CoRWM

Committee on Radioactive Waste Management

POSITION PAPER: CoRWM CONSIDERATION OF THE UK URANIUM INVENTORY, MANAGEMENT AND DISPOSAL OPTIONS

July 2023

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Document Details	
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Approved by:	
Issue:	1
Status:	FINAL
Recipients:	
Report Instigated:	February 2021
Confidential:	No
Additional notes:	
CoRWM Document No:	xxxx

REVISION RECORD

Date	Version	Status	Comments
24/09/2022	1	Draft 1	Issued for internal review
1/11/2022	2	Draft 2	Issued for stakeholder review
04/07/2023	3	FINAL	Issued for publication

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1 Executive Summary

1.1 The UK has a large inventory of uranium materials, comprising depleted, natural and low-enriched uranium (DNLEU), which require management to an end point. Most, but not all, of this material is enriched to a low level[1] and the inventory is largely radiologically benign.

1.2 The uranium inventory owned by Nuclear Decommissioning Authority (NDA) comprises approximately 54,000 tonnes of uranium. NDA's current strategic options for its uranium inventory are continued safe and secure storage pending either sale for reuse where practicable or conditioning to an appropriate form for disposal. About half of this material is yet to be produced, from fuel enrichment activities performed by independent organisations. The future growth of the uranium inventory therefore depends upon the growth of UK and international nuclear power and gives rise to great uncertainty in the uranium inventory. CoRWM conclude that the UK Nuclear Materials Inventory should, continue to include scenario-based forecasts of future uranium arisings, which can be enabled by close cooperation between the NDA and third party owners of uranium.

1.3 A series of options for managing the UK inventory of uranium were considered by the NDA in 2014 prior to the finalisation of its strategy for managing uranium. It is evident that management decisions will ultimately be made based on the market value of materials and the costs of continued storage and disposal. Although international events are likely to influence the market for future reuse of uranium, the potential for such reuse seems very limited because nuclear power operators will find it cheaper to enrich new ore from plentiful world supplies. CoRWM consider that it is inevitable that the end point for a substantial part of the uranium inventory is disposal as waste. Early declaration of the intent to dispose of (portions of) the uranium inventory would provide Nuclear Waste Services (NWS) with the information necessary to develop disposal concepts and their relative costs. A "one UK" strategy for uranium management, exploring credible options for uranium disposal would be welcomed by CoRWM.

1.4 Based on the work presented by NWS, CoRWM consider the disposal of the uranium inventory in a geological disposal facility (GDF) to be a viable option. CoRWM are satisfied that NWS possess the tools and methodologies to develop operational and post-closure safety cases for this option, and understand that they will do so when a site-specific safety case is required in the future. At that stage, it may be necessary

[1] Most of this material is enriched to a level of < 1%.

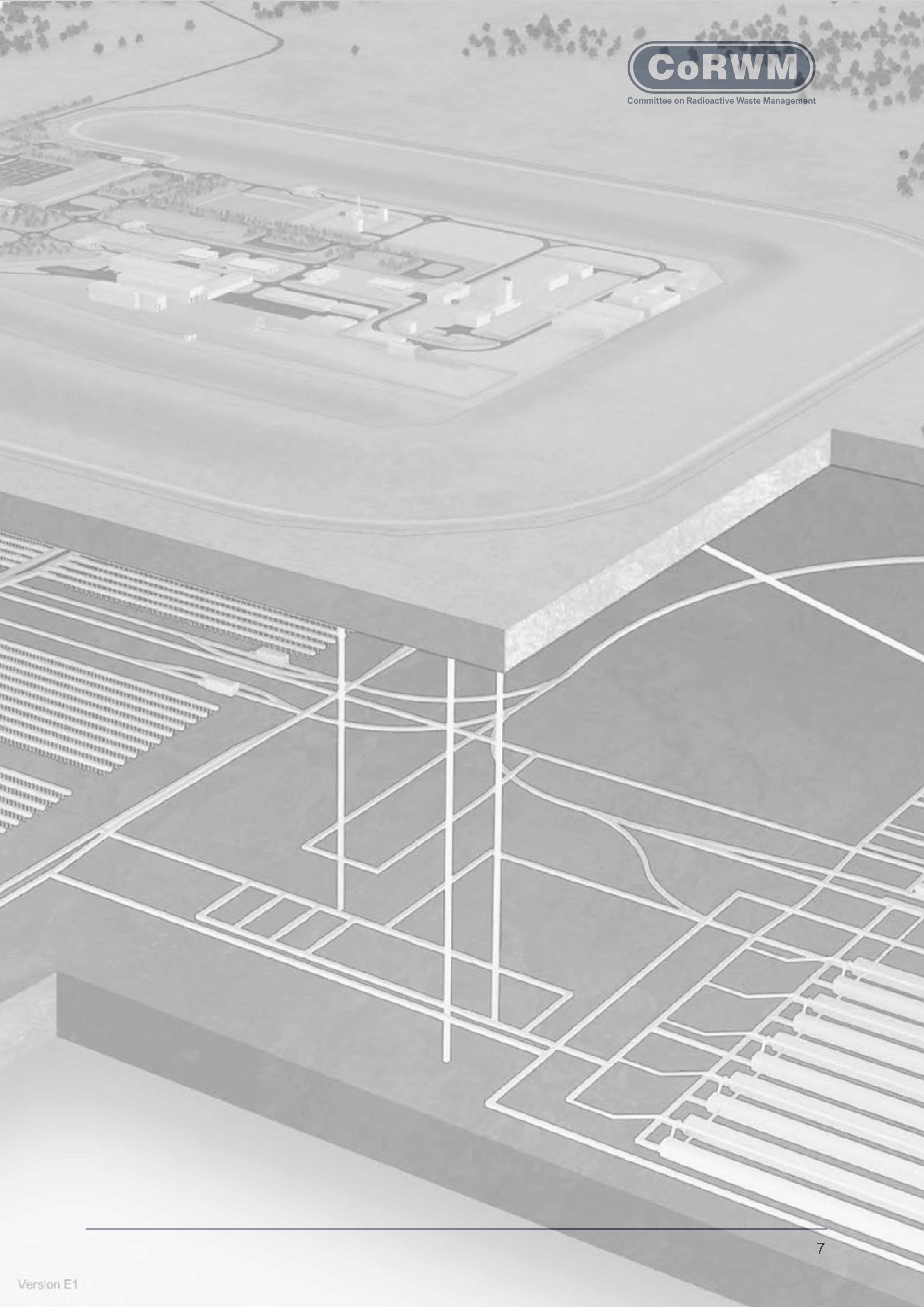
for CoRWM to reappraise their conclusions regarding the safety of uranium disposal in a GDF.

1.5 It has become evident to CoRWM that, given the benign nature of a portion of the uranium inventory, costly immobilisation, e.g. by cement grout encapsulation, may not be proportional to the hazard and risk posed by the material. Investigation into alternatives to GDF disposition by NWS is in its infancy and CoRWM wish to see further work to explore credible alternative approaches to disposal that are proportional to the risk.

2 CoRWM Recommendations

No	Recommendation
1	The NDA should continue to periodically update the UK Nuclear Materials Inventory to include scenario-based forecasts of future DNLEU arisings, and particularly those from third parties, e.g. Urenco UK.
2	Regardless of whether re-use is an economically viable option, it is inevitable that a substantial portion of the uranium inventory will require disposal as waste. As such, CoRWM recommend that the NDA expand their engagement with the owners of uranium material to cooperatively develop a “one UK” strategy for uranium disposal, exploring credible options for disposal, and engage with NWS and regulators as appropriate.
3	NWS should undertake an assessment of whether the operational and post-closure hazards posed by the uranium inventory can be reduced by cement-encapsulation. They should engage with the relevant regulators in developing any plans for disposal of unencapsulated uranium in a GDF.
4	Once a site for a GDF has been selected, NWS should update the post-closure and operational safety cases to provide further confidence in the option of GDF as a potential disposal route for (a portion of) the uranium inventory, beyond the arguments made in the generic disposal system safety case.

5	A credible options analysis should be undertaken, and periodically reviewed, by NDA / NWS to consider alternative options for the disposal of (a portion of) the uranium inventory. This analysis should assess a wide range of disposal options in proportion to the radiological risk posed, with consideration given to each individual portion of the uranium inventory (e.g. TPU, LEU etc.). Such an analysis should involve close cooperation with the relevant regulatory organisations and should consider the cost benefit of alternative options in comparison with disposal in a GDF.



3 Introduction

3.1 The UK has a large inventory of uranium materials, comprising depleted, natural and low-enriched uranium (DNLEU), which require management to an end point. This material has been produced over more than 70 years of nuclear fuel cycle activities, including enrichment, fuel fabrication, and reprocessing.

3.2 The uranium material inventory is synonymously (and historically) referred to as uranics; this paper will use the term *uranium* in reference to the inventory, consistent with NDA Strategy 4 [1].

3.3 The uranium inventory is part of the UK Nuclear Materials Inventory, which is managed by NDA. It comprises several categories of material, each with different chemical characteristics and / or different levels of fissile content, which may influence potential long-term management / disposal options.

3.4 The current NDA strategy is to continue safe and secure storage of the uranium inventory, indefinitely in existing facilities or replacement facilities, and to support its reuse where cost effective, and to ensure its final disposition.

3.5 In the last OECD published report on the management of uranium, in 2001 [2], countries that also planned to follow this strategy included: France, the Netherlands, Japan, China, Republic of Korea and the USA. Each country differs somewhat in the chemical form of storage (UF_6, or deconverted to U_3O_8).

3.6 The focus of this Position Paper is a consideration of the UK uranium inventory and management options.

4 The UK Uranium Inventory

4.1 The UK uranium inventory comprises primarily (unirradiated) DNLEU and a smaller quantity of reprocessed (irradiated) uranium (or, Rep-U).

4.2 The inventory includes:

- Material owned by the Nuclear Decommissioning Authority (NDA);
- Material owned by domestic (EDF Energy) and foreign customers of NDA, with reprocessing or storage contracts;
- Material owned by Urenco UK; and
- Material owned by the Ministry of Defence and managed by the NDA on its behalf.

4.3 The UK inventory of Highly Enriched Uranium (HEU) is estimated to be less than 1 tU which is insignificant in comparison to the DNLEU and Rep-U components of the uranium inventory, which exceed 110,000 tU combined. Nearly all of the NDA's HEU inventory (nearly 700 kg), stored on the Dounreay site, was transferred to the USA between 2016 – 2018, for down-blending and reuse in civil nuclear fuel, in exchange for a supply of HEU to a European research reactor for medical isotope production. HEU management is considered in NDA's exotic fuels strategic theme [3] and is therefore not considered further in this paper not least because it raises quite different management and disposal issues.

4.4 The NDA owned uranium inventory is published within the UK Radioactive Waste Inventory, last updated in 2022 [4]. The uranium component of the derived inventory for geological disposal (the IGD) is published by NWS, last updated in 2021 [5]. However, the last detailed breakdown regarding uranium appears in the 2016 derived disposal inventory [6]. The IGD ignores market-related changes to the DNLEU inventory forecast and assumes, for the purposes of disposal planning, that all DNLEU will be disposed of. Importantly, the Radioactive Material Inventory and the IGD are not identical, with the IGD including the NDA, Urenco UK, EDF Energy, and MoD owned material, for GDF planning assumptions.

4.5 The NDA UK Radioactive Material Inventory (2022) reports the quantity of depleted, natural and low enriched uranium material to be ~110,000 tHM (equivalent to tU), over all sites, at 1 April 2022 [4]. This excludes nuclear materials owned by the MOD. The ONR published quantity is 120,000 tHM (31 December 2020), which includes uranium present in spent fuels, and foreign owned uranium, that are reported separately in the Radioactive Material Inventory.

4.6 The NDA uranium inventory as of 2014 [7] is summarised in Table 1 (N.B. The more recent radioactive material inventories published (e.g. in 2022 [4]) do not give the same level of detail as [7]). The inventory was stated to contain uranium as UO_2, uranium metal and uranium carbides, and material in the form of residue powder, and pellets.

Table 1: Approximate NDA owned uranium inventory in 2014.

Uranium material	Approximate quantity (tU)
UF_6 tails	21,500
Magnox depleted uranium, MDU (UO_3)	26,000
ThORP product uranium, TPU (UO_3)	300
UF_4	230
Other forms of uranium	
Depleted	400
Natural	300
Low enriched	120
High enriched (excluded from uranium inventory)	1

4.7 Further detail on the categories of uranium in the NDA inventory, and the location of these materials as of 2014 [7], is given in Table 2.

4.8 A summary of the uranium materials component of the Derived Inventory for Disposal was synthesised by CoRWM from: (a) the inventory reported in the NWS derived inventory for disposal of 2016 [6] and; (b) the NWS report on Investigating the Implications of Managing Depleted, Natural and Low Enriched Uranium through Geological Disposal of 2016 [8]. This is shown in Table 3.

Table 2: Location based representation of uranium inventory (in tU) in 2014, with notes.[2]

Location	MDU	TPU	UF_6 tails	UF_4	LEU	DU	NU	DNLEU	Total (tU)
Capenhurst[a]	26,000[b]		20,500	230	5.75[c]				>46,736
Harwell and Winfith								30[d]	30
Dounreay					0.3[e]	22[f]	7.3[g]		30
Springfields			900		800[h]	8[i]	5[i]		1,765

Table 3: Summary of uranium materials component in derived inventory for disposal; miscellaneous DNLEU includes natural uranium for Magnox fuel.

Material	Owner	Source	Location	Total mass (tU)
Unirradiated depleted UF_6 tails	Urenco UK	Fuel enrichment	Capenhurst	108,500
Irradiated depleted UF_6 tails	NDA	Re-enrichment of reprocessed uranium	Capenhurst, Springfields	15,500
Magnox Depleted Uranium, MDU.	NDA	Reprocessing Magnox fuel	Capenhurst	38,000
ThORP Product Uranium, TPU.	NDA EDF Energy	Reprocessing AGR and LWR fuel	Sellafield	5,000
Miscellaneous DNLEU	NDA	Residue and scraps from uranium purification, conversion, fuel fabrication. Small quantity from UK fast reactor research	Various	3,000
Depleted uranium from defence enrichment	MOD	Defence enrichment	Capenhurst?	15,000
Total				**185,000**

[2] Notes to table
a. Excludes URENCO UK owned material as UF_6 tails on site adjacent to NDA Capenhurst; material stored on behalf of MoD of unspecified quantity; metal, MDU, UF_6 tails; foreign owned MDU of unspecified quantity.
b. Plus 2,600 teU MDU from Magnox reprocessing post 2010.
c. Comprising 4.5 tU residues and 1.25 UF_6 cylinder washings.
d. DNLEU as metal and oxide, with LEU enriched to 5-10%
e. As metal, oxide, UF_4; a proportion is enriched to 5-19.9% U-235.
f. As carbide, metal, and oxide.
g. As carbide, metal, oxide, UF_4, uranyl nitrate liquor.
h. As metal, U_3O_8, UO_3, UO_3 and residues (graphite, cutting oil etc).
i. As metal and oxide from Winfrith and Harwell.
j. Excludes foreign owned TPU of unspecified quantity.
k. DU and NU, mostly as UO_2 and metal.

Resolution of Inventory Information

4.9 Consideration of the derived inventory for disposal shows that this is, in fact, expected to be dominated by depleted UF_6 tails owned by Urenco UK, which will be deconverted to, and stored as, U_3O_8.

4.10 Comparison with the UK Radioactive Material Inventory 2022 shows that about half of the projected derived inventory of is yet to be produced, which must arise from fuel enrichment activities, owned by Urenco UK.

4.11 The data for ThORP Product Uranium (TPU) in the derived inventory and NDA Uranics credible options paper [7] were published prior to the cessation of reprocessing in 2022. At the time of publication of [7], it was suggested that almost all of the projected 6,000 tU arising, stored on the Sellafield site, is owned by EDF Energy.

4.12 Although a small fraction of the total inventory, there is a discrepancy in the DNLEU estimate in the derived inventory in Table 3 (3,000 tU) and the total DNLEU arisings in Table 2 (1,123 tU). The data in these Tables refer to NDA owned material, which presumably means that some NDA owned DNLEU arisings were expected to be generated after 2010, possibly in relation to Magnox fuel production.

4.13 The key source of uncertainty in the uranium inventory is the DNLEU produced from future enrichment operations. For example, the Radioactive Material Inventory 2022 states there will be future arisings of UK owned DNLEU of about 88,000 tHM, mostly depleted uranium from fuel enrichment operations. This figure assumes enrichment operations continuing over the next twenty years. It also states an expectation that there will be 63,000 tHM of foreign owned UF_6 scheduled for enrichment at Capenhurst, affording around 80,000 tHM of depleted uranium tails.

4.14 Through engagement with Urenco UK and NDA, CoRWM has identified three important parameters that will govern future growth of the uranium stockpile:

- The growth and disposition of the domestic fleet of nuclear power stations, utilising fuel enriched by Urenco UK in the UK;
- The growth and disposition of the foreign fleet of nuclear power stations, utilising fuel enriched by Urenco UK in the UK; and
- Any changes to Urenco enrichment capacity in Germany or the Netherlands, or the USA which increased utilisation for UK capacity.

4.15 Urenco UK advised CoRWM that the UK is a small segment of the international enrichment market. The most significant impact on future UK DNLEU arisings would result from reduced capacity at its overseas facilities.

4.16 Urenco UK informed CoRWM that they take ownership of the depleted uranium tails from their enrichment operations, both for UK and foreign customers (with some exceptions). Customers have a right to the tails from the enrichment process, but, in general, do not elect to exercise it.

4.17 Urenco make a balance sheet provision, as net debt, for depleted uranium tails, to cover the cost of interim storage as UF_6, deconversion (including secondary wastes), storage as oxide for 100 years and transport. Provision is also made for disposal should this be an available option.

4.18 Since reprocessing in the UK has now ceased, future growth of the uranium inventory will result only from Urenco UK enrichment and deconversion activities.

4.19 As such, the UK Radioactive Material Inventory should, in the future, include scenario based forecasts of future uranium arisings. Urenco UK have apparently undertaken work to assess future deconversion and storage requirements under a growth scenario, from which the future arisings could be obtained or derived.

Recommendation 1
The NDA should continue to periodically update the UK Radioactive Material Inventory to include scenario based forecasts of future uranium arisings, and particularly those from third parties, e.g. Urenco UK.

5 UK Uranium Management Strategy

5.1 The current summary of the NDA position and progress in managing its uranium inventory is given in the Managing Nuclear Materials and Spent Fuels section of the NDA website. Key strategy documents relevant for the consideration by CoRWM include:

- NDA, Uranium and plutonium macro-economic study, 2007 [9].
- NDA, Uranics: credible options summary paper, 2014 [7].
- NDA, Strategy for NDA owned uranium hexafluoride tails, 2010 [10].
- NDA, Strategy – Effective from March 2021, 2021 [1].
- RWM, Investigating the Implications of Managing Depleted, Natural and Low Enriched Uranium through Geological Disposal, 2016 [8].
- BEIS, Implementing Geological Disposal – Working With Communities, 2018 [11].

5.2 The NDA owned uranium inventory is managed as a zero value asset nuclear material, "pending long term options and cost estimates" (with the exception of the HEU material, discussed previously).

5.3 The rationale for this position is that the uranium inventory has the "potential, subject to availability of the appropriate power stations and supporting infrastructure, to be used as nuclear fuel generating significant quantities of electricity".

5.4 According to the NDA's interpretation of its obligation under the Energy Act 2004, to manage the material in the most practical and cost-effective way, the material is considered a zero value asset and is not considered as a waste.

5.5 However, simply regarding material indefinitely as an asset without any evidence as to future use does not appear to CoRWM a sustainable long term strategy. It is logical, therefore, that in the absence of a clear economic case for reuse for future uranium arisings, it would seem prudent to assume this material will need to be managed as a waste for future disposal.

5.6 NDA consider that no single option will be appropriate to manage the uranium inventory in its entirety due its diverse nature. The preferred option is to be determined for each component of the inventory on a case by case basis. NDA states that continued storage does not provide an end point for uranium materials.

5.7 The NDA strategy governs the material it owns and material it manages on behalf of customers.

5.8 The following summarises CoRWM's assessment of the NDA credible management options for the uranium inventory. Recycle and reuse of uranium outside of the nuclear fuel cycle was not considered by the NDA and is therefore presumed to be not credible.

Continued Storage

5.9 This option is based on storage and/or immobilisation and disposal of the uranium inventory typically held in containers of various types, some already for over 50 years. It would require confidence in managing the inventory safely in secure storage for several decades more, and in the availability of technology and budget to repackage material if necessary. It may be preferable to consolidate uranium materials from sites with small holdings such as Harwell and Winfrith CoRWM understand that this is already underway.

5.10 Some uranium materials require conditioning or treatment to be suitable for long term interim storage, for example deconversion of UF_6 to U_3O_8.

5.11 Urenco UK have informed CoRWM that it has plans for sufficient capacity for deconversion and storage arrangements under a growth scenario for its enrichment business. In future, CoRWM may wish to scrutinise the current state of cylinder storage and the strategy, planning and arrangements for future uranium storage, to provide assurance of credibility given the underpinning nature of this option.

Recycle

5.12 This option only considers recycle in the context of returning uranium material to the nuclear fuel cycle. A constraint on the implementation of the recycle option is the availability of suitable facilities for processing clean (unirradiated) and reprocessed (irradiated) uranium. Whilst the UK has facilities for handling and processing unirradiated uranium, to permit recycle, there are currently no such facilities for irradiated uranium such as Magnox Depleted Uranium (MDU) and TPU.

5.13 It is noted that some NDA customers have recycled TPU using processing facilities in Russia, presumably by re-enrichment. CoRWM understand that the current geopolitical situation has effectively closed this recycling route.

5.14 The economic viability of recycling uranium depends on the prevailing market conditions. When the price of producing nuclear fuel from freshly mined uranium resource, including enrichment, is low and stable, such as at the present time, it is not cost effective to recycle uranium. However, when the price of fuel production from freshly mined uranium resource is high, recycle of uranium may become cost effective, depending on the uranium-235 concentration. It is arguable that decisions on whether to recycle are distorted by availability of storage capacity.

5.15 Further to the credible options report [7], NDA conducted analysis to evaluate potential markets for recycle of its uranium inventory and its near term value [9]. As part of its work programme, CoRWM should maintain a watching brief of this study and any subsequent work to understand the likely potential to realise recycle of the uranium inventory.

Recycle in Light Water Reactors

5.16 Some of the uranium inventory has suitable properties for re-use but any implementation of recycle requires a suitable reactor fleet and associated fuel cycle facilities.

5.17 Current Government policy considers only the deployment of further large scale (GW) light water reactors and potentially small modular variants. Since light water reactors use LEU fuels, the most attractive material for recycle is TPU, with a variable uranium-235 concentration, which exceeds natural abundance (0.7 %). The majority of MDU and all DU has a uranium-235 concentration lower than natural abundance, however, economics could still favour recycle when the uranium-235 concentration exceeds that of the DU tails produced by enrichment service providers.

5.18 Re-enrichment of unirradiated DU could be undertaken in UK owned facilities. Re-enrichment of irradiated MDU and TPU would rely on use of foreign facilities, principally in Russia, or the establishment of re-enrichment capabilities for these materials in the UK.

5.19 It is important to note that re-enrichment would clearly not result in any significant reduction in the overall uranium inventory, since the quantity of the arising tails would only be marginally smaller than the quantity of MDU / TPU feed. It is understood that the UK would be required to retain title to this material.

5.20 Current NDA strategy seeks to maximise the value of its uranium inventory by maintaining it in stock until such time as market conditions are in favour of recycle, compared to use of freshly mined uranium resource. However, given that this is the point at which demand for re-enrichment services will be high, then the service cost may also be high.

5.21 Recycle of unirradiated and irradiated uranium in mixed oxide fuel, or in a disposal MOX wasteform, both with plutonium, was not explicitly considered in the NDA credible options study after an earlier project proved unviable. If this option is adopted, it would result in a relatively small reduction in the uranium inventory for management. Assuming the 140 tHM plutonium inventory was recycled, this would consume of the order of 10,000 tHM of uranium.

Recycle in Advanced Reactors

5.22 A UK fast reactor fleet would provide a plausible means to consume part of the uranium inventory, through use of depleted uranium in the breeder blanket to produce plutonium. While Government is looking to enable future nuclear technology, it currently has no plans for deployment of fast reactors and associated fuel recycle facilities to realise this approach.

5.23 It may be possible to utilise some of the uranium inventory in advanced modular reactors which do not use light water as a moderator, however, although Government has demonstrated interest in such reactor systems, there are no firm plans for deployment.

CoRWM Assessment of Uranium Management Strategy

5.24 CoRWM concludes that the options considered by NDA are inter-related and that management decisions will ultimately be made based on the market value of materials and the costs of continued storage and disposal.

5.25 If recycle is employed as an option to use the uranium inventory, a significant portion of the uranium inventory would still remain. Moreover, there are some portions of the inventory that are challenging to reuse due to economic factors and reliance on non-UK facilities.

5.26 The market potential for future reuse of uranium seems very limited. CoRWM consider that it is inevitable that the end point for at least part of the uranium inventory is disposal as waste.

5.27 CoRWM understand that decisions to declare any of the inventory as waste will be made by the owners of the uranium as part of their business plans. NDA advised CoRWM that if an owner of uranium decided it had no further use and wished to dispose of that material, it could be possible to transfer the ownership to NDA. It would then be managed according to their extant strategy.

5.28 CoRWM understand that early declaration of the intent to dispose of (portions of) the uranium inventory would provide NWS with the information necessary to develop disposal strategies.

Recommendation 2

Regardless of whether recycle is an economically viable option, it is inevitable that a substantial portion of the uranium inventory will require disposal as waste. As such, CoRWM recommend that the NDA expand their engagement with the owners of uranium material to cooperatively develop a "one UK" strategy for uranium disposal, exploring credible options for disposal, and engaging with NWS and regulators as appropriate.

6 Disposal Options for the UK Uranium Inventory

6.1 The uranium inventory is not classified as a waste but is included in the derived inventory for disposal, for planning purposes, should disposal be required.

6.2 The Implementing Geological Disposal - Working With Communities Policy, 2018 [11], states:

"In addition to existing wastes, there are some radioactive materials that are not currently classified as waste, but would, if it were decided at some point that they had no further use, need to be managed as wastes through geological disposal. These include spent fuel (including spent fuel from new nuclear power stations), plutonium and uranium".

6.3 The inventory for disposal specified in this policy incorporates "uranium stocks – including that arising from enrichment and fuel fabrication activities (yet to be declared waste)". Thus, provision is made in the Geological Disposal Facility (GDF) disposal system safety case for disposition of uranium stocks should they be classified as waste in the future.

6.4 The NWS (then RWM) Uranium Integrated Project Team (IPT) considered the feasibility of deep geological and near surface disposal of the uranium inventory.

6.5 The uranium inventory constitutes approximately 17% of the packaged higher activity waste inventory, by volume, but much less than 1% by activity, within the NDA's 2010 generic disposal system safety case (DSSC) [12]. It is re-emphasised that the actual disposal inventory is highly uncertain, depending on the scale and duration of future Urenco UK enrichment operations.

6.6 The major radionuclide constituent of the uranium inventory is uranium-238, with a long half-life of 4.5 billion years. The decay chain of uranium-238 is shown in Figure 1. Uranium-238 is also the major constituent, by volume, although not by radioactivity, of spent nuclear fuel.

6.7 Unlike other parts of the disposal inventory, the mean risk posed by uranium increases with time over 1 million-years post-closure, due to the ingrowth of the daughter nuclides of uranium-238, especially radium-226. This is important since, for modelling purposes, the host rocks are considered by NWS to be the only barrier to radionuclide migration beyond 100,000 years.

6.8 The uranium inventory makes the greatest contribution to the residual radioactivity in the GDF over a 1 million-year period, although post-closure safety models only extend to 300,000 years due to the uncertainties in the future state of the geosphere and biosphere beyond this time.

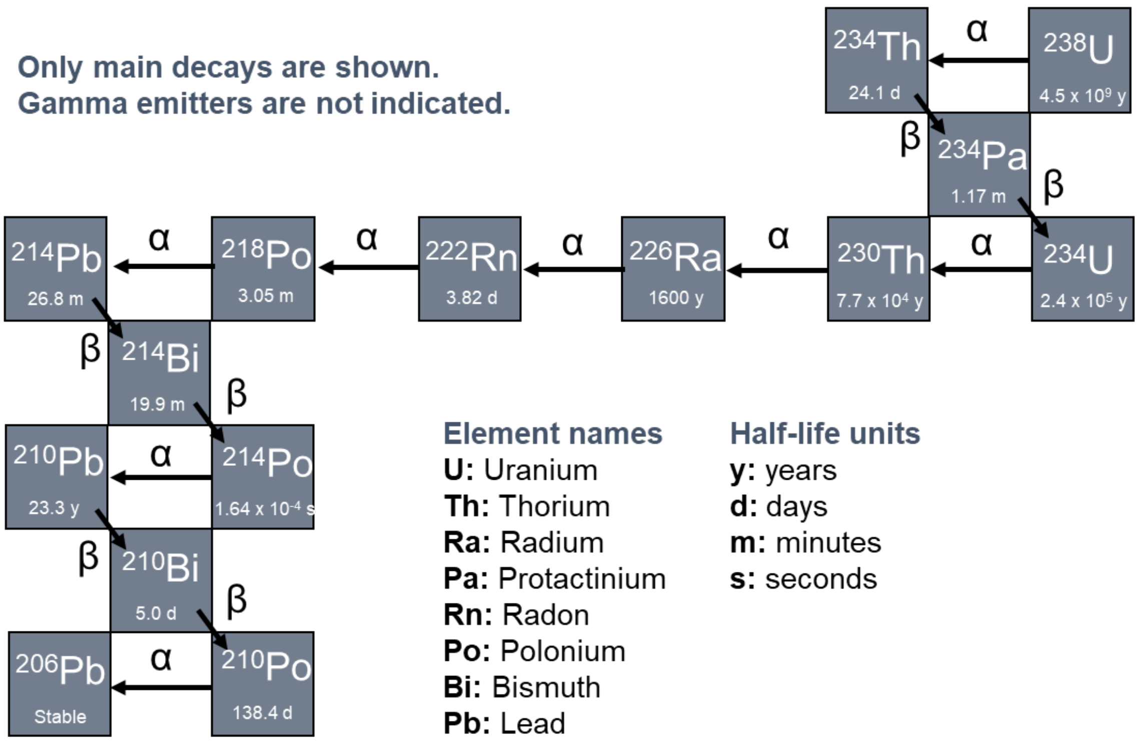


Figure 1. The radioactive decay series of ^{238}U.

Deep Geological Disposal

6.9 Based on the work presented by NWS, CoRWM consider the disposal of the uranium inventory in a GDF to be a viable option.

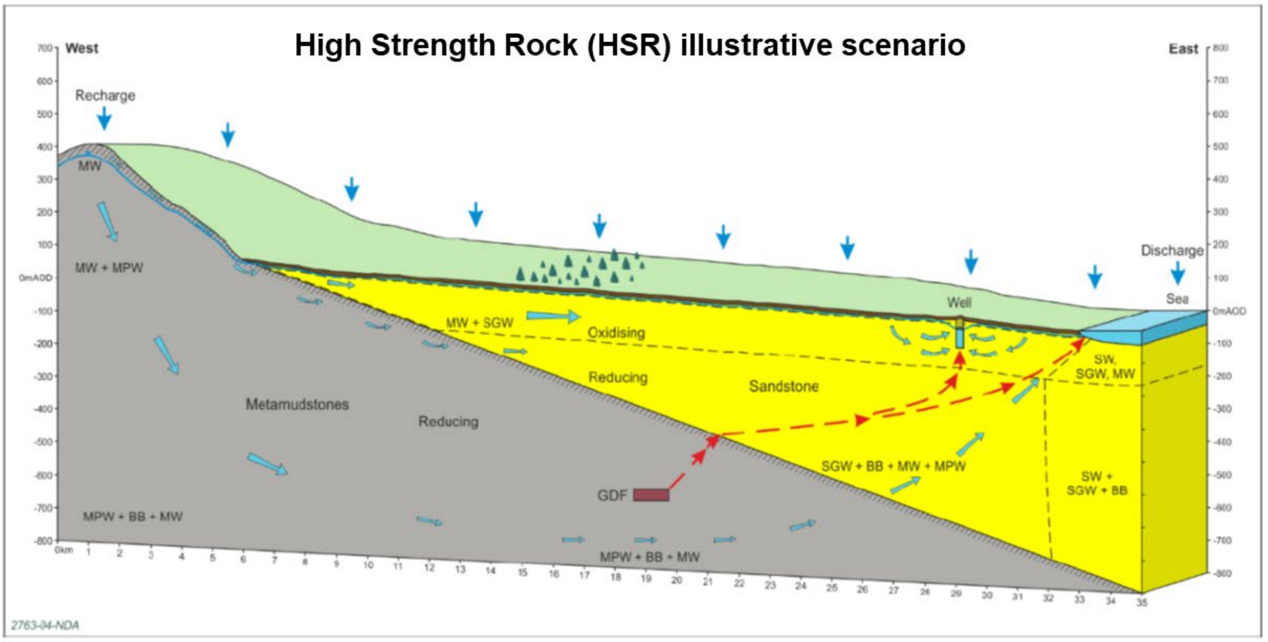
6.10 The following section presents CoRWM's consideration of work to date by NWS to determine the feasibility of uranium disposal in a GDF.

6.11 The post closure safety assessment performed within the generic Disposal System Safety Case (DSSC) 2010 considered two illustrative environments: high strength rock (HSR) with advective groundwater flow; and low strength sedimentary rock (LSSR) with diffusion-controlled groundwater movement, as shown in Figure 2.

6.12 Probabilistic models of the disposal of the uranium inventory within these illustrative environments meets the Risk Guidance Level of 10^{-6} set out in Requirement 6 of the Environment Agency Guidance for Requirements on Authorisation [13], with the no- to low-permeability LSSR environment giving the best performance. In the "worst-case" scenario developed for the HSR environment, which involves advective transport of groundwater and human intrusion *via* a well pathway, the estimates of mean annual individual risk marginally exceed the regulatory Risk Guidance Level.

6.13 NWS explained to CoRWM that these probabilistic calculations were not well refined with respect to radium-226 and that, in the future, with additional work, the total mean radiological risk *via* the well pathway would likely fall below the RGL.

6.14 CoRWM are satisfied that NWS possess the tools and methodologies to perform this work, and understand that they will do so when a site-specific post-closure safety assessment is required in the future. At that stage, it will be necessary for CoRWM to reappraise their conclusions regarding the safety of uranium disposal in a GDF.



Low Strength Sedimentary Rock (LSSR) illustrative scenario

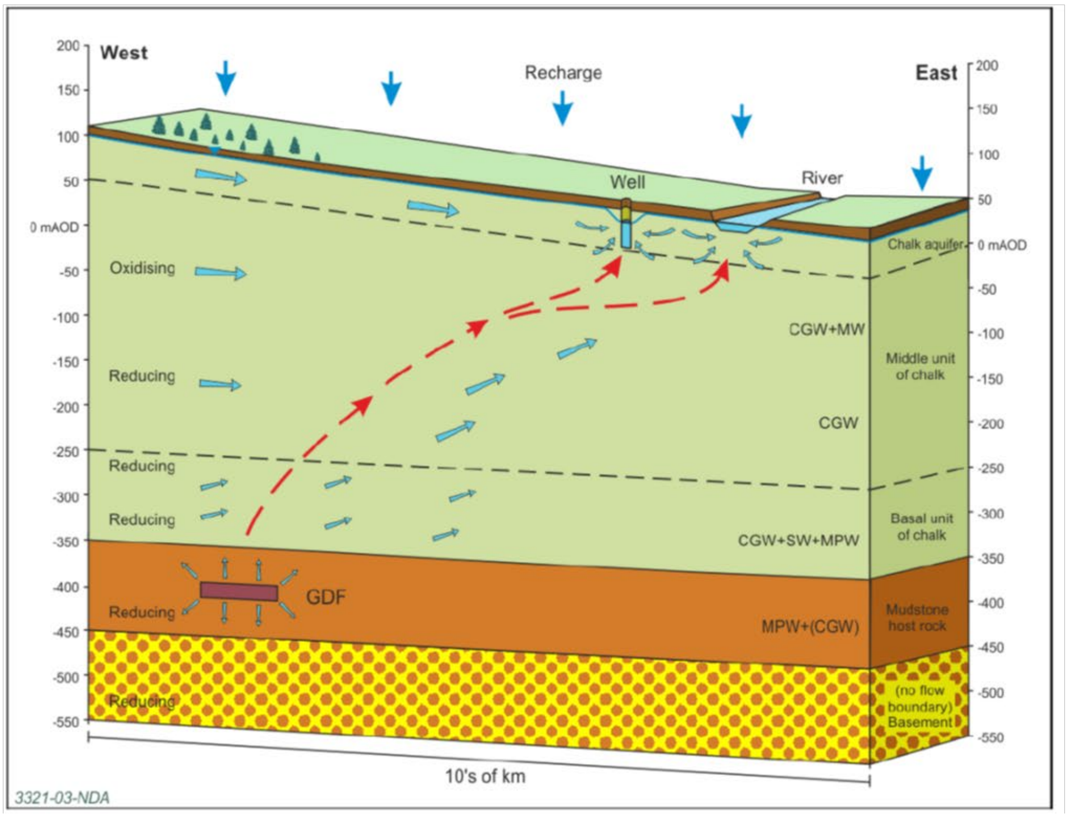


Figure 2. Schematics of the two illustrative scenarios used in the post-closure safety assessment for the determination of the radiological risk arising from radioactive waste disposal in a GDF. These images highlight the possible transport pathways for high strength rock (HSR) overlain by a series of sedimentary formations (top) and low-strength sedimentary rock (LSSR) mudstone overlain by sedimentary formations where a river is the receptor (bottom). From [14].

6.15 The generic DSSC 2010 assumed a baseline disposal concept of UO_3 and U_3O_8 powder, encapsulated by cement within 500 litre stainless steel drums. Because the post-closure safety assessment relies strongly on uranium solubility arguments, should the chemical form of uranium differ from that in the baseline option, further post-closure safety assessment should be undertaken to provide confidence in the safety of disposal. Indeed, NWS acknowledge that several portions of the uranium inventory, e.g. UF_6 powder and uranium metal items, require further investigation prior to considering disposal in a GDF.

6.16 An assessment of alternative packaging options was undertaken by the NWS Uranium IPT [8]. It was concluded that the disposal of unencapsulated uranium powders in a GDF, within the original storage containers, offered the best accident performance. Disposal of uranium in unencapsulated form also decreased the number of packages for disposal compared to the baseline cement-encapsulation option, per tonne of uranium, by up to 97%. This could result in significant cost savings in the GDF programme.

6.17 CoRWM understand that NWS plan to undertake further work regarding the operational safety of the transport and handling of unencapsulated uranium material, building on current best-practise employed by Urenco.

6.18 It should be noted that the disposal of unencapsulated uranium powder will <u>not</u> be suitable for the whole uranium inventory. In particular, NWS acknowledge that uranium with a high fissile content (e.g. LEU, TPU, MOD DNLEU and Misc DNLEU, >1% uranium-235) is not suitable for disposal in unencapsulated form and have explicitly excluded it from consideration

6.19 CoRWM concur with this assessment as it meets their 2006 Recommendation 7 [15], which states that:

"If a decision is taken to manage any uranium, spent nuclear fuel and plutonium as wastes, they should be immobilised for secure storage followed by geological disposal."

6.20 While CoRWM are committed to their recommendation to immobilise spent nuclear fuel and plutonium prior to geological disposal, it has become evident that for a portion of the uranium inventory, immobilisation, e.g. by cement grout encapsulation, may not be proportional to the hazard and risk posed by the material. This portion of the inventory includes material that is already converted to stable oxide form and that does not contain significant fissile content or contamination from other radionuclides.

6.21 CoRWM wish to see further work, performed by NDA and NWS, in close cooperation with the relevant regulators, to determine whether the hazard posed by the uranium inventory can be reduced by immobilisation, or whether the hazard remains unchanged regardless of encapsulation *vs* unencapsulation. For example, one outstanding question surrounds the potential impact of voidage associated with loose powder materials on the post-closure and operational safety cases.

6.22 CoRWM also consider that it would also be beneficial to explore whether alternative disposal options may be credible. Such alternatives were mooted in the NWS Uranium IPT, e.g. utilisation of a portion of the uranium inventory as mass backfill, or co-disposed with other waste streams. While plausible, such options are yet to be assessed from a post-closure safety perspective and, if employed, would only use 5 – 10% of the inventory, at most.

Recommendation 3

NWS should undertake an assessment of whether the operational and post-closure hazards posed by the uranium inventory can be reduced by cement-encapsulation. They should engage with the relevant regulators in developing any plans for disposal of unencapsulated uranium in a GDF.

Recommendation 4

Once a site for a GDF has been selected, NWS should update the post-closure and operational safety cases to provide further confidence in the option of GDF as a potential disposal route for (a portion of) the uranium inventory, beyond the arguments made in the generic disposal system safety case.

Disposal near surface disposal facilities

6.23 The RWM Uranium IPT considered near surface disposal of the uranium inventory, both at the surface and tens of meters below the surface. Waste packaging was assumed to be U_3O_8 and UO_3 powders in long term storage containers (i.e., not encapsulated in cement grout), with a reusable or combined transport and disposal container.

6.24 Near surface disposal of the uranium inventory, near the surface in a capped facility, was determined to be vulnerable to large scale human intrusion. Given that the mean risk posed by uranium increases with time over 1 million-years, it seems reasonable to conclude that during this time period human intrusion could occur at a surface facility. Therefore, this disposal option would exceed the dose level in the current guidance for authorisation of surface disposal facilities.

6.25 Near surface disposal of the uranium inventory within a few tens of metres of the surface, was considered by the Uranium IPT to be "unlikely to be feasible for much of the UK" because erosion over periodic glaciation cycles has the potential to bring the disposal zone within reach of large scale human intrusion.

6.26 The Uranium IPT concluded that disposal of the uranium inventory at a depth of between 100 – 300 m is feasible in principle, but dependent on site specific conditions. It was considered that such depth provided sufficient protection against large scale human intrusion and future glaciation. A near surface disposal facility at depth was assumed to be co-located with the GDF, with sharing of access shafts or drifts in some concepts; however, the host rock was not required to be the same as that of the GDF.

6.27 An option for disposal of the uranium inventory in a near surface facility at 100 - 300m below ground would offer two opportunities:

- Earlier emplacement of waste in more simple, purpose-built facilities, assuming no delay to the disposal of other wastes in GDF, reducing lifetime management costs.
- Diversion of the DNLEU waste inventory from the GDF, in a scenario where the volume of host rock is constrained and disposal of the entire inventory cannot be achieved.

6.28 Since the potential challenge to GDF performance from disposal of the uranium inventory is from daughter nuclides arising from decay of long lived uranium-238, and radium-226 in particular, CoRWM notes that it may be difficult to achieve an acceptable safety margin at shallower depth than the GDF.

~~6.29~~ The potential to reduce the overall cost of uranium management, through savings in stores and storage costs, achieved by early emplacement in near-surface facilities, seems hypothetical given the uncertainty in siting and construction scheduling. A near surface facility at a depth of 100 – 300 m and co-located with a GDF would need to be developed to the same timeframe as the GDF which would impede the opportunity of earlier waste emplacement since its development could not proceed independently.

6.30 CoRWM nonetheless believe that further consideration of the potential for disposal of the uranium inventory in near surface disposal concepts is warranted, if only so that sentencing to a GDF can be demonstrably justified as a result of the lack of any reasonable alternative disposal option.

Recommendation 5
A credible options analysis should be undertaken by NDA / NWS, and periodically reviewed, to consider alternative options for the disposal of (a portion of) the uranium inventory. This analysis should assess a wide range of disposal options in proportion to the radiological risk posed, with consideration given to each individual portion of the uranium inventory (e.g. TPU, LEU etc.). Such an analysis should involve close cooperation with the relevant regulatory organisations and should consider the cost benefit of alternative options in comparison with disposal in a GDF.

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