

# Developing UK policy for the management of radioactive waste

This is the Royal Society's response to the DEFRA consultation document *Managing Radioactive Waste Safely*. It has been prepared by a working group chaired by Professor Geoffrey Boulton FRS (Department of Geology and Geophysics, University of Edinburgh) and comprising Professor Charles Curtis (Department of Earth Sciences, University of Manchester), Sir Francis Graham-Smith FRS (Nuffield Radio Astronomy Laboratories, University of Manchester), Sir Martin Holdgate CB, Professor Ekhard Salje FRS (Department of Earth Sciences, University of Cambridge) and Professor Brian Wynne (Centre for the Study of Environmental Change, University of Lancaster), with support from Miss Ruth Cooper and Miss Marisa Goulden (Secretariat). This response has been endorsed by the Council of the Royal Society.

## Summary

- The problem of disposal of existing radioactive waste is serious and urgent. It needs to be resolved regardless of whether a new generation of nuclear power stations produces fresh volumes of waste.
- The DEFRA consultation document appears to assume that the principal problems of radioactive waste management concern public presentation and acceptance, and the formulation of long-term policies for ultimate storage and disposal. But, meanwhile, the management of wastes while they are awaiting disposal needs to be improved by adopting currently available waste management technologies and addressing uncertainties about appropriate solutions for some problematic existing waste streams.
- We also need new research into waste treatment, leading to new techniques that will ensure that existing and new wastes from both civil and military nuclear activities are conditioned to forms that are passively safe and robustly stored.
- Unfortunately, the relevant scientific and technological research base has been seriously diminished, and needs urgently to be reinvigorated to address these pressing issues.
- Whilst a public debate about radioactive waste management is important, public confidence will not be restored unless there is confidence in the institutions that manage consultation and debate and develop policy. For this, new institutions will be required that must meet criteria of independence, authority, transparency and accountability. They should be put in place as soon as is reasonably possible and not wait until the consultation process is completed in 2007.
- These institutions will be required to manage a three-step process:
  - a) public consultation eliciting values, priorities and the wishes of the electorate;

Policy document 12/02

April 2002

ISBN 0 85403 577 X

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- b) a process of detailed analysis and technical advice leading to the formulation of waste disposal policy;
- c) the implementation of that policy.

A Waste Management Commission should be created to undertake the first two roles. A separate waste management executive will be required to undertake the third. Its relationship with the Liabilities Management Authority and the Waste Management Commission will need to be clearly defined.

- International involvement, especially through the European Union, should be an essential element of future research on the problems of radioactive waste. Although this response concerns the UK, we recommend that European and other international collaborations (including the USA) should be explored in parallel with the present consultations. With the events of 11 September 2001 in mind, we advocate an urgent safety review which should take into account the possibility of extreme terrorist intervention.

## 1. Introduction

1.1 The Royal Society welcomes the opportunity to give its views on the development of policy on the management of nuclear waste in the UK as addressed in the consultation document (September 2001) produced by the Department of Environment Food and Rural Affairs (DEFRA). The views that the Society expresses remain consistent with those that it submitted to the House of Lords Select Committee on Science and Technology for its report on Management of Nuclear Waste (1999) and those in the Society's report on *Disposal of Radioactive Wastes in Deep Repositories* (1994). The Society's 1999 report, *Nuclear Energy – the future climate*, was concerned with the potential future role of nuclear power in UK energy policy rather than with public policy for waste management.

1.2 The DEFRA consultation document seeks responses on three sets of issues:

- processes through which a public debate on national nuclear waste policy, which takes into account public values, might be managed
- institutions through which this debate is managed, policy developed and ultimately the policy implemented and
- a series of questions about technical issues of waste management

1.3 In its consultation document, DEFRA appears to take the view that radioactive waste is currently "safely" stored, that wastes will be managed in surface stores for up to a further 50 years, and that the only major technical problem is how to manage this waste in the longer term. We note that the Nuclear Installations Inspectorate requires operators to reduce hazard by converting wastes to more passive forms and to reduce stocks of hazardous wastes to minimum volumes as quickly as possible. We believe, however, that there are fundamental scientific, engineering and technological questions arising from the nature of the wastes and their treatment that need to be addressed before policies for safe long-term management can be laid before the public. The need for such research was identified in the Royal Society's report *Nuclear Energy – the Future Climate*.

1.4 We do agree with DEFRA that a UK-wide debate is a pre-requisite for progress in developing a policy for waste management. But the Department also appears to believe that the single most pressing current issue is to determine the processes by which this debate will be stimulated and managed. Here we disagree. We believe that public confidence in the institutions that develop and implement policy is a vital prior issue. Current institutions and processes do not command public confidence. Re-designed institutions will be required if they are effectively to manage debate and develop policy.

1.5 The problem of disposal of existing radioactive waste is serious and urgent, and ought not to be delayed while discussions take place on future energy policy. Changes are essential regardless of whether a new generation of nuclear power stations produces fresh volumes of waste.<sup>1</sup> Any proposals for new nuclear power generation would of course need to be associated with acceptable proposals for management of the resultant wastes.

1.6 In our response, we first comment on technical issues for waste management and the capacity of the research base to address these issues. We then enunciate key principles for a UK radioactive waste management policy and address the vital issue of the institutions and processes that will be required if a robust national waste policy that will command public confidence and consent is to be developed.

## 2. Scientific and technical problems

2.1 The UK has a major legacy of wastes from the weapons programme and early nuclear power

<sup>1</sup> In the case of separated plutonium for example, the Royal Society, in its report *Management of Separated Plutonium* (February 1998), reviewed current practice and technical options for the management of plutonium separated by reprocessing and urged the Government to carry out an independent review of its strategy and options for stabilizing and then reducing the separated plutonium stockpile.

generation. To these wastes must be added the committed wastes from on going power generation from Magnox, Advanced Gas-cooled Reactor (AGR) and Pressurised Water Reactor (PWR - Sizewell B only) plants. A high proportion (something like 90%) of existing High Level (HLW) and Intermediate Level (ILW) wastes remain in unconditioned form. De-commissioning will generate a further significant quantity of wastes needing management for at least 100 years. These wastes must be rendered safe irrespective of any decisions about new nuclear installations.

2.2 Passivisation is not a single conditioning process that can be applied to all types of HLW (spent fuel component) and ILW. A major difficulty is that the United Kingdom's HLW is chemically very reactive. This is especially true of Magnox fuel, which consists of metallic uranium within metallic magnesium cladding. It has been argued that reprocessing this fuel is a necessary first step in the production of more passive waste forms. Reprocessing recovers fissile uranium and plutonium together with highly radioactive and very hazardous liquids, which are energetic and mobile and have a very high natural tendency to disperse. Although tanks at Windscale have been in operation without leakage for around 50 years, the need for further consideration of long-term management of waste cannot be ignored. Current practice for conditioning is vitrification, which gives a major improvement in passivity. But vitrification (and all similar procedures) inevitably produces some liquid effluent which has hitherto been discharged to sea. The ever more stringent targets imposed under the North Atlantic (OSPAR) Convention make passivisation increasingly difficult and expensive.

2.3 Fissile uranium and plutonium may also need management as wastes, but may be re-used as second cycle fuels, eventually creating still more complicated wastes. The most promising approach to long-term stabilisation of such large, fissile nuclides would appear to be within novel ceramics. AGR and PWR fuels are themselves ceramic oxides and are substantially more stable in surface environments than Magnox fuels, which is why the management policies of several nations are based on the direct disposal of spent fuel. Current practice in UK is surface storage without a clear policy on eventual disposal. Although the US regards such spent MOX fuel as being equivalent to ordinary fuel for long-term storage, there are concerns amongst UK scientists about its disposal, an issue which still needs to be resolved.

2.4 Much LLW (Low Level Waste) and some ILW contains organic matter (resins, paper, cloth) all of which, if incorporated into "final" waste forms, will eventually generate methane and carbon dioxide. Reactions involving metals will generate hydrogen. Gases escaping to the environment might include radionuclide traces.<sup>2</sup>

2.5 For these reasons we consider that there is a strong case that the current review of UK policy on nuclear waste, especially HLW and ILW, should be fundamental. During the last 50 years the nuclear industry has assumed that passivisation of nuclear waste is a simple matter of engineering, based on straightforward scientific principles. It also seems to have been assumed that such solutions could be implemented rapidly while nuclear waste was being produced. The industry therefore seems to have regarded treatment of waste as of secondary importance, and to have focused its efforts on countering what it saw as unfounded hostile public opinion and on economic concerns. We believe that today's problems are more serious than currently acknowledged and that a fundamental cause of them has been the error of the above assumptions.

2.6 We conclude:

- changes in waste management are essential regardless of whether a new generation of nuclear power stations generates fresh volumes of waste;
- industry and government have placed insufficient emphasis on continued technical developments as a basis for improved waste management, compared with their efforts to address public concern, although we welcome attempts to address the former by setting up three new research centres in universities;
- the current waste management regime falls short of that which could be achieved through the use of currently available technologies.
- in this interim period, BATNEEC (best available technology not entailing excessive cost) should be adopted;
- the variety and complexity of waste forms is such that fundamental research into optimisation of conditioning of each for long-term storage or disposal must have a high priority;
- this is even more essential if the strategy ultimately chosen involves surface storage or shallow burial, because of the proximity of the wastes to the biosphere and the risk of exposure of workers;
- the geological settings suitable for different types of store or disposal need critical examination, drawing on the substantial experience gathered

<sup>2</sup> These issues were discussed in the Royal Society's report on *Disposal of Radioactive Wastes in Deep Repositories* (November 1994)

in other countries which suggests, *inter alia*, that several other lithologies might be preferred to the crystalline basement concept that is at the core of the Longlands farm proposal.

We now discuss the capacity of the research base to address these issues.

### 3. The research base in relation to short and long term waste management needs

- 3.1 It has been noted repeatedly in the last decade that the science base for fundamental research on issues such as encapsulation, novel vitrification techniques, geological containment, and radiochemistry has been eroded in the UK, whilst research into transmutation as a means of disposing of waste has had little funding. Prior to five years ago, some fundamental research was supported by Nirex, but the large reduction in that programme has led to a decline in the knowledge base necessary for the development of advanced radioactive waste disposal strategies. Although some new research efforts have been initiated since 1996, they are inadequate in aggregate to address the need. A focused national initiative is needed to restore an adequate knowledge base in the UK.
- 3.2 The absence of investment in relevant areas of basic science, and in technological capability to keep pace with increasingly stringent requirements, has led to a situation where the costs of safe disposal of the legacy of accumulated civilian and military wastes may now exceed £85 billion.<sup>3</sup> These liabilities may increase as a consequence of the operations of power stations that use Mixed Oxide Fuel (MOX), since there does not yet appear to be a proven concept for the encapsulation and management of spent MOX fuel.
- 3.3 We argue strongly that a reinvigoration of science and technology is needed in this field, and are confident that it would do much to foster public confidence. But for this to be the case, we advise that Government should reverse the past policy of leaving such R & D largely to the industry. Hitherto, the Research Councils and the Office of Science and Technology (OST) have played a very limited role in sustaining and developing UK research capacity in the field. We strongly recommend that OST and the Research Councils now undertake, in partnership with industry and in the light of the current DEFRA review of information needs, a review of research priorities, and recommend that the necessary investment is then put in place to address them.<sup>4</sup>

<sup>3</sup> DTI (November 2001) UKAEA Quinquennial Review. This report is available from <http://www2.dti.gov.uk/energy/ukaeareview/ukaeareport/index.htm>

<sup>4</sup> Figures for government expenditure on R&D, available from the International Energy Agency ([www.iea.org/stats/files/rd.htm](http://www.iea.org/stats/files/rd.htm)), show a decline in nuclear fission research to near zero levels in 1999 and 2000. Renewable and fossil fuel energy technologies also show a steady decline in R&D budgets from 1990 to 1998/1999 and then a slight increase in 1999/2000.

- 3.4 International involvement, especially through the European Union, should be an essential element of future research on the problems of radioactive waste. We are here concerned primarily with the UK, but we recommend that possible European and other international collaborations (including the USA) should be explored in parallel with the present consultations. An independent report at EU level might be appropriate.

### 4. Key principles for a national waste management policy

- 4.1 There is an evident and urgent need for HM Government and the Devolved Administrations to develop a *comprehensive* policy for management of radioactive waste for both short-term and long-term management. We suggest that it should have the following attributes.
- 4.2 The accumulated HLW and ILW from earlier phases of both civil and military nuclear activities should be conditioned to forms that are passively safe and robustly stored. This means a requirement for the minimum of active management in order to protect the biosphere from harmful dispersal by either natural processes or rogue human intervention. With the events of 11 September 2001 in mind, an urgent safety review should take into account the possibility of extreme terrorist intervention.
- 4.3 The policy and the management practices that follow from it should be put in place as soon as reasonably practicable. The present hazard is real and the risk only maintained at acceptably low levels by very active management systems. These are costly and inevitably bring some risk of worker exposure. There are therefore good economic arguments for moving ahead expeditiously.
- 4.4 Policy should cover all forms of radioactive waste since they are often interdependent. The present consultation is about solid wastes alone. Industrial scale conditioning inevitably results in radioactive discharges to atmosphere and ocean that are integral elements in the waste equation. This is particularly true for reprocessing and subsequent manufacture of more stable glass and ceramic waste forms. Discharges are currently the subject of separate government consultations because they may affect the environment of other states or the high seas, involving issues of international law.

4.5 The UK should have in place a substantial research, development and training programme in order to guarantee best technical management practice, to address public safety concerns and to generate the trained manpower needed to maintain a substantial and sustained waste management programme.

## 5. Gaining public confidence and consent

5.1 Whilst there has been a failure to recognise that nuclear waste management, decommissioning and clean-up require the same concentration on research and technological innovation as the original nuclear development programme, there has also been a failure to recognise the need for public consent to policies related to toxic and long-lived wastes and public confidence in the institutions that manage them. It is vital that the correct choices are made about the way in which policy is developed and implemented. The starting point for a new era of policy development for nuclear waste management must be recognition of past and present failure, and the determination to develop institutions and processes designed to avoid repeating them. We fear the DEFRA approach, reflected in the consultation document, does not take a sufficiently radical view of the need for new processes and policies and the urgency of many technical issues.

5.2 The consultation document rightly recognises that an effective “public debate” must be at the heart of a process that will ultimately lead to the development of a national waste management policy. But we do not agree with the implicit assumption that public participation, properly designed and conducted, is the single important issue in remedying the widespread public mistrust of radioactive waste management policy. On the contrary, if new policies are created with this as the only major change from the past, they are likely to create further disillusion, not only on the part of the public, but also on the part of officials and experts who are awaiting new policies that will avoid past mistakes. Public mistrust is not confined to existing policies and the processes of decision making but also extends to institutions. The institutional framework does not presently command public confidence and needs radical change before processes of public consultation are undertaken. Without this, the deep public mistrust that has undermined processes of rational policy formation is likely to recur.

5.3 For these reasons we do not agree with DEFRA's apparent view that the choice of processes of public consultation is the most problematic issue. We take the view that the processes of public consultation are more or less well known and could be readily

designed by experienced social scientists working with relevant technical and policy experts. We consider that the primary task is the re-design of effective institutional arrangements.

5.4 Re-designed institutions are needed to undertake three key tasks:

- to manage an ongoing process of public consultation, including the provision of accessible technical information;
- to develop waste management policies;
- to implement those policies (particularly the accommodation of new arrangements for liabilities management).

In the following sections we first consider the content and management of the consultative process (section 6), and then turn to policy formulation (section 7) and implementation (section 8).

## 6. Managing the debate

6.1 If the debate is to lead to widely accepted policies:

- it must be seen to be open and give full opportunity for public participation;
- those managing and responding to it must be willing to consider public views and values;
- the views of people affected by radioactive waste disposal or storage facilities must be listened to, even if the UK Parliament and the Devolved Administrations determine overall national needs and priorities.

The fundamental goal of the debate will be to articulate long-term waste management solutions that meet environmental, social and economic tests and are consistent with public values.

6.2 The public debate is likely to be effective only if the institutions managing it command public confidence. They must be, and be seen to be, authoritative and independent, effective in managing an open and participatory process, able to procure and disseminate rigorously reviewed technical information, and able to commission independent research and evaluation where necessary.

6.3 A number of techniques for public consultation are now available. We endorse the broad approach set out by the Royal Commission on Environmental Pollution in Chapter 7 of their twenty-first report, *Setting Environmental Standards* (Cm 4053, 1998). We advise that if DEFRA is to oversee the debate, it should do so by establishing an independent advisory panel of social scientists experienced in these new techniques, together with scientific and

technical experts. We emphasise that public trust is most likely to be won if Government assigns the actual conduct of the consultative process to a wholly independent body with an established track record in eliciting public opinion.

- 6.4 Practice has shown that the definition of an issue by experts may not be shared by the public. The starting point for debate should not therefore be to elicit responses to a predefined issue, but to determine the issue itself. For example, the issue of how to deal with existing inventories of UK radioactive waste, carries for some the implication that the same disposal route would be acceptable for wastes from possible new-build future nuclear power stations. For them, the question of whether there should be a new nuclear power generation programme precedes that of how to dispose of waste. Identification of the issues is itself an important function of public consultation. The Royal Commission on Environmental Pollution's report *Setting Environmental Standards* (1998), and the US National Research Council's report *Understanding Risk* (1995) concur on the importance of public and stakeholder involvement in framing issues.

## 7. The development of waste management policies

- 7.1 The institutional arrangements for the development of actual waste management policies would be an outcome of the consultative process, but involvement of scientific and technical experts in informing the latter should ensure that feasible options were laid before the public.
- 7.2 A primary task of the new institution would be to define the standards that must be satisfied in a waste management regime, including the criteria to be satisfied in the selection of disposal techniques and possible waste repositories. In doing so it would take account of:
- rate and nature of production of all types of radioactive wastes, and techniques for their handling, storage and processing;
  - best available techniques not entailing excessive cost (BATNEEC);
  - capacity for "final" disposal methods to be adjusted in the light of new knowledge and changing politico-social conditions (including any elevated risk of terrorism);
  - criteria that a waste monitoring regime should follow.

The criteria and advice provided by the new institution would form the basis upon which the UK

Government and Devolved Administrations developed their radioactive waste management policies, and the regulatory agencies undertook actual management and disposal.

- 7.3 Although we would prefer the institutional arrangements to emerge from the consultative process, DEFRA have suggested options for them. We therefore comment on DEFRA's options before presenting our own preference.
- 7.4 DEFRA has suggested five options for the advice and research management functions. Our views are:

- **The Radioactive Waste Management Advisory Committee (RWMAC) to fulfil the advice function with a separate organisation to fulfil the research role.** RWMAC has performed a valuable function, but it has been a part of the past framework, is perceived as an "establishment body", and as having been associated with past, failed solutions. Public credibility would be more readily secured if it were abolished and replaced by an entirely new body that would subsume some of its functions and possibly some of its membership, but with a more broadly based membership that is not entirely dominated by experts.
- **The Royal Society was suggested as a manager.** Its great value is its independence. It would not wish to be involved formally as a direct Government agent responsible for public policy formation.
- **Nirex to continue as the waste management agency.** For understandable historical reasons, Nirex is closely associated with the failed policies of the past. There would be inevitable scepticism about the independence of its technical advice.
- **A Research Board.** This might be appropriate, but as part of the Waste Management Commission that we propose below rather than as an independent body.
- **A Research Institute** might be an appropriate means of doing much of the necessary research under contract to the Waste Management Commission, and as a means of capacity building rather than determining the research programme that is required.

### **A waste management commission**

- 7.5 In preference to any of the options set out in paragraph 7.4, we strongly support the recommendation of the House of Lords Select Committee's Report on the Management of Nuclear Waste, that an independent and scientifically

authoritative Nuclear Waste Management Commission should be set up. Such a body was advocated in the Royal Society's submission to the Committee. The Waste Management Commission should have three functions:

- to facilitate and manage the debate described in section 6;
- to advise on waste management regimes, criteria (including modes of waste-production, not merely packaging), and processes for site selection;
- to provide and procure the research needed to inform the debate (on science, technology and the social science of policy) and to manage the process of independent peer review of research.

7.6 The latter function is of great importance. Much past research has been undertaken by limited circles of contractors who have also been responsible for reviewing each other's work. It is important that research in the field is brought into the international scientific mainstream, rationally planned, competitively tendered, subject to rigorous independent review and able to ask some of the awkward questions that past research has tended to avoid. It is important that research commissioned to inform the development of policy or the public debate is reviewed by high calibre experts, who should be appropriately remunerated.

7.7 We believe it to be important that all three functions described in 7.5 are managed and promoted through a single body. The functions interact strongly, and need to be managed by a single independent and accountable body that can command public confidence. We do not support the option described in the DEFRA consultation document that the advice and research functions should be managed separately.

7.8 The purpose of the proposed "public debate" is to provide the basis for a more acceptable public policy. If current proposals by Government are adopted, and if radioactive waste disposal is considered a major issue, national policy would be formulated by the UK Parliament and (where appropriate) by the devolved Parliaments/Assemblies. We assume that in doing this, they would take account of the public debate and the advice of the Waste Management Commission. It would then be for the responsible executive agency (section 8) to bring forward specific proposals for waste management, storage and/or disposal facilities. These would be considered by local public inquiries which would examine the appropriateness of the proposals for the local setting, but would not question national policy (for example on the need for disposal sites). This restriction would be legitimated by prior public debate (section 6) of the principles that should

govern relationships between national policy and local interests. We consider that acceptance would be facilitated by the involvement of local communities in the process of site selection and other relevant matters, as is happening in, for example, Sweden. We also consider that should the Waste Management Commission believe that arguments advanced at a local inquiry raised issues of national policy, the Waste Management Commission should be enabled to bring these to the attention of ministers and Parliament.

7.9 Although we are diffident about suggesting machinery of Government, we do so to exemplify the approach that we believe is appropriate. The Waste Management Commission should be a UK-wide body, and its membership should combine scientific and technical expertise with economic, social and environmental awareness. It would need balanced representation of all parts of the United Kingdom. Members would presumably be appointed by the Secretary of State for the Environment, Food and Rural Affairs following consultation with other relevant UK departments, with the Devolved Administrations and other bodies such as the Royal Society. The Royal Commission on Environmental Pollution might serve as a model (though we do not advocate Royal Commission status), in that the new Waste Management Commission must be independent, would be appointed following a wide consultative process, and funded through DEFRA which would approve its budget and to whom its Secretary would account for expenditure. The funding implications for DEFRA and the devolved administrations should be considered in the current spending review.

## 8. Regulation and implementation

8.1 Once UK Government and the Devolved Administrations have adopted a waste management and disposal policy, who will execute it? On 28 November 2001, the Secretary of State for Trade and Industry announced the creation of a Liabilities Management Authority (LMA) to take responsibility and manage liability for clean-up of the public sector nuclear legacy. The announcement did not make clear what the relationship would be between the proposed LMA and the public debate that is the central issue for the current DEFRA consultation, and adds considerable confusion to the consideration of institutional arrangements in the DEFRA paper. It is our assumption that the LMA, or a new executive body, will be asked to make detailed technical proposals for long-term management and disposal within the framework set by Government policy on the advice of the Waste Management Commission. However this remains to be clarified with respect to

waste streams. The regulatory agencies will then determine whether the proposals adequately fulfil legal and policy requirements. Whether the executive implementation body is a division of the LMA or a newly-constituted body remains to be clarified.

8.2 It is important to make a clear distinction between the LMA, which will in practice be a waste producer through its responsibility for decommissioning and clean-up, the Waste Management Commission, responsible for advising on policy, and an executive body responsible for managing waste streams. It is vital that the role of each is clearly defined and well-understood and that they are mutually independent.

8.3 There is much to be gained by separating waste management activities from commercial activities within the BNFL ambit, and there should now be real incentives to move ahead more quickly with conditioning of the untreated waste legacy. There are four potential areas for concern:

- the timetables proposed by the DTI and DEFRA overlap and it is not apparent that the two departments are working together in developing the framework in which an effective and integrated national policy might arise. The sensitivity and difficulty of the issues demand that they should do so.

- there is every reason for government to move ahead as quickly as practicable in pursuing the developments we believe are needed. The current timetable implies a management strategy in place by 2007. It is important that electoral considerations are not permitted to delay the process.
- the precise role of the LMA in relation to the principal regulators is not clear. Problems often occur at regulatory interfaces. They can cause delays and increase costs. There is a risk that new interfaces and new problems will emerge at the LMA/regulator interfaces. They need to be anticipated.
- it is not clear how liabilities arising from military activities will be incorporated into national policy for waste management. They should be.

8.4 Public attention will be focused on an executive body, since it will be closest to the waste-producers, most engaged in detailed negotiation and, no doubt, regularly under intense pressure, legitimately so, from producer interests. Public suspicions of the capture of such bodies by producer interests are intense. It is essential to ensure that waste disposal decisions and options are not driven exclusively by pre-commitments to upstream production stages, for example the commitment to reprocessing.

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ISBN 0 85403 577 X

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