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SD: SPUR

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Site decommissioning: 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

Large volumes of radiologically clean and slightly radioactive wastes will be generated by the decommissioning of nuclear sites in the UK. How this is dealt with is of interest to a broad range of stakeholder groups. This document contains guidance on sustainable practices in managing this material and has been produced following extensive involvement of stakeholders. The guidance is supported by a case study of the Dounreay nuclear site. It is of particular interest to national policy makers and managers who operate at the site-wide strategy level but there is much that is useful to waste management practitioners.

Site Decommissioning: 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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Executive summary

The SD:SPUR project had the aim of developing guidance for waste managers on nuclear sites to help them deal appropriately with redundant buildings and decommissioning wastes. 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 predictions for the quantities of these wastes are not yet available but estimates suggest the volumes will be around 1 500 000 m^3 of waste that is radiologically clean[1] and a further similar amount of slightly radioactive waste at the lower end of the low-level waste (LLW) category. The dominant materials contained within both waste classes are concrete, unsorted building rubble, ferrous metals and soil.

The radiologically clean wastes potentially can be recycled and reused on or off nuclear sites as construction materials without further regulatory control under the Nuclear Installations Act (NIA 65) or the Radioactive Substances Act 1993 (RSA 93) but will remain subject to control under the Waste Management Licensing Regulations 1994 (WML Regulations). It should be noted that there exist a number of views concerning the relative acceptability and sustainability of this regulatory approach. Thus the demand for recycled materials arising from nuclear sites is depressed due to public safety concerns and perceived health impacts. The slightly radioactive wastes must always remain subject to control under NIA 65 and RSA 93 but they cannot all be removed to the existing LLW repository at Drigg because their total volume exceeds the remaining capacity of that 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 which are themselves 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 types one at a time.

1 Including wastes that are excluded and exempt from control under the Radioactive Susbstances Act 1993.

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 material segregation for later 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 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) was 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 wastes, against these sustainability indicators plus the other standard BPEO attributes. Not every sustainable waste management 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 use in public places of recycled materials derived from nuclear sites, even when they are considered to be radiologically clean. Little is achieved by processing wastes 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 wastes 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 potential sustainable applications for decommissioning wastes that are currently considered to be radiologically clean. A core component of this consensus-building approach is respect for, and the integration of, a diverse range of public and stakeholder views within elements of the IWS decision-making process.

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 decommissioning waste could be reused or recycled for 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. It 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 wastes.

The slightly radioactive wastes must always remain subject to control under NIA'65 and RSA'93 (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 wastes on nuclear sites that might offset the use of virgin or other sources of recycled materials. The types of uses to which certain recycled slightly radioactive decommissioning 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
- 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 wastes. 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 (eg 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 Nuclear Decommissioning Authority (NDA) to promote such an approach, although individual sites are encouraged to consider installing local processing facilities for their own or locally shared use.

Further details of the SD:SPUR project can be found on the website: <www.sdspur.com>

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Abbreviations

ALARA	as low as reasonably achievable
ALARP	as low as reasonably practicable
BAT	best available technique
BNFL	British Nuclear Fuels (PLC)
BPEESO	best possible ethical, environmental and social option
BPEO	best practicable environmental option
BPM	best practicable means
CATNIP	cheapest available technology not involving prosecution
CDW	construction/demolition wastes
CIRIA	Construction Industry Research and Information Association
CoRWM	Committee on Radioactive Waste Management
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department for Environment, Transport and the Regions
DFR	Dounreay fast reactor
DRWI	Dounreay radioactive waste inventory
DSRP	Dounreay site restoration plan
DSETF	Decommissioning Safety and Environment Task Force
DTI	Department for Trade and Industry
EA	Environment Agency (of England and Wales)
EIA	environmental impact assessment
EPA'90	Environmental Protection Act 1990
GDP	gross domestic product
HLW	high level waste
HMSO	Her Majesty's Stationery Office
HSE	Health & Safety Executive
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	intermediate level waste
IPC	integrated pollution control
IRR'99	Ionising Radiations Regulations 1999
IWS	integrated waste strategy
JASM	jointly agreed sampling and monitoring (working group)
JET	Joint European Torus
LCBL	life cycle base line (plans)
LLW	low level waste
MOD	Ministry of Defence
NDA	Nuclear Decommissioning Authority
NIA'65	Nuclear Installations Act 1965
NII	Nuclear Installations Inspectorate (of the HSE)
NPPs	nuclear power plants

NTWP	near term work plans
NRPB	National Radiological Protection Board
ODPM	Office of the Deputy Prime Minister
OSPAR	Oslo-Paris (convention)
PSRE	Phosphatic and Rare Earths etc (Exemption Order)
RCEP	Royal Commission on Environmental Protection
RWI	radioactive waste inventory
RSA'93	Radioactive Substances Act 1993
RWMAC	Radioactive Waste Management Advisory Committee
SAFEGROUNDS	Safety and Environmental Guidance for the Remediation of Contaminated Land on Nuclear and Defence Sites (project)
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
WRAP	waste and resources action programme

1 Introduction

1.1 Background to the project

Several 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 (eg 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, the majority of which by volume will contain no artificial radioactivity or levels of radioactivity that are so low they may be treated and regulated in the same manner as conventional wastes.

The Safety Issues Task Force (SITF) of the DTI's Liabilities Management Group[2] identified a need for guidance to address the sustainable management of assets and the large amounts of demolition and deconstruction wastes being generated. Consequently, a project was launched under the management of CIRIA to develop this guidance through a process of extensive stakeholder consultation. A scoping report was published by CIRIA (*Establishing sustainable practise in managing very low level waste and free-release construction materials in nuclear industry decomissioning – Scoping study report*, Kersey, 2003) which led to the current project, 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 the decommissioning of nuclear sites. The scope of the project also included the following specific objectives which were intended to help inform the development of the guidance:

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

A further aim of the project was to develop a site specific case-study and planning model for the 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.

2 SITF is no longer in operation.

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 types of wastes that arise on UK nuclear sites undergoing decommissioning and some defence sites:

- radiologically clean wastes that have never been contaminated with artificial radionuclides – in regulatory terms these are conventional, non-radioactive wastes;
- wastes that contain concentrations of artificial radionuclides that are so low that they can be managed in the same way as the radiologically clean wastes; and
- slightly radioactive wastes, due to either contamination or activation, at the lower end of the low level waste (LLW) category.

The first two types of wastes are included in the scope because potentially they could be made available for reuse or recycling either on or off a nuclear licensed site subject to the appropriate approvals. For example, radiologically clean concrete from demolition could be crushed for use as a construction aggregate.

The third type of waste is included in the scope because it is recognised that sustainability considerations such as its disposal (eg to the existing LLW repository at Drigg) may not represent the most sustainable use of disposal capacity. 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), 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 and there is no suggestion that these wastes should be freed from regulatory control under NIA '65 or the Radioactive Substances Act 1993 (RSA '93). Defra is currently undertaking a review of policy for the management of LLW which aims to produce a policy statement for the future management of LLW which will update that set out in Cm 2919. It is anticipated that the new policy framework will define the principles and requirements within which decisions about the management of LLW will be made.

As a working definition, slightly radioactive waste may be considered to comprise the lowest of the five orders of magnitude activity range covered by LLW[3]. Further information on radioactive waste classes and their regulation is provided in the appendices.

This report recognises that the first objective of a site operator is to ensure the protection of people and of the environment, and consequently that the management of decommissioning wastes must be undertaken within the established framework of health and safety, and environmental regulation that ensures all risks are as low as reasonably practicable.

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 assets, and radiologically clean and slightly radioactive decommissioning wastes.

3 The activity range for LLW is from 0.4 MBq/te (which is the level highlighted in the Substances of low activity exemption order issued under RSA'93) to 12 GBq/te of beta-gamma activity (the upper threshold for LLW).

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[4] to develop the guidance through a process of open dialogue. Throughout the project, stakeholder views have been sought by a number of mechanisms:

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

Many varied and interesting views were expressed during the consultation and these have been 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 decommissioning wastes on their sites for use in this project. Further details of the consultation and its outcomes are provided in the appendices and on the project website at: <www.sdspur.com>

1.2 Nuclear site decommissioning and waste management

1.2.1 Decommissioning plans

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

Large volumes of wastes will be generated by decommissioning. Some of these wastes 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 and subject to control under the Waste Management Licensing Regulations 1994 (WML Regulations). It should be noted that once material has been declared as radioactive waste, it must always be designated so, and its treatment should be appropriate to the hazard it poses. The regulations governing the management of these wastes are described in the appendices.

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.

Decommissioning of nuclear reactors is subject to the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 (EIADR '99). The EIADR'99 regulations require an Environmental Impact Assessment (EIA) to be carried out by the site operator and this will also need to account for environmental effects arising from the management of both radioactive and non-radioactive wastes.

There is a standard condition (Condition 35) contained in all site licenses issued to operators of nuclear sites under NIA '65 that requires the operator to make adequate provisions for decommissioning, including the production of decommissioning programmes. There is also a requirement in the Government's radioactive waste management policy (Cm 2919) for all site operators to establish strategies for the management of their redundant plant and radioactive wastes[5]. These strategies are subject to quinquennial review by the Health & Safety Executive's Nuclear Installations Inspectorate (HSE/NII) in conjunction with the environment agencies. Such decommissioning and waste management strategies have been produced for all nuclear sites and these are at various stages of development and implementation. 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. The nuclear site decommissioning plans are discussed further in the appendices.

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 excluded, and slightly radioactive wastes resulting from decommissioning.

1.2.2 Waste inventory

Waste is defined in the Waste Framework Directive (EEC, 1991) 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 threat to human health or the environment.

In UK regulations, there is no single agreed definition of the term "waste" and different working definitions of the term are used in RSA'93 to describe radioactive wastes compared to those in the WML Regulations to describe non-radioactive wastes. Under RSA '93, a clear distinction is made between radioactive materials and radioactive wastes. These definitions and regulations are discussed further in the appendices.

5 Note that those parts of Cm 2919 pertaining to decommissioning were superseded by a Government statement dated September 2004 (DTI, 2004).

Wastes 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 version current at the time of writing, dated 2001 (RWI '01), only includes data for wastes that are declared as radioactive wastes and reports these data in accordance with the UK radioactive waste classification scheme. 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 wastes they classify as radiologically clean, RSA exempt and excluded, and slightly 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 m^3 of radiologically clean, and RSA exempt and excluded wastes
- 1 500 000 m^3 of slightly radioactive wastes.

Information provided by the site operators indicates 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.

These volumes are broadly comparable with estimates given by Defra within supporting documents for their LLW policy review which are 2 300 000 m^3 for all LLW and 600 000 m^3 for "low" LLW which they define as below 1 Bq/g alpha or 40 Bq/g beta-gamma activity (UCL, 2004). 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 national inventory 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). The uncertainties associated with the inventory are due, among other things, to issues such as:

- the difficulty in estimating the degree of contamination of buildings when not all parts may be readily accessible for sampling and analysis
- the assumed efficiency of any sorting and segregation methods planned to be used
- assumptions for clearance and exemption criteria that will be applicable at the time the wastes actually arise.

The estimated waste arising from the decommissioning of the nuclear sites can be compared to the total amount of conventional construction/demolition wastes (CDW) generated in England and Wales in 2003 which was around 45 million m^3 and the production of recycled aggregates in the same year of around 16 million m^3 (ODPM, 2004a). Clearly the amount of decommissioning wastes arising on 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 m^3, and because of the public reluctance to adopt recycled materials derived from nuclear sites. Further details of the inventory of radiologically clean, RSA exempt and excluded, and slightly radioactive wastes is provided in the appendices.

1.2.3 Waste management

The management of decommissioning wastes from nuclear sites is subject to NIA '65 and the overlapping regulatory regimes of RSA'93 and the WML Regulations.

The majority of LLW, not subject to an Exemption Order under RSA '93, is currently disposed of to the national facility at Drigg in Cumbria. Other radioactive wastes are stored either at their place of arising or centrally at Sellafield, pending a review of Government policy on radioactive waste management.

The disposal of non-radioactive wastes is regulated under Part II of the Environmental Protection Act 1990 (EPA, 1990) which sets out provisions for the management of controlled wastes. This Act prohibits the unlicensed management or disposal of waste and is implemented through the WML Regulations which set out a waste management licensing regime that allows for exemptions of certain waste management activities. Exemptions need to be agreed with the relevant environment agency to minimise the risk to an overall waste management strategy. Landfills to which radiologically clean decommissioning wastes may be disposed are regulated under the Landfill (England and Wales) Regulations 2002 (Landfill Regulations, 2002) which is implemented through the Pollution Prevention and Control (England and Wales) Regulations 2000 (PPC, 2000)

In broad detail, the disposal of decommissioning wastes arising on nuclear sites will be subject to the provisions of either RSA'93 if they are radioactive or the WML Regulations if they are non-radioactive. In either case, the disposal of wastes is strictly controlled by the relevant environment agency through systems of authorisations, licenses and exemptions.

In all cases, site operators have a legal responsibility under the Environmental Protection (Duty of Care) Regulations 1991 (as amended) to ensure that all wastes they generate are handled safely and are properly disposed, recovered or recycled in accordance with the law. This duty of care has no time limit, and extends until the waste has either been finally and properly disposed of or fully recovered, or transferred to another authorised person. The regulations require the establishment and maintenance of a formally auditable chain of custody.

1.2.4 Reuse and recycling of waste materials

The reuse and recycling of CDW from the construction industry is a well established practice. The Waste and Resources Action Programme (WRAP) has developed a Quality Protocol, which has been endorsed by the environment agencies, 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 WRAP 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.

If the Quality Protocol is followed for appropriate wastes, then it removes the requirement for exemptions to be applied in the management of solid inert, radiologically clean wastes arising from site decommissioning, and therefore simplify the process by which these wastes can be released for reuse and recycling rather than sentenced for disposal. The Quality Protocol should be used in parallel with this report by waste managers on the nuclear sites to ensure the efficient delivery of a sustainable waste management strategy.

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, including metals, concrete, glass, timber and so on. In some cases, these segregated wastes 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 (eg 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 wastes is provided in the appendices.

Of the 45 million m^3 of CDW generated in England and Wales in 2003, around 90 per cent was reused (eg recycled as aggregate or soil, and backfilling of quarry voids) and only 10 per cent was disposed to landfill. The reuse and recycling of demolition wastes arising on nuclear sites is not as advanced as conventional sites but the same level of material recovery, segregation, processing and reuse should be achievable for all radiologically clean wastes. 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
- measurable or auditable information regarding the quality of product, material type, history and extent of impurities and contamination
- added value processing to achieve higher utility or grade of product
- location and transport costs
- comparative 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 wastes, demand for materials arising from nuclear sites may be affected by issues relating to public concern, and perceived health and safety impacts. While all recycled radiologically clean wastes should pose no radiological hazard and 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 (eg buildings and other facilities) and waste arisings on decommissioning nuclear sites. This guidance offers zan 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 in no particular order:

- use of the waste hierarchy
- taking costs and benefits into account
- timely, progressive and systematic reduction in hazard
- 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
- application of the proximity principle
- application of the precautionary principle.

The use of the waste hierarchy is intended to ensure that wastes (of any type) are not generated unnecessarily and that those arisings which 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 reuse in preference to disposal, is enshrined within the International Atomic Energy Agency (IAEA) standards (IAEA, 2000). Waste producers and waste managers are 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 Cm 2919 is also based on the principle of sustainable development. That said, neither Cm 2919 nor any associated 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 to demonstrate to the HSE/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. 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 that a BPEO-type approach may need to be applied to all wastes to establish the IWS.

2.2.1 Sustainability guidance in the context of BPEO studies

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 verified by a BPEO study that evaluates alternative options against an appropriate set of attributes, and takes into account stakeholder views. The relationship between this guidance on the sustainable reuse of decommissioning wastes, the IWS and supporting BPEO study are illustrated in Figure 2.1.

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. It is intended to be flexible and the methodology need not be time consuming to implement or record, so that waste management decisions can be made in a timely and cost effective manner within the overall context of a site's IWS and in the knowledge of existing disposal and recycling routes. The approach is also intended to provide a transparent record of the decision making process that may be required by the regulators.

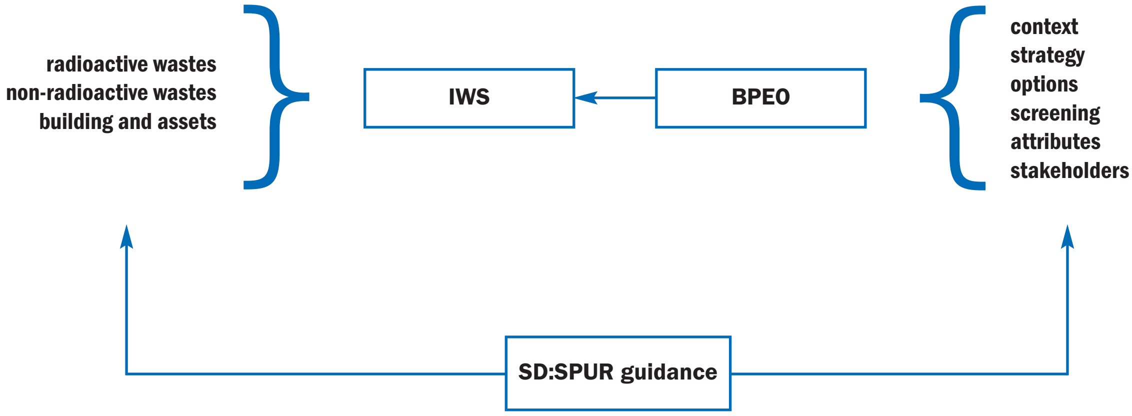

Figure 2.1 *The relationship between this guidance on the sustainable reuse of decommissioning wastes, the IWS and supporting BPEO study*

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 considering only options for the management of rubble arising from the demolition of a building, alternatively using the building so as to avoid its demolition may be considered. If that is not practicable (eg because it does not meet appropriate standards), 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 (2004) on the application of BPEO to the management of radioactive wastes because this will already be familiar to waste managers on 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 wastes. 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 formulated 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 (eg best to worst) or a numerical score.

6 **Weighting factors:** weightings may be applied to each attribute to reflect its relative importance. 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 regard 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 explicitly to build sustainability considerations into a BPEO study for the coherent management of assets and decommissioning wastes (eg when developing an IWS). In this case, the key stages are:

- identification of options
- screening of options
- selection of attributes
- 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 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 wastes, rather than just disposal, which 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 radiologically 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 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, material reuse and recycling, and disposal 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 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 on a nuclear site

It is recommended that this guidance is first applied at the site-wide 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, or across several sites, to examine whether a coherent sustainable management approach could be applied, 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 types 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 type was considered in separate BPEO studies.

There is no guidance yet available on how to develop 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. While 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 (eg 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 be 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 option 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 optimal sustainable site strategy option is likely to be the one that promotes the greatest reuse of existing buildings and facilities on a site, avoids the need for new construction and minimises the amount of waste generated. It is recommended 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, safety, environmental 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. For this approach, the optimal sustainable site strategy option may be the one that allows the greatest amount of decommissioning wastes for recycling (rather than disposal) to become available, and also involves processing these wastes 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 to consider the total of all sources of clean and slightly radioactive wastes on the site (the fabric from all of the buildings and structures) as the starting point, and then options should be identified to maximise the utility and reuse of the materials generated from it. This will mean consideration of how the buildings may be taken down (planned deconstruction or routine demolition) as well as the processing of the wastes (eg 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 amount of 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 wastes are defined at a site-wide scale (eg supporting the IWS) by the process described above, it need not then be necessary for individual BPEO studies to be undertaken for each individual waste type or for each separate building when it becomes redundant. All that will be required is a simple demonstration or justification that what 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.

When developing an IWS, issues other than sustainability will need to be considered and balanced with other drivers such as cost and programme constraints. The purpose of this guidance is to ensure that sustainability issues are given high priority in establishing the IWS and when making a business case for the site decommissioning strategy. Another aspect of sustainability that may need to be taken into consideration in the wider business planning is the long term maintenance of an experienced workforce and site infrastructure.

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 wastes 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 often have a number of options available to them when they consider how best to manage particular assets and decommissioning wastes. These options will, to some extent, reflect the nature of the wastes (eg their physical, chemical and radiological characteristics) and the nature of any processing of the wastes that may already have taken place (eg demolition and deconstruction practices, sorting and segregation of wastes). In general, 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 NII's Safety Assessment Principles and the IAEA safety standards (IAEA, 2000) 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 but 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 wastes. If, however, 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.

Sustainability considerations can apply in two cases:

- at an early stage when deciding on how to manage an intact redundant asset (building or other facility)
- at a later stage when deciding on how to manage demolition or deconstruction wastes from a previously demolished structure.

These two cases are illustrated in Figure 2.2. In reality, however, these cases represent end-points of a whole range of possibilities. For example, it would be possible to remove a few materials from a building (eg to remove any copper wiring and piping) and then to demolish the rest of the building without sorting and segregating the remaining wastes. For the purpose of examining sustainability issues in relation to particular waste management options, these two cases provide a useful starting point. 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.

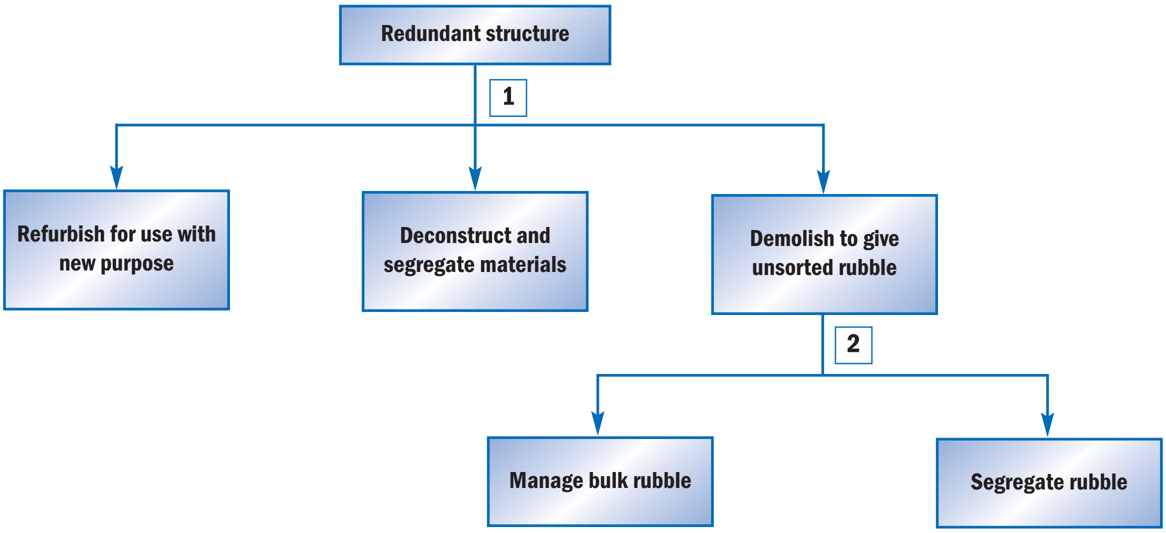

Figure 2.2 *The end-points of the possible range of options for managing a redundant structure or rubble from a previously demolished structure*

While the situation in Figure 2.2 represents an 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 so it is not always practicable or sensible to consider options for waste management starting with how best to reuse a redundant structure. In some cases, structures will already have been demolished and the waste management decision is one of how to deal with the demolition rubble. In others, some remaining structures will have no potential for further reuse: this may be 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 need to be able to screen out any potential 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 to provide an opportunity to scope the potential for material reuse and recycling. 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 BPEO study. An option should only be screened out from the assessment when there is no reasonable doubt that it would not be viable for particular site conditions.

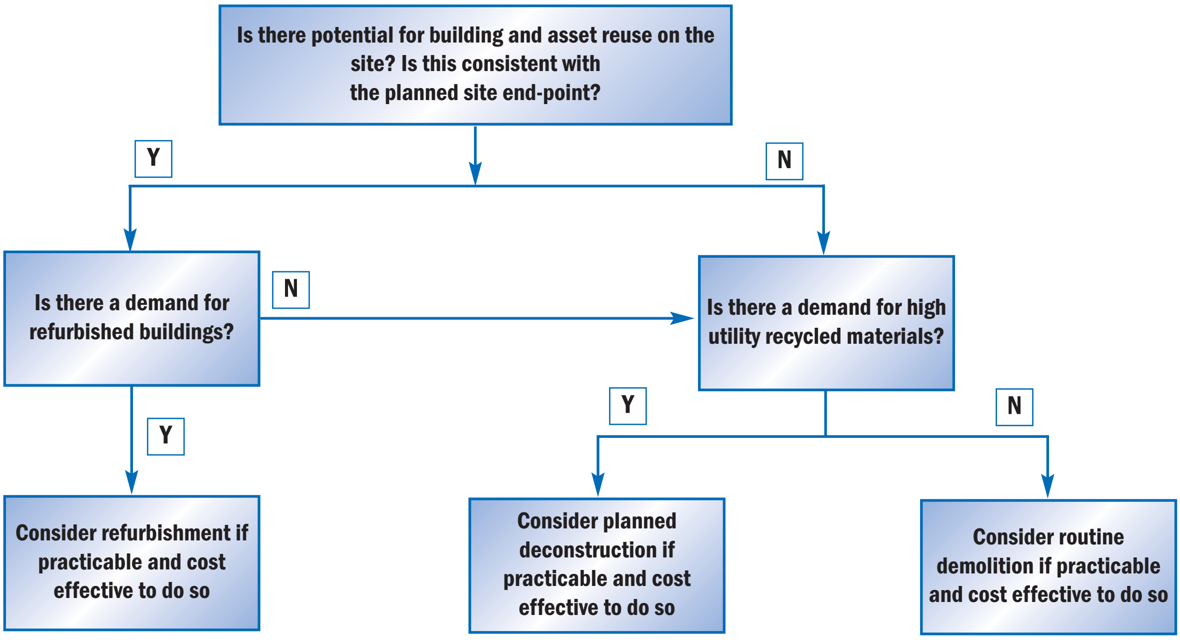

Figure 2.3 *Simple decision tree to help screen out those management options that are not viable on a site*

Another important consideration that may be used to screen options is whether or not a structure is radioactively contaminated or activated. If so, especially if it was an active building (eg used for the handling of radioactive materials), then deconstruction and/or demolition of the structure would need to be carefully completed to ensure that radioactive wastes were segregated from radiologically clean wastes (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 considerater the local conditions both on the site itself (eg in terms of planned end-points) and in the surrounding area (eg demand for office rented accommodation). The option which is most sustainable will need to be identified on a site specific basis.

There are a number of comments that could be made for 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 or 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 (eg bitumen coated roof) of a building, that material 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 (eg as light industrial units, office accommodation etc). The extent of demand will clearly vary from site to site, in relation to 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 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 sustainable scenario. If 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 per cent of the site became available for unrestricted use. 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 carefully taking apart a building with the primary intention of maximising the sorting and segregation of wastes (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 wastes (eg asbestos) that required careful removal for disposal. Otherwise, contaminated buildings may be decontaminated prior to routine demolition.

Radiologically clean or RSA exempted and excluded wastes could be segregated during deconstruction and released for reuse in the construction industry. Some of the segregated wastes would require minimal processing that could be done on-site to meet the quality requirements of the market (eg old bricks would need simple cleaning and sorting, and bulk concrete would need crushing and sizing). On the other hand, some wastes may require more extensive off-site processing for the market (eg 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 brownfield 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). However, it provides the maximum potential for the reuse and recycling of decommissioning wastes.

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 wastes 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 to 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 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 discourage 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 m^3 of radiologically clean decommissioning rubble will be used as landscaping to fill voids to within 1 m of the ground surface (topped by soil), and 17 000 m^3 of other radiologically clean concrete and metal will be sent off-site for recycling.

Routine demolition

Routine demolition involves basic, low technology methods to demolish a building with the primary intention of clearing the site as quickly as possible without any intent to sorting or segregating decommissioning wastes. 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 (eg surface decontamination prior to demolition) to protect the workers and to minimise releases of activity to the environment.

Unsorted CDW may be reusable without further processing as low-grade fill for on-site landscaping or sent for landfill disposal, provided its constituent wastes are inert. Such management methods would be subject to authorisation or exemption under the WML Regulations. 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 brownfield 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 wastes will be required, even if it is planned to landfill them, as a minimum to separate inert wastes from non-inert wastes to meet the standard waste acceptance criteria for landfills.

2.3.3 Options for the reuse and recycling of segregated wastes

As described above, planned deconstruction involves the careful taking apart of a building with the primary intention of maximising the sorting and segregation of wastes to facilitate their reuse or recycling. Some reuse and recycling would also be possible if the routine demolition approach was 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 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.

The management of non-radioactive decommissioning wastes would normally be subject to authorisation or exemption under the WML Regulations. When waste managers intend to adopt options for the reuse and recycling of wastes, they should ensure they follow the WRAP Quality Protocol (WRAP, 2004) as this will remove the requirement for exemptions to be applied in the management of solid inert wastes and simplify the process by which wastes can be released for reuse and recycling rather than sentenced for disposal.

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

Material	Potential applications	Current recycling/disposal practices
Aggregate	Crushed used as bulk filler, haul roads and an alternative to virgin aggregate.	Currently approximately 50 per cent of demolition material is recycled as aggregate, 40 per cent is otherwise reused and the remainder is sent to landfill for
Excavation soil	Reprofiling of land, reclamation of quarries and borrow pits.	There is a low demand for waste soil unless it is of high nutrient demand and of use in agricultural improvement or landscape gardening. Currently almost all topsoil is used for on-site applications such as landscaping or ground raising.
Road plannings	Reprocessed for reuse on or off-site for construction or repair of roads.	Most road planings nationally are recycled.
Timber	Reused 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 per cent concrete from building demolition is reused in some form.

Table 2.2 *Typical reuse applications for high value wastes*

Material	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 old bricks and blockwork typically those of rarer stone types such as granite. Other newer bricks are generally crushed prior to reuse as aggregate and this is likely to be the case with bricks from the nuclear sites.
Steel	Sent 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, roofing materials and the so on.	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. Use in concrete as an aggregate replacement, filter material etc. Alternative uses 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 metal (Al, Cu, Zn, Pb)	Sold and sent to scrap metal merchants or fed directly back into the production stream where they form part of new metal products.	Currently an unknown percentage of waste 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

The refurbishment of a redundant building or the reuse and recycling of wastes 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-SEPA (2004) 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). That 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 that 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 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–SEPA (2004) 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 (eg noise, odour, visual impact).
B.6	Indirect impacts (eg 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 (eg noise, odour, visual impact).
D.2	Residual restrictions on access following remedial action.
D.3	Positive/negative effects on local economy.
Group E	**Costs**
E.1	Indicative lifetime costs (eg construction, operation, decommissioning).

The sustainability indicators recommended for use in sustainable waste management 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 (2004) 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 stakeholder 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, Defra (2004))
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 (eg contact with recycled wastes). 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 (eg those from processing and later reuse operations). Future workforces should be afforded at least the 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 best available techniques (BAT) and best practicable means (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. This includes coverage of the provisions of the Habitats Directive. (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 LLW repository at Drigg 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 wastes 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 (eg CO_2 emissions from burning hydrocarbons). (A1, D3)

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

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 and sustain expertise that 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 them. That is not to say that every sustainable waste management 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 which 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 all decommissioning wastes 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.

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 of 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 POSSIBLE alternatives available to a waste manager on a nuclear site, these were:

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

These options reflect the waste hierarchy, involving options for reuse and recycling. However, it is not simple to say that an option involving the reuse of a building is the most sustainable because other factors reflected 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 (eg 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 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 (eg 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 (eg environmental impacts of certain materials)
- assumptions about future developments (eg 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 should 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 should not be used to constrain the initial identification of options but it 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 (hundreds of years) 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 clearly highlighted in the submission.

With regard to options for the reuse and recycling of decommissioning wastes, it is reasonable to include in the assessment any revenue that may accrue from the sale of a recycled material or product, or from sale or lease of land made available for unrestricted use (eg remediated to achieve delicensing). However, it may be more appropriate to account for any reduction in liabilities (disposal costs) achieved by way of diverting wastes 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 may not 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 that provides for good overall performance but does not incur disproportionately high costs.

2.5 Stakeholder engagement and public acceptance

This guidance emphasises the need for a sustainable waste management BPEO study to be done at an early stage. This will determine the most appropriate way to manage redundant assets and decommissioning wastes as part of an IWS. In some cases, the most practicable approach may be to refurbish a redundant building for reuse, or else demolish the building in such a way that the decommissioning wastes generated can be made available for reuse and recycling with the highest possible utility.

With the exception of radioactive wastes, it is possible that some of the reused or recycled decommissioning wastes may 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 materials derived from nuclear sites. This was evident from the feedback during the stakeholder workshop and from anecdotal evidence from some sites where demonstrably clean decommissioning wastes such as crushed concrete have not found off-site uses in even basic, low grade applications as aggregate.

Little is achieved by processing wastes 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 decommissioning wastes 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 for several sites whereby large volumes of inert clean decommissioning wastes are to be used for landscaping. However, not all decommissioning wastes can be used this way and broadley, it does not necessarily represent the most sustainable use of these wastes.

The second approach is to *engage the public and stakeholders at an early stage* so that broad-based agreement can be sought for sustainable applications of processed decommissioning wastes. Most nuclear sites have an established local liaison group or site stakeholder group. 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 wastes could potentially be used at places remote from the nuclear sites. The local stakeholders at the proposed place of use 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 be easier to implement. While 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

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 from either on- or off-site landfill disposal.
2	Health and safety of the workforce	Workers may face hazards during refurbishment (eg asbestos in the structure) but these would be similar to those faced in normal building work.	Workers may face hazards during deconstruction (eg asbestos in the structure) but these would be similar to those faced in normal building work.	Workers may face hazards during demolition (eg asbestos in the structure) but these would be similar to those faced in normal building work.
Group	**Impacts on natural, physical and built environments**			
3	Discharges to water bodies	Not likely to be significant.	Not likely to be significant.	Not likely to be significant because only inert waste is allowed to be disposed of in most new landfills.
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.	Limits the amount of CDW and other materials sentenced for disposal or storage. Some wastes would, however, need to be disposed if there is no market for their reuse.	Maximises the amount of CDW and other wastes 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 wastes.	Provides limited opportunity for reuse and recycling of wastes.
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 (eg landscaping), all materials will need to be transported from site to the market or disposal site.
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.

Table 2.5 (contd)

Group C	**Technical performance and practicability.**			
10	Quality of recycled product.	Amount of recycled product for use elsewhere would be small.	Dependent on the efficiency of the segregation methods employed.	Only low-grade product likely to produced from unsorted CDW rubble.
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 (eg to remove metal components from reactors that are clean or could be surface decontaminated).	Industry standard demolition techniques used.
12	Finality of option.	Is not a final solution and affects options for ultimate site end-point.	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 other than visual impact.	Not likely to be significant other than visual impact.	Not likely to be significant other than visual impact.
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 except for sites very close to populations when nuisance factor may be reduced.	Not likely to be significant except for sites very close to populations when nuisance factor may be reduced.
17	Investment.	Inward investment may be enhanced by the provision of suitable premises for industrial or commercial activities.	Not likely to be significant unless cleared site provides opportunity for substantial new business.	Not likely to be significant unless cleared site provides opportunity for substantial new business.
Group E: Costs.				
18	Costs.	Refurbishment costs may be higher than the cost of routine demolition but potential saving from disposal costs for CDW.	Planned deconstruction costs may be higher than the cost of routine demolition.	Likely to be the cheapest option for demolition but likely to have highest costs for disposal of unsorted CDW and unsegregated LLW to the repository at Drigg.
19	Revenue.	Revenue from sale or lease of the refurbished buildings may be anticipated, or from sale of land particularly in southern sites.	Revenue from sale of recycled product may be anticipated. Possible high revenue from sale of lease of land particularly in southern sites.	Not likely to be significant from recycled product. Possible high revenue from sale of lease of land particularly in southern sites.

cannot be brought to the market and, thus, the option cannot be implemented. In this case, 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 the 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 project 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 making decisions.*

The SAFEGROUNDS project 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 regard to the use of recycled radiologically clean wastes in public places relate to having satisfactory evidence to show that:

- the wastes are uncontaminated with both radiation and other chemically toxic substances
- 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 material (see Section 2.6). 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 project.

2.6 Waste characterisation

2.6.1 Waste inventory and pre-demolition sampling

To support plans for the sustainable use of construction resources, it is recommended that site operators make continued 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 their composition. 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 for the viability of processing decommissioning wastes for reuse or recycling.

It is understood that better quality inventory information may be included in the 2004 version of the RWI, which is the next version of the national inventory, but it is unlikely that this iteration will contain all the information that is required.

An important aspect for reducing the uncertainty in the inventory is comprehensive pre-demolition sampling and surveys of redundant buildings and facilities to characterise the extent of any radiological and chemical contamination. This information can be used to develop detailed plans for the refurbishment or deconstruction of the buildings that adopt best practice to decontaminate and to sort and segregate wastes. It is not always possible to survey all parts of a contaminated or activated building and so the uncertainty cannot be completely eliminated. Detailed surveys undertaken early, perhaps several years before a building is due to be decommissioned, provide the best way to reduce the uncertainty associated with the inventory of anticipated future arisings of clean and exempt wastes, and radioactive wastes.

2.6.2 Waste sampling and clearance

Before any decommissioning waste could be reused or recycled for 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. If it can be demonstrated that a waste may be cleared from control under RSA '93, its further management will remain subject to control under the WML Regulations.

Sampling, measurement and analysis to prove the radioactivity content of a waste can be prone to uncertainty, particularly in reference to heterogeneous distributions, and statistical approaches. There is no regulatory procedure for waste producers to follow when demonstrating that a decommissioning waste is clean, or RSA 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 proposals 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, 2005). This provides guidance on the sampling, measurement and analysis, and on sentencing for different types of wastes. It is recommended that this code of practice be consulted when planning a sustainable waste management strategy to ensure that decommissioning wastes 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 when considering the safety of recycled wastes 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 recycled wastes within the nuclear section is likely to generate far less concern than possible uses in public places.

How the public and stakeholders may be included in the sampling and analysis processis defined in 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 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 among 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 wastes that may enable them to find wider support and utility.

Radiologically clean and RSA exempt wastes that are inert but which cannot be reused or recycled may be sentenced for disposal to landfill subject to control under the WML Regulations. Additional sampling and testing may be required for waste acceptance at any licenced landfill site, and this may be particularly important for soils and potentially chemically contaminated wastes. Strict acceptance criteria for inert wastes will limit the disposal route available for wastes which contain leachable substances in excess of certain thresholds.

2.7 Reuse of slightly radioactive wastes

The slightly radioactive wastes arising from decommissioning must always remain under regulatory control under the terms of NIA ’65 and RSA ’93 and 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 wastes on nuclear sites that might offset the use of virgin or other sources of recycled wastes.

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

- operating NPPs
- MOD sites that handle radioactive materials
- industrial sites that manufacture radioactive sources
- hospitals and universities etc that use radioactive materials
- decommissioning sites under the remit of the NDA
- current and future radioactive waste disposal and storage facilities.

The uses to which certain recycled slightly radioactive decommissioning 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
- reuse of lead to fabricate new shielding bricks and shielding walls for various facilities
- 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 (eg 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 slightly radioactive decommissioning wastes, particularly metals (eg 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 wastes is that, even if they can be decontaminated so as to be cleared from further regulatory control under RSA '93, they will still be subject to control under the WML Regulations and there is likely to be considerable public concern regarding their use in everyday construction applications. There is a considerable benefit to be gained if these wastes 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 wastes (radiologically clean or decontaminated) from nuclear sites:

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

It is unlikely that a nuclear site could meet all of its construction material requirements from processing and recycling its own decommissioning wastes. However, it is recommended that, as part of a site-wide IWS, a mass balance calculation is undertaken to assess the extent to which a site could satisfy its own requirements and the financial and environmental implications of doing so.

It is feasible that the nuclear industry could become the main consumer of its own recycled wastes if a centralised approach were taken to the provision of processing and recycling plants (eg 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). It would appear to be within the remit of the NDA to promote this approach, although individual sites are encouraged to consider installing local processing facilities for their own or shared use.

2.8 Impacts on decommissioning programmes

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

- impacts on the development and assessment of an IWS
- impacts on the implementation of decommissioning programmes.

In the first case, the impacts on the development and assessment of an 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 decommissioning wastes, 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 on 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 wastes 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.

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1 Including wastes that are excluded and exempt from control under the Radioactive Substances Act 1993.

2 SITF is no longer in operation.

3 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 12 GBq/te of beta/gamma activity (which is the upper threshold for LLW).

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. Go to: <www.safegrounds.com>

5 Note that those parts of Cm2919 pertaining to decommissioning were superseded by a Government statement dated September 2004 (DTI, 2004).