UK Long Term Nuclear Waste Management: Next Steps?

A report of the Loughborough University workshop 6 – 7 November 2006

Report launched 6 February 2007

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UK LONG TERM NUCLEAR WASTE MANAGEMENT: NEXT STEPS?

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FOREWORD AND DISCLAIMER

This report summarises the material presented, and some key points arising from discussions, at the scientific and technical workshop “UK Long Term Nuclear Waste Management: Next Steps?” held at Loughborough University on 6-7 November 2006.

The Technical Organising Committee has aimed to present this material fairly. Nevertheless, the report should not be taken as representing the formal positions of all the organisations whose staff have served on the Technical Organising Committee, nor of the sponsoring organisations. Moreover, it may not include all the points raised in discussion.

GLOSSARY OF TERMS

AGR	Advanced Gas-cooled Reactor
CoRWM	Committee on Radioactive Waste Management
Defra	Department for Environment, Food and Rural Affairs
HLW	High Level Waste
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository
MOX	Mixed Oxide Fuel
MRWS	Managing Radioactive Waste Safely
NDA	Nuclear Decommissioning Authority
NORM	Naturally Occurring Radioactive Materials
PGRC	Phased Geological Repository Concept
PWR	Pressurised Water Reactor
R&D	Research and Development
SF	Spent Fuel
TRU	Transuranic
WIPP	Waste Isolation Pilot Plant

EXECUTIVE SUMMARY

Introduction

The UK has a complex inventory of radioactive waste generated by nuclear power, military defence, medical applications and detection and control technology. There is currently no agreed long term management method for these wastes.

In July 2006 the Committee on Radioactive Waste Management (CoRWM) made their final recommendations on managing UK radioactive waste safely (MRWS). They recommended that geological disposal coupled with safe and secure interim storage is the way forward for the long term management of the UK's higher activity wastes. In October 2006, Government announced that it accepted CoRWM's recommendations and gave details of how it intends to implement Stage 3 of its MRWS Programme and gave an indicative timetable for consultation and decisions on key aspects of the eventual delivery of the interim storage and geological disposal programmes.

This report represents the material presented, and some key points arising from discussions at the workshop "UK Long Term Nuclear Waste Management: Next Steps?" held at Loughborough University on 6-7 November 2006. The purpose of the workshop was to bring together scientists, engineers, regulators, policy makers and others in order to have an open debate on the next steps towards realising the geological disposal of UK radioactive waste.

The workshop concluded that there are no insurmountable scientific or technical barriers to deep geological disposal of radioactive waste in the UK. The tools, techniques and relevant experience already exist for investigating the properties of a site, for designing and operating a repository and for its construction; and much of the science for assessing the long term engineered and natural containment of a repository is established. There is a significant body of valuable international experience covering both technical and community aspects that can be applied to the UK situation.

The workshop identified several areas where further work is needed in order to proceed with the implementation of a UK radioactive waste disposal programme. The next steps should focus on *framing the strategic requirements of the radioactive waste disposal programme, identifying the remaining research and development (R&D) needs of the programme, engaging potential host communities, devising a rigorous regulatory framework and defining procedural requirements for the various stages of site identification and waste processing and developing the workforce required for implementing the programme.*

Strategic requirements

Both nuclear waste and spent nuclear fuel arising from any future UK nuclear power station building programme may need to be considered in repository designs.

Decisions are required as to whether spent fuel, together with civil and military plutonium, should be classified as a waste or a resource; if classified as waste then further development of appropriate waste forms is required. Dependent upon these decisions a strategy for the management and disposal of these materials will need to be developed.

Final repository concepts are contingent upon several critical factors. A decision is required as to whether High Level Waste (HLW), Intermediate Level Waste (ILW), and Low Level Waste (LLW), and, possibly, spent fuel and plutonium can be disposed of together in a single repository, or whether segregation might be required to some extent into dedicated repositories. Waste management must include the strict application of the waste hierarchy to minimise burden on existing and future disposal facilities.

The *phased* geological repository concept, where the repository is monitored to confirm initial performance as expected and left open for access, maintenance and potentially the retrieval of wastes, raised some key issues. It will be necessary to balance the public desire for monitoring waste *in situ* and allowing its retrieval, with the concerns that such a concept could reduce the effectiveness of the engineered containment as well as the engineering challenges associated with retrieving waste. The workshop accepted CoRWM's recommendation that sufficient above ground interim facilities capable of storing radioactive materials and allowing for their retrieval from a repository will need to be available for approximately the next 100 years. Some of the features of the store design will be common to the repository with regard to requirements to manage radioactivity, radiotoxicity and heat.

Additionally, there is a need for waste package records to be maintained in a format suitable for long term use.

Research and development (R&D) requirements

A focussed but substantial R&D programme will be required to support an implementation plan for a UK radioactive waste disposal programme. It is important that the geological environments of repository sites and the requirements for interim storage are well understood in order to determine the most appropriate and stable waste forms.

There are several problematic UK radioactive waste streams, including large volumes of contaminated land, non-compactable waste arising from building decommissioning, poorly characterised historic waste, graphite and spent fuel.

These require further research so that the best waste form and/or disposal route can be developed in light of final repository concepts.

Long term safe containment of radioactive waste in a repository environment will be assured by the waste form, the engineered containment barrier, the buffer and backfill and the surrounding host rock and overlying geology. Research and development effort is required to demonstrate the suitability and performance of these barriers in relation to stresses that they will be exposed to in the long-term. Equally it is important to understand the mobility of radionuclides in both near- and far-field and apply this knowledge in minimising the risk of their escape.

Finally, alternatives to the deep geological repository option, such as borehole disposal, should continue to be researched. The technical feasibility of alternatives should be subjected to detailed scrutiny by appropriate experts.

Community engagement

It is absolutely critical that the community and wider stakeholder engagement process is transparent and that uncertainty is managed openly. Stakeholders should be engaged as early as possible and should help to frame the issues and identify where scientific understanding is required. This will also help to ensure that the debate is informed by impartial and robust scientific evidence. In particular, scientists and engineers need to understand how the public perceive risk and uncertainty and accordingly be more forthcoming and sensitive when addressing these issues. Universities and learned and professional bodies could be among the main sources of trust in building this relationship.

Rigorous screening criteria to identify suitable locations for a storage site will need to be developed in close consultation with stakeholders. Broadly speaking, UK geology is well mapped out and potential host sites with desirable geological characteristics for repository sites can be identified. However, public engagement may identify other issues not directly related to the geology such as transportation issues related to moving the waste to the site.

Regulatory framework

From a regulatory perspective it is feasible that a safety case[1] could be made for a geological repository. The regulatory process is more complex than a simple numerical assessment, and it is important that the implications for overall waste management are considered throughout.

[1] The term 'safety case' is used to encompass the totality of a licensee's (or dutyholder's) documentation to demonstrate high standards of nuclear safety and radioactive waste management, and any sub-set of this documentation that is submitted to Her Majesty's Nuclear Installations Inspectorate (NII). See www.hse.gov.uk/nuclear/saps/saps2006.pdf

A nuclear skills base

There has been a very significant decline in R&D funding in nuclear fission, and equally a decline in the nuclear skills base. There is a need for a nuclear skills renaissance to address this trend in order to support the implementation of the repository and to provide the scientists and engineers of the future. The creation of the Dalton Nuclear Institute, the BNFL University Research Alliances, Nuclear Technology Education Consortium and the Nuclear Engineering PhD are the first steps toward this renaissance. In addition, the recent announcement of the creation of a national nuclear laboratory may provide additional momentum for this process.

INTRODUCTION AND AIMS

In July 2006 the Committee on Radioactive Waste Management (CoRWM) made their final recommendations on managing UK radioactive waste safely (MRWS). They recommended that geological disposal coupled with safe and secure interim storage is the way forward for the long term management of the UK's higher activity wastes.

In October 2006, Defra formally responded to the CoRWM recommendations stating that "Higher activity waste, which includes waste from the nuclear and medical industries, military uses and academic research will be managed in the long term through geological disposal. This involves placing radioactive waste in facilities deep underground, where the rock structure provides a barrier against radioactivity. Until geological disposal facilities are available, there will be a continuing need for safe and secure interim storage".

On 6 -7 November 2006, a meeting was held at Loughborough University aiming to cover the scientific, engineering, technological and regulatory issues that need to be addressed for the geological disposal of UK nuclear waste. At the 'Next steps' meeting 135 delegates heard and debated presentations from 29 expert speakers on five key topic areas. The full programme can be found on pages 9 and 10 of this report. The full presentations are available at the following weblink:

http://www.lboro.ac.uk/departments/cm/research/LTNWM/index.html

The delegates included 69 research providers (including 12 from learned and professional societies, 28 from academia and 29 technology providers) and 48 research users (including 12 from the nuclear industry, 8 representing regulators, 10 representing the implementers and 8 from Government). The remaining attendees represented other interested parties including international experts, local councils and interested members of the public.

This report presents a summary of the discussion and key recommendations from this meeting. It is intended to inform key decision makers of the scientific and engineering challenges in moving forward with geological disposal of UK nuclear waste.

The report was formally launched on 6 February 2007 at the Royal Society. Professor Charles Curtis of the Geological Society presented the report.

TECHNICAL ORGANISING COMMITTEE

The following people are thanked for their help in organising the workshop and input into this report. Particular thanks are offered to Dr Nick Evans (Loughborough University) and Dr Jeff Hardy (Royal Society of Chemistry) for their efforts in organising the workshop and the subsequent report launch.

Professor Peter Warwick (Loughborough University)

Dr Nick Evans (Loughborough University)

Dr Jeff Hardy (Royal Society of Chemistry)

Dr Adrian Bath (Intellisci Ltd)

Professor Bruce Yardley (Leeds University)

Dr Edmund Nickless (Geological Society)

Dr Colette Grundy (Environment Agency)

Jocelyn Bia (Energy Institute)

Dr Alan Hooper (UK Nirex)

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Dr Antoni Milodowski (British Geological Survey)

Dr Julia West (British Geological Survey)

Dr Gráinne Carpenter (UKAEA)

Mark Bentley (SAFEGROUNDS)

Professor David Read (Enterpris, Aberdeen University)

Dr Richard Heap (Royal Society)

Dr Fred Plumb (Ministry of Defence)

Dr John Roberts (University of Sheffield)

Rob Sears (ES International Ltd)

SPONSORING ORGANISATIONS

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WORKSHOP PROGRAMME – 6-7 NOVEMBER 2006

6 November 2006	
Time	**Event**
09.00	Registration
10.00	**CHAIRS INTRODUCTION - Professor Peter Warwick**
	INTRODUCTORY SESSION – THE CURRENT POSITION
10.15	**SPEAKER 1:** Implementation recommendations by CoRWM (Andrew Blowers, CoRWM)
10.30	**SPEAKER 2:** Planning/timeline for a repository (Bruce McKirdy, Nirex)
10.45	**SPEAKER 3:** Government position (Nick Evans, Loughborough University)
11.00	Coffee Break
	SESSION 1: INTERNATIONAL CASE STUDIES
11.15	**SESSION CHAIR: Professor David Read**
11.20	**SPEAKER 1:** Finland proceeds towards direct disposal of spent fuel (Juhani Vira, Posiva Oy)
11.35	**SPEAKER 2:** High level and long-lived radioactive waste management: The French case (Frederic Plas, Andra)
11.50	**SPEAKER 3:** The Swiss HLW programme – status and future challenges (Jürg Schneider, Nagra)
12.05	**SPEAKER 4:** ESDRED project (Wolf Seidler, Andra)
12.20	**PANEL DISCUSSION**
12.50	Lunch
	SESSION 2: GEOLOGICAL REPOSITORY
13.50	**SESSION CHAIR: Professor Peter Styles**
13.55	**SPEAKER 1:** Potential geological settings in the UK (Richard Shaw, BGS)
14.10	**SPEAKER 2:** Repository design concepts (Alan Hooper, Nirex)
14.25	**SPEAKER 3:** Geological disposal environment – their characteristics (Tim McEwen, McEwen Consulting)
14.40	**SPEAKER 4:** Phasing, retrievability and early/late closure (Fiona Neall, Neall Consulting Limited)
14.55	**SPEAKER 5:** The deep borehole option for spent nuclear fuel (Fergus Gibb, University of Sheffield)
15.05	**PANEL DISCUSSION**
15.45	Coffee break
	SESSION 3: LONG TERM SAFETY, CHEMICAL AND PHYSICAL PROCESSES
16.15	**SESSION CHAIR: Dr Neil Smart**
16.20	**SPEAKER 1:** Regulation of a future long-term radioactive waste management facility (Steve Griffiths, HSE)
16.35	**SPEAKER 2:** Technical status of the programme for a deep geological repository: A regulatory view (Andy Baker, EA)
16.50	**SPEAKER 3:** Engineered barriers and post-closure near-field interactions (Patrik Sellin, SKB)
17.05	**SPEAKER 4:** Far field interactions (Peter Warwick, Loughborough)
17.20	**SPEAKER 5:** Long-term stability and containment: key geosphere attributes and reassurance (Charles Curtis, The Geological Society)
17.35	**PANEL DISCUSSION**
18.30	Mixer reception (sponsors exhibition in lounge area)
19.30	Dinner

7 November 2006	
Time	Event
09.00	Coffee + Registration
	SESSION 4: WASTES FOR STORAGE AND DISPOSAL
09.30	**SESSION CHAIR: Professor Francis Livens**
09.35	**SPEAKER 1:** Key waste issues as seen by NDA (Phil Davis, NDA)
09.50	**SPEAKER 2:** UK LLW management strategy – determining the future for LLW disposition (Alan Wareing, Nexia Solutions)
10.05	**SPEAKER 3:** Plutonium disposition (Joe Small, Nexia Solutions)
10.20	Coffee
10.50	**SPEAKER 4:** The CoRWM inventory (Mark Dutton, CoRWM)
11.05	**SPEAKER 5:** Problem wastes, wasteforms and knowledge gaps (Bill Lee, Imperial College London)
11.20	**SPEAKER 6:** Waste from new build (Adrian Bull, BNFL)
11.35	**SPEAKER 7:** EU Framework VI project on near-field processes (Neil Hyatt, University of Sheffield)
11.50	**PANEL DISCUSSION**
12.30	Lunch
	SESSION 5: IMPLEMENTATION
13.30	**SESSION CHAIR: Professor David Williams**
13.35	**SPEAKER 1:** Waste package management (Gráinne Carpenter, UKAEA)
13.50	**SPEAKER 2:** Above ground storage of waste (Peter Wylie, BNG)
14.05	**SPEAKER 3:** Experience of stakeholder engagement (Beth Taylor, UKAEA)
14.20	**SPEAKER 4:** Skills/training/funding needs (Francis Livens, University of Manchester)
14.35	**SPEAKER 5:** International repository operation experience (David Kessel, DoE)
14.50	**PANEL DISCUSSION**
15.30	Coffee break
16.00	**RAPPORTEUR/CHAIR FEEDBACK AND CLOSE**

SUMMARY OF THE WORKSHOP SESSIONS

The following sections summarise the presentations and subsequent discussion from the five sessions of the UK long term nuclear waste management workshop held at Loughborough University on 6-7 November 2006.

The reports were written by dedicated rapporteurs and have been peer reviewed by the session presenters, session chairs and the technical organising committee.

The recommendations arising from the workshop are shown in **bold** in the text.

Thanks are given to the rapporteurs for there efforts in drafting these reports.

Session 1: Professor David Read (Enterpris, University of Aberdeen)
Session 2: Dr Adrian Bath (Intellisci Ltd)
Session 3: Dr Alan Hooper (UK Nirex)
Session 4: Dr Jeff Hardy (Royal Society of Chemistry)
Session 5: Dr Colette Grundy (Environment Agency)

Session 1: INTERNATIONAL CASE STUDIES

Introduction

Around the world, success in implementing disposal plans for radioactive waste has been mixed, with only the Finnish programme progressing broadly as originally envisaged. In other countries progress has been hampered by factors including lack of public trust in the industry, disputes over siting, opposition at the local level and, particularly in the UK, changes in Government policy.

CoRWM's (2006) recommendations focus on:

(i) geological disposal as the end point for long-term waste management;

(ii) storage in the interim period with contingencies against delay or failure to dispose; and

(iii) a flexible, staged implementation process in partnership with volunteer host communities.

These recommendations can be viewed in the light of experience elsewhere.

Geological Disposal

Geological disposal is recognised internationally as the preferred method of ensuring the long-term safety of radioactive wastes. Geological repositories for intermediate level waste (ILW) have been in operation for a number of years, for example, in Finland (crystalline rocks) and the USA (salt). Underground research laboratories at repository depths have also been constructed in argillaceous formations (e.g. Belgium, France and Switzerland). It is technically feasible to develop similar facilities in this country; moreover the diverse geology of the UK affords a greater choice of potential host rocks than is often the case elsewhere.

The decision of Finland and Sweden to site repositories in crystalline, igneous host rocks is one largely borne of necessity given the geology of these countries. Nevertheless, successful cases have already been made for the disposal of LLW/ILW in fractured, crystalline rock (in Finland and Sweden) and a rock characterisation facility, that may become a HLW repository, is under construction in Finland (ONKALO). A lack of appropriate geological settings is unlikely to be an impediment to disposal in the UK.

Considerable resources could be expended unnecessarily in seeking to find 'the best site' for disposal. Social, political and economic factors will intervene and local acceptance is obviously crucial. A key lesson from other countries is that the site chosen need not be ideal from a geological perspective but rather it should meet certain pre-defined acceptance criteria.

Recommendation 1-1: Selection of potentially suitable regions on geological grounds ought not to be over-prescriptive. The UK has a range of geologies in which repositories could be constructed and all should be considered.

The long and diverse history of the nuclear industry in the UK has produced a correspondingly large and complex inventory of wastes. Until the last few years, Nirex's remit for a deep repository concerned only ILW and some streams of LLW. CoRWM's remit extends the volume of higher activity materials under consideration to important materials for which the picture is unclear, for example, spent fuel, plutonium, depleted uranium and naturally occurring radioactive materials (NORM). This situation does not exist in other countries, where wastes are clearly defined and disposal routes assigned accordingly.

Recommendation 1-2: Clear categorisation of waste streams is required so as to inform decisions on disposal strategies. Additional waste arising from site decommissioning and any new build will need to be accounted for in the national inventory prior to site selection.

In the case of HLW disposal, relatively little research has been undertaken in the UK for almost 30 years. Inevitably, recourse is being made to data, facilities and resources overseas in line with national policy. It is noted that the Finnish programme, which is currently the most advanced in terms of disposal scheduling, commenced only in the early 1980s and benefited greatly from Swedish expertise. The establishment of cooperation agreements by Nirex (now NDA) with organisations such as SKB (Sweden) and the initiation of a Nirex-led European Commission coordination action on technology transfer are strongly supported.

Interim Storage

This is the *de facto* option at present and likely to remain so into the future. Other countries operate interim stores but, in many cases, the final destination of the waste has been established. In the absence of a final repository design, it will be important to ensure that immobilisation matrices do not constrain disposal options.

The relative merits of long term storage versus early disposal have been debated in a number of countries. In Finland, there was little enthusiasm for the former whereas both France and Switzerland, for example, stress the importance of retrievability and a prolonged period of monitoring before the facility is sealed. As noted by CoRWM, surface stores are inherently less secure than an underground repository. While acknowledging the validity of the concerns, there is a risk that the availability of interim stores will lead to further delays in decision-making and implementation of disposal plans.

CoRWM's conclusion that storage should be viewed as a stage towards disposal and not an end point in itself is strongly supported.

Finally, packaging and re-packaging to allow safe storage is costly and inevitably leads to the production of additional waste volumes requiring disposal.

Gaining Acceptance

CoRWM recommends a staged approach with key decision points. This would bring the UK into line with other countries where sequential applications are made for exploration, site investigation, underground construction, *in situ* testing, waste disposal and, ultimately, repository closure. While this would not guarantee public acceptance, it would generate confidence in the decision-making process. Invoking a transparent 'decision in principle' for ratification by parliament would place the onus on the Government to provide a clear mandate for industry to progress to the next stage.

There is benefit to be gained in simplifying the organisational structure for the management of radioactive waste in the UK. Creation of the NDA is a positive step in this regard, though the effects of Scottish and Welsh devolution have yet to be fully explored.

CoRWM advocates volunteer communities that negotiate community packages to facilitate siting. Such an approach has met with some success in France, where this mechanism is frequently used in initiating major developments. This approach was not followed in Finland. Here, the sites were pre-selected by industry, though subject to local veto. In this case a commitment to the local area was demonstrated by re-locating the organisation's headquarters and supporting certain local development plans. National differences will dictate the practicality of volunteerism, however, the use of inducements is a contentious issue.

The Government's acceptance of CoRWM's recommendation that a staged approach will be applied with an associated timetable of actions to be taken over the next year is strongly supported. The proposed public consultation in 2007 on the implementation process, including a voluntary/partnership approach and site selection, an outline geological disposal delivery programme, and interim storage programme align with views at the 'next steps' meeting.

The remit of the NDA to cover all waste streams and all aspects of radioactive waste management is also well aligned with views expressed at the meeting.

Session 2: GEOLOGICAL REPOSITORY

Introduction

The geology of the UK offers many options for siting a geological repository at a depth between 300 and 1000 metres. Enough is already known about geological conditions to guide the siting process to areas where it is probable that safe containment can be achieved. General geological screening criteria include whether there are natural resources, what level of containment would be provided, and how complex are the relevant characteristics such as geological structure and hydrogeology. Many other socio-economic and safety issues such as waste transport and cost will also have to be addressed in screening sites. The overall approach to screening and site selection will have to uphold the principle of a potential host community's involvement.

In general, tools for investigating the properties of a site, engineering capabilities to design, construct and operate a repository, and science for assessing the long-term engineered and natural containment of a repository already exist. Well-advanced international projects provide guidance for site investigations and safety assessment and demonstrate the feasibility of constructing and operating a repository. Preparatory work will be necessary to ensure that these capabilities and methods are developed appropriately for the host rock conditions available in the UK and for the particular inventory and repository requirements. Information from detailed investigations at a candidate site will test conclusively whether or not a site is suitable in terms of engineering and safety. The procedure will need to be transparent, the evidence will need to be demonstrable and the uncertainties will need to be manageable to provide the host community and wider stakeholders with the necessary confidence in site selection.

A number of strategic questions about repository siting and design have yet to be addressed, such as those arising from the complex overall inventory of higher activity waste (i.e. HLW) and the much larger volume of ILW, as well as the possibility of other materials such as spent fuel, plutonium and uranium. For example, ILW and HLW/SF could possibly be 'co-located' in a single facility or alternatively separate repositories could be sited at different locations. These strategic issues will need to be considered in the context of siting options, the geological characteristic of potential host sites, and existing design work carried out for phased repository development and disposal.

Geological settings

UK geology is varied and is tectonically stable, so there are several geologically suitable settings and many possibilities for repository locations that would provide long-term isolation. In addition to physical stability, the properties to be considered include land surface topography, rock permeability, porosity and hydraulic gradient, and chemical composition of groundwaters. Aquifers and other zones with high groundwater fluxes, potential natural resources, and geologically-complex formations are less suitable geological features. The extent of existing knowledge about geology at depths of interest is dependent mainly on information from historical deep boreholes and on data from seismic surveys. The availability of such geological information is critical in the site selection process.

Recommendation 2-1: Maps showing characteristics such as topography, geology and hydrogeology that indicate potentially suitable and unsuitable regions of host rocks and geological environments should be available as information to support stakeholder dialogue and to inform communities in potential siting regions as part of the site selection process.

Design concepts

A repository will need to be designed to meet the requirements of the waste inventory, the geological setting, and the preferences of stakeholders, whilst achieving long-term safety. Multi-barrier containment, whereby the engineered system and the natural rock system both contribute to safety, is a central principle of design and is represented by a number of safety functions whose role and significance vary over time to ensure continuity of containment in the long term. There are alternative designs for HLW canisters, the choice depending amongst other things on the nature of surrounding rocks. For ILW, Nirex has developed the Phased Geological Repository Concept (PGRC) which includes designs for waste packages, chemical conditioning within and outside the packages, and for repository layout. Other programmes have different designs, reflecting geological conditions, preference for waste segregation, etc. Providing this information to stakeholders will enable understanding of the interdependency between design alternatives and siting possibilities.

Recommendation 2-2: Development of the range of design concepts and assessment of their suitability dependent on geology and waste types/volumes should be continued. This is particularly important given that HLW and SF are included in the CoRWM inventory whereas Nirex's remit was to consider geological disposal of ILW and some LLW only. Stakeholders need this information in order to understand how the feasible design alternatives are interdependent with siting possibilities.

Recommendation 2-3: Potential interactions between disposed HLW/SF and ILW need to be considered in the context of co-located or separate repositories.

Characteristics of disposal environments

Geological formations that are of interest as potential repository hosts are crystalline, argillaceous or evaporitic rocks. They all have low permeability and thus slow movement and low fluxes of groundwaters. In other respects their characteristics are different. Fracturing of hard rocks can be very variable with permeability and radionuclide transport properties being scale-dependent, whereas sedimentary rocks are more predictable with the possibilities that movement of radionuclides would be controlled by diffusion and that fracturing would be self-sealing, though weaker rock strength may place limits on design. Research, especially in underground laboratory projects, natural analogue systems and repository siting programmes in other countries provide the UK with valuable precedents for investigating the available range of such environments in this country. This experience illustrates, for example, how geosphere safety functions such as long groundwater travel times and diffusion-controlled solute movement can be demonstrated by data for the natural system. Experience also shows that uncertainty about the natural system appears to increase in the early stage of a site characterisation and will be subsequently reduced by targeting investigations on features and properties that most affect safety.

<u>Recommendation 2-4</u>: The physical, chemical and mechanical properties of potential host rock environments in the UK should be compared with those in other countries where investigations are well-advanced. This will inform the planning of site characterisations as to the scope of the site-specific data that will be necessary. The initiative of Nirex/NDA to work with other countries to identify information requirements for geosphere characterisation is strongly supported.

<u>Recommendation 2-5</u>: Aspects of assessing the suitability of potential disposal environments should be demonstrating stability and identifying rock properties and geosphere safety functions. This should include the investigation of natural isotopes and scientifically analogous systems that contain evidence of stability and other relevant properties over long timescales.

Phasing, early/late repository closure and waste retrievability

Various concepts for phased disposal have been developed to help address public concerns. The general idea is that a repository would be monitored to confirm initial performance as expected and left open for access, maintenance and potential removal of wastes if monitoring were to indicate non-conformance. Monitoring raises various issues such as how can it be achieved without reducing the effectiveness of the engineered containment and what actions in reality could and would be taken in response to observations. Examples of designs for phased disposal are those in the UK and Switzerland for L/ILW and in Japan, Switzerland and USA for HLW. Inevitably some degrees of phasing and potential retrievability are implicit in all repository plans, depending on the sequence and timing of operations and especially with respect to sealing and backfilling. Materials used in these operations also have an impact. There is no perfect option that in reality could address public concerns and would also be compatible with engineering and long-term safety priorities, but a range of options are being devised to meet specific requirements.

Recommendation 2-6: Work should be continued to develop and evaluate phased disposal concepts and associated approaches to monitoring and retrievability in order to inform public and stakeholder dialogue, which, as noted by CoRWM is expected to be strongly influential in this area.

Alternative disposal options for restricted waste inventories

CoRWM recommends that alternative options which might become practicable in the future should be left open, and that their development should be actively pursued. One such option is that of deep boreholes (typically 1 metre diameter at 4-5 kilometres depth), but this could only ever be practicable for relatively low volume, high activity wastes, such as vitrified high level wastes and also for materials that potentially may be declared as wastes such as spent fuel and plutonium. It is therefore an additional concept, having potential advantages for part of the inventory, and does not replace the need for a mined repository. Positive points suggested by proponents include security, safety, cost, environmental impact and implementation timescale. Negative points raised in discussions were that it is at the edge of current viable drilling technology and would thus be inherently risky, retrievability would be excluded (although this is a positive point in terms of security), criticality risks would be increased, and that the perceived technical challenges of emplacement would pose unacceptable risks in terms of safety, confidence and costs. Variants of deep borehole disposal have so far been researched by desk study, modelling and laboratory-scale experimentation but no pilot projects have yet been carried out.

Recommendation 2-7: Technical feasibility of alternatives to the deep geological repository option should be subjected to detailed scrutiny by appropriate experts. Deep borehole disposal, for example, should be assessed in the light of likely future developments in drilling technology and emplacement methods over a reasonable period. Alternatives should be assessed for suitability for all or part of the inventory to assess possibilities for co-location with a mined repository. This would inform the decisions relating to whether a pilot project would be justified.

Session 3: LONG-TERM SAFETY, CHEMICAL AND PHYSICAL PROCESSES

Introduction

The development of a convincing long-term safety case is a key challenge for the implementation of geological disposal, given the long timescales that are relevant to this concept and the associated uncertainties in its future evolution. The implementer has to demonstrate how decisions on the design of the disposal facility and the selection of a site lead to a robust system that will support a safety case compliant with regulatory standards in respect of health and safety and environmental protection. The development of a suitable regulatory framework and associated guidance, including on key elements of a satisfactory safety case, is challenging in itself.

Regulation of a future long-term radioactive waste management facility

There is a drive for cooperation between the relevant regulators to ensure that the responsibilities of the 'duty holder' are clear, and that joint goals are established to deliver efficient and effective regulation and to ensure wastes are appropriately managed in both the short and long term.

It is expected that a future geological repository will require a site licence under the Nuclear Installations Act 1965 and that new regulations are therefore required. The environment agencies are currently revising the guidance on requirements for authorisation of a disposal facility under the Radioactive Substances Act 1993.

A number of uncertainties currently require accommodation within a developing regulatory framework, including:

- identification of the future 'operator';
- timescales for implementation;
- choice of repository concept and its impact on the developed safety case;
- retrievability;
- definition of the site licence footprint; and
- delicensing.

Technical status of the programme for a deep geological repository: A regulatory view

The environment agencies believe that the current generic safety assessments developed by Nirex provide confidence in the viability of the relevant repository concept. However, further work in developing the safety case to address issues that have been raised by the environment agencies scrutiny of the Nirex programme will be required. In particular it is recognised that a safety case is more than a numerical evaluation and the key attributes of a future post-closure safety case would include:

- verification and validation of models;

- alternative calculations;
- a range of performance indicators; and
- a demonstration of understanding.

Three key technical issues are identified by the Environment Agency, namely R&D challenges, development of repository design and design optimisation, and the link between the nature and availability of a repository and current waste management activities.

In summary:

- it is feasible to make a safety case for a geological repository;
- the safety case is more than a numerical assessment;
- a focussed but substantial research programme is needed to support implementation;
- there is a need to review design options currently available; and
- implications for overall waste management must be considered.

Engineered barrier and post-closure near-field interaction

There is a widely shared view between national programmes on the characteristics of engineered barriers and the types of materials that are suitable, for example, for waste containers and buffers. Increasingly, use is made of ‘function indicators’, in relation to a safety function provided by the barrier, to test its suitability and performance.

A number of examples are available to show how focussed R&D effort can be used to test the required functionality of barriers under different chemical and physical stresses. Examples of such stresses where confidence has been obtained in the resilience of barrier function include radiation-induced changes, lowered temperatures (during glaciations), gas-induced groundwater flow through buffer material, and geomechanically-induced deformation of waste containers.

Far-field interactions and transport

The transport of radionuclides in deep groundwater systems is mediated by a number of processes, including sorption, diffusion, dispersion and advection. The process of radionuclide uptake of mineral surfaces comprises a number of different physico-chemical processes in itself. Information on these key processes is dominated by laboratory-scale data and methods are now under development to provide a reliable representation of the operation of these processes at field scale for application in repository performance assessments.

Long-term stability and containment: key geological attributes and reassurance

The need for improved communication of the intrinsic safety of geological disposal is recognised by waste management scientists and key stakeholders (e.g. regulators, CoRWM) alike. The geological record gives confidence in the operation of key processes over relevant timescales in the past. However, it is recognised that we are concerned with the future and need to understand future rates of change in geological systems. In order to do this, it is necessary to harness arguments for the stability of systems of interest in terms of the mechanical regime (e.g. using plate tectonics analysis) or the chemical regime (e.g. stable saline waters at depth or diffusion control of contaminant movement). Examples are available of analogues that build confidence in the kinetics of processes operating over a range of timescales. In discussion, the need was emphasised for further technical assurances to gain stakeholder confidence in geological disposal.

<u>Recommendation 3-1</u>: Information that may need to be developed to inform future involvement of local communities in a siting process should include:

- **a. communication of the role of the geosphere in providing long-term safety and environmental protection, and the underlying scientific evidence;**
- **b. a range of alternative repository design concepts showing how barrier functions can be matched to different types of wastes and geological settings; and**
- **c. how the suitability of UK geologies could be tested in the context of this information.**

<u>Recommendation 3-2</u>: Technical guidance that has relevance to siting requirements should be developed before implementing any future siting process.

<u>Recommendation 3-3</u>: A focussed R&D programme should be implemented on a timescale consistent with key stages in a nationally agreed repository development plan, to provide the necessary information to match the regulators' stated expectations of a multi-factor repository safety case.

Session 4: WASTES FOR STORAGE AND DISPOSAL

Introduction

Waste immobilisation is the incorporation of waste into the structure of a host matrix, for example, ceramic, cement or glass. In interim waste storage and final repository disposal the following factors are important in managing radioactive waste: the atomic level; the microstructural level; packaging; the near-field environment; and the far-field environment.

The majority of current waste is taken care of by immobilisation of HLW in glasses and ILW and LLW in cements. The waste form is the first line of defence against radioactive escape to the environment.

A number of wastes remain problematic as a result of characteristics such as their chemical reactivity, radiotoxicity, content of long-lived or highly mobile or bioavailable radionuclides. Equally, high volume, mixed (chemically and radioactively hazardous) or uncharacterised wastes and radioactively contaminated land may prove difficult to manage. Appropriate waste forms and/or management technologies must be developed for these wastes.

It is important that the geological environment(s) of any repository site(s) is/are understood so as to drive durability experiments and modelling to determine most appropriate and stable waste forms[2].

Waste management must ensure the strict application of the waste hierarchy (minimise > reuse > recycle > recover energy > landfill) to minimise the burden on existing disposal facilities. It is recognised that there are good case studies where industries working in decommissioning are already applying this principle.

A nuclear new build programme would result in an 8% increase in the UK total waste volumes[3]. The total activity of UK waste would be increased broadly in proportion to the additional nuclear energy generated. The significant cost of a nuclear repository is based on the volume of waste, not activity. In a once through fuel strategy, without reprocessing and recycling of uranium and plutonium, spent fuel would require disposal; this will need to be considered in repository design.

Low Level Waste

A policy statement from the Defra LLW consultation is due in the near future. The policy is expected to support application of the waste hierarchy, outlined above, and the proximity principle for disposal options. Where options higher up

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[2] Some of this material is derived from the presentation by Prof. Bill Lee (Royal Society of Chemistry – Materials for nuclear waste management workshop) – www.rsc.org/policy.

[3] CoRWM report - based on 10 new AP1000 reactors, which would approximately replace the UK's current nuclear generating capacity - www.corwm.org.uk

the waste hierarchy cannot be applied (i.e. reuse, recycle, etc.) then there are essentially two high-level options for UK LLW waste disposal:

1) LLW goes to the LLW repository (LLWR) or an equivalent future replacement (except for that going to LLW repository at Dounreay).
2) Suitable LLW waste is disposed of either *in situ* at the site where it is created or at a purpose-built facility on or near to the site where it is created.

To ensure continuous disposal is an option until any replacement LLWR is commissioned, the LLWR requires at least four new vaults to accommodate LLW arising up to 2020 – this is urgent regardless of future waste strategy. There remain several problematic waste streams in LLW (particularly graphite wastes – see further discussion under ILW).

The priorities for research into LLW include (no fixed order):

- reducing the volume of contaminated land sent to LLWR – currently this could account for millions of cubic metres;
- reducing the volume of non-compactable waste arising from decommissioning of buildings;
- characterising and separating mixtures of contaminated and non-contaminated materials;
- developing further recycling or disposition options for contaminated metals (including lead); and
- further technologies to manage contaminated asbestos waste.

Recommendation 4-1: Research into options for reducing the volume of LLW sent to the LLWR is required.

Recommendation 4-2: Technologies are needed to manage problem and poorly characterised LLW waste streams.

Intermediate Level Waste (ILW)

Significant quantities of ILW exist in poorly characterised forms (e.g. Magnox sludges, historic mixtures of materials, etc.); there are significant technical challenges in remotely characterising, separating and optimising waste forms for these materials. The work programme of NDA, for example on Sellafield Legacy Ponds and Silos, for remotely characterising, separating and immobilising poorly characterised ILW waste streams is supported.

The NDA has stated that there is to be no intermediate option for storing ILW from reactor decommissioning. This means that until a repository is built there cannot be any reactor decommissioning.

There is a particular problem in the UK with irradiated graphite wastes arising from operations and reactor decommissioning. Graphite waste is both high volume (80,000 tonnes) and contains relatively high concentrations of ^{14}C and

^{36}Cl (the LLWR authorisation for ^{14}C is sufficient to accommodate only 2% of the total UK graphite waste and will be reached by 2011). The abundance of ^{14}C and ^{36}Cl may have an impact on geological repository because of chloride and methane mobility. There are R&D and treatment technology opportunities for managing graphite waste.

<u>Recommendation 4-3</u>: Research and development currently underway in the Nirex/NDA programme on the long-term management of irradiated graphite wastes, including options for treatment leading to volume reduction, should be continued.

High Level Waste (HLW)

There are currently 1345 cubic metres of HLW in the UK; this accounts for 50% of the total radioactivity of UK radioactive waste. In addition to high radioactivity, HLW is by definition heat generating; combined, these properties demand strict waste form criteria.

A significant proportion of HLW waste is presently stored as a liquid in cooled tanks. The NDA is driving to reduce this volume to the minimum level required by regulators by 2015.

Currently, HLW is immobilised in borosilicate glass in one of three vitrification lines at Sellafield. There is a need to improve the understanding of the mechanism of dissolution of vitrified HLW under repository conditions in order to more precisely quantify the protection the waste form offers against radioactive release. This will require further modelling than databases available from other national programmes currently allow.

Spent Fuel

If the UK stops reprocessing, as has been suggested, a system for encapsulating spent fuel will need to be designed. UK Advanced Gas-cooled Reactors (AGR) contain uranium dioxide fuel pellets (in some cases also graphite) with stainless steel cladding with various ribbed designs. These are currently stored under both wet and dry conditions. Little research has been performed on AGR spent fuel as a wasteform.

Currently, it is not planned to reprocess spent fuel from a new UK nuclear power station building programme and therefore a strategy for its management and disposal is necessary. International experience, for example the Swedish concept - KBS3, is particularly relevant here and Nirex is currently using this as a reference concept should AGR and Sizewell PWR spent fuel be declared as waste.

<u>Recommendation 4-4</u>: A strategy for the management of existing AGR spent fuel and future spent fuel from new build is required – this will require research programmes.

Plutonium

Plutonium is currently safely stored pending long-term management policy decisions. It is currently designated as a zero-value asset. There is a civil plutonium stock of 100 tonnes and also a stock of military plutonium. Currently there is no UK waste form for plutonium and its disposal has implications upon the design of the final repository because of criticality issues.

If treated as a resource, plutonium would be burned as Mixed Oxide (MOX) fuel. The UK does have experience of operating a prototype fast reactor. However, some (ca 5% of the stock) of the plutonium is contaminated or in a form that cannot be used for fuel without costly treatment and a strategy is more likely to be required for the disposal of this material.

NDA research into plutonium has examined:

- the technology feasibility of the options;
- the knowledge and research gaps; and
- the discriminators for option decision making, including safety and environmental consequences discharges, long-term storage and final disposal.

Currently glass, ceramics and MOX pellets are being considered as plutonium waste forms. In all cases nuclear criticality safety is an important consideration.

Recommendation 4-5: A decision on plutonium management is required to guide R&D programmes to focus on national policy direction, in particular in respect of a suitable wasteform, if classified as waste, but R&D such as that currently conducted by NDA is in any case required to inform decision-making in this area.

Research in the USA

In the USA, significant research funding for basic research into future nuclear power and nuclear waste management is being made available by the Department of Energy through the Global Nuclear Energy Partnership. A research theme based on advanced waste forms has three key fundamental challenges that need addressing:

- design waste stream composition to utilise all its components (radioactive and non-active) so as to reduce volume;
- develop fundamental understanding of atomic-scale to meso-scale mechanisms of radionuclide incorporation, chemical corrosion, and alteration mechanisms/rates, and the response of these new waste forms to the radiation fields of incorporated radionuclides; and
- evaluate the long term performance of these new waste forms in the complex, highly coupled natural environment of the near field in a geological repository.

Recommendation 4-6: Recognising that new nuclear build may occur in the UK, the UK should contribute to the areas of basic research identified by the US Department of Energy Global Nuclear Energy Partnership including research based on Generation IV reactor fuels and wasteforms.

Session 5: IMPLEMENTATION

Introduction

There is a legacy of radioactive waste arising from operations on nuclear licensed and defence sites and further waste volumes are arising as a result of the accelerated decommissioning of such sites. Wastes from operations, decommissioning and potential new build need to be managed. Furthermore, robust interim storage is required whilst the repository concepts are developed. CoRWM recommendations provide for long term geological disposal as the end point for nuclear waste management. Implementation is necessarily a phased process involving community participation in the siting process for any long term repositories for such wastes.

One of the key aspects of implementation is the management and communication of scientific uncertainty to engender stakeholder trust. Scientists and engineers need to demonstrate safety in the long-term and invest time in building public confidence and trust in the safety of long term repositories. Equally it is important that issues and expectations that the public highlight are addressed through the engagement process. The decline in funding and resources in the UK needs to be reversed in order to address issues such as scientific uncertainty and long-term safety. For example, nuclear R&D needs significant investment. We need to consider the implications of not having repositories, for example, the consequent need for more interim stores at very significant cost.

Waste Package Management

Waste from nuclear sites is undergoing interim surface storage in the absence of a repository. Such wastes arise from decommissioning activities, and as a result of retrieval from waste storage facilities where there is insufficient assurance of passive safety. The Nirex letter of compliance forms one part of the wider process for NII approval of safety cases for the conditioning and interim storage of wastes. This process also ensures considerations regarding the final disposability of waste packages are also taken into account.

There is a need to maintain knowledge of the waste package for the future, particularly at a time when the nuclear industry is restructuring and site management companies are changing. There is a need for waste package records to be independent of time and technology, i.e. records need to be maintained in a format suitable for long term use; paper records are currently envisaged as being the most suitable form.

<u>Recommendation 5-1</u>: Waste package records need to be maintained in a format suitable for long term retrieval. Work underway and planned by the UK Radioactive Waste Policy Group and internationally by the IAEA in this area is strongly supported.

Above Ground Storage of Waste
Site waste stores need to be made available for radioactive materials storage, and to allow retrieval for removal to final disposal. Interim above ground stores will need to last in the order of 100 years. For example, based on current estimates, the decommissioning of Sellafield will not occur until 2070, therefore any waste repository will need to stay open for a period of decades. The Sellafield site operators are already planning to construct four additional stores for ILW. If no repository is constructed then a further fourteen stores will be needed at very significant cost. Some of the features of the store design will be common to the repository with regard to requirements for managing radioactivity, radiotoxicity and heat.

<u>Recommendation 5-2</u>: In line with Government's response to CoRWM recommendations, there is a need to develop an optimised storage and disposal strategy.

Experience of Stakeholder Engagement
UKAEA discussed their experience in engaging with stakeholders. This is at a local community level concerning local issues that may affect them. They talked about their experience gained at the Dounreay Site in communication of issues to the local community. UKAEA's experience demonstrates the need for inclusion of stakeholders at all stages and particularly during the early stages.

There is a need to try and develop consensus and to build trust in the UK's waste management process. This will require open and full engagement throughout the entire process. Scientists need to understand how the public perceive risk and uncertainty and accordingly be more forthcoming and empathic when addressing these issues. Universities and unbiased learned and professional societies could be among the main sources of trust in building this relationship.

<u>Recommendation 5-3</u>: The need for stakeholder engagement at all, and especially the early, stages of implementation is crucial in developing a successful outcome to the process of siting and constructing a repository.

<u>Recommendation 5-4</u>: Universities and learned societies should be involved in the stakeholder engagement process as a source of trusted independent advice.

Skills/Training/Funding Needs
There has been a very significant decline in R&D funding in nuclear fission, and equally a decline in the nuclear skills base, something that has been recognised by the learned and professional societies. There is a need for a nuclear skills renaissance to address the decline in the skills base, support implementation of the repository and develop the scientists and engineers of the future. The creation of the BNFL University Research Alliances, Dalton Nuclear Institute, the Nuclear Technology Education Consortium and the Nuclear Engineering PhD are

the first steps toward this renaissance. In addition, there has been a recent announcement about the creation of a national nuclear laboratory.

Recommendation 5-5: There is a need to revitalise the nuclear skills base in the UK to support those organisations responsible for the implementation and long term management of repositories.

International Repository Operation Experience

The Waste Isolation Pilot Plant (WIPP) is a US Department of Energy facility located in New Mexico, 26 miles southeast of Carlsbad. The facility is the USA's first geological repository for permanent disposal of transuranic (TRU) radioactive waste. Congress authorised the development of WIPP in 1980 to demonstrate the safe disposal of radioactive waste resulting from defence programmes of the US.

Various sites were shortlisted and the Carlsbad site was selected on the basis of a stable geologic formation, hydrogeology and salt formation. The site was seismically stable and had a surrounding low density of population. The local community volunteered on the basis of economic incentives and the introduction of a new industry and significant job opportunities in the area.

We should learn from and apply the lessons of other countries in implementing solutions for nuclear waste management.

SUMMARY OF RECOMMENDATIONS

In this section the recommendations from the UK long-term nuclear waste management workshop are mapped onto the CoRWM recommendations (bold). For clarity, an abbreviated version of the Government response (from Defra[4]) is also included (italics).

CoRWM Recommendation 1 – Geological disposal is the best available approach for the long-term management of all the material categorised as waste when compared with the risks associated with other methods of management. The aim should be to progress to disposal as soon as practicable, consistent with maintaining public and stakeholder confidence.

Govt response: Accepts recommendation, will move forward as fast as practicable in a way that is scientifically sound, develops and maintains public confidence and uses public money effectively. NDA will be responsible for geological disposal and safe and secure interim storage. Development work and day-to-day operation of disposal facility will be carried out by contractor. Regulators will take an interest in NDA enhancing its skills base and intellectual property.

Next Steps Recommendation 1-1: Selection of potentially suitable regions on geological grounds ought not to be over-prescriptive. The UK has a range of geologies in which repositories could be constructed and all should be considered.

Next Steps Recommendation 2-1: Maps showing characteristics such as topography, geology and hydrogeology that indicate potentially suitable and unsuitable regions of host rocks and geological environments should be available as information to support stakeholder dialogue and to inform communities in potential siting regions as part of the site selection process.

Next Steps Recommendation 2-2: Development of the range of design concepts and assessment of their suitability dependent on geology and waste types/volumes should be continued. This is particularly important given that HLW and SF are included in the CoRWM inventory whereas Nirex's remit was to consider geological disposal of ILW and some LLW only. Stakeholders need this information in order to understand how the feasible design alternatives are interdependent with siting possibilities.

Next Steps Recommendation 2-3: Potential interactions between disposed HLW/SF and ILW need to be considered in the context of co-located or separate repositories.

[4] www.defra.gov.uk/environment/radioactivity/waste/pdf/corwm-govresponse.pdf

Next Steps Recommendation 2-4: The physical, chemical and mechanical properties of potential host rock environments in the UK should be compared with those in other countries where investigations are well-advanced. This will inform the planning of site characterisations as to the scope of the site-specific data that will be necessary. The initiative of Nirex/NDA to work with other countries to identify information requirements for geosphere characterisation is strongly supported.

Next Steps Recommendation 3-1: Information that may need to be developed to inform future involvement of local communities in a siting process should include:

a. communication of the role of the geosphere in providing long-term safety and environmental protection, and the underlying scientific evidence;
b. a range of alternative repository design concepts showing how barrier functions can be matched to different types of wastes and geological settings; and
c. how the suitability of UK geologies could be tested in the context of this information.

Next Steps Recommendation 3-2: Technical guidance that has relevance to siting requirements should be developed before implementing any future siting process.

Next Steps Recommendation 5-5: There is a need to revitalise the nuclear skills base in the UK to support those organisations responsible for the implementation and long term management of repositories.

CoRWM Recommendation 2 – A robust programme of interim storage must play an integral part of the long-term management strategy owing to uncertainties surrounding the implementation of geological disposal.

Govt response: Accepts this recommendation. Planning and development of geological disposal will take several decades. Safe and secure storage of radioactive wastes in the interim is essential. NDA already has responsibility for storage and will review its storage needs in the light of this recommendation. Design of new stores will allow for interim storage of at least 100 years. Wastes should be made passively safe as soon as possible.

Next Steps Recommendation 5-1: Waste package records need to be maintained in a format suitable for long term retrieval. Work underway and planned by the UK Radioactive Waste Policy Group and internationally by the IAEA in this area is strongly supported.

Next Steps Recommendation 5-2: In line with Government's response to CoRWM recommendations, there is a need to develop an optimised storage and disposal strategy.

CoRWM Recommendation 3 – A flexible and staged decision-making process is recommended with reviews at key decision points and opportunities for re-evaluation before proceeding to the next stage.

Govt response: Accepts this recommendation. Government will set out the main elements and stages in implementation framework in 2007, including process for site selection and approach to partnerships and public and stakeholder engagement.

Next Steps Recommendation 2-6: Work should be continued to develop and evaluate phased disposal concepts and associated approaches to monitoring and retrievability in order to inform public and stakeholder dialogue, which, as noted by CoRWM is expected to be strongly influential in this area.

CoRWM Recommendation 4 – An intensified R&D programme is needed, with the aim to reduce uncertainty for geological disposal.

Govt response: Accepts this recommendation. There is a need for ongoing research and development to ensure optimised delivery of geological disposal programme and safe and secure storage in the interim. The NDA already has responsibility for carrying out research for design of future facilities for ILW and HLW. Research will also have to support the preparation of a safety case. NDA should also undertake horizon-scanning activities to improve future manner in which these functions and long-term management are delivered.

Next Steps Recommendation 2-5: Aspects of assessing the suitability of potential disposal environments should be demonstrating stability and identifying rock properties and geosphere safety functions. This should include the investigation of natural isotopes and scientifically analogous systems that contain evidence of stability and other relevant properties over long timescales.

Next Steps Recommendation 3-3: A focussed R&D programme should be implemented on a timescale consistent with key stages in a nationally agreed repository development plan, to provide the necessary information to match the regulators' stated expectations of a multi-factor repository safety case.

CoRWM Recommendation 5 – The possibility that other options (e.g. borehole disposal) could emerge as practical alternatives should be left open. Developments in alternative options should be actively pursued through monitoring of and/or participation in R&D programmes.

Govt response: Accepts this recommendation. Failure to recognise inevitable change would constrain future policy and lead to inappropriate decisions. Developments in storage and disposal options should be taken into account. Government and NDA will develop a programme to ensure flexibility.

International R&D in storage and disposal technologies will be monitored including new options.

Next Steps Recommendation 2-7: Technical feasibility of alternatives to the deep geological repository option should be subjected to detailed scrutiny by appropriate experts. Deep borehole disposal, for example, should be assessed in the light of likely future developments in drilling technology and emplacement methods over a reasonable period. Alternatives should be assessed for suitability for all or part of the inventory to assess possibilities for co-location with a mined repository. This would inform the decisions relating to whether a pilot project would be justified.

CoRWM Recommendation 6 - The waste inventory must be clearly defined and communicated to stakeholders– including waste from new build.

Govt response: Accepts this recommendation. Inventory needs to be clearly defined before agreements with potential host communities can be finalised and before technical options are developed in any depth. Decisions on classification of existing materials will be made I in a timely manner.

Next Steps Recommendation 1-2: Clear categorisation of waste streams is required so as to inform decisions on disposal strategies. Additional waste arising from site decommissioning and any new build will need to be accounted for in the national inventory prior to site selection.

Next Steps Recommendation 4-6: Recognising that new nuclear build may occur in the UK, the UK should contribute to the areas of basic research identified by the US Department of Energy Global Nuclear Energy Partnership including research based on Generation IV reactor fuels and wasteforms.

CoRWM Recommendation 7 – If any uranium, spent fuel or plutonium will be managed as wastes, they should be immobilised, and securely stored prior to geological disposal.

Govt response: Accepts this recommendation. These materials are not currently considered wastes. NDA is developing and assessing options for future management of these materials. Proposed approach will be reflected in future revisions of NDA strategy. If this leads to decision to manage any of these materials as wastes, government agrees that they must be immobilised for secure storage prior to geological disposal.

Next Steps Recommendation 4-4: A strategy for the management of existing AGR spent fuel and future spent fuel from new build is required – this will require research programmes.

Next Steps Recommendation 4-5: A decision on plutonium management is required to guide R&D programmes to focus on national policy direction, in particular in respect of a suitable wasteform, if classified as waste, but R&D such as that currently conducted by NDA is in any case required to inform decision-making in this area.

CoRWM Recommendation 8 – All options (including LLW disposal options) for reactor decommissioning wastes should be considered.

Govt response: Accepts this recommendation. NDA will review whether a safety case could be made for other non-geological disposal of such wastes, including on-site or near-site disposal to minimise transport.

Next Steps Recommendation 4-1: Research into options for reducing the volume of LLW sent to the LLWR is required.

Next Steps Recommendation 4-2: Technologies are needed to manage problem and poorly characterised LLW waste streams.

Next Steps Recommendation 4-3: Research and development currently underway in the Nirex/NDA programme on the long-term management of irradiated graphite wastes, including options for treatment leading to volume reduction, should be continued.

CoRWM Recommendation 9 – There should be continuing public and stakeholder engagement to build trust and confidence in the proposed long-term management approach, including siting of facilities.

Govt response: Accepts this recommendation. The extensive and successful public and stakeholder engagement carried out by CoRWM is recognised. Government if committed to continuing work with public and stakeholders, for which a variety of mechanism will be developed. NDA has statutory duty to consult with regulators and other bodies about its plans.

Next Steps Recommendation 5-3: The need for stakeholder engagement at all, and especially the early, stages of implementation is crucial in developing a successful outcome to the process of siting and constructing a repository.

Next Steps Recommendation 5-4: Universities and learned societies should be involved in the stakeholder engagement process as a source of trusted independent advice.

CoRWM Recommendation 10 - Community involvement in proposals for the siting of any long term radioactive waste facilities should be based on the principle of volunteerism, that is, an expressed willingness to participate.

CoRWM Recommendation 11 – Willingness to participate should be supported by the provision of community packages, based on the expectation that the well-being of the community will be enhanced.

CoRWM Recommendation 12 - Community involvement should be achieved through the development of a partnership approach based on an open and equal relationship between potential host communities and those responsible for implementation.

CoRWM Recommendation 13 – Communities should have the right to withdraw from this process up to a pre-defined point.

CoRWM Recommendation 14 – Key decisions should be ratified by the appropriate democratically elected body/bodies.

Govt response to recommendations 10-14: Government is not seeking to impose a facility for higher activity wastes on any community, and is committed to a solution based on a partnership approach. Details of this approach need to be considered and developed into proposed framework for future stages of the Managing Radioactive Waste Safely programme. Government will shortly begin to engage stakeholders on siting process for which the framework will be published in first part of 2007. All of the issue that have been raised by CoRWM, plus others, will be considered in the implementation framework. Ultimately the regulator will have to be assured that proposed facility will provide required levels of protection. Therefore geological disposal facilities will only be built in a geologically-suitable area.

Recommendation 15: An independent body should be appointed to oversee the implementation process without delay.

Govt response to recommendations 10-14: Government believes that an independent advisory committee should be established to provide advice on the development and implementation of the geological disposal facility development programme.