Implementation and R&D Needs for Storage and Geological Disposal of the UK's Intermediate and High Level Radioactive Wastes.

A Personal Materials View.

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Summary

- Political Scene.
- Materials Issues in:
  - Difficult Wastes (e.g. Pu, graphite).
  - Interim Storage.
  - Implementation of a Geological Disposal Facility (GDF).
- The Way Forward.

Radioactive Waste.

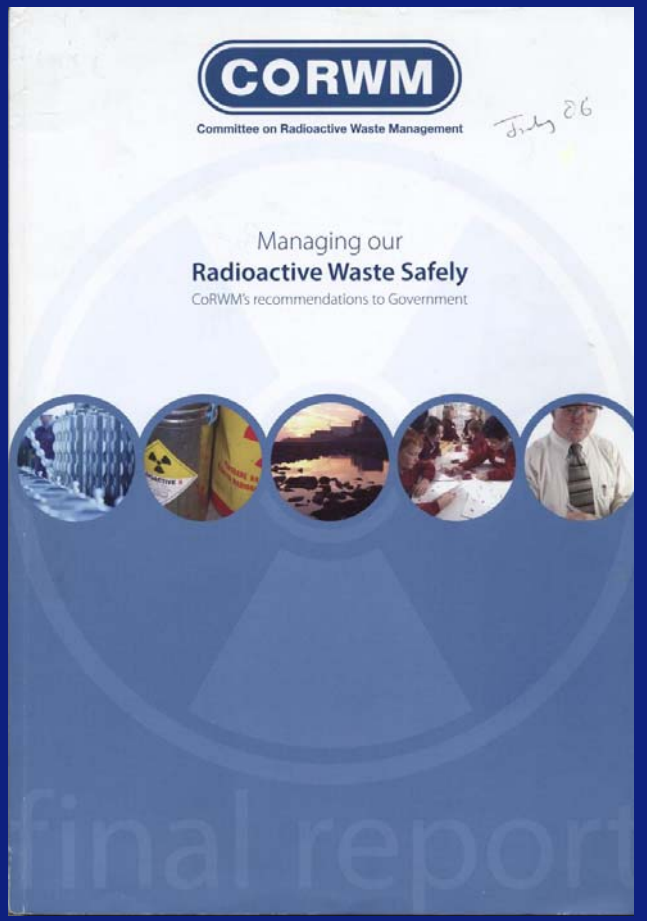
- Globally we have been slow to address the problem. Some countries e.g. Sweden, Finland moving quicker than others.
- USA, Russia, Ukraine, France, UK, Japan have most significant problems.
- UK, due to the large number of reactor designs used (Magnox, AGR and PWR), has complex range of waste types.
- Dynamic UK nuclear scene. E.g. BNFL R&D → Nexia Solutions → National Nuclear Laboratory. Westinghouse. Foreign ownership concerns.

Waste Issue Often Used as Argument Against New Nuclear Reactors.

- History of inaction culminating in UK Govt. decision in late 1980's not to pursue planned examination of suitability of geology under Sellafield for potential repository site.
- In 2004 Govt. set up Committee on Radioactive Waste Management (CoRWM).
- In 2005 Govt. set up Nuclear Decommissioning Authority (NDA) with responsibility for UKs radwaste-contaminated site clean up with £80B budget.
- Govt. announced in 2006 that NDA would take extended role as single UK body responsible for implementing geological disposal of higher activity radioactive waste.

CoRWM Recommendations to Govt. (July 2006).

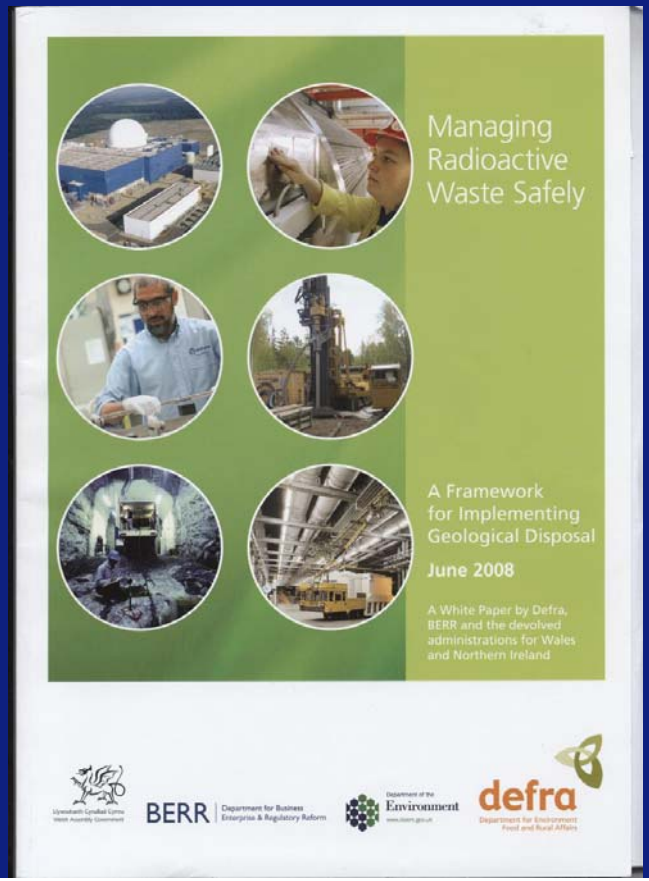
- Geological disposal as end point for long-term management of radioactive wastes.
- Robust storage in interim period with provision against delay or failure in reaching end point.
- Need for a staged process with flexibility in decision making and partnership with communities willing to participate in siting process.

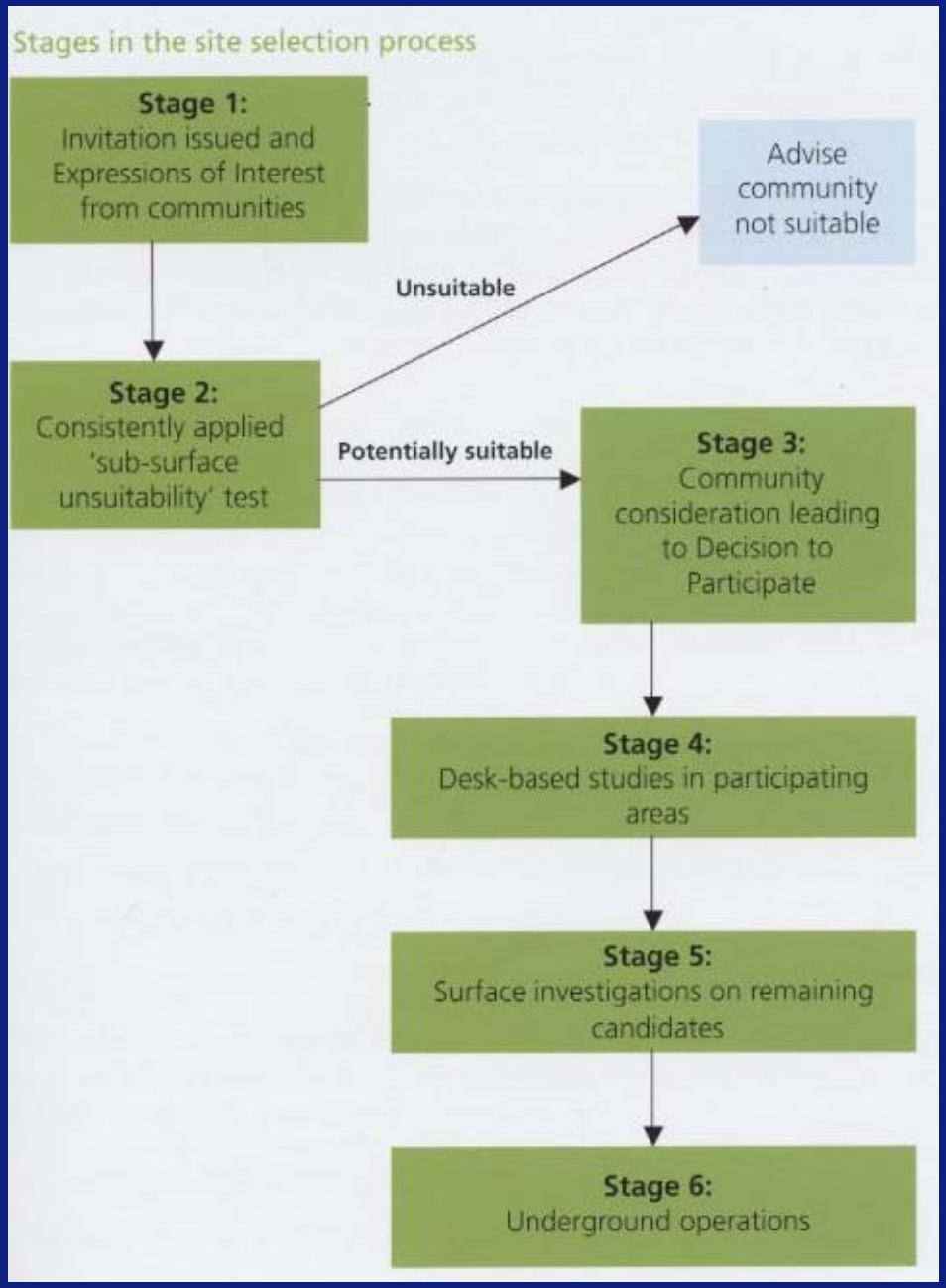


- **CoRWM did not suggest suitable locations for any potential GDF.**
- **Agreeing on location and building GDF will take decades.**

Managing Radioactive Waste Safely (MRWS) Programme

- Government White Paper outlining process and stages.





Radioactive Wastes.

- Classified by radionuclide concentration and half lives, typically by activity level into low level waste (LLW), Intermediate Level Waste (ILW) and High Level Waste (HLW).
- In UK most ILW encapsulated in cement, HLW from reprocessing vitrified in glass.
- Some wastes are difficult: a materials opportunity.

Difficult Wastes.

Wastes are difficult because they:

- Contain highly radiotoxic radionuclides emitting high-energy (α) radiation (^{239}Pu, ^{241}Am, ^{237}Np).
- Contain radionuclides with long half lives (^{14}C 5730y, ^{239}Pu 24110y, ^{129}I 15.7My, ^{99}Tc 213000y).
- Contain highly mobile (water soluble or volatile) radionuclides (gases: ^{226}Ra, ^{3}H and $^{14}CO_2$, alkalis: ^{137}Cs, ^{90}Sr, halogens: ^{36}Cl,^{129}I).
- Contain radionuclides easily assimilated with long biological half lives (^{129}I thyroid, ^{90}Sr bones).
- Are high volume (graphite).
- Are in uncharacterised sludges.
- Have escaped into the environment (Hanford, Dounreay) as mobile species/particles.

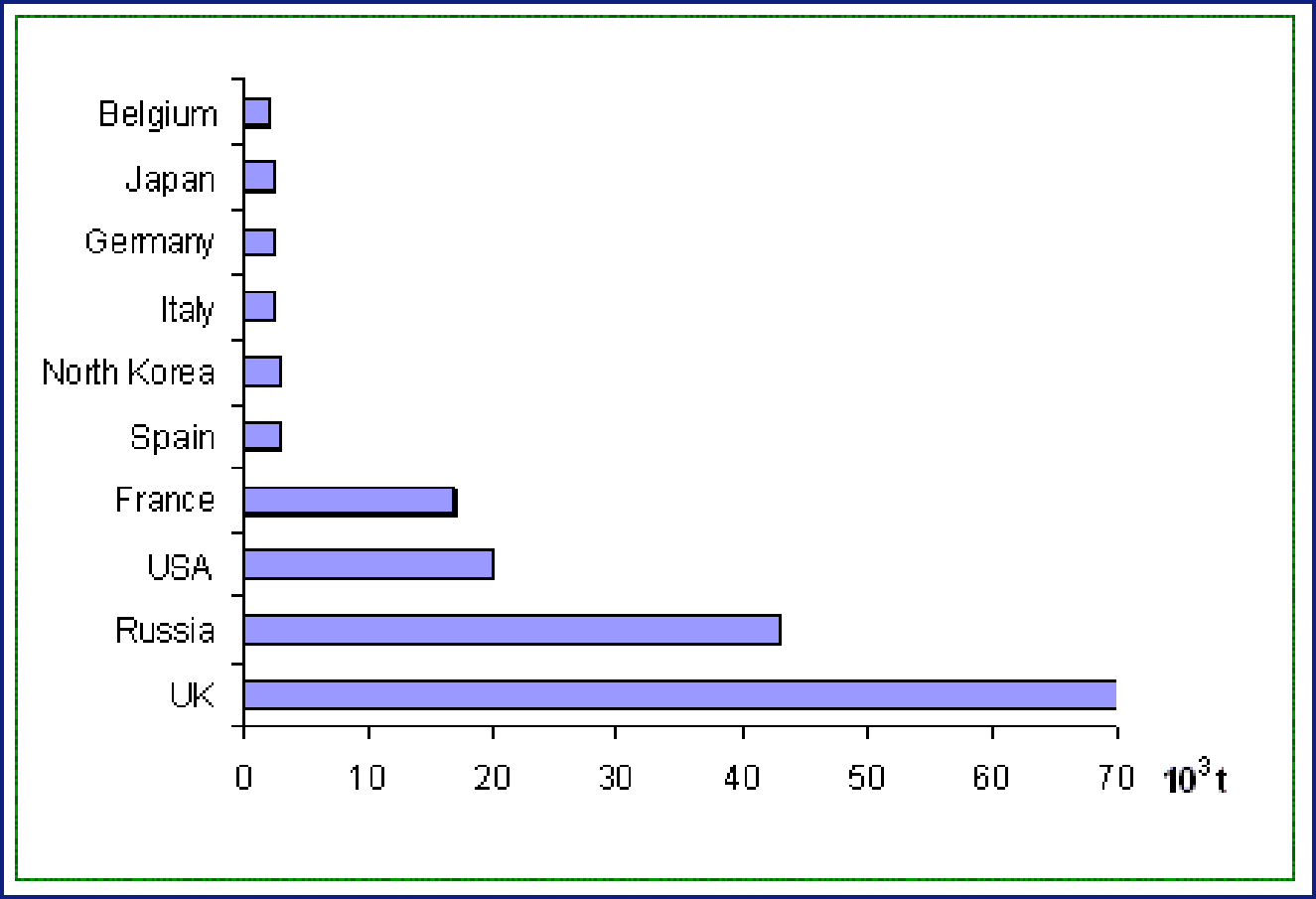
Plutonium Options.

- UK has ~100 tonnes of Pu mostly in form of oxide powder.
- Some contaminated and must be disposed of.
- Options for rest e.g. dispose in various forms (ceramic, glass) or reuse in Mixed Oxide (MOX) fuel which can be burned in PWR reactors or Inert Matrix Fuel (IMF) (e.g. ZrO_2) that could be directly disposed of after burning the Pu.
- R&D needed to support choice of option.

NDA Plutonium Options

For comment: August 2008 - October 2008

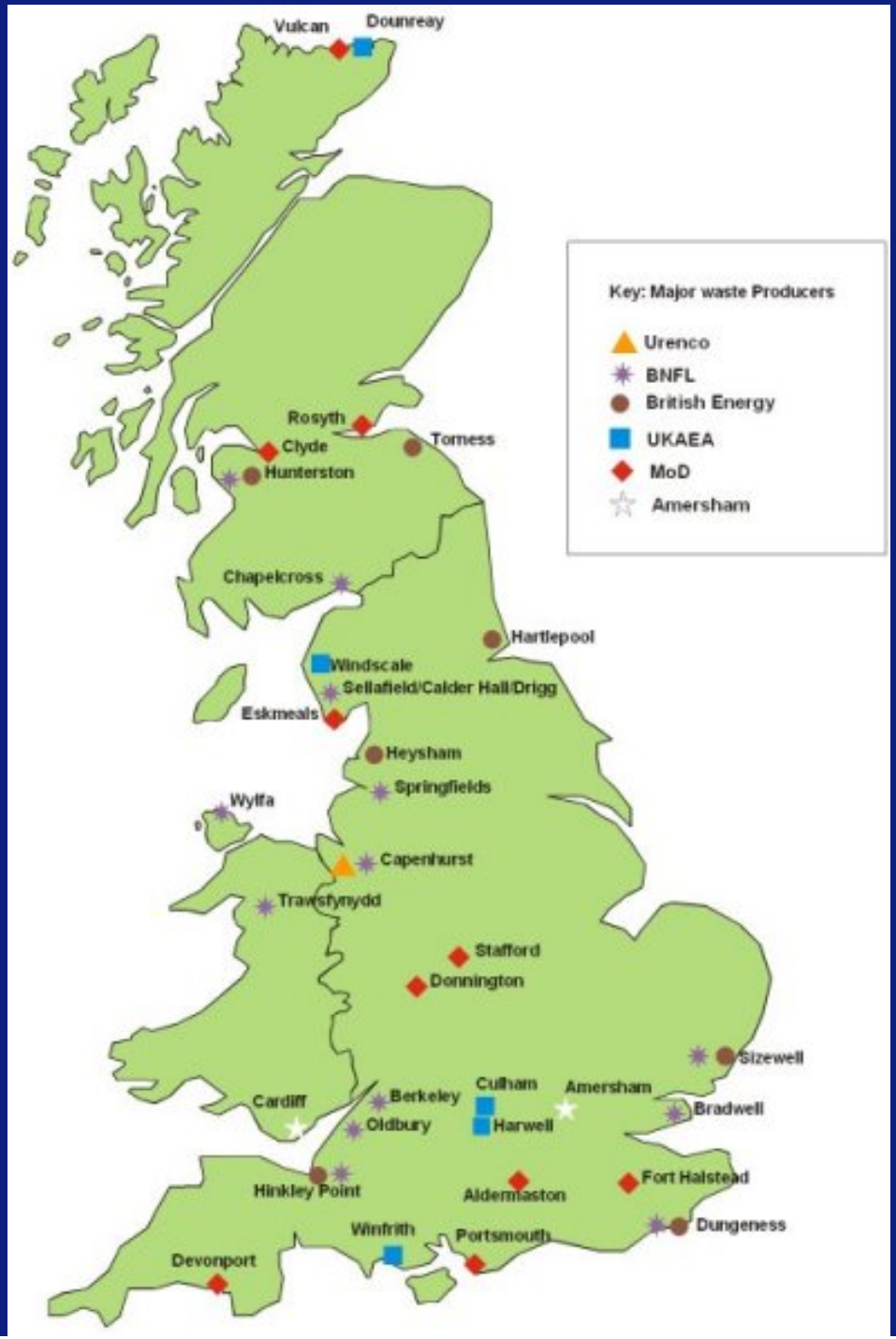
Graphite.



- **UK has large proportion of worlds graphite waste from our graphite-moderated Magnox and AGR reactors.**

Graphite.

- ^{14}C can be 1wt% of used reactor graphite and is mobile in groundwater systems as carbonates and atmosphere as CO_2.
- UK has no chosen immobilisation route.
- Options include packaging and direct disposal (but large volume), incineration and immobilisation of the ash formed (but gaseous species).
- Transmutation products and ^{14}C concentrated on outside of graphite so could remove surface and incinerate bulk.



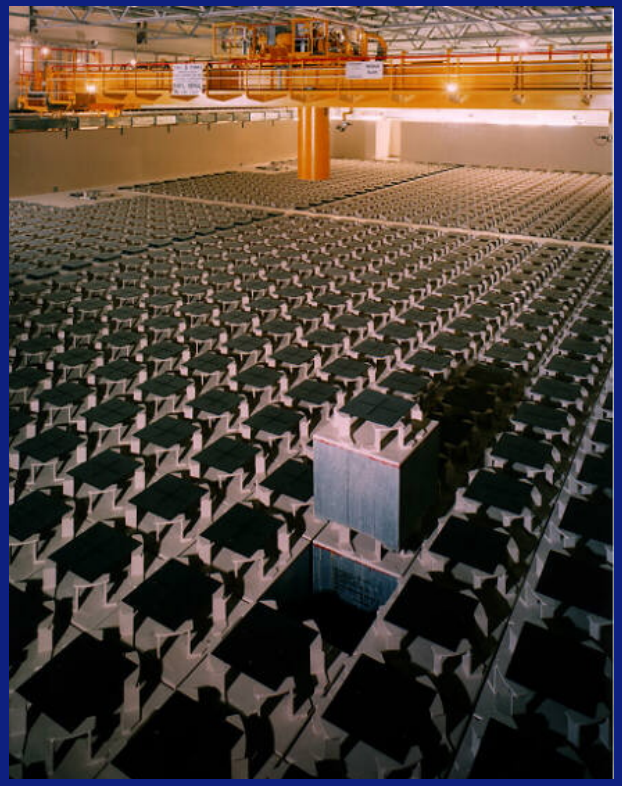
Location UK Radwaste.

- Vast majority of UK's waste at Sellafield and Dounreay.
- Scottish Government supports **long term interim storage** and ongoing R&D but is not participating in MRWS process.

Storage Issues.

- Stores need to last at least 100 years.
- Wasteforms need to be stable for this period and then transportable and stable in GDF.
- Need to tailor box to wasteform it contains.

ILW Temporary Storage at Sellafield.



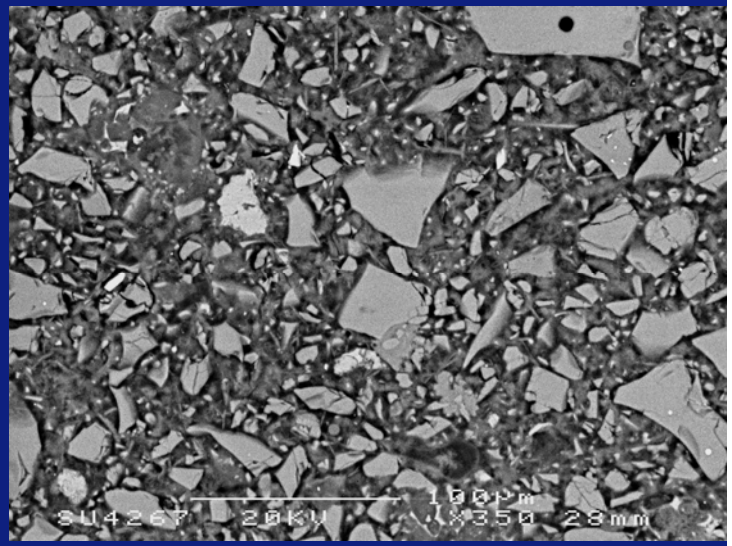
- 17000 containers ILW currently stored at Sellafield.
- ILW stored at many other sites. Each 3m^3 box costs £25K.
- Current use of different container designs, materials and wasteforms. Early mild steel drums, later 316L and 304L stainless steel. More durable steels e.g. duplex or super duplex under consideration.
- Need for standardisation.

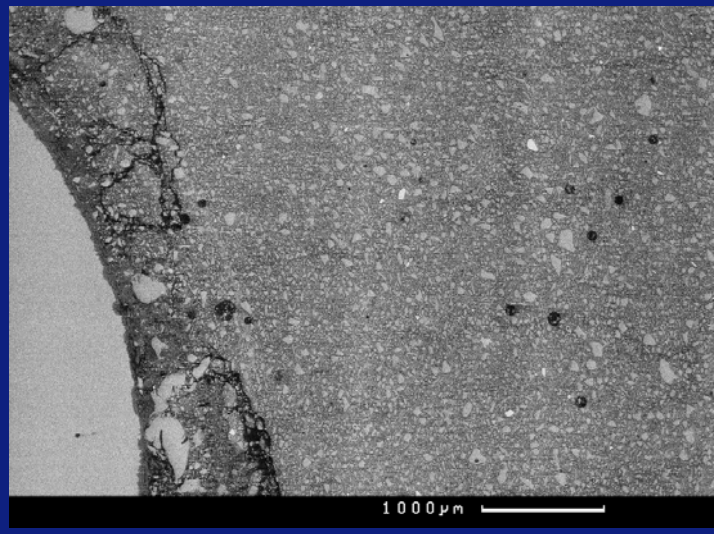
Storage Issues

- Concerns over durability of some current ILW drums. R&D into corrosion of U metal in cement matrix.
- R&D needed into possible reworking or overpacking ILW wasteforms containing reactive metals where durability is not consistent with store lifetime.
- R&D into long-term performance and monitoring of ILW + reactive metals and graphite.

ILW Wasteform R&D.

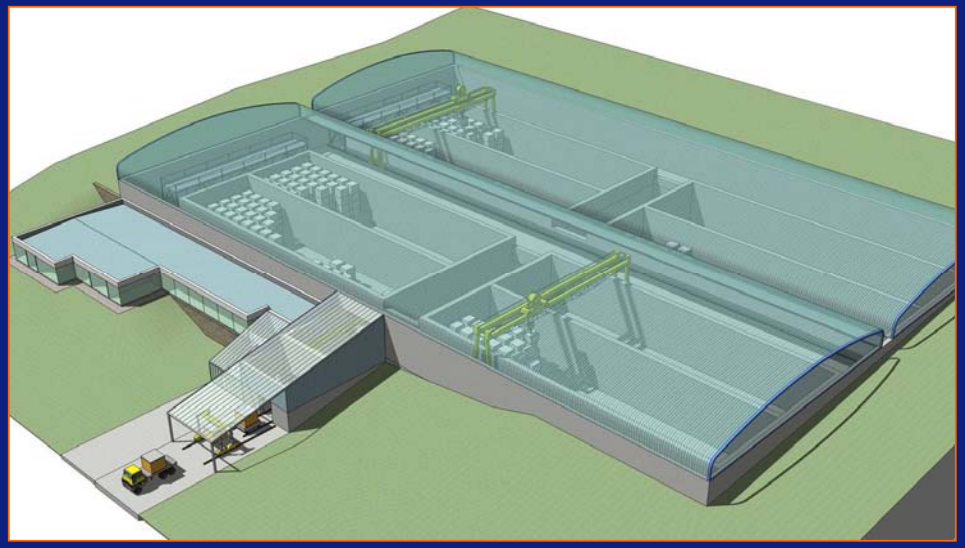
- Current composite system: Ordinary Portland Cement (OPC) + Blast Furnace Slag (BFS) or Pulverised Fuel Ash (PFA).
- Need for toolbox of matrices compatible with various waste streams (some metals incompatible with alkali matrix)
- Need new systems giving less alkaline environment, alleviating waste/matrix interactions.
- Potential systems include calcium sulpho-aluminates, alkali-activated slag cements, inorganic geopolymers, polymers and bitumens.



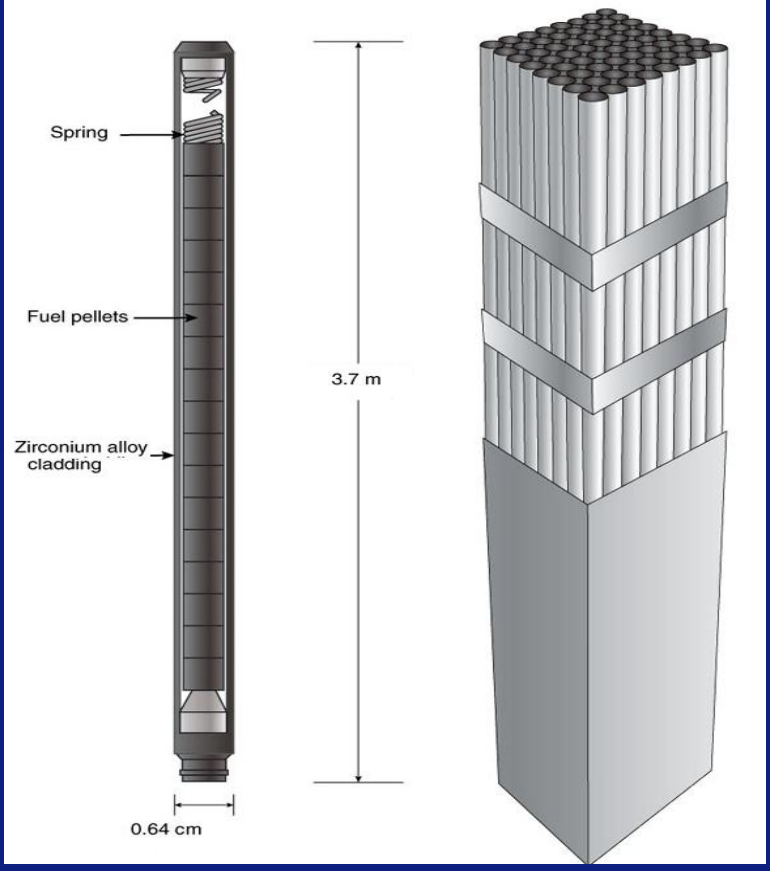


Other Storage R&D Needs

- Evaluation and performance of new wasteform and container materials (e.g. mini stores).
- Develop wasteforms for short-lived fission products (e.g. ^{137}Cs, ^{90}Sr) that generate substantial amounts of heat as well as a strong field of ionising radiation but need only ~300 years storage.
- Long-term (>100years) storage concepts which may address Scottish question.



Spent Fuel Encapsulation and Storage.



AGR consolidation element/slotted can

- "Once through" spent fuel reasonably stable wasteform (oxide ceramic pellets in metal rods).
- Directly encapsulated in steel or steel/copper canisters.
- UK has no track record in long-term spent fuel storage for eventual disposal.
- Need UK specific materials system.

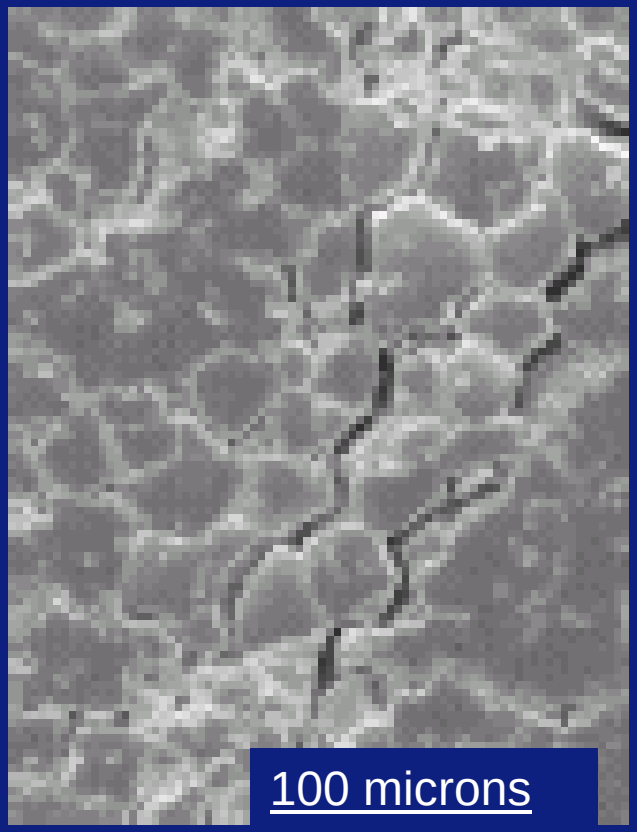
Storage Options for Magnox and UK AGR Spent Fuels?

- Need for R&D into:
  - Options
  - Container Systems and Materials.

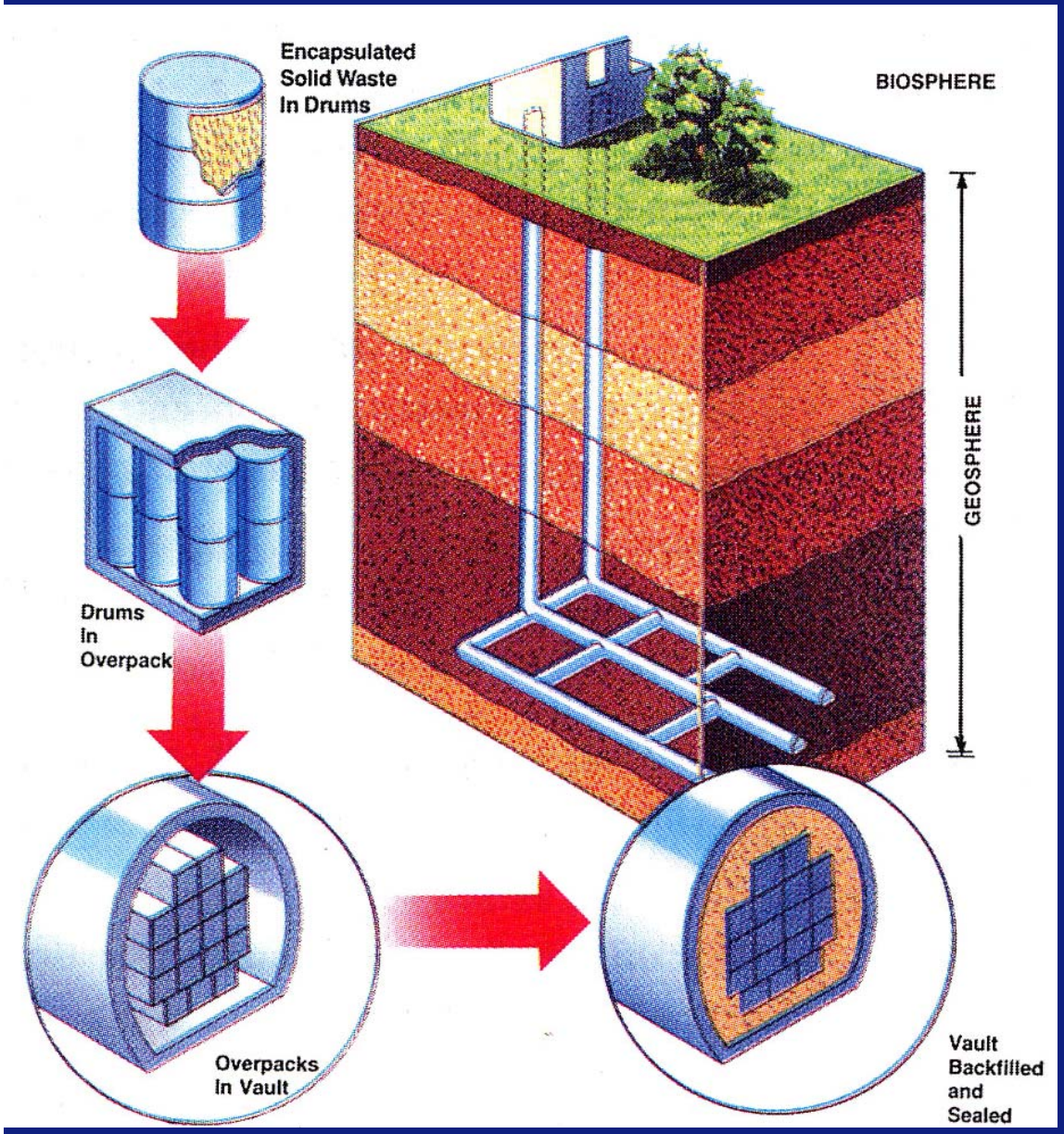
Interim Storage Casks

Away From Reactor (AFR) Storage

Durability of UK Spent Fuel



- Long-term durability of Magnox alloy clad U metal fuel?
- Long-term durability UO_2 fuels complex due to:
  - escape of e.g. ^{129}I, ^{137}Cs from grain boundaries,
  - O^{2-}conducting behaviour,
  - pH behaviour with water,
  - sensitivity to radiation damage.



Geological Disposal Facility (GDF).

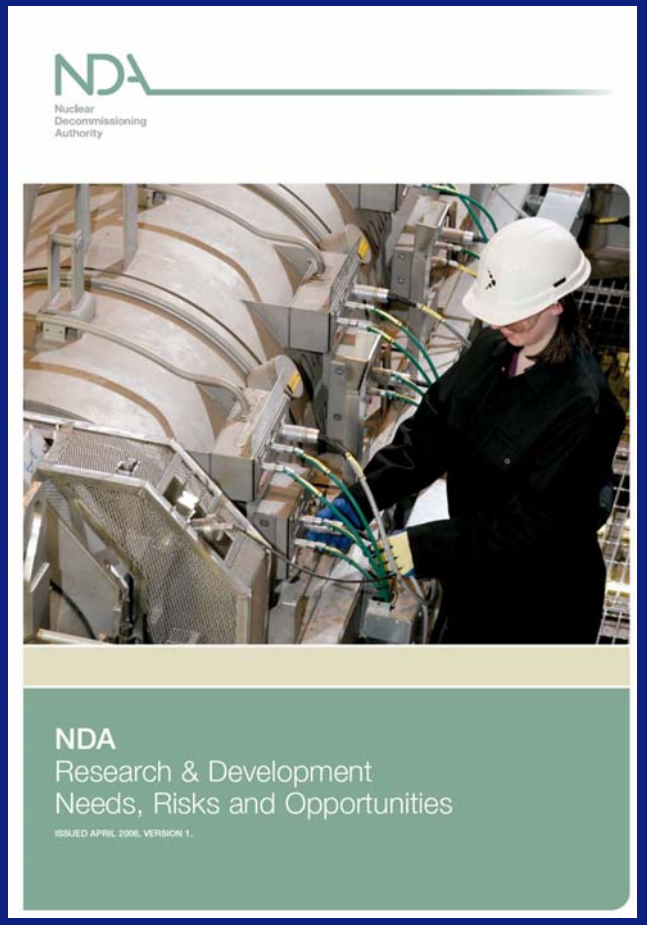
- Multibarrier System.
- Designed to prevent any release of radionuclides to biosphere.
- Usually reducing conditions with water ingress.

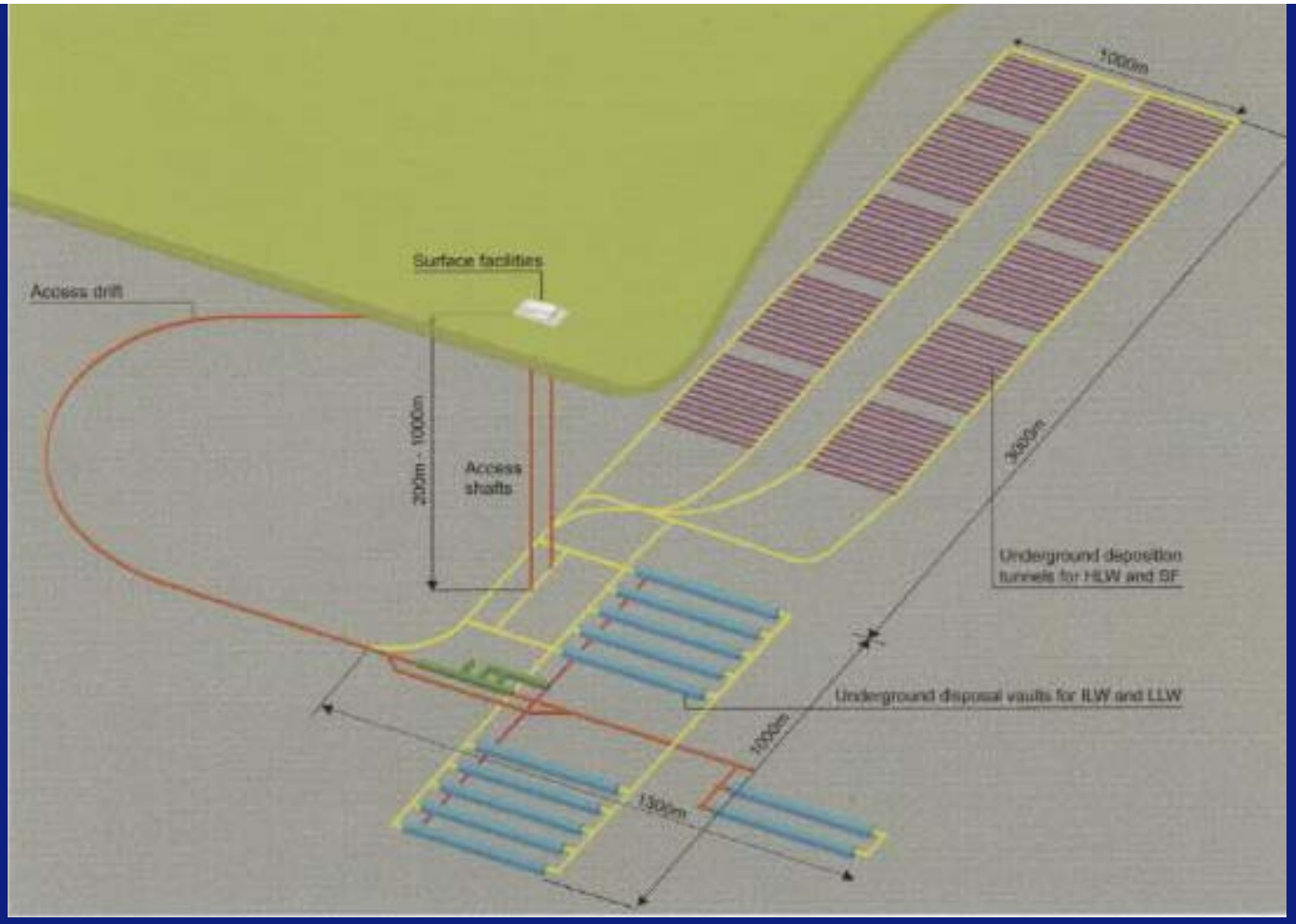
GDF Programme

- Important Materials Issues:
  - Container
  - Wasteform
  - Chemical Barrier or Buffer
  - Geological Barrier
- Corrosion and interaction of materials with geosphere over very long times.

Materials-relevant GDF R&D

- Gas generation from wasteform corrosion.
- Interaction of wasteform with geosphere and radionuclide transport and retardation mechanisms.
- Colloids, natural organics and microbes.
- Engineered Disturbed Zone.
- Alkali Disturbed Zone (backfill).



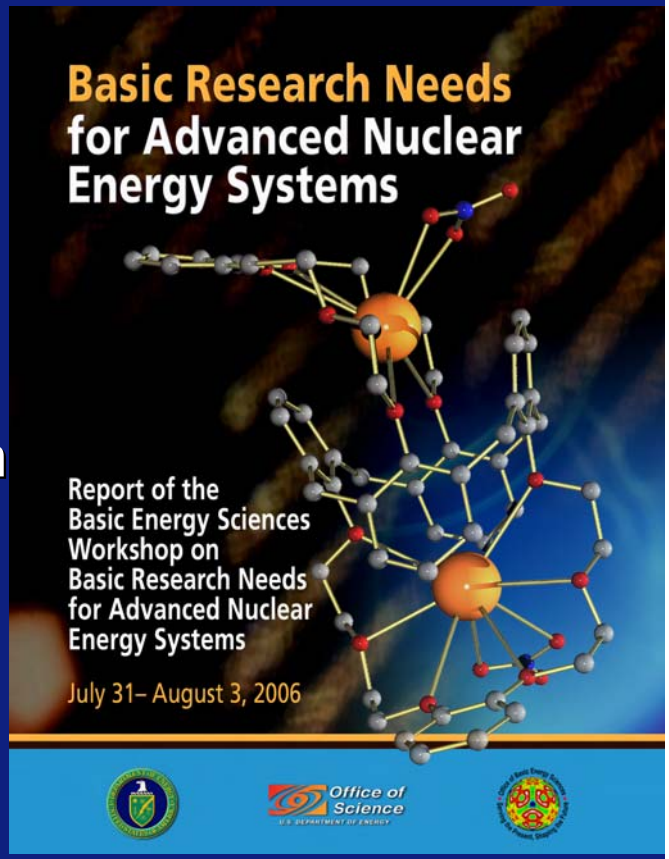


Co-Location in Single GDF

- Interaction of differing types of waste located in different sections.
- Alkali ILW system but acid HLW glass system.
- Need to understand materials degradation, corrosion product transport and interactions over geological times.
- Multi scale and long timescale modelling needs.

Other R&D Needs

- See DoE Workshop report on R&D Needs for Advanced Nuclear Energy Systems. Be able to:
  - Predict wasteform performance in geosphere.
  - Identify steps in wasteform dissolution mechanism, nucleation of secondary phases and surface sorption/desorption reactions, formation/decomposition of radiolytically-produced species in solution.
  - Need for underpinning thermodynamic data.



Skills Needs

- Engineers/graduates with general materials, nuclear, mining, hydrogeology and geology skills.
- Batchelors and Masters courses in nuclear engineering and relevant mining/geology.
- Training in use of radioactive materials.
- Continuity of skills: programme over hundreds of years.

Infrastructure

- Current active experimental and analytical facilities limited compared to our international competitors.
- Some stability needed in UK nuclear industry.
- Facilities at Sellafield Central Lab. available for R&D community.
- Need for *in situ* geology/hydrogeology studies in GDF or underground rock laboratory.

Technology Transfer

- Much potential for technology transfer to the nuclear field particularly in clean up, storage and disposal.
- Military have good remote handling equipment and techniques e.g. remotely operated vehicles (ROV).
- Self Assembled Monolayers on Mesoscale Supports (SAMMS) separating specific radionuclides from aqueous waste streams.

The Way Forward

- Improve Knowledge Transfer into the nuclear industry.
- Extend skills base notably in geology/hydrogeology.
- Ensure facilities for experimental work and training internationally competitive.
- Focussed R&D programmes:
  - Difficult wastes,
  - Durability of current cemented ILW,
  - Short-lived radionuclide-containing wastes,
  - >100 year store concepts.
- Expand UK corrosion capability, including long-term testing of active systems and multiscale modelling.
- Support for geology R&D (NERC).
- Cross RCUK calls in GDF research at the materials/geology interface .
- Support for taking lead role in international storage and GDF programmes.