Dounreay Site Restoration Ltd

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SUMMARY

This report is the 2008 Site Waste Best Practicable Environmental Option (BPEO) assessment for the Dounreay site. The report outlines the methodology used, underpinning constraints and assumptions, and the key differences between it and the previous Site Waste BPEO study (undertaken in 2003). The report presents the process used for selecting the waste streams which required assessment and provides a justification for why the remaining waste streams did not require further consideration. The treatment for most of the ILW, LLW and Non-radioactive waste streams were determined to be BPEO, through this initial screening process. The following waste streams required assessment: CHILW Graphite (THTR and Activated graphite), LLW Sludges (Granular, Putrescible and LSA Scale), Clean Hazardous Sludge and Exempt Hazardous Sludge.

The report also records the process and outcome of the final option selection, selection of the attributes and sub-attributes for scoring and the results of the scoring exercise. The outcome of applying the weightings to the scores and the effect this has on the selection of the preferred management option is presented along with the sensitivity analysis of the decision making process.

The Dounreay Environment Committee (DEC) has endorsed the following:

- The report fully covers the requirement under Schedule 11 (Item 1) of Dounreay Site Restoration Ltd's regulatory authorisations granted under the Radioactive Substances Act 1993.
- The report should be submitted to the Scottish Environment Protection Agency (SEPA) as DSRL's response to Schedule 11 (Item 1) of the aforementioned Authorisations.

Issue	Date	Author Name Signature	Checked by Name Signature	Endorsed by Name Signature	Accepted by DEC
1	April 2009	Submitted to the Dounreay Environment Committee for comment			
2	June 2009	G Beaven	E Mackenzie	A Anderson	S Middlemas

Distribution:

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ACRONYMS

ADU	Ammonium Diuranate
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
CHILW	Contact Handleable Intermediate Level Waste
DCP	Dounreay Cementation Plant
DFR	Dounreay Fast Reactor
DMTR	Dounreay Materials Test Reactor
DRWI	Dounreay Radioactive Waste Inventory
DSG	Dounreay Stakeholder Group
DSRL	Dounreay Site Restoration Ltd
FHISO	Full Height ISO container
GDF	Geological Disposal Facility
GLEEP	Graphite Low Energy Experimental Pile
HHISO	Half Height ISO container
HAL	High Active Liquor
HEPA	High Efficiency Particulate Air
HVLA	High Volume Low Activity
IEP	Immobilisation and Encapsulation Plant
ILW	Intermediate Level Waste
IX	Ion Exchange
IXC	Ion Exchange Column
LLLETP	Low Level Liquid Effluent Treatment Plant
LSA	Low Specific Activity
LLW	Low Level Waste
LoC	Letter of Compliance
MADA	Multi Attribute Decision Analysis
MAL	Medium Active Liquor
NDA	Nuclear Decommissioning Authority
NDP	NaK Destruction Plant
Nirex	Previous title for RWMD
OAP	Options Assessment Panel
OPC	Ordinary Portland Cement
PCM	Plutonium Contaminated Materials
PFA	Pulverised Fuel Ash
PFR	Prototype Fast Reactor
RHILW	Remote Handleable Intermediate Level Waste
RSA	Radioactive Substances Act
RSRL	Research Sites Restoration Ltd.
RWMD	Radioactive Waste Management Directorate
SEPA	Scottish Environmental Protection Agency
SDP	Sodium Disposal Plant
SNM	Special Nuclear Materials
SoLA	Substances of Low Activity
TCM	Thorium Contaminated Materials
THTR	Thorium High Temperature Reactor
TSV	Temporary Storage Vessel
UCM	Uranium Contaminated Materials
UKAEA	United Kingdom Atomic Energy Authority
VLRM	Very Low Radioactive Material
WTP	Waste Treatment Plant

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EXECUTIVE SUMMARY

The objective of the Dounreay Site Waste Best Practicable Environmental Option (BPEO) Study is to undertake a systematic examination of potential options for the management of wastes, radioactive and non-radioactive, arising from current and future DSRL operations at Dounreay, and to identify the BPEO for the management of the waste streams identified.

The BPEO is the option for a given practice that provides the most benefit or least damage to the environment as a whole, in the long term as well as in the short term, taking into account operational doses and risks, and social and economic factors.

A Site Waste BEPO study was first undertaken in 2003 to underpin the Dounreay Site Restoration Plan. This 2008 Site Waste BPEO study for the Dounreay site provides an update to the 2003 study and its production is a requirement of DSRL's RSA '93 Authorisations (as identified in Schedule 11, Item 1).

The approach used for the 2008 BPEO Study differs from the 2003 BPEO Study as a review of all the Dounreay waste streams was carried out at the start to identify where current waste management strategies were largely compliant with best practice and/or were already underpinned by existing BPEO studies and hence did not require further detailed consideration. This screening exercise drew on the findings of a review of national and international best practice on waste minimisation (ref. 1) and enabled a more transparent overall approach, with a more concise front end phase. Thus, the emphasis of the BPEO Workshop was placed on waste streams where there was a clear need for an updated assessment.

The report presents the process used for selecting the waste streams which required assessment and provides a justification for why the remaining waste streams did not require further consideration. The treatment for most of the ILW, LLW and Non-radioactive waste streams were determined to be BPEO, through this initial screening process. Only the following waste streams required assessment at the BPEO Workshop:

- CHILW Graphite (THTR and Activated Graphite),
- LLW Sludges (Granular, Putrescible and LSA Scale),
- Clean Hazardous Sludge and Exempt Hazardous Sludge.

The report records the process and outcome of the final option selection, selection of the attributes for scoring and the results of the scoring exercise. This process was undertaken by an Options Assessment Panel (OAP) at the BPEO Workshop, held at Dounreay on the 18th and 19th of November 2008. The OAP was made up of employees from DSRL and UKAEA Ltd in addition to an external stakeholder representative.

In addition to external stakeholder representation within the BPEO Workshop further efforts were made to engage with the wider public. This was carried out in such a way as to ensure the completion date, specified within DSRL's RSA '93 Authorisations, could be met. DSRL recognise the importance of a consultative approach and as a means of reflecting stakeholder views, a process that involved parallel working was adopted to allow feedback and involvement during the BPEO study development, via the web-site: *www.dounreay.com/waste/waste-options-review*.

The report also records the outcome of applying the weightings to the scores and the effect this has on the selection of the preferred management option is presented along with the sensitivity analysis of the decision making process.

In summary, the output of the Site Waste BPEO and its comparison with that undertaken in 2003 is presented in Table 1.

It is important to note that the identification of a BPEO for a particular waste stream is made in support of decision making. Often final decisions on the way forward with any particular project or modification can involve other factors that cannot be taken into account during the BPEO process. Indeed, regulatory guidance on BPEO (ref. 2) states:

> "*In practice, very few decisions are made solely on the basis of a BPEO study. A BPEO study informs consideration of the balance between the various factors that need to be taken into consideration, and helps reveal the key issues and assumptions, but in general does not define the solution.*"

Table 1: Comparison of Results of 2003 and 2008 DSRL Site Waste BPEO Studies

Waste category	Waste form	Wastes covered by study	2003 Strategy – Representative treatment method	2008 Strategy	2003 and 2008 Strategy comparison
Remote Handleable ILW	Solid	2003 Shaft and Silo RHILW RHILW in stores RHILW metals, concrete and rock 2008 Other (operational and decommissioning wastes) SNM declared as wastes Ion exchange columns	Segregate and decontaminate to LLW classification in so far as practicable. Otherwise supercompact, grout and package (Shaft and Silo RHILW and RHILW in stores) Cut, grout and package (metals) Grout and package (concrete and rock)	**Deemed BPEO** Current strategy is to segregate and decontaminate to LLW classification in so far as practicable. Otherwise: Sort and size/volume reduce as required prior to encapsulation and packaging into a passively safe form (applies to all RHILW solid).	No change to 2003 BPEO
	Liquid	2003 PFR raffinate DFR raffinate MALs 2008 Reprocessing liquors (from DMTR, PFR and DFR) Small volume liquors Liquid metals SNM declared as wastes	Cement PFR raffinate, DFR raffinate and MALs. DMTR raffinate and liquid metals not assessed as at the time they were about to be conditioned in existing or soon to be constructed facilities.	**Deemed BPEO** Current strategy is to encapsulate and package reprocessing liquors into a passively safe form. Following some type of pre-treatment SNM liquors and other small volume liquors will be managed in the same way as the reprocessing liquors. Similarly, liquid metals are treated in the existing and operational SDP and NDP facilities.	No change to 2003 BPEO
	Sludge	2003 ADU floc Shaft and silo Sludge Fuel storage pond Sludges 2008 ADU floc Shaft and Silo Sludge Fuel storage pond Sludges	Cement ADU floc, shaft and silo Sludges and fuel storage pond Sludges.	**Deemed BPEO** Current strategy is to encapsulate and package RHILW Sludges into a passively safe form.	No change to 2003 BPEO

Waste category	Waste form	Wastes covered by study	2003 Strategy – Representative treatment method	2008 Strategy	2003 and 2008 Strategy comparison
Contact Handleable ILW	Solid	2003 Graphite CHILW including PCM Boron carbide 2008 Graphite PCM, UCM, TCM SNM declared as wastes	Incinerate graphite followed by cementation of the ashes. Segregate and decontaminate CHILW to LLW classification in so far as practicable. Otherwise supercompact, grout and package. Release tritium from boron carbide by washing or dissolving with direct discharge of the washing liquid.	**PCM, UCM, TCM and SNM strategies deemed BPEO.** Current strategy for PCM, UCM and TCM is supercompaction and grouting in 500 litre drums. Current strategy for SNM is encapsulation and packaging into a passively safe form. THTR Graphite - Polymer infiltrate THTR Graphite and cement 200 litre drums in 500 litre drums. Activated Graphite – package in shielded/unshielded boxes and encapsulate/leave unencapsulated. Package choice will be determined by 1) how the unencapsulated option is viewed by RWMD and 2) practicality of box type management within the Site ILW strategy. Boron carbide stream included as part of graphite streams.	Change to 2003 BPEO for graphite as this waste does not burn and thus is unsuitable for incineration.
	Liquid	2003 Solvents and oils 2008 Solvents and oils SNM declared as wastes (thorium nitrate liquor)	Either direct solidification of the solvents and oils or incineration, with cementation of any solid waste.	**Deemed BPEO** Current strategy for solvents and oils is incineration. Current strategy for thorium nitrate liquor is cementation.	No change to 2003 BPEO
Low Level Waste	Solid	2003 General metals Concrete and building materials Non-cellulosic compactables Bulk non-compactable, non-combustible Cellulosic materials Tritiated metals Soils Pits wastes 2008 Compactable Bulk Spoil	Segregate and decontaminate to achieve Exempt waste in so far as practicable. Otherwise grout and package. (Applies to general metals, concrete and building materials, non-cellulosic compactable and bulk non-compactable, non-combustible wastes). Incineration of cellulosic materials. Smelting of tritiated metals. Leave contaminated soils in-situ and do not treat, except for more active areas e.g. active drains. Not emptying the Pits.	**Deemed BPEO** Current strategy for bulk and compactable LLW is to sort wastes and size/volume reduce as required followed by grouting and packaging into a passively safe form which is acceptable for disposal at the proposed on-site LLW repository. Spoil will be packaged in bags within HHISOs and transferred to the proposed on-site LLW repository.	Change to 2003 BPEO for cellulosic materials, tritiated metals and soils. Change to 2003 BPEO in that the current strategy at Dounreay is to retrieve the wastes from the Pits and transfer to the proposed on-site LLW repository.
	Liquid	2003 Low level liquid Solvents and oils 2008 Effluent for discharge Solvent and oils	Direct discharge of low level liquid via treatment in LLLETP. Either direct solidification of the solvents and oils or incineration with cementation of any solid waste.	**Deemed BPEO** Current strategy for solvents and oils is incineration. Current strategy for effluents is direct discharge to sea via treatment in LLLETP.	No change to 2003 BPEO

Waste category	Waste form	Wastes covered by study	2003 Strategy – Representative treatment method	2008 Strategy	2003 and 2008 Strategy comparison
	Sludge	2003 LLLETP Sludge LSA Scale 2008 LSA Scale Sludge/ Granular media (LLLETP Sludge) Putrescible wastes from milliscreens	Dissolve and direct discharge of LLLETP Sludge.	LSA Scale may not be suitable for disposal at the proposed LLW facility due to its high Ra-226 content. The preferred waste management strategy is packaging of the wastes, in accordance with NDA RWMD guidance, for eventual consignment to the proposed GDF. This can be in either an encapsulated or an unencapsulated form. De-water, bag and dispose Granular Sludge as HVLA waste/LLW. Process and incinerate off-site or bioremediate Putrescible Sludges.	Change to 2003 BPEO for LLLETP Sludge. Dissolve and direct discharge is not consistent with the concentrate and contain principle and the solid part of the sludge would precipitate out again after it had been discharged.
High Volume Low Activity Low Level Waste	Solid	2008 Construction and demolition material Spoil	Waste stream not assessed.	**Deemed BPEO** Current strategy is to store and use as backfill for proposed on-site LLW facility.	Waste stream not covered in 2003 BPEO
RSA Exempt and Clean Wastes	Solid	Construction and demolition materials, Soil, Recyclable (other) materials, Non recyclable (other) materials	Waste stream not assessed.	**Deemed BPEO** Current strategy is segregation, decontamination and assay to maximise the amount of material managed in these categories. In line with the waste hierarchy principles the volume of waste for disposal will be minimised by using volume reduction techniques and by maximising the reuse and recycle of materials for use on-site. Wastes which cannot be re-used or recycled will be consigned to landfill for disposal.	Waste streams not covered in 2003 BPEO
	Liquid	Recyclable, non recyclable	Waste stream not assessed.	**Deemed BPEO** Recycle, transfer to a specialist contractor for disposal or discharge to site drain as appropriate.	
	Sludge	Putrescible	Waste stream not assessed.	Off-site disposal	
Gaseous	Gas	2003 Particulates from active process and building ventilation Particulates from treating contaminated ground H-3 (tritium) C-14 (carbon-14) Kr-85 (krypton-85) Iodines 2008 Routine gaseous discharges	Particulates from active process and building ventilation - HEPA filter discharges to remove particulates Other gaseous waste streams – direct discharge	**Deemed BPEO** Much of the radioactivity is associated with particulate within the gaseous discharge. HEPA filtration is predominantly used to remove such particulate. Other abatement techniques, such as condensers and scrubbers, are also used, but to a lesser degree, where appropriate. The gaseous discharges are made in compliance with the appropriate site discharge authorisations	No change to 2003 BPEO

1 INTRODUCTION

1.1 Objective

The objective of the Dounreay Site Waste Best Practicable Environmental Option (BPEO) Study is to undertake a systematic examination of potential options for the management of wastes, radioactive and non-radioactive, arising from current and future DSRL operations at Dounreay, and to identify the BPEO for the management of the waste streams identified.

The BPEO process establishes the option for a given practice that provides the most benefit or least damage to the environment as a whole in the long term as well as in the short term, taking into account operational doses and risks, and social and economic factors.

The study is fully compliant with the RSA Authorisation requirement as identified in Schedule 11 (Item 1), and provides support to the development of DSRL's Integrated Waste Strategy and future applications for authorisation of the disposal of radioactive wastes under the Radioactive Substances Act 1993.

1.2 Purpose and Significance of the BPEO Study

A Dounreay Site BPEO assessment has been completed for submission to SEPA in June 2009. This is a requirement under Schedule 11 of DSRL's regulatory authorisation granted under the Radioactive Substances Act 1993.

A further requirement of Schedule 11 (Item 2) is to: "*provide SEPA with a full report of a comprehensive review of national and international developments in best practice for minimising all radioactive waste disposals, together with a strategy for achieving reductions in such disposals*." DSRL therefore reviewed waste minimisation options as the first step in the BPEO assessment so that it would provide input to the identification of relevant options for further investigation [1]. This review was subsequently used to develop the workshop strategy.

The Site Waste BPEO Study Workshop was held on the Dounreay site on 18th and 19th November 2008. It was attended by an Options Assessment Panel (OAP) made up of employees from DSRL and UKAEA Ltd in addition to an external stakeholder representative. Additionally, in accordance with SEPA and DSRL BPEO assessment guidance, the public has been engaged on this study through the Dounreay Stakeholder Group and through publication of web-based material for access via the Internet (see Section 1.7).

This report details the overall approach to the BPEO assessment in addition to the scope and methodology adopted for the workshop and the analysis and interpretation of the final results.

It is important to note that the identification of a BPEO for a particular waste stream is made in support of decision-making. Often final decisions on the way-forward with any particular project or modification can involve other factors that cannot be taken into account during the BPEO process.

1.3 Summary of the Methodology

The first step was a review to identify best practice techniques and future developments for the minimisation of waste disposals. The results of the best practice review were compared with the current and planned waste management strategies at Dounreay to identify any areas for potential improvement. This process demonstrated that DSRL waste management strategies are largely compliant with best practice and/or are already underpinned by existing BPEO studies. Where waste streams were identified as having scope for further assessment or consideration of their waste strategy, these waste streams were taken forward for further review by the BPEO assessment process.

Prior to the BPEO Workshop a delegate pack was circulated to all attendees. This contained the necessary supporting information for the workshop to enable the delegates to discuss the waste management options for the waste streams under consideration. The delegate pack consisted of the following components:

- Description of the workshop methodology which was developed using SEPA and DSRL guidance on BPEO assessments (Refs 2,3);
- Description of workshop objective, assumptions and constraints;
- A high level description of all of the waste streams which form part of the overall process;
- A detailed description of the nature of the wastes, the waste volumes and radionuclide data for each of the waste streams to be considered in the BPEO Workshop;
- A summary of the results of an options brainstorming workshop for each waste stream and the options deemed appropriate for consideration at the workshop;
- A summary of the attributes selected to score the waste management options and proposed weightings for these options.

Following the workshop, a report was circulated to all attendees containing a record of the discussions and the scoring assessment of the waste management options. The content was agreed by all attendees and has been used to produce this Site Waste BPEO Report. Following completion of the Site Waste BPEO Report, a strategy for the implementation of any changes to the baseline strategy identified was drawn up, DEC(09)P197, and that together they fully address the requirement under Schedule 11 (Item 1) of DSRL's regulatory authorisation granted under the Radioactive Substances Act 1993.

1.4 Assumptions and Constraints

The following assumptions and constraints have been made in relation to the BPEO:

- **Options must be consistent with UK Government policy on waste management**

  Although the SEPA/EA guidance states that there is no requirement to include consistency with Government policy explicitly in a BPEO study, it is important in determining how the UK meets international commitments and sets regulation on radioactive waste management. It is therefore considered that to progress the DSRL site restoration plan, any waste management option which is not consistent with Government policy would be difficult to implement.

- **Options are technically feasible using existing or reasonably foreseen methods and processes and enable the achievement of the DSRL site interim end state by 2025**

  Waste management options need to exist and be able to be implemented over a reasonable timescale in line with the site programme and scheduled interim end state.

- **Options must be consistent with regulatory requirements**

  Options must be capable of being legally implemented and therefore must not include any practices that are prohibited or do not meet legal requirements.

- **Options must comply with international conventions**

  The option must not cause a breach of duty of care to the environment outside national boundaries, breach international agreements / treaties or breach non-UK law.

1.5 Waste Streams at Dounreay

The various waste streams that have or will arise at Dounreay can be grouped into a number of broad waste categories, largely dependent on the waste activity. The complete list of Dounreay waste categories, with waste stream specific examples, is given in Table 2.

Table 2: Summary of Waste Streams for DSRL Site Waste BPEO Study

Waste category	Waste form	Waste type
Remote Handleable ILW	Solid	Other (these are general operational and decommissioning wastes), Special nuclear materials declared as wastes, Ion exchange columns
	Liquid	Reprocessing liquors (from PFR, DFR and DMTR), Special nuclear materials declared as wastes, Liquid metals, Small volume liquors
	Sludge	Shaft and Silo Sludge, ADU floc
Contact Handleable ILW	Solid	Special nuclear materials declared as wastes, Plutonium contaminated wastes, Uranium contaminated wastes, Thorium contaminated wastes, Irradiated graphite, Contaminated graphite
	Liquid	Special nuclear materials declared as wastes (thorium nitrate liquors), Contaminated solvents and oils (from fuel reprocessing)
Low Level Waste	Solid	Compactable, bulk and spoil
	Liquid	Effluent for discharge, solvent and oils
	Sludge	Sludge/Granular media, Putrescible wastes from milliscreens and LSA scale
High Volume Low Activity Low Level Waste	Solid	Construction and demolition material, and spoil
RSA Exempt Non-Hazardous Waste	Solid	Construction and demolition materials, Soil, Recyclable (other) materials, Non-recyclable (other) materials
	Liquid	Recyclable, Non-recyclable
RSA Exempt Inert Waste	Solid	Construction and demolition materials, Soil, Recyclable (other) materials, Non-recyclable (other) materials
	Liquid	Recyclable, Non-recyclable
RSA Exempt Hazardous Waste	Solid	Construction and demolition materials, Soil, Recyclable (other) materials, Non-recyclable (other) materials
	Liquid	Recyclable, Non-recyclable
	Sludge	Putrescible wastes from milliscreens
Clean Non-Hazardous Waste	Solid	Construction and demolition materials, Soil, Recyclable (other) materials, Non-recyclable (other) materials
	Liquid	Recyclable, Non-recyclable
Clean Inert Waste	Solid	Construction and demolition materials, Soil, Recyclable (other) materials, Non-recyclable (other) materials
	Liquid	Recyclable, Non-recyclable
Clean Hazardous Waste	Solid	Recyclable, Non-recyclable
	Liquid	Recyclable, Non-recyclable
	Sludge	Putrescible wastes from milliscreens
Gaseous	Gas	Routine gaseous discharges

For the purposes of this study the following waste category definitions have been used.

Table 2: Waste Category Definitions

Waste Category	Definition
ILW	Wastes exceeding the upper boundaries for LLW, but which do not need heat to be taken into account in the design of storage or disposal facilities. Operations such as storage, transport and processing require the waste to be shielded or contained during the operation.
LLW	Radioactive waste having a radioactive content not exceeding 4 gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta-gamma activity.
HVLA	Waste at the lower end of the LLW range, sometimes also called VLRM. The waste is still legally LLW. The activity levels for this waste are <0.04GBq/te beta-gamma and 0.001–0.002GBq/te alpha activity.
Exempt	The SoLA exemption order specifies that waste is exempt from the regulatory requirements under the Radioactive Substances Act 1993 (RSA 93) provided that it is substantially insoluble in water and has an activity that does not exceed 0.4 Bq/g. Material is also classed as Exempt waste even though it may be Clean waste due to lack of historical evidence of its providence.
Clean	An article or substance which has had no reasonable potential to have become contaminated or activated, and upon or within which no radioactivity other than normal background is detectable when suitable comprehensive measurement (monitoring and sampling) is practicable and has been undertaken.

1.6 The 2003 Site Waste BPEO Study

In 2003, a BPEO study for management of radioactive waste arisings from the Dounreay Site Restoration Plan was carried out [5]. The findings of the 2003 study and key differences between it and the 2008 study can be found in Table 1 and Appendix 1.

1.7 External Stakeholder Engagement

In addition to external stakeholder representation within the BPEO Workshop further efforts were made to engage with the wider public. This was carried out in such a way to ensure the completion date, specified by the RSA Authorisation, could be met. DSRL recognise the importance of a consultative approach and as a means of reflecting stakeholder views, a process that involves parallel working was adopted to allow feedback and involvement during the BPEO study development.

The manner of consultation is consistent with the Regulator's own BPEO Assessment Guidance [2], which identifies the following statements with regards to stakeholder management and public consultation:

- "*…where the main considerations are technical rather than societal, consultation may focus simply on the outcome of the BPEO process*." (Section 4.2 of Ref. 2)
- *"….Alternative weighting sets can be used to test the sensitivity of the conclusions to different perceptions of relative importance (e.g. in order to reflect the perspectives of different stakeholder groups)"*. (Section 3 of Ref. 2)
- *"….There may be valid reasons, unrelated to environmental performance or practicability, why stakeholders might not prefer an option, but these should be taken into account outside the core BPEO study*." (Section 8 of Ref. 2)

Wider public consultation was achieved through the Dounreay Stakeholder Group and the internet via a website (www.dounreay.com/waste/waste-options-review).

Items on the website include:

- An overview of the methodology used for the Site Waste BPEO process;

- A means of feedback allowing external stakeholders to express concerns, opinions and views to be taken into account;

- BPEO Workshop summary report;

- Results of stakeholder scoring the attributes for use in assessing the BPEO for reviewed waste management strategies.

2 METHODOLOGY

The Site Waste BPEO Workshop was held over two days (18th and 19th of November 2008) and the aims of the workshop were as follows:

- To discuss the basis upon which waste streams were included or excluded from assessment;
- To finalise the list of those waste streams excluded from the assessment along with the justification for doing so;
- To review the underpinning information used as a basis for the workshop discussions;
- To review, amend and finalise the waste management options proposed for each waste stream;
- To review and finalise the attributes and sub-attributes the waste management options would be scored against;
- To score the management options for each waste stream against the attributes and sub-attributes.

Once all the waste management options were scored the data would then be used to select the preferred waste management options.

The Options Assessment Panel (OAP) for both days is given below.

Name	Present on		Organisation/Function/Position
	Day 1	Day 2	
Randall Walker	Yes	Yes	DSRL (embedded from CH2MHill) – Waste Operations and Compliance Manager
Ted Hopkins	Yes	Yes	DSRL (embedded from CH2MHill) – Works Control and Site Safety Integrations Manager
Lynne Jones	Yes	Yes	DSRL – Clean/exempt waste strategy specialist
Graham Beaven	Yes	Yes	DSRL – Gaseous & Liquid Wastes Manager; member of the site's Qualified Expert Body
Alan Mowat	Yes	Yes	DSRL – Radioactive waste strategy specialist
Doug Graham	Yes	Yes	DSRL – Environment Manager; member of the site's Qualified Expert Body
Morris MacLeod	Yes	Yes	DSRL – Environmental Embedded Advisor to Waste Services; member of the site's Qualified Expert Body
Elizabeth Mackenzie	No	Yes	DSRL – Fuel and Wastes Strategy Manager
Alistair MacDonald	Yes	Yes	External stakeholder representative and Chairman of the Dounreay Stakeholder Group
Michelle Wise	Yes	Yes	UKAEA Ltd – Waste management specialist
Paul McMorn	Yes	Yes	UKAEA Ltd – Facilitator
Lesley Oliphant	Yes	No	UKAEA Ltd – Scribe
Lynsey Valentine	Yes	Yes	UKAEA Ltd – Scribe

The identification of the waste streams that were to be included or excluded from the BPEO assessment was determined. The OAP agreed that waste streams should be included for discussion in the workshop where there was scope for further assessment or consideration of the waste strategy as identified by the review of national and international best practice on waste minimisation (Ref.1). However, it was agreed that waste streams should be excluded from the BPEO assessment if they fell under one or more of the four principles below:

1. The current waste management strategy for the waste stream has been determined through a waste stream specific BPEO study at DSRL or it is consistent with best practice on another nuclear site which has been determined through a BPEO assessment. The current waste management strategy for the waste stream is considered mature and changing the management strategy will not be practical or may jeopardise the site achieving its interim end state by 2025. Specific factors taken into account include:

a. Facilities used for implementing the waste management strategy are at an advanced design stage, under construction or already operational and processing the waste.

b. Facilities that are used or planned to be used to process multiple and diverse waste streams whereby changing the management process of one waste stream may adversely impact on the management of the others.

2. The current waste management strategy for a specific waste stream is underpinned by a NDA RWMD Letter of Compliance.

3. The current waste management strategy involves application of the waste hierarchy principles; an industry standard that is considered to be BPEO (applicable to Clean, Exempt and HVLA wastes only).

By applying the above principles the OAP was able to come to a consensus regarding which waste streams should be taken forward to the BPEO assessment (Section 3).

The BPEO assessment used a Multi-Attribute Decision Analysis (MADA) approach to review the management options for each waste stream. MADA involves the evaluation of candidate waste management options or solutions against a range of performance measures or attributes to inform judgements about a preferred option. These may include their effects on the health and well-being of people and the environment (‘environmental’ factors) as well as on their technical features and financial costs (‘practicable’ factors). The MADA approach comprised the following steps:

1. Identify and agree objectives, assumptions and constraints (Section 1.1 and 1.4);
2. Identify and agree the options (Section4);
3. Identify and agree the attributes (Section 2);
4. Score the options with respect to the attributes (Section 5);
5. Weight the attributes in terms of their differentiation (Section 5);
6. Weight the attributes in terms of their perceived importance/significance (Section 5)
7. Undertake a sensitivity analysis (Section 6).

During the workshop the attributes against which the waste management options would be assessed were discussed. The initial list of attributes was drawn from SEPA [2] and from Dounreay guidance [3] and the final agreed list of attributes is presented in Table 3.

Table 3: Attribute groups and attributes

Attribute Group	Attribute	Description
1. Human Health and Safety	1.1 Routine radiation doses	Impact of routine processes on the radiological dose received by workers and members of the public as a result of the implementation of the option. For workers dose may be received through processing, packaging and handling of wastes. For members of the public dose may be received through exposure to discharges, leachate, air-borne particles, shine etc.
	1.2 Radiological accident risks	Impact of accident scenarios upon the release of radioactive material to the environment or to the effective dose received by workers and the public. Scenarios include extreme external events such as earthquake, erosion, fire, faulty engineering and weather in addition to the risks from accidents during transport.
	1.3 Non radioactive hazards and risks	Potential for non-radiological routine hazards and accident risks to both workers and members of the public associated with implementing an option. To consider slips, trips, falls, manual handling injuries, electricity, traffic accidents etc.
2. Environmental impact	2.1 Air and water quality	Quantity and frequency of discharges to air and water and comparison with current and future site and facility discharges, authorised limits and notification levels. This covers long- and short-term impacts to: • Air quality due to the emission of dust, pollutants, ozone depletors, greenhouse gases (excluding transport impacts); • Surface and groundwater quality due to the emission of pollutants.
	2.2 Primary and secondary waste generation (solid)	Overall packaged waste volume requiring disposal plus volume of secondary waste associated with option. This includes volumes of decommissioning waste from facilities built to implement management options.
	2.3 Visual impact	This reflects the disturbance to the affected population from the visual impact of each option for example if the option involves the build of a facility which would alter the skyline.
	2.4 Nuisances	This reflects the disturbance to the affected population from each option including, where relevant, odours, construction nuisance (noise, vibration) and light pollution.
3. Financial	3.1 Cost	Total costs (discounted and undiscounted) arising from the implementation of any option through the lifetime of the process.
	3.2 Financeability / affordability	This assesses whether there is sufficient funding available to implement an option, and that once in place the costs entailed in operating and maintaining the system are affordable to all involved. In looking at funding, issues about the potential for private sector involvement are relevant. Another issue to consider is whether an option will leave the authorities with long-term contracts for waste disposal services which could become inappropriate in the future and whether these contracts could be renegotiated such that they fit with the proposed new arrangements.
4. Socio-economic	4.1 Public acceptability	Is the option likely to meet with the public's approval?
	4.2 Economic impacts	This assesses the effects of an option on the local economy. Such effects may include providing business opportunities or adversely affecting existing businesses; creating new sources of supply or markets for goods and services; increasing or reducing costs to local businesses; creation of employment opportunities.
5. Technical	5.1 Making best use of existing facilities and expertise	This assesses whether an option makes good use of existing resources such as current infrastructure, waste management facilities, disposal capacity and expertise/skills as discarding these will be a waste of resources already committed and available.
	5.2 Practical deliverability	This assesses whether it is practically possible to implement an option on the required timescale (Site End State 2025) and should consider issues such as planning consents, availability of financial resources, availability of sufficient skills and personnel or training to achieve this, compliance with current legislation etc.
	5.3 Maturity of technology	This assesses the level of knowledge/experience from related technologies/processes.

After a consensus was reached on the details of the objectives, assumptions, constraints, management options and attributes, the management options were scored against the attributes. Each attribute was scored in turn for all the options to enable a proper discussion around the attribute. The scoring system worked by first defining the Best and Worst option for the particular attribute, to define the bounds of the discussion. It was possible to have more than one Best and more than one Worst. The remaining options were then assigned a rating of Good, Medium or Bad, depending on how they ranked when compared with the Best and Worst options. The scores were converted into a numerical scale by the following scoring mechanism:

- Best = 100
- Good = 75
- Medium = 50
- Bad = 25
- Worst = 0

Once the options had been rated against a particular attribute, the attribute was assigned a swing weight. The swing weight defines how large the relative spread between the Best and Worst option is, not the significance of the attribute (which is assessed during sensitivity analysis). This helps to focus the score on areas where the options are more differentiating. The swing weight was assigned one of three values:

- 1 - narrow spread
- 5 - medium spread
- 10 - wide spread

The attribute and sub-attribute groups were also weighted according to their perceived importance and these are summarised in Appendix 2. The scores obtained were used to determine the ‘best’ option by applying three different weighting regimes (i.e. unweighted, weighted and swing-weighted) to the scores and assessing the effects these have on the final outcome. These scores provided the basis for performing the sensitivity analysis used to assess the degree of uncertainty associated with the scores and hence the uncertainty associated with the preferred option.

The impact of replacing the average scores determined in the workshop with those provided by the public was assessed and the findings are also included within Appendix 2.

3 IDENTIFICATION OF WASTE STREAMS REQUIRING DETAILED ASSESSMENT

Descriptions of the current management strategies for all the waste streams on the Dounreay site are provided in the following sections along with detailed reasoning for the inclusion/exclusion of the waste streams from the BPEO assessment.

3.1 RHILW

3.1.1 RHILW Solids

The RHILW Solid waste stream at the Dounreay site comprises of the following:

- Special Nuclear Materials (SNM) declared as wastes
- Other (operational and decommissioning wastes)
- Ion exchange columns

The current management strategies for these wastes are shown in Figure 1. RHILW Solid waste will be assayed, sorted and size/volume reduced as required prior to encapsulation and packaging into a passively safe form either through the planned Waste Treatment Plant (WTP) or the new RHILW Immobilisation and Encapsulation Plant (IEP) (which has just completed the scheme design phase [7]) in addition to bespoke facilities within DFR, PFR and D1208.

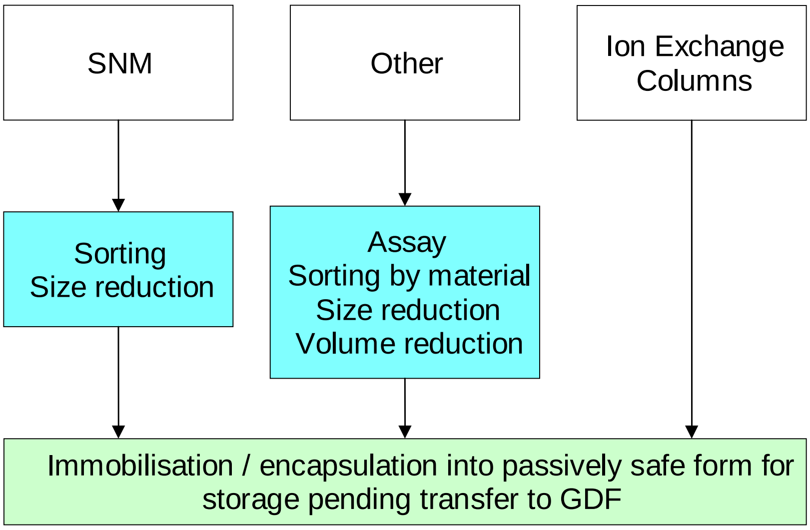


Figure 1: Current Management Strategies for RHILW Solids

All components of the RHILW Solids waste stream were excluded from the BPEO assessment because in addition to being at a mature stage of development, the strategies for their management are underpinned by RWMD Letters of Compliance (LoCs). Dounreay has received an Interim stage LoC for the historic RHILW currently in storage [8] and it is assumed that future arisings from decommissioning will have been bound by the physical and radionuclide data in this submission (although if the waste differs significantly then these will be the subject of separate submissions in the future). For the ion exchange columns there are Letters of Compliance in place before they are generated [9].

The RHILW Solid waste management strategies are also underpinned by a workshop held in Denver in July 2007 [10] to optimise the programme for the ILW strategy of the Dounreay site. This review essentially consolidated the strategy for dealing with the identified ILW on the Dounreay site, by solidifying the waste into a cemented product meeting RWMD conditions for packaging. Since the workshop in Denver, DSRL has produced an integrated ILW strategy, making best use of current facilities and streamlining the plans for the new Immobilisation and Encapsulation Plant and store.

3.1.2 RHILW Liquids

The RHILW Liquid waste stream at the Dounreay site comprises of the following:

- Reprocessing liquors (from MTRs, PFR and DFR)
- Special Nuclear Materials (SNM) declared as wastes
- Small volume liquors (Temporary Storage Vessel (TSV) liquors)
- Liquid metals – Sodium (Na) and Sodium/Potassium alloy (NaK) coolants from PFR and DFR

The current management strategies for these wastes are shown in Figure 2.

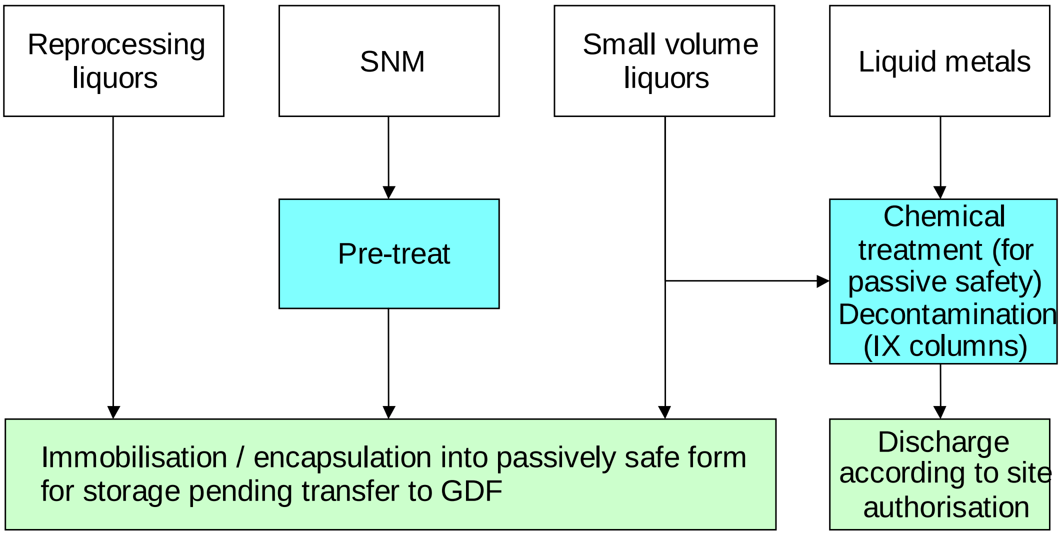


Figure 2: Current Management Strategies for RHILW Liquids

Reprocessing liquors were excluded from the BPEO assessment because their management strategies are well developed and have been endorsed by the RWMD LoC process. In addition the PFR raffinate stream was subject to a BPEO Study with stakeholder consultation before agreement was reached on the strategy being implemented [9].

MTR raffinate is currently being immobilised and packaged into a passively safe form through the Dounreay Cementation Plant (DCP). A Final LoC has been received from NDA RWMD endorsing the immobilised product from twelve of thirteen tanks. Only Tank 12 remains without a LoC although once the tank is sampled, an assessment will be made on whether it fits within the existing LoC envelope.

PFR and DFR raffinates will be encapsulated and packaged into a passively safe form through the new RHILW-IEP. Dounreay has received an Interim Stage LoC from NDA RWMD for the packaging of the PFR raffinate waste stream and, as stated above, this strategy is also underpinned by a BPEO study. For DFR raffinate a Conceptual LoC for the proposed wasteform has been received from NDA RWMD and an Interim stage submission has recently been made for two of the tanks whilst sampling of the third one is awaited to allow development work to take place.

SNM declared as wastes, small volume liquors and liquid metals have also been excluded from the BPEO assessment as the strategies for their management are well developed and will use planned or existing facilities. Following some type of pre-treatment (filtration and/or chemical treatment) SNM liquors declared as wastes and other small volume liquors will be managed in the same way as the reprocessing liquors. Liquid metals are being treated in the Sodium Destruction Plant (SDP) and NaK Destruction Plant (NDP), which chemically treat the Na/NaK before passing the resultant liquor through filters and ion exchange columns [6].

3.1.3 RHILW Sludges

The RHILW Sludges waste stream at the Dounreay site comprises of the following:

- ADU floc
- Shaft and silo Sludge

The current management strategies for these wastes are shown in Figure 3.

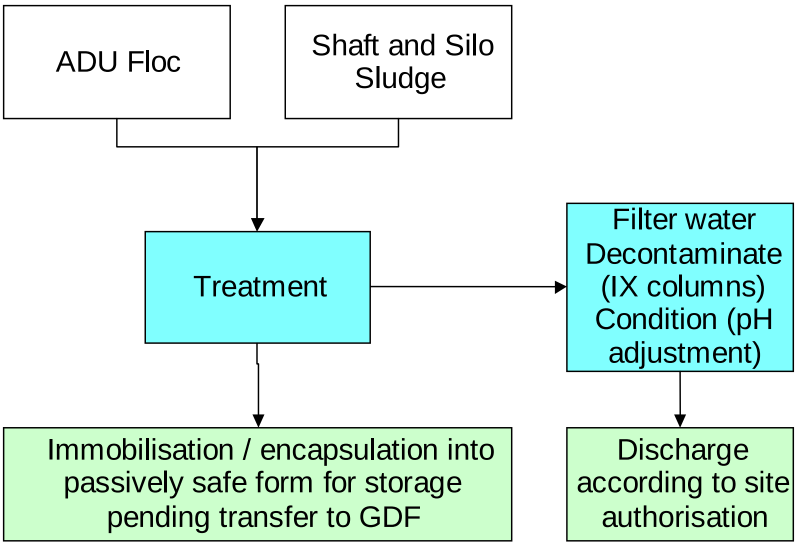


Figure 3: Current Management Strategies for RHILW Sludges

All components of the RHILW Sludges waste stream were excluded from the BPEO assessment because the strategies for their management are mature, with the facilities to be used at advanced design stages, and they have been or will be endorsed by the RWMD LoC process.

The current reference strategy for the ADU Floc is to encapsulate and package it into a passively safe form through the RHILW-IEP, following the conditioning of the DFR and PFR raffinates. A Conceptual LoC has been received for this waste stream. Shaft and Silo Sludges will be treated through the planned Waste Treatment Plant (WTP) at Dounreay, which is at an advanced design stage. A Conceptual LoC has been received for this waste stream.

3.2 CHILW

3.2.1 CHILW Solids

The CHILW Solids waste stream at the Dounreay site comprise the following:

- Plutonium, Uranium and Thorium Contaminated Material (PCM, UCM and TCM)
- Special Nuclear Materials (SNM) declared as wastes

- Graphite – THTR Graphite and Activated Graphite

The current management strategies for these wastes are shown in Figure 4.

PCM, UCM, TCM were excluded from the BPEO assessment as the strategy for their management is underpinned by an existing BPEO Study which was undertaken in February 2008 and concluded that DSRL should continue to develop the LTP08 reference strategy of supercompaction and grouting in 500 litre drums [11]. Additionally a Conceptual LoC for supercompacted waste was received from Nirex for PCM in 2001. An updated Conceptual LoC will be prepared in 2008/09 which will also cover the UCM and TCM.

SNM declared as waste was also excluded from the BPEO assessment. The strategy for these materials is well developed and involves encapsulation and packaging through the planned WTP.

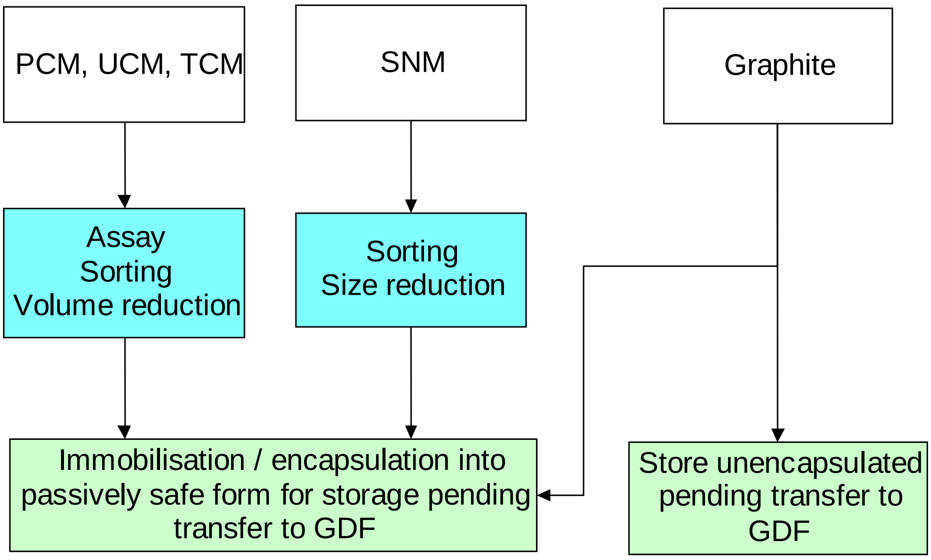


Figure 4: Current Management Strategies for CHILW Solids

For the graphite wastes on the Dounreay site, the management strategy is to package the wastes unencapsulated in 4m boxes. The 2003 Dounreay BPEO Study [5] identified incineration as the BPEO for graphite, however this option is flawed as graphite does not burn efficiently in air and there are no current examples where incineration has been proven to be Best Practice for these wastes. Carbon-14 and tritium would be released by heat treatment but the graphite could still be classed as ILW due to the europium levels. Still there is scope for other types of thermal treatment processes as well as other management options to be applied. For these reasons the graphite wastes were included in the BPEO assessment.

3.2.2 CHILW liquids

The CHILW Liquids waste stream at the Dounreay site comprises of the following:

- Special Nuclear Materials (SNM) declared as wastes – thorium nitrate liquors
- Solvents

The current management strategies for these wastes are shown in Figure 5.

The SNM liquors were excluded from the BPEO assessment as Dounreay already has a Conceptual LoC for cementation of the thorium nitrate liquors into 500 litre drums either using a mobile cementation facility or existing facilities on the Dounreay site [9].

Bulk solvents will be incinerated. Small volumes of oil, from cell operations, will be absorbed and immobilised rather than incinerated. The CHILW Solvents were excluded from the BPEO assessment because the strategy for their management (destruction in a new incinerator after passing the ILW solvent through a decontamination process to remove much of the activity) has been endorsed following a publicly consulted BPEO [12]. Off-site incineration is an established process for such wastes and is used by other nuclear operators e.g. RSRL for CHILW solvents and oils [1].

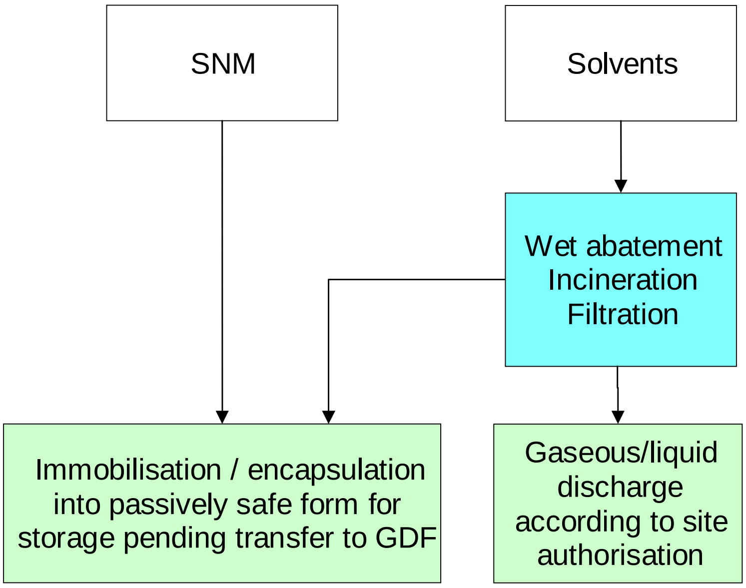


Figure 5: Current Management Strategies for CHILW Liquids

3.3 LLW

3.3.1 LLW Solids

The LLW Solids waste stream at the Dounreay site comprises of the following:

- Compactable
- Bulk
- Spoil

The current management strategies for these wastes are shown in Figure 6.

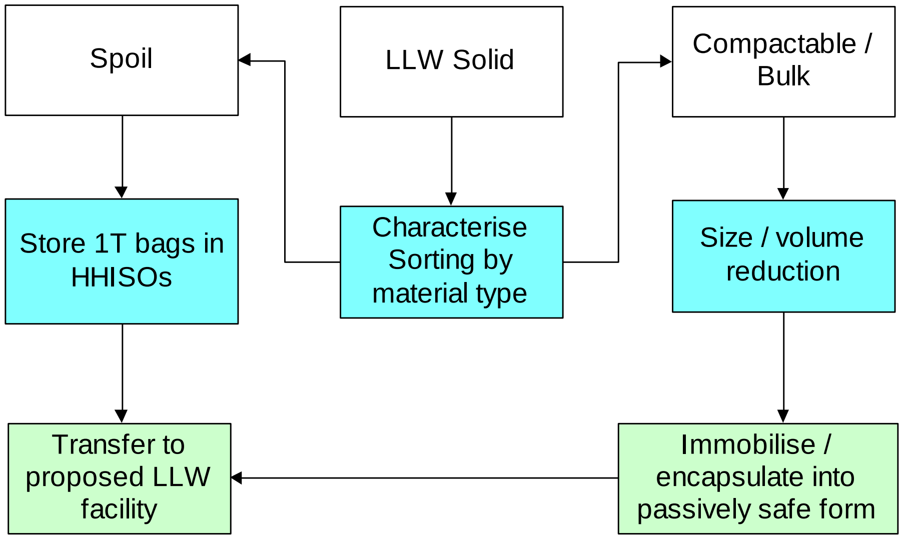


Figure 6: Current Management Strategies for LLW Solids

The high level objective for LLW management on the Dounreay site is the treatment of wastes into a conditioned, passively safe form which is acceptable for disposal at the proposed LLW repository. This strategy accords with the proximity principle and is underpinned by a publicly consulted BPEO Study [13] which was reviewed in 2007. Hence these wastes were excluded from the BPEO assessment.

3.3.2 LLW Liquids

The LLW Liquids waste stream at the Dounreay site comprises of the following:

- Solvents and oils
- Effluents

The current management strategies for these wastes are shown in Figure 7.

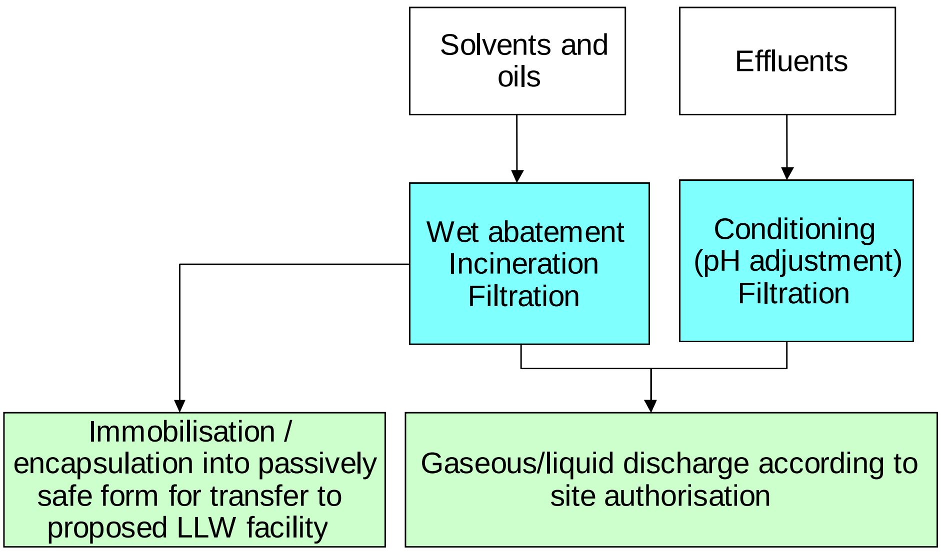


Figure 7: Current Management Strategies for LLW Liquids

The strategy for the solvents and oils is decontamination using a wet abatement system followed by incineration. LLW solvents and oils were excluded from the BPEO assessment as the strategy for their management has been endorsed following a publicly consulted BPEO [12].

Major sources of effluents produced by active facilities are generally filtered at source and, where radionuclide levels are expected to be significant, ion exchange plants are operated in accordance with BPM considerations. The effluents are then transferred to the Low Level Liquid Effluent Treatment Plant (LLLETP) where they undergo pH adjustment and filtration prior to discharge. LLW liquid effluents were also excluded from the BPEO assessment as the strategies for their management are both mature and consistent with best practice [1].

3.3.3 LLW Sludges

The LLW Sludges waste stream at the Dounreay site comprises of the following:

- Low Specific Activity (LSA) Scale
- Granular
- Putrescible

The current management strategies for these wastes are shown in Figure 8.

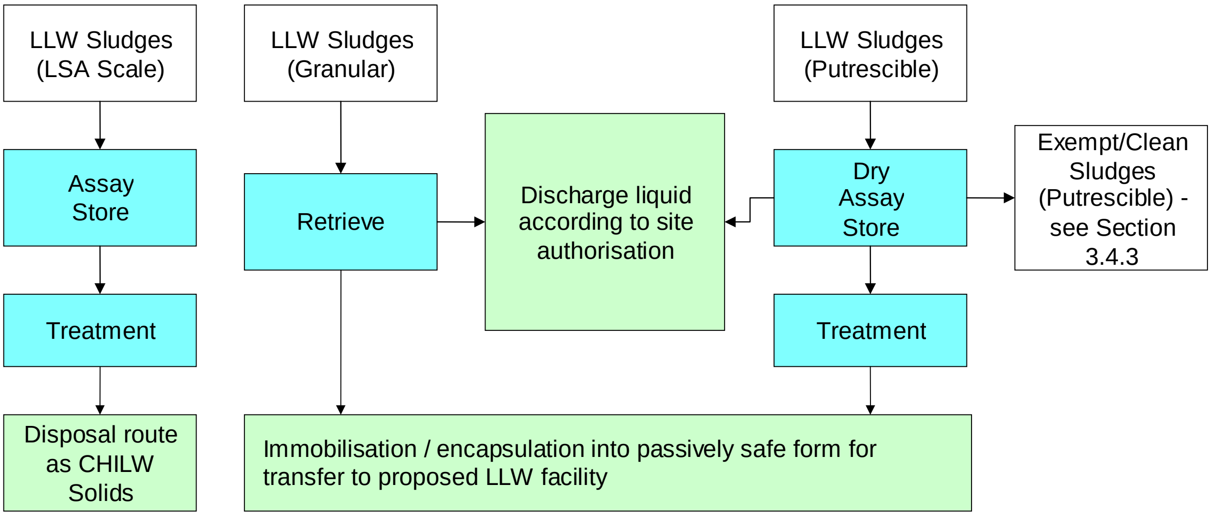


Figure 8: Current Management Strategies for LLW Sludges

The management strategy for the Putrescible Sludges is under development. As an interim measure the sludges have been collected (milliscreens), dried, bagged and placed in interim storage, awaiting characterisation. As such, proper consideration has not yet been given to the application of the waste hierarchy to these materials. Although characterisation work had started, it was unclear prior to the Waste BPEO Workshop what the outcome of this work would be. It was assumed that if any were characterised as LLW then the management options should be taken forward for inclusion in the BPEO assessment. However, the expectation was that this waste would be categorised as either clean/exempt (see Section 3.4.3).

The management strategy has not been finalised for the Granular Sludges or the LSA Scale and there are no current BPEO studies for these wastes.

For these reasons the LLW Sludges (LSA Scale, Granular and Putrescible) were taken forward for inclusion in the BPEO assessment.

3.3.4 HVLA Waste

HVLA Solids waste stream typically comprises of construction/demolition materials and contaminated soil. The current and planned waste management strategy for this waste is shown in Figure 10.

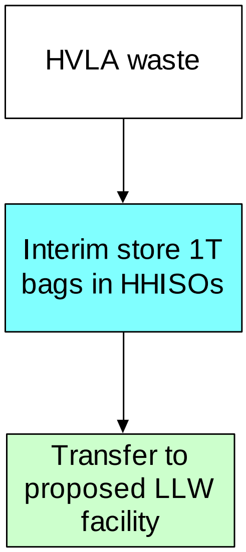


Figure 9: Current Management Strategy for HVLA Waste

HVLA is packaged in 1te bags and placed in interim storage in HHISOs. In keeping with the waste hierarchy, wastes which fall into this radiological category will have undergone sorting and assaying to maximise the amount of material which is correctly disposed of as Clean or Exempt wastes.

HVLA wastes were excluded from the BPEO assessment as their management strategy is covered by the LLW BPEO.

3.4 Clean and Exempt Wastes

3.4.1 Clean and Exempt Solids

The Clean and Exempt Solids waste stream at the Dounreay site comprises of the following:

- Hazardous
- Non-Hazardous
- Inert

The current management strategies for these wastes are shown in Figure 10. These wastes will have undergone segregation (by radiological classification), characterisation and decontamination (where appropriate) to maximise the amount of material managed in these categories. In line with the waste hierarchy principles the volume of waste for disposal will be minimised by using volume reduction techniques and by maximising the reuse and recycle of materials for use on-site. Wastes which cannot be re-used or recycled will be consigned to landfill for disposal.

For Solid Exempt Hazardous Wastes, segregation will be carried out to ensure that only wastes which are covered by the definition of hazardous materials are managed as such. Additionally, materials will be treated for on-site reuse where possible and those which cannot be reused will be consigned to a specialist waste contractor. Solid Clean Hazardous Wastes will be managed in a similar manner to Solid Exempt Hazardous Wastes. The major differences being a greater scope for recycle or down categorising of wastes (as dictated by current legislation) and the opportunity to treat chemically contaminated materials. The actual mode of treatment will be determined using cost benefit principles.

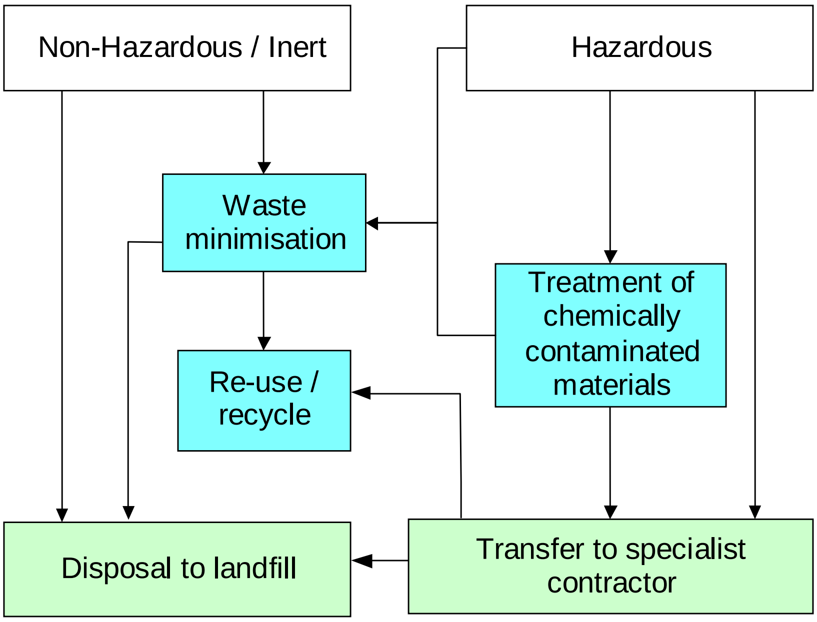


Figure 10: Current Management Strategies for Clean and Exempt Solids

These strategies all involve application of the waste hierarchy, which is industry standard and considered to be BPEO. Hence Clean and Exempt solids were excluded from the BPEO assessment.

3.4.2 Clean and Exempt Liquids

The current management strategies for Clean and Exempt liquids are shown in Figure 11.

All liquids which fall within this category will either be recycled or transferred to a specialist contractor for disposal. Liquids generated as part of routine non-radiological site operations (such as waste water) will be discharged to the site drain.

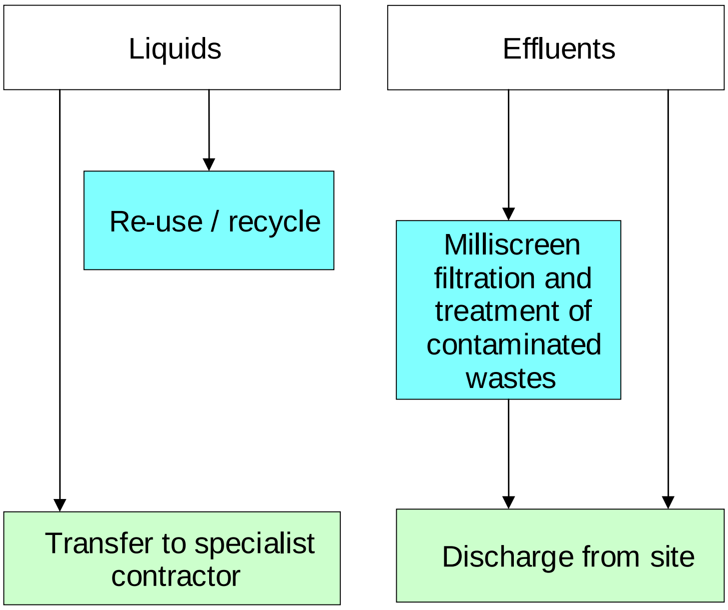


Figure 11: Current Management Strategies for Clean and Exempt Liquids

Liquid discharges were excluded from the BPEO assessment as the strategies for their management are mature and involve application of the waste hierarchy, which is industry standard, and is therefore considered to be BPEO.

3.4.3 Clean and Exempt Sludges

The Clean and Exempt Sludges on the Dounreay site are Hazardous Putrescible Sludges. At the BPEO Workshop it was unclear whether some or all such sludge will be characterised as clean/exempt or even LLW (see Section 3.3.3). The management strategy for these sludges is under development and there are no current BPEO studies for these wastes. As an interim measure the sludges have been collected (milliscreens), dried, bagged and placed in interim storage (awaiting characterisation) as shown in Figure 12.

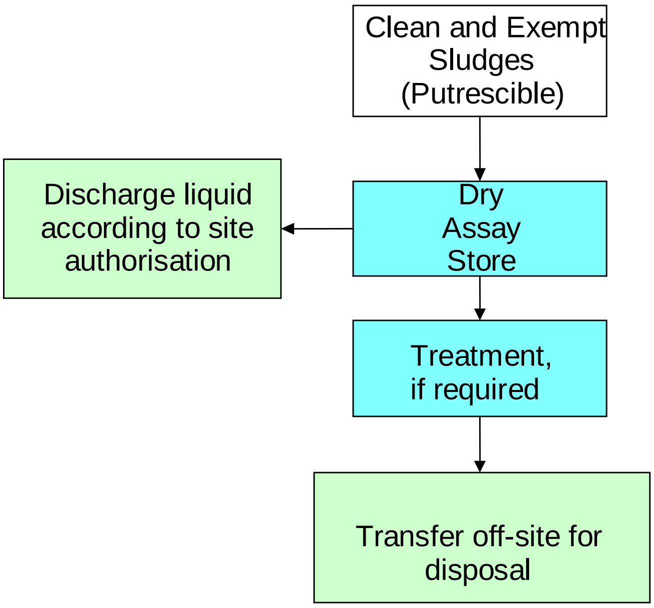


Figure 12: Current Management Strategies for Clean and Exempt Sludges

As such proper consideration has not yet been given to the application of the waste hierarchy to these materials. For these reasons the Clean and Exempt Putrescible Sludges were taken forward for inclusion in the BPEO assessment.

3.5 Gaseous Discharges

The current management strategy for gaseous discharges is shown in Figure 13.

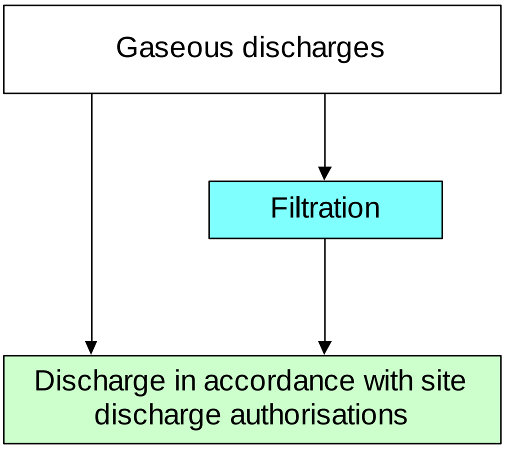


Figure 13: Current Management Strategies for Gaseous Discharges

Much of the radioactivity in gaseous discharges is associated with particulate. HEPA filtration is predominantly used to remove such particulate. Other abatement techniques, such as condensers and scrubbers, are also used, where appropriate. Gaseous discharges can also contain radioactive gases, such as tritium and Krypton-85. Gaseous effluent is discharged in compliance with the appropriate site discharge authorisations. The use of HEPA filtration to minimise the radioactive content of gaseous discharges is used across all civil nuclear sites [1].

Gaseous discharges were excluded from the BPEO assessment as the strategy for their management is both mature and consistent with best practice.

3.6 Summary

Table 4 provides a summary of the waste streams on the Dounreay site and the reasons for their inclusion or exclusion from the Site Waste BPEO assessment. The following waste streams were taken forward for further review by the BPEO assessment process:

- Solid CHILW Graphite – THTR graphite and Activated graphite
- LLW Sludge - LSA Scale, Granular and Putrescible
- Clean and Exempt Hazardous Sludge - Putrescible

Table 4: Inclusion/Exclusion of Waste Streams from BPEO Assessment

Waste category	Waste form	Under-pinned by existing BPEO Study	Mature strategy/ facilities operational or at an advanced design stage	Under-pinned by RWMD LoC	Consistent with best practice	Waste hierarchy applied (Exempt/ Clean/HVLA)	Management strategy under development	Include in BPEO Assessment?
Remote Handleable ILW	Solid		✓	✓	✓			No
	Liquid	✓	✓	✓	✓			No
	Sludge		✓	✓	✓			No
Contact Handleable ILW	Solid (excluding graphite)	✓	✓	✓	✓			No
	Solid (graphite)						✓	Yes – Options prefixed A and B
	Liquid	✓	✓	✓	✓			No
Low Level Waste	Solid (excluding LSA scale)	✓	✓		✓			No
	LSA Scale						✓	Yes – Options prefixed C
	Liquid	✓	✓		✓			No
	Sludge – Putrescible and Granular						✓	Yes – Options prefixed D and E
HVLA waste	Solid				✓	✓		No
Clean and Exempt Inert and Non-Hazardous Waste	Solid				✓	✓		No
	Liquid		✓		✓	✓		No
Clean and Exempt Hazardous Waste	Solid				✓	✓		No
	Liquid		✓		✓	✓		No
	Sludge - Putrescible						✓	Yes – Options prefixed F
Gaseous discharges	Gaseous		✓		✓			No

4 SCREENING OF WASTE MANAGEMENT OPTIONS

4.1 Introduction

Once the waste streams requiring assessment of the waste management options were identified, a brainstorming session was undertaken to generate alternative management options. These then underwent an initial screening process and options which were deemed to have merit were taken forward for assessment.

This section provides an overview of the waste stream information used as a basis for generating the final list of waste management options, a description of the waste management options discussed and whether these options were deemed credible (or not) by the workshop attendees. Those deemed credible were then taken forward for scoring against the sub-attributes.

4.2 Selection of Options for the Management of Radioactive Wastes

4.2.1 CHILW Graphite (THTR Graphite)

The THTR graphite waste stream comprises two components; the major component is the residual graphite from the reprocessing of THTR fuel and the minor component is graphite stored in C-bins (mild steel 200 litre drums).

The residual graphite from the reprocessing of THTR fuel is stored as a loose powder in 200 litre drums. The drums for both types of graphite material are stored in FHISOs.

The table below shows the current raw waste stocks and future arisings of the above wastes.

Waste Type	(Raw) Waste Volumes (m^3)		
	Stocks (2008)	Arisings	Total
CHILW THTR Graphite and C-Bin Graphite	89	0	89

4.2.1.1 Current DSRL waste management strategy

The current DSRL waste management strategy for the THTR graphite is encapsulation of the material in the 200 litre drums followed by cementation of the 200 litre drums into 500 litre drums. The 200 litre drums are approximately 80% full. Therefore, it is likely that the THTR graphite will be infiltrated with polymer rather than being mixed with cement as cementation typically requires at least 50% cement by volume (meaning that the drums would need to be emptied first). The resulting encapsulated 500 litre drums would be stored at Dounreay until the GDF becomes available.

4.2.1.2 Options taken forward to scoring assessment

The management options for THTR graphite are shown in Figure 14 and described below. Options which were proposed in the delegate pack are shown in the green filled boxes and additional options which were proposed at the workshop and taken forward for assessment are shown in the white boxes.

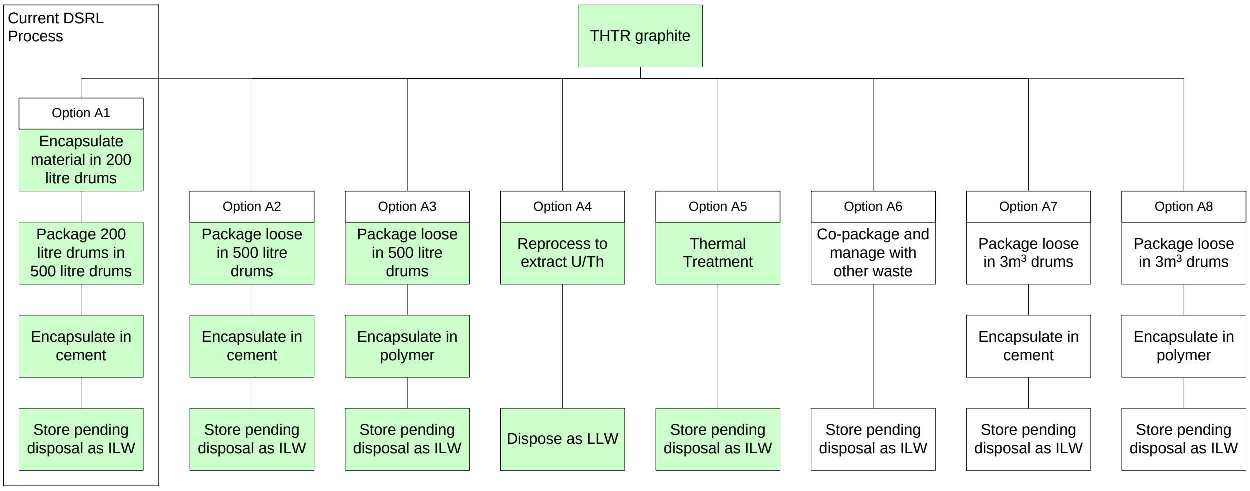


Figure 14: Management options for CHILW Graphite (THTR Graphite)

A1 Polymer encapsulation in 200 litre drums then cementation in 500 litre drums (current DSRL strategy)

The current DSRL strategy involves polymer infiltration of the material in the 200 litre drums followed by cementation of the 200 litre drums into 500 litre drums to form a stable product. The resulting encapsulated 500 litre drums would be stored at Dounreay until the GDF becomes available.

This option will use existing or planned facilities on the DSRL site hence there will be no visual impact from its implementation and the option was considered less expensive to implement compared to options such as reprocessing (Option A4) or thermal treatment (Option A5).

Although polymer encapsulation in 500 litre drums has already been developed elsewhere, the lack of on-site experience may mean there is a longer process optimisation phase compared with options utilising direct cementation in 500 litre drums. This option is considered more practical than options such as reprocessing (Option A4) or thermal treatment (Option A5) because of the on site practical experience of encapsulation.

From a waste management perspective, Option A1 (along with Options A2 and A3) will generate the least amount of primary waste and virtually no secondary solid waste when compared to the other options. These options all involve the purchase of 500 litre drums. Handling facilities for these waste packages already exist on the DSRL site. No distinction was made in the workshop between the cost of polymer and cement as although polymer is more expensive than cement, much less is required to achieve encapsulation and hence the resulting primary waste package volume would be less with polymer compared with cement.

From a safety perspective this option involves the least amount of handling and therefore the least potential for exposure to dose as the wastes are immobilised without removal from their current waste package. It also has the least potential for radiological and industrial accidents.

This option does not involve opening up the 200 litre drums containing the loose THTR graphite powder therefore there will be minimal discharges to air and water. This option will also generate the least amount of primary and secondary solid waste as it does not involve emptying and throwing away the 200 litre drums.

A2 Package loose in 500 litre drums and encapsulate in cement

This option would involve removal of the graphite from the 200 litre drums followed by loose tipping and direct cementation of the THTR graphite directly into 500 litre drums to form a stable product. The resulting cemented 500 litre drums would be stored at Dounreay until the GDF becomes available.

This option involves the use of mature technology that is currently in use at DSRL (cementation of waste in 500 litre drums). This option will use existing or planned facilities on the DSRL site hence there will be no visual impact from the implementation of this option. This option involves the purchase of 500 litre drums. Handling facilities for these waste packages already exist on the DSRL site.

Lower waste loadings are generally achieved with cementation compared to polymer encapsulation and thus Option A3 would be preferred over this option on waste minimisation grounds. This option is considered more practical than options such as reprocessing (Option A4) or thermal treatment (Option A5) because of the on site practical experience of encapsulation.

There is a greater potential for radiological and industrial accidents with this option (compared to Option A1) as the waste needs to be repackaged prior to encapsulation.

Repackaging raw waste to allow encapsulation has the potential to generate airborne contamination (dust) and will therefore require ventilation etc; however the releases will not be as large as those associated with thermal treatment (Option A5). It will also generate empty 200 litre drums as secondary waste from the repackaging process but does not involve the generation of significant additional decommissioning wastes.

A3 Package loose in 500 litre drums and encapsulate in polymer

This option would involve removal of the graphite from the 200 litre drums followed by loose tipping and direct cementation of the THTR graphite directly into 500 litre drums to form a stable product. The resulting 500 litre drums would be stored at Dounreay until the GDF becomes available.

This option involves the use of mature technology that is currently not in use at DSRL. This option will use existing or planned facilities on the DSRL site hence there will be no visual impact from the implementation of this option. This option involves the purchase of 500 litre drums however handling facilities for these waste packages already exist on the DSRL site.

From a technical perspective this option involves the use of polymer for infiltration/encapsulation which DSRL has less experience in operating compared to cementation as used in options A2, A7 and probably A6. Although polymer encapsulation in 500 litre drums has already been developed elsewhere, the lack of on-site experience may mean there is a longer process optimisation phase compared with options utilising direct cementation in 500 litre drums. This option is considered more practical than options such as reprocessing (Option A4) or thermal treatment (Option A5) because of the on site practical experience of encapsulation.

From a waste management perspective, Option A3 (along with Options A1 and A2) will generate the least amount of primary waste and virtually no secondary solid waste when compared to the other options. These options all involve the purchase of 500 litre drums. Handling facilities for these waste packages already exist on the DSRL site. No distinction was made in the workshop between the cost of polymer and cement as although polymer is more expensive than cement, much less is required to achieve encapsulation and hence the resulting primary waste package volume would be less with polymer compared with cement.

There is a greater potential for accidents with this option (compared to Option A1) as the waste needs to be repackaged when raw and therefore has a greater potential for radiological and industrial accidents compared with the current strategy.

The retrieval of the waste to allow encapsulation has the potential to generate airborne contamination (dust) and will therefore require ventilation etc; however the releases will not be as large as those associated with thermal treatment (Option A5). It will also generate empty 200 litre drums as secondary waste from the repacking process but does not involve the generation of significant additional decommissioning wastes.

A4 Reprocess to extract Uranium/Thorium

This option involves recovery of the Uranium (U) and Thorium (Th) from the wastes to allow it to be re-used, followed by disposal of the remaining graphite waste as LLW. The specific recovery process would need to be determined however one such process makes use of Ag(II). In this process the waste is contacted with aqueous nitric acid solution which contains a compound of $Ag^{2}+$ soluble in the solution, for oxidising the U/Th present in the waste and dissolving it in the nitric solution.

There is already some capability for reprocessing on the DSRL site using the glove boxes in D1203 however there is a risk that these facilities may no longer be available when needed. As such there will be a requirement for a new facility or a significant conversion of an existing facility. This makes this option more expensive to implement than options which use existing facilities such as Options A1, A2 and A3 and there could be a visual impact from the construction of new facilities.

The perception of reprocessing is extremely negative. Like thermal treatment (Option A5) there will be discharges associated with reprocessing. This option also involves glovebox operations whereas all other options will be performed in purpose built cells and therefore involves the greatest likelihood of routine exposure to dose. Therefore this option has the highest potential for radiological accidents. This option involves more processing steps than all other options and coupled with the use of hazardous chemicals associated with reprocessing, this and thermal treatment (Option A5) have the most potential for industrial accidents.

Reprocessing will use chemical processing in glove boxes and will therefore have significant particulates/discharges associated with it. Along with thermal treatment, this option will generate the most secondary waste discharges to air and water. It will also generate empty 200 litre drums as secondary waste once the contaminated graphite is removed and contaminated equipment once operations cease. It will require the build of new facilities or the conversion of existing facilities which will generate significant decommissioning wastes.

A5 Thermal treatment

Thermal treatment involves the use of high temperatures in the absence of air, free oxygen or a flame to change the character of the waste. The high temperatures cause the organic components to decompose into a gaseous discharge and the remaining solids can then be disposed of as ILW. There are a number of different thermal treatment methods that could be used however it was agreed that the BPEO study would consider thermal treatment as a single management option and if it is determined to be the BPEO then the choice of a particular technique could be determined through a BPM study.

Thermal treatment involves the use of a recently developed technology hence DSRL have no existing facilities or expertise in this particular application. This option will require the build of a new facility on the DSRL site (which will require design work and planning permission in addition to its construction) and will hence have the most visual impact but the greatest positive effect on the local economy. This option will incur the highest cost as a new facility will be required and is considered one of the least practical options in terms of deliverability.

Public perception of high temperature processing is more negative than most of the other options and is considered to be only slightly better than reprocessing. Heating is required for this option and there will be hot gases associated with the process. This coupled with the transport of the graphite to the facility can give a relatively high potential for radiological and industrial accidents from this option compared to other options such as A1, A2 and A3.

Along with reprocessing (Option A4), this option will generate the most discharges to air and water. It will also generate empty 200 litre drums as secondary waste from the drum emptying process and will require the build of new facilities which will generate significant decommissioning wastes. Therefore this option (along with reprocessing, Option A4) is expected to generate the highest amount of primary and secondary waste.

A6 Co-package

This option would involve co-packaging the THTR graphite with other wastes, for example the Shaft or Silo waste or other RHILW streams.

Co-packaging involves the use of existing DSRL processes, facilities and expertise. This option may only require a slight modification of an existing facility on the DSRL site and hence have the lowest visual impact. This option is anticipated as a low cost solution but there may be some issues with practicality as it relies on finding a suitable waste stream for co-packaging over an appropriate timescale. A new LoC may be needed, especially if the co-packaging waste already has a LoC.

Co-packaging will be undertaken in a shielded facility therefore the potential for dose uptake is slightly less than Options A2, A3, A7 and A8. Poorer waste loadings are achieved with cementation compared to polymer encapsulation. Co-packaging is likely to involve cementation hence this option was considered comparable to Options A2 and A7 in terms of changes to overall waste volumes.

The perception of co-packaging is favourable although it involves repackaging raw material and therefore has a greater potential for radiological accidents compared with the current strategy (Option A1). It also has the potential to generate airborne contamination (dust) and will therefore require ventilation etc. This option is expected to generate little additional primary waste but will generate empty 200 litre drums as secondary waste from the repackaging process.

A7 Package loose in 3m^3 drums and encapsulate in cement

This option is identical to Option A2 except that the THTR graphite will be packaged in 3m^3 drums rather than 500 litre drums as this gives greater waste packaging efficiencies. Other waste packages were considered but were rejected for the reasons recorded below:

- 2m and 4m boxes – these boxes are non-fissile packages and would therefore not be suitable for the THTR graphite inventory

- $3m^3$ boxes - lost paddle mixing will be required to mix the loose powder with the grout mix therefore $3m^3$ drums would be more suitable than $3m^3$ boxes as this allows the formation of a more homogeneous waste product

This option predominantly involves the use of mature technology that is currently in use at DSRL. However $3m^3$ drums will be required for the wastes and as there are no current handling facilities for this particular waste package there will be a requirement for a new facility or a significant conversion of an existing facility. This makes this option more expensive to implement than options which do not require construction of new facilities such as Options A1, A2 and A3. There could also be a visual impact from the implementation of this option.

Lower waste loadings are generally achieved with cementation compared to polymer encapsulation and thus Option A8 would be preferred over this option on waste minimisation grounds. This option is considered more practical than options such as reprocessing (Option A4) or thermal treatment (Option A5) because of the site's experience of encapsulation but less practical than Options A1, A2 or A3 because of the lack of experience in working with $3m^3$ drums.

There is a greater potential for radiological and industrial accidents with this option (compared to Option A1) as the waste needs to be repacked prior to processing.

Repacking raw waste to allow encapsulation has the potential to generate airborne contamination (dust) and will therefore require ventilation etc; however the releases will not be as large as those associated with thermal treatment (Option A5). It will also generate empty 200 litre drums as secondary waste from the repacking process and will involve the generation of significant additional decommissioning wastes.

A8 Package loose in $3m^3$ drums and encapsulate in polymer

This option is identical to Option A2 except that the THTR graphite will be packaged in $3m^3$ drums rather than 500 litre drums as this gives greater waste packaging efficiencies. Other waste packages were considered but were rejected for the reasons recorded below:

- 2m and 4m boxes – these boxes are non-fissile packages and would therefore not be suitable for the THTR graphite inventory

- $3m^3$ boxes - lost paddle mixing will be required to mix the loose powder with the grout mix therefore $3m^3$ drums would be more suitable than $3m^3$ boxes as this allows the formation of a more homogeneous waste product

This option predominantly involves the use of technology that is untested at DSRL. $3m^3$ drums will be required for the wastes and as there are no current handling facilities for this particular waste package there will be a requirement for a new facility or a significant conversion of an existing facility. Polymerisation in $3m^3$ drums will be harder to implement than cementation as DSRL has no experience of this immobilisation method especially on this scale. This makes this option more expensive to implement than options which use existing facilities such as Options A1, A2 and A3 and there will be a visual impact from the implementation of this option.

Higher waste loadings are generally achieved with polymer encapsulation compared to cementation and thus this option would be preferred over Option A7 on waste minimisation grounds. This option is considered more practical than options such as reprocessing (Option A4) or thermal treatment (Option A5) because of the relative simplicity of the process but less practical than Options A1, A2 or A3 because of the lack of experience or planned capability in working with $3m^3$ drums.

There is a greater potential for radiological and industrial accidents with this option (compared to Option A1) as the waste needs to be repackaged prior to processing.

The retrieval of the waste to allow encapsulation has the potential to generate airborne contamination (dust) and will therefore require ventilation etc; however the releases will not be as large as those associated with thermal treatment (Option A5). It will also generate empty 200 litre drums as secondary waste from the repacking process and will involve the generation of significant additional decommissioning wastes.

4.2.1.3 Screened out options

A9 Send off-site

Sending the waste off-site was proposed as an additional option however it was agreed that waste cannot be sent off-site if no suitable agreement (known as a hand-off agreement) is in place with the recipient site [15]. Therefore sending the THTR graphite off-site was screened out as a non-credible option as no such agreements are in place.

4.2.2 CHILW Graphite (Activated Graphite)

The Activated Graphite wastes comprise two waste stream sources; the major component is graphite from the decommissioning of the DFR reflector with the minor component being graphite from the decommissioning of the DMTR reflector.

The DFR and DMTR graphite is treated as a single waste stream for the purposes of the BPEO assessment due to the similarity in chemical, physical and radiological properties of the graphite.

DFR Graphite

The outside of the DFR reactor tank is surrounded by a 1.2m thick borated graphite jacket, which provides a thermal neutron reflector and shield. This jacket contains approximately 200 tonnes of borated carbon which, for the purposes of the BPEO study, are assumed to be removed in blocks.

Boronated carbon is not true graphite: due to the inclusion of boron in the lattice, the temperature that the blocks are pressed at is lower than conventional graphite. As a result the borated carbon contains significantly more impurities that conventional graphite and hence more radionuclides when irradiated. Also the irradiation of boron leads to a significantly higher inventory of tritium being present in the borated graphite. The presence of the boron also reduces the strength of the graphite lattice and can lead to crumbling of the blocks.

The borated carbon used in the DFR reactor jacket was manufactured by grinding Windscale graphite off-cuts and mixing the powder with anhydrous sodium pyroborate, and pitch and tar blenders. The mixture was pressed into blocks and baked at 1200 deg C.

The nature of the boronated carbon and the irradiation temperature incurred at DFR means that there should be no easily releasable Wigner energy present, however this remains an untested assumption.

DMTR Graphite

The DMTR decommissioning graphite is part of the DMTR reactor vessel dismantling wastes, which collectively are made up of graphite (17wt%), shot aggregate concrete (33wt%), steel (24wt%) and aluminium (26wt%). This BPEO study is considering the 17wt% graphite part only as the concrete and metal wastes will be managed as RHILW solids.

The DMTR graphite has had the lowest irradiation of any MTR reflector in the UK. There is a possibility that the graphite is LLW. This would need to be demonstrated by sampling or calculation. This low level of irradiation should also mean that there is no Wigner energy of significance present.

The table below shows the current raw waste stocks and future arisings of the above wastes.

Waste Type	(Raw) Waste Volumes m^3		
	Stocks (2008)	Arisings	Total
DFR graphite	0	194	194
DMTR graphite reflector (data for full waste stream)	0	1	1

4.2.2.1 Current DSRL waste management strategy

The current DSRL strategy involves packaging the Activated Graphite directly into 4m boxes and leaving unencapsulated. The packaging of this waste would need to meet the requirements for unencapsulated wastes as defined by NDA RWMD. The waste would be stored at Dounreay until the GDF becomes available.

4.2.2.2 Options taken forward to scoring assessment

The management options for the Activated Graphite are shown in Figure 15 and described below. Options which were proposed in the delegate pack are shown in the green filled boxes and additional options which were proposed at the workshop and taken forward for assessment are shown in the white boxes.

It was noted that recent calculations which have been carried out for the DFR graphite indicate that by 2040 it could be LLW; however this is beyond the site interim end date of 2025 and thus decay storage has been ruled out as a management method. The DMTR graphite has also been sampled and the measurements are currently being analysed. However it was agreed by the OAP that the BPEO study should be based on current knowledge and therefore the graphite should be treated as ILW. However it was recognised that for all options there would be an opportunity for segregation of LLW and Exempt waste and possible recycling of certain items during the dismantling of the reactors. This could in turn mean that a smaller quantity of graphite will require management as ILW and there could be generation of some lower level waste streams. It was agreed that the potential for such segregation should be revisited at an appropriate point prior to dismantling the reactor.

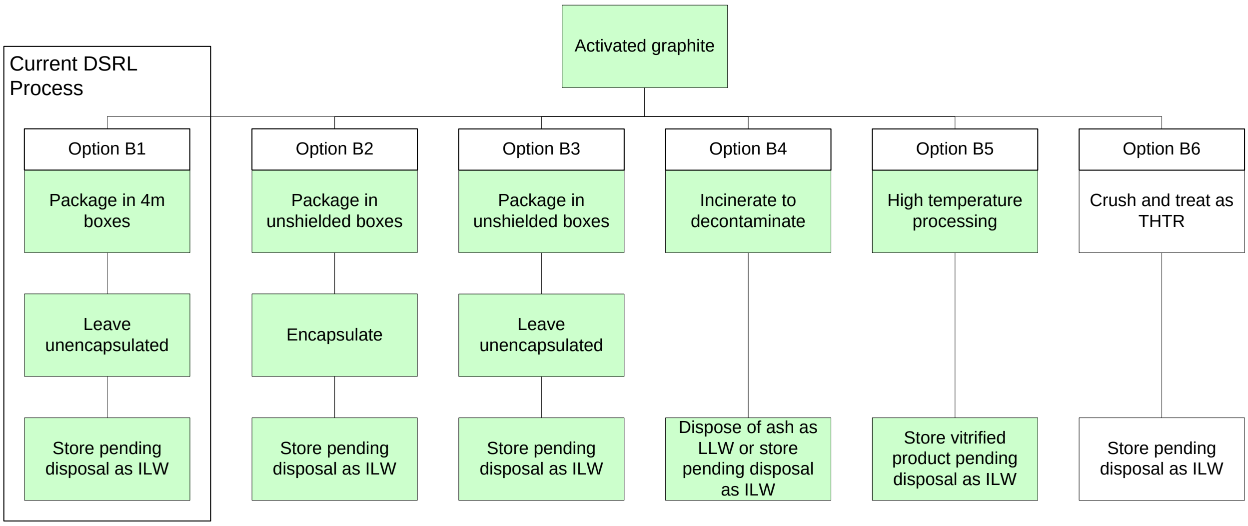


Figure 15: Management Options for CHILW Graphite (Activated Graphite)

B1 Package in 4m boxes and leave unencapsulated (current DSRL strategy)

The current DSRL strategy involves packaging the Activated Graphite directly into 4m boxes and leaving the waste unencapsulated. The packaging of this waste would need to meet the requirements for unencapsulated wastes defined by NDA RWMD and this management option would not close out future improved management options. The waste would be stored at Dounreay until the GDF becomes available. 2m boxes were also considered as potential waste packages however it was agreed that they were very similar to 4m boxes and would offer no benefit over 4m boxes.

Packaging graphite unencapsulated in 4m boxes involves the use of mature technology most of which is currently in use at DSRL. This option will use existing or planned facilities on the DSRL site hence there will be little visual impact from its implementation. Option B1 requires fewer waste packages than Options B2 and B3. However, this option assumes the use of a planned shielded store for the 4m boxes (even though the packages will not require shielding). This will be more expensive than the storage costs for Options B2 and B3 as these options would make use of an unshielded store.

Packaging the wastes in 4m boxes generates the least amount of primary waste (~37 x 4m boxes) and virtually no secondary solid waste. However this option involves leaving the waste unencapsulated and hence not as stable as an encapsulated wasteform. It may be difficult to make the case for and gain endorsement from NDA RWMD for an unencapsulated wasteform. This option is considered less practical than Options B2 and B3 as unlike $3m^3$ boxes, 4m boxes are still in the development stage.

This option involves the least amount of waste handling steps and therefore the least potential for industrial accidents and exposure to dose as the box itself is shielded. However, there will be a slightly higher impact from a radiological transport accident compared with Option B2 because the waste is unencapsulated. Since the waste is packaged in its current form without encapsulation it will generate the least airborne or liquid discharges.

B2 Package in unshielded boxes and encapsulate

This option would involve direct encapsulation of all the Activated Graphite directly into unshielded boxes such as the $3m^3$ box. There are various options available for the encapsulating material, including PFA/OPC grouts, alternative cements and polymers. The waste would be packaged with other reactor decommissioning wastes. The waste would be stored at Dounreay until the GDF becomes available. Although encapsulation closes out future management options, it provides a more stable wasteform that is easier to gain acceptance for disposal at the GDF through the LoC process.

Packaging in $3m^3$ boxes involves the use of mature technology most of which is currently in use at DSRL and waste packages which have been used for similar applications in the past. This option will use existing or planned facilities on the DSRL site although a provision will need to be made to allow the handling of $3m^3$ boxes. Hence, there will be little visual impact from its implementation. Option B2 will generate more waste packages than Option B1. However, Option B1 makes use of a shielded store for the 4m boxes whereas for Option B2, which uses unshielded boxes, there is potential for savings to be made by not using a shielded store.

This option will generate more than 100 boxes (more than the related options B1 and B3), however, it will generate less solid waste than Options B4 and B5. This option also involves minimal handling however there will be a greater number of waste packages compared to Option B1 and therefore more transport operations. For Option B3 neither the box nor the store is shielded however as the graphite is contact handleable and is also in a non-mobile (block) form, there is minimal potential for exposure to dose regardless of the type of box (shielded/unshielded).

Although there is some additional processing involved (encapsulation) compared to Options B1 and B3, the process is a simple addition of pre-mixed wet grout to the waste. This option generates the highest integrity wasteform therefore the potential impact from an accident during transportation to the GDF would be minimal. This option involves grouting the waste therefore there will be some discharges to water from the grout washings.

B3 Package in unshielded boxes and leave unencapsulated

This option would involve packaging of all the Activated Graphite directly into unshielded boxes such as the $3m^3$ box and leaving it unencapsulated. The packaging of this waste would need to meet the requirements for unencapsulated wastes defined by NDA RWMD. The waste would be stored at Dounreay until the GDF becomes available. Leaving the waste unencapsulated does not close out future alternative waste management options.

Packaging in $3m^3$ boxes involves the use of mature technology most of which is currently in use at DSRL and waste packages which have been used for similar applications in the past. This option will use existing or planned facilities on the DSRL site although a provision will need to be made to allow the handling of $3m^3$ boxes. Hence, there will be little additional visual impact from its implementation. Option B3 will generate more waste packages than Option B1. However, Option B1 makes use of a shielded store for the 4m boxes whereas for Option B3, which uses unshielded boxes, there is potential for savings to be made by not using a shielded store.

Option B3 will generate ~100 x $3m^3$ boxes (assumes $2m^3$ per box), more than the current strategy but slightly less than Option B2. However, this option involves leaving the waste unencapsulated and hence not as stable as an encapsulated wasteform. It may be difficult to make the case for and gain endorsement from NDA RWMD for an unencapsulated wasteform.

This option involves the least amount of handling and therefore the least potential for industrial accidents and exposure to dose. However, as the waste is unencapsulated there will be a slightly higher impact from a radiological transport accident compared with Option B2. There will be a greater number of waste packages compared to Option B1 and therefore more transport operations. Since the waste is packaged in its current form with no grouting it will generate the least airborne or liquid discharges.

B4 Incinerate to decontaminate

Graphite will only burn efficiently in an incinerator under very carefully defined conditions. This option involves heating the Activated Graphite to release the C-14 and tritium with the resulting ash disposed of as ILW or LLW (depending on the activity of the remaining radionuclides). This approach has been used for 550 tonnes of GLEEP (Harwell) graphite. In this particular case the graphite was then suitable for disposal as Exempt waste in a hazardous landfill. For the purposes of the scoring assessment it was assumed that the graphite would be sent to the incinerator in its current block form, without the prior need for crushing. It was also assumed that the incinerator would be a bespoke facility built on the Dounreay site as the only suitable existing incinerator is at Fawley near Southampton, which in addition to being a long way from Dounreay, could have its discharge limits challenged by the graphite inventory. DSRL have no existing facilities or expertise in this particular application. The build of a new facility on the DSRL site (which will require design work and planning permission in addition to its construction) and will hence have the most visual impact but potentially a positive effect on the local economy. This option will incur the highest cost as a new facility will be required and is considered one of the least practical options in terms of deliverability due to its bespoke nature.

The perception of incineration is more negative than most of the other options. Heating is required for this option and there will be hot gases associated with the process. This coupled with the transport of the graphite to the facility can give a relatively high potential for radiological and industrial accidents compared to other options such as B1, B2, B3 and B6.

The degree to which the volume of waste is reduced is uncertain but can be engineered to be high. This option potentially has the benefit of leaving only the inorganics in the form of ash. This option has one of the highest potential for industrial accidents because of the high temperatures used and the generation of hot gases.

Incineration will generate airborne discharges and will therefore require the use of filters and scrubbers which will generate solid and liquid wastes. The requirement of a new facility for this management option will mean the generation of the most decommissioning wastes of all the options assessed. Therefore this option is expected to generate the highest amount of primary and secondary waste.

B5 High temperature processing

In this process waste is mixed with constituents for glass making. This is then heated to high temperature and compressed to seal the waste within the glass matrix. The vitrified product is then disposed of as ILW.

Thermal treatment involves the use of a recently developed technology hence DSRL have no existing facilities or expertise in this particular application. This option will require the build of a new facility on the DSRL site (which will require design work and planning permission in addition to its construction) and will hence have the most visual impact but potentially a positive effect on the local economy. This option will incur the highest cost as a new facility will be required and is considered one of the least practical options in terms of deliverability. The degree to which the volume of waste is reduced is uncertain and is still untested on an industrial scale.

The perception of high temperature processing is more negative than most of the other options. There will be hot gases associated with the process, containing C-14, tritium and particulate secondary wastes, the latter requiring filtration. This coupled with the transport of the graphite to the facility can give a relatively high potential for radiological and industrial accidents for this option compared to other options such as Options B1, B2 and B3.

There will be discharges associated with high temperature processing however these will be controlled, however along with reprocessing (Option B4), this option will generate the most discharges to air and water. It will also generate empty 200 litre drums as secondary waste from the repacking process and will require the build of new shielded facilities, which themselves will generate significant decommissioning wastes. This option (along with incineration, Option B4) is expected to generate the highest amount of primary and secondary waste.

B6 Crush and treat as THTR graphite

This option would involve crushing the Activated Graphite into a loose powder to be managed via the BPEO determined for the THTR graphite waste stream. This would require a shielded facility and provision would need to be made for the abatement/filtration of dust generated by the crushing process.

Crushing of materials is a routine operation and DSRL have expertise in this particular application although the treatment of these types of materials is not as mature as the treatment of bulk wastes. This option will require modifications to be made to an existing facility to accommodate the crushing process and may have some visual impact. This option will be relatively cheap to implement, as the main cost would be modifying an existing facility.

Crushing and the subsequent inclusion in the THTR graphite waste stream involves an extra processing step compared with Options B1, B2 and B3 and has the potential to generate airborne contamination (dust). This option would also involve transporting the THTR graphite as a powder. Therefore this option has the highest potential for radiological and industrial accidents. This option also has the highest potential for exposure to dose and will require active ventilation and HEPA filtration to capture any airborne particulate generated from the crushing process. Therefore this option is expected to generate a large amount of primary and secondary waste.

4.2.2.3 Screened out options

B7 Recycle

There is potential to recycle the boronated carbon. This material is no longer manufactured and could potentially be sold. However it was agreed that the option to recycle would be captured under the options that leave the graphite in a packaged but unencapsulated form.

B8 Co-package

It was suggested that the Activated Graphite could be co-packaged with other waste streams. However it was agreed that this would not be practical as the graphite is scheduled to be removed from the reactors in discrete campaigns over a long timeframe. It will therefore be difficult to identify suitable waste streams requiring processing over the same time scale as the graphite would be removed. A new LoC may be needed for the waste especially if the co-packaging waste already has a LoC which does not include a provision for the packaging of Activated Graphite.

4.2.3 LLW Sludges (LSA Scale)

The LSA Scale is deposited on pipeline tubulars and platform components originating from North Sea offshore operations. The scale contains low levels of naturally occurring Uranium and Thorium daughter products and after removal was loaded into 200 litre drums. The waste is in temporary storage within HHISO containers on the Dounreay site pending its ultimate disposal. Although this waste is classed as LLW on the grounds of activity, the presence of long lived nuclides (such as radium isotopes) prevents the waste from complying with the Conditions for Acceptance for the LLWR near Drigg. It is assumed, for the purposes of this study, that the proposed LLWR at Dounreay will have similar Conditions for Acceptance as that of Drigg and therefore needs to be packaged and disposed of as ILW.

The table below shows the current raw waste stocks and future arisings of the above wastes.

Waste Type	(Raw) Waste Volumes m^3		
	Stocks (2008)	**Arisings**	**Total**
LSA Scale	232	0	232

4.2.3.1 Current DSRL waste management strategy

The current waste management strategy is to package the 200 litre drums containing the LSA Scale into 4m boxes and encapsulate. It is assumed that 30 drums can be packaged into each 4m box.

4.2.3.2 Options taken forward to scoring assessment

The management options for the LSA Scale are shown in Figure 16 and described below. Options which were proposed in the delegate pack are shown in the green filled boxes and additional options which were proposed at the workshop and taken forward for assessment are shown in the white boxes.

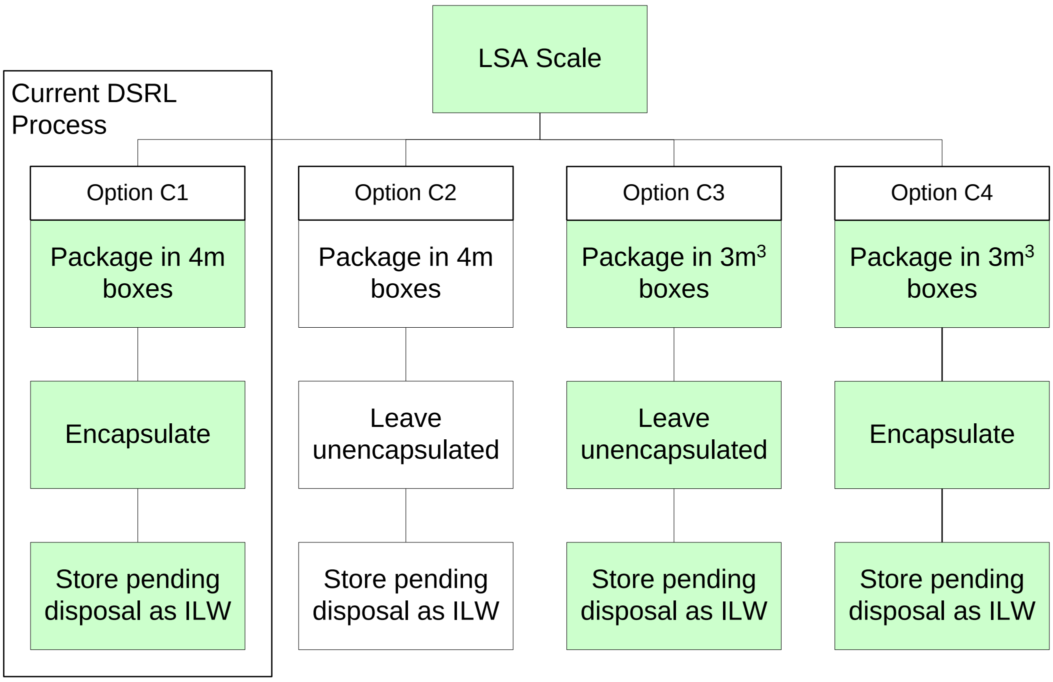


Figure 16: Management Options for LSA Scale

Since the only four credible options involve encapsulation versus non-encapsulation in different types of RWMD approved boxes the OAP agreed that the options for the management of LSA

Scale did not need to be scored. The drums could be grouted into their respective boxes at some later date if DSRL decides that this is what is required and the decision between 4m boxes and $3m^3$ boxes should be determined through BPM consideration via the LoC process.

C1 Package 200 litre drums in 4m boxes and encapsulate (current DSRL strategy)

This is the current DSRL strategy and involves cementation of the 200 litre drums containing LSA Scale directly into 4m boxes, which are unlikely to require any shielding. This process would not require a shielded facility and would generate minimal secondary wastes. The waste would be stored at Dounreay until the GDF becomes available. Encapsulating the waste will close out future waste management options but does leave the waste in a passively safe form.

C2 Package 200 litre drums in 4m boxes and leave unencapsulated

This option involves packaging of the 200 litre drums containing LSA Scale directly into 4m boxes and leaving the waste unencapsulated. This process would not require a shielded facility and would generate minimal secondary wastes. The packaging of this waste would need to meet the requirements for unencapsulated wastes as defined by NDA RWMD. The waste would be stored at Dounreay until the GDF becomes available. Leaving the waste unencapsulated will not close out future waste management options but an appropriate case would need to be made if it was to be sent for disposal in this form.

C3 Package 200 litre drums in $3m^3$ boxes and leave unencapsulated

This option would involve packaging of the 200 litre drums containing LSA Scale directly into $3m^3$ boxes and leaving the waste unencapsulated. This process would not require a shielded facility and would generate minimal secondary wastes. The packaging of this waste would need to meet the requirements for unencapsulated wastes as defined by NDA RWMD. The waste would be stored at Dounreay until the GDF becomes available. Leaving the waste unencapsulated will not close out future waste management options but an appropriate case would need to be made if it was to be sent for disposal in this form.

C4 Package 200 litre drums in $3m^3$ boxes and encapsulate

This option would involve cementation of the 200 litre drums containing LSA Scale directly into $3m^3$ boxes. This process would not require a shielded facility and would generate minimal secondary wastes. There are various options available for the encapsulating material, including PFA/OPC grouts, alternative cements and polymers. The waste would be stored at Dounreay until the GDF becomes available. Encapsulating the waste will close out future waste management options but does leave the waste in a passively safe form.

4.2.3.3 Screened out options

C5 Make case to consign as LLW at Dounreay

It is currently thought that it would be difficult to make a post-closure safety case for disposal of the LSA Scale at the proposed Dounreay LLW facility due to its high Ra-226 content. However, it was agreed that an underlying assumption for all credible options should be that sorting and segregation would be carried out at the start in order to identify any drums that are suitable for disposal as LLW, with the remainder to be managed as ILW.

C6 High temperature processing

In this process waste is mixed with constituents for glass making. This is then heated to a high temperature and compressed to seal the waste within the glass matrix. The vitrified product is then disposed of as ILW. The OAP agreed that this option would not be feasible as the heat would not drive off the Radium but could liberate C-14 and tritium containing gases in addition to particulates (which would require filtration) as secondary wastes.

C7 Dissolve and cement into 500 litre drums

This option would involve dissolving the LSA Scale and cementing the resulting waste stream into 500 litre drums. The waste would be stored at Dounreay until the GDF becomes available. The OAP agreed that this option offers no benefit over simple encapsulation.

C8 Dissolve and discharge

This option would involve dissolving the LSA Scale and discharging it to sea via LLLETP. Although this was once a credible option for the oil and gas industry, SEPA have required such operations to cease by December 2008 [14]. These recent developments would make it unlikely that Dounreay, as a nuclear licensed site, would be able to gain an appropriate discharge authorisation if this were considered a possible method for dealing with the waste.

4.2.4 LLW Sludge (Granular)

This waste stream consists of sludges, which are produced as a result of operations in the LLLETP at Dounreay. The sludge is a sand/silt like grit or particulate entrained within the effluent. A sample of the material has been fingerprinted and has been confirmed to fall within the LLW definition used for this study.

The table below shows the current raw waste stocks and future arisings of the above wastes.

Waste Type	(Raw) Waste Volumes m^3		
	Stocks (2008)	Arisings	Total
LLW Sludges	16	34	50

4.2.4.1 Current DSRL Waste Management Strategy

The current and planned waste management method for the LLW Sludges is to de-water as required and cement in 200 litre drums. The sludges will be separated and immobilised in cement in such a way that they will be accepted for disposal in the proposed on-site LLW repository.

4.2.4.2 Options to be taken forward for assessment

The management options for the LLW Sludges are shown in Figure 17 and described below. Options which were proposed in the delegate pack are shown in the green filled boxes and additional options which were proposed at the workshop and taken forward for assessment are shown in the white boxes.

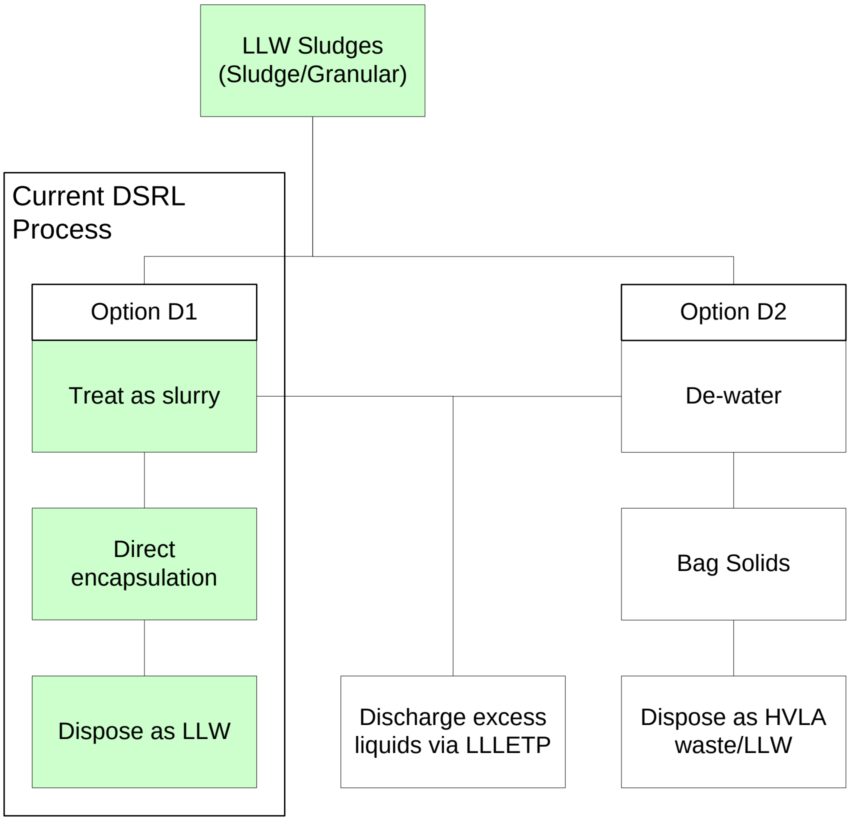


Figure 17: Management Options for LLW Sludges (Granular)

D1 Treat as slurry (current DSRL strategy)

This is the current DSRL strategy and involves partial de-watering then direct encapsulation of the LLW Sludges into 200 litre drums for disposal as LLW. The encapsulated product would be stored on the Dounreay site pending the availability of the proposed on-site LLW repository.

This method would generate a liquid effluent secondary waste stream which would require management through LLLETP.

The storage tank which holds the granular sludge was constructed without any engineered means for its retrieval. Therefore a new facility will be required to recover, treat and package the waste. This is the same for both management options considered in the workshop.

There will be larger product waste volumes associated with this option compared to Option D2 and therefore a greater amount of package handling and transportation required. As grout will be added to the waste stream there will also be an overall volume increase and a corresponding greater number of waste packages. There will be slightly less liquid discharges associated with this option compared to Option D2 as Option D2 involves complete de-watering of the sludge.

Although there is more handling for this option compared to Option D2, the resulting encapsulated wasteform will have a lower activity and therefore the potential impact from a radiological accident would be minimal.

D2 De-water, bag and dispose as HVLA waste/LLW

This option would involve de-watering the waste (for example by centrifuge – the specific de-watering technique would be determined by a BPM study) and then bagging the dry waste (in

1te bags) and disposing of it as HVLA waste or LLW as appropriate (bags of LLW would be loaded into HHISOs prior to disposal). Liquid effluent stream and airborne particulates are secondary waste streams, which would require management.

The storage tank which holds the granular sludge was constructed without any engineered means for its retrieval. Therefore a new facility will be required to recover, treat and package the waste. This is the same for both management options considered in the workshop.

There will be smaller product waste volumes associated with this option compared to Option D1 and therefore a fewer number of packages, resulting in less package handling and transportation.

De-watering will have the effect of concentrating the radioactivity in the waste and hence increasing the potential for dose uptake. With a dry product there is a greater potential for airborne releases in an accident scenario. There will be slightly more liquid discharges associated with this option compared to Option D1 due to the de-watering process.

4.2.4.3 Screened out options

D3 Separate solids and liquids and encapsulate solid

This option first involves separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated and the solid part would be directly encapsulated in 200 litre drums for disposal as LLW.

The OAP agreed that this option was essentially the same as the current strategy, treat as slurry, but that it included optimisation of the liquid content of the sludge, which is a BPM consideration. Therefore this option was screened out.

D4 Separate solids and liquids and thermally treat and encapsulate solid

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated and the solid part would then be thermally treated.

The OAP agreed that thermal treatment in this case was essentially a higher temperature form of evaporation and therefore this option was screened out on the same basis as for Option D3 i.e. it is a variation of part of the current strategy where the thermal treatment would constitute a form of de-watering and thus should be considered as part of a BPM study.

D5 Separate solids and liquids and compact and encapsulate solid

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated and the solid part would then be compacted in sacrificial containers to reduce its volume prior to encapsulation for disposal as LLW.

This option is essentially the same as de-watering, bagging and disposing as HVLA waste/LLW. Optimisation of the volume sent for disposal, by compaction for example, is a BPM consideration.

D6 Dissolve and discharge to sea

This option was determined to be the preferred option through the 2003 BPEO Study. However, the solid part of the sludge would precipitate out again after it had been discharged. Therefore this option was screened out as a non-credible option.

4.2.5 LLW Sludges (Putrescible)

The Putrescible Sludges are the solid wastes trapped from the sewage produced on the Dounreay site; the liquid component being discharged to sea from a number of outfalls. The Dounreay site inactive drainage system is a single, combined, system that copes with sewage, surface water and inactive trade effluent. Historically, there have been spills etc that have left a legacy of contamination within the system. Therefore, it is possible that putrescible material may pick up contamination on its passage through the system. A radiological survey has been completed to determine where the contamination is to allow DSRL to take remedial action. This stream has been split into LLW, Exempt Hazardous and Clean Hazardous waste (the sludges are bio-hazardous), as, at the time of the BPEO Workshop, waste characterisation was ongoing and it was uncertain as to what volume of waste would be in each of the waste categories.

4.2.5.1 Current DSRL Waste Management Strategy

There is currently no sewage treatment plant at Dounreay. For all the Putrescible Sludges (Clean, Exempt and LLW) the current waste management practice is that the materials are dried, bagged and stored until a disposal solution can be found. The material will then be segregated into LLW, Exempt and Clean wastes, as required, for onward consignment.

Clean waste will follow the same route as other Clean Hazardous materials generated on the DSRL site. It was agreed that this was the only feasible option for the Clean Putrescible Sludges, recognising the fact that the sludges would need to be de-watered before being sent off-site to an appropriate landfill facility. Therefore, there was no requirement for a scoring exercise for Clean wastes.

However for the potential Exempt / LLW portions, there are the following issues:

- The LLW fraction will not be acceptable in its current form at the proposed on-site LLW facility, nor can they be disposed on-site as HVLA wastes, due to their putrescible content.
- Vulcan will not take LLW / Exempt sewage from DSRL into their sewage treatment facility. In fact they send their LLW to DSRL. Vulcan will only accept Clean wastes.

Therefore, any LLW / Exempt Sludge will require some type of processing to destroy the organic content of the waste. Putrescible LLW and Exempt Sludges were treated as separate waste streams for the purposes of the scoring assessment.

4.2.5.2 Options to be taken forward to scoring assessment

For LLW Putrescible Sludges the options which were taken forward to the scoring assessment are shown in Figure 18 and described below. Options which were proposed in the delegate pack are shown in the green filled boxes and additional options which were proposed at the workshop and taken forward for assessment are shown in the white boxes.

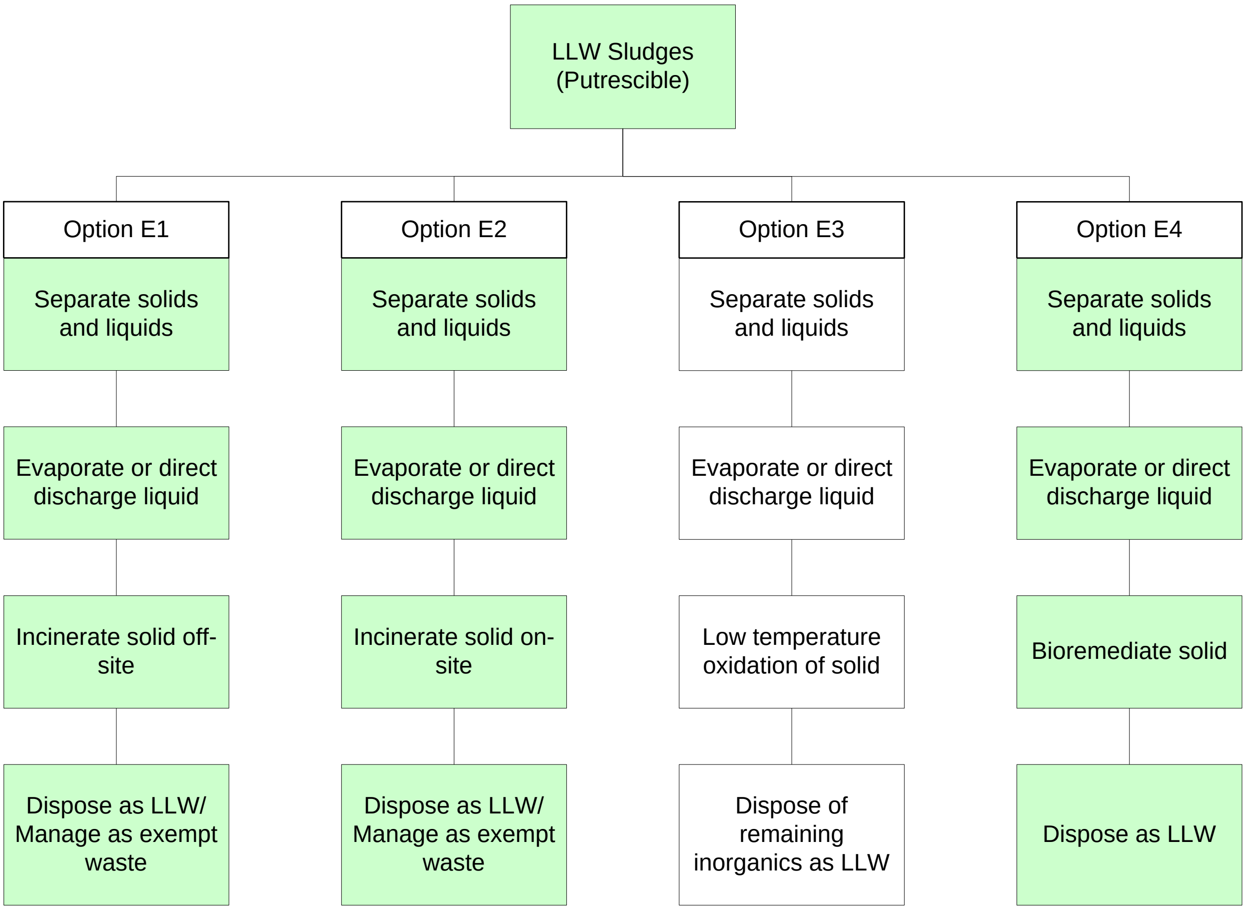


Figure 18: Management Options for LLW Sludges (Putrescible)

E1 Process and incinerate off-site

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be packaged and sent off-site for incineration.

Process and incinerate off-site involves the use of mature technology that is currently in use however a suitable off-site incinerator would need to be identified, which has an appropriate discharge authorisation. This option will be the least expensive as it involves minimal processing of the waste on the DSRL site. As it does not require the build of a new facility on the DSRL site, its implementation will have no visual impact and no effect on the local economy.

The degree to which the volume of waste is reduced is uncertain but likely to be high. It also has the benefit of also removing all organics (rather than just the putrescibles) leaving only the inorganics (in the form of ash) to be managed. It is unlikely that the receiver of the sludge will return the residual wastes, however if they do they will be small in volume and DSRL have a method in place for their disposal.

The perception of incineration is more negative than other options however the public wants to see DSRL dealing with their own wastes instead of sending them elsewhere. There will be issues with transporting LLW off-site, one of which being that DSRL would require an RSA authorisation to permit off-site processing.

This option will generate the least amount of primary and secondary waste at DSRL as the waste is incinerated off-site.

E2 Process and incinerate on-site

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be incinerated on-site.

Process and incinerate on-site involves the use of mature technology that is currently in use elsewhere. This option will require the build of a new facility on the DSRL site (which will require design work and planning permission in addition to its construction) and will hence have the most visual impact but the greatest positive effect on the local economy. This option will incur the highest cost as a new facility will be required.

The degree to which the volume of waste is reduced is uncertain but likely to be high and has the benefit of also removing all organics (rather than just the putrescibles) leaving only the inorganics (in the form of ash) to be managed.

The perception of incineration is more negative than the other options however incineration is a shorter term process than bioremediation and therefore less potential for exposure to dose. Heating is required for incineration and there will be hot gases associated with the process. Incineration will generate airborne discharges and will therefore require the use of scrubbers which will generate liquid wastes. The requirement of a new facility for this management option will mean the generation of the most decommissioning wastes of all the options assessed. Therefore this option is expected to generate the highest amount of primary and secondary waste.

E3 Low temperature oxidation

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be treated by a low temperature oxidation process (e.g. Silver II) in order to remove the organic content of the waste. The remaining inorganic solids would be encapsulated in 200 litre drums and disposed of as LLW.

Low temperature oxidation is not as well developed as the other options and has never been applied to this type of waste. An existing facility could be used after modification (with a small additional visual impact) but DSRL have limited expertise in the practical application of this option compared to other options such as bioremediation. DSRL would require a licence to operate the process which could be difficult to obtain at present.

The degree to which the volume of waste is reduced is uncertain for this option but the overall process is likely to be quicker than bioremediation and slower than incineration. Like bioremediation it is not a complete solution to the problem as there will be residual organic and inorganic materials remaining after digestion which will need to be managed. It is not certain at this stage what radiological classification these wastes will have.

Low temperature oxidation, in particular the Silver II process, is perceived positively by the public. Because low temperature oxidation is deemed to be a relatively quick process the potential for exposure to dose is considered smaller than longer term processes like bioremediation. However, hazardous chemicals are required for low temperature oxidation which increases the potential for radiological and industrial accidents. Following the destruction of the organics, the activity (Pu, U) will be in a mobile liquid form hence the impacts of radiological accidents will be greatest for this option. Gases will be generated from the low temperature oxidation process but the quantity generated is expected to be slightly less than for incineration options. Low temperature oxidation will generate additional decommissioning waste, therefore this option is expected to generate a large amount of primary and secondary waste.

E4 Bioremediation

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be bioremediated and the residual solid encapsulated in 200 litre drums and disposed of as LLW. Ex-situ bioremediation is a process whereby solid waste is added to a bioreactor, and microbes are used to decompose the organic material.

Bioremediation is a proven process for dealing with putrescible wastes but not in this particular application. DSRL have some expertise in bioremediation and this option could utilise an existing facility after some modification and may therefore have a small visual impact. It is anticipated this will be a relatively small and simple facility which is relatively inexpensive to construct and operate.

Bioremediation can result in a volume reduction factor of between 10 and 20 for organic wastes although the time taken to complete the digestion process will be longer than other methods scored in the workshop. Bioremediation itself is not a complete solution to the problem as there will be residual organic and inorganic materials remaining after digestion which will need to be managed. It is not certain at this stage what radiological classification these wastes will have.

This option was deemed to be the best in terms of public perception and has the least potential for radiological and industrial accidents as the solid waste is simply added to a bioreactor and microbes are used to decompose the organic material. This option will generate the least amount of discharges to air and water and should only give a small increase in the amount of additional decommissioning wastes generated.

4.2.5.3 Screened out options

E5 Treat as slurry

This option would involve direct encapsulation of the LLW portion of the sludges into 200 litre drums for disposal as LLW. This option is not feasible as the LLW will not be acceptable at the on-site LLW facility due to its putrescible content.

E6 Separate solids and liquids and compact LLW portion of the solid

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be compacted in sacrificial containers to reduce its volume prior to encapsulation for disposal as LLW.

This option is not feasible as the LLW will not be acceptable at the on-site LLW facility due to its putrescible content.

E7 Separate solids and liquids and encapsulate solid

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be directly encapsulated in 200 litre drums for disposal as LLW.

This option is not feasible as the LLW will not be acceptable at the on-site LLW facility due to its putrescible content.

4.3 Selection of Options for the Management of Non-Radioactive wastes

4.3.1 Exempt Sludges (Putrescibles)

The Putrescible Sludges are the solid wastes trapped from sewage produced on the Dounreay site. The sludges are bio-hazardous. This waste stream has been split into LLW, Exempt and Clean Hazardous waste until characterisation can identify the appropriate waste category (see Section 4.2.5 for further details).

4.3.1.1 Current DSRL Waste Management Strategy

See Section 4.2.5.1 for further details.

4.3.1.2 Options to be taken forward to scoring assessment

For Exempt Putrescible Sludges the options which were taken forward to the scoring assessment are shown in Figure 19 and described below. Options which were proposed in the delegate pack are shown in the green filled boxes and additional options which were proposed at the workshop and taken forward for assessment are shown in the white boxes.

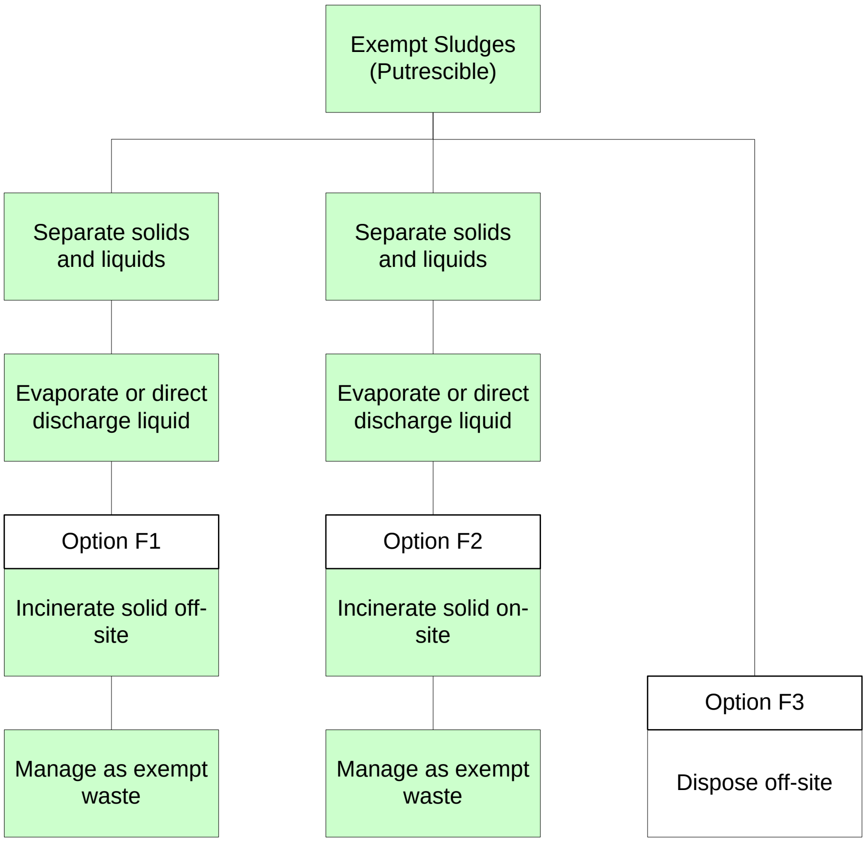


Figure 19: Management Options for Exempt Sludges (Putrescible)

F1 Process and incinerate off-site

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be sent off-site for incineration.

Process and incinerate off-site involves the use of mature technology that is currently in use however a suitable off-site incinerator would need to be identified. This option does not require the build of a new facility on the DSRL site (the processing stages are already done on-site) and will hence have the least visual impact and will have no effect on the local economy as it will not use any facilities or employees on the DSRL site. This option will be the least expensive as it involves minimal processing of the waste on the DSRL site. Public perception of incineration is more negative than the other options.

The degree to which the volume of waste is reduced is uncertain but likely to be high. It also has the benefit of also removing all organics (rather than just the putrescibles) leaving only the inorganics (in the form of ash) to be managed. It is unlikely that the receiver of the sludge will return the residual wastes, however if they did, it would be small in volume and DSRL would have a disposal route. This option will generate the least amount of primary and secondary waste at DSRL as the waste is incinerated off-site.

F2 Process and incinerate on-site

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be incinerated on-site.

Process and incinerate on-site involves the use of mature technology that is currently in use elsewhere. This option will require the build of a new facility on the DSRL site (which will require design work and planning permission in addition to its construction) and will hence have the most visual impact but the greatest positive effect on the local economy. This option will incur the highest cost as a new facility will be required.

The degree to which the volume of waste is reduced is uncertain but likely to be high. It has the benefit of also removing all organics (rather than just the putrescibles) leaving only the inorganics (in the form of ash) to be managed.

The perception of incineration is more negative than other options however the public wants to see DSRL dealing with their own wastes instead of sending them elsewhere. Heating is required for incineration and there will be hot gases associated with the process. Therefore there is a high potential for an industrial accident for this option. Additionally, incineration will generate airborne discharges and will therefore require the use of scrubbers which will generate liquid wastes. The requirement of a new facility for this management option will mean the generation of the most decommissioning wastes of all the options assessed. Therefore this option is expected to generate the highest amount of primary and secondary waste.

F3 Off-site disposal

This option would involve de-watering the waste and disposing of the sludge to an appropriate off-site landfill facility. There is a precedent for off-site disposal of exempt waste therefore this option was considered the most practical to implement. The processing (de-watering) of the waste is already carried out using existing DSRL staff and facilities therefore there should be little additional visual impact from the implementation of the option and the option is also likely to be the most cost effective to implement.

This option involves sending waste off-site to be managed elsewhere and therefore is least favourable in terms of public perception. However, this option will generate the least amount of discharges to air and water and the least amount of primary and secondary waste at DSRL, as the waste is disposed off-site.

4.3.1.3 Screened out options

F4 Low temperature oxidation

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be treated by a low temperature oxidation process (e.g. Silver II) in order to remove the organic content of the waste. The remaining inorganic solids would be managed as Exempt waste.

This option was screened out as it is not necessary to remove the organic content of Putrescible Exempt wastes in order that they can be disposed to landfill. They can be disposed directly in their current form.

F5 Bioremediation

This option would first involve separating the solid and liquid parts of the sludge using a technology such as filtration, dewatering or drying. The liquid part would then be directly discharged or evaporated. The solid part would then be bioremediated and the residual solid wastes managed as Exempt waste. Ex-situ bioremediation is a process whereby solid waste is added to a bioreactor, and microbes are used to decompose the organic material.

This option was screened out as it is not necessary to remove the organic content of Putrescible Exempt wastes in order that they can be disposed to landfill. They can be disposed directly in their current form.

4.3.2 Clean Sludges (Putrescibles)

The Putrescible Sludges are the solid wastes trapped from the sewage produced on the Dounreay site. The sludges are bio-hazardous. This waste stream has been split into LLW, Exempt and Clean Hazardous waste until characterisation can identify the appropriate waste category (see Section 4.2.5 for further details).

4.3.2.1 Current DSRL Waste Management Strategy

See Section 4.2.5.1 for further details.

4.3.2.2 Options to be taken forward to scoring assessment

Clean waste will follow the same route as other Clean Hazardous materials generated on the DSRL site. It was agreed that this was the only feasible option for the Clean Putrescible Sludges, recognising the fact that the sludges would need to be de-watered before being sent off-site to an appropriate landfill facility. Therefore, there was no scoring exercise carried out for Clean wastes.

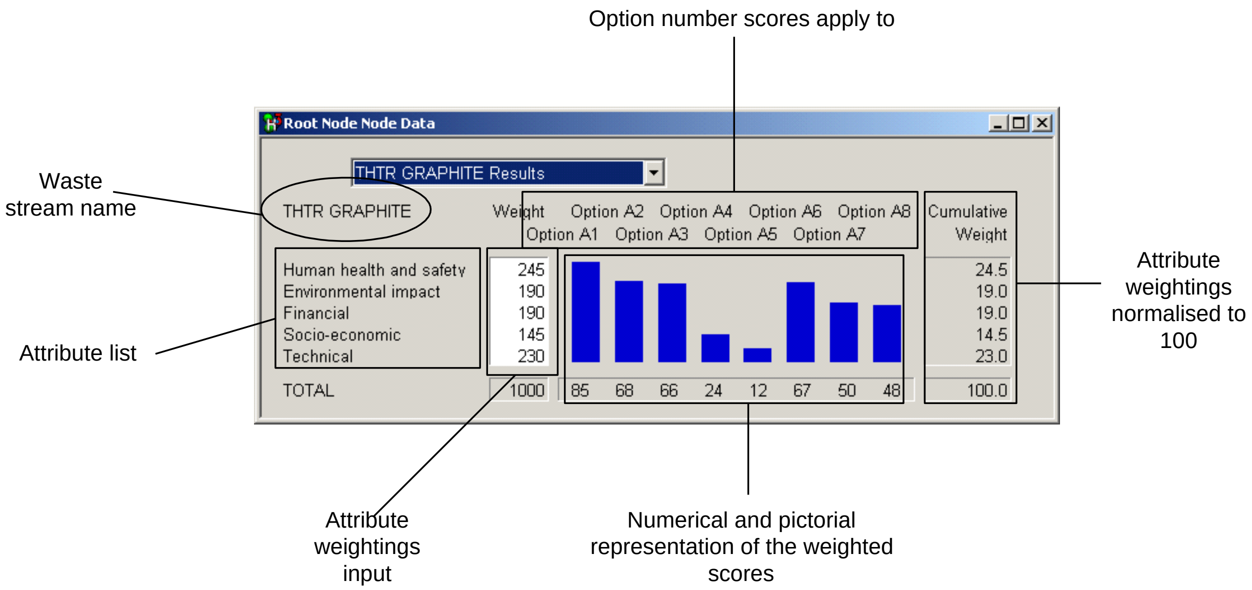
5 RESULTS

5.1 Introduction and Methodology

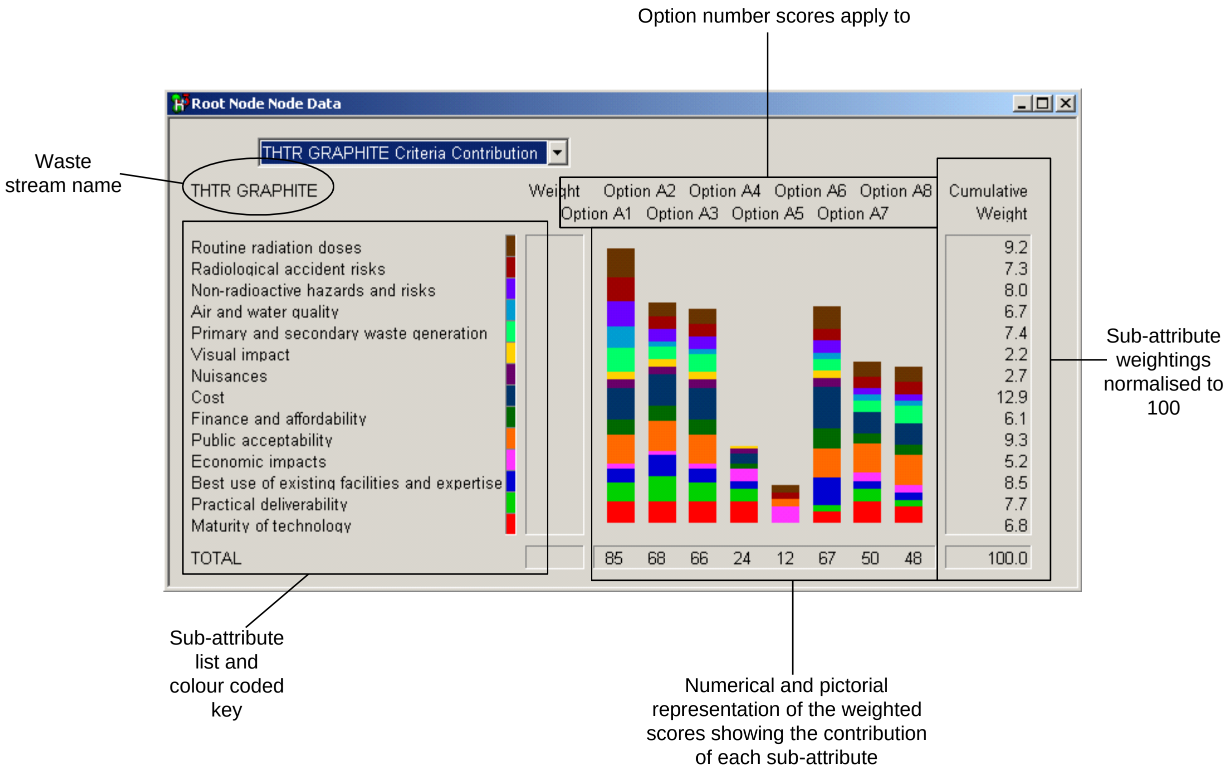
This section provides an overview of the scores obtained from the 2008 DSRL Site Waste BPEO Workshop and the results of applying the various weightings to the data. For each waste stream the following data are presented:

1. A table summarising the waste management options and the assigned option number which is used as a short-hand identifier when discussing the options;
2. A table summarising the scores allocated and the swing weighting assigned during the workshop, the unweighted total score and the normalised total score for each waste management option. The normalisation is carried out to allow the comparison of these data with data which has had swing and significance weighting(s) applied;
3. A Hi-View plot showing the overall scores at the attribute level when the attribute and sub-attribute weightings are applied;
4. A Hi-View plot showing the overall scores and the contribution of each sub-attribute to that score when the attribute and sub-attribute weightings are applied;
5. A Hi-View plot showing the overall scores at the attribute level when the swing, attribute and sub-attribute weightings are applied;
6. A Hi-View plot showing the overall scores and the contribution of each sub-attribute to that score when the swing, attribute and sub-attribute weightings are applied.

The Hi-View plots (such as Figure 20 to Figure 23 and the example plots below) show the outputs obtained from Hi-View. Two different types of plot are presented; the first shows an example of the overall normalised scores for the weightings applied (e.g. Figure 20 and Figure 22) and the second plot shows an example of the individual contributions for each sub-attribute to the final score obtained for the weightings applied (e.g. Figure 21 and Figure 23). Both of these plots are derived from the same data source and show different aspects of the same data. A summary of the information contained within the plots is given below:



The attribute weightings input are derived from the average attribute weightings determined from each workshop attendee's attribute scoring and these are used to determine the cumulative weightings which in turn are used by Hi-View to calculate the attribute scores. Hi-View only allows integer inputs so the percentage values are inputted as per-thousand values to ensure the correct cumulative weight is obtained. These are constant for all waste streams. The numerical and pictorial representation of the weighted scores shows the final score for each option for the particular weighting system used. Different weighting systems will give different sets of scores.



The sub-attribute cumulative weightings are derived from the average weightings determined from each workshop attendee's attribute and sub-attribute scoring. These are constant for all waste streams. The numerical and pictorial representation of the weighted scores shows the final score for each option for the particular weighting system used. Different weighting systems will give different sets of scores.

A comparison of the normalised raw data, the attribute/sub-attribute and swing/attribute and sub-attribute data is discussed in Section 6.

5.2 Radioactive Wastes

Of the radioactive waste streams considered as part of this study, 4 were determined to require further consideration of their current waste management strategy against alternative waste management strategies. These were CHILW Graphite (THTR Graphite and Activated Graphite), LLW Sludge (LSA Scale), LLW Sludge (Granular), and LLW Sludge (Putrescibles). The finalised management options and the results of the scoring exercise are presented below along with the results of the data analysis.

5.2.1 CHILW Graphite (THTR Graphite)

The options scored in the workshop are listed below. An overview of each of the management options can be found in Section 4.2.1:

Option no.	Description
A1	Encapsulate in 200l drums the cement in 500l drums
A2	Encapsulate loose in cement in 500l drums
A3	Encapsulate loose in polymer in 500l drums
A4	Reprocess to extract Th/U
A5	Thermal treatment
A6	Co-Package
A7	Encapsulate loose in cement in $3m^3$ drums
A8	Encapsulate loose in polymer in $3m^3$ drums

The results of the workshop scoring against the sub-attributes are presented below in Table 5 and this represents the raw data and the normalised totals (referred to as the normalised raw data) are used when comparing these data with the Hi-View data. Figure 20 shows the Hi-View output summarising the total scores for each option for the attribute and sub-attribute weighted data. Figure 21 shows the breakdown by sub-attribute of the weighted scores. Figure 22 shows the Hi-View output summarising the total scores for each option for the data which firstly has the swing weighting applied to it followed by the attribute and sub-attribute weightings. Figure 23 shows the breakdown by sub-attribute of the weighted scores.

Table 5: Summary of raw scores, swing weights, total raw scores and normalised total raw data for THTR graphite management options

Attributes	Sub-attributes	Encapsulate material in 200l drums and cement in 500l drums (Option A1)	Encapsulate in cement in 500l drums (loose) (Option A2)	Encapsulate in polymer in 500l drums (loose) (Option A3)	Reprocess to extract U/Th (Option A4)	Thermal treatment (Option A5)	Co-package (Option A6)	Encapsulate in cement in $3m^3$ drums (loose) (Option A7)	Encapsulate in polymer in $3m^3$ drums (loose) (Option A8)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	100	50	50	0	25	75	50	50	5
	Radiological accident risks	100	50	50	0	25	50	50	50	5
	Non radioactive hazards and risks	100	50	50	0	0	50	25	25	10
2. Environmental Impact	Air and water quality	100	25	25	0	0	25	25	25	10
	Primary and secondary waste generation (solid)	100	50	75	0	0	50	50	75	10
	Visual impact	100	100	100	50	0	100	0	0	1
	Nuisances	100	100	100	50	0	100	0	0	1
3. Financial	Cost	75	75	75	25	0	100	50	50	10
	Financeability / affordability	75	75	75	25	0	100	50	50	1
4. Socio-economic	Public acceptability	100	100	100	0	25	100	100	100	10
	Economic impacts	25	25	25	75	100	0	50	50	5
5. Technical	Making best use of existing facilities and expertise	50	75	50	25	0	100	25	25	10
	Practical deliverability	75	100	75	50	0	25	50	25	5
	Maturity of technology	100	100	100	100	0	50	100	75	5
Un-weighted Totals		1200	975	950	400	175	925	625	600	
Normalised Totals		21	17	16	7	3	16	11	10	

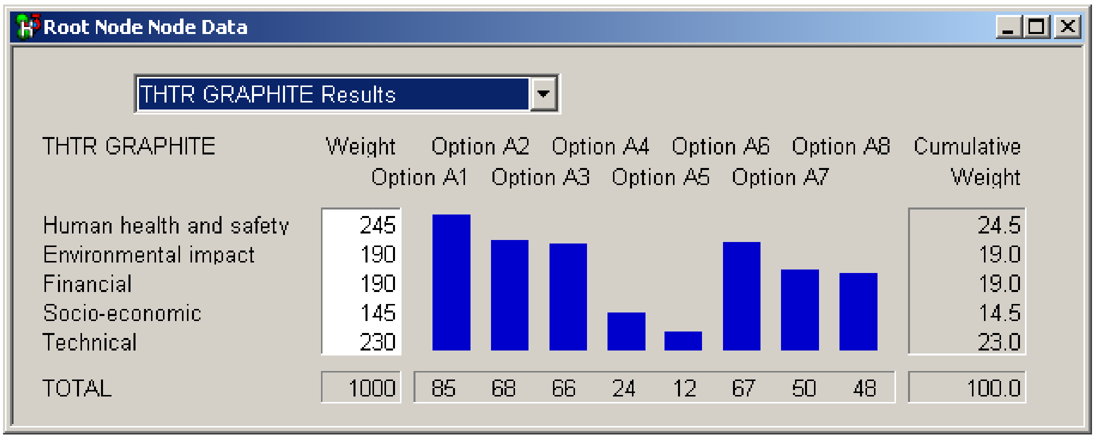


Figure 20: Results of applying attribute and sub-attribute weighting to the THTR graphite raw data

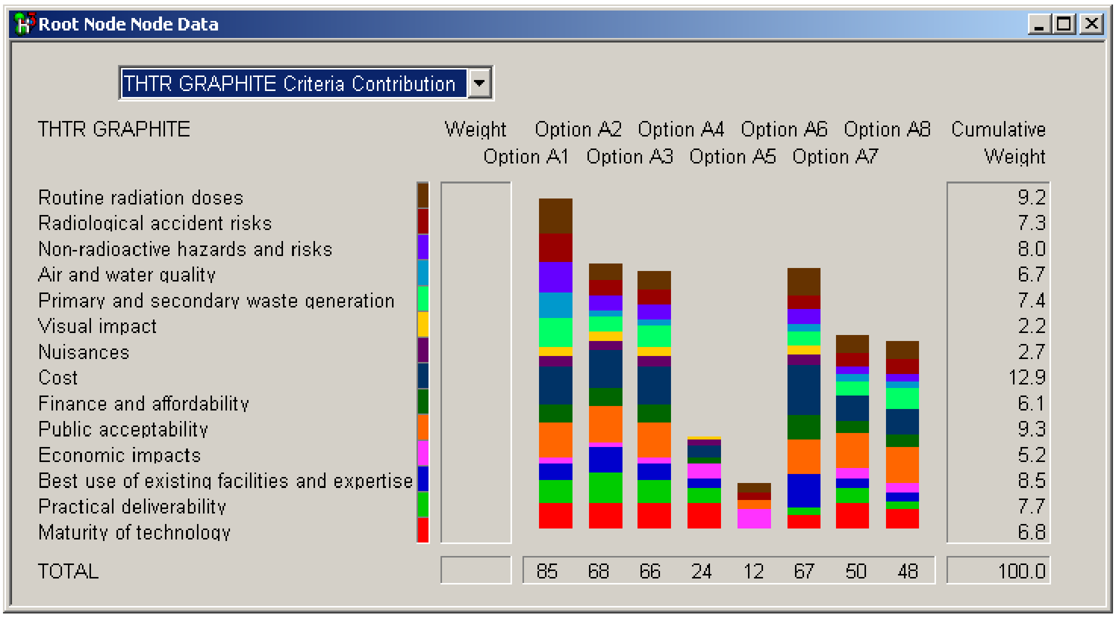


Figure 21: Breakdown (by sub-attribute) of attribute and sub-attribute weighted scores for THTR graphite

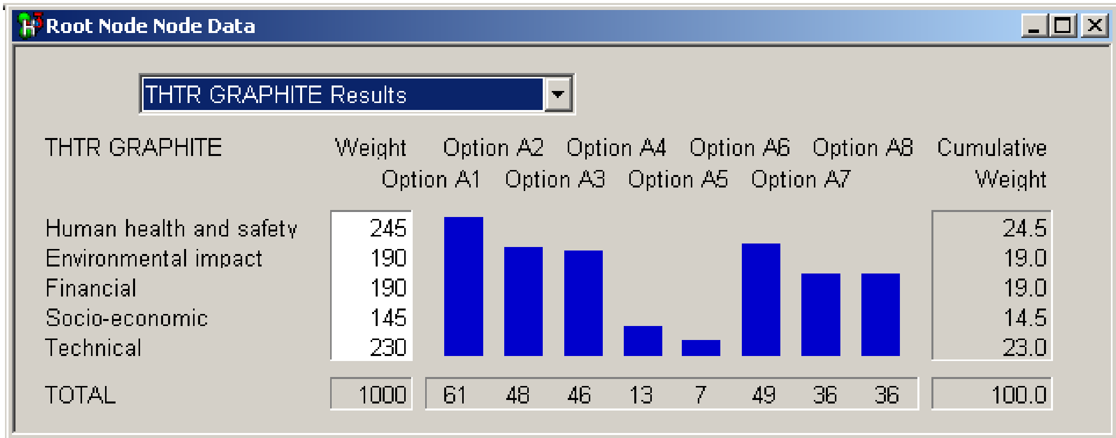


Figure 22: Results of applying swing, attribute and sub-attribute weightings to the THTR graphite raw data

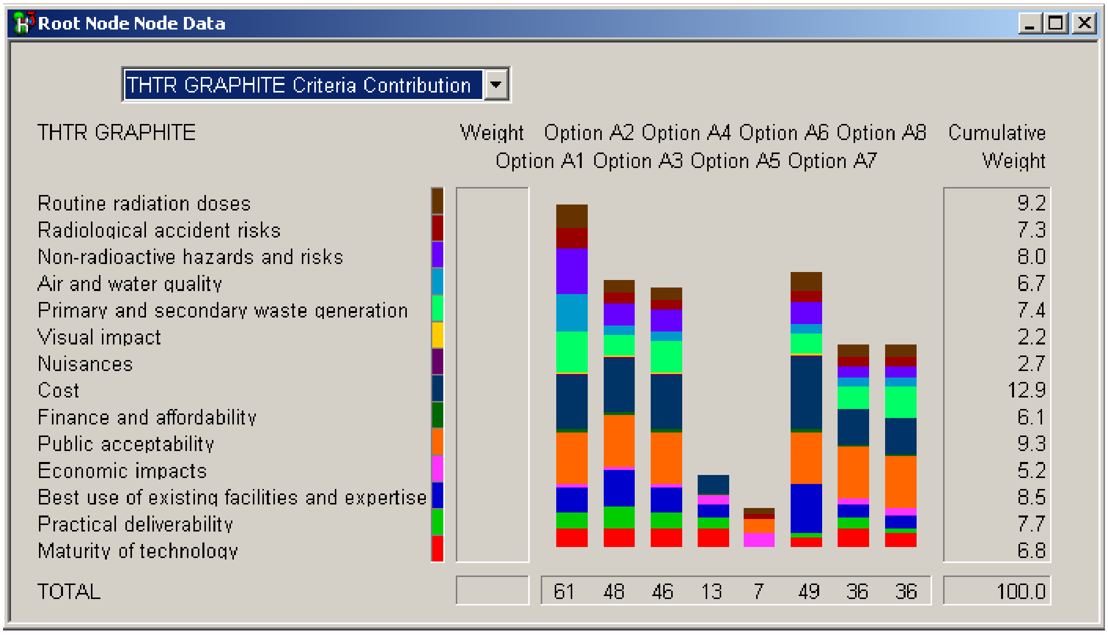


Figure 23: Breakdown (by sub-attribute) of swing, attribute and sub-attribute weighted scores for THTR graphite

A comparison of the normalised raw data with the results of the application of various weighting systems (as shown in Figure 20 and Figure 22) demonstrates that the preferred option (Option A1: Encapsulate in 200l drums then cement in 500l drums) is the same for each. This is the current DSRL management strategy for this type of waste material.

5.2.2 CHILW Graphite (Activated Graphite)

The options scored in the workshop are listed below. An overview of each of the management options can be found in Section 4.2.2:

Option no.	Description
B1	Package unencapsulated in 4m boxes
B2	Package and encapsulate (unshielded boxes)
B3	Package unencapsulated (unshielded boxes)
B4	Incineration to decontaminate
B5	High temperature processing
B6	Crush and treat as THTR

The results of the workshop scoring against the sub-attributes are presented below in Table 6 and this represents the raw data. Figure 24 shows the Hi-View output summarising the total scores for each option for the attribute and sub-attribute weighted data. Figure 25 shows the breakdown by sub-attribute of the weighted scores. Figure 26 shows the Hi-View output summarising the total scores for each option for the data which firstly has the swing weighting applied to it followed by the attribute and sub-attribute weightings. Figure 27 shows the breakdown by sub-attribute of the weighted scores.

Table 6 Summary of raw scores, swing weights, total raw scores and normalised total raw scores for Activated Graphite management options

Attribute	Sub-attribute	Package unencapsulated (4m boxes) (Option B1)	Package and encapsulate (unshielded boxes) (Option B2)	Package unencapsulated (unshielded boxes) (Option B3)	Incineration to decontaminate (Option B4)	High temperature processing (Option B5)	Crush and treat as THTR (Option B6)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	100	100	100	25	25	0	1
	Radiological accident risks	75	100	75	25	25	0	5
	Non radioactive hazards and risks	100	75	75	0	0	0	10
2. Environmental Impact	Air and water quality	100	75	100	0	0	25	10
	Primary and secondary waste generation (solid)	100	75	75	25	25	0	10
	Visual impact	100	100	100	0	0	50	1
	Nuisances	100	100	100	0	0	50	1
3. Financial	Cost	100	100	100	0	0	25	10
	Financeability / affordability	100	100	100	0	0	25	10
4. Socio-economic	Public acceptability	75	100	75	0	0	50	5
	Economic impacts	0	0	0	100	100	75	1
5. Technical	Making best use of existing facilities and expertise	100	100	100	0	0	50	10
	Practical deliverability	75	100	75	0	0	50	5
	Maturity of technology	75	100	100	25	0	50	5
Un-weighted totals		1200	1225	1175	200	175	450	
Normalised Totals		27	28	27	5	4	10	

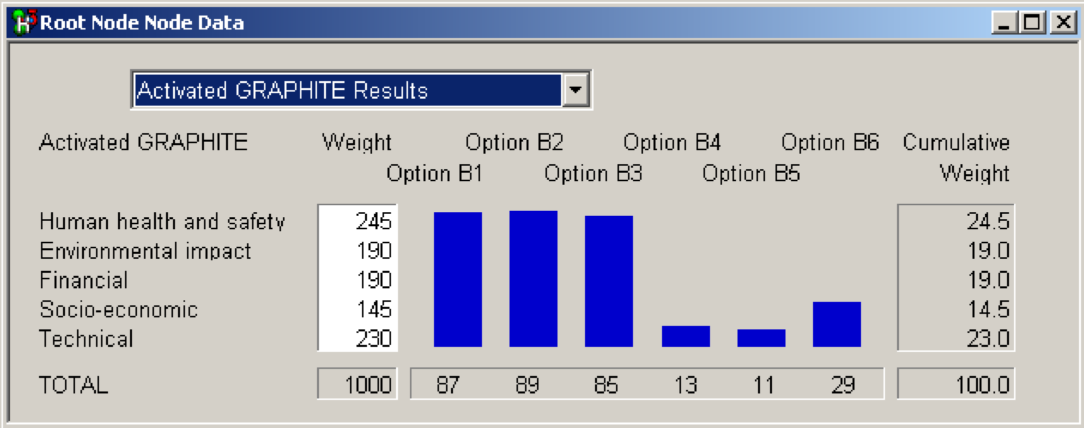


Figure 24: Results of applying attribute and sub-attribute weighting to the Activated Graphite raw data

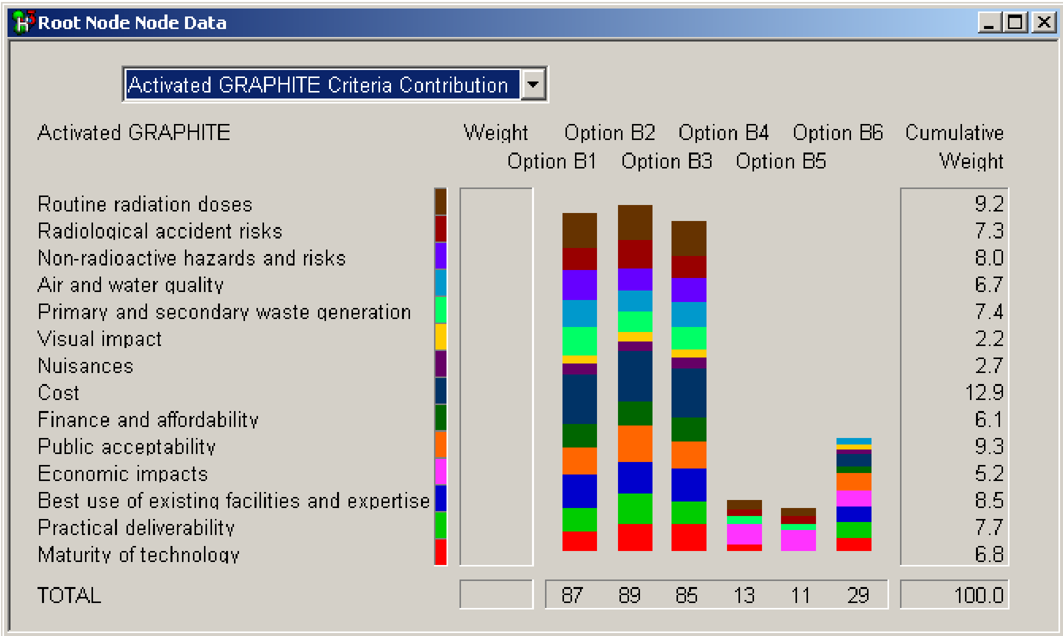


Figure 25: Breakdown (by sub-attribute) of attribute and sub-attribute weighted scores for Activated graphite

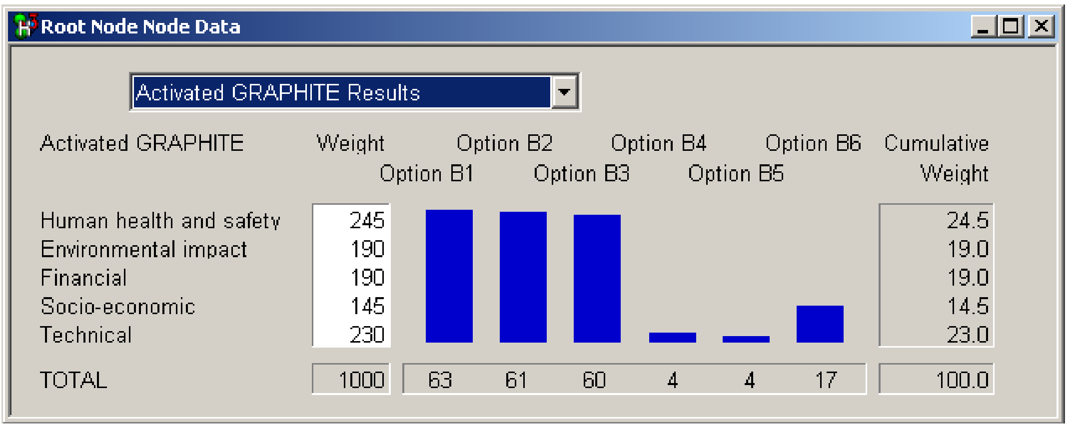


Figure 26: Results of applying swing, attribute and sub-attribute weighting to the Activated Graphite raw data

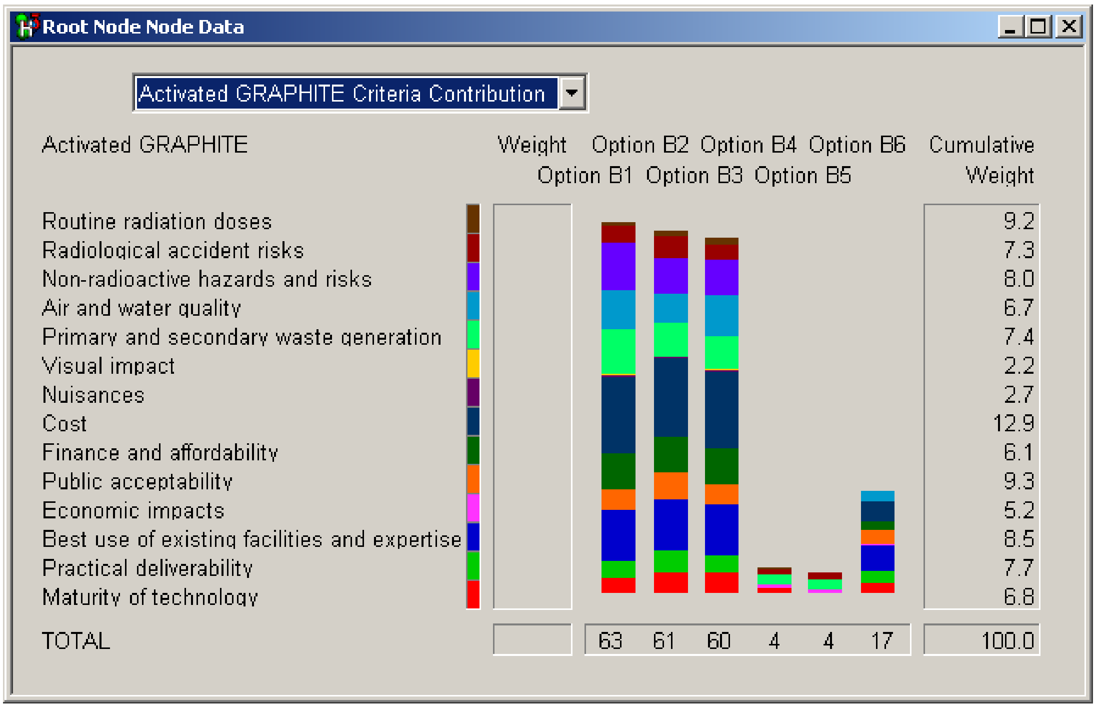


Figure 27: Breakdown (by sub-attribute) of swing, attribute and sub-attribute weighted scores for Activated graphite

A comparison of the normalised raw data with the results of the application of various weighting systems (as shown in Figure 24 and Figure 26) shows there are three options which are preferred (B1: Package unencapsulated in 4m boxes, B2: Package and encapsulate (unshielded boxes), B3: Package unencapsulated (unshielded boxes)). The similarity of the scores obtained across all attributes and sub-attributes suggests that to differentiate between the three, the study may need to go to a level of detail more appropriate for the LoC process; from a strategic viewpoint there is little significant difference between the three options.

5.2.3 LLW Sludges (LSA Scale)

The options scored in the workshop are listed below. An overview of each of the management options can be found in Section 4.2.3:

Option no.	Description
C1	Package 200 litre drums in 4m boxes and encapsulate
C2	Package 200 litre drums in 4m boxes and leave unencapsulated
C3	Package 200 litre drums in unshielded boxes and leave unencapsulated
C4	Package 200 litre drums in unshielded boxes and encapsulate

Since the only four credible options involve encapsulation versus non-encapsulation in different types of NDA RWMD approved boxes the OAP agreed that the options for the management of LSA Scale did not need to be scored. The drums could be grouted into their respective boxes at some later date if DSRL decides that this is what is required and the decision between 4m boxes and unshielded boxes should be determined through BPM considerations via the LoC process.

5.2.4 LLW Sludges (Granular)

The options scored in the workshop are listed below. An overview of each of the management options can be found in Section 4.2.4:

Option no.	Description
D1	Treat as slurry
D2	Dewater, bag and treat as HVLA / LLW as appropriate

The results of the workshop scoring against the sub-attributes are presented below in Table 7 and this represents the raw data. Shaded sub-attributes were deemed by the OAP to be non-differentiating for this particular waste stream (i.e. all the attributes would score the same) and thus were not scored. Figure 28 shows the Hi-View output summarising the total scores for each option for the attribute and sub-attribute weighted data. Figure 29 shows the breakdown by sub-attribute of the weighted scores. Figure 30 shows the Hi-View output summarising the total scores for each option for the data which firstly has the swing weighting applied to it followed by the attribute and sub-attribute weightings. Figure 31 shows the breakdown by sub-attribute of the weighted scores.

Table 7 Summary of raw scores, swing weights, total raw scores and normalised total raw scores for LLW Sludges (Granular) management options

Attributes	Sub-attributes	Treat as slurry (Option D1)	Dewater, bag and dispose as HVLA/LLW (Option D2)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	100	0	1
	Radiological accident risks	100	0	1
	Non radioactive hazards and risks	0	100	5
2. Environmental Impact	Air and water quality	100	0	1
	Primary and secondary waste generation (solid)	0	100	10
	Visual impact			
	Nuisances			
3. Financial	Cost	0	100	5
	Financeability / affordability			
4. Socio-economic	Public acceptability			
	Economic impacts			
5. Technical	Making best use of existing facilities and expertise			
	Practical deliverability			
	Maturity of technology			
Un-weighted totals		300	300	
Normalised Totals		50	50	

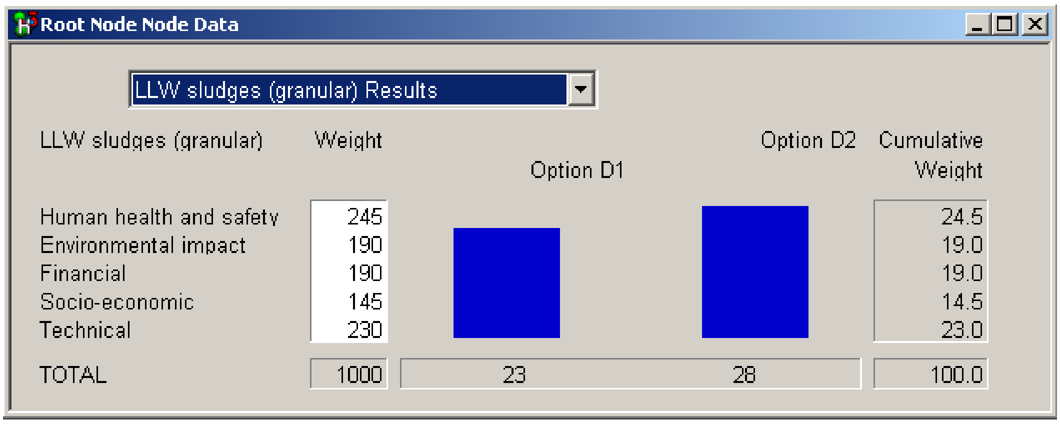


Figure 28: Results of applying attribute and sub-attribute weighting to the LLW Sludge (Granular) raw data

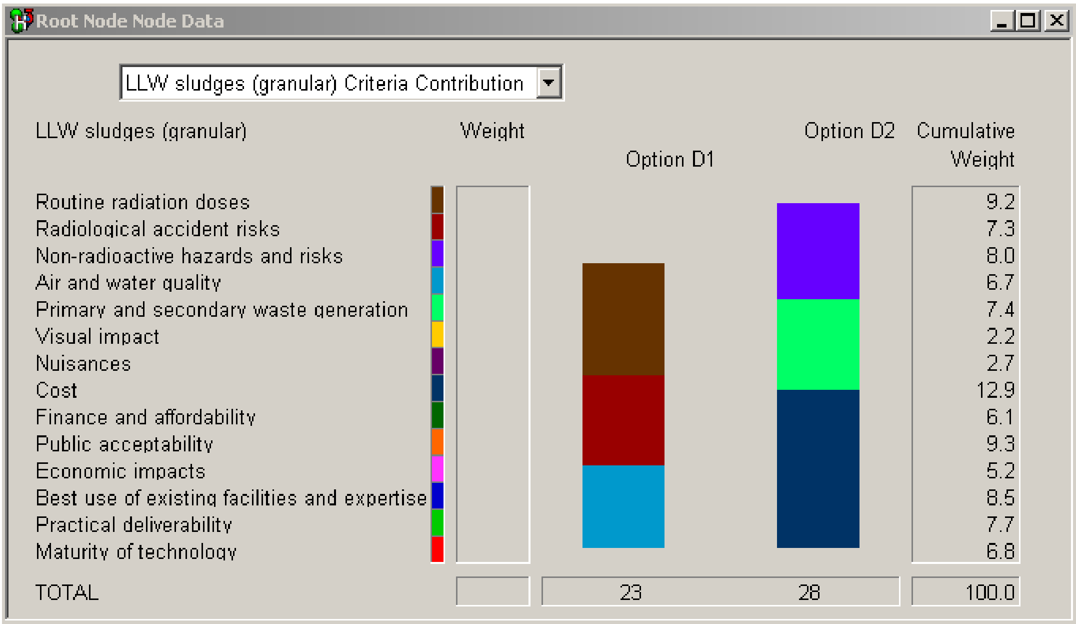


Figure 29: Breakdown (by sub-attribute) of attribute and sub-attribute weighted scores for LLW Sludge (Granular)

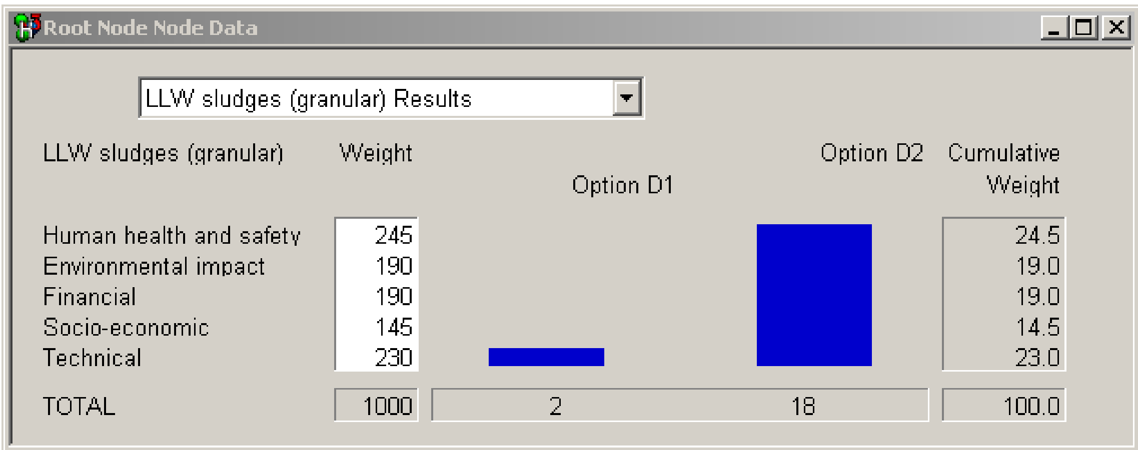


Figure 30: Results of applying swing, attribute and sub-attribute weighting to the LLW Sludge (Granular) raw data

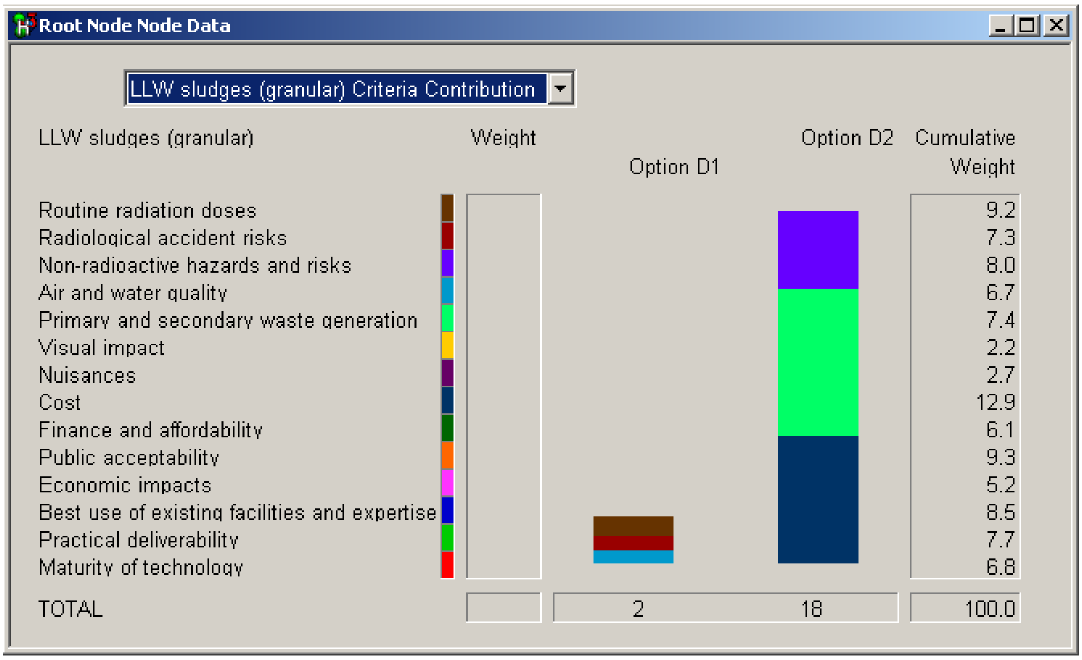


Figure 31: Breakdown (by sub-attribute) of swing, attribute and sub-attribute weighted scores for LLW Sludge (Granular)

A comparison of the raw data with the results of the application of various weighting systems (as shown in Figure 28 and Figure 30) demonstrates the preferred option is Option D2 (Dewater, bag and treat as HVLA / LLW as appropriate) for the weighted data but a marginal decision based on the un-weighted data.

5.2.5 LLW Sludge (Putrescible)

The options scored in the workshop are listed below. An overview of each of the management options can be found in Section 4.2.5:

Option no.	Description
E1	Process and incinerate offsite
E2	Process and incinerate on site
E3	Low temperature oxidation
E4	Bioremediation

The results of the workshop scoring against the sub-attributes are presented below in Table 8 and this represents the raw data. Figure 32 shows the Hi-View output summarising the total scores for each option for the attribute and sub-attribute weighted data. Figure 33 shows the breakdown by sub-attribute of the weighted scores. Figure 34 shows the Hi-View output summarising the total scores for each option for the data which firstly has the swing weighting applied to it followed by the attribute and sub-attribute weightings. Figure 35 shows the breakdown by sub-attribute of the weighted scores.

Table 8 Summary of raw scores, swing weights, total raw scores and normalised total raw scores for LLW Sludge (Putrescible) management options

Attributes	Sub-attributes	Process and incinerate off-site (Option E1)	Process and incinerate on-site (Option E2)	Low temperature oxidation (Option E3)	Bioremediation (Option E4)	Swing (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	100	100	100	0	1
	Radiological accident risks	50	50	0	100	1
	Non radioactive hazards and risks	0	25	25	100	5
2. Environmental Impact	Air and water quality	0	0	25	100	5
	Primary and secondary waste generation (solid)	100	0	0	50	5
	Visual impact	100	0	50	50	1
	Nuisances	100	0	50	50	1
3. Financial	Cost	100	0	25	50	10
	Financeability / affordability	100	0	25	50	10
4. Socio-economic	Public acceptability	0	25	50	100	5
	Economic impacts	0	100	75	50	1
5. Technical	Making best use of existing facilities and expertise	100	0	0	25	5
	Practical deliverability	0	25	0	100	5
	Maturity of technology	100	100	0	50	10
Un-weighted totals		850	425	425	875	
Normalised Totals		33	17	17	34	

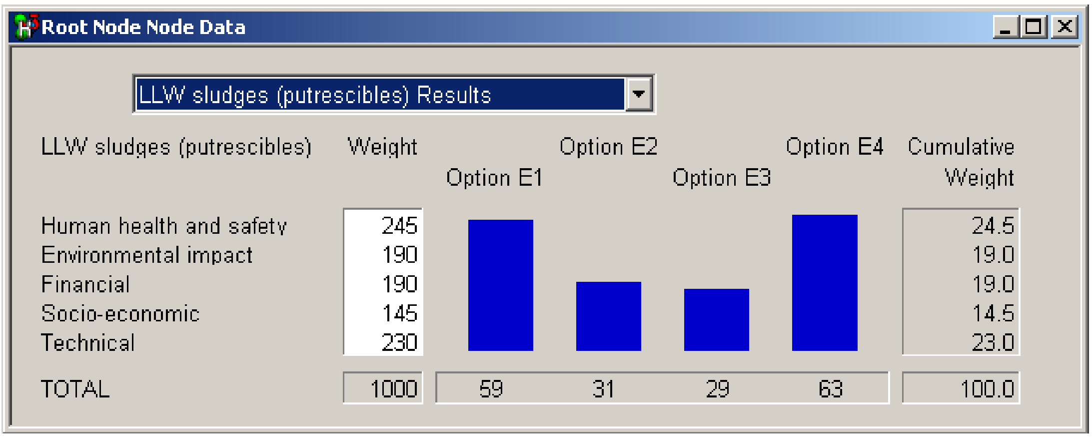


Figure 32: Results of applying attribute and sub-attribute weighting to the LLW Sludge (Putrescible) raw data

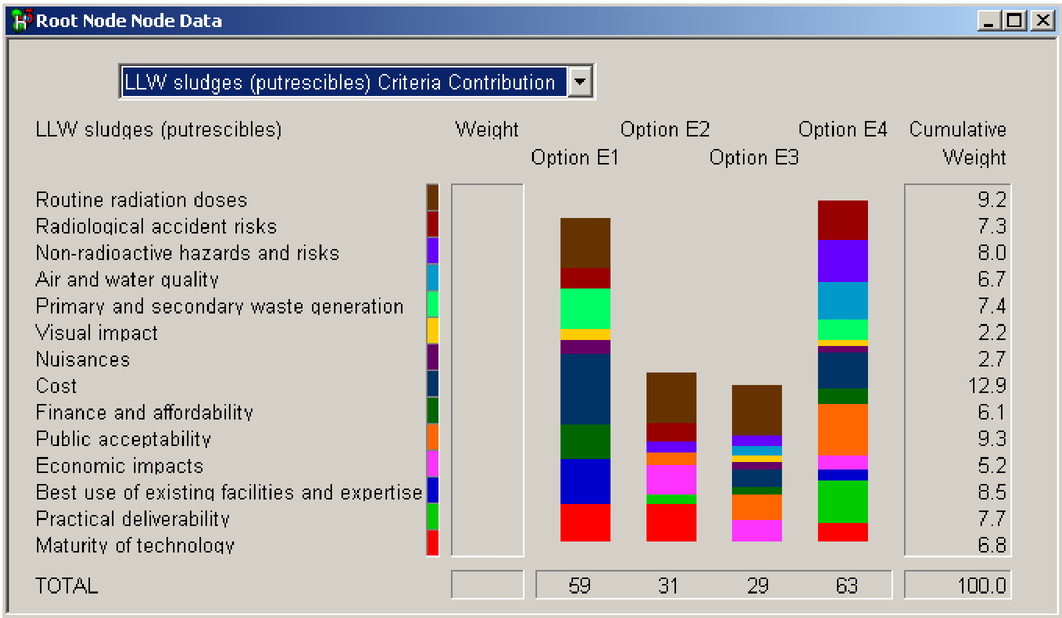


Figure 33: Breakdown (by sub-attribute) of attribute and sub-attribute weighted scores for LLW Sludge (Putrescible)

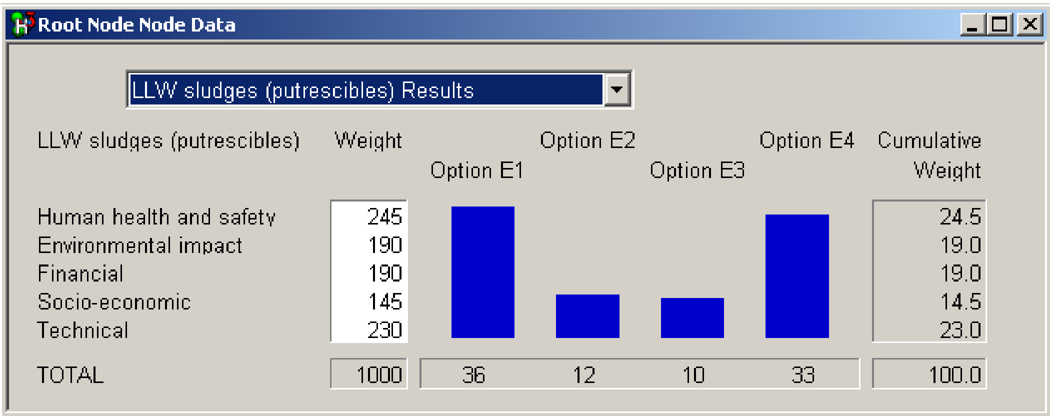


Figure 34: Results of applying swing, attribute and sub-attribute weighting to the LLW Sludge (Putrescible) raw data

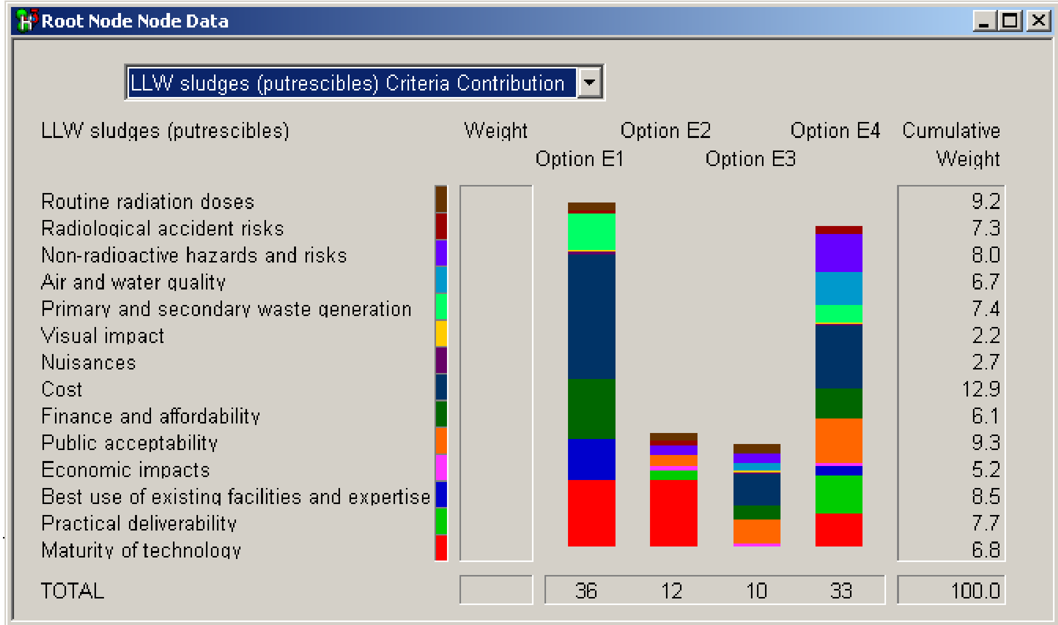


Figure 35: Breakdown (by sub-attribute) of swing, attribute and sub-attribute weighted scores for LLW Sludge (Putrescible)

A comparison of the raw data with the results of the application of various weighting systems (as shown in Figure 32 and Figure 34) demonstrates the difference between the higher ranked options (Option E1: Process and incinerate offsite and Option E4: Bioremediation) is marginal for each analysis method.

5.3 Non-Radioactive Wastes

Of the non-radioactive waste streams considered as part of this study, 2 were determined to require further consideration of their current waste management strategy. These were the Exempt Hazardous Sludge (Putrescibles) and Clean Hazardous Sludge (Putrescibles). The finalised management options and the results of the scoring exercise are presented below along with the results of the data analysis.

5.3.1 Exempt Hazardous Sludge

The options scored in the workshop are listed below. An overview of each of the management options can be found in Section 4.3.1:

Option no.	Description
F1	Process and incinerate offsite
F2	Process and incinerate on site
F3	Off-site disposal

The results of the workshop scoring against the sub-attributes are presented below in Table 9 and this represents the raw data. Shaded sub-attributes were deemed by the OAP to be non-differentiating for this particular waste stream (i.e. all the attributes would score the same) and thus were not scored. Figure 36 shows the Hi-View output summarising the total scores for each option for the attribute and sub-attribute weighted data. Figure 37 shows the breakdown by sub-attribute of the weighted scores. Figure 38 shows the Hi-View output summarising the total scores for each option for the data which firstly has the swing weighting applied to it followed by the attribute and sub-attribute weightings. Figure 39 shows the breakdown by sub-attribute of the weighted scores.

Table 9 Summary of raw scores, swing weights, total raw scores and normalised total raw scores for Exempt Sludge (Putrescibles) management options

Attributes	Sub-attributes	Process and incinerate off-site (Option F1)	Process and incinerate on-site (Option F2)	Off-site disposal (Option F3)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses				
	Radiological accident risks				
	Non radioactive hazards and risks	50	0	100	5
2. Environmental Impact	Air and water quality	0	0	100	1
	Primary and secondary waste generation (solid)	50	0	100	10
	Visual impact	100	0	100	1
	Nuisances	100	0	100	1
3. Financial	Cost	75	0	100	10
	Financeability / affordability	75	0	100	5
4. Socio-economic	Public acceptability	0	100	0	1
	Economic impacts	0	100	50	1
5. Technical	Making best use of existing facilities and expertise	100	0	100	10
	Practical deliverability	50	0	100	5
	Maturity of technology				
Un-weighted totals		600	200	950	
Normalised Totals		34	11	54	

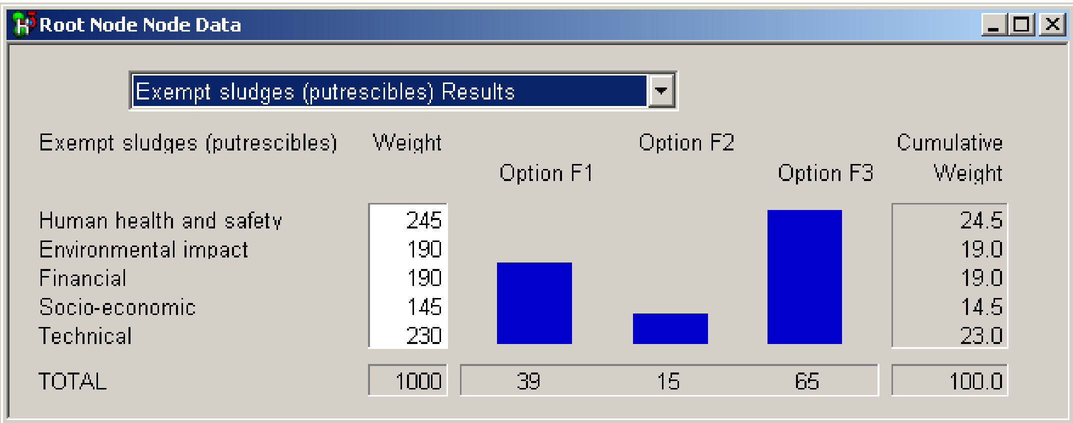


Figure 36: Results of applying attribute and sub-attribute weighting to the Exempt Sludge (Putrescible) raw data

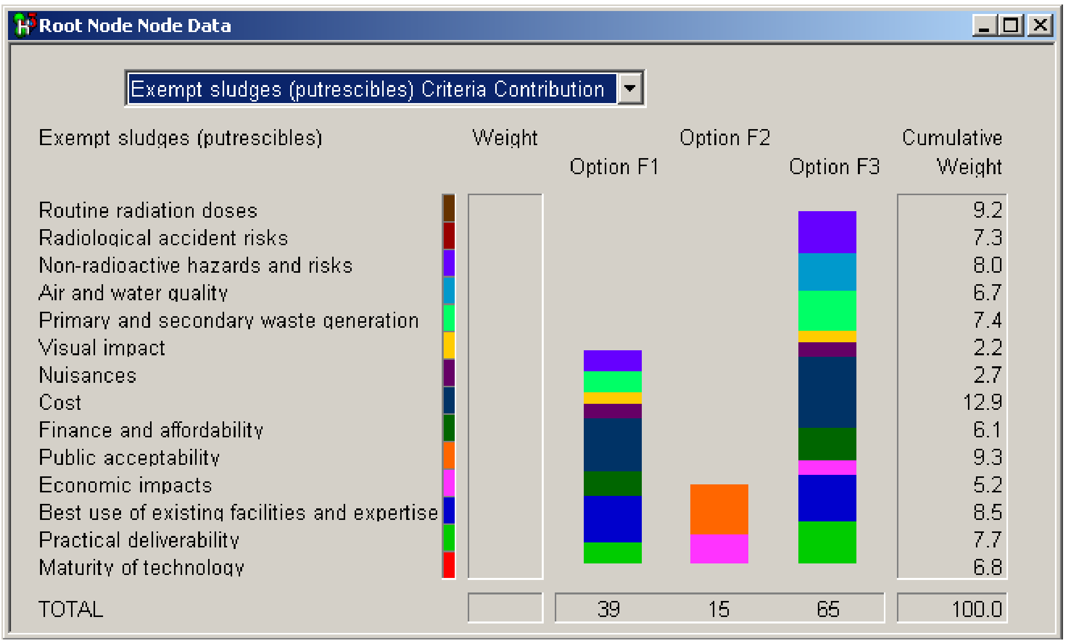


Figure 37: Breakdown (by sub-attribute) of attribute and sub-attribute weighted scores for Exempt Sludge (Putrescible)

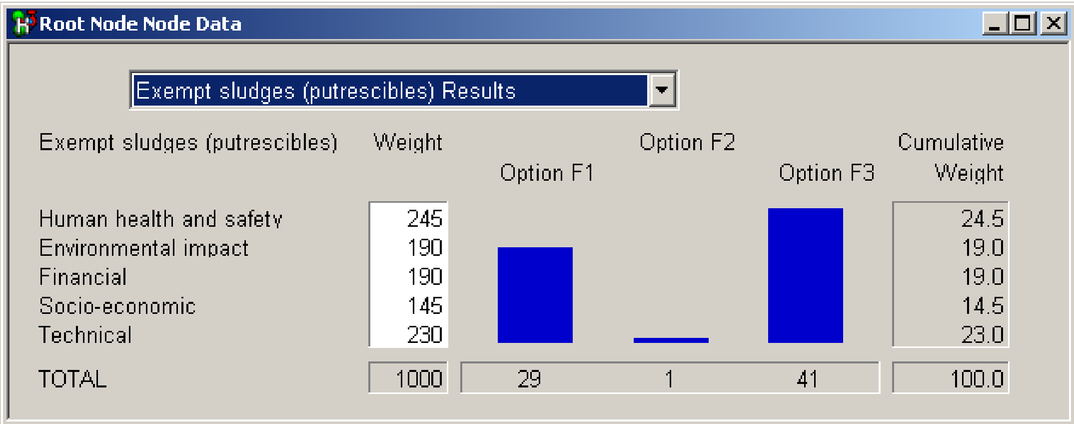


Figure 38: Results of applying swing, attribute and sub-attribute weighting to the Exempt Sludge (Putrescible) raw data

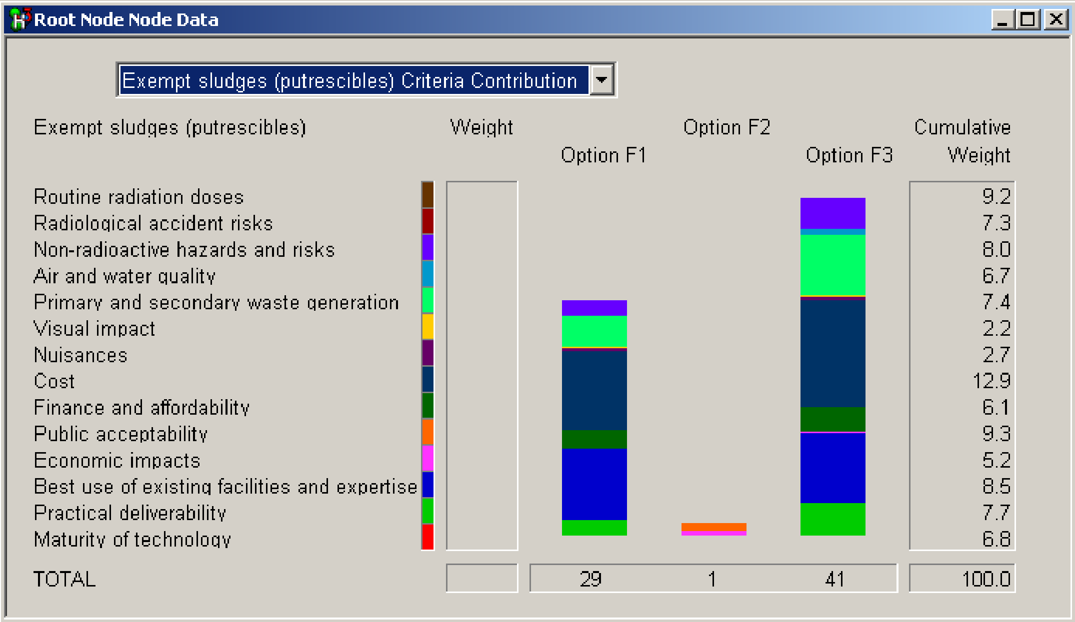


Figure 39: Breakdown (by sub-attribute) of swing, attribute and sub-attribute weighted scores for Exempt Sludge (Putrescible)

A comparison of the raw data with the results of the application of various weighting systems (as shown in Figure 36 and Figure 38) demonstrates the preferred option is Option F3 (Off-site disposal).

5.3.2 Clean Hazardous Sludge

Clean waste will follow the same route as other Clean Hazardous materials generated on the DSRL site. This was the only feasible option for the Clean Hazardous Putrescible Sludges, recognising the fact that the sludges would need to be de-watered before being sent off-site to an appropriate landfill facility. Therefore, there was no requirement for a scoring exercise for Clean wastes.

6 DISCUSSION

This section contains a discussion of the results obtained in the 2008 DSRL Site Waste BPEO Workshop and the outcome and significance of the sensitivity analysis carried out. An overview of the method used for the sensitivity analysis is included within Appendix 3.

The effects of replacing the workshop determined attribute and sub-attribute weightings with those provided by the public have also been assessed and the results of this can be found in Appendix 2. In almost all cases the differences do not change the preferred option for a given attribute when analysed by waste stream. In the few cases where the scores obtained by the public do change the preferred option for a given attribute, the change this makes to the overall total is small, especially when compared to the degree of uncertainty in the accuracy of the final scores typical for this type of workshop.

6.1 Radioactive Wastes

Waste streams included within this section are the two CHILW Graphite streams (THTR Graphite and Activated Graphite) and the three LLW Sludge streams (Granular, Putrescible and LSA Scale). With the exception of the LLW Sludge (LSA Scale) waste stream the discussion focuses on the scores obtained in the workshop in their raw form, the scores after two different weighting systems have been applied and the subsequent sensitivity analysis of data at the attribute level. As the LLW Sludge (LSA Scale) waste stream was not scored in the workshop, the discussion focuses on why this was the case.

6.1.1 CHILW THTR Graphite

The results obtained for THTR graphite are summarised in Section 5.2.1. A comparison of the raw data, the data obtained by the application of attribute/sub-attribute weightings and the data obtained by the application of swing/attribute/sub-attribute weightings (as shown in Table 5, Figure 20 and Figure 22) demonstrates the preferred option is the same for each analysis method used and is Option A1 (Encapsulate in 200l drums then cement in 500l drums). This is the current DSRL management strategy for this type of waste material.

The results of the sensitivity analysis for the application of attribute/sub-attribute weightings and swing/attribute/sub-attribute weightings are broadly the same (see Appendix 3 CHILW Graphite (THTR Graphite) Figure 40 to Figure 44 and Figure 63 to Figure 67 for sensitivity plots). For the Environmental Impact and Human Health and Safety attributes, Option A1 (Encapsulate in 200l drums the cement in 500l drums) is the preferred option over all cumulative weighting values. For the Financial, Socio-economic and Technical attributes Option A1 (Encapsulate in 200l drums the cement in 500l drums) is the preferred option at the average attribute weighting determined during the workshop and remains the preferred option over a wide range of cumulative weightings as summarised below. For these latter attributes the weighting would need to be increased 2-3 fold before other options become the preferred option. Therefore it can be concluded the decision making process is robust for THTR graphite.

Table 10: Summary of sensitivity analysis data for both swing/attribute/sub-attribute and attribute / sub-attribute weightings for THTR graphite

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option A1	0-100	
Environmental impact	19	Option A1	0-100	
Financial	19	Option A1	0-50	Above 50 Option A6 preferred
Socio-economic	14.5	Option A1	0-80	Above 80 Option A2 preferred
Technical	23	Option A1	0-60	Above 60 Option A2 preferred

a: Approximate values only

6.1.2 CHILW Activated Graphite

The results obtained for Activated Graphite are summarised in Section 5.2.2. A comparison of the normalised raw data, the data obtained by the application of attribute/sub-attribute weightings and the data obtained by the application of swing/attribute/sub-attribute weightings (as shown in Table 6, Figure 24 and Figure 26) shows there are three options which are preferred. The similarity of the scores obtained across all attributes and sub-attributes suggests that differentiating between the three may be difficult.

The results of the sensitivity analysis for the application of attribute/sub-attribute weightings are presented in Appendix 3 CHILW Graphite (Activated Graphite) (Figure 45 to Figure 49). For all of the attributes Option B2 (Package and encapsulate (unshielded boxes)) scores the highest and for all attributes (other than Environmental Impact), a significant change in weighting would be required before a different option becomes the preferred option.

Table 11: Summary of sensitivity analysis data for attribute/sub-attribute weightings only for Activated Graphite

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option B2	0-80	Marginal advantage over Options B1 and B3 at the attribute weighting
Environmental impact	19	Option B2	0-25	Marginal advantage over Options B1 and B3 at the attribute weighting
Financial	19	Option B2	0-100	Marginal advantage over Options B1 and B3 at the attribute weighting
Socio-economic	14.5	Option B2	0-100	Marginal advantage over Options B1 and B3 at the attribute weighting
Technical	23	Option B2	10-100	Marginal advantage over Options B1 and B3 at the attribute weighting

a: Approximate values only

The results of the sensitivity analysis for the application of swing/attribute/sub-attribute weightings are presented in Appendix 3 Figure 68 to Figure 72. For all of the attributes Option B1 (Package and encapsulate (unshielded boxes)) scores the highest and for all attributes (other than Environmental impact), a significant change in weighting would be required before a different option becomes the preferred option.

Table 12: Summary of sensitivity analysis data for both swing/attribute/sub-attribute weightings for Activated Graphite

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option B1	0-100	Marginal advantage over Options B2 and B3 at the attribute weighting
Environmental impact	19	Option B1	10-100	Marginal advantage over Options B2 and B3 at the attribute weighting
Financial	19	Option B1	0-100	Marginal advantage over Options B2 and B3 at the attribute weighting
Socio-economic	14.5	Option B1	0-30	Marginal advantage over Options B2 and B3 at the attribute weighting
Technical	23	Option B1	0-35	Marginal advantage over Options B2 and B3 at the attribute weighting

a: Approximate values only

Options B1 (Package unencapsulated in 4m boxes) or B2 (Package and encapsulate (unshielded boxes)) can be determined to be the highest scoring option depending on how the weightings are applied, however, the differences between Options B1, B2 and B3 (Package unencapsulated (unshielded boxes)) are small and thus no clear recommendation can be made in favour of a single option from the data obtained. On reflection this is unsurprising as the preferred three options are closely related variations on a single theme, where the differences between the options are more at the BPM level rather than the Site Waste BPEO level and thus need to be considered at a greater level of detail than is appropriate for this study. Therefore, it is recommended that Options B1, B2 and B3 are represented by single option for the purpose of Site Waste BPEO and this option is the preferred management option as summarised below:

> 'Package the waste, in accordance with NDA RWMD guidance, for eventual consignment to the proposed ILW repository. This can be in either an encapsulated or an unencapsulated form.'

6.1.3 LLW Sludges (LSA Scale)

Four credible waste management options were generated for this waste stream. However, the differences between the options were deemed to be at the BPM level and thus the options were not scored as part of the 2008 DSRL Site Waste BPEO Workshop. The preferred waste management strategy is summarised as:

'Package the waste, in accordance with NDA RWMD guidance, for eventual consignment to the proposed ILW repository. This can be in either an encapsulated or an unencapsulated form.'

6.1.4 LLW Sludges (Granular)

The results obtained for the LLW Sludges (Granular) wastes are summarised in Section 5.2.4. The assessment of this waste stream differs from the others in that only three of the five attributes were scored as all of the sub-attributes within the Socio-economic and Technical attributes were deemed to be non-differentiating and thus not scored. Other non-differentiating sub-attributes were Visual Impact, Nuisances (both part of the Environmental Impact attribute) and Financeability/Affordability (part of the financial attribute).

Analysis of the raw data (as shown in Table 7) shows both options to be identical overall but analysis of the attribute/sub-attribute and swing/attribute/sub-attribute weighted data (Figure 28 and Figure 30) suggests Option D2 (Dewater, bag and treat as HVLA/LLW as appropriate) is the preferred option.

The results of the sensitivity analysis for the application of attribute/sub-attribute and swing/attribute/sub-attribute weightings are presented in Appendix 3 LLW Sludge (Granular) Figure 50 to Figure 52 and Figure 73 to Figure 75. When the scores are weighted using the swing, attribute and sub-attribute weightings, Option D2 is the preferred option for all attributes over all cumulative weightings. If only the attribute/sub-attribute weightings are applied then Option D2 is the highest scoring option for each attribute at the weightings determined in the workshop and for environmental impact this is the preferred option over the full range of cumulative weightings. For Human Health and Safety the assigned attribute weighting would need to increase from 24.5% to above 35% before Option D1 becomes the preferred option and for the financial attribute the weighting would need to reduce from 19% to below 12% before D1 becomes the preferred option.

Table 13: Summary of sensitivity analysis data for attribute/sub-attribute weightings for LLW Sludges (Granular)

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option D2	0-35	Above 35 Option D1 preferred
Environmental impact	19	Option D2	0-100	
Financial	19	Option D2	10-100	Below 10 Option D1 preferred
Socio-economic				Not scored
Technical				Not scored

a: Approximate values only

Option D2 (Dewater, bag and treat as HVLA/LLW as appropriate) is deemed to be the preferred management option compared to the current management option represented by Option D1 (Treat as slurry). A BPM study for this waste is planned for 2009 and this will help further determine how the waste will be managed.

6.1.5 LLW Sludges (Putrescible)

The workshop results for the LLW Sludges (Putrescible) waste stream are summarised in Section 5.2.5. A comparison of the raw data, the data obtained by the application of attribute/sub-attribute weightings and the data obtained by the application of swing/attribute/sub-attribute weightings (as shown in Table 8, Figure 32 and Figure 34) shows there are two preferred options, Option E1 (Process and incinerate offsite) and Option E4 (Bioremediation).

The results of the sensitivity analysis for the application of attribute/sub-attribute weightings are presented in Appendix 3 LLW Sludge (Figure 53 to Figure 57). Option E4 scores the highest for all attributes at the significance weighting for that attribute, however, the difference between the preferred option and the next highest scoring option (Option E1) is marginal and therefore there is only a slight preference for Option E4.

For the Environmental Impact and Human Health and Safety attributes, Option E4 is the preferred option over the full range of cumulative weightings and for the Technical attribute a significant increase in the cumulative weighting is required (increase from 23% to 45%) to switch the preferred option to Option E1. A smaller change in the cumulative weightings for the remaining attributes would give rise to a change in the preferred option for that attribute. For the Financial attribute, an increase in cumulative weighting from 19% to 25% would result in Option E1 becoming the preferred option. For the Socio-economic attribute the same result is obtained by reducing the cumulative weighting from 14.5% to 10%.

Table 14: Summary of sensitivity analysis data for attribute/sub-attribute weightings only for LLW Sludges (Putrescibles)

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option E4	0-100	
Environmental impact	19	Option E4	0-100	
Financial	19	Option E4	0-25	Above 25 Option E1 preferred
Socio-economic	14.5	Option E4	10-100	Below 10 Option E1 preferred
Technical	23	Option E4	0-45	Above 45 Option E1 preferred

a: Approximate values only

The results of the sensitivity analysis for the application of swing/attribute/sub-attribute weightings are presented in Appendix 3 (Figure 76 to Figure 80). In contrast to the above analysis, once the swing weightings are included in the analysis the preferred option switches from Option E4 to Option E1 both in terms of the overall score and as the preferred option for each attribute at the appropriate cumulative weightings determined in the workshop. However, the actual difference between Option E1 and E4 for each attribute is marginal at the cumulative weightings determined in the workshop.

For the Technical attribute, Option E1 is the preferred option over the full range of cumulative weightings and for the Environmental Impact attribute a significant increase in the cumulative weighting is required (increase from 19% to 40%) to switch the preferred option to Option E4. A smaller change in the cumulative weightings for the remaining attributes would give rise to a change in the preferred option for that attribute. An increase in cumulative weighting for the Socio-economic attribute (from 14.5% to 20%) and Human Health and Safety attribute (24.5% to 35%) would result in Option E4 becoming the preferred for each attribute respectively. Conversely, a reduction in the Financial attribute weighting from 19.5% to 15% would result in Option E4 becoming the preferred option for that attribute.

Table 15: Summary of sensitivity analysis data for swing/attribute/sub-attribute weightings only for LLW Sludges (Putrescibles)

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option E1	0-35	Above 35 Option E4 preferred
Environmental impact	19	Option E1	0-40	Above 40 Option E4 preferred
Financial	19	Option E1	15-100	Below 15 Option E4 preferred
Socio-economic	14.5	Option E1	0-20	Above 20 Option E4 preferred
Technical	23	Option E1	0-100	

a: Approximate values only

There is no clearly preferred option for the management of LLW Sludges (Putrescibles). Two lead candidates have been identified, Option E1 (off-site incineration) and Option E4 (bioremediation). Depending on the analysis method applied either of these two management methods can be the top scoring method although the difference is only marginal in each case. However, since the BPEO Workshop, characterisation has demonstrated that there are no current waste holdings that fall into this waste category.

6.2 Non-Radioactive Wastes

Waste streams included within this section are the Clean and Exempt Hazardous Sludge (Putrescible) waste streams. The Exempt Hazardous Sludge (Putrescible) waste stream discussion focuses on the scores obtained in the workshop in their raw form and the scores after two different weighting systems have been applied and the subsequent sensitivity analysis of data at the attribute level. The Clean Hazardous Sludge (Putrescible) waste stream was not scored as there was only one credible waste management option identified and thus has only limited discussion associated with it.

6.2.1 Exempt Hazardous Sludges (Putrescible)

The workshop results for the Exempt Hazardous Sludge (Putrescible) waste stream are summarised in Section 5.3.1. A comparison of the raw data, the data obtained by the application of attribute/sub-attribute weightings and the data obtained by the application of swing/attribute/sub-attribute weightings (Table 9, Figure 34 and Figure 36 respectively) shows Option F3 (offsite disposal) to be the preferred waste management option.

The results of the sensitivity analysis for the application of attribute/sub-attribute weightings and swing/attribute/sub-attribute weightings are presented in Appendix 3 Exempt Sludge (Figure 58 to Figure 62 and Figure 81 to Figure 85). For all analysis methods used, Option F3 scores the highest for all attributes at the significance weighting for that attribute.

For the Human Health and Safety, Environmental Impact, Financial and Technical attributes Option F3 is the preferred option over the full range of cumulative weightings for all the analysis methods.

For the Socio-economic attribute a significant increase in the cumulative weighting is required before Option F2 becomes the preferred management method. For the attribute/sub-attribute weighting method this occurs when the cumulative weighting is increased from 14.5% to 47% and for the swing/attribute/sub-attribute weighting method the increase is from 14.5% to 85%.

Table 16: Summary of sensitivity analysis data for attribute/sub-attribute weightings only for Exempt Hazardous Sludges (Putrescibles)

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option F3	0-100	
Environmental impact	19	Option F3	0-100	
Financial	19	Option F3	0-100	
Socio-economic	14.5	Option F3	0-45	Above 45 Option F2 preferred
Technical	23	Option F3	0-100	

a: Approximate values only

Table 17: Summary of sensitivity analysis data for swing/attribute/sub-attribute weightings only for Exempt Hazardous Sludges (Putrescibles)

Attribute	Ave cumulative weighting (from workshop)	Preferred option at Ave weighting	Weighting range where this is preferred option[a]	Comment
Human health and safety	24.5	Option F3	0-100	
Environmental impact	19	Option F3	0-100	
Financial	19	Option F3	0-100	
Socio-economic	14.5	Option F3	0-85	Above 85 Option F2 preferred
Technical	23	Option F3	0-100	

a: Approximate values only

Option F3 (off-site disposal) is deemed to be the preferred management option for this waste stream and the decision making process is deemed robust. Since the BPEO Workshop, characterisation has demonstrated that the current waste holdings are exempt.

6.2.2 Clean Hazardous Sludges (Putrescible)

The waste BPEO process has identified that clean Hazardous Sludges (Putrescible) waste will follow the same route as other Clean Hazardous materials generated on the DSRL site. It was agreed at the BPEO Workshop that this was the only feasible option for the Clean

Hazardous Putrescible Sludges and as a result of this scoring was not required. However, since the BPEO Workshop, characterisation has demonstrated that there are no current waste holdings that fall into this waste category.

7 CONCLUSIONS

The Site Waste BPEO Workshop was used to identify the waste streams on the Dounreay site that should be included or excluded from the BPEO assessment. Waste streams were included where there was scope for further assessment or consideration of the waste strategy as determined by:

- The review of national and international best practice on waste minimisation;
- Existence of current waste stream specific BPEO studies;
- Underpinning of the management strategy through the LoC process;
- Maturity of the management strategy with respect to the current status of waste management facilities;
- Application of the waste hierarchy.

It was concluded that the current waste management strategies for the gaseous and all RHILW waste streams did not require further consideration along with most of the CHILW waste streams. It was also concluded that the majority of the LLW, HVLA, Clean and Exempt waste streams did not require review. The following waste streams were identified as requiring further assessment:

1. Solid CHILW Graphite – THTR Graphite and Activated Graphite
2. LLW Sludge - LSA Scale, Granular, and Putrescible
3. Clean and Exempt Hazardous Sludge - Putrescible

For each of these waste streams, a description of the current management strategy was agreed and alternatives were then generated and discussed. Once the options were finalised they were scored against 14 sub-attributes, selected from DSRL [3] and regulatory guidance [2], and organised into the following 5 attribute groups:

- Group 1- Human Health and Safety
- Group 2- Environmental Impacts
- Group 3- Financial
- Group 4- Socio-Economic
- Group 5- Technical

After the options were scored for each waste stream, the data underwent three different weighting methods to better understand the influence the weighting methods have on the outcome. The methods used were:

- No weighting (raw data analysed)
- The application of attribute and sub-attribute weighting
- The application of swing, attribute and sub-attribute weighting

The results of the three methods were then used in conjunction with the sensitivity analysis to select the preferred management option(s) and to assess how robust the choice is to changes in attribute weighting. A summary of these findings is presented in Table 18 below and are compared with the current waste management option.

Members of the public were invited to participate in the attribute and sub-attribute scoring process. Although differences were observed between the scores determined in the workshop (which included external stakeholder representation) and those provided by the public, the differences did not have a significant impact on the overall outcome of the process i.e. the differences were not sufficiently different to change the preferred management option(s) for any of the waste streams by any analysis method used.

Table 18: Current vs Recommended Waste Management Options according to the 2008 DSRL Site Waste BPEO

Waste Stream	Current Waste Management Option	Recommended Waste Management Option from Workshop	Comment
CHILW THTR Graphite	Encapsulate in 200l drums the cement in 500l drums and consign as ILW	Encapsulate in 200l drums the cement in 500l drums and consign as ILW	No change
CHILW Activated Graphite	Package unencapsulated in 4m boxes and consign as ILW	Package the wastes, in accordance with RWMD guidance for consignment to the proposed ILW repository.	The basis of the management strategy is sound; however, further consideration through the LoC process is required to further develop the detail of the management method
LLW Sludge (LSA scale)	Package encapsulated in 4m boxes and consign as ILW	Package the wastes, in accordance with RWMD guidance for consignment to the proposed ILW repository.	The basis of the management strategy is sound; however, further consideration through the LoC process is required to further develop the detail of the management method
LLW Sludge (Granular)	Dewater and cement in 200l drums and consign as LLW	Dewater, bag and dispose of as LLW or HVLA as appropriate	This will give an overall lower waste volume for disposal but some underpinning work required
LLW Sludge (Putrescible)	Bag and interim storage	Two options identified: Incinerate off-site and Bioremediation	Characterisation has determined no Putrescible Sludge falls within this waste category.
Exempt Hazardous Sludges (Putrescible)	Bag and interim storage	Off site disposal	The basis of the management strategy is sound.
Clean Hazardous Sludges (Putrescible)	Bag and interim storage	Use current site disposal route for Clean Hazardous material (off site disposal)	Characterisation has determined no Putrescible Sludge falls within this waste category.

This 2008 DSRL Site Waste BPEO report will be used as:

- An auditable record of the Site Waste BPEO decision making process and outcomes;
- A document for updating key DSRL information sources such as the IWS, Dounreay Radioactive Waste Inventory etc;
- A means of providing a starting point for waste stream and facility specific BPM studies to enable further development and refinement of waste management strategy and methodology;

as well as underpinning the programme (Appendix 4) for implementation of the BPEO study as required in Schedule 11 Item 1 of RSA ’93 Authorisations.

8 REFERENCES

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APPENDIX 1 – COMPARISON OF RESULTS OF 2003 AND 2008 DSRL SITE WASTE BPEO STUDIES

Overview of Findings of the 2003 Study

In 2003, a BPEO study for management of radioactive waste arisings from the Dounreay Site Restoration Plan was carried out. This section gives an overview of the approach used in 2003 and notes the key differences and improvements made in support of the 2008 approach.

2003 Approach

To make the BPEO study manageable, 268 radioactive waste streams identified in the Dounreay Radioactive Waste Inventory (DRWI) were rationalised to 36 waste streams with similar physical, chemical and radiological characteristics.

Three strategy groups were defined, composed of a total of 12 strategy options:

- Strategies that generate minimum discharges and solid waste volumes (Liq_{Min}, Atm_{Min}, ILW_{Min} & LLW_{Min})
- Strategies that generate maximum discharges and solid waste volumes (Liq_{Max}, Atm_{Max}, ILW_{Max} & LLW_{Max})
- Strategies that are intermediate, between the maximum and minimum (Liq_{Inter}, Atm_{Inter}, ILW_{Inter} & LLW_{Inter})

Each of the 12 strategy options were scored against 32 sub-attributes which were organised into the following 6 attribute groups:

- Group 1- Health and Safety
- Group 2- Environmental Impacts
- Group 3- Technical Performance
- Group 4- Socio-economic Considerations
- Group 5- Environmental Objectives
- Group 6- Financial Cost

The maximum and minimum strategy options were then optimised to take account of regulatory and financial constraints to produce 8 new optimised strategy options for liquid and airborne discharges, and solid ILW and LLW volumes. These 8 optimised strategy options were then re-scored, to conclude that the preferred optimised strategy options were as follows:

- Liq_{MaxOpt} for liquid discharges where "$_{Opt}$" indicates that most liquid waste streams are cemented (compared to direct disposal in Liq_{Max}). The recommendation was that the most radioactive liquid waste streams are cemented;
- Atm_{MaxOpt}* for airborne discharges where "$_{Opt}$" denotes additional discharge abatement to the processing facilities compared with Atm_{Max} and "*" indicates cementation rather than vitrification of the HALs as compared with Atm_{MaxOpt}. The recommendation was to filter gaseous discharges which contain particulates;
- ILW_{MinOpt}* for solid ILW volumes where "$_{Opt}$" denotes immobilisation of the HALs, MALs, Raffinates and most Sludges and Flocs, and incineration of solvents and oils (compared to direct discharge in ILW_{Min}) and "*" indicates cementation rather than vitrification of the HALs as compared with ILW_{MinOpt}. Here the recommendation was cementation for all ILW solid and Sludge waste streams and most liquid waste streams with the exception of solvents and oils which would undergo incineration;
- LLW_{MinOpt} for solid LLW volumes where "$_{Opt}$" indicates that all LLW streams derived from MALs, DFR and PFR Raffinates and most Flocs and Sludges are cemented and solvents and oils are incinerated (compared to direct disposal in LLW_{Min}). The recommendation was that LLW would be cemented except in the case of solvents and oils which would undergo incineration.

Representative treatment methods were defined for each of the waste streams implied by this BPEO approach. These were intended to suggest representative approaches to treating individual waste streams, rather than prescribing the actual approach. A sensitivity study was performed to examine the robustness of the conclusions, using a weighting scheme. However, the application of weightings did not change the overall conclusions.

Key Differences

The coverage of both the 2003 Site Waste BPEO Study and the 2008 Site Waste BPEO Study is shown in Table 1. The coverage of both studies is similar with the main differences being in the breakdown of the LLW solid waste stream and the inclusion of Clean and Exempt wastes in the 2008 BPEO Study. In addition, the 2003 BPEO Study did not re-examine management options for specific legacy wastes or materials that were already being treated or conditioned at the time, such as the Dounreay Material Test Reactor (DMTR) raffinate, or that were about to be treated or conditioned in plant that had been built or was in construction, such as alkali metals from the PFR and DFR reactors. Although these streams were also excluded from the 2008 BPEO Study for similar reasons following discussions at the BPEO Workshop, they were included at the outset for completeness and to ensure a fully auditable trail.

The approach used for the 2008 BPEO Study differs from the 2003 BPEO Study as a review of all the Dounreay waste streams was carried out at the start of the workshop to identify where current waste management strategies were largely compliant with best practice and/or were already underpinned by existing BPEO studies and hence did not require further detailed consideration. This screening exercise drew on the findings of the review on national and international best practice on waste minimisation (ref. 1) and enabled a more transparent overall approach, with a more concise front end phase. This allowed the emphasis of the workshop to be placed on waste streams where there was a clear need for an updated assessment. Management options for such waste streams were then able to be considered more thoroughly, taking account of the nature of the wastes, waste volumes and radionuclide data.

APPENDIX 2 – SUMMARY OF ATENDEE ATTRIBUTES AND SUB-ATTRIBUTE WEIGHTINGS AND SCORES RECORDED DURING THE WORKSHOP

Table 19: Attendee Attribute and Sub-Attribute Weightings (according to their perceived importance)

Attribute	Attribute Weighting (%)											Sub-Attribute	Sub-Attribute Weighting (%)										
	Individual scores from workshop participants										Av		Individual scores from workshop participants										Av
1. Human Health and Safety	25	30	20	30	15	25	30	30	15	25	25	A1.1 Routine radiation doses	60	10	30	45	15	30	25	70	60	30	38
												A1.2 Radiological accident risks	15	20	30	10	50	45	25	15	30	60	30
												A1.3 Non radioactive hazards and risks	25	70	40	45	35	25	50	15	10	10	33
2. Environ-mental Impact	25	20	20	25	15	25	25	10	5	20	19	A2.1 Air and water quality	20	60	35	40	40	30	30	20	40	40	36
												A2.2 Primary and secondary waste generation (solid)	70	20	40	30	25	45	50	50	30	30	39
												A2.3 Visual impact	5	10	15	20	5	15	10	15	10	10	12
												A2.4 Nuisances	5	10	10	10	30	10	10	15	20	20	14
3. Financial	15	15	25	15	35	15	20	20	10	30	19	A3.1 Cost	50	80	70	50	75	60	75	60	70	90	68
												A3.2 Financeability / affordability	50	20	30	50	25	40	25	40	30	10	32
4. Socio-economic	10	15	10	5	10	10	5	10	60	10	15	A4.1 Public acceptability	80	60	80	30	90	70	50	60	30	90	64
												A4.2 Economic impacts	20	40	20	70	10	30	50	40	70	10	36
5. Technical	25	20	35	25	25	25	20	30	10	15	23	A5.1 Making best use of existing facilities and expertise	10	60	25	40	35	40	50	30	50	30	37
												A5.2 Practical deliverability	60	20	45	30	35	20	25	40	30	30	34
												A5.3 Maturity of technology	30	20	30	30	30	40	25	30	20	40	30

Table 20: Public consultation Attribute and Sub-Attribute Weightings (according to their perceived importance)

Attribute	Attribute Weighting (%)									Sub-Attribute	Sub-Attribute Weighting (%)								
	Individual scores from public								Av		Individual scores from public								Av
1. Human Health and Safety	35	15	50	40	30	--	50	30	35.7	A1.1 Routine radiation doses	60	30	35	10	35	50	20	40	35
										A1.2 Radiological accident risks	30	60	15	20	35	25	40	30	31.9
										A1.3 Non radioactive hazards and risks	10	10	50	70	30	25	40	30	33.1
2. Environ-mental Impact	20	25	10	10	30	--	15	35	20.7	A2.1 Air and water quality	50	15	50	30	40	40	50	45	40
										A2.2 Primary and secondary waste generation (solid)	20	25	40	50	25	20	20	30	28.8
										A2.3 Visual impact	20	30	5	10	15	20	10	10	15
										A2.4 Nuisances	10	30	5	10	20	20	20	15	16.3
3. Financial	10	5	5	10	15	--	5	10	8.6	A3.1 Cost	40	50	40	50	40	0	50	40	38.8
										A3.2 Financeability / affordability	60	50	60	50	60	100	50	60	61.3
4. Socio-economic	25	45	25	30	15	--	20	15	25	A4.1 Public acceptability	30	40	60	30	40	55	70	35	45
										A4.2 Economic impacts	70	60	40	70	60	45	30	65	55
5. Technical	10	10	10	10	10	--	10	10	10	A5.1 Making best use of existing facilities and expertise	50	50	65	50	45	30	40	35	45.6
										A5.2 Practical deliverability	30	20	25	30	35	60	30	35	29.8
										A5.3 Maturity of technology	20	30	10	20	20	20	30	30	22.5

-- denotes not scored

Table 21: Workshop vs Public Attribute Weightings and the impact on waste stream scores for attribute and sub-attribute weighted data

Attribute	Attribute weighting % (average)		Comments
	Workshop	Public	
1. Human Health and Safety	25	35.7	• THTR Graphite: No impact • Activated Graphite: No impact • LLW Sludge (Granular): Moderate impact but does not change overall outcome • LLW Sludge (Putrescible): Low impact • Exempt Sludge (Putrescible): No impact
2. Environ-mental Impact	19	20.7	• THTR Graphite: No impact • Activated Graphite: No impact • LLW Sludge (Granular): No impact • LLW Sludge (Putrescible): No impact • Exempt Sludge (Putrescible): No impact
3. Financial	19	8.6	• THTR Graphite: No impact • Activated Graphite: No impact • LLW Sludge (Granular): No impact • LLW Sludge (Putrescible): Low impact • Exempt Sludge (Putrescible): No impact
4. Socio-economic	15	25	• THTR Graphite: No impact • Activated Graphite: No impact • LLW Sludge (Granular): Not scored in workshop • LLW Sludge (Putrescible): Moderate impact but does not change overall outcome • Exempt Sludge (Putrescible): No impact
5. Technical	23	10	• THTR Graphite: No impact • Activated Graphite: No impact • LLW Sludge (Granular): Not scored in workshop • LLW Sludge (Putrescible): Low impact • Exempt Sludge (Putrescible): No impact

Table 22: Workshop vs Public Attribute Weightings and the impact on waste stream scores for swing, attribute and sub-attribute weighted data

Attribute	Attribute weighting % (average)		Comments
	Workshop	Public	
1. Human Health and Safety	25	35.7	• CHILW THTR Graphite: No impact • CHILW Activated Graphite: No impact • LLW Sludge (Granular): No impact • LLW Sludge (Putrescible): Low impact • Exempt Sludge (Putrescible): No impact
2. Environ-mental Impact	19	20.7	• CHILW THTR Graphite: No impact • CHILW Activated Graphite: No impact • LLW Sludge (Granular): No impact • LLW Sludge (Putrescible): No impact • Exempt Sludge (Putrescible): No impact
3. Financial	19	8.6	• CHILW THTR Graphite: No impact • CHILW Activated Graphite: Low impact • LLW Sludge (Granular): Low impact • LLW Sludge (Putrescible): Low impact • Exempt Sludge (Putrescible): No impact
4. Socio-economic	15	25	• CHILW THTR Graphite: No impact • CHILW Activated Graphite: No impact • LLW Sludge (Granular): Not scored in workshop • LLW Sludge (Putrescible): No impact • Exempt Sludge (Putrescible): No impact
5. Technical	23	10	• CHILW THTR Graphite: No impact • CHILW Activated Graphite: No impact • LLW Sludge (Granular): Not scored in workshop • LLW Sludge (Putrescible): No impact • Exempt Sludge (Putrescible): No impact

Table 23: Summary of the options scores for CHILW THTR Graphite obtained in the 2008 DSRL Site Waste BPEO

Attributes	Sub-attributes	Encapsulate material in 200l drums and cement in 500l drums (Option A1)	Encapsulate in cement in 500l drums (loose) (Option A2)	Encapsulate in polymer in 500l drums (loose) (Option A3)	Reprocess to extract U/Th (Option A4)	Thermal treatment (Option A5)	Co-package (Option A6)	Encapsulate in cement in 3m3 drums (loose) (Option A7)	Encapsulate in polymer in 3m3 drums (loose) (Option A8)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	**b**	**m**	**m**	**w**	**ba**	**g**	**m**	**m**	5
	Radiological accident risks	**b**	**m**	**m**	**w**	**ba**	**m**	**m**	**m**	5
	Non radioactive hazards and risks	**b**	**m**	**m**	**w**	**w**	**m**	**ba**	**ba**	10
2. Environmental Impact	Air and water quality	**b**	**ba**	**ba**	**w**	**w**	**ba**	**ba**	**ba**	10
	Primary and secondary waste generation (solid)	**b**	**m**	**g**	**w**	**w**	**m**	**m**	**g**	10
	Visual impact	**b**	**b**	**b**	**m**	**w**	**b**	**w**	**w**	1
	Nuisances	**b**	**b**	**b**	**m**	**w**	**b**	**w**	**w**	1
3. Financial	Cost	**g**	**g**	**g**	**ba**	**w**	**b**	**m**	**m**	10
	Financeability / affordability	**g**	**g**	**g**	**ba**	**w**	**b**	**m**	**m**	1
4. Socio-economic	Public acceptability	**b**	**b**	**b**	**w**	**ba**	**b**	**b**	**b**	10
	Economic impacts	**ba**	**ba**	**ba**	**g**	**b**	**w**	**m**	**m**	5
5. Technical	Making best use of existing facilities and expertise	**m**	**g**	**m**	**ba**	**w**	**b**	**ba**	**ba**	10
	Practical deliverability	**g**	**b**	**g**	**m**	**w**	**ba**	**m**	**ba**	5
	Maturity of technology	**b**	**b**	**b**	**b**	**w**	**m**	**b**	**g**	5

Table 24: Summary of the options scores for CHILW Activated Graphite obtained in the 2008 DSRL Site Waste BPEO

Attribute	Sub-attribute	Package unencapsulated (4m boxes) (Option B1)	Package and encapsulate (unshielded boxes) (Option B2)	Package unencapsulated (unshielded boxes) (Option B3)	Incineration to decontaminate (Option B4)	High temperature processing (Option B5)	Crush and treat as THTR (Option B6)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	**b**	**b**	**b**	**ba**	**ba**	**w**	1
	Radiological accident risks	**g**	**b**	**g**	**ba**	**ba**	**w**	5
	Non radioactive hazards and risks	**b**	**g**	**g**	**w**	**w**	**w**	10
2. Environmental Impact	Air and water quality	**b**	**g**	**b**	**w**	**w**	**ba**	10
	Primary and secondary waste generation (solid)	**b**	**g**	**g**	**ba**	**ba**	**w**	10
	Visual impact	**b**	**b**	**b**	**w**	**w**	**m**	1
	Nuisances	**b**	**b**	**b**	**w**	**w**	**m**	1
3. Financial	Cost	**b**	**b**	**b**	**w**	**w**	**ba**	10
	Financeability / affordability	**b**	**b**	**b**	**w**	**w**	**ba**	10
4. Socio-economic	Public acceptability	**g**	**b**	**g**	**w**	**w**	**m**	5
	Economic impacts	**w**	**w**	**w**	**b**	**b**	**g**	1
5. Technical	Making best use of existing facilities and expertise	**b**	**b**	**b**	**w**	**w**	**m**	10
	Practical deliverability	**g**	**b**	**g**	**w**	**w**	**m**	5
	Maturity of technology	**g**	**b**	**b**	**ba**	**w**	**m**	5

Table 25: Summary of raw scores, swing weights, total raw scores and normalised total raw scores for LLW Sludge (Granular) management options

Attributes	Sub-attributes	Treat as slurry (Option D1)	Dewater, bag and dispose as HVLA/LLW (Option D2)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	**b**	**w**	1
	Radiological accident risks	**b**	**w**	1
	Non radioactive hazards and risks	**w**	**b**	5
2. Environmental Impact	Air and water quality	**b**	**w**	1
	Primary and secondary waste generation (solid)	**w**	**b**	10
	Visual impact			
	Nuisances			
3. Financial	Cost	**w**	**b**	5
	Financeability / affordability			
4. Socio-economic	Public acceptability			
	Economic impacts			
5. Technical	Making best use of existing facilities and expertise			
	Practical deliverability			
	Maturity of technology			

Note: Attributes in grey were determined as non-differentiating and thus were not scored in the workshop

Table 26: Summary of raw scores, swing weights, total raw scores and normalised total raw scores for LLW Sludge (Putrescible) management options

Attributes	Sub-attributes	Process and incinerate off-site (Option E1)	Process and incinerate on-site (Option E2)	Low temperature oxidation (Option E3)	Bioremediation (Option E4)	Swing (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses	**b**	**b**	**b**	**w**	1
	Radiological accident risks	**m**	**m**	**w**	**b**	1
	Non radioactive hazards and risks	**w**	**ba**	**ba**	**b**	5
2. Environmental Impact	Air and water quality	**w**	**w**	**ba**	**b**	5
	Primary and secondary waste generation (solid)	**b**	**w**	**w**	**m**	5
	Visual impact	**b**	**w**	**m**	**m**	1
	Nuisances	**b**	**w**	**m**	**m**	1
3. Financial	Cost	**b**	**w**	**ba**	**m**	10
	Financeability / affordability	**b**	**w**	**ba**	**m**	10
4. Socio-economic	Public acceptability	**w**	**ba**	**m**	**b**	5
	Economic impacts	**w**	**b**	**g**	**m**	1
5. Technical	Making best use of existing facilities and expertise	**b**	**w**	**w**	**ba**	5
	Practical deliverability	**w**	**ba**	**w**	**b**	5
	Maturity of technology	**b**	**b**	**w**	**m**	10

Table 27: Summary of raw scores, swing weights, total raw scores and normalised total raw scores for Exempt Sludges (Putrescible) management options

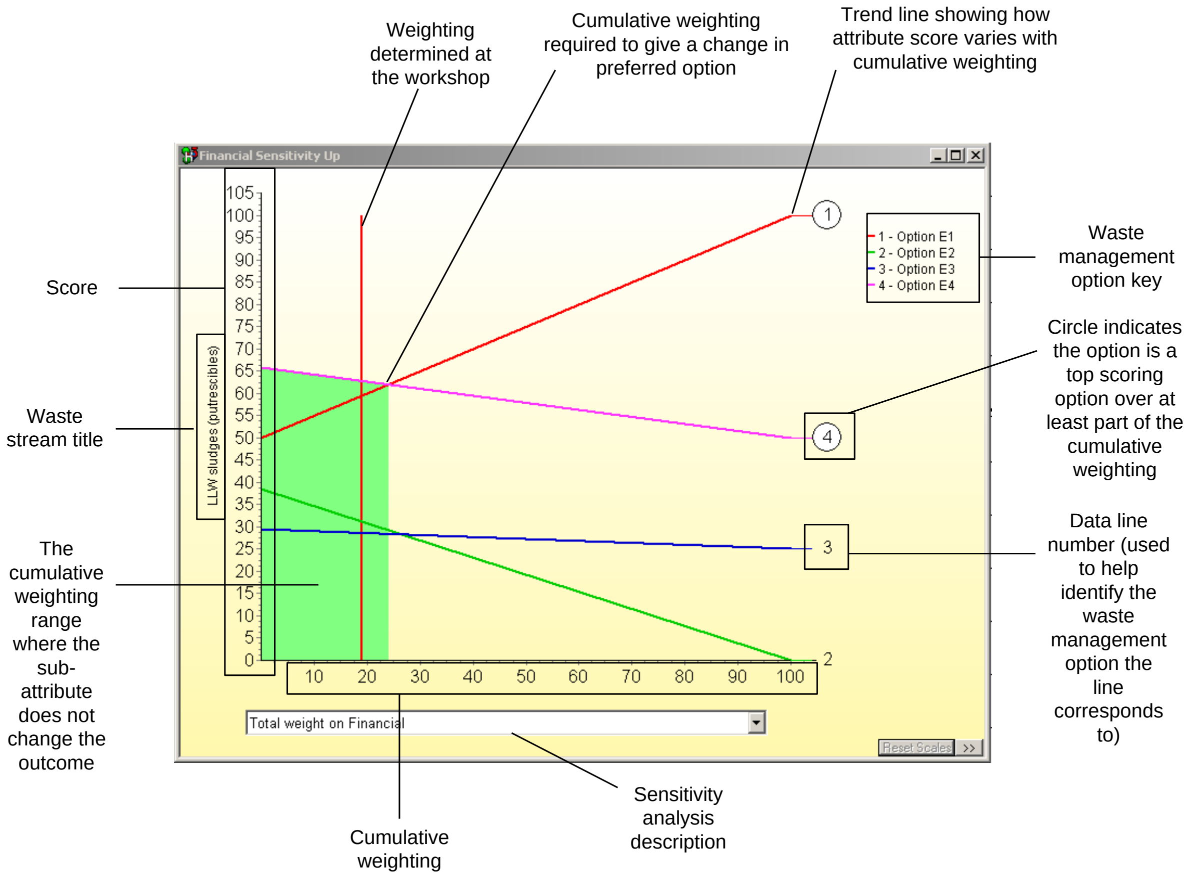
Attributes	Sub-attributes	Process and incinerate off-site (Option F1)	Process and incinerate on-site (Option F2)	Off-site disposal (Option F3)	Swing Wt (1, 5 or 10)
1. Human Health and Safety	Routine radiation doses				
	Radiological accident risks				
	Non radioactive hazards and risks	**m**	**w**	**b**	5
2. Environmental Impact	Air and water quality	**w**	**w**	**b**	1
	Primary and secondary waste generation (solid)	**m**	**w**	**b**	10
	Visual impact	**b**	**w**	**b**	1
	Nuisances	**b**	**w**	**b**	1
3. Financial	Cost	**g**	**w**	**b**	10
	Financeability / affordability	**g**	**w**	**b**	5
4. Socio-economic	Public acceptability	**w**	**b**	**w**	1
	Economic impacts	**w**	**b**	**m**	1
5. Technical	Making best use of existing facilities and expertise	**b**	**w**	**b**	10
	Practical deliverability	**m**	**w**	**b**	5
	Maturity of technology				

Note: Attributes in grey were determined as non-differentiating and thus were not scored in the workshop

APPENDIX 3 – SENSITIVITY ANALYSIS PLOTS

INTRODUCTION

The plots obtained for the sensitivity analyses are presented in this appendix and discussed in Section 6. An overview of the information contained within the plots and an annotated example is given below.



The sensitivity analysis has been carried out at the attribute level and each plot shows how the overall scores for each management option varies as the cumulative weighting associated with the sub-attribute varies. At a cumulative weighting of zero the attribute contributes nothing to the final score and at a cumulative weighting of 100% the overall score is dependant only on the attribute presented (i.e. all of the other attributes contribute zero to the overall score). These plots allow an assessment of the preferred option and the degree of confidence which can be attributed to the robustness of this conclusion. In the above example Option 4 is the preferred option at cumulative weightings below 25% and Option 1 the preferred option at cumulative weightings above 25%. At the weighting determined in the workshop (indicated by the vertical red line), Option 4 is the preferred option but as the crossing point occurs close to this point there is a significant degree of uncertainty that Option 4 is really a better option than Option 1. In this particular case it would be concluded there is a slight preference for Option 4 over Option 1 but the difference is likely to be marginal when based on the weightings determined in the workshop.

For some plots there are no crossing points and so one option is preferred over all cumulative weightings. In these cases there can be much greater confidence that the top scoring option is the best option.

ANALYSIS BASED ON ATTRIBUTES AND SUB-ATTRIBUTE WEIGHTINGS ONLY

CHILW Graphite (THTR Graphite)

Option no.	Description
A1	Encapsulate in 200l drums the cement in 500l drums
A2	Encapsulate loose in cement in 500l drums
A3	Encapsulate loose in polymer in 500l drums
A4	Reprocess to extract Th/U
A5	Thermal treatment
A6	Co-Package
A7	Encapsulate loose in cement in $3m^3$ drums
A8	Encapsulate loose in polymer in $3m^3$ drums

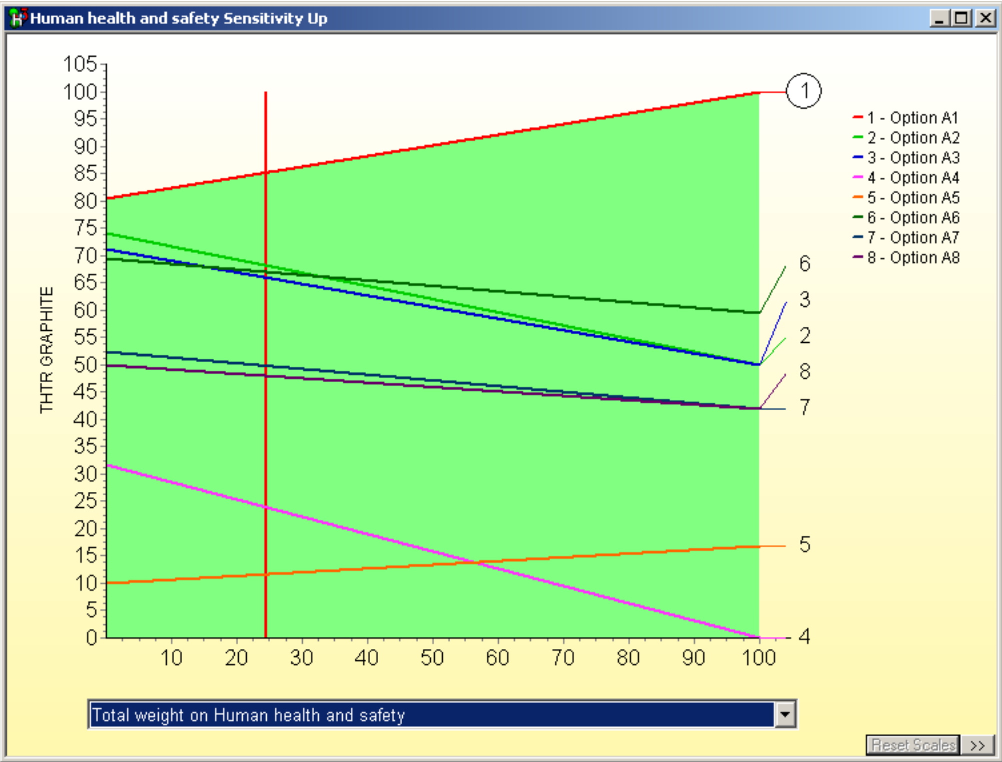


Figure 40: Sensitivity analysis of THTR graphite scores for the Human health and safety attribute (attribute and sub attributes weightings only)

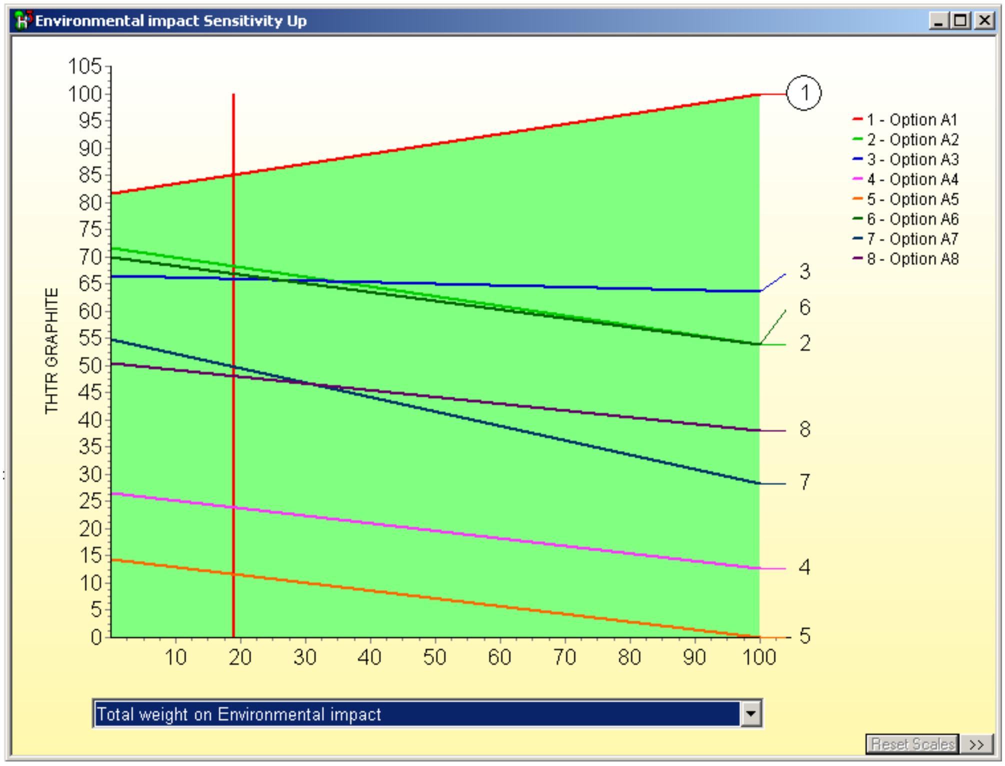


Figure 41: Sensitivity analysis of THTR graphite scores for the Environmental impact attribute (attribute and sub attributes weightings only)

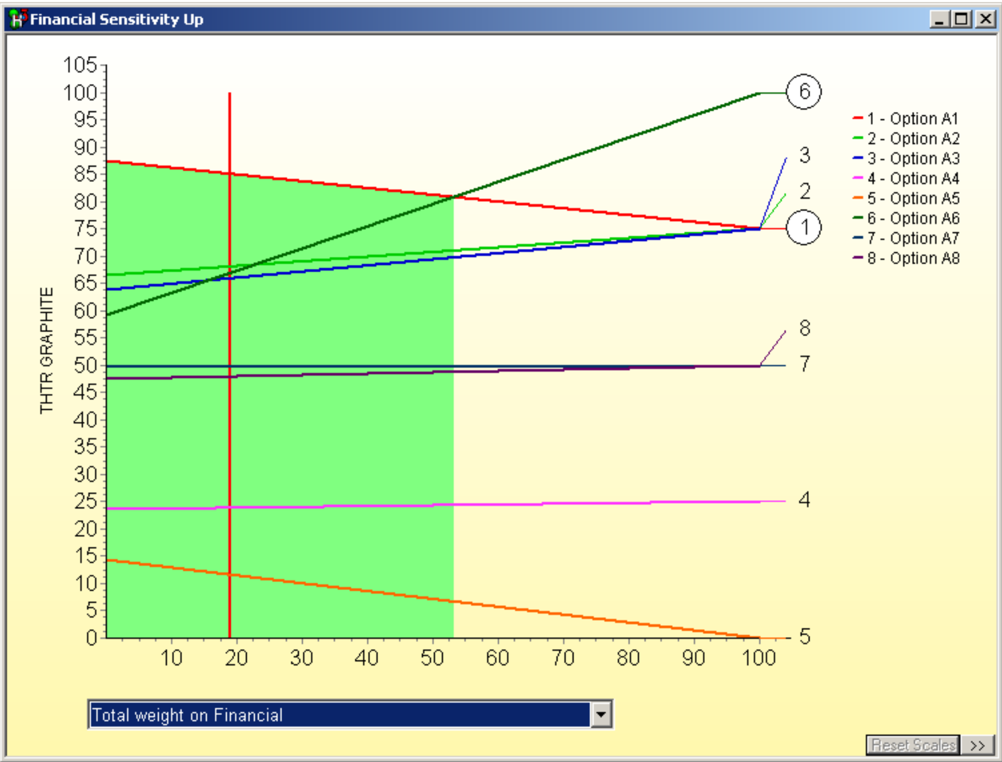


Figure 42: Sensitivity analysis of THTR graphite scores for the Financial attribute (attribute and sub attributes weightings only)

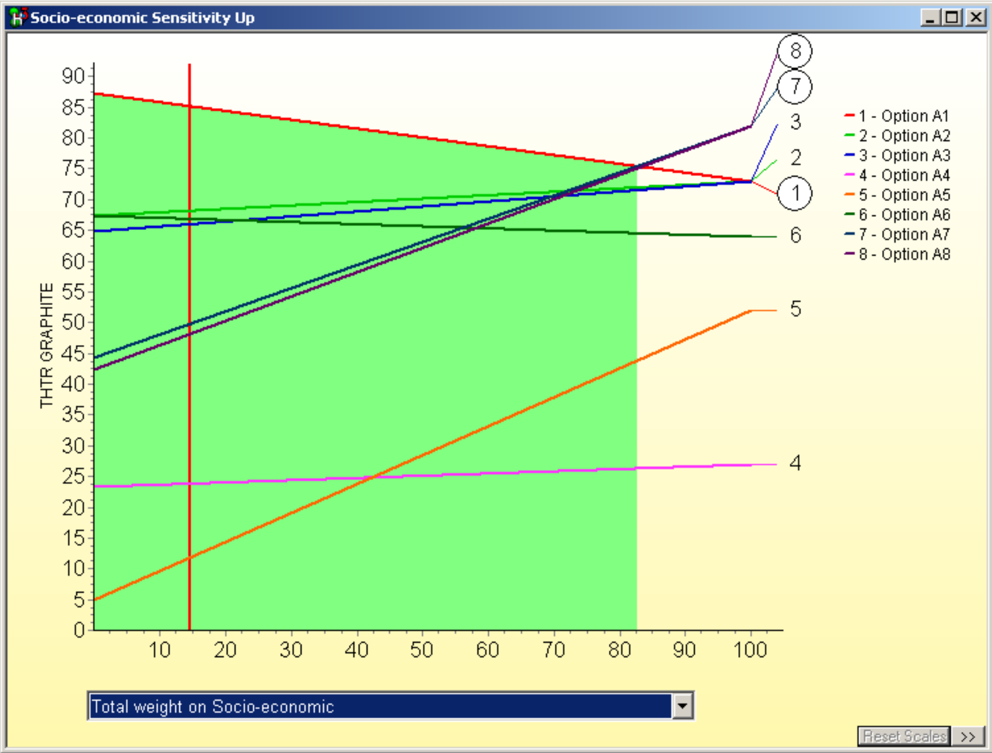


Figure 43: Sensitivity analysis of THTR graphite scores for the Socio-economic attribute (attribute and sub attributes weightings only)

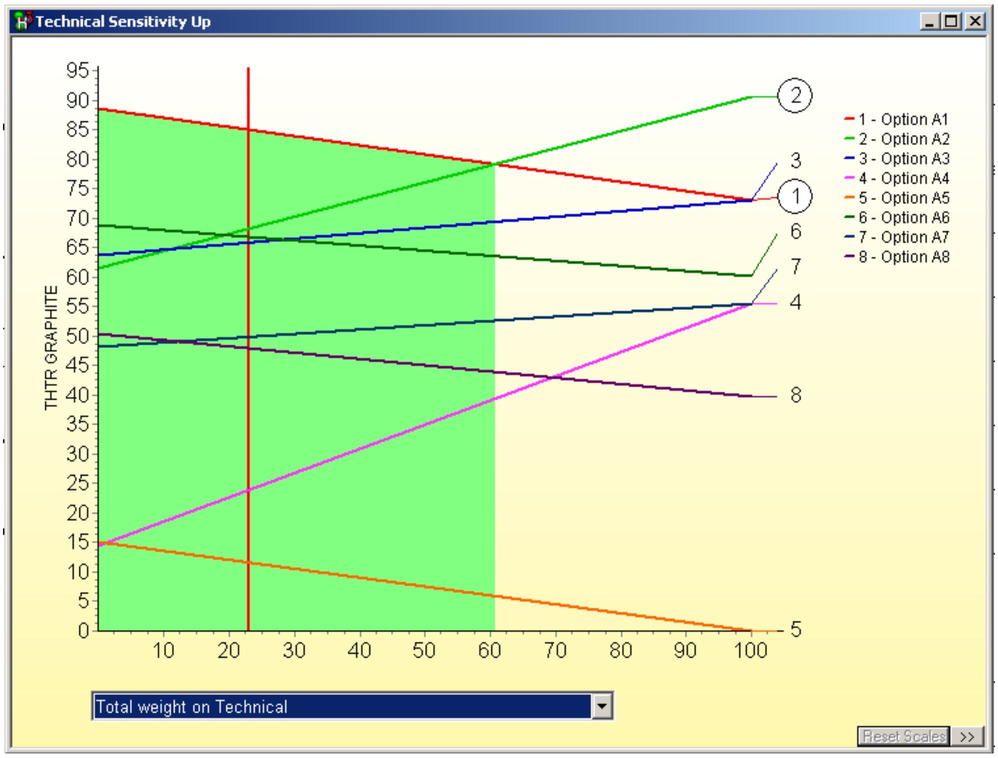


Figure 44: Sensitivity analysis of THTR graphite scores for the Technical attribute (attribute and sub attributes weightings only)

CHILW Graphite (Activated Graphite)

Option no.	Description
B1	Package unencapsulated in 4m boxes
B2	Package and encapsulate (unshielded boxes)
B3	Package unencapsulated (unshielded boxes)
B4	Incineration to decontaminate
B5	High temperature processing
B6	Crush and treat as THTR graphite

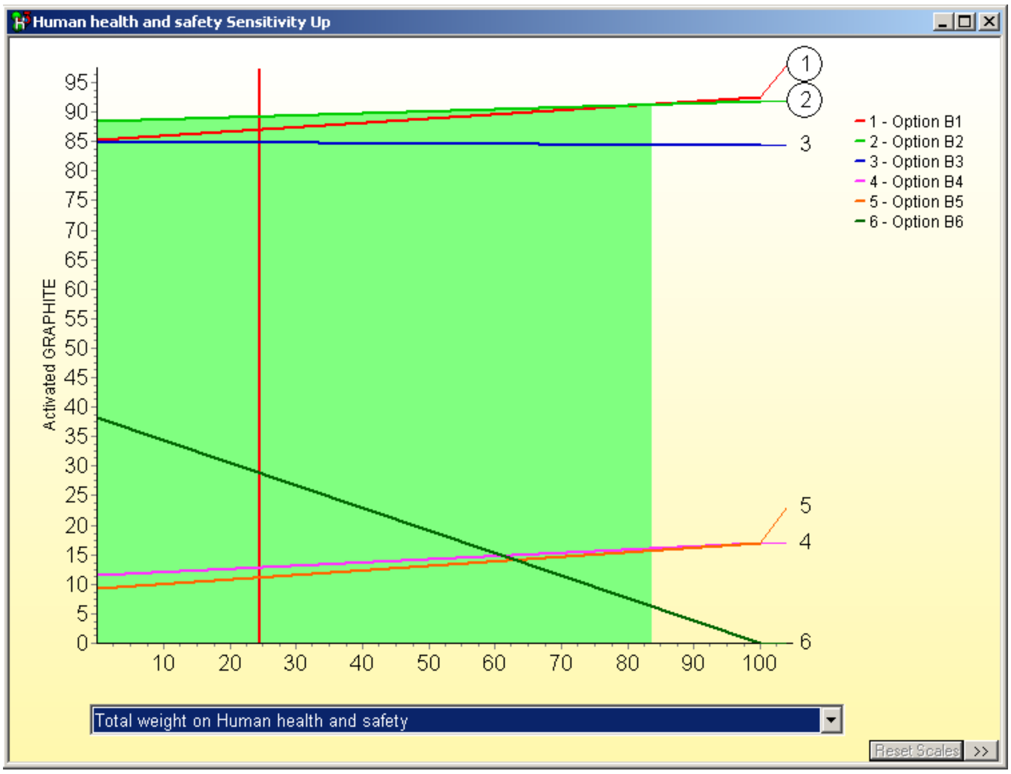


Figure 45: Sensitivity analysis of Activated Graphite scores for the Human health and safety attribute (attribute and sub attributes weightings only)

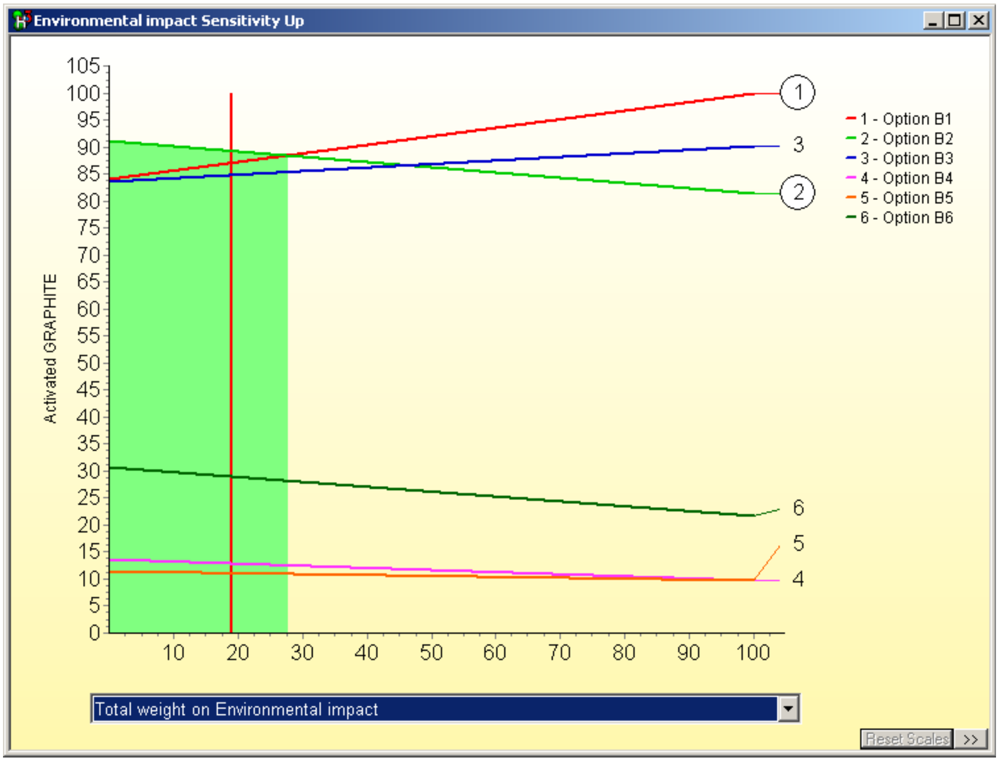


Figure 46: Sensitivity analysis of Activated Graphite scores for Environmental impact attribute (attribute and sub attributes weightings only)

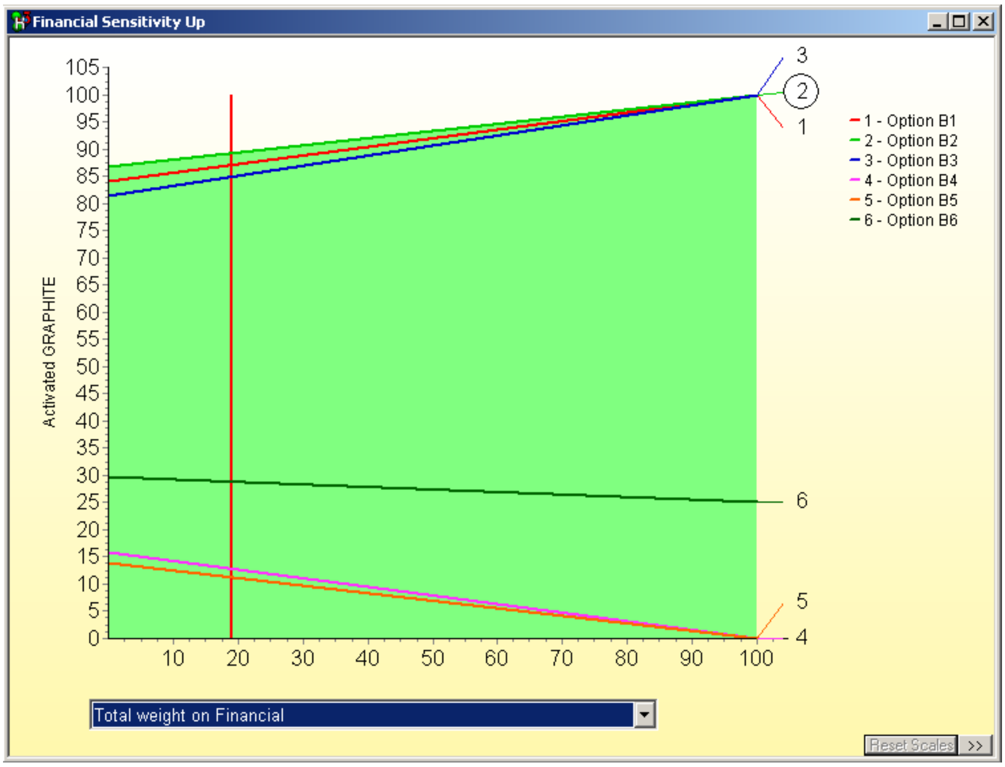


Figure 47: Sensitivity analysis of Activated Graphite scores for the Financial attribute (attribute and sub attributes weightings only)

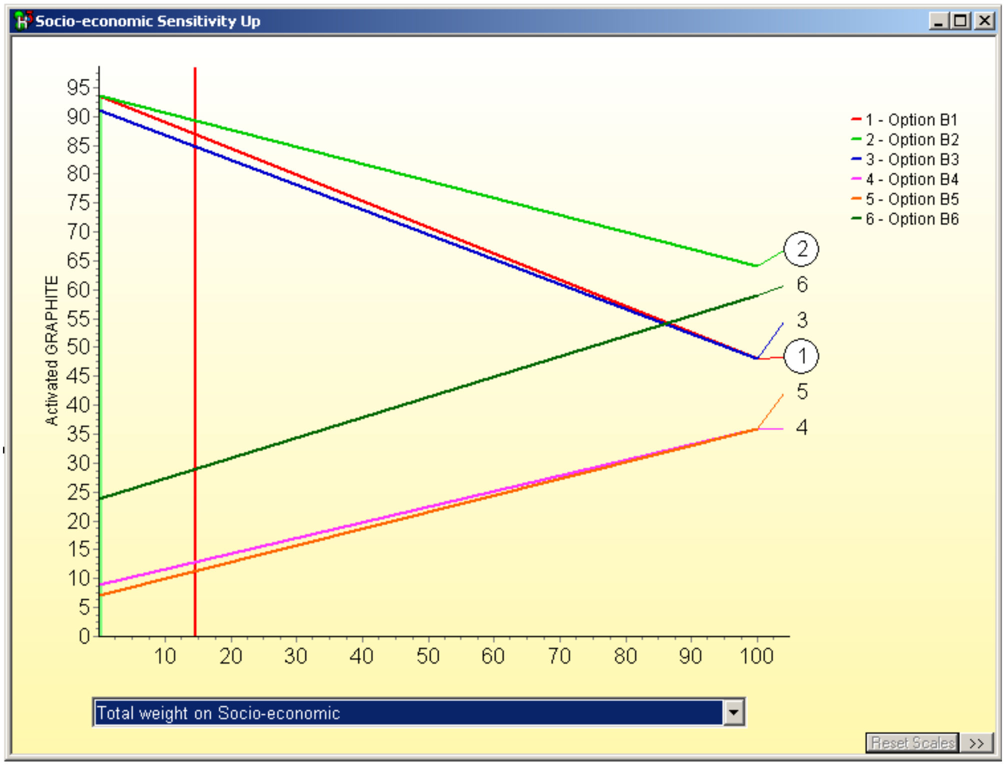


Figure 48: Sensitivity analysis of Activated Graphite scores for the Socio-economic attribute (attribute and sub attributes weightings only)

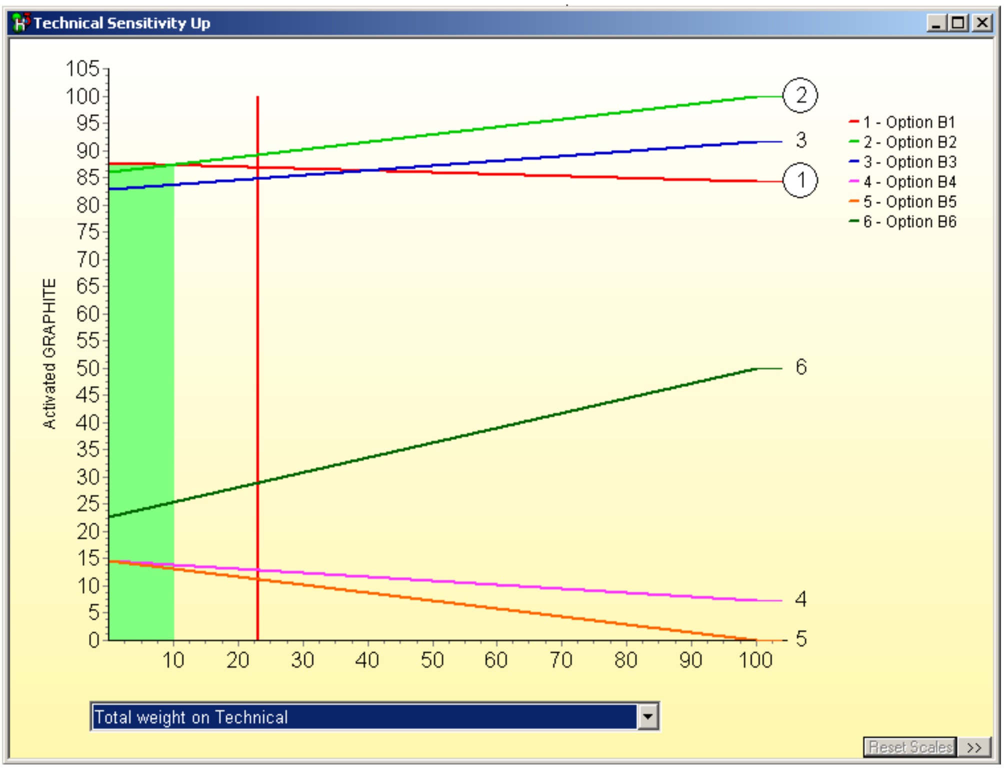


Figure 49: Sensitivity analysis of Activated Graphite scores for the Technical attribute (attribute and sub attributes weightings only)

LLW Sludge (Granular)

Option no.	Description
D1	Treat as slurry
D2	Dewater, bag and treat as HVLA / LLW as appropriate

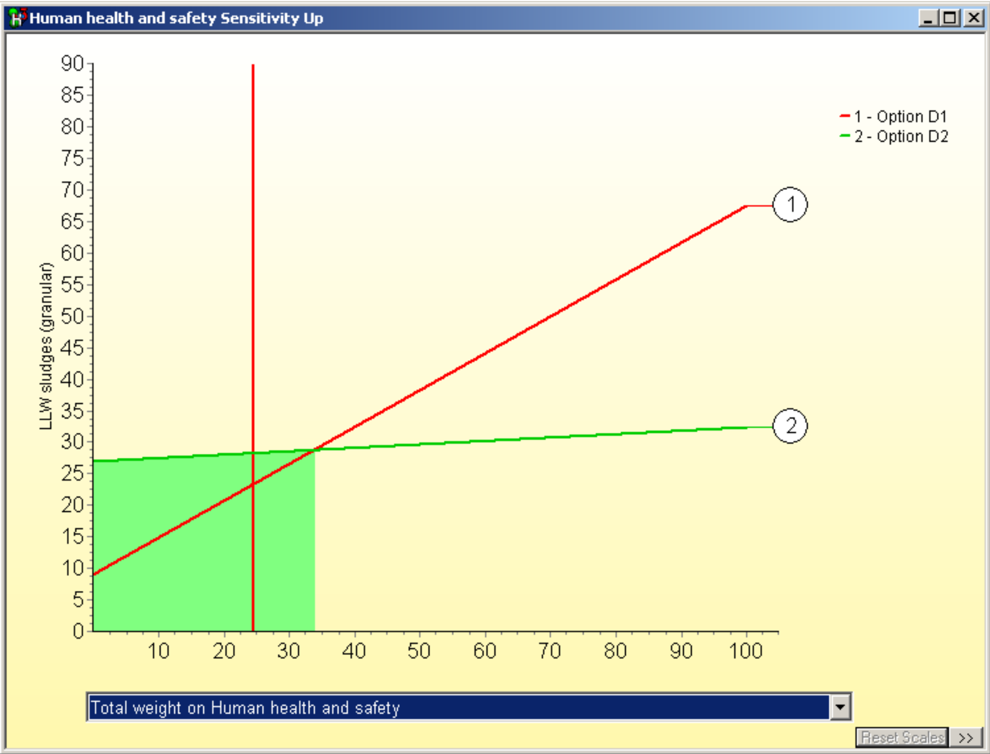


Figure 50: Sensitivity analysis of LLW Sludge (Granular) scores for the Human health and safety attribute (attribute and sub attributes weightings only)

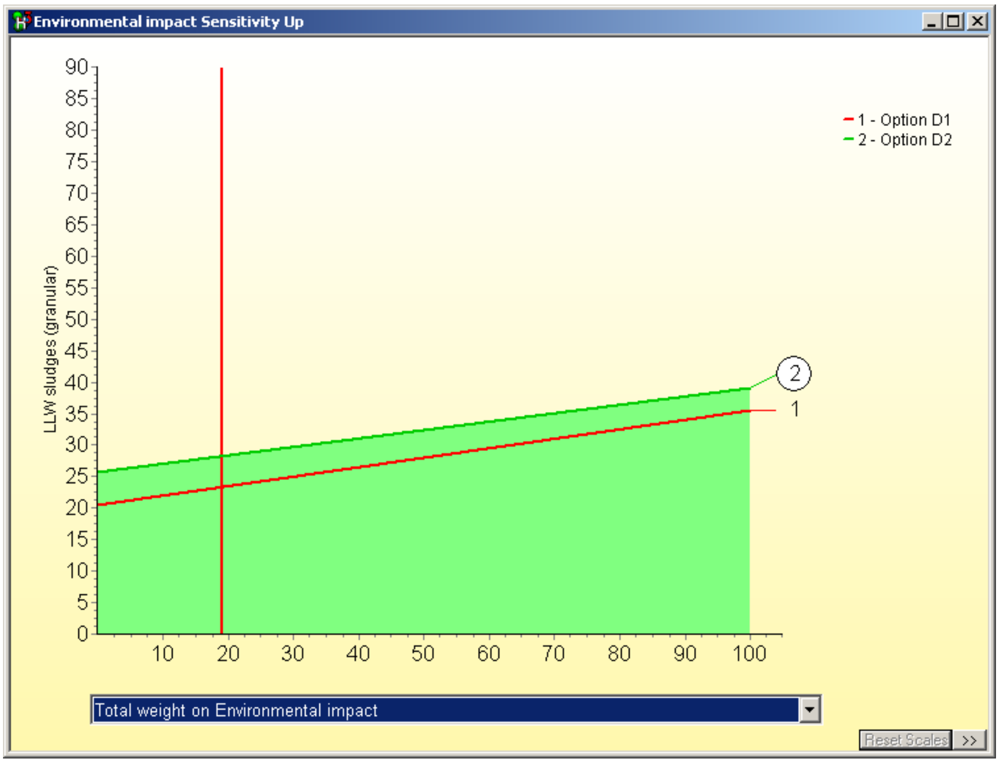


Figure 51: Sensitivity analysis of LLW Sludge (Granular) scores for the Environmental impact attribute (attribute and sub attributes weightings only)

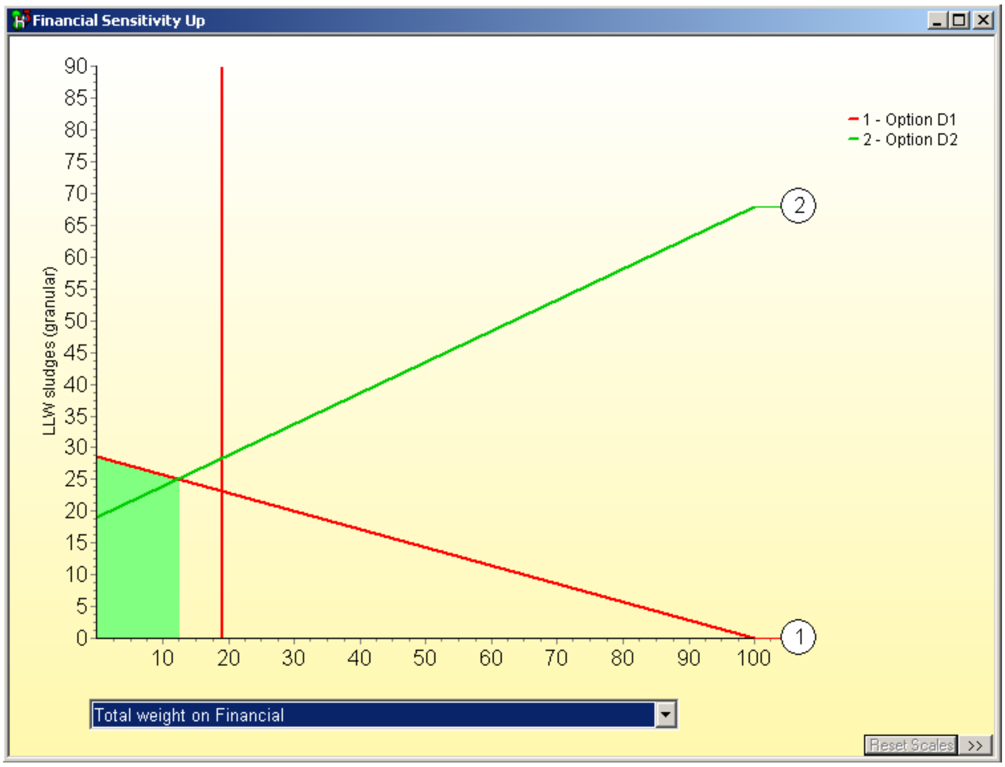


Figure 52: Sensitivity analysis of LLW Sludge (Granular) scores for the Financial attribute (attribute and sub attributes weightings only)

LLW Sludge (Putrescible)

Option no.	Description
E1	Process and incinerate offsite
E2	Process and incinerate on site
E3	Low temperature oxidation
E4	Bioremediation

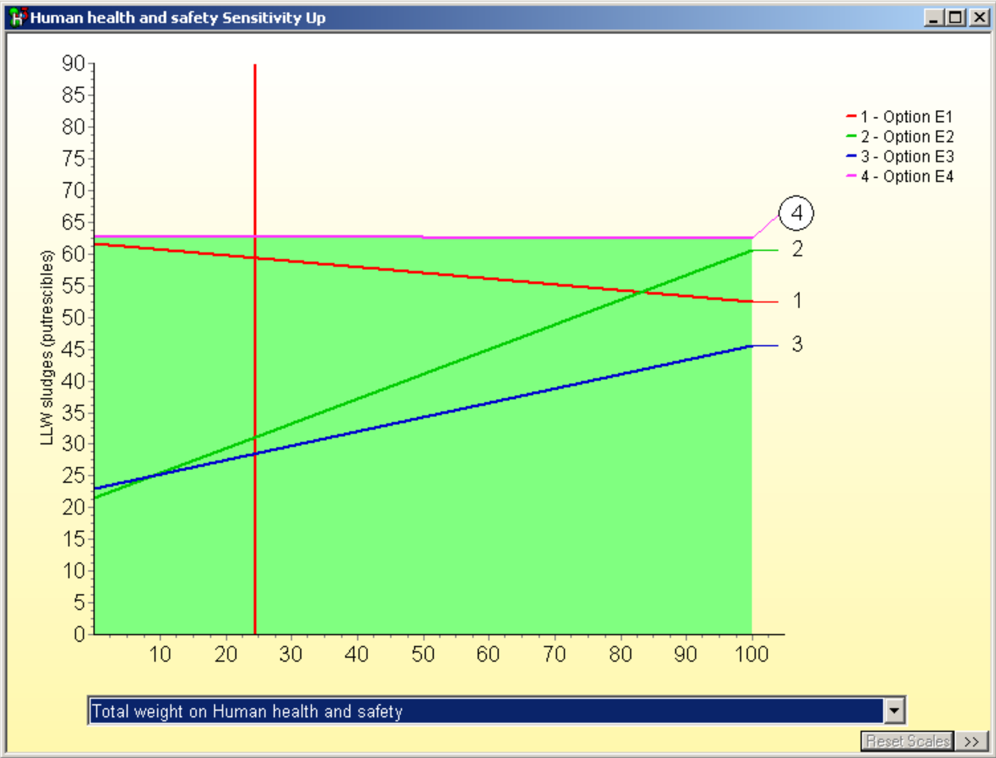


Figure 53: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Human health and safety attribute (attribute and sub attributes weightings only)

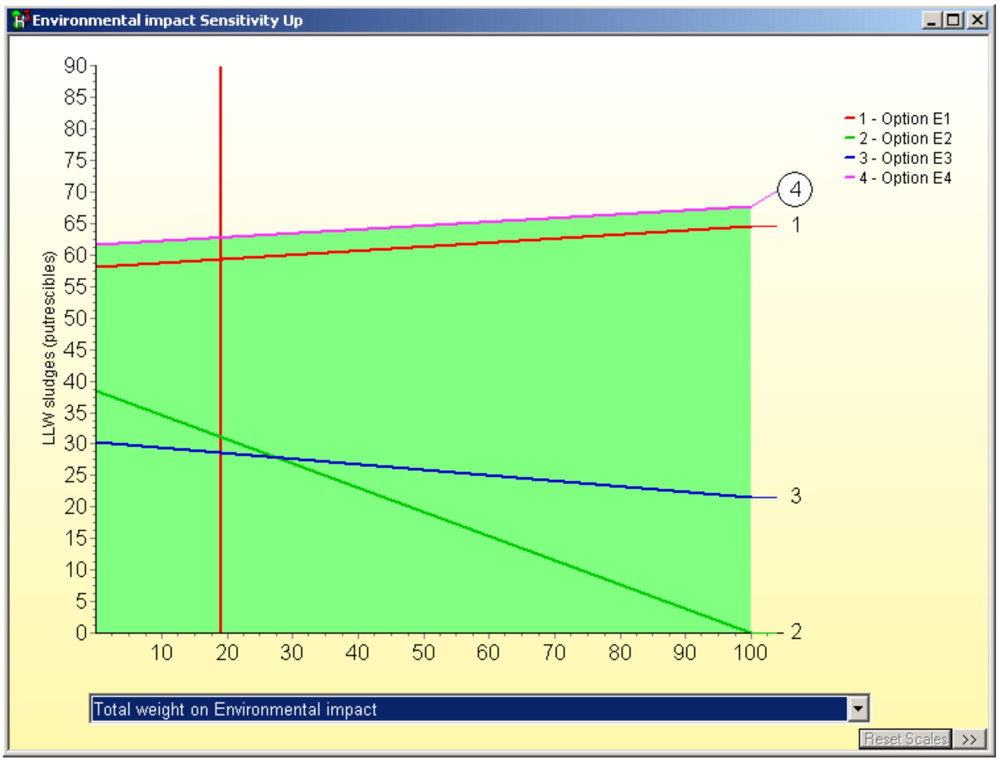


Figure 54: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Environmental impact attribute (attribute and sub attributes weightings only)

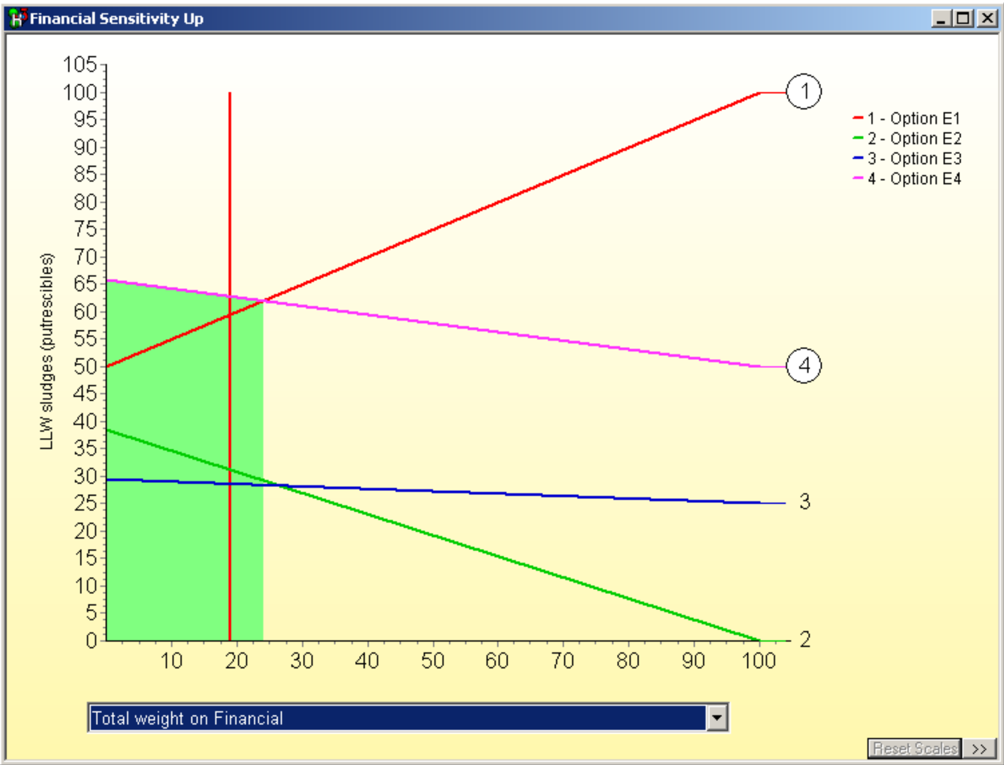


Figure 55: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Financial attribute (attribute and sub attributes weightings only)

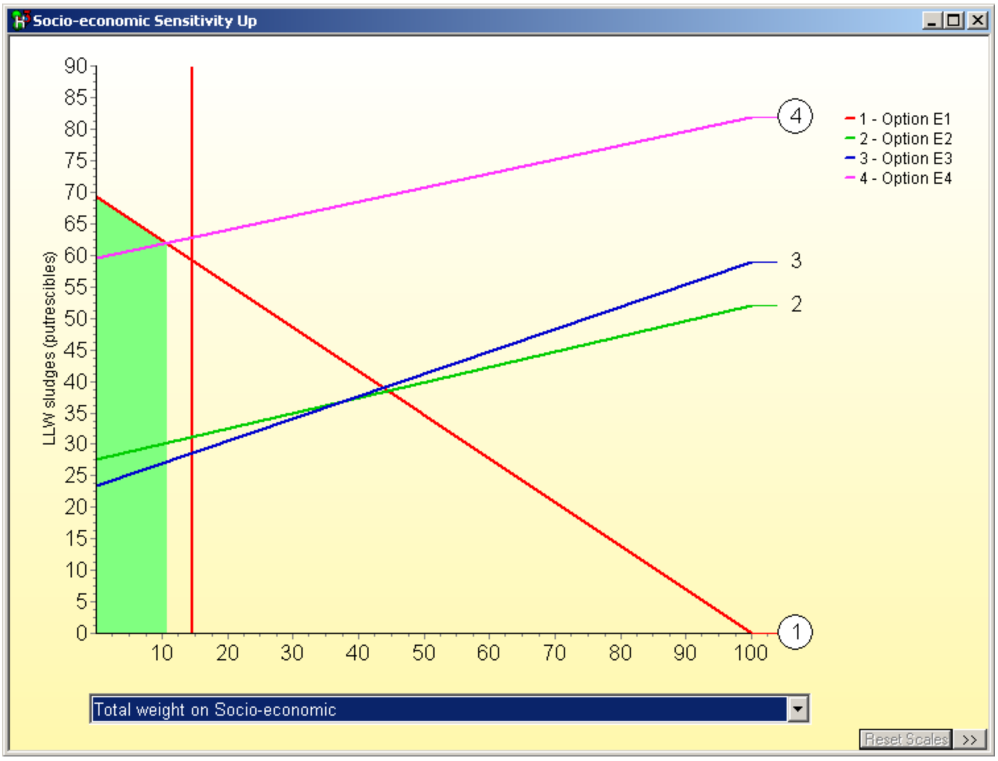


Figure 56: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Socio-economic attribute (attribute and sub attributes weightings only)

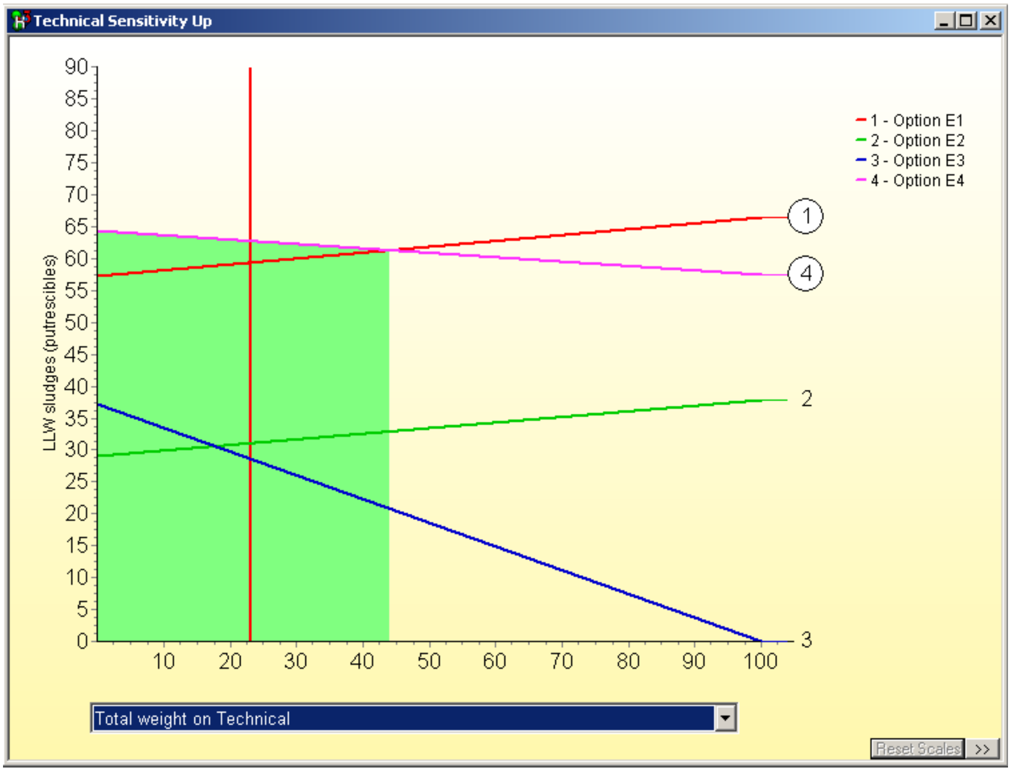


Figure 57: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Technical attribute (attribute and sub attributes weightings only)

Exempt Sludge Putrescible

Option no.	Description
F1	Process and incinerate offsite
F2	Process and incinerate on site
F3	Off-site disposal

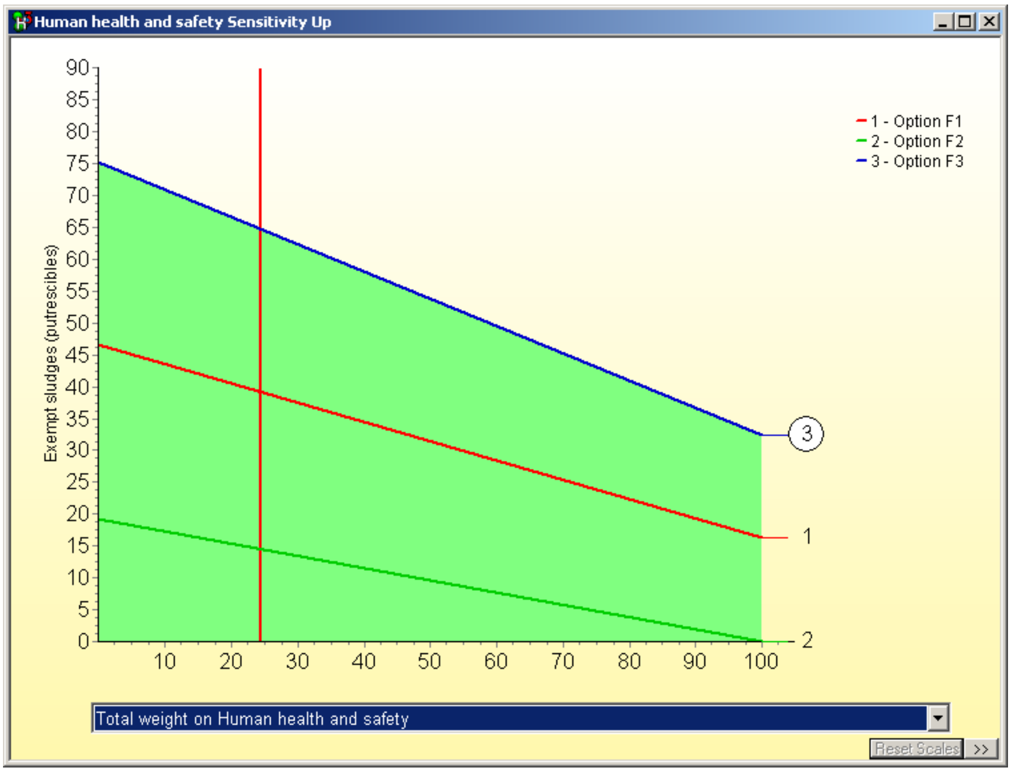


Figure 58: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Human health and safety attribute (attribute and sub attributes weightings only)

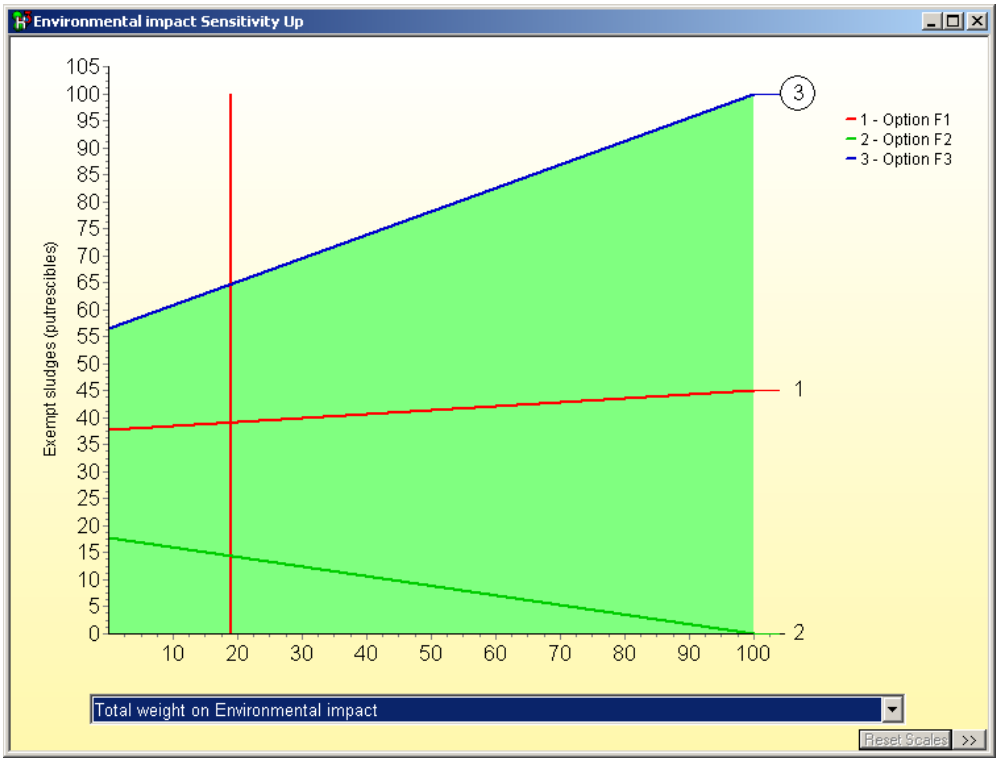


Figure 59: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Environmental impact attribute (attribute and sub attributes weightings only)

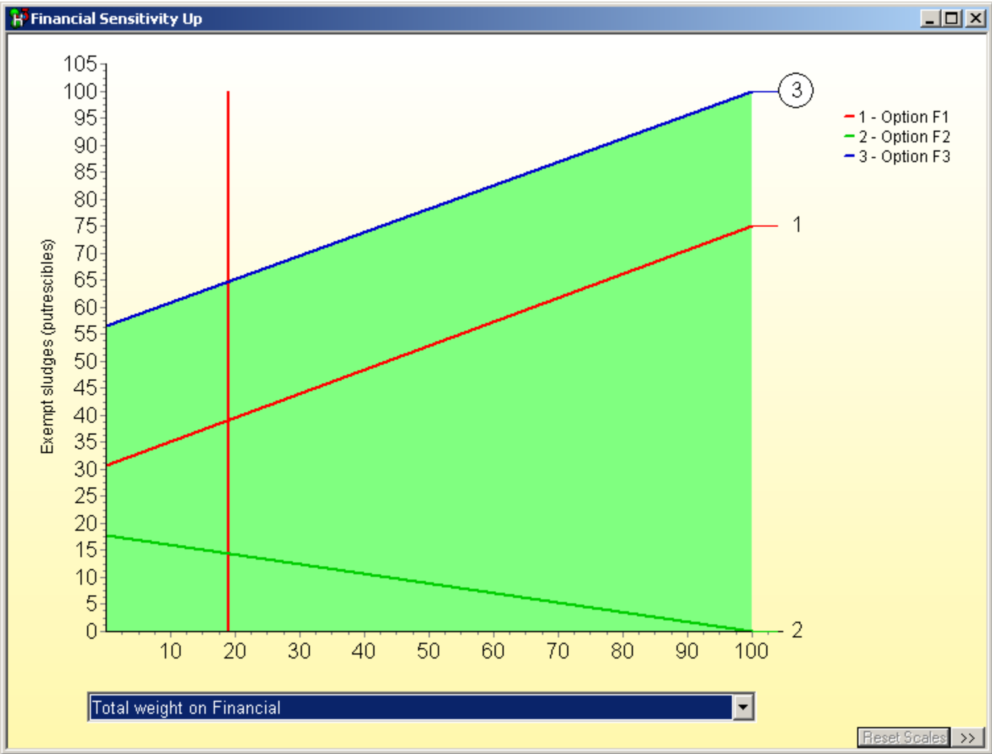


Figure 60: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Financial attribute (attribute and sub attributes weightings only)

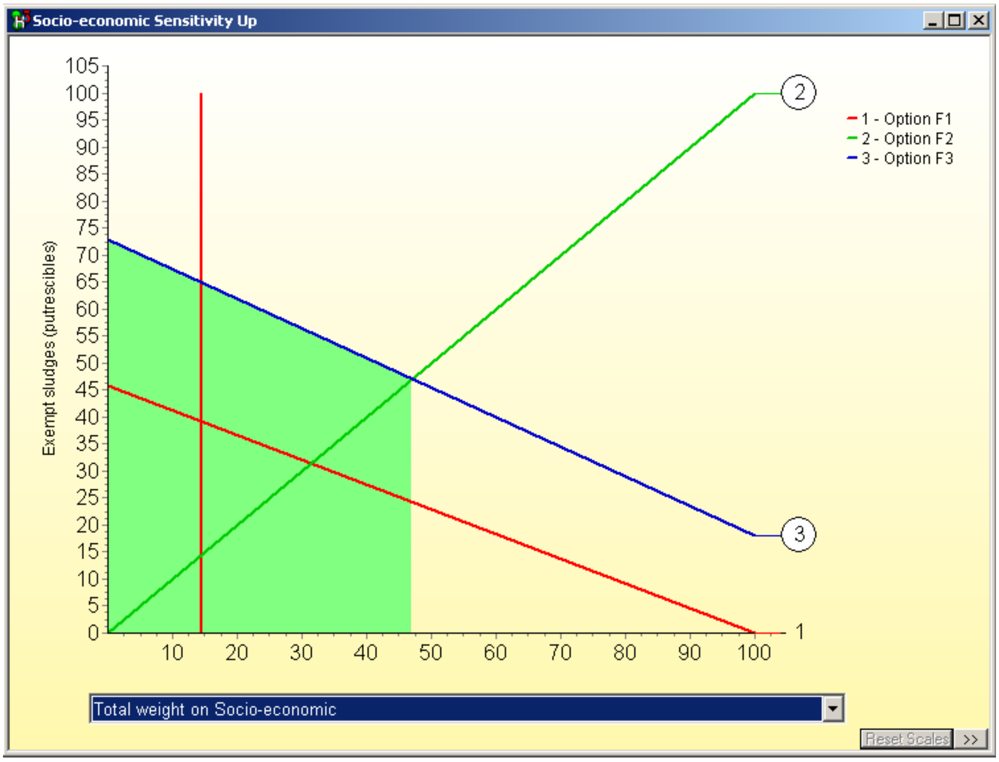


Figure 61: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Socio-economic attribute (attribute and sub attributes weightings only)

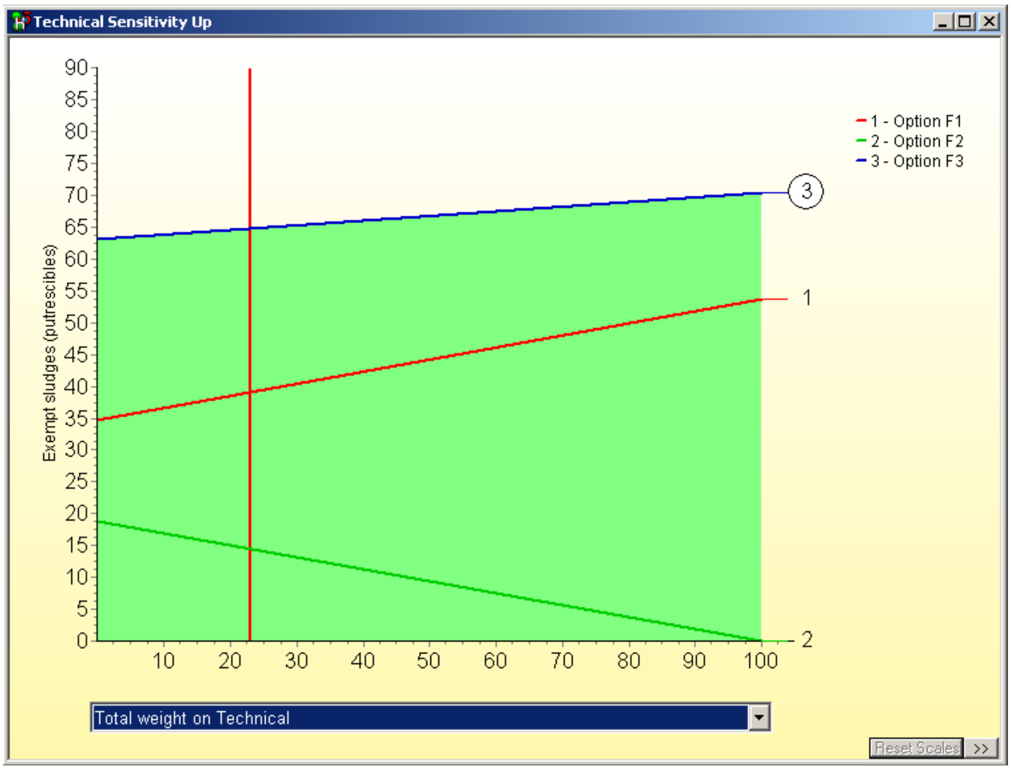


Figure 62: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Technical attribute (attribute and sub attributes weightings only)

ANALYSIS BASED ON ATTRIBUTES AND SUB-ATTRIBUTE WEIGHTINGS ONLY

CHILW Graphite (THTR Graphite)

Option no.	Description
A1	Encapsulate in 200l drums the cement in 500l drums
A2	Encapsulate loose in cement in 500l drums
A3	Encapsulate loose in polymer in 500l drums
A4	Reprocess to extract Th/U
A5	Thermal treatment
A6	Co-Package
A7	Encapsulate loose in cement in $3m^3$ drums
A8	Encapsulate loose in polymer in $3m^3$ drums

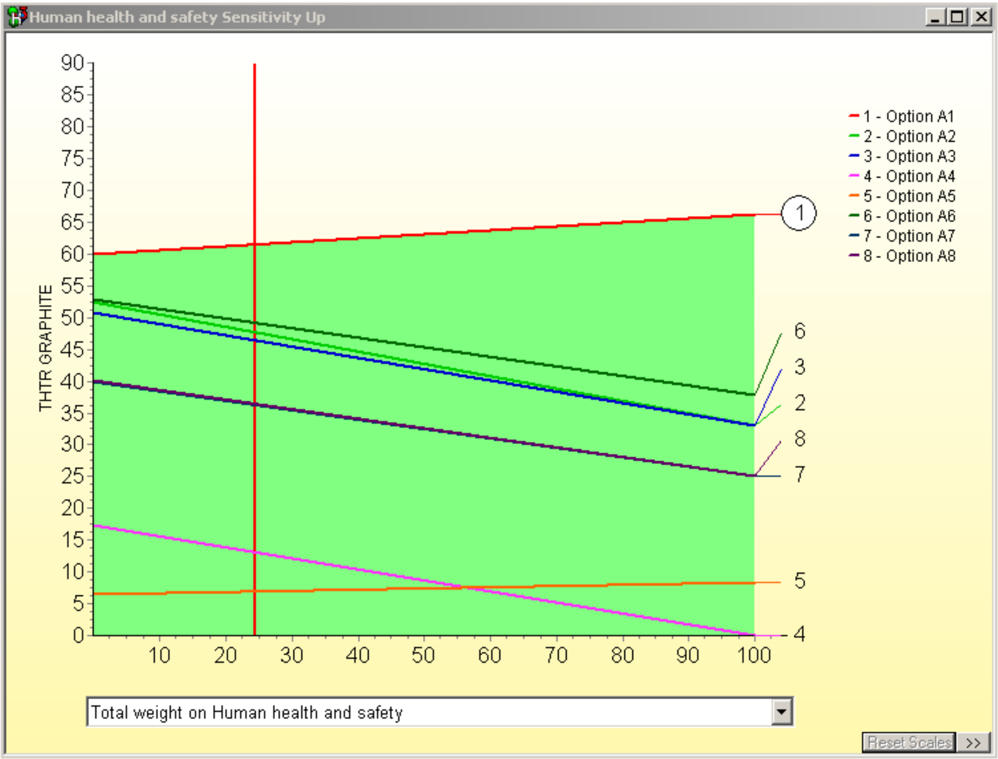


Figure 63: Sensitivity analysis of CHILW THTR graphite scores for the Human health and safety attribute (swing, attribute and sub attributes weightings)

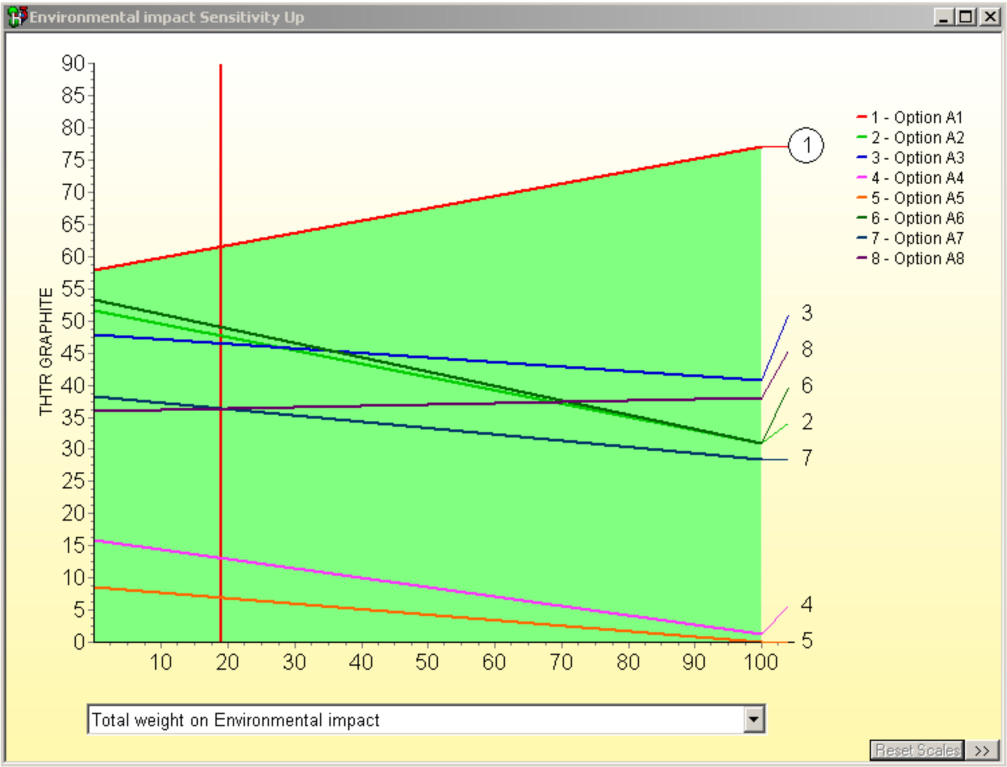


Figure 64: Sensitivity analysis of CHILW THTR graphite scores for the Environmental impact (swing, attribute and sub attributes weightings)

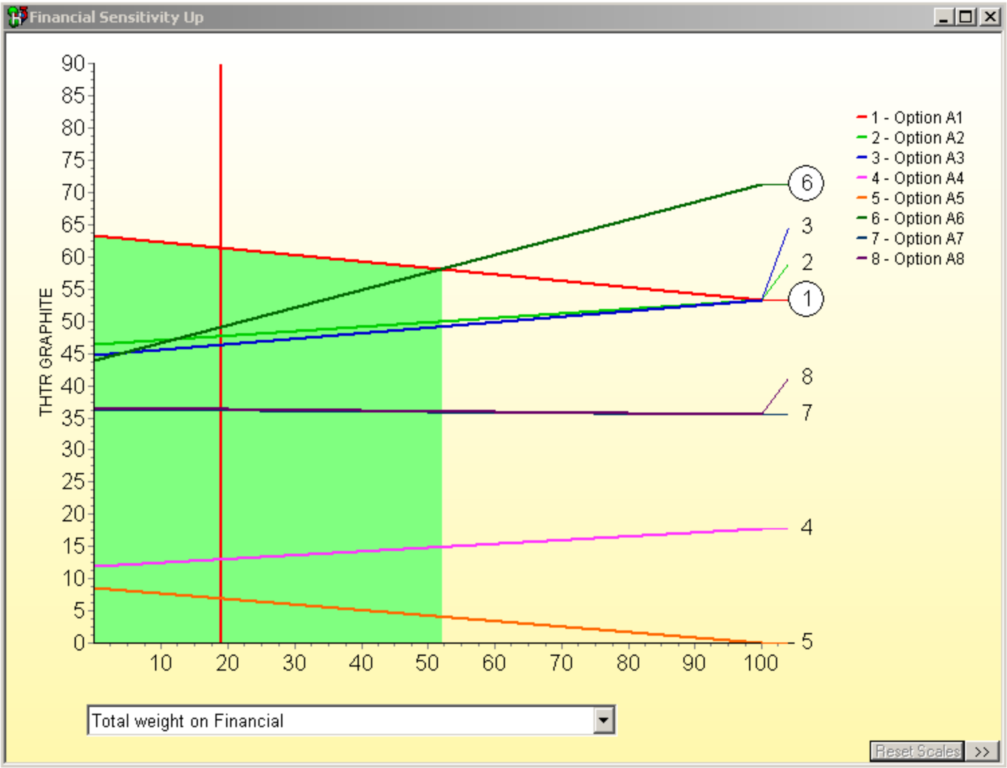


Figure 65: Sensitivity analysis of CHILW THTR graphite scores for the Financial attribute (swing, attribute and sub attributes weightings)

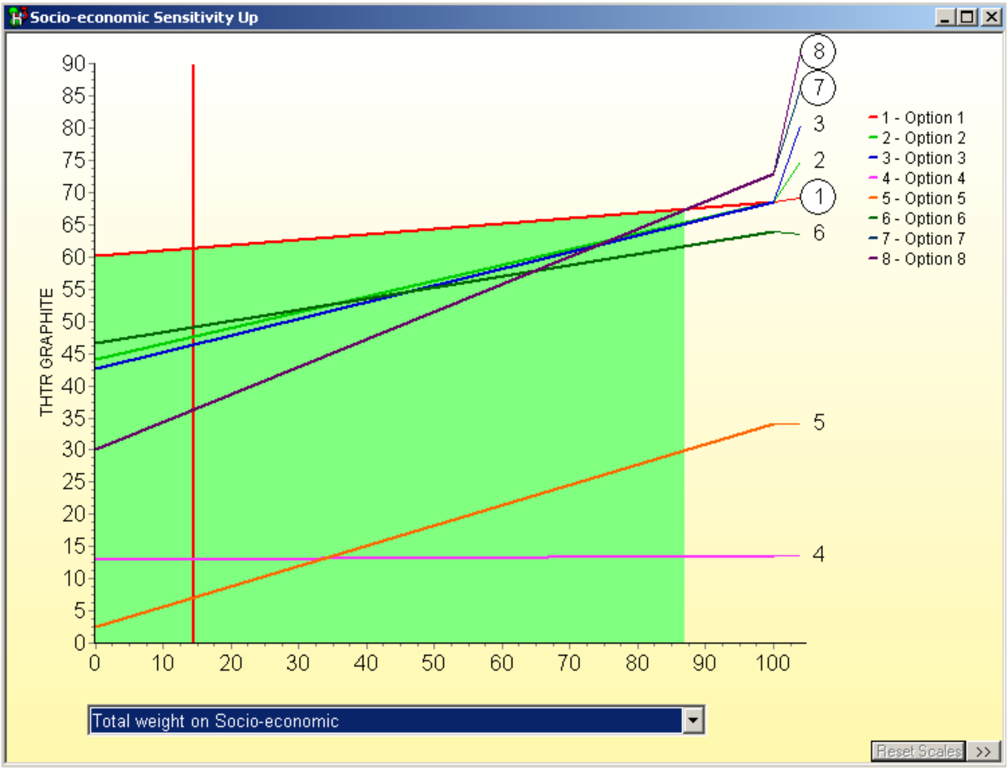


Figure 66: Sensitivity analysis of CHILW THTR graphite scores for the Socio-economic attribute (swing, attribute and sub attributes weightings)

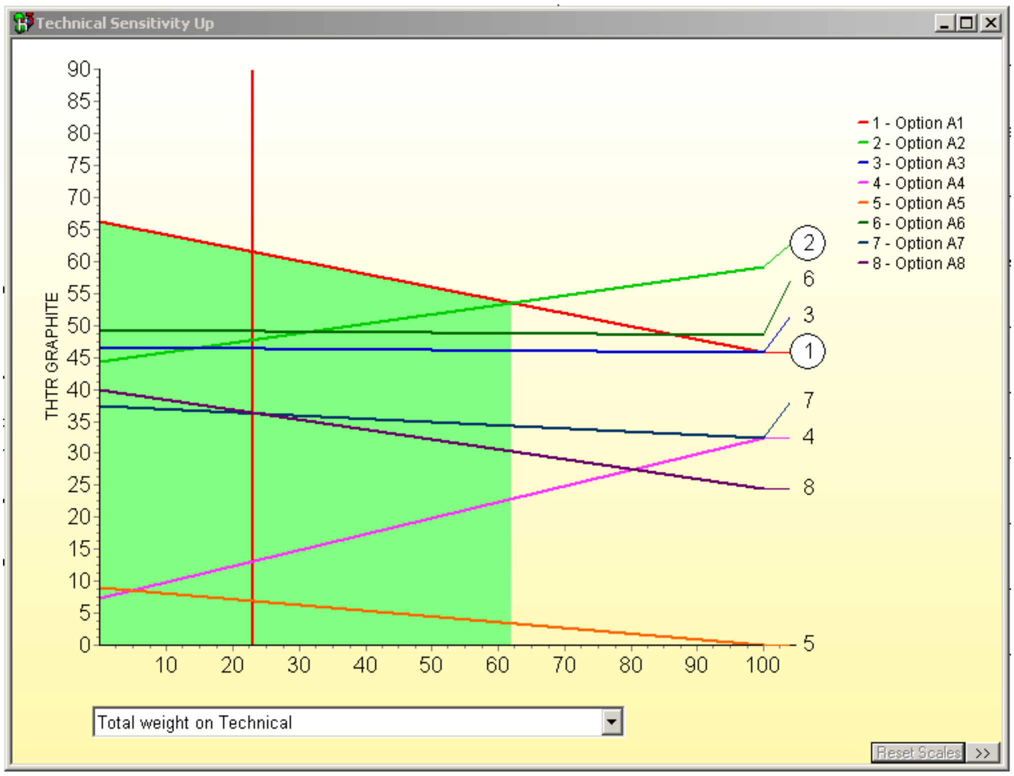


Figure 67: Sensitivity analysis of CHILW THTR graphite scores for the Technical attribute (swing, attribute and sub attributes weightings)

CHILW Graphite (Activated Graphite)

Option no.	Description
B1	Package unencapsulated in 4m boxes
B2	Package and encapsulate (unshielded boxes)
B3	Package unencapsulated (unshielded boxes)
B4	Incineration to decontaminate
B5	High temperature processing
B6	Crush and treat as THTR

Figure 68: Sensitivity analysis of CHILW Activated Graphite scores for the Human health and safety attribute (swing, attribute and sub attributes weightings)

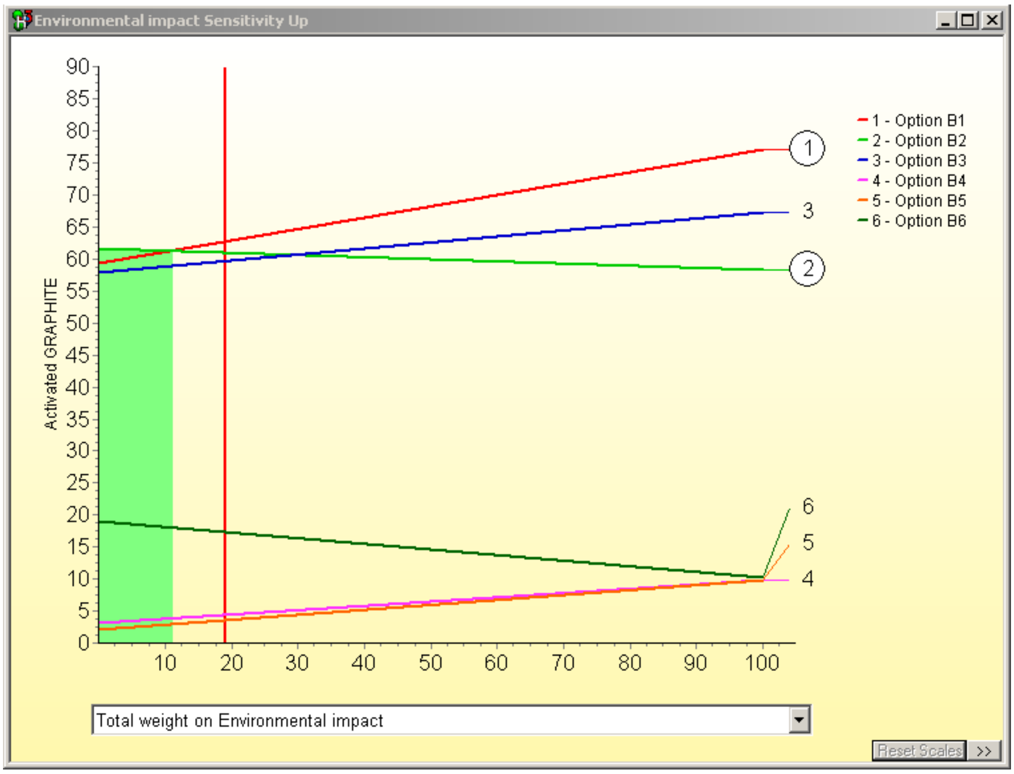


Figure 69: Sensitivity analysis of CHILW Activated Graphite scores for the Environmental impact attribute (swing, attribute and sub attributes weightings)

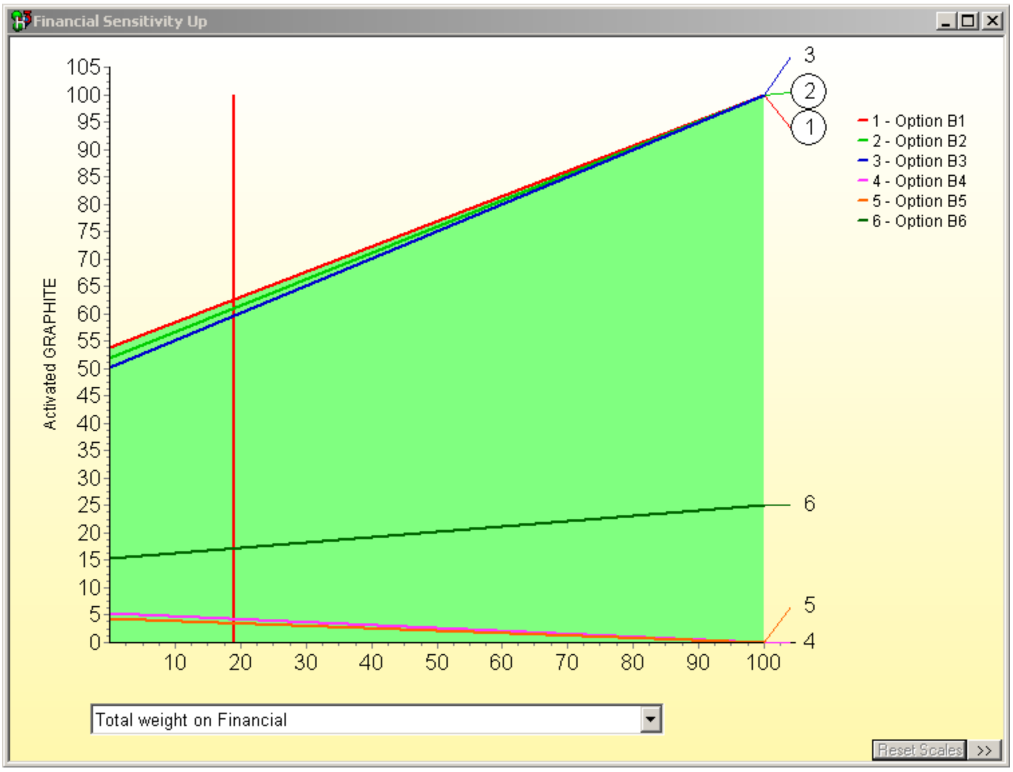


Figure 70: Sensitivity analysis of CHILW Activated Graphite scores for the Financial attribute (swing, attribute and sub attributes weightings)

Figure 71: Sensitivity analysis of CHILW Activated Graphite scores for the Socio-economic attribute (swing, attribute and sub attributes weightings)

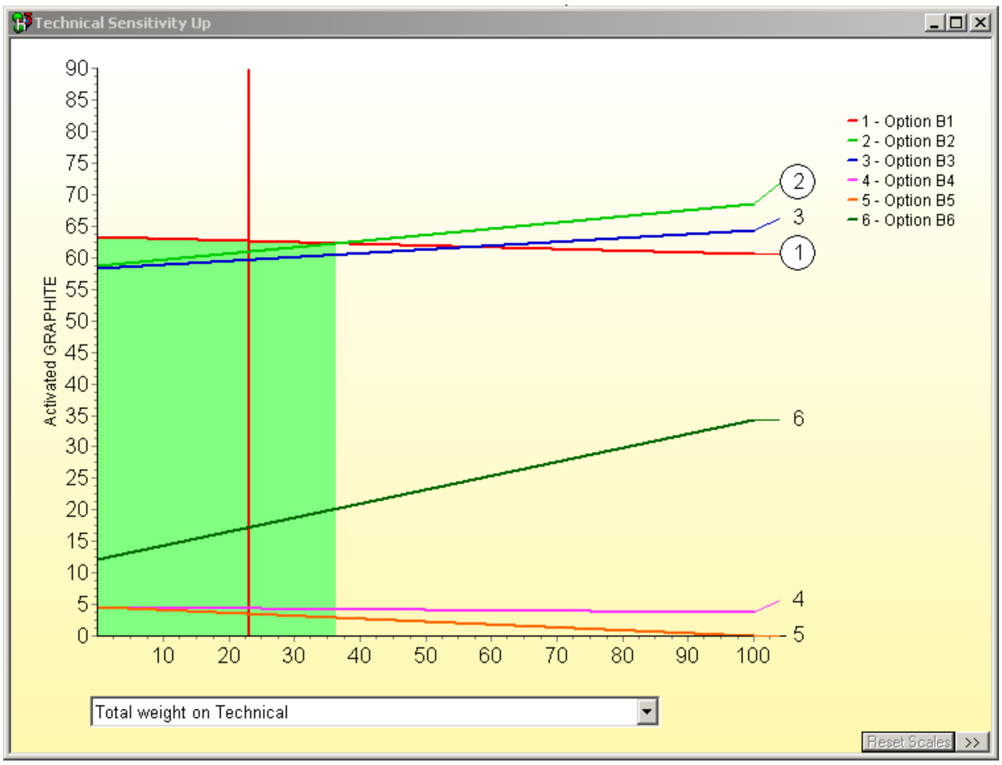


Figure 72: Sensitivity analysis of CHILW Activated Graphite scores for the Technical attribute (swing, attribute and sub attributes weightings)

LLW Sludge (Granular)

Option no.	Description
D1	Treat as slurry
D2	Dewater, bag and treat as HVLA / LLW as appropriate

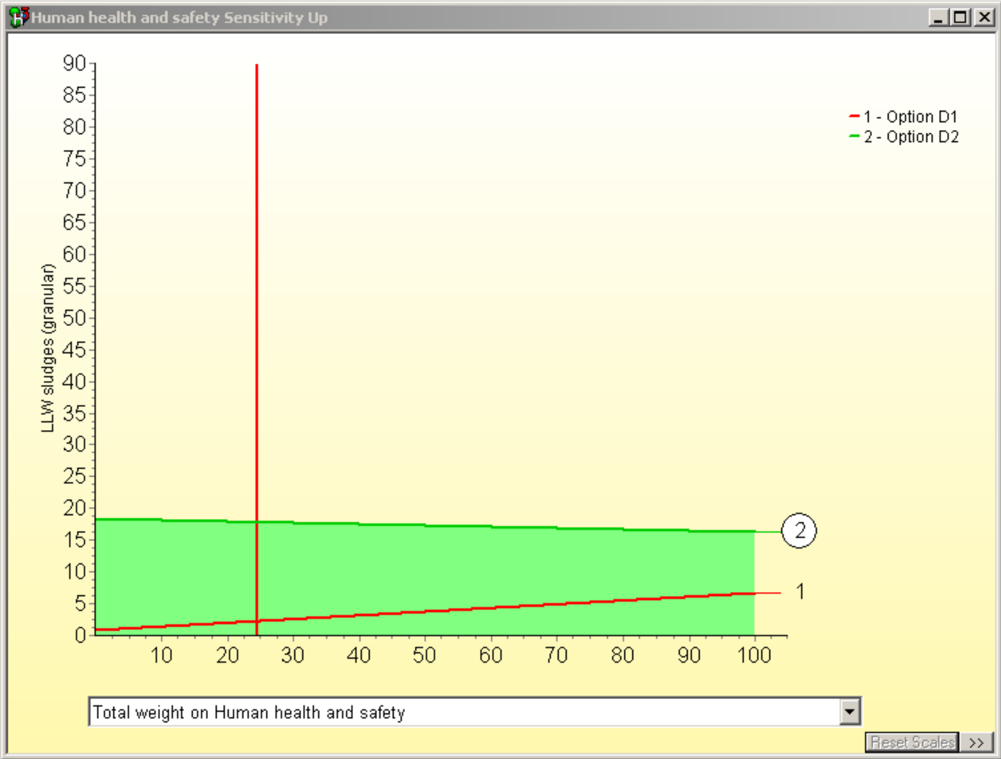


Figure 73: Sensitivity analysis of LLW Sludge (Granular) scores for the Human health and safety attribute (swing, attribute and sub attributes weightings)

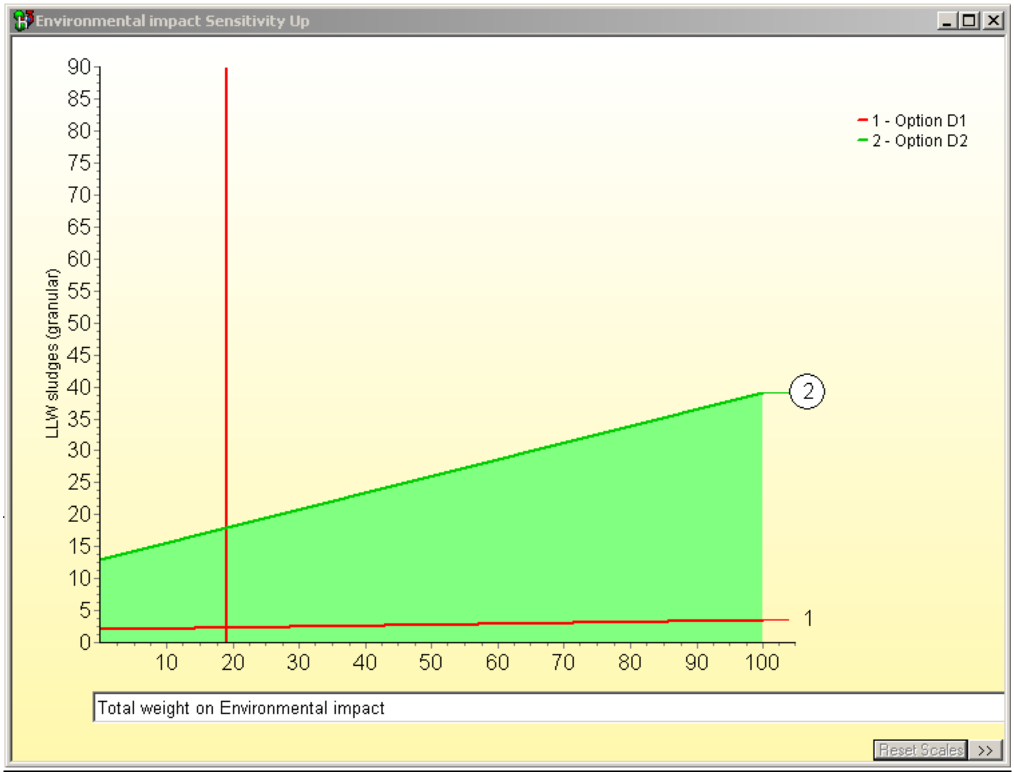


Figure 74: Sensitivity analysis of LLW Sludge (Granular) scores for the Environmental impact attribute (swing, attribute and sub attributes weightings)

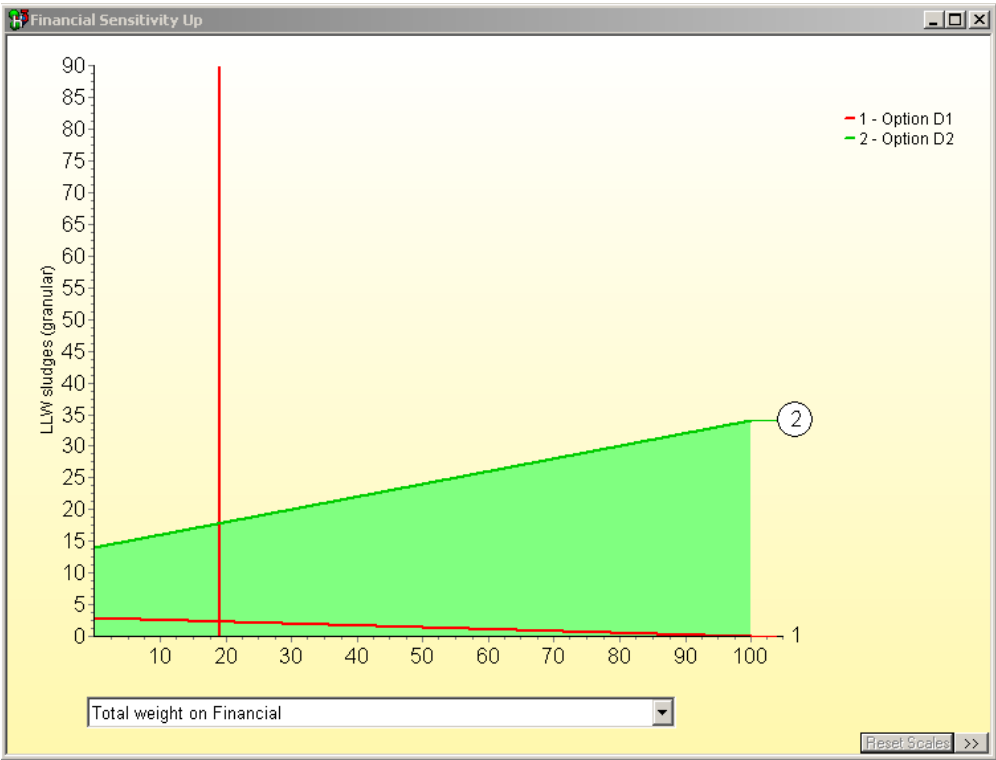


Figure 75: Sensitivity analysis of LLW Sludge (Granular) scores for the Financial attribute (swing, attribute and sub attributes weightings)

LLW Sludge Putrescible

Option no.	Description
E1	Process and incinerate offsite
E2	Process and incinerate on site
E3	Low temperature oxidation
E4	Bioremediation

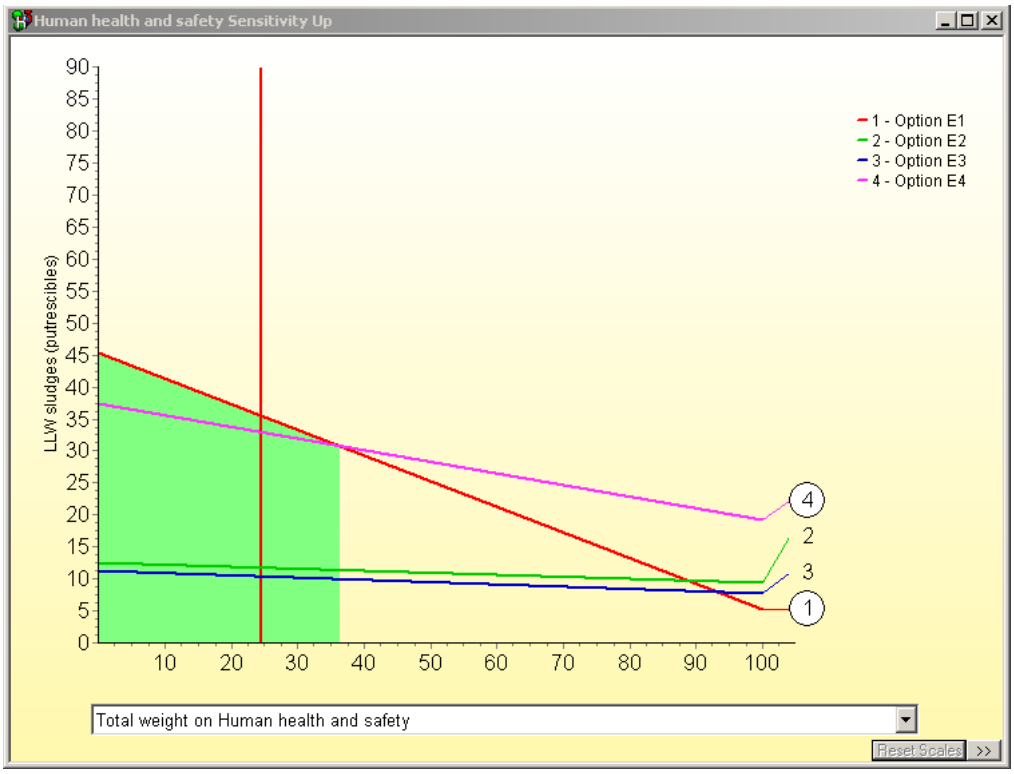


Figure 76: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Human health and safety attribute (swing, attribute and sub attributes weightings)

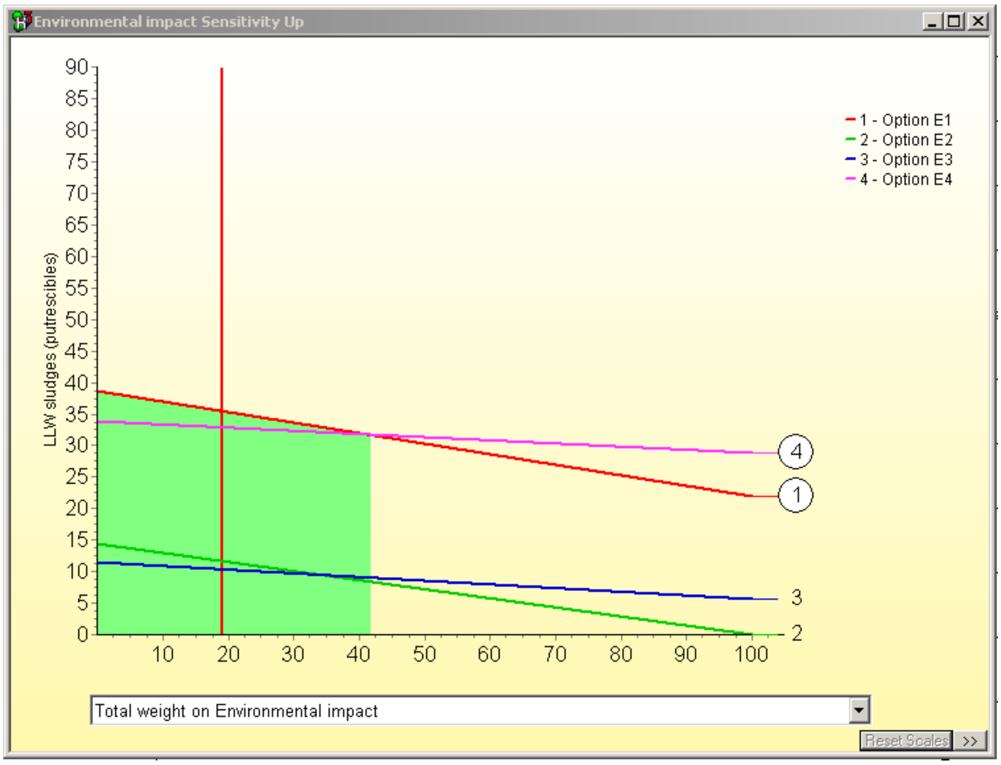


Figure 77: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Environmental impact attribute (swing, attribute and sub attributes weightings)

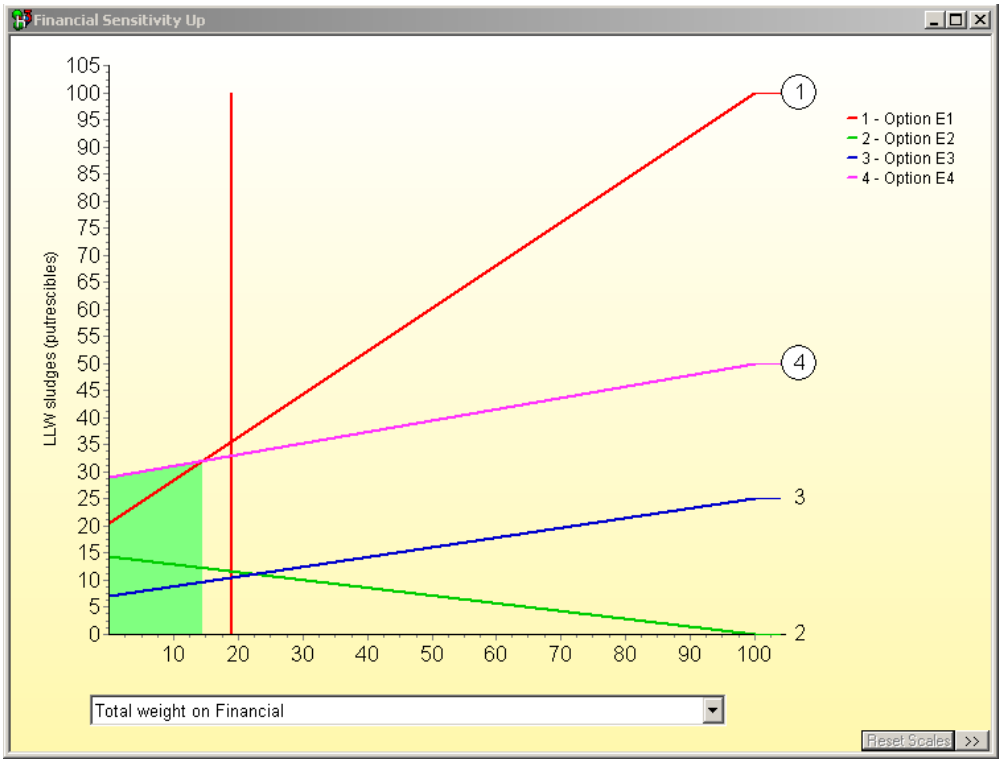


Figure 78: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Financial attribute (swing, attribute and sub attributes weightings)

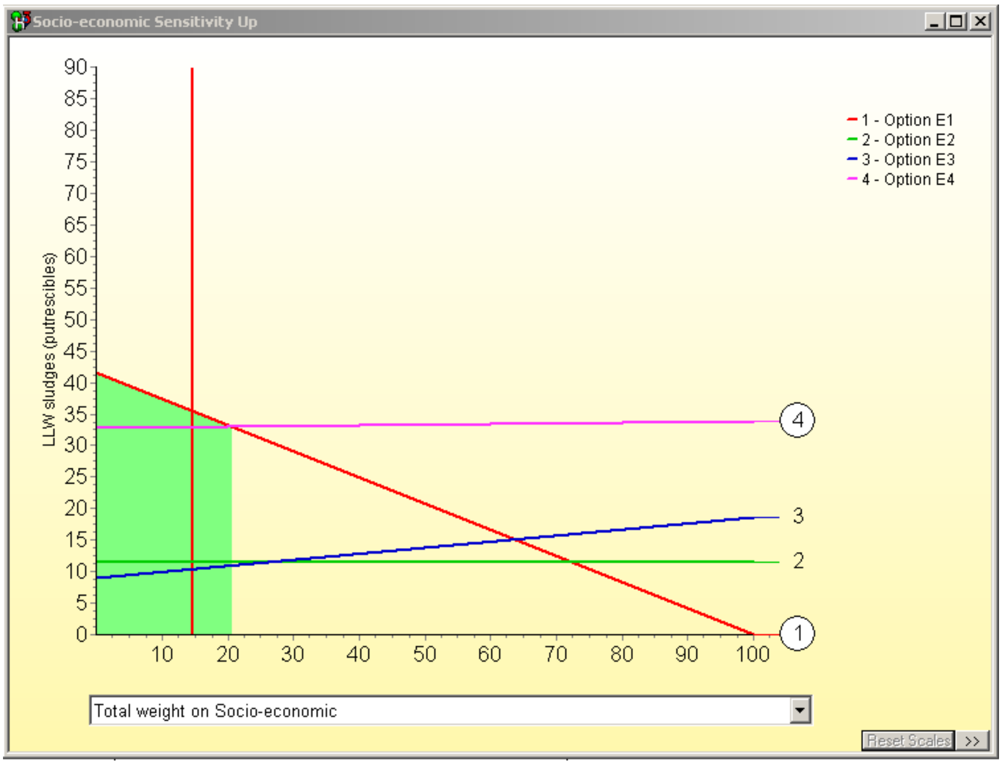


Figure 79: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Socio-economic attribute (swing, attribute and sub attributes weightings)

Figure 80: Sensitivity analysis of LLW Sludge (Putrescible) scores for the Technical attribute (swing, attribute and sub attributes weightings)

Exempt Sludge Putrescible

Option no.	Description
F1	Process and incinerate offsite
F2	Process and incinerate on site
F3	Off-site disposal

Figure 81: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Human health and safety attribute (swing, attribute and sub attributes weightings)

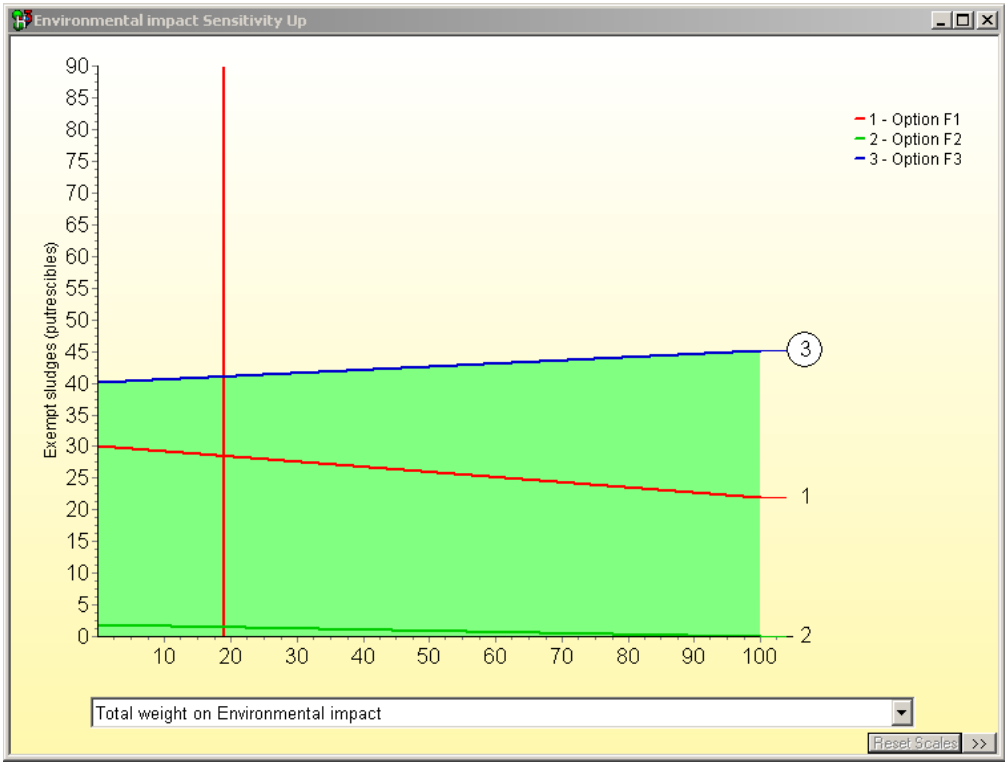


Figure 82: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Environmental impact attribute (swing, attribute and sub attributes weightings)

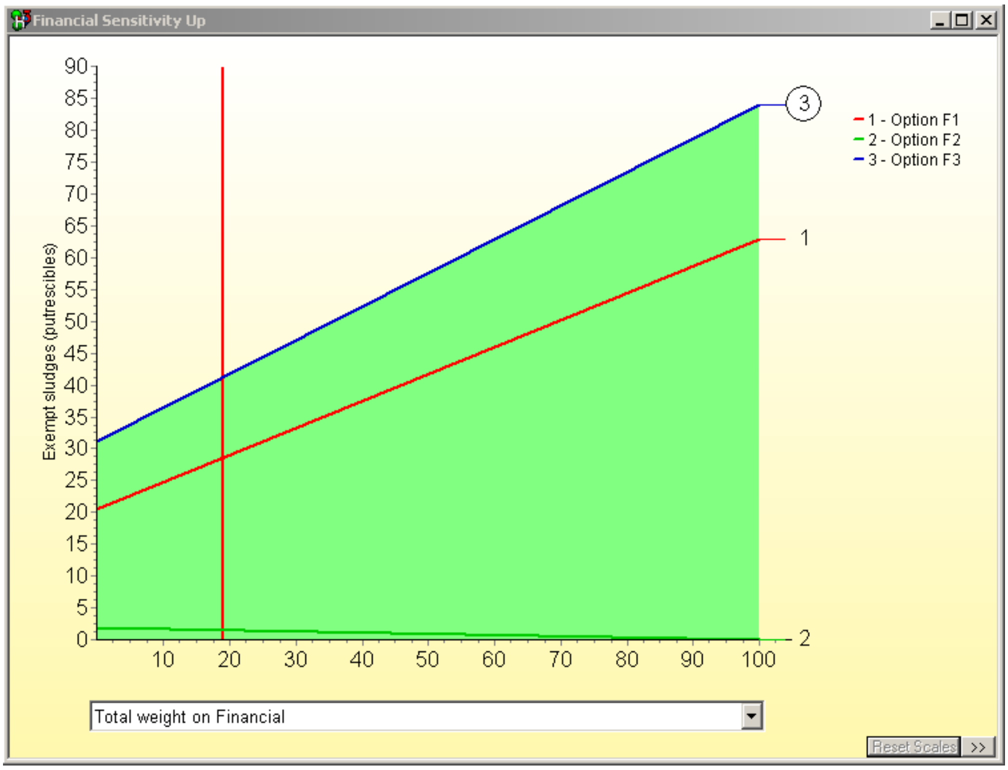


Figure 83: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Financial attribute (swing, attribute and sub attributes weightings)

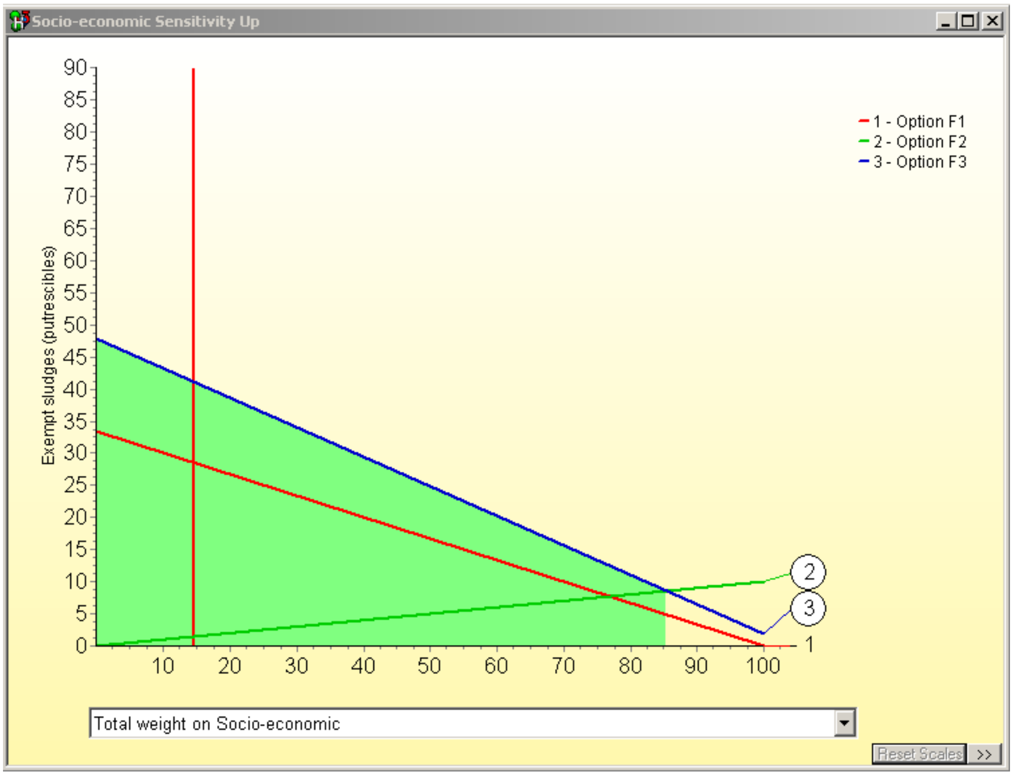


Figure 84: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Socio-economic attribute (swing, attribute and sub attributes weightings)

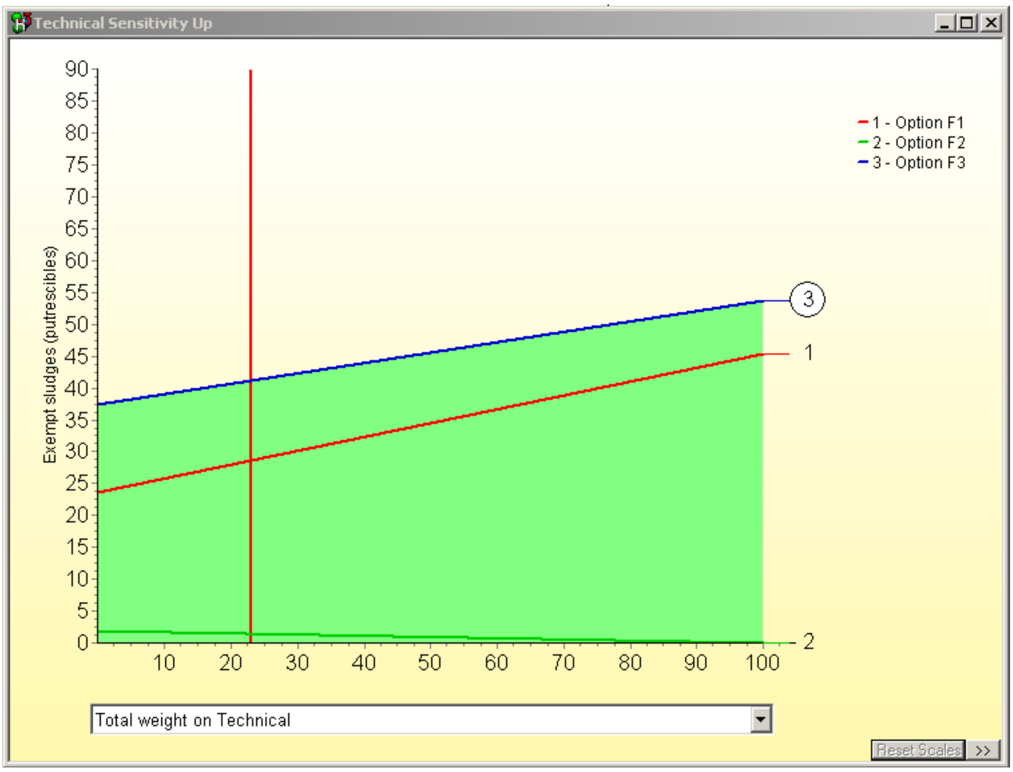


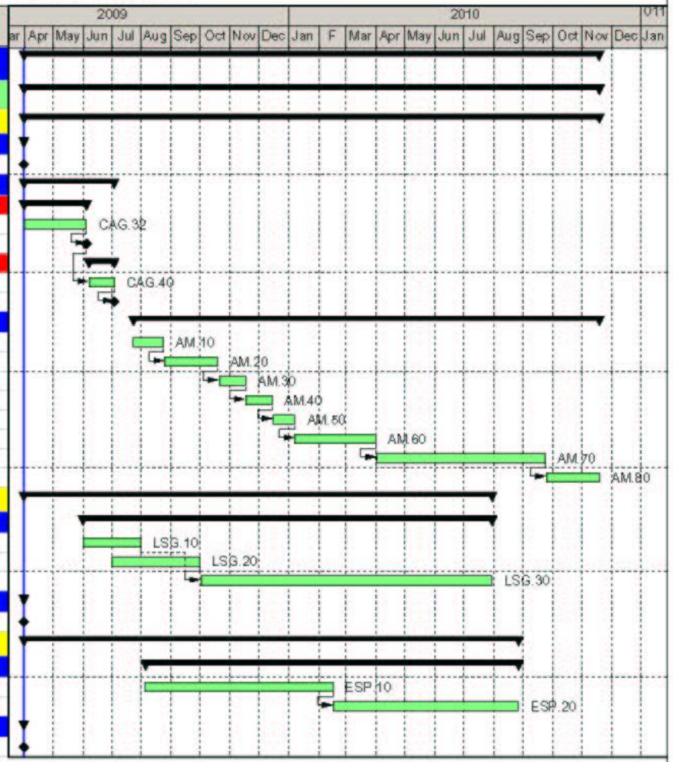
Figure 85: Sensitivity analysis of Exempt Sludge (Putrescible) scores for the Technical attribute (swing, attribute and sub attributes weightings)

APPENDIX 4 – FORWARD PROGRAMME FOR BEPO IMPLEMENTATION

DSRL BPEO Near Term Tasks for Implementation

01-Jun-09 15:33

Activity ID	Activity Name	Original Duration	Start	Finish
Total		408d	01-Apr-09	18-Nov-10
BNTT	DSRL BPEO Near Term Tasks for Implementation	408d	01-Apr-09	18-Nov-10
BNTT.01	ILW Strategy Implementation	408d	01-Apr-09	18-Nov-10
BNTT.01.01	CHILW THTR Graphite	0d	01-Apr-09	01-Apr-09
CTG.10	No changes to the current strategy required	0d		01-Apr-09
BNTT.01.02	CHILW Activated Graphite	64d	01-Apr-09	03-Jul-09
BNTT.01.02.03	LoC Assessment by NDA RWMD	44d	01-Apr-09	05-Jun-09
CAG.32	NDA RWMD Assessment of LoC Submission	44d	01-Apr-09	05-Jun-09
CAG.33	Letter of Compliance/Letter of Advice Received from NDA RWMD	0d		05-Jun-09
BNTT.01.02.04	Letter of Advice (LoA) Response	20d	08-Jun-09	03-Jul-09
CAG.40	Review LoA; Provide Feedback to Project Team	20d	08-Jun-09	03-Jul-09
CAG.41	LoA Feedback Completed	0d		03-Jul-09
BNTT.01.03	LLW Sludge (LSA Scale)	330d	24-Jul-09	18-Nov-10
AM.10	Review available data	20d	24-Jul-09*	24-Aug-09
AM.20	Produce & gain Approval of Baseline Inventory report	40d	25-Aug-09	19-Oct-09
AM.30	Produce & gain Approval of Waste packaging options report	20d	20-Oct-09	16-Nov-09
AM.40	Produce Spec for Conceptual LoC	20d	17-Nov-09	14-Dec-09
AM.50	Tender Selection	10d	15-Dec-09	06-Jan-10
AM.60	Prepare Conceptual LoC	60d	07-Jan-10	31-Mar-10
AM.70	NDA RWMD Assesment	120d	01-Apr-10	23-Sep-10
AM.80	Produce Strategy Paper & SoR	40d	24-Sep-10	18-Nov-10
BNTT.02	LLW Strategy Implementation	331d	01-Apr-09	30-Jul-10
BNTT.02.01	LLW Sludge (Granular)	292d	01-Jun-09	30-Jul-10
LSG.10	Review BPM and Optioneering studies	45d	01-Jun-09	31-Jul-09
LSG.20	Prepare Specification for Concept Design	64d	01-Jul-09	30-Sep-09
LSG.30	Initiate Concept Design	206d	01-Oct-09	30-Jul-10
BNTT.02.02	LLW Sludge (Putrescible)	0d	01-Apr-09	01-Apr-09
LSP.10	Characterisation has established no waste is in this category	0d	01-Apr-09	
BNTT.03	Clean / Exempt Strategy Implementation	348d	01-Apr-09	26-Aug-10
BNTT.03.01	Exempt Sludge (Putrescible)	264d	05-Aug-09	26-Aug-10
ESP.10	Identify Suitable Landfill Sites	132d	05-Aug-09	15-Feb-10
ESP.20	Package Waste and Complete First Shipment	132d	16-Feb-10	26-Aug-10
BNTT.03.02	Clean Sludge (Putrescible)	0d	01-Apr-09	01-Apr-09
CSP.10	Characterisation has established no waste is in this category	0d	01-Apr-09	



Remaining Work
Actual Work
Critical Remaining Work
◆ Milestone
summary

Page 1 of 1

Date	Revision	Checked	Approved
01-Apr-09	Data Date	GGC	GB