Plutonium Management

Nuclear Decommissioning Authority

October 2008

1. Summary

1.1. There are significant geopolitical, technical and engineering implications in the management of plutonium. The intention of this response from the Royal Academy of Engineering to the Nuclear Decommissioning Authority's consultation on plutonium options is to address the questions posed in the consultation document. Fellows of the Academy have worked with the Royal Society to produce a more encompassing response which addresses more general questions around the management of plutonium stocks and builds on previous reports from the Society.

1.2. In a world where there are increasing concerns about energy security on the global stage and the long term cost of electricity, it is important to note that unlike any other options, industrial scale deployment of plutonium as mixed oxide (MOX) fuel in light water reactors (LWRs) is a proven technology on the international stage. If policy makers so choose, the UK has in its plutonium stockpile a significant energy resource with low technology risk which could begin to be deployed in systems which will be available in the UK in the near-medium term.

1.3. A plutonium management strategy has been long overdue and its current emergence must be applauded. The long hiatus in new nuclear build and the prolonged deliberation at Government level on energy policy has allowed the management of the UK civil plutonium stockpile to be ignored for too long. The future management of plutonium needs to take into account the current renaissance in civil nuclear power and the likelihood that it will become viewed as a potential fuel or fuel component. The management strategy for plutonium needs to be developed as an integral part of the UK energy policy and not in isolation.

1.4. Whilst challenging, the civil engineering of facilities associated with disposal options should be achievable. However there is more concern about the mechanical systems that will be required in both above ground interim storage facilities and in any eventual deep geological disposal facility. Maintenance of ventilation and mechanical handling systems, potentially for hundreds of years, could become a higher risk factor than is currently envisaged. Similar concerns exist over the performance of monitoring and control & instrumentation subsystems over such prolonged periods of time.

1.5. The Royal Academy of Engineering's believes the NDA should immediately:

- implement a programme to determine a route, both process definition and waste-form product qualification, for the plutonium residues and wastes (which have to be dealt with anyway);
- commission proper engineering studies of the process route and product waste-form qualification for the bulk of the stockpile;
- commission a study of options for re-use as a readily available and secure fuel including modification of the Sellafield MOX Plant (SMP) or new plant taking international experience into account; and
- ensure the UK is able to effectively participate in the current international research programmes (GenIV and GNEP) which are targeted towards deployment of next generation (Gen IV) reactor systems and their associated fuel cycles.

These are relevant to plutonium management strategies and will enable the UK to keep its options open for the long term on how it deals with the valuable fissile and fertile energy resources bound up in both its historic inventory and that to come from a fleet of new light water reactors (LWRs) over their lifetime.

1.6. The specific questions posed in the consultation document are addressed in order below.

2. ***NDA's Role and Responsibilities****: The factors we are planning to include in our consideration are described above and can broadly be categorised to be economic, socio-economic and safety (including security) or environmental. Are there any other significant drivers you think we should be considering in the final analysis?*

2.1. The NDA report does not recognise that Government strategy for plutonium management must be an integral part of its energy (sustainability and climate change objectives) and waste management options. The scene which NDA sets fails to put into context the unique nature of the UK's plutonium stockpile. It doesn't take account of the significant changes which have occurred in attitudes and expectations of energy security on the global stage. It does not adequately reflect the historic policies and strategies of successive governments over the past 50years which led to the creation of the stockpile in the first place (as a strategic energy resource for future deployment in Fast Reactors) and which form an important backdrop in determining next steps. The NDA fails to quantify the immense energy potential of the stored plutonium and hence presents the options as broadly equivalent when they are not. The NDA fails to adequately articulate the fact that the bulk of the UK's material is of high isotopic purity (in comparison with the plutonium derived from systems elsewhere in the world) and therefore more readily processed for the foreseeable future (60+yrs). Americium issues are overplayed and imply unnecessary complexity. Also omitted is the fact that the UK's civil stockpile is the largest in the world by some margin: a fact which has political significance in a world which sees proliferation as a major issue.

2.2. Thus the additional key strategic drivers that should be taken into consideration are:

- the contribution plutonium can make to the future security of UK electricity supplies;
- maintenance and development of the UK's scientific and nuclear engineering capabilities;
- UK's political influence and international standing in the area of the development and use of nuclear reactor technology for global electricity generation to combat climate change.

2.3. There are a number of factual inaccuracies in the introductory paragraphs of the consultation which may lead non-expert readers to be more sceptical about re-use options for the plutonium stockpile.

2.3.1. Fast Reactors

2.3.1.1. The Fast Reactors (FRs) have never been erroneously described as "20-30yrs away ever since 1960" and their lack of commercially deployment has been implied to be due to technology issues. This is not so. While some FR prototypes did encounter technical problems with the integrity of the Na/water systems, the main factor opposing the widespread commercial deployment of fast reactors hitherto has been economics and specifically the higher capital cost and associated financing of the reactor making it some 25-30% more expensive than an LWR of equivalent output. A European Consortium of Utilities and vendor companies (including the UK's NNC, CEGB, BNFL and UKAEA) developed a European FR to design maturity

and placed the design ‘on the shelf’ under the custodianship of EdF in the late 1990’s. UK FR research did not stop in 1994. The Government of the day said as a conclusion to the 1994 review that it was up to Industry rather than Government to fund ongoing research. This it did via BNFL to the tune of £1M to £2M for the subsequent decade enabling key companies and University groups to continue participation in the international research endeavour, particularly in the EU.

2.3.1.2. Government via the then DTI now BERR, originally committed to continue this funding to allow the UK to participate in the emerging international Generation IV research programme. However, funding issues and other priorities caused DTI to withdraw from the programme. This has had the effect of damaging the UK’s position as a credible research partner and causing the mainstream nuclear nations of France, the US, Russia and Japan to move ahead building relationships without UK presence of any significance. Government needs to address the research issue if it is to keep future options open. The NDA should at least articulate the strategic plans of other nations regarding commitment to recycling fuel cycles and future deployment of FRs. The future of the UK’s valuable fissile and fertile resources should not be determined without setting them in a global context of energy options.

2.3.2. Magnox Derived Plutonium

2.3.2.1. It is not strictly true to say that the Sellafield MOX Plant (SMP) is not licensed to handle Magnox plutonium. SMP is currently restricted under the justification ruling to deal with oxide fuel derived material. It would be a political and not a technical issue for SMP to handle Magnox derived material. A separate strategy is not required for Magnox derived plutonium. More information is needed to demonstrate the benefits of using Magnox plutonium as a blending feed stock.

2.3.3. THORP Derived Material.

2.3.3.1. The use of SMP or any new UK MOX plant for UK generated materials is a political and not a technical issue. The obvious way of dealing with LWR generated plutonium is to have real time reprocessing and MOX manufacture with only very short term buffer storage. The provision of an oxide derived plutonium export facility is not a technical problem, but could be a political one.

2.3.4. Foreign Owned Plutonium.

2.3.4.1. The NDA should give more details on the state of SMP in relation to its ability to meet foreign contracts. If SMP’s performance cannot be improved to that required to meet foreign demands, then the alternative strategies including the development of a new MOX plant should be explored.

2.3.5. Credible Options.

2.3.5.1. The NDA states that if the reuse option is chosen, then the spent fuel would be disposed of directly to a repository. This is only one option as it is technically feasible to reprocess spent MOX to reuse the uranium and plutonium and only the small quantity of high level waste would need to go to a repository.

2.3.6. Degradation in Store.

2.3.6.1. It is well recognised that there is degradation of the product as a result of long term storage, but recanning is a well developed procedure and manageable. The NDA erroneously gives the impression that this is a very expensive and risky job for workers.

3. ***Immobilise and Dispose:*** *We are considering the factors above, addressing the behaviour of packages in the repository and the process to treat the waste to produce a form suitable for disposal. Are there any other significant factors that you think should be taken into consideration?*

3.1. Missing from the factors is the important issue of waste-form qualification and process route qualification which will be very onerous and must be comparable with those for other wastes destined for the repository. Decades and significant millions of pounds were spent and still are being spent in deriving internationally accepted standards for glass and cement based waste-forms. The engineering challenge in deriving both appropriate process plant and engineered waste form are significant and not to be underestimated.

3.2. The UK also has an imperative to drive towards a repository location in the coming decade. Placement of waste-forms with significant quantities of plutonium will have a major impact on volume in the repository and on its design. The NDA for contingency reasons will need to take account of this as the repository is progressed. Optioneering to take account of the challenges of disposing of significant quantities of plutonium bearing material should be included. Also the impact of plutonium bearing wastes on other wastes and if appropriate spent fuel should also be considered

3.3. The NDA indicates that, if reuse is pursued, the resulting spent fuel will be physically hotter and have a higher radioactivity than the current separated plutonium from which it was derived. This is like comparing apples and pears and is therefore hardly material to the options. The UK's repository will have to cope with

- existing legacy wastes
- radioactive wastes arising from the current and future nuclear programmes
- existing unreprocessed spent fuel including that from Sizewell B if this is declared a waste
- future unreprocessed spent fuel from a new fleet of reactors now confirmed as Government policy if this is again declared as a waste

3.4. If the bulk of the UK's existing plutonium stockpile was mixed with uranium and used as MOX fuel in modern LWRs this would equate to 2 reactors worth of fuel for their lifetimes out of a fleet which could be at least 10 within the next two decades and possibly trebling by 2050.

3.5. When considering disposal the most important factor is the repository safety case. The safety case defines the requirements that must be met to ensure the safety of the workers that are operating the repository at the time of loading, the safety of the public (both current and future generations) from

3.6. In the case of plutonium disposal, the safety case has to address issues relating to containment during pre-closure repository operation, the long half life of some of the isotopes, and the mobility pathways from the repository to man and the environment. However, unlike radioactive waste, plutonium is fissile and hence the safety case needs to address the probability and impact of criticality on the overall safety and performance of the repository.

3.7. Plutonium, being a fissile material, also has a potential value and hence intrusion to recover it in future years is another factor that needs to be considered. The use of some of the plutonium isotopes for military purposes may be an issue and hence non – proliferation safeguards arrangements may introduce additional complications to the repository design and operation.

3.8. Immobilisation can be for two reasons: long-term repository performance or for non-proliferation. Immobilisation for either reason will require the development of new technology and new facilities that will be expensive and will have uncertainty in relation to success.

3.9. There are two key issues that NDA should address, assuming that criticality is covered under the heading of the repository safety case. These issues are:

- The effectiveness of immobilisation technology to deliver the twin aims of proliferation resistance and long-term repository performance. It is no use spending time, effort and cost on concepts that at the end of the day, given the long timescales under consideration, will not deliver the required outcome.

- The impact of international safeguard requirements on the design and operation of the repository.

3.10. *Low Specification MOX*. There are a number of key issues which make this option less attractive. The first is the cost of a new MOX plant with no income generation benefit. The second is the increase in volume of the product and hence the increased size of interim storage. The third is that it would not be particularly difficult to recover the plutonium from sintered pellets.

3.11. *Cement*. Cement immobilisation is not particularly attractive or effective because of the very large increase in storage volume, the design complexity of any plutonium cementation facility and the relative ease with which the plutonium could be recovered.

3.12. *Hot Isostatic Pressing*. We agree with the NDA's analysis. This option has attractions but there are significant technical and safety case issues to convert this concept into a production facility capable of processing UK plutonium stocks. Given these issues, there is great uncertainty about the cost and feasibility of this option.

3.13. *Vitrification*. There are considerable technical and safety challenges with this option. The development of a commercially viable vitrification process for

high level fission products has proved a considerable challenge for the UK, France and Japan, and has taken many years to deliver. The prospect of introducing plutonium into the process will present a considerable technical and safety challenge. The resultant facility will need to be more complex than current vitrification plants. Product qualification and homogeneity would also be an issue

3.14. It is sensible of the NDA to indicate the solution may be a combination of store, use and dispose. Since some of the material is in the form of generally agreed intractable residues, a serious programme of work should begin now to identify and qualify both waste-form and process routes for this material.

4. ***Reuse and dispose****:*

4.1. The NDA implicitly implies that the most practical use of MOX fuel is to use it in current reactors as part of a thermal reactor programme, but this is not the most productive use of separated plutonium. The use of MOX in a fast breeder programme dramatically increases its utilisation. The potential value of the UK plutonium stockpile to a future fast breeder programme should be acknowledged.

4.2. The NDA also assume a "once through" process with the spent MOX fuel going for direct disposal. It is technically feasible to reprocess MOX fuel and hence recover valuable uranium and residual plutonium, making them available for re-use in, for example, a fast reactor programme. Also, although there are some proposals for the disposal of spent fuel there is currently no wholly proven route. Hence, the NDA needs to acknowledge the potential benefits for recycling and the uncertainty over the feasibility of direct disposal. Potential increased competition for uranium supplies fuelled by the current renaissance in civil nuclear power could also make reprocessing of MOX more attractive in the future.

4.3. In addition to the economic benefit to be gained from using the plutonium to generate and sell electricity, there are other strategic benefits that should be listed. The first is the use of nuclear energy to provide a secure supply of electricity for current and future generations. The second is the use of nuclear energy as a means of combating global warming and associated climate change. The UK plutonium stockpile can contribute to both. If the plutonium were used in a fast breeder programme the UK could have secure and environmentally friendly electricity for hundreds of years. The NDA should list the strategic benefits associated with the reuse of our plutonium.

5. ***Immobilisation with High Level Waste****: Technically this option may be deliverable; however, it is likely to be very expensive and would involve slowing down the hazard reduction at Sellafield. We believe that the advantages in terms of increased proliferation resistance are outweighed by the disadvantages in slower hazard reduction at Sellafield. Do you think that this is a valid assumption?*

5.1. There are easier ways to ensure increased proliferation resistance than pursuing this option which NDA are right to propose eliminating on the grounds of slower hazard reduction at Sellafield and technical difficulty (and hence cost which consultation does not actually discuss). It is much more important to complete the vitrification programme of the existing and projected high level waste and reduce the hazard of the current HLW stocks.

6. ***Fuel Manufacture:*** *Inert Matrix Fuel (IMF) is an unproven technology, requiring significant further development and as such carries a higher risk than other fuel options. We believe that this means that IMF is not a credible option at this time. Do you agree that is it sensible to exclude the IMF option from the credible options that we present to Government?*

6.1. NDA does not need to dismiss IMF technology at this stage. Firstly if a decision is taken to re-use the stockpile as fuel, it will be for the reactor operators and vendors to specify the fuel design options. At present international research programmes involving IMF fuel are generally funded by the EU and some Member States with in kind contribution from potentially interested utilities. There are many advantages to having non fertile matrices for plutonium fuels including the fact that that they can be optimised for disposal. Just as with any new fuel, an extensive qualification and irradiation programme would have to be completed before commercial use. There may well be merit in NDA maintaining a research interest in ceramic matrices for waste purposes which have commonality with fuel matrices, thus contributing to the international knowledge base which may result in deployment of IMF fuels whilst gaining leverage for NDA interest in waste matrices.

6.2. If, as implied, in the consultation, the NDA wants to place restrictions on the drivers for plutonium bearing fuel use (e.g. maximum plutonium burndown) then FRs are a more efficient way to achieve this.

7. ***Sell:*** *Do you believe that selling plutonium to allow fuel manufacture, in compliance with all the requisite security and international treaty requirements, should be considered as a credible option?*

7.1. Given the political sensitivities surrounding plutonium and perceptions of proliferation, this does not seem a credible way forward. “Sell” means move it somewhere else in the world which in the UK’s case means sea journeys. We have 100te plus of plutonium and given that only small quantities of Plutonium can be transported for safety and security reasons, means there would be hundreds of material movements all carrying risk. Furthermore there is no current market as such and probably significant international objection to trying to create one. The NDA addresses some of the technical issues relating to transport but no indication is given of costs associated with the construction of new export facilities, new packages, licensing, security, safeguards and political activity that would be required to export plutonium

7.2. The proposal to sell the UK’s plutonium stockpile is extremely controversial and has significant technical and political challenges. The NDA does not mention or address the political, social and intergenerational implications of this option. The NDA claims that in many ways selling the UK’s plutonium can be considered to be an attractive option. We disagree and would like the NDA to say what the many ways are. We also question the claim that it could be the cheapest option. It is unlikely that any buyer would take all the UK’s plutonium and the UK would be left with a quantity of the more complex plutonium residues that would need to be treated, stored and disposed of.

7.3. Selling the 'good stuff' could be seen by some as the UK wanting to get rid of what some consider to be a liability, and under these circumstances it is unlikely that the UK could sell at a price that truly reflected the energy content of the plutonium. The UK could not only lose out on the potential income from the use of MOX for electricity generation, but also not get a price that would be sufficient to cover the costs of dealing the plutonium residues in the UK.

7.4. There is a moral dimension to selling the UK plutonium. Selling this important energy source would deprive future generations of an indigenous source of energy that could be vital to their independence and prosperity. The UK invested in a nuclear strategy to produce separated plutonium to support a future FR programme and we believe it would be unwise to give away this energy reserve at a time when the security and sustainability of our electricity supply is now regarded as being vital to our independence and national security.

7.5. More significant is the fact that this plutonium could be used by future generations in the UK to produce electricity in either thermal or fast breeder reactors. This would enable the UK to not only have the benefits from the income from the sale of electricity produced from UK MOX, but also have an indigenous supply of fuel to reduce dependence on foreign fuel.

7.6. The rationale in the NDA's argument is all about 'removing the plutonium from the NDA's financial responsibility' i.e. the implication is that it is a liability not an asset. In today's world the plutonium has enormous future energy potential which the NDA is ignoring which, in an energy hungry world, may become a significant strategic UK asset in the decades to come. We have a moral duty to future generations to ensure that the UK's plutonium is available for them to use to safeguard their prosperity and security.

8. ***Summary:*** *Is there anything else you would like to tell us or comment on in relation to the options in this paper, for example are there any of the initial traffic lights that you think seem to be categorised wrongly?*

8.1. The summary of the consultation is incomplete because the traffic light table does not include the following key factors:

- contribution to UK security of supply;
- economic value to UK from electricity sales generated from UK MOX;
- transport security and costs.

8.2. Regarding the traffic lights, it would have been helpful to have the NDA definition of what Red, Amber and Green mean in the context of the various options and the NDA criteria for judging how each colour is allocated.

8.3. Additional factors relating to foreclosure of inter-generational options, UK security of energy supply, income generation capacity for the UK, and transport security and costs, should be included to give a true reflection of the impact of each option. The definition of what the traffic lights represent in relation to the options should be defined.

8.4. In relation to the allocated traffic lights assuming green means “proven”, amber means “needs further work to make a decision” and “red” means not acceptable, we would argue, based upon the evidence in the paper, the traffic lights allocated need further justification. For example, more information is needed to support the “green” light for spent fuel disposal costs when there is no fully proven technology for the safe disposal of spent fuel and no realistic repository costs for spent fuel or other high level waste. In relation to the “Sell” option, more information is needed to justify the green light for lead time when there are currently no technical facilities available to enable the export and transport of such large quantities of plutonium. Also, given that not all the UK’s plutonium would be sold and the UK would be left with the residues that would require storage and eventual disposal, there should be a traffic light for disposal costs.

8.5. Overall the table needs to incorporate additional factors and more justification for the allocation of the traffic lights should be given before it can be considered to be a valuable contribution to option evaluation

8.6. The Royal Academy of Engineering’s believes the NDA should immediately:

- implement a programme to determine a route, both process definition and waste-form product qualification, for the plutonium residues and wastes (which have to be dealt with anyway);

- commission proper engineering studies of the process route and product waste-form qualification for the bulk of the stockpile;

- commission a study of options for re-use as a readily available and secure fuel including modification of the Sellafield MOX Plant (SMP) or new plant taking international experience into account; and

- ensure the UK is able to effectively participate in the current international research programmes (GenIV and GNEP) which are targeted towards deployment of next generation (Gen IV) reactor systems and their associated fuel cycles.

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3rd October 2008