

# Exotic Fuels and Nuclear Materials - Dounreay

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## **Credible Options**

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## **Contents**

Executive Summary .....	3
1 Background.....	4
1.1 Dounreay Exotic fuels and nuclear materials .....	4
2 Credible Options .....	6
2.1 Options Analysis .....	6
2.2 Credible Options Summary .....	6
3 Value Framework Analysis of Credible Options.....	7
3.1 Analysis Summary .....	7
4 Transportation.....	9
5 Next steps - Timeframe and stakeholder engagement .....	9
6 Summary and Conclusions .....	10
Appendix 1 : Description of exotic groups at Dounreay .....	11
Appendix 2 : Definitions of option Categories .....	12
Appendix 3 : Options Analysis.....	13

## **Executive Summary**

A number of different forms of nuclear fuels and materials are currently safely and securely stored on the Dounreay site. Some of these fuels and materials require enhanced site security arrangements to be in place. The materials currently stored at Dounreay include unirradiated plutonium and high enriched uranium bearing fuels. For brevity, these are termed Dounreay “exotics”.

The Energy Act (2004) requires us to have a strategy to safely and securely manage exotics in the most practical and cost effective way. Modern facilities are either under construction or planned at Sellafield, and investment will soon be required to maintain the storage capability at Dounreay. It is therefore a good time to consider management options for this material.

This paper outlines the strategic and financial issues associated with the management options for the Dounreay exotics. It identifies the credible options but makes no recommendations as to a preferred management option.

This study identifies two high level credible options:

- To continue to manage the exotics at Dounreay, which is the current baseline plan
- To transport the exotics to Sellafield for management

Both are compliant with current UK and Scottish Government policies.

Our Value Framework analysis of the credible options shows that the option to transport the exotics from Dounreay to Sellafield offers many advantages, but this option needs to be discussed with regulators and stakeholders before any approved strategic decision can be made. Under this option, the number of transports would depend on the mode, but as a guide, there would be in the region of 30-60 journeys during a 6 year period, commencing probably around 2014/15.

Our purpose in publishing this paper is to engage with regulators and other stakeholders and hear their views before any decision is reached. Following this engagement we will make a decision in March/April 2012. Work still needs to be completed by the Site Licence Companies (SLC's) before we can be confident that the preferred option can be fully implemented.

Beyond March / April 2012, the SLCs and NDA will engage further with regulators and planning authorities to understand their views and obtain any appropriate permissions to pursue a preferred strategy for management of this material.

## **1 Background**

### **1.1 Dounreay Exotic fuels and nuclear materials**

There are many different forms of nuclear fuels and materials currently safely and securely stored on the Dounreay site. Some of it is unirradiated and some has been irradiated in experimental reactors since the 1950s. In total, there are of the order of 100 tonnes of these materials which require enhanced site security arrangements.

It is possible to summarise these forms into three main categories:

- Dounreay Fast Reactor (DFR) Breeder material
- Natural and depleted Uranic material
- Exotic fuels and nuclear materials

The preferred option for DFR Breeder material has already been determined following publication and engagement around a combined credible and preferred options paper<sup>1</sup>. The natural and depleted uranic material is covered by our uranics credible options study and is therefore not covered here.

This paper focuses on the remaining category of materials held at Dounreay (for brevity referred to as “exotics” hereafter) and for simplicity this category is broken down into 3 groups. (Further details are given in Appendix 1):

1. Unirradiated plutonium bearing fuels consisting of plutonium, mixed uranium and plutonium oxide and mixed uranium and plutonium carbide fuels.
2. Unirradiated high enriched uranium fuels consisting of uranium oxides, uranium metal, uranium alloy, uranium tetrafluoride, uranium hexafluoride and other miscellaneous enriched uranium fuels.
3. Irradiated fuels, comprising oxide and carbide fuel consisting mainly of Prototype Fast Reactor (PFR) fuel and the HELIOS material that was irradiated in experimental work.

Whilst the materials in groups 1-3 above, remain on site in their current form Dounreay will be a Category I site for security purposes, with the associated security requirements. As noted above the exotics are currently stored safely and securely. However, in around 10-15 years, many of the storage facilities will need to be replaced with new facilities which usually take 8-10 years to design, construct, build

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<sup>1</sup> at <http://www.nda.gov.uk/strategy/spentfuelsmgmt/exoticfuel/index.cfm>

and commission. While at Sellafield there are a range of modern facilities in existence, under construction or being planned capable of receiving these materials and the necessary workforce skills to properly manage them. As a result it is now timely to consider the management options.

## **1.2 Objective**

There are two strategic themes, Spent Fuels and Nuclear Materials, within our Strategy<sup>2</sup> which are relevant in the consideration of the management of the exotics. Within our Strategy there are several key statements of principle which underpin our approach, such as:

*“...we will ensure the continued safe management of these fuels, maximising opportunities to use existing facilities where value to the UK taxpayer can be secured. This may involve consolidating material at one or more locations for storage and treatment, and storage may be needed for several decades”.*

The principle objective is to ensure the future safe and secure management of exotics currently stored at Dounreay in a cost effective manner. To achieve this requires the following criteria to be met:

- The management of high security classification exotics continues to be carried out safely and securely, while providing the taxpayer with value for money.
- The management of these exotics does not compromise the planned hazard reduction programme at any impacted sites.
- Alternative strategies for processing the exotics are similar or better in terms of cost, hazard reduction and environmental benefit to those originally planned at Dounreay.
- If applicable, there are proven means of transporting the exotics wherever the destination, for example internal site transfers or external site to site transfers.

Our approach to making strategic decisions is to consider options against our Value Framework<sup>3</sup>, in order to reach a preferred management option. This paper seeks to identify credible options for each type of the exotics and analyse them against the Value Framework criteria.

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<sup>2</sup> NDA Strategy, April 2011

<sup>3</sup> <http://www.nda.gov.uk/stakeholders/newsletter/value-framework.cfm>

### **1.3 Policy Context**

Any matter of national security, such as the safe and secure management arrangements for certain nuclear materials in the UK is a matter for the UK Government and is not a devolved matter.

All the exotics held at Dounreay are not considered to be a waste, rather spent fuel or nuclear material, and all are currently potentially recyclable. The recently published Scottish Higher Activity Waste Policy (2011) specifically exempts spent nuclear fuels held in Scotland (sections 1.13 and 2.03.04).

## **2 Credible Options**

### **2.1 Options Analysis**

An options analysis has been completed and is included in Appendix 3. A range of management options were developed and, for each of the exotics groups outlined above, an analysis against the objectives was undertaken to assess credibility, against the definitions outlined in Appendix 2. Those options identified as credible were then subject to more in depth analysis via our Value Framework.

In the analysis we considered the credible options for each of the groups (see Appendix 1) separately. However it should be recognised that the principle benefit from moving materials from Dounreay would be the reduction in security classification of the Dounreay site, which can only be achieved if all these exotics leave the site.

### **2.2 Credible Options Summary**

We believe that there are two high level options for the future management of exotics which deliver the objectives:

- To continue to manage the exotics at Dounreay, which is the current baseline plan
- To transport the exotics to Sellafield for management

It should be noted that the only two of our sites in the UK with the capability of managing the exotics are Dounreay and Sellafield and as such all other sites were excluded from the option analysis. The credible options for the exotics are all considered to be compliant with current UK and Scottish Government policies, as described in section 1.3

### 3 Value Framework Analysis of Credible Options

#### 3.1 Analysis Summary

A comparison of the high-level credible options of (i) transporting the exotics to Sellafield for management and (ii) manage the exotics at Dounreay has been carried out against our Value Framework.

The following table is a summary of the value framework analysis against the credible options.

ATTRIBUTE	Transport the exotics to Sellafield for management	Manage the exotics at Dounreay
Hazard Reduction	<ul style="list-style-type: none"> <li>◆ Safety and Environmental Detriment (SED) of the exotics is many orders of magnitude less than that posed by the inventory held at Sellafield. The small increase in volume will result in no noticeable difference in Sellafield SED scores, but a reduction in SED scores at Dounreay.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Retention at Dounreay means that no reduction in the site hazard potential associated with the exotics is possible until they are removed at the end of the site life.</li> <li>◆ The Interim End State would need to include management of exotics in the long term.</li> </ul>
Security	<ul style="list-style-type: none"> <li>◆ Nuclear material stored with similar protected material at Sellafield</li> <li>◆ Net reduction in security risk at Dounreay by transferring nuclear material to a site with existing long term secure facilities which will be retained until at least 2080.</li> <li>◆ Will be carried out in compliance with security requirements so negligible security risk increase associated with transport.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Dounreay would continue to be guarded, aligned to the quantity of fissile material and Vital Areas on the site, until the fuel and materials are transferred to a disposal facility, or are managed in alignment with any potential future Scottish Policy for Spent Fuels and Nuclear Materials.</li> <li>◆ Physical security requirements would need to be maintained at a level commensurate with Category I material until beyond 2075. This requires new stores to be constructed.</li> </ul>

**Exotic Fuels and Nuclear Materials - Dounreay**  
**Credible Options**  
**February 2012**

Safety	<ul style="list-style-type: none"> <li>◆ There would be a slight safety detriment due to the increase in off-site movements. This could be kept at a minimum depending on the transport mode.</li> <li>◆ No new stores (beyond that already planned for Sellafield) would need to be constructed.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Retention at Dounreay would require new fuel stores to be constructed, with an inherent increase in construction safety risk.</li> <li>◆ The continued presence of exotics on the Dounreay site means enhanced security arrangements need to be maintained.</li> </ul>
Environment	<ul style="list-style-type: none"> <li>◆ Some environmental detriment (e.g those arising from emissions from fuel consumed during transport) due to the transfer of material packages from Dounreay to Sellafield.</li> </ul>	<ul style="list-style-type: none"> <li>◆ Environment detriment due to the use and transport of construction materials required to build new facilities and modify existing facilities.</li> <li>◆ There is no recycle opportunity at Dounreay, so exotics would probably require indefinite storage as near surface disposal would not be possible .</li> </ul>
Socio-economic	<ul style="list-style-type: none"> <li>◆ No meaningful difference between options</li> <li>◆ Sellafield 'business' would increase and extra resources for processing exotics would be required.</li> <li>◆ Through delivery of this option, transfer of exotics would support an earlier attainment of an interim end state at Dounreay site.</li> </ul>	<ul style="list-style-type: none"> <li>◆ No meaningful difference between options</li> <li>◆ Retention of exotics at Dounreay would require continued resources for processing and appropriate site security</li> </ul>
Cost	<ul style="list-style-type: none"> <li>◆ Overall infrastructure and security savings is expected to be in the hundreds of millions of pounds. The exact figure would depend on the detailed implementation plans, cost of potential reutilisation of existing facilities at Dounreay, and the mode of off-site transport.</li> <li>◆ These cost savings would be subject to economic discounting.</li> </ul>	<ul style="list-style-type: none"> <li>◆ No savings against the current plan.</li> </ul>



## **4 Transportation**

If “transport to Sellafield for management” is chosen as the preferred option, a number of transport options will need to have been considered. Further discussions with specific stakeholders and in particular the Office for Nuclear Regulation (ONR) will need to take place before transport options can be summarised with greater clarity. Agreement would need to be obtained with all relevant parties on the transport mode to be utilised. For unirradiated fuels, the options under consideration are road, sea and/or rail and for irradiated fuels the options are road and/or rail. This is in line with advice received from Security Regulators.

The number of transports would depend on the mode, but as a guide, there would be in the region of 30-60 journeys during a 6 year period, commencing probably around 2014/15.

## **5 Next steps - Timeframe and stakeholder engagement**

These strategic themes were formally consulted upon through our Draft Strategy public consultation in Autumn 2010, and also through our Draft Business Plan 2011-14 in December 2010.

This paper provides supporting information to enable engagement with interested stakeholders and provides further detail than that given in the earlier formal consultations.

For this programme, the Dounreay and Sellafield SLCs have jointly prepared the approach. We have taken information provided and used it to produce this paper to support its stakeholder engagement. Some of the source information is security restricted, which means it cannot be shared under the terms of UK security regulations.

Our Executive will assess this strategic proposal and consider whether an approval in principle decision can be made. This consideration is expected around March / April 2012, and will be informed by the views of stakeholders arising from the engagement process.

Beyond March / April 2012, the SLCs and NDA will need to further engage with regulators and planning authorities to understand their views and obtain any appropriate permissions to pursue a preferred strategy for management of this material.

A programme of engagement, supported by this paper, will be undertaken with offers of briefings to relevant organisations and individuals. Furthermore any interested party can let us know their views by e-mailing [strategy@nda.gov.uk](mailto:strategy@nda.gov.uk). This engagement programme will run until Friday 23<sup>rd</sup> March. We will publish a summary of all views received and our response.

## **6 Summary and Conclusions**

There are many different forms of exotic fuels and nuclear materials currently safely and securely stored on the Dounreay site some of which require enhanced site security arrangements.

The Energy Act (2004) requires us to have a strategy to safely and securely manage exotics in the most practical and cost effective way. Modern facilities are either under construction or planned at Sellafield, and investment will soon be required to maintain the storage capability at Dounreay. It is therefore a good time to consider management options for this material.

We have studied the high level management options associated with the exotics and identified those it believes are credible and considers these to be compliant with current UK and Scottish Government policies. The options need now to be discussed with regulators, Government departments, local communities and other interested parties before any preferred option can be selected.

Our Value Framework analysis of the credible options shows that the option to transport the exotics from Dounreay to Sellafield offers many advantages, but these need to be discussed with regulators before any approved strategic decision can be made. Under this option, the number of transports would depend on the mode, but as a guide, there would be in the region of 30-60 journeys during a 6 year period, commencing probably around 2014/15.

We will take a decision on the preferred option in March / April 2012, and will be informed by the views of stakeholders arising from this engagement process. Work still needs to be completed by the Site Licence Companies (SLCs) prior to us being confident that the preferred option can be fully implemented.

## **Appendix 1 : Description of exotic groups at Dounreay**

### *Group 1: Unirradiated plutonium bearing fuels*

There are approximately 13 tonnes of group 1 material, containing around 2 tonnes of plutonium. It is stored in several locations around the site, and is in the form of powders, pellets and pins. The vast majority of this material is unsuitable for either continued long term storage at Dounreay or for off-site transportation without some form of pre-treatment. The Dounreay Lifetime Plan (LTP) has provision for the installation of an Unirradiated Fuels Conditioning Facility (UFCF) which would provide such pre-treatment.

### *Group 2: Unirradiated high enriched uranium fuels*

There is approximately 1 tonne of group 2 material stored on the site, in the form of oxide powders and pellets, and also some uranium metal and alloys. It is stored individually in several locations in small quantities and would benefit from consolidation into larger, more robust containers suitable for long term storage.

The unirradiated high enriched uranium has a wide range of enrichment values, presenting operational and disposability difficulties.

Some of the items such as swab ash, slag and graphite crucibles contaminated with small quantities of unirradiated high enriched uranium are irrecoverable, are considered to be uranium contaminated waste which has a lower security classification. They are planned to be conditioned as intermediate level waste by Dounreay Site Restoration Limited (DSRL) and stored on the Dounreay site and so they are not considered in the scope of this paper.

### *Group 3: Irradiated fuels*

There is approximately 15 tonnes of this material, and the spent Prototype Fast Reactor (PFR) fuel (which is the vast majority of this material) has achieved very high burn-ups which means it requires special handling and transportation arrangements. It is currently safely and securely stored on the Dounreay site.

## Appendix 2 : Definitions of option Categories

<b>Term</b>	<b>Definition</b>
Credible option	An option which could be delivered to meet the key objectives as defined.
Contingent option	An option which warrants further development in case the credible options turn out to be undeliverable.
Dormant option	Dormant options represent potential options but which do not need further development at this time.
Rejected option	Rejected options will not be developed further.

### **Appendix 3 : Options Analysis**

*Group 1: Unirradiated plutonium bearing fuels*

As these exotics contain plutonium, the only viable UK site for this material other than Dounreay is Sellafield. Therefore the credible options are:

1. Leave material at Dounreay, process for long term storage and store prior to decision on final disposition route.
2. Condition material for long term storage at Dounreay and then transfer to Sellafield and store in appropriate storage facilities (such as the Sellafield Product and Residues Store, SPRS), prior to decision on final disposition route.
3. Transfer material to Sellafield, condition for long term storage, and then store in SPRS, prior to decision on final disposition route.
4. Send material overseas for reprocessing and utilise products.

Each of the above four options are considered below.

Option	Our current view	Supporting Information
1	Credible	<ul style="list-style-type: none"> <li>• Compliant material would be placed in welded cans suitable for long term storage. The total plutonium containing powders stored on the Dounreay site would not change.</li> <li>• To package the material for long term storage it will be necessary to condition and characterise the material at Dounreay using the planned Unirradiated Fuels Characterisation Facility (UFCF).</li> <li>• Dounreay would have to keep its current security categorisation, which would not realise the opportunity for security cost savings at the site.</li> </ul>

**Exotic Fuels and Nuclear Materials - Dounreay**  
**Credible Options**  
**February 2012**

		<ul style="list-style-type: none"> <li>• There would be no meaningful change in Dounreay site hazard profile.</li> <li>• Would require new build at Dounreay with their associated environmental impact of such major construction.</li> </ul>
2	Credible	<ul style="list-style-type: none"> <li>• Material would be placed in welded cans suitable for Sellafield Storage. The total plutonium containing powders would add about 8% to the planned storage volumes of plutonium and less than 2% to the mass of separated plutonium already at Sellafield.</li> <li>• To provide the data to support transport safety cases and to package the material for transport it will be necessary to condition and characterise the material at Dounreay using the planned UFCF.</li> <li>• There would be a lowering in Dounreay site hazard profile.</li> <li>• Sellafield already has similar materials so there would be no meaningful change in the Sellafield site hazard profile.</li> <li>• Avoids new build at Dounreay and the environmental impact of such major construction.</li> </ul>
3	Contingent	<ul style="list-style-type: none"> <li>• It is considered unlikely that a transport safety case would be obtained without characterisation and pre-treatment of material at Dounreay. (This consideration is under discussion with relevant advisors and Regulatory bodies, and will be either considered credible or rejected in the near future)</li> </ul>
4	Contingent	<ul style="list-style-type: none"> <li>• This option is not applicable to all materials but could be viable for pelleted material, pins and assemblies.</li> <li>• Contracts already in place with AREVA for reprocessing some unirradiated MOX from Sellafield.</li> <li>• DSRL material has much higher plutonium enrichment and products could be used to support wider MOX subcontracts.</li> </ul>

*Group 2: Unirradiated high enriched uranium fuels*

As these exotics contain uranium where the <sup>235</sup>U enrichment of is above 20%, the only viable UK site for this material other than Dounreay is Sellafield. Therefore the credible options are:

**Exotic Fuels and Nuclear Materials - Dounreay**  
**Credible Options**  
**February 2012**

1. Leave material at Dounreay, process for long term storage and store prior to decision on final disposition route.
2. Condition material for long term storage at Dounreay and then transfer to Sellafield and store in appropriate long term storage facilities (such as the Sellafield Product and Residues Store, SPRS), prior to decision on final disposition route.
3. Transfer material to Sellafield, condition for long term storage, and then store in appropriate long term storage facilities (such as SPRS), prior to decision on final disposition route.
4. Send material overseas for reprocessing and utilise products.

Each of the above four options are considered below.

Option	Our current view	Supporting Information
1	Credible	<ul style="list-style-type: none"> <li>• Compliant Material would be placed in welded cans suitable for long term Storage. The total high enriched uranium containing powders stored on the Dounreay site would not change.</li> <li>• To package the material for long term storage it will be necessary to condition and characterise the material at Dounreay using the planned UFCF.</li> <li>• Dounreay would have to keep its current security categorisation, which would not realise the opportunity for security cost savings at the site.</li> <li>• There would be no meaningful change in Dounreay site hazard profile.</li> <li>• Would require new build at Dounreay with their associated environmental impact of such major construction.</li> </ul>

**Exotic Fuels and Nuclear Materials - Dounreay**  
**Credible Options**  
**February 2012**

2	Credible	<ul style="list-style-type: none"> <li>• HEU material adds about 2% to the total storage volume requirements of category one nuclear materials at Sellafield.</li> <li>• Wide range of materials with very different characteristics in terms of chemical composition and origin. To provide the data to support transport safety cases and to package the material for transport it will be necessary to condition and characterise the material at Dounreay.</li> <li>• Sellafield already has similar materials so no meaningful change in site hazard profile.</li> <li>• Avoids new build at Dounreay and the environmental impact of this.</li> <li>• No impact on safety as existing Dounreay plan assumes material will be shipped off site to another UK location prior to site closure.</li> <li>• Planning consents and conditions for acceptance will require revision at Sellafield.</li> <li>• Storage of HEU in appropriate stores at Sellafield may require additional inspection regimes to satisfy Safeguards due to lack of gamma signature.</li> </ul>
3	Contingent	<ul style="list-style-type: none"> <li>• HEU material adds about 2% to the total storage volume requirements of category one nuclear materials at Sellafield.</li> <li>• Would add to the workload at Sellafield to treat this material. Sellafield only has a small volume of similar material.</li> <li>• Transport safety case will be difficult without characterisation and pre-treatment of material at Dounreay.</li> <li>• Sellafield already has similar materials so no meaningful change in site hazard profile.</li> <li>• Avoids new build at Dounreay and the environmental impact of this.</li> <li>• No impact on safety as existing Dounreay plan assumes material will be transported off site to another UK location.</li> </ul>
4	Dormant	<ul style="list-style-type: none"> <li>• Some material may have economic value but market unwilling to engage without additional characterisation which could be done through Dounreay treatment facility.</li> <li>• Much of the material has been reprocessed a number of times which has enhanced U236 and other isotopes which lowers its attractiveness to the market.</li> </ul>



**Exotic Fuels and Nuclear Materials - Dounreay  
Credible Options  
February 2012**

*Group 3: Irradiated fuels*

Because the material is heavily irradiated with a high fissile inventory there are no facilities in the UK outside of Sellafield that can readily handle this material. Based on this, the options are:

1. Leave material at Dounreay, and store prior to immobilization at Dounreay and eventual disposal.
2. Transfer to Thorp at Sellafield and store in Irradiated Fuel Containers within sealed, dry cans, prior to immobilisation or reprocessing.
3. Dry storage in casks at Dounreay prior to transfer to Sellafield for immobilisation or reprocessing.
4. Transfer to Sellafield and dry store in dry storage casks prior to immobilization or reprocessing with other similar materials.
5. Reprocess overseas.

Each of the above five options are considered below.

Option	Our current view	Supporting Information
1	Credible	<ul style="list-style-type: none"> <li>• Fuel is currently safely and securely stored on the Dounreay site. Potentially would need to be repackaged in the medium to long term.</li> <li>• Dounreay would have to keep its current security categorisation, which would not realise the opportunity for security cost savings at the site.</li> <li>• There would be no meaningful change in Dounreay site hazard profile.</li> <li>• Would require new build at Dounreay with their associated environmental impact of such major construction.</li> </ul>

**Exotic Fuels and Nuclear Materials - Dounreay**  
**Credible Options**  
**February 2012**

2	Credible	<ul style="list-style-type: none"> <li>• Sellafield already has similar materials so no meaningful change in Sellafield site hazard profile.</li> <li>• Avoids new build at Dounreay and the environmental impact of this.</li> <li>• Planning consents and conditions for acceptance will require revision at Sellafield.</li> <li>• Existing, mature and simple technology</li> <li>• Very flexible and does not foreclose any options at Sellafield (including cask storage)- associated sub-options will remain open until finalisation of the Change Control Request</li> <li>• Passively safe storage with sealed double containment in Sellafield storage location</li> <li>• Makes best use of existing facilities and infrastructure at Dounreay and Sellafield</li> <li>• Other MOX fuel is already stored for reprocessing or disposal in similar configuration at Sellafield, so no meaningful impact on hazard inventory or remediation activities</li> <li>• The potential storage configurations facilitate future management and disposal</li> </ul>
3	Reject	<ul style="list-style-type: none"> <li>• Dounreay would not reduce its current security categorisation, which would not realise the opportunity for security cost savings at the site.</li> <li>• There would not be a lowering in Dounreay's site hazard profile.</li> <li>• A new cask handling and storage facility would be required</li> <li>• Complex and novel technology in the UK</li> <li>• Cask can be used as a transport container but will weigh over 100 tonnes and present a challenge to transport infrastructure</li> <li>• Delays transport from Dounreay to Sellafield whilst casks and suitable reception facilities are built</li> <li>• Constrains future handling and storage options at Sellafield</li> </ul>

**Exotic Fuels and Nuclear Materials - Dounreay**  
**Credible Options**  
**February 2012**

4	Contingent	<ul style="list-style-type: none"><li>• No specific location for this at Sellafield has yet been selected though it is anticipated that adequate space exists</li><li>• Material is currently dry stored on the Dounreay site although in a wet environment.</li><li>• Fuel storage casks are a proven technology but currently none are licensed for use in the UK.</li><li>• Casks can also be used as transport containers but each flask weighs upwards of 100te and this may prove challenging for future transfers.</li><li>• Some environmental impact from manufacture of new casks and storage building.</li><li>• Minimal impact on Sellafield hazard profile as site already has similar material.</li><li>• No material safety impact.</li></ul>
5	Dormant	<ul style="list-style-type: none"><li>• MOX material has been reprocessed in France but not commercially at the high burn up and enrichment of PFR.</li><li>• Unclear if their current processes can handle this material and UK unirradiated material still presents issues.</li></ul>