CoRWM Position Paper: Why Geological Disposal?

17th November 2018

This Position Paper reflects the Committee on Radioactive Waste Management's (CoRWM) current view on why geological disposal is the best option for disposal of higher activity radioactive waste. This paper gives an overview of CoRWM's work 2003 – 2006 providing a traceable outline of the path that led CoRWM to recommend geological disposal from the six waste streams it considered. This paper will be updated and revised if or when more information becomes available.

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1. . Introduction

The most fundamental question to be asked when considering '*what to do with higher activity radioactive waste*' is '*why is geological disposal being recommended*'. The adoption of geological disposal as a policy has been pursued by many countries world-wide and is the subject of several studies and recommendations by the International Atomic Energy Agency[1] and of a policy declaration by the European Union[2]. However, this paper concentrates on policy development in the UK, and in particular outlines the process followed by CoRWM, which led to its recommendations in July 2006[3].

CoRWM's work was driven by Principles[4] which it developed and published in 2004. In this document, CoRWM stated:

> *What is our task?*
>
> *Our objective is to carry out a review of the options for managing the wastes. The review will involve members of the public and stakeholders, providing them with the opportunity to express their views.*
>
> *If people are to have confidence in our work, including our recommendations, they must be actively involved in what we are doing and be able to see how we make our decisions. So our task involves listening to their concerns and suggestions and taking these into account. Drawing on this work, we will then make recommendations to Government on what to do with the waste so that people and the environment are protected.*

This lays down an inclusive process, which was diligently followed, with an abundance of stakeholder involvement and the use of recognised consultative techniques to elicit the broadest possible appreciation of the spectrum of stakeholder views. The process of identifying a preferred radioactive waste management option involved four years of concentrated effort with resources and budget to match. This position paper seeks only to outline the process and its outcome, while providing sufficient references to enable more extensive studies to be pursued as required.

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[1] E.g. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, the "Joint Convention,", adopted 5 September 1997 at https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste

[2] Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011L0070

[3] Managing our Radioactive Waste Safely, CoRWM's Recommendations to Government, Doc 700, July 2006

[4] CoRWM Principles Document, CoRWM doc. 5, January 2004

2. *The Waste Streams*

Before examining different options for radioactive waste management, it is essential to form a clear view of which waste streams are identified as requiring management. Specialist examination led to the identification of seven waste streams[5], which, it was believed, had sufficient unique characteristics to merit separate assessment[6]. These were

- high level waste
- spent nuclear fuel
- plutonium
- highly enriched uranium
- intermediate-level waste and low-level waste not suitable for the Low-Level Waste Repository (LLWR) (intermediate-level waste and non-LLWR low-level waste)
- depleted, natural and low enriched uranium
- reactor decommissioning waste.

These seven streams were then reduced to six, when stakeholder examination pointed out that the small amount of highly enriched uranium in the inventory could and would be mixed with the other uranium streams making just one category of uranium for potential disposal.

3. *Identifying Options*

The '*Managing Radioactive Waste Safely*' (MRWS) programme commenced with the paper '*Proposals for developing a policy for managing solid radioactive waste in the UK*'[7] published by the Department of Environment, Food and Rural Affairs (DEFRA) and devolved administrations in September 2001. This included consideration of nine alternatives for long-term radioactive waste management, namely:

1. Above Ground Storage
2. Underground Disposal
3. Underground Storage
4. Partitioning and Transmutation
5. Disposal at Sea
6. Sub-Seabed Disposal
7. Outer Space
8. Subduction Zones
9. Ice Sheets

After this paper, but prior to the formation of CoRWM, Defra commissioned a study to examine the '*Information Needed to Decide with Confidence on the Long Term Management of Options for Long Lived Radioactive Waste*'[8] to assist with further stages in the MRWS programme. The study examined the nine MRWS options, but also introduced the concept of international solutions, giving a total of fourteen options as below:

1. Above ground storage
2. International above ground storage
3. Underground storage
4. International underground storage

[5] Or, in the case of spent nuclear fuel, plutonium, and uranium (all enrichments), streams which may be declared waste in future

[6] CoRWM Document 700, page 76

[7] 'Proposals for developing a policy for managing solid radioactive waste in the UK', DEFRA, at https://webarchive.nationalarchives.gov.uk/20031221042814/http:/www.defra.gov.uk/environment/consult/radwaste/pdf/radwaste.pdf

[8] Wilkinson Environmental Consulting Ltd., Identification of Information Needed to Decide with Confidence on the Long Term Management of Options for Long Lived Radioactive Waste, October 2002, DEFRA Report No: DEFRA/RAS/02.014 https://webarchive.nationalarchives.gov.uk/20081025022110/http://www.defra.gov.uk/environment/radioactivity/publications/complete/pdf/defra_ras-02-014.pdf

5. Underground disposal
6. International underground disposal
7. Direct injection – injection of waste as liquid into deep geological strata.
8. Disposal at sea – disposal onto the sea bed
9. Sub-seabed disposal - disposal in sediments beneath the sea bed
10. Disposal in ice sheets
11. Disposal in subduction zones - disposal at tectonic plate boundaries.
12. Partitioning and Transmutation – the transformation of long- lived substances into shorter-lived or more stable forms.
13. Disposal in space
14. Dilute and Disperse - diluting and dispersing into the general environment

On CoRWM's foundation in 2003, its terms of reference made it clear that the Committee would need to start from a '*blank sheet of paper'* in considering which radioactive waste management option or options to recommend to Government. Drawing on the '*Identification of Information*' study and advice from Nirex Ltd,[9] CORWM arrived at a long list of fifteen options by a process detailed in the paper '*How CoRWM short-listed the options*'[10], these were:

1. Storage
2. Near-surface disposal;
3. Deep disposal;
4. Phased deep disposal;
5. Direct injection;
6. Disposal at sea;
7. Sub-seabed disposal;
8. Disposal in ice sheets;
9. Disposal in subduction zones;
10. Disposal in space;
11. Dilute and disperse;
12. Partitioning and transmutation;
13. Burning in reactors;
14. Melting of metals;
15. Incineration.

4. Identifying and Weighting Criteria

The criteria against which the options should be judged were developed with input from many sources and modified as a result of the public and stakeholder process as described in Chapter 7 of CoRWM's Recommendations to Government[11]. The result was a 'Value Tree' which captured the majority of the issues that people considered to be important and grouped these into 11 headline criteria and an associated 27 sub criteria. These are tabulated on page 76 of Document 700, with the headline criteria of:

1. Public Safety, Individual – short term (up to 300 years)
2. Public Safety, Individual – long term (longer than 300 years)
3. Worker Safety

[9] UK Nirex Limited, "Description of Long-term Management Options for Radioactive Waste Investigated Internationally" Nirex Report N/050, May 2002 at https://tools.nda.gov.uk/publication/009-description-of-long-term-management-options-for-radioactive-waste-investigated-internationally-2002/ Note that at this location this is password protected

[10] Committee on Radioactive Waste Management, "How CoRWM short-listed the options", CoRWM Doc. 1001.4, May 2005 and Committee on Radioactive Waste Management, "Outcome of short-listing", CoRWM Doc. 1340, September 2005.

[11] Managing our Radioactive Waste Safely, CoRWM's Recommendations to Government, CoRWM Doc. 700, July 2006

4. Security
5. Environment
6. Socio-economic
7. Amenity
8. Burden on future generations
9. Implementability
10. Flexibility
11. Costs

The key factor in the use of criteria in option assessment is the fact that they must all be weighted according to their perceived importance. This weighting was carried out by CoRWM in public using a multitude of expert and stakeholder inputs and arrived at the weightings given in Table 11.2 of Document 700. This will not be quoted fully here, but its '*values led'* nature is perhaps underlined by the fact that '*Public Safety up to 300 years*' was weighted at 23.3%, while '*Socio— economic Factors'* rated 0.9% and Costs were excluded from the Multi-Criteria Decision Analysis (MCDA) and dealt with during sensitivity testing. This was because:

> *'There was a great deal of uncertainty associated with their figures, and a resulting large spread between the low and high estimates. There was also less difference between the options than expected. CoRWM therefore decided to keep the cost criterion separate from the other criteria in the MCDA, and to assess the impact of cost through a form of sensitivity testing'.*

5. Shortlisting Options

The descriptions of the 15 options adopted by CoRWM are given in Appendix 1 of this paper, which also describes the result of CoRWM's short-listing activity. The key feature of CoRWM's shortlisting deliberations was its statement (Document 1001.4, Page 48) that:

> *'CoRWM takes the view that it is sensible to short-list only those options that could be implemented in the reasonably foreseeable future. An option meets this requirement if it has been implemented on an industrial scale somewhere in the world, if there is sufficient practical demonstration of it (for example, at laboratory level), or if there is confidence within the scientific community (based on assessment of research and development) that it could be implemented within the reasonably near future'.*

This clearly limits the more esoteric options such as disposal in subduction zones and in space, and the 'implemented somewhere in the world' excludes several options. Overall the application of these shortlisting criteria led to the exclusion of 13 of the original 15 possible routes, as seen below:

1. Storage forever – implemented in no other country
2. Near Surface Disposal – not suitable for long lived wastes
3. Disposal by direct injection - abandoned in the USA
4. Disposal at sea – prohibited under international law
5. Sub-seabed disposal – not implemented anywhere in the world
6. Disposal in ice sheets - not implemented anywhere in the world
7. Disposal in subduction zones - implemented in no other country
8. Disposal in space – cost – and not implemented anywhere in the world
9. Dilute and disperse – release after most of the radioactivity has decayed
10. Partitioning and transmutation – not a complete solution for all wastes
11. Burning in reactors - not a complete solution for all wastes
12. Melting of metals - not a complete solution for all wastes
13. Incineration - not a complete solution for all wastes

CoRWM reduced the number of options to be studies to four, the options being:

1. Long term interim storage – considering only "*storage that is chosen as a key stage of a longer-term management strategy*"
2. Near-surface disposal of short-lived wastes
3. Deep geological disposal
4. Phased deep geological disposal

Much of the thought and methodology behind the shortlisting was arrived at during public meetings in Birmingham on 17-18 November 2004, Cleator Moor in Cumbria on 26-27 January 2005, and Manchester on 15-16 February 2005. The process was summarised in Section 5 of the 2005 CoRWM Annual Report[12], which is reproduced as Appendix 2. This summary gives a sense of the comprehensiveness and degree of stakeholder inclusiveness in the process, and the references in the reports quoted would allow a detailed study of this innovative initiative.

6. Option Assessment

The key achievement of shortlisting was to allow a clearly traceable down-selection to the four options, with an agreed process, and a set of criteria and sub-criteria (also given in Appendix 2), which allowed a final assessment of each of the options to proceed. This involved, for example:

- Multi-criteria decision analysis, where specialists in the relevant fields judged and 'scored' the performance of each option against the criteria
- Citizens' panels expressed judgments about the relative importance of the different criteria ('weighting'), and also performed a holistic assessment of options
- Stakeholder groups were able to comment on the scoring, and contribute to the weighting of criteria

CoRWM used these and other inputs in an open plenary session to perform its own options assessment to create a "base case". The inputs were also used in sensitivity testing, to explore the impact of varying scores and weights on overall option performance, enabling CoRWM to develop a deeper understanding of the key factors that make different options perform well or badly.

The option assessment process is most easily followed by reference to Chapter 11 of CoRWM's Recommendations to Government[13]. Overall, it was found that geological disposal options outperformed storage options, with the findings that:

- *The key discriminators between geological disposal and storage options were burdens on future generations and public safety (up to 300 years). This was because the specialists had judged that, within the limitations of the assessment process, disposal options perform significantly better than storage options against these criteria and they were highly weighted by CoRWM.*
- *Phased geological disposal ranked slightly higher than geological disposal because, based on the specialist scores, the former performs better against the flexibility criterion, which was weighted heavily*

These conclusions were found to be very robust to sensitivity changes of weighting:

- *Although some scenarios included large changes to individual criteria weights, these did not change the overall ranking of geological disposal and storage options. In all instances, the geological disposal options were ranked higher than the long-term storage options, although in some cases the 'gap' between them was significantly reduced.*

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[12] Committee on Radioactive Waste Management, Second Annual Report, CoRWM Doc. 1393, 2005

[13] Managing our Radioactive Waste Safely, CoRWM's Recommendations to Government, CoRWM Doc. 700, July 2006

- *For the sensitivity testing of the cost criterion, the highest cost estimates for disposal and the lowest cost estimates for storage were fed into the model. The storage options, despite their lower costs, continued to perform less well than disposal.*

The most severe test was posed by what was termed the *'NGO limiting (bounding) case*' where much more weight was placed on environment, amenity, flexibility and implementability criteria. Even in this case, geological disposal still ranked highest, though followed extremely closely by underground local stores.

7. Conclusions

Though it is recognised that this paper provides only an outline summary of the work that was undertaken by CoRWM in the years 2003 – 2006, it does provide a traceable outline of the path that led CoRWM to recommend geological disposal for the six waste streams it considered. The path was rigorously tested by expert opinion and stakeholder dialogue, and the results were extensively sensitivity tested. Overall the choice of geological disposal was found to be both clear and robust.

Nothing during the work for this paper has suggested any parameters of the waste management options or the assessment criteria used would have changed significantly in the interim. The waste categories also remain relevant, though it should be noted that the 2006 CoRWM recommendations were made on the basis of the then-current view of nuclear capacity which did not include new build.

Since 2006, CoRWM has produced several papers on its position on new build and new build wastes, with the general theme that:

> *'CoRWM's position on the desirability or otherwise of building new nuclear power stations remains neutral. The Committee is neither for nor against new build'.*[14]

To date, the Committee has not been requested to provide any particular advice on, or scrutiny of, the effect of new build wastes on the overall management of higher active radioactive waste in the UK.

[14] CoRWM Statement of its position on New Build Wastes, CoRWM Doc. 2749, March 2010

Appendix 1. Descriptions of options from Annex A of '*How CoRWM short-listed the options*', Paper 1001.4 (revised 6 May 2005)

Options which CoRWM proposes not to carry forward for detailed assessment:

Storage forever (formerly 'indefinite storage')

This option involves storing radioactive wastes in purpose built facilities, either above or below ground, with no intention to implement any other management option at any point in the future. The option was renamed storage forever by CoRWM in February 2005 in order to clarify the different variations of storage options being considered. The defining aspect of this 'storage forever' option is that storage is itself the ultimate solution. No country has implemented this option.

Near-surface disposal

In this option, radioactive waste is buried below ground in a facility with engineered barriers. This may be either just below the surface with a protective covering, deeper in underground caverns or in engineered vaults accessed by a tunnel. The important difference from deep geological disposal is that this option does not use the geology to provide a barrier for the waste, and is therefore possible in areas without the geological features required for deep geological disposal.

Initially, CoRWM referred to this generic option simply as 'near-surface disposal' and did not specify the kind of waste to be managed. After further consideration, however, CoRWM proposes that this option should be screened out for those longer-lived wastes (HLW and some ILW) which remain radioactive beyond several hundred years, but retained for shorter-lived ILW. For longer-lived wastes, the option would pose risks to the health of future generations and place an unacceptable burden on future generations who would have to continue to maintain institutional control over a near surface facility.

Disposal by direct injection

This option involves injecting liquid radioactive wastes into layers of rock that have an appropriate geological formation to contain the waste and to provide a barrier. The waste can be mixed with other materials, such as cement, to reduce the risk of leakage into surrounding rock and groundwater. The USA used this option in the 1970s but has since abandoned it; it has also been carried out in Russia.

Disposal at sea

In this option, radioactive waste is placed in containers and dropped by ship or aircraft at suitable, remote locations on the seabed with no intention of retrieval. The containers are designed either to reach the seabed intact or to break up under pressure at great depth. If the containers are designed to remain intact, the option relies on the delay in release of radioactivity provided by the time it takes the packaging to disintegrate, followed by dilution and dispersal in the sea. This option was used by the UK for low and intermediate level waste up until 1983. Sea disposal is currently prohibited under international law and is not practised anywhere in the world.

Sub-seabed disposal

This option envisages placing the waste deep under the seabed in highly stable geological formations. Possible variants include dropping the waste into the sea using weighted, shaped containers that will penetrate deeply into the sub-seabed sediments, or placing waste containers in boreholes beneath the seabed, or building a sub-seabed repository for wastes. It relies on the stability of the seabed and the physical isolation of the wastes from human populations and the food chain. The option was researched in depth by the OECD countries up to the mid-80s but it has not been implemented anywhere in the world.

Disposal in ice sheets

An example of this option involves placing containers of heat-generating wastes in very thick, stable ice sheets. The containers would melt the surrounding ice and be drawn deep into the ice sheet, where the ice would refreeze around the wastes, creating a thick barrier. It would be most suitable for HLW. It has been considered for use by the USA but has never been implemented anywhere in the world.

Disposal in subduction zones

A 'subduction zone' is an area where one denser section of the Earth's crust (usually part of an ocean floor) is moving towards and underneath another, lighter section. For example, the Pacific Ocean floor is moving slowly under the west coast of the USA. The idea is that the waste gradually would be drawn down into the Earth's mantle by the subduction process. Once in the mantle, the waste would become diluted and might only be returned to the biosphere after millions of years. Like the sub-seabed disposal option, this option involves disposal in the seabed, but whereas the first could involve disposal in the most stable parts of the ocean floor, this option uses the most dynamic parts. No country has adopted this option.

Disposal in space
This option aims to remove radioactive waste from the Earth forever by ejecting it into space (either into a high Earth orbit or out beyond the solar system) or by aiming it into the sun where intense heat would vaporise it. Waste would be placed in a rocket or space shuttle and launched. It has only been considered for small amounts of HLW, due to the high cost for each load, using present-day technology. This option has never been implemented anywhere in the world.

Dilute and disperse radioactivity into the environment
Dilution and dispersal will be the final fate of some of the more mobile radioactive wastes over the very long term for any disposal option - other than disposal in space or very deep regions of the Earth. No container or barrier, whether engineered or natural, can be expected to last forever, so some radioactivity will be released into the environment at some point in the future. In most options, however, it is envisaged that the release will not take place until most of the radioactivity has decayed. With this option, the intention is deliberately to dilute and disperse the wastes now, or to plan to do so in the future. An example would be to manage solid wastes by mixing them with very large amounts of other materials. The idea is that the waste and the radiation hazard it poses is dispersed around the environment. (The UK currently authorises and regulates discharges of small amounts of radioactivity into the sea and the emission of gaseous and particulate waste into the atmosphere.)

Partitioning & transmutation
Partitioning and transmutation (P&T) is only a means of processing radioactive wastes; it is not an option for long-term management. The processing involves separating the waste into its constituent parts (partitioning) and then changing one type of radionuclide into another so that the radioactive and toxic properties of the waste are changed (transmutation). The idea is to change long-lived radioactive substances into shorter-lived, less toxic ones. It is probably most suitable for processing high level waste, spent nuclear fuel and plutonium. After processing, there would still need to be long-term management by one or more of the other options. Research into P&T is being conducted in France, Japan and the USA, mainly with a view to using it to treat waste from nuclear fuel in new designs of reactors. None of these countries regard it as a realistic option in the short term.

Incineration
Incineration has been proposed as a way of reducing the volume of radioactive wastes that have to be managed in the long term. As wastes are burned at high temperatures the radioactivity is contained in the residues. These residues will have to be managed as radioactive waste. This option is well understood and widely practised in many countries. The burning of limited quantities of combustible LLW is allowed in the UK.

Melting of metals
This option involves melting radioactive waste metals in furnaces in order to reduce their volume and to disperse the radioactivity into slag. Some metal can be reused if its low radioactivity makes this safe, but as with incineration, there will still be leftover radioactive waste that requires management. Melting of radioactive metals is practised in several European countries (including the UK) and in the USA.

Options which CoRWM proposes to short-list:

Long-term interim storage (formerly 'interim storage')

CoRWM has limited its consideration of interim storage to long-term interim storage, because short-term interim storage is merely what is being done at present and is unacceptable as a long-term strategy. CoRWM proposes that this option should only be implemented in the UK.

Long-term interim storage involves packaging radioactive wastes and storing them in purpose built facilities. Variants of this option are that stores could be above or below ground, at centralized locations or at the current locations of wastes, and with various degrees of security and protection. With periodic refurbishment, long-term interim stores might last for 300 years or more, depending on the design.

In order to identify variants of long-term interim storage, CoRWM suggests that this option can be defined as “storage that is chosen as a key stage of a longer-term management strategy”. This option can accommodate two different intentions: (i.e., where the intention is):

a. to identify a preferred option or options, but to defer implementation, for example, until there is sufficient confidence to proceed; or

b. delaying a decision until, at a point in the future, there is enough information to decide which of one or more options should be implemented.

The required storage facilities may be the same for (a) and (b), but the research and development for the option that follows it, is required at different points in time.

Most countries currently store radioactive waste in purpose built facilities until it can be placed in a repository. The Netherlands, which has only two small reactors, has selected disposal as the long-term management option but has decided to postpone its implementation for at least 100 years and so has built a long-term interim store. France has also selected disposal as the long-term management option, but is nevertheless carrying out research into the long-term storage of HLW and spent nuclear fuel in case it is not ultimately possible to prove the safety of disposal (the long-term storage itself is not regarded as a solution.) In the UK, wastes are currently being stored on an interim basis at the nuclear sites where they are produced (though some spent nuclear fuel is being transported for storage at Sellafield), and waste from small producers, such as hospitals, is stored at Harwell.

Near-surface disposal of short-lived wastes

The near-surface disposal of short-lived wastes would only be considered for implementation in the UK. In this option radioactive waste is buried below ground in a facility with engineered barriers. This may be either just below the surface with a protective covering, or several tens of metres deeper in underground caverns or vaults accessed by a tunnel. The important difference from deep geological disposal is that this option does not use the geology to provide a barrier for the waste, and is therefore possible in areas without the geological features required for deep geological disposal. It differs from storing wastes underground in that it would involve permanent disposal with no intention to retrieve the wastes in the future. However, the facility could be designed so that if radioactivity were to leak, it could be detected by environmental monitoring and the waste could be removed.

Near surface disposal is suited to short-lived wastes which lose their radioactivity over a few hundred years. Wastes can be disposed of either at a number of sites where they were produced, or at a centralised site. Several countries, including France and Spain, currently use this option.

Deep geological disposal

This option (called simply deep disposal in the first Consultation Document) involves placing packaged radioactive wastes deep underground in places where the geology can provide a secure barrier. The option would not be implemented overseas if it could be undertaken in the UK. A conventional model is a repository excavated several hundred metres under the land surface in natural rock formations accessed by shafts. A variant is to place the packaged wastes in deep boreholes or disused mines which are then sealed off by engineered or natural barriers. The intention is to contain the wastes over the very long timescales during which some wastes remain radioactive (in some cases hundreds of thousands of years) so that the amount of radioactivity which does eventually reach the surface is very small. The intention is to leave the wastes in the repository permanently, with no further intervention. Research into this option is more advanced than for most others, and it has been seriously considered and/or adopted by most countries with a nuclear power programme, including Canada, Finland, France, Germany, Japan, the USA, the Netherlands, Russia, Sweden, Switzerland. UK Nirex Ltd was investigating this option for the UK up to 1997.

A form of deep disposal consists of placing the waste in boreholes drilled down to between 3 to 5 km below the earth's surface, levels at which the only groundwater flow is brine, which has remained separated from the biosphere over a very long period - offering a potentially long-lasting barrier to the migration of radioactivity to the surface. CoRWM may evaluate this variant separately. Countries such as Sweden are keeping a watching brief on the technological developments that would allow waste to be placed at this depth.

Borehole disposal is probably only suitable for relatively small quantities of long-lived radioactive wastes and materials. It has been suggested that if heat-generating HLW was placed deep in boreholes it would fuse with the surrounding rock, fixing the waste in place.

There is also the concept of an offshore facility in the sub-seabed, accessed by tunnels from land. Although this could be termed a repository, it would not necessarily rely on geological (rather than engineered) barriers to provide containment. Practical constraints on the length of the tunnels would limit the location of such a facility under UK territorial waters.

Phased deep geological disposal

This option (formerly called phased deep disposal) involves placing radioactive waste into an engineered repository deep underground in places where the geology can provide a secure barrier. It differs from the previous option in that the repository is designed to function as a store with access and monitoring for an interim period until it is finally closed and backfilled at some future date. At that point the option becomes disposal. Future generations may decide when to close it. It therefore uses similar technology and has the same geological requirements as deep disposal, but with additional features for interim access, monitoring and retrievability. As with option 3, this would not be implemented overseas if it could be carried out in the UK. Phased deep geological disposal has been proposed in response to concerns about the difficulty of retrieving waste in the deep geological disposal option. Nirex has developed a concept for this option for intermediate level wastes in the UK, and a similar concept has been developed in other countries, such as Switzerland.

CoRWM puts forward the following proposals for work in relation to dealing with radioactive materials:

Plutonium and uranium (and the spent fuel from which these materials can be separated out by reprocessing) are not currently categorised as radioactive wastes. This is because they can be used as components of fuel in nuclear reactors. However, they are not being used for that purpose at the moment because new uranium is currently a cheaper source of reactor fuel. They are therefore being stockpiled.

CoRWM has been asked by Government to advise on what to do with these radioactive materials in case they need to be managed as wastes in the future. This is important for various reasons, including the fact that uranium and plutonium can also be used to make nuclear weapons.

Burning the uranium and plutonium stockpile in reactors attracts controversy because new UK nuclear reactor plants would probably have to be built or some existing ones modified. (Nuclear energy is outside CoRWM's terms of reference.)

The option of burning uranium and plutonium in reactors has not been included in CoRWM’s short-list of management options because it is not a complete solution by itself. The spent fuel and radioactive wastes produced as a consequence of using plutonium and uranium in reactors would still need to be managed over the long-term. Moreover, depending on the type of fuel used, more plutonium could be created.

If it were decided that the UK should not maintain its stockpiles of separated plutonium and uranium, there would be two choices:

- to use them to make fuel for use in reactors, either as mixed oxide fuel (MOX - a blend of plutonium and uranium oxides) or inert matrix fuel (which does not create more plutonium); or
- to convert them into a waste form that is suitable for long-term management (by mixing and bonding them with another material, such as high specification ceramics).

Using plutonium in MOX fuel in reactors is practiced widely overseas in countries such as Belgium, France, Germany Japan, Russia and Switzerland.

These alternatives have advantages and disadvantages. Burning in reactors is a form of energy recycling, but managing the resulting wastes (and spent fuel) could complicate the storage or disposal of the existing waste inventory. Managing plutonium directly as a waste requires particular care to be exercised in the design of the waste form and its management facilities.

Appendix 2. Shortlisting and Assessment from CoRWM Second Annual Report, Doc 1393, 2005

5 How we short-listed the most promising options for more detailed assessment

14. We had already decided to draw up a set of screening criteria to apply to each option. This would enable us to determine whether it was promising enough to go forward for detailed assessment. Having invited comments on our proposed criteria, we added another, and invited comments on them in our second round of engagement in April-June 2005.

15. We used these criteria:

An option will not be short-listed if:

1. There is no "proof of concept" (i.e. no proof that it could work) in the form of either:
   - actual implementation of the option in the UK or elsewhere, or evidence of ability to achieve implementation within the foreseeable future; or
   - sufficient research and development on the part of the international scientific community to demonstrate confidence that the option can be implemented.
2. It causes us to breach our duty of care to the environment outside national boundaries.
3. It causes harm to areas of particular environmental sensitivity.
4. It places an unacceptable burden (in terms of cost, effort, or environmental damage) on future generations.
5. It involves a risk to future generations greater than that posed to the present generation that has enjoyed the benefits.
6. It results in unacceptable risk to the security of nuclear materials.
7. It poses unacceptable risk to human health.
8. Cost is disproportionate to the benefits achieved.
9. It breaches internationally recognised treaties or laws and there is no foreseeable likelihood of change in the future.
10. It involves implementation overseas when implementation could, in principle, be achieved in the UK.

16. We considered information we received during phase 2, particularly the results of our second round of public engagement. In July, we decided that four options looked promising for the UK and should be assessed in detail:

(1a) Long-term interim storage.

(2) Near-surface disposal of short-lived wastes. We are now considering this in relation to reactor decommissioning wastes.

(3) Deep geological disposal.

(4) Phased deep geological disposal.

17. Our Phase 2 Report explains on what screening criteria the remaining options failed. It also describes the detailed methodology for assessing the short-listed options. This methodology was agreed in our July meeting though we are refining it as we go. Here is a summary.

6 How we are assessing the short-listed options and identifying the best strategy for the UK

18. By the end of July 2006 we shall send Government our recommendations on a long-term UK strategy. To achieve this, we have 3 main processes:

- We are assessing the performance of each option against a set of performance criteria, using a process called multi-criteria decision analysis. This involves looking at the performance of each option, criterion by criterion, in a bottom up approach.
- We are assessing the performance of each option as a whole, by a more "holistic" top down approach.
- These two processes will enable us to identify how the options perform in different circumstances, but this alone will not give us "the answer". So we have a process for integrating and going beyond these 2 assessments, including looking at how we might best combine options, how we can reduce or manage uncertainties, and ensuring that we address strategic, cross-cutting issues such as whether waste should be retrievable.

19. Our process is designed to incorporate relevant and reliable information; to involve a broad range of participants in ways that enable them to make an effective contribution; and to integrate the outputs of each process into a coherent and conclusive set of recommendations that inspires confidence.

20. Here are some examples of how we are involving different groups of people:

- - In the multi-criteria decision analysis, specialists in the relevant fields are judging the performance of each option against our criteria. They have developed ‘scoring schemes’ and identified information needed to facilitate the scoring. We are gathering this information. Scoring workshops are taking place in December. We say more about this process in section 8.
- - Citizens' panels have expressed judgments about the relative importance of the different criteria (‘weighting’). They have also done an holistic assessment of options.
- - Stakeholder groups will be able to comment on the scoring, and contribute to the weighting of criteria.
- - We, in open plenary session, will use these and other inputs when we do our own options assessment to create a "base case". They will also be used in sensitivity testing, which will explore the impact of varying scores and weights on overall option performance. This will enable us to develop a deeper understanding of the key factors that make different options perform well or badly.

21. The "headline" criteria we are using are set out below, with their subcriteria in brackets. Each is broken into a set of detailed questions. "Environment" gives examples.

- - public safety, individual – up to 300 years, (radiation and nonradiation)
- - public safety, individual – longer than 300 years, (radiation)
- - worker safety, (radiation and non-radiation)
- - security, (misappropriation and vulnerability to terrorist or other attack)
- - environment (chemical pollution, physical disturbance, and use of natural resources.
- - socio-economic, (employment and spin-off)
- - amenity, (visual, noise, transport and surface land-take)
- - burden on future generations, (cost, effort, worker dose and environmental impacts)
- - implementability, (technical, legal and regulatory acceptability, and land use planning requirements)
- - flexibility, and
- - costs.

22. A flow-chart on pages 18-19 shows the programme in more detail[15].

[15] Not included here

23. At the end of November, our programme is on track. With our specialists, we have developed and tested a system for scoring each option; identified the data needed to complete the scoring to a high level of confidence; and have gathered most of the data. Our Citizens' Panels have met, advised us on weighting the criteria and have done an holistic assessment of the options. We too have contributed to the holistic process by testing each option against a set of ethical tests. Section 9 reports events by month.