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SD:SPUR

Sustainable practices in the use of construction resources

Guidance on the application of sustainable practices to the management of decommissioning wastes from nuclear licensed sites

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Summary and recommendations

The SD:SPUR project had the aim of developing guidance for waste managers on nuclear sites to help them manage redundant buildings, and radiologically clean and slightly radioactive decommissioning waste streams. The project was supported by a Project Steering Group comprising operators of nuclear sites, Government departments and agencies, and non-governmental organisations, and sought wider views through a stakeholder consultation programme.

Large volumes of radiologically clean and slightly radioactive wastes will be generated by the decommissioning of nuclear sites in the UK. Exact quantities of wastes are not yet available but estimates suggest the volumes will be around 1,500,000 m3 of radiologically clean, RSA exempt and excluded wastes, and a further similar amount of slightly radioactive wastes. The dominant materials contained within both waste classes are concrete, unsorted building rubble, ferrous metals and soil.

The radiologically clean, RSA exempt and excluded wastes potentially can be recycled and reused on or off nuclear sites as construction materials without further regulatory control. The demand for recycled materials arising from nuclear sites may be depressed, however, due to the concerns of some stakeholders and perceived health and safety impacts. The slightly radioactive wastes must always remain under regulatory control. They cannot all be disposed to the existing low-level waste (LLW) repository at Drigg because their total volume exceeds the remaining capacity of the repository. They potentially may be reused as construction materials on nuclear sites provided that the requirements of environmental, and health and safety legislation are met.

The regulators now require site operators to develop integrated waste strategies (IWS) that adopt coherent approaches to the management of both radioactive and non-radioactive wastes to take account of the Government's environmental policies that are based on the concept of sustainable development. An IWS is likely to need underpinning by a best practicable environmental option (BPEO) study to identify the best option that provides a sensible balance between aspects such as human health and safety, environmental impacts, technical feasibility, and cost.

This guidance is intended to be directly applicable to, and complementary with, this requirement on operators to use BPEO in the development of an IWS. As a result, this guidance should not result in any disproportionate additional effort on the part of a nuclear site operator nor cause any delay in making decisions. The guidance is focussed on the explicit inclusion of sustainability considerations into key stages of a BPEO study: namely, options identification and screening, the selection of attributes and options analysis, and public and stakeholder engagement.

With regard to ***options identification and screening***, it is recommended that site operators first consider collectively all of the buildings and structures on a site to examine whether a coherent sustainable management approach could be applied across the site, rather than considering individual buildings and waste streams one at a time. Options should be identified for the refurbishment and reuse of buildings, as well as options for planned deconstruction and routine demolition of buildings using different methods that achieve variable degrees of waste segregation for later material recycling.

Once a comprehensive range of options has been identified, some options may be screened from the BPEO study if they are clearly not viable. A simple decision tree has been designed around a series of questions to help screen out options when there is no actual demand for refurbished buildings or high utility recycled materials (particularly at sites that are remote from centres of business or industry) or because planning constraints mean that the certain site end-states must be achieved. The viability of options will be strongly site-specific and no option for building or waste management should ever be screened out from a BPEO study when there could be reasonable doubt that it may prove viable for particular site conditions.

With regards to the ***selection of attributes and options analysis***, waste managers require a simple and transparent system to allow them to assess different aspects of sustainability so that different management options may be compared. This guidance recommends the use of a system of *sustainability indicators*, that can be considered as broadly equivalent to BPEO attributes with a sustainable focus. The following set of 19 sustainability indicators (and an additional 38 sub-indicators) were derived through extensive stakeholder consultation. These have been correlated to the UK Government's sustainable development strategy and the environment agencies guidance on the application of BPEO studies to the management of radioactive wastes.

1 Health and safety of the public
2 Health and safety of the workforce
3 Discharges to water bodies
4 Discharges to the atmosphere
5 Biodiversity
6 Solid waste disposal
7 Waste material reused
8 Material transport
9 Resource use
10 Quality of recycled product
11 Technical developments
12 Finality of option
13 Employment
14 House prices and land value
15 Landscape and heritage
16 Quality of life
17 Investment
18 Costs
19 Revenue

The core of a sustainable waste management BPEO study will be the systematic assessment of the performance of short-listed options for the management of redundant buildings and decommissioning waste streams, against these sustainability indicators plus the other standard BPEO attributes. Not every decommissioning waste BPEO study will need to include all of these sustainability indicators. The selection of attributes should be systematic and justified in order for the final decision to be transparent and acceptable to stakeholders.

With regard to ***public and stakeholder engagement***, it is likely that there will be a degree of mistrust and concern from some stakeholders about the reuse in public places of waste materials derived from nuclear sites, even when they are radiologically clean and indistinguishable from conventional demolition wastes. Little is achieved by processing materials for reuse if no application or buyer for the product can be found and, therefore, this issue is critical to the implementation of a sustainable policy for the management of decommissioning wastes from nuclear sites. To minimise this problem, it is recommended that two approaches be adopted by site operators when developing their IWS. The first is to reuse waste materials on site (or on other nuclear sites) so that the nuclear industry becomes the primary customer for its own recycled products. The second is to engage the public and stakeholders at an early stage so that broad-based agreement can be sought for sustainable off site applications of processed decommissioning wastes and other materials.

There is an obvious similarity with regards public and stakeholder concerns between the reuse and recycling of decommissioning wastes from nuclear sites and the remediation of contaminated land on nuclear sites to allow the sites to be reused for other purposes. As a consequence, it is recommended that site operators consult best practice guidance on public and stakeholder engagement from the SAFEGROUNDS project and other similar sources.

Before any waste material could be reused or recycled for uncontrolled use either on or off a nuclear site, appropriate demonstrations need to be made to the regulators that it is either radiologically clean or that its levels of radioactivity are appropriate for it to be classed as RSA exempt or excluded. An industry code of practice on clearance and exemption has been promulgated that is likely to be adequate when making demonstrations to regulators in support of waste management proposals. It may not, however, be sufficient to allay the concerns and fears of some stakeholders with regard to the safety of recycled materials derived from nuclear sites, even those that are radiologically clean. In is recommended that site operators consult best practice examples of joint industry-stakeholder agreed sampling and monitoring programmes that have been developed by the Environment Council when seeking consensus on a methodology for clearance and exemption of recycled materials.

The slightly radioactive wastes must always remain under regulatory control (unless they can be decontaminated) and, thus, can never be considered for reuse or recycling in public places. There are, however, a number of possibilities for the sustainable reuse and recycling of these materials on nuclear sites that might offset the use of virgin or other sources of recycled materials. The types of uses to which certain recycled decommissioning slightly radioactive wastes might be put could include:

- fabrication of steel ISO containers, waste cans and overpacks for radioactive wastes;
- cementitious grouts and backfills to infill ILW and LLW waste packages;
- incorporation into the reinforced concrete structures of waste repositories and storage facilities; and
- construction of waste processing equipment such as supercompactors and cementation plants.

It is unlikely that a nuclear site could meet all of its construction material requirements from processing and recycling its own wastes. It is recommended, however, that as part of an IWS a site operator undertakes mass balance calculations to assess to what extent a site could satisfy its own material requirements, and the financial and environmental implications of doing so.

It is recommended that the nuclear industry takes steps to become the main consumer of its own recycled materials. This approach would be consistent with the Government's sustainable development policy and should provide value for money by offsetting the costs of raw materials. It has the added advantage that public and stakeholder concerns are minimised. Such an approach would require centralised support and management to provide such services as dedicated processing and recycling plants (e.g. metal processing plants to take waste steel for the fabrication of ISO containers and waste drums, or concrete crushing and batch plants to provide aggregate for use as a backfill in waste packages or in the construction of future waste repositories).

It would appear to be within the remit of the NDA to promote such an approach, although individual sites are encouraged to consider installing local processing facilities for their own or locally shared use.

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Contents

	Summary and recommendations		i
1	Introduction		1
	1.1	Background to the project	1
		1.1.1 Project objectives	1
		1.1.2 Project scope	1
		1.1.3 Audience for this report	2
		1.1.4 Consultation	2
	1.2	Nuclear site decommissioning and waste management	2
		1.2.1 Decommissioning plans	2
		1.2.2 Waste inventory	3
		1.2.3 Reuse and recycling of waste materials	4
2	Sustainability guidance for asset and waste management on nuclear sites		5
	2.1	Thinking strategically about waste management	5
	2.2	Decision making systems and options studies	5
		2.2.1 Sustainability guidance in the context of BPEO studies	6
	2.3	Asset management scenarios, and waste reuse and recycling options	7
		2.3.1 Strategic options for waste management at a site	8
		2.3.2 Identification and screening of options for the management of individual buildings and decommissioning wastes	9
		2.3.3 Options for the reuse and recycling of segregated materials	13
	2.4	Sustainability indicators and their use in a BPEO study	15
		2.4.1 Assessment of management options against the sustainability scenarios	18
	2.5	Stakeholder engagement and public acceptance	21
	2.6	Waste characterisation	22
		2.6.1 Waste inventory	22
		2.6.2 Waste sampling and clearance	22
	2.7	Reuse of slightly radioactive waste	23
	2.8	Impacts to decommissioning programmes	24
3	Dounreay case study		26
	3.1	Background to Dounreay	26
	3.2	Waste arisings at Dounreay	26
	3.3	Options for reuse and recycling of clean and exempt wastes	27
		3.3.1 Current plans	27
		3.3.2 Applying the sustainability guidance to Dounreay	28
	3.4	Opportunities for reuse and recycling of slightly radioactive wastes	33
	3.5	Potential improvements	33
	3.6	Lessons for other UK sites	34
	References		35
	Appendices (in separate volume)		
A	Nuclear site decommissioning plans		
B	Waste classification and regulations		
	B1	Radioactive waste classification	
	B2	Regulations governing radioactive waste management	
C	The inventory of clean, exempt and slightly radioactive waste in the UK		
D	Reuse and recycling of waste materials		
	D1	Potential reuse and recycling of clean and excluded wastes	
	D2	Factors controlling the supply and demand of recycled wastes	
E	Consultation		

Abbreviations

ALARP	as low as reasonably practicable
BPEO	best practicable environmental option
BPM	best practicable means
CDW	construction/demolition wastes
CIRIA	Construction Industry Research and Information Agency
DSETF	Decommissioning Safety and Environment Task Force
EA	Environment Agency (of England and Wales)
EPA'90	Environmental Protection Act 1990
HLW	high level waste
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ILW	intermediate level waste
IPC	integrated pollution control
IRR'99	Ionising Radiations Regulations 1999
IWS	integrated waste strategy
LCBL	life cycle base line (plans)
LLW	low level waste
NIA'65	Nuclear Installations Act 1965
NII	Nuclear Installations Inspectorate (of the HSE)
NDA	Nuclear Decommissioning Authority
NPPs	nuclear power plants
NTWP	near term work plans
ODPM	Office of the Deputy Prime Minister
PSRE	Phosphatic and Rare Earths etc. (Exemption Order)
RWMAC	Radioactive Waste Management Advisory Committee
RSA'93	Radioactive Substances Act 1993
SD:SPUR	Site Decommissioning: Sustainable Practices in the Use of Resources
SEPA	Scottish Environment Protection Agency
SITF	Safety Issues Task Force
SoLA	Substances of Low Activity (Exemption Order)
UKAEA	United Kingdom Atomic Energy Authority
VLLW	very-low level waste
VLRM	very low-level radioactive material

1 Introduction

1.1 Background to the project

Several of the nuclear research sites and nuclear power plants (NPPs) in the UK are now being decommissioned and many others are due to begin decommissioning within the next decade. Many assets on these sites (e.g. buildings and other facilities) will become redundant and some potentially could be refurbished for reuse. Others will be demolished and deconstructed, generating large volumes of waste material, the majority of which by volume will contain no artificial radioactivity or levels of radioactivity that are so low they may be treated in ways similar to that of conventional wastes.

The Safety Issues Task Force (SITF) of the DTI's Liabilities Management Group[1] identified a need for guidance to address the sustainable management of assets and the large amounts of demolition and deconstruction waste materials being generated. Consequently, a project was launched under the management of the Construction Industry Research and Information Agency (CIRIA) to develop this guidance through a process of extensive stakeholder consultation. A scoping report was published by CIRIA [Kersey, 2003] which led to the current project, which is entitled *Site Decommissioning: Sustainable Practices in the Use of Resources* (SD:SPUR), being launched in 2004. The SD:SPUR project was funded by member organisations of SITF and the RMC Environment Fund, and was supported by a Project Steering Group comprising operators of nuclear licensed sites, Government departments and agencies, and non-governmental organisations.

1.1.1 Project objectives

The SD:SPUR project had the primary aim of developing generalised (non-statutory) guidance for dealing sustainably with the assets and large volumes of radiologically clean and slightly radioactive solid wastes that arise from decommissioning of nuclear sites. The original scope of the project also included the following specific objectives which were intended to help inform the development of the guidance.

1. To develop and characterise an inventory of the radiologically clean and slightly radioactive solid decommissioning wastes arising on nuclear licensed sites in the UK.
2. To identify and evaluate the potential applications for the reuse and recycling of these materials, and the factors controlling their supply and demand.
3. To develop a set of sustainability indicators that could be used by site operators when identifying and choosing between options for these materials.

A further aim of the project was to develop a site specific case-study and planning model for United Kingdom Atomic Energy Authority's (UKAEA) nuclear licensed site at Dounreay as a demonstration of how the generalised guidance could be applied to a site under active decommissioning.

1.1.2 Project scope

The scope of the project was limited to consideration of the potential reuse of assets and the recycling applications for the following waste classes that arise on UK nuclear sites undergoing decommissioning and some defence sites:

1. radiologically clean wastes and wastes that are excluded from control under the Radioactive Substances Act 1993 (RSA'93);
2. wastes that are subject to an Exemption Order under RSA'93; and
3. slightly radioactive wastes, due to either contamination or activation, at the lower end of the low level waste (LLW) category.

The first two waste classes are included in the scope because potentially they could be made available for uncontrolled reuse or recycling either on or off a nuclear licensed site without authorisation from the regulators under RSA'93 (although other approvals are likely to be required under other environmental regulations). For example, radiologically clean concrete from demolition could be crushed for use as a construction aggregate.

[1] SITF is now under the auspices of Nuclear Industry Safety Directors Forum and will be known in future as the Decommissioning Safety and Environment Task Force (DSETF).

The third waste class is included in the scope because it is recognised that sustainability considerations suggest that its disposal as waste (e.g. to the Drigg repository) may not represent the most sustainable use of disposal capacity and because options may arise in certain circumstances when these wastes could be reused within the nuclear sector where they would remain under regulatory control via the Nuclear Installations Act 1965 as amended (NIA'65), thus saving virgin construction materials, without increasing the hazard posed to people or the environment. For example, slightly radioactive steel could be reused to make waste containers for other radioactive wastes.

This report makes no recommendations for the reclassification of radioactive wastes at the lower end of LLW and there is no suggestion that these wastes should be reused in an uncontrolled manner and freed from further regulatory control. As a working defining, slightly radioactive waste may be considered to comprise the lower of the four orders of magnitude activity range covered by LLW[2]. Further information on radioactive waste classes and their regulation is provided in the appendices.

1.1.3 Audience for this report

This report is intended to provide guidance to waste managers and strategy developers on nuclear sites on how they can explicitly incorporate the concepts of sustainability and the waste hierarchy into their decision-making procedures when identifying options for the management of the assets and radiologically clean or slightly radioactive decommissioning waste streams.

It is recognised, however, that this report will also provide some useful reference material for other interested stakeholders, including both governmental and non-governmental organisations, and members of the public.

1.1.4 Consultation

It was recognised throughout this project that stakeholders, both individuals and organisations, hold a range of diverse but legitimate views on the issue of the reuse and recycling of wastes from nuclear sites. It was the intention that this project would build on the good relationships between stakeholders and the nuclear industry fostered by CIRIA through the scoping study and the SAFEGROUNDS project[3] to develop the guidance through a process of open dialogue. Throughout the project, stakeholder views have been sought by a number of mechanisms:

1. participation of a variety of stakeholders in the Project Steering Group,
2. peer review of project documents including drafts of this report,
3. opportunities for input and feedback via the SD:SPUR website, and
4. participation in a workshop to discuss sustainability indicators.

Many varied and interesting views were expressed during the consultation and these have been fed into this project and are used to frame the guidance provided in this report. In addition to the consultation process, operators of nuclear sites were asked to provide information on the anticipated arisings of clean, RSA exempt and slightly radioactive wastes on their sites for use in this project. Further details of the consultation and its outcomes are provided in the appendices.

1.2 Nuclear site decommissioning and waste management

1.2.1 Decommissioning plans

Nuclear site decommissioning activities generally will involve the extensive clean out, refurbishment or demolition of buildings and other facilities, and remediation of the land, although the details of how this will be done will vary from site to site. The anticipated timescales for achieving decommissioning also vary from site to site, and depend on a number of factors including the dates when operating facilities are expected to close and the complexity of the clean-up operations. The anticipated timescales for

[2] The activity range for LLW effectively ranges from 0.4 MBq/te (which is the level laid down in the Substances of Low Activity Exemption Order issued under RSA'93) to 12GBq/te of beta/gamma activity (which is the upper threshold for LLW).
[3] SAFEGROUNDS is a forum for developing and disseminating good practice guidance on the management of radioactively and chemically contaminated land on nuclear and defence sites in the UK. See www.safegrounds.com

decommissioning range from a few years after the shutdown for some sites, to several decades into the future for the more complex sites.

Large volumes of waste materials will be generated by decommissioning. Some of these materials will be contaminated or activated with radioactivity and must be managed on nuclear licensed sites in accordance with the requirements of NIA'65 and disposed of in accordance with the requirements of RSA'93. Substantial volumes will, however, be radioactively clean and can be treated in the same manner as other conventional wastes. It should be noted, however, that once material has been declared as radioactive waste, it must always be designated so, but its treatment should be appropriate to the hazard it poses. The regulations governing the management of these wastes are described in the appendices.

It is a requirement of the Government's radioactive waste management policy [Cm 2919] that the operators of nuclear sites establish strategies for the decommissioning of their sites, and strategies for the management of their radioactive wastes. Such strategies have been produced for all nuclear sites and these are at various stages of development. Various assumptions are made in these strategies concerning the site decommissioning end-states and the possible future uses for the sites which could range from industrial and commercial use to unrestricted use. The potential future use is a significant factor in determining the extent of decommissioning operations, and the Government expects site operators to discuss this issue with the local planning authority, the regulators, and local and public stakeholder groups.

Discussions are now under way between the Nuclear Decommissioning Authority (NDA), the regulators and the site operators concerning the further development of the existing waste management strategies, and in particular to encourage further integration of them. A working definition of an Integrated Waste Strategy (IWS) has been agreed which takes account of the need for such strategies to be based on a suitable balance of all relevant factors, which include safety, environmental and security considerations, as well as stakeholder views. A specification for IWS is being developed, which covers all waste types, both radioactive and non-radioactive, including the large volumes of radiologically clean, RSA exempt and slightly radioactive wastes resulting from decommissioning.

1.2.2 Waste inventory

Waste is defined in the Waste Framework Directive (75/442/EEC as amended by 91/156/EEC) as any substance or object that the holder discards, intends to discard or is required to discard. As a result of European and national case law over the last few years, the circumstances under which a substance or object may be said to have been discarded have broadened considerably. Furthermore, it is considered that once a substance or object has become waste, it will remain waste until it has been fully recovered and it no longer poses a potential threat to the environment or human health.

Materials defined as radioactive wastes in the UK are listed in the United Kingdom Radioactive Waste Inventory (RWI). This records the quantities, origins and characteristics of radioactive wastes, both those currently managed and those predicted to arise. The current version (RWI'01) only includes data for materials that are declared as radioactive wastes and reports these data in accordance with the UK radioactive waste classification scheme. Thus, it does not contain any information on the arising of radiologically clean wastes, and RSA'93 excluded and exempt wastes, nor does it report on the slightly radioactive wastes separately from other LLW.

As part of the SD:SPUR project, questionnaires were sent to nuclear site operators requesting information on their current and predicted future arisings of materials they classify as radiologically clean, RSA exempt and lightly contaminated. Responses were received from a number of operators but not all and some operators were unable to provide information because they are still developing their own datasets. On the basis of RWI'01 and the information collected in this project, the volume of wastes that will arise across all of the decommissioning nuclear sites in the UK is in the region of:

– 1,500,000 m3 of radiologically clean, and RSA exempt and excluded wastes; and
– 1,500,000 m3 of slightly radioactive wastes.

Information provided by the site operators shows that these wastes are largely comprised of concrete, building rubble, ferrous metals and soil, with lesser amounts of non-ferrous metals, wood, plastics, rubber, glass etc.

It is evident that there remains considerable uncertainty about the actual magnitude of both radiologically clean and slightly radioactive waste arisings from nuclear sites and, therefore, the volumes given above should be viewed only as order of magnitude approximations. A similar conclusion was reached by the Government's Radioactive Waste Management Advisory Committee (RWMAC) who reviewed current policy on the management of low activity solid radioactive wastes within the UK. RWMAC commented that the RWI probably significantly underestimates the volumes of low activity wastes that need to be managed because many future arisings have either not yet been identified or have not yet been classified to be radioactive [RWMAC, 2003].

These arisings can be compared to the amount of conventional construction/demolition wastes (CDW) generated in England and Wales in 2003 which was around 36,000,000 m3 and the production of recycled aggregates in the same year of around 16,000,000 m3 [ODPM, 2004a]. Clearly the amount of decommissioning wastes arising from the UK nuclear sites is a small fraction of the total demolition wastes arising from the construction sector. They pose a disproportionately large problem, however, because of the limited current opportunities for the disposal of radioactive wastes with the remaining volumetric capacity of the LLW repository at Drigg being only around 800,000 m3 and because of the public reluctance to adopt recycled radiologically clean materials. Further details of the inventory of radiologically clean, RSA exempt and excluded and slightly radioactive wastes is provided in the appendices.

1.2.3 Reuse and recycling of waste materials

The reuse and recycling of CDW from the conventional construction industry is a well established practice. The Waste and Resources Action Programme (WRAP) has developed a protocol for the production of aggregates from inert waste that addresses some of the difficulties in the interpretation and application of the Waste Framework Directive [WRAP, 2004]. The purpose of the Quality Protocol is to provide a uniform control process for producers from which they can reasonably state and demonstrate that their product has been fully recovered and is no longer a waste.

Specialist demolition contractors are available to undertake deconstruction of buildings and other facilities so as to recover and segregate various material components from the fabric of buildings, such as metals, concrete, glass, timber etc. In some cases, these segregated materials can be processed to increase their utility and value, and be sold back to the construction industry. Certain types of processing equipment can be mobile and brought to a demolition site (e.g. mobile crushing plant to process concrete) but, in other cases, raw materials will need to be transported for processing. Further information on the potential for reuse and recycling of CDW and other materials is provided in the appendices.

Of the 36,000,000 m3 of CDW generated in England and Wales in 2003, around 90% was beneficially reused (e.g. recycled as aggregate or soil, and backfilling of quarry voids) and only 10% was disposed to landfill. The reuse and recycling of demolition wastes arising on nuclear sites is generally not so well advanced as for conventional sites but, in general, the same level of material recovery, segregation, processing and reuse should be achievable for all radiologically clean waste materials. A number of factors will influence the potential for reuse or recycling of decommissioning wastes from nuclear sites. The most important of these are:

– local and regional demand for construction materials;
– production and processing costs;
– quality of product and extent of impurities and contamination;
– added value processing to achieve higher utility of grade of product;
– location and transport costs; and
– costs and availability of virgin material or recycled materials from other sources.

In addition to these factors, which would impact on all sources of recycled materials, demand for materials arising from nuclear sites may be affected by issues relating to public concern, and perceived health and safety impacts. Whilst all recycled radiologically clean, and RSA exempt and excluded materials should pose no radiological hazard and, in this regard, are indistinguishable from recycled conventional wastes, waste managers on nuclear sites should be aware of this additional factor and the fact that its impact is difficult to quantify. Issues associated with public and stakeholder concerns are addressed in Section 2.5.

2 Sustainability guidance for asset and waste management on nuclear sites

This section sets out guidance for waste managers and strategy developers when considering how best to manage assets (e.g. buildings and other facilities) and waste arisings on decommissioning nuclear sites. This guidance sets out an approach to decision making that allows different options for the management of assets and decommissioning wastes to be compared and assessed in terms of their sustainability. This guidance has no legal basis and is not prescriptive. It is intended, however, to provide practical advice and a framework within which the sustainable reuse and recycling of decommissioning wastes may be considered.

2.1 Thinking strategically about waste management

The regulators require site operators to plan the decommissioning of nuclear sites and to manage wastes in accordance with the Government's policy of environmental protection which is framed around the key principles of sustainable development and human rights. Underpinning this policy are a number of specific environmental protection objectives and aims that are relevant to the management of assets and decommissioning wastes on nuclear sites, examples include:

- use of the waste hierarchy;
- taking costs and benefits into account;
- justification of practices and optimisation of practices with respect to impact;
- progressive reduction in discharges to the marine environment;
- protection of human species and non-human species;
- protection of people's use of the environment; and
- application of the precautionary principle.

The first of these, the waste hierarchy, is intended to ensure that wastes (of any type) are not generated unnecessarily and that those arisings that do occur are either reused or recycled in preference to being disposed. This is the main policy driver for site operators explicitly to examine options for the reuse of redundant buildings and structures, and to consider decommissioning waste arisings as potential resources that can be reused or recycled. A similar waste management hierarchy based on avoiding or minimising the production of waste, and recycling or re-use in preference to disposal, is enshrined within the International Atomic Energy Agency (IAEA) standards [IAEA, 2000]. Waste producers and waste managers are thus being encouraged to apply the waste hierarchy when managing their wastes and, consequently, they should actively be investigating imaginative options for reuse and recycling rather than simply options for bulk waste disposal.

The Government's radioactive waste management policy set down in Cm2919 is also based on the principle of sustainable development. That said, neither Cm2919 nor any statutory guidance provides for a regulatory requirement that a separate *sustainability assessment* is undertaken by a site operator when making waste management or planning decisions. Site operators are required, however, to demonstrate to the NII how sustainability has been taken into account when developing their waste management strategies under NIA'65, and the environment agencies apply conditions to site authorisations under RSA'93 which they consider to implement the Government's policy of sustainable development.

2.2 Decision making systems and options studies

The environment agencies require waste producers and waste disposal organisations, irrespective of the types of waste involved, to use 'best practice' to ensure that people and the environment are protected and the waste hierarchy is applied during all waste management operations.

The process of identifying what represents 'best practice' involves a comparative assessment of different options, often involving a multi-attribute decision assessment approach. Various types of multi-attribute assessment are possible but the most widely used is the Best Practicable Environmental Option (BPEO) study which identifies a 'best' option that provides a sensible balance between aspects such as human health and safety, environmental impact, technical feasibility, and cost [RCEP, 1988]. Operators of nuclear sites are required by the environment agencies under RSA'93 to undertake BPEO studies in support of decisions on radioactive waste disposals and discharges, and this forms a standard condition in

Authorisations granted by the environment agencies to site operators. In this regard, the environment agencies have published guidance on the application of BPEO to radioactive waste management [EA - SEPA, 2004].

There is no similar requirement on site operators to undertake a BPEO to support management decisions for non-radioactive wastes but the environment agencies now increasingly expect proposals for any large scale plan and programme to be supported by some form of environmental assessment. The requirement on site operators to develop an IWS that covers both radioactive and non-radioactive wastes suggests, however, that a BPEO-type approach would necessarily need to be applied to all wastes to underpin the IWS.

2.2.1 Sustainability guidance in the context of BPEO studies

With the above thoughts in mind, this guidance recommends that site operators should incorporate plans for the sustainable reuse of assets and decommissioning wastes within their IWS, and that the IWS should be underpinned by a BPEO study that evaluates alternative options against an appropriate set of attributes, and takes due regard of stakeholder views. The relationship between this guidance on the sustainable reuse of decommissioning wastes, the IWS and supporting BPEO study are indicated graphically in Figure 2.1.

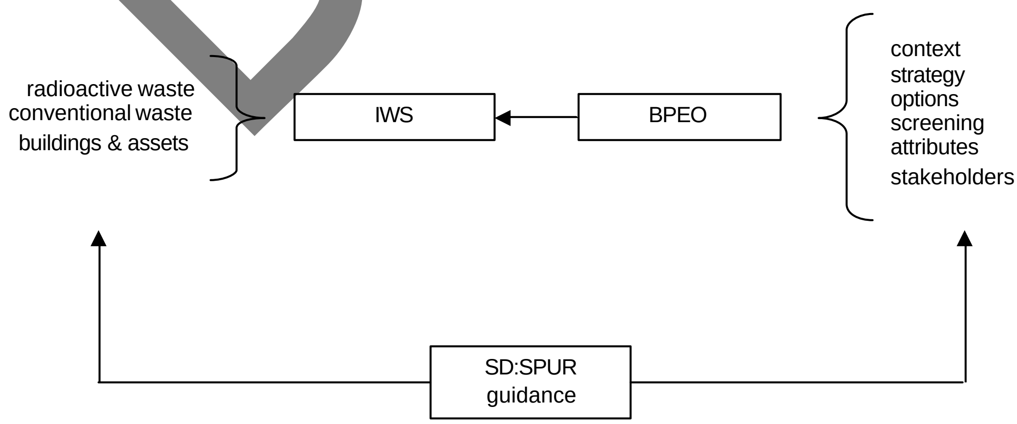

Figure 2.1 *The relationship between this guidance on the sustainable reuse of decommissioning wastes, the IWS and supporting BPEO study.*

In this way, the guidance is intended to be directly applicable to, and complementary with, existing requirements on operators to use BPEO in the development of radioactive waste disposal and discharge plans. As a result, this guidance should not result in any disproportionate additional effort on the part of a nuclear site operator nor cause any delay in making decisions. What the guidance does require an operator to do is to consider a suitably wide range of options at an early stage in the decision making process. For example, rather than consider options only for the management of rubble arising from the demolition of a building, options could be considered for alternative uses of the building that may avoid the need for its demolition or, if that is not practicable, options could be considered for how the building may be deconstructed to enhance the potential for sustainable reuse and recycling of segregated building materials.

This guidance is structured in such a way as to make it compatible with the undertaking of a BPEO study. There are no hard and fast rules on how a BPEO study should be planned and performed, and existing guidance on BPEO studies such as those produced by the EA and SEPA [2004] and the ODPM [2002] differ in terms of detail, but it is generally acknowledged that there are a number of key stages in a BPEO that need to be undertaken in a logical manner.

This guidance adopts the BPEO structure referred to in the report by the EA and SEPA on the application of BPEO to the management of radioactive wastes because this will already be familiar to waste managers on the nuclear sites. It is recognised that many of the facilities and wastes on nuclear sites will be radiologically clean (and therefore their disposal is not subject to control under RSA'93) but it is recommended here that a consistent approach to sustainable decision making is adopted for both radioactive and non-radioactive materials. The main stages of a BPEO study are:

1. ***Definition of purpose and scope:*** the purpose of the study is defined, the methodology is selected and key assumptions are identified.
2. ***Identification of options:*** a broad list of options is drawn up and characterised in sufficient depth for initial screening.
3. ***Screening of options:*** decisions are made regarding the principles to be applied in deciding the criteria for screening out options from further consideration, and then the criteria themselves are defined. The criteria are applied to select a short list of options from the initial long list of alternatives.
4. ***Selection of attributes:*** the principles to be applied in deciding the attributes against which options are to be compared need to be decided, and then the attributes themselves.
5. ***Options analysis:*** each option on the short list is evaluated against each attribute. The results of the evaluation are recorded either as a ranking (e.g. best to worst) or a numerical score.
6. ***Weighting factors:*** weightings may be applied to each attribute to reflect its relative importance and alternative weighting sets can be used to test the sensitivity of the conclusions to different perceptions of relative importance.
7. ***Identification of the BPEO:*** the results of the option analysis and the application of weighting factors identifies the BPEO.
8. ***Integration into decision making:*** identification of the BPEO is an important input to strategic decision making but, in practice, few decisions will be made solely on the basis of such a study.

These stages are described in the EA -SEPA guidance in some detail with regards to the determination of a BPEO for the disposal or discharge of any particular radioactive wastestream. In the following text, reference is made to the additional considerations that would be required to build sustainability considerations explicitly into a BPEO study for the coherent management of assets and decommissioning wastes (e.g. when developing an IWS). In this regard, the key stages are:

2. ***Identification of options***
3. ***Screening of options***
4. ***Selection of attributes***
5. ***Options analysis***

Other stages in a BPEO may be followed according to the EA -SEPA guidance.

2.3 Asset management scenarios, and waste reuse and recycling options

It is implicit in the discussions of BPEO for radioactive wastes in the context of an RSA'93 authorisation that the method is about determining the best *disposal* route for a waste. It is recommended here, however, that waste managers on nuclear sites should consider the wider context and that the identification of options should include, where appropriate, options for the refurbishment and reuse of buildings, and options for the reuse and recycling of decommissioning wastes, as well as options for disposal, in line with the expectations of the *waste hierarchy*.

It is the inclusion of options for the reuse of materials, rather than just disposal, that distinguishes a *sustainable waste management BPEO* from a normal study. Note that this approach is only recommended for wastes for which reuse and recycling possibilities are likely. For the majority of operational LLW and higher activity wastes, reuse and recycling are not available options.

The range of options that needs to be taken into account and the detail to which options are specified will vary according to the issue at hand but, in all cases, the effort in identifying options should be proportionate to the likely hazard posed to people and the environment. For clean and RSA'93 excluded and exempt wastes, it is appropriate to consider a wide range of off site reuse and recycling options. For the slightly radioactive wastes, it would be appropriate to consider only on site (or at another nuclear site) reuse options within the nuclear industry where they would remain under NIA'65 control.

The range of options should not be unreasonably restricted, and imaginative thinking is encouraged although it is recognised that many options would be identified on the basis of currently available technology as well as available disposal routes or known markets for recycled products. Nonetheless, an open approach to options identification which breaks down strategic alternatives into groups of intact building reuse, disposal, material reuse and recycling is likely to ensure that the widest range of options is identified. The wider the range of options considered, the greater the opportunity for identifying the most sustainable solution that fits with the other regulatory and business drivers that influence the decision.

In a comprehensive BPEO, the regulators would expect to see some degree of stakeholder participation. This can extend to stakeholder input to options identification which would help to ensure that options are unconstrained by preconceptions and would engender a sense of shared stakeholder ownership in the process and of the solution (see Section 2.5).

Once identified, options need to be characterised in sufficient detail to allow them to be differentiated and assessed against the sustainability indicators and other attributes used in the decision making process. It should be recognised, however, that the BPEO concept is intended to discriminate between options at a reasonably high, strategic level (see Section 2.4).

2.3.1 Strategic options for waste management at a site

It is recommended that this guidance is applied first at the site level when making strategic decisions to support the development of an IWS to meet requirements set by the regulators.

The objective is to consider collectively all of the buildings, structures and existing wastes on a site to examine whether a coherent sustainable management approach could be applied across the site, rather than considering them one at a time. The development of a site-wide management strategy should enhance sustainability because, if done well, it should avoid duplicate or inconsistent approaches being implemented, resulting in more rapid restoration of a site and better value for money. It should be recognised that a coherent site-wide IWS for all buildings and waste streams on a site is synergistic and it is unlikely to be simply the aggregate of the individual management approaches that would be identified if each building and waste stream was considered separately in a BPEO study.

There is no guidance yet available on how to perform an IWS but a step-wise approach is recommended based on the BPEO method and the following may provide some useful structure to capture sustainability considerations.

1. The primary aspects that will influence the decision making process should be identified. Whilst such aspects as time (schedule), worker safety, off site impacts and cost are likely to be included as a matter of course, it is recommended that sustainability is included explicitly as a further unique aspect.

2. Site-wide strategy options for the management of assets and decommissioning wastes should then be defined in terms of the plant, processes, discharges/disposal techniques, schedule etc. that would be required to maximise each of the primary aspects (e.g. to define what would be required to achieve the most rapid restoration of the site, the cheapest restoration of the site etc).

3. Each strategy option should then assessed against a series of attributes but specific *sustainability indicators* need to be included in the assessment alongside the more traditional health and safety, environmental impact, technical viability and cost attributes used in BPEO (see Section 2.4).

4. Each strategy options should then be optimised by replacing any poorly performing processes or techniques identified during the assessment in Step 3 with better performing alternatives. For example, if the most rapid strategy results in unacceptable impacts to worker safety due to the use of a particular waste processing method then a safer alternative is adopted.

5. The optimised strategy options are then reassessed and, if no option yet achieves acceptable performance against all of the attributes, a further round of optimisation is undertaken. The net affect of optimisation is to cause the options to converge towards a common approach that should represent the 'best' or optimal management strategy that provides an appropriate balance between each of the primary aspects that will influence the decision.

6. The optimal management strategy is then tested for robustness against a series of weightings applied to the attributes, that reflect differing viewpoints. Stakeholder input to the identification of weighting schemes may be appropriate.

The maximum sustainable site strategy option is likely to be the one that promotes the greatest reuse of existing buildings and facilities on a site, and thus avoids the need for new construction and minimises the amount of waste generated. It is recommended, therefore, that the development of an IWS should be intimately connected to the identification of site end-points, and that decision makers need to be imaginative when identifying and promoting possible opportunities for alternative site reuse. This clearly has social and political implications which need to be taken into account when defining the strategy options.

In some cases, the likely site end-point would not allow for the reuse of all or some of the existing buildings and facilities on a site, and they would have to be taken down. This may be because there is no demand for them, it would not be efficient or cost effective to refurbish them or because planning considerations require the site to revert to a semi-natural state. In this scenario, the maximum sustainable site strategy option may be the one that makes available the greatest amount of the decommissioning waste materials for recycling (rather than disposal) and also involves processing of the waste materials to achieve their highest value and utility.

To enhance the sustainability of a strategy option when buildings and structures must be demolished, it is recommended that the starting point should be consideration of the total of all sources of clean and slightly radioactive wastes on the site (the fabric from all of the buildings and structures) and then options should be identified to maximise the utility and reuse of the waste materials generated from it. This will involve consideration of how the buildings may be taken down (planned deconstruction or routine demolition) as well as the processing of the waste materials (e.g. cleaning of reclaimed brick, crushing and size sorting of concrete, segregation of glass, metals, wood etc). The purpose of this approach is to test for the financial and technical viability of using the most sophisticated deconstruction, segregation and processing methods. For example, it may not be viable to use such methods for the amounts of waste material generated from any single building or structure but it might be viable when the total amounts from all buildings are taken together.

If sustainable approaches to the management of assets and decommissioning waste arisings are defined at a site-scale (e.g. supporting the IWS) by the process described above, then it need not then be necessary for individual BPEO studies to be undertaken for each individual waste stream or for each separate building when it becomes redundant. All that generally will be required is a simple demonstration or justification that was is intended to be done is consistent with the site-wide sustainable strategy. There may, however, be cases where a separate BPEO type assessment may be required because peculiar or specific issues confront the waste manager but these should be the exception rather than the rule. Thus a hierarchical approach to waste management and decision making can be established.

2.3.2 Identification and screening of options for the management of individual redundant buildings and decommissioning wastes

It is recommended that options for the management of specific assets (buildings and facilities) and decommissioning waste arisings need to be considered broadly and imaginatively to ensure sustainability considerations can be balanced against other factors when making a decision (such as health and safety, technical issues, cost etc).

A planner or waste manager on a nuclear site will usually have a number of options available to them when they consider how best to manage particular assets and decommissioning waste streams. These options will, to some extent, reflect the nature of the materials (e.g. their physical, chemical and radiological characteristics) and the nature of any processing of the materials that may already have taken place (e.g. demolition and deconstruction practices, sorting and segregation of materials). In general terms, the earlier assets are identified as being redundant or materials are identified as waste, the greater will be the number of options available and the more sustainable they may be.

It is a requirement of the IAEA safety standards (Predisposal Management of Radioactive Waste, including Decommissioning, WS-R-2) that the eventual need to decommission a facility is taken into account at the planning and design stage, for example by the consideration of construction materials, in order to minimise so far as reasonably practicable, future waste generation and the radiation exposure to operators. Older facilities were clearly not designed with decommissioning in mind, however there is also an IAEA requirement for decommissioning plans to be maintained and updated during the operational phase so that waste management is considered in good time before a building becomes redundant. In line with international standards, it is recommended that waste management and sustainability issues are taken into account at the design stage for new facilities, particularly those that are planned to assist with waste management such as processing plants, and during the operational phase for existing facilities on nuclear sites. This will allow strategic decisions on waste management to be made in good time and in accordance with the Government's environmental policies. Guidance on sustainable building methods should be followed.

Options that should be considered by waste managers on nuclear sites as decommissioning plans are developed range from refurbishment and reuse of the structure for other purposes through to planned deconstruction to allow for sorting and segregation of individual materials. If, however, waste management and sustainability issues are considered only after a structure has been demolished using traditional techniques, then the range of options becomes more restricted and essentially relate to bulk treatment of unsorted demolition waste.

Broadly speaking, therefore, sustainability considerations can be considered to apply to two cases:

1. At an early stage when deciding on how to manage an intact redundant asset (building or other facility).
2. At a later stage when deciding on how to manage demolition or deconstruction materials from a previously demolished structure.

These two cases are indicated graphically in Figure 2.2. In reality, however, these cases represent end-points to a whole range of possibilities. For example, it would be possible to remove a few certain materials from a building (e.g. to remove any copper wiring and piping) and then to demolis h the rest of the building without sorting and segregating the remaining materials. However, for the purpose of examining sustainability issues in relation to particular waste management options, these provide a useful starting point but it is recommended that waste managers attempt to define their own options in line with their site specific conditions, rather than adopting only the end-points discussed here.

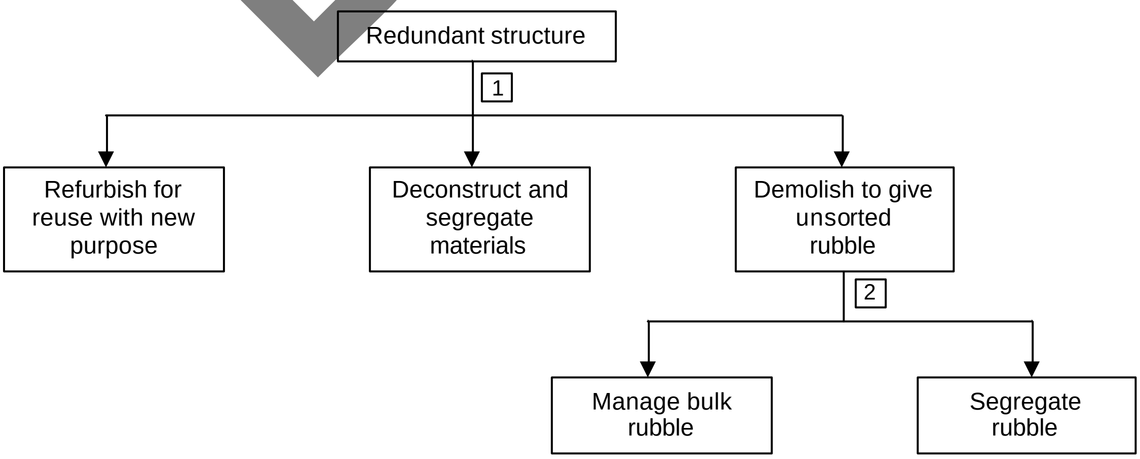

Figure 2.2 *The end-points to the possible range of options for managing a redundant structure or rubble from a previously demolished structure.*

Whilst the situation in Figure 2.2 represents the ideal case, in reality waste management on a nuclear site has to embody day-to-day practical considerations as well as long-term strategic ones and, thus, it is not always practicable or sensible to consider options for waste management starting with how best to reuse a redundant structure. In other cases, structures will already have been demolished and the waste management decis ion is one of how to deal with the demolition rubble. In other cases, some remaining structures will have no potential for further reuse: this may because there is no actual demand for refurbished buildings (particularly at sites that are remote from centres of business or industry) or because planning constraints mean that the end-point for the site must be a return to a semi-natural state.

Waste managers and strategy developers thus need to be able to screen out any potential waste management options from Figure 2.2 that are not viable because they are inconsistent with constraints imposed by planning and the reality of demand for refurbished buildings and recycled materials. Figure 2.3 provides a simple decision tree that may be useful in helping to screen out those waste management options that may not be viable on a particular site as part of a BPEO study (Stage 3 of a BPEO study as described in Section 2.2).

The decision tree in Figure 2.3 should only be used as a component within a BPEO study to support the screening of options and should not be used as an alternative to undertaking a full comprehensive assessment. The purpose is to help short-list the type of management options that are viable for a particular site and which are carried forward for detailed assessment in a sustainable waste management BPEO study. An option should only be screened out from the assessment when there is no reasonable doubt that it would be not be viable for particular site conditions.

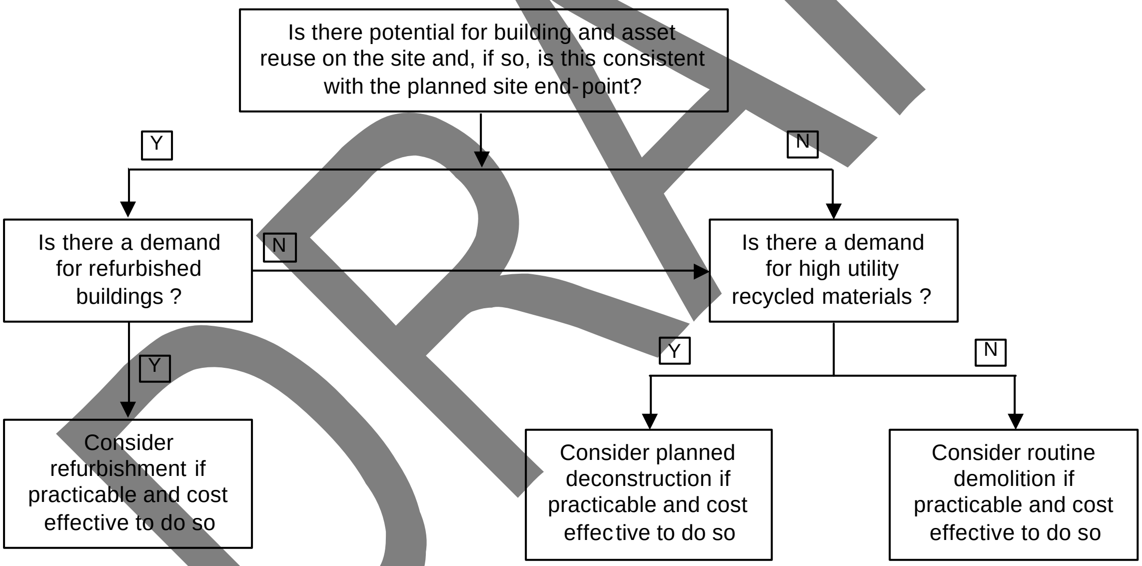

Figure 2.3 *Simple decision tree to help screen out those waste management options that are not viable on a site.*

Another important consideration that may be used to screen options is whether or not a structure is radioactively contaminated or activated. If so, especially of it was an active building (e.g. used for the handling of radioactive materials), then deconstruction and/demolition of the structure would need to be done with care to ensure that radioactive materials were segregated from radiologically clean materials (as well as to ensure the safety of the workers).

Each of the options identified in Figure 2.2 for the possible management of a redundant structure on a nuclear site presents various advantages and disadvantages in a sustainability context. In practice, a site operator will need to identify the most sustainable option in a BPEO study set against the other health and safety, environmental, technical and cost factors in the decision. It is recommended that every BPEO study should pay due consideration to the local conditions both on the site itself (e.g. in terms of planned end-points) and in the surrounding area (e.g. demand for office rented accommodation) and, thus, the option which is *most sustainable* will need to be identified on a site specific basis.

That said, there are a number of comments that could be made of each management option and which should be taken into account when applying the guidance to identify and assess options for the management of redundant structures or decommissioning wastes, depending on what is the starting point for the decision.

Building refurbishment for reuse

Building (or asset) refurbishment involves the keeping of the integral structure of a building, and appropriately modifying and improving it so that it is suitable for reuse. To a large extent, the type of new uses to which a refurbished building could be put would depend on its original nature and purpose. For example, a warehouse, hanger of other large enclosed space may be suitable for industrial reuse, whereas an office block is likely to be reused again as offices.

Building refurbishment would generally not be appropriate for radioactively contaminated buildings, unless it could be demonstrated that the contamination was minimal and easily removed. For example, where contamination was limited to the roofing material (e.g. bitumen coated roof) of a building that could be replaced. Significantly contaminated buildings almost certainly would not be refurbished for unrestricted reuse.

It would be appropriate to consider refurbishment of buildings if the planned end-point of the site involved redevelopment and there is likely to be a demand for the building afterwards (e.g. as light industrial units, office accommodation etc). The extent of demand will clearly vary from site to site, in relation to the economic and demographic factors. Furthermore, if the planned end point of the site was delicensing, then the delicensed criteria current at that time would have to be met. Similar considerations apply to other assets and facilities. For example, roads and hardstanding may potentially be left in place to provide services for redevelopment of a nuclear site.

The amount of effort (cost, time and materials) that would be required to refurbish a building or other facility would need to be determined on a case-by-case basis. The buildings on nuclear sites range in age from recently built to around 50 years old. As a general rule, the older the building, the greater would be the effort required to refurbish it to modern standards.

Refurbishment of buildings and other facilities could be undertaken as part of a planned regional or local economic and social regeneration programme, whereby employment and investment opportunities are provided on the site to replace those historically provided by the nuclear industry. This may be particularly important for remote sites where few other industrial or business operations exist.

To determine whether building refurbishment is a sensible and sustainable practice, it needs to be judged against a series of attributes (see Section 2.4) as well as other business and programme issues on a case-by-case basis. Overall, provided there is a demand for the building and the effort required for refurbishment does not exceed that of new construction, then building refurbishment would be seen as a highly sustainable scenario. Because the fabric of the building is reused, only limited amounts of waste materials arise that may be reused or recycled elsewhere. Furthermore, if refurbishment is an alternative to building new structures in the locality, then considerable savings on virgin construction resources could be made.

Building refurbishment is being adopted on some nuclear sites. For example, at the UKAEA owned Winfrith site in Dorset the first phase of site delicensing meant that 45% of the site became available for unrestricted use. In addition, many of the redundant office buildings have been refurbished and buildings previously used for laboratories and nuclear instrumentation have been decommissioned and fitted out for occupation by new tenants. This has resulted in the establishment of a thriving business and science centre, the Winfrith Technology Centre. Management of the Technology Centre was transferred to the English Partnerships Group, allowing UKAEA to focus on restoring the rest of the Winfrith site.

Planned deconstruction

Planned deconstruction involves the careful taking apart of a building with the primary intention of maximising the sorting and segregation of materials (by type, composition etc.) to facilitate their reuse or recycling. Planned deconstruction might also be adopted if a building was known to contain areas of radioactive contamination or hazardous materials (e.g. asbestos) that required careful removal for disposal. Otherwise, contaminated buildings may be decontaminated prior to routine demolition.

Radiologically clean or RSA exempted materials could be segregated during deconstruction and released for uncontrolled reuse in the construction industry. Some of the segregated materials would require minimal processing that could be done on site to meet the quality requirements of the market (e.g. old bricks would need simple cleaning and sorting, and bulk concrete would need crushing and sizing). On the other hand, some materials may require more extensive off site processing for the market (e.g. metals would need to be sorted and may need to be sent for processing/smelting at specialist facilities).

Planned deconstruction might be considered where there is no obvious requirement to refurbish a structure for reuse, where new construction would clearly be cheaper or more efficient, or where the intended end-point of a site is return to brown-field status.

The amount of effort (cost, time and equipment) that would be required to deconstruct a building would need to be determined on a case-by-case basis but, in general, this approach would be more labour intensive and take longer than routine demolition (see below) but provides the maximum potential for the reuse and recycling of materials.

The types of material that could be segregated during planned deconstruction would vary between buildings and between sites. As a consequence of the buildings on nuclear sites ranging in age from recently built to around 50 years old, many different building technologies and materials would arise. Considerable amounts of brick could be segregated from sites developed from old airforce bases, where large brick-built hangers were retained. Newer buildings are more likely be constructed from concrete and steel.

To determine whether planned deconstruction is a sensible and sustainable practice, it can be judged against a series of attributes (see Section 2.4) as well as other business and programme issues on a case-by-case basis. Overall, provided there is a local or regional market for the materials that could be segregated during planned deconstruction this would be a sustainable option that provides the maximum amount of segregated waste materials for reuse or recycling, and which may be processed to achieve the highest utility and added value. However, in very remote areas, transport of the segregated materials to the market may prove costly which may mitigate against their reuse.

Planned deconstruction has been adopted by some sites for the management of certain buildings and structures. For example, the planned decommissioning of the Joint European Torus (JET) reactor located on the UKAEA owned Culham site involves careful deconstruction to maximise the segregation of radiologically clean wastes from slightly radioactive wastes, and the sorting of the radiologically clean wastes into material types. Headline figures for JET decommissioning indicate that roughly 11,500 m3 of radiologically clean decommissioning rubble will be used as landscaping to fill voids to within 1 meter of the ground surface (topped by soil), and 17,000 m3 of other radiologically clean concrete and metal will be sent off site for recycling.

Routine demolition

Routine demolition involves crude, low technology methods to demolish a building with the primary intention of clearing the site as quickly as possible without any intent to sort and segregate materials. The primary product would be unsorted construction/demolition wastes (CDW) comprised of concrete, brick, rubble, metal etc. depending on the materials used in the construction of the fabric of the building.

Routine demolition would normally only be applied to buildings known to comprise materials that are radiologically clean or RSA exempt. All active or contaminated structures would require management by more sophisticated techniques (e.g. surface decontamination prior to demolition) to protect the workers and to minimise releases of activity to the environment.

Unsorted CDW may be useable without further processing as low-grade fill for on site landscaping or sent for landfill disposal, provided its constituent materials are inert. Post-demolition sorting and segregation of the demolition rubble would be possible but the extent of segregation that could be achieved is likely to be lower than that achieved by planned deconstruction.

Routine demolition might be considered where there is no obvious requirement to refurbish a structure for reuse or where the intended end-point of a site is return to brown-field status.

The amount of effort (cost, time and equipment) that would be required for routine demolition is minimal and provides the fastest way to clear a site, which may be important on sites with limited free space where new structures or facilities are required to support the site remediation programme or where the site restoration schedule is tight and rapid progress is required.

To determine whether routine demolition is a sensible practice, it can be judged against a series of attributes (see Section 2.4) as well as other business and programme issues on a case-by-case basis. Overall, routine demolition is likely to be the least sustainable scenario but may provide the site with the least business and programme constraints, since the site may be cleared cheaply and quickly. As a result, this approach has been used widely on nuclear sites. Some degree of segregation of the demolition materials will be required, even if it is planned to landfill them, as a minimum to separate inert materials from other materials.

2.3.3 Options for the reuse and recycling of segregated materials

As described above, planned deconstruction involves the careful taking apart of a building with the primary intention of maximising the sorting and segregation of materials to facilitate their reuse or recycling. Some reuse and recycling would also be possible if the routine demolition approach were used but this is likely to achieve less efficient segregation.

Waste managers on nuclear sites need to be aware of the potential for reuse and recycling of materials that may be recovered from deconstructed and demolished buildings and other facilities on sites. Tables 2.1 and 2.2 provide a brief summary of the potential applications and the current recycling practices adopted by the conventional construction industry for high volume, low value materials and high value materials respectively. Further details of the potential reuse and recycling opportunities for waste materials are provided in the appendices.

Table 2.1 *Typical reuse applications for high volume, low value materials.*

Source	Potential applications	Current recycling/disposal practices
Aggregate	Crushed used as bulk filler, haul roads and an alternative to virgin aggregate.	Currently approximately 50% of demolition material is recycled as aggregate, 40% is otherwise beneficially reused and the remainder is sent to landfill for disposal.
Excavation soil	Reprofiling of land, reclamation of quarries/ borrow pits.	There is a low demand for waste soil unless it is of high nutrient demand and off use in agricultural improvement or landscape gardening. Currently almost all topsoil is used for on site applications such as landscaping or ground raising.
Road planings	Reprocessed for re-use on or offsite for construction or repair of roads.	There is a variable local demand for road planings, which is dependant on the waste arising at a time of road construction or maintenance taking place within an economic transport distance of the demolition site.
Timber	Re-used around the site for applications such as fencing or sent to be processed in to chipboard.	Currently an unknown percentage of timber from building demolition is recycled and the remainder is sent to landfill as controlled waste.
Concrete	Crushed into aggregate, bulk filler, haul roads or alternative to virgin aggregate.	Approximately 90% concrete from building demolition is beneficially reused.

Table 2.2 *Typical reuse applications for high value materials.*

Source	Potential applications	Current recycling/disposal practices
Reclaimed bricks and blocks	Brick and block work from old buildings is in demand for restoration work and new buildings in areas of conservation. Such material is also used for fireplaces and other interior work.	There is a high demand for certain types of bricks and blockwork typically those of rarer stone types such as granite. Currently only a small percentage of brickwork from building demolition is recycled and the remainder is sent to landfill as controlled waste or crushed prior to re-use as aggregate.
Steel	Send off site for recycling.	Steel can be readily segregated from other demolition wastes and currently almost all waste steel is recycled due to the high demand and market value of the material.
Plastics	Remould into an alternative use by a specialist re-processor such as fences, piling, slates or alike.	Plastic recycling is in its infancy at the moment, processes are likely to be refined and new applications developed in coming years.
Glass	Likely to be sent off site for specialist reprocessing i.e. separation of component parts, use in concrete as an aggregate replacement, filter material etc. Alternative use for recycled glass are still being developed.	Currently an unknown percentage of window pane glass from building demolition is recycled. The majority of recycled glass comes from bottles and glass containers.
Non-ferrous	Sold and sent to scrap metal	Currently an unknown percentage of waste

Source	Potential applications	Current recycling/disposal practices
metal (Al, Cu, Zn, Pb)	merchants or fed directly back into the production stream were they form part of new metal products.	non-ferrous metals from building is recycled and the remainder is sent to landfill as controlled waste.

2.4 Sustainability indicators and their use in a BPEO study

In broad terms, the refurbishment of a redundant building or the reuse and recycling of materials arising from planned deconstruction can be considered as sustainable practices but, at the practical level, waste managers require a simple and transparent system to allow them to assess different aspects of sustainability so that alternative management options may be compared.

This guidance proposes the use of a system of *sustainability indicators*, where an indicator can be considered as a discrete attribute or parameter that reflects the performance of a management option and is amenable to either quantitative measurement or qualitative description. The concept of attributes is well established in environmental decision making through their use in BPEO studies and sustainability indicators could be thought of as broadly equivalent to BPEO attributes with a sustainable focus. The EA and SEPA guidance on BPEOs for proposed radioactive waste disposal and discharge options lists 19 examples of attributes used in past BPEO studies concerned with radioactive waste management (Table 2.3). The EA-SEPA BPEO guidance does not suggest that this list is complete but it is intended to highlight the type of issue that would be considered in most BPEO studies.

An evaluation of environmental impacts should be at the heart of every BPEO study and it is reasonable to consider than sustainability considerations should be part of the assessment of environmental impacts. Many of the attributes in Table 2.3 have a sustainability aspect to them but sustainability as an issue is not directly discussed in the EA-SEPA BPEO guidance document. As a result, it is recommended that additional attributes which explicitly address sustainability should be included in BPEO studies when options for the sustainable reuse of buildings or the reuse and recycling of decommissioning wastes are assessed.

Table 2.3 *Examples of attributes in BPEO studies from the EA and SEPA guidance document.*

Ref.	Name
Group A: Actual and perceived impact on human health and safety	
A.1	Radiation dose to critical groups from projected discharges and collective dose to the population as a whole under normal conditions
A.2	Potential dose to critical groups from accidental releases
A.3	Individual and collective occupational exposures for workers
A.4	Occupational risks from other industrial hazards
Group B: Impacts on natural, physical and built environments	
B.1	Impact on marine ecosystems and habitats
B.2	Impact on terrestrial ecosystems and habitats
B.3	Long-term contaminant residues
B.4	Non-radioactive waste arisings
B.5	Nuisance (noise, odour, visual impact)
B.6	Indirect impacts (e.g. global warming)
Group C: Technical performance and practicability	
C.1	Aggregated project risk
C.2	Requirements for technical development
C.3	Timescale for implementation
C.4	Flexibility
C.5	Impacts on site operability
Group D: Social and economic impacts/quality of life	
D.1	Nuisance (noise, odour, visual impact)
D.2	Residual restrictions on access following remedial actions
D.3	Positive/negative effects on local economy
Group E: Costs	
E.1	Indicative lifetime costs (construction, operation, decommissioning)

The sustainability indicators recommended for use in sustainable BPEO studies were derived in the SD:SPUR project through extensive stakeholder consultation (see Section 1.1.4 and the appendices) and have been correlated to the UK Government's sustainable development strategy and Quality of Life Barometer [Defra, 2004]. A total of 19 sustainability indicators and 38 sub-indicators were derived and these are listed in Table 2.4. These indicators are ordered under the headings referred to in the EA -SEPA BPEO guidance document so that they should be capable of being considered within a BPEO study without the need to change the overall assessment methodology or increasing significantly the effort required to perform the study.

Table 2.4 *The set of sustainability indicators derived for the project from the workshop comments, ordered under the headings referred to in the radioactive waste management BPEO guidance document [EA-SEPA, 2004].*

Ref.	Sustainability indicator	Comment [Relevant indicators in the Government's sustainable development strategy]
Group A: Actual and perceived impact on human health and safety		
1	Health and safety of the public 1.1 – current generations 1.2 – future generations	Health and safety of members of the public in all affected communities, from all sources of hazard (e.g. contact with recycled materials). Future generations should be afforded same level of protection as current generations: intergenerational equity. [H6, F1, F2]
2	Health and safety of the workforce 2.1 – current workforce 2.2 – future workforce	Health and safety of workers in all affected groups, from all sources of hazard (e.g. those from processing and later reuse operations). Future workforces should be afforded same level of protection as the current workforce. [C10]
Group B: Impacts on natural, physical and built environments		
3	Discharges to water bodies 3.1 – radioactive discharges 3.2 – chemical discharges	Ground and surface water bodies should be protected from unnecessary discharges of all pollutants, and BAT and BPM approaches should always be used to reduce discharges. [D19, H12, M2, M4]
4	Discharges to the atmosphere 4.1 – radioactive discharges 4.2 – CO2, NOx, SOx 4.3 – other chemical discharges	The atmosphere should be protected from unnecessary discharges of all pollutants, and BAT and BPM approaches should always be used to reduce discharges. Greenhouse gases and gases contributing to acidification have specific reduction targets. [H9, D19, P1, P2, P3, M4]
5	Biodiversity 5.1 – impact on number/viability of species 5.2 – impact on extent of natural habitats	Flora and fauna on land and in the sea are to be protected from unnecessary impacts, and steps taken to reverse the decline in UK wildlife and habitats. [R3, S4]
6	Solid waste disposal 6.1 – amount of waste disposed as radioactive 6.2 – amount of waste disposed as hazardous 6.3 – amount of inert waste disposed to landfill 6.4 – amount of waste stored without disposal route	Waste production and disposal should be minimised. Use of the Drigg repository and hazardous waste disposal facilities should be restricted to certain waste types to conserve capacity. [A7, D10, H15]
7	Waste material reused 7.1 – amount of material reused on site 7.2 – amount of material reused off site	The reuse and recycling of waste materials is encouraged through the waste hierarchy. [A6, H15, S14]
8	Material transport 8.1 – number of transport consignments 8.2 – number of transport miles	Transport should be minimised where possible, and local reuse options to be encouraged: proximity principle. [D21, H11, G3, G4]

Ref.	**Sustainability indicator**	**Comment** **[Relevant indicators in the Government's sustainable development strategy]**
9	Resource use 9.1 – amount of energy consumed 9.2 – amount of clean water used 9.3 – amount of other natural resources used 9.4 – amount of natural primary resources displaced	Natural resources should be used efficiently and preserved to maintain stocks and minimise impacts from their use (e.g. CO2 emissions from burning hydrocarbons). [A1, D3]
Group C: Technical performance and practicability		
10	Quality of recycled product 10.1 – grade of reused or recycled product	Waste materials should, within reason, be processed to achieve the highest grade of product to preserve high-grade primary resources. [A6, S14]
11	Technical developments 11.1 – new developments with market potential	Promoting research and development, and investment allows new technologies to be brought to market. [H1, H2]
12	Finality of option 12.1 – amount of further effort/work needed	Options that achieve a clear end-point are usually preferred to those that require further effort or work to achieve a waste management solution. [A1]
Group D: Social and economic impacts/quality of life		
13	Employment 13.1 – direct and indirect current employment 13.2 – direct and indirect future employment	Options are usually preferred that provide high and stable levels of employment will support financial viability of local communities and community spirit. [H3]
14	House prices and land value 14.1 – change in house prices and land values	Options that cause substantial changes to house prices and land values would impact on local and regional financial systems. [E1]
15	Landscape and heritage 15.1 – access to countryside 15.2 – impacts on local heritage	The wider environment should be protected and access to the land encouraged. Local and regional cultural and historical heritage should be preserved. [S7, S8]
16	Quality of life 16.1 – community spirit and community viability 16.2 – nuisance factors 16.3 – impact on the quality of surroundings	People's quality of life should be maintained or improved. The quality of surroundings should be high and nuisance (noise, visual impact etc.) minimised. Community spirit should be fostered. [K6, L2, L3]
17	Investment 17.1 – level of inward investment 17.2 – regional GDP	Maintaining high and stable economic growth is important for developing communities and enhances regional competitiveness. Inward investment for waste management is encouraged. [E1]
Group E: Costs		
18	Costs 18.1 – full life-cycle costs of implementation	The full life-cycle (cradle to grave) costs of options should be quantified. [E1, T5]
19	Revenue 19.1 – revenue from sale of product	Any revenue from sale of recycled product or saving on waste disposal liabilities may be included in cost assessments. [E1, T5]

This list of sustainability indicators is not intended to replace the standard BPEO attributes but to be additional or complementary to it. That is not to say that every decommissioning waste BPEO study has to include all of these sustainability indicators. Only those standard attributes and those sustainability indicators that relate to the issue under investigation and discriminate significantly between options need to be included in the study. In simple cases, where only a few management options are available to the site operator and any decommissioning waste can clearly be demonstrated to be radiologically clean and inert, then only a few of these indicators may be relevant to the decision. On the other hand, for more complex cases where a greater number of options are available or where potentially larger safety and environmental impacts may arise, then it would be appropriate to consider all or most of these indicators. In any case, the total number considered should not be too large otherwise the whole assessment process may become difficult to manage and the effort disproportionate to the issue at hand.

There is a case for including some sustainability indicators that do not discriminate between options if they are of fundamental importance or relate to the key concerns of stakeholders to demonstrate that the issue is addressed in the study. Furthermore, although safety issues are included as a sustainability indicator when considering options, any proposal for the management, reuse, storage etc for radioactive waste on a nuclear licensed site will be subject to the conditions of the nuclear site licence. These include the requirement for suitable safety cases, which should be proportionate to the hazard.

The selection of attributes should be systematic and justified in order for the final decision to be transparent and acceptable to stakeholders. Again, as with the identification of options, stakeholder participation in the selection of attributes is likely to result in wider acceptability of the final decision.

2.4.1 Assessment of management options against the sustainability scenarios

In Section 2.3, a number of asset and waste management scenarios were discussed as likely alternatives that may be available to a waste manager on a nuclear site, these were:

- building refurbishment for reuse,
- planned deconstruction, and
- routine demolition.

In broad terms, these options reflect the waste hierarchy, involving options for reuse and recycling. It is not so simple, however, to say that an option involving the reuse of a building is the most sustainable because other factors reflecting in the sustainability indicators from Table 2.4 need to be taken into account. To indicate how the sustainability indicators could be applied to these general waste management scenarios, Table 2.5 provides some qualitative comments that indicate whether an option is likely to perform well, poorly or result in no significant impact against each indicator.

In a real situation for an actual nuclear site, the various options available to a waste manager would need to be fleshed out in some detail (e.g. in terms of processes used, volumes of material created etc.) and assessed against the sustainability indicators in either quantitative or qualitative terms. The core of a sustainable waste management BPEO study will be this assessment of the performance of each option. The assessment may be done in a relative manner *(ranking)* in which the performance of all of the options are ordered from best to worst or it may be done in an absolute manner *(scoring)* in which the performance of each option is defined and awarded a numerical score on an integer scale (e.g. 1 to 10). Usually ranking is reserved for when there is limited information as may be the case when new or novel options are considered with little experience on which to judge their performance.

As some of the options for reuse and recycling of assets and decommissioning wastes may not have previously been attempted on the nuclear sites, then it is inevitable that some information will be unknown or uncertain and this is likely to relate to the validity of:

- models and data used to compare options (e.g. environmental impacts of certain materials)
- assumptions about future developments (e.g. market values and demand)
- business and project risks, including uncertainty about costs, practicality and timescales.

The management of these forms of uncertainty is an important part of the decision making process and must be handled transparently. Different stakeholders are likely to hold different views on the significance of uncertainty when making the final decision. This would be an important aspect for the stakeholder engagement process to address, particularly if stakeholders have been included in the BPEO process itself (see Section 2.5). Uncertainties and any associated assumptions that might have a significant impact on the conclusions have to be made explicit.

A particular issue for the assessment is the manner in which financial issues are addressed. The list of sustainability indicators (Table 2.4) includes two relevant indicators 18 (Costs; full life-cycle costs of implementation) and 19 (Revenue; revenue from sale of product). Cost themselves should not be used to constrain the initial identification of options but cost can be used in the assessment as an attribute. It is normal in BPEO studies to consider *undiscounted costs* to avoid any bias that may arise from discounting costs over the very long time periods considered in site remediation and waste disposal programmes. Discounting may be taken into account in the eventual decision, providing that it is done transparently and any related assumptions are set out clearly in the submission.

Table 2.5 *Qualitative assessment of the possible asset and waste management scenarios discussed in the text (Section 2.3) against the sustainability indicators (Section 2.4).*

Ref	Sustainability indicator	Building refurbishment	Planned deconstruction	Routine demolition
Group A: Actual and perceived impact on human health and safety				
1	Health and safety of the public	There should be no danger to the public from refurbishment work or from reuse of the building afterwards.	There should be no danger to the public from planned deconstruction or from reuse of the segregated materials afterwards.	There should be no danger to the public from demolition or either on site or off site landfill disposal.
2	Health and safety of the workforce	Workers may face hazards during refurbishment (e.g. asbestos in the structure) but these would be similar to those faced in normal building work.	Workers may face hazards during deconstruction (e.g. asbestos in the structure) but these would be similar to those faced in normal building work.	Workers may face hazards during demolition (e.g. asbestos in the structure) but these would be similar to those faced in normal building work.
Group B: Impacts on natural, physical and built environments				
3	Discharges to water bodies	Not likely to be significant.	Not likely to be significant.	Potential for contamination of the ground and surface waters if soluble materials remain in the CDW when landfilled.
4	Discharges to the atmosphere	Not likely to be significant. There would be some saving in CO2 emissions from cement manufacture compared to constructing a new replacement building.	Not likely to be significant.	Not likely to be significant other than dust nuisance from demolition.
5	Biodiversity	Not likely to be significant.	Not likely to be significant.	Not likely to be significant.
6	Solid waste disposal	Minimises the amount of CDW for disposal or storage. Some wastes would, however, be generated as old materials are stripped out, and walls, floors etc. removed or replaced.	Minimises the amount of CDW and other materials sentenced for disposal or storage. Some materials would, however, need to be disposed if there is no market for their reuse.	Maximises the amount of CDW and other materials landfilled
7	Waste material reused	Likely to maximise the reuse of assets provided the fabric of the structure is sound and does not require wholesale replacement.	Provides the maximum opportunity for reuse and recycling of segregated materials.	Provides limited opportunity for reuse and recycling of materials.
8	Material transport	Minimises the transport of waste and materials.	Unless on site uses can be identified, all materials will need to be transported from site to the market.	Unless on site uses can be identified (e.g. landscaping), all materials will need to be transported from site to the market.
9	Resource use	Minimises resource use provided the fabric of the structure is sound and does not require wholesale replacement.	Reused and recycled materials displace certain primary resources, depending on the level of processing. Some energy/water resources would be used during processing.	Minimal resources required for demolition but few primary resources displaced as majority of waste landfilled.
Group C: Technical performance and practicability				
10	Quality of recycled product	Amount of recycled product for use elsewhere would be small.	Dependent on the level of processing undertaken to produce a product.	Only low-grade product likely to produced from unsorted CDW rubble.

Ref	Sustainability indicator	Building refurbishment	Planned deconstruction	Routine demolition
11	Technical developments	Limited opportunity for new technical developments.	Likely to require novel solutions for the deconstruction and segregation of materials from some nuclear facilities (e.g. to remove metal components from reactors that are clean or could be surface decontaminated).	Industry standard demolition techniques used.
12	Finality of option	May be considered as a final solution, assuming long-term reuse of the building.	May be considered as a final solution, assuming market for the segregated materials	May be considered as a final solution.
Group D: Social and economic impacts/quality of life				
13	Employment	Refurbishment of buildings as an integral part of redeveloping a site for beneficial industrial or commercial purposes would provide for continued employment.	Short-term employment for workers to undertake the deconstruction and segregation/processing of materials.	Limited to short-term demolition teams.
14	House prices and land value	May be significant for sites close to urban centres or where population and economic growth is rapid.	May be significant for sites close to urban centres or where population and economic growth is rapid.	May be significant for sites close to urban centres or where population and economic growth is rapid.
15	Landscape and heritage	Not likely to be significant.	Not likely to be significant.	Not likely to be significant.
16	Quality of life	Refurbishment of buildings as an integral part of redeveloping a site for beneficial industrial or commercial purposes would maintain the local quality of life.	Not likely to be significant.	Not likely to be significant.
17	Investment	Inward investment may be enhanced by the provision of suitable premises for industrial or commercial activities.	Not likely to be significant.	Not likely to be significant.
Group E: Costs				
18	Costs	Refurbishment costs may be higher than the cost of routine demolition.	Planned deconstruction costs may be higher than the cost of routine demolition.	Likely to be the cheapest option.
19	Revenue	Revenue from sale or lease of the refurbished buildings may be anticipated.	Revenue from sale of recycled product may be anticipated.	Not likely to be significant.

With regard to options for the reuse and recycling of decommissioning wastes, then it is reasonable to include in the assessment any *revenue* that may accrue from the sale of a recycled material or product. However, it may be more appropriate to account for any reduction in liabilities (disposal costs) achieved by way of diverting waste materials from disposal routes to reuse and recycling routes.

It requires considerable effort to assemble meaningful cost data and potential revenue data for options, particularly new or novel alternatives that have not previously been adopted by nuclear sites. A full financial breakdown will not, however, usually be required in the BPEO but data will be required to a level of detail adequate to allow the options to be ranked and the magnitude of the costs/revenue for each option to be estimated.

In the assessment, it is recommended that cost and revenue (liability reduction) attributes be considered only in the final stage. Initially, the performance of the options against the other attributes and sustainability indicators would be established, and the options ranked in order of best to least overall performance. At this stage the options would then also be ranked by cost. The preferred option would be the one the provides for good overall performance but does not incur disproportionately high costs.

2.5 Stakeholder engagement and public acceptance

The broad thrust of this guidance is that, where a sustainable BPEO study indicates that it is practicable to do so, a site operator should seek to refurbish a redundant building for reuse, or else demolish the building in such a way that the waste materials generated can be made available for reuse and recycling with the highest possible utility.

With the exception of radioactive wastes, it is possible that this may cause some of the reused or recycled materials to be transferred off nuclear sites and be used in public places or used on a licensed site which is subsequently delicensed. Despite these materials being free from radioactivity, it is likely that there will be a degree of mistrust and concern from some stakeholders about the reuse in public places of waste materials derived from nuclear sites. This was evident from the feedback during the stakeholder workshop and from anecdotal evidence from some sites whereby demonstrably clean decommissioning materials such as crushed concrete have not found off site uses in even basic, low grade applications as aggregate.

Little is achieved by processing materials for reuse if no application or buyer for the product can be found and, therefore, this issue is critical to the implementation of a sustainable policy for the management of assets and decommissioning wastes from nuclear sites. To minimise this problem, it is recommended that two approaches be adopted by sites when developing their sustainable waste management strategy.

The first approach is to ***reuse waste materials on site*** (or on another nuclear site) so that the nuclear industry becomes the primary customer for its own recycled products. This approach is already planned to be followed on several sites whereby large volumes of inert clean decommissioning wastes are to be used for landscaping. However, not all decommissioning materials can be used this way and, taking a broader view, this does not necessarily represent the most sustainable use of these materials.

The second approach is to ***engage the public and stakeholders at an early stage*** so that broad-based agreement can be sought for sustainable off site applications of processed decommissioning wastes and other materials. Most nuclear sites have an established local liaison group or stakeholder dialogue forum. These may provide a starting point for dialogue about sustainable reuse of decommissioning wastes but are unlikely to include all relevant parties given that recycled materials could potentially be used at places remote from the nuclear sites and the local stakeholders at the proposed place of use (or place of processing, if different) would be valid participants in the engagement process.

At the SD:SPUR stakeholder workshop, many participants suggested that a ‘stakeholder acceptance’ sustainability indicator should be adopted because options that are broadly supported by stakeholders (both the general public and statutory consultees) will generally be easier to implement. Whilst this sentiment is undoubtedly true, it is recommended that ‘stakeholder acceptance’ should not be used as an indicator but, rather, the entire issue of stakeholder engagement and consumer acceptance should be considered at the highest level and be integral to all aspects of a sustainability assessment rather than just at the detailed assessment stage. This is consistent with recommendations in the radioactive waste management BPEO guidance [EA-SEPA, 2004]. The issue of stakeholder engagement and consumer acceptance is most critical for options that entail off site applications of decommissioning wastes because these cannot be implemented without the active support of relevant stakeholders. For example, if there are no customers for a recycled product because the public or industrial stakeholders do not accept it, the product cannot be brought to the market and, thus, the option cannot be implemented. In this regard, options for reuse and recycling are fundamentally different to options for disposal that may be implemented without full public acceptance.

There is an obvious similarity with regards public and stakeholder concerns between the reuse and recycling of decommissioning wastes from nuclear sites and the remediation of contaminated land on nuclear sites to allow the sites to be reused for other purposes. The latter issue was addressed in the SAFEGROUNDS learning network which proposed a number of Principles for achieving good practice. The second of these addressed the need for public and stakeholder engagement:

> ***Principle 2: Stakeholder involvement*** *Site owners/operators should develop and use stakeholder involvement strategies in the management of contaminated land. In general, a broad range of stakeholders should be invited to participate in decision-making.*

The SAFEGROUNDS learning network provided detailed advice on good practice in stakeholder involvement in decisions relating to contaminated land and subsequently during project implementation [Collier, 2002]. It is recommended that this SAFEGROUNDS advice plus other practical experience that can be gathered from previous and ongoing stakeholder dialogues such as BNFL's Stakeholder Dialogue process [Environment Council, 2004] and the Environment Council's best practice guidelines [Environment Council, 2003] be consulted when planning a sustainable waste management strategy to enable a productive stakeholder engagement process to be implemented.

It was evident from the stakeholder workshop for the SD:SPUR project that the primary concerns of many stakeholders with regards to uncontrolled use of recycled clean wastes in public places relate to having satisfactory evidence to show that:

1. the wastes are indeed uncontaminated with both radiation and other chemically toxic substances; and
2. all potential hazards to the public and the environment have been identified and are minimised.

In addressing these concerns, there are two issues that may be considered within a stakeholder engagement process. The first is the development of an appropriate programme and methodologies for sampling and characterisation of the waste (see Section 2.5). The second is the use of peer reviewers, independent of both the nuclear site and the environment agencies, to give oversight to the process. Both of these were requested frequently through the stakeholder consultation for this workshop.

2.6 Waste characterisation

2.6.1 Waste inventory

To support plans for the sustainable use of construction resources, it is recommended that site operators make immediate efforts to reduce the uncertainties associated with the inventory of radiological clean, RSA exempt and excluded, and slightly radioactive wastes in terms of both the amount of arisings and the material content of these wastes. As discussed in Section 1.2.2 and by RWMAC [2003], the current inventory may significantly underestimate the amount of waste that needs to be managed. This study concludes that the existing inventory information is inadequate to allow quantitative assessments to be made of the viability of processing decommissioning wastes for reuse or recycling.

It is understood that better quality inventory information may be included in RWI'04 but it is unlikely that this iteration of the national inventory will contain all the information that is required.

2.6.2 Waste sampling and clearance

Before any waste material could be reused or recycled for uncontrolled use either on or off a nuclear site, appropriate demonstrations need to be made to the regulators that it is either radiologically clean or that its levels of radioactivity are sufficiently low to be classed as exempt or excluded from control under RSA'93. These demonstrations may comprise a combination of gathering information on the provenance, keeping and use of the waste, along with some sampling, measurements and analysis to assess the radioactivity content.

Sampling, measurement and analysis to prove the radioactivity content of a waste can be prone to uncertainty, particularly with regard to heterogeneous distributions, and statistical approaches are required. There is no regulatory procedure for waste producers to follow with regard to demonstrating that a waste material is clean, excluded or exempt and, traditionally, each site operator was able to adopt their own practices. These practices would then be tested by the regulators when proposal were made to transport, dispose or discharge of wastes.

To provide for some consistency of approach, an industry code of practice on clearance and exemption has been adopted by the Nuclear Industry Safety Directors Forum [Clearance and Exemption Working Group, 2003]. This provides guidance on the sampling, measurement and analysis, and on sentencing for different types of materials. It is recommended that this code of practice be consulted when planning a sustainable waste management strategy to ensure that waste materials are appropriately sentenced for reuse and recycling.

The industry code of practice is likely to be adequate when making demonstrations to regulators in support of waste management proposals. It may not, however, be sufficient to allay the concerns and fears of some stakeholders with regard to the safety of recycled materials derived from nuclear sites, even those that are radiologically clean. As mentioned in the previous section, concerns about the safety of recycled wastes were frequently expressed during the consultation for the SD:SPUR project, and calls were made for stakeholder involvement and peer reviews of the sampling and analysis process.

The approach a site would need to make to allay the concerns and fears of some stakeholders may vary from site to site but is most likely to relate to the type of material recycled and the use to which it may be put. The reuse of waste materials within the nuclear section is likely to generate far less concern that possible uses in public places.

With regard to how the public and stakeholders may be included in the sampling and analysis process, there is some useful information from the Jointly Agreed Sampling and Monitoring Working Group (JASM) project which has close links to the BNFL National Stakeholder Dialogue. The JASM project related to a dialogue that sought, and achieved, a resolution to a problem which arose when BNFL, and its rail freight subsidiary Direct Rail Services, announced their intention to use Cricklewood sidings in North London as a marshalling site for trains carrying used nuclear fuel [Environment Council, 2001].

JASM agreed to *discuss the characteristics of a possible jointly-agreed monitoring and sampling programme, and thereby start the process of developing mutual trust and respect*. It was recognised that in areas of environmental concern the objectivity of data is often questioned when the work has been conducted on behalf of one stakeholder only and that a new approach was needed to obtain objective data with a widely accepted provenance. An approach was developed amongst a wide range of stakeholders that involved engaging an independent organisation to undertake confirmatory monitoring. The stakeholder group agreed the scope of work, the methodology to be used and the selection of the organisation to carry out the work. This approach would appear to offer a way forward for seeking consensus on a methodology for measuring and assessing the radioactivity content of recycled materials, that may enable them to find wider support and utility.

2.7 Reuse of slightly radioactive wastes

The slightly radioactive wastes arising from decommissioning must always remain under regulatory control (unless they can be decontaminated to below exemption order limits) and, thus, can never be considered for reuse or recycling off a nuclear site. There are, however, a number of possibilities for the sustainable reuse and recycling of these materials on nuclear sites that might offset the use of virgin or other sources of recycled materials.

The types of nuclear site that potentially could make use of certain recycled decommissioning slightly radioactive wastes include:

– operating NPPs;
– MOD sites that handle radioactive materials;
– industrial sites that manufacture radioactive sources;
– decommissioning sites under the remit of the NDA; and
– current and future radioactive waste disposal and storage facilities.

The types of uses to which certain recycled decommissioning slightly radioactive wastes might be put could include:

– fabrication of steel waste cans and overpacks for vitrified HLW and spent fuel;
– fabrication of steel drums, packages and ISO containers for ILW and LLW;
– cementitious grouts and backfills to infill ILW and LLW waste packages;

- reinforced concrete walls, floors and structural supports etc. in deep or surface waste repositories;
- cementitious grouts and backfills to infill between waste packages in deep or surface waste repositories;
- reinforced concrete walls, floors and structural supports etc. in interim waste storage facilities and spent fuel stores; and
- construction of waste processing equipment such as supercompactors and cementation plants.

In all of these cases, the slightly radioactive wastes would need to be processed and/or decontaminated so as to achieve a suitably high quality material (e.g. so waste packages meet structural design specifications) and to ensure workers are not exposed to doses that would exceed applicable dose limits or contravene the 'as low as reasonably practicable' (ALARP) principle.

A considerable amount of international work has been underway to examine the possibility of the reuse and recycling of decommissioning slightly radioactive wastes, particularly metals [e.g. European Commission 1998, 1999 and 2000] and it is recommended that this is referred to by waste managers.

An important consideration with regard to the reuse of metals and other slightly radioactive materials is that, even if they can be decontaminated so as to be cleared from further regulatory control, there is likely to be considerable public concern regarding their use in everyday construction applications. There is thus a considerable benefit to be gained if these materials could be reused within the nuclear sector, for example in the uses listed above. Three advantages may be cited for a strategy whereby the nuclear industry becomes the main consumer of recycled materials (radiologically clean or decontaminated) from nuclear sites:

- potentially the level of decontamination that would be necessary to achieve might not be as high as that required for uncontrolled off site uses;
- there may be a cost saving by replacing virgin materials with recycled materials; and
- concerns from the public and other stakeholders regarding safety of these materials can be minimised.

It is improbable that a nuclear site could meet all of its construction material requirements from processing and recycling its own wastes but it is recommended that, as part of a site-wide IWS, a mass balance calculation is undertaken to assess to what extent a site could satisfy its own requirements and the financial implications of doing so are also quantified.

It is most feasible that the nuclear industry as a whole could become the main consumer of its own recycled materials if a centralised approach were taken to the provision of processing and recycling plants (e.g. to establish one or more dedicated metal processing plants to take material from nuclear sites for use in the fabrication of ISO waste containers and waste drums, or to process concrete for use as backfill in LLW ISO containers or future repository construction). This would appear to be the remit of the NDA, although individual sites are encouraged to consider installing local processing facilities for their own or shared use.

2.8 Impacts to decommissioning programmes

The impacts to decommissioning nuclear sites from following this sustainability guidance arise in two areas:

1. impacts to the development and assessment of an IWS;
2. impacts to the implementation of decommissioning programmes.

In the first case, the impacts to the development and assessment of and IWS are likely to be relatively minor. The difference between what is currently done and what is suggested should be done relates to the inclusion in BPEO studies in support of IWS of (i) strategic options for the reuse of redundant buildings and the reuse and recycling of waste materials, and (ii) additional attributes in the form of sustainability indicators that explicitly relate to the Government's sustainable development policy. Given that an IWS is already a requirement imposed on the sites by the regulators and the IWS needs to be underpinned by BPEO studies, the additional effort from implementing these recommendations in time, money and trouble should not be large.

In the second case, the impacts to the implementation of decommissioning programmes potentially could be very significant for sites that are currently pursuing a site restoration and waste management strategy that is not consistent with the Government's sustainable development policy. The greatest impact would be for sites that are currently planning to demolish buildings so as to achieve a brownfield site end-point, when it would be practicable and cost effective to refurbish those buildings, and where a resale or rental demand is evident. It is not considered that the majority of nuclear sites would be affected in this way.

It is more likely that some nuclear sites would be affected by the recommendation to adopt more efficient methods for segregation of deconstruction and demolition wastes, so as to enable better processing to achieve higher utility and added value recycled construction materials.

Furthermore, few sites appear actively to be adopting a policy of recycling materials for reuse within their own or other nuclear sites other than use of low grade CDW for landscaping. This would appear to be the greatest opportunity for enhancing sustainable uses of construction resources that minimises the demand for virgin materials and negates some of the public and stakeholder concerns associated with the reuse and recycling of radiologically clean wastes in public places.

3 Dounreay Planning Model and Case Study

3.1 Background to Dounreay

The Dounreay site is located on the Caithness coast in the north of Scotland, 14 km west of Thurso on a former naval air base, and comprises 505 hectares of land of which the nuclear licensed site occupies 53 hectares. It is owned and operated by UKAEA and has been a research and development centre for a wide range of nuclear research activities since 1954. These activities have included the operation of two prototype fast reactors and the development of their fuel cycle, the operation of a material test reactor and its fuel cycle, and the management of radioactive wastes arising from these activities. The site has a comprehensive infrastructure covering most of the licensed site area which provides facilities for the engineering and administrative effort required to support the research programme.

The fast breeder reactor research programme has now ended and the Dounreay site is being decommissioned in such a way that it may be made available for alternative use or to achieve a permanently safe condition that requires minimal institutional care. Certain operations will continue to take place on the Dounreay site for the next few years, these are mainly care and maintenance operations prior to decommissioning, but also include some operations to fulfil current commercial contracts. Operational wastes are arising now and wastes from care and maintenance operations will continue to arise for several decades.

In 2000, UKAEA published the Dounreay Site Restoration Plan (DSRP) which set out the overall approach planned to be taken to decommission and clean-up the site over a 50 to 60 year time period [UKAEA, 2000]. The anticipated end-state of the site is the removal of all buildings, with the exception of the sphere that housed the Dounreay Fast Reactor (DFR) which is a listed building, and remediation of the ground to achieve brownfield status. The restoration of the site involves the evolution of the site in four distinct phases:

– operational phase
– decommissioning phase
– care and surveillance phase
– post restoration phase

The operational phase of the site has been effectively concluded. The decommissioning phase is currently underway and involves staged decontamination, dismantling and demolition of all facilities on the site and the management of waste arising from these activities.

UKAEA have completed a strategic BPEO study with the aim of helping to define a coherent management strategy to deal with the majority of the different radioactive waste streams that will arise during the restoration of the Dounreay site, including solid decommissioning LLW. The outcome of that study has been used by UKAEA to develop separate waste strategies for solid, liquid and gaseous radioactive wastes. UKAEA is currently developing a complementary strategy for the management of non-radioactive wastes on the Dounreay site, including the radiologically clean decommissioning wastes. It is intended to combine the radioactive waste strategies with the conventional waste strategy to produce an overarching IWS for all waste materials arising at Dounreay.

Radioactive wastes generated on the site are conditioned and packaged so as to be suitable for long term storage or disposal. UKAEA is in the process of making an application to transport and dispose of some LLW to the Drigg repository but it is envisaged that a new disposal facility may be constructed on the Dounreay site to dispose of the majority of the site's solid LLW. Conventional wastes generated on the site are segregated into material type. Some of these are sent for disposal to authorised landfills while the majority of the inert demolition wastes will be stored and are planned to be used for landscaping the site once all of the buildings are removed.

3.2 Waste arisings at Dounreay

UKAEA maintains a detailed record in the Dounreay Radioactive Waste Inventory (DRWI) of its existing radioactive wastes together with predictions of those wastes that are expected to arise in the future during decommissioning work on the site. As restoration progresses, DRWI is updated annually and the current version of DRWI (DRWI'04) includes details of over 304 individual waste streams and distinguishes between wastes whose origin is from decommissioning separately from wastes whose origin is from past, current or planned future operations involving nuclear materials.

Separately from DRWI, records are maintained for actual and anticipated arisings of decommissioning wastes that are radiologically clean, RSA exempt and excluded. Both the information in DRWI'04 and the separate clean wastes datasheets contain some information on the material composition of the different waste streams but this is not yet fully developed and there remains a level of uncertainty with regard to this aspect of the Dounreay inventory.

Inventory data supplied by the site for this project, plus additional information extracted from DRWI'04, is summarised in Table 3.1.

Table 3.1 *Estimates of clean, RSA exempt and slightly radioactive decommissioning waste arisings from the Dounreay site. Sources: (1) DRWI'04, (2) Extracted DRWI'04 data reported by B.Barton pers.comm. 19/10/04. (3) Demolition quantity exercise November 2004.*

Waste type/material	Volume (m3)	Source
Slightly radioactive wastes:		
Soil and building rubble, poorly characterised.	40,000	1 (p41)
Exempt wastes from active building decommissioning:		
Mainly concrete and other building materials. Some of this waste may be clean but breakdown is not available.	57,000	2
Exempt soil from new construction projects.	22,000	2
Clean wastes from active building decommissioning:		
Mainly concrete and other building materials.	58,000	2
Clean soil from new construction projects.	7,000	2
Clean wastes from inactive building decommissioning:		
Masonry	27,000	3
Asphalt and insulation	1,800	3
Concrete	3,800	3
Excavation spoil	7,500	3
Structural steel and metal sheeting	370	3

Thus the total volume of radiologically clean and slightly radioactive wastes predicted to arise from the Dounreay site is approximately 225,000 m3. The majority of this comprises poorly characterised building rubble and soils, although at the time of arising better characterisation and segregation of these wastes may be assumed.

3.3 Options for reuse and recycling of clean and exempt wastes

3.3.1 Current plans

The DSRP assumes that the end-state for the Dounreay site will be demolition of all of the buildings, with the exception of the DFR sphere, and the remainder of the site landscaped and grassed over. The majority of the site would be delicensed but parts may remain under control, particularly if a LLW disposal facility is built there.

Current plans involve the use of the inert radiologically clean and exempt decommissioning wastes (such as excavation spoil and rubble) in the landscaping works, particularly to fill voids left behind from demolition of facilities with deep foundations and basements. Detailed designs for landscaping have not yet been developed and the material requirements have not yet been quantified but preliminary estimates suggest that all of the site's inert clean and exempt decommissioning wastes may be used for landscaping [M.Tait pers.comm. July 2004].

Plans for the management of the non-inert clean and exempt decommissioning wastes (e.g. timber, steel etc.) are not yet fully developed but the DSRP assumes that these wastes would be handled in the same way as conventional wastes derived from other sources.

3.3.2 Applying the sustainability guidance to Dounreay

The sustainability guidance (Section 2) is intended to support the development of an IWS. UKAEA is currently planning for the development of an IWS and has previously undertaken a strategic site-wide BPEO study for the radioactive wastes on site that followed the step-wise approach described in Section 2.2. The next stage will be for this work to be complemented by a similar study for the non-radioactive wastes. The guidance identified (Section 2.2.1) two important steps in a BPEO study that need explicitly to consider sustainability issues:

– Identification and screening of options
– Selection of attributes and the assessment of short-listed options

Identification and screening of options for the Dounreay site

Section 2.3.2 makes it clear that as part of a BPEO study to support the development of an IWS, waste managers and strategy developers need to identify a comprehensive list of all possible options and then screen out those that are clearly not viable because they would be inconsistent with constraints imposed by planning and the reality of demand for refurbished buildings and recycled materials etc. Figure 2.3 provides a simple decision tree that may be useful in helping screen out options that may not be viable on a particular site. Applying the decision boxes from Figure 2.3 to Dounreay leads to the following options screening conclusions:

Is there potential for building and asset reuse on the site and, if so, is this consistent with the planned site end-point ? No. The planned Dounreay site end-state involves the demolition and removal of all buildings and reversion to brownfield status. This, however, is a UKAEA decision that is not subject to planning constraints by the local planning authority and, therefore, could be changed.

Is there a demand for refurbished buildings ? No. Caithness is a remote location with a low population density and limited construction activity. Apart from the Dounreay site and local suppliers, there is no other established large industrial or service industry in the immediate area. It is unlikely that UKAEA would be able to find a buyer or tenant for refurbished buildings on the Dounreay site after all site restoration works had ended.

On this basis, the option to refurbish the Dounreay buildings does not appear to be viable and may be screened out from the main assessment in a sustainable waste management BPEO. This decision may, however, need to be revisited if Government were to provide substantial active support for regeneration and inward investment that might lead to new businesses locating to Caithness.

Is there a demand for high utility recycled materials ? Uncertain. In support of the Dounreay site restoration programme, several new buildings and facilities will need to be built and these potentially could use high utility recycled materials derived from the site. The viability of this scenario depends on when recycled materials could be produced relative to the time they are required, as well as material quality and costs issues etc. Furthermore, the central belt of Scotland and some larger towns in northern Scotland are experiencing growth and demand that potentially may be met by transporting recycled materials derived from the site.

It is, therefore, not immediately obvious whether there is or is not a demand for high utility recycled materials derived from the site and, therefore, the options for (i) planned deconstruction that may generate high utility recycled materials and (ii) routine demolition that may provide lower quality materials, should both be assessed in detail against the sustainability indicators to determine which approach is most viable.

Assessing options for Dounreay against the sustainability indicators

Section 2.4.1 indicates how different options for asset and waste management may be assessed against the sustainability indicators as part of a strategic BPEO study. Table 2.5 provides a generic, qualitative assessment of the likely options against the indicators. In an actual assessment, a substantially more comprehensive and quantitative assessment would be required, based on site-specific information and conditions.

Table 3.2 *Assessment of the planned deconstruction and routine demolition options for the Dounreay site using information available to the project. HIGH is considered to be the best performance and LOW the worst performance.*

Ref	Sustainability indicator	Planned deconstruction	Routine demolition	Commentary
Group A: Actual and perceived impact on human health and safety				
1	Health and safety of the public	HIGH	HIGH	Health and safety, and environmental legislation will have to be followed regardless of the option adopted which will ensure that the health and safety of the public is protected at all times. Greater efforts may be required in routine demolition to ensure public safety such as additional dust prevention etc. There may be greater off site risks associated with transport in planned deconstruction as more materials for recycled are transported away from the site, and landscaping material is brought on site.
2	Health and safety of the workforce	HIGH	MEDIUM	Routine demolition is likely to entail basic methods that would result in worker accident rates equivalent to those in the conventional construction industry and higher than those that might entail from planned deconstruction using more sophisticated methods.
Group B: Impacts on natural, physical and built environments				
3	Discharges to water bodies	HIGH	MEDIUM	Discharges to water bodies from landscaping using inert decommissioning wastes in the routine demolition option and primary rock in the planned deconstruction are possible, although there is a greater risk of groundwater contamination occurring in the routine demolition option because less sophisticated segregation methods are adopted.
4	Discharges to the atmosphere	HIGH	MEDIUM	Discharges to the atmosphere in the form of dust are likely to be greatest in the routine demolition option. CO2 and other gaseous releases may be minimised in the planned deconstruction option because recycled materials offset the manufacture of virgin materials.
5	Biodiversity	HIGH	HIGH	No species are threatened with extinction by either option and the site will be available for recolonisation by plants and animals in both cases although the landscape will be different in the two options, with minimal landscaping being done in the planned deconstruction option.
6	Solid waste disposal	HIGH	MEDIUM	The planned deconstruction option results in minimal disposal of solid wastes. The routine demolition option results in the majority of the waste materials being disposed to the site in the form of landscape material or to off site landfill.
7	Waste material reused	HIGH	LOW	The planned deconstruction option is designed to maximise the amount of waste material made available for reuse and recycling. No waste material is reused in the routine demolition option other than for landscaping of the site.
8	Material transport	MEDIUM	HIGH	The planned deconstruction option results in the most transport miles as material is sent elsewhere for reuse and recycling. The routine demolition option results in the least transport miles as the inert materials are used on site for landscaping.
9	Resource use	LOW	HIGH	The planned deconstruction option results in the greatest resource use as energy and water etc. will be required over a long period of time to achieve careful deconstruction of buildings, and processing and recycling of the waste materials. Minimal resource use is required for routine demolition, although some would be necessary to achieve post-demolition segregation of the inert materials for landscaping.

Ref	Sustainability indicator	Planned deconstruction	Routine demolition	Commentary
Group C: Technical performance and practicability				
10	Quality of recycled product	HIGH	LOW	The planned deconstruction option is designed to maximise the amount and quality of waste material made available for reuse and recycling. The routine demolition option results in low grade materials suitable for landscaping the site.
11	Technical developments	MEDIUM	LOW	The planned deconstruction option may result in the development of new deconstruction and segregation methods that could be applied elsewhere such as on other nuclear sites. The routine demolition option is unlikely to result in any new technical developments as industry standard methods are employed.
12	Finality of option	LOW	HIGH	The planned deconstruction option will be associated with a high project risk that the recycled materials it generates cannot find a market due to the remoteness of the site from major construction activity. If this were to occur, then the recycled materials may have to be disposed as waste. The routine demolition option is associated with low project risk and represents a clear end-point for the materials.
Group D: Social and economic impacts/quality of life				
13	Employment	HIGH	LOW	The planned deconstruction option may generate employment for more people and over a longer period of time that the routine demolition option because it entails more labour intensive techniques.
14	House prices and land value	LOW	LOW	Both options entail the closure of the site at similar times. Once restoration ends, house prices may fall if no alternative employment opportunities are created in the region.
15	Landscape and heritage	MEDIUM	HIGH	No man-made heritage would be affected by either option. The landscape of the site would be different in the planned deconstruction option compared to the routine demolition options because, in the former, only minimal landscaping would occur.
16	Quality of life	MEDIUM	LOW	No differences between the options with regards to quality of life in the long term would occur as they both result in similar site end-points. In the short term, the additional employment offered by the planned deconstruction option may maintain the current quality of life.
17	Investment	MEDIUM	LOW	The planned deconstruction option would be associated with additional investment because it entails more labour intensive and sophisticated techniques than the routine demolition option.
Group E: Costs				
18	Costs	MEDIUM	HIGH	The costs of the planned deconstruction option would be higher than for the routine demolition option.
19	Revenue	MEDIUM	LOW	Some revenue may be associated with the sale of recycled product in the planned deconstruction option.

Table 3.2 provides a descriptive assessment of the planned deconstruction and routine demolition options for the Dounreay site using information available to the project. For this assessment, it was assumed that:

- the intent of the planned deconstruction option is to maximise the generation of high utility recycled materials that may be used on or off site, with minimal landscaping of the Dounreay site being undertaken;

- the intent of the routine demolition option is to provide segregated inert decommissioning material suitable for landscaping the Dounreay site with the remainder of the waste materials being disposed as waste.

The assessment does not account for the management of slightly radioactive or higher levels of radioactive wastes which are assumed to be managed by identical means in both options and therefore do not differentiate between the options.

In this assessment, the performance of each option against each sustainability indicator was ranked as HIGH, MEDIUM, or LOW, whereby high is considered to be the best (good) performance and low the worst (poor) performance. The right hand column in Table 3.2 provides some commentary on the rankings.

The assessment of performance by ranking options as good or poor is consistent with the approach recommended in several environmental impact assessment methodologies, including guidance from the ODPM on strategic environmental assessment [ODPM, 2004b]. It is usually adopted when input data are subject to uncertainties and, therefore, is most often used in preliminary assessments. Given the UKAEA are still developing DRWI and, particularly, inventory datasheets for radiologically clean wastes, this ranking approach to the assessment is appropriate at this stage. In future assessment, however, reduced uncertainties should enable more quantitative analysis of the options to be undertaken.

If numerical values of 3, 2 and 1 are associated with the HIGH, MEDIUM, or LOW rankings, respectively, then total scores for each of the options can be derived:

- planned deconstruction, 44
- routine demolition, 37.

Total scores on their own do not indicate that one option is better or more sustainable than the other. The best option is most likely to be the one that provides good performance across all attributes and indicators considered. The number of HIGH, MEDIUM, or LOW rankings given to each option in the Dounreay assessment are listed in Table 3.3 which shows that the planned deconstruction option has more HIGH scores and fewer LOW scores that the routine demolition option.

Table 3.3 *Number of HIGH, MEDIUM, or LOW rankings given to each option.*

Rankings	Planned deconstruction	Routine demolition
HIGH	9	7
MEDIUM	7	4
LOW	3	8

So far in the assessment, no account has been taken of the relative importance of the different sustainability indicators. Weighting factors would need to be derived to include stakeholder viewpoints, and different weighting schemes applied to test for the robustness of a final decision. Without prejudging the input of stakeholders that would be engaged in a decision for Dounreay, the sustainability indicators that were perceived as most important by participants at the sustainability workshop included:

- health and safety of the public,
- finality of option
- house prices and land value, and
- quality of life.

The rankings given to the options against these sustainability indicators is given in Table 3.4.

Table 3.4 *Rankings for the options against certain sustainability indicators perceived as being most important by the participants at the sustainability workshop.*

Rankings	Planned deconstruction	Routine demolition
Health and safety of the public	HIGH	HIGH
Finality of option	LOW	HIGH
House prices and land value	LOW	LOW
Quality of life	MEDIUM	LOW

In addition to these sustainability indicators, stakeholder acceptance would also be an important aspect to the decision. As discussed in Section 2.5, this aspect was not included as a sustainability indicator because it was felt that the entire issue of stakeholder engagement and consumer acceptance should be considered at the highest level and be integral to all aspects of a sustainability assessment rather than just at the detailed assessment stage. It could be expected that the local community may be less accepting of the planned deconstruction option if recycled materials from Dounreay were planned to be used in public places. Such views would need to be confirmed, however, through an appropriate stakeholder engagement process

No firm conclusions can be made from this assessment because there remains uncertainty regarding much of the information needed to evaluate the performance of the options against the sustainability indicators and because there is no Dounreay stakeholder input to the process to validate the rankings or to apply weightings. That said, a number of observations can be made from this exercise:

1. If the same extent of landscaping is assumed for both options, then very little difference in their sustainable use of materials would be evident because the waste materials recycled and reused off site in the planned deconstruction option would have to be replaced with other materials for landscaping of the site. In Caithness, these other materials are likely to be primary aggregate or secondary quarry wastes. The sustainable use of materials would be enhanced if the site was not landscaped so as to reinstate its natural flat profile but such material benefits would need to be weighed against aspects such as the landscape and heritage value of the final site end-state.

2. The likelihood of finding an off site market for recycled aggregate materials derived in the planned deconstruction option is questionable, given the remoteness of the site from major construction activity and the relatively cheap primary aggregate produced in the area. This presents a significant project risk to this option and is the reason why it was ranked as LOW against indicator 12 (Finality of option).

3. The social aspects of sustainability, such as employment and quality of life, will be affected much more substantially by the loss of employment resulting from closure of the site, than by the option chosen to manage the waste materials. Stakeholders are likely to apply large weightings to these aspects in a wider assessment.

4. The greatest sustainable opportunities in terms of both social aspects and material reuse aspects would be associated with options for the redevelopment of the site or development of a nearby site to provide further employment, inward investment and to promote local demand for recycled construction materials. This option is, however, unlikely to be viable unless supported by central Government which is the reason why it was screened out from the assessment because such matters are outside of the direct control of UKAEA.

From a practical point of view, if no new construction is planned on or near the site, and planning constraints require the Dounreay site to be landscaped so as to reinstate its natural flat profile, then the most sustainable use of decommissioning waste resources is likely to involve:

- routine demolition of the inactive buildings followed by industry standard techniques for segregation of ferrous metals and non-inert waste materials from inert concrete and building rubble;
- planned deconstruction and decontamination of the active buildings to segregate slightly radioactive and other radioactive wastes from the radiologically clean and RSA exempt and excluded materials;
- use of the inert radiologically clean concrete and building rubble for site landscaping to avoid the need to use primary aggregate or secondary quarry wastes;
- recycling of the ferrous metals at the closest suitable facility; and
- disposal of the non-inert radiologically clean waste materials (timber, paper etc.) at the closest suitable facility.

Alternative options may be chosen depending on other factors that would affect the business case. These might relate to the implementation of a national strategy and facilities for managing wastes from nuclear sites or the desire to enhance the environmental credentials of the site operator. To a large extent, the decision will need to involve the input of the public and other stakeholders which will require a suitable stakeholder engagement process to be used (see Section 2.5).

3.4 Opportunities for reuse and recycling of slightly radioactive wastes

The estimated inventory of slightly radioactive wastes arising on the Dounreay site is 40,000 m3 of poorly characterised soil and building rubble.

The controlling factor for the reuse and recycling of these slightly radioactive wastes is that they must always remain under regulatory control. Given that the anticipated end-state for the site is remediation to brownfield status with the possible construction of a LLW disposal facility, the broad possibilities for the reuse of slightly radioactive wastes from Dounreay are:

1. incorporation within the structure of the proposed LLW disposal facility at Dounreay and/or within waste packages disposed there; and
2. incorporation within waste packages disposed at another site (e.g. as backfill in ISO sent to the Drigg repository).

Neither of these options could be implemented unless better characterisation and segregation of the materials within the slightly radioactive materials were achieved. It may be assumed that, at the time of arising, it will be possible to segregate the inert material that may be used as aggregate.

The first option may not be feasible for the majority of the slightly radioactive wastes because the anticipated LLW disposal facility is likely to be constructed and be operational before most of the active buildings are due to be decommissioned. In any case, approvals would be required from the regulators who would seek demonstrations that the operational and long-term post-closure safety of the facility is not compromised by the use of slightly radioactive wastes and relevant public and worker dose limits would not be exceeded.

The second option may also be achievable but would require further approvals from the regulators with regard to transport of the waste packages and their disposal at an existing facility. It is expected that these approvals would be more difficult to obtain that in the first option.

A further option is that the segregated slightly radioactive aggregate from Dounreay could be reused on another nuclear site that undergoes decommissioning a later date, providing sufficient time to extract, segregate and process the Dounreay slightly radioactive waste to make it available for reuse elsewhere. Inter-site reuse of slightly radioactive waste would require centralised planning and programming, and the support of the regulators.

If very large volumes of recycled materials from Dounreay were reused elsewhere, then their transport from the site is likely to become an issue for the local community and the impacts of this transport would need to be assessed. The greatest impacts are likely to arise from road transport, although sea transport would be possible between Dounreay and other coastal sites.

3.5 Potential improvements

The single biggest improvement that would enhanced plans for the sustainable use of construction resources arising at Dounreay would be to reduce the uncertainties associated with the inventory of radiological clean, RSA exempt and excluded, and slightly radioactive wastes in terms of their volumes and material content.

At present, the inventory indicates that these waste classes will comprise a mixture of materials such as building rubble and soil. It is not known how readily these materials may be segregated, either by employing planned deconstruction techniques or post-demolition sorting of wastes, to make them suitable for recycling as high utility resources.

It would appear that current plans for the sorting and segregation of the radiological clean, RSA exempt and excluded wastes are predicated on the assumption that they will be used in the main for site landscaping (the current plan) and, therefore, the information recorded in the inventory is designed to ensure that the characteristics of these wastes make them suitable for this use. This information would be inadequate to make quantitative assessments of how viable it would be to process these materials for other uses. That said, the remoteness of Dounreay from the main industrial centres means that it is unlikely that there would be an obvious off site market for high utility recycled materials but a firm conclusion cannot be made without better quality data on which to make an assessment.

Reaching a final decision on disposal routes for solid LLW is likely to influence management decisions for the decommissioning wastes. A decision to build an on site LLW disposal facility at Dounreay would provide opportunities for the use of some recycled aggregate in its construction whilst a decision to transport LLW for disposal at the Drigg repository would provide opportunities for the use of recycled aggregate as backfill in LLW waste packages. In either case, there would be greater sustainable benefits from adopting better sorting and segregation methods so that recycled materials may be used in both LLW waste management options. Similarly, reaching a final decision on the site end-state may also influence management decisions for the decommissioning wastes, particularly with regard to the requirements for materials for landscaping. From a sustainable development perspective, UKAEA is encouraged to move forward with these decisions, although it is recognised that other organisations have an influence on these decisions, including the NDA, the environment agencies and the local planning authority.

Finally, UKAEA is developing an IWS for the Dounreay site. It is important that the sustainability considerations described in this guidance are addressed in that IWS, particularly with regard to public and stakeholder engagement. UKAEA has experience in consulting stakeholders as part of BPEO studies and this experience should be extended to consultations with regard to attitudes on material recycling options.

3.6 Lessons for other UK sites

The Dounreay site differs from most other nuclear sites in terms of its remoteness from centres of industry and population. As a consequence, options to refurbishing buildings for reuse or to recycle decommissioning wastes to generate high utility construction materials are less likely to be sustainable propositions than at other sites. Nonetheless, there are a number of lessons that can be drawn from the Dounreay case study that are directly applicable to other nuclear sites.

In all cases, it is difficult to make firm decisions on the sustainable use of decommissioning wastes based on the current inventory data due to uncertainties that are associated with the volumes, material content, and the ability to segregate those materials. It is understood that better quality inventory information may be included in RWI'04 but it is unlikely that this iteration of the national inventory will contain all the information that is required.

The anticipated use of inert but unsorted CDW for landscaping on most sites would appear to use a considerable proportion of the anticipated decommissioning waste arisings. That said, again the uncertainty in the inventory combined with uncertainty in the site end-states means that it is not possible to perform an accurate mass balance calculation. Most sites would appear to be making decisions to use CDW for landscaping without having undertaken an assessment of this and alternative options, assuming landscaping to be a simple solution but it is not immediately obvious that this represents the most sustainable use of these resources. It is recommended that these sites include this aspect of waste management in their IWS so that landscaping decisions using CDW can be justified.

Most nuclear sites appear to be developing waste management plans in isolation, without making detailed reference to the anticipated waste arisings and material requirements of other sites. There is an obvious opportunity for the NDA to provide centralised planning with regard to the options for inter-site uses of decommissioning wastes and for recycling them for productive use in waste management activities.

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NII, Guidance to Inspectors on Decommissioning on Nuclear Licensed Sites.

SD:SPUR

Sustainable practices in the use of construction resources

Guidance on the application of sustainable practices to the management of decommissioning wastes from nuclear licensed sites

Appendices

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Revised following PSG4 and subsequent comments

sharing knowledge ▪ building best practice

Contents

A	Nuclear site decommissioning plans		1
B	Waste classification and regulations		3
	B1	Radioactive waste classification	3
	B2	Regulations governing radioactive waste management	3
		B2.1 Nuclear Installations Act	4
		B2.2 Radioactive Substances Act	5
		B2.3 Ionising Radiations Regulations	7
		B2.4 Environmental Protection Act	7
C	The inventory of clean, exempt and slightly radioactive waste in the UK		10
D	Reuse and recycling of waste materials		12
	D1	Potential reuse and recycling of clean and excluded wastes	12
	D2	Factors controlling the supply and demand of recycled wastes	14
E	Consultation		16
	E1	Sustainability indicators workshop	16

Abbreviations

ALARP	as low as reasonably practicable
BPEO	best practicable environmental option
BPM	best practicable means
CDW	construction/demolition wastes
CIRIA	Construction Industry Research and Information Agency
DSETF	Decommissioning Safety and Environment Task Force
EA	Environment Agency (of England and Wales)
EPA'90	Environmental Protection Act 1990
HLW	high level waste
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ILW	intermediate level waste
IPC	integrated pollution control
IRR'99	Ionising Radiations Regulations 1999
IWS	integrated waste strategy
LCBL	life cycle base line (plans)
LLW	low level waste
NIA'65	Nuclear Installations Act 1965
NII	Nuclear Installations Inspectorate (of the HSE)
NDA	Nuclear Decommissioning Authority
NPPs	nuclear power plants
NTWP	near term work plans
ODPM	Office of the Deputy Prime Minister
PSRE	Phosphatic and Rare Earths etc. (Exemption Order)
RWMAC	Radioactive Waste Management Advisory Committee
RSA'93	Radioactive Substances Act 1993
SD:SPUR	Site Decommissioning: Sustainable Practices in the Use of Resources
SEPA	Scottish Environment Protection Agency
SITF	Safety Issues Task Force
SoLA	Substances of Low Activity (Exemption Order)
UKAEA	United Kingdom Atomic Energy Authority
VLLW	very-low level waste
VLRM	very low-level radioactive material

A Nuclear site decommissioning plans

Many of the UK's nuclear licensed sites are being decommissioned or are planned to be decommissioned. The nature of decommissioning works will vary from site to site but, in most cases, will involve either the extensive clean out, refurbishment or demolition of buildings and other facilities, and remediation of the land. Large volumes of waste materials will be generated by decommissioning. Some of these materials will be contaminated or activated with radioactivity and must be managed on nuclear licensed sites in accordance with the requirements of Nuclear Installations Act 1965 (NIA'65) and disposed of in accordance with the requirements of Radioactive Substances Act 1993 (RSA'93). Substantial volumes will, however, contain no artificial radioactivity or levels of radioactivity that are so low they can be treated in the same manner as convention wastes. It should be noted, however, that once material has been declared as radioactive waste, it must always be designated so, but its treatment should be appropriate to the hazard it poses. Further information on waste types and regulations is provided in Appendix B.

It is a requirement of Government radioactive waste management policy [Cm 2919] that the operators of nuclear sites establish strategies for the decommissioning of their sites, and strategies for the management of decommissioning wastes. Such strategies have been produced for all nuclear sites and these are at various stages of development. As required under Cm 2919, the Nuclear Installations Inspectorate (NII) has reviewed these strategies, in consultation with the environment agencies, and the results of these reviews are published on the Health and Safety Executive (HSE) website. A common theme running through many of these reviews was the need to develop the strategies for the large volumes of radiologically clean and slightly radioactive decommissioning wastes.

There is a now a requirement, for those sites within the remit of the Nuclear Decommissioning Authority (NDA), for the production of Life Cycle Base Line (LCBL) plans and Near Term Work Plans (NTWP). The LCBLs set out the work required for the decommissioning of the sites in the longer term, whereas the NTWPs identify the detailed work to be done in the next few years. It will be NDA's responsibility to consolidate the overall LCBLs into an overall national plan for the NDA sites that will outline the work needed to be undertaken to achieve decommissioning and remediation using best practice and value for money for the tax payer.

Discussions are also under way between the NDA, the regulators and the site operators concerning the further development of the existing radioactive waste management strategies, and in particular to encourage further integration of them. A working definition of an Integrated Waste Strategy (IWS) has been agreed which takes account of the need for such strategies to be based on a suitable balance of all relevant factors, which include safety, environmental and security considerations, as well as stakeholder views. A specification for IWS is being developed, which covers all waste types, including the large volumes of clean, RSA exempt and slightly radioactive wastes resulting from decommissioning.

An IWS will be a plan to ensure that waste management approaches are both optimised and applied consistently across a site (or multiple sites) to all actual and potential sources of waste, both radioactive and non-radioactive, as well as materials that may become waste in the future. It will need to address what wastes are disposed of to the environment, what wastes are required to be stored, as well as waste minimisation issues. Both on-site and off-site considerations will be addressed in an IWS, and this will require a site to take best advantage of existing waste management facilities elsewhere in the UK. Specifically, when formulating an IWS, a site will need to develop policies and strategies, including principles, that explain how they will manage their wastes so that:

– wastes are stored and treated in processes that are consistent with the ALARP principle ('as low as reasonably practicable');
– any disposals represent the best practicable environmental option (BPEO) with associated best practicable means (BPM) abatement and monitoring arrangements;
– decommissioning plans are prioritised with respect to safety, health and the environment;
– the operator can demonstrate compliance with regulatory requirements; and
– that all of the above is to the satisfaction of the stakeholders.

The environment agencies will consider an IWS to be *optimised* when it is the outcome of a systematic and consultative decision-making process that has considered a range of options and their practicability. It is anticipated that a strategic BPEO study would be required to identify an optimised strategy and to ensure that options for waste minimisation, and waste reuse and recycling are given precedence over options for waste disposal.

The need to develop an acceptable management route for waste materials is also recognised in the NDA Strategic Issues Register, which covers those high-level strategic issues requiring resolution and which could have a significant impact on site operators' strategies. Such issues will be taken forward by co-operative working between the NDA, the regulators and the site operators, in consultation with other stakeholders where appropriate. Specific requirements for the developments of these strategies will be included in future NTWPs and LCBLs as appropriate.

The existing plans and strategies set out the timescales over which decommissioning is expected to be undertaken. The anticipated timescales for site decommissioning vary from site to site, and depend on a number of factors including the dates when operating facilities are expected to close and the complexity of the clean-up operations. The anticipated timescales for decommissioning range from a few years after the shutdown for some sites, to several decades into the future for the more complex sites. Various assumptions are made in the existing plans and strategies concerning the site decommissioning end states. The Government envisages that the future use of a site could be a significant factor in determining the extent of decommissioning operations, and that the potential uses could range from industrial and commercial use to unrestricted use. The Government expects operators to discuss the potential uses with the local planning authority, the regulators, and local and public stakeholder groups.

Decommissioning and waste management strategies and plans are subject to regular review and update to take account of new developments in technology, Government policy, regulatory requirements, improved waste characterisation, future land use, and stakeholder views etc. The current timescales, assumed end states and waste predictions should therefore only be regarded as estimates.

References

Review of Radioactive Waste Management Policy: Final Conclusions (Cm2919). HMSO. July 1995.

Further information on Government policy on decommissioning can be found at:
http://www.dti.gov.uk/nuclearcleanup/index.htm

Further information on the NDA can be found at:
http://www.nda.gov.uk/

B Waste classification and regulations

B1 Radioactive waste classification

In the UK, solid radioactive waste types are categorised as follows.

1. **High-level waste (HLW).** This waste has a high radioactivity content which makes it heat generating. Most of this waste has accumulated since the early 1950s at Sellafield and Dounreay, primarily from the reprocessing of spent nuclear fuel. This waste type is not considered further in this report.

2. **Intermediate-level waste (ILW).** This waste has a radioactivity content exceeding 4 GBq/tonne alpha or 12 GBq/tonne tonne of beta/gamma activity but which is not heat generating. It arises mainly from the reprocessing of spent fuel, and from general operations, maintenance and decommissioning of nuclear facilities. This waste type is not considered further in this report.

3. **Low-level waste (LLW).** This waste has a radioactivity content below the lower limit for ILW. It arises mainly from contamination of equipment, clothing and cleaning materials during routine operations and maintenance of nuclear facilities, and during decommissioning. The waste can be chemically and materially heterogeneous, and includes a wide range of materials such as metal, soils, building rubble and miscellaneous scrap. There is no formal lower threshold for LLW but in practice many would regard it to be 0.4 Bq/g which is the level laid down in the Substances of Low Activity (SoLA) Exemption Order issued under RSA'93 (see Appendix B2).

4. **Very-low level waste (VLLW).** This waste is a subset of LLW and is uniquely defined in terms of activity and volume because it is intended to cover small volumes of low-activity wastes that may be disposed of with ordinary refuse. It is defined as each 0.1m3 containing less than 400 kBq of beta/gamma activity or single items containing less than 40 kBq of beta/gamma activity.

A further category of radioactive waste, provisionally termed Very Low-level Radioactive Material (VLRM), has been suggested for the large volumes of low-activity radioactive waste arising from decommissioning with a radioactivity content not exceeding 40 Bq/g of beta/gamma activity and 1-2 Bq/g of alpha activity, and excluding all organic material. It has been further suggested that these wastes, following an application from a site operator, could be disposed by on-site controlled burial to minimise the impact on the Drigg repository. This suggestion has not been put to regulators for approval but has been recommended for further consideration by the Radioactive Waste Management Advisory Committee [RWMAC, 2003].

In addition to the radioactive wastes, there are wastes that are radiologically clean. These are wastes which may be similar in terms of material and composition to LLW but which have either never been contaminated or by analysis has been shown to be not contaminated or are wastes complying with Schedule 1 of RSA'93 (see Appendix B2).

B2 Regulations governing radioactive waste management

Any reuse or recycling of decommissioning wastes on or from a nuclear licensed site must conform with the appropriate health and safety and environmental regulatory requirements, The primary legislative Acts that control the potential for reuse and recycling of radioactive decommissioning wastes are the Nuclear Installations Act 1965 (as amended) and the Radioactive Substances Act and for non-radioactive decommissioning wastes it is the Environmental Protection Act with its associated regulations.

The management of all radioactive waste arising on a nuclear site will be subject to the requirements of the NIA'65 and any disposal of radioactive waste from nuclear licensed sites requires prior authorisation under RSA'93 unless it can be demonstrated to the satisfaction of the environment agencies that the wastes are radiologically clean or excluded. Determining whether a waste may be released from further controls under RSA'93 is on the basis of whether the activity is below exclusion or exempt levels (see below). This concept is widely referred to as *free release* but a better term is *controlled clearance* because it reflects the strict regulatory controls governing the process. There are a number of terms that are used in relation to controlled clearance which are important in the context of the potential reuse and recycling of waste materials and, to avoid ambiguity, these are defined here.

- ***Clean:*** An article or substance which has had no reasonable potential to have become contaminated or activated, or upon or within which no radioactivity other than normal background is detectable when suitable comprehensive measurement (monitoring and sampling) is practicable and has been undertaken.

- ***Clearance:*** The process to confirm that an article or substance is clean (free from radioactivity), or excluded or exempt from further control under all relevant legislation on the basis of its radioactivity.

- ***Excluded:*** An article or substance that is not radioactive under RSA'93 and not subject to any control under the Act because it does not contain levels of any of the specified radioelements above the limits in Schedule 1 of RSA'93 or any non-specified radioelements at levels above normal backgrounds.

- ***RSA exempt:*** An article or substance that is radioactive or contaminated under the RSA'93 because it contains levels of specified radioelements above RSA'93 Schedule 1 exclusion limits or because it contains other radioelements wholly or partly attributable to either an artificial process or as a result of the disposal of radioactive waste, but in both cases at levels below relevant limits in Exemption Orders under the Act. An RSA'93 exempt article or substance may be subject to control as radioactive under other legislation.

B2.1 Nuclear Installations Act

The main legislation governing the safety of nuclear installations in the UK is the Health and Safety at Work etc. Act 1974 and the associated relevant statutory provisions of the Nuclear Installations Act 1965 (as amended) (NIA'65). Under NIA'65 no person may use any site for the purposes of installing or operating a nuclear installation unless a licence to do so has been granted by the HSE and is in force. NIA'65 enables HSE to attach conditions to the nuclear site licence in the interests of safety, or which HSE think fit, with respect to the handling, treatment of nuclear materials (which includes radioactive waste). Once a license has been issued, the licensee's period of responsibility and the provisions of NIA'65 continue to apply throughout operation and decommissioning until, in the opinion of HSE, there has ceased to be any danger from ionising radiations from anything on the site. HSE has delegated its roles under NIA'65 to the NII.

The assessment of what constitutes 'no danger' is not a straightforward matter, particularly if radioactive contamination remains. HSE has recently undertaken a public consultation on the criteria for delicensing nuclear licensed sites, the outcome of which is currently being considered [HSE, 2002]. Any option for the management of slightly radioactive decommissioning wastes which involves the reuse, storage, accumulation, treatment etc. of such material on a nuclear licensed site must take account of the eventual end point for the site, including any requirement for delicensing.

There are 36 standard Licence Conditions associated with nuclear site licences, and they apply to activities involving the management of radioactive waste. The Licence Conditions are non-prescriptive, and most require the licensee to make and implement adequate arrangements for compliance. NII expects these arrangements to be proportionate taking account of the hazard. Some of the Licence Conditions are of particular relevance to the management of radioactive waste and these include:

Licence Condition 4: Restrictions on nuclear matter on the site. The purpose of this licence condition is to ensure that the licensee carries out its responsibilities to control the introduction and storage of nuclear matter (which includes radioactive waste) on a site.

Licence Condition 6: Documents, records, authorities and certificates. The purpose of this is to ensure that adequate records are held by the licensee for a suitable period to demonstrate compliance with licence conditions.

Licence Condition 14. Safety documentation. The purpose of this licence condition is to ensure that the licensee sets up arrangements for the preparation of safety related documentation comprising 'safety cases' to ensure that the licensee justifies safety during design, construction, manufacture, commissioning, operation, and decommissioning.

Licence Condition 25. Operational records. The purpose of this licence condition is to ensure that adequate records are kept regarding operation, inspection, and maintenance of any safety-related plant and includes recording the amount of all radioactive material, including radioactive waste.

Licence Condition 32. Accumulation of radioactive waste. The purpose of this licence condition is to ensure that the production rate and accumulation of radioactive waste on the site is minimised, held under suitable storage arrangements, and that adequate records are made.

Licence Condition 33. Disposal of radioactive waste. The purpose of this licence conditions is to give discretionary powers to NII to direct that radioactive waste be disposed of in a specified manner. This is related to the similar powers available to the environment agencies under RSA'93. Such disposals will need to in accordance with the authorisations granted under RSA'93.

Licence Condition 34. Leakage and escape of radioactive material and radioactive waste. The purpose of this licence condition is to ensure, so far as reasonably practicable, that radioactive material and radioactive waste is adequately controlled or contained so as to prevent leaks or escapes, and that any unauthorised leak or escape can be detected and reported.

Licence Condition 35. Decommissioning. The purpose of this licence condition is to require the licensee to make adequate provisions for decommissioning, including the production of decommissioning programmes. It also gives discretionary powers to NII to direct that decommissioning of any plant or process be commenced in accordance with the programme or halted.

Requirements for the radiological protection of workers and the public are contained in the Ionising Radiation Regulations 1999 (IRR'99), which are enforced on nuclear licensed sites by NII.

B2.2 Radioactive Substances Act

The Radioactive Substances Act 1993 (RSA'93) sets out the regime which, on nuclear licensed sites, controls the disposal of radioactive waste. It is a consolidation of the Radioactive Substances Act 1960 (RSA'60) which was amended by the Environmental Protection Act 1990 (EPA'90). The purpose of the consolidation was to restructure the provisions of RSA'60 in such a way as to reflect and clarify Parliaments intentions more accurately. RSA'93 reflects the recommendations and objectives published in the White Paper *The control of radioactive waste* (Cmnd 884).

Section 57 of RSA'93 defines a *waste* generally as:

> *including any substance which constitutes scrap material or an effluent or other unwanted surplus substance arising from the application of any process, and also includes any substance or article which requires to be disposed of as being broken, worn out, contaminated or otherwise spoilt*.

More specifically, Section 2 of RSA'93 defines *radioactive waste* as:

> *waste which consists wholly or partly of (a) a substance or article which, if it were not waste, would be radioactive material, or (b) a substance or article which has been contaminated in the course if the production, keeping or use of radioactive material, or by contact with or proximity to other waste falling within paragraph (a) or this paragraph.*

This definition refers to the *radioactive material* which is defined in Section 1 of RSA'93 as:

> *(1) anything which, not being waste, is either a substance to which this subsection applies or an article made wholly or partly from, or incorporating, such a substance.*
> *(2) Subsection (1) applies to any substance falling within either or both of the following descriptions, that is to say:*
>> *(a) a substance containing an element specified in the first column of Schedule 1, in such a proportion the number of becquerels of that element contained in the substance, divided by the number of grams which the substance weighs, is a number greater than that specified in relation to that element in the appropriate column of that schedule:*
>> *(b) a substance possessing radioactivity which is wholly or partly attributable to a process of nuclear fission or other process of subjecting a substance to bombardment by neutrons or to ionising radiations, not being a process occurring in the course of nature, or in consequence of the disposal of radioactive waste, or by way of contamination in the course of the application of a process to some other substance.'*

In effect, this means that a material is radioactive for regulatory purposes if it contains any of the naturally-occurring elements specified in Schedule 1 (see Table B.1) at concentrations higher than specified activity levels or if it contains any artificial radionuclides at any concentration.

Table B.1 *Schedule 1 from RSA'93. The specified elements and their limiting specific activities.*

Element	Becquerels per gram (Bq/g)		
	Solid	Liquid	Gas or vapour
Actinium	0.37	7.40×10^{-2}	2.59×10^{-6}
Lead	0.74	3.70×10^{-3}	1.11×10^{-4}
Polonium	0.37	2.59×10^{-2}	2.22×10^{-4}
Protoactinium	0.37	3.33×10^{-2}	1.11×10^{-6}
Radium	0.37	3.70×10^{-4}	3.70×10^{-5}
Radon	-	-	3.70×10^{-2}
Thorium	2.59	3.70×10^{-2}	2.22×10^{-2}
Uranium	11.1	0.74	7.40×10^{-5}

Section 13 of RSA'93 requires the disposal of radioactive waste to be carried out in accordance with an Authorisation granted by the competent authorities which are The Environment Agency (EA) in England and Wales, and the Scottish Environment Protection Agency (SEPA) in Scotland. Section 15 of RSA'93 allows, however, the Secretary of State or Scottish Ministers to exclude particular descriptions of radioactive waste from any provisions, whether absolutely or subject to limitations or conditions. This is done by way of Exemption Orders and a suite of Exemption Orders has been defined but only two are likely to apply to decommissioning wastes, these are:

1. The ***Radioactive Substances (Substances of Low Activity) Exemption Order 1986*** (the SoLA Exemption Order) which exempts waste of certain types from the requirements for an authorisation to dispose radioactive waste under Section 13 of the Act. This order exempts activity which is substantially insoluble in water the activity of which when it became waste does not exceed 0.4 Bq/g. This order was amended in 1992 but the amendment relates to organic liquid radioactive waste and is unlikely to be relevant to this project.

2. The ***Radioactive Substances (Phosphatic and Rare Earths etc.) Exemption Order 1962*** (the PSRE Exemption Order) which exempts material that is radioactive solely because of the presence of one or more of the Schedule 1 elements and is substantially insoluble in water provided that the specific activity of each of the Schedule 1 elements present does not exceed 14.8 Bq/g (expressed in the Exemption Order as 4E-4 mCi/g). This exemption includes waste disposal and is particularly relevant to wastes arising from operations involving naturally occurring radionuclides.

These Exemption Orders mean that materials to which they apply are exempt from the regulatory requirements for their keeping and use, and wastes to which they apply are exempt from the regulatory requirements for disposal under RSA'93. The SoLA Exemption Order is most relevant to waste and materials that contain artificial radionuclides whilst the PSRE Exemption Order is most relevant to waste and materials that contain naturally-occurring radionuclides.

Further guidance on the limits given in RSA'93 and the SoLA and PSRE Exemption Orders were provided by DETR [DETR, 2000] and EA [EA, 2002] in relation to the interpretation of the limits which are specified in Schedule 1 of RSA'93 in terms of *elements* when the actual measured activities are due to *radionuclides* within decay chains. The accepted practice is that, for the SoLA Exemption Order, only the longer-lived nuclides of the specified elements need be considered when comparing their activities with the Exemption Order limits. In contrast, for the PSRE Exemption Order, the limits refer to the sum of radioactivity concentrations of all the radionuclides for each specified element, and secular equilibrium is usually assumed. When considering activities for elements not specified in Schedule 1 or the Exemption Orders, all radionuclides must be considered when establishing compliance.

Conditions of Authorisation

The direct responsibility of the environment agencies in relation to the management of radioactive waste on nuclear licensed sites is in granting Authorisations for discharges and disposals under RSA'93, subject to appropriate limitations and conditions. One of the regulatory requirements of the environment agencies is for operators to adopt the best practicable environmental option (BPEO) when managing their radioactive wastes. A standard condition in radioactive waste disposal authorisations requires best practicable means (BPM) to be used to minimise the activity of wastes disposed and the radiological effects of those disposals. Clause 2(1)(a) of the Basic Safety Standards Direction 2000 states that:

> *In discharging its functions in relation to the disposal of radioactive waste under the Radioactive Substances Act 1993, the Agencies shall, wherever applicable, ensure that … all exposures to ionizing radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.*

The environment agencies meet these requirements by, among other things, ensuring that the BPEO is taken into account when choosing the radioactive waste strategies adopted at nuclear sites. The environment agencies have issued guidance on BPEO [EA-SEPA, 2004] and contributed to an advice note on BPM [Miller, 2005] that make it clear that both BPEO and BPM must be applied to ensure that radioactive wastes are not generated unnecessarily and that those arisings that do occur are either reused or recycled in preference to being disposed. Similar requirements are contained in NII's internal guidance for the management of radioactive waste which is based on IAEA standards [NII, 2001].

There is no similar requirement on site operators to undertake a BPEO to support management decisions for non-radioactive wastes but the environment agencies now increasingly expect proposals for any large scale plan and programme to be supported by some form of environmental assessment. To ensure, however, that operators of nuclear sites apply consistent approaches to environmental protection in relation to both radioactive and non-radioactive wastes, the environment agencies are planning to include a new standard condition in Authorisations that will require the operator to submit an IWS. The requirement on site operators to develop an IWS that covers both radioactive and non-radioactive wastes suggests that a BPEO-type approach would necessarily need to be applied to all wastes to underpin the IWS.

B2.3 Ionising Radiations Regulations

The Ionising Radiations Regulations 1999 (IRR'99) impose duties on operators to protect their workers and the public against ionising radiation arising from work involving radiation and radioactive materials, and address the need to minimise, contain and control radioactivity and contamination.

IRR'99 adopts a different definition of radioactive material than RSA'93 and uses the definition of a radioactive substance as one *which contains one or more radionuclides whose activity cannot be disregarded for the purposes of radiation protection*.

The regulations also require the NII to be notified of any work that would take place outside of a nuclear site that involves any radionuclide specified in Schedule 8 of IRR'99 that exceed certain bulk radioactivity concentrations. In some cases, these concentrations are lower than those specified in Schedule 1 of RSA'93 and most are considerably lower than the PSRE Exemption Order limit of 14.8 Bq/g. This implies that even when a waste material may be exempt from regulatory control under RSA'93 and reuse or recycling applications that occur off-site may remain subject to regulation under IRR'99.

B2.4 Environmental Protection Act

The Environmental Protection Act 1990 (EPA'90) defines and contains provisions for controls on *controlled waste* under Part II, notably Section 33 (Prohibition of unauthorised treatment or disposal) and Section 34 (Duty of care). The Act prohibits the unlicensed management or disposal of waste and requires that a waste management licensing system is established.

Various regulations apply under EPA'90 to the management and disposal of wastes that are demonstrated to be radiologically clean, RSA excluded or exempt. Which set of regulations apply depends, in part, on the physical and chemical properties of the waste, its potential for causing harm to the environment, and the manner in which the waste is planned to be disposed. The relevant regulations in terms of the reuse and recycling of decommissioning wastes are:

- Waste Management Licensing Regulations 1994 (WML Regulations) which sets-out the waste management licensing regime and related provisions required under EPA'90.
- Special Waste Regulations 1996 which place additional controls on certain controlled wastes with specific hazardous properties, which are known as *special wastes*.

- Controlled Waste Regulations 1992
- Waste Management Regulations 1994
- Landfill Regulations 2002

Decommissioning waste which is *exempt* under any of the Exemption Orders associated with RSA'93 remains radioactive for the purposes of regulation provided that it is not excluded by Schedule 1 of RSA'93. This RSA exempt waste is not, therefore, subject to the WML Regulations but if it has other hazardous properties (e.g. radioactively contaminated asbestos) then it is good industry practice to treat it as if it were *special waste*, although this is not mandatory under legislation

Decommissioning waste which is *clean* or *excluded* is not radioactive for the purposes of regulation and is subject to control as a controlled or special waste according to its other properties and is subject to the WML Regulations. The WML Regulations define a waste as either:

- discarded, disposed or got rid of by the holder, or
- intended to be discarded, disposed or got rid of by the holder, or
- required to be discarded, disposed or got rid of by the holder.

Schedule 3 of the WML Regulations lists activities which are exempt from waste management licensing.

- ***Waste for the benefit of land*** Wastes which are permitted to be spread on agricultural land include waste food, drink, lime, gypsum etc. None of these specified wastes would, however, routinely be produced during decommissioning of nuclear sites. Other wastes which may be used for the benefit of agriculture or for ecological improvement is limited to waste soil, compost, wood, bark or other plant matter for certain categories of land e.g. forest, woodland, garden, verge, landscaped area, sports ground etc. Of interest here is the exemption of waste soil for landscaping as long as a benefit can be demonstrated.

  Land reclamation The spreading of waste consisting of soil, rock, ash or waste arising from construction or demolition work may be deposited on land in connection with the reclamation or improvement of that land so long as it can be demonstrated that (i) the land would be unusable for industrial or other development without treatment, (ii) spreading of the waste is done in accordance with planning permission for land reclamation or improvement, and (iii) no more than 20,000 m3 per hectare of these wastes may be spread within the terms of the exemption. In Scotland for this exemption, SEPA also impose a 2m maximum height for the spreading of waste for the purposes of land reclamation.

- ***Construction and soil materials*** An exemption applies to the manufacture of specified materials from specified wastes, all of which are related to construction. The specified wastes include (i) waste arising from demolition, construction work, tunnelling and other excavations, and (ii) waste which consists of ash, slag, clinker, rock, wood, bark, paper, straw or gypsum. The construction materials which may be made from such wastes are timber products, straw board, plasterboard, bricks, blocks, roadstone or aggregate.

  The manufacture of soil or soil substitutes from specified wastes must occur either at the place where the waste is produced or where it is to be applied to the land, and the quantity manufactured must not exceed 500 tonnes per day. In the case of waste soil or rock the waste is only exempt if it is spread onto land under the terns of an exemption for beneficial use or land reclamation and this must occur at either the place where the waste is produced or where it is to be applied to land, and must not exceed 100 tonnes per day.

  In terms of storage, the exemption allows storage only where the exempted activity takes place. For the manufacture of roadstone, no more than 50,000 tonnes can be stored at any one time and for all other specified wastes no more than 20,000 tonnes can be stored at any one time.

There are significant charges associated with disposals and exemptions under the WML Regulations. These are rated according to the amount of material that is to be handled and need to be brought into the cost/benefit calculations by a site operator when determining how to handle particular wastes streams.

References

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NII (2001) Guidance for Inspectors on the Management of Radioactive Material and Radioactive Waste on Nuclear Licensed Sites. Unnumbered HSE report.

RWMAC (2003) Advice to Ministers on management of low activity solid radioactive waste within the United Kingdom. Unnumbered report, March 2003.

C The inventory of clean, exempt and slightly radioactive waste in the UK

Materials defined as radioactive wastes in the UK are listed in the United Kingdom Radioactive Waste Inventory (RWI). This records the quantities, origins and characteristics of radioactive wastes, both those currently managed and those predicted to arise. It is updated at three-yearly intervals, with the current version (RWI'01) published at the end of 2002 with a reference date of 1st April 2001. A new version (RWI'04) is currently in preparation and is likely to be published towards the end of 2005. At the time of writing (spring 2005) the nuclear sites are in the process of preparing data for submission to RWI'04. The current version (RWI'01) only includes data for materials that are declared as radioactive wastes and are not subject to an Exemption Order. Thus, it does not contain any information on the arising of radiologically clean wastes, and RSA'93 excluded and exempt wastes. Although RWI'01 does include information on LLW, it does not recognise slightly radioactive wastes as a separate waste type.

RWMAC previously reviewed current policy on the management of low activity solid radioactive wastes within the UK [RWMAC, 2003a] and, in a separate review, examined the RWI [RWMAC, 2003b]. From these reviews, RWMAC made a number of important observations and recommendations of relevance to this project. One key observation was the RWI probably significantly underestimates the volumes of low activity wastes that need to be managed because many future arisings have either not yet been identified or have not yet been classified to be radioactive.

As part of the SD:SPUR project, questionnaires were sent to nuclear site operators requesting additional information on their current and predicted future arisings of materials they classify as radiologically clean, RSA exempt and slightly radioactive wastes. Responses were received from some operators but not all and some operators were unable to provide information because they are still developing their own datasets. It is evident that there remains considerable uncertainty about the actual magnitude of both radiologically clean and slightly radioactive waste arisings from nuclear sites, although the uncertainty associated with the radiologically clean wastes is the greater, partly because there is no regulatory requirement for data on these wastes to be collated in the RWI or any other database.

On the basis of the information collected, the volume of wastes that will arise across all of the decommissioning nuclear sites in the UK is in the region of:

- 1,50,000 m3 of radiologically clean, and RSA exempt and excluded wastes; and
- 1,500,000 m3 of slightly radioactive wastes.

Due to the uncertainties described above, however, these volumes should be viewed only as order of magnitude approximations. Best estimates of the waste arisings for some individual sites and operators are given in Table C.1.

Table C.1 *Estimates of the inventory of radiologically clean, RSA exempt and slightly radioactive waste arisings for some individual nuclear sites and site operators. * At Sellafield an additional 2,000,000 m3 of contaminated land and waste from existing landfills is also recorded in RWMAC [2003a].*

Site/operator	Volume of clean and RSA exempt waste (m^3)	Volume of slightly radioactive waste (m^3)
Dounreay	144,000	40,000 – 50,000
Harwell	200,000	52,000
Winfrith	50,000 – 100,000	10,000 – 15,000
Culham	No data	1000 – 2000
Windscale	12,000	15,000
Sellafield	> 1,000,000	> 1,100,000*
Magnox sites	No data	10,000 – 50,000
AWE	No data	>122,000

To place these volumes into context, RWI'01 records current holdings of LLW of 15,700 m3 and predicted future arisings of 1,490,000 m3. Comparing the arisings information collected in this project with data from RWI'01 would suggest that the vast majority of waste would fall into the lower order of magnitude of the activity range covered by LLW.

These arisings can also be compared to the amount of conventional construction/demolition wastes (CDW) generated in England and Wales in 2003 which were around 36 million m3 (90.37 million tonnes) and the production of recycled aggregates in the same year of around 16 million m3 [ODPM, 2004] as discussed in Appendix D. Clearly the amount of decommissioning wastes arising from the UK nuclear sites is a small fraction of the total demolition wastes arising from the construction sector. They pose a disproportionately large problem, however, because of the limited current opportunities for the disposal of radioactive wastes with the remaining volumetric capacity of the LLW repository at Drigg being only around 800,000 m3 and because of the public reluctance to adopt recycled radiologically clean materials.

In addition to total volumes, information was also sought on the types of material that comprise the waste. RWI'01 provides some information on the composition of the LLW arisings for each of the nuclear sites but does not separately record this information for slightly radioactive wastes and provides no information on radiologically clean, RSA exempt and excluded wastes. Inspection of the LLW data in RWI'01 shows that the materials arising at each site are broadly the same with the major material components reported being concrete, building rubble, ferrous metals and soil, with lesser amounts of non-ferrous metals, wood, plastics, rubber etc. Some of the sites that responded to the questionnaire were able to provide a breakdown of the component materials in the different waste types, and this information is summarised in Table C.2.

Table C.2 *Estimates of the proportions of different material types arising on nuclear sites in certain waste classes. *Note, Dounreay slightly radioactive waste is reported to comprise rubble plus soil.*

Waste class/material	Harwell (%)	Culham (%)	Windscale (%)	Dounreay (%)
Clean and exempt:				
- concrete (excluding rubble)	25	75	70	
- demolition rubble	72			64
- bricks		3	5	15
- steel/stainless steel	3	14	25	
- soil				20
- glass		0.3		
- non-ferrous metals		2		
- timber		3		
- plastics		2		
- road pavement		0.4		
- asphalt				1
- other		0.3		
Slightly radioactive:				
- concrete (excluding rubble)	2		38	
- demolition rubble	2			100*
- bricks			3	
- steel/stainless steel			14	
- soil	96		45	

The relative proportions reported of the major components (concrete, building rubble, ferrous metals and soil) clearly vary between sites and this is likely to be due to the different nature of buildings and facilities on the different sites and plans for their decommissioning. A large part of this apparent variation, however, is also likely to be due to the different approaches the sites take to waste classification and reporting.

References

ODPM (2004) Survey of Arisings and Use of Construction, Demolition and Excavation Waste as Aggregate in England in 2003. Unnumbered report.

RWMAC (2003a) Advice to Ministers on management of low activity solid radioactive waste within the United Kingdom. Unnumbered report, March 2003.

RWMAC (2003b) Advice to Ministers on the United Kingdom Radioactive Waste Inventory. Unnumbered report, March 2003.

D Reuse and recycling of waste materials

D.1 Potential reuse and recycling of clean and excluded wastes

Waste is defined in the Waste Framework Directive (75/442/EEC as amended by 91/156/EEC) as any substance or object that the holder discards, intends to discard or is required to discard. As a result of European and national case law over the last few years, the circumstances under which a substance or object may be said to have been discarded have broadened considerably. Furthermore, it is considered that once a substance or object has become waste, it will remain waste until it has been fully recovered and it no longer poses a potential threat to the environment or human health.

The Waste and Resources Action Programme (WRAP) has developed a protocol for the production of aggregates from inert waste that addresses some of the difficulties in the interpretation and application of the Waste Framework Directive [WRAP, 2004]. The purpose of the Quality Protocol is to provide a uniform control process for producers from which they can reasonably state and demonstrate that their product has been fully recovered and is no longer a waste. This protocol is particular relevant to the sustainable reuse and recycling of decommissioning wastes from nuclear sites.

In general, the clean and excluded decommissioning wastes arising from a nuclear site are similar in material characteristics to those wastes that arise from any other construction or demolition project and, therefore, the potential applications to which these materials may be put are essentially the same.

The construction industry is experienced in the reuse and recycling of CDW, and approximately 90 % of all CDW is now beneficially reused in some form or other. In most cases, CDW is processed for use in low grade applications (e.g. as low performance aggregate) displacing certain primary raw materials, although considerable attention is being given to better processing of demolition wastes to allow them to be used in higher grade applications. Recent estimates of CDW arisings and reuse applications in England are summarised in Table D.1.

Various services are available to waste producers and recyclers to ensure that materials are processed to achieve appropriate quality standards. AggRegain is a free web based sustainable aggregates information service provided by the WRAP Aggregates Programme http://www.aggregain.org.uk/. It is designed to assist with the specification of recycled and secondary aggregates and is an important input to the development of plans for the sustainable reuse and recycling of decommissioning wastes from nuclear sites.

Table D.1 *Summary of the extent of reuse and recycling of CDW in England from the conventional construction industry [ODPM, 2004a].*

Uses and applications of CDW	Amounts ('000 tonnes)	% of total
Total production of hard CDW and excavation waste	90,932	100
Amount recycled as aggregate or soil	45,448	50
Amount used for landfill engineering or restoration	6,454	7
Amount used to back-fill quarry voids	13,410	15
Amount used at registered exempt sites	16,429	18
Amount disposed of at landfills	9,192	10

The reuse and recycling of demolition wastes arising on nuclear sites is generally not so well advanced as for conventional sites but, in general, the same level of material recovery, segregation, processing and reuse should be achievable for all radiologically free waste materials.

CDW and individual segregated materials are sometimes categorised as either high volume, low value materials and as high value materials. Although this distinction is crude and does not apply equally to all waste arisings or all regions, it is a useful rule-of-thumb because different opportunities for reuse apply to the two types of material, driven by the economics of supply and demand. The typical types of reuse applications to which these categories may be put are summarised in Tables D2 and D3.

Table D2 *Typical reuse applications for high volume, low value materials.*

Source	Potential applications	Current recycling/disposal practices
Aggregate	Crushed used as bulk filler, haul roads and an alternative to virgin aggregate.	Currently approximately 50% of demolition material is recycled as aggregate, 40% is otherwise beneficially reused and the remainder is sent to landfill for disposal.
Excavation soil	Reprofiling of land, reclamation of quarries/ borrow pits.	There is a low demand for waste soil unless it is of high nutrient demand and off use in agricultural improvement or landscape gardening. Currently almost all topsoil is used for on site applications such as landscaping or ground raising.
Road planings	Reprocessed for re-use on or offsite for construction or repair of roads.	There is a variable local demand for road planings, which is dependant on the waste arising at a time of road construction or maintenance taking place within an economic transport distance of the demolition site.
Timber	Re-used around the site for applications such as fencing or sent to be processed in to chipboard.	Currently an unknown percentage of timber from building demolition is recycled and the remainder is sent to landfill as controlled waste.
Concrete	Crushed into aggregate, bulk filler, haul roads or alternative to virgin aggregate.	Approximately 90% concrete from building demolition is beneficially reused.

Table D3 *Typical reuse applications for high value materials.*

Source	Potential applications	Current recycling/disposal practices
Reclaimed bricks and blocks	Brick and block work from old buildings is in demand for restoration work and new buildings in areas of conservation. Such material is also used for fireplaces and other interior work.	There is a high demand for certain types of bricks and blockwork typically those of rarer stone types such as granite. Currently only a small percentage of brickwork from building demolition is recycled and the remainder is sent to landfill as controlled waste or crushed prior to re-use as aggregate.
Steel	Send off site for recycling.	Steel can be readily segregated from other demolition wastes and currently almost all waste steel is recycled due to the high demand and market value of the material.
Plastics	Remould into an alternative use by a specialist re-processor such as fences, piling, slates or alike.	Plastic recycling is in its infancy at the moment, processes are likely to be refined and new applications developed in coming years.
Glass	Likely to be sent off site for specialist reprocessing i.e. separation of component parts, use in concrete as an aggregate replacement, filter material etc. Alternative use for recycled glass are still being developed.	Currently an unknown percentage of window pane glass from building demolition is recycled. The majority of recycled glass comes from bottles and glass containers.
Non-ferrous	Sold and sent to scrap metal	Currently an unknown percentage of waste

Source	Potential applications	Current recycling/disposal practices
metal (Al, Cu, Zn, Pb)	merchants or fed directly back into the production stream were they form part of new metal products.	non-ferrous metals from building is recycled and the remainder is sent to landfill as controlled waste.

D2 Factors controlling the supply and demand of recycled wastes

A number of factors will influence the potential for reuse or recycling of CDW and decommissioning wastes from nuclear sites. The most important of these are outlined below:

Production and processing costs: the cost of preparing the waste materials for reuse needs to be balanced against the potential value of the resulting product. In many cases, perfectly good and valuable recycled concrete aggregate has been contaminated with soil and brick rubble, rendering it fit only for use as foundation material, which is inherently less valuable.

Added value processing: as well as ensuring that the waste materials are appropriately segregated for use, it is also important, where feasible, to add value to the recycled materials. Where recycled concrete aggregate is available, more value can in some cases be added to the materials before they leave the site by making concrete blocks or other concrete products. A higher value achieved at the site means that the catchments area within which the material remains economically viable is greater. It would be possible for a local contractor to undertake the processing on behalf of the site, rather than the site being involved in making products. It is also possible to let contracts to construction companies focussing on the basis of realising the inherent value of the waste materials rather than on the demolition and disposal of ‘wastes’.

Transport costs and geographical controls on supply and demand: in remote and rural areas, the costs of transporting recycled goods some distance to market erodes the competitiveness of the recycled good against those sourced (in much greater bulk and with greater economies of scale) from primary sources. In the south-east, where supplies of primary aggregates are low, the market value of aggregates is high, making recycling quite competitive, but in the north of Scotland, for example, primary aggregates quarries are plentiful and therefore the value of aggregates are low. Thus recycled aggregates have to be available to the market at the right time and within a limited catchment area in order to remain competitive

Quality of product: the quality of the recycled material has to meet the appropriate products standards and be fit for purpose. The path of least resistance is to ‘down-cycle’ such as turning recycled concrete aggregate that could be used as high strength concrete as a low grade bank fill. As some effort would be invested to separate radioactive materials from non-radioactive materials, it is possible to keep high value materials separate from low value materials.

Non-radioactive contaminants (e.g. heavy metals): if a recyclable waste is contaminated with non-radioactive contaminants such as heavy metals or chemicals it will be very difficult to recycle. Not only will the contaminants present a threat to the environment in the new use location but also the contaminants can reduce the ability of the new product to be fit for purpose. For example, oily contaminants in aggregates can retard the cementation process of concrete reducing its structural integrity.

Costs and availability of virgin material: markets values in local areas are dictated by the availability and cost of sourcing virgin material in the local area.

Legal constraints (exemptions): waste management activities are control by increasingly stringent legal controls through the Controlled Waste Regulations 1992 (as amended) dictates which materials are classed as waste. Broadly speaking anything which its is intended to dispose of is classed as waste from a legal perspective. The Waste Management Regulations 1994 (as amended) details legal constraints for treatment and disposal of waste, but also outlines exemptions from legal control for the beneficial use of waste material. Exemptions are set out in Schedule 3 of the Waste Management Licensing Regulations 1994 (as amended) and these are discussed in Appendix B.

Product acceptability: As long as a material has been demonstrated to be radiologically clean there should be no major issue with respect to using recycled materials in products. The concerns are often when providing a raw material to another company or organisation such that it forms a part of a feedstock for a product they are manufacturing. They will be concerned that the recycled material exactly meets their quality standards at all times, which can be difficult when processing waste materials. If a product is created at the point of production of the wastes, then the producer of the wastes has greater control over the quality of materials and can ensure that liability issues such as contamination are not introduced into the product.

Economics and practical issues of storage of processed construction materials: processed construction material must be stored and used in line with the appropriate exemptions as discussed in Appendix B. The precise conditions relating to tonnages and length of time material can be stored is constantly under review and subject to amendment. It would be prudent to check with the local regulator office prior to the outset of any project.

Policy on the designation of waste (no longer part of the commercial chain of utility): the designation of wastes has been a complex problem for many years with little certainty over when a waste has been sufficiently reprocessed to the point that it ceases to be a waste. European case-law has made it difficult for materials that form a raw material for a future product, like crushed CDW, to be deemed fully 'recycled'. A new protocol developed by the industry and the Waste and Resources Action Programme (WRAP) is intended to provide greater certainty regarding the quality standards required to be met before a waste aggregate can be designated as recycled [WRAP, 2004]. This protocol, however, only refers to inert wastes and would not apply to radioactive wastes.

References

ODPM (2004a) Survey of Arisings and Use of Construction, Demolition and Excavation Waste as Aggregate in England in 2003. Unnumbered report.

WRAP (2004) The quality protocol for the production of aggregates from inert waste. http://www.aggregain.org.uk/the_quality.html

E Consultation

It was recognised throughout the SD:SPUR project that stakeholders, both individuals and organisations, hold a range of diverse but legitimate views on the issue of the reuse and recycling of wastes from nuclear sites. It was the intention that this project would build on the good relationships between stakeholders and the nuclear industry fostered by CIRIA through the scoping study and the SAFEGROUNDS project[4] to develop the guidance through a process of open dialogue. Throughout the project, stakeholder views have been sought by a number of mechanisms:

5. participation of a variety of stakeholders in the Project Steering Group,
6. peer review of project documents including drafts of this report,
7. opportunities for input and feedback via the SD:SPUR website, and
8. participation in a workshop to discuss sustainability indicators.

Many varied and interesting views were expressed during the consultation and these have been fed into this project and are used to frame the guidance provided in this report.

E1 Sustainability indicators workshop

The sustainability indicators workshop was held on 13th July 2004 at which a range of stakeholders was invited to suggest and debate what principles may be important when defining sustainability indicators in the context of managing the decommissioning wastes from nuclear sites.

At the workshop, participants proposed and discussed principles under the four main headings of health and safety, environment, society and economy. The discussion on principles was wide ranging and more than 200 separate comments were made and recorded in the photo-report. Many of the comments were related to general points of principle or to expectations of the nature of the guidance from the SD: SPUR project, whilst others were focussed on specific technical or environmental issues.

To rationalise these comments and to enable them to be used to help define a set of sustainability indicators, a step-wise process was follow by the project team after the sustainability workshop that allowed similar comments to be grouped and considered. The steps in this process were as follows.

1. Each comment in the photo-report was uniquely numbered. This was to allow for a transparent method for recording how each comment was handled within the project.

2. Each comment was then correlated to the attributes listed in the BPEO guidance (Table E.1). This was done because the guidance suggests that sustainability issues should be included explicitly within the BPEO process to determine appropriate management options for decommissioning wastes.

3. Each comment was then also correlated to the sustainability indicators included in the UK Government's sustainable development strategy and Quality of Life Barometer (Table E.2). This was done to ensure that no sustainability issues that relate to the Government's overarching environmental policy had been omitted from consideration. Many of the indicators in the Government's sustainable development strategy were not correlated in this process because they are not relevant to managing decommissioning wastes (e.g. social investment as a proportion of GDP). A large number were correlated, however, because they have direct or indirect relevance to decommissioning waste management, and these are listed in Table E.3.

4. Those correlations identified in steps 2 and 3 were used to group the comments into similar themes and issues. Where grouped comments related to a specific quantitative or qualitative parameter, this was defined as a sustainability indicator and these were then ordered under the same top-level headings referred to in the BPEO guidance document, namely (i) human health and safety, (ii) environmental impacts, (iii) technical, (iv) social and economic/quality of life, and (v) costs. The resulting list of sustainability indicators derived for this project is listed in Table E.4.

[4] SAFEGROUNDS is a forum for developing and disseminating good practice guidance on the management of radioactively and chemically contaminated land on nuclear and defence sites in the UK. See www.safegrounds.com

5. Where grouped comments related to a general issue or a point of principle (rather than a specific parameter), these were defined and used to order a list of issues that the guidance would need to address. The resulting list of sustainability issues is given in Table E.5.

Table E.1 *Examples of attributes in BPEO studies from the EA and SEPA guidance document.*

Ref.	Name
Group A: Actual and perceived impact on human health and safety	
A.1	Radiation dose to critical groups from projected discharges and collective dose to the population as a whole under normal conditions
A.2	Potential dose to critical groups from accidental releases
A.3	Individual and collective occupational exposures for workers
A.4	Occupational risks from other industrial hazards
Group B: Impacts on natural, physical and built environments	
B.1	Impact on marine ecosystems and habitats
B.2	Impact on terrestrial ecosystems and habitats
B.3	Long-term contaminant residues
B.4	Non-radioactive waste arisings
B.5	Nuisance (noise, odour, visual impact)
B.6	Indirect impacts (e.g. global warming)
Group C: Technical performance and practicability	
C.1	Aggregated project risk
C.2	Requirements for technical development
C.3	Timescale for implementation
C.4	Flexibility
C.5	Impacts on site operability
Group D: Social and economic impacts/quality of life	
D.1	Nuisance (noise, odour, visual impact)
D.2	Residual restrictions on access following remedial actions
D.3	Positive/negative effects on local economy
Group E: Costs	
E.1	Indicative lifetime costs (construction, operation, decommissioning)

Table E.2 *Indicators in the Government's sustainable development strategy deemed relevant to decommissioning waste management, grouped according to the top-level headings referred to in the BPEO guidance document*

Objective and sustainable development strategy paragraph reference number		Indicator
Group A: Actual and perceived impact to human health and safety		
Maintain a safe and healthy environment for workers	C10	Work fatalities and injury rates; working days lost through illness
Improve health of the population overall	H6	Expected years of healthy life
Deliver key health targets	F1	Death rates from cancer, circulatory disease, accidents and suicides
Environmental factors affecting health	F2	Respiratory illness
Address major factors leading to health inequalities	F3	Health inequalities
Group B: Impacts on natural, physical and built environments		
Continue to reduce our emissions of greenhouse gases now, and plan for greater reductions in the longer term	H9	Emissions of greenhouse gases
Reduce air pollution and ensure air quality continues to improve through the longer term	H10	Days when air pollution is moderate or higher
Improving river quality	H12	Rivers of good or fair quality
Reverse the long-term decline in populations of farmland and woodland birds	H13	Populations of wild birds
Reduce environmental impact of chemicals	D19	Chemical releases to the environment
Develop distribution systems which support economic growth, protect the environment and benefit society	D20	Freight transport by mode
	D21	Heavy goods vehicle mileage intensity
Improve choice in transport; improve access to education, jobs, leisure and services; and reduce the need to travel	H11	Road traffic
	G3	Average journey length by purpose

Objective and sustainable development strategy paragraph reference number		**Indicator**
Attractive streets and buildings, low levels of traffic, noise and pollution, green spaces, and community safety	K8	Noise levels
Must not store up pollutant problems for the future	M1	Concentrations of persistent organic pollutants
	M2	Dangerous substances in water
Continue to reduce our emissions of greenhouse gases now, and plan for greater reductions in the longer term	H9	Emissions of greenhouse gases
	N3	Carbon dioxide emissions by end user
Reduce air pollution and ensure air quality continues to improve through the longer term	P1 P2	Concentrations of selected air pollutants Emissions of selected air pollutants
Ensure that polluting emissions do not cause harm to human health or the environment	P3	Sulphur dioxide and nitrogen oxides emissions
Reduce or eliminate inputs of hazardous and radioactive substances of most concern	R1	Estuarine water quality, marine inputs
Protection of marine habitats and species	R3	Biodiversity in coastal/marine areas
Protection for individual landscape features such as hedges, dry stone walls and ponds	S5	Landscape features - hedges, stone walls and ponds
Protecting the wider landscape	S7	Countryside quality
Group C: Technical performance and practicability		
Greater resource efficiency	A1	UK resource use
Move away from disposal of waste towards waste reduction, reuse, recycling and recovery	H15	Waste arisings and management
	A6	Materials recycling
	A7	Hazardous waste
Take-up of best practice in key sectors	D3	Energy and water consumption by sector/Waste and hazardous emissions by sector
Greater use of sustainable construction materials	D10	Construction and demolition waste going to landfill
Must not store up pollutant problems for the future	M3	Radioactive waste stocks
	M4	Discharges from the nuclear industry
Safeguarding resources and ensuring affordable supplies	Q2	Water demand and availability
Group D: Social and economic impacts/quality of life		
Maintain high and stable levels of employment so everyone can share greater job opportunities	H3	Proportion of people of working age who are in work
Improve economic performance and enhance regional competitiveness	E1	Regional variations in GDP
Ensure that development takes account of history and look for opportunities to conserve local heritage	K5	Buildings of Grade I and II* at risk of decay
Attractive streets and buildings, low levels of traffic, noise and pollution, green spaces, and community safety	K6	Quality of surroundings
Voluntary and community activity can promote social inclusion and cohesion	L2	Voluntary activity
Help build a sense of community by encouraging and supporting all forms of community involvement	L3	Community spirit
Promoting public access and enjoyment of the landscape	S8	Access to the countryside
New Group: Procedures		
Encourage businesses to assess environmental impacts and set targets, and produce environmental reports	D6	Environmental reporting
Cost-effective ways to comply with pollution abatement and aim to move to cleaner processes in the long term	T5	Expenditure on pollution abatement
Take-up of best practice in key sectors	D3	Energy and water consumption by sector / Waste and hazardous emissions by sector

Table E.4 *The set of sustainability indicators derived for the project from the workshop comments, ordered under the headings referred to in the radioactive waste management BPEO guidance document [EA-SEPA, 2004].*

Ref.	Sustainability indicator	Comment [Relevant indicators in the Government's sustainable development strategy]
Group A: Actual and perceived impact on human health and safety		
1	Health and safety of the public 1.1 – current generations 1.2 – future generations	Health and safety of members of the public in all affected communities, from all sources of hazard (e.g. contact with recycled materials). Future generations should be afforded same level of protection as current generations: intergenerational equity. [H6, F1, F2]
2	Health and safety of the workforce 2.1 – current workforce 2.2 – future workforce	Health and safety of workers in all affected groups, from all sources of hazard (e.g. those from processing and later reuse operations). Future workforces should be afforded same level of protection as the current workforce. [C10]
Group B: Impacts on natural, physical and built environments		
3	Discharges to water bodies 3.1 – radioactive discharges 3.2 – chemical discharges	Ground and surface water bodies should be protected from unnecessary discharges of all pollutants, and BAT and BPM approaches should always be used to reduce discharges. [D19, H12, M2, M4]
4	Discharges to the atmosphere 4.1 – radioactive discharges 4.2 – CO_2, NO_x, SO_x 4.3 – other chemical discharges	The atmosphere should be protected from unnecessary discharges of all pollutants, and BAT and BPM approaches should always be used to reduce discharges. Greenhouse gases and gases contributing to acidification have specific reduction targets. [H9, D19, P1, P2, P3, M4]
5	Biodiversity 5.1 – impact on number/viability of species 5.2 – impact on extent of natural habitats	Flora and fauna on land and in the sea are to be protected from unnecessary impacts, and steps taken to reverse the decline in UK wildlife and habitats. [R3, S4]
6	Solid waste disposal 6.1 – amount of waste disposed as radioactive 6.2 – amount of waste disposed as hazardous 6.3 – amount of inert waste disposed to landfill 6.4 – amount of waste stored without disposal route	Waste production and disposal should be minimised. Use of the Drigg repository and hazardous waste disposal facilities should be restricted to certain waste types to conserve capacity. [A7, D10, H15]
7	Waste material reused 7.1 – amount of material reused on site 7.2 – amount of material reused off site	The reuse and recycling of waste materials is encouraged through the waste hierarchy. [A6, H15, S14]
8	Material transport 8.1 – number of transport consignments 8.2 – number of transport miles	Transport should be minimised where possible, and local reuse options to be encouraged: proximity principle. [D21, H11, G3, G4]
9	Resource use 9.1 – amount of energy consumed 9.2 – amount of clean water used 9.3 – amount of other natural resources used 9.4 – amount of natural primary resources displaced	Natural resources should be used efficiently and preserved to maintain stocks and minimise impacts from their use (e.g. CO_2 emissions from burning hydrocarbons). [A1, D3]
Group C: Technical performance and practicability		

Ref.	Sustainability indicator	Comment [Relevant indicators in the Government's sustainable development strategy]
10	Quality of recycled product 10.1 – grade of reused or recycled product	Waste materials should, within reason, be processed to achieve the highest grade of product to preserve high-grade primary resources. [A6, S14]
11	Technical developments 11.1 – new developments with market potential	Promoting research and development, and investment allows new technologies to be brought to market. [H1, H2]
12	Finality of option 12.1 – amount of further effort/work needed	Options that achieve a clear end-point are usually preferred to those that require further effort or work to achieve a waste management solution. [A1]
Group D: Social and economic impacts/quality of life		
13	Employment 13.1 – direct and indirect current employment 13.2 – direct and indirect future employment	Options are usually preferred that provide high and stable levels of employment will support financial viability of local communities and community spirit. [H3]
14	House prices and land value 14.1 – change in house prices and land values	Options that cause substantial changes to house prices and land values would impact on local and regional financial systems. [E1]
15	Landscape and heritage 15.1 – access to countryside 15.2 – impacts on local heritage	The wider environment should be protected and access to the land encouraged. Local and regional cultural and historical heritage should be preserved. [S7, S8]
16	Quality of life 16.1 – community spirit and community viability 16.2 – nuisance factors 16.3 – impact on the quality of surroundings	People's quality of life should be maintained or improved. The quality of surroundings should be high and nuisance (noise, visual impact etc.) minimised. Community spirit should be fostered. [K6, L2, L3]
17	Investment 17.1 – level of inward investment 17.2 – regional GDP	Maintaining high and stable economic growth is important for developing communities and enhances regional competitiveness. Inward investment for waste management is encouraged. [E1]
Group E: Costs		
18	Costs 18.1 – full life-cycle costs of implementation	The full life-cycle (cradle to grave) costs of options should be quantified. [E1, T5]
19	Revenue 19.1 – revenue from sale of product	Any revenue from sale of recycled product or saving on waste disposal liabilities may be included in cost assessments. [E1, T5]

Table E.5 *The set of general issues arising from the sustainability workshop that were not correlated to a specific sustainability indicator. This list is not ordered in any specific way.*

Ref.	Issue
a	Monitoring of public and worker health, and of the wider environment
b	Identification of exposed groups, their levels of exposure and risks
c	Low level radiation impacts on health and the environment
d	Public and stakeholder engagement, communication and aspects of risk perception
e	Demonstrating best practice, application of international standards, and the use of BPM, BPEO with the associated concepts of ALARA and ALARP

Ref.	Issue
f	Proportionate engineering and management responses to hazards and BPM
g	Sampling and characterisation of waste materials, and evaluation of levels of contamination
h	Peer review and independence of the review process.
i	Transparency and presentation of process, decisions and records
j	Health and environmental impact modelling approaches and treatment of uncertainty
k	Full life cycle cost modelling, aspects of financial discounting and treatment of uncertainty
l	Duty of care and transfer of liabilities
m	Application of the precautionary principle
n	Application of weighting factors in a multi-attribute decision making process
o	Drigg and landfill costs as comparators
p	The decision making process, inclusion of different views and ethical considerations
q	Regulatory bodies and the regulatory framework
r	Waste management funding processes

Table E.3 *Correlation between the comments recorded at the sustainability indicators workshop, the Government's sustainable development strategy (SDS) issues and the sustainability indicators and issues derived in SD:SPUR.*

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
HEALTH AND SAFETY						
H&S/1	***Workers' Health (On-site/Off-site)***					
H&S/1.1	Risks on site are better understood and managed than for off-site workers.	A.1 – A.4	H6, C10, F1, F2	Range of risks to be considered, not just radiological.	none	b
H&S/1.2	Monitoring the health of workers & family for their life time. - full, available records - especially MoD	A.1 – A.4	H6, C10, D6, F1		none	a
H&S/ 1.3	Gamma monitoring nbg must capture internal (especially inhalation)	A.1 – A.4	H6, C10, D6, F1		none	a
H&S/1.4	Intergenerational equity of health and safety	A.1 – A.4	H6, F1, F2, F3		1	m
H&S/1.5	Intergeographical equity.	A.1 – A.4	H6, F1, F2, F3		1	m
H&S/2	***???***					
H&S/3	***Public health***					
H&S/3.1	Specific groups at more risk	A.1 – A.4	H6, F1, F2, F3		none	b
H&S/3.2	Public part of the process (public perception) - at site level engage with local communities - communication of site specific information - principle of stakeholder dialogue	none	L2, L3		13	d
H&S/3.3	Monitoring health of public (see workers' health)	A.1, A.2	H6, D3, D6, F1, F2		none	a
H&S/3.4	ECRR/NRPB > Self-selecting ICRP/IAEA > Self perpetuating ISO/ICRU/WHO > Oligarchy > ICIA?	none	D3	Ambiguous, range of issues suggested in this comment.	none	e
H&S/3.5	Standards? National, International?	none	D3		none	e
H&S/4	***Conventional and radiological safety***					
H&S/4.1	Understand & quantify the different risks.	A.1 – A.4	H6, C10, F1, F2	Range of risks to be considered, not just radiological.	none	e

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
H&S/4.2	Risk minimisation (ALARA, ALARP, BPEO)	A.1 – A.3	D3, T5	Range of risks to be considered, not just radiological as implied by ALARA and ALARP	none	e
H&S/4.3	Sampling & methodology	none	D3, D6	Assumed this comment refers to sampling of waste materials	none	g
H&S/4.4	ALARP – applied case by case, though need for consistency	A.1 – A.3	H6, C10, D3, D6, F1		none	e
H&S/4.5	What is reasonable ethical?	none	L2, L3		none	p
H&S/4.6	How do we decide what is acceptable and what is it ?	none	L2, L3		none	p
H&S/5	***Conventional and radiological safety (cont.)***					
H&S/5.1	Complex, rad-bio, rad-phyto, rad-geo, rad-epi science is over simplified in regulation - relative uncertainty is translated into relative certainty.	none	F2, D3	Operators must work within current regulatory system	none	j
H&S/5.2	Need for proportionality	none	D3, T5		none	f
H&S/6	***Independent scrutiny and current legislation***					
H&S/6.1	Conflicting and overlapping legislation and regulation, differing interpretation	none	none		none	q
H&S/6.2	Credibility and competence of scrutiny	none	D6		none	h
H&S/6.3	Open, transparent, robust regulations - Public confidence in regulators and regulations and operators, scientific advice	none	D6		none	h, q
H&S/6.4	Dose definitions (low dose) and outing understanding of uncertainty	none	D3		none	c, j
H&S/7	***No title***					
H&S/7.1	Principle of concentrate & contain/control vs dilute & disperse?	none	M2, M4, T5	Draft 'Statutory Guidance on the Regulation of Discharges from Nuclear Sites' states that there is a preference for 'concentrate and contain' over 'dilute and disperse'.	3, 4	q
H&S/7.2	Transparency & certainty needed in health detriment assessment as a result of any practice.	none	D3		none	i, j

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
H&S/7.3	Maintenance of independent monitoring bodies/national centre of excellence.	none	D6		none	a, q
H&S/8	***No title***					
H&S/8.1	Allocation of risk of health detriment – How?	A.1 – A.4	H6, C10, F1, F2		none	b
H&S/8.2	Risk Assessment - Understanding of all pathways - What is the universal currency of risk to health e.g. model? - Best Possible Ethical, Environmental and Social Option (BPEESO)	A.1 – A.4	H6, C10, D3, F1, F2		none	b, j, p
H&S/8.3	We should understand, evaluate and minimise the impact on human health of this activity - there needs to be certainty - minimise (i.e. numbers of people exposed & amount)	A.1 – A.4	H6, C10, D3, F1, F2		none	b
H&S/P(10)	***Health and safety plenary discussion***					
H&S/P(10).1	On-site/off-site	A.1 – A.4	H6, C10, F1, F2		none	b
H&S/P(10).2	Uncertainty – relative uncertainty of models. No fundamental agreement of what SAFE is. - Are you trying to achieve SAFE i.e. within regulatory framework or by consensus agree what is SAFE ?	none	D3, L2, L3		none	j
H&S/P(10).3	Be safe & be perceived as safe (How do you define safe?)	none	D3, L2, L3		none	j, p
H&S/P(10).4	Duty of care	none	none		none	l
H&S/P(10).5	Risk communication & perception	none	L2, L3		none	d
H&S/P(10).6	Need to find a management way through this issue & get as wide buy-in as possible to the options applied.	none	L2, L3		none	p
H&S/P(11)	***Health and safety plenary discussion (cont.)***					
H&S/P(11).1	For each category compile all data and scientific and regulatory information.	none	D6		none	a, i
H&S/P(11).2	Point raised that in order to know what health risks are to people need monitoring for long-term.	none	D6		none	a

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
H&S/P(11).3	Risk comparators/risk synergies – work needed	none	none	Relates more to presentation of risk ?	none	none
H&S/P(11).4	Trust - need an independent body's verification - how do you establish independence? - co-operation & access to information	none	D6, L2, L3		none	j, i
H&S/P(11).5	Lack of funding & expertise	none	T5	Assumed to relate to funding for waste management programmes.	none	r
H&S/P(11).6	Independent verification - improve what we have, wider involvement.	none	D6, L2, L3		none	h, q
H&S/P(11).7	Higher political & public profile	none	D6, L2, L3	Not certain what this comment implies	none	none
H&S/P(12)	***Health and safety plenary discussion (cont.)***					
H&S/P(12).1	Independent body to verify the process	none	D6, L2, L3		none	h
H&S/P(12).2	Protocols - robust testing, robust recording, - level of acceptance of results - what do you do with the results when you get them?	none	D3, L2, L3		none	h, j
H&S/P(12).3	Full characterisation of materials involved (industry does this as code of practice, need this to be public, is published now on SAFEGROUNDS website, degree of endorsement)	none	D3		none	g
H&S/P(12).4	Was the material fully characterised (Principle)	none	D3		none	g
ENVIRONMENT						
ENV/1	***Things we have already***					
ENV/1.1	OSPAR	B.1, B.3	R1, D3, T5		3	e
ENV/1.2	European safety standards	A.1 – A.4	C10, H6, F1, F2		1, 2	e
ENV/1.3	ICRP principles	A.1 – A.3	C10, H6, F1, F2		1, 2	e

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ENV/1.4	IAEA	many	H15	Many IAEA recommendations, assume that all are intended to apply	none	none
ENV/1.5	Clearances code of practice	none	H15		none	g
ENV/1.6	Discharge reduction (aerial, liquid, solid)	B.1, B.2, B.3	H9, H12, D3, D19, N3, P2, P3, R1, T5	Draft 'Statutory Guidance on the Regulation of Discharges from Nuclear Sites'	3, 4	e
ENV/1.7	Minimise pollution to zero if possible	B.1, B.2, B.3	H9, H12, D3, D19, N3, P2, P3, R1, T5	Draft 'Statutory Guidance on the Regulation of Discharges from Nuclear Sites'	3, 4	e
ENV/1.8	Minimise footprint to zero if possible (to background without enhancement)	B.1, B.2, B.3	H9, H12, D3, D19, N3, P2, P3, R1, T5		3, 4	e
ENV/1.9	Access to small area cancer registration data – openness	none	D6		none	c, i
ENV/1.10	Need continuous EIA	none	D6		none	j
ENV/1.11	Quantify the impacts on human health	A.1 – A.4	H6, C10, F1, F2		1, 2	b
ENV/2	***No title***					
ENV/2.1	Continuous monitoring - Human health - Cumulative effects (in space and time) on aerosphere, biosphere, hydrosphere, atmosphere, flora and fauna, built environment, ecological - Discharges	A.1 – A.4, B.1, B.2, B.3	H6, C10, F1, F2, H9, H12, D3, D6, D19, N3, P2, P3, R1, T5		none	a, j
ENV/2.2	Balance discharges with effects on human health	none	T5		none	f
ENV/2.3	Review monitoring data and review acceptability of discharges	none	D6		none	i
ENV/3	***No title***					
ENV/3.1	Polluter pays	none	none		none	l
ENV/3.2	Dilute and disperse (don't)	none	M2, M4, T5		3, 4	q
ENV/3.3	Concentrate and contain	none	M2, M4, T5		3, 4	q
ENV/3.4	Precautionary principle	none	none		none	m

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ENV/3.5	ALARP/ALARA	A.1 – A.3	H6, C10, D3, D6, F1		none	e
ENV/3.6	Proximity principle	B.5, D.1	H11, E1, D20, D21		8	m
ENV/3.7	Acceptable to an informed public	none	L2, L3		13	d, p
ENV/3.8	Transparency and openness - co-work (in-depth critical review)	none	D6, L2, L3		none	h, i
ENV/3.9	Someone with an overarching monitoring role to look at the breadth of data (cf Black IAG)	none	D6	Do not know what reference relates to.	none	h
ENV/3.10	The tyranny of "safety"	none	none	Ambiguous comment	none	none
ENV/3.11	Be aware of the impact of the environment of the process and physical form of the contamination.	A.1 – A.4, B.1 – B-3	D6		3, 4, 5	b, j
ENV/4	***No title***					
ENV/4.1	End product fit for purpose	C.2	none		10	none
ENV/4.2	Volume reduction of waste and recycle of materials	B.3, B.4	H15, A6, S14	Assume comment relates to minimisation of waste arisings rather than compaction of waste	6, 7	none
ENV/4.3	Balance impacts of new materials vs. recycled materials	none	S14		6, 7	none
ENV/4.4	Compare levels with background radiation (don't – they are additive)	B.3	D6, R1		none	j
ENV/4.5	Case by case: assess the significance and impact of process and end result	A.1 – A.4, B.1 – B-3	D6		none	b, j
ENV/4.6	Note: public perception of risk vs. benefit will vary a lot	none	D6, L2 – L3		none	d
ENV/4.7	Intergenerational equity	none	F3		1	a, m
ENV/4.8	Weigh up money spent preventing small risk in the future vs. high risk today (saving lives now)	none	T5		none	f
ENV/5	***No title***					
ENV/5.1	Note: bear in mind that radioactivity does decay overtime - some chemicals (toxic materials) don't have a half life - radioactivity can be trapped, some other chemicals can't	none	none	Both radiotoxic and chemotoxic risks need to be assessed	none	none
ENV/5.2	Health impact assessment, a continuous one needed	A.1 – A.4	H6, C10, F1 – F3		none	j

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ENV/5.3	Caveat emptor	none	none	Ambiguous comment	none	none
ENV/5.4	Impact on everything (Biota etc etc)	A.1 – A.4, B.1 – B-3	D6		5	j
ENV/5.5	Health assessment is not just about humans	B.1, B.2	H13, R3		5	j
ENV/5.6	Balance with environmental impacts of disposal	none	T5		none	o
ENV/6	***No title***					
ENV/6.1	Other materials in the waste may preclude some options	none	none		none	g
ENV/6.2	Does adding small amounts tip the overall balance, and do we have the right to increase the burden?	B.3	D6, R1	Assume comment relates to small amounts of radioactivity added to the environment	none	j
ENV/6.3	Need series of staged safety case assessments	none	H6, F2, D3		none	p
ENV/6.4	Note: could engineer solutions to environmental threats	none	T5		none	f
ENV/6.5	Do nothing may be an option (in -situ containment) depending on geological and hydro geological issues.	none	T5		none	f
ENV/6.6	BPEO	none	T5		none	e
ENV/6.7	CATNIP (Cheapest Available Technology Not Involving Prosecution)	none	T5	Assume this is not proposed as a preferred management solution	none	f
ENV/7	***No title***					
ENV/7.1	BPM – best practical means	none	T5		none	e
ENV/7.2	Minimise transport	B.5, D.1	H11, E1, D20, D21		8	m
ENV/7.3	Balance transport impacts with any alternative routes	B.5, D.1	H11, E1, D20, D21		8	m
ENV/7.4	CO2 emission reduction, and measuring/monitoring	B.6	H9, N3		4	none
ENV/7.5	Look at mutagenicity and teratogenicity as well as toxicology	none	F2, D3		none	c
ENV/7.6	Measure and take into account the energy costs of each option	B.6	A1, D3		9	k
ENV/7.7	Evaluate use of virgin material resulting in mining etc	B.6	S14		9	k
ENV/7.8	Life cycle approach	E.1	none		19	k
ENV/8	***No title***					

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ENV/8.1	Don't export the problem to people who don't get the benefit!	none	L2, L3		none	m
ENV/8.2	Minimise production and accumulation of waste	B.3, B.4	H15, A6, S14		6	none
ENV/8.3	Maximise recovery/utility of natural resources in the environment	B.3, B.4	H15, A6, S14		7, 9	none
ENV/8.4	When is it waste/when is it a resource? - What is the point of recovery from waste?	B.3, B.4	H15, A6, S14		7, 9	none
ENV/P(13)	***Environment plenary discussion***					
ENV/P(13).1	Don't export the problem to people who don't get the benefit. - Keep on site - Proximity principle – solve problem locally (how do you define?)	B.5, D.1	H11, E1, D20, D21		8	m
ENV/P(13).2	Keep an eye on what's going on elsewhere: other countries may adopt more stringent standards.	none	D3, T5		none	e
ENV/P(13).3	Need to think about impacts at all stages of the process	A.1 – A.4, B.1 – B-3	D6		none	b, j
ENV/P(13).4	Compare levels to background – i.e. levels without nuclear testing or discharges etc	B.3	D6, R1		none	j
ENV/P(13).5	If can't take off site, control and contain (but what does this mean?) and may disperse on-site by doing this.	none	D3, T5		3, 4	none
ENV/P(14)	***Environment plenary discussion (cont.)***					
ENV/P(14).1	Minimise the dispersal	none	M2, M4, T5		3, 4	q
ENV/P(14).2	Contain and control	none	M2, M4, T5		3, 4	q
ENV/P(14).3	Don't pollute the environment anymore than it is already	none	M2, M4, T5		3, 4	q
ENV/P(14).4	Understand what the potential impacts may be	A.1 – A.4, B.1 – B-3	D6		1	b, j
ENV/P(14).5	Case by case – assess waste, process you want to use and the end result - Different wastes will have different best options	A.1 – A.4, B.1 – B-3	D6		none	f
ENV/P(14).6	May be overarching principles, but they may need local interpretation. - Agreed models, need to input local conditions	none	none		none	p

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ENV/P(14).7	Need an overarching body with an overview of all the data available – co-working arrangement.	none	D6		none	h, i
ENV/P(15)	***Environment plenary discussion (cont.)***					
ENV/P(15).1	Consistent approach to ecological indicators – keep an eye on other species as impacts may show up in these before humans	B.1, B.2	H13, R3		5	j
ENV/P(15).2	Regulatory side of the proximity principle is missing	none	none		none	h, q
ECONOMY						
ECON/1	***Economy***					
ECON/1.1	Consider UK and the World (cannot consider the world, but can develop expertise to export).	none	none		18, 19	k
ECON/1.2	What is the value/cost of the materials we are talking about?	none	none		19, 20	k
ECON/1.3	Establish a benchmark e.g. cost of disposing at Drigg.	none	none		none	o
ECON/2	***No title***					
ECON/2.1	Need economic models – full cost accounting (full cost - life cycle analysis) to include - Employment costs. - Health costs - Social costs - Processing costs - Environmental costs - Transport costs - Energy costs - Segregation costs	E.1	T5		19, 20	k
ECON/3	***No title***					
ECON/3.1	Resource valuation - avoidance of cost of sending to Drigg - and potential for adding/retaining value.	none	T5		19, 20	k, o
ECON/3.2	What weight will economic factors be given vs the other factors?	none	T5		none	n

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ECON/3.3	Accounting practices need to incorporate: - Changing market value – over 50-year time frame. - Changing social costs – next generation - Discounted costs DCF – Moral inequity of discounting - Sensitivity analysis – what ifs - Cost Benefit Analysis – but recognise	E.1	none		19	k, p
ECON/3.4	Cost Benefit Analysis – but recognise that not all impacts can be directly characterised	none	D3, T5		19, 20	k
ECON/4	***Principles***					
ECON/4.1	Polluter (liability owner) pays	none	none		19	l
ECON/4.2	Aim is to maximise economic benefits including inter-generational	none	none		19, 20	k
ECON/4.3	Safety is paramount within the balance between econ/socil/H&S/Env	none	T5		none	f
ECON/4.4	If there is economic benefit it should go to those impacted (Community Benefit)	none	L2, L3		17, 18	k
ECON/4.5	Proximity principle	B.5, D.1	H11, E1, D20, D21		8	m
ECON/4.6	Engineering principles should be consistent	C.2	none		none	f
ECON/4.7	Minimise economic detriment to future generations	none	none		19	m
ECON/4.8	When dealing with nuclear waste economy should not come into it – Disagree! See other comments.	none	T5		none	f
ECON/5	***No title***					
ECON/5.1	There are regional differences – the same rule won't apply everywhere, but there should be consistency of engineering approach	none	E1		none	f
ECON/5.2	Tough regulation can be a driver for innovation to reduce life-cycle costs - but note risk that regulation could hinder innovation because it involves taxation.	none	none		none	f
ECON/5.3	Need to establish a clear segregated fund (NDA) as political time-scales are short and environmental time-scales are long.	none	none		none	r

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ECON/6	***Principles***					
ECON/6.1	Precautionary principle can be used in economic context to take into account uncertainty of economic models.	none	none		none	m
ECON/6.2	Should not spend money unnecessarily. - Question is at what point do you stop spending more to minimise risk – law of dimishing returns.	none	D3, T5		none	f
ECON/6.3	Efficiency/effectiveness - use stakeholder dialogue to manage subjective judgements about what is 'necessary' or 'resonable' or 'ethical'	none	L2, L3		none	d, p
ECON/7	***No title***					
ECON/7.1	Need a contingency fund as financial bond for future.	none	none		none	r
ECON/7.2	Avoid short-termism in planning life cycle costing for beyond the time it takes to clean up.	none	none		19	k
ECON/8	***No title***					
ECON/8.1	Cost in human health can be evaluated by comparing decommissioning spend to benefit human health in other ways.	none	none		none	f
ECON/8.2	Possible economies of scale from looking at limited number of waste repositories in Europe.	none	none	Not appropriate for this guidance to make recommendations on waste export. CoRWM to advise on programme and policy.	none	none
ECON/8.3	Best use of Drigg needs to be in the equation – it is a limited resource.	none	none		none	o
ECON/8.4	Decommissioning should be safe first and cost effective second.	none	T5		none	f
ECON/9	***No title***					
ECON/9.1	ALARP – 'Reasonably Practical' can be used to evaluate how much needs to be spent.	none	D3, T5		none	e, f
ECON/9.2	Need to have regular scheduled audits to ensure that we are getting maximum decommissioning per £ spent.	none	D3, T5		none	f
ECON/P(16)	***Economy plenary discussion***					

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
ECON/P(16).1	Drigg has limited capacity - best/optimise use of Drigg.	none	none		none	o
ECON/P(16).2	Assess full through-life costs in all economic proposals - Every decisions economic impact.	none	none		19	k
ECON/P(16).3	Be open about the fact that not everything can be costed.	none	none		19	k
ECON/P(16).4	Problem of comparing benefits/disadvantages	none	D3, T5		none	f
ECON/P(16).5	Drigg is a starting point – can be used as a benchmark for costings.	none	none		none	o
ECON/P(17)	***Economy plenary discussion (cont.)***					
ECON/P(17).1	Sensitivity analysis vital in any economic model so that assumptions can be varied.	none	none		none	k
ECON/P(17).2	Be clear about how economics can be weighted against the social/environment	none	T5		none	k, n
ECON/P(17).3	Recognise there is not a bottomless wallet.	none	D3, T5		none	f
ECON/P(17).4	Public need to understand the costs and impacts.	none	D3, L2, L3, T5		none	f
ECON/P(17).5	Information on costs is not currently brought together – can it be brought together.	none	none		19	k
ECON/P(17).6	Treasury prioritisation between priorities – what principles are being used? - principles need to be prioritised on a local & national level	none	none	Project team has no information on treasury views other than stated in Government policy	none	none
ECON/P(18)	***Economy plenary discussion (cont.)***					
ECON/P(18).1	Need to gather information about health costs/costs of alternative health interventions.	none	none		19	k
ECON/P(18).2	How does the Treasury make decisions – what weightings are used – can we ask?	none	none	Project team has no information on treasury views other than stated in Government policy	none	none
ECON/P(18).3	Consider general benefits for economy e.g. recycling companies	none	none		18	k
ECON/P(18).4	Need a clear economic model	none	none		none	k
SOCIETY						

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
SOC/1	***Society***					
SOC/1.1	Trust - Transparency > Audit/Access to information - Engagement - Accountability - Integrity	none	L2, L3		none	d, i
SOC/1.2	Understand the history and context - Legacy	none	L2, L3		none	d
SOC/1.3	Communication	none	L2, L3		none	d, i
SOC/2	***No title***					
SOC/2.1	Safety/security	A.1 – A.4	H6, C10, F1, F2		1, 2	b, d
SOC/2.2	Risk	A.1 – A.4	H6, C10, F1, F2		1, 2	d, j
SOC/2.3	Impacts on housing	D.1, D.3	E1, K5, K6		15	k
SOC/2.4	Second order feedback	none	none	Ambiguous comment	none	none
SOC/2.5	Cross cutting externabilities - Employment - Housing	D.1, D.3	H3, E1, K5, K6		14 – 18	k
SOC/2.6	Road traffic accidents	D.1	D21, H11		8	m
SOC/2.7	Housing value	D.1, D.3	E1, K5, K6		15	none
SOC/2.8	Identify the benefits too	D.3	E1		17, 20	none
SOC/3	***No title***					
SOC/3.1	Access to information - Beyond current regulation e.g. “public interest” - Freedom of information - Environmental information - Data protection - Be proactive about it	none	D6		none	i
SOC/3.2	Access to alternative expertise for critical appraisal – supporting co-work	none	D6		none	h
SOC/3.3	In-depth assessment - Problems around this e.g. conflict of interests	none	D6		none	p

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
SOC/4	***No title***					
SOC/4.1	Prior information - Engage in scoping at early stages	none	L2, L3		none	d
SOC/4.2	Resources to enable local and external s/holders to assess information/engage/liberate - Via an honest broker	none	L2, L3		none	d, h
SOC/4.3	Accreditation of experts, individuals etc.	none	D6		none	h
SOC/4.4	Public understanding of science - Expert knowledge/public knowledge - Create time/resources	none	D6		none	d
SOC/5	***No title***					
SOC/5.1	Media understanding	none	D6		none	d
SOC/5.2	Scientists to understand public	none	L2, L3		none	d
SOC/5.3	Measurability – were all views considered and captured?	none	L2, L3		none	d, p
SOC/5.4	Did anyone feel extended?	none	L2, L3	Assume this comment refers to people's sense of involvement	none	d
SOC/5.5	Appropriate arenas - Citizen's juries - Stakeholder dialogue	none	L2, L3		none	d
SOC/5.6	Local management/national engagement - Different methods - Interplay between different levels	none	L2, L3		none	d, p
SOC/6	***No title***					
SOC/6.1	Uncertainty - Public questions – how good is the science and what are the drivers?	none	D6		none	d, j
SOC/6.2	Managing the uncertainty around managing nuclear waste	none	D6	Ambiguous comment	none	none
SOC/6.3	Need for plain language	none	D6		none	d
SOC/6.4	Need honesty about the uncertainties - Measure this	none	D6		none	j
SOC/6.5	Identity (key affected) stakeholders, with a range of perspectives/views etc. [‘all’ key affected stakeholders ??]	none	L2, L3		none	d

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
SOC/7	***No title***					
SOC/7.1	What process of decision making is being used? - Does anyone understand this?	none	L2, L3		none	p
SOC/7.2	Childhood leukaemia - e.g. benefits to society as a whole against those of individual	none	H6, F2		none	p, f
SOC/7.3	Justification - Proposals need to illustrate benefits/deficits	none	none		none	f
SOC/7.4	Perception of risk	none	L2, L3		none	d
SOC/8	***No title***					
SOC/8.1	Categorised and configured - Doing it in a way which is understandable to future generations - Use in consumer products is problematic because of uncertainties	none	L2, L3	Assumed to relate to communication issues	none	d
SOC/8.2	Perception of risk - Is this a choice? e.g. difference between driving a car and a discharge from a power station - Comparatives risks e.g. Smoke stack - Visible pollutant e.g. could be seen as safer than invisible	none	L2, L3		none	d
SOC/9	***No title***					
SOC/9.1	Impact on employment - Internal and external - Impact over time - Can plan	D.3	H3		14	none
SOC/9.2	What new technologies can be developed for export etc? - Decommissioning technology	none	E1		11	none
SOC/9.3	What is government thinking about sustainability? - e.g. re-working materials etc	none	none	Project team has no information on Government views other than stated in policy	7	p
SOC/9.4	People/government – issues of distrust	none	L2, L3		none	d, h
SOC/10	***No title***					

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
SOC/10.1	Small part of CoRWM is about sustainability - Principle – government to be certain about its thinking on sustainability - If no clarity, hard to act.	none	none	Project team cannot influence Government policy	none	p
SOC/10.2	Respectful of local culture and community - Don't want to damage or change it too much e.g. inward investment may destroy community.	D.3	H3, E1, K5		15, 17	none
SOC/10.3	Respectful of wider notions - world culture.	none	K5		17	none
SOC/11	***No title***					
SOC/11.1	Active identification of stakeholders	none	L2, L3		none	d
SOC/11.2	ALARP, ALARA, reasonable, practicality, economic, social factors are subjective and ethical. Liable to be interpreted through a utilitarian approach, which is out of date - Use a "rights" based ethic	none	none		none	p
SOC/P(19)	***Society plenary discussion***					
SOC/P(19).1	Impact of "policing" on rights and freedoms	none	L2		none	p
SOC/P(19).2	Clean-up should be responsible and extensive to ensure security at all levels of waste.	none	M1		none	f
SOC/P(19).3	Legal system imposes constraints on industry	none	none	Operators have to work within exisiting legal framework at all times	none	p
SOC/P(19).4	Risk analysis is vital or guidance could have detrimental effect on other activities e.g. recycling	none	none		none	b, j
SOC/P(19).5	Consider all pitfalls – don't put all eggs in one basket	none	none	Ambiguous comment	none	f, p
SOC/P(19).6	Trust	none	none		none	d, h, q
SOC/P(20)	***Society plenary discussion (cont.)***					
SOC/P(20).1	Be aware of effect of our recommendations on whole waste economy and beware "perverse" outcomes	none	none		none	f, p
SOC/P(20).2	More important to characterise and configure waste on-site than to move it off-site: shouldn't be a burden on future generations.	none	none		none	g

Original comment reference	Comment	Related BPEO criteria	Related SDS issues	Note	SD:SPUR sustainability indicators	SD:SPUR sustainability issues
SOC/P(20).3	Confrontational nature of planning processes – need to avoid public enquiry if possible and reach decisions via stakeholders	none	none		13	d
SOC/P(20).4	Involve EA and SEPA in process of dialogue to ensure their views are heard	none	none		13	q
SOC/P(20).5	Good practice examples form Canada on dialogue/engagement	none	D3		none	d
SOC/P(21)	***Society plenary discussion (cont.)***					
SOC/P(21).1	Use a rights based approach	none	none		none	h, p