DECOMMISSIONING OF NUCLEAR POWER PLANTS WITH URANIUM-GRAPHITE REACTORS,
HANDLING OF IRRADIATED REACTOR GRAPHITE.
CHALLENGES AND POSSIBLE SOLUTIONS
17-10-2020

Special Issues of Irradiated Graphite Legacy Management in the UK

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Reception

Safety fears as Hunterston reactor cracks predicted to rise to 1000

The Ferret, 11th October 2020

https://www.thenational.scot/news/18785686.safety-fears-hunterston-reactor-cracks-predicted-rise-1000/

Technical reports released by [the nuclear safety regulator [ONR] also reveal that a credible earthquake could trigger "overloads" and 500 more cracks [in the reactor graphite blocks] , further eroding safety margins [at the Hunterson reactor in Scotland. On September 24, ONR gave permission to restart reactor four at Hunterston, which had an estimated 209 cracks, for another six months.

Magnox graphite core decommissioning and disposal issues

IAEA symposium

https://www-pub.iaea.org/MTCD/publications/PDF/TE_1647_CD/PDF/TECDOC_1647.pdf

Graphite core dismantling and disposal will be a key issue for the decommissioning of the United Kingdom (UK) Magnox reactors. The irradiated graphite arisings from the UK gas cooled reactor programme represent a significant proportion of the radioactive wastes currently destined for the UK geological repository.

Data on the graphite and radionuclide inventory of the Magnox reactor graphite cores are presented together with data on the core designs. Magnox reactor cores represent a significant fraction of the worldwide irradiated graphite inventory and the paper recognizes that there may be alternatives to geological disposal.

Sources and arisings of carbon-14, which is one of the major long lived radionuclides of concern, are discussed along with wider aspects of the arisings and behaviour of carbon-14 in the environment. Indubitably, core graphite disposal and the technical challenges it poses is one of the major issues to address in achieving final site clearance in a cost effective manner and reducing the liability cost associated with disposal of graphite.

UK Graphite inventory

- The total arisings of Magnox reactor core graphite in the UK are of the order 45 600 m_3, which equates to around 57 000 t using a bulk density of 1.25 t m_{-}......... In addition, there are about 2300 t of graphite fuel struts and sleeves which were employed on the Berkeley and Hunterston A reactors;
- these arisings are stored in vaults on these sites.

Core design

- **The graphite cores were constructed from machined blocks and the core was assembled in situ. Moderator blocks are assembled to leave a small clearance between the blocks. The core is keyed together to produce a structure which allows for some movement in the event of a seismic event. The moderator blocks have, of course, holes passing through them that form the fuel channels.**
- **The outer reflector blocks do not have channels and there are no clearances between the blocks. The Magnox core designs underwent progressive development and changes in the brick location and peripheral restraint arrangement**

Dismantling

- **Removal of the graphite from the core will be a key issue in any dismantling work carried out to effect final site clearance. A report on efficient methods for removal of the typically 30,000 separate graphite blocks was presented at the *1999 IAEA meeting on Nuclear Graphite Waste Management*.**
- **Not surprisingly, this showed that the dismantling time was decreased if more blocks could be removed in a single lift. Various techniques for gripping graphite blocks for removal have been investigated . These have included:**
- ***Inside gripping***
- ***Inside screw threading***
- ***Inside grooving***
- ***Rubber expanding***
- ***External gripping***
- **More rapid techniques may also need to be considered. It might be worth considering approaching mining and bulk handling companies to provide input on innovative methods of removal of the graphite from the core in effect looking at this exercise more as a mining exercise rather than a careful and time consuming reversal of construction. Rapid dismantling techniques might save time and radiation dose. Underwater dismantling of reactors to provide shielding has been discussed as an option. The effect of any such activity on graphite would need to be considered.**

Dismantling

Disposal

- The current UK Radwaste Management Directorate (RWMD) position is that irradiated graphite is destined for the deep geological repository largely on account of the long lived carbon-14 and chlorine-36 content. It will be disposed of in 4 m length stainless steel RWMD approved boxes and encapsulated. The geological repository post-closure safety case relating to radionuclide release and transport assumes no benefit from the waste container. Consideration ought to be given to use of larger capacity multi-trip reusable transport containers. This would need to be accompanied by investigations of loading and unloading of such containers.
- The 55 000 t of Magnox graphite equates to about 100 000 m3 of packaged material and a significant overall disposal cost.
- The RWMD position is based around the presence of long lived radionuclides in graphite. The RWMD (Nirex) Report on the ***Viability of a Phased Geological Repository*** develops the overall strategy and summarises safety and risk considerations for the repository .. the report talks in terms of a target radiological risk for the repository of less than 10–6 per year. The report accepts that natural background radiation gives a risk of 10–3 to 10–4 on the same basis.

Carbon-14 in the environment

- An important question regarding irradiated graphite disposal is whether the graphite will be stable with negligible degradation or isotopic exchange with the surrounding environment. The evidence with naturally occurring graphite suggests that it would be stable although obviously the consequences of release of any radioactivity in particular carbon-14 would need to be assessed. The following section looks at this issue.
- The annual production rate of carbon-14 from cosmic rays is about 1000 TBq and there is of the order of 140 000 TBq in the atmosphere and 10 million TBq in the deep oceans. This helps to put the carbon-14 arisings from the nuclear industry in perspective.
- There are more recent acute big variations in atmospheric carbon-14 concentrations as a result of atmospheric bomb tests (doubled the concentrations) and consumption of fossil fuels (now acting to slowly reduce C-14 concentrations in terms of specific activity, i.e. carbon-14 per gram of carbon).
- Typical annual airborne radioactive discharges of carbon-14 from Magnox plant are shown in data presented in the ***BNFL Annual Report on Monitoring our Environment*** .
- The total discharges of carbon-14 from the operating Magnox stations range from 1.1 TBq for Sizewell A to 3.1 TBq for Dungeness A. The total discharges from Magnox stations have fallen from 12 TBq to 8 TBq from 1999 to 2004.
- During this period, of course, a number of stations have closed. It is apparent that discharges from the decommissioned sites are very low, <0.1% of the levelon generating sites.

Magnox reactor graphite disposal is a major unresolved issue

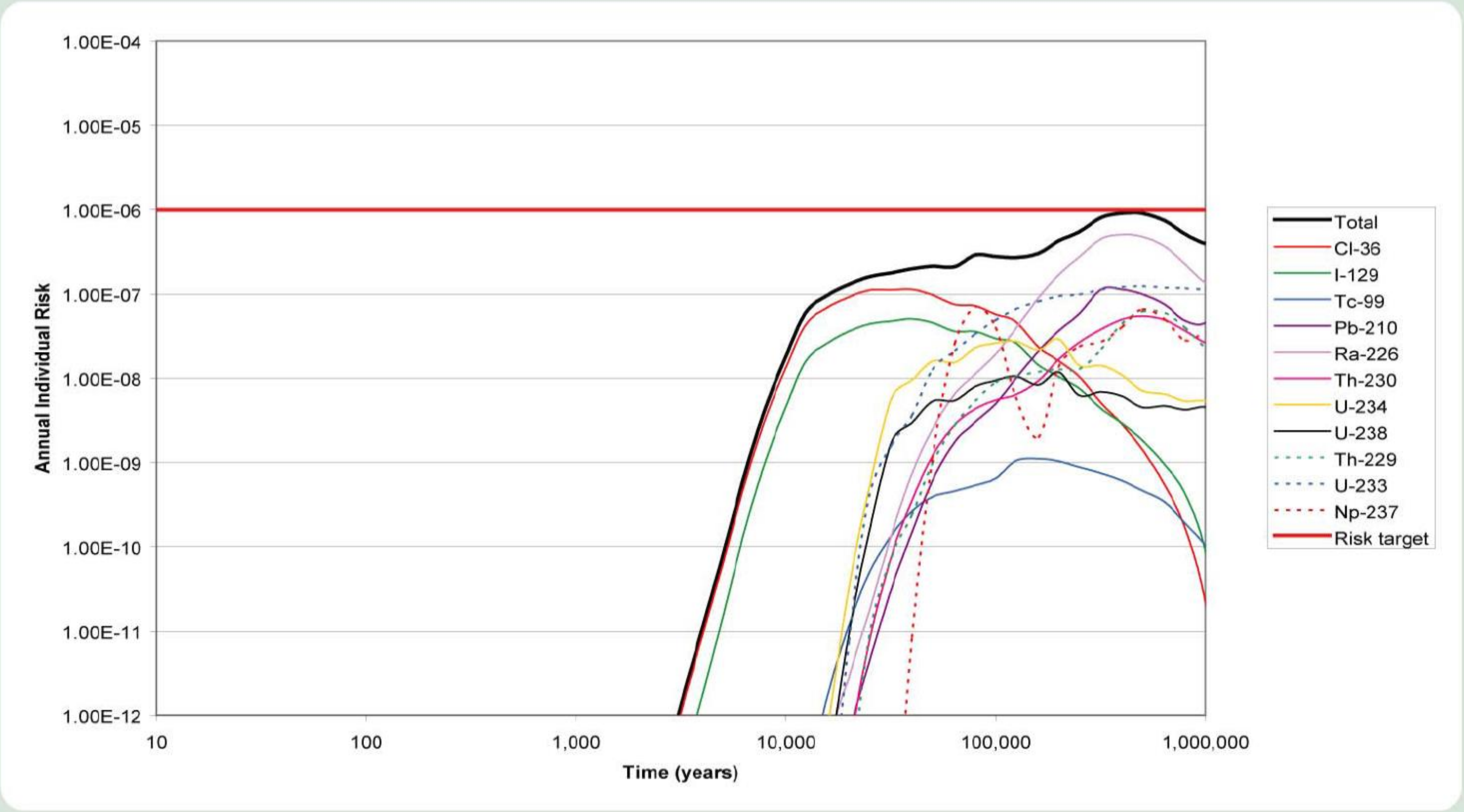
- Key outstanding issues are:
- • Radionuclide inventory and behaviour
- • Graphite handling and core removal techniques
- • Graphite disposal techniques
- • Carbon-14/carbon-12 separation techniques
- • Graphite leaching behaviour
- • Collective and critical group dose issues for disposal scenarios

Key conclusions

- The disposal of UK irradiated graphite in the proposed deep geological repository will take up ~30% of the volume and incur a significant cost. Alternative options may be cheaper and available sooner.
- There may be options for disposal of graphite in existing near surface facilities. In addition, there may be an option of incinerating the graphite and separating the carbon-14 component as a small volume for disposal. Alternative options could reduce the liability cost of graphite disposal and also facilitate *Early Final Site Clearance* (EFSC) where graphite core dismantling would be one of the first steps
- The “cautious and conservative” approach taken to date to the disposal of irradiated graphite, whilst appropriate with the information available at the time, should be re-examined.

Graphite Wastes: Disposal Issues
By David Lever, 3 October 2006

Figure 27
Annual Individual Risk vs Time for Final Stage Decommissioning Wastes Added to GPA Reference Case



THE UNCERTAIN FUTURE FOR NUCLEAR GRAPHITE DISPOSAL: CRISIS OR OPPORTUNITY?

A.J. WICKHAM, G.B. NEIGHBOUR, Department of Materials Science and Engineering, University of Bath, United Kingdom & M. DUBOURG, Société Carbone-14 SARL, Le Mesnil St. Denis, France

October 1999

The Authors concluded

…….it would be timely to review all options for disposal of irradiated graphite waste from a purely objective scientific viewpoint, unfettered by these pre-conditions, with a view to making a technical case to Government agencies and to the publicfor a change of policy should this be deemed necessary. This may include a rationalisation of controls on radioactive discharges within and without the nuclear industry, *to avoid undue restrictions being placed upon the industry*.

Ideally this position will be reached with international participation and consensus. However, socio-economic and political pressures are recognised as very powerful in this area, despite the irrationally high costs associated with palliative procedures compared with the true risks involved. Given that all present options satisfy current safety limits, the need to minimise the objective risk is found to be a minor need in comparison to the public's want of demonstrable control, responsiveness and ability to reverse/change the disposal options in the future if circumstances dictate the need to do so.

Essentially, the choice of a final disposal option for graphite waste must optimise the beneficial attributes of subjective risk experienced by the general public coupled with a revised public education strategy to reflect the comparative risks of all options.

[paper has 29 primary references]

Reactor Decommissioning Update - Summary of Options for Waste Graphite
UK Nuclear Decommissioning Authority, February 2011

Committee on Radioactive Waste Management (CoRWM) Recommendation:

- In determining what reactor decommissioning wastes should be consigned for geological disposal, *due regard should be paid to considering other available and publicly acceptable management options*, including those that may arise from the low level waste review.

Government's Response:

- Government accepts this recommendation. The NDA will review whether a safety case could be made for other non-geological disposal of reactor decommissioning wastes, including on-site, or near-site, disposal in order to minimise transport. In doing this it will take account of the outcome of the Government's Low Level Waste management policy review, as well as public and stakeholder views. The NDA will use the outcome of these reviews, which will be published, in developing its outline geological disposal implementation plan.
- In response to the above statements NDA launched the **Reactor Decommissioning Wastes project** in 2009 to build on our work supporting the **EU Carbowaste project**. This project examines the potential benefits and costs of options for the alternative management of reactor decommissioning waste, whilst also considering the implementation of the waste hierarchy.
- It focuses on Magnox reactors in the NDA estate, but in considering the position with regard to the large volume estimate of waste graphite, also takes account of the eventual decommissioning of graphite moderated Advanced Gas-Cooled Reactors (AGRs) owned by British Energy.

Current UK NDA strategy (in 2011)

The baseline strategy for graphite management is to dismantle reactor cores following a period of ***Safestore*** during the *Care and Maintenance* phase (typically 85 years) and package the graphite for disposal.

Disposal in a geological disposal facility (GDF) is the planned end point for the packaged waste in England and Wales.

In Scotland, [which operates under separate legal arrangements] the Scottish Government policy is that the long-term management of higher activity radioactive waste should be in *near-surface facilities*.

Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how waste packages, or waste, could be retrieved.

The Long-term Management of Reactor Core Graphite Waste Credible Options (Gate A)
UK NDA, September 2013 (40 pages)

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/457088/The_long-term_management_of_reactor_core_graphite_credible_options__Gate_A_.pdf

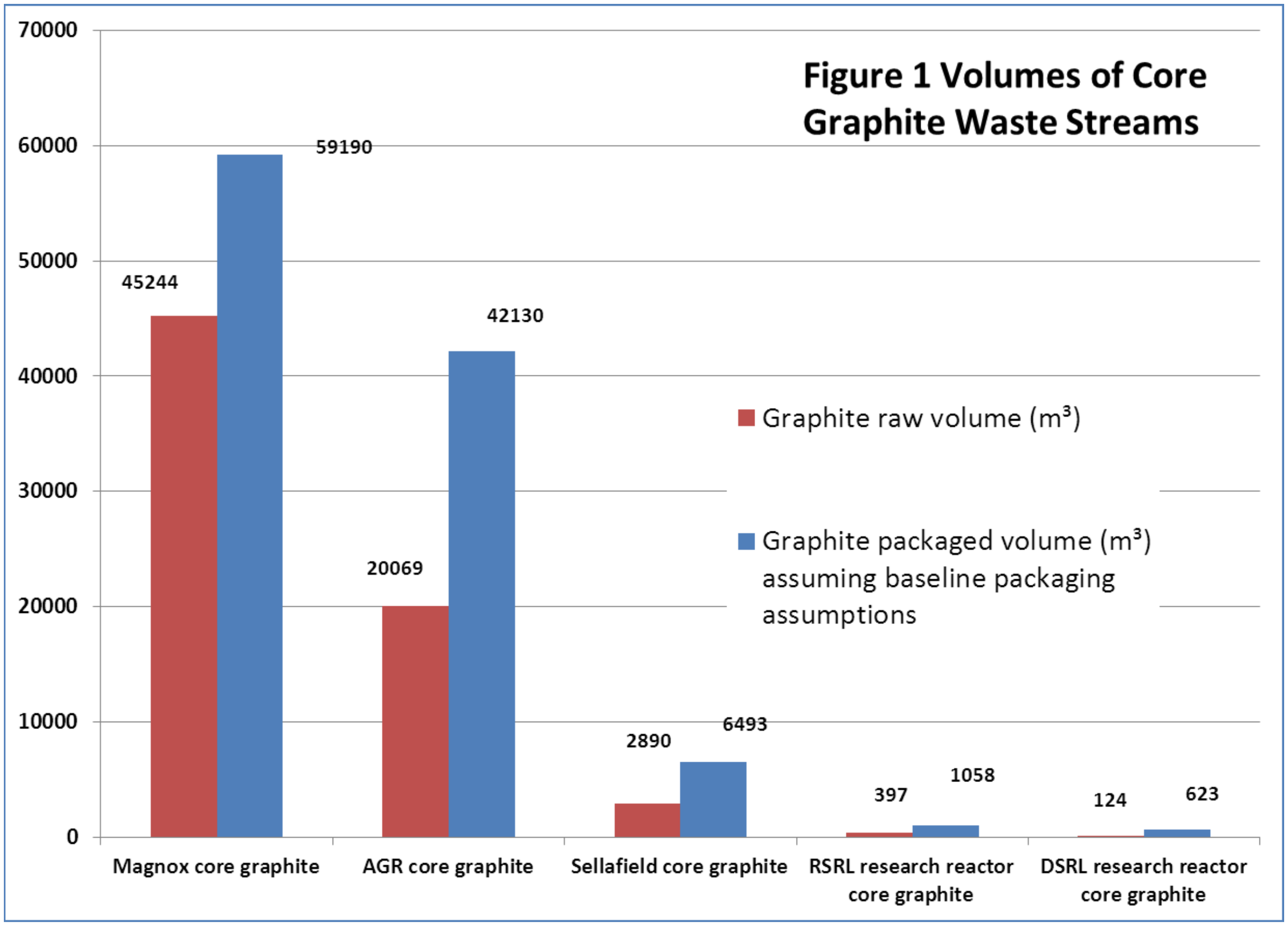
Executive Summary

- This paper establishes the credible options for the long term management of graphite wastes arising from the final decommissioning of reactors. The scope of the paper includes core and reflector graphite wastes arising from the final decommissioning of the **Magnox** and AGR reactors, and from the Sellafield Ltd., RSRL and DSRL research reactors.
- There is an established strategy for managing reactor core graphite that is embedded in site lifetime plans and is broadly similar across them, with the vast majority of the inventory from the final decommissioning of the Magnox and AGR reactors not planned to be generated for several decades. ***As such, there will be frequent opportunities to review the credible options set out in this paper as time progresses***. The strategic tolerances to alternative site restoration strategies and GDF availability scenarios are explored in this paper.
- This paper identifies a number of potential options for the management of reactor graphite including both ***direct disposal*** and ***pre-disposal treatment options***. These options are screened against four criteria for each of the Site Licence Companies (SLCs) within scope. The conclusion of this screening exercise is that it is not currently considered credible to directly dispose of reactor graphite to either the Low Level Waste Repository (LLWR) or to other radioactive waste permitted landfill sites.
- Opportunities are highlighted for the use of near-term waste arisings (for example RSRL and DSRL research reactor graphite) as pathfinder material for core dismantling or treatment trials to inform decisions on the management of larger volume, later arising Magnox, Sellafield and EDF Energy reactor graphite.

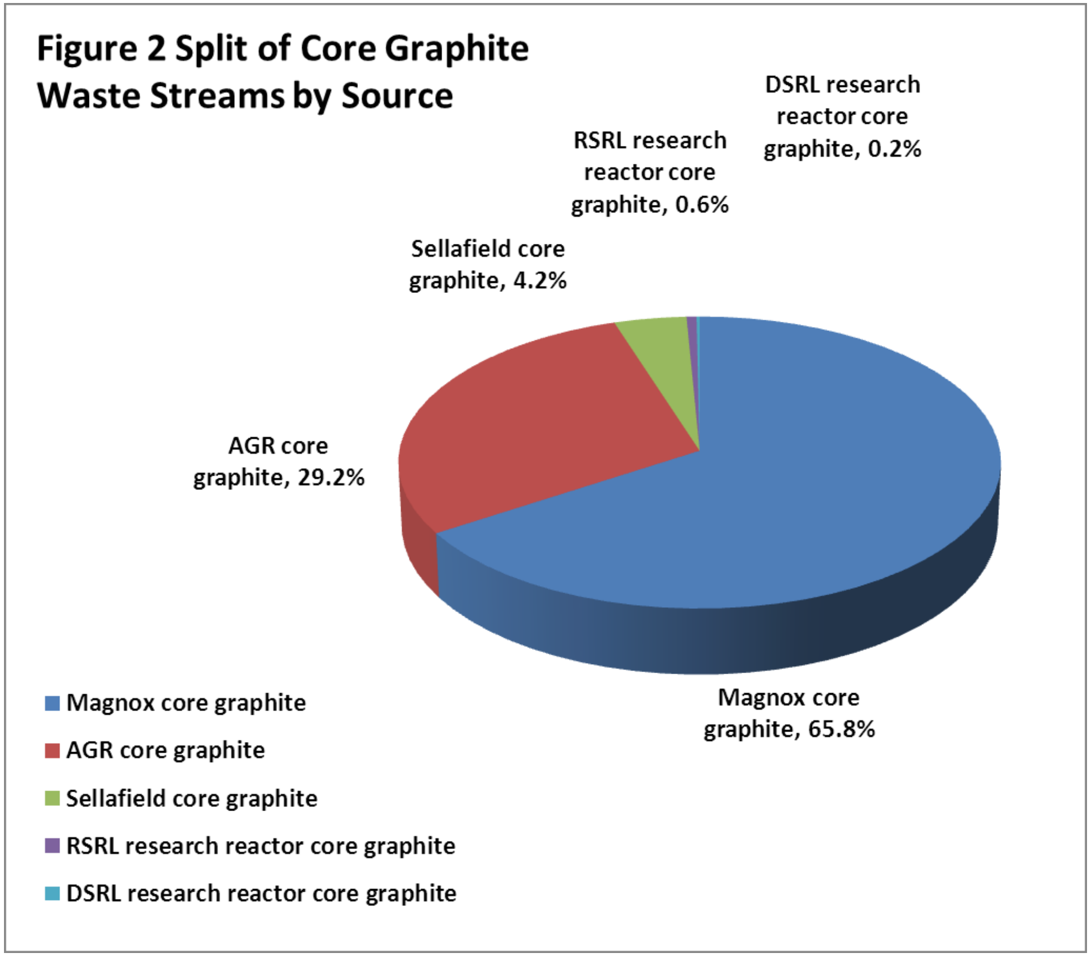
Graphite volumes

- The decommissioning of reactors in the UK will generate substantial amounts of higher activity radioactive waste. A significant proportion of these wastes will be graphite. The UK graphite inventory comprises operational and reactor decommissioning waste streams.
- Core graphite waste streams amount to *circa 22 % on a packaged volume basis* assuming baseline packaging plans of the total UK ILW inventory; by comparison, operational graphite waste streams comprise a further 6 % of the UK ILW inventory.
- In total, these graphite wastes comprise about 136,000 m3, or almost 30% on a packaged volume basis of the total inventory of ILW forecast to arise across the UK of 488,000 m3.
- If consigned to the planned Geological Disposal Facility (GDF) it is estimated by RWMD that graphite wastes would occupy less than 2 % of the facility footprint.

The core graphite waste inventory is illustrated as follows



Magnox core graphite dominates the inventory (about 65% by raw volume), with AGR core graphite contributing a significant proportion (about 30%) and Sellafield (circa 4%) and the RSRL and DSRL research reactors (both less than 1%) making up the remainder of the inventory.



NDA statements on strategy for reactor graphite

- NDA documents acknowledged the link between reactor decommissioning strategy and the availability of a waste route for reactor graphite. They also highlighted the possibility for alternative management options which could avoid the need to consign large volumes of graphite to the GDF.

- There are a number of more recent statements in the current NDA Strategy of direct relevance to strategy for reactor graphite. Plans for decommissioning reactors rely upon the availability of a final disposal solution for the waste.

- It is recognised that reactor decommissioning will generate substantial amounts of radioactive waste and that a significant proportion will be graphite waste.

- There is an interface and dependency between the timing and strategy for site restoration of Magnox and AGR reactor sites and the availability of waste routes for the reactor decommissioning wastes that will be produced. The availability of a waste route for reactor graphite is a key enabler for final reactor decommissioning.
- If this waste were to be generated prior to the availability of a suitable route, such as the GDF or a near surface facility in Scotland, *an alternative strategy for reactor graphite would be needed*.

UK Timetable for Decommissioning

- The final decommissioning of the EDF Energy AGR reactors is currently assumed to take place between 2105 and 2114.
- Much smaller volumes of core graphite waste will be produced earlier from the decommissioning of the BEPO, DIDO, PLUTO and DRAGON (Harwell) research reactors by RSRL from 2016, the DFR and MTR research reactors (Dounreay) by DSRL from 2017 and the Windscale Piles 1 and 2 (Sellafield) from 2030 by Sellafield Ltd.
- Final decommissioning of both the Magnox and the AGR reactors *will not commence until well after the start date for first emplacement of waste in the GDF which is assumed to be 2040*.
- Final decommissioning of Sellafield, RSRL and DSRL reactors will commence *before* planned GDF availability and the graphite wastes produced will consequently require a period of *interim storage*

Issues and concerns

- • Perception about transport of large volumes of graphite and wider reactor decommissioning wastes to an off-site facility c.f. CoRWM document8.
- • De-licensing, de-designation, divestment and Paris & Brussels liability implications in relation to disposal facilities for some options.
- • Status of environmental safety case work for near surface disposal of graphite - a small number of environmental safety case issues were not closed out with SEPA following completion of the ***Graphite Pathfinder Project***.
- • Understanding under what circumstances near surface disposal may be preferable to geological disposal.
- • Perceptions concerning any treatment options involving the release of large inventories of C-14 or Cl-36 to the environment in gaseous or liquid form.
- • The acceptability of in-situ disposal options, particularly at coastal sites where reactor mounding would eventually be impacted by coastal evolution.
- • Do treatment options deliver any net benefit over disposal for reactor graphite wastes, given the suitability of the waste form for direct disposal and the need to manage any secondary wastes stemming from treatment

UK Graphite Disposal options

- 1. **GDF disposal** to the planned disposal facility for higher activity wastes arising in England & Wales.
- 2. **Near surface disposal** 4 to a new specialised facility Permitted in line with the Near Surface Guidance for Requirement on Authorisation (GRA).
- 3. **In-situ disposal** (necessarily assumes reactor mounding is selected as an alternative site restoration and decommissioning strategy).
- 4. **LLWR disposal** (existing specialised facility).
- 5. **Permitted landfill disposal** (existing or future commercial facilities).

Conclusions on future pathways in UK Graphite management

- **This paper establishes the credible options for the long term management of graphite wastes arising from the final decommissioning of reactors. The scope of the paper includes core and reflector graphite wastes arising from the final decommissioning of the Magnox and AGR reactors, and from the Sellafield Ltd., RSRL and DSRL research reactors.**
- **There is an established strategy for managing reactor core graphite that is embedded in site lifetime plans and is broadly similar across them, with the vast majority of the inventory from the final decommissioning of the Magnox and AGR reactors not planned to be generated for several decades.**
- **As such, there will be frequent opportunities to review the credible options set out in this paper as time progresses. The strategic tolerances to alternative site restoration strategies and GDF availability scenarios are explored in this paper.**
- **A high level plan for progressing the topic strategy and options for supporting R&D that there may be merit in undertaking is also described.**

RISKS!

- • There is a risk that development work on enabling alternative graphite waste options is not available at the appropriate time to support strategic work on alternative site restoration and decommissioning strategies.
- • There is a risk that the supply chain does not invest in R&D to develop alternative treatment options if there is perceived to be no strategic need for near or medium term solutions.
- • There is a risk that the regulators do not consider the extent of planned strategic development work and R&D for graphite waste to be adequate.
- • There is a risk that the legal, policy, planning or regulatory framework changes, resulting in increased costs and or timescales to implement the preferred options e.g. standards become more restrictive.
- • There is a risk that societal views change, impacting upon the options which may be considered to be publicly acceptable.
- • There is a risk that the costs and or availability of raw materials and energy change e.g. for manufacture of waste containers, or construction of facilities.
- • There is a risk that the availability of the GDF is delayed.
- • There is a risk that the marginal cost for consigning graphite waste to the GDF is higher than currently estimated.
- • There is a risk that funding will not be available for development of options.
- • There is a risk that the presence of graphite dust will require changes to assumed condition and packaging plans.

OPPORTUNITIES

- • There is an opportunity to apply learning gained from other sources such as international experience, Carbowaste and EDF Energy to improve graphite management strategy.
- • There is an opportunity to assess alternative options which could be enablers for alternative site restoration strategies e.g. alternative timescales for final decommissioning of one or more Magnox reactors.
- • There is an opportunity to undertake R&D on alternative management options which could contribute to the development of treatment technologies at a higher level of the waste hierarchy for such wastes.
- • There is an opportunity to assess alternative management options which could contribute to lifecycle cost savings for the NDA and other waste owners.
- • There is an opportunity to trial alternative waste management options using research reactor graphite.
- • There is an opportunity to improve knowledge of graphite retrieval, handling and waste management approaches during management of research reactor and Sellafield wastes.

Opportunities for the long term management of short lived ILW and reactor graphite by means of near surface disposal
By Dr Adam Meehan, Reactor Sites Management Company, Energy*Solutions*

- A strategy of consigning short lived ILW and reactor graphite to near surface disposal would result in significant benefits:
- • substantially reducing lifecycle costs for the management of ILW across the UK;
- • minimising UK interim storage requirements i.e. the number and/or size of ILW stores;
- • reducing the time period for which suitable operational ILW must be stored prior to disposal;

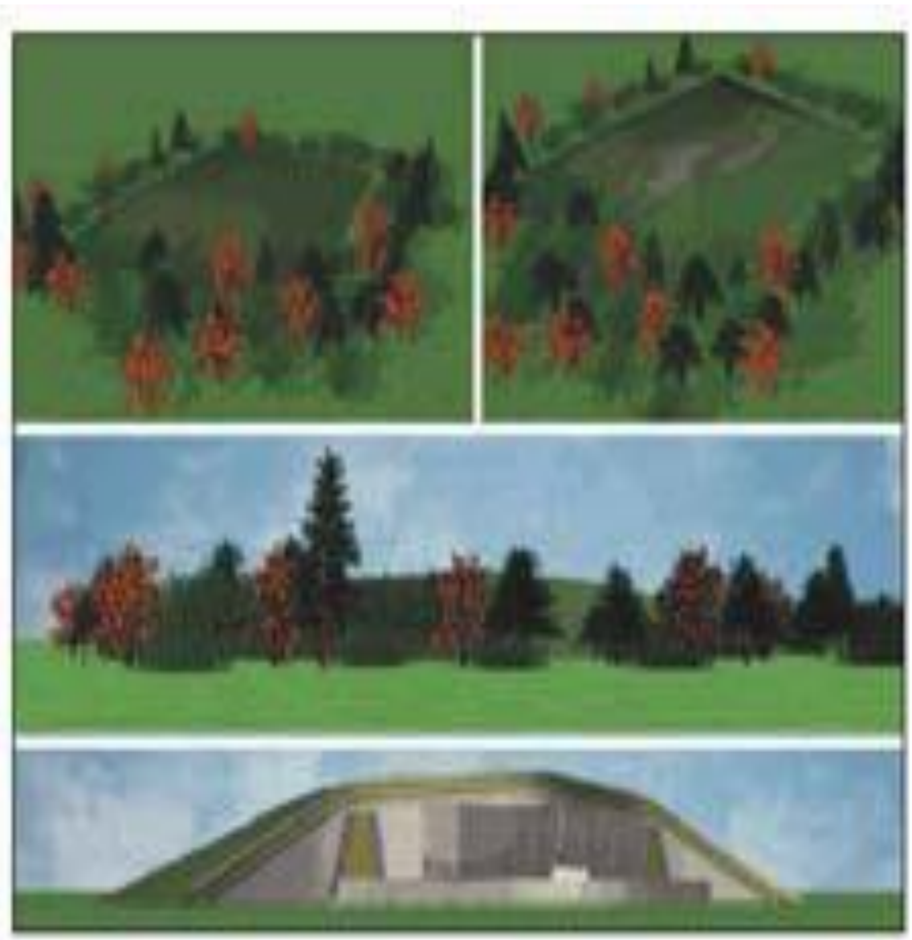
Co-disposal

- In CoRWM document 1305 Dr Mark Dutton concluded:
- “thus, with this [IAEA] categorisation, it is appropriate to dispose of waste in a non-geological repository provided that an acceptable safety case can be made but it is recognised that *this is unlikely to be the case if the recommended concentrations of alpha-emitting radionuclides are exceeded*.”
- Indeed, [*EnergySolutions*] consider that near surface disposal is in accord with international best practice for certain types of ILW. ***We believe that there is merit in consideration of near surface disposal, both in available overseas facilities and at facilties that might be developed in the UK.*** Such approaches could significantly reduce the inventory that needs to be consigned for deep geological disposal.

La Manche in France•Closed and capped near surface L&ILW disposal facility

Proposals for an above surface L&ILW repository in Belgium, based on a concrete vault concept

El Cabril in Spain•Near surface L&ILW disposal facility



Some international comparative graphite management experiences

- Core graphite waste from the **Brookhaven Graphite Research Reactor** (BGGR) with broadly similar activity concentrations of C-14 to Magnox core graphite has been disposed of to a near surface disposal facility in the US.
- Also in the US, there are plans for the prompt decommissioning of the **K-reactors** that include the disposal of the core graphite to a near surface disposal facility.
- A test cavern at 50–100 m depth has been excavated at **Rokkasho in Japan**, for a facility designed for the disposal of long-lived reactor wastes.
- There is a programme of work in **France for the disposal of reactor graphite** to a proposed national disposal facility sited at a minimum of 50–100 m depth within a thick, low permeability clay formation.
- A considerable amount of work has also been undertaken in the US, Germany, France and Japan on the application of thermal treatment technologies to core graphite wastes.

Selected Comparative International Experience

- • short-lived ILW is disposed of to near surface disposal facilities in many countries;
- • there is growing international interest in opportunities for the non-geological disposal of reactor graphite;
- • there is considerable evidence regarding the stability of graphite within the natural environment;
- • the long-lived radionuclides C-14 and Cl-36 are both low energy beta-emitters, with a low biological half-life in the body;
- • releases of C-14 and Cl-36 to the environment will be subject to isotopic dilution and will result in relatively low activity concentrations within well mixed compartments e.g. the oceans, or the atmosphere; and
- • scoping calculations suggest that risks and conditional doses associated with the near surface disposal of graphite could be well be acceptable i.e. result in risks to the public that are less than [UK] Government’s risk target.

Graphitech: EDF, Veolia team up to decommission graphite reactors

World Nuclear News, 10 December 2019

https://world-nuclear-news.org/Articles/EDF,-Veolia-team-up-to-decommission-graphite-react

- **A joint venture for the decommissioning of reactors that use graphite technology has been established by France's EDF and Veolia. Graphitech will seek contracts for assisting in the dismantling of such reactors in France, Italy, Japan, Lithuania, Spain and the UK.**
- The companies, through their respective subsidiaries Cyclife Holding and Asteralis, today launched **Graphitech**, which will be responsible for the technological development and engineering studies required in preparation for decommissioning nuclear reactors that use graphite technology. The venture will develop remote-operated tools to break up complex, large-scale concrete and metal structures, as well as tools to extract activated graphite bricks and piles. It will also design systems and articulated arms to enable deployment of these tools.

International examples of non-geological disposal facilities that accept short lived ILW

Country	Facility	Type of facility	Waste disposed	Commissioned in
Bulgaria	Novi Han	Surface	Institutional and waste from research reactor	1962
Czech Republic	Richard	Surface	SL-LILW and storage of LL-LILW	1964-2070
	Bratrstvi	Surface	LL-LILW (but not fission products)	1972-2030
	Dukovany	Surface	SL-LILW from NPP operation	1995-2100
Finland	Loviisa	100 m	LLW/SL-ILW	1997
	Olkiluoto	200 m	LLW/SL-ILW	1992
France	La Manche	Surface	LLW/ SL-ILW	1969 Closed 1994
	Centre de l'Aube	Surface	LLW/SL-ILW	1992
Hungary	Püspökszilágy	Surface	Institutional waste	1976
Japan	Rokkasho-mura	Surface	LLW/SL-ILW	1992
Romania	Baita-Bihor	Surface	LLW/SL-ILW	1985
Slovakia	Mochovce	Surface	SL-LILW.	1999
Spain	El Cabril	Surface	LLW/SL-ILW	1992
Sweden	Forsmark	50 m	SL-LILW	1988
USA	Barnwell	Surface	Class C LLW	
	Richland	Surface	Class C LLW	
	Clive	Surface	Class A & B LLW	
	Several DoE sites	Surface		

U.K. nuclear entity hires Jacobs to research radioactivity in graphite cores

https://www.power-eng.com/2020/05/12/u-k-nuclear-entity-hires-jacobs-to-research-radioactivity-in-graphite-cores/#gref

Power Engineering magazine reported on 12 May 2020 that:

"Dallas-based energy engineering firm Jacobs will lead a study of radioactive impacts in graphite reactor cores at nuclear power stations in the United Kingdom..... RWM has commissioned Jacobs to measure and characterize releases of the radioactive isotope carbon-14 and compare it with releases from irradiated graphite in earlier reactor types, including the U.K.'s first generation of Magnox civil nuclear power stations... The contract has an initial duration of two years. Subject to experimental program results, it may be extended by an additional two years"

Near-Surface Disposal: Strategic Position Paper
UK Nuclear Decommissioning Authority, August 2020

- **The [UK] NDA believes that there is a proportion of Intermediate Level Waste (ILW) that could be more appropriately managed in *near-surface* disposal (NSD) facilities and initiated an investigation to explore the technical feasibility of this disposal capability.**
- **Exploratory work supports UK government policy, which requires us to consider other disposal options, as well as a GDF, that could potentially improve our overall long-term management of Higher Activity Waste (HAW).**
- **The policy was developed following earlier recommendations by the government's independent *Committee on Radioactive Waste Management* (CoRWM).**

Summary of current graphite management policy priorities in UK

- The development of **<u>Near Surface Disposal (NSD)</u>** facilities could help to accelerate decommissioning and hazard reduction and provide increased flexibility within the waste management system, including, in some cases, reducing the need for interim storage. A proportion of wastes planned for interim storage or currently in storage at Sellafield may be suitable for NSD, which would save the costs of constructing new stores. In addition, final site clearance of Magnox reactor sites is likely to generate a large proportion of wastes which may be more appropriate for disposal in an NSD facility.

There are two main concepts for NSD: at-surface-level NSD and at-depth NSD, several tens of metres below the surface.

- Such an approach aligns with our *Radioactive Waste Strategy* that recommends ***risk-informed waste management*** and flexible decision-making, focused on the most appropriate treatment and disposal routes that take account of the risks posed by the nature of wastes rather than strict classification.
-

There are two main concepts for NSD: at-surface level NSD and at-depth NSD, several tens of metres below the surface.

- **• Disposal vaults at surface level:**
- This is similar to the LLW Repository system where waste packages are stacked in shallow engineered concrete vaults up to the approximate level of the surface. The
- closure phase consists of an engineered cap installed over the vaults to prevent rain-water entering and inadvertent intrusion, ensuring that no harmful quantities of radioactivity reach the surface.

Disposal vaults several tens of metres below ground:

- Waste would be placed in a series of rectangular vaults tens of metres (up to around 80metres) below the surface. Waste would be placed via a crane spanning the vault space. The vaults would consist of multiple barriers, including waste packages, grout, walls and backfill material to provide secure containment and resistance to ground water. Once complete, an isolation layer would cover the waste together with thick reinforced inner and outer caps, mass backfill and earth landscaping.
- The disposal depth would protect against the impact of natural processes such as coastal erosion and the potential for inadvertent human intrusion, ensuring the waste is undisturbed for thousands of years, so that no harmful quantitiesof radioactivity reach the surface.

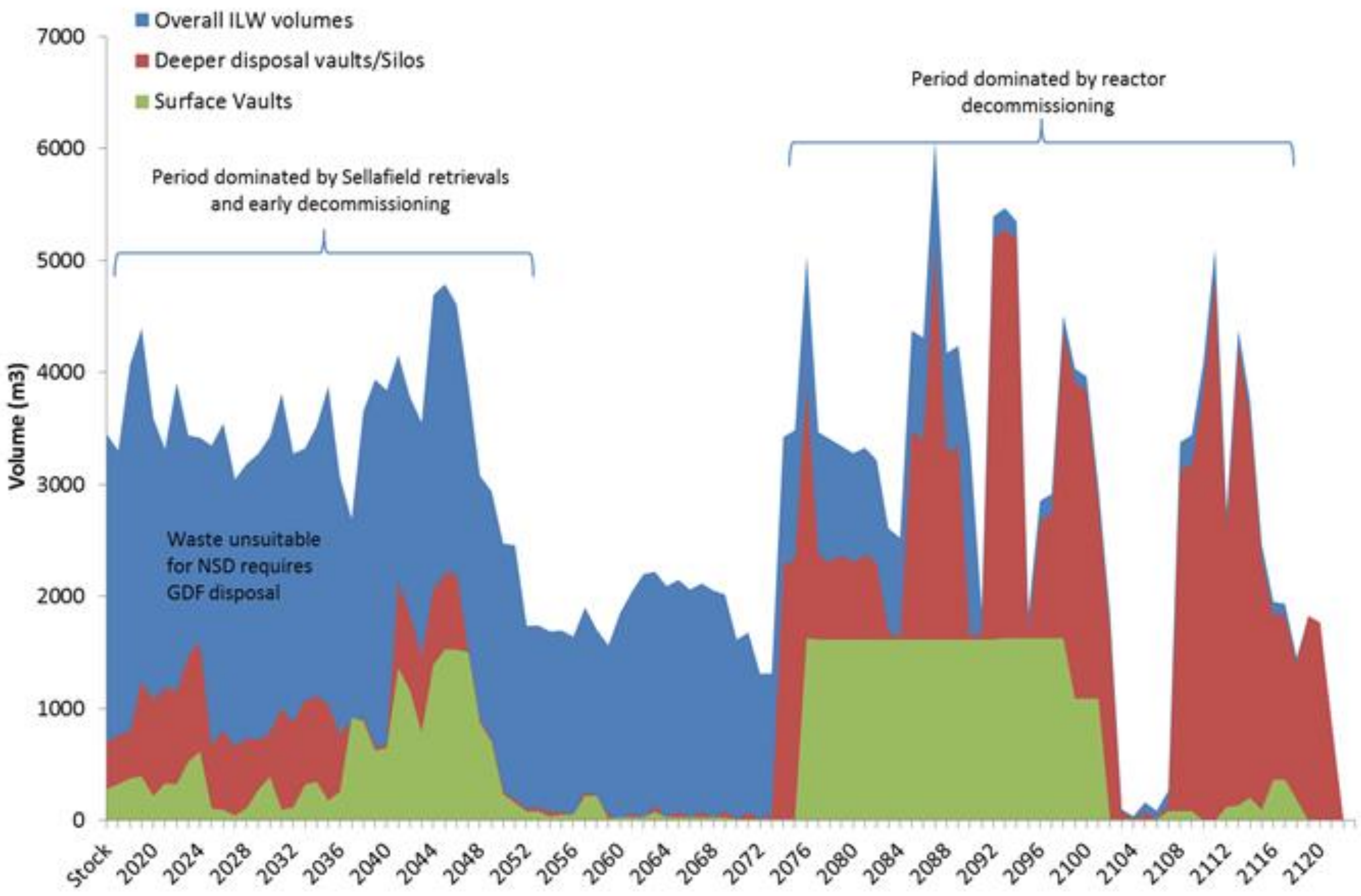
Disposal silos several tens of metres below ground:

- Similar to the vaults, this option would be developed up to around 80 metres below the surface and suitable for weaker near-surface rock structures, where a number of conjoined cylindrical silos will offer greater structural strength than rectangular vaults.

- As with the previous option, a multi-barrier containment would surround the packaged waste, which would be lowered remotely into place by a crane. Three levels of waste are currently being considered, separated by reinforced concrete floors. Once a silo is full, an isolation layer would cover the waste together with thick reinforced inner and outer caps, mass backfill and earth landscaping. The disposal depth would again protect against the impact of natural processes such as coastal erosion and thepotential for inadvertent human intrusion, therefore ensuring the waste is undisturbed for thousands of years, so that no harmful quantities of radioactivity reach the surface. equipment and/or forklift trucks would transport packages for stacking in one of the caverns.

- Each cavern would require independent multiple-barrier containment. Once full, each cavern is sealed and shielded. The disposal depth would again protect against the impact of natural processes such as coastal erosion and the potential for inadvertent human intrusion, therefore ensuring the waste is undisturbed for thousands of years, so that no harmful quantities of radioactivity reach the surface.

You might call it the Manhattan Model!



Criteria for siting UK NSD facility

- The criteria are based on consideration of:
- • water resources
- • nature conservation and
- local heritage
- • suitability of the local
- infrastructure for transport
- of workforce and wastes
- • proximity of the potential
- site to the wastes that will
- be consigned for disposal
- • climate and landscape
- change
- • flooding

Conclusions

- Safety of both people and the environment is a priority at all times. As UKNDA continues to explore the technical features of NSD options, NDA are equally committed to demonstrating that any system selected would remain **safe and secure**, both during operations and at all times in the future including once a site is no longer actively managed.
- As NSD facilities will be closer to the surface, we are focusing on the containment barriers that will prevent waste from causing harm to people or the environment. These will be specific to a location and will take account of the potential for wastes to be disturbed, either through ***accidental human intervention*** or natural processes such as coastal erosion.
- The long-term safety performance is site specific and will be evaluated to develop the environmental safety case. The environmental safety case will assess the potential for the wastes to be disturbed by **human and natural processes** and, in such an event, ensuring that people and the environment are protected.
- **An NSD facility would only be permitted on the basis of a robust environmental safety case.**