant is the only UK current example where ILW material is cut-up. The messages we too from the NDA team that operate this is that it is very expensive and unreliable. If at all possible we should look at options that do not immediately size reduce. (The Packaged Waste Options) *Costs blanked out due to commercial sensitivity.*

marginal differentiator in WLC. The Devonport-only Option is c.2.5% more expensive when compared to the Dual Site Option due to the additional cost of moving seven submarines from Rosyth to Devonport. The cost of moving submarines comprises preparation of the submarine (to ensure sea worthiness for open water towing) and the cost of the transport itself. Whereas a Dual Site Option requires some investment in facilities at both Rosyth and Devonport dockyards to enable RC deplanting, RPV removal and Low Level Waste (LLW) size reduction.

6.14.2. Each move is estimated at c.1% of the Devonport only option, broadly split between 0.75% for submarine tow preparation and 0.25% to transport the submarine. This cost has been generated through a study by Salvage Marine Operations (SALMO) and verified through discussions with MOD SMEs from the Design Authority, Laid Up Submarines and SALMO. To test sensitivity, transport costs have been reduced at significant intervals as shown in Table 9 below.

WLC Differential Dual Site (9B) against 9D Devonport Only	
Submarine Transport (£m)	**NPV delta (£m)**
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Table 9 Sensitivity Analysis on Submarine Transport[91]

6.14.3. This shows that if the submarines require less preparation work or the towing costs are less than currently expected then a Devonport only solution could be considered as more economic. However, the likelihood of the cost of submarine preparation and tow reducing by 50% is low based on the age and condition of the submarines at Rosyth. For example, HMS Dreadnought was launched in 1960 and has been decommissioned since 1982 and, therefore, would represent a challenge to move her in open sea.

6.14.4. The potential duplication of facilities represents 7% of the financial commitment for a Dual Site Option as there are site specific upgrades and not all facilities are portable. As a comparator, the expected cost of the RPV de-planting facility and LLW size reduction facility in a Devonport-only solution would be 5%.

6.14.5. The current assumption is that the RC de-planting facilities will be mostly portable so approximately 10-20% more expensive whereas the LLW processing is not portable and a Dual Site Option would require investment in LLW facilities at both Rosyth and Devonport dockyards.

6.14.6. Therefore, the sensitivity analysis is on the RC de-planting facilities element and its portability between sites. The current cost assumption is for a de-planting facility 5% of the financial commitment for a Dual Site Option and sensitivity analysis has assessed changes to the assumed portability.

WLC Differential Dual Site (9B) against 9D Devonport Only		
RC Deplanting Facilities (£m)	**Increased level of portability**	**NPV delta (£m)**

[91] As per JSP507, sensitivity analysis is used to show how changes to assumptions affect NPV and options rankings. Due to commercial sensitivity this sensitivity analysis has been redacted however the range of variation within this sensitivity analysis has been deemed plausible and approved by DASA/DESA.

[redacted]	-	[redacted]
[redacted]	10%	[redacted]
[redacted]	25%	[redacted]
[redacted]	50%	[redacted]
[redacted]	100%	[redacted]

Table 10 Sensitivity on the portable element of the RPV deplanting facility[92]

6.14.7. Table 10 shows that even if very little of the de-planting facility was portable, and both sites required investment, it would not reverse the preference for dual-site dismantling.

6.14.8. The impact of sensitivity analysis has shown that there is an economic argument to undertake sequential dual-site dismantling. This cost analysis alone is not conclusive since future studies may show that if submarine movement is less expensive and facilities less portable than currently estimated, then the Devonport-only Option might become more economic.

6.15. RPV Options differentiators – ILW Storage

6.15.1. A joint assessment has been undertaken with NDA to determine, generically, whether it would be more cost-effective to use NDA storage facilities or to develop bespoke MOD facilities.[93]

6.15.2. The interim report from this assessment identified a potential saving from using NDA storage facilities. These would be direct savings to MOD in the cost of building and operating the ILW store. When schedule risk and uncertainty had been taken into account, the use of NDA facilities was found to be 4% less than developing bespoke MOD facilities. This is currently a generic assessment and the level of accuracy will depend on the specific sites and stores considered. Moreover, it is important to note that schedule alignment with specific NDA stores and risks to wider NDA programmes have not been considered in these estimates.

6.16. Summary of IA Findings

6.16.1. The financial analysis concludes that the technical approach that provides the cheapest option is the RPV one. The economic differences between this and the best of the other technical approaches is significant and even following sensitivity analysis on the key cost drivers RPV options remain the cheapest. However, the cost differences between the remaining four RPV options are less conclusive.

6.16.2. The cost differences in favour of the dual site dismantling option (the costs required to tow seven submarines are greater than the costs of facility duplication) are marginal. However, there are significant and high profile Other Contributory Factors that discriminate in favour of dual site.

6.16.3. The analysis shows that a NDA/MOD joint approach on an ILW Storage solution will have some economic benefits over a MOD bespoke approach. DECC and NDA are due to communicate their decision in October 2012. The actual store siting decision

[92] As per JSP507, sensitivity analysis is used to show how changes to assumptions affect NPV and options rankings. Due to commercial sensitivity this sensitivity analysis has been redacted however the range of variation within this sensitivity analysis has been deemed plausible and approved by DASA/DESA.
[93] SDP / NDA Interim Report on Storage Options

will take place after the MGBC1 following further public consultation on the named storage sites.

6.16.4. The assessment of cost (KUR 1.1.1.) demonstrates that the RPV removal and storage options are the most economic, illustrating that the delay of RPV size reduction is preferable to immediate size reduction. The economic argument shows that there is a financial argument for initial dismantling to be undertaken at a both sites and although not conclusive by itself, is supported by non-financial arguments articulated in the OCF.

7. COEIA Results

7.1. Objective

7.1.1. The COEIA plot combines the results of the OE and IA reported above and shows the cost-effectiveness of the SDP options. On a COEIA plot, an option is best (i.e. most cost-effective) 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 (i.e. least cost-effective).

7.2. COEIA Plot

7.2.1. Figure 7 shows the SDP COEIA, which uses the key described in Table 1 in Section 4 to identify the options, each of which is shown as a point with the uncertainty around their OE and WLC shown as error bars. The labels show the different technical approaches which might be used to dismantle the submarines: the Do Minimum (Do Min) option, RC separation, removal of the RPV and early size reduction to form Packaged Waste (PW).

7.2.2. Note that Option 1R, which was a comparator in the OE and OCF analyses, is not included on the COEIA as it demonstrated relatively poor OE performance and does not need to be considered further.

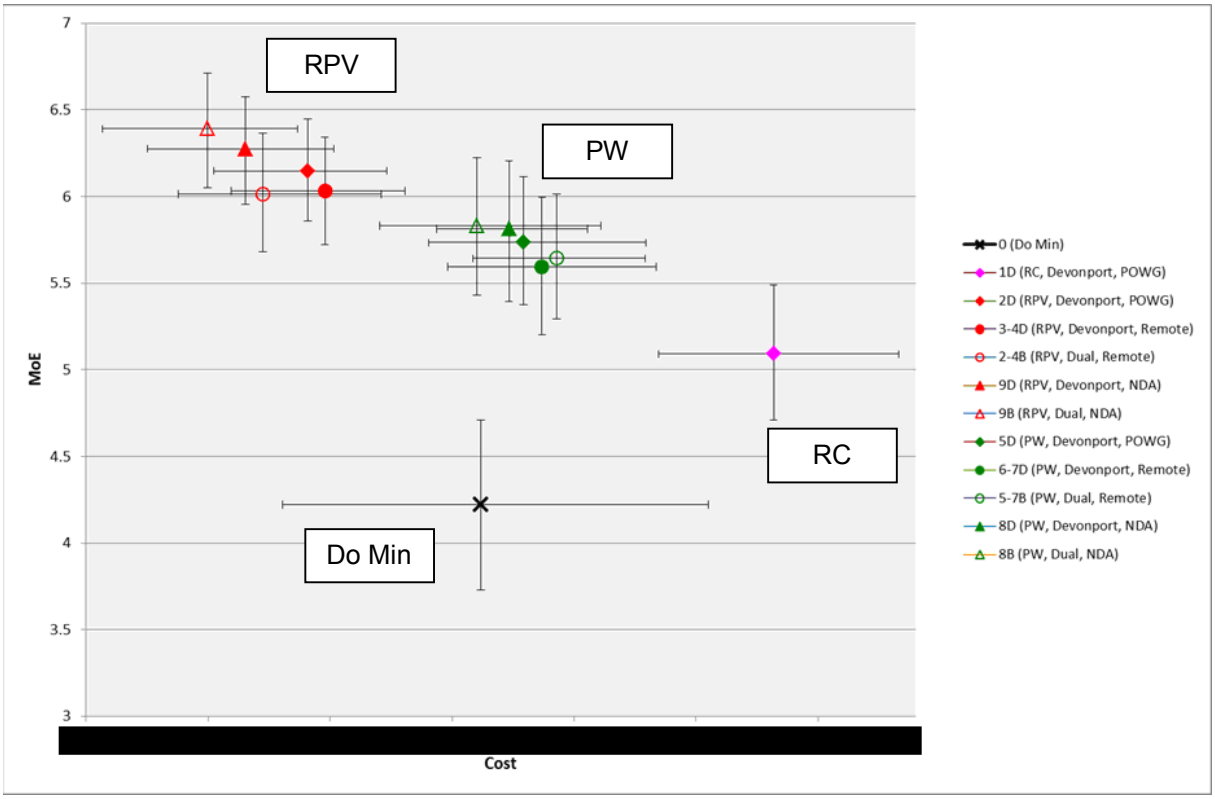

Figure 7 – SDP COEIA

7.2.3. Figure 7 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 and infrastructure, which have associated time, operational and environmental implications. It demonstrates that:

- Option 0 (Do Minimum) is significantly less effective that the other Do Something options. Additionally, specific OE results indicate that is it not compliant with UK policy and poses an unacceptably high risk to maritime operations[94].
- Option 1D (RC) is significantly more costly than the other Do Something options.
- The Packaged Waste options are nearly all more costly than the RPV options (the exception is for Option 8B). Further, each pair of comparable options (such as 8B and 9B) are separated by a statistically significant cost margin.

7.2.4. It should be re-stated that all options except for Option 0 do eventually lead to the same end-point that is final storage at the GDF. Option 0 exhibits poor cost-effectiveness, as shown in Figure 7.

7.3. Summary of COEIA Findings

7.3.1. The COEIA has not identified a single option which provides a demonstrably more cost-effective solution to SDP than all other options. Although some options are separated by a statistically significant margin, the COEIA (by itself) remains inconclusive in respect of site options for initial dismantling and storage. Nonetheless, the COEIA demonstrates a clear preference for options involving RPV removal.

7.3.1. The IA, in particular, concludes that the only technical option that provides a viable economic approach is the RPV one. The economic differences between this and the best of the other technical approaches is significant and, even following sensitivity analysis on the key cost drivers, this argument remains the same. However, the economic reasons to further separate the remaining four RPV options are less clear-cut.

7.3.2. This finding is supported by the fact that the RPV options allow for the possibility of whole RPV disposal in the GDF. Although this remains a project opportunity, it would offer the possibility of significant further financial savings, and is only supported by adopting the RPV option

7.3.3. Whilst NDA storage site options perform slightly better (in terms of effectiveness and cost to MOD), none of the storage options can be significantly differentiated without further assessment of specific sites.

[94] The Do Minimum option explicitly fails one of the SDP Key User Requirements, 3.4.1, “the user requires that the capability is in service before the decommissioned submarine storage capacity is reached.”

8. Other Contributory Factors

8.1. Context

8.1.1. The identification and analysis of OCF is an integral part of an OASP and helps to inform the MGBC1 recommendations. The level of public and stakeholder interest in SDP, and the potential influence of key stakeholders over project delivery, means that the project must consider a wider range of OCFs than for many MOD projects. Some of these OCFs will have a major bearing on the MGBC1 decisions, so the analysis has to provide an audit trail and be robust against challenge.

8.1.2. This Section summarises the main points from the OCF Report[95], which describes the OCF methodology and presents the analysis results. That document is in turn supported by the OCF Analysis Report (OAR)[96], a working document developed during the analysis to collate all the relevant source information, ongoing analysis detail, and workshop results.

8.2. Analysis Process

8.2.1. The basic approach remains as normal for MOD projects. A set of 'Headline' OCFs was first derived and included for comment in the Public Consultation Document. These Headline OCFs were then broken down as shown in Figure 8 into 20 Sub-factors for detailed analysis.

8.2.2. A workshop was held with SMEs and stakeholders to consider the results of this analysis and consultation feedback[97]. Participants allocated each Sub-factor in turn to one of three categories: 'Potential Deal Breaker'; delivery or communications 'Challenge'; or 'Note Only' (see Table 11).

8.2.3. There is no OCF 'score' for the options and OCF output does not influence or append the COEIA plot in any way. Instead the results are brought together in Section 9.

8.2.4. Data sources for the SDP OCF analysis included:

- Knowledge held by project team members and other MOD stakeholders.
- Direct external stakeholder engagement (particularly in relation to OGDs, local authorities, and through the SDP AG).
- Structured analysis of consultation responses from stakeholders and potentially-affected communities.
- Analysis carried out for comparable non-MOD radioactive waste decisions (eg DEFRA's CoRWM[98] programme).

[95] SDP OCF Report, v2.0, October 2012
[96] SDP OCF Analysis Report, v1.0, October 2012.
[97] Responses are documented in SDP Post Consultation Report. v1.0, July 2012.
[98] Committee on Radioactive Waste Management. See www.corwm.org.uk.

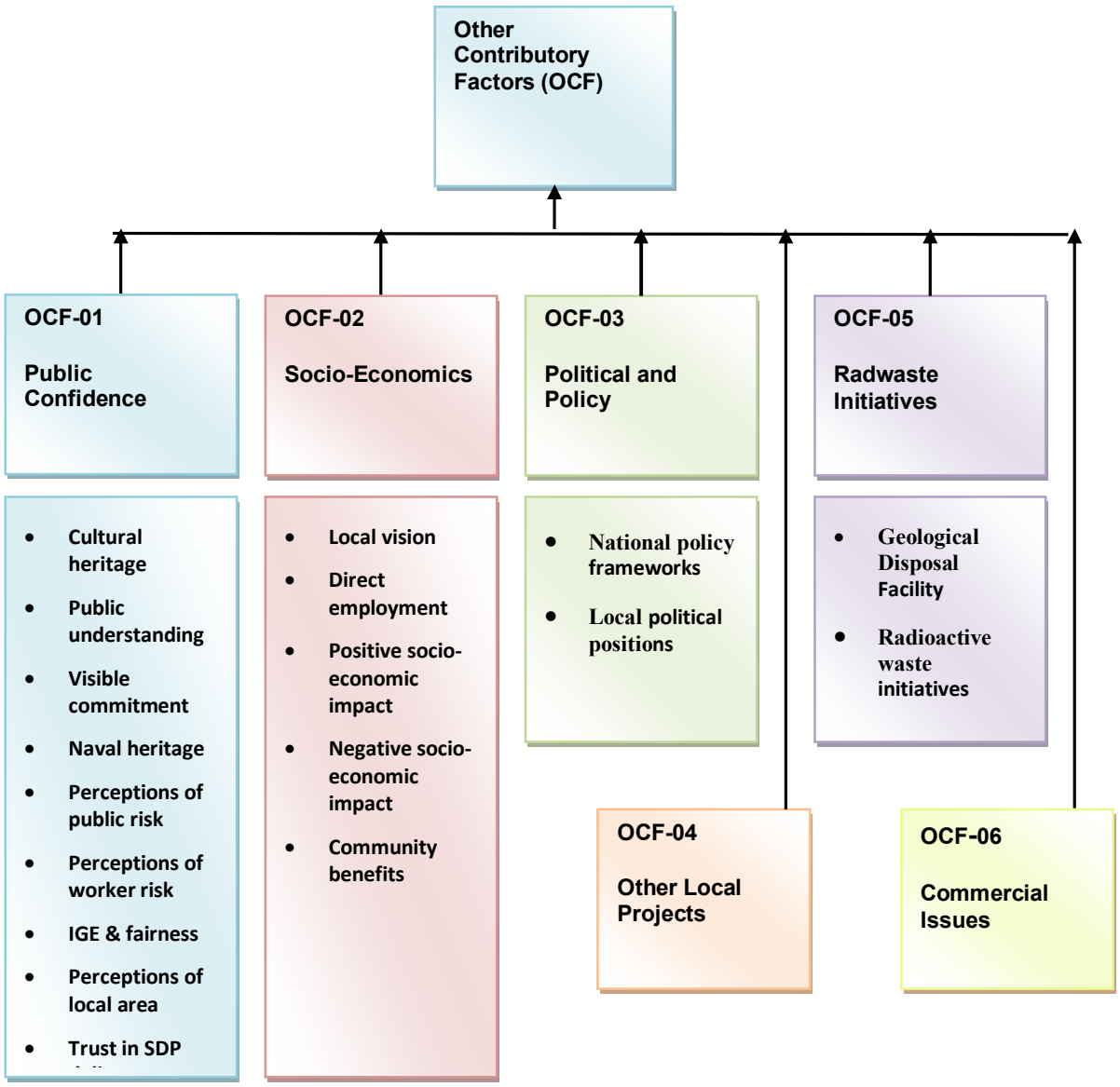

Figure 8 Headline OCFs and Sub-factors

8.3. Results of Analysis

8.3.1. Table 11 below shows the category to which OCF Sub-factors were allocated at the Main OCF Workshop. The Sub-factors in each category are then discussed in more detail.

OCF-01	**Public Confidence**	**Category**
OCF-01/1	Cultural Heritage	Note Only
OCF-01/2	Public Understanding	Note Only
OCF-01/3	Visible Commitment	Note Only
OCF-01/4	Naval Heritage	Note Only
OCF-01/5	Perceptions of Public Risk	'Potential Deal Breaker'
OCF-01/6	Perceptions of Worker Risk	Note Only
OCF-01/7	Inter-Generational Equity & Fairness	'Potential Deal Breaker'
OCF-01/8	Perceptions of Local Area	Covered by OCF-02/1
OCF-01/9	Trust in SDP Delivery	Challenge
OCF-02	**Socio-Economics**	
OCF-02/1	Local Vision	Note Only
OCF-02/2	Direct Employment	Note Only
OCF-02/3	Positive Socio-Economic Impact	Note Only
OCF-02/4	Negative Socio-Economic Impact	Challenge
OCF-02/5	Community Benefits	Note Only
OCF-03	**Political & Policy Frameworks**	
OCF-03/1	National Policy Positions	'Potential Deal Breaker'
OCF-03/2	Local Political Positions	'Potential Deal Breaker'
OCF-04	**Other Local Projects**	
OCF-04/1	Other Local Projects	Note Only
OCF-05	**Radioactive Waste Initiatives**	
OCF-05/1	Geological Disposal Facility	'Potential Deal Breaker'
OCF-05/2	Other Initiatives	'Potential Deal Breaker'
OCF-06	**Commercial Issues**	
OCF-06/4	Commercial Interest	'Potential Deal Breaker'

Table 11 OCF Categorisation

8.3.2. 'Potential deal breakers'

- *Perceptions of Public Risk* militates against POWG ILW storage (Options 2D and 5D), and by inference against the RC dismantling options (1D and 1R) that require it (but only on the basis of limited consultation at non-POWG sites). It also militates to a lesser extent in favour of dual site dismantling, to avoid moving submarines.
- *Inter-Generational Equity & Fairness* militates against the RC storage options (1D and 1R) on Inter-Generational Equity (IGE) grounds, and in favour of dual site dismantling (those options with suffix B rather than D) on wider fairness grounds. Some perceptions of fairness argue for separate dismantling and ILW storage sites; more generally, there was a strong message from the dockyard communities that dismantling sites should not become storage sites 'by default'. Another view was that all potential sites should be considered on a 'level playing field'.
- *National Policy Positions* (primarily Scottish Government) militates against POWG ILW storage at Rosyth (Option 1R), and by inference against the RC options (1D and 1R) that require it. It also militates against some NDA storage sites and Rosyth-only dismantling.
- *Local Political Positions* also militates against POWG ILW storage (Options 2D and 5D), and by inference against the RC options that require it (but only on the basis of limited consultation at non-POWG sites). It also militates against both Devonport-only (options with suffix D) and Rosyth-only dismantling (Option 1R).
- *Geological Disposal Facility* militates against some NDA ILW storage sites located near potential GDF volunteer communities which are engaged in sensitive negotiations with DECC and NDA.
- *Other Initiatives* militates against NDA ILW storage sites, particularly Magnox.
- *Commercial Interest* militates against commercial sites which do not respond positively to market testing.

8.3.3. 'Challenges'

- *Trust in SDP Delivery* militates against the RC dismantling options (Options 1D and 1R). Also, trust may vary according to ILW site owner.
- *Negative Socio-Economic Impact* militates against POWG ILW storage, and by inference against the RC options that requires it - but potentially also against other ILW storage locations.

9. Conclusions

9.1. COEIA & OCF

9.1.1. The COEIA identifies that the preferred option should be one of the RPV dismantling options (2D, 3-4D, 2-4B, 9D and 9B) but it does not clearly separate them. The OCF analysis, however, does provides enough evidence to make a recommendation.

9.1.2. The OCFs *Perceptions of Public Risk, Inter-Generational Equity and Fairness*, and *'Local Political Positions'* all favour dual site dismantling over Devonport-only dismantling. OCFs do, therefore, discriminate between dismantling sites. Given the closeness in WLC and OE between dual site and Devonport-only, it is recommended that the former is selected to avoid potentially lengthy and/or costly delays arising from particular opposition to dismantling at Devonport-only and the attendant movement of submarines.

9.1.3. A number of OCFs currently militate against those options for *generic* POWG ILW storage relative to a *generic* remote storage location. These OCFs reflect widespread misgivings about POWG impacts and concern that dismantling sites should not become storage sites 'by default'. This could translate to significant local or national opposition, leading to delays and greater cost.

9.1.4. This does not, however, mean that a *specific* POWG storage site will necessarily be discriminated for or against relative to *specific* remote sites. Importantly, potential host communities for storage remote from the POWG have not yet had a chance to make their input, and their insights and views may shape the decision making leading up to MGBC2, when specific ILW storage locations will be selected.

9.1.5. The situation with respect to other generic ILW storage site types is also complex, with different OCFs and different stakeholder positions pointing to different and potentially contradictory solutions. For instance, *GDF* and *Other Initiatives* both discriminate against some NDA ILW storage sites - particularly in Cumbria and South West England because of potential conflicts with the GDF programme and Magnox sites where there may be conflict with other storage initiatives.

9.1.6. Although the NDA options (9D and 9B) perform somewhat better than the other RPV storage options in terms of both OE and WLC, they are only marginally more cost-effective (in direct costs) and are likely to incur wider risks to NDA programmes. The joint assessment work undertaken with NDA indicates that the most cost effective site (whether NDA or MOD) can only be adequately resolved and selected in a legally robust manner on the basis of a site specific assessment.

9.1.7. The judgement is, therefore, that neither the COEIA nor OCFs currently discriminate sufficiently between generic ILW storage site type options to make a decision. OCF analysis and direct feedback from key stakeholders both lead to the conclusion that SDP must consider all potential ILW storage sites, including NDA sites, on a 'level playing field' to avoid potential delays and costs when negotiating with local communities.

9.2. Recommended Option

9.2.1. The recommendation which emerges from this analysis is **RPV removal and storage with initial dismantling at both Devonport and Rosyth Dockyards**. No specific site is currently proposed for ILW storage but it is recommended that the assessment considers all potential options, including NDA sites (if agreement is reached between DECC and MOD). POWG option(s) shall be considered amongst the other ILW storage options. The recommended option set to be taken forward is therefore **Option 2-4B and/or 9B**.

9.2.2. This recommendation is supported by the COEIA, which demonstrates that RPV removal is the most cost-effective approach to submarine dismantling. Commentary from public consultation has been valuable in refining this further such that dual-site dismantling is recommended, and that the decision on ILW storage site should be made across sites irrespective of whether they are NDA, MOD, commercial and/or POWG.

9.3. Further Work

9.3.1. At the commencement of the Assessment Phase it had been the intention to arrive at a decision on a specific site for ILW storage. To be robust and deliverable, such a decision requires a fair and transparent assessment of all short-listed nuclear sites (whether MOD, NDA or commercially owned). To date it has not been possible to generate such a short-list because NDA was developing its own strategy for ILW storage on its sites.

9.3.2. This requirement remains unfulfilled. Moreover, none of the analyses (COEIA or OCF) conclusively support the selection of a 'type' of site for ILW storage and such an approach was challenged by consultation responses that argued for comparison of specific sites 'on a level playing field'. Thus a further assessment of which specific site(s) to use for ILW storage will be made after MBGC decisions are announced on the initial dismantling sites and methodology.

9.3.3. This further assessment will require engagement with potential host local communities and OCFs are expected to be still more dominant than in the current work. In this regard, and because the storage site is likely to be the most controversial decision faced by SDP, it is sensible to approach this further assessment with clarity over what the project needs to store (whether RCs, RPVs or packaged waste) and where it will be come from (whether Devonport and / or Rosyth).

9.3.4. One of the key findings of public consultation was the need to continue engagement with stakeholders and local communities throughout the SDP decision making process, and the key findings from this analysis, especially where they differ from the results contained in the 2011 Interim OASP, will be put into the public domain.[99]

[99] Although the proposed option in the 2011 Interim OASP was the same: RPV removal and storage with initial dismantling at both Devonport and Rosyth Dockyards, with interim ILW storage at either a POWG or remote NDA or MOD/commercial site.

A Annex A: Abbreviations

Abbreviation	Meaning
AG	Advisory Group
ARM	Active Risk Manager
BC	Business Case
CAAS	Cost Assurance Advisory Services
CBO	Community Based Organisation
CDAL	Cost Data Assumptions List
COEIA	Combined Operational Effectiveness and Investment Appraisal
CoA	Concept of Analysis
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
DSA	Disposal Services Authority
DUWC	Deterrent and Underwater Warfare Capability
ENV	Environmental
GDF	Geological Disposal Facility
H&S	Health and Safety
IA	Investment Appraisal
IAC	Investment Approvals Committee
IGE	Intergenerational Equity
ILW	Intermediate Level Waste
ISM	In Service Submarines
KUR	Key User requirement
LLW	Low Level Waste
LUSM	Laid-up Submarine
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

Abbreviation	Meaning
MPOS	MOD Proposed Option Study
NDA	Nuclear Decommissioning Authority
NGO	Non-Governmental Organisation
NPV	Net Present Value
OAR	OCF Analysis Report
OASP	Operational Analysis Supporting Paper
OCF	Other Contributory Factors
OE	Operational Effectiveness
OGD	Other Government Department
OPS	Operations
PASE	Planning Assumption Service Entry
PMP	Project Management Plan
POL	Policy
POWG	Point of Waste Generation
PW	Packaged Waste
RAG	Red Amber Green
RC	Reactor Compartment
RPV	Reactor Pressure Vessel
RWMD	Radioactive Waste Management Directorate
SALMO	Salvage Marine Operations
SDP	Submarine Dismantling Project
SEA	Strategic Environmental Assessment
SME	Subject Matter Expert
SRO	Senior Responsible Owner
SSUN	Single Statement of User Need
TOS	Technical Options Study
UR	User Requirement
URD	User Requirement Document
V&V	Validation & Verification
VfM	Value for Money
VLLW	Very Low Level Waste
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."[100]
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."[101]
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 19 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."[102]
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."[103]

[100] Taken from the Acquisition Operating Framework (AOF), Through Life Capability Management, Version 1.1.4, March 2010.
[101] Taken from JSP507, MOD Guide to Investment Appraisal and Evaluation, Version 3.0, dated December 2006.
[102] Taken from Foundations for the Business Case – Operational Analysis, DG(S&A), 2003.
[103] 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…"[104]
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."[105]
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.
Recommended Option	The option for SDP recommended for approval by the IAC as part of the MGBC.
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."[106]
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'.

[104] 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.
[105] 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.
[106] 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	Classification
Managing our Radioactive Waste Safely, CoRWMs recommendations to Government, 31/07/06	CoRWM		Jul 06	Unclassified
MOD Guide to Investment Appraisal and Evaluation	MOD	JSP 507 v5.0	Apr 11	Unclassified
Response to the Report and Recommendations from the Committee on Radioactive Waste Management (CoRWM), by the UK Government and he devolved administrations.	HMG		Oct 06	Unclassified
Review of SDP MCDA Monte-Carlo Model and Associated Data Checking	Nuvia	Issue 1.0	Jun 11	None
SDP Benefits Report	ISM	Issue 1.0	Feb 11	Protect - Policy
SDP Benefits Realisation Plan	ISM	Issue 0.3	Dec 11	Protect - Policy
SDP Concept of Analysis (CoA)	ISM	Issue 1.1	Mar 11	Protect-Policy
SDP Factsheet 1: Project History	ISM		Oct 11	Unclassified
SDP Integrated Options Report	ISM	Issue 1.0	Feb 11	Protect – Commercial – MOD Eyes Only
SDP Interim OASP	ISM	Issue 1.0a	Oct 11	Unclassified
SDP Investment Appraisal (IA)	ISM	Issue 1.0	October 12	Protect - Commercial
SDP MOD Proposed Options Study (MPOS)	FNC	36995/36702R Issue 1	Aug 10	Protect - Policy
SDP Operational Effectiveness (OE) Report	ISM	Issue 1.0	October 12	Protect - Policy
SDP Options De-selection Report	ISM	Issue 1.0	May 12	Protect - Commercial
SDP Other Contributory Factors (OCF) Report	ISM	Issue 2.0	October 12	Protect - Policy
SDP OCF Analysis Report (OAR)	ISM	Issue 1.0	October 12	Protect - Policy
SDP Post-Consultation Report	ISM	Issue 1.0	Jul 12	Unclassified
SDP Project Management Plan (PMP)	ISM	Issue 11.0	May 12	Protect - Policy
SDP Proposed Site Criteria & Screening Paper	ISM	Issue 2.1	Mar 11	Protect - Policy
SDP Public Consultation Report	ISM	Issue 1.0	Oct 11	Unclassified

Title	Originator	Reference/ Version	Date	Classification
SDP Selection of Criteria for MPOS Study	FNC	36995/63406V	Aug 10	Protect - Policy
SDP Technical Options Study	FNC	35114/35042R Issue 1	Jun 10	None
SDP User Requirements Document	ISM	Issue 5.0	Nov 11	Restricted - Commercial
SEA Non-technical Summary	ISM	Issue 2.0	Oct 11	Unclassified
SEA Environmental Report	ISM	Issue 1.0	Oct 11	Unclassified

D Annex D: SDP Benefits

Benefit	Type	Short Description	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[107], 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

[107] 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	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	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 planned 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	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. The additional cost of remote storage of RCs has been estimated as significant.
- A working assumption was made for the RPV options, 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.
- For the Packaged Waste options, 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.
- The Demonstrator is expected to commence [redacted] and In-service Date (ISD) [redacted] across all options (also in the MDAL).
- ILW must be packaged into 3m³ boxes before it can enter the planned GDF;
- The planned GDF is assumed to be available from 2040 (also in the MDAL).
- Submarines will be dismantled at the rate of one per year (also in the MDAL).

Financial Assumptions

These assumptions used in this IA are in line with the SDP MDAL:

- All Costs are in pounds sterling.
- NPV discounts constant prices at the HM Treasury approved rate of 3.5% for 1-35 years then 3% thereafter.
- Year 0 is FY13/14 therefore any costs incurred prior to April 2013 have been treated as sunk cost and excluded from this analysis.
- VAT at 20% has been excluded from costs subject to the economic case.
- Inflation is at the planning round approved rate of 2.5% per annum;
- The WLC includes the full cost of ILW Storage and disposal in the planned GDF.
- Costs include associated afloat storage costs (such as maintenance, berthing and potential infrastructure improvements) as submarines wait dismantling.

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 Marine (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 top [redacted].
- If SSNs are moved to Devonport, 3 basin would reach the 14 submarine capacity in [redacted], and the 16 submarine capacity in [redacted].

[108] *Costs blanked out due to commercial sensitivity.*

F Annex F: OE Results

Ranked in terms of OE (high to low).

Rank	Option	10th%	50th%	90th%
1	9B: RPV removal at Devonport & Rosyth with interim storage at an approved NDA site	6.10	6.44	6.76
2	9D: RPV removal at Devonport with interim storage at an approved NDA site	6.01	6.33	6.63
3	2D: RPV removal at Devonport with interim storage at POWG	5.89	6.18	6.48
4	3-4D: RPV removal at Devonport & Rosyth with interim storage at remote commercial or MOD site(s)	5.77	6.08	6.39
5	2-4B: RPV removal at Devonport & Rosyth with interim storage at POWG or a remote commercial or MOD site	5.72	6.05	6.40
6	8B: RPV removal & size reduction at Devonport & Rosyth to form Packaged Waste with interim storage at an approved NDA site	5.51	5.91	6.30
7	8D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at an approved NDA site	5.47	5.89	6.28
8	5D: RPV removal & size reduction at Devonport to form Packaged Waste with interim storage at POWG	5.41	5.77	6.15
9	5-7B: RPV removal & size reduction at Devonport & Rosyth with interim storage at POWG or a remote commercial or MOD site	5.36	5.71	6.08
10	6-7D: RPV removal & size reduction at Devonport to form Packaged Waste at remote commercial or MOD site(s)	5.26	5.65	6.05
11	1R: RC separation at Rosyth with interim storage at POWG	5.10	5.50	5.89
12	1D: RC separation at Devonport with interim storage at POWG	4.85	5.23	5.63
13	0: Continued Afloat Support	3.77	4.26	4.75

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	9B - RPV storage dismantling at Dual sites - storage at a NDA site	Most Economic		
2	9D- RPV storage dismantling at Devonport - storage at a NDA site	+3.86%	+2.98%	+2.68%
3	2-4B - RPV storage dismantling at Dual sites - storage at MOD	+ 6.50%	+4.37%	+6.20%
4	2D - RPV storage dismantling at Devonport - storage at POWG	+ 9.56%	+7.91%	+6.61%
5	3-4D - RPV storage dismantling at Devonport - storage at MOD	+11.03%	+9.25%	+7.94%
6	8B - Packaged Waste at Dual sites with storage at a NDA site	+23.78%	+21.24%	+22.39%
7	0 - Do Minimum	+15.44%	+21.55%	+30.31%
8	8D - Packaged Waste at Devonport with storage at a NDA site	+28.71%	+23.76%	+21.36%
9	5D - Packaged Waste at Devonport with storage at POWG	+28.04%	+24.91%	+25.69%
10	6-7D - Packaged Waste at Devonport with storage at a MOD site	+29.68%	+26.36%	+26.45%
11	5-7B - Packaged Waste at Dual sites with storage at a MOD site	+31.84%	+27.53%	+25.62%
12	1D RC Storage - Removal at Devonport	+47.48%	+44.65%	+44.29%

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