Nuclear Decommissioning Authority

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TOPIC STRATEGY: Oxide Fuel

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Glossary of Terms

AGR	Advanced Gas Cooled Reactor, owned and operated by British Energy
BE	British Energy, now owned by EDF Energy
Exotic	Non-standard fuels which are a legacy from earlier nuclear industry activities such as the development of prototype, experimental or research reactors
FHP	Fuel Handling Plant
GDF	Geological Disposal Facility, for higher activity wastes
HAW	Higher Activity Wastes
HA	Highly Active
HLW	High Level Waste, being ILW but of such high radioactivity content as to be self heat generating
ILW	Intermediate Level Waste
LLW	Low Level Waste
LWR	Light Water Reactor (comprising PWR (pressurised water reactor) and BWR (boiling water reactor designs)
MoD	Ministry of Defence
MOP	Magnox Operating Plan (now in its eighth edition)
MOX	Mixed Oxide Fuel, comprising plutonium and uranium oxides
NM & SF TOG	Nuclear Materials and Spent Fuel Topic Overview Group
PuO_2	Plutonium dioxide, a product of reprocessing
PWR	Pressurised Water Reactor. Sizewell B is a PWR
SL	Sellafield Limited
SF	Spent Fuel
THORP	Thermal Oxide Reprocessing Plant – a chemical plant owned by NDA and operated by Sellafield Ltd for the reprocessing of oxide spent fuels from AGRs and LWRs
UKAEA	United Kingdom Atomic Energy Authority
UO_3	Uranium Trioxide, a product of reprocessing

Executive Summary

The NDA is responsible for the development of a strategy for the management of spent oxide fuel within its liability and for the management of fuel under commercial contracts held by the NDA. The NDA holds contracts for the management of spent oxide fuel with British Energy and a number of overseas Energy utilities. This strategy paper describes the options for the management and ultimate disposition of this spent oxide fuel.

Oxide fuel is used in modern nuclear reactors such as Advanced Gas Cooled Reactors (AGRs) and Pressurised Water Reactors (PWRs). An oxide fuel assembly (or element) consists of enriched uranium dioxide pellets stacked inside fuel pins which are then grouped together to form a fuel assembly.

The greater proportion of this spent oxide fuel comes from the AGR power stations owned and operated by British Energy (BE). The NDA is committed through its contracts with BE to supply spent fuel management services for lifetime arisings of spent fuel from the AGR power stations. Current plans are to reprocess some of this fuel with the remainder to be stored at Sellafield, pending a decision on whether to reprocess it or dispose of it to a deep geological disposal facility (GDF), once it becomes available.

There is also a quantity of overseas-owned Light Water Reactor (LWR) fuel which is contracted for reprocessing at Sellafield. In addition, the NDA also inherited a small quantity of fuels formerly owned by the UKAEA, generally arising from prototype reactors from the UK's historic nuclear energy development programmes. This fuel is also held at Sellafield and contracted for reprocessing.

The NDA is undertaking an assessment of the lifecycle implications of the management of this oxide spent fuel: looking at the options for managing the fuel and what it believes is the best way forward.

At a high level, the technical options for the disposition of spent oxide fuel are to;

- Reprocess the fuel
- Longterm store the fuel prior to disposal in a deep geological facility.

This paper describes how spent oxide fuel is currently managed within the UK and how this fuel could be managed in both the short to longterm future.

The paper describes the principles, associated issues, the key steps and programme of work to define and evaluate credible options for the management of spent oxide fuel.

A.1 *Introduction*

A 1.1: Background

The NDA is responsible for the development of a strategy for the management of spent oxide fuel within its liability and for the management of fuel under commercial contracts held by the NDA. This strategy paper describes the options for the management and ultimate disposition of this spent oxide fuel.

Oxide fuel is used in modern nuclear reactors such as Advanced Gas Cooled Reactors (AGRs) and Pressurised Water Reactors (PWRs). An oxide fuel assembly (or element) consists of enriched uranium dioxide pellets stacked inside fuel pins which are then grouped together to form a fuel assembly.

By far, the bulk of the spent oxide fuel for which we are responsible comes from the seven AGR power stations that are owned and operated by British Energy (BE) in England and Scotland.[i] There is also a quantity of overseas-owned Light Water Reactor (LWR) fuel which is contracted for reprocessing at Sellafield. In addition, the NDA also inherited a small quantity of fuels formerly owned by the UKAEA, generally arising from prototype reactors from the UK's historic nuclear energy development programmes. This fuel is also held at Sellafield and contracted for reprocessing.[ii]

We are committed through our contracts with BE to supply spent fuel management services for the lifetime arisings of spent fuel from the AGR power stations, including any potential operating life extensions. These spent fuel management services covers receipt, storage, reprocessing and disposal of AGR fuels and wastes, and safeguards the ability of BE to discharge fuel from its reactor sites to maintain electricity generation at its seven AGR power stations.

The total amount of AGR fuel to manage depends on a number factors including how, and for how long, reactor stations are operated. Based on current estimates this is expected to result in somewhere between about six to eight thousand tonnes of spent fuel.[iii]

All the fuel to be delivered under existing contracts with European and Japanese utilities has now been received at Sellafield and the great majority of this fuel has already been reprocessed through Thorp. Currently, AGR fuel received at Sellafield is stored prior to reprocessing through Thorp; for contractual reasons this fuel is termed 'historic' AGR.[iv] A good proportion of the 'historic' AGR fuel has also already been reprocessed.

[i] On 3rd February 2009, following its acquisition by EDF, British Energy Group were delisted from the stock exchange and became a business unit of EDF Energy.

[ii] The NDA's Oxide Fuel Strategy does not include fuel from the British Energy operated PWR Sizewell B or any fuel that might arise if new nuclear power stations are built and operated. It is the responsibility of the electricity generator to develop disposition options for these fuels, including safe and compliant storage regimes, until disposal facilities are available to receive the fuel, if it is declared a waste.

[iii] The first AGR reactors were connected to the electricity grid in 1976 and based on current estimates the last reactor will finish generating electricity in 2023, although British Energy may choose to seek approval for extended electricity generating operations at any of its AGR stations. This estimate includes fuel already received at Sellafield.

[iv] The distinction between the two types of AGR fuel is based on the solvent restructuring of British Energy that occurred in May 2003. Fuel loaded into reactors up to 14th January 2005 is referred to as 'historic' fuel. Fuel loaded after midnight on 14th January 2005 is referred to as 'future' fuel.

A large tonnage of AGR fuel – for contractual reasons termed 'future' fuel - will be delivered to Sellafield from the BE reactors over approximately the next 15 years (possibly longer if reactor lifetimes are extended). Current plans are to store this fuel at Sellafield, pending a future decision on whether this fuel is reprocessed or disposed of to a deep geological disposal facility (GDF), subject to approvals (see A.10). Current assumptions for the basis of lifetime plans are that the fuel will be stored at Sellafield prior to disposal in the GDF.

The NDA is undertaking an assessment of the lifecycle implications of the management of this oxide spent fuel including waste management. This means: the NDA is in the process of determining what the options are for its spent oxide fuel and what it believes is the best thing to do with it.

Simply put, the options for the disposition of spent oxide fuel are (i) to declare the fuel as waste and dispose of it when a facility is available (ii) to Reprocess the fuel, as practised currently, (iii) to longterm store the fuel pending a decision on whether to dispose (as waste) or reprocess.

A 1.2: Purpose of the Oxide Topic Strategy

The purpose of developing a strategy for oxide fuels is to;

- Provide confidence to Regulators, Stakeholders and the Public that future plans for safely receiving and managing oxide fuel continue to be properly evaluated and are suitably underpinned
- Provide clear strategic guidance to Sellafield Ltd for the management of oxide fuel
- Provide confidence to NDA's customers that its contractual commitments will be fulfilled
- Understand the impact and interdependency of the Oxide Fuels Strategy on other relevant NDA strategies, especially those for nuclear materials, other spent fuels, waste management and decommissioning
- Ensure that the strategies for spent fuel, nuclear materials and nuclear licensed sites are compatible and consistent

We are developing a strategy for oxide fuels through an assessment of the lifecycle implications of the management of spent oxide fuel (including wastes), that is, an evaluation of individual strategic options that may apply (reprocess, dispose) and possible combinations. The criteria used to examine the options of what to do with spent oxide fuel include safety, security, environmental and economic considerations – all at both local and national level.

In evaluating options the NDA places great emphasis on categories such as hazard reduction and waste management. We made this commitment to undertake a lifecycle assessment of options for spent fuel management in our first published strategy.[v] The assessment is also looking at key risks and opportunities associated with each of the strategic options.

The management of spent oxide fuel and associated products and wastes will span many decades. The final inventory of AGR fuel to manage is uncertain as it is possible that further

[v] NDA Strategy, Nuclear Decommissioning Authority, 2006, http://www.nda.gov.uk/documents/upload/NDA_Final_Strategy_published_7_April_2006.pdf

AGR station life extensions may be declared by BE. We believe a clear assessment and evaluation of strategic options for spent oxide fuel is required for a number of reasons:

In the short term, to underpin business and investment decisions relating to operations at Sellafield and, to identify and develop contingency options for the management of spent oxide fuel. This is largely, related to infrastructure requirements for the treatment of highly active (HA) liquid effluents coming from Thorp reprocessing and options for the longterm storage of AGR fuel, pending a decision on its potential disposal to a GDF.

In the medium term, to ensure the continued receipt and safe management of oxide fuel and thereby safeguard the ability of BE to discharge fuel from its AGR reactor sites.

This requires maintaining adequate storage capacity for receiving fuel and also the ability to consolidate and interim store fuel at Sellafield, pending a final decision on whether to dispose or reprocess it. Significant technical and engineering work is likely to be required to support this aspect of the strategy in the medium term.

In the longterm to ensure that the strategic option(s) implemented are optimised for the lifecycle of the spent fuel including storage, reuse and disposal of all products and wastes, as appropriate. The focus here will be on the disposability of the wastes and products from spent fuel management, especially the potential direct disposal of AGR fuel to a GDF.

A.2 Current Baseline Strategy

A 2.1: The Spent Oxide Fuel Inventory

The spent oxide fuel inventory managed by the NDA consists of three types of fuel.

1. AGR Fuel ('historic' and 'future')
2. Overseas LWR fuel
3. 'UKAEA contract' fuels

The fuels from the AGR power stations are uranium oxide pellets in stainless steel pins, whereas the overseas LWR fuel is predominantly uranium oxide fuel in zircaloy pins.

The current declared lifetimes for the AGR power stations from British Energy will result in the generation of approximately 8,800 te of AGR fuel across the whole AGR fleet. Of this inventory over 2,300 te has been reprocessed to date, meaning there is estimated to be about 6,600 te of spent fuel to manage.[vi] Potential lifetime extensions to the AGR stations could increase the inventory of spent AGR fuel to manage.

Overseas LWR fuel has come from European and Japanese utility companies. Deliveries of fuel to Sellafield under contract with these companies have been completed and there remains less than 700 te of this fuel to process through Thorp. There is also an inventory of oxide fuels which

[vi] The estimated masses given are based on tonnes of uranium prior to irradiation in the reactor.

NDA has inherited from the UKAEA which generally came from prototype reactors from the UK's historic nuclear energy development programmes, amount to approximately 150 te, and are also contracted to be reprocessed in Thorp.

The UKAEA fuels and a small proportion of the overseas fuel are non-standard oxide fuels and are also included as part of the Exotic fuels inventory, which is the subject of a separate Topic Strategy.

A2.2: Our Current Strategy

In 2005 the NDA took over ownership of the Sellafield site from BNFL and inherited contracts for the management of a range of spent oxide fuels at Sellafield, and to receive and manage future deliveries of AGR spent oxide fuel from BE. [vii]

The objectives of the Oxide Fuel Strategy are to;

1. **Ensure the safe management then ultimate disposition of UK-owned oxide fuel**
2. **Optimise the management of overseas fuel stored in the UK**

We are developing a spent oxide fuel strategy to;

- Fulfil our contractual obligations for the management of spent fuel on behalf of UK and overseas customers.
- Ensure there is sufficient available capacity to receive and safely manage all AGR spent fuel from the BE reactor stations.
- Evaluate options and determine a longterm solution for the management of AGR fuel

The options for AGR fuel are whether it should be reprocessed, or longterm stored prior to disposal to a deep geological disposal facility (GDF).[viii] Current plans are to reprocess some of the AGR fuel and to longterm store the remainder prior to disposal. The current lifetime plan for Sellafield shows this fuel to be wet stored in pond prior to emplacement in the GDF.

The development of a facility for deep geological disposal of spent fuel and high level waste is the responsibility of the Radioactive Waste Management Directorate (RWMD) of the NDA. The assumed date for when the GDF can start receiving HLW and spent fuel is 2075, although this is subject to review. We must, therefore, make provision for, and ensure that, the longterm storage of spent AGR fuel at Sellafield leaves the fuel in the best possible condition for safe and cost-effective disposal.

Recent operational events at Sellafield, namely the Thorp FCC event[ix] and the currently limited evaporator capacity available for the treatment of reprocessing effluents from oxide fuels, have placed heavy restrictions on Thorp throughputs in recent years. The NDA is committed to investing to improve evaporator capacity at Sellafield, and with Sellafield Ltd and its new parent

[vii] The proposal by BNFL to reprocess AGR fuel in Thorp was subject to a Public Inquiry, The Windscale Inquiry. A précis of the background to reprocessing AGR fuel and Thorp is provided in Appendix A.
[viii] Further information on spent fuel disposal can be found in "Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal, A White Paper by Defra, BERR and the devolved administrations for Wales and Northern Ireland, http://www.official-documents.gov.uk/document/cm73/7386/7386.pdf
[ix] For further information see, Nuclear Installations Inspectorate report at: http://www.hse.gov.uk/nuclear/thorp.htm

body Nuclear Management Partners jointly committed to building a site with the necessary infrastructure that can support both the short and longterm needs for spent fuel management. However, the current restrictions on Thorp throughput mean that the date for completion of the reprocessing programme and the assumed closure of Thorp has been pushed out from 2011, although this date is still under review.

Given these circumstances, the NDA believes that it is appropriate to understand the strategic options for the management of the spent oxide fuel inventory. The approach to this is to assess the lifecycle options for spent oxide fuel management to determine the way forward.

Strategy within the NDA is developed in accordance with the Strategy Management System (SMS).[x] The Oxide Fuels Strategy is working towards Gate A: the establishment and assessment of credible options.

A.3 Credible Strategic Options

At a high level the strategic options for the disposition of the NDA's spent oxide fuel are summarised in Figure 1. The diagram shows that for spent oxide fuel there are only two main options under consideration: (i) to longterm store, condition and then potentially dispose of the fuel to a GDF or (ii) to reprocess the fuel.

It is important to stress that a strategy for oxide fuels could, in principle, include pursuit of one or a combination of these two options to manage the complete inventory. Indeed, the current baseline strategy for management of the UK's AGR fuel assumes a proportion of the fuel will be reprocessed and a proportion will be longterm stored and then disposed of. Therefore, it is more meaningful to refer to the strategic options as strategic directions. That is, we will determine whether for AGR fuel the best longterm management strategy is to either reprocess it or to store the fuel pending conditioning and potential disposal.

[x] Further details can be obtained from the NDA website, see http://www.nda.gov.uk/strategy/

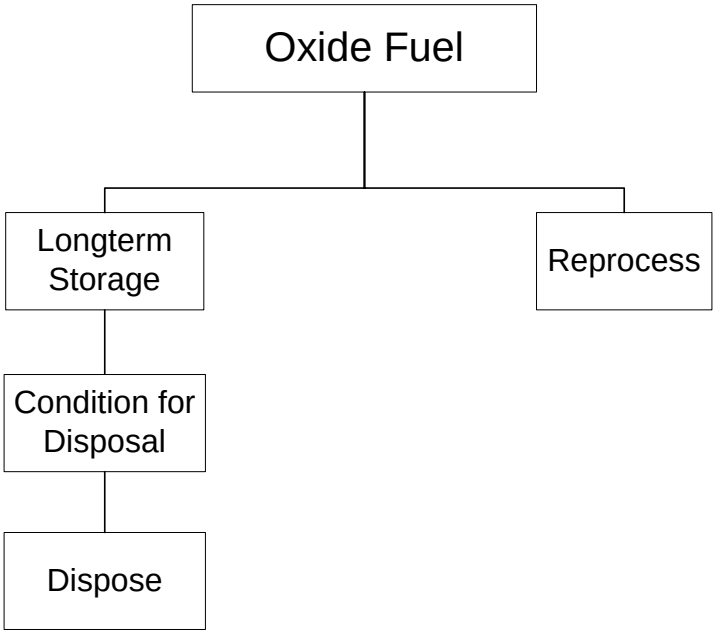

Figure 1: The High-level Strategic Options (Directions) for the Disposition of Spent Oxide Fuel

The NDA recognises that the management of spent nuclear fuels will span many decades and is an inter-generational issue. Therefore, placing the spent fuel into longterm storage with a view to disposal would not preclude the option to reprocess at a later date. This is because the fuel would be maintained in condition suitable for retrieval, inspection and recovery.

Option 1 – Storage and Disposal

Spent oxide fuel is stored either wet or dry in a suitable pond, cask, module or vault and then disposed of to a GDF.[xi]

The UK has elected to dispose of HLW arising from reprocessing UK fuel and spent UK fuel (if it is declared a waste) in a GDF. This decision by Government was made after a series of studies and following the recommendations of the CORWM. The NDA is charged with the implementation of a GDF in the UK.[xii]

Store-then-dispose is a longterm waste management option favoured by some countries, e.g. Finland, Sweden, Germany and Switzerland. It involves the use of the so-called 'multi-barrier system' where combinations of engineered barriers are incorporated into the repository design, intended to prevent the ingress of water, thereby restricting the transport of radionuclides into the environment while the radioactivity decays. Waste would be packaged in suitable containers, which are then placed in boreholes within the repository tunnel floor. The tunnel would eventually be back-filled with rock or clay.

[xi] This will place requirements on the storage regime to maintain the fuel in a condition for transport, ultimately to the GDF, and to maintain documentation associated with the fuel to support this.
[xii] For further information on options for geological disposal of spent fuel see, http://www.nda.gov.uk/aboutus/geological-disposal/documentation.cfm

There are a number of sub-options and variants available for storage followed by disposal. They can be summarised as;

Wet Store - Where fuel is held underwater in storage ponds until the GDF is available. The fuel is monitored and conditions within the pond optimised to maintain the fuel in the best practicable condition for disposal. Based on current estimates wet storage of fuel is likely to be required for at least 50 to 100 years depending on when the GDF is available to receive fuel.

The UK has considerable experience in the wet storage of AGR oxide fuel. There are three ponds at Sellafield that can store AGR fuel. The most modern of these ponds may be suitable for the longterm wet storage of fuel until the GDF is available. Sellafield Ltd are performing work to establish whether AGR fuel can be longterm wet stored prior to disposal.

Dry Store - We are examining a number of options for longterm dry storage of fuel including;

- Cask fuel storage – fuel is placed in sealed containers (metal) within casks (concrete or metal), which provide shielding and passive cooling, that are housed in a weather-proof building
- Modular Vault Dry Storage – fuel is placed in vertical storage tubes within a modular concrete vault that provides passive cooling and shielding

The dry storage of LWR fuel is a mature technology used by some nuclear energy companies across the world. There are a number of designs of dry fuel storage systems that meet US and European Regulatory requirements.

AGR fuel is stainless steel clad and unique to the UK. The technical case for the longterm dry storage of AGR fuel has not yet been developed. One option being examined for AGR fuel is dismantling the fuel bundles into their individual fuel pins and placing into sealed, inerted canisters that are then emplaced within casks or storage tubes within modular-type vaults. Previous work was carried out in the 1990s by Scottish Nuclear on the dry storage of undismantled AGR fuel in a vault-type store, however, the development work was not completed and taken through Regulatory approval.

Ongoing and previous work on dry storage technology is helping inform options for the management of AGR fuel. For longterm storage the fuel has to be maintained in conditions that are secure, and ensure the fuel is both retrievable and suitable for disposal in the GDF.

Examples of factors which may influence the selection of this option or sub-options could include;

- Amount of fuel to be disposed of
- Waste management including types, volumes, disposability and storage regimes
- Performance of reprocessing operations at Sellafield
- Condition and type of fuel involved
- Time period over which receipt is required
- Time period of longterm storage
- Constraints introduced as a result of disposability assessments of the spent fuel or spent fuel waste package

- Planning approvals and the timescales for obtaining
- Contractual obligations and customer requirements
- Views of the local community
- Government energy policy
- Emerging technology
- Cost

A combination of wet/dry storage techniques could be deployed to ensure storage capacity is sufficient and to optimise the storage regime for the fuel. This option may involve an initial period of wet storage in ponds followed by transfer to dry storage, to better maintain the fuel over the longterm. Significant technical work is required to evaluate and compare the attributes and performance of wet and dry storage systems over the longterm.

Finally, storage prior to disposal will require conditions that retain the fuel in a good condition. Such a storage regime will maintain the fuel in a retrievable form that would be suitable for reprocessing, if future generations required it. Although shown in the strategic options diagram 'Store then reprocess' is not being actively considered, beyond normal interim storage prior to reprocessing.

Option 2 – Reprocess

Reprocessing to segregate the components of spent fuel and produce nuclear materials for reuse and waste forms compatible with national disposal strategies is practised by several nuclear energy states including the UK, France, Russia and Japan.

The UK has a long history of reprocessing spent fuel and currently has two operating industrial-scale reprocessing plants, Magnox and Thorp, for the treatment of metal and oxide spent fuels respectively. There are a number of options and variants available for reprocessing the spent oxide fuel and these are subtly different for UK and overseas fuel, examples of which are;

- **Reprocess All spent oxide fuels**

The lifetime of the AGR power stations may extend beyond the predicted lifetime of Thorp. Therefore, to reprocess all AGR fuel would require either major refurbishment of Thorp and associated plant, new contracts with overseas reprocessing facilities or the build of a 'new Thorp'.

- **Reprocess all spent oxide fuels to the end of Thorp**

Operate Thorp and associated plant as long as practicable and reprocess as much fuel as possible; this is a hybrid strategy resulting in an, as yet, undetermined amount of fuel to be disposed of directly to the GDF

- **Reprocess to the end of contractual commitments**

This is the NDA strategy for overseas LWR fuels

- **Reprocess the minimum amount of spent oxide fuel**

Reprocess only fuel for which the option of longterm storage and disposal would be more onerous, taking account of contractual obligations.

Examples of factors which may influence the selection of the 'Reprocess' option and its sub-options are:

- Amount of fuel to be managed and disposed of
- Waste management including types, volumes, disposability and storage regimes Performance of reprocessing operations at Sellafield
- Condition and type of fuel involved
- Time period over which receipt is required
- Time period of longterm storage
- Constraints introduced as a result of disposability assessments of the spent fuel or spent fuel waste package
- Contractual obligations and customer requirements
- Views of the local community
- Government energy policy
- Emerging technology
- Cost

A.4 The Way Forward

The NDA has established a project team to define the options available and to progress the development of the Oxide Fuel Strategy, using the NDA Strategy Management System (SMS).

This section outlines the programme of work and processes that will be undertaken to generate underpinning data on the credible strategic options, evaluate the strategic options and allow NDA to further develop its Oxide Fuel Strategy. The NDA will be supported in this analysis by its SLCs, especially Sellafield Ltd. The work identified, has in some cases already been initiated; wherever possible it will make use of assessment and analysis already completed (or in progress) by SLCs.

The project is currently in Stage A of the Strategy Management System where credible options are defined.

The OFS will be developed by an assessment of the lifecycle implications of the management of spent oxide fuel inventory including waste management. The assessment will perform an evaluation of the individual strategic options (Recycle, Store then dispose), relevant sub-options, and, if appropriate, combinations of the above. The assessment will examine and highlight risks and opportunities associated with the strategic options, including the sensitivity and robustness of the strategy to risks. The criteria used to evaluate the options of what to do with spent oxide fuel include safety, security, environmental and economic considerations – all at the local, national and, where applicable, international level.

Inventory and fuel delivery scenarios

This work is to develop and describe the scenarios to predict the arisings of spent oxide fuels. We consider it prudent to understand the sensitivity and robustness of our oxide fuel strategy to possible AGR reactor lifetime extensions.

Further work to collate data on the physical characteristics, radionuclide and fissile/nuclear material inventory and categorisation of the spent oxide fuel will be undertaken to support and ensure technical data is available for assessments on the lifecycle options.

Develop the 'Credible Options' for Spent Oxide Fuel

The strategic options diagram for spent oxide fuels has been developed. Process descriptions of the credible options, including both technical and engineering data, are required that illustrate key features and allow cost, infrastructure and other impact estimates to be made to evaluate the various management options. These process descriptions of the credible options will use the latest available data. This work will include assessments of the technology readiness of the various credible options and outline the type of work required to develop candidate technologies to a deployable level.

Safety and environmental assessments will be undertaken to support the evaluation of management options for Oxide fuels. This should encompass the hazard associated with reprocessing and that of longterm storage of the fuels under wet and dry conditions.

The NDA considers it very important to undertake work to understand the potential disposal and disposability of UK-owned spent oxide fuels. Constraints imposed by disposability aspects will have major impacts on the analysis and evaluation of the credible options. A description of the technical and engineering option for disposal of spent fuel is required. Projected costs for the disposal of spent fuel are required.

Life Cycle Analysis of 'Credible Options' Scenarios for Disposition through Macro-economic Modelling

The scope of this work package is undertake a macro-economic evaluation of the strategic options for spent oxide fuel disposition. The approach is to further develop models that describe costed lifecycle for the categories of oxide fuels and their wastes based on the credible options.

In addition, the NDA will include other attributes derived from its Value Framework (and also related to strategic environmental assessment) and where possible attempt to quantify the impacts against these criteria.

The model can be used to help optimise current and new infrastructure covering storage, treatment and disposal and technology development and acquisition for the development of disposition options for oxide fuels.

A scenario approach will be used that illustrates the current strategy and compares and contrasts alternative strategies. The scenario approach will also illustrate the impact of key risks (e.g. loss of evaporative capacity) and the deployment of key opportunities (e.g. consolidated fuel storage and avoidance of complex support infrastructure).

The Identification of Key Risks and Opportunities for the Oxide Strategy

The output from this work stream will be the identification of key risks and opportunities with the potential to impact upon the credible options for the disposition of spent oxide fuels. Examples might include assessing the likelihood and impact of the risk of losing evaporative capacity, pond capacity, fuel dismantling capability etc. Opportunities might include the development of alternative dry-storage regimes, the dry storage of some difficult fuels, and inclusion of some of the Exotics fuels inventory. This work will feed into the scenario-based lifecycle analysis described above.

An Assessment of the Implications associated with Policy, Regulatory, Planning and Stakeholder Positions

This work package should highlight those policy, regulatory, planning and stakeholder issues that might impact the selection, scope and implementation of the credible options. Proposals and a programme of work to identify and engage stakeholders in addressing these issues will be provided.

Analysis and evaluation of strategic options

The scope of this work package is to analyse, evaluate and summarise the options of the disposition of spent oxide fuel, in the form of a series of internal strategy papers as per the requirement of the Strategy Management System.

These papers will describe credible strategic options for the disposition of oxide fuels in the context of other interdependent strategies and will also define further work to improve analysis and evaluation of the credible options.

The analysis and evaluation will provide an overview of;

- Descriptions of ‘Credible Options’ for both reference and alternative strategies with timescales, key features, costs and impacts
- Scenarios covering the inventory and categorisation of Oxide fuel
- Macro-economic evaluation of the ‘Credible Options’
- The utilization of NDA facilities for processing materials
- The need, scope and requirement for new facilities
- Need and scope of interim and longterm storage facilities
- Technology needs for the above
- A preliminary review of the disposability of UK spent oxide fuel and packages arising from baseline and alternative approaches
- Definition of gaps, risks & opportunities

- Interactions with other key Topic strategies (e.g. other spent fuel and nuclear materials)

A.5 Topic Lifecycle

We are working closely with Sellafield Ltd to progress implementation of the current oxide fuel strategy.

We are working to develop a new Oxide Fuel Strategy and are supported in this by Sellafield Ltd. The Oxide Fuel Strategy is currently working towards Gate A in the SMS.

Key findings and progress updates will be summarised and communicated through a series of short, summary papers that will be available on the NDA website. However, much of the underpinning information will be of a commercial or security sensitive nature and may not be appropriate to release.

A.6 Key Interfaces

The Oxide Fuel Strategy has the potential to influence, and be influenced by, a number of other topic strategies. Some of these interactions are fundamental and time-limiting.

The Oxide Fuel Strategy has direct linkages with the following topic strategies:

- Other nuclear materials and spent fuel topics: Plutonium, Uranics, Magnox, Exotics
- Asset Optimisation, Business Optimisation
- Higher Activity Wastes and the GDF, Site End States
- Clean-Up and Decommissioning

<u>Magnox and Exotic Fuels</u>
The reprocessing of Magnox fuel utilizes some of the same ancillary infrastructure (e.g. evaporative capacity) as the reprocessing of oxide fuel, and therefore the oxide fuel strategy has an interaction with the Magnox Operating Plan (MOP).

There are a variety of Exotic fuels that could potentially be managed through similar options to those for Oxide and Magnox fuels, including reprocessing. Some of these fuels are already scheduled to be reprocessed through Thorp. The management of this strategic interface requires a sound, current knowledge of both the MOP and the emerging options for the management of Exotic type Fuels.

<u>Plutonium and Uranium</u>
The management of spent oxide fuel involves the reprocessing of spent fuel through THORP facility at Sellafield. Reprocessing produces separated plutonium and uranium oxides and, therefore, any change to the current plan will affect a change in the amount of plutonium and uranium to be stored and, therefore, potentially impact on the uranics and plutonium topic strategy papers.

Asset Optimisation and Business Optimisation

Asset Optimisation ensures the best use of existing facilities to meet NDA business needs. Business Optimisation is the maximisation of value of assets or the minimisation of liabilities for the NDA. The management of Oxide Fuels requires utilisation of existing facilities and possibly the development of new or replacement facilities. Additionally, the management of Oxide Fuels earns revenues for the NDA which contribute to funding clean-up activities.

High Activity Wastes, RWMD and Site End States

For UK fuels, there is a strong interaction of the Oxide Fuels Strategy with Higher Activity Wastes and the planned Geologic Disposal Facility (GDF). Reprocessing produces ILW and HLW that are conditioned and stored at Sellafield. Choosing not to reprocess AGR fuel will markedly increase the amount of spent fuel that is assumed to be disposed of to a potential GDF.

The operation and decommissioning of facilities used for either reprocessing or longterm storage of fuel will produce different types and volumes of wastes, that will need to be factored in to the HAW and GDF strategies. The uncertainties around the disposal concept, the disposability and volumes of the different waste forms, including AGR fuel, are key aspects to making decisions on the project.

These issues will be incorporated into the project scope and the development of the GDF concept, which will take place in parallel to the Oxide Fuels Strategy development project. The end point for the Oxide Fuel Strategy is when the last of the fuel leaves the Sellafield site for the GDF or when the last of the fuel is reprocessed. This is expected to be predominantly impacted by the date for when the GDF can receive conditioned spent fuel and also the schedule for fuel disposal, which is dependent on the amount to be disposed of. The amount of oxide fuel to be disposed of to the GDF has not been determined at this time, as it is dependent on the end date for reprocessing and the lifetimes of the AGR reactor stations.

Clean-Up and Decommissioning

For the management of Oxide Fuels, the THORP facility and associated plants are critical to delivery of the reprocessing contracts, and are also critical in the timeline for the decommissioning of the Sellafield site. Additional facilities are likely to be required at Sellafield, as a result of the underpinning of the current strategy. The result will be an increase in the decommissioning scope which may require a change in the overall site strategy. This will be continually reviewed by the relevant NDA Strategic Authority.

Funding

It is likely that to deliver optimised lifecycles for Oxide fuels additional funding will be required. The selection and prioritisation of management strategies will be dependent on the NDA contractual obligations and the NDA's prioritisation process, which takes cognisance of safety and security aspects and especially hazard.

R&D and Skills

R&D activities related to the mitigation of key strategic risks, underpinning key skills and supporting credible options evaluation will be required to underpin strategic option selection. This will cover activities related to reprocessing technology, development of longterm wet and dry storage systems technology, disposal and disposability of spent fuel, and skills retention and development especially those relating to storage technologies. Common R&D requirements with those for managing exotic and non-standard fuels will also be explored and developed.

A.7 Site Interfaces

NDA recognises the impact that any credible options will potentially have on Sellafield site. In addition, there may be impacts on planning for the Geological Disposal Facility. At all times, NDA will ensure that interfaces are fully considered as part of the credible options deliberations.

A.8 Key Policy Issues

There are a number of central and regional Governmental policy uncertainties and constraints which influence the scope of strategy development, or can conversely be changed by it.

Government policy on spent fuel management is that it is for the owner to decide on the disposition option. However, the NDA's remit is quite narrow and under the terms of the Energy Act, the NDA has a limited mandate to enter into new commercial contracts which could earn revenue and contribute to funding of clean-up activities. Such decisions would require the prior approval of Government and a possible increase in funding levels. The NDA does however, have a responsibility to operate its assets as efficiently and effectively as possible, where it is financially beneficial to do so, and where it is consistent with safety and environmental considerations.

The UK currently has no defined policy regarding future use of nuclear materials (i.e. uranium and plutonium) from reprocessing. However, the Government wants to develop proposals for plutonium management and is planning to launch a public consultation in the autumn.[xiii] However, this outcome is key to decisions, e.g. on whether to pursue an aggressive reprocessing strategy, or adopt a long term storage-only approach and, if so, whether the fuel should be retrievable once 'disposed'.

All this poses difficulties for bounding credible strategic options and generating a decisions hierarchy.

These considerations provide major challenges for the NDA in terms of constructing Credible Options and agreeing 'the way forward'.

[xiii] http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/issues/plutonium/plutonium.aspx

A.9 Regulatory and Planning Engagement

Decisions regarding future strategic direction and changes to the baseline referred to in Section A2 will require close engagement and consultation with Regulators. Decision points and milestones will need to reflect an appropriate period for regulatory review. There are regular interface meetings between representatives of the NDA, Regulators (EA, NII, SEPA, OCNS) and Sellafield to discuss the oxide fuel strategy and ongoing operations at Sellafield. These meetings are helping to progress the oxide fuel strategy by providing Regulators and some key stakeholders (HMG, Scottish Executive) opportunity to shape the strategy development.

A.10 Sustainability Issues

As part of the options evaluation environmental factors will be analysed including potential impacts on UK radioactive discharge strategy and CO_2 emissions. However, the potential reuse of nuclear materials, namely Pu and U, will not feature in the options evaluation as this is a matter for HMG, see A.8.

A.11 Stakeholder Engagement

Developing and implementing disposition options for spent oxide fuels will involve transport, disposal and treatment of nuclear fuels and materials.

NDA fully accepts there will be a strong stakeholder interest at local, national and international level in both the development of options and their implementation, see for example Appendix A.

The early identification of Stakeholders and development of a Stakeholder Engagement plan is required. Development of Stakeholder engagement plan will reduce the risk that issues are raised at a later date that can block implementation and ensure decision making is informed, robust and transparent.

The next phases of engagement are currently being planned with the intention of designing an engagement process around the indicative high level plan and utilising the emerging public and stakeholder engagement framework from the SMS. This engagement plan will also address how we gain stakeholder views with respect to the planned engagement and revise it as necessary.

Initial engagement on the options for the disposition of spent oxide fuel will take place through the publication of this document. Further engagement will be supported through a series of short, summary papers on oxide fuels that will be available on the NDA website. However, much of the underpinning information will be of a commercial or security sensitive nature and may not be appropriate to release.

A.12 Governance Arrangements

Recognising the long timescales for completion of the programme for the management of oxide fuel, we will ensure that governance and management systems will be maintained to provide oversight and decision making throughout the life of the strategy.

Advice and guidance on strategy development will be sought through regular meetings (e.g. SDDG) with Regulators and some key Stakeholders (HMG, Scottish Executive) and internal committees e.g. Strategic Authorities Forum (SAF).[xiv] Where there are deliverables that impact on the SLCs, the relevant Site Strategic Committee will also be asked to provide endorsement.

The strategy will be approved at the NDA's Strategy and Planning Board (SPB) and the NDA Board with final endorsement by Government where this is required.

[xiv] The Strategic Authorities Forum is an NDA peer working group. The Strategy and Planning Board (SPB) is made up of the NDA Executive. The Strategy Development and Delivery Group is a Governmental and Senior Regulatory strategy advisory group.

Appendix A

Appendix A1 Background to Oxide Reprocessing in the UK

In 1977 British Nuclear Fuels Ltd (BNFL), the company then responsible for the management spent oxide fuel from the UK AGR stations, requested permission to build a plant for reprocessing oxide fuel at Sellafield, the Thermal Oxide Reprocessing Plant (Thorp). Due to local and national interest this request was the subject of a Public Inquiry, called the Windscale Inquiry, led by Justice Parker which heard objections and representations on the matter.

Justice Parker bound the scope of the Inquiry through seeking to answer three questions;

1. Should oxide fuel from United Kingdom AGR reactors be reprocessed in this country at all?
2. If yes, should reprocessing be carried on at Windscale?
3. If yes, should the reprocessing plant be about double the estimated size required to handle UK oxide fuels and be used, as to the spare capacity, for reprocessing foreign fuels?

In 1978 Parker reported to the Secretary of State for the Environment finding in BNFL's favour and stating that 'a new plant for reprocessing oxide spent fuel from UK reactors is desirable and that a start should be made without a delay'.

In arriving at this conclusion Parker based his arguments on four key areas;

- That unless reprocessed, stocks of spent oxide fuel and plutonium will continue to build up and present an ever growing threat and burden to future generations
- Reprocessing would provide sufficient plutonium to fuel the start-up of a UK fast reactor programme, exploit an indigenous energy resource and thereby help preserve an energy 'mix'
- Prolonged storage of fuel would be costly to develop and implement
- The detriments of reprocessing, namely the risks of emissions, accidents and terrorist incidents, were tolerable

Based on this BNFL developed and implemented the strategic option of reprocessing for the management of spent oxide fuel from the AGR fleet. In addition, BNFL sought and obtained reprocessing contracts from overseas European and Japanese utility companies for their LWR fuel to support the reprocessing business and support the efficiency of the operation. For this reason Thorp was built at approximately three times the capacity required to treat oxide fuel from the UK AGR fleet. To support both Oxide and Magnox fuel reprocessing considerable ancillary plant was also built to store and treat the wastes and effluents coming from reprocessing operations.

Oxide spent fuel was delivered to Sellafield for reprocessing through Thorp. In 1994 Thorp was commissioned and started to reprocess oxide fuel. To date the plant has reprocessed some six thousand tonnes of domestic and overseas oxide fuel. Thorp was planned to operate until 2011 to meet contractual commitments for AGR and overseas LWR fuel. However, following the Feed Clarification Cell event in April 2005 Thorp was shut down for nearly two years and has since then been operating on reduced capacity due to constraints over evaporator capacity. The projected date for Thorp completing current contracts is under review.