Strategic BPEO For Metal Waste Management – Options Evaluation

Studsvik Contract Reference:	P0090
Studsvik Report Reference:	P0090/TR/002
Customer Contract Ref:	
Revision:	A
Date:	11/04/06

Prepared By:	.... **DAVID ROSSITER**	**Date: 11/04/06**
Checked By:	.... **JOE ROBINSON**	**Date: 11/04/06**
Approved By:	.... **MARK LYONS**	**Date: 11/04/06**

Studsvik UK Limited
Unit 14, Princes Park
Fourth Avenue
Team Valley Trading Estate
Gateshead
Tyne and Wear
NE11 0NF

Technical Report

REVISION SHEET

Rev.	Description	Revised By	Checked By	Approved By
DRAFT	First Issue	D Rossiter	J Robinson	M Lyons
A	Incorporation of additional information and NDA comments	D Rossiter	J Robinson	M Lyons

LIMITATIONS

This report has been prepared by Studsvik UK Limited in their professional capacity as Consultants, with all reasonable skill, care and diligence within the terms of the Contract with the Client. The advice and opinions in this report are based upon the information made available at the date of this report and on current UK standards, codes and legislation. The contents of this report do not, in any way, purport to include any manner of legal advice or opinion.

Should the Client release this report to a Third Party, that Third Party does not acquire any rights, contractual or otherwise, whatsoever against Studsvik UK Limited and accordingly, Studsvik UK Limited assumes no duties, liabilities or obligations to that Third Party.

Glossary

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Techniques
BNFL	British Nuclear Fuels Limited
BNG	British Nuclear Group
BNGSL	British Nuclear Group Sellafield Limited
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
CO_2	Carbon Dioxide
CoRWM	Committee on Radioactive Waste Management
EA	Environment Agency
EIA	Environmental Impact Assessment
EU	European Union
FSA	Food Standards Agency
HGV	Heavy Goods Vehicle
HHISO	Half-Height ISO Container
HSE	Health and Safety Executive
ISO	International Organisation of Standardisation
LAHV	Low-Activity High Volume
LCBL	Life-Cycle Baseline
LLW	Low Level Waste
NDA	Nuclear Decommissioning Authority
NO_x	Nitrogen Oxides
NTWP	Near-Term Work Plan
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)
PCM	Plutonium Contaminated Materials
PCSC	Post Closure Safety Case
R&D	Research and Development
RSA	Radioactive Substances Act
SEA	Strategic Environmental Assessment
SO_2	Sulphur Dioxide
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
US	United States
VOC	Volatile Organic Compound
WT	Waste Treatment

Executive Summary

This report is the second report for this BPEO study and sets outs findings of the Options Evaluation phase of the BPEO. The agreed objective of this study was as follows:

To provide NDA with a full understanding of the technical and commercial arguments, justifications and issues relevant to the implementation of various management techniques on low level radioactive metals wastes in the UK. This will be achieved through the application of a BPEO assessment methodology to determine metal management options for significant aggregated waste streams in the UK.

The key outcome would be an objective understanding of the strength of case for a centralised UK metals / recycling facility.

The identification and screening of options is described in detail in the first strategic BPEO report (P0090/TR/001). Originally 66 options for metallic waste management were identified which were subsequently screened down in stages to 5 options to be taken forward for detailed evaluation. These options were also placed in the context of route-maps which showed that certain processes should be common to all options such as waste minimisation, improved assay, re-use and decontamination as part of an optimised waste management strategy.

This BPEO study was undertaken at a strategic level and evaluated a series of options for management of metallic LLW against a number of safety, environmental, economic, and technical attributes. The options were scored in a workshop against each attributes and weighting factors were applied. Further analysis has been undertaken on specific issues such as operational costs and environmental impact.

The weighted scores were subjected to a sensitivity analysis to provide confidence that the order of the options is robust against variations in the weighting of particular categories.

Following the scoring and analysis, the best option was considered to be waste treatment in an overseas facility. The worst option was considered to be disposal at a national LLW facility such as Drigg. The waste treatment overseas option has several advantages over the other options such as immediate availability, low construction and decommissioning costs, reduction in solid waste disposal, low nuisance, recycling of material and associated resource conservation. In addition there is very little risk of project delays and cost overruns compared to the other options as the facilities are currently operating and licensed.

The waste treatment overseas option also strongly aligns with the principles of the waste hierarchy, the presumption towards early solutions and the NDA's accelerated decommissioning strategy and could play a significant part in helping to preserve the strategic resource of existing capacity at Drigg in short term. It is therefore recommended that full advantage should be taken of these waste routes for metallic LLW.

A number of recommendations have been made where further work may be warranted including stakeholder consultation.

Contents

Page

1. Introduction

1.1 Objective

This report has been prepared on behalf of the NDA by Studsvik UK Limited. The NDA has the aim to ensure that the UK's 20 civil public sector nuclear sites are decommissioned and cleaned up safely and effectively. In terms of Low Level Waste, the NDA is currently considering options for the management of LLW in order to assess whether there are more cost effective and environmentally better options for the disposal of LLW than at the Drigg facility in Cumbria.

Studsvik is a specialist nuclear and waste management company with significant knowledge and experience of LLW management and in particular for metallic LLW. To this end, Studsvik has been engaged by the NDA to develop a strategic BPEO study into metal waste management. The agreed objective of this study is as follows:

To provide NDA with a full understanding of the technical and commercial arguments, justifications and issues relevant to the implementation of various management techniques on low level radioactive metals wastes in the UK. This will be achieved through the application of a BPEO assessment methodology to determine metal management options for significant aggregated waste streams in the UK.

The key outcome will be an objective understanding of the strength of case for a centralised UK metals / recycling facility. It was agreed that it is a priority to establish the key metallic wastes in the UK (i.e. the 'big hitters') and where they are located.

This report is the second for this BPEO study and sets outs findings of the Options Evaluation phase of the BPEO. It also presents the analysis work following the second workshop on 12th December 2005 and the conclusions from the options scoring process. The first report, P0090/TR/001[4], for this BPEO study covers the options identification and screening assessment undertaken in the first workshop on 30th September 2005.

1.2 Strategic BPEO Approach

A BPEO assessment is a systematic approach to decision analysis that typically includes a number of environmental, economic, safety and technical attributes.

The Environment Agency has produced best practice guidance on the BPEO methodology[1] which addresses their expectations with respect to the nature and balance of attributes that might be used. In addition, the strategic nature of this particular study makes it appropriate to consider the requirements of the Strategic Environmental Assessment (SEA) Directive[2].

Individual nuclear licensed sites often undertake BPEO studies for their specific waste streams to satisfy the requirements of their Radioactive Substances Act 1993 authorisation. However, the best options identified through these localised BPEO studies may not represent BPEO when the issue of solid metallic waste is assessed from a nationwide viewpoint. That is to say, individual sites may not consider new technologies to be practicable if substantial investment, planning and construction work is required, whereas a UK-wide strategic BPEO study could show that such fiscal and time investment is warranted if it provides a suitable solution for all such waste produced in the UK.

This Strategic Metal Waste Management BPEO study therefore incorporates aspects of both the Environment Agency guidance note and the SEA Guidance and looks at metallic LLW from a national perspective.

The EA guidance on BPEO studies includes provisions for stakeholder consultation at various points in the BPEO assessment process. At the request of the NDA, stakeholder consultation at this stage of the BPEO study has not been undertaken, although this may be undertaken by the NDA following assessment of the technical arguments arising from this study. The intention of this BPEO is to provide the NDA with internal advice on the issues surrounding management of LLW in the UK and to recommend areas of further work that would include stakeholder engagement as a fundamental part of the process.

This strategic BPEO study also recognises the limitations of the Drigg LLW Repository capacity and the predicted LLW waste arisings under the decommissioning programme proposed in the NDA Strategy[3]. This strategic BPEO assessment also attempts to capture the true cost of disposal of Drigg and explore the costs and benefits of other alternative management options and disposal routes.

2. Options Evaluation Workshop

2.1 Workshop Information

The options evaluation workshop was undertaken on 12th December 2005 and facilitated by Lise Stoyell of Studsvik UK Ltd. The attendees and their specific areas of expertise are listed in Appendix A.

The objectives of the workshop were:

- To review the option screening activities that had been undertaken since the last workshop.
- Agree the shortlisted options for LLW management.
- Evaluate the shortlisted options for alternative management of aggregated low level radioactive metal waste streams in the UK using agreed scoring criteria.

In order to provide a framework for the Options Evaluation exercise, information on the previous phases of work undertaken to define the metallic LLW inventory, option identification, screening and route-mapping process was presented at the workshop. This presentation is included in Appendix B and sets out summary information on the route-mapping process and a description of the shortlisted options for evaluation. A full description of the shortlisting process is included in the first technical report-P0090/TR/001[4].

Following the presentation, a brief description and discussion of the shortlisted options was undertaken to ensure all attendees had a common understanding of the options being evaluated and to review if any further options should be added to be shortlist.

3. Options for BPEO Evaluation

3.1 Short listed Options

As requested during the screening exercise[4], route-mapping was undertaken to show how options could fit together into complete waste management solutions. This resulted in five options being shortlisted (out of 66 originally identified) for further evaluation. These were:

- Option 2.4 – National LLW Facility (Drigg or Drigg II)
- Option 2.15 – Engineered Onsite LLW Facility
- Option 11.2 – Overseas Waste Treatment
- Option 11.1A – Regional Waste Treatment Facility
- Option 11.1B – National Waste Treatment Facility

It is important to note that the route-mapping process highlights the need to consider each short listed option in the context of an overall management solution from waste generation through to final disposal.

These shortlisted options were discussed and agreed with the panel at the workshop. A technical description of each option proposed for detailed BPEO evaluation is included below.

3.1.1. Option 2.4 – National LLW Facility (Drigg or Drigg II)

This option represents a continuation of current practice for disposal of the majority of LLW in the UK. Waste is packed into ISO containers at site and transported by road or rail to the national LLW repository at Drigg. Waste is then compacted (where practical), grouted into half-height ISO containers (HHISO) or third-height ISO containers, and placed in concrete-lined trenches or vaults.

The capacity of the existing Drigg site is limited in both the short-term by licensing issues and in the long-term by both volume and radionuclide inventory.

For the purposes of this option it is therefore assumed that, a new LLW waste repository facility (i.e. 'Drigg II') would be required at some stage to accommodate metallic and non-metallic waste arisings from the NDA's approved decommissioning strategy. This may be located close to the existing Drigg facility in Cumbria or in another area of the country.

It is assumed that a new national LLW facility would be based on the existing disposal technology currently applied at Drigg (i.e. burial in engineered trenches) rather than a 'European Type' above-ground disposal facility or an intermediate or deep LLW disposal facility.

It is however possible that the new facility may be based on more conventional landfill technology (e.g. clay or membrane lined trenches) and be designed for disposal of lower activity wastes whilst higher activity wastes are disposed of at the existing Drigg facility.

3.1.2. Option 2.15 – Engineered Onsite LLW Facility

Waste would be appropriately packaged and placed in an engineered onsite LLW facility which would eventually be closed off by engineered caps and landscaped. This option requires significantly less transportation of LLW offsite.

An engineered onsite facility could be based on the approach used at Drigg (i.e. near surface disposal in concrete lined vaults or trenches) or on above ground, intermediate or deep LLW disposal solutions. An engineered near surface onsite disposal facility is likely to be utilised at Dounreay to accommodate LLW waste arisings from that site.

It is however possible that an onsite LLW facility could utilise more conventional landfill design techniques (e.g. clay or membrane lined trenches) for less active wastes (e.g. Low Activity-High Volume (LAHV) decommissioning wastes and soil) or utilise existing site structures such as turbine hall basements in conjunction with an impermeable membrane and/or clay liner. In addition to the engineered LLW waste facility at Dounreay it is proposed to construct a more simply engineered disposal facility (based on lined trench technology) to accommodate LAHV wastes from decommissioning activities.

It is unknown if the onsite disposal option is technically feasible at all UK nuclear licensed sites due to localised geological factors and risk of coastal erosion. There is currently some uncertainty over the number of onsite facilities that would be required and the feasibility of shared facilities between neighbouring sites needs to be determined. These issues are beyond the scope of this BPEO study.

Long-term management and monitoring of site discharges is likely to be necessary for onsite LLW facilities. The presence of a LLW facility would also impact on the permitted future site land usage and the ability to de-licence and release some sites for unrestricted use (i.e. the site end-state).

3.1.3. Option 11.2 – Overseas Waste Treatment using Existing Routes

The aim of treating metallic waste is to reduce the volume and weight of the waste that has to be disposed of and recycle as much material as possible.

Several candidate LLW treatment processes were documented in the options identification workshop including melting, complete dissolution, chemical separation and corrosion. It is important to note that in the context of this study ‘waste treatment’ refers to processes that change the chemical state of the waste material. This is distinct from ‘decontamination’ which typically only alters the surface of the material. As shown in the route-mapping exercise, decontamination is considered a desirable precursor to both ‘waste treatment’ and ‘disposal’ options.

It is thought that complete dissolution, chemical separation and corrosion facilities do not currently exist on a significant scale whereas overseas melting LLW treatment facilities exist in countries such as Sweden, Germany and the United States.

In this option metallic waste would be packaged onsite into ISO containers and transported by road or rail to a UK port. Containerised LLW can then be transported by sea to the overseas treatment facility. Alternatively large components could be shipped 'whole'.

Metal is received, characterised, size reduced and decontaminated prior to melting in an induction or electric-arc furnace. Once melted, the radioisotopes concentrate into the floating slag layer which can be collected and subjected to further size reduction via compaction or simply packaged for final disposal or storage. This radioactive waste is then usually returned to the customer for disposal as LLW. Where melting is undertaken in the US it may be possible for waste to be permanently disposed of in the US rather than being returned to the country of origin. The homogenised metal is then cast into an ingot which can be more easily assayed, handled, stored and recycled or cast into components for the nuclear industry such as shielding blocks. Sampling and analysis of the bulk metallic mass is undertaken in the melted state which allows representative sampling to occur (i.e. a small sample represents the characteristics of the homogenised bulk).

Even if the original radioactive contamination is too high to provide a recyclable ingot the reduced volume and stable form of the ingot facilitates easy storage of the scrap metal. In many cases a reasonable decay time may render ingots suitable for recycling. After melting the metal ingots are released for recycling subject to the Exemption Criteria prevailing in the country of treatment (it is noted that a standardised approach to this exemption exists across most of Europe).

Treatment processes such as melting can allow up to 95% of the original metal to be free-released into the steel industry for recycling. Radioactive residues and secondary wastes (estimated at around 5% of the original waste material) are returned to the UK for disposal.

As this is route uses existing facilities and proven technology there is the potential to relieve the pressure on Drigg immediately.

3.1.4. Option 11.1A – Regional Waste Treatment Facility

The aim of treating metallic waste is to reduce the volume and weight of the waste that has to be disposed of and recycle as much material as possible. Several candidate LLW treatment processes were documented in the options identification workshop including melting, complete dissolution, chemical separation and corrosion.

Metallic waste would be packaged onsite into ISO containers and transported by road or rail to the regional facility or large components could be transported 'whole'. It is assumed that a treatment facility would be constructed in each NDA region (i.e.

North, South, Central and Scotland) to service the sites within that area. It is assumed that appropriate sites for the treatment facilities can be found in each region and successfully licensed/authorised.

3.1.5. Option 11.1B – National Waste Treatment Facility

The aim of treating metallic waste is to reduce the volume and weight of the waste that has to be disposed of and recycle as much material as possible. Several candidate LLW treatment processes were documented in the options identification workshop including melting, complete dissolution, chemical separation and corrosion.

Metallic waste would be packaged onsite into ISO containers and transported by road, rail or sea to a national treatment facility. Large components could be transported 'whole'. The national treatment facility would be capable of dealing with large volumes of metallic waste and benefit from economies of scale when compared to smaller regional facilities.

4. Decision Attributes and Scoring

4.1 Attribute Descriptions

In order to undertake a robust decision analysis of metal waste management options, it is necessary to base the underpinning assessment on a set of attributes that capture all key aspects of the option set.

At the outset of the project it was agreed that the attributes for decision criteria should include a mix of environmental, safety, technical and economic criteria, in alignment with the Environment Agency's guidance on BPEO[1]. It was also requested that the chosen criteria are also aligned with the intent of the SEA / EIA Directive[2] as far as possible.

The list of attributes was discussed and agreed during the options evaluation workshop prior to the scoring exercise. Some changes to the preliminary list of attributes were made to avoid overlaps and clarify the definition of some of the attributes. The EA and SEA attributes and the agreed finalised attributes that are to be taken forward for this BPEO study are listed in Table C1 of Appendix C.

The finalised attributes draw from both the EA BPEO guidance and the SEA directive requirements and are adapted to capture the context of the issues surrounding management of metallic radioactive waste. Attributes, such as political and societal acceptance and those attributes that can only be effectively scored on a site-specific basis are not considered at this stage. However, it is anticipated that these factors would be examined in a second phase of the work, via stakeholder consultation.

An agreed description and definition of each finalised attribute used in the BPEO scoring process is included in Table 4.1 below.

TABLE 4.1 – ATTRIBUTE DESCRIPTIONS

ATTRIBUTE	FULL ATTRIBUTE DESCRIPTION
SAFETY	
Critical group dose to public	Critical group dose to public during construction, commissioning, operations and decommissioning of metal management option.
Occupational dose to workforce	Occupational dose to workforce during construction, commissioning, operations and decommissioning of metal management option.
Risks from conventional hazards to public	Conventional safety hazards to public during the option's life-cycle i.e. traffic.
Occupational risks from conventional hazards to workforce	Conventional safety hazards to workforce during the option's life-cycle i.e. impact, falls, asphyxiation, fire etc.
ENVIRONMENTAL	
Impact on water quality and marine systems (including impact on OSPAR targets)	Radioactive and non-radioactive discharges to water during the options life-cycle
Impact on air quality	Radioactive and non-radioactive discharges to air during the options life-cycle
Legacy of long-term contaminant residues i.e. impact on land quality.	Legacy of the contaminant residues that will remain at the end of the option's operational phase.
Solid waste generation	Radioactive and non-radioactive waste (includes primary and secondary wastes - i.e. total amount that requires disposal)
Life-cycle materials and energy requirement (resource conservation)	Assessment of the potential for conservation of energy and material resources throughout the lifecycle (i.e. the positive impact) by implementing a particular option.
Life-cycle materials and energy requirement (resource consumption)	Assessment of the input (i.e. consumption) of energy and material throughout the lifecycle (construction, commissioning, operations, modifications, decommissioning and site restoration) of the option.
Transport-related environmental discharges	Transport-related emissions incurred due to the transfer of waste metal during the option's life-cycle, including road, rail and sea.
Hazard Withstand to natural and man-made external hazards	Consideration of the option's siting and vulnerability to natural and man-made disasters, such as flooding or terrorist attack.
TECHNICAL	
Confidence in technology	Will the option be effective?
Availability of technology within required timescale	Is the option available in the required timescales? Development times, safety cases, permitting, etc
Flexibility of option	Can the option cope with uncertain input waste volumes and inventories?
SOCIO-ECONOMIC	
Nuisance (noise, odour, visual)	Nuisance during the option's life-cycle (noise, odour, visual)
Impact on cultural heritage.	Consider whether the option will impact on archaeology or historic woodland during it's' life-cycle.
Impact on local economy	Consider the option's effect on employment levels and the socio-economic status of the local area that will benefit / disbenefit.
ECONOMIC	
Construction cost	Financial cost of construction.
Operational cost	Financial cost of operations.
Decommissioning cost	Financial cost of decommissioning and site restoration.
Project Risks	Delays, public issues, project risk, regulatory environment

4.2 Scoring Methodology

It was agreed that a 'Simple Additive Weighting' method would be applied for the multiple attribute decision analysis, using a relative scoring index of 1-5 in conjunction with swing weighting. This is considered a robust technique which has been widely used for similar studies and is in accordance with the suggested scoring methods outlined in the EA BPEO Guidance[1].

The performance of each option on the short list is discussed and evaluated against each attribute relative to the other options. The results of the evaluation are recorded as a numerical 'score' between 1 and 5. A high score (i.e. 5) represents the most favourable option with respect to the particular attribute. Intermediate options were then scored as appropriate. A full record was taken of the justification and reasoning for the scoring decisions of the panel.

Where there was very little discernable difference between two (or more) shortlisted options, the same score has been awarded to each option (e.g. both may be ranked as a 3).

Weighting factors are then applied to each attribute to reflect the relative performance between the best and the worst option and hence the relative importance of the attribute to the overall selection of the BPEO.

The weighting factors for each attribute were discussed and agreed by the panel and the reasoning recorded. For the purposes of this study, weighting factors of 1, 3 or 5 have been allocated to each attribute. Weights were assigned as follows:

- 1 = insignificant difference between the performance of the best and worst option
- 3 = significant difference between the performance of the best and worst option
- 5 = highly significant difference between the performance of the best and worst option

To calculate the weighted score for an attribute the weighting factor is multiplied by the option's score. The weighted scores for all attributes are then summed to give a total score for each option.

Sensitivity analysis was undertaken following the workshop on the most significant attributes by varying the weighting factors to test the robustness of the scoring process and conclusions of the option evaluation.

5. Results of Scoring Exercise

The agreed option scores for each attribute and the associated weighting factors are shown in Table 5.1 below. The weighting factors that have been subjected to sensitivity analysis are also shown.

TABLE 5.1 – ATTRIBUTE SCORES AND WEIGHTING

CATEGORY	ATTRIBUTE	WEIGHTING[1]	OPTION 2.4 – NATIONAL LLW FACILITY	OPTION 2.15 – ENGINEERED ONSITE LLW FACILITY	OPTION 11.2 – OVERSEAS WASTE TREATMENT	OPTION 11.1A – REGIONAL WASTE TREATMENT FACILITY	OPTION 11.1B – NATIONAL WASTE TREATMENT FACILITY
SAFETY	Critical group dose to public	1	4	5	1	2	1
	Occupational dose to workforce	1	1	1	3	5	5
	Risks from conventional hazards to public	3 (5)	2	5	1	3	2
	Occupational risks from conventional hazards to workforce	1	5	5	1	1	1
ENVIRONMENTAL	Impact on water quality and marine systems	1	1	1	5	5	5
	Impact on Air Quality	1 (3)	5	5	1	1	1
	Legacy of long-term contaminant residues	3	1	2	5	5	5
	Solid Waste Generation	5	1	1	5	5	5
	Life-cycle materials and energy requirement (resource conservation)	3	1	2	5	5	5
	Life-cycle materials and energy requirement (resource consumption)	1 (3)	4	5	3	1	2
	Transport-related environmental discharges and nuisance	3 (1)	1	5	3	3	1
	Hazard Withstand to natural and man-made external hazards	1	2	1	2	5	5
TECHNICAL	Confidence in technology[2]	-	-	-	-	-	-
	Availability of technology within required timescale (Short-term)	5	5	1	5	2	1
	Flexibility of option (Short-term)	3	3	1	5	1	1
	Flexibility of option (Long-term)	1	1	3	4	5	5
SOCIO-ECONOMIC AND POLITICAL	Nuisance (noise, odour, visual)	1	1	3	5	4	4
	Impact on cultural heritage[2]	-	-	-	-	-	-
	Impact on local economy[2]	-	-	-	-	-	-
ECONOMIC	Construction cost	5 (3)	1	2	5	3	4
	Operational cost[2]	-	-	-	-	-	-
	Decommissioning cost	5	1	2	5	3	3
	Project Risks	3	1	4	5	4	3
		UNWEIGHTED TOTAL	41	54	69	63	59

Notes: 1 – Weightings in brackets were suggested as secondary attribute weightings for sensitivity analysis
2 – Attribute not scored in workshop

During the workshop discussions it was felt that it was not appropriate to score some attributes at this time, although it is expected that these attributes may be evaluated in more detail at a later phase of the BPEO study. Where an attribute has not been scored, the reasoning is included in the relevant discussion section below.

5.1 Discussion and Scoring of Attributes

This section sets out a summary of the collective discussions from the option evaluation workshop for each attribute.

5.1.1. Safety Attributes

Critical group dose to public

Public dose describes the dose of ionising radiation that could be received by the members of the public in the critical group during construction, commissioning, operation and decommissioning of the option. Exposure to the public is considered for all foreseeable pathways (i.e. air, water or land). A more detailed assessment environmental discharges and resulting doses to the public from the different options is presented in Appendix D.

The onsite disposal option scores highest as it is considered to have the lowest overall dose to members of the public as waste would not be transported off-site and it was considered that any identified contaminant pathways could be successfully managed (e.g. engineered leachate collection system). This conclusion is based on the assumption that any new onsite facility would be designed and engineered to meet the relevant operational and post-closure risk criteria and be supported by a full hazard and safety case analysis.

Waste treatment overseas or waste treatment in a national facility was considered to be the worst option as these options would generate some additional solid and gaseous wastes compared to the onsite or Drigg disposal options. Gaseous emissions of tritium from the melting process could result in a very small increase in public dose close to the facility. Evidence from existing metal melting facilities[5] indicates that public doses to the critical group from the melting process are in the order of 10 million times below the UK regulatory dose constraint for members of the public from any single source of 300μSv/yr.

The EA have stated[6] that the general principles for assessing public exposure from authorised discharges indicate that if an initial simple and cautious assessment results in critical group doses that are below 20μSv/yr, then no further assessment is warranted for the purposes of authorising the discharge of radioactive waste to the environment.

Transport of LLW for treatment will also involve some very minor public dose along the transfer route and treatment overseas would represent the longest transfer route. Because of the shorter transport routes and the lower gaseous emissions in each locality the regional treatment facility option is considered slightly better than overseas or national treatment.

Disposal at Drigg or Drigg II was considered to give a low dose to the public. This is based on the premise that future waste disposals at Drigg (or at a Drigg II facility) in engineered vaults would be designed to meet the HSE's risk acceptability criteria hence Drigg received a score of 4. It should be noted in the workshop that this conclusion was based on future LLW disposals only and excludes the dose to the public arising from historic activities and burials at Drigg.

Estimates of current and future dose to the critical group from Drigg vary considerably. Some estimates[7] of current doses to the critical group from disposal operations at Drigg are 88μSv/yr and that future doses will increase to around 100μSv/yr during the remaining operation of the site. In comparison the Food Standards Agency (FSA)[6] has predicted a lower maximum 'possible' dose from Drigg as 11μSv/yr and the maximum 'probable' dose as 1μSv/yr to the critical group from all pathways. Whilst it is recognised that the majority of the Drigg dose predicted will arise from historic waste disposals it is possible that the dose from future waste disposals at Drigg or another national LLW facility would be greater than from an equivalent overseas or UK waste treatment facility (based on the very low doses at from existing waste treatment facilities[5]). Although this could potentially question the scoring of the options in the workshop, it is recognised that there is significant uncertainty over the comparative doses from future facilities and therefore the workshop scoring scheme has not been altered.

The overall level of public dose is considered to be low for all options as the licensing process for new facilities or disposals would require a safety case that demonstrates that all doses are reduced to ALARP and that the HSE's risk criteria can be met. This attribute is therefore assigned a weighting score of 1 and is not likely to be a significant factor in determining the BPEO.

Occupational dose to workforce

Occupational dose describes the dose of ionising radiation that could be received by the members of the workforce during the construction, commissioning, operation and decommissioning of the option.

The onsite disposal and Drigg disposal options received the worst scores as it was considered that these options would be likely to result in the greatest dose to workers. It was concluded that the majority of dose would be received during the extensive waste handling, sorting, size reduction and decontamination activities that would be required prior to disposal. It was assumed that these activities would mainly be undertaken manually onsite with minimal shielding.

The best option was considered to be regional and national waste treatment as these options allow the higher dose activities (such as handling, size reduction and decontamination) to be undertaken in a more controlled environment in purpose built facilities. It was considered that when designing a new waste treatment facility there would be significant opportunities to reduce worker doses to ALARP by utilising remote (or semi-remote) techniques for handling, size reduction and decontamination in conjunction with appropriate shielding.

Overseas waste treatment scores a 3 as the discussions concluded that worker doses are likely to be lower than for the onsite or Drigg disposal options due to the application of more remote handling, size reduction and decontamination, however it was considered that there would be fewer opportunities to minimise worker exposures in an existing overseas facility than for a new design in the UK.

The scoring above was based on the premise that for the waste treatment options, larger objects (that require the most size reduction) would be transported to the waste treatment facility prior to significant size reduction and decontamination activities.

The overall level of worker dose is considered to be low for all options as the licensing process for new facilities or disposals would require a safety case that demonstrates that all doses are reduced to ALARP and that the HSE's risk criteria can be met. This attribute is therefore assigned a weighting score of 1 and is not likely to be a significant factor in determining the BPEO.

It was noted during the discussions that in order for the overseas treatment option to be viable, standards of radiological protection in overseas facilities should be roughly equivalent to UK standards and align with the ALARP/ALARA principles.

Risks from conventional hazards to public

This attribute covers conventional safety risks to the public during the option's life-cycle. During the discussions it was concluded that risk to the public was dominated by transport of the waste. It was considered that transport by road (i.e. potential for road traffic accidents) was more risky (per tonne per km travelled) than transport of waste by rail or by sea. The discussion and scoring was therefore primarily based on the extent, distance and mode of transport associated with each option.

The onsite disposal options was considered to be the best option as it involves the least transport of waste on public roads, however it was noted that this option would require some deliveries to site of construction materials (e.g. concrete, clay, etc).

Transport of waste overseas was considered to be the worst option due to the long distances involved with transport to a waste treatment facility in Europe or elsewhere. It should be noted that although the transport distances are large, a significant portion of the overall journey would be via ship which presents a very low risk to the general public per km travelled.

Disposal at Drigg and the national waste treatment facility options scored a 2 as the geographical spread of LLW producing sites around the UK would lead to a significant amount of transport to these centralised facilities.

It was noted that construction and capping of the new vaults at Drigg would require a significant quantity (estimated at over 1million m^3) of materials (e.g. sand, gravel, concrete, clay, etc). The roads around Drigg are small and not suited to large numbers of HGV movements although it is planned to make increasing use of rail transport for waste and material shipments to Drigg.

Regional waste treatment facilities scored a 3 as the transport distances of untreated (and hence bulky) LLW would be shorter. Once processed, the volume of remaining LLW that requires disposal would be significantly reduced and hence fewer vehicle movements to a central LLW disposal site (e.g. Drigg) would be required.

It was noted that construction of new regional or national waste treatment facilities would present opportunities to optimise the transport infrastructure (provision of good road and rail connections) during the site selection stage.

Although the risks to public safety from LLW transport are small in the overall context of traffic volumes in the affected locations, the potential seriousness of road traffic accidents lead to the assignment of a weight of 3 or 5. It was considered that there would be large relative differences in risk between the options due to the distances and modes of transport required. A sensitivity analysis will be applied to determine if the most conservative weighting factor would change the overall BPEO.

Occupational risks from conventional hazards to workforce

This attribute considers the conventional safety hazards to workforce during the option's life-cycle. The group discussed risks from aspects such as waste handling, impact, falls, chemicals, asphyxiation, fire, etc and considered that the options would primarily be scored on the basis of the introduction of new conventional hazards to the waste treatment cycle.

Onsite disposal and disposal to Drigg were considered to introduce the fewest additional conventional hazards and therefore was assigned a score of 5. Waste treatment (overseas, regional and national) was considered to introduce some additional process hazards such as heat, chemicals, fire risk, etc and were therefore were assigned a score of 1.

The overall risk to workers from conventional hazards judged to be low with little relative difference between all options therefore a weighting score of 1 was assigned. It is assumed that the principles of ALARP would be applied to conventional safety for all facilities however the design of new facilities may present greater opportunities to introduce further safety measures.

5.1.2. Environmental Attributes

Impact on water quality and marine systems

This attribute considers the radioactive and non-radioactive discharges to water throughout the options lifecycle and the potential influence on terrestrial and marine water quality including the impact on OSPAR convention targets. A more detailed description of discharges to water for the different options is included in Appendix D.

The worst options were considered to be onsite LLW and national LLW disposal as these options have the greatest potential for both operational and post closure discharges of radioactive effluent and materials to water. As an example the current liquid discharges from Drigg are thought to be around[7] 0.06GBq/year (alpha) and 200GBq/year (beta\gamma) (see Appendix D).

All disposal facilities require engineered barriers or membrane liner(s) to prevent any uncontrolled discharges to ground and systems to collect and treat leachate arising from the waste prior to discharge. Long-term management and monitoring of site discharges is likely to be necessary for onsite LLW facilities and Drigg.

It has been estimated by BNG that the Drigg site may be breached by coastal erosion within 500 to 1000 years leading to a significant release of radioactivity into the aquatic environment. Any future disposal facility (i.e. Onsite or Drigg II) would be appropriately sited and engineered to reduce the risk from discharges to water and coastal erosion to an acceptable level.

It was considered that discharges to water from overseas, regional and national waste treatment facilities would be low and these options were assigned a score of 5. It is expected that most decontamination techniques used in the waste treatment options would be based on dry processes (e.g. grit blasting) to minimise the amount of liquid waste generated. Data from the Studsvik facility supports this conclusion as the discharges of radioactive and non-radioactive liquids from the melting process are minimal (See Appendix D).

When considering the different options, the positive benefits to water quality from metal recycling were not directly considered in the scoring, however it was recognised that there would be some additional benefit to water quality from offsetting non-radioactive water discharges arising from production of virgin metal. The indicative benefits of metal recycling are summarised in Appendix D. It should be noted that all metallic LLW management options require some material to be disposed.

The overall risk to water quality from all options was considered to be low therefore a weighting factor of 1 has been applied. All future disposal and waste treatment facilities would be designed in accordance with current UK regulations, the relevant Environment Agency discharge criteria, and would implement Best Available Techniques (BAT) and Best Practicable Means (BPM) to control discharges.

Impact on Air Quality

This attribute considers the radioactive and non-radioactive discharges to air throughout the options lifecycle and the potential influence on air quality.

It was considered that disposal at Drigg and onsite disposal were the best options and would result in relatively low emissions to air over the lifecycle of the facility. It was noted that the majority of current air emissions from the Drigg facility are as a result of historic disposals and that future waste disposals would have much lower gaseous discharges. Current gaseous discharges from Drigg have been estimated[7] as 0.02MBq of alpha emitting radionuclides and 0.1MBq beta/gamma radionuclides (See Appendix D). These emissions are likely to reduce slightly following completion of Plutonium Contaminated Material (PCM) retrieval operations.

Waste treatment in overseas, regional or national facility was considered to have higher emissions to air than disposal and these options were therefore assigned a score of 1. [redacted] (See Appendix D) and are therefore broadly comparable with Drigg.

The melting process results in some non-radioactive emissions to air including particulates and trace amounts of heavy metals (See Appendix D) however these are well within the UK and Swedish regulatory limits and are unlikely to have a significant negative impact on air quality. The melting process also uses significant amounts of electricity [redacted] therefore these options also lead to indirect emissions from power generation.

When considering the different options, the positive benefits to air quality from metal recycling were not directly considered in the scoring, however it was recognised that there would be some additional benefit to air quality from offsetting non-radioactive gaseous and particulate discharges arising from production of virgin metal. This is discussed further in Appendix D.

The overall risk to air quality from all options was considered to be low and weighting factor of 1 has been applied, however due to the potential public perception issues associated with gaseous radioactive discharges, sensitivity analysis will be undertaken using a weighting factor of 3. All future disposal and waste treatment facilities would be designed in accordance with current UK regulations, the relevant Environment Agency discharge criteria, and would be required to implement BAT and BPM to control discharges.

Legacy of long-term contaminant residues

This attribute considers the legacy of the contaminant residues that will remain at the end of the option's operational phase. After some discussion about the definition of 'legacy' it was agreed that for the purposes of this BPEO study the attribute should consider the potential for contamination of land.

Disposal at Drigg was considered to be the worst option as it is likely that future disposals, in addition to historic disposals, would result in the largest amount of land that would require ongoing management. It was stated that it was possible that the Drigg site may never be fully de-licensed as a result of historic disposals.

The onsite disposal option was assigned as score of 2 as this option also creates areas of land that would require long term management, however there fewer issues regarding historic disposals than at Drigg. It was noted that having multiple disposal sites geographically spread around the UK may make long-term management of the legacy challenging.

Waste treatment in an overseas, regional or national facilities were considered the best options as the volume of LLW requiring disposal is significantly reduced and the resulting waste product is in a more stable form as volatile contaminants are removed and immobilised during processing.

It was considered that there may be significant differences between the different options therefore a weighting score of 3 has been assigned.

Solid Waste Generation

This attribute considered the quantity of radioactive and non-radioactive waste generated during the life-cycle of the option including both primary and secondary wastes (i.e. total amount that requires disposal).

The onsite disposal and Drigg disposal options were considered to be the worst as they provide no reduction in primary radioactive waste volumes. Excavation and construction of these disposal options may also generate significant quantities of non-radioactive secondary wastes such as spoil and give rise to indirect quarrying wastes that would all require management.

Waste treatment in overseas, regional or national facilities were considered the best options as the volume of waste requiring disposal is significantly reduced. Treatment processes such as melting could allow up to 95% of the original metal to then be free-released into the steel industry for recycling. The decontamination and melting processes give rise to some radioactive residues and radioactive secondary wastes (estimated at around 5% of the original waste volume) which are then sent for disposal. Secondary wastes from the decontamination (e.g. grit blasting residues, filters, etc) are usually in a dry, compact and easily disposable form.

Recycling also brings the additional indirect benefits of a reduction in non-radioactive solid waste arisings from the mining and production of virgin metal. For example, the recycling of 1te of steel results in a saving of 1.28te of solid waste and the wastes associated with mining and extraction of 1.5te of iron ore and 0.5te of coal[8] (See Appendix D).

It was considered that there were very large differences in the magnitude of solid waste generation between the different options and due to the predicted short term pressure on the capacity of Drigg it was felt that a weighting factor of 5 should be applied.

Life-cycle materials and energy requirement (resource conservation)

This attribute considers the potential for conservation of energy and material resources that would be achieved throughout the lifecycle by implementing a particular option. The aspect of conservation of energy and raw materials is detailed further in Appendix D.

Disposal at Drigg was considered the worst option as this option does not promote significant recycling of waste and hence conservation of resources. The onsite disposal option received a score of 2 as it was considered that this option may allow some limited opportunities for re-use and recycling of waste onsite.

Waste treatment in overseas, regional or national facilities were considered the best options as the melting process could allow up to 95% of the original metal to then be free-released into the steel industry for re-use and recycling.

Recycling of metals leads to significant energy (~75% for steel and ~95% for aluminium) and resource savings compared to production of new virgin metal material. Recycling of steel offsets energy and resource consumption (and associated radioactive and non-radioactive gaseous, liquid and solid waste arisings) from coal and iron ore extraction, steel manufacturing and power generation (See Appendix D).

The difference between the best and worst options was considered to be significant and therefore a weighting factor of 3 has been assigned.

Life-cycle materials and energy requirement (resource consumption)

This attribute considers the input (i.e. consumption) of energy and material throughout the lifecycle (construction, commissioning, operations, modifications, decommissioning and site restoration) of the option.

The best option was considered to be onsite disposal as it was considered that whilst this option would require energy and material resources for excavation, construction, grouting and site restoration, the overall consumption of energy and resources would be lower than for the other options. As onsite facilities may use existing voids and structures (e.g. turbine hall basements) it was considered that the overall level of resource consumption would be lower than for the disposal at Drigg option.

The disposal at Drigg option scores a 4 as it is expected to require more energy and resources for construction of new vaults, grouting, capping and landscaping compared to the onsite disposal option. It has been estimated by BNG that over 1million m^3 of materials (top soil, sand, gravel, boulders, aggregate and clay) will be required for the construction and capping of the future vaults at Drigg. If a new national LLW facility is required (i.e. Drigg II) it can be assumed that significant amounts of energy and materials would be required for construction, operation, capping and site restoration.

The worst option was considered to be regional waste treatment facilities as the melting process would consume significant amounts of electricity throughout its operational phase. In addition, a small amount of energy and materials would be required to construct these processing facilities and associated transport infrastructure. The national waste treatment option was scored a 2 as the energy and material requirements would be similar to the regional waste treatment facilities, however a single larger facility would benefit from economies of scale.

[redacted]

It was not thought that the resource consumption attribute would be a significant factor in determining the BPEO therefore a weighting of 1 has been assigned. The discussion and scoring was based on qualitative assumptions about the potential areas of energy and resource consumption during the lifecycle of each option. Without a more detailed assessment it is difficult to quantify the relative magnitude of the differences between options and therefore sensitivity analysis will be undertaken using a weighting score of 3.

Transport-related environmental discharges and nuisance

This attribute considers the transport-related emissions incurred due to the transfer of waste metal during the option's life-cycle, including road, rail and sea. Emissions from transport include carbon dioxide (CO_2), particulates, nitrogen oxides (NO_x), sulphur dioxide (SO_2) and volatile organic compounds (VOCs). However for a given cargo the level of emissions depend on the mode of transport and the distance travelled.

The best option was considered to be onsite disposal as this involves the smallest transportation distances for the waste. It was recognised that this option would result in emissions from transportation of materials to the site (primarily by road) for construction, operation, capping and site restoration.

The worst options were considered to be disposal at Drigg and national waste treatment facility. Most LLW is currently transported by road in ISO containers to the Drigg site for disposal. Due to the geographical spread of LLW producing sites around the UK it was felt that these options would require the greatest distances to be travelled primarily by road. There may also be a significant impact from the transportation of materials to the Drigg site for construction, operation, capping and site restoration of the future vault extensions. If materials are not delivered by rail, this will create a significant number of additional lorry movements around the Drigg area where the roads are unsuitable for HGVs.

Regional waste treatment facilities were assigned a score of 3 as this option was considered to have shorter waste transportation routes distances from the originating sites to the regional facility and would not concentrate the traffic in one location.

The overseas waste treatment option was assigned a score of 3 as although this option has longer transport routes, the majority of the distance would be covered at sea. Transport by sea results in significantly lower emissions per km travelled than road transport and causes very little nuisance.

The difference between the worst option which require significant transport of waste and materials by road and the best option which requires very little transport was considered to be significant therefore a weighting of 3 has been assigned. It was agreed that the impact from transportation of LLW was not significant in the context of overall emissions and nuisance from all transport in the UK (and overseas) and hence a sensitivity analysis should be undertaken using a weighting of 1.

Hazard Withstand to natural and man-made external hazards

This attribute includes a consideration of the option's vulnerability to natural and man-made disasters, such as flooding, coastal erosion, human disturbance or terrorist attack.

The best options were considered to be regional and national waste treatment facilities. These options could be appropriately sited and constructed to present a very low risk from natural disasters such as flooding and coastal erosion or human activities during the lifetime of the facility. The risk is present for a significantly shorter period of time than for onsite disposal or the Drigg disposal options.

The waste treatment overseas option was considered to increase the risk of contamination to the environment, during the transportation of LLW by sea, in the event of an accident and was therefore assigned a score of 2. The overseas waste treatment facility itself is likely to present a low risk.

The worst option was considered to be onsite LLW disposal as this option presents the fewest opportunities to optimise the location of the disposal facility. It was recognised that some UK LLW producing sites may not be suitable for onsite disposal due to factors such as flooding or coastal erosion (e.g. Dungeness). The potential hazard arising from natural or human disturbance of the buried waste may be present for a long period of time, possibly requiring some form of long-term monitoring or management of the site to mitigate this risk.

Disposal at Drigg was assigned a score of 2. The Drigg option presents a long term hazard from natural or human disturbance as many of the radionuclides have half lives of several thousand years. It was thought likely that the Drigg site may never be fully de-licensed and will be subject to some form of long term institutional control and management. BNG have predicted that the Drigg site may be breached by coastal erosion within 500-1000 years leading to a large release of radioactivity to the environment.

If a new national disposal facility was to be constructed (i.e. Drigg II) there would be significant opportunities to optimise the location of such as facility to mitigate the risk from natural hazards such as flooding or coastal erosion.

There are always considerable uncertainties associated with estimating risk from natural and man-made hazards into the future. A weighting score of 1 has been assigned to this attribute as it was considered that this factor would not have a significant impact on the overall outcome of this strategic BPEO.

5.1.3. Technical Attributes

Confidence in technology

This attribute assesses the confidence that can be placed in the technology in terms its effectiveness in dealing with the metallic LLW problem.

Following discussion it was agreed that the technologies to be employed as part of all options are currently used either in the UK or overseas for management of LLW and there were no insurmountable difficulties with technology deployment or scale-up. It was agreed that this attribute should therefore not be included in the scoring process as all of the shortlisted technologies were well proven and this attribute has already been used as part of the initial screening process.

Availability of technology within required timescale (Short-term)

This attribute assesses the timescale within which an option can be operational and available in the context of the pressure on current LLW disposal routes.

In the next few years existing capacity at Drigg (Vault 8) may be extremely limited due to operational constraints and licensing issues. It was stated in the discussions that there may be significant pressure on the capacity of the existing Vault 8 within the next few years prior to Vault 9 becoming operational in late 2008. It is therefore desirable for an option to be capable of being operational on a significant scale within the next 2-3 years (i.e. by 2008) to relieve the pressure on the existing Drigg capacity. Several issues were discussed such as times required for development, design, construction, safety cases and licensing of the particular option.

The best option was considered to be overseas waste treatment as the facilities are already operational. This route has already been used to treat metallic LLW from the UK and it was felt that there is sufficient capacity in countries such as Sweden, Germany and the Untied States to accept a significant proportion of UK waste. As these are existing facilities, there are considerably fewer regulatory issues over permitting and consents. It is estimated that existing overseas capacity for metal treatment is [redacted]

Disposal at Drigg was also awarded a score of 5 as it is an existing waste route, although it is subject to some constraints due to ongoing licensing and regulatory issues. It is not likely that a Drigg II facility could be built quickly as the siting of this facility is likely to be subject to planning issues.

The onsite disposal and national waste treatment options were considered to be the worst. Engineered onsite LLW disposal facilities do not currently exist at most UK nuclear sites were judged to be unlikely to be operational within the 2008 timescale. It is currently projected that the Dounreay LLW facility is unlikely to be operational prior to 2012. Onsite disposal facilities would be based on proven landfill technologies however it was thought that there may be some planning permission and licensing issues associated with onsite disposals that may delay the implementation of this option at some sites.

It was considered that whilst a national waste treatment facility would be based on well proven technology, it may not be feasible to be operational within the 2008 timescale due to safety case, planning and licensing issues. Regional waste treatment option was awarded a score of 2 as it was considered that this option would take less time to design and construct than a national scale facility and would be easier to permit.

In the discussion it was concluded that for all options the most significant uncertainties are likely to be associated with the time required for site selection, planning permission and licensing.

Due to the pressure on the existing capacity at Drigg and the accelerated decommissioning schedule presented in the NDA's Strategy, it was agreed that this attribute would be a major differentiator in the selection of the BPEO and hence a weighting factor of 5 has been applied.

Flexibility of option (Short-term)

This attribute evaluates the ability of the option to cope with variation and uncertainty in the volumes and inventory of metallic LLW waste within a short–term timescale (i.e. up to 2008). It was recognised that there is the potential for significantly higher short-term LLW arisings than the historic assumptions and forecasts if the proposed NDA accelerated decommissioning strategy is implemented.

The best option was considered to be waste treatment in existing overseas facilities. It was felt that there was sufficient spare processing capacity in the short-term in countries such as Sweden, Germany and the Untied States to accept a significant proportion of UK waste and adequately cope with fluctuations in volumes. It is estimated that existing overseas capacity for metal treatment is [redacted]

Disposal at Drigg was assigned an intermediate score of 3 as it is an existing facility with capacity to dispose of LLW. It was stated in the discussions that there may be significant pressure on the capacity of the existing Vault 8 within the next few years prior to Vault 9 becoming operational in late 2008. This is based on the current forecasts of LLW arisings and the discussion raised some issues over the flexibility of Drigg to accept significantly higher short-term LLW arisings if the accelerated decommissioning schedule outlined in the NDA's Strategy is implemented.

Onsite disposal, regional waste treatment and national waste treatment facilities were all assigned a score of 1 as these facilities do not currently exist as a disposal route for LLW and are unlikely to be capable of accepting significant quantities of waste in the short term.

It is recognised that this attribute is important due to the inherent uncertainties associated current waste estimates arising from the decommissioning programme therefore a weighting score of 3 of has been applied.

Flexibility of option (Long-term)

This attribute evaluates the ability of the option to cope with variations and uncertainty in the volumes and inventory of metallic LLW waste in the long–term.

The regional and national waste treatment options were considered the best options as new facilities could be designed to accommodate the predicted accelerated LLW arisings and would also be designed to allow some capacity flexibility.

Treatment in a facility overseas was assigned a score of 4 as it was considered that overseas facilities should be able to expand their processing capacity in the longer term if the demand existed. The discussions noted that the availability of processing capacity in overseas facilities would inevitably be subject to competition from decommissioning activities in other countries.

The onsite disposal option was assigned a score of 3 as it was considered that although there may be some site-specific limitations on capacity and types of acceptable waste, there would be sufficient flexibility within the overall network of onsite facilities to accept the required quantity and types of waste. In the discussions it was recognised that there would have to be careful consideration of the number of onsite disposal facilities that would be required, where they should located and what types of waste can be disposed of in each.

The worst option was considered to be disposal at Drigg due to the long-term constraints on the exiting facility's conditions for acceptance and radionuclide capacity in order to meet the regulator's post closure risk targets. If a new national LLW facility was to be constructed (Drigg II) then this facility could be designed to accept a large capacity of LLW if required.

A weighting score of 1 has been assigned to this attribute as it was considered that there would be a reasonable amount of flexibility over the long-term for all options.

5.1.4. Socio-economic and Political Attributes

Nuisance (noise, odour, visual)

This attribute assesses the nuisance that may occur during the option's life-cycle. This includes factors such as noise, dust, odour, and visual impact. The nuisance arising from transportation of waste and materials is covered by a separate attribute.

In the discussions it was recognised that this attribute was difficult to score with much certainty as the potential magnitude of the nuisance would be highly dependant on site specific factors such as the proximity of local communities, local meteorology and local topography. The scoring was therefore based on the generic sources of nuisance that are associated with each option and likely to be encountered.

The best option was considered to be overseas waste treatment as this would be based in existing facilities which were considered to present a low nuisance impact to local communities. For example, the waste treatment facility at Studsvik in Sweden is surrounded by trees which limit the offsite visibility of the buildings.

A score of 4 has been assigned to the regional and national waste treatment options as it was considered that these options would also be unlikely to present a significant visual impact. A waste treatment facility could be contained within low-rise industrial buildings that would not present a significant visual impact. It was considered that the impact from noise, dust and odour would be very low and could be further minimised by the design, layout and siting of the facility.

The worst option was considered to be disposal at Drigg as there would be the potential for significant nuisance from noise, dust and visual impact particularly during excavation, vault construction, capping and landscaping activities at the existing Drigg facility or a Drigg II facility. Onsite disposal was awarded a score of 3 as it was considered to have a lower nuisance impact that the Drigg option as each facility would be smaller and therefore have a lower impact on local communities.

A weighting score of 1 has been assigned to this attribute as it was considered that the differences between the best and worst option would not be significant at a strategic level.

Impact on cultural heritage

This attribute considers whether the option will impact on the cultural heritage of the area (e.g. archaeology or historic woodland) during its life-cycle.

Following discussion it was concluded that the impact on cultural heritage would be heavily dependant on the option's chosen location and a number of site-specific factors and therefore could not be usefully scored at this stage.

Impact on local economy

This attribute considers the option's effect on employment levels and the socio-economic status of the local area including both positive and negative affects.

Following discussion it was concluded that the impact on the local economy would be heavily dependant on an option's chosen location and therefore could not be usefully scored at this stage.

5.1.5. Economic Attributes

Construction cost

Workshop Discussion

This attribute evaluates the financial cost of construction of the option.

The worst option was considered to be disposal at Drigg due to the high cost of constructing the future vault extensions. It was also concluded that the costs associated with constructing a Drigg II facility would also be very high.

In the scoring workshop it was suggested that many of the onsite facilities could be engineered to a lower integrity than the concrete trench design currently used at Drigg this would result in lower overall construction costs for the option. Whilst the cost of constructing several smaller onsite disposal facilities may be higher than for an equivalent large facility the overall cost of this option would be dependant on the design of these facilities. This option has therefore been awarded a score of 2.

The best option was considered to be treatment in an overseas facility as the processing plant and associated infrastructure already exist. There may be some cost associated with expanding an existing facility but this would be less than for construction of new facilities.

Some construction costs would be incurred to build regional waste treatment facilities and associated infrastructure, therefore this option was assigned a score of 3. It was thought that the expected cost of this option would be lower than for onsite disposal and Drigg disposal options. Due to economies of scale, the cost of a single national waste treatment facility was considered to be lower than the cost of several smaller regional facilities therefore this option was assigned a score of 4.

It was considered that there may be large variations in the costs of construction between the different options therefore it was agreed that a weighting of 5 should be applied however sensitivity analysis using a score of 3 should be undertaken.

Post Workshop Analysis

A review has been undertaken of LLW facility cost data and a more detailed analysis of available data on the costs of construction is included in Appendix E.

Based on information in the Drigg LCBL[10] it has been estimated that the direct cost of construction for the new vaults at Drigg is around £172/m^3 or £165/te-£220/te of capacity (see Appendix D). The construction cost however does not include the cost of aspects such as site support and services that would be required for the construction programme. Any new facility (Drigg II) would require significant expenditure on transport infrastructure in addition to the cost of vault construction.

Based on the information in the CoRWM cost discussion paper[11] the costs of development of several onsite facilities would be around 50% more than a single centralised facility (see Appendix E). The CoRWM paper estimated that for an 83,000m^3 LLW facility at Dounreay the construction costs would be £110M or £1,325/m^3. In the Dounreay LLW BPEO report[12] the construction cost for each individual facility was not explicitly stated in the report however the construction cost for the LAHV facility could be around £15M (for 45,000m^3 of waste = £333/m^3) and £53M (for 64,000m^3 of waste = £828/m^3) for the LLW facility (see Appendix E).

It has been estimated that the construction costs associated with an overseas waste treatment facility would be [redacted]

It is estimated in Appendix E that the construction costs for a national facility may be [redacted]

Conclusions

The post-workshop analysis indicates that the construction cost of a 'small' (45,000m^3) LAHV facility at the Dounreay site could be around £333/m^3 compared to costs of around £172/m^3 for a larger (and more highly engineered) facility such as Drigg. This could cast uncertainty on the assumption used in the scoring workshop. i.e. that construction costs for several small simply engineered onsite facilities would be lower that for a single highly engineered LLW facility.

The post-workshop construction cost analysis for the waste treatment options broadly validates the conclusions and scoring reached during the workshop.

Operational cost

Workshop Discussion

This attribute evaluates the financial cost of operation of the option over its lifetime. In the context of this report 'Operational costs' have been defined as all costs that are not attributed to either construction of the facility or with facility closure, decommissioning, capping and landscaping.

The cost of operating the existing Drigg facility was discussed and it was concluded that the costs associated with the operation of a national LLW disposal facility are significant. It was thought that the true cost of operation of the existing Drigg facility is not fully represented in the current BNG commercial waste charging scheme and it has been suggested that the 'true' cost of disposal at Drigg is around twice the current Drigg market cost. For the purpose of this study it is assumed that any new national LLW repository (Drigg II) would have roughly similar operational costs to the existing Drigg facility although if a decision was taken not to use ISO containers or grout wastes prior to emplacement in a new repository, then the operational costs could be lower.

The group was unable to fully evaluate the cost of operating onsite waste disposal facilities due to the uncertainties over required number of facilities, their locations and the integrity of engineering that would be employed. A comparison of the cost of operating several small onsite facilities compared to a national LLW facility would be strongly dependant on the number, size and level of engineering employed for onsite facilities.

The operating cost of waste treatment overseas was considered in the workshop to be lower than disposal at Drigg. It was also noted that the fixed overhead part of the operating costs will be partly shared with other foreign waste producers.

The cost of operating a regional or national waste treatment facility was thought in the workshop to be lower than the cost of Drigg disposal however the extent will depend on the contractual and commercial model used to finance the development and operation of a UK facility. The operational costs of a national scale facility are likely to be lower than for regional facilities due to the benefits of economies of scale.

In the discussion it was noted that in addition to environmental benefits, there would have to be measurable financial benefits for waste producers to use the waste treatment route compared to Drigg.

Following the workshop discussion it was felt that more information would be needed to differentiate between the different disposal and the different waste treatment options but due to the uncertainty over the definition of some options (e.g. onsite disposal) it would not be possible to score this attribute within the workshop.

Post Workshop Analysis

A review has subsequently been undertaken of LLW facility cost data and a more detailed analysis of available data on the costs of operation is included in Appendix E.

For the disposal options operational costs would include aspects such as transportation, regulatory costs, waste compaction/conditioning/grouting costs, emplacement cost, labour costs, effluent treatment, etc over the operating lifetime of the facility.

Based on information in the Drigg LCBL[10] it has been estimated that the total operational costs for Drigg are estimated at around £1,462/m^3 or £1,425/te-£1,901/te of metal waste (See Appendix E).

In the Dounreay LLW BPEO report[12] the operational cost for each individual facility was not explicitly stated in the report however it can be inferred to be could be around £30M (£660/m^3) for the LAHV facility(see Appendix E). The operational costs of an onsite facility for LAHV materials could therefore be around 1/3rd of the cost of Drigg. In comparison the operational costs of the LLW facility at Dounreay are calculated to be around £105M (£1,650/m^3) which is slightly higher than the operational costs of Drigg. The recent CoRWM cost discussion paper[11] estimated a similar operational cost of £1,687/m^3 (although based on a larger capacity) for a LLW facility at Dounreay.

For waste treatment options operational costs include aspects such as transportation, regulatory costs, melting costs, maintenance costs, labour costs, etc. In addition, the operational costs associated with disposal of the small amount of secondary waste at Drigg or an equivalent facility must also be factored in.

The estimated operational costs of overseas treatment [redacted]

The operational costs of a UK based national waste treatment facility could range from [redacted]

It is recognised that it is very difficult to make quantitative comparisons of cost for the different options as there is considerable uncertainty attached to the definition of some of the options in terms of capacity and the likely regulatory costs. The operational costs of disposal of are also likely to be shared across a number of different waste streams and as these streams may vary in volume, form and activity it is difficult to separate out costs for metals only. Indeed it is likely that the operational costs for different types and levels of radionuclide activity will be highly variable for metals alone.

Conclusions

[redacted]

Although this attribute was not scored during the workshop and hence is not included in the main option scoring results it is recognised that it may have a significant impact on the overall decision making framework. It is therefore appropriate to test the impact of including this attribute on the scoring results in the sensitivity analysis section.

Decommissioning cost

Workshop Discussion

This attribute evaluates the financial cost of decommissioning, monitoring and site restoration of the option.

The worst option was considered to be disposal at Drigg as this was considered to have high costs of facility closure, decommissioning, capping and landscaping. The option will also require significant ongoing site control and monitoring over a long period of time.

Onsite disposal was awarded a score of 2 as it was thought that the decommissioning costs would be lower than disposal at Drigg option. This option would still require significant ongoing site control and monitoring over a long period of time.

The best option was considered to be overseas waste treatment as the direct decommissioning costs would be very low. These costs would be paid indirectly as part of the operational charge for processing waste.

Regional and national waste treatment options were awarded a score of 3 as there would be some cost of decommissioning of the UK facilities after closure. These costs are not anticipated to be significant as a new plant would be designed to easily decontaminated and dismantled.

As there are large variations between the decommissioning costs of the best and the worst options it was agreed that a weighting score of 5 should be applied to this attribute.

Post Workshop Analysis

The decommissioning costs of Drigg have been estimated at around £533/m^3 or £520/te-£693/te in Appendix E. It is noted that this cost includes provision to address a number of legacy issues that would not be applicable to a new national LLW facility (Drigg II).

The CoRWM paper[11] suggests that decommissioning costs for onsite facilities may represent 15-20% of total lifetime cost and using this factor the decommissioning costs of the Dounreay LAHV facility have been estimated at around £250/m^3 from the Dounreay BPEO study[12] in Appendix E.

The decommissioning costs for an overseas waste treatment facility are assumed to be paid indirectly through the operational costs to UK and other foreign customers during the facility lifetime.

The decommissioning costs of the regional waste treatment facility option have [redacted]

Conclusions

The post-workshop decommissioning cost analysis is broadly validates the conclusions and scoring reached during the workshop.

Project Risks

This attribute assesses the risk associated with implementation of each option caused by planning issues, public perception issues, safety issues or the regulatory environment. These factors may cause additional risk to the financial viability of the project and/or cause substantial delays to the programme.

The best option was considered to be waste treatment overseas as the facilities are currently licensed and operating. There is therefore very little risk associated with this option. It was noted that there may be perception issues associated with transport and recycling of metals from the nuclear industry.

It was thought that there would be few significant risks associated with the regional waste treatment option hence a score of 4 has been assigned as it would be easier to site and license several smaller facilities. It was felt that more difficulties may be encountered when trying to site and license a large national scale facility therefore this option has been given a score of 3.

The worst option was considered to be disposal at Drigg due to the existing regulatory and licensing issues. These may impose limits on the long-term capacity and radionuclide inventory that can be deposited at the existing Drigg facility. Given the current public and regulatory environment it was suggested that there may be some significant planning and public perception difficulties encountered when attempting to site and license a new Drigg II facility that may cause costs to rise.

Onsite disposal was awarded a score of 4 as it was thought that smaller onsite facilities could be successfully licensed provided the safety case justification could be made in the particular location. There may however be some issues over the public perception of the retention of a radioactive inventory on each site in the long term and the possible restrictions on future land usage.

The discussions concluded that there may be some significant differences between the best and worst options regarding the overall level of project risk that may be encountered therefore a weighting score of 3 has been applied.

5.1.6. Other Attributes Discussed in Workshop

During the workshop the inclusion of additional attributes to reflect aspects of UK government waste policy was discussed as these could have an influence on the selection of the BPEO. The government has recently launched a consultation on proposed changes to LLW policy[13] which aims to address a number of key issues associated with the use of Drigg for LLW disposal and availability of other routes for LLW disposal. In support of these objectives there are a number of aspects that are relevant that are discussed in further detail such as application of the waste hierarchy, the timing of any solution and the proximity and precautionary principle.

Although these aspects were regarded as important in the overall context of the decision it was agreed that these issues could be adequately covered within the exiting set of attributes and therefore should not be scored separately at this stage. A description of these factors is included below.

Waste hierarchy

The government's draft LLW policy[13] states that LLW owners should plan for management of their waste in accordance with the waste management hierarchy principles set out in UK waste strategy documents. For LLW this is applied as:

1. Not creating waste where practicable ("avoidance")
2. Reducing waste arisings to the minimum (through the appropriate design and operation of processes and equipment and making effective use of techniques such as waste characterisation and segregation, volume reduction and surface contamination removal)
3. Otherwise minimising quantities requiring disposal through decay storage, re-use and/or recycling, and incineration
4. Disposal (which includes incineration).

The application of the waste hierarchy to the options considered in this BPEO study is discussed further in Section 3 of TR001[4]. For the purposes of this report it is be assumed that steps 1 & 2 above are common to all options as part of an optimised waste strategy.

The waste treatment options (overseas, regional and national) which aim to recycle as much metal as possible (and reduce the secondary waste requiring disposal) have scored more highly on attributes such as Legacy of long-term contaminant residues, Solid waste generation, and Life-cycle materials and energy requirements (resource conservation) than the onsite LLW or national LLW facilities as these would be considered as disposal options only.

Timing of solution

In the draft LLW policy[13] the issues of intergenerational equity and long term sustainability feature prominently. The government would expect that operators should consider the timing of a solution when preparing LLW management plans and that early solutions should score more highly than postponed options or those that would take much longer to implement.

It would therefore be desirable for the BPEO to reflect a preference towards early waste management solutions rather than leaving problems for the next generation to solve. This preference is also reflected in the NDA decommissioning strategy.

It was concluded that there would be some differences between the options with regard to intergenerational equity however the ability of the option to provide an early solution would be indirectly captured when evaluating the "Availability of technology within required timescale" and "Flexibility of option" attributes. It is recommended that the issue of intergenerational equity should be further explored in the stakeholder consultation phase.

Proximity Principles

The draft LLW policy[13] framework incorporates a number of issues that may have an influence on the selection of a BPEO for metallic LLW such as the proximity principle. The proximity principle is widely used in municipal and hazardous waste management and dictates that waste should generally be disposed of as near to its place of origin as possible. This is in part to ensure that producers do not simply export the problem to other regions of the UK or other countries. It also involves the recognition that the transportation of waste can have a significant environmental impact. The proximity principle is embodied in the current UK Government policy as a preference for self-sufficiency described in Cm2919[14].

Whilst the proximity principle is important and could lead to environmental benefits in some situations it should be applied appropriately to radioactive waste management as radioactive waste disposal is a specialised activity and the waste volumes are relatively small compared to other non-radioactive waste streams.

These were recognised as significant issues for discussion particularly about how far the proximity principle should be applied to radioactive waste management. The draft LLW policy states that the use of centralised facilities such as Drigg may be the appropriate point of disposal for much LLW, however, option assessments must consider other solutions and employ the proximity principle where possible with the presumption towards waste being managed in the nearest appropriate disposal (or waste treatment) facility. In this respect onsite LLW facilities and regional waste treatment options would score more highly than national or overseas treatment or disposal options. It was noted that overseas waste treatment involves transfrontier waste shipments that may raise significant stakeholder concerns.

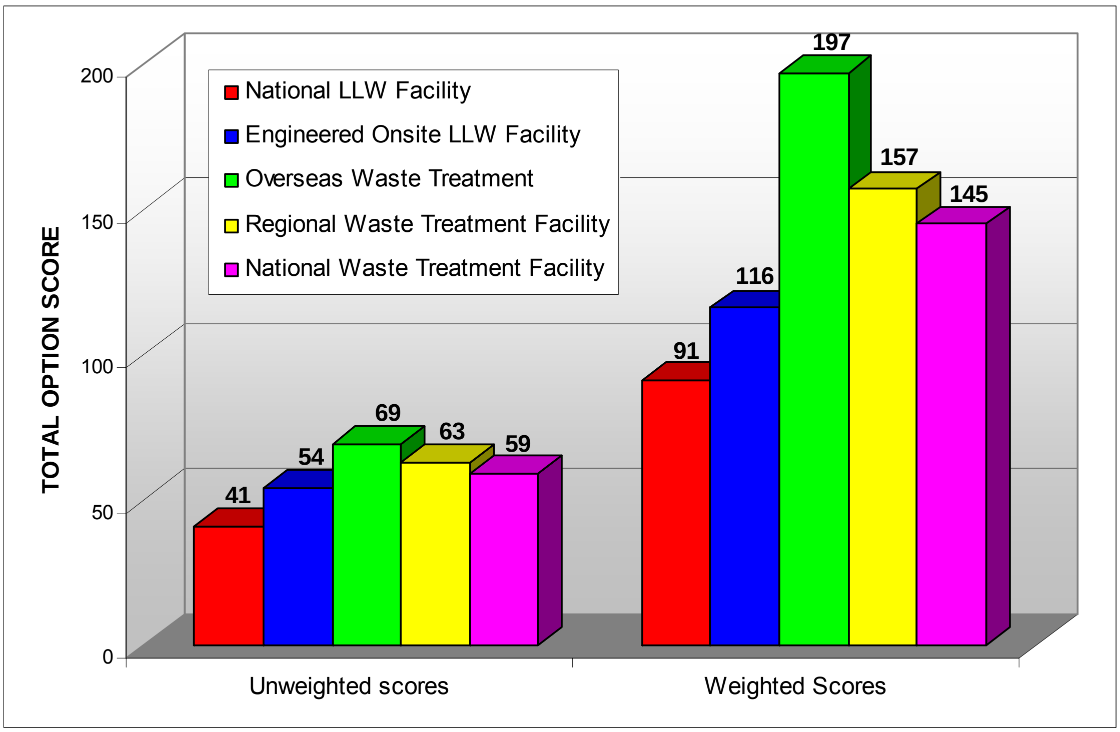
It was felt that this issue was partially captured under the “transport related environmental discharges” and “Risks from conventional hazards to public” attributes but that it should be further explored in the stakeholder consultation phase.

6. Results of Workshop

The scores for each attribute have been summed to provide a total option score for each option considered. The option with the highest score represents the BPEO in the methodology adopted.

Figure 6.1 below shows the total un-weighted and weighted score for each option. The weighted option scores show utilise the primary weighting factor that was agreed in the workshop (i.e. prior to sensitivity analysis).

FIGURE 6.1 – UNWEIGHED AND WEIGHTED SCORES



The un-weighted and weighted scores show that the highest scoring option is overseas waste treatment followed by waste treatment on a regional and national scale. Of the 'disposal' options the onsite LLW facility option is preferable to the national LLW facility (i.e. Drigg or Drigg II) option.

7. Sensitivity Analysis

7.1 Attribute Sensitivity Weightings

As discussed in Section 5, during the workshop it was proposed to subject several attributes to a sensitivity analysis by varying the attribute weightings. The specific attributes proposed for sensitivity analysis are described in Table 7.1 below.

TABLE 7.1 – ATTRIBUTE SENSITIVITY WEIGHTING

CATEGORY	ATTRIBUTE	PRIMARY WEIGHTING	SENSITIVITY WEIGHTING
SAFETY	Risks from conventional hazards to public	3	5
ENVIRONMENTAL	Impact on Air Quality	1	3
	Life-cycle materials and energy requirement (resource consumption)	1	3
	Transport-related environmental discharges and nuisance	3	1
ECONOMIC	Construction cost	5	3

Different combinations of the primary and sensitivity weighting values for these attributes can be applied to the option scoring process to evaluate the impact. There are 32 different variations in weighting values that can be applied and these are shown in Table F1 of Appendix F.

The total scores for each option are shown in Figure 7.2 for these variations of sensitivity weightings, which thereby consider all possible variations in the weighting factors identified in the workshop.

FIGURE 7.2 – ATTRIBUTE SENSITIVITY ANALYSIS

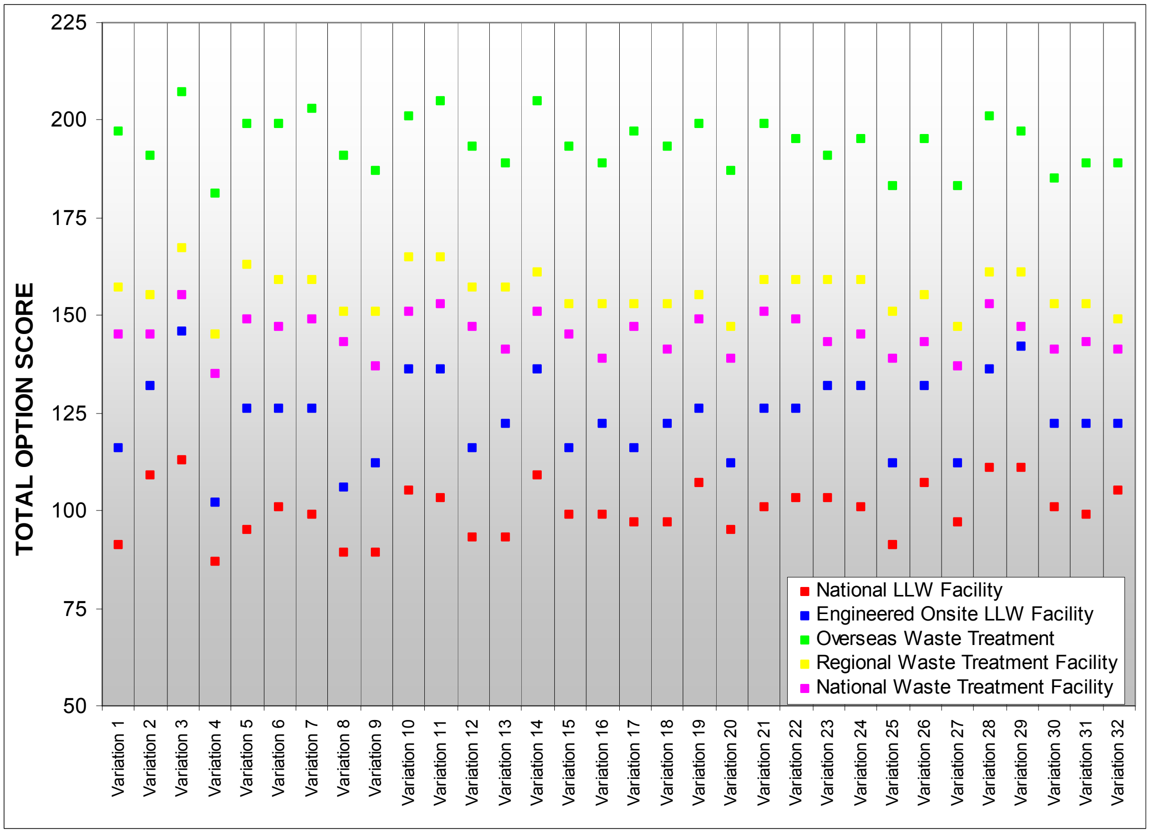


Figure 7.2 shows that for all combinations of the primary and sensitivity weightings, the order of the options remains unchanged although the relative difference between options does change. It is therefore concluded that varying the weighting of these specific attributes does not significantly affect the selection of the BPEO.

7.2 Category Bias

In addition to the attribute weightings that were specifically identified in the workshop for sensitivity analysis, the impact of the weighting of the different categories of attributes (i.e. Safety, Environmental, Technical, Socio-economic and Economic) can be analysed by applying a bias factor towards a particular category.

To show the impact of a bias towards a particular category the weighting factors of all attributes within that category can be multiplied by a factor of 2. All attribute weightings in other categories remain unchanged (i.e. the safety bias scenario, the weighting of all safety attributes is multiplied by 2). Where an attribute had been proposed for sensitivity analysis (i.e. listed in Table 7.1) then the highest weighting factor was used to maximise the effect. Table F2 of Appendix F shows these modified weighting factors that were applied in each bias scenario.

Figure 7.3 shows the option scores when a bias factor of 2 is applied to Safety, Environmental, Technical, Socio-economic and Economic attributes. The options scores when the primary, sensitivity, highest and lowest weightings are applied are also shown as a comparison.

FIGURE 7.3 – ATTRIBUTE BIAS SENSITIVITY ANALYSIS

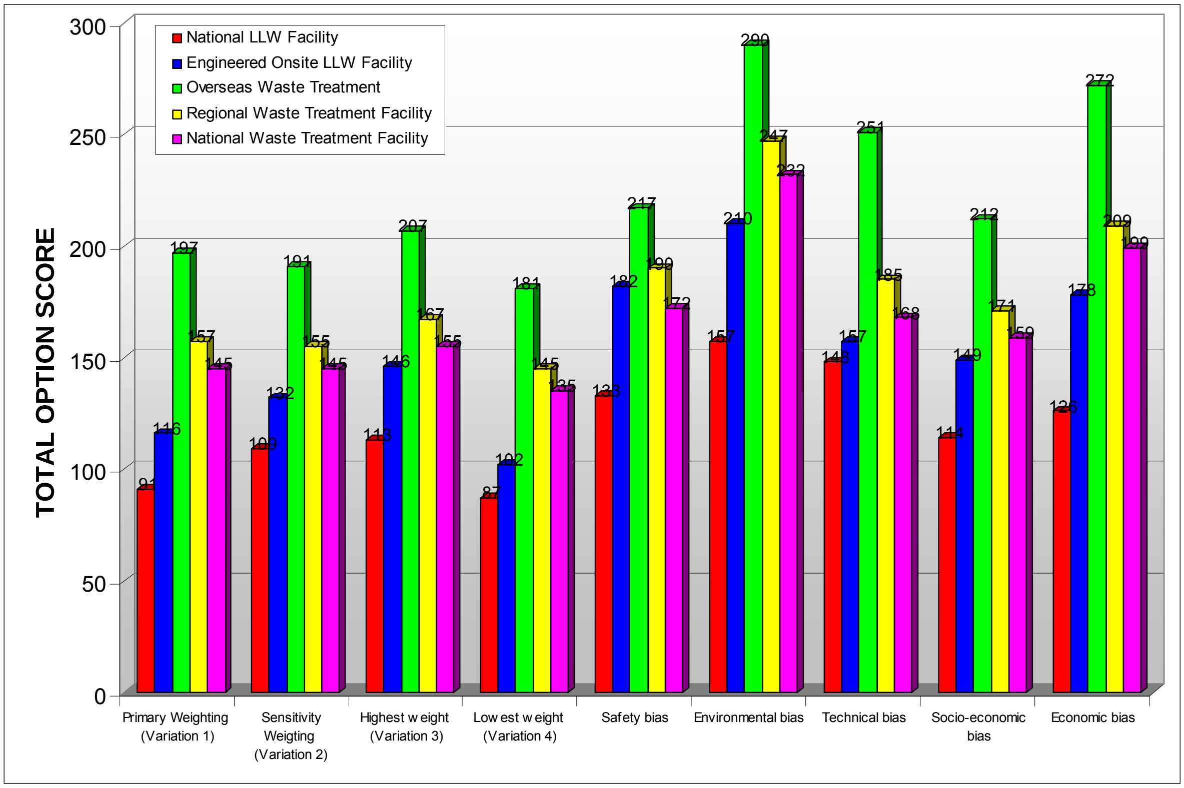


Figure 7.3 shows that the order of the options is unchanged in all cases except where the safety bias factor is applied to the scoring. When the safety bias factor is applied, the Onsite disposal option is ranked 3rd above the national waste treatment option. This is largely as a result of the increased emphasis on the reduced risk from conventional hazards to the public associated with the onsite option compared to the national waste treatment option.

7.3 Sensitivity to Operational Cost

Although the operational cost attribute was not scored in the workshop this attribute was recognised by the group as being significant to the overall outcome of the BPEO study. Subsequently, indicative operational costs have been estimated and it is therefore possible to assign scores to the options outside of the workshop.

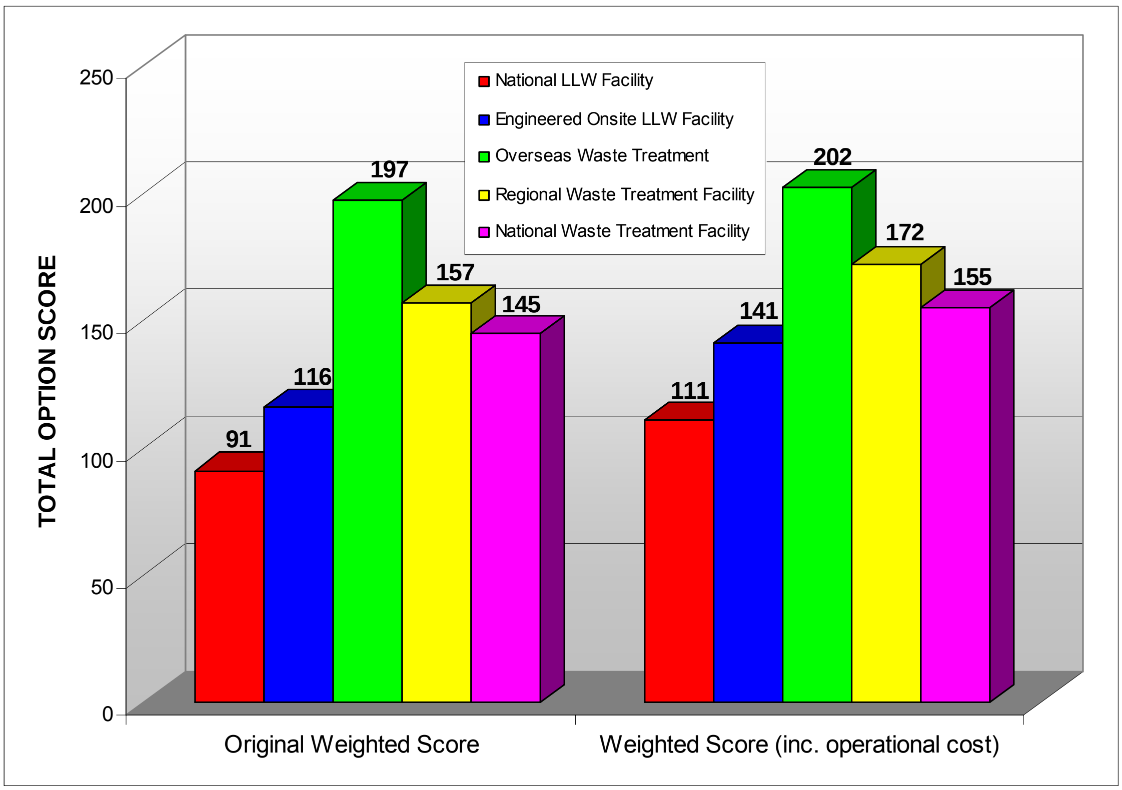
The operational costs are discussed in detail in Section 5.15 and Appendix D. The best option is considered to be onsite waste disposal and this option is awarded a score of 5. Drigg was assigned a score of 4 as the operational cost could be slightly lower than the waste treatment options although this is dependent on the packaging efficiencies that can be achieved for Drigg.

National waste treatment was assigned a score of 3, regional waste treatment a score of 2. Overseas waste treatment is regarded as having the highest operational cost and therefore has been assigned a score of 1.

The differences between the best and worst options are likely to be significant over the life-cycle of operation of the option and hence a weighing of 5 has been assigned for the purposes of this sensitivity analysis.

Figure 7.4 below shows the effect of including operational cost on the baseline option scores.

FIGURE 7.4 – IMPACT OF OPERATIONAL COST ON SCORES



This demonstrates that inclusion of the operational cost attribute does not change the order of the results however onsite LLW facilities become more competitive compared to the waste treatment options.

7.4 Sensitivity Analysis Conclusions

This sensitivity and bias analysis therefore provides confidence that the order of the options is robust against variations in the weighting of particular categories. In all cases the best option is overseas waste treatment followed by regional waste treatment facilities. The worst option in all cases is disposal in a national LLW disposal facility.

8. Factors outside the scope of study

There are a number of additional external factors to consider that may influence the final decision. Such developments may include changes to the relevant regulatory frameworks or Government policy. In addition, public and stakeholder acceptability issues may influence selection of the preferred option.

8.1 European and UK Clearance Levels

In the initial workshop[4], "regulatory change" was identified as a possible "solution" for metallic LLW management. It is highlighted here that changes to the definition of LLW could significantly change the inventory to be managed. Furthermore, the adoption of European criteria (radionuclide-specific) on the release of materials would significantly improve the case for national or regional waste treatment in the UK.

8.2 Political Acceptability

In line with the BPEO guidance produced by the Environmental Agencies it was decided that Political Acceptability would not be included as an attribute as it represents a complex combination of the existing attributes, and as such would introduce double-counting.

The current UK radioactive waste policy[14] as set out in Cm2919 states that with regard to the import or export of waste there should be a presumption towards self-sufficiency, but with some flexibility in view of the highly specialised nature of the waste. Further it is stated that radioactive waste should not be imported to or exported from the UK except where the primary purpose is the recovery of reusable materials (i.e. recycling), or for treatment that will make the subsequent storage and disposal more manageable in cases where processes are at a developmental stage or involve quantities that are too small for the processes to be practicable in the country of origin. In the context of self-sufficiency, a UK based solution would therefore score more highly than an overseas waste treatment option.

The new draft UK radioactive waste policy[13] which will replace Cm2919 does not comment on the issue of self-sufficiency however it addresses this issue through specific emphasis on factors such as the use of risk-informed decision making, application of the waste hierarchy, consideration of all practicable options for management of LLW, presumption towards early solutions and appropriate consideration of the proximity principle and waste transport issues.

In this context the waste treatment options (overseas, regional, national) would score more highly that disposal options for the waste hierarchy aspect and UK based solutions would score more highly than overseas options on considerations such as proximity principle and waste transport. It should be noted that the draft policy requires operators to consider <u>all</u> practicable options for LLW management and favour options that provide early solutions. In this context the overseas waste treatment option would score more highly than the UK based options as it is immediately available. The incorporation of these issues into this BPEO study is considered further in Section 5.1.6.

It is recognised that the UK radioactive waste policy is currently undergoing consultation[13] and that changes to the UK or EU policy framework have the potential to influence the BPEO by influencing the overall weightings of the attributes and scoring of the options.

8.3 Acceptability to Stakeholders

It is possible that some of the options considered in this assessment could be considered unacceptable to some stakeholders. For example, it is possible that some stakeholders may consider onsite disposal of LLW to be unacceptable and not the most desirable site 'end-point'. It is also possible that some stakeholders may perceive that the transportation of waste to a facility overseas represents a disproportionate risk and that wastes should be dealt with locally. Furthermore there may be public perception issues associated with the recycling of material from nuclear sites. These issues should be explored in further studies which should also include stakeholder consultation.

9. Selection of the Best Practicable Environmental Option

At the outset the objective of this study was agreed as follows[4]:

To provide NDA with a full understanding of the technical and commercial arguments, justifications and issues relevant to the implementation of various management techniques on low level radioactive metals wastes in the UK. This will be achieved through the application of a BPEO assessment methodology to determine metal management options for significant aggregated waste streams in the UK.

The key outcome would be an objective understanding of the strength of case for a centralised UK metals / recycling facility.

The first BPEO report[4] considered the different options in the context of route-maps to highlight a number of processes that should form part of any optimised waste management solution. These included measures such as waste minimisation, improved assay, re-use and decontamination.

The evaluation process undertaken as part of this study has identified and evaluated a range of options and concluded that the best option is waste treatment in an overseas facility. Several clear advantages were identified for this option in the workshops compared to the other options:

- The waste treatment overseas option is available immediately. Therefore the option has the potential to alleviate the short-term pressure on the capacity of the Drigg facility. There is sufficient existing spare processing capacity in facilities in various countries in Europe and elsewhere to accept a significant proportion of UK waste in the short-term, and be adequately flexible to cope with fluctuations in volumes.
- Treatment in an overseas facility would not require significant construction cost as the processing plant and associated infrastructure already exist. All other options require substantial construction investment. The direct decommissioning costs would also be very low for overseas waste treatment especially compared to disposal options.
- Solid waste generation is significantly reduced and there is a considerably lower legacy of long-term contaminant residues compared to the onsite or national disposal options. The option has low impact on water quality as the operational discharges would be low and the option would reduce long-term post closure discharges from Drigg.
- Waste treatment allows a significant quantity of material to be recycled thereby reducing the overall life-cycle material and energy requirement by conserving resources.
- Existing overseas waste treatment facilities operate under strict licensing conditions and were considered to present a low nuisance impact to local communities.

The waste treatment overseas option is also likely to be subject to the least overall risk as it is a proven route for metallic LLW which is available now. There is very little risk of project delays and cost overruns compared to the other options as the facilities are currently operating and licensed.

There is also very little risk associated with potential delays caused by siting and planning permission issues that may prove to be formidable obstacles for other options such as onsite disposal facilities, a second Drigg facility or establishment of a UK waste treatment facility.

Beyond the short-term, waste treatment on a national or regional scale in the UK may be favoured option which may reduce some of the risks and possible stakeholder sensitivities. A UK based waste treatment solution may also align more closely with the proximity, waste transport and self-sufficiency principles.

The results have been subjected to a sensitivity analysis which demonstrates that the conclusions of the scoring process are robust and that in general terms the waste treatment options perform more favourably than disposal options irrespective of the weighing applied to the different types of attributes.

The waste treatment overseas option also strongly aligns with the principles of the waste hierarchy and the NDA's accelerated decommissioning strategy and could play a significant part in helping to preserve the strategic resource of existing capacity at Drigg in short term.

10. Recommendations

This BPEO study has highlighted several areas where uncertainties exist and further work may be valuable:

1. Further work may be required to review the longer-term issues and to determine if a UK based waste treatment facility would represent the BPEO. The most significant attributes that score the Overseas WT option above regional and national WT options are:

    - Availability of technology with required timescale
    - Flexibility of option (short-term)
    - Construction cost
    - Decommissioning cost

    These attributes make the most difference to the total score due to their high weightings. It is possible that a UK regional or national facility may score more highly and may represent the BPEO in long run when life-cycle cost and transport impact are accounted for. Further assessment of these factors is therefore recommended.

2. In general this study has considered metallic LLW as a whole, although steel has been used for some comparisons as this is the dominant metallic waste stream in the UK waste inventory. Further BPEO studies could be tailored to more specific waste streams (e.g. to evaluate streams containing aluminium, lead, brass, mixtures of metals, etc). It may be useful to consider if centralised facilities are more suited to the treatment of these smaller waste streams.

3. This study has been produced to provide the NDA with internal advice therefore significant stakeholder consultation has not been undertaken at this stage. There are a number of aspects that may influence the decision making process that could be explored further via stakeholder consultation:

    - Political and Societal acceptability
    - Intergenerational equity
    - Transfrontier shipments of waste
    - Site 'end points' and delicensing
    - Perception of recycling of metals from nuclear sites

    Further assessments should actively engage with a wide range of stakeholders to draw out views and opinions regarding different LLW management options. It may be possible to combine the considerations for metals with other materials\waste types.

4. Review the effect of changes to the government policy and the regulatory regime on the case for UK based treatment facilities. This BPEO has highlighted areas where policy and regulatory changes would provide a more favourable environment for achieving the NDA goal of optimised LLW

management whilst maintaining high standards of protection to both people and the environment. It is therefore recommended that the NDA pursue these issues as a matter of urgency.

5. Onsite LLW facilities would have a significant impact on the permitted future site land usage and the ability to de-licence and release some sites for unrestricted use (i.e. the site end-state). There is currently some uncertainty over the number of onsite facilities that would be required and the feasibility of shared facilities between neighbouring sites needs to be determined. These issues were beyond the scope of this BPEO study but could have a major impact on the overall viability of this option.

11. References

1. Guidance for the Environment Agencies' Assessment of Best Practicable Environmental Option Studies (BPEO) at Nuclear Sites; Environment Agency; February 2004.
2. A Draft Practical Guide to the Strategic Environmental Assessment Directive; Office of Deputy Prime Minister; 2004. http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_plan_029817.pdf
3. NDA Strategy; Nuclear Decommissioning Authority; April 2006.
4. Strategic BPEO for Metal Waste Management – Options Identification and Screening; P0090/TR/001; Studsvik UK; Revision C; March 2006
5. Miljökonsekvensbeskrivning för utvidgning av smältverksamheten i Studsvik *(in Swedish)*; N-05/167; Studsvik Nuclear AB; June 2005
6. Explanatory Document - To assist public consultation on proposals for the future regulation of disposals of radioactive waste on/from the Low-Level Waste Repository at Drigg, Cumbria operated by British Nuclear Group Sellafield Ltd.; Environment Agency; June 2005
7. NDA Strategy–Draft for Consultation: Environmental Report; Nuclear Decommissioning Authority; August, 2005
8. Waste Online; Metals - aluminium and steel recycling; http://www.wasteonline.org.uk/resources/InformationSheets/metals.htm; Accessed January 2006
9. Literature Review of the Potential Application of Metal Melting in the UK Nuclear Sector; HSE (NNC); November 2004
10. Lifecycle Baseline 2004 - Low Level Waste Repository at Drigg - Executive Summary; British Nuclear Group; 2004.
11. CoRWM Criteria; Discussion Paper: Cost; Galson Sciences; June 2005
12. Dounreay LLW Strategy Development – Best Practicable Environmental Option Study Final Report; UKAEA; April 2004
13. A Public Consultation on Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom; DEFRA; February 2006
14. Cm2919 – Review of Radioactive Waste Management Policy; Secretary of State for the Environment; 1995
15. Near Term Work Plan, 2005/06 to 2007/08 – Site Support; British Nuclear Group; 2005
16. IPPC, Secretary of State's Guidance for the A2 Ferrous Foundries Sector; Sector Guidance Note IPPC SG3; Issue 2; DEFRA; January 2006
17. Best Available Techniques Reference Document on the Production of Iron and Steel; European Commission; December 2001

Appendix A – List of Attendees at Options Evaluation Workshop

Joanne Fisher	NDA (LLW Strategy)
Martin Robb	NDA (Regional Engineer)
Dr Les Smith	NDA (Civil / Structural Engineering)
Andrew Craze	NDA (Environment Manager)
Madog Jones	BNG Trawsfynydd (Decommissioning)
Lise Stoyell	Studsvik UK (BPEO specialist, Workshop Facilitator)
Geoff Carver	Studsvik UK (Decommissioning Manager)
Bo Wirendal	Studsvik Nuclear AB (Metals Melting Technical Manager)
Joe Robinson	Studsvik UK (Project Manager, Environmental)
Peter Holmes	Studsvik UK/EMS (Nuclear Safety/Metallurgy)
David Rossiter	Studsvik UK (Project Engineer, Environmental)

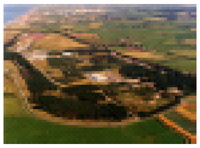
Appendix B – Option Evaluation Workshop Presentation

Studsvik® NDA

Strategic BPEO for Metals Waste Management

Workshop 2 – Options Evaluation

12th December 2005



Objective

- To provide the NDA with a full understanding of the technical, commercial arguments, justifications and issues relevant to the implementation of various management techniques on low level radioactive metals wastes in the UK. This will be achieved through the application of a BPEO assessment methodology to determine metal management options for significant aggregated waste streams.

- The key outcome will be an objective understanding of the strength of case for a centralised UK metals / recycling facility

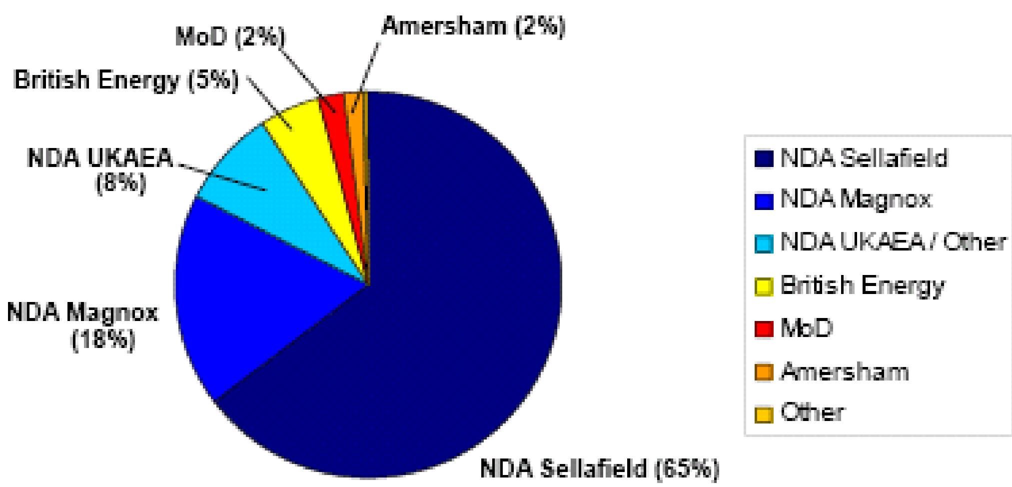
Studsvik® NDA

Summary of Waste Inventory

- 22% of all LLW arisings are metallic
- Total bulk metallic LLW arisings are **450,000 t,** of which the majority (93%) are ferrous metals
- Sellafield is the dominant source (**177,000 t**) although Magox sites may contribute **80,000t** or more

Studsvik® NDA

Summary of Waste Inventory



Studsvik® NDA

Options Identification

- Options Identification was undertaken at Workshop 1 on 30th September 2005
- 66 Candidate Techniques / Technologies were identified for management of metallic LLW
- Techniques were grouped into parent headings and strengths & weakness considered:

- Storage
- Disposal
- "Transfer Elsewhere"
- Regulatory Change
- Assay
- Re-use
- Recycle (nuclear)
- Recycle (non-nuclear)
- Treatment – decontamination
- Treatment – Size reduction
- Treatment – Process
- Waste minimisation
- Mixing

Studsvik® NDA

Screening Criteria

- Workshop 1 decided on Short & Long Term Criteria

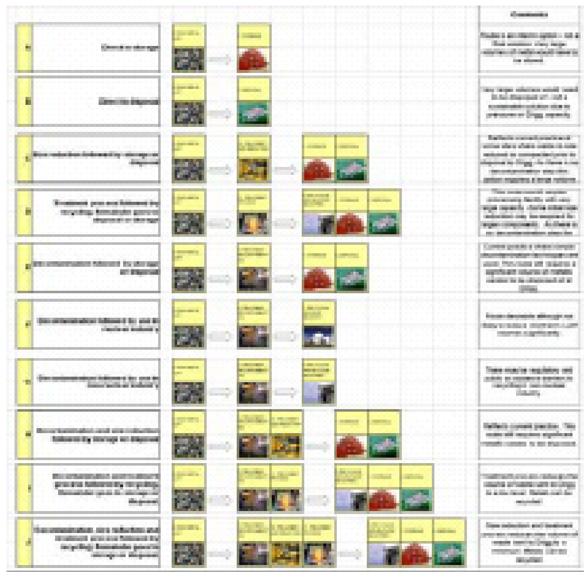
Short-Term Criteria	Long-Term Criteria
Option must be operational by 2008	Option must be available by 2020 with a 10yr development timetable
Technology must be available now	Technology must be available in 5 years
Technology must be proven	Option must reduce LLW liabilities
Option must relieve short-term pressure on Drigg Capacity	Option must align with international conventions
Option must be with existing regulatory / policy framework	

- 66 candidates => 33
- 66 candidates => 34

Studsvik® NDA

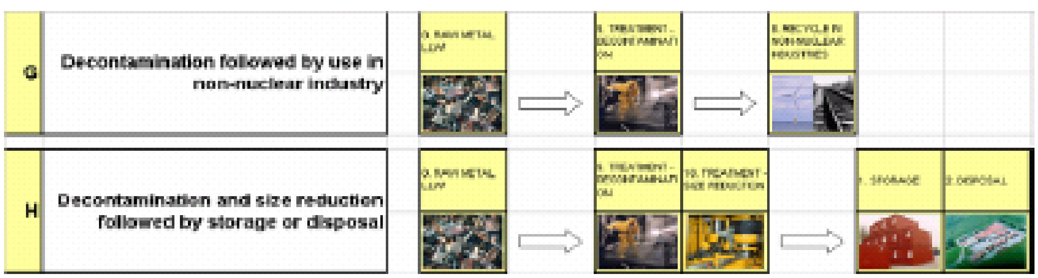
Route Mapping

- Each option identified does not represent a total solution to metal waste management
- Studsvik has used a "route mapping" technique to consider options further



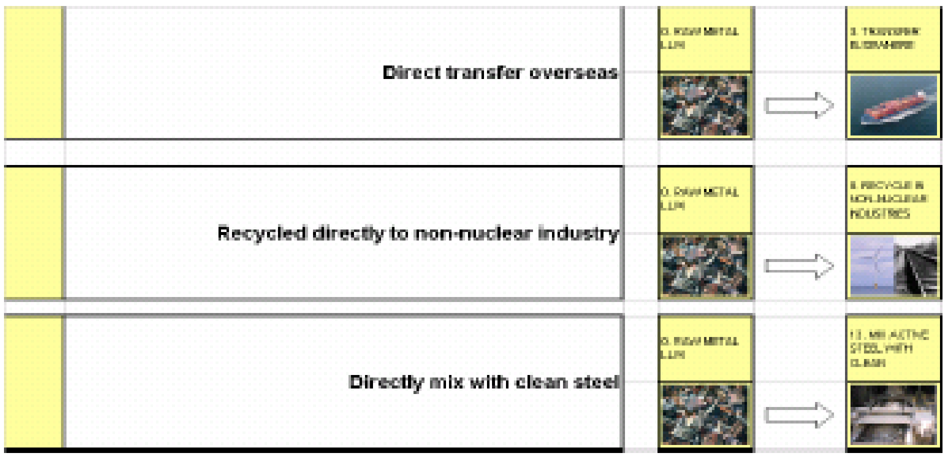
Studsvik® NDA

Route Mapping - Examples

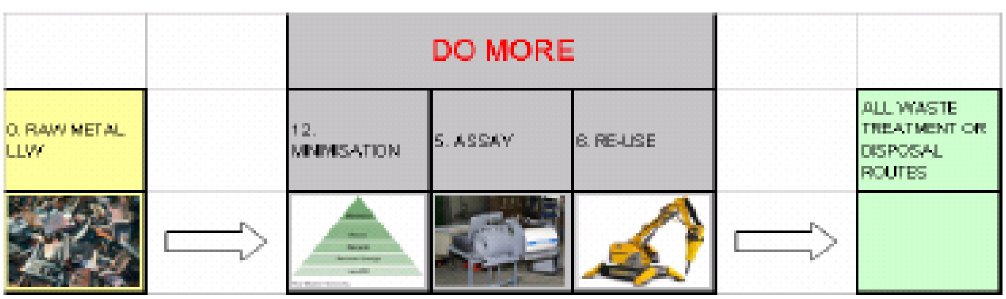


Studsvik® NDA

Route Mapping – Rejected routes



Route Mapping – "Do More"



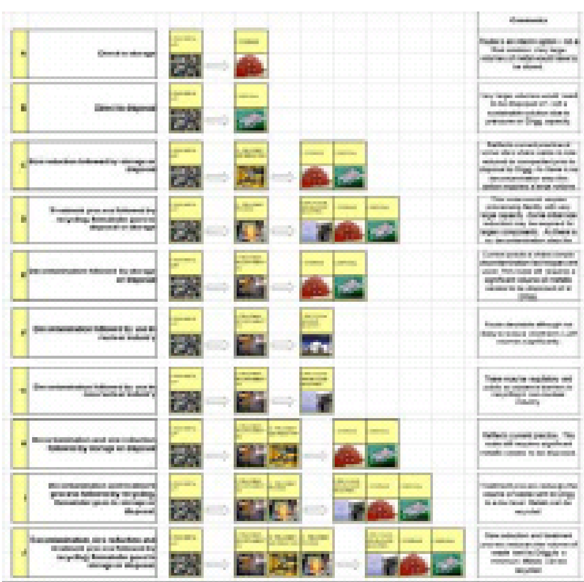
- Ten "valid" route maps remained following screening

Recap of Objective

- Determine metal management options for significant aggregated waste streams
- The key outcome will be an objective understanding of the strength of case for a centralised UK metals / recycling facility

Studsvik® NDA

Route Mapping => Short listed options



- Drigg II
- On-site LLW disposal
- Existing global waste routes
- Regional Waste Treatment Facilities
- National Waste Treatment Facility

Studsvik® NDA

Option 1 – Drigg / Drigg II

- Initially screened out as it does not reduce LLW liability
- Included as a comparator and represents current practice
- Route assumes that waste is decontaminated where possible and size reduced locally for optimum packing efficiency
- Drigg LCBL costs are £1.3Bn, estimated capital cost of new facility £100M+
- Long-term solution only

Studsvik® NDA

Option 2 – On-site LLW Facilities

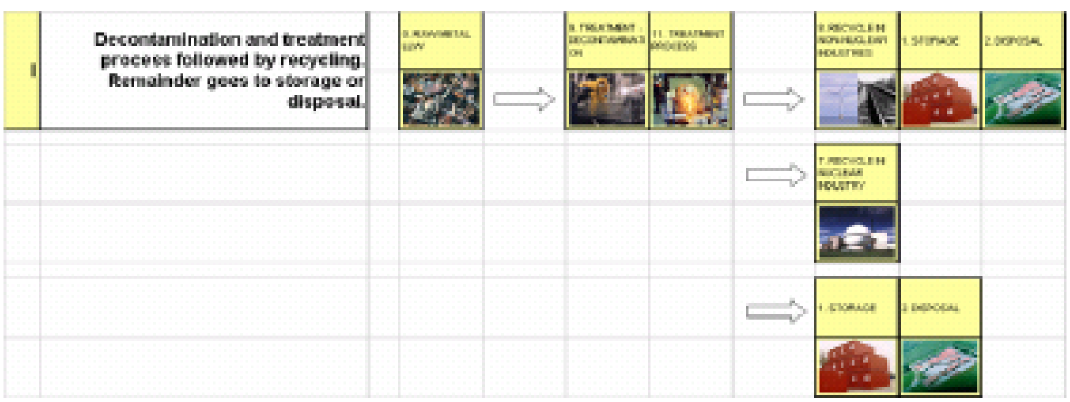
- On-site engineered LLW disposal facilities at each site of arising, as planned at UKAEA Dounreay
- Initially screened out as it does not reduce liability
- Route assumes that waste is decontaminated where possible and size reduced locally for optimum packing efficiency
- Costruction costs £50M-£100M, lifecycle costs c£200M per facility
- Long-term solution only

Studsvik® NDA

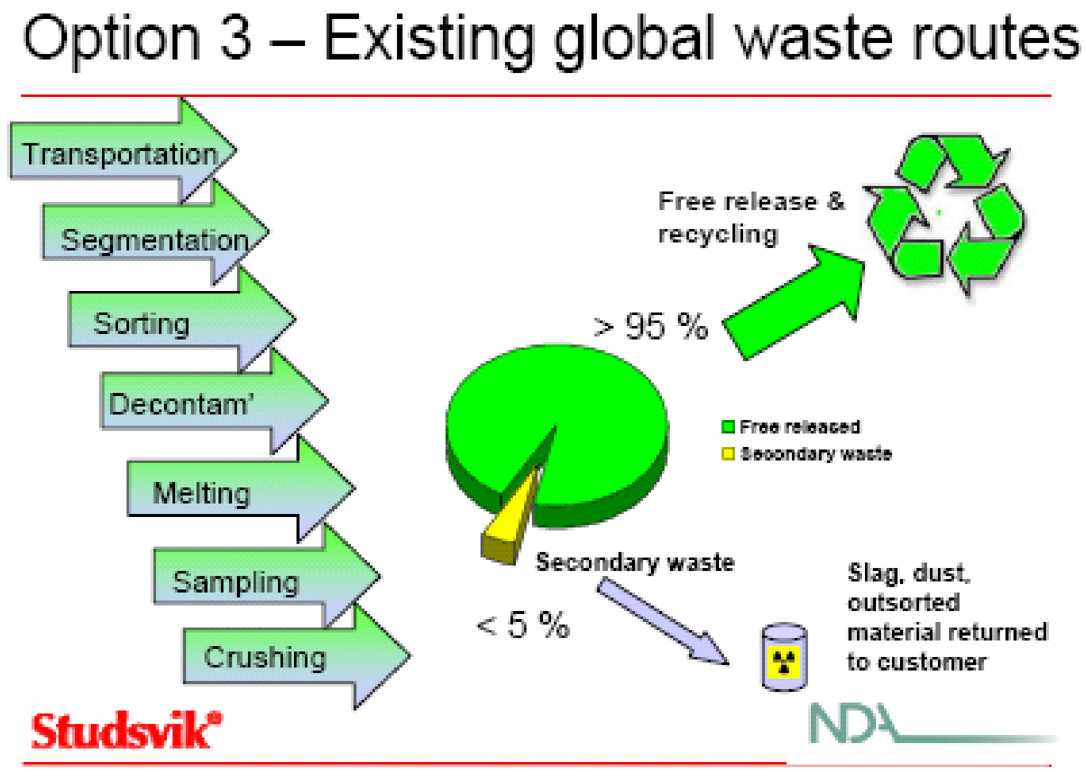
[redacted]

Option 3 – Existing global waste routes

- Various treatment concepts are feasible including recycling, re-use of treated materials in the nuclear industry or treatment purely for volume reduction



Studsvik® NDA


Option 3 – Existing global waste routes
Transportation
Segmentation
Sorting
Decontam'
Melting
Sampling
Crushing
Free release & recycling
> 95 %
Free released
Secondary waste
Secondary waste
< 5 %
Slag, dust, outsorted material returned to customer
Studsvik
NDA

[redacted]

Multi-attribute Decision Analysis

- Options will be assessed against a list of decision attributes
- You will score the options 1-5 against each attribute (1 represents the worst, undesirable performance score; 5 represents the best, desirable performance score).
- It is not a ranking process, therefore you can have more than 1 option which does best, or more than 1 option that does worst. There must be at least one option that scores best, and one that scores worst.
- You will agree a weight, based on how decisive the attribute is with respect to the overall decision.

Studsvik® NDA

Safety Attributes

Attribute	Full Attribute Description
SAFETY	
Critical group dose to public	Critical group dose to public during construction, commissioning, operations and decommissioning of metal management option.
Occupational dose to workforce	Occupational dose to workforce during construction, commissioning, operations and decommissioning of metal management option.
Risks from conventional hazards to public	Conventional safety hazards to public during the option's life-cycle i.e. traffic.
Occupational risks from conventional hazards to workforce	Conventional safety hazards to workforce during the option's life-cycle i.e. impact, falls, asphyxiation, fire etc.

Studsvik® NDA

Environmental Attributes

Attribute	Full Attribute Description
ENVIRONMENTAL	
Impact on marine systems (including impact on OSPAR targets)	Liquid and solid discharges to marine waters during the option's life-cycle.
Impact on terrestrial ecosystems and habitat, giving consideration to designated wildlife sites and protected species.	Aerial, liquid and solid discharges to terrestrial habitats during the option's life-cycle, with consideration of the quality and capacity of the receiving environment.
Legacy of long-term contaminant residues i.e. impact on land quality.	Legacy of the contaminant residues that will remain at the end of the option's operational phase.

Studsvik® NDA

Environmental Attributes

Attribute	Full Attribute Description
ENVIRONMENTAL	
Non-radioactive waste arisings (air / water / land)	
Life-cycle materials and energy requirement	Assessment to consider the input of energy and material throughout project lifecycle as relevant. In addition, the options positive impact with respect to materials and energy i.e. the re-use and recycling of metal waste to generate by-products and products.
Transport-related environmental discharges	Transport-related emissions incurred due to the transfer of waste metal during the option's life-cycle, including road, rail and sea.
Vulnerability to natural and man-made disasters	Consideration of the option's siting and vulnerability to natural and man-made disasters, such as flooding or terrorist attack

Studsvik® NDA

Technical Attributes

Attribute	Full Attribute Description
TECHNICAL	
Confidence in technology	Will the option be effective?
Availability of technology within required timescale	Is the option available in the required timescales?
Flexibility of option	Can the option cope with uncertain input waste volumes and inventories?

Studsvik® NDA

Socio-Economic Attributes

Attribute	Full Attribute Description
SOCIO-ECONOMIC	
Nuisance (noise, odour, visual)	Nuisance during the option's life-cycle (noise, odour, visual)
Impact on cultural heritage. **during scoring, make clear whether positive or negative impact*	Consider whether the option will impact on archaeology or historic woodland during it's' life-cycle.
Impact on local economy	Consider the option's effect on employment levels and the socio-economic status of the local area that will benefit / disbenefit.

Studsvik® NDA

Economic Attributes

Attribute	Full Attribute Description
ECONOMIC	
Construction cost	Financial cost of construction.
Operational cost	Financial cost of operations.
Decommissioning cost	Financial cost of decommissioning and site restoration.
Intangible costs	Intangible costs, such as Public Relations and the Planning Process.

Studsvik® NDA

Relative Scoring System

- Determine the best option/s in terms of its performance against attribute *x*. Score this as 5.
- Determine the worst option/s in terms of its performance against attribute *x*. Score this as 1.
- Allocate intermediate scores as appropriate to remaining options.

Studsvik® NDA

Weighting System

- Apply swing weights 1, 3 or 5.
- Swing weights are weights based on how 'decisive' or 'influential' the attribute is. Is the difference between the best option and worst option large / moderate or insignificant?
- Example:
- The difference between the best and worst option for annual dose is 1 µSv
- Radiological safety is important to us (**value** weight). However, the **swing** weight is low, as in this case, the difference in annual dose is insignificant in the context of the overall decision.

Studsvik® NDA

Workshop Protocol

- Time is very tight - we have approximately **15** minutes per attribute.
- If there is no agreement after reasonable debate, we will park the score until later and return if we have time.
- The facilitator will record key assumptions and uncertainties that arise during discussion.
- The secretary will record the scores, weights and underpinning justification. Keep an eye on the live record / minutes as they are being taken and ensure your meaning has been captured accurately.

Studsvik® NDA

Appendix C – Attributes

TABLE C1 – BPEO ATTRIBUTES

ATTRIBUTE / INDICATOR	ENVIRONMENT AGENCIES' BPEO GUIDANCE	STRATEGIC ENVIRONMENTAL ASSESSMENT OBJECTIVES	PROPOSED ATTRIBUTE FOR METAL WASTE STUDY
HEALTH & SAFETY	Critical group dose from planned release	Protect and enhance human health	**Critical group dose to public**
	Collective dose to population	Reduce and prevent crime	**Occupational dose to workforce**
	Critical group dose from accidental release	Reduce fear of crime	**Occupational risks from conventional hazards to public**
	Occupational dose to workers	Decrease noise and vibration	**Occupational risks from conventional hazards to workforce**
	Occupational risks from conventional hazards		
IMPACTS ON NATURAL, PHYSICAL AND BUILT ENVIRONMENT	Impact on marine systems	Avoid damage to designated wildlife sites and protected species	**Impact on water quality and marine systems (including impact on OSPAR targets)** ***during scoring, make clear whether positive or negative impact***
	Nuisance (noise, odour, visual)	Provide opportunities for people to come into contact with and appreciate wildlife and wild places.	**Impact on air quality** ***during scoring, make clear whether positive or negative impact***
	Long-term contaminant residues	Restore full range of characteristic habitats and species.	**Legacy of long-term contaminant residues i.e. impact on land quality.** ***during scoring, make clear whether positive or negative impact***
	Impact on terrestrial ecosystems and habitat	Maintain biodiversity, avoiding irreversible losses	
	Non-radioactive waste arisings	Ensure the sustainable management of key wildlife sites and the ecological processes on which they depend	**Solid waste generation**
	Indirect impacts (e.g. climate change)	Limit water pollution to levels that do not damage natural systems	**Life-cycle materials and energy requirement** ***during scoring, make clear whether positive or negative impact***
		Maintain water abstraction, run-off and recharge within carrying capacity (including future capacity)	**Transport-related environmental discharges and nuisance**
		Reduce contamination and safeguard soil quality and quantity	**Hazard withstand to natural and man-made external hazards**
		Minimise waste then reuse or recover it through recycling, composting or energy recovery.	

ATTRIBUTE / INDICATOR	ENVIRONMENT AGENCIES' BPEO GUIDANCE	STRATEGIC ENVIRONMENTAL ASSESSMENT OBJECTIVES	PROPOSED ATTRIBUTE FOR METAL WASTE STUDY
		Maintain and restore key ecological processes (e.g. hydrology, water quality coastal processes).	
		Limit air pollution to levels that do not damage natural systems	
		Reduce the need to travel	
		Reduce climate change gases	
		Reduce vulnerability to effects of climate change e.g. flooding, disruption to travel by extreme weather etc.	
		Preserve historic buildings, archaeological sites, and other culturally important features.	
		Create places, spaces and buildings that work well, wear well and look well.	
		Enhance countryside and townscape character	
		Value and protect diversity and local distinctiveness	
		Improve quantity and quality of publicly accessible open space.	
TECHNICAL PERFORMANCE AND PRACTICABILITY	Aggregated project risk		**Confidence in technology**
	Requirements for technical development		**Availability of technology within required timescale**
	Timescale to implementation		**Flexibility of option** ***scored separately for short-term and long-term flexibility***
	Flexibility		
	Impacts on site operability		
SOCIO-ECONOMIC IMPACTS / QUALITY OF LIFE	Nuisance (noise, odour, visual)	Improve access to skills and knowledge	**Nuisance (noise, odour, visual)**
	Residual restrictions on access following remedial actions	Make opportunities for culture, leisure and recreation readily accessible.	**Impact on cultural heritage**
	Positive effects on local economy	Redress inequalities related to age, gender, disability, race, faith	**Impact on local economy**
	Negative effects on local economy	Give access to satisfying and rewarding work, reduce unemployment	
		Increase investment in people, equipment, infrastructure, and other assets.	
		Increase the efficiency of transport and economic activities	

ATTRIBUTE / INDICATOR	ENVIRONMENT AGENCIES' BPEO GUIDANCE	STRATEGIC ENVIRONMENTAL ASSESSMENT OBJECTIVES	PROPOSED ATTRIBUTE FOR METAL WASTE STUDY
ECONOMIC IMPACT	Lifecycle cost (construction, operation, decommissioning)		**Construction cost**
			Operational cost
			Decommissioning cost
			Project Risks

Appendix D – Environmental Discharge Analysis

Drigg

Contaminated leachate from the historical disposals and current operations at Drigg is discharged via a marine pipeline to the Irish Sea in accordance with the site's RSA authorisation.

The disposed LLW at Drigg gives rise to radioactive gaseous releases which are dominated by tritium and Radon-222. In addition, radioactive discharges occur from various processing activities such as the Drigg Grouting Facility, Backlog Processing Facility and the Plutonium Contaminated Materials (PCM) Retrial Facility.

The NDA Draft Strategy-Environmental Report[7] states that current liquid discharges are 0.06GBq of alpha emitting radionuclides and 200GBq of beta/gamma emitting radionuclides (dominated by Tritium) and these are anticipated to remain similar up to vault closure. Current gaseous discharges[7] are 0.02MBq of alpha emitting radionuclides and 0.1MBq beta/gamma radionuclides and are likely to reduce slightly following completion of PCM retrieval operations.

It is noted that the vast majority of the discharges and consequential dose to the public are associated with legacy wastes at Drigg disposed in Trenches 1-7. A much smaller amount is predicted to arise from disposal of future waste. The predicted discharges from future waste disposal include all waste streams and it not clear how much the disposal of metallic wastes is likely to contribute to the total.

The NDA Strategy Environmental Report[7] states that current doses to the critical group from disposal operations at Drigg are 88µSv/yr and that future doses will increase to around 100µSv/yr during the remaining operation of the site.

There are no significant non-radiological discharges regulated under the PPC regulations. Data from the Drigg NTWP[15] suggests that 3,000MWh of electricity is used at the Drigg site every year. For comparison purposes it can be assumed that if around 500 HH ISO containers are grouted and emplaced in a year and each HH ISO contains around 20te metallic waste then this equates to an electricity consumption of 0.3MWh/tonne of disposed metal.

The rate of coastal erosion at Drigg is around 1 metre per year[7], and the facility is roughly 1 kilometre from the current shoreline. The post closure safety case for the Low Level Waste disposal facility near Drigg indicated that the site may be challenged by coastal erosion in between 500 and 5,000 years. It is thought that this would produce a risk to the critical group that is significantly greater than the current regulatory targets of 1×10^{-6}/yr.

The Environment Agency has recently reviewed the Drigg Operational Environmental Safety Case and Post-Closure Safety Cases and has consulted[6] on proposed changes to the way the site's RSA authorisation is implemented.

Predicted doses to the most exposed group from discharges to atmosphere and to the local marine environment at the current discharge levels, as estimated by BNGSL using a generic, cautious, initial assessment methodology, are 0.0006µSv/yr and 1.1μSv/yr, respectively. An independent Food Standards Agency (FSA) assessment has predicted a maximum 'possible' dose as 11μSv/yr and the maximum 'probable' dose as 1μSv/yr to the critical group from all pathways. It is noted that these numbers are significantly lower than those stated by the NDA for Drigg.

The EA have stated[6] that the general principles for assessing public exposure from authorised discharges indicate that if an initial simple and cautious assessment results in critical group doses that are below 20μSv/yr, then no further assessment is warranted for the purposes of authorising the discharge of radioactive waste to the environment. This can also be compared with the dose constraints for members of the public from any single source of 300μSv/yr, from any single site of 500μSv/yr and the legal public dose limit of 1000μSv/yr.

Waste Treatment Facilities

Section Redacted

Environmental Benefits of Recycling Metals

Around 11Mte of iron and steel scrap is produced in the UK every year. Around 70% of this is recovered and recycled leading to substantial energy and resource savings[8].

To produce 1te of virgin steel at an integrated steelworks requires around 18GJ or 5MWh of energy[17]. The majority of this energy is used at the blast furnace stage of the process therefore recycling scrap steel brings significant energy savings.

It is estimated that every tonne of steel recycled makes the following environmental savings compared to production of virgin steel[8]:

- 1.5te of Iron ore
- 0.5te of Coal
- 40% of the water required for virgin steel production
- 75% of the energy required for virgin steel production (i.e. ~3.75MWh)
- 1.28te of solid waste
- Reduction in emissions to air of 86%
- Reduction in emissions to water by 76%

Recycling aluminium requires only 5% of the energy and produces only 5% of the CO_2 emissions as compared with primary production[8]. Recycling 1te of aluminium can save up to 6te of bauxite, 4te of chemicals and approximately 50GJ or 14MWh of electricity[8].

Appendix E – Cost Analysis

Appendix Redacted

Appendix F – Sensitivity Analysis

TABLE F1 – VARIATIONS OF ATTRIBUTE SCORING USED IN SENSITIVITY ANALYSIS

ATTRIBUTE	RISKS FROM CONVENTIONAL HAZARDS TO PUBLIC	IMPACT ON AIR QUALITY	LIFE-CYCLE MATERIALS AND ENERGY REQUIREMENT (RESOURCE CONSUMPTION)	TRANSPORT-RELATED ENVIRONMENTAL DISCHARGES AND NUISANCE	CONSTRUCTION COST
Primary weighting (Variation 1)	**3**	**1**	**1**	**3**	**5**
Sensitivity weighting (Variation 2)	**5**	**3**	**3**	**1**	**3**
Highest Weightings (Variation 3)	**5**	**3**	**3**	**3**	**5**
Lowest Weightings (Variation 4)	**3**	**1**	**1**	**1**	**3**
Variation 5	5	1	1	3	5
Variation 6	3	3	1	3	5
Variation 7	3	1	3	3	5
Variation 8	3	1	1	1	5
Variation 9	3	1	1	3	3
Variation 10	5	3	1	3	5
Variation 11	5	1	3	3	5
Variation 12	5	1	1	1	5
Variation 13	5	1	1	3	3
Variation 14	3	3	3	3	5
Variation 15	3	3	1	1	5
Variation 16	3	3	1	3	3
Variation 17	3	1	3	1	5
Variation 18	3	1	3	3	3
Variation 19	3	3	3	1	5
Variation 20	3	1	3	1	3
Variation 21	5	1	3	1	5
Variation 22	5	3	1	1	5
Variation 23	5	3	1	3	3
Variation 24	5	1	3	3	3
Variation 25	5	1	1	1	3
Variation 26	3	3	3	3	3
Variation 27	3	3	1	1	3
Variation 28	5	3	3	1	5
Variation 29	5	3	3	3	3
Variation 30	5	3	1	1	3
Variation 31	5	1	3	1	3
Variation 32	3	3	3	1	3

TABLE F2 – VARIATIONS OF ATTRIBUTE WEIGHTING AND BIAS ANALYSIS

CATEGORY	ATTRIBUTE	Primary Weighting (Variation 1)	Sensitivity Weighting (Variation 2)	Highest weight (Variation 3)	Lowest weight (Variation 4)	Safety bias	Environmental bias	Technical bias	Socio-economic bias	Economic bias
SAFETY	Critical group dose to public	1	1	1	1	2	1	1	1	1
	Occupational dose to workforce	1	1	1	1	2	1	1	1	1
	Risks from conventional hazards to public	3	5	5	3	10	5	5	5	5
	Occupational risks from conventional hazards to workforce	1	1	1	1	2	1	1	1	1
ENVIRONMENTAL	Impact on water quality and marine systems (including impact on OSPAR targets)	1	1	1	1	1	2	1	1	1
	Impact on Air Quality	1	3	3	1	3	6	3	3	3
	Legacy of long-term contaminant residues i.e. impact on land quality.	3	3	3	3	3	6	3	3	3
	Solid Waste Generation	5	5	5	5	5	10	5	5	5
	Life-cycle materials and energy requirement (resource conservation)	3	3	3	3	3	6	3	3	3
	Life-cycle materials and energy requirement (resource consumption)	1	3	3	1	3	6	3	3	3
	Transport-related environmental discharges and nuisance	3	1	3	1	3	6	3	3	3
	Hazard Withstand to natural and man-made external hazards	1	1	1	1	1	2	1	1	1
TECHNICAL	Availability of technology within required timescale	5	5	5	5	5	5	10	5	5
	Flexibility of option (Short-term)	3	3	3	3	3	3	6	3	3
	Flexibility of option (Long-term)	1	1	1	1	1	1	2	1	1
SOCIO-ECONOMIC AND POLITICAL	Nuisance (noise, odour, visual)	1	1	1	1	1	1	1	2	1
ECONOMIC	Construction cost	5	3	5	3	5	5	5	5	10
	Decommissioning cost	5	5	5	5	5	5	5	5	10
	Project Risks	3	3	3	3	3	3	3	3	6

Note: Bias weightings for each attribute are derived by multiplying the highest weighting by a factor of 2