British
Pugwash
Group

Meeting 26 November 2009 on
Securing Fissile Materials: National and International Aspects

The Management of Separated Plutonium in the UK

Report of a Working Group of the

British Pugwash Group

presented by

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Outline of presentation

- Introduction to problem: its history and recent work
- The British Pugwash approach
- Review of Options for the management of the stockpile
  - Option 1 Do nothing
  - Option 2 Bury it
  - Option 3 Burn it
- Summary and conclusions

- The British Pugwash Group members were:
  - General Sir Hugh Beach
  - Dr Ian Crossland
  - Prof Roger Cowley
  - Dr Jack Harris (died 3 February 2009)
  - Dr Christopher Watson

Introduction

- UK at a technical and strategic cross-roads.
- It now has a stockpile of ~100 tons of separated plutonium
- Initial motivation: fuel for **fast breeder reactors** in the UK
- Strategic vision: full use of the energy in natural uranium
- This vision not yet realised, and many have doubts about it
- But the technical infrastructure to produce separated plutonium exists, and is still operating
- The problem is:
  - what to do about this stockpile
  - should the policy of separating plutonium continue?

Brief history of plutonium management in the UK

- 1947 Sellafield starts making plutonium for **nuclear weapons** use
- 1965 Production becomes primarily for **civil** (**Fast Breeder)** fuel
- 1988, HMG stops fast breeder programme
- UK switches to making **MOX** fuel for non-breeder reactors
- 1993 BNFL starts up commercial MOX Demonstration Facility **MDF**
- 2001 BNFL starts up **Sellafield MOX Plant (SMP),** design 120 t/yr

  But there are problems:
  - **SMP** for unpublished reasons, **never achieves its design throughput**
  - **No UK power reactor is yet licensed to burn MOX fuel**
  - The 9/11 attack led to major security re-evaluation: plutonium stores were judged to be at risk of theft of Pu or sabotage

In summary: by 2004 the UK strategy for managing its plutonium stockpile was in disarray.

Recent developments on the problem

- In 2004 HMG dismantled BNFL; responsibility for Pu passed to the **NDA**
- During 2006-8 **NDA** undertook optioneering studies
  - January 2009 publication of documents setting out
    - The current position on the Pu stockpile
    - Possible ‘credible options’ for its management
- Valuable step in direction of **openness** on Pu policy. But:
  - no quantitative cost information
  - little new scientific data
  - no information about security aspects.
  - timescales not explained and mostly extremely long
- Two important studies by the **Royal Society:**
  - the **Mason report** (1998) recommending HMG review
  - the **Boulton report** (September 2007) reviewed options, and made recommendations.
- July 2009 HMG published ‘The Road to 2010’ , promising a discussion document

So the current situation is:

- No agreed policy on management of stockpile
- No agreed plans to correct historical mistakes
- The stockpile is vulnerable to theft or sabotage
- The world does not have a sustainable (1000 year) energy strategy which does not involve plutonium
- If other countries were to follow the UK’s example on plutonium production, the risk of nuclear weapon proliferation would increase.

So UK policy for managing plutonium is still in disarray

Why BPG undertook this study

- The published information did not:
  - Explain why SMP was currently operating well below its design output, or indicate feasibility and cost of remedying this;
  - Quantify the risks of leaving the stockpile in its present form;
  - Give enough cost information to inform discussion on way forward;

Work started within BPG in September 2007

- Since then, there have been three further developments:
  - The 2008 Energy White Paper proposed a substantial ‘new build’ of nuclear reactors, and ten possible sites have been identified
  - IPFM has highlighted the security risks of plutonium stockpiles, and urged direct disposal
  - The price of uranium has risen erratically from $7/lb to $136/lb in June 2007, and is now $48/lb.
    - This strengthens the economic case for making and burning MOX fuel.

Strategic context for this study

- National policy needs to address **two objectives** in parallel:
  - A stable energy supply policy, with built-in diversity and low CO_2 emissions
  - An international nuclear security regime, which contains threats from rogue states and terrorists
- The UK relies on **nuclear energy** to provide part of its **energy mix,** and now proposes up to 11 new reactors
- The international **nuclear security** situation is deteriorating.
  - Nine countries now own nuclear weapons, and others approaching the threshold.
  - At least two of them (India and Pakistan) have been close to military confrontation, and tensions could flare up there
  - Both Iran and North Korea are in dispute with the international community over their nuclear programmes
  - The Non-Proliferation Treaty is not a guarantee of good behaviour, and it may disintegrate unless the forthcoming quinquennial review is more successful than the last
  - **Thefts of nuclear materials** reported to the IAEA are increasing. None have yet involved enough material to make a bomb, but some of them have been getting close
  - The general level of **terrorism** has risen sharply in the past decade.

Methodology of the study

- Opinion within BPG and beyond largely divides between two overall views:
  1. **Security considerations** should be paramount, so the UK should take steps to prevent the emergence of the ‘plutonium economy’.
  2. A world-wide civil ‘**nuclear renaissance**’ is essential and unstoppable, so we should identify appropriate national and international security arrangements.
- So we decided that the BPG study should take the form of:
  - a ‘champion’ to make the case for each option
  - a ‘devil’s advocate’ to present the contrary arguments.
- The report is therefore an optioneering study
  - Final recommendations not made
  - Data and arguments made to assist decision-makers to come to valid conclusions
- Some relevant information is **classified**.
  - We have exclusively used public domain information, but have tried to draw conclusions where possible.
  - But in reaching its final decisions, HMG will need to use classified information
  - We have therefore identified questions which they may need to consider.

Options for the management of the UK stockpile

1. **Do nothing**
    - Leave the plutonium in its current physical form
    - Do only what is necessary to keep the storage risks acceptably low

2. **Bury it**
    - Put the plutonium into a form which can be safely disposed as waste when a repository becomes available.
    - The wasteform should make recovery for malign purposes difficult

3. **Burn it**
    - Convert the plutonium into nuclear fuel suitable for use in existing or foreseeable future reactors, either in the UK or abroad

Option 1: Do nothing

Champion: General Sir Hugh Beach

- **The default option**, i.e. it is what happens until (if) an alternative decision is taken.
- **Characteristics of the ‘plutonium’ at Sellafield:**
  - ~100 tons total weight (world’s largest stockpile: France second)
  - Stored as powdered plutonium oxide PuO_2, packed into ~17,000 heavy duty **steel cans** containing 5-7kg each.
  - Isotopic composition seems to be almost entirely ‘**reactor grade**’ rather than ‘weapons grade’ (ie < 93% of Pu-239),
  - Reactor grade plutonium contains a significant fraction of Pu-241, which decays (with a half-life of 14 years) to form Am-241.
    - This **‘in-growth’ of americium** makes the older currently-stored material more difficult to handle (gamma-emission and heat source).
    - The stores are air cooled, to remove the **heat** generated by radioactive decay (about 125 W/can)

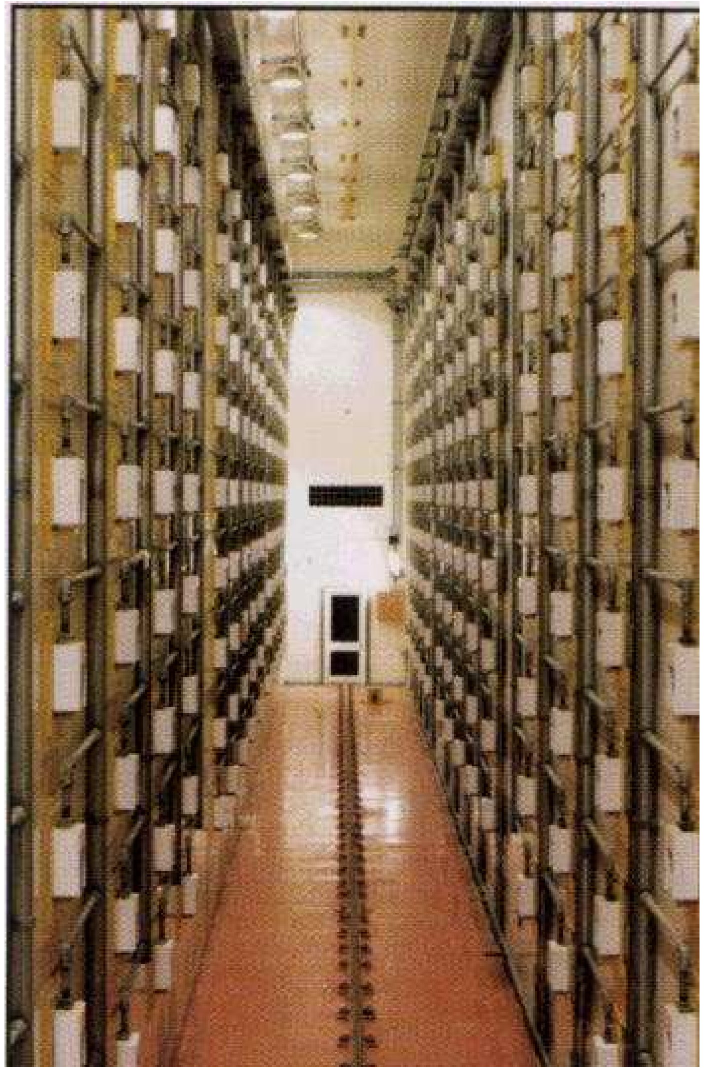
Aerial view of Sellafield plant

Sellafield has two operational plutonium stores:

- Magnox store capacity extended to 80 tons
- THORP store capacity approximately 45 tons.

The locations of these stores are shown on several unofficial maps accessible on the web:

Option 1: Do nothing contd.



These stores are mini-vaults containing racks of cans. This picture was first shown publicly on TV (Channel Four) in November 1989.

In January 2002, the *Observer* reported having sight of a highly confidential report which described the plutonium stores as ‘inadequate buildings that needed to be rebuilt’, and unable to resist attack or fire.

Option 1: Do nothing contd.

Recent improvements

- Since 9/11, BNFL has developed plans to build a blast-proof concrete **protective barrier** around the two plutonium stores.
- The plutonium stores are now in a protected **inner area** with stringent personnel vetting, ‘bank vault’ type doors, and an automated loading system so that human access is rare.
- A new store - the **Sellafield Product and Residue Store** (SPRS) – is nearing completion
  - Plutonium from the older stores will be transferred here in phases.
  - It is not large enough (reported capacity 9600 cans) to hold the entire plutonium inventory (~17,000 cans)

Security management arrangements

- These are complex
  - They involve the IAEA, the OCNS, the NDA, and the site managers Nuclear Management Partners Limited.
  - There is a Civil Nuclear Constabulary, an armed force with ~800 staff.
  - UK submits to IAEA a SECRET ‘Design Basis Threat’ document
  - This lists some 38 scenarios, including mortar attacks, vehicle borne bombs, suicide bombers and insider threats.
  - Eight counter-terrorist exercises are held each year.

Option 1: Do nothing contd.

The hazards created by the stored plutonium

Radiological hazard

- Pu not particularly hazardous externally
  - but when inhaled, 0.05 mg likely to cause cancer
- High-temperature fire or explosion needed to make it airborne
  - but a few kg of Semtex, or an aeroplane crash, would suffice.

Nuclear weapon hazard

- A terrorist group might steal say half a dozen cans, and seek to use contents to make a crude atomic bomb, or sell them to a rogue country
- A nuclear weapon can be made from '**reactor grade**' plutonium,
  - But it would be less reliable and less powerful than a 'weapons grade' bomb
  - Even if it only produced a 1 kt 'fizzle', it would have a catastrophic effect in an urban area, and would create significant radioactive fallout.
  - If a full-scale (say 20 kiloton) explosion, it would be even more catastrophic.
- The construction of such a device from PuO_2 powder is not enormously technologically demanding, and a PhD terrorist could access most (if not all) of the required information

Option 1: Do nothing contd.

Assessment of the risks involved in option 1

(i) Deterioration of the storage facility

- A minor problem

(ii) Natural hazards

- Hopefully a minor problem (but Cumbria has been in the news this week!)

(iii) Terrorist theft attack

- Our report discusses several scenarios, and concludes (with some reservations) that the stores are not an attractive target for burglary

(iv) Terrorist sabotage attack

- Possibilities include:
  - A **mortar attack**
  - A light aircraft attack
  - A **rocket propelled grenade**
  - An improvised bomb with a shaped-charge warhead.

  Our analysis suggests that these would have limited effect
- The **crashing of a large aircraft** (9/11 style) could be much more effective
  - Some 700 airliners/week pass within 50 miles of Sellafield
  - A Boeing 747 with 150 tons of fuel would ignite on impact and volatilise Pu
  - The threat of such an attack could be very hard to identify in time.
  - From publicly available information, it is not possible to assess the effectiveness of the concrete barriers in protecting the older stores against this

Option 1: Do nothing contd.

Feasibility of anti-aircraft defence

The **no-fly zone** around Sellafield is only 2 miles radius and 2,200 ft high (cf la Hague 10km and 5000 feet)

- A Rapier **defensive missile system** could be deployed to detect and destroy an incoming airliner.
  - But there are major operational, moral and political problems with this approach.

- **A fighter aircraft** from an adjacent airfield could be alerted
  - Not a plausible option for operational reasons.

Either option would depend on a **high-speed (5-minute) political decision** to order shooting the aircraft down

- With the consequent killing of 200-300 innocent civilians by shooting the aircraft down.
- It seems doubtful whether a decision could be taken fast enough

Commentary on option 1 by devil's advocate:

There are many unanswered questions relating to the current situation, requiring access to classified information:

1. Are the theft scenarios still credible, on the basis of the best available security information?
2. Are the stores currently adequately protected against sabotage?
3. Are the proposed counter-measures to crash a civil airliner on the store credible?
   - noting the decision times and the probable consequences
4. What is the timescale for planned improvements in the situation?
   - are those sufficiently short?
5. How long does the NDA envisage maintaining the current level of protection of the plutonium?
   - What store maintenance may be required?
6. Managerial and economic questions:
   - Sellafield's very uneven safety record does not inspire confidence.
   - With money tight, ideal solutions to problems may not be taken as they arise.
   - Al Qaeda and their ilk make a habit of outflanking expectations.

Option 2: Bury it

Champions: Dr Ian Crossland and Dr Jack Harris

Bury the whole UK stockpile as soon as possible in a deep geological repository

- No UK repository exists
  - HMG plans one as soon as technical and planning issues have been resolved
  - it will be 'non-retrievable'.
- The planned repository will hold ~7 tons of plutonium, dispersed within disposed intermediate level waste.
  - Scaling up to 100 tons seems feasible.
- Even if option 3 ('burn it') were taken initially, the spent fuel will have to be sent for eventual deep geological disposal.
  - So the question is not 'whether', but 'when'?
- France, Sweden and Finland are making progress towards providing a deep disposal facility.
  - The UK is trailing behind.

Design of a repository for large amounts of separated plutonium not started

- Three main design issues:
  - To avoid **criticality**,
  - To distribute the **heat** released over a sufficient volume of rock,
  - To select an appropriate **wasteform.**
- All three issues need further R&D, but look soluble

Option 2: Bury it

Example of a wasteform: copper canister for deep disposal of spent nuclear fuel in Sweden and Finland

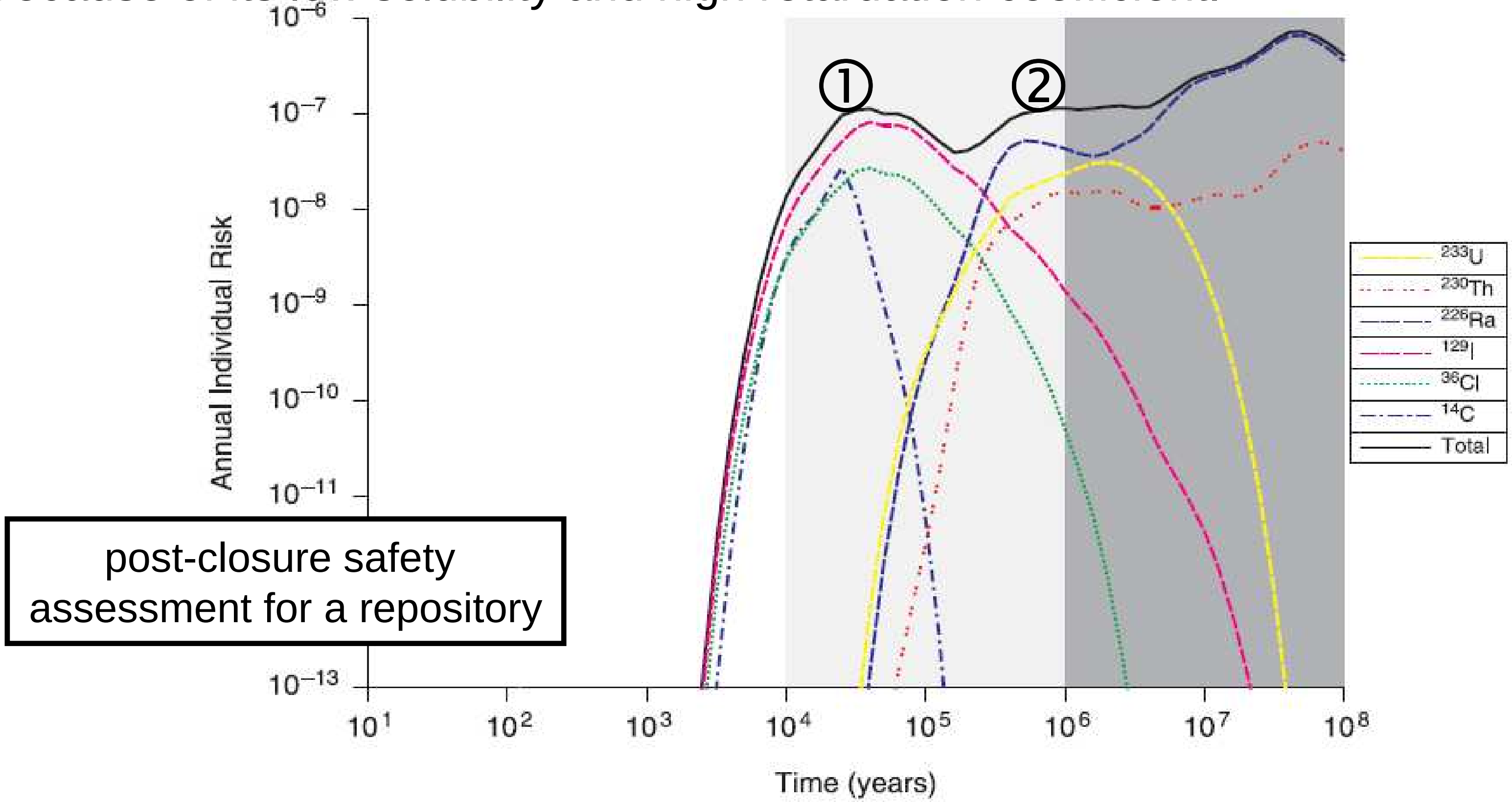
Option 2: Bury it

Results of safety studies are presented as a risk-time curve

- Peak ① at ~10,000 years: freely soluble radionuclides reach the surface
- Peak ② at ~ one million years when the slowly-migrating uranium-238 gets there.

Plutonium makes no significant contribution to the total risk

- Because of its low solubility and high retardation coefficient.



Risk-time curve showing the contributions from the most significant radionuclides

Option 2: Bury it

Above analysis applies <u>after</u> plutonium disposed and repository closed
<u>Prior</u> to deep disposal, pre-processing measures can be taken to increase its 'proliferation resistance'

1. Convert the stockpile to 'low-specification' MOX
2. Disperse the plutonium within vitrified high-level waste,
3. Jacket the plutonium with vitrified high-level waste,
4. Use Hot Isostatic Pressing to create a solid 20kg ceramic block

Debate over the need for such pre-processing

- If the existing arrangements at Sellafield are **acceptable** on an interim basis, subsequent disposal in a repository in a suitable wasteform would arguably give it sufficient 'proliferation- resistance' thereafter

- If **not,** some of the above measures would relatively quickly bring it up to the **'spent fuel standard'**
  - it would emit sufficient radiation to kill anyone close to it within a matter of minutes
  - therefore a malefactor wishing to remove the plutonium would have to use a large shielded facility which would be readily detectable.

- Other measures would give some lesser degree of 'proliferation-resistance' by increasing the technical difficulty of extracting the Pu

Commentary on option 2 by devil's advocate:

1. Technical feasibility of deep disposal of separated plutonium

- It is not proven that a suitable wasteform can be developed.
  - US DOE work on a vitrified wasteform was discontinued: for technical difficulties?

2. Proliferation resistance of plutonium during interim storage or after disposal

- It is not proven that it is un-necessary to pre-process so as to achieve the 'spent fuel standard'.
  - Plutonium could be extracted clandestinely from any of the proposed low-radiation wasteforms by a technically competent terrorist.
- Deep disposal is likewise an imperfect barrier:
  - repository has to be accessible during its operational phase
  - post-closure, access channels could be re-opened by a determined engineer.

3. The timetable for achieving disposal of the whole plutonium stockpile

- Some studies have suggested that the timescale to realise a UK repository could be very long – perhaps as much as 100 years.
  - So the timescale for option 3 might end up being shorter.

4. Possible public acceptance problems with option 2

- The inhabitants around Sellafield (the only community to have expressed interest in being chosen for repository) might oppose option 2, claiming that it was a misuse of economically valuable material to classify plutonium as waste.
  - Their attitude might influence the public acceptance of the strategy.

5. The comparative cost of options 2 and 3

- Discussed later in Option 3.

Option 3: Burn it

Champion: Prof Roger Cowley

Convert the stockpile into a nuclear fuel, and 'burn' this fuel in a suitable reactor/facility to produce electrical energy.

- Cannot be implemented immediately
  - The UK does not have a properly operational MOX plant
  - The UK does not have a reactor/facility able to burn MOX
    - though it could try to sell its plutonium to countries which do have such reactors.
- But the UK does have a semi-operational MOX plant (SMP)
  - HMG is generally sympathetic to the idea that its 'new build' nuclear power plants should be capable of burning MOX.
  - So it should have the courage of its convictions, and gear up to 'burn' its plutonium.
- This will involve a two-stage process
  - (i) establish and operate a MOX production facility with sufficient throughput to convert the stockpile into fuel on a reasonable timescale,
  - (ii) construct or modify sufficient reactors (conventional or accelerator-driven) to burn this fuel at a suitable rate.

Option 3: Burn it

- This is a continuation of a nuclear strategy which has developed within the UK nuclear industry over decades. The underlying logic is:
  - existing thermal reactors extract about 1% of the energy contained in mined uranium
  - in the long run, we are going to have to find a way of extracting the remaining 99%

- Adopting the MOX fuel cycle is a defensible first step in this direction, to be followed by the fast breeder reactor as the next step.
  - The **MOX step makes economic sense** now, and is already being implemented in a number of countries.
  - Some are also developing fast reactors.

- The failure of the **SMP** plant to operate as planned means that it will take considerable further investment to get it **back on course**.

- But if the UK does so, it will be able to make **full use of its plutonium stockpile**,
  - This will immediately acquire a commercial value
    - it could generate electricity with a current wholesale value of £27b
    - this will displace some 1 billion tons of fossil fuels.
  - The alternative options 1 or 2 involve major, un-rewarding, public expenditure

- The down side of option 3: it will contribute to the establishment of a ‘plutonium economy’
  - This will arguably have implications for international security and non-proliferation.
  - The strength of this argument is **questioned** below.

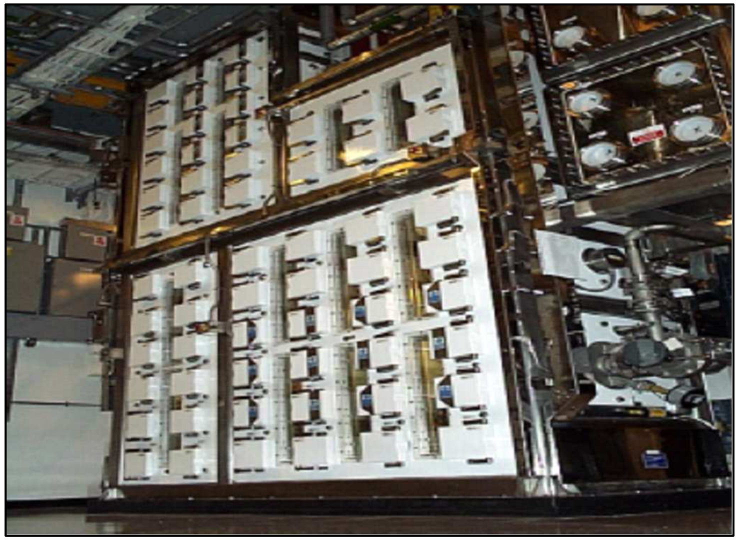
Option 3: Burn it

The conversion of the existing stockpile into MOX fuel

The history of MOX manufacture at Sellafield

- Sellafield has been making plutonium oxide into MOX fuel since 1960.
- Initially, production was carried out in an experimental facility in **B33**.
- In 1993, it was transferred to the MOX Demonstration Facility (**MDF**), a small-scale plant based on glove boxes, using semi-automated procedures.
- In the early 1980s Sellafield started to develop an improved manufacturing process, which was eventually incorporated into the design of a new fully-automated production facility, the Sellafield MOX Plant (**SMP**).

View of SMP at Sellafield



The Powder Processing Tower

Option 3: Burn it

Rod fabrication glovebox

Fuel assembly area

Option 3: Burn it

The history of this plant is a long and sad story

- The decision to build SMP was taken in 1991: it was completed in 1996, and cost £473M
- In 1999, the MDF plant ran into a problem over a Japanese contract.
  - BNFL staff had been fabricating the QA data
  - After involvement of UK & Japanese governments, BNFL closed MDF down
- Consequently, the go-ahead for SMP operation was delayed until 2001
  - after an independent review of the SMP Business Case by Arthur D Little reported that it would show a significant economic benefit.
  - Following the start of commissioning, technical problems were encountered
  - Annual production forecasts progressively dropped from 120 tons to 72 tons to 40 tons.
- Details of these technical problems have never been published in full
  - A highly ‘redacted’ version of a further report by Arthur D Little was published in July 2006
  - Media reports claim that SMP tried to introduce radically new technology without having tested it at the pilot plant scale.
- The magnitude of SMP’s technical problems can be inferred from the production figures given to Parliament on 22 February 2008:
  - the highest figure was 2.6 t/year (ie 2% of the design throughput)
- A recent NDA report discounted the possibility of taking technical measures to recover from this situation
  - but did not give reasons for this.
- On the face of it, there is no obvious reason why Sellafield should not be able to recover
  - Melox, the French MOX plant at Marcoule, has been producing at 140 tons/year

Option 3: Burn it

Measures to remedy the SMP situation

- To convert the 100 ton plutonium stockpile into MOX within say 15 years, the UK needs a plant with an output of at least 100 tons of MOX/year.
  - So either SMP needs to be fixed, or a new plant needs to be built.
    - A completely new plant might cost between £600m (Japan) and £1.5b (US).
    - Hopefully, the cost of reconstructing SMP would be considerably less.

Measures to establish a cohort of reactors able to burn MOX

- No power reactor in the UK is licensed to burn MOX fuel
  - Sizewell B could probably be adapted to burn it
  - The next-generation reactors could be specified to include **MOX-burning capability**
  - It seems likely that most, if not all, of the UK's 'new build' reactors will be able to burn MOX.

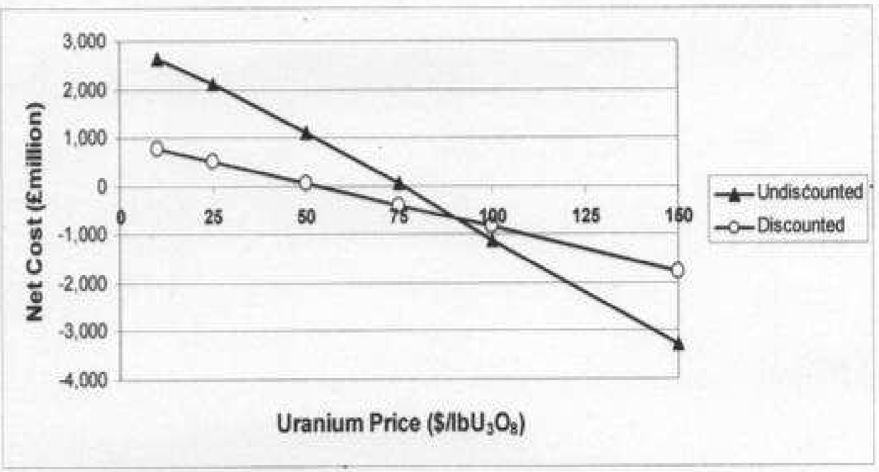
- A thermal reactor with a full-core load of MOX will burn about 25 tons/year of MOX fuel, containing about 1.6 tons of plutonium
  - so Sizewell B alone would not be able to burn the whole of the UK stockpile before its currently-planned closure date of 2035.
  - However it would be sufficient if **at least four** of the 'new build' reactors are able to operate with MOX fuel.

Option 3: Burn it

The economics of the MOX fuel cycle as compared with direct disposal

- This subject is bedevilled by arguments about historically-incurred costs and uncertainties about the future cost of uranium.
  - In our view, any historically-incurred costs should be treated as '**sunk costs**', and
  - for planning purposes it should be assumed that uranium will cost $50-100/lb over the next two decades (it is currently $48/lb)
- The only 'official' costing of these two options comes from the ERM study commissioned by NDA in 2007. On their assumptions:
  - the direct disposal option (our option 2) would cost £2-3b
  - the MOX option (our option 3) would have a **cost or net benefit** depending on the price of uranium as shown:

Figure 5 *Net Costs from Use Bounding Scenario as a function of Uranium Price*



Option 3: Burn it

- In short, the ERM report indicates:
  - the net cost of the 'MOX burning' option is **less** than the cost of the disposal option for almost any uranium price
  - the activity becomes **profitable** if the price of uranium exceeds $50/lb (on a discounted basis) or $75/lb (on an un-discounted basis).
- This conclusion is apparently contradicted by a widely cited publication by Bunn, Holdren, Fetter and Zwaan
  - That concludes that recycling plutonium as MOX costs **more** than direct disposal until the price of uranium exceeds $168/lb.
  - However these two studies do not make the same comparison.
- The NDA study examines precisely the comparison which is relevant to this report – the cost of disposing of a **pre-existing** stockpile of separated **plutonium** in two different ways.
- Bunn et al compares the cost of two **commercial** operations, both aimed at generating power from **uranium**, and starting from scratch.
  - Their study naturally includes the **capital cost** of both the **reprocessing** facility and the MOX fabrication facility.
- Unsurprisingly, their calculation is dominated by these plant costs,
  - they conclude that reprocessing is uneconomic unless the cost of uranium is rather high.
  - In the NDA-commissioned report, the capital cost of both the THORP reprocessing plant and the SMP are regarded as sunk costs, and do not feature at all.

Option 3: Burn it

Other variants of the ‘burn it’ option

- Restart a fast breeder reactor programme, or a thorium-cycle breeder reactor programme, and use the plutonium for the initial fuel inventory.
- Start an accelerator transmutation programme, by building such a facility in the UK, perhaps modelled on the ATW facility which has been proposed by Los Alamos, USA, or the facility being developed by J-PARC in Japan.
- Ship the plutonium to a ‘reliable’ country that either has MOX fabrication facilities or a fast breeder reactor programme or an accelerator transmutation facility.

We do not regard these as credible solutions to the problem of burning the UK stockpile in the short run,

- – though they may become so on a longer timescale.
- – In this context, we regret that the UK government has withdrawn from the Generation 4 International Forum

Option 3: Burn it

The 'plutonium economy' issue

- We have presupposed that management of the stockpile should be part of a larger ongoing UK nuclear power programme, in which reprocessing and the conversion of the resulting separated plutonium into MOX fuel are carried out.
- This is precisely the outcome which some opponents of this option fear,
  - it makes the UK part of the world-wide 'plutonium economy', instead of being one of the nations leading the movement to eliminate plutonium altogether.
- There are several arguments which can be deployed to weaken the 'plutonium economy' argument.

The limited value of reactor grade plutonium as a nuclear explosive

- All the nations which have sought to go down the plutonium route to produce a nuclear weapon have chosen to use 'weapons grade' plutonium
- The plutonium route to a nuclear weapon is more technically demanding than the uranium-235 route,
  - a very high core density has to be achieved using shaped explosive charges.
  - If the plutonium is of reactor grade there is a greatly increased probability of getting only a 'fizzle'. So a terrorist would greatly prefer to go down the uranium route

The relatively inert chemical form of MOX

- MOX fuel is a very inert material, and rather unsuitable for making a 'dirty bomb'

Option 3: Burn it

Commentary on option 3 by devil's advocates:

The americium in-growth problem

- The more americium there is in the plutonium feedstock, the more expensive it becomes to shield the operators of the MOX plant and the reactor.

Uncertainties and costs of SMP reconstruction

- The wall of silence surrounding the SMP plant makes it difficult for an outsider to have an informed view on the likely cost of getting its output up to 120 tons/year.
  - Publishing the 2006 Arthur D Little review in its full form would be helpful, since almost all the relevant technical and cost information has been 'redacted' out.

Uncertainties over availability/ economic performance of MOX-burning reactors

- It is not certain that it would be cost-effective to convert Sizewell B to burn MOX
- none of the potential operators of the 'new build' reactors in the UK have committed to making them capable of burning MOX.
- Although France is burning MOX, the economics of this are not very clear

Comparative costs of options 2 and 3

- It would be helpful if the NDA would published the commercial calculations, and the technical and economic assumptions underlying the ERM report.
  - It may be premature to base policy on that report.

The 'plutonium economy' argument

- The case made against the 'plutonium economy' arguments is rather overstated

Summary and conclusions

- We had hoped that this study would develop each of three options up to the point where we could recommend a preferred best strategy.
  - Sadly, we have been unable to do that, because too much of the required information is not in the public domain.
- This is partly for **security** reasons, and partly for **commercial** reasons.
  - But it is difficult to resist the conclusion that it is partly because publication would draw attention to **failures** in HMG and public/private sector management.
    - The history of the UK nuclear programme is rather full of expensive mistakes
    - It has been rather too easy to invoke commercial or security considerations to conceal technical, commercial and political mis-judgements.
    - We hope that this report will assist in the process of achieving greater openness in future.
- It is likely that the eventual solution will involve a **mixture** of two, or very possibly all three options.
  - Primarily because of the timescales involved.
  - Neither option 2 nor 3 can be implemented in full very quickly –
    - option 2 requires the creation of a UK repository for nuclear wastes (with NIMBY delays)
    - option 3 involves putting right the technical failures of the past decade in the establishment of a reliable plant for the manufacture of MOX.
  - So in the short run, the UK has no alternative but to make option 1 work,
    - that is again difficult because of the inadequate protection of our existing plutonium stores against the latest manifestations of the terrorist threat.

Summary and conclusions

The case for option 1 ('do nothing')

- This has been the *de facto* approach for two decades.
- Actions to cope with the evolving terrorist threat are generally being well managed.
- The key threats are theft of plutonium, or in crashing a large airliner onto the store.
- The measures taken to protect against theft are probably adequate.
- The counter-measures taken so far against an aircraft crash have not been publicised and may be insufficient,
  - doing more would involve pouring large amounts of concrete, which takes time
  - the alternative - shooting down civilian airliners which get within a 'danger zone'- would require very rapid decision-taking, have an appalling human cost, and horrendous possibilities of error or misinformation.

Summary and conclusions

The case for option 2 (‘bury it’)

- This option puts all the separated plutonium into a repository 500 m below the surface.
  - It would be difficult to access,
  - it could perhaps be made self-protecting by mixing it with highly radioactive material
- This will take a considerable time to implement, because the UK does not yet possess such a repository.
  - Given the history of delays in attempts to create one, the NDA is currently planning on the basis that it will take many years to reach agreement on a site, and construct a repository capable of accepting conditioned Pu.
- Work still needs to be done on selecting an appropriate wasteform.
  - However the experts seem agreed that this is a soluble problem.

Summary and conclusions

The case for option 3 (‘burn it’)

- If mankind is going to rely on nuclear energy, it will have to learn to use more than 1% of the energy in the uranium which it mines.
- So the ‘once-through’ fuel cycle which many countries operate is going to have to be replaced by a cycle involving reprocessing
  - in the short-to-medium run using MOX fuel in thermal reactors
  - in the long run, using fast breeders or accelerators.
- Once that has been accepted, the plutonium in the UK stockpile becomes a major asset
  - it could generate electricity with a value of at least £27b.
- The cost of solving the problems facing THORP and SMP is relatively small. However there are difficulties:
  - The situation on SMP is scandalous.
    - A plant with a design throughput of 120 tons/year, which was fully constructed in 1996, is still only operating at ~2% of its design throughput, and is beset by technical problems.
    - Until the reasons for this are published it will be impossible to have an informed view about how best to remedy the situation;
  - The UK currently has no reactors capable of burning MOX, though Sizewell B could help, and the ‘new build’ reactors could be specified to burn MOX.

Summary and conclusions

Deciding between the three options

- Economic considerations may well prove decisive
  - but it is still far from clear which of the options (or what combination of them) will eventually win in strictly financial terms.
  - The ERM study commissioned by the **NDA** has conclusions that are rather **supportive of option 3**.
    - However their technical assumptions and economic calculations have not yet been published, so it is not easy to validate them. More work remains to be done in this area.
- The UK economic calculation is, by its nature, different from that elsewhere in the world
  - We have made very considerable investments in the reprocessing route, which must now be regarded as **sunk costs**.
  - This can operate to our benefit

Summary and conclusions

- It is to be hoped that before the NDA and (eventually) HMG reach a decision on how to move forward in this area, it will satisfy itself that it has answers to the many questions identified in this report
  - especially those highlighted in the **commentaries by the ‘devil’s advocates**’).
- In our view most of these answers could properly be made publicly available.
  - A few cannot, for obvious security reasons, and this will have to be taken into account in reaching the final decision.
  - However, before then, it would be very good if the decision-takers sought to involve the public in their decision to the maximum possible extent, since a positive outcome will depend strongly on **public acceptance**.