Overview of Used Nuclear Fuel Management in the UK

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Nuclear Decommissioning Authority

Outline Presentation

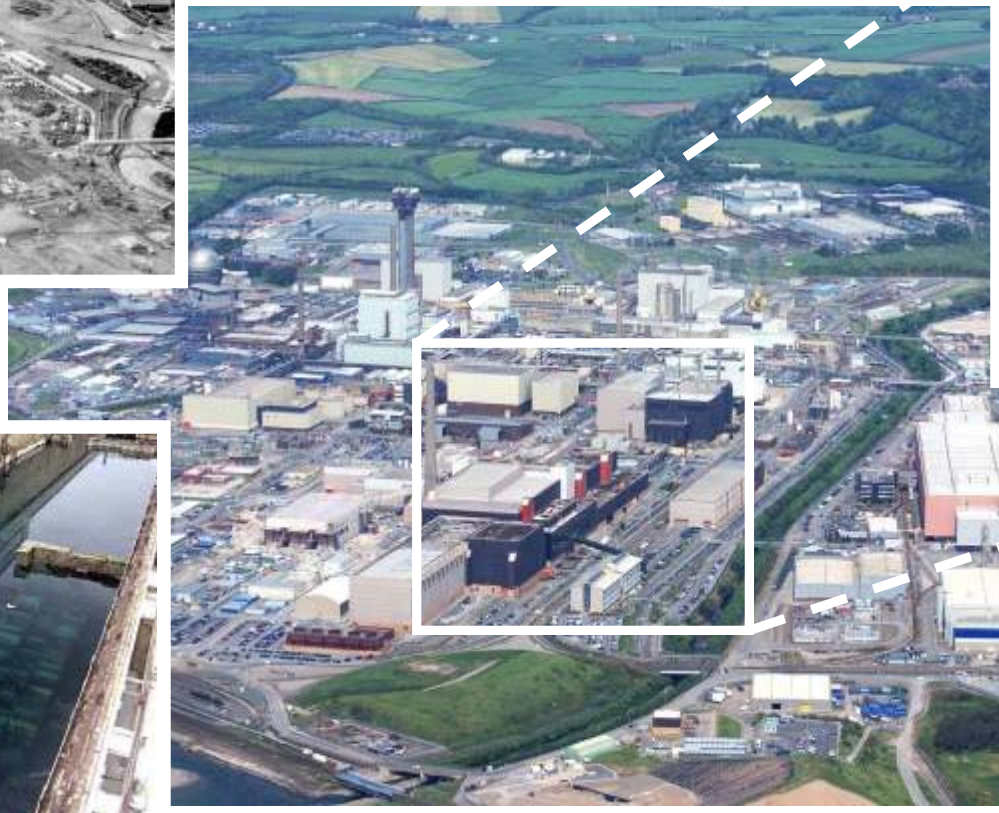
- **NDA – Who We Are**
- **UK Spent Fuel Strategy**
  - Fuel Types
  - High Level Position
  - How Did We Get There?
- **Magnox Fuel Strategy**
- **Oxide Fuel Strategy**
- **“Exotic” Fuel Strategy**
- **Existing Infrastructure Challenges**
- **Summary**

About NDA

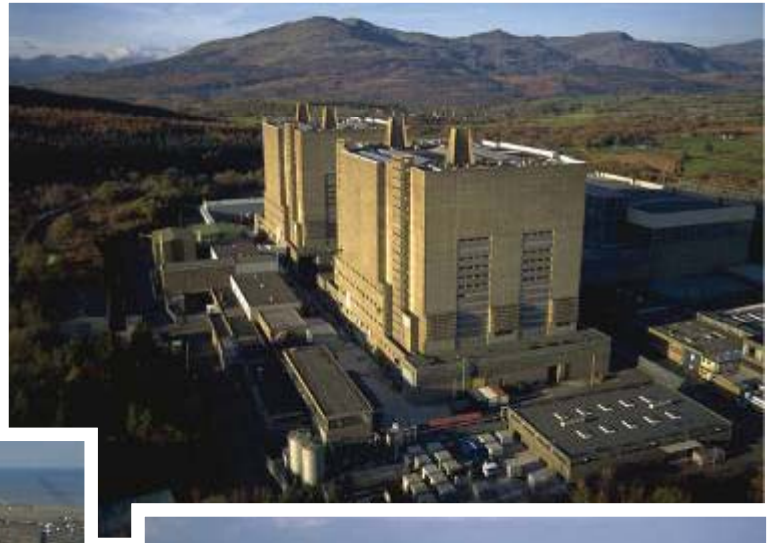
- **A "Non- Departmental Government Body" (NDPB)**
- **Formed as a result of the UK 2004 "Energy Act"**
- **Start date 1st April 2005**
- **Assumed accountability for, and ownership of, the UK's Legacy Nuclear Facilities, principally :**
  - Spent Fuel Management at Sellafield
  - Magnox Reactors Operation and Decommissioning
  - Fuel Manufacturing
  - Research Reactor Sites, such as Harwell and Dounreay
  - Liability for a significant proportion of British Energy's AGR Oxide spent fuel

UK Locations

Our legacy - Sellafield



Our legacy – Magnox



Our legacy - Research

What we do

We are:

- delivering the largest and most important environmental clean-up programme in Europe
- retrieving, making safe and disposing of some of the most hazardous material in the world
- providing the fuel management services that enable UK nuclear power stations to 'keep the lights on'
- developing the UK's waste management infrastructure to reduce the risks to this and future generations
- focused on dealing with a complex legacy built up from the 1940's onwards – with safety, security, environmental responsibility and value for taxpayers' money our top priorities
- scrutinising BE decommissioning plans on behalf of Nuclear Liabilities Fund
- transforming Britain's decommissioning programme from an enormous public project into a competitive, government-regulated market that brings the skills and innovation of the private sector to bear

The scale of our mission

- We own the largest industrial complex in Britain at Sellafield in West Cumbria
- We are cleaning-up 19 existing nuclear facilities and ensuring all waste products – radioactive and non-radioactive – are safely managed
- We have generated over £7 billion of income in the last five years from commercial assets
- We control expenditure of £2.8 billion a year
- We pay the wages of an 18,000-strong workforce vital to UK economy and nuclear skills base, and administer their pension schemes
- We are designing the disposal facility for higher level legacy waste (and potentially UK nuclear new build)

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Fuel Types and High Level Management Strategy

- **MAGNOX SFUEL STRATEGY**
  - Uranium metal bar (circa 1 inch diameter & 10kg weight), Magnesium Alloy ("Magnox") cladding
  - Interim short term pond store and then
  - Reprocess **all** spent Magnox fuel through Sellafield Magnox Reprocessing Plant
- **SPENT OXIDE FUEL (AGR) STRATEGY**
  - Stainless Steel Clad UO2 Fuel Pellets, circa 3% initial enrichment
  - Interim short term pond store and then
  - Reprocess all contracted fuel through THORP (or until end of life of THORP) and pond store remainder
- **"Customer" SPENT OXIDE FUEL (LWR) STRATEGY**
  - Mostly Zirconium Clad UO2 Fuel Pellets, ex - PWR or BWR
  - Pond store then reprocess through THORP
- **EXOTIC FUELS STRATEGY**
  - Mainly Research Reactor Fuels (many types)
  - Store and treat through existing facilities where available. Develop potential disposition options.

UK Nuclear Industry - Start

- The UK's nuclear industry commenced in 1946 following intense UK involvement in the Manhattan Project
- The industry was aimed entirely at nuclear weapons production
- It set up, with a rapidity that now verges on the incredible, an entire nuclear fuel cycle to produce plutonium and highly enriched uranium for the UK deterrent.
- The Windscale Piles were built as the first reactors.

Initial UK Reactor Choice

1. For simplicity and speed, the Windscale piles used natural uranium fuel, graphite moderation and gas cooling
2. The Capenhurst Diffusion Enrichment Plant was small and very expensive to run – *necessary for weapons, but expensive for nuclear power*

- The above two factors steered UK nuclear power build towards natural uranium systems and graphite moderation – Magnox –
  - even the second generation “AGR” reactors initially used *very* low enrichments

Early Vision – Fast Reactors

- Fast reactors need quite large amounts of plutonium to provide their initial fuel charges
- Foreseeing a fast reactor future, the USA, Russia, France, Japan and the UK all decided to reprocess the fuel from their thermal reactors to provide plutonium
- UK built Reprocessing Facilities:
  - Magnox Reprocessing, operating for over 40 years
  - THORP, agreed in 1977 and operational since 1994
- However, the cost of fast reactor technology, and the reprocessing needed to sustain it rose, and the price of uranium didn't

What happened next.....USA

- Fast reactor programmes were cut back, and the urgency of acquiring bulk supplies of Pu disappeared

- Also, the availability of plutonium gave rise to fears of proliferation of weapons production

- So in 1976 the US (Carter) announced the cessation of all commercial reprocessing programmes and reversion to a ‘once through’ thermal cycle with disposal of the spent fuel.

What happened next.....France

- Fast reactor programme suspended – but fast reactor strategy retained
- ‘Commercial’ reprocessing continues (La Hague) with throughput tied to MOX manufacture (MELOX, Marcoule) – this limiting PuO2 stocks
- 1,175 tonnes of MOX fuel heavy metal as of the end of 2006
- MOX is used in EdF reactors and then stored – retaining Pu inventory for fast reactor startup in ‘Spent Fuel Standard’ form.

What happened next.....UK

•Fast reactor programme included DFR (1959-77) and 250MWe PFR (1974-94) - funding then withdrawn

•All of Magnox programme (1956-2011) scheduled to be reprocessed (to 2016/17), plus some of AGR programme scheduled for reprocessing in THORP

•~100te separated Pu stock envisaged

- No policy change for UK Pu since 1994 – de facto storage
- currently under consideration

•New Nuclear Power Build announced and expected to be around 10GWe, starting generation from 2018.

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Magnox Context

Current Inventory:

Magnox fuel : 4500 te to be reprocessed, of which:

- Wetted fuel ~500 te (Mostly at Sellafield)
- Dry Fuel ~ 4000 te (at reactor sites, e.g. in cores)

It is important to control the amount of Magnox fuel stored in ponds:

- Magnox fuel can start to corrode after approximately 5 years in fuel ponds

Example of potential additions to inventory:

- Dounreay Fast Reactor Breeder: < 45 te (i.e. 1% extra)
- Wylfa and Oldbury extension: < 20 te (i.e. 0.5% extra)

Magnox – Main Issues

- **Magnox reprocessing uses oldest facilities**
  - Increasingly expensive to maintain

- **Risk of early plant failure**
  - Reprocessing process operates in series
    - Single plant failure can slow / stop the whole process
  - Contingency work progressing but still immature
  - NDA has now set Failure Criteria / Strategic Tolerances for the MOP associated with plant longevity, e.g.
    - Dissolver life
    - Avoidance of new plant requiring major investment

Current Magnox Strategy

Deliver Magnox Operating Plan (MOP)

- Extend power generation as far as is economic
- Predicted finish 2016/2017

Maximise opportunities to incorporate other materials in reprocessing stream

- For some spent metal type fuels this is the only technically underpinned management option

Develop contingency options in event of plant failure

- Fuel drying and long term dry storage
- Alternative options

Magnox Drying and Dry Storage

- **Significant investment in fuel drying and dry fuel storage project**
  - Commenced during last half of 2007
  - Investment increased 2009/10
  - Further increase in investment planned for 2010/11

- **Loosely based on metal fuel drying project completed at Hanford, USA.**
  - Dried and dry stored 2100 te of pond stored metal fuel.

- **Now incorporating the options to dry and dry store other fuel types, such as oxide and exotics**

Oxide Reference Strategy

- **Current reference oxide strategy**
  - Reprocess contracted “overseas” LWR fuel
    - ~700 te
  - Receive and manage AGR fuel
    - ~3000 te Historic Fuel will be reprocessed
    - ~3000 te Future Fuel will be stored and may be reprocessed
    - Need to keep extra space available if British Energy extend AGR station lifetimes
  - Very small amount of corroded fuel – given priority reprocessing

Oxide Fuel Credible Options

1. **Reprocess minimum contracted fuel and stop**
   - no new plant

2. **Reprocess until the end-of-life of the existing plant**

3. **Reprocess all UK & Overseas fuel**
   - Refurbish & replace plant as required
   - Eventually throughput circa 250 te p.a. from UK AGRs

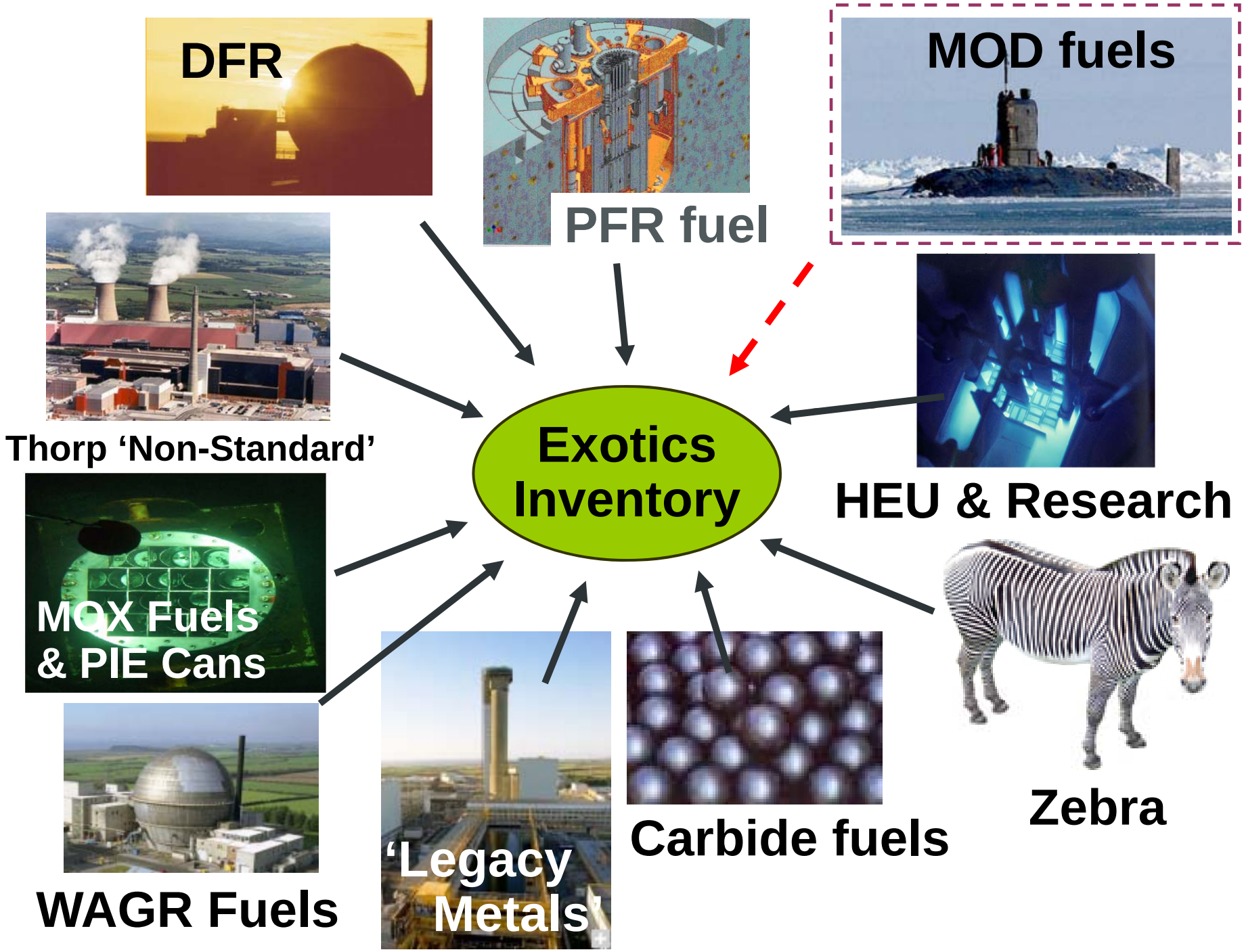
4. **Reprocess all UK & Overseas fuel**
   - Consider extra business to offset costs and optimise use of the assets
   - Refurbish & replace plant as required

5. **Stop Repro – store, immobilise and dispose**

Oxide: Issues & Further Info

Issues

- **THORP operations constrained by supporting infrastructure**
- **Major new investment required to support reprocessing**
- **Strategy required for managing fuel from AGR station extensions**
- **Work required to underpin long term AGR fuel storage strategy**
- **Should Exotic fuels be reprocessed through THORP?**


DFR
PFR fuel
MOD fuels
Thorp 'Non-Standard'
Exotics Inventory
HEU & Research
MOX Fuels & PIE Cans
Zebra
WAGR Fuels
'Legacy Metals'
Carbide fuels

Exotics Strategy / Issues

UK Exotics Disposition: To ensure the continued safe management, optimised lifecycle approach and then ultimate disposition of Exotic fuels

- **Total Inventory liability (circa 500te)**
- **TREAT – Could be reprocess, condition or immobilise**
- **Outside standard arrangements:**
  - transport, storage, reprocessing and disposal
- **Unique challenges**
  - Bespoke solutions required for some exotic fuels

Exotic Fuels Risks & Opportunities

- **Multi-track plans for fuels needs to be optimised for all fuel types:**
  - Reprocess some fuels (e.g. THORP Non-Standard)
  - Immobilise, Store and Dispose (e.g. PFR Fuels)
- **Significant part of the inventory has technically immature solutions at present**
- **NDA wants to consider reprocessing exotic fuels using the existing NDA estate wide infrastructure**
  - Where technology and logistics (timings) allow

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UK Spent Fuel Management Infrastructure

- **Pond Storage**
  - 5 Ponds currently in use at Sellafield
  - Nuclear Power Stations have small ponds for interim cooling prior to transport.
- **Dry Storage**
  - Fuel from 1 Magnox Reactor (Wylfa) is dry stored on site pending transport to Sellafield for Reprocessing.
- **Magnox Reprocessing has circa 1000 te/yr capacity, 40+ years old.**
- **THORP has circa 650 te/ye capacity**
  - Reduced from circa 1000 te capacity in 2005 due to plant failure
- **3 Evaporators, all in the latter stages of life, with material challenges**
- **21 Highly Active Storage Tanks, of which circa 6 are currently operational, with material challenges**
- **3 Vitrification Lines.**

Disposal Facilities

- **Radioactive Waste Management Division (RWMD) accountable for the development of a Geological Disposal Facility (GDF) for all UK nuclear waste and spent fuels.**

- **No site selected – 2 communities have expressed an interest in hosting the GDF**

- **Spent Fuel disposability studies underway by RWMD**
  - Significant liaison with other International “Disposal” organisations to develop Spent Fuel Disposability Concepts.

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Summary

- UK has been reprocessing fuels continuously for over 40 years, and has considerable experience in running such facilities
- Reprocessing facilities are getting towards the end of their life, and so strategies are being developed to enable future management of spent fuel beyond the use of existing facilities
- Contingency options are being developed in case of acute early failure of the existing reprocessing facilities
- Geological Disposal Facility being developed for UK spent fuels