The Environment Council

BNFL National Stakeholder Dialogue

SPENT FUEL MANAGEMENT OPTIONS WORKING GROUP

REPORT

July 2002

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The Environment Council

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Foreword to the report from the Spent Fuel Management Options Working Group in the BNFL National Stakeholder Dialogue

Aim of the BNFL National Dialogue

The BNFL National Dialogue involves a wide range of organisations and individuals interested in or concerned about nuclear issues. Its aim is:

> *"To inform BNFL's decision-making process about the improvement of their environmental performance in the context of their overall development."*

The dialogue is open to national organisations and regional groups as well as well as expert and specialist concerns. If you believe you are affected by the issues, think you can contribute or wish to participate (or if you know of anyone else who should be involved) then please contact The Environment Council on 020 7632 0117. Please note the Criteria for Membership below.

Guidance on Interpreting the Report

The principle purpose of working group reports is to inform the deliberations of the Main Group of stakeholders in the dialogue and any related decisions or activities they might undertake.

This report from the working group must be read carefully. The working group has been very careful to outline where they agree and disagree and they have tried to be as explicit as possible.

Participation (by organisation or individuals) in either the overall dialogue or the working groups must not be taken as an indication of support or disagreement with the dialogue itself, its outputs or BNFL's activities.

Any quotes from the reports used in talks, articles, consultation papers and/or other documents published on paper or electronically must be put within the context given within the relevant section of the working group's report. The Environment Council strongly advise those considering quoting from the reports to forward their proposed text for review to Rhuari Bennett at The Environment Council (e-mail: rhuarib@envcouncil.org.uk)

The role of the convenor

The convenor of the dialogue is The Environment Council, an independent UK charity. The Environment Council is responsible for designing and facilitating each stage in the dialogue, and provides relevant support, such as issuing invitations and booking venues.

The Environment Council is not responsible for any issue discussed in the dialogue, and holds no formal position on any of the substantive issues that are or might be considered. It is for the participants to decide what issues are raised, how they might be addressed and how any observations, conclusions and recommendations might be recorded and communicated.

The website of The Environment Council, www.the-environment-council.org.uk displays a full history and evolution of the Dialogue, as well as all of the reports that have been produced from the process.

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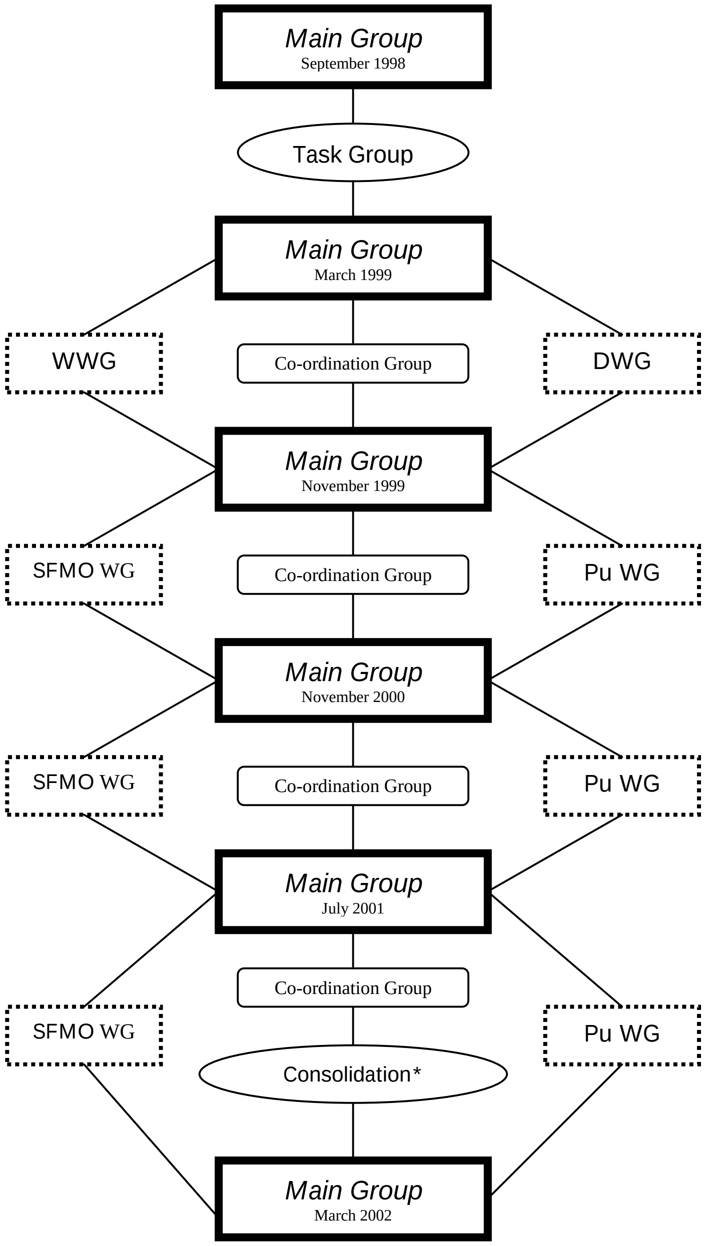
July 2002.

History of the BNFL National Stakeholder Dialogue

The diagram below outlines the inception and evolution of the BNFL National Stakeholder Dialogue process. A more detailed history and explanation of each of the groups, together with the reports produced and lists of group members is available on The Environment Council website: www.the-environment-council.org.uk



Key:

WWG	Waste Working Group
DWG	Discharges Working Group
BF WG	Business Futures Working Group
Pu WG	Plutonium Working Group
SFMO WG	Spent Fuel Management Options Working Group

* **Consolidation**: this was a phase of work including:
- Reconvening of:
  - Magnox Task Group
  - WWG & DWG
  - Transport Task Group
- LLR Task Group
- BF WG startup
- Evidence gathering

Notes:
- The Coordination Group is responsible for providing guidance on linkages and continuity between groups, as well as identifying problems and "potential wobbles."
- "Socio-Economic" and "Transport" issues were discussed throughout the process

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The Environment Council

BNFL : NATIONAL STAKEHOLDER DIALOGUE

GROUNDRULES

6th DRAFT

17th November 2000

SELECTION CRITERIA FOR WORKING GROUPS

One output from Main Group meetings of stakeholders in the BNFL National Stakeholder Dialogue will be the formation of Working Groups. These Working Groups will carry forward more detailed elements of the work and report back to the next Main Group meeting.

Experience of Working Group meetings demonstrates that around 15 members provides a cohesive, practical and effective group. If there are more volunteers than places, a number of criteria will inform the Co-ordinating Group's selection from the volunteers.

People participating in the Working Groups must:

- represent a particular constituency and/or have relevant experience or expertise relevant to the Working Group;
- have been inducted into the process and style of working;
- accept and conform to the ground rules, and participate in their review and development;
- develop, observe and work in a co-operative spirit in the Working Group, while respecting that profound differences of opinion may exist;
- be a competent and collaborative negotiator (rather than a positional/competitive bargainer);
- be available for the full series of Working Group meetings (which may be 1 to 1½ days every month or 6 weeks) and Main Group meetings;
- be willing to undertake work between meetings, signposting or providing papers and reviewing information within the timescales agreed within the Working Group (this may be up to 1 week's work per month).

In addition to the above, the overall group profile will also influence Co-ordinating Group's choice. Ideally, each working group will need to contain representatives from the following sectors

- communities;
- company;
- customers;
- environmental NGOs;
- other NGOs;
- government;
- regulators;
- workforce;

and will need to be balanced in terms of the necessary skills.

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Executive Summary

The Spent Fuel Management Options Working Group (SFMO WG) examined the options available to BNFL ('the Company') within the overarching National Dialogue objective of advising the Company how to improve its environmental performance in the context of its commercial development. The SFMO WG met in the period 2000-2002.

The Group interpreted 'environmental performance' in terms of the broader concept of sustainable development. In the opinion of the Group this report, in conjunction with the ERM Socio-Economic report, represents the most comprehensive study to date of the implications for sustainable development of a range of management options addressing the whole spectrum of societal, economic and environmental factors.

The working process was cyclic in nature, drawing on the positive outcomes of the previous Waste and Discharge Working Groups[1], in particular using the scenarios developed by those groups.

The Group originally developed a large number of potential spent fuel management options, many of which were then eliminated by agreement. This allowed eight scenarios to be defined, ranging from 'stop now' (immediate cessation of Magnox generation and of THORP reprocessing with no MOX production) to 'blue sky' (BNFL's planned Magnox reactor lives and maximum assumed THORP business, requiring a second MOX plant).

A detailed list of 18 evaluation criteria was developed using a list of 'issues' from the Main Group of the Stakeholder Dialogue. A matrix was constructed, which contained as much hard data as possible on the scenarios.

Two major inputs to the decision making process were a socio-economic study, conducted by ERM, which provides a transparent assessment of the effects and timing of the different scenarios on the West Cumbrian economy and its population; and a cost report produced by Company and Green experts.

The Group agreed on Multi-Attribute Decision Analysis (MADA) as the technique to be used to initially evaluate the scenarios. Application of the MADA methodology led to an agreement on the ranking of the scenarios against all the criteria, but disagreement on the relative weightings ascribed to the criteria.

These divergent views led to the development of two profiles within the generic principle of sustainable development - one with a bias towards rapidly reducing environmental impacts and the other with a bias towards beneficial socio-economic aspects.

To accommodate these two perspectives, the SFMO WG used an approach called Strategic Action Planning (SAP). The aim of SAP is to make underlying assumptions explicit, and develop contingency plans for situations where assumptions turn out to be wrong. The SAP process allowed different points of view to be assimilated in plans that highlight the key areas where choices have to be made.

The Group commends this report to BNFL and to other decision-makers in the Spent Fuel Management Options study area, including its use as an input to the process of the development and role definition of the Liabilities Management Authority. The Group also believes that the report can contribute to the wider debate on the application of sustainable development principles.

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[1] These reports are available on www.the-environment-council.org.uk

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S1. SUMMARY

S1.1 The Spent Fuel Management Options Working Group suggests that this summary should provide an adequate overview of all the work undertaken and the conclusions and recommendations reached by the Group. Detailed information on the process and methodology is contained in the main body of the report and the appendices.

S2. Introduction

S2.1 This report summarises the progress achieved by the Spent Fuel Management Options Working Group (SFMO WG or 'Group'), which was one of the two working groups established at the November 1999 Main Group Meeting, the other being the Plutonium Working Group (Pu WG). These two groups represented the second stage in the stakeholder dialogue process and followed on from the positive outcomes of the Waste and Discharges Working Groups. The Group's work was informed by the commissioning of a Socio-Economic study, as recommended by the Waste Working Group[1] and Discharges Working Group[2]. This was undertaken by Environmental Resource Management (ERM) Ltd[3]. Further comment was also received from the Transport Sub Group[4]. The work of these groups was taken into account by the use of data (such as that on waste generation and stocks, on discharges, transport issues, and employment), and by the presence of a significant shared membership with the earlier and parallel groups.

S2.2 The SFMO WG met 19 times in the period 2000 to 2002, to examine the issue of spent fuel management options available to BNFL ('the Company') with reference to the overarching national dialogue objective of advising the company on how it can improve its environmental performance within the context of its commercial development. It interpreted 'environmental' in terms of the broader concept of sustainable development. The original title of the Group was to have been the Reprocessing Working Group, but it was rapidly realised that this allowed too narrow a view. In the event, the Group decided to deal with the reprocessing issue within the broader remit of examining a wide range of Spent Fuel Management Options, and the Group feels that this approach has enabled a much more complete and useful analysis to be presented.

[1] Waste Working Group Interim Report (28 February 2000)
[2] Discharges Working Group Report (28 February 2000)
[3] ERM Economics (November 2001). 'West Cumbria: Socio-economic Study'
[4] Appendix 6 – Transport Sub-Group Terms of Reference and Comments

S2.3 Previous Working Groups had identified Magnox Fuel as a priority because of problems with its long term storage and the environmental detriment associaed with its reprocessing. In contrast, both AGR and PWR oxide fuels can be stored wet or dry for long periods, and do not therefore present the urgency of decision making required for Magnox. Consequently, the Group focussed much of its attention on the Magnox options, although all fuels were dealt with fully.

S2.4 The events in the USA on 11 September 2001 occurred in the later stages of the work of the Group and prompted a review of our processes. These are discussed in paragraphs 1.14 and 5.44 et seq. The Group's assessment showed that the original rankings are robust to the concerns about increased terrorist risk.

S3. Process and Methodology

S3.1 The methodology applied was developed as work progressed as an essential part of the trust and consensus building process. Parts of the process are by their very nature iterative, though this report presents a simplified "linear" version of the discussions and conclusions. In reality the process was cyclical in nature and far less tidy.

S3.2 The Group realised at an early stage that in order to assess the impact of various spent fuel management options, it would be necessary to construct some form of matrix of options and their characteristics which, to enable comparison, would contain as much hard data as possible.

S3.3 The Group took into account the earlier reports of the Discharges and Waste Working Groups, in particular using the scenarios developed by those groups to inform the early data acquisition and select preliminary 'bounding' scenarios. It concurred with the Discharge Group's conclusion of the need for the company to be seen to strive to the utmost in reducing discharges.

S3.4 As had been the practice in earlier groups, BNFL provided technical expertise in the form of advisors to the Group. These were termed 'BNFL experts' (BX's). The need to consider cost and technical considerations led to the identification of a need for independent advice for NGO stakeholders, which in turn led to the identification of appropriate 'green experts' (GX's) to collaborate with the BX's on cost and technical matters. This collaboration proved valuable and resulted in profitable and positive discussions as well as peer reviewed data. The terms of reference for the GX's can be found in Appendix 7.

Scenario Development

S3.5 The Group originally developed a large number of potential options as illustrated in Figures 3.1-3.3. A series of examinations and iterations aided by technical input from the experts reduced this number. The options involving oxide and Magnox reprocessing without separation, long term Magnox wet storage and partition and transmutation were eliminated (paragraphs 3.9-3.12).

S3.6 The Group then constructed a series of spent fuel management scenarios between the extremes of ‘stop now’ (immediate cessation of Magnox generation and of THORP reprocessing with no MOX production) and ‘blue sky’ (BNFL planned Magnox reactor lives and maximum assumed THORP business, requiring a second MOX plant) to allow comparison with the overall objective of improving BNFL’s environmental performance as noted above. ‘Options’, defined as choices of process or activity, were generated for each nuclear fuel type. ‘Scenarios’, defined as assemblages of options which make up a possible future programme, were then developed to enable evaluation. The Group recognised that the practicality of options would vary between the different nuclear fuel types. Any ‘show stoppers’ that would clearly render the option impracticable were agreed by the application of a set of filters (see paragraph 3.7).

Scenario Management

S3.7 Having identified a large number of scenarios to accommodate various combinations of oxide and Magnox fuel management possibilities, and having identified the criteria against which the various options would be assessed, it was necessary to bound the range of business scenarios considered. A range of ‘preferred scenarios’ under the ‘stop now’ and ‘blue sky’ categories for Magnox, AGR and LWR fuels was considered.

S3.8 At the end of this extensive and highly iterative process, 13 scenarios were finally produced. Of these, five were rejected by applying the filters noted above, which left eight scenarios to be evaluated (see paragraphs 3.33 to 3.85) - they were:

- SF1a ‘stop now’ – immediate Magnox reactor and THORP closure. Leave final Magnox fuel loading in the reactor and reprocess wetted fuel in B205.
- SF1c immediate Magnox reactor and THORP closure but reprocess all current Magnox fuel through B205.
- SF1T as SF1a, including reprocessing of wetted fuel in B205, but final Magnox fuel loading is reprocessed in a new THORP head end plant when available.

- SF2 current business plan
- SF2T current business, but Magnox fuel reprocessed through a new THORP head end plant when available.
- SF3 'blue sky'
- SF3T 'blue sky', but Magnox fuel reprocessed through a new THORP head end plant when available.
- SF3T+ hybrid – As SF3T, but the availability of the new THORP head end plant enables Wylfa and Oldbury Magnox stations to operate on Magnox fuel to dates as in Appendix 4.

Criteria Development

S3.9 Having selected the scenarios, it was necessary to agree the list of criteria or characteristics against which to evaluate them. As a result of inheriting the list of 'issues' from the Main Group at the SFMO WG's inception, together with many meetings during which the criteria were analysed in an iterative process, the Group arrived at a set of initial criteria (paragraph 4.2).

S3.10 The final list of agreed criteria is given below. These were used as short-hand for a further, more detailed set of parameters which were grouped beneath agreed criteria (see paragraph 4.18 and Table 4.2).

1. Lifetime Arisings
2. Magnox Storage
3. AGR storage
4. CO_2 avoidance
5. Worker deaths
6. Environmental discharges
7. BNFL jobs
8. Rail miles
9. Sea Miles
10. Environmental Impact
11. Hazard
12. Risk
13. Transport Risk

Data Acquisition

S3.11 The development of data requirements and the generation of data was progressed in parallel to the definition of scenarios so as to minimise this work during evaluation of the scenarios. Much of the data was similar to that used for the previous working groups, and as most of the Group had been involved in these there was a reasonable level of familiarity with the units and quantities involved.

S3.12 An evaluation by the Group led to a more detailed list of criteria for judging possible scenarios:

- *Transport – amount and mode*
- *Jobs/socio-economic effects*
- *Waste, fuel and products*
- *Discharges*
- *Carbon Dioxide emissions*
- *Dose – to workforce and public*
- *Health effects*
- *Reactor lifetimes*
- Risk and hazard
- Environmental impact
- Proliferation
- Licensing and planning
- Cost
- Technical feasibility
- Public acceptability
- Profit
- Customer requirements
- Contractual obligations

The *italicised* factors were judged capable of yielding verifiable factual data, either directly or by modelling. This data was obtained and used in the analysis of options.

S4. Analytical Techniques and Analysis of the Data

Multi Attribute Decision Analysis

S4.1 Over a series of meetings the Group returned to the question of which techniques should be applied to analyse the differences between the scenarios. The Group received presentations on alternative approaches to decision analysis and on key problems in understanding the meaning and appropriate use of the data available.

S4.2 Those given most attention were Multi Attribute Decision Analysis (MADA) and the Strategic Action Planning (SAP). Decisions are made difficult (especially for complex, value-rich issues like the future of the nuclear industry) by a range of factors including:

- lack of information
- multiple stakeholders
- the desire to 'balance' pro's and con's
- uncertainty about the future
- uncertainty about objectives
- the very real complexity involved.

S4.3 The key steps in a MADA are shown in Appendix 13. They are to:

- Establish the context (identifying decision makers and key stakeholders);
- Define what "options" are available ('scenarios' as described in Section 3);

- Agree which (non overlapping) attributes may distinguish better from poorer options, by identifying "values" to facilitate checking and weighting (agreeing the criteria and associated data set – see Section 4);
- Assess expected performance – producing a table of "options" by "performance" values;
- Assign weights to attributes – with careful discussion amongst "stakeholders" – with weightings agreed adding up to 1;
- Combining weights and scores for each option (usually facilitated by specialised computer software) but only introducing aspects such as cost or public acceptability after that stage;
- All this leading to the identification of a provisional choice (or choices);
- Applying sensitivity testing.

S4.4 The SFMO WG developed its list of criteria and confirmed that, as is commonly used in the MADA technique, it would score them between 0 ('worst') and 10 ('best'). In applying the technique, the Group noted that there were no obviously stronger scenarios without weighting the criteria, so it progressed into the application of weightings. The Group collectively assessed the effects of the weightings and looked at where it thought that unjustifiable weight had been applied and collectively re-assessed the weights. There was agreement on the ranking of the scenarios against all the criteria, but disagreement on the relative weightings ascribed to the criteria. There was also agreement on a number of criteria (generally those given lower weight), including transport. However, the MADA confirmed the divergence of views on the weighting to be applied to five influential criteria: lifetime arisings, CO_2 detriment, environmental discharges, BNFL jobs and risk.

S4.5 This divergence could be characterised as differing viewpoints under the generic principle of sustainable development. Sustainable development seeks to integrate the need to protect the environment with the socio-economic well-being of people. Many of the elements of sustainable development are difficult to reconcile in practice and can be taken selectively to promote a spectrum of views from emphasis on environmental protection to emphasis on socio-economic development.

S4.6 These differing viewpoints were significantly driven by the factors examined in Appendix 10 and the polarisation of these views is summarised in Table S.1 on the following page.

Factor	Environmental Protection View	Socio-economic View
Public Dose	Any additional public dose is not seen to be justifiable; ‘world all time’ collective doses should therefore be taken into account; collective doses and hence detriments are large.	Any additional public doses should be subject to tolerability of risk, doses >10 Microsieverts per year are therefore most relevant, collective doses and hence detriments are small
Dose-risk relationship	This is inadequately represented by ICRP and NRPB models, and is currently under review by the CERRIE study. [5, 6]	This is conservatively represented by ICRP and NRPB models
Jobs, unemployment detriment etc.	The socio-economic advantages of continued operation are significant, but carry less weight than environmental detriments.	The socio-economic advantages of continued operation are significant, and carry more weight than environmental detriments.
CO_2 Detriment	Magnox reactor closure would not add significantly proportion to UK CO_2 discharges and is irrelevant to the central argument of whether to continue reprocessing.	The CO_2 avoided by continuing Magnox Generation is significant in total and can be imputed to have a significant value.
Material stocks and plant operations	The hazards and risk of radioactive material stocks, and of continued plant operation, are held to be a more significant factor in weighting options.	The hazards and risk of radioactive material stocks, and of continued plant operation, are held to be a less significant factor in weighting options.

Table S.1

[5] Consultative Exercise on Radiation Risks from Internal Emitters (CERRIE), within the auspices of COMARE.

[6] The Main Group recommended that these considerations were reviewed in the light of LLR concerns. The SFMO WG have had insufficient time to revise the SAP’s however they have considered LLR concerns and are of the opinion that a ten-fold increase in the radiological impact of ionising radiation would not alter the outcome of the report. This is because environmental discharges were weighted heavily during the MADA work and additional weight would not affect the MADA results.

S4.7 Analyses of these polarised views allowed the development of two illustrative profiles - one with a bias towards incorporating sustainable development criteria by rapidly reducing environmental discharges and the other by using a bias towards socio-economic aspects. These two outcomes were termed Profile 1 (environmental) and Profile 2 (socio-economic). Broadly speaking, under Profile 1 the SF1 ('stop now') alternatives ranked highest and the SF3 ('blue sky') alternatives lowest. Under Profile 2, ranking of the alternatives was reversed. This is consistent with Profile 1 concentrating on environmental protection – e.g. the environmental improvements from the 'stop now' scenarios outweigh the socio-economic benefits of longer operation, while Profile 2 concentrates on socio-economic well-being – e.g. the extension of work gives a socio-economic benefit which outweighs the detrimental environmental effects.

Costs

S4.8 Costs are an important determinant in the MADA process. The plotting of the costs against the weightings of various scenarios provide a final sensitivity analysis to produce an 'efficiency frontier' against which to view those scenarios which best meet the measures of cost-effectiveness and environmental improvement (see paragraph 5.24 et seq). The cost figures used by the Group were those provided by the GX and BX.

S4.9 The GX's and BX's worked together to develop the cost report, which is attached at Appendix 14. The appendices of this GX/BX report are available on the internet[7]. Some members of the Group were strongly in favour of including these appendices in this report, but making them available via the web was felt to be a more appropriate way to avoid unbalancing the report. The BX's pointed out that the actual prices and costs assumed were not underwritten by BNFL. In addition, the level of detail presented in the report and its appendices had not been agreed by the Company. However, the Company did agree that the figures were not unreasonably inaccurate. The cost figures provided by the Company for use in the ERM socio-economic study had not been made available to the Green Experts.

[7] The Environment Council website address: www.the-environment-council.org.uk

Strategic Action Planning

S4.10 At its May 2001 meeting, the SFMO WG was given an introduction to 'strategic action planning' (SAP), a technique within the "management of uncertainty" portfolio. A typical Strategic Action Planning table would look like this:

ASSUMPTION	ACTIONS	EXPLORATIONS	DEFERRED ACTIONS (OR DECISIONS)	CONTINGENCY

ASSUMPTIONS:
Assumptions are used in strategic action planning where an uncertainty cannot be easily or quickly reduced. These are made explicit and then clearly stated. Each assumption (or group of related assumptions under an "Issue" heading) then starts a row of the table.

Typical Question(s) (TQ) - What assumptions are being made in order that this scenario can work?

ACTIONS:
What is to be done in the short term. These tend to be actions about which there is little or no uncertainty, especially with regard to their relevance or impact.

TQ – What short term action is required in order for this scenario to be pursued?

EXPLORATIONS:
Those areas of uncertainty to be researched or investigated, starting in the short term. Explorations are aimed at reducing the uncertainty relevant to the assumption and often are intended to support decisions which can safely be put off to a future date (or deferred - see below).

TQ – What needs to be known in order that the uncertainty can be reduced? How can we find out?

DEFERRED DECISIONS OR ACTIONS:
Decisions, or actions, which can be safely deferred – often pending the outcome of explorations when the uncertainty has been reduced.

These are usually decisions which present a risk if they are taken now (based on an assumption) and are better deferred until more is known and the associated risk can be reduced.

TQ – What decision/action can be deferred? When does the decision have to be made or implemented?

CONTINGENCY:
What will be done in the event that the assumption turns out to be wrong? N.B. When a number of scenarios are being considered it is common for one scenario to be the ultimate contingency for another.

TQ – e.g. What will be done if the plant suffers a catastrophic failure?

S4.11 The aim of the planning is to make underlying assumptions explicit, and develop contingency plans for situations where assumptions turn out to be wrong. The plan focuses in detail on the short term, and results in assessments which identify the impact of actions taken now and what they enable or exclude in the longer term.

The Group applied strategic action planning by taking three scenarios:

- SF1c favouring Profile 1
- SF2 representing the median business case
- SF3T+ favouring Profile 2.

S4.12 The emphasis of the work was to highlight the importance for BNFL and stakeholders of exploring the consequences of decisions that needed to be taken in the short term and to begin the necessary design work on those new plants that could be required under the contingencies identified.

S4.13 Strategic Action Planning does not identify a single end point, but provides a framework for future discussion and work. It enables decisions to be made in the future with full understanding of the consequences and implications.

S4.14 The cost information as detailed in paragraph 5.24 et seq led to the Group considering whether some scenarios should be favoured above others, or if other hybrids should be examined. There was agreement that the analysis of options by both MADA and SAP was sufficient to allow interpolation to cover hybrid scenarios within the total range, and that the study of more cases was not necessary.

S4.15 The Group found the Strategic Action Planning exercise to be of great value in allowing different points of view to be assimilated within one overall plan and to illustrate the key areas where choices have to be made. The Group strongly recommends that readers of this report examine the Strategic Action Plans (SAP's) in Section 5 thoroughly to appreciate how SAP's were applied to the range of scenarios and contingencies.

S4.16 If the changes made to assumptions for contingency planning purposes are sufficiently radical, a default to an entirely different scenario may be appropriate.

S4.17 On 28 November 2001 the Government announced the creation of a Liabilities Management Authority (LMA). This will transfer responsibility for BNFL's liabilities and associated assets to the LMA. Establishment of the LMA will require primary legislation. It was announced that a White Paper will be published in Spring 2002 covering the Government's proposals for the management of UK public sector civil nuclear liabilities. The Group noted that this would have implications for its work and recommendations and these are reflected below.

S5. Conclusions

S5.1 This is a baseline report which, after a thorough examination of all the issues, has narrowed the realistic range of choices available. It moves away from both the 'stop now' and 'blue sky' ends of the spectrum, giving greater emphasis to storage options compared to long term reprocessing. The rejection of extreme scenarios has stood the test of cyclic re-examination by the Group and peer review by the Green and Company Experts.

S5.2 The Group adopted an iterative process which emphasises that complex issues cannot be reduced to simplistic choices. Though many effects can be numerically evaluated, all decisions also involve subjective and value judgements. The Group's discussions mainly focussed on the implications of the Magnox power stations operation and the associated spent fuel route (see paragraph S2.3). This was seen to dominate the ability of BNFL to achieve early wins in the areas of discharge reduction, waste minimisation and ensuring early passivity.

S5.3 The work of the Group has revealed that that the choice of spent fuel management options is a genuinely complex area. The study has revealed, and to a great extent quantified, a wide range of environmental, health and environmental effects.

S5.4 It has not been possible to identify a single preferred future, but analysis using Multi Attribute Decision Analysis on agreed criteria has done much to make clear the competing factors. Following this, the use of Strategic Action Planning enabled the Group to derive forward plans which recommend agreed actions and decision points in a transparent format.

S5.5 The Group believes that this work can do much to clarify the difficult choices affecting decision makers in the area of spent fuel management options, who will have to optimise the competing factors across the whole range of environmental, health and socio-economic effects.

S5.6 In trying to recommend to BNFL ways in which it can improve its environmental performance, the Group has come to two ‘bounding’ views, emphasising environmental aspects and socio-economic aspects respectively. However, these two views do not adequately reflect the broad areas of consensus that were developed by the Group on the significance of many criteria notably: Magnox and oxide fuel storage, worker deaths, transport; the environmental impact of construction and the hazard associated with the plants. Conversely those areas where a broad consensus could not be achieved included the importance of lifetime arisings, carbon dioxide avoidance, environmental discharges, BNFL jobs and the risk associated with the processes. The most significant aspect lacking in consensus was the effect and implications of collective dose.

S5.7 This analysis reinforces the importance of reaching timely conclusions regarding storage and the implications for any eventual disposal. The Group believes that the report could help to inform the Government’s consultations into Solid Radioactive Waste Management and the creation of a Liabilities Management Authority.

S5.8 The Group recognised that the ‘stop now’ scenarios (SF1) which require early closure include considerable costs which BNFL could not realistically be expected to meet from its own resources. Early termination of current core activities at Sellafield, should this route be decided upon, would be of national significance. The Group recognised that the Government would have to consider the political and fiscal implications of financing SF1 ‘early closure’ options.

Socio-economic Impacts

S5.9 The Group considers that the jointly sponsored Socio-economic Study, conducted by ERM, provides a transparent assessment of the effects and timing of the different scenarios on the West Cumbrian economy and its population. It also exposes the tension between the socio-economic and environmental components of sustainability. The report makes clear that whichever future option is followed, there will be issues of employment and infrastructure support which will require mitigation. Given the impact of all scenarios on the local economy in West Cumbria, the Group concluded that the ERM report provides a firm foundation for joint action by all key stakeholders to secure new employment opportunities in West Cumbria. This is clearly reflected in the Strategic Action Plans.

S5.10 Whatever the scenario eventually adopted, in the light of the SFMO WG and Pu WG reports and embodied in future BNFL strategic planning, there is a need for an urgent and comprehensive review (based on the ERM report) of the economic impacts of BNFL's activities on the West Cumbrian economy. The Group is pleased that the ERM report has been published following careful consideration by local stakeholders. This is now the subject of further joint consideration by BNFL, the Unions, Local Authorities, government organisations and NGOs.

Spent Fuel Management

S5.11 A wide range of options was examined, as indicated in Figures 3.1 - 3.3. These were only narrowed down after an extensive iterative process involving the Group, GX's and BX's.

<u>Reprocessing</u>

S5.12 The benefits and detriments of both Magnox and oxide fuel reprocessing were examined through the MADA process. The consequential actions associated with the various SFMO WG scenarios are reflected in the SAP's. These allow for a default from reprocessing to storage at every stage of the developing plans.

S5.13 The associated socio-economic detriments and benefits are mentioned above.

<u>Magnox Fuel</u>

S5.14 The chemical reactivity of Magnox fuel compared to that of either AGR or PWR oxide fuels limits the applicability of some of the possible fuel management options, hence the importance of reprocessing Magnox fuel. There is strong agreement that the performance of B205 Magnox Reprocessing Plant at BNFL Sellafield is the key determinant of the end of the Magnox programme. A joint study of processes by the GX's and BX's plus a review of regulatory views has led the Group to agree that:

- Options involving the drying of already wetted Magnox fuel are not practical, mainly because the time taken to develop and institute drying techniques exceeds the safe wet storage time of the fuel. This would be a major regulatory concern.
- Dry storage of Magnox which has not been wetted, including storage in reactors, is technically feasible as a short term option. Longer term storage gives major regulatory concern about issues such as the availability of a long term management option addressing passivity.

S5.15 The Group reiterates the conclusions of the Waste Working Group[8], which emphasised the concept of passive storage. Passivity may be difficult to establish in absolute terms but relative values are easier to define. The more passive the waste form the lower the level of institutional control required. From the MADA the Group was able to conclude that, of all the SF1 scenarios, the SF1a scenario was 'least attractive' to all participants.

S5.16 The SAP's are based on a reference minimum B205 programme as seen in Appendix 4. This matches projected lifetime arisings of spent Magnox fuel as closely as possible to the performance of B205 without compromising reactor operations. Recognising concerns about B205 throughput, the SAP's recommend further monitoring, exploration and contingency planning of Magnox fuel storage options in the event of a shortfall.

S5.17 The programmes under 'environmental' and 'socio-economic' viewpoints coalesce if B205 does not perform i.e. 'stop now' is a subset of 'business as usual'.

THORP

S5.18 If decisions are not taken to curtail the operation of THORP, its closure date will be determined by the amount of business contracted and plant throughput. In the event that operation beyond 2020 were contemplated, abatement of discharges may be necessary to meet Ospar commitments: these aspects are all covered in the relevant SAP's. In the event of shortfalls in either plant performance or business demand, the SAP's also provide a framework for earlier shutdown by default to the SF1 options.

S5.19 The performance of the vitrification plant affects THORP operation rather than B205 (note the NII have issued a Specification regarding HAL storage volume).

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[8] Waste Working Group Interim Report (28 February 2000)

Oxide Fuel Storage

S5.20 Oxide fuels may be stored for a period of decades either wet or dry. The Group did not consider store location, either at reactors or centralised storage at Sellafield. It was noted that planning permission for the current Sellafield stores is on the basis of interim storage before reprocessing. The increased emphasis on storage in the SAP's requires decisions on timescales, safety case, permitting and siting of storage well in advance of the cessation of reprocessing of AGR fuel in THORP. Any choice involving dry interim storage for AGR fuel must be accompanied by the development and regulatory approval of a drying process and storage regime. These issues raise questions of public acceptability in West Cumbria and at reactor sites.

Cost

S5.21 The Group recognised that the 'stop now' scenarios (SF1), which require early closure, include considerable costs that BNFL could not realistically be expected to meet from its own resources and will require financing from the public purse. Early termination of current core activities at Sellafield, should this route be decided upon, would be of national significance. The Group recognised that the Government would have to consider the political and fiscal implications of financing SF1 'early closure' options.

Process Conclusions

S5.22 Strategic Action Planning based on the information derived from the MADA study proved to be a valuable exercise. It allows potentially conflicting points of view and beliefs to be accommodated within a single strategic framework. This allows default to be triggered as events unfold over time. Strategic Action Plans were derived for a 'stop now' scenario (SF1c), the 'business as usual' scenario (SF2), and the 'blue sky' scenario (SF3T+), which cover the spectrum of spent fuel management options available to BNFL.

S5.23 The subject area of this report is genuinely complex and decisions within it cannot be reduced to simple choices.

S5.24 The process was inevitably cyclic, with much iteration and revisiting of problem areas. Though much data is available, values and subjectivity mean that decisions cannot be made merely on a numerical basis.

S5.25 MADA is not a decision making tool but clarifies issues, agreement and disagreement: the combination of MADA with subsequent SAP is felt to offer a very powerful approach

S5.26 Access to information provided by the Company was critical to the Group's work. Jointly agreed procedures and joint fact-finding increases the credibility of the data.

S5.27 Commercial confidentiality will inevitably mean that costs cannot be dealt with in detail. Methods of minimising this problem need to be transparently considered at the beginning of any process.

S5.28 Making an equal level of expertise available to all stakeholders helps data credibility, information exchange and exploration of views.

S5.29 Environmental and health effects played a large part in the analysis. This is a very contentious area, especially as there is very little policy guidance. The examination of radiological risk factors by CERRIE is indicative of the fundamental differences of view that exist.

S5.30 The process allows a spectrum of views to be considered, but stakeholders can only engage if their positions are not fixed. The dialogue process cannot be used as a campaign forum

S5.31 The process must be properly timed and adequately resourced to maintain ownership

S5.32 Each stakeholder must be prepared to treat the dialogue process as a personal priority, and must work to involve and take feedback from their constituency.

S5.33 The process has enhanced understanding and would work for other sectors. While agreed conclusions have not been reached, the Group believes that the work has considerably narrowed the envelope of viable futures and makes a significant contribution to informing the decision makers.

S5.34 The Group noted that the Government's announcement of the creation of a Liabilities Management Authority (LMA) would have implications for its work and recommendations and these are reflected in the Recommendations below.

General Conclusions

S5.35 The Company has a future in spent fuel management but must recognise that how it proceeds has implications for the environment, the local economy and the workforce. Long term business focus will change from reprocessing to decommissioning and spent fuel management. The proposed Business Futures Working Group will have to consider the pace of this change, taking into account the spent fuel management option adopted and mitigation of the socio-economic impacts revealed by the ERM report.

S6. RECOMMENDATIONS

S6.1 The Group commends this report to BNFL and to other decision makers in the Spent Fuel Management Options study area, including its use as an input to the process of the development and role definition of the Liabilities Management Authority.

S6.2 In this context BNFL should seek guidance from the Government on the availability of public funds to underpin the costs involved if SF1 early closure scenarios are chosen.

S6.3 The SAP's contain the scenario-based conclusions of the Group and should be studied (Appendix 12). Key milestones from this process are given in Section 7 of this Summary.

S6.4 BNFL should ensure that its Strategic Planning:

- takes adequate account of the issues and recommendations raised in this report, and in particular the identified contingency planning needs;
- is transparent in its identification of how the conflicting needs of the environmental aspects and the socio-economic aspects have been taken into account.

S6.5 BNFL should match the projected lifetime arisings of spent Magnox fuel as closely as possible to the performance of B205 without compromising reactor operations. In the event of sudden or terminal failure of B205 the objective is to ensure that there is a minimum amount of Magnox fuel remaining in ponds. No plans should include long term storage of wetted Magnox fuel.

S6.6 BNFL should ensure that, within whichever scenario is adopted by the company, every effort is transparently made to reduce discharges and minimise waste at the earliest opportunity and that the achievement of early passivity is a defined target.

S6.7 In the light of the ERM report, BNFL and other relevant stakeholders should develop mitigation plans to counter the adverse socio-economic effects which all options involve.

S6.8 The Group recommends that the Business Futures Working Group, if it is constituted, should use the work of the Spent Fuel Management Options Working Group as a basis for further advance rather than revisit matters already covered

S6.9 BF WG may wish to consider whether there are any alternative uses for THORP after the termination of whichever current option is adopted.

S6.10 BNFL should consider the need for, and benefit of, a future group to:

- refine this report's contingency plan conclusions; and
- review the Discharge and Waste Working Group report's conclusions

S6.11 Any future dialogues should employ jointly agreed procedures, with the application of joint fact finding, selection of contractors, agreed terms of reference and joint monitoring where appropriate.

S6.12 Future working groups may wish to consider building formal peer review into their report production process

S6.13 BNFL is asked to consider the value of this report and forward this report, when finalised, to the appropriate Government Minister(s) for consideration in the light of the previous Working Group reports and the ongoing Government consultation on radioactive waste and their considerations on a national discharge strategy.

S7. MILESTONES FROM SAP's

S7.1 From the individual SAP's, the Group has identified a number of key review dates or milestones many of which are scenario dependent. The milestones common to all scenarios are given below. Other milestones should be considered in the context of the appropriate SAP.

<table>
<tr><th>Date</th><th>Action</th><th>By whom</th></tr>
<tr><td>Mid 2002</td><td>Start development of socio-economic mitigation packages.</td><td>Joint: Company, TU's Local Authorities and any other relevant stakeholders</td></tr>
<tr><td>2002-2004</td><td>Arrive at decision on future THORP programme based on
• Throughput
• Contracts
• Pond storage capacity
• Vitrification plant performance</td><td>Company</td></tr>
<tr><td rowspan="3">Latest end 2004</td><td>Decide whether or not to build head end on THORP.</td><td>Company</td></tr>
<tr><td>Develop B205 abatement option.</td><td>Company</td></tr>
<tr><td>Develop contingency plan for wetted fuel, and dry fuel in reactor cores.</td><td>Company</td></tr>
<tr><td>By 2009</td><td>Close Magnox stations to 23 May 2000 programme.</td><td>Company</td></tr>
<tr><td>Latest end 2012</td><td>Close B205</td><td>Company</td></tr>
<tr><td>2020</td><td>Sellafield site to comply with OSPAR requirements as defined.</td><td></td></tr>
</table>

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1. BACKGROUND AND TERMS OF REFERENCE

1.1 This report aims to summarise the progress achieved by the Spent Fuel Management Options Working Group for consideration by the National Stakeholder Dialogue Main Group.

1.2 The Spent Fuel Management Options Working Group (SFMO WG or 'Group') was one of two working groups to be established at the November 1999 Main Group Meeting, the other being the Plutonium Working Group (Pu WG). These two groups represented the second stage in the stakeholder dialogue process and followed on from the positive outcomes of the Waste and Discharges Working Groups.[9]

1.3 The Main Group meeting in November 1999 identified a number of issues for potential discussion; these are summarised at Appendix 1. The original terms of reference for the SFMO WG were to focus exclusively on reprocessing issues, although it was decided to widen this brief at an early stage to consider the issues of spent fuel management more generally.

1.4 The Waste and Discharge Working Groups (WWG and DWG) had played a major role in identifying the amount and type of discharges and waste associated with a range of scenarios which would underpin much of the work of the SFMO WG. In particular, the DWG had given a shared knowledge of the discharges and their relationship to operations, and similarly the WWG led to a body of credible data on waste types and volumes from different processes and programmes. The WWG had also developed principles which could be applied to the SFMO WG task – notably the agreement that the priority was for the *"prompt treatment of current and early recovery and treatment of historical wastes into adequately long-lived forms for above ground passively safe retrievable storage".* [10]

1.5 One common feature of the DWG and WWG conclusions was that neither the waste nor discharge aspects could determine the best way forward for BNFL. In particular, both groups concluded that socio-economic effects were crucial, and the WWG recommended that *"Research must be commissioned by the Company in partnership with stakeholders to model socio-economic effects. The study should look primarily but not exclusively at West Cumbria and should be conducted through a mutually acceptable process".*

[9] The Environment Council website address: www.the-environment-council.org.uk
[10] Waste Working Group Interim Report (28 February 2000)

1.6 The SFMO WG met 19 times in the period 2000 to 2002, to examine the issue of spent fuel management options available to BNFL ('the Company') with reference to the overarching national dialogue objective of advising the company on how it can improve its environmental performance within the context of its commercial development. The terms of reference developed by the Group are shown in Appendix 2 together with the terms of reference of the BNFL National Dialogue, the SFMO WG membership is shown in Appendix 3.

1.7 Although stakeholders accepted the fact that the topic of spent fuel management options (directly embracing the issue of reprocessing) would present the Working Group with a more challenging task than the earlier issues of waste management and discharges, the work proved to be far more complex than was at first expected.

1.8 At an early stage in the work of the SFMO WG, it was agreed, in line with the previous working groups' recommendations, that in order to carry out a comprehensive assessment of spent fuel options in a manner defined by these terms of reference, the socio-economic impacts of various scenarios would need to be examined as they have a direct and indirect bearing on environmental quality.

1.9 Moreover, post-Rio Earth Summit[11] definitions of 'environment' call for an holistic interpretation embracing aspects hitherto largely ignored in the environmental debate such as jobs, health, crime and social infrastructure. In short, 'environment' is thus seen as short-hand for sustainability or sustainable development, recognising that these are capable of wide interpretation.

1.10 The value of setting up a socio-economic study was agreed by the Main Group in November 1999. The SFMO WG and the Pu WG progressed the implementation of this at an early stage in their work. The value of the study was confirmed at the Main Group meeting in November 2000 when an inception report detailing the project content and timescales was endorsed[12].

1.11 The workload generated at early meetings of SFMO WG soon grew to formidable proportions. The Group was required to consider three different types of fuel (Magnox, AGR and LWR[13]), complicated by the origin of the fuel in the case of PWR arisings - domestic or foreign -

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[11] Rio Declaration on Environment and Development. Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992. Obtainable from United Nations Environment Programme website: www.unep.org

[12] BNFL National Stakeholder Dialogue: Main Group Meeting (23-24 November 2000)

together with a multiplicity of variables based on reactor exit routes, potential management regimes, regulatory issues, costs and storage requirements. As the Group immersed itself in these issues, it was clear that more meetings would be required to meet the workload.

1.12 In May 2000, during the early work of the SFMO WG, the company announced its Magnox power station closure programme, which predicted the Magnox fuel reprocessing plant (B205) at BNFL Sellafield would cease reprocessing by around 2012 (see Appendix 4). This date was later than the Reference Case previously accepted by some NGO stakeholders in WWG deliberations. The date was also dependent on B205 increasing its throughput to a programme planned to exceed 1000 tonnes per annum[14], a throughput which some stakeholders regard with scepticism.

1.13 The combination of the greater demand for meetings, the increased paperwork and the apparent lack of impact the dialogue was having on BNFL's business decisions led some NGOs to question the value of the dialogue. To address this issue, a Process Review Group, (later known as the Dialogue Review Group) was established (separate from the SFMO WG and Pu WG) where it was agreed that the dialogue was in need of streamlining. It was concluded that there needed to be fewer meetings and greater emphasis put on incorporating 'milestones' in the reports of the working groups by which the impact of the working groups - or lack of it - on the company's decisions could be gauged.

1.14 Since the attacks in the USA on 11 September 2001, attitudes to conceivable terrorist acts have changed. The attack has caused the developed world to examine its vulnerability to such events and unsurprisingly nuclear plants have been amongst the installations re-emphasised as potential targets.

1.15 In response to these fears, the SFMO WG considered the implications of the events on its work to date, and decided that, though hazard remains the same, the risk or perception of risk may have increased as a function of terrorist action. Scenarios which involve the movement or storage of larger amounts of nuclear material in a more vulnerable form may therefore be viewed as more undesirable.

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[13] Magnox: uranium metal fuel clad in magnesium alloy
AGR: Advanced Gas-Cooled Reactor Fuel – uranium oxide fuel clad in stainless steel in a graphite sleeve.
LWR: Light Water Reactor Fuel – Pressurised Water Reactor (PWR) and Boiling Water Reactor (BWR) – uranium oxide fuel clad in zirconium alloy

[14] Fuel quantities are expressed as tonnes of heavy metal (in this case uranium).

1.16 The SFMO WG revisited the MADA to factor in the increased perception of risk. This affected five criteria: *Lifetime arisings* and *Magnox storage* – to reflect the greater concern on increased inventories discussed in (1) above, *Hazard* and *Accident Risk* – to reflect a new perception that terrorist action at the site would be the initiator for the major events envisaged in this criterion, and an increased perception of terrorist action on *Transport*.

1.17 The Group's assessment is that the original rankings are robust to the concerns about increased terrorist risk. This is not to say, however, that the change in risk perception is irrelevant overall. Higher risk may require countermeasures that change cost profiles. These considerations do not affect the individual SAP's because they are scenario based.

1.18 The Group reviewed the assumptions it had previously made in relation to the various scenarios considered in its Strategic Action Plan. It found that it was unable to reflect the heightened concerns over security issues by adding assumptions related to the scenarios. The Group felt it was unable to discuss security issues in detail as these were outside the group's expertise, but their concerns were embodied in the assumption which focuses on a regulatory regime encompassing Security Safeguards and Transport as well as the Nuclear Installation Inspectorate (NII) and the Environment Agency (EA). However, decision makers will need to bear the terrorist risk element in mind when deciding on spent fuel management options.

2. PROCESS AND METHODOLOGY

2.1 The SFMO WG adopted essentially the same ground rules with regard to confidentiality, and sharing of information used successfully in the Waste and Discharges Working Groups. The SFMO WG ground rules are reproduced in Appendix 2. A key feature of this approach is that the methodology has been developed by the Group as work has progressed and this approach has been an essential part of the trust and consensus building process. Inevitably, progress has not always been straightforward, with new approaches having to be found to address difficulties as they occur. Some parts of the process are by their very nature iterative, and other initiatives were abandoned when it became clear that they were not working. The following report therefore presents a simplified ‘linear’ version of the discussions and conclusions. In reality, the process was cyclical in nature and far less tidy.

Setting the Questions

2.2 The Group recognised that there were essentially three main questions that would need to be addressed;

- What options are conceivably available for managing spent fuel?
- Which of these options are not practicable and for what reasons?
- Of the practicable options, which ones are preferred and for what reasons?

2.3 The Group realised at an early stage that in order to assess the impact of various spent fuel management options, it would be necessary to construct some form of matrix of options and their characteristics which, to enable comparison, would contain as much hard data as possible (i.e. waste arisings, discharges, capital spend, facilities required etc) and other effects. These other effects and impacts would by their very nature be less quantifiable (e.g. risk, hazard and public acceptability) and for some stakeholders their importance or relevance would largely be interpretive and a matter of judgement rather than fact.

2.4 It was therefore agreed that a data matrix would be constructed, initially for illustrative purposes, which would contain data on the various parameters for the spent fuel management options selected. This developed into tables of reference data, which are reproduced later.

2.5 A notable category of data concerned transport issues which, together with socio-economic effects, had been identified as important issues by the November 1999 Main Group Meeting from which the SFMO WG was formed, and was included in the Cricklewood agreement[15]. Accordingly, two sub-groups were identified to work on transport and socio-economic issues.

2.6 The Socio-Economic Sub-Group (see Appendix 5 for the Framework Document and membership of the sub-group) was appointed in April 2000, with representation from both the SFMO WG and Pu WG. After a well-defined tendering procedure, Environmental Resource Management (ERM) Ltd was appointed to carry out the socio-economic study. ERM's final report[16] has now been published.

2.7 The Transport Sub-Group (see Appendix 6 for terms of reference) was not convened so promptly because it was considered that the issue could not be realistically addressed until the data matrix and the analysis of SFMO WG options was available. This led to some timescale problems for that group, and these are discussed in Sections 4 and 5 and Appendix 6 of this report.

2.8 Thus the process and methodology adopted by the SFMO WG was to construct a series of spent fuel management scenarios between the extreme cases involving:

- Immediate cessation of Magnox generation and of THORP reprocessing with no MOX production.
- BNFL planned Magnox reactor lives and maximum assumed THORP business, requiring a second MOX plant.

This approach would be used to develop the quantitative and qualitative aspects of all scenarios to inform a later process which would allow comparison with the overall objective of improving the company's environmental performance as previously defined.

2.9 The process of obtaining the data on waste, discharges, doses etc., though technically complex and time consuming, was familiar from the work of the previous two working groups. The key task that differentiates the SFMO WG from its predecessors is the need to evaluate complex outcomes to compare a range of scenarios. The methodology by which this process was achieved is tracked in the following sections of the report.

[15] Cricklewood Stakeholder Dialogue (March 2000), "The Cricklewood Dialogue Process: Agreed Resolution"
[16] ERM Economics (November 2001), 'West Cumbria: Socio-economic Study'

2.10 At an early stage in the process, NGOs felt the need to seek input from their own experts as a means of verifying the data upon which many decisions to reject scenarios was based. This data was predominantly provided by the experts the company had seconded to assist the SFMO WG and it was felt that the process would benefit from dealing with data which had been verified previously as a result of the collaboration of green experts (GX) and BNFL experts (BX). This collaboration proved valuable and resulted in profitable and positive discussions as well as peer reviewed data. The terms of reference for the GX's can be found in Appendix 7.

3. SCENARIO DEVELOPMENT

3.1 In this report 'options' are generally used to mean choices of process or activity. 'Scenarios' are assemblages of options which make up a possible future programme to enable evaluation. Thus there may be several 'options' for operating THORP, with earlier or later closure, and with or without adding an ability to reprocess Magnox fuel. One of these 'options' can be combined with an assumed Magnox programme and a programme of waste management and decommissioning to give a 'scenario'. As there are many 'options' available for several different processes, the combination and permutation of these 'options' could give a very large number of 'scenarios' and this section attempts to plot SFMO WG's course in steering a manageable route through this complex task.

Identifying the Options

3.2 The range of possible options for each of the fuel types was generated and the results are summarised as below. Note that options such as disposal may not be accepted as feasible by some stakeholders, but were included as possible processes at this stage[17]. An identical list was derived for both Magnox and Oxide fuels.

- Wet store
- Dry store
- Reprocess with separation
- Reprocess without separation (without separating plutonium and uranium from the fission products)
- Store, treat then dispose (or passively safe store)
- Partition and Transmutation

3.3 It can be seen that, at this stage of the analysis, the range of possible options for Magnox and Oxide fuel is identical.

Practicality of Options

3.4 The Group recognised that the practicality of options would vary between the different nuclear fuel types. Five categories were therefore considered.

1. Magnox fuel
2. AGR oxide fuel
3. LWR oxide fuel (domestic)
4. LWR oxide fuel (foreign) in UK
5. LWR oxide fuel (foreign) not yet in UK

[17] Waste Working Group Interim Report (28 February 2000), Section 8

3.5 As a parallel activity, the previously mentioned BNFL announcement on Magnox station lifetimes of 23 May (see Appendix 4) was examined by a separate Task Group set up by the Co-ordinating Group. This reported independently and its report was used as an input by the SFMO WG. The announcement had caused considerable controversy, and the Task Group was able to clarify the implications of the announced programme, particularly in terms of throughput and timescale requirements for B205, though the 2012 date was subsequently fixed by the company. The main conclusions of the Magnox Task Group are given in Appendix 8.

3.6 Early in the analysis it became apparent that practicability would also depend on time scales. For example, some options would not be available in the short term because of long design and construction lead times, but may be available later. Conversely some management techniques, which may be acceptable in the short term, may be problematic if used for an extended period of time. Three time scales were therefore chosen:

- Short term – up to 10 years
- Medium term – up to 40 years
- Long term – up to 100 years

It was soon recognised that these timescales varied from those used by the Pu WG, but joint consideration identified no real need for rationalisation.

3.7 The original process options listed in paragraph 3.2 above were subject to an initial analysis to identify any 'show stoppers' that would clearly render the option impracticable. The questions were:

- Can you do it? (technical feasibility)
- Can it be done in time? (considering closure dates, construction lead times etc)
- Can you afford it? (assessed firstly for UK fuel only then for imports to see if the picture changes)

By asking each of these questions in turn for each option, successive filters are applied. If the overall answer at any of the three filters is "No" then that option can be set aside. The running order of the filters also ensures that impracticable options are ruled out at an early stage. The need to consider cost and technical considerations led to the identification of a need for independent advice for NGO stakeholders, which in turn led to green expert (GX) involvement (see below).

3.8 Regulatory views from within the Group were sought, and it was considered that the scenarios involving re-drying Magnox fuel would cause difficulty. It was however decided to carry on with these scenarios in order to assess the consequences if these problems could be overcome (see paragraph 3.26 regarding the dry storage of Magnox fuel).

3.9 Options involving oxide reprocessing without separation were discounted because of the cost of a new plant, the lack of any obvious funding route, and the fact that all of the output would end up as HLW. Continued storage of AGR fuel was preferable on cost, waste volume and discharges grounds.

3.10 Magnox reprocessing without separation was rejected for the same reasons as above.

3.11 Long term Magnox wet storage was rejected because of the fuel corrosion, which would lead to contaminated pond water and inevitable liquid discharges.

3.12 Partition and Transmutation was rejected because its application to existing waste streams was doubtful, it was currently unproven and might take 30 years to fully develop. This alone meant that it could not be considered for the current spent fuel management options which were all required to operate within this period.

3.13 Taking into consideration different fuel types (Magnox, AGR and LWR) in conjunction with the presence of foreign fuel in the UK awaiting reprocessing, the impending importation of other spent fuel under contract and the variety of future options through which this fuel could be dealt, nine spent fuel management categories emerged. These were:

1. Magnox reprocessing
2. Magnox dry store
3. Domestic oxide reprocessing
4. Domestic oxide dry store
5. Domestic interim wet store
6. Overseas oxide reprocessing
7. Overseas oxide dry store
8. Overseas oxide interim wet store
9. Oxide direct disposal

3.14 Applying the three time scales (short, medium, long) to these options resulted in a plethora of possible spent fuel management strategies. These can be summarised in tree diagrams such as the one below, which is reproduced as an example. As can be seen from the diagram, the Group decided to split the 'condition and dispose' technique into two options: 'condition and dispose' (which assumes the availability of a repository) and 'condition and store' (which makes no such assumption).

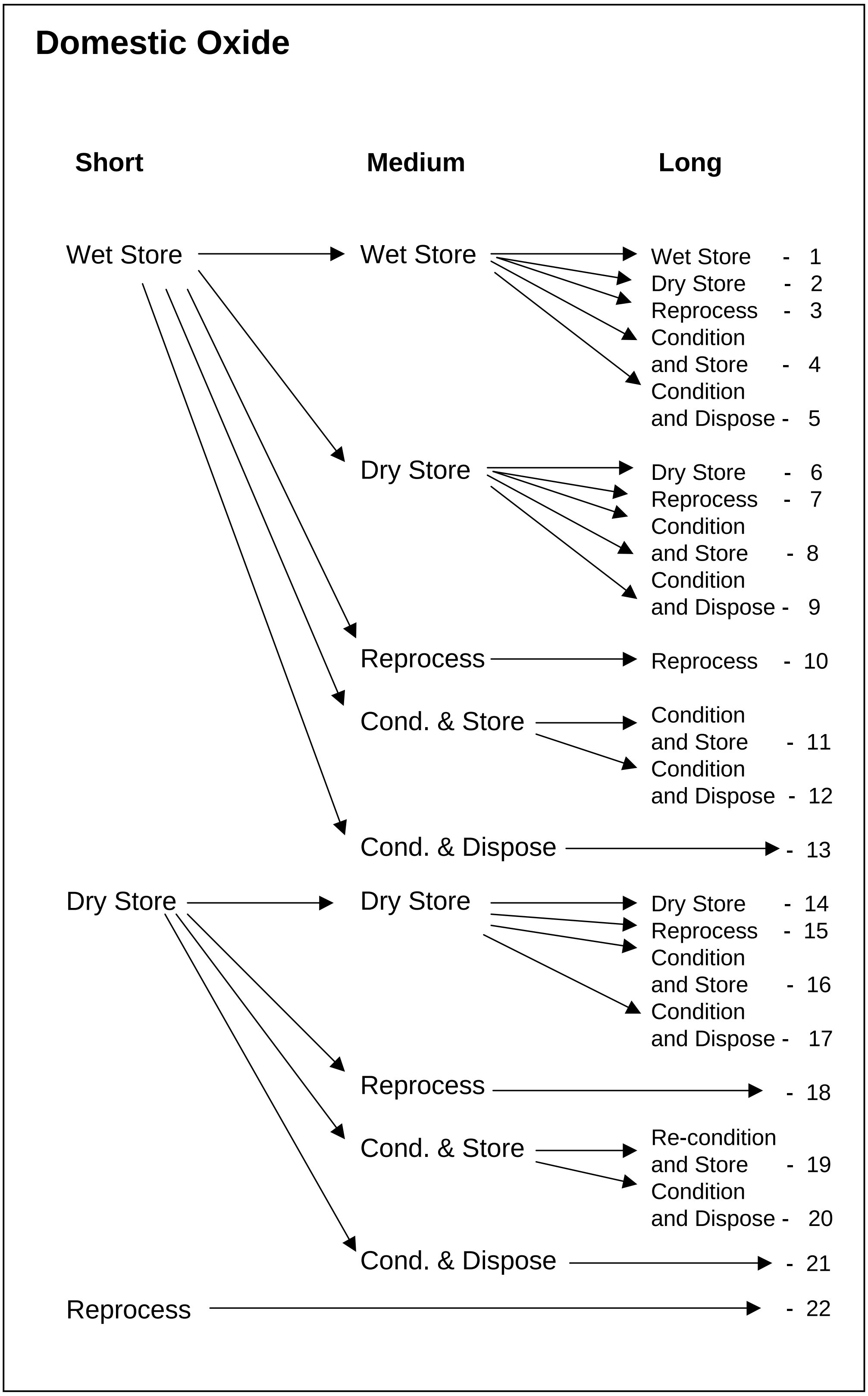


Figure 3.1. Option Diagram: Domestic Oxide Fuel

3.15 The equivalent diagrams for the other fuel categories were also produced by the Group. As a more general presentation, however, the following diagrams show, for UK fuel (excluding Sizewell B LWR oxide fuel), the various paths from spent fuel, via reprocessing where this is carried out, to a passively safe stored form from which disposal can be considered.

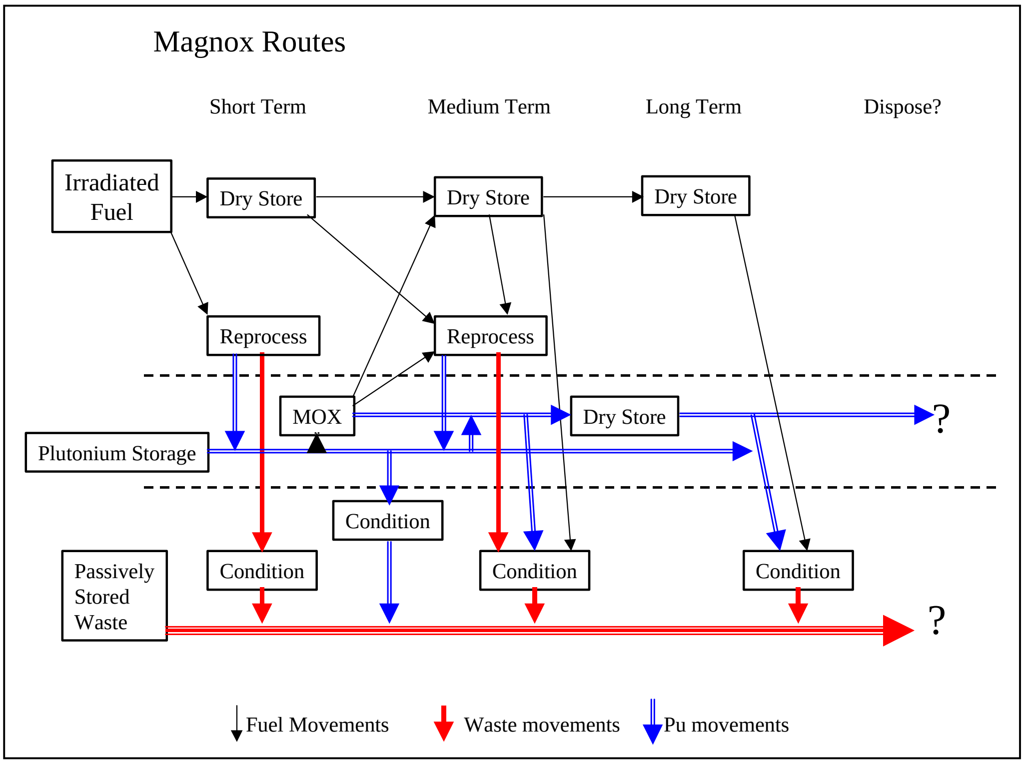


Figure 3.2. UK Spent Fuel Management Options – Magnox

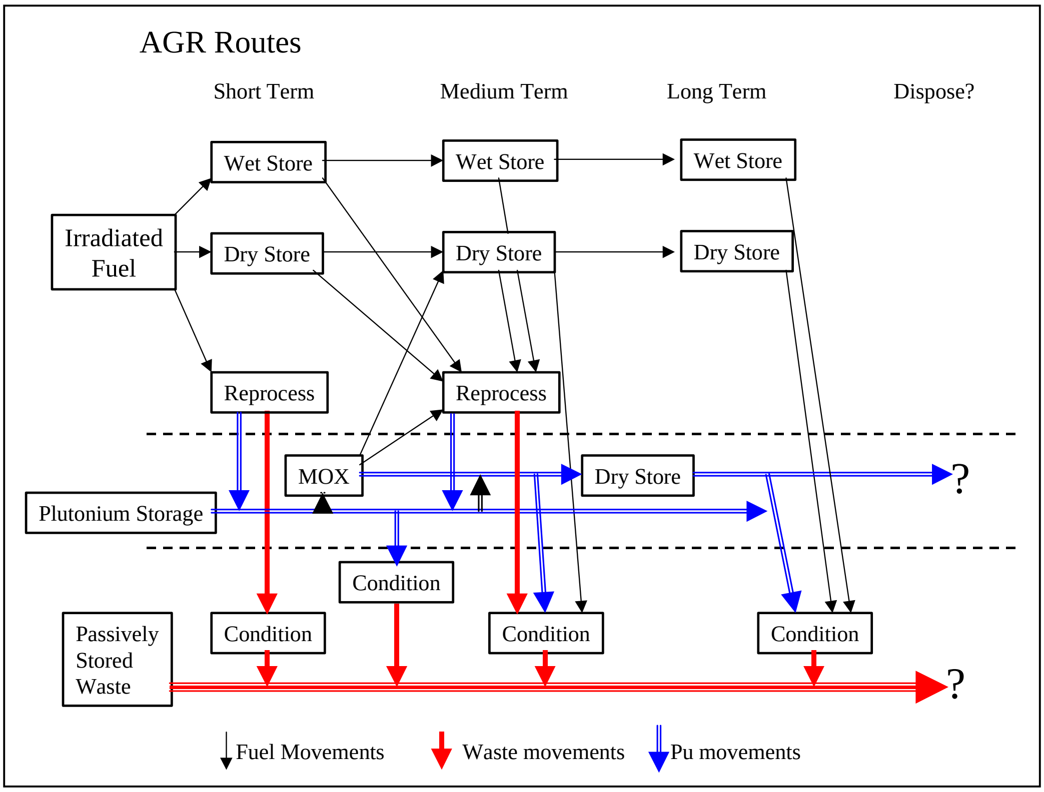


Figure 3.3. UK Spent Fuel Management Options - AGR

3.16 Note that the various process stages in these diagrams will entail liquid and aerial discharges, worker dose and other effects that are not represented in the diagrams.

3.17 Having identified a large number of scenarios to accommodate various combinations of oxide and Magnox fuel management possibilities, and having identified the criteria against which the various options would be assessed, it was now necessary to bound the range of business scenarios considered. The upper and lower bounding cases would be examined, together with a 'middle case' in order to determine what orders of magnitude the study might produce between the extremes.

3.18 This gave a range of 'preferred scenarios' under the 'stop now' category for four different fuel types (Magnox, domestic oxide - AGR and LWR - foreign LWR existing in the UK and foreign LWR new and existing but not in the UK). As a result, the set of scenarios for evaluation became:

Magnox

1. *'Stop now whatever the consequences'*
   Stop Magnox reprocessing and generation immediately – consider storing current cores in the shutdown stations.

2. *'Stop earliest practical'*
   Stop Magnox generation immediately and reprocess the fuel in ponds and reactors. This would be in B205 or possibly in a modified head end on the THORP plant.

3. *'BNFL business plan'* to the May 2000 announcement

Oxide Fuel

1. *'BNFL business case'*

2. *'Blue sky'*

3. *'Stop now'* cases below:
   "Foreign LWR fuel in UK"
   - Return (Short term)

   "Foreign LWR fuel (new and existing) not yet in UK"
   - Return (Short term)
   - Wet store and return (Medium term possibly after conditioning).

   "Domestic oxide"
   - Wet store (Short, Medium term), condition for storage/disposal (Long term)
   - Wet Store (Short term), condition for storage (Medium term)
   - Recondition for storage/disposal (Long term)

3.19 Though the possible conditioning of foreign LWR fuel for eventual disposal is considered above, it cannot take place until a specification for conditioning and disposal is adopted. This is viewed as a very long-term activity, and the timescale and uncertainty are such that this option was not studied further.

3.20 Although in theory evaluation should be a sequential step, following on from option selection and practicability, in practice, work on evaluating the different options began at a very early stage. BNFL assigned technical advisers with a remit of providing detailed data on the different spent fuel management options.

3.21 The evaluation stage adds a further two questions:

4. Evidence for and against.
5. So should we do it?

to the three already posed, which had been:

1. Can you do it? (technical feasibility)
2. Can it be done in time? (considering closure dates, construction lead times etc)
3. Can you afford it? (assessed firstly for UK fuel only then for imports to see if the picture changes)

Question 4 is largely concerned with issues of "fact" or verifiable data. Question 5 is essentially a matter of value judgements.

3.22 In the event, a process over several meetings refined the options available within the timescales required and the technology available – essentially producing a range of scenarios that passed the first two filters. The evidence for and against each scenario was gathered by calculating the outcomes in terms of waste forms and volumes, discharges, transport miles and other factors. This process is covered in Section 4 of this report.

3.23 The overall judgement of the evidence for each scenario, including cost aspects and perception issues, involved the comparison of very different factors – some quantitative, some qualitative, and many dependent for their importance on the value-sets of the people making the judgement. The techniques examined, those adopted and the results of the evaluation are given from Section 5 onwards.

3.24 The process also benefited from the work being done for the socio-economic sub-group. Their analysis needed to break down the Sellafield operations into meaningful sub-sets (termed 'blocks') to allow economic analysis of future scenarios[18]. This approach clarified the common features of many of the SFMO WG scenarios and helped the Group to simplify the range of possibilities.

3.25 From November 2000 onwards the SFMO WG work in developing and selecting scenarios was peer reviewed and commented on by the GX's working in conjunction with the BX's. This process was key in surfacing and attempting to resolve differences in interpretation, derivation or significance of data.

[18] ERM Economics (November 2001). 'West Cumbria: Socio-economic Study' - Especially see sections 3.4 – 3.10

3.26 In particular, a joint study of processes by the GX's and BX's, plus a review of regulatory views (see also paragraphs 3.8 – 3.12), led the SFMO WG to agree that:

- Passivity may be difficult to establish in absolute terms, but relative values are easier to define: the more passive the waste form the lower the level of institutional control required.
- Options involving the drying of already wetted Magnox fuel are not practical, mainly because the time taken to develop and institute drying techniques exceeds the safe wet storage time of the fuel. This would be a major regulatory concern.
- Dry storage of Magnox which has not been wetted, including storage in reactors, is technically feasible as a short term option. Longer term storage gives major regulatory concern due to issues such as the availability of a long term management option addressing passivity.
- 'Hybrid' scenarios, where options such as using Magnox reactors as stores, dry transport of Magnox fuel, and reprocessing of Magnox fuel through a new head end on THORP, were examined, and would be included.

3.27 At the end of this extensive and highly iterative process, thirteen scenarios were finally selected. In all cases a block diagram of the scenario is given below, together with the main characteristics and notes on the main considerations needing to be brought into the evaluation process. This analysis led to five of the scenarios being rejected and the reasons for their rejection are given. The remaining eight scenarios to be evaluated were those for which additional data was required (see Section 4).

3.28 The Group noted that 'stop now' scenarios (SF1) are different from the other scenarios in requiring direct funding from the public purse to cover the loss of income caused by closing the Magnox stations and shutting THORP. Later this was further evaluated as part of the work of the technical experts, the results of which are given in paragraph 5.24 et seq, and in Appendix 14.

Final Scenarios Examined

3.29 Note that all 'stop now' options envisage closure of plants (some or all of reactors, B205 and THORP, according to option) on a reference date, which for the purposes of consistency the Group set at 31 March 2001. All data are normalised to this date.

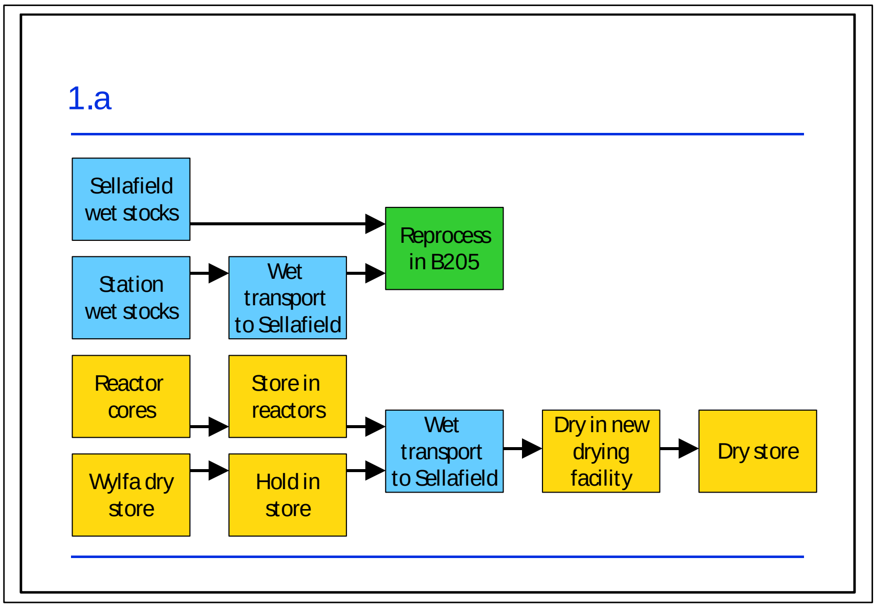
3.30 Scenario 1a includes drying of wet Magnox fuel and subsequent dry storage. As mentioned above this had been ruled out by the Group as an option. It is, however, firmly held to be practical by some NGOs.

At this phase of the analysis it was decided to reinstate the scenario and run it through the weighting and ranking process – returning to the practical and regulatory objections if the scheme survived to that stage.

3.31 Another simplification in the scenarios analysed was to deal with the treatment of AGR and any foreign LWR fuel remaining after THORP closure as variants. It had been recognised that wet storage of AGR fuel presented no problems in the medium term, but there may be a case for switching to dry storage at some stage. Both dry and wet storage would therefore be considered for all relevant options. Any LWR fuel remaining would still be owned by the foreign utility, and under current UK Government policy would be returned. There were however views that continued storage in the UK or even conditioning in some way before return might become practicable, and therefore return or continued storage in existing (wet) facilities would also be examined for relevant scenarios.

3.32 During the iterative process of scenario development it was noted that reprocessing has ceased in all options before 2030, i.e. well before the end of the ‘Medium Term’ of 40 years. It was therefore decided to consider the longer-term aspects of the scenarios in terms of a ‘stock take’ on their inventories at 2030. There are many features common to all scenarios (e.g. all have some AGR fuel un-reprocessed, all have quite similar amounts of ILW etc.) so dealing with the post 2030 situation by carrying out a review of the status of all scenarios at that date would be more effective and would cut down the number of options considered initially.

Scenario SF1a



3.34 *Summary of scenario*

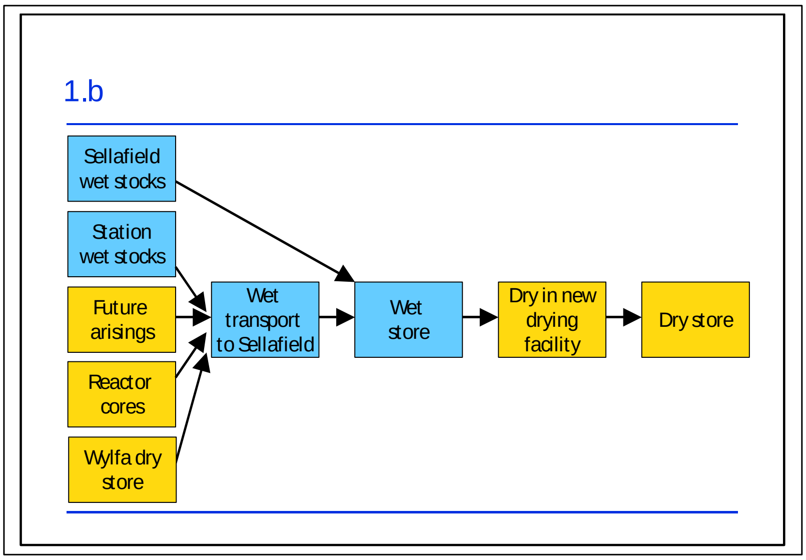
- Immediate Magnox reactor closure at reference date.
- Reprocess wetted Magnox fuel in B205 at Sellafield
- Dry store Magnox cores, initially in the reactors and the Wylfa dry store then in a dry store at Sellafield.
- Once drying facilities and a dry store are available at Sellafield (~2010) transport the fuel to Sellafield wet then dry it for long-term storage.
- Against background of immediate THORP closure (at reference date).

3.35 *Main Issues (and where applicable reasons for not considering further)*

- Would transport be wet? If not requires development and regulatory clearance of dry route – cost and timescale implications.
- Would or could the wetted fuel be dried? Vacuum drying not proved for Magnox fuel. Would need to prove drying as a technology and obtain regulatory approval – with cost (£300M and US experience of $0.5M/te mentioned) and timescale (8 years for design and build) implications. Problems of leaking fuel.
- Fuel stored in reactors in advance of dry/store availability gives regulatory concern.
- Would dry store be at Sellafield?

3.36 *OPTION RETAINED. This scenario has four variants – with AGR fuel remaining after THORP closure either wet or dry stored, and with LWR fuel either returned or wet stored. These variants will be looked at using the blocks/bricks and presented as a sensitivity analysis. The differences are thought to be relatively small in the overall context.*

3.37 ***Scenario SF1b***



3.38 *Summary of scenario*

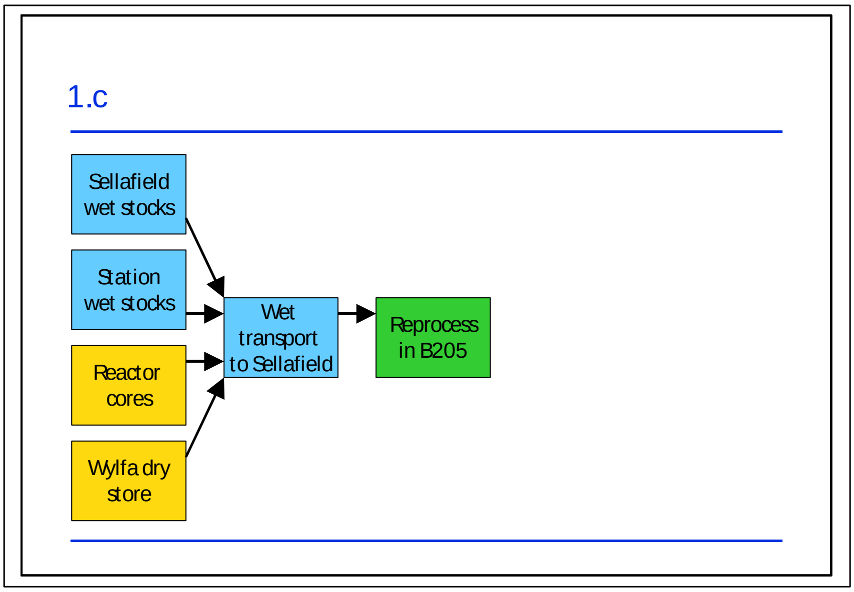
- Continue to operate reactors
- Wet store current stocks and future arisings of Magnox fuel at Sellafield
- Build a Magnox fuel drying facility and a dry store at Sellafield
- Dry/condition the wetted Magnox fuel and dry store
- Against background of immediate THORP closure at reference date

3.39 *Main Issues (and where applicable reasons for not considering further)*

- Sellafield ponds would fill by about 2003-2004 and reactors would have to close
- Requires wet storage for over 7 years at stations – not viable. Any storage over about 3 years would need to be containerised with caustic-dosed water – currently only available at Sellafield.
- Storage of wet fuel in ponds with no guaranteed way of dealing with it would not be acceptable to regulators

3.40 *OPTION REJECTED*

3.41 ***Scenario SF1c***



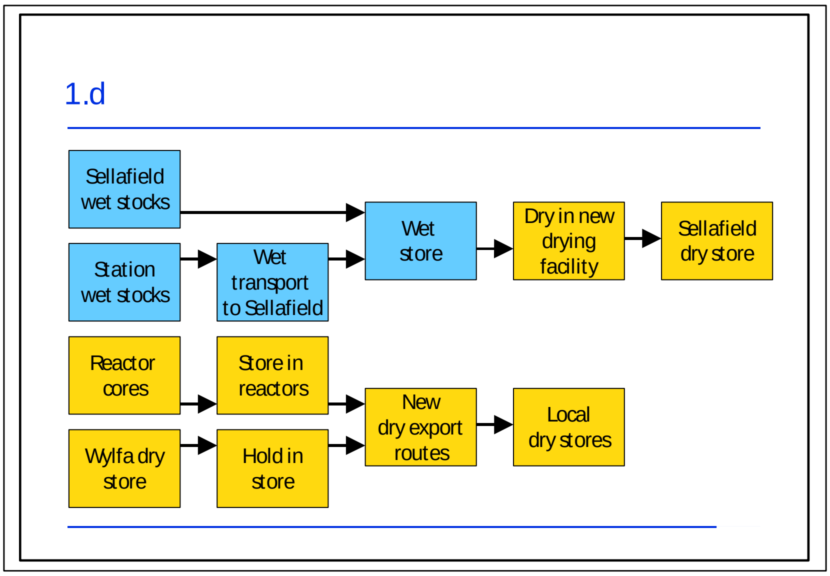
3.42 *Summary of scenario*

- Immediate Magnox reactor closure at reference date.
- Reprocess all Magnox fuel in B205 at Sellafield
- Against background of immediate THORP closure at reference date

3.43 *Main Issues (and where applicable reasons for not considering further)*
This scenario has four variants – with AGR fuel remaining after THORP closure either wet or dry stored, and with LWR fuel either returned or wet stored. These variants will be looked at using the blocks/bricks and presented as a sensitivity analysis. The differences are thought to be relatively small in the overall context.

3.44 *OPTION RETAINED*

3.45 ***Scenario SF1d***



3.46 *Summary of scenario*

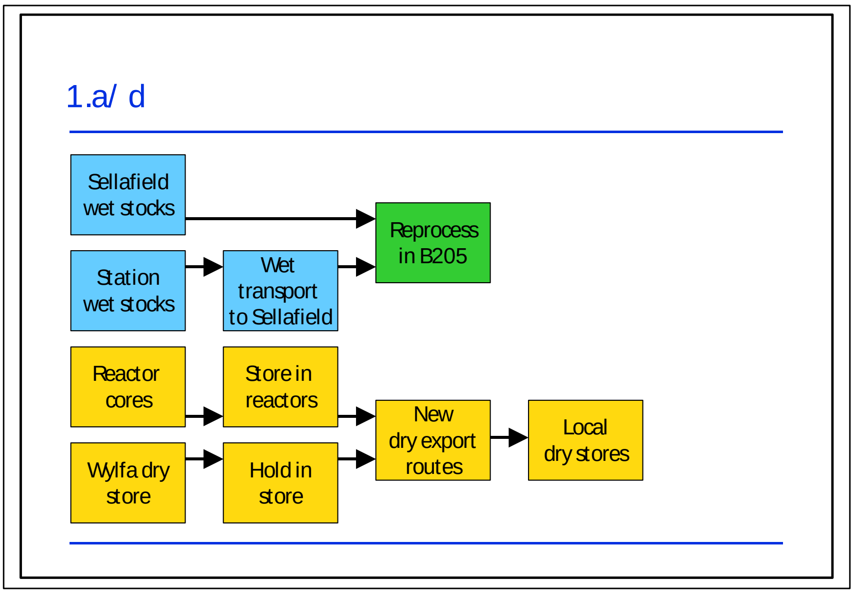
- Immediate Magnox reactor closure at reference date
- Transfer wetted Magnox fuel to Sellafield and wet store until a drying facility and dry store are available (~2010)
- Dry wetted Magnox fuel and dry store at Sellafield
- Dry store Magnox cores, initially in the reactors then in dry stores at stations. Export the fuel from the reactor cores through new dry discharge routes
- Against background of immediate THORP closure at reference date

3.47 *Main Issues (and where applicable reasons for not considering further)*

- Regulatory issues as 1b - Storage of wet fuel in ponds with no guaranteed way of dealing with it would not be acceptable to regulators
- Retrofitting dry fuel exit route to existing mature reactors would not be practicable, and would be prohibitively expensive

3.48 *NOT FEASIBLE - OPTION REJECTED*

3.49 ***Scenario SF1a/d***



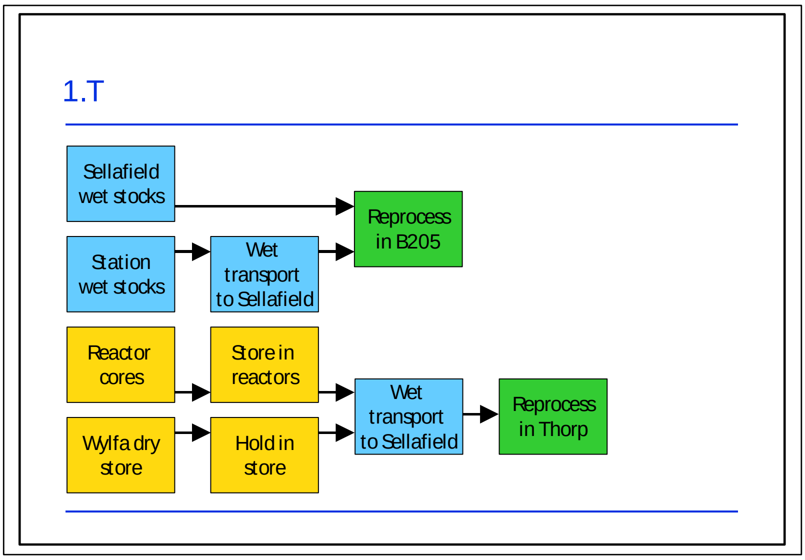
3.50 *Summary of scenario*

- Immediate Magnox reactor closure at reference date.
- Reprocess wetted Magnox fuel in B205 at Sellafield
- Dry store Magnox cores, initially in the reactors then in dry stores at stations. Export the fuel from the reactor cores through new dry discharge routes
- Against background of immediate THORP closure (at reference date)

3.51 *Main Issues (and where applicable reasons for not considering further)*
Retrofitting dry fuel exit route to existing mature reactors would not be practicable, and would be not be commercially viable

3.52 *NOT FEASIBLE - OPTION REJECTED*

3.53 ***Scenario SF1T***



3.54 *Summary of scenario*

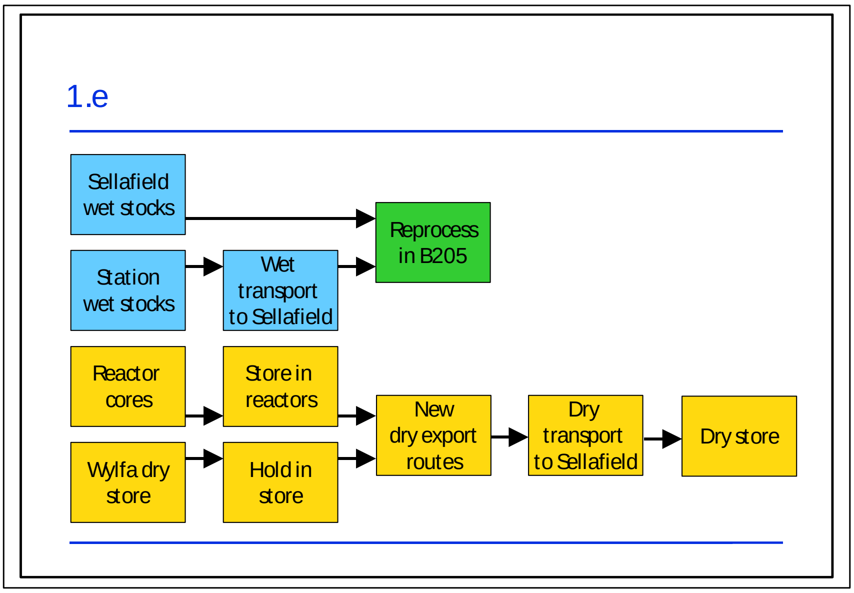
- Immediate Magnox reactor closure at reference date. Reprocess existing wetted Magnox fuel through the B205 Magnox reprocessing plant at Sellafield and then shut down B205
- Dry store Magnox cores in reactors and the Wylfa dry store
- Convert THORP to accept Magnox fuel, and once available transport dry stored fuel to Sellafield in wet flasks and reprocess
- Against background of immediate THORP closure for oxide reprocessing business (at reference date).

3.55 *Main Issues (and where applicable reasons for not considering further)*

- Potentially allows earlier B205 shutdown than 1c
- Not very practical: implies shutting THORP for around 9 years while a Magnox head end is designed, built and commissioned. Capital cost of around £350M to reprocess 5,500 te of Magnox.
- Fuel stored in reactors in advance of head end availability gives regulatory concern.
- After extended THORP shutdown could well need a public inquiry to start up again
- Timescales could give problems with OSPAR – driven discharge reductions as 205 will lead to a drop, but subsequent THORP restart would give an increase

3.56 *OPTION RETAINED - Four options of AGR and PWR storage retained as in 1a*

3.57 ***Scenario SF1e***



3.58 *Summary of scenario*

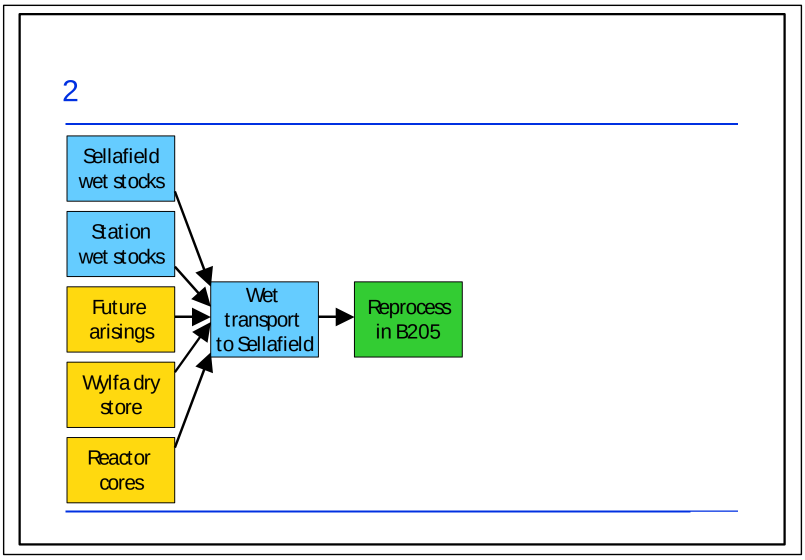
- Immediate Magnox reactor closure
- Reprocess wetted Magnox fuel
- Dry store Magnox cores, initially in the reactors and the Wylfa dry store then in a dry store at Sellafield. Provide a dry export route from the reactors and a dry transport route to Sellafield (by about 2010)
- Empty the reactor cores and Wylfa dry store and transfer to Sellafield
- Against background of immediate THORP closure at reference date

3.59 *Main Issues (and where applicable reasons for not considering further)*

- No technology for dry Magnox transport
- Fuel stored in reactors in advance of export route and drystore availability gives regulatory concern.

3.60 *OPTION REJECTED*

3.61 ***Scenario SF2***



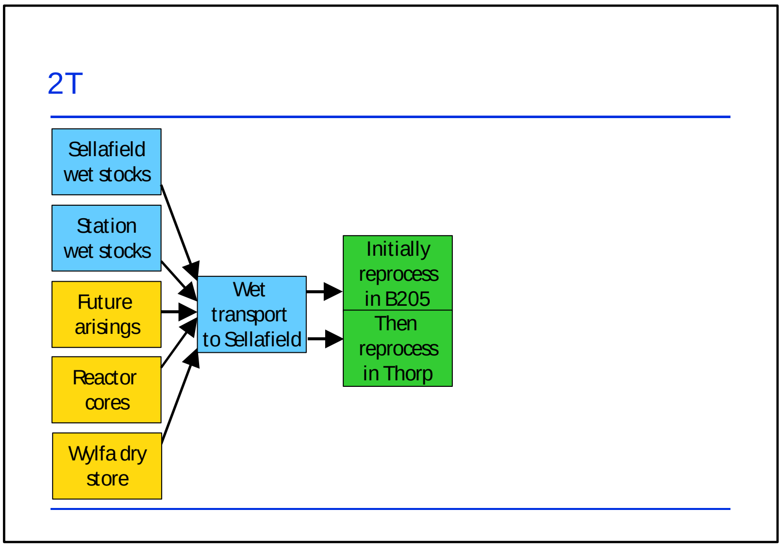
3.62 *Summary of scenario*

- Continued Magnox generation to May 23rd 2000 announced lives, but no Magrox so Wylfa & Oldbury close early
- Reprocess wetted Magnox fuel by 2012
- Against background of continued THORP operation to 2014 in line with BNFL Business Plan
- SMP starts up

3.63 *Main Issues (and where applicable reasons for not considering further)*
Original 'BNFL Business Plan' case modified by announcement of abandonment of Magrox

3.64 *OPTION RETAINED – This scenario has two variants with AGR fuel remaining after THORP closure either wet or dry stored.*

3.65 ***Scenario SF2T***



3.66 *Summary of scenario*

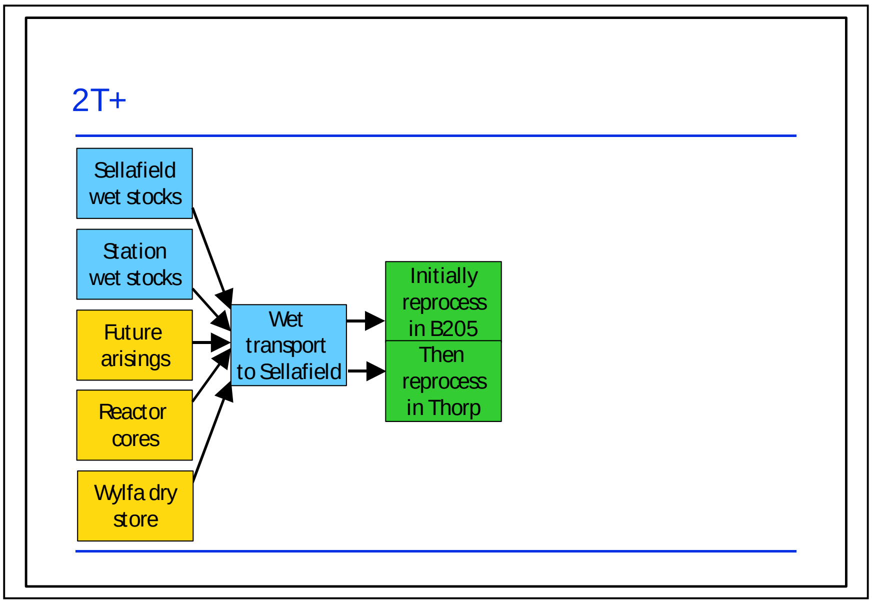
- Continued Magnox generation to May 23rd 2000 announced lives, but no Magrox so Wylfa & Oldbury close early
- Convert THORP to accept Magnox fuel
- Reprocess wetted Magnox fuel initially in B205, but once the THORP route is available and proven (~2010), close B205 and complete Magnox reprocessing in THORP
- Against background of continued THORP operation for oxide to at least 2014 in line with BNFL Business Plan
- SMP starts up

3.67 *Main Issues (and where applicable reasons for not considering further)*

- Magnox programme is original 'BNFL Business Plan' case modified by announcement of abandonment of Magrox.
- Introduction of Magnox head end at THORP should allow earlier closure of B205

3.68 *OPTION RETAINED – This scenario has two variants with AGR fuel remaining after THORP closure either wet or dry stored.*

3.69 ***Scenario SF2T+***



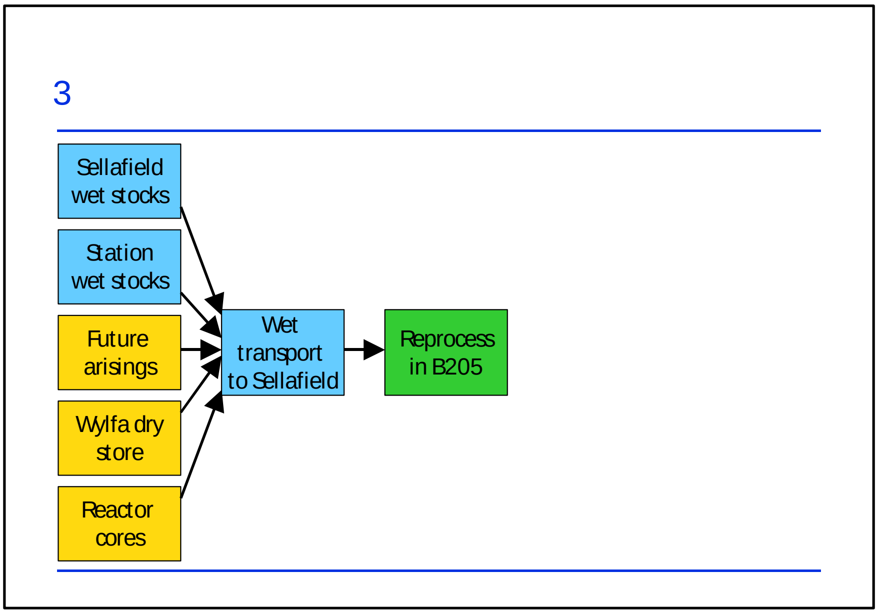
3.70 *Summary of scenario*

- Continued Magnox generation to May 23rd 2000 announced lives, but no Magrox
- Continue to Operate Wylfa/Oldbury to May 23rd 2000 announced end dates, but on Magnox not Magrox
- Convert THORP to accept Magnox fuel
- Reprocess wetted Magnox fuel initially in B205, but once the THORP route is available and proven, close B205 and complete Magnox reprocessing in THORP
- Against background of continued THORP operation for BNFL Business Plan levels of oxide reprocessing
- SMP starts up

3.71 *Main Issues (and where applicable reasons for not considering further)*
THORP would be extended to 2024 to support the Wylfa end date, but oxide business would have ceased a decade earlier - not economic

3.72 *OPTION REJECTED*

3.73 ***Scenario SF3***



3.74 *Summary of scenario*

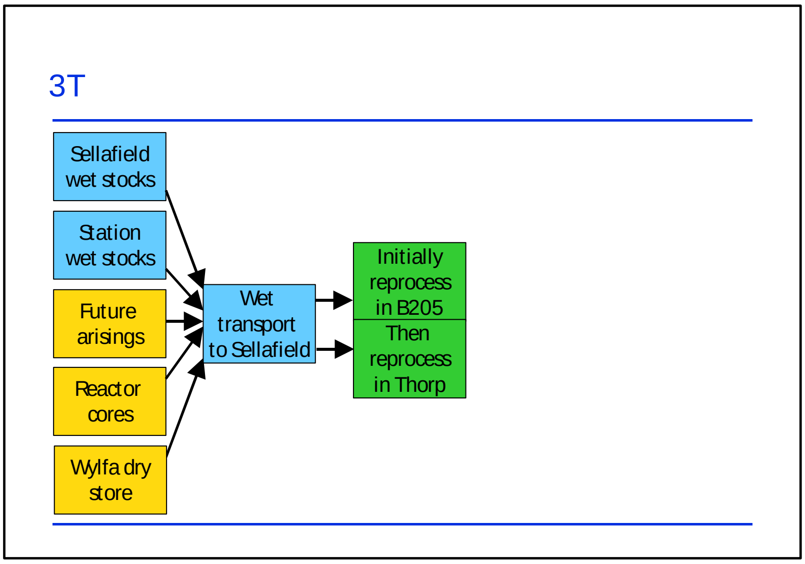
- Continued Magnox generation to May 23rd 2000 announced lives, but no Magrox so Wylfa & Oldbury close early
- Reprocess wetted Magnox fuel by 2012
- Against background of continued THORP operation to 2024 with additional oxide reprocessing business
- SMP starts up. The amount of MOX to be manufactured from overseas plutonium requires a second MOX plant at Sellafield

3.75 *Main Issues (and where applicable reasons for not considering further)*

- Original 'blue sky' BNFL option but modified by abandonment of Magrox

3.76 *OPTION RETAINED – This scenario has two variants with AGR fuel remaining after THORP closure either wet or dry stored.*

3.77 ***Scenario SF3T***



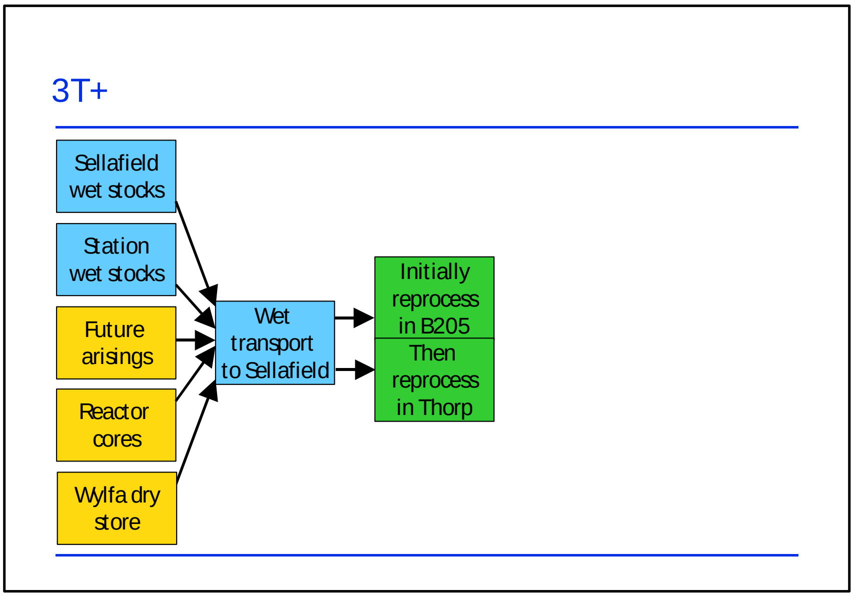
3.78 *Summary of scenario*

- Continued Magnox generation to May 23rd 2000 announced lives, but no Magrox so Wylfa & Oldbury close early
- Convert THORP to accept Magnox fuel
- Reprocess wetted Magnox fuel initially in B205, but once the THORP route is available and proven, close B205 and complete Magnox reprocessing in THORP
- Against background of continued THORP operation to 2024 with additional oxide reprocessing business
- SMP starts up. The amount of MOX to be manufactured from overseas plutonium requires a second MOX plant at Sellafield

3.79 *Main Issues (and where applicable reasons for not considering further)*
THORP throughput needs to be adequate for concurrent oxide and Magnox reprocessing from closure of B205

3.80 *OPTION RETAINED – This scenario has two variants with AGR fuel remaining after THORP closure either wet or dry stored.*

3.81 ***Scenario SF3T+***



3.82 *Summary of scenario*

- Continued Magnox generation to May 23rd 2000 announced lives, but no Magrox
- Continue to Operate Wylfa/Oldbury to May 23rd 2000 announced end dates, but on Magnox not Magrox
- Convert THORP to accept Magnox fuel
- Reprocess wetted Magnox fuel initially in B205, but once the THORP route is available and proven, close B205 and complete Magnox reprocessing in THORP
- Against background of continued THORP operation to at least 2024 with additional oxide reprocessing business
- SMP starts up. The amount of MOX to be manufactured from overseas plutonium requires a second MOX plant at Sellafield

3.83 *Main Issues (and where applicable reasons for not considering further)*

- THORP throughput needs to be adequate for concurrent oxide and Magnox reprocessing from closure of B205, over a longer period than for 3T

3.84 *OPTION RETAINED*

Summary of Scenarios Retained

3.85 Following the analysis of options detailed above, there were eight scenarios put forward for detailed data gathering and subsequent analysis – they were:

- SF1a ‘stop now’ – immediate Magnox reactor and THORP closure. Leave final Magnox fuel loading in the reactor and reprocess wetted fuel in B205.
- SF1c immediate Magnox reactor/ THORP closure but reprocess all current Magnox fuel through B205.
- SF1T As SF1a, including reprocessing of wetted fuel in B205, but final Magnox fuel loading is reprocessed in a new THORP head end plant when available.
- SF2 current business plan.
- SF2T current business, but Magnox fuel reprocessed through a new THORP head end plant when available.
- SF3 ‘blue sky.’
- SF3T ‘blue sky’, but Magnox fuel reprocessed through a new THORP head end plant when available.
- SF3T+ hybrid – As SF3T, but the availability of the new THORP head end plant enables Wylfa and Oldbury Magnox stations to operate on Magnox fuel to dates as in Appendix 4.

4. DATA AND DATA ACQUISITION

4.1 The development of data requirements proceeded in parallel to the definition of scenarios, with the aim that the necessary information gathering could proceed so that there was a minimum of work after the final definition of the scenarios. Much of the data was similar to that used for the previous working groups, and as most of the Group had been involved in these there was a reasonable level of familiarity with the units and quantities involved.

4.2 An evaluation by the Group led to an initial list of criteria for judging possible scenarios:

- *Transport – amount and mode*
- *Jobs/socio-economic effects*
- *Waste, fuel and products*
- *Discharges*
- *Carbon Dioxide emissions*
- *Dose – to workforce and public*
- *Health effects*
- *Reactor lifetimes*
- Risk and Hazard
- Environmental impact
- Proliferation
- Licensing and planning
- Cost
- Technical feasibility
- Public acceptability
- Profit
- Customer requirements
- Contractual obligations

4.3 Of these factors the italicised were judged capable of yielding verifiable factual data, either directly or by modelling. These and the other factors are briefly analysed below.

4.4 *Transport.* BNFL undertook to provide the distances (in miles) travelled on rail and sea for all scenarios. The cases without substitution (i.e. worst case) were considered for sea transport. It was hoped that the Transport Sub-Group would suggest any other data that might be needed. The conventional accident risk (i.e. harm due to conventional transport accidents rather than any effect of the cargo being nuclear) could then be derived from standard studies in terms of statistical deaths. In the event, the timing of the Transport Sub-Group precluded a proactive input from them before the SFMO WG engaged in the MADA analysis. The methodology adopted was therefore that the SFMO WG comments and weightings on transport matters were conveyed to the Sub-Group who then commented back to SFMO WG. This exchange is given in Appendix 6 and is referred to in the relevant parts of Section 5.

4.5 *Jobs and socio-economic effects*. These effects were being investigated in depth through the ERM socio-economic study, but BNFL agreed to produce direct BNFL jobs in person-years for each scenario, from which a figure of UK jobs could be produced using a standard multiplier.

4.6 *Waste, fuel and products*. For convenience this data was broken down into two forms. “Lifetime arisings” would give the total amount of each substance produced in the UK or for overseas customers if each scenario operated. “Future arisings” would give the quantity of each substance to be produced from the reference date (31 March 2001) to the end of the programme. The categories to be measured were:

- ILW (UK and overseas) in cubic metres
- HLW (UK and overseas) in cubic metres
- LLW (UK) in cubic metres
- Plutonium (UK and overseas) in tonnes
- Stored Magnox fuel in tonnes
- Stored AGR fuel in tonnes
- Magnox fuel for reprocessing from the reference date in tonnes
- AGR fuel for reprocessing from the reference date in tonnes
- Overseas LWR fuel for reprocessing from the reference date in tonnes
- MOX fuel fabrication in tonnes
- Magnox electricity generation from the reference date in tonnes

4.7 *Discharges*. Environmental discharges, both aerial and liquid would be estimated by BNFL and expressed in Becquerels.

4.8 *Carbon Dioxide emissions*. In the scenarios that limit Magnox reactor lives, there will be a reduction in Magnox generation. This would involve replacing this generation, and it would be assumed that it was replaced with a typical generation mix of 50% coal and 50% gas, to give a carbon dioxide figure in millions of tonnes. This would not fully describe the replacement power detriment, as such variables as SOx, NOx, and particulates would also need to be taken into account. There was disagreement as to how (or if) to take alternative generation into account, but this is discussed later.

4.9 *Dose – workforce and public*. The discharges estimated above would then be modelled to produce figures of the collective dose to people over particular areas and times in units of man Sieverts. Discharges for Sellafield and from the Magnox reactors would be estimated. This became a controversial area and is discussed more fully in paragraph 5.17 and Appendix 10. Additionally the dose to the workforce would be estimated, again in man Sieverts. To aid common understanding, Professor Steve Jones of Westlakes made a presentation on aspects of radiation covering natural and man-made radiation, the effects of radiation on humans, the concept of dose and committed effective dose, and the acute and delayed health effects of radiation. This is given as Appendix 17.

4.10 *Health effects*. The health effects of the various programmes cover both conventional and radiation detriments. Conventional effects would be derived from the amount of work represented by the various scenarios using standard accident rates and expressed as fatalities. These would simply rise as the amount of work and the number of person-years rises. In the case of dose to the workforce, the man Sievert figures would be converted into fatalities using a recognised ICRP factor. This factor is discussed briefly in Appendix 10. Similarly, the collective dose figures were also converted into a number of fatalities using the factor. Other public health effects are discussed in Annex A of the ERM Report[19], which calculates the relative change in mortality between the scenarios. Theoretical comparisons of mortality as a result of health effects are explored more fully in Appendix 10.

4.11 *Reactor lifetimes*. The reactor lifetimes would be defined for each scenario and quoted in reactor years.

4.12 *Other factors.* The other 10 factors listed in paragraph 4.2 were not susceptible to simple data generation. They were dealt with at various stages through the process of evaluation and are addressed in succeeding sections of the report.

4.13 The quantifiable data as described above was provided as a table by BNFL, which is reproduced Table 4.1 on the next page.

[19] ERM Economics (November 2001). 'West Cumbria: Socio-economic Study'

Table 4.1 Assessment of Working Group scenarios - Summary Cumulative impacts

				SF1a	SF1c	SF1T	SF2	SF2T	SF3	SF3T	SF3T+
	Reactors			Stop	Stop	Stop	Continue	Continue	Continue	Continue	Extend
	Magnox fuel route			B205/dry store	B205	B205/Thorp	B205	B205/Thorp	B205	B205/Thorp	B205/Thorp
	B205 end date			2003	2008	2003	2012	2010	2012	2010	2010
	Thorp end date			2001	2001	2017	2014	2017	2024	2027	2029
	SMP end date			N/A	N/A	N/A	2015	2015	2024 (1)	2027 (1)	2029 (1)
	Magnox repro	te	from 1/4/2001	1,500	7,400	7,600	11,100	11,100	11,100	11,100	13,500
	AGR repro	te	from 1/4/2001	0	0	0	4,300	4,300	4,300	4,300	4,300
	Overseas LWR repro	te	from 1/4/2001	0	0	0	4,900	4,900	15,300	15,300	15,300
	Mox fabrication	tHM	from 1/4/2001	0	0	0	910	910	3,500	3,500	3,500
			Timescale								
Lifetime Arisings	ILW - UK	m3 (thousands)		196	203	203	211	211	211	211	214
	- overseas	m3 (thousands)		2	2.1	2.1	6	6	14.3	14.3	14.3
	HLW - UK	m3		770	890	890	1,300	1,300	1,300	1,300	1,350
	- overseas	m3		140	140	140	530	530	1,780	1,780	1,780
	LLW - UK (2)	m3 (thousands)		1,844	1,862	1,862	1,900	1,900	1,931	1,931	1,938
	Pu - UK	te PuO_2		68	86	87	118	118	118	118	125
	- overseas	te PuO_2		16	16	16	70	70	267	267	267
Future Arisings	ILW - UK	m3 (thousands)	to 2030	1.8	8.9	9.1	16.7	16.7	16.7	16.7	19.6
	- overseas	m3 (thousands)	to 2030	0	0	0	3.9	3.9	12.2	12.2	12.2
	HLW - UK	m3	to 2030	30	150	150	560	560	560	560	610
	- overseas	m3	to 2030	0	0	0	390	390	1640	1640	1640
	Pu - UK	te	to 2100	5	23	23	55	55	55	55	62
	- overseas	te	to 2100	0	0	0	54	54	251	251	251
	Mx storage	te	to 2100	5,900	0	0	0	0	0	0	0
	AGR storage	te	to 2100	7,200	7,200	7,200	2,900	2,900	2,900	2,900	2,900
	Generation	TWh	to 2100	0	0	0	125	125	125	125	220
	Avoided CO_2	Mte	to 2100	0	0	0	56-119	56-119	56-119	56-119	99-209
Safety	Worker dose	manSv	to 2100	300	310	330	360	360	410	430	470
		Theoretical deaths	to 2100	12	12	13	15	15	17	17	19
	BNFL Ind. Safety	Statistical deaths	to 2100	3	2	4	4	4	5	5	5
Environment	Discharges (3)										
	Sellafield	Liquid PBq (4)	to 2028	4	10	11	56	56	122	122	121
		Aerial PBq (4)	to 2028	100	510	310	2,730	2,650	5,130	5,050	5,130
		UK manSv	to 2500	23	42	27	80	76	117	111	110
		UK theoretical deat	to 2500	2	3	2	5	4	6	6	6
	Reactors (5)	Aerial TBq	to 2025	0	0	0	140	140	140	140	200
		UK manSv	to 2500	0	0	0	50	50	50	50	70
		UK theoretical deat	to 2500	0	0	0	3	3	3	3	4
Society	BNFL jobs	Thousand man year	to 2030	210	160	230	240	260	310	320	350
Transport	Rail	Journeys	to 2100	1,600	1,600	1,600	2,000	2,000	2,000	2,000	2,400
		Rail miles (thou)	to 2100	620	620	630	820	820	820	820	950
		Statistical deaths	to 2100	0.33	0.33	0.34	0.44	0.44	0.44	0.44	0.51
	Sea (no substitution)	Journeys	to 2100	170	170	170	480	480	1,360	1,360	1,360
		Sea miles (thou)	to 2100	1,800	1,800	1,800	6,200	6,200	27,400	27,400	27,400

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(1) For the Thorp Blue Sky scenarios, a second SMP plant would be required to meet the additional Mox fabrication demand
(2) Crude assessment based on RWMAC data. Excludes additional LLW from the decommissioning of new facilities
(3) Excludes decommissioning, and does not include any discharges associated with novel processes (e.g. drying Magnox fuel)
No allowance is made for the impact of additional abatement beyond that currently planned
(4) One PetaBecquerel (PBq) is equivalent to 1000 TeraBecquerels (TBq)
(5) Only discharges associated with C-14 are shown. C-14 dominates the UK collective dose

Data Handling

4.14 During the course of the data definition, there was concern at the volume of data to be handled. At the December 2000 SFMO WG meeting it was agreed that there was enough data to undertake a ‘first pass’ analysis of a limited range of indicators for the main scenarios agreed at that time (4 early closure cases, the current business case and one 'blue sky' case). This was simply, at this stage, to help focus discussion. It would build on what was already known and provide a challenge to discussion on methodology. Information was produced from data to hand on:

- Waste arisings (tabular form)
- Plutonium stocks (tabular form)
- Discharge profiles (graphical form)
- BNFL Jobs (graphical form)
- Highly Active Liquor stocks (graphical form)
- CO_2 effects (tabular form)
- Local economy (graphical form, derived from BNFL Jobs)

These provided the means of a first ballpark assessment of the various scenarios. The tables and graphs using the actual data derived later are reproduced in Table 4.1 and Appendix 11 respectively.

Derivation of Criteria for Evaluating Scenarios

4.15 Having selected the scenarios and obtained data, it was necessary to finalise and agree the list of criteria or characteristics against which to evaluate them.

4.16 As a result of inheriting the list of 'issues' from the Main Group at the SFMO WG's inception, initial group work led to the preliminary list of criteria already given in paragraph 4.2. After many discussions, during which the criteria were analysed in an iterative process, the Group arrived at a set of 'headline' criteria. These were used as shorthand for a further, more expansive set of criteria that were subsumed beneath the 'headlines'. Categories were determined by grouping criteria which had similar qualities and which lent themselves to units capable of being ranked.

4.17 The other yardstick used to determine categories of criteria was to ensure that a 'headline' issue could be used as a proxy for other issues, taking care that the list of categories arrived at as an end-point avoided 'double-counting'.

4.18 The original list of criteria was finalised as seen in the following table (Table 4.2). The sub-criteria are listed below each main criterion, and the notes identify key points and aspects that were considered by the Group during the weighting procedure.

Criterion	Lifetime Arisings (1)	Magnox Storage (2)	AGR Storage (3)	CO_2 Avoidance (4)	Worker Deaths (5)	Environ. Disch. (6)		BNFL Jobs (7)	Rail Miles (8)	Sea Miles (9)	Env. Impact (10)	Hazard (11)	Accident Risk (12)	Terrorist Transport Risk (13)
	Lifetime UK - ILW	Future Arisings Magnox Storage	Future Arisings AGR Storage	Future Arisings Avoided CO_2	Safety – Worker Dose man Sv	Env Disch. Aerial PBq (Sellafield)		Society BNFL Jobs '000 person-years	Rail journeys	Sea journeys	Cons-truction related – on site building and site traffic – includes visual impact	Hazard potential of material in process	Major accidents in operations converting one form to another	Risk of terrorist attack and diversion during transport.
	Lifetime ILW - overseas													
	Lifetime Pu - UK								Rail Miles '000	Sea miles				
	Lifetime Pu - overseas													
	Lifetime LLW UK			Future Arisings other Generation Effects	Safety – Worker Dose Theoretical Deaths	Env Disch. liquid PBq (Sellafield)				Sea deaths				
	Lifetime HLW overseas													
	Lifetime HLW UK													
	Future arisings HLW UK							Society UK Jobs '000 person-years	Rail deaths	(no substitution)				
	Future arisings HLW overseas					Env Disch. UK man Sv (Sellafield)								
	Future arisings ILW UK				Safety BNFL Ind Safety Theoretical deaths									
	Future arisings ILW overseas													
	Future arisings Pu UK					Env Disch. UK theoretical deaths (Sellafield)								
	Future arisings Pu overseas													
						Env Disch. Aerial TBq (Reactors)								
						Env Disch. UK man Sv Reactors								
						Env Disch. UK theoretical deaths (Reactors)								
Units	HLW m3	tonnes	tonnes	Millions tonnes	Statistical deaths	PBq	Stat death	'000 person years	0,000 miles	'0,000 miles	No. of Major buildings	Reactor years	MADA risk units (4)	te PuO2
Range	770-1350	0-5900	2900-7900	0-155 over 20 years	15-24	(6)	(6)	160-350	620 - 950	140 - 2340	(3)	0-57	371- 6628	0-16

Table 4.2

Notes on Criteria

1. *Lifetime arisings*: covering plutonium, LLW, ILW, HLW, calculated in m3 and using HLW as the tracker. Separated uranium was not included. This was an oversight but is not considered important in terms of risk or volume as it too would track HLW and is insignificant in MADA context in terms of detriment.

2. and 3. Magnox storage, AGR storage: PWR storage not considered as it did not vary across the scenarios. Calculated in tonnes.

NB Lifetime arisings, Magnox and AGR storage viewed with respect to the detriment of the post 2030 legacy of arisings and storage requirements.

4. *CO2 avoidance*: CO2 avoided or required to be generated by different scenarios calculated in millions of tonnes.

5. *Worker deaths*: number of statistical deaths resulting from worker dose in man Sieverts.[20]

6. *Environmental discharges*: aerial and liquid discharges from Sellafield and UK reactors represented in statistical deaths (see 4.9) calculated from activity in Petabequerels.

7. BNFL jobs: BNFL and UK dependent jobs in person/years.

8 and 9. Rail and sea miles: calculated in statistical deaths per mile travelled. 'No substitution' assumed for sea miles - i.e. maximum number of voyages, worst case scenario.

10. *Environmental impact:* non-radiological impact of construction on site – including traffic variations, noise, vibration, visible intrusion etc.

11. *Hazard**: hazard potential of related material represented as reactor operating years.

12. *Accident risk**: calculated in 'risk units' and viewed as the impact potential rather than as the accident probability. The yardstick 'low probability, high impact' was applied.

13. *Terrorist transport risk**: *the availability of plutonium for diversion by terrorists in tonnes of PuO2.*

** These terms were subsequently more rigorously defined arising from the discussions on security held following the events of 11 September 2001. These definitions are given in paragraph 5.46.*

[20] The Main Group subsequently recommended that these considerations were reviewed in the light of LLR concerns. The SFMO WG have had insufficient time to revise the SAP's, however they have considered LLR concerns and are of the opinion that a 10-fold increase in the radiological impact of ionising radiation would not alter the outcome of the report. This is because environmental discharges were weighted heavily during MADA work and additional weight would not affect the MADA results.

5. ANALYTICAL TECHNIQUES AND ANALYSIS OF THE DATA

Introduction

5.1 Previous sections have reviewed the iterative processes gone through by the SFMO WG in developing scenarios and ensuring appropriate data was available to undertake informed analysis. Over a series of meetings the Group returned to the question of which techniques should be applied to analyse the differences between the scenarios. As noted in Section 3, the Group received presentations on both alternative approaches to decision analysis and on key problems in understanding the meaning and appropriate use of the data available. The Group had also been kept informed of the initial findings of the ERM Socio-Economic Study, which affected a key area for analysis in the next stage of the work.

5.2 In particular, the SFMO WG was introduced to various techniques used to assist in analysing complex decisions. Those given most attention were the Multi Attribute Decision Analysis (MADA) and the Management of Uncertainty, in particular Strategic Action Planning (SAP).

5.3 Professor Pearman, of the Centre for Decision Research at the University of Leeds, was requested to facilitate the Group in its use of MADA. He introduced the technique by looking at the issue of "why decisions are difficult", and exploring why MADA can help focus on key issues in decision taking. It was explained that decisions are made difficult (especially for complex value rich issues like the future of the nuclear industry) by a range of factors including:

- lack of information
- multiple stakeholders
- the desire to "balance" pro's and con's
- uncertainty about the future
- uncertainty about objectives
- the very real complexity involved

5.4 Professor Pearman suggested that MADA can assist decision makers by distinguishing poorer options. It provides tools to assess the 'performance' of each 'option' against each 'attribute'. However, numeric techniques, including that of assigning 'weights' to attributes and the subsequent combining of weights and scores should not be regarded as providing 'the answer(s)' but rather as providing a map to identify a provisional choice that can then be tested. Throughout the analysis the MADA technique requires extensive discussion amongst the participants and is by its very nature a cyclic process. The MADA technique has a strong academic foundation in "decision research" and it has both strengths (such as shared exploration and the understanding of context, and the ability to track the factors as they are applied) and weaknesses (such as reflecting debate within the decision taking group which may not be apparent to those not engaged). It is important to note that the MADA technique cannot make fundamental disagreements disappear.

5.5 "Management of Uncertainty" describes a class of methodologies available to help managers access uncertainties facing them as decision makers. These can be many and various. There are uncertainties in data available, and also because key data is not available. External influences, such as the regulatory framework, can be subject to change, as can shocks to the business, affecting public or customer support. The management of uncertainty technique seeks to analyse options with regard to their robustness against uncertainty. Subsequently the Group adopted the 'Strategic Action Planning' approach.

5.6 At the November 2000 meeting it was agreed that the Group would initially pursue the MADA technique, but be conscious in its application of the uncertainties applying to the future scenarios being evaluated. The Group worked with MADA from December 2000 through to March 2001. Appendix 13 is a summation of the iterative process followed in practice in the Group's use of MADA while paragraph 5.53 et seq indicates how the Group went on to finally apply a management of uncertainty technique, 'strategic action planning', to help identify the critical decision points facing BNFL as it sought to improve its environmental performance. This last work built on the useful evaluation of alternative scenarios assessed through the lengthy but beneficial MADA process.

Multi Attribute Decision Analysis

<u>Background</u>

5.7 The SFMO WG considered how MADA works by taking steps to define more precisely the context of the analysis; by looking at questions such as who are the decision makers and key stakeholders, and by reviewing the options available. The key steps in a MADA are shown in Appendix 13. They are to:

- Establish the context (identifying decision makers and key stakeholders);
- Define what "options" are available ('scenarios' as described in Section 3);
- Agree which (non overlapping) attributes may distinguish better from poorer options, by identifying "values" to facilitate checking and

weighting (agreeing the criteria and associated data set – see Section 4);

- Assess expected performance – producing a table of "options" by "performance" values;
- Assign weights to attributes – with careful discussion amongst "stakeholders" – with weightings agreed adding up to 1;
- Combining weights and scores for each option (usually facilitated by specialised computer software) but only introducing aspects such as cost or public acceptability after that stage;
- All this leading to the identification of a provisional choice (or choices);
- Applying sensitivity testing.

Throughout the analysis the MADA technique required extensive discussion amongst the participants and is by its very nature cyclic.

Discussion of MADA results

5.8 The results of the MADA discussed in Appendix 13 showed clearly that:

- there was full agreement on the assessment of scenarios against each criterion
- there was broad agreement on the weighting of several criteria, and in particular agreement on several of the lower-rated factors
- there was, however, a wide divergence on the weighting of several key criteria: BNFL jobs, discharges, lifetime arisings, CO_2 avoidance, hazard and risk.

5.9 Discussion around the weightings revealed that two different value sets could account for the different weightings. These could be characterised as differing viewpoints under the generic principle of sustainable development. Sustainable development seeks to integrate the need to protect the environment with the socio-economic well-being of people. Many of the elements of sustainable development are difficult to reconcile in practice and can be taken selectively to promote a spectrum of views from emphasis on environmental protection to emphasis on economic development.

5.10 It was agreed that all scenarios being analysed could be characterised using sustainable development as a yardstick. However, it was recognised that the range from the SF1's to the SF3's demanded a change of emphasis to allow the development of two illustrative profiles - one with a bias towards incorporating sustainable development criteria by rapidly reducing environmental discharges and the other by incorporating the same criteria by using a bias towards socio-economic aspects. It was felt that this would be a useful exercise to reflect the outcomes resulting from a swing in bias from one to the other and that it would genuinely present the range of views in the Group. These two outcomes were termed Profile 1 (environmental) and Profile 2 (socio-economic). Broadly speaking, under Profile 1 the SF1 alternatives ranked highest and the SF3 alternatives lowest. Under Profile 2, ranking of the alternatives was reversed.

5.11 Some sensitivity analysis was undertaken which revealed no cases of very high sensitivity to single weight changes, although larger changes in weights did lead to some ranking changes, including possibilities for the SF2 alternatives to come into contention with the others.

5.12 The differences between the two ranking Profiles were underpinned by differing views as to the interpretation and importance of some of the data from the data matrix. In particular a wide divergence of views on collective dose was largely responsible for the different weightings attributed to environmental discharges, while the socio-economic viewpoint attributed higher importance to the adverse effects of unemployment as explained in the ERM West Cumbria Economic Study[21]. There was also a large divergence of views on the importance and relevance of replacement generation effects as represented by '$C0_2$ avoidance'.

5.13 The issue of global, untruncated collective dose was introduced relatively late in proceedings. Its introduction was prompted by the wish that different environmental detriment profiles stemming from a rapid run-down of activities at Sellafield as proposed by the SF1 scenarios and those arising from continued discharge and waste generation from the SF3's, could be examined from the perspective of the most pessimistic dose assumptions.

5.14 The detriment calculated from a collective dose impact constrained to the UK over a 500 year period changes significantly if the collective dose is calculated without those constraints. Global, untruncated collective dose impacts, as demonstrated in Appendix 10, dramatically alter the number of statistical deaths calculated from discharges which need to be balanced against those resulting from unemployment.

5.15 However, when collective dose figures were considered by the Group, it was clear that - given the uncertainties and widely divergent views held on this issue - the best course of action was to refer the reader to a considered examination of the issues, which is given in Appendix 10.

5.16 The discussion on weighting was informed by the development of a diagram comparing the difference in data between SF3 and SF1a. In

[21] ERM Economics (November 2001). 'West Cumbria: Socio-economic Study'

particular this sought to set out the data on a comparable basis where possible including the use of the concept of statistical lives. It should be emphasised that while providing an important framework for discussion and providing some influence on weightings, it was not adopted as a definitive approach by the Group. This diagram and the discussion are reproduced in Appendix 10.

5.17 The differing viewpoints were significantly driven by the factors examined in Appendix 10 and the polarisation of these views is summarised below.

Factor	Environmental Protection View	Socio-economic View
Public Dose	Any additional public dose is not seen to be justifiable; 'world all time' collective doses should therefore be taken into account; collective doses and hence detriments are large.	Any additional public doses should be subject to tolerability of risk, doses >10 Microsieverts per year are therefore most relevant, collective doses and hence detriments are small
Dose-risk relationship	This is inadequately represented by ICRP and NRPB models, and is currently under review by the CERRIE study[22].	This is conservatively represented by ICRP and NRPB models
Jobs, unemployment detriment etc.	The socio-economic advantages of continued operation are significant, but carry less weight than environmental detriments.	The socio-economic advantages of continued operation are significant, and carry more weight than environmental detriments.
CO_2 Detriment	Magnox reactor closure would not add a significant proportion to UK CO_2 discharges and is irrelevant to the central argument of whether to continue reprocessing.	The CO_2 avoided by continuing Magnox Generation is significant in total and can be imputed to have a significant value.
Material stocks and plant operations	The hazards and risk of radioactive material stocks, and of continued plant operation, are held to be a more significant factor in weighting options.	The hazards and risk of radioactive material stocks, and of continued plant operation, are held to be a less significant factor in weighting options.

[22] Consultative Exercise on Radiation Risks from Internal Emitters (CERRIE), within the auspices of COMARE.

Moving On

5.18 The SFMO WG took the view, following discussion, which included observations from Professor Pearman, that the Group had progressed the MADA technique as far as was appropriate. This approach had helped the Group understand the components of the scenarios and recognise that analysis of scenarios against profiles weighted towards environmental and economic perspectives clearly produced two divergent outcomes, the former favouring ‘stop now’ variants, the latter ‘blue sky’ variants.

5.19 The MADA learning process was concluded by a final sensitivity assessment that demonstrated that if either Profile 1 or 2 was taken as a basis and any of 5 criteria with significant disagreement (between the Profiles) were reapplied with the weight reduced to 0 for each criterion in turn, only in 2 cases were the rankings of scenarios significantly affected, namely:

For Profile 1, by reducing the weighting on Risk (criterion 12) to 0
For Profile 2, by reducing the weighting on BNFL jobs (criterion 7) to 0

5.20 This lead to a discussion of how much value there was in spending further time debating weight differences. From which it was generally agreed that the MADA technique had been very helpful in gaining shared understanding of why different perspectives matter.

MADA learning points

5.21 The MADA work was reviewed by the Group to identify lessons from the process. The Group acknowledged the clear point that MADA does not give an “answer”. It forces an appreciation of the difference between data in itself and the significance attached to it. There was agreement that the MADA approach was helpful in encouraging debate, and highlighting the issues around weighting, and in particular that the visual presentation made possible by the specialist software was helpful. While it had identified some areas of agreement, it had brought differences of perspective into sharp focus. It had gradually narrowed down areas of contention, and identified priority areas of debate. There were often differences within stakeholder groups, and the issue of “tactical voting” when trying to agree weights was an initial problem. The process followed also allowed sensitivities to be explored. There was recognition that it does not, of itself, build consensus.

5.22 It was recognised as the process progressed that two divergent perspectives emerged, influenced by fundamental differences of approach on the following issues:

- The acceptability of involuntary exposure to discharges / risk
- The weight given to intergenerational equity (the legacy issue)
- Whether absolute or incremental doses should be considered
- Pre / post mitigation - i.e. whether the precautionary principle should be applied
- Understanding of the measure – ensuring that the measure used to compare attributes is identifiable, or whether a measure can be agreed as a proxy
- Local, national or international perspective adopted
- Double counting – e.g. is worker dose a valid proxy for health impact

5.23 There was common agreement on a number of criteria (generally those given lower weight), including transport. However, the MADA confirmed significant divergence of view on the weighting to be applied to five influential criteria: lifetime arisings, C02 detriment, environmental discharges, BNFL jobs and risk. The two alternate weighting profiles favoured SF1c (environment) and SF3T (socio-economic).

Costs

5.24 Costs are an important determinant in the MADA process. The plotting of the costs against the weightings of various scenarios provide a final sensitivity analysis to produce an 'efficiency frontier' against which to view those scenarios which best met the measures of cost-effectiveness and environmental improvement.

5.25 The task of providing this data to the Group was allocated to the green experts (GX's) who worked with the BNFL experts (BX's) at a number of meetings over the course of several months to arrive at estimates of capital and operating costs and future income streams.

5.26 The provision of financial data was a matter of some sensitivity for BNFL due to the commercial implications of divulging such information and the Financial Services Act also hindered the transfer of this data. Over a considerable period a great deal of work was performed by the GX's who made the best estimates they could of various capital and operating costs and future income. The outcome of this GX analysis was presented at the June 2001 meeting to the SFMO WG, see Appendix 14. The appendices associated with the analysis are available on The Environment Council website[23].

[23] The Environment Council website address: www.the-environment-council.org.uk

5.27 The GX's and BX's worked together to develop the cost report, which is attached at Appendix 14. The appendices of this report are available via the web[24]. Some members of the Group were strongly in favour of including these appendices in this report, but making them available the web was felt to be more appropriate to avoid unbalancing the report. The BX's pointed out that the actual prices and costs assumed were not underwritten by BNFL. In addition, the level of detail presented in the report and its appendices had not been agreed by the Company. However, the Company did agree that the figures were not unreasonably inaccurate. The cost figures provided by the Company for use in the ERM socio-economic study had not been made available to the Green Experts.

5.28 The undiscounted costs (in £millions throughout this Section) are given in Table 5.1 [25]. The 'Lower Net Cost' figures have been prepared using optimistic assumptions for both costs (i.e. costs low) and incomes (i.e. incomes high). The Higher Net Costs figures assume high costs and low income.

Scenario	Lower Net Cost	Higher Net Cost
SF1a	3600	6000
SF1c	3900	5900
SF1T	7900	11300
SF2	300	3600
SF2T	1600	5300
SF3	-1200	7900
SF3T	900	10500
SF3T+	1400	11300

Table 5.1

These figures include future costs and possible income streams. They do not include past income streams and therefore this is a partial view of the overall financial transaction.

5.29 The cost information led to the Group considering whether some scenarios should be favoured above others, or if other hybrids should be examined. There was agreement that the analysis of options by both MADA and SAP was sufficient to allow interpolation to cover hybrid scenarios within the total range, and that the study of more cases was not necessary.

[24] The Environment Council website address: www.the-environment-council.org.uk

[25] These figures have been rounded from those quoted in Appendix 14. The apparent precision of the figures quoted in this Appendix is to preserve an audit trail through the GX calculations.

5.30 It was noted that contingency plans will cost money and will make the cash situation worse, and that both extreme cases ‘stop now’ (SF1) and ‘blue sky’ (SF3) have the greatest uncertainty over their funding – SF1 because of its direct cost to the public purse, and SF3 because of the uncertainty of costs, prices and availability of business. SF3 carries more business risk and would need a favourable combination of timing and price to make the extra business viable.

5.31 The cost of the ‘T’ scenarios raised doubts on the viability of a Magnox head end on THORP, though there were some possibilities of a lower cost, lower throughput option. Scenario 1T looked particularly vulnerable in this regard.

5.32 Figures were also provided on a 2.5% discounted basis as shown in Table 4.3 of Appendix 14, but these did not materially affect the ranking of options.

5.33 These costs can be plotted against the MADA scores for the two profiles previously described, and repeated below.

MADA scores

Scenario	Environmental Profile - Profile 1	Socio-economic Profile - Profile 2
SF1a	0.560	0.333
SF1c	0.812	0.416
SF1T	0.626	0.473
SF2	0.421	0.535
SF2T	0.437	0.579
SF3	0.366	0.615
SF3T	0.358	0.615
SF3T+	0.276	0.692

Table 5.2

5.34 Efficiency frontier diagrams were prepared separately for each of the two weight profiles, for upper and lower cost assessments, and for discounted and undiscounted costs, a total of eight world views each with corresponding efficiency frontiers. An example is reproduced in Figure 5.1.

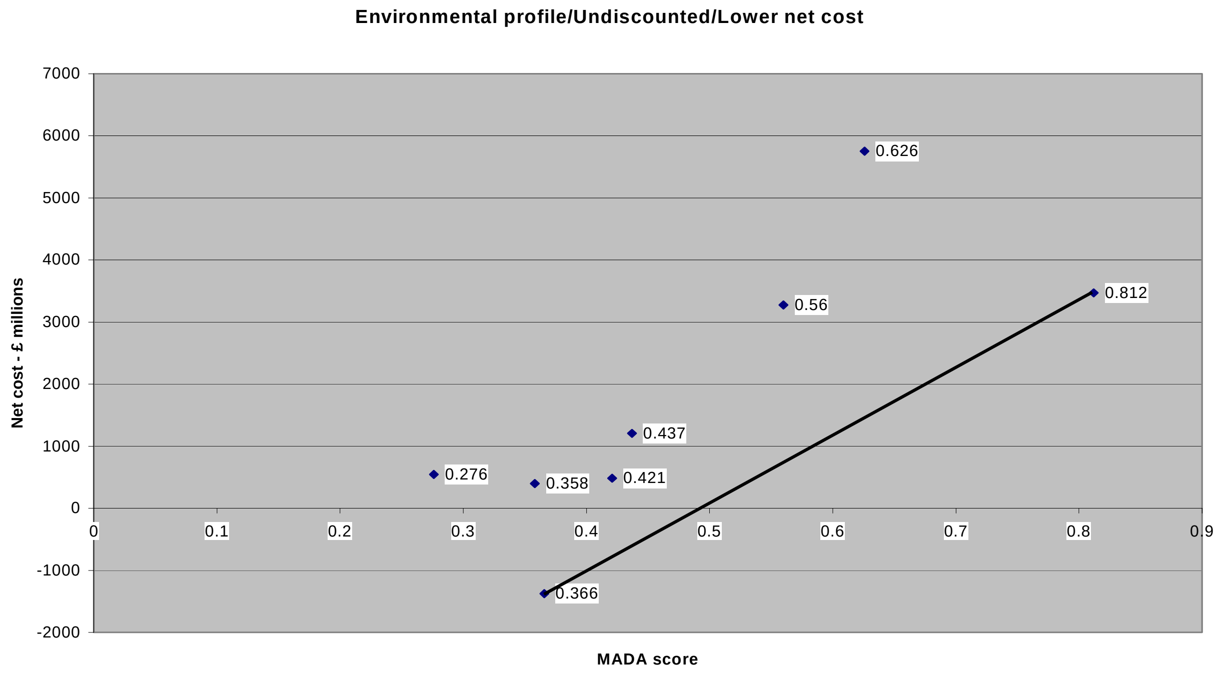

Figure 5.1

5.35 Each efficiency frontier highlights those alternatives that are most promising in terms of having low net cost and high performance, the latter as assessed through the MADA score. It is possible to show mathematically that, in any one diagram and taking the numbers purely at face value, only scenarios that lie on an efficiency frontier are candidates for the most preferred choice. Seeking low cost and high performance means that the efficiency frontier will lie towards the bottom right-hand corner of each diagram.

5.36 Points on the frontier can be viewed as representing increasing net cost and increasing performance as one moves from left to right along the frontier. All scenarios on the frontier are in a sense "efficient" and the choice to be made is between low cost/low performance at the left-hand extremity through to progressively higher levels of both cost and performance for each step to the right along the frontier.

5.37 Clearly the best option is one having a high MADA score and low cost – so bottom right (high MADA score low cost) is preferred to top left (low MADA score high cost). In this example the option marked 0.366 is low cost but relatively low MADA score, while the option 0.812 is higher in MADA score but higher costs. Other points are further towards the "high cost/low score" area and will generally not be preferred.

5.38 Plotting all the efficiency frontiers led to the table below. This shows that the SF1c option appears on all Environmental profile frontiers, while all Socio-economic frontiers contain the 3T+ option. A 'world view' is some combination of weight profile (**E**nvironmental and **S**ocio-economic), discounting assumption (**U**ndiscounted and **D**iscounted at 2.5%) and net cost estimate (**L**ow or **H**igh). A 'dominated' scenario is one where, for the 'world view' row concerned, there exists an alternative scenario with both lower costs and better performance.

World view	Lies on the Efficiency Frontier	Dominated
E/U/L	SF1c, SF3	SF3T+, SF3T, SF1T
E/U/H	SF1c, SF2	SF1a, SF1T, SF3, SF3T, SF3T+
E/D/L	SF1c, SF3	SF1T, SF3T, SF3T+
E/D/H	SF1c, SF2	SF1a, SF1T, SF2, SF3, SF3T, SF3T+
S/U/L	SF3T+, SF3	SF1a, SF1c, SF1T, SF2, SF2T, SF3T
S/U/H	SF3T+, SF2T, SF2	SF1a, SF1T, SF1c
S/D/L	SF3T+, SF3	SF1a, SF1c, SF1T, SF2, SF2T, SF3
S/D/H	SF3T+, SF2T, SF2	SF1a, SF1T, SF1c

Table 5.3

5.39 It is clear from the above that adding the cost element to the MADA process has not markedly changed the overall range of preferred options, which concentrate on scenario 1 options when viewed from an environmental viewpoint and towards scenario 3 options where a socio-economic viewpoint is taken.

Review of individual efficiency frontiers

5.40 The combination of the two profiles (environmental and socio-economic), and two views on costs generates a rectangular area for each scenario on the MADA / Cost plot. This is shown in Figure 5.2 for representative scenarios which appear on any of the eight efficiency frontiers.

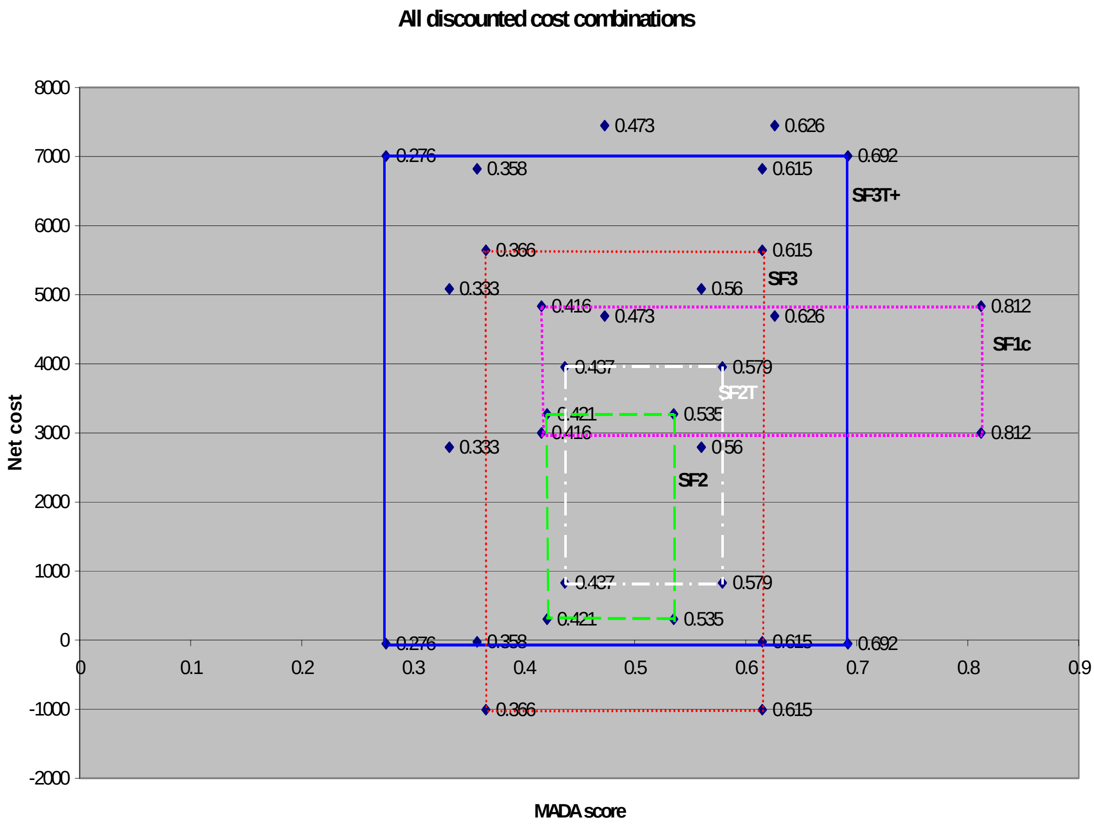

Figure 5.2

5.41 This illustrates that using these cost figures which have not been iterated with the BX's, the SF1c option illustrates a relatively small range of costs, while having a large range of MADA scores. This reflects that this option has limited ongoing activity and relatively short-term, and therefore certain costs, while being (a) very desirable on an 'environmental' basis but (b) very undesirable on a 'socio-economic' basis.

5.42 On the other hand the area occupied by SF3 options shows a large range in both costs and MADA scores. This is explained by the greater amount and timescale of future operations, and therefore the degree of uncertainty in both costs and incomes, and the polarised MADA scores (in this case undesirable from an 'environmental' basis).

5.43 In between are the 'scenario 2' options, which are intermediate in range on both a cost and MADA basis. This 'tighter' definition signifies their perceived lower cost 'risk' and the reduced level of difference within the Group on their 'acceptability'.

Review of Security Aspects

5.44 Following the events of 11 September 2001, it is possible, in choosing between scenarios, that greater weight might be placed on those attributes in the original MADA analysis that could be seen as reflecting some element of terrorist risk. The major security issues are:

- nuclear materials inventories, particularly HAL
- effects on civil liberties
- security resourcing (IAEA, UK resources etc)
- priorities for hazard and risk reduction.

5.45 Analyses were carried out to throw light on how sensitive the original rankings of scenarios might be to attaching greater weight to such attributes. The attributes considered were:

- Lifetime arisings
- Hazard
- Risk
- Transport Risk.
- Magnox Storage (added later).

5.46 The way in which risk and hazard were dealt with in the MADA and subsequent SAP work was reviewed. The following definitions, which clarify the way in which these criteria had been used, are:

- Hazard: the potential of the material to cause harm
- Risk: the probability of an incident occurring
- Outcome: the consequence of an incident
- Mitigation: action taken in response to the potential outcome.

The full results of the analysis are included as Appendix 15.

5.47 Varying the weights associated with individual factors revealed that no one attribute had a significant effect on the ranking of scenarios. The MADA was then rerun re-weighting all five attributes simultaneously.

5.48 A simple graphical representation is the best way to get an initial idea of how likely significant ranking changes are in the light of possible changes to weights. This shows how the ranking of scenarios would change if the weight attached to the five attributes was to be varied anywhere between 0 (no importance at all to the ranking of scenarios) through to 1 (100% on the diagram - only the five attributes matter). As the weight on the chosen attributes alter, all other weights are scaled (to ensure weights continue to add to 1). The scaling is done such that the *relative* weights attached to all other attributes are unaltered. In each case, the intermediate vertical line in the figure denotes the initial weight for the attributes and, where relevant, a thicker dotted line indicates how far the weight would have to increase before a change in preferred scenario would take place

5.49 The graphs representing the 'environmental' (Profile 1) and 'socio-economic' (Profile 2) views are presented in Figures 5.3 and 5.4 respectively.

Environmental Profile reweighted for security aspects.

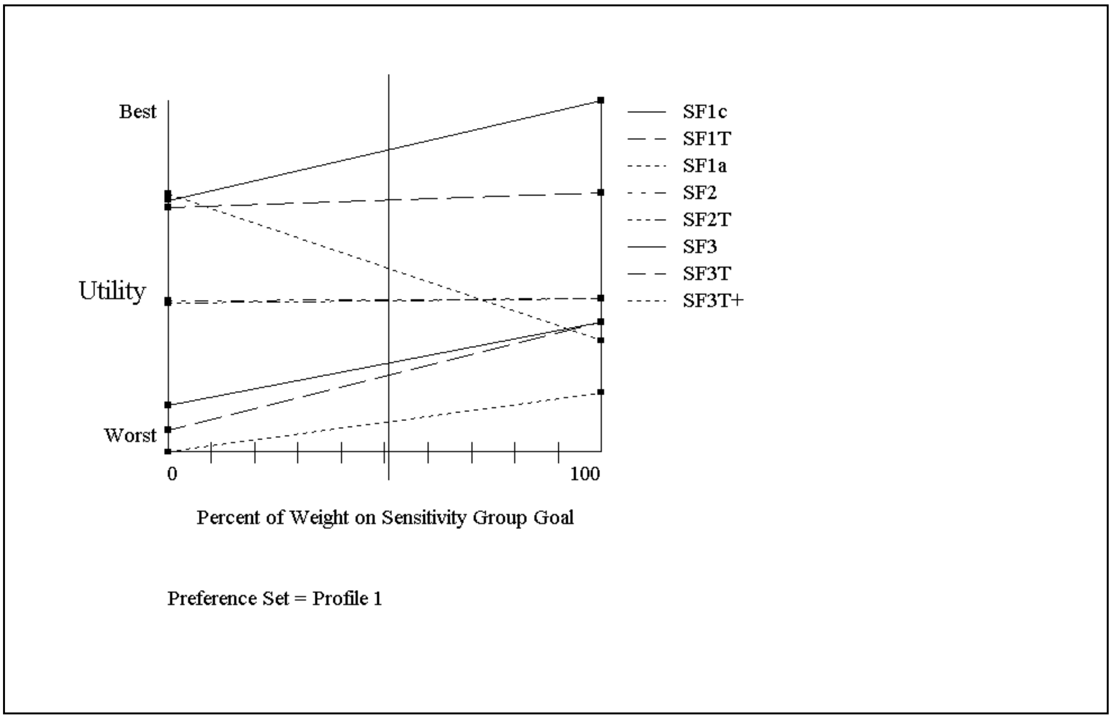

Figure 5.3

Socio-economic Profile reweighted for security aspects

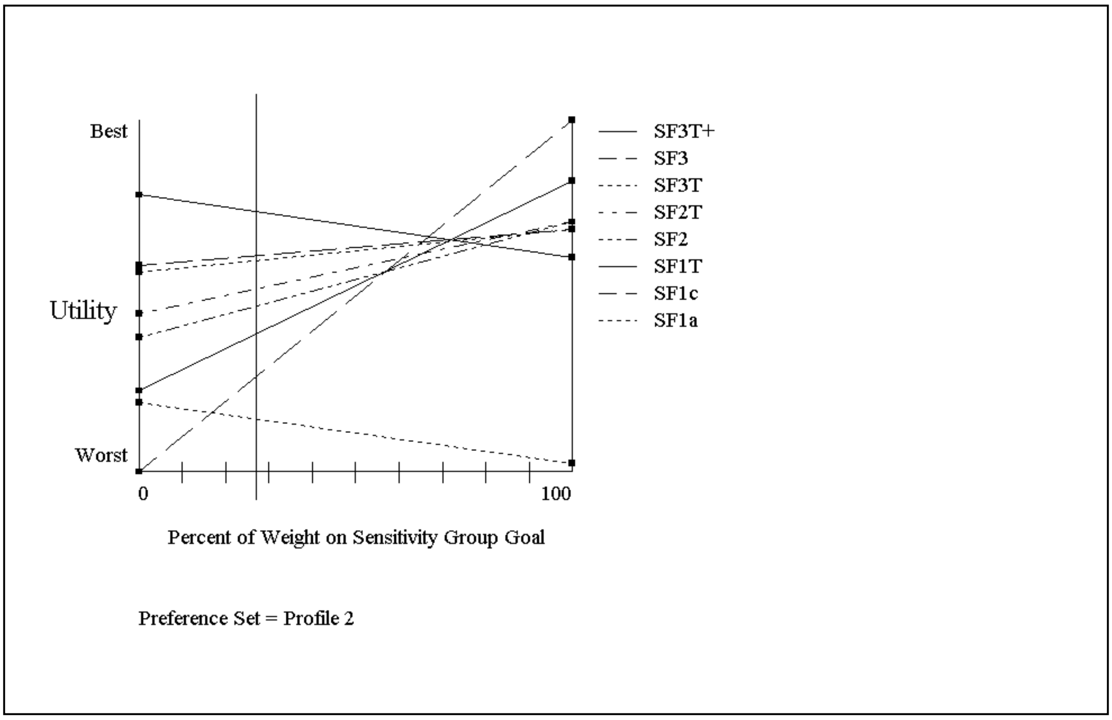

Figure 5.4

5.50 For SF3 scenarios, all scores are quite similar, so preferred scenarios will move broadly in unison and SF3's will only be displaced when the weight falls quite substantially. SF2's and SF3's also have broadly similar performance on all chosen attributes.

5.51 For SF1's, again, scores are quite similar, except in relation to Risk and to Magnox Storage for SF1a. In the case of Risk, SF1c, which already ranks first, performs even better if more emphasis is placed on the Risk attribute. For SF1a, its performance deteriorates rapidly as more weight is put on Magnox Storage. Thus in Profile 1, for the Sensitivity Groups as a whole and for all individual attributes except Risk and Magnox Storage, SF1 performances will move broadly in unison and will only fall in the rankings when either weight on all attributes combined, or on Transport Risk alone (SF2's and SF3's score well, SF1's do not), change quite substantially and allow the other scenario groups to rise to the top as a consequence.

5.52 The Group's assessment is that the original rankings are robust to the concerns about increased terrorist risk. This is not to say, however, that the change in risk perception is irrelevant overall. Higher risk may require countermeasures that change cost profiles. It may also have significant implications for the Strategic Action Planning part of the overall SFMO WG exercise.

Preparation of a Strategic Action Plan

5.53 At its May 2001 meeting, the SFMO WG was given an introduction to 'strategic action planning', a technique within the "management of uncertainty" portfolio. This can be represented as:

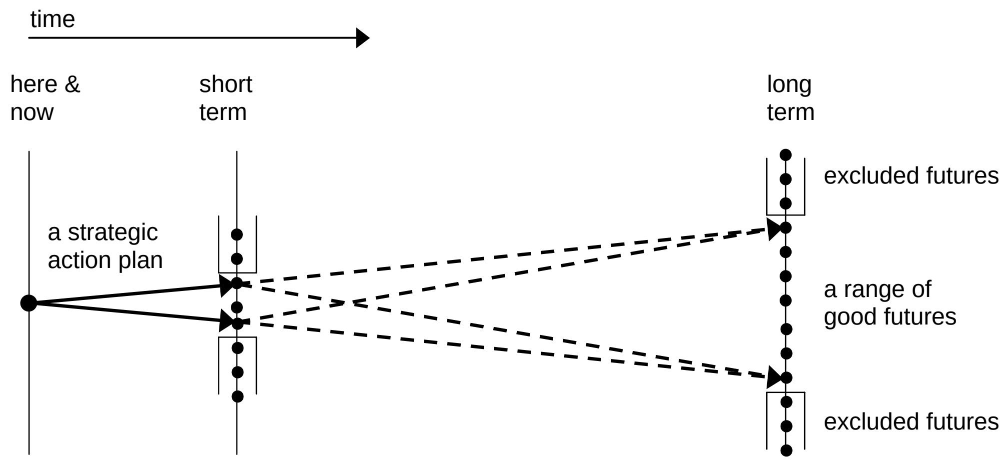

Figure 5.5 A strategy with management of uncertainty

and is further explained in Appendix 12.

5.54 A typical Strategic Action Planning table will look like this:

ASSUMPTION	ACTIONS	EXPLORATIONS	DEFERRED ACTIONS (OR DECISIONS)	CONTINGENCY

ASSUMPTIONS:
Assumptions are used in strategic action planning where an uncertainty cannot be easily or quickly reduced. These are made explicit and then clearly stated. Each assumption (or group of related assumptions under an "Issue" heading) then starts a row of the table.

Typical Question(s) (TQ) - What assumptions are being made in order that this scenario can work?

ACTIONS:
What is to be done in the short term. These tend to be actions about which there is little or no uncertainty, especially with regard to their relevance or impact.

TQ – What short term action is required in order that this scenario is to be pursued?

EXPLORATIONS:
Those areas of uncertainty to be researched or investigated, starting in the short term. Explorations are aimed at reducing the uncertainty relevant to the assumption and often are intended to support decisions which can safely be put off to a future date (or deferred - see below).

TQ – What needs to be known in order that the uncertainty can be reduced? How can we find out?

DEFERRED DECISIONS OR ACTIONS:
Decisions, or actions, which can be safely deferred – often pending the outcome of explorations when the uncertainty has been reduced. These are usually decisions which present a risk if they are taken now (based on an assumption) and are better deferred until more is known and the associated risk can be reduced.

TQ – What decision/action can be deferred? When does the decision have to be made or implemented?

CONTINGENCY:
What will be done in the event that the assumption turns out to be wrong? N.B. When a number of scenarios are being considered it is common for one scenario to be the ultimate contingency for another.

TQ – e.g. What will be done if the plant suffers a catastrophic failure?

5.55 The aim of the planning is to make underlying assumptions explicit, and develop contingency plans for situations where assumptions turn out to be wrong. The plan focuses in detail on the short term, and results in assessments along the line of ‘if you do this’ now what does it enable or exclude in the longer term. It allows non-urgent or consequent decisions to be deferred until they can be better informed – either through an explicit programme of investigation or the occurrence of events over the passage of time.

5.56 The Group applied strategic action planning by taking from its MADA output the two profiles which represented the less radical “socio-economic” variant (Profile 2) and the more radical “environmental” variant (Profile 1). It took these from the MADA as described above, having particular regard to the weighting issues noted in paragraph 5.11 et seq. Based on this approach, the two scenarios subject by the Group to the development of a Strategic Action Plan, were – Scenario 1c (a 'stop now' variant) and Scenario 3T+ (the most optimistic 'blue sky' variant). A further median analysis of Scenario 2 was added subsequently.

5.57 The purpose of this exercise was to look in detail at the consequences for BNFL of pursuing each scenario, tracking what the key decision points are, when the scenarios became established and what chain of further consequential decisions followed. The Group used the term 'Block' to describe each set of issues being analysed. For each scenario a set of 'assumptions' was first identified, sometimes being added to as implications were noticed.

5.58 An overarching assumption was that new developments have to be funded from ongoing activities and /or the shareholder i.e. the public purse. Second, the implications for each major plant were tracked – Magnox Reactors, B205 (Magnox Reprocessing at Sellafield), THORP, Vitrification Plant and the SMP. Finally some of the external implications were assessed covering: Socio-Economic Mitigation, Contract Arrangements, and Inter Government Agreements.

5.59 For each component of the analysis four questions were asked:

- what <u>Action</u> is needed?
- what <u>Exploration</u> is needed?
- what <u>Deferred Actions</u> do these lead to?
- what <u>Contingency Plans</u> must be put in place?

5.60 For some of the plants, and in particular for some of the external implications assessed, not all of these questions were pursued or developed – hence the blanks in the Tables below. Finally as each analysis was concluded and compared, notes were added of key points affecting each block.

5.61 The following tables (Tables 5.5 to 5.7) list the assumptions made for each scenario, and their associated actions, explorations, deferred actions and contingency plans.

5.62 If the changes made to assumptions for contingency planning purposes are sufficiently radical, a default to an entirely different scenario may be appropriate. For example, a permanent failure of B205 would move a 'business as usual' scenario into the appropriate 'stop now' scenario.

Strategic Action Planning

Tables 5.5 – 5.7 follow on pages 78 – 90.

TABLE 5.5 - Strategic Action Plan 1 (the 1c scenario)

Assumptions

1 B205 will continue to operate within current regulatory and environmental regimes and closes no later than 2012
2 Early closure of Magnox reactors is possible i.e. it is OK to remove 8% of UK electricity supply through early closure
3 Restart of THORP after suspension of operations for a significant length of time is not practical
4 Overseas oxide fuel will be returned from 2010, and domestic AGR fuel will be wet stored at Sellafield
5 It is possible to renegotiate contracts and intergovernmental arrangements
6 AGR and LWR Spent fuel storage is permitted in Sellafield ponds in the absence of reprocessing, and the required capacity can be made available.
7 Vitrification plant does not constrain reprocessing throughput (note that this SF1c scenario minimises HAL generation by stopping Oxide reprocessing)
8 Discharge authorisations do not constrain the operation of Sellafield plants
9 Regulatory regime[26] does not change significantly in the foreseeable future
10 Adequate funding is available, linked to definition of legacy waste[27]
11 Overseas transport routes remain open
12 Once wetted, Magnox fuel must be reprocessed
13 Separated plutonium will be returned to overseas customers as PuO2 powder

[26] Regulatory regime includes NII, EA, security, safeguards and transport (see paragraph 1.14)
[27] Costs are dealt with in paragraphs 5.32 et seq

Plant/Issue	Actions	Explorations	Deferred actions	Contingency Plans
Magnox reactors	Close immediately			If immediate Magnox reactor closure isn't possible close as soon as possible.
B205 Magnox Reprocessing Plant	Close as soon as current irradiated Magnox fuel stocks are reprocessed.	Monitor B205 performance. Explore feasibility of modified head end on THORP to reprocess Magnox fuel. Develop contingency plan for wetted fuel. Develop contingency plan for long term dry fuel in cores.	As soon as exploration complete (2002 - 2004 but earlier if possible) decide whether to build THORP head end or fit abatement to B205.	If B205 can't perform then close no later than 2012 and put Magnox fuel through THORP. In the event of sudden and terminal failure of B205 store dry fuel in cores, and urgently develop contingency plans for wetted fuel.
THORP	Stop oxide fuel reprocessing Convert to interim storage and maintain operational plant.	Consider how to keep THORP operable, including whether minimal reprocessing is necessary to maintain plant integrity as a contingency route.	2002 decide whether to keep reprocessing or not About 2004 decide whether to close down or re-start THORP	In the event that THORP is not available if required for reprocessing Magnox fuel, store dry fuel in cores, and urgently develop contingency plans for wetted fuel.
Oxide Fuel Storage	Seek modified planning permission to allow continued storage of fuel on site.	Examine storage options for timescale, siting and viability, including choices of wet or dry storage and centralised or dispersed siting, and safety case work. Examine transport implications of any change of storage siting.	If dry storage selected, develop drying and dry storage process for AGR fuel. Design and construct further storage to allow continued AGR operation.	If permissions and/or storage capacity are not available in time, shut down AGR stations.

Plant/Issue	Actions	Explorations	Deferred actions	Contingency Plans
Vitrification Plant	Operate lines 1 and 2. Commission line 3. Monitor performance. Monitor tank condition.	Continue to explore ways in which reliability can be improved.		In the event that performance does not improve, balance the detriment from HAL arisings with the increased hazard from wetted fuel storage, and/or consider replacement HAL tankage or ultimately a need for alternative vitrification capacity.
SMP	Do not start. * [28]			If oxide form of Pu not acceptable for return, determine form that is acceptable. Decide the form of return of overseas Pu.
Transport	Maintain UK transport system to meet delivery programme. Improve individual flask payload to design levels.	Monitor UK transport system performance against programme. Monitor UK route availability.		
Socio-Economic	Release ERM report to relevant Government and local agencies. *	Evaluate consequences for workforce and local economy of early closure. Develop mitigation packages and timing.	Agree mitigation package and timing for implementation.	Reassess mitigation package in the light of any of the other contingency plans being implemented.

[28] * Denotes items which have been completed or overtaken by events.

Plant/Issue	Actions	Explorations	Deferred actions	Contingency Plans
Contract Arrangements	Open discussions with customers about renegotiation of contracts and timing of LWR fuel returns.	Renegotiate contracts. Assess available fuel storage capacity at Sellafield and at reactor sites. Explore acceptability of alternative forms of Pu return. Review national storage strategy.	Within 12 months of THORP closedown decision decide whether to continue to accept AGR fuel (consider implications for energy supply). Decide where to build additional storage capacity (consider implications for AGR's and energy supply and public acceptability).	If LWR return not possible, seek change in Government policy (see below).
International / Government Agreements	Confirm applicability of international and Government agreements. Seek Government/ Shareholder agreement to fund the scenario.	Explore how existing agreements will be implemented or modified. Review national storage strategy.	Agree methodology for implementing agreements. Implement program of return of material.	Decide the form of return of overseas Pu. If no agreement for the return of material, explore the possibility of a change of government policy to allow storage and / or undertake limited reprocessing and waste storage.

Table 5.6 - Strategic Action Plan 2 (the 2 scenario)

Assumptions

1 Magnox reactors will operate to currently announced closure dates, and all fuel will be reprocessed
2 Economic factors will not cause early closure of stations
3 There will therefore be 11,100t of fuel to be reprocessed from 1.4.01
4 B205 will continue to operate within current regulatory and environmental regimes, and all Magnox fuel can processed by 2012, this involves an average throughput of 1,000 t/yr from 2002 until 2012
5 The infrastructure and transport capacity is sufficient to deal with all fuel, as per planned programme
6 THORP will continue operation to at least 2014, meet contractual throughput targets, and there will be 1600 tonnes of post base load contracts
7 SMP will get Authorisation – but no SMP 2.
8 All overseas Pu will be returned to customers as MOX.
9 Vitrification plant does not constrain reprocessing throughput and HAL reduction commitments are met (target 330 containers/yr)
10 Discharge authorisations do not constrain the operation of Sellafield plants
11 Regulatory regime[29] does not change significantly in the foreseeable future
12 Overseas transport routes remain open
13 Once wetted Magnox fuel must be reprocessed
14 The company considers that scenario 2 is commercially viable[30]
15 There is no constraint on transport routes being available

[29] Regulatory regime includes NII, EA, security, safeguards and transport.
[30] Costs are dealt with in paragraphs 5.32 et seq

Plant/Issue	Actions	Explorations	Deferred actions	Contingency Plans
Magnox reactors	Continue to operate to announced lifetimes subject to all fuel being able to be processed through B205 by 2012.	Monitor reactor performance and B205 throughput for any implications on closure dates. Keep economics under review.	Annually review reactor closure dates against planned irradiated fuel stock profile. Close new fuel production process once sufficient is made to stock.	Shut reactors if: • B205 can't deliver • Economics are poor • Significant plant failure
B205	Improve performance to allow all Magnox fuel to be reprocessed through B205 by 2012.	Monitor performance and impact of improvement projects against the planned irradiated fuel stock profile. Explore feasibility of modified head end on THORP to reprocess Magnox fuel. Check feasibility of fitting B205 with abatement compared with THORP Head End. Explore technical feasibility and public acceptability of other processes for achieving passive storage which does not preclude treatment for eventual disposal.	As soon as exploration complete (2002 - 2004 but earlier if possible) decide whether to build THORP head end or fit abatement to B205.	If throughput rate is inadequate or if it cannot operate within future environmental and regulatory trends then • close reactors early or • put Magnox fuel through THORP Head End or • fit more abatement. • or further contingencies arising out of explorations In the event of sudden and terminal failure of B205, store dry fuel in cores, and urgently develop contingency plans for wet fuel.

Plant/Issue	Actions	Explorations	Deferred actions	Contingency Plans
Transport	Maintain UK transport system to meet delivery programme. Improve individual flask payload to design levels.	Monitor UK transport system performance against programme. Monitor UK route availability.		If UK transport system under-performs, improve it and, in extremis, consider bringing forward closure dates
THORP	Continue operation until at least 2014. Monitor performance.	Explore feasibility of new THORP Head End for Magnox fuel. Check feasibility of fitting B205 with abatement compared with THORP Head End.	2002 - 2004, decide to build THORP Head End or not, depending on feasibility and need (with respect to B205 and reactor performance).	If no post-baseload contracts close THORP by around 2008 or manage throughput of oxide fuel prior to diverting Magnox fuel to a new THORP Head End. If THORP Head end is built, consider extending Oldbury and Wylfa lifetimes subject to safety and commercial liability. In the event of severe THORP throughput problems store fuel, or ultimately seek to return it. In the event of lack of post baseload contracts examine alternative uses for THORP.
Vitrification Plant	Operate lines 1 and 2. Commission line 3. Monitor performance.	Continue to explore ways in which reliability can be improved.		In the event that performance constrains throughput, reduce HAL arisings e.g. by reducing throughput through THORP, or in extremis bringing forward Magnox reactor closure.
SMP	Start it up* [31]	Explore SMP role in Pu UK stocks management.		If SMP does not operate successfully resolve form of Pu return to customers.

31 * Denotes items which have been completed or overtaken by events.

Plant/Issue	Actions	Explorations	Deferred actions	Contingency Plans
Oxide Fuel Storage		For AGR fuel not covered by reprocessing contracts, examine storage options for timescale, siting and viability, including choices of wet or dry storage, centralised or dispersed siting, and safety case work. Examine transport implications of any change of storage siting.	If dry storage selected, develop drying and dry storage process for AGR fuel. Design and construct further storage to allow continued AGR operation.	If THORP underperforms, feed in any extra storage requirements to the considerations of storage capacity and timing.
Socio-Economic	Release ERM report to relevant Government and local agencies. *	Evaluate consequences for workforce and local economy. Develop mitigation packages and timing.	Agree mitigation package for implementation if appropriate.	Reassess mitigation package in the light of any of the other contingency plans being implemented.
Contract Arrangements	Secure additional base load business – to 1600 tonnes total.	Continue sales contract discussions.	Annually review closure date for THORP.	Reassess closure date for THORP (see THORP section above) in the light of volume of post-baseload obtained. In the event of severe THORP throughput problems seek contractual agreement to store fuel, or ultimately to return it. If SMP does not operate successfully discuss and agree form of Pu return with customers.
International / Government Agreements	Confirm continued applicability of international and Government agreements.			In the event of using the contingency plans above, achieve an international/Government agreement regime to cover this. Explore changes to operations required by any changes in agreements regime.

Table 5.7 - Strategic Action Plan 3 (the 3T+ scenario)

Assumptions

1	Magnox reactors will operate to announced closure dates, and other reactors to currently planned lifetimes
2	There will be more post base load business for THORP
3	B205 will continue to operate within current regulatory and environmental regimes
4	THORP will run beyond 2020 within the constraints of the OSPAR convention
5	THORP Head End will be feasible and commissioned by 2010
6	SMP is Authorised and operates
7	There is enough post base load business for THORP to justify SMP 2
8	All Pu will be returned to foreign customers as MOX
9	Vitrification plant does not constrain reprocessing throughput and HAL reduction commitments are met (Target 330 containers per year). Note that the post-baseload THORP reprocessing takes place at a time when vitrification throughput must match reprocessing output
10	Discharge authorisations do not constrain the operation of Sellafield plants
11	Regulatory regime[32] does not change significantly in the foreseeable future
12	Overseas transport routes remain open
13	Once wetted Magnox fuel must be reprocessed
14	The Company considers that Scenario 3 is commercially viable[33]

[32] Regulatory regime includes NII, EA, security, safeguards and transport.
[33] Costs are dealt with in paragraphs 5.32 et seq

	Actions	Explorations	Deferred actions	Contingency Plans
Magnox reactors	Continue to operate to announced lifetimes subject to all fuel being able to be processed through B205 by 2012.	Monitor reactor performance and B205 throughput for any implications on closure dates. Keep economics under review.	Annually review reactor closure dates against planned irradiated fuel stock profile and economics. Close new fuel production process once sufficient fuel made.	Shut reactors if: • B205 performance indicates a shortfall in B205 reprocessing capacity before THORP Head End comes online • Economics are poor • Significant plant failure.
B205	Improve performance to allow all Magnox fuel arisings to be reprocessed through B205 until THORP head end available.	Monitor performance and impact of improvement projects against the planned irradiated fuel stock profile. Explore feasibility of modified head end on THORP to reprocess Magnox fuel. Check feasibility of fitting B205 with abatement compared with THORP Head End. Explore technical feasibility and public acceptability of other processes for achieving passive storage which does not preclude treatment for eventual disposal.	As soon as exploration complete (2002 - 2004 but earlier if possible) decide whether to build THORP head end.	If throughput rate is inadequate or if it cannot operate within future environmental and regulatory trends then • close reactors early or • put Magnox fuel through THORP Head End or • fit more abatement. In the event of sudden and terminal failure of B205, store dry fuel in cores, and urgently develop contingency plans for wet fuel.

	Actions	Explorations	Deferred actions	Contingency Plans
Transport	Maintain UK fuel transport system to meet delivery programme. Improve individual flask payload to design levels.	Monitor UK fuel transport system performance against programme. Monitor UK fuel route availability .		If UK fuel transport system under-performs, improve it and, in extremis, consider bringing forward closure dates.
THORP	Continue to operate beyond 2020 within the constraints of the OSPAR convention.	Explore feasibility of new THORP Head End for Magnox fuel. Explore implications of OSPAR for continued operation post 2020. Review required infrastructure (including stores and downstream plants) for THORP extension. Check feasibility of fitting B205 with abatement compared with THORP Head End.	2002 - 2004, decide to build THORP Head End or not, depending on feasibility and need (with respect to B205 and reactor performance). Research abatement measures if necessary. Install infrastructure for THORP extension to meet contract needs.	Reassess closure date for THORP (see THORP section above) in the light of volume of post-baseload obtained. If THORP Head end is built, consider extending Oldbury and Wylfa lifetimes subject to safety and commercial viability. If new THORP Head End isn't feasible, see Magnox contingencies under scenario 2. If THORP doesn't meet OSPAR requirements abate discharges. In the event of lack of post baseload contracts examine alternative uses for THORP.

	Actions	Explorations	Deferred actions	Contingency Plans
Vitrification Plant	Operate lines 1 and 2. Commission line 3. Monitor performance.	Continue to explore ways in which reliability can be improved.		In the event that performance constrains throughput, reduce HAL arisings e.g. by reducing throughput through THORP, or in extremis bringing forward Magnox reactor closure.
SMP	Start it up. * [34]	Explore feasibility of SMP 2 and design SMP 2. Explore SMP role in Pu UK stocks management.	2004 start approval process for building SMP 2 providing expectation of contracts is high enough.	If SMP does not operate successfully resolve form of Pu return to customers If SMP2 not Authorised accept no additional business.
Oxide Fuel Storage		For AGR fuel not covered by reprocessing contracts, examine storage options for timescale, siting and viability, including choices of wet or dry storage, centralised or dispersed siting, and safety case work. Examine transport implications of any change of storage siting.	If dry storage selected, develop drying and dry storage process for AGR fuel. Design and construct further storage to allow continued AGR operation.	If THORP underperforms, feed in any extra storage requirements to the considerations of storage capacity and timing.
Socio-Economic	Release ERM report to relevant Government and local agencies. *	Evaluate consequences for workforce and local economy.		

[34] * Denotes items which have been completed or overtaken by events.

	Actions	Explorations	Deferred actions	Contingency Plans
Contract Arrangements	Secure additional post base load business sufficient to justify operation of THORP beyond 2020 and construction and operation of SMP2.		Annually reassess forecast closure date for THORP (see THORP section above) in the light of volume of post-baseload obtained and throughput performance.	In the event of severe THORP throughput problems seek contractual agreement to store fuel, or ultimately to return it. If SMP does not operate successfully discuss and agree form of Pu return with customers.
International / Government Agreements	Confirm continued applicability of international and Government agreements.			In the event of using the contingency plans above, achieve an international/government agreement regime to cover this. Explore changes to operations required by any changes in agreements regime.

Elements of an Agreed Action Plan

5.63 The emphasis of the work was to highlight the importance for BNFL and stakeholders of exploring the consequences of decisions that needed to be taken in the short term and to begin the necessary design work on those key plants that could be required under the contingencies identified.

5.64 Because the need to improve B205 performance is vital to BNFL's announced Magnox strategy, the Group considered that it is essential for BNFL to monitor performance to see if targets are being achieved and, if they are not, to follow the consequential paths identified. SFMO WG also agreed that the contingency which involved putting wetted Magnox fuel through THORP, and which would require a modified Head End to be fitted as soon as possible, needed BNFL to initiate urgent early decisions and design work. The Group has been informed of B205 performance through the Magnox Task Group. The company provided a graph of the minimum throughput required from B205 in order to maintain its closure date of 2012 and reactor operation to announced dates (see Appendix 9 for November 2001 update and graph).

5.65 A key Action identified under all 3 strategic action plans is that the ERM report should be released for consideration by BNFL, affected communities, and government. The ERM study has already provided the necessary information base concerning the way the area around Sellafield will change as a result of early run down. It notes that for all scenarios, including 'blue sky', employment in the study area will decline by between 8,000 and 10,000 jobs by 2025. It is the rate of these job losses that changes between the scenarios. For the 'stop now' scenario some 8000 jobs would be lost by 2008. Even with the current business plan some 10,000 jobs would be lost by 2018: ERM have estimated the difference between the SF1 and SF3 scenarios as 150,000 (direct) person years. However, the ERM Report concludes that there are a number of committed or potential projects that could help protect the employment base in West Cumbria. With effort to secure that amelioration, the employment decline could be reduced to between 3000 and 8000 jobs over the same period, and population levels in West Cumbria stabilised. That report, steered by a Group representing both the SFMO WG and Pu WG, makes a number of recommendations of relevance to BNFL, the affected communities, Unions and government which should be further developed.

5.66 The Group took into account the earlier reports of the Discharges and Waste Working Groups, in particular using the scenarios developed by those groups to inform the early data acquisition and select preliminary 'bounding' scenarios. It concurred with the Discharge Working Group's conclusion of the need for the company to be seen to strive to the utmost in reducing discharges, in particular given the OSPAR drivers. In addition, the Group considered that in taking forward any scenario the recommendations of the

Waste Working Group that *"All existing waste and waste arisings must be packaged in passively safe, monitorable and retrievable interim storage in the shortest possible time"* should be taken fully into account.

5.67 Integral to the SFMO WG Strategic Action Plans above are key review dates or 'milestones' by which progress in implementation would be monitored and reviewed. In determining its future strategic direction BNFL should develop its own future Strategic Plan where these 'milestones' would be clearly identified, reviewed and made operational.

5.68 From the individual SAP's, the Group has identified a number of milestones many of which are scenario dependent. The milestones common to all scenarios are given below. Other milestones should be considered in the context of the appropriate SAP.

Date	Action	By whom
Mid 2002	Start development of socio-economic mitigation packages.	Joint: Company, TU's Local Authorities and any other relevant stakeholders
2002-2004	Arrive at decision on future THORP programme based on • Throughput • Contracts • Pond storage capacity • Vitrification plant performance.	Company
Latest end 2004	Decide whether or not to build head end on THORP.	Company
	Develop B205 abatement option.	Company
	Develop contingency plan for wetted fuel and dry fuel in reactor cores.	Company
By 2009	Close Magnox stations to 23 May 2000 programme.	Company
Latest end 2012	Close B205.	Company
2020	Sellafield site to comply with OSPAR requirements as defined.	

6. CONCLUSIONS

6.1 This is a baseline report which, after a thorough examination of all the issues, has narrowed the realistic range of choices available. It moves away from both the 'stop now' and 'blue sky' ends of the spectrum, giving greater emphasis to storage options compared to long term reprocessing. The rejection of extreme scenarios has stood the test of cyclic re-examination by the Group and peer review by the Green and Company Experts.

6.2 The Group adopted an iterative process which emphasises that complex issues cannot be reduced to simplistic choices. Though many effects can be numerically evaluated, all decisions also involve subjective and value judgements. The Group's discussions mainly focussed on the implications of the Magnox power stations operation and the associated spent fuel route (see paragraph S2.3). This was seen to dominate the ability of BNFL to achieve early wins in the areas of discharge reduction, waste minimisation and ensuring early passivity.

6.3 The work of the Group has revealed that that the choice of spent fuel management options is a genuinely complex area. The study has revealed, and to a great extent quantified, a wide range of environmental, health and socio-economic effects.

6.4 It has not been possible to identify a single preferred future, but analysis using Multi Attribute Decision Analysis on agreed criteria has done much to make clear the competing factors. Following this, the use of Strategic Action Planning enabled the Group to derive forward plans which recommend agreed actions and decision points in a transparent format.

6.5 The Group believes that this work can do much to clarify the difficult choices affecting decision makers in the area of spent fuel management options, who will have to optimise the competing factors across the whole range of environmental, health and socio-economic effects.

6.6 In trying to recommend to BNFL ways in which it can improve its environmental performance, the Group has come to two 'bounding' views, emphasising environmental aspects and socio-economic aspects respectively. However, these two views do not adequately reflect the broad areas of consensus that were developed by the Group on the significance of many criteria notably: Magnox and oxide fuel storage, worker deaths, transport, the environmental impact of construction and the hazards associated with the plants. Conversely those areas where a broad consensus could not be achieved included the importance of lifetime arisings, carbon dioxide avoidance, environmental discharges, BNFL jobs and the risk associated with the processes. The most significant aspect lacking in consensus was the effect and implications of collective dose.

6.7 This analysis reinforces the importance of reaching timely conclusions regarding storage and the implications for any eventual disposal. The Group believes that the report could help to inform the Government's consultations into Solid Radioactive Waste Management and the creation of a Liabilities Management Authority.

6.8 The Group recognised that the 'stop now' scenarios (SF1) which require early closure include considerable costs which BNFL could not realistically be expected to meet from its own resources. Early termination of current core activities at Sellafield, should this route be decided upon, would be of national significance. The Group recognised that the Government would have to consider the political and fiscal implications of financing SF1 'early closure' options.

Socio-economic Impacts

6.9 The Group considers that the jointly sponsored Socio-economic Study, conducted by ERM, provides a transparent assessment of the effects and timing of the different scenarios on the West Cumbrian economy and its population. It also exposes the tension between the socio-economic and environmental components of sustainability. The report makes clear that whichever future option is followed, there will be issues of employment and infrastructure support which will require mitigation. Given the impact of all scenarios on the local economy in West Cumbria, the Group concluded that the ERM report provides a firm foundation for joint action by all key stakeholders to secure new employment opportunities in West Cumbria. This is clearly reflected in the Strategic Action Plans.

6.10 Whatever the scenario eventually adopted, in the light of the SFMO WG and Pu WG reports and embodied in future BNFL strategic planning, there is a need for an urgent and comprehensive review (based on the ERM report) of the economic impacts of BNFL's activities on the West Cumbrian economy. The Group is pleased that the ERM report has been published following careful consideration by local stakeholders. This is now the subject of further joint consideration by BNFL, the Unions, Local Authorities, government organisations and NGOs.

Spent Fuel Management

6.11 A wide range of options was examined, as indicated in Figures 3.1 - 3.3. These were only narrowed down after an extensive iterative process involving the Group, GX's and BX's.

<u>Reprocessing</u>

6.12 The benefits and detriments of both Magnox and oxide fuel reprocessing were examined through the MADA process. The consequential actions associated with the various SFMO WG scenarios are reflected in the SAP's. These allow for a default from reprocessing to storage at every stage of the developing plans.

6.13 The associated socio-economic detriments and benefits are mentioned above.

Magnox Fuel

6.14 The chemical reactivity of Magnox fuel compared to that of either AGR or PWR oxide fuels, limits the applicability of some of the possible fuel management options, hence the importance of reprocessing Magnox fuel. There is strong agreement that the performance of B205 Magnox Reprocessing Plant at BNFL Sellafield is the key determinant of the end of the Magnox programme. A joint study of processes by the GX's and BX's plus a review of regulatory views has led the Group to agree that:

- Options involving the drying of already wetted Magnox fuel are not practical, mainly because the time taken to develop and institute drying techniques exceeds the safe wet storage time of the fuel. This would be a major regulatory concern.
- Dry storage of Magnox which has not been wetted, including storage in reactors, is technically feasible as a short term option. Longer term storage gives major regulatory concern about issues such as the availability of a long term management option addressing passivity.

6.15 The Group reiterates the conclusions of the Waste Working Group[35], which emphasised the concept of passive storage. Passivity may be difficult to establish in absolute terms but relative values are easier to define. The more passive the waste form the lower the level of institutional control required. From the MADA the Group was able to conclude that, of all the SF1 scenarios, the SF1a scenario was 'least attractive' to all participants.

6.16 The SAP's are based on a reference minimum B205 programme as seen in Appendix 4. This matches projected lifetime arisings of spent Magnox fuel as closely as possible to the performance of B205 without compromising reactor operations. Recognising concerns about B205 throughput, the SAP's recommend further monitoring, exploration and contingency planning of Magnox fuel storage options in the event of a shortfall.

6.17 The programmes under 'environmental' and 'socio-economic' viewpoints coalesce if B205 does not perform i.e. 'stop now' is a subset of 'business as usual'.

[35] Waste Working Group Interim Report (28 February 2000)

THORP

6.18 If decisions are not taken to curtail the operation of THORP, its closure date will be determined by the amount of business contracted and plant throughput. In the event that operation beyond 2020 were contemplated abatement of discharges may be necessary to meet Ospar commitments: these aspects are all covered in the relevant SAP's. In the event of shortfalls in either plant performance or business demand, the SAP's also provide a framework for earlier shutdown by default to the SF1 options.

6.19 The performance of the vitrification plant affects THORP operation rather than B205 (note the NII have issued a Specification regarding HAL storage volume).

Oxide Fuel Storage

6.20 Oxide fuels may be stored for a period of decades either wet or dry. The Group did not consider store location, either at reactors or centralised storage at Sellafield. It was noted that planning permission for the current Sellafield stores is on the basis of interim storage before reprocessing. The increased emphasis on storage in the SAP's requires decisions on timescales, safety case, permitting and siting of storage well in advance of the cessation of reprocessing of AGR fuel in THORP. Any choice involving dry interim storage for AGR fuel must be accompanied by the development and regulatory approval of a drying process and storage regime. These issues raise questions of public acceptability in West Cumbria and at reactor sites.

Cost

6.21 The Group recognised that the 'stop now' scenarios (SF1) which require early closure include considerable costs which BNFL could not realistically be expected to meet from its own resources and will require financing from the public purse. Early termination of current core activities at Sellafield, should this route be decided upon, would be of national significance. The Group recognised that the Government would have to consider the political and fiscal implications of financing SF1 'early closure' options.

Process Conclusions

6.22 Strategic Action Planning based on the information derived from the MADA study proved to be a valuable exercise. It allows potentially conflicting points of view and beliefs to be accommodated within a single strategic framework. This allows default to be triggered as events unfold over time. Strategic Action Plans were derived for a 'stop now' scenario (SF1c), the 'business as usual' scenario (SF2), and the 'blue sky' scenario (SF3T+) which cover the spectrum of spent fuel management options available to BNFL.

6.23 The subject area of this report is genuinely complex and decisions within it cannot be reduced to simple choices.

6.24 The process was inevitably cyclic, with much iteration and revisiting of problem areas. Though much data is available, values and subjectivity mean that decisions cannot be made merely on a numerical basis.

6.25 MADA is not a decision making tool but clarifies issues, agreement and disagreement: the combination of MADA with subsequent SAP is felt to offer a very powerful approach

6.26 Access to information provided by the Company was critical to the Group's work. Jointly agreed procedures and joint fact-finding increases the credibility of the data.

6.27 Commercial confidentiality will inevitably mean that costs cannot be dealt with in detail. Methods of minimising this problem need to be transparently considered at the beginning of any process.

6.28 Making an equal level of expertise available to all stakeholders helps data credibility, information exchange and exploration of views.

6.29 Environmental and health effects played a large part in the analysis. This is a very contentious area, especially as there is very little policy guidance. The examination of radiological risk factors by CERRIE is indicative of the fundamental differences of view which exist.

6.30 The process allows a spectrum of views to be considered, but stakeholders can only engage if their positions are not fixed. The dialogue process cannot be used as a campaign forum

6.31 The process must be properly timed and adequately resourced to maintain ownership

6.32 Each stakeholder must be prepared to treat the dialogue process as a personal priority, and must work to involve and take feedback from their constituency.

6.33 The process has enhanced understanding and would work for other sectors. While agreed conclusions have not been reached, the Group believes that the work has considerably narrowed the envelope of viable futures and makes a significant contribution to informing the decision makers.

6.34 The Group noted that the Government's announcement of the creation of a Liabilities Management Authority (LMA) would have implications for its work and recommendations and these are reflected in the Recommendations below.

General Conclusions

6.35 The Company has a future in spent fuel management but must recognise that how it proceeds has implications for the environment, the local economy and the workforce. Long term business focus will change from reprocessing to decommissioning and spent fuel management. The proposed Business Futures Working Group will have to consider the pace of this change, taking into account the spent fuel management option adopted and mitigation of the socio-economic impacts revealed by the ERM report.

7. RECOMMENDATIONS

7.1 The Group commends this report to BNFL and to other decision makers in the Spent Fuel Management Options study area, including its use as an input to the process of the development and role definition of the Liabilities Management Authority.

7.2 In this context BNFL should seek guidance from the Government on the availability of public funds to underpin the costs involved if SF1 early closure scenarios are chosen.

7.3 The SAP's contain the scenario-based conclusions of the Group and should be studied (Appendix 13). Key milestones from this process are given in Section 7 of this Summary.

7.4 BNFL should ensure that its strategic planning:

- takes adequate account of the issues and recommendations raised in this report, and in particular the identified contingency planning needs;
- is transparent in its identification of how the conflicting needs of the environmental aspects and the socio-economic aspects have been taken into account.

7.5 BNFL should match the projected lifetime arisings of spent Magnox fuel as closely as possible to the performance of B205 without compromising reactor operations. In the event of sudden or terminal failure of B205 the objective is to ensure that there is a minimum amount of Magnox fuel remaining in ponds. No plans should include long term storage of wetted Magnox fuel.

7.6 BNFL should ensure that, within whichever scenario is adopted by the company, every effort is transparently made to reduce discharges and minimise waste at the earliest opportunity and that the achievement of early passivity is a defined target.

7.7 In the light of the ERM Report, BNFL and other relevant stakeholders should develop mitigation plans to counter the adverse socio-economic effects which all options involve.

7.8 The Group recommends that the Business Futures Working Group, if it is constituted, should use the work of the Spent Fuel Management Options Working Group as a basis for further advance rather than revisit matters already covered.

7.9 BF WG may wish to consider whether there are any alternative uses for THORP after the termination of whichever current option is adopted.

7.10 BNFL should consider the need for, and benefit of, a future group to:

- refine this report's contingency plan conclusions; and
- review the Discharge and Waste Working Group report's conclusions.

7.11 Any future dialogues should employ jointly agreed procedures, with the application of joint fact finding, selection of contractors, agreed terms of reference and joint monitoring where appropriate.

7.12 Future WG's may wish to consider building formal peer review into their report production process.

7.13 BNFL is asked to consider the value of this report and forward this report, when finalised, to the appropriate Government Minister(s) for consideration in the light of the previous Working Group reports and the ongoing Government consultation on radioactive waste and their considerations on a national discharge strategy.

8. LIST OF APPENDICES

Appendix 1 Original suggestions for work topics from Main Group Meeting – November 1999

Appendix 2 Spent Fuel Management Options Working Group – Terms of Reference and Ground Rules

Appendix 3 List of Spent Fuel Management Options Working Group Members

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Appendix 5 Terms of Reference of Socio-economic Sub-Group

Appendix 6 Transport Sub-Group Terms of Reference and Input to SFMO WG

Appendix 7 Green Expert Terms of Reference

Appendix 8 Magnox Task Group, Summary and Conclusions

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Appendix 10 Scenario Benefits and Detriments – Ranges of Views

Appendix 11 Variation of key variables with time

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Appendix 14 Cost (GX/BX)

Appendix 15 Cost analysis in the MADA

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Appendix 17 Radiation Dose and Related Concepts

9. GLOSSARY

AGR / AGR fuel	Advanced Gas Cooled Reactor (AGR) – the second generation of nuclear power stations in the UK. Uses a uranium oxide fuel clad in stainless steel in a graphite sleeve. There are contracts for reprocessing this fuel through THORP.
B205	The 'B205' plant at Sellafield was commissioned in 1964 for the reprocessing of used Magnox uranium metal fuel from UK reactors and is still in operation.
Becquerel (Bq)	A unit used to define the quantity of radioactivity in discharges, environmental samples, etc. 1 Bq is only quite a small amount of radioactivity; the human body contains about 4000 Bq of naturally occurring radioactivity. 'Multipliers' are often used to conveniently describe larger quantities, e.g. in discharges: 1 Gigabecquerel (GBq) = 1,000,000,000 Bq (10^9 Bq) 1 Terabecquerel (TBq) = 1,000,000,000,000 Bq (10^{12} Bq)
BWR	Boiling Water Reactor – a type of Light Water Reactor in which steam is raised directly by passing over the fuel elements.
Calder, Calder Hall (reactors)	The Calder reactors, which began operation in 1956, are located on the Sellafield site and are the prototypes for the Magnox reactor design.
CERRIE	Consultative Exercise on Radiation Risks of Internal Emitters under the auspices of COMARE – the Committee on the Medical Aspects of Radiation Exposure (this study is examining risk factors appropriate to man-made radiation).
CO_2	Carbon Dioxide – a “greenhouse” gas agreed to potentially cause global warming / climate change.
Collective dose	The total dose received by a specified population group as a result of discharges; that is, the summation of all the doses received by individuals in the population. The calculation of collective dose takes account of the persistence of radioactivity in the environment after discharge and is therefore

	'integrated' over a specified period of time after the discharge has been made. Usually collective dose is calculated for large groups, e.g. the UK, European or world populations and for integration periods of hundreds to thousands of years following the discharge.
COMARE	Committee on the Medical Aspects of Radiation Exposure.
Critical group	A small group of people who, by virtue of location or habits (such as food consumption) receive the highest radiation doses as a result of discharges from a particular nuclear installation. For a particular nuclear installation there may be several critical groups; e.g. the group most highly exposed as a result of liquid discharges will generally not be the same as the group most highly exposed as a result of aerial discharges.
EARP	The Enhanced Actinide Removal Plant at Sellafield was commissioned in 1995 with the main object of removing plutonium and americium from liquid discharges and so reducing discharge to the environment of these radionuclides.
Effluent	Liquid or gaseous material arising from a chemical process as waste which requires treatment and disposal.
HAL	Highly Active Liquor – by-product of reprocessing, containing 97% of residual radioactivity – currently stored in cooled tanks at Sellafield, prior to vitrification (solidification in a glass matrix) in the Sellafield vitrification plant.
Hazard	The potential of a material to cause harm.
Half life	The period of time required for the radioactivity associated with a particular radioactive isotope to diminish by half.
Head End	A plant for the mechanical processing of spent fuel to prepare it for chemical reprocessing.
HLW	High Level Waste.
ILW	Intermediate Level Waste.

Legacy / Legacy Waste / Legacy discharges	Stored waste from old processes subject to ongoing conditioning to convert it into a form more suitable for extended storage and/or ultimate disposal. It also denotes those discharges that will arise from the decommissioning of old plants.
Lifetime Arisings	Waste stocks arising during operational plant life. In this report taken to cover plutonium, LLW, ILW, HLW, calculated in m^3. Separated uranium was not included.
LLW	Low Level Waste.
LMA	Liabilities Management Authority – at the time of writing - a proposed new organisation to take on responsibility for the management of all UK plant (currently owned by BNFL) and wastes subject to future management.
LWR / LWR fuel	Light Water Reactor / used in this report to describe fuel from Pressurised Water (PWR) and Boiling Water (BWR) Reactors – a uranium oxide fuel clad in zirconium alloy.
MADA (Multi Attribute Decision Analysis)	MADA is a decision making technique which mixes numerical data analysis and application of agreed weightings. It involves a staged approach to establish the context, define "options", agree attributes, assess expected performance, assign weights and then combine weights and scores for each option, leading to the identification of a provisional choice, which is then subject to sensitivity testing.
Magnox (fuel / reactors or reprocessing)	'Magnox' is the name given to a particular type of nuclear fuel used in the first generation of nuclear reactors used for electricity generation in the UK. Magnox fuel consists of a uranium metal bar encased in cladding made from a magnesium alloy. Both the cladding and the uranium metal are potentially susceptible to corrosion and storage of the used fuel for any extended period (more than a few years) requires great care.
Man-Sievert	A measure of Collective Dose (see also Microsievert (μSv)). The total dose predicted to be received by a specified population over a specified timescale.

Microsievert (µSv)	A unit used to quantify radiation dose, that is a measure of the potential biological effects of exposure to radiation. The average annual dose to the UK population from natural radioactivity in the environment is about 2200 µSv; the Environment Agency judges the acceptability of proposed discharges from nuclear installations against an upper 'dose constraint' of 300 µSv per year to the 'critical group'.
MOX	Mixed Oxide Fuel - a fuel type using a mixture of plutonium and uranium oxides (see also SMP).
OSPAR	The Oslo and Paris Commission: an international commission which establishes conventions on the limitation of marine pollution in the North-East Atlantic.
Oxide (reprocessing)	'Oxide' nuclear fuels typically consist of pellets of uranium oxide, produced in a ceramic form, encased in cladding made of stainless steel or steel/zirconium alloy to make a fuel 'rod' or 'pin'. The second generation of nuclear electricity generation reactors in the UK (Advanced Gas cooled Reactors, or AGR's) used this type of fuel, as do the most common type of reactors in use worldwide - the Pressurised Water Reactor (PWR). Oxide fuel is much more corrosion resistant than Magnox and is easier to store for extended periods, if necessary, prior to reprocessing or disposal.
Pu	Plutonium: all of the isotopes of the element plutonium are radioactive. One of the most important is plutonium-239 with a half-life of 24,000 years.
Reprocessing	Reprocessing of nuclear fuel involves subjecting the used fuel to a series of mechanical and chemical processes, the end product being the separation of unused uranium, plutonium which has been produced within the fuel as a by product of the nuclear reactions which occur within the nuclear reactor, and highly radioactive waste products. In addition to these main 'products', the processes result in the production of liquid and gaseous discharges which, after appropriate treatment, may be discharged to the environment.

Risk	The probability of an incident occurring.
Sellafield	A site operated by BNFL, located in Cumbria, which is the main UK site for the reprocessing of Magnox and oxide nuclear fuels and for the conditioning and storage of associated waste products.
SMP	Sellafield Mixed Oxide Fuel (MOX) Plant. A plant built to take plutonium and uranium resulting from spent fuel reprocessing and produce a new fuel suitable for use in reactors.
Spent fuel	Fuel rods in a state of depletion after irradiation in a reactor.
Strategic Action / Plan	Strategic Action Planning provides a structured time and issue-based approach to managing decision making. There are two elements in a strategic action plan around which analysis is framed: • NOW: Actions / Explorations • FUTURE: Delivery decisions / Contingency Plans The aim is to make underlying assumptions explicit, and develop contingency plans for situations where assumptions turn out to be wrong. The Plan focuses in detail on the short term, and results in assessments along the line of "if you do this" it enables OR excludes "that" in the longer term.
THORP	The Thermal Oxide Reprocessing Plant is located at Sellafield and was brought into operation in 1994 for the purpose of reprocessing oxide fuels from reactors in the UK and overseas. The plant was financed by advance payments on reprocessing contracts and there are binding contractual commitments to reprocess a 'baseload' of fuel over the first decade of operation.

10. REFERENCES

BNFL National Stakeholder Dialogue (February 2000), 'Discharges Working Group Interim Report', The Environment Council

BNFL National Stakeholder Dialogue (November 2000), 'Discharges Working Group Update Report', The Environment Council

BNFL National Stakeholder Dialogue (February 2000), 'Waste Working Group Interim Report', The Environment Council

BNFL National Stakeholder Dialogue (November 2000), 'Waste Working Group Update Report', The Environment Council

Cricklewood Stakeholder Dialogue (March 2000), 'The Cricklewood Dialogue Process: Agreed Resolutions', The Environment Council

ERM Economics (November 2001), 'West Cumbria: Socio-economic Study', The Environment Council on behalf of the BNFL National Stakeholder Dialogue

All reports are available from The Environment Council or on their website:

www.the-environment-council.org.uk

Appendix 1

Original Suggestions for Work Topics from Main Group Meeting November 1999

Issues raised by Main Group at meeting November 1999, in descending order of importance:

- Implications of stop now / exit strategy
- Transport (imports and exports)
- Why reprocess? (including the benefits) - both for Magnox and for oxides
- Local social / economic effects of scenarios
- Methods of comparison (options)
- Total evaluation of life-cycle
- Status and implications of contracts, including future markets
- Customer views
- Recyclability (Pu/U, closed loop, is it happening?)
- Decommissioning at Sellafield and at power stations

A further 28 issues were also raised, and a 'Graffiti Wall' comment asked if fuels other than Magnox, AGR & commercial LWR's would be considered (e.g. nuclear submarine fuel, research reactor fuel)

Information Main Group members suggested would be useful:

1. Database of questions and answers on UK transport of spent fuel
2. Reprocessing contracts and letters of intent
3. Studies by Frans Berkhout (SPRU) and Ian Fairlie (Imperial College) on the environmental / economic costs of reprocessing and other options
4. NEA study on Spent Fuel Management Options (available Spring 2000)

Appendix 2

Spent Fuel Management Options Working Group - Terms of Reference

Background

These Terms of Reference are based on the outcomes of the Main Group meeting of November 1999, with amendments and additions following the first Spent Fuel Management Options Working Group (SFMO WG) meeting 24-25 February 2000. It is open to the SFMO WG to amend them, or to set itself wider or more restricted terms, always bearing in mind that it should not diverge from the consensus of the Main Group, and will be reporting back to the Main Group.

The Working Group (WG) has agreed to follow the *'National Stakeholder Dialogue Groundrules' 6th* Draft, with the following clarification and addition:

- 'Agreement' in para 21 of Draft 6 can also include areas where WG members have agreed to disagree.
- The following should be added to the current paragraph 6:
  "…with the objective of ensuring that at each stage of the dialogue, consensus has been achieved on the previous stage reached or that concerns are aired and resolved before further progress is attempted"

Overall

1. The agreed Terms of Reference will be circulated to the Main Group
2. The WG will need to agree criteria for judging its own success.
3. Wherever possible there should be continuity of individuals as members of the WG membership, with substitutes deputising only where absolutely necessary.
4. Photo-reports and written reports after each WG meeting are for WG members only (and the Coordination Group) and not for wider circulation. They may be used as a basis for WG members to inform their constituencies. A mid-term progress report will be drafted for circulation to Main Group members.
5. WG members should keep their constituencies informed of progress in terms of the principles of the discussion.

Scope and Aim

- Based on the recommendations of the Main Group meeting of November 1999, the WG has set itself the following Aim:
  "To evaluate a range of policies for the responsible management of spent nuclear fuel and recommend options to BNFL.
  We will do this by:
  - *Developing a framework, including the criteria to use, for the comparison / evaluation of options*
  - *Identifying practical available options*
  - *Evaluating the options*
  - *Taking into consideration the issues identified by the Main Group"*

- The WG will take the issues raised at the Main Group meeting into account, and will be able to demonstrate that this has been done.

Planning

1. The WG needs neutral facilitation, and preferably should not be chaired by a WG member.
2. The WG will need administrative and logistical support (secretariat), which will be provided by The Environment Council.
3. The WG can request external experts to attend meetings.
4. The WG will need to agree an Agenda for its term of operation - roles, meetings, and timings. A framework methodology has been agreed, and a framework time-plan has also been agreed.
5. The funding of the WG and recovery of costs by individual members must be agreed. They must be transparent, and be seen not to affect the WG's neutrality.

Sub-groups

- A Socio-Economic Study sub-group has been set up, to which the Plutonium WG is invited to contribute. This sub-group will examine the areas recommended for further study by the DWG and WWG.
- Further sub-groups may be set up as work progresses.

Information Needs

1. Information will be needed both from BNFL and other sources, surrounding the issues to be addressed.
2. This will provide an informed basis for discussion. All organisations represented on the WG will make information needed by the Group available to it. Where information is held by third parties, a decision will be made as to whether the WWG or the CG will obtain it. Ground rules for the use of such information are covered by *'National Stakeholder Dialogue Groundrules'*, 6th Draft, para 5.

Appendix 3

Spent Fuel Management Options Working Group - Membership

Peter Addison	Nuclear Installations Inspectorate	peter.addison@hse.gsi.gov.uk
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Pete Roche*	Greenpeace	
Patrick Van den Bulck*	Campaign for Nuclear Disarmament (CND)	
William Waddington (Replacement for Carl Carter)	Amalgamated Engineering and Electrical Union (AEEU)	c/o peter.kane@bnfl.com
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Ian Fairlie	Green Technical Advisor	
Jeff Ferguson	BNFL Technical Advisor	
Gordon McKerron	Green Technical Advisor	
Mike Sadnicki	Green Technical Advisor	
Pete Wylie	BNFL Technical Advisor	
Alan Pearman	MADA Advisor	

And The Environment Council, facilitators

* Indicates those who have not attended any SFMO WG meetings since end November 2000

NOTE: Although Friends of the Earth originally had a representative in the group, due to long-term illness, the representative was not able to attend meetings. However, Friends of the Earth support the process and have expressed interest in remaining actively involved.

Appendix 4

BNFL Statement of 23 May 2000

BNFL/1566/00

BNFL confirms Magnox station lifetimes

BNFL is today announcing a lifetime strategy for its fleet of Magnox nuclear power stations. The strategy provides a phased programme for the cessation of electricity generation at the eight stations, most of which began operating in the 1950s and 1960s.

The reactors are licensed to operate for between 33 and 50 years and this early announcement of the Company's strategy for the lifetimes of the stations will allow operational plans to be optimised. For business reasons, Hinkley Point A will not be brought back into service from its current shutdown.

With today's announcement the Magnox station lifetimes will be planned as follows: -

Station	Licensed lifetime	Age at Cessation of Generation	Latest date for end of Generation
Calder Hall	50	50	2006 – 2008
Chapelcross	50	50	2008 – 2010
Bradwell	40	40	2002
Hinkley Point A	40	35	2000
Dungeness A	40	40	2006
Sizewell A	40	40	2006
Oldbury*	40	45	2013
Wylfa*	33	45 / 50	2016 / 2021

* Continuing to run Oldbury and Wylfa to these dates depends upon the development and use of Magrox fuel. Magrox is a fuel in which uranium is used in ceramic oxide rather than metal form. A decision on the use of Magrox fuel will be taken in around 2003. Oldbury and Wylfa will also need to undergo a Periodic Safety Review in order to secure operation to these dates.

BNFL's Chief Executive Norman Askew said: "Everyone knows that these stations have a finite life and there has been speculation as to our intention regarding their operating lives.

The reason we are making this announcement today, well ahead of time, is to provide certainty about the future for all concerned. It will bring clarity to the Company's business plans, explains our plans to our employees and provides us with time to work with the communities around our stations on plans for decommissioning.

"These stations were pioneers in the nuclear industry and have made, and are continuing to make, a huge carbon-free contribution to the electricity generating industry. This decision will mean that the reactors will not be run beyond the dates announced. However, both market conditions and technical issues could result in earlier closure."

The lifetime strategy announcement means that the Magnox reprocessing plant (B205) at Sellafield will close once all Magnox fuel has been reprocessed. It is expected that this will be around 2012 although this could be later depending on throughput schedules achieved. Based on the same programme, Magnox fuel production, which is carried out at the Company's fuel manufacturing site at Springfields, near Preston, will cease by 2010.

The end of Magnox reprocessing at Sellafield will significantly reduce discharges even further and virtually eliminate the already low discharges of Technetium. Total liquid discharge impact, which is already minute, will further reduce by more than 80 per cent. In the meantime BNFL will continue to work on abatement technology for Technetium and, if successful, will reduce discharges even sooner.

-ends-

Notes to Editors

BNFL took over responsibility for the UK's Magnox power stations in January 1998 when the former Magnox Electric plc was merged into BNFL.

There are three other stations in the Magnox fleet which are currently undergoing decommissioning – Berkeley (which closed in 1989), Hunterston A (1990) and Trawsfynydd (1993).

In December 1999, BNFL announced that the Bradwell Power station in Essex will close in 2002 when it reaches its 40^{th} birthday.

The stations employ on average around 350 people each and we expect job numbers to remain fairly constant for up to a year after cessation of generation. From experience at other Magnox sites, we would expect to retrain around 250 staff for the next phase, defuelling, which usually takes 3-4 years. After this phase we would expect numbers employed at the sites to fall gradually to around 50 people.

B205 is the plant built in 1964 to reprocess fuel from the UK's Magnox power stations. Overseas and UK oxide fuel is reprocessed in the separate, more modern, thermal oxide reprocessing plant (Thorp) at Sellafield.

Appendix 5

The Environment Council

BNFL NATIONAL STAKEHOLDER DIALOGUE
4th DRAFT SOCIO ECONOMIC RESEARCH.

Framework Document

1. Introduction

1.1 In 1998 BNFL, via the Environment Council, launched a Stakeholder Dialogue process with the intention of informing the Company's environmental strategy.

1.2 Over 80 people, with knowledge of the nuclear industry, joined the process. A very wide range of groups, with all shades of opinion represented, now participate in the Dialogue. In fact the number of stakeholders has grown. Local authorities, Government, NGO's, trade unions and the Company itself have been present from the outset.

1.3 The Environmental Council acts as an independent facilitator to the process. Stakeholders agreed that sub groups be formed to examine and report back on particular aspects of BNFL. The first two sub groups have published reports, arriving at some conclusions, and making certain recommendations in respect of discharges and nuclear waste management.

Collectively stakeholders then agreed, in November 1999, that two further sub groups should be formed. These sub groups are now looking at spent fuel management (including reprocessing) and plutonium (including mixed oxide (Mox) fuel fabrication). The terms of reference of these two groups are attached to this document.

1.4 Stakeholders have found that a helpful method of fostering dialogue is to take existing BNFL performance data and feed it into agreed potential scenarios. Consequences of policy decisions can therefore be discussed in a structured manner.

1.5 There are obvious links between different aspects of the Company's activities. Change in one area will have effects elsewhere. All stakeholders are agreed that one major group of effects, on which there is little available empirical data, is the socio-economic impact on people living in West Cumbria and beyond. This community will be affected in different ways depending on the business options available to BNFL in the light of market and regulatory constraints.

1.6 The study now being commissioned will help us to understand the nature of these impacts.

1.7 Sellafield employs in excess of 10,000 people on site including the workforce of on-site contractors. This figure (which will need to be confirmed) forms a substantial part of the Copeland workforce and the West Cumbria workforce. The potential benefits, or costs, of strategic change in the BNFL business in this geographically remote and relatively self-contained part of the country might clearly be considerable. This research project will need to assess what they might be.

2. Principles of the Research Project

2.1 The starting point for the project is three basic business scenarios for the future of spent fuel management, fuel fabrication, power generation and waste management on the site. These will be developed from assessments previously used in the dialogue process in relation to waste management and discharge reduction.

The three scenarios are

(i) Blue Sky, the Company's most optimistic expansion of reprocessing, licensing and operation of the SMP (Sellafield Mox Plant) and growth in the waste management and decommissioning business

(ii) Current Business plan implemented as agreed (as defined by the post-Magnox station closure announcement)

(iii) Minimum case, i.e. earliest possible end to reprocessing (THORP and Magnox), with non licensing of the SMP

Stage 1 of the project will involve building a workable model of employment and spend aspects of Sellafield and West Cumbria and this will enable variations in scenarios to be incorporated in the work at a later stage. As and when the current Working Groups agree on different scenarios, they will be adopted by the Socio-Economic study. See Appendix 1 for the full definitions of the scenarios.

2.2 For each scenario the research must establish all the expenditure involved by the company in human resources, supplies, service, capital projects and community support and assess the total impact of change on the local community.

2.3 BNFL will assist the project by providing comprehensive information on projected employment numbers broken down by operation, job types and pay bill for each of the three scenarios. This should include the Company's best assessment of employment and other benefits which would result from the alternative uses of any plant being considered under the scenarios. BNFL will also provide information on the residential location of its current workforce broken down by job location within the business and pay bill. This breakdown will include figures for dedicated contractors both at Sellafield and elsewhere.

2.4 As this data will drive the research, agreement on accuracy is essential. An initial paper setting out this information will need to be considered by the Working Groups. Using this information as a base, the project will then need to assess the secondary effect of BNFL expenditure in the local economy. The principle focus for this will be Copeland and West Cumbria (the travel to work areas of Whitehaven and Workington and the town of Millom). A secondary focus will be the implications for Cumbria and beyond.

2.5 As West Cumbria, Copeland and the Nuclear Industries have special economic circumstances it will not be sufficient to apply employment multipliers derived from previous studies. Original research into the effect of flows of expenditure through the local economy will be required.

2.6 The set of economic and financial impacts derived from research into each scenario must be translated into an assessment of social impacts and measured costs/benefits to the community.

2.7 For each scenario the study should identify the timing of the impacts on the community.

3. Study Phasing

The Environment Council

3.1 Phase 1

Will comprise a full report on what constitutes each of the three scenarios including

Employment numbers
Age profile of workforce
Job location and type within the business
Remuneration
Employee residence
Skill level
Company expenditure on supplies and services
Human resources split by residential location

BNFL will have a significant role in assisting with this information

A report setting out the details of the scenarios should be presented to the Working Groups to achieve an agreed building block for future phases.

3.2 Phase II

A detailed study into the secondary impacts of BNFL expenditure into the local economy. This will involve original research tracing the flow of expenditure through the economy to identifying a proven multiplier directly relevant the local economy of the host community
For each scenario the research project should report the number of jobs supported/lost in the community and the changes in aggregate local spend arising from each scenario taking into account the recirculation of revenue generated by each of the scenarios through the economy.

A report setting out the findings of this phase should be presented to the Working Groups to achieve a further agreed building block for the next phase.

3.3 Phase III

Information from Phases I & II should be used to develop three visions of the future based on the timescales for change that would arise out of each of the three scenarios described in 2.1. Each vision should be developed to identify and, wherever possible, quantify the extent of costs or benefits derived. The vision should not only set out the level of these costs or benefits but also the timescales within which they would occur.

The current position in Copeland and West Cumbria should be used as baseline for this work

Within this phase the work would be expected to address socio-economic impacts in the following areas:

- jobs supported in the Whitehaven TTWA, Workington TTWA, Millom
- changes in jobs supported in " as above "
- unemployment/long term unemployment
- health
- income levels
- housing – private
  public
- social exclusion
- crime
- local skill base
- business failure/start up
- education attainment/facilities
- population levels
- environmental decay
- other environmental issues related to socio-economic change in the community
- costs of support falling to public sector
- Business investment/individual investment
- External perceptions of the area by public, investors
- Investment in roads
- Tourism
- Costs of retraining
- Other identifiable impacts

To take a balanced view of the future the project should consider what additional sources of support might be triggered and when (e.g. Objective 1, Objective 2, Development Area Status, likely eligibility of Comprehensive SRB support etc) and the effect these may have in remediation.

In arriving at these developed community scenarios you should take account of the geographically isolated nature of the area and its potential for regeneration.

4. Research Objectives

4.1 Research methodology must take cognisance of the Stakeholder Dialogue and management/liaison arrangements between the research contractor and the Socio-economic Research sub group will need to be regular and robust. A schedule of interim reporting meetings will be agreed

4.2 The results must be presented in a manner that allows easy comparison between the effects of the three different scenarios. In addition, the structure and presentation of the information should recognise that the 3 scenarios represent a wider range of possible actions. Thus if a scenario which lies in between the three studied is selected, it should be possible to make judgements from the data presented as to its likely effect on the community. Disaggregation of calculations based on component data should be retained in support material, to facilitate the making of such judgements by the Stakeholders.

4.3 The Research will comprise a final report, and interim reports and presentations as set out in the section of timescales

4.4 The final report will not draw conclusions as to the effects of each scenarios. It will report comprehensively the modelled effects of each scenario, and the range of forecast impacts. It is the role of the Stakeholder dialogue to discuss the relative merits or concerns of forecasts.

5. Project Timescale

The Environment Council

5.1 The timetable for implementation is

Submissions received from contractors by	28 June
Short-listing of contractors, at Environment Council Offices	5 July
Presentations from short listed contractors, at Whitehaven	14 July
Contract signing, first contract meeting, comment Of research, at Environment Council offices	24 July
Contract Monitoring Meeting	17 August
Report back on Phase I to Spent Fuel Management Options Working Group	29/30 August
Report back on Phase I to Plutonium Working Group	5/6 September
Contract Monitoring Meeting	28 September
Report back on Phase II to SFMO Working Group	9/10 October
Report back on Phase II to Pu Working Group	12/13 October
Decision on Phase III	16 October
Contract Monitoring Meeting	26 October
Presentation on progress to the entire Stakeholder Group	23/24 November
Contract Monitoring Meeting	30 November
Presentation on research to combined SFMO and Pu Working Groups	11/14 December
Report produced 200 copies	TBA

6. Tenders

The Environment Council

6.1 Tenders for the study (8 copies) should be submitted to:

Schia Mitchell
The Environment Council
212 High Holborn
LONDON
WC1V 7BF

By 28th June 2000

6.2 The following information should be provided with tender submission

- Details of previous relevant experience, including client references
- Names of Personnel involved, their qualifications and experience
- Daily roles for each individual. Planned time input for each individual.
- Details of Quality Control Accredition/Procedures
- All sub contractors/Partners proposed
- Full information, as above, for all sub contractors/partners
- Any additional value the project team can bring to the study
- Full details of methodology, timetables and sources used.
- Full details of information requirements from Stakeholder Partners and other Local & National Agencies

6.3 Selection will be based firstly on an assessment of the tenderers ability to deliver a robust, quality report that will be credible to a wide range of Government and non Governmental organisations and secondly on the cost.

6.4 If Tenderers wish to submit suggestions for altering the brief an improving the study these should be included as additional separately costed options.

6.5 Joint submissions will be considered as will submissions from a Lead Contractor. In such circumstances information on the experience and qualifications of each Contract must be supplied.

The Socio-Economic Sub-group - Membership

Fred Barker	Nuclear Policy Analyst[1] (from October 2000)
Gregg Butler	Westlakes Research Institute
Martin Forwood	Cumbrians Opposed to a Radioactive Environment (CORE) (until end April 2001)
John Hetherington	Cumbria County Council
John Kane	General and Municipal Boiler Makers Union (GMB)
Grace McGlynn	BNFL
Fergus McMorrow	Copeland Borough Council
Shirley Williams	BNFL
Pete Wilkinson	Wilkinson Environmental Consulting
Jon Samuel	ERM
David Elliot	ERM
Roger Howsley	BNFL (attended a few meetings)
Brian White	Copeland Borough Council (attended a few meetings

[1] Fred Barker's participation in the socio-economic group is sponsored by the Nuclear Free Local Authorities Steering Committee

Appendix 6

Transport Sub-Group Terms of Reference

The aim of the transport sub-group is three fold.

1) To assist the Spent Fuel Management Options Working Group in its analysis of different options
2) To ensure that the relevant recommendations of the Cricklewood agreement are being carried out
3) To address the concerns of a large number of the main group on the issue of transport

Due to time implications, the co-ordination group has suggested that the group tackle these in the following manner;

a) Address the terms of reference provided by the SFMO WG

<u>ToR from SFMO WG</u>

What we will give you….

You will be provided with mileage/ no's of transfers/ risks for each of the options being considered by SFMO WG. These will have been peer reviewed by 'Green Experts'.

What we need you to do is…

Identify the consequences of the options from a transport perspective only.

Highlight what factors need to be considered by SFMO WG to enable transport to be included in the overall weighting process including global implications where relevant.

b) Review whether the Cricklewood Agreement recommendations have been satisfied through the action of a).
c) Make a recommendation to the Process Review Group (due to meet in April 2001) of any general transport issues which should be considered.

Transport Sub-Group Membership

Frank Barnaby	Oxford Research Group
John Cogger	RMT
Linda Hayes	CANT
Malcolm Miller	BNFL
David Milner	NTAG
Rick Nickerson	KIMO
Patrick van den Bulck	CND
Rupert Wilcox-Baker	BNFL

And The Environment Council, facilitators.

Comments to SFMO WG from Transport sub-group
(with SFMO WG responses in italics)

The following are questions/ points of clarification raised by the transport sub-group while going through the work the SFMO WG did on their MADA exercise in order to provide a 'sanity check' on the work. The group was asked to provide comments in order to inform the work of the SFMO WG rather than to endorse their work due to time limitations.

The group acknowledges that some of the points have more significant implications than others, but raised questions in their minds and are therefore likely to raise questions for other stakeholders. Therefore, it is hoped that by including explanations to the transport group's questions within the SFMO WG report, the number of questions raised by other stakeholders at the July main group meeting will be reduced.

There is no significance attached to the ordering of these points.

- Public perception (& stakeholders) may not share the relatively low weighting of transport issues in SFMO's consideration. But, given the SFMO WG Terms of Reference, the weighting given to transport is not unreasonable.

  This was welcome – as we had debated the positioning of the transport issues particularly strenuously. Public perception was examined separately (see later)

- 'Stop now' scenarios would result in transport (i.e. returning unreprocessed overseas spent fuel already at Sellafield and any products) - appears not to have been considered, especially volume, and needs to be made explicit. **N.B. This could alter scenario scores or at least needs to be reflected in table of raw data used for MADA exercise.**

  These factors were in the data set examined by both sets of experts and provided to SFMO WG. We believe they are suitably reflected in the MADA.

- Terrorism aspect assumptions
  a) PuO_2/ Mox most interesting to terrorists
  b) PuO_2 *(factor of 10 – seems arbitory figure to this group)* more interesting/ useable *(given equal availability)*

  Both seem right to the transport sub group (with slight changes made in italics).

  The 'factor of ten' was used for discussion, but was not reflected in any arithmetical way in the weightings etc.

- Question assumption that 'more miles is worse and less miles is better'.
  This statement may not apply to all modes of transport (i.e. road, rail, sea and air)
  This assumption may be too crude.
  - What about number of inter-modal transfers? Has this been considered? May impact on risks?
  - Depends upon different routes and traffic densities. A short but complex journey may present more risk than a long but simple journey, e.g. the differences between sea transport through the English Channel to Europe or to Japan through much less congested waters.

It is recognised that these factors exist and are significant. However, the scenarios used – particularly the 2's and 3's – have more or less of the same type of journeys. We think it is true to say that none of the scenarios change drastically the transport mix or journey length.

- Mode/fuel list
- missing AGR by road
- missing PuO_2/ Mox by air (not current practice but a future possibility)
- missing Mox by road (into Europe)
- missing PuO_2 by road (e.g. as part of transport to overseas customers – 1st 3 scenarios)

These will be added to the list for consideration

- Definition of hazard by SFMO WG is that it is related to the total amount of radioactive material. Transport sub group feel it is better to consider the total radioactivity rather than the amount of material. (IMO sea transport code (INF) applies this definition)

In effect, SFMO WG considered 'hazard' to be the total potential for harm – and hence total radioactivity would be a reasonable measure. Where we used tons or volume we did so in the sense of 2 x tons = 2 x radioactivity. We did not use tons or volume to compare different materials.

- The SFMO WG identified 2 main areas of transport risk – environmental leak and terrorism. The transport sub- group feels that the following should also be considered;
- risk from non-fixed and fixed flask contamination. May be significant in public perception. Actual frequency of flask contamination events is far greater than 'catastrophic incident'. **NB May affect probability consideration** (and therefore weightings?)

If we had any detriment figures from this contamination (doses etc.) we would use them. The public perception point is well made and has been considered as part of the MADA process after the main 'scoring of the matrix'.

- social/ economic impacts on tourism and produce resulting from an accident (whether or not it involves a radiological leak). N.B. This also applies to other hazardous cargoes.

Noted and agreed

- Has a pro-rata assessment of nuclear rail miles been done and compared with accidents per total conventional freight rail mile?

  The conventional freight rail miles impact gives an upper bound for these conventional accidents.

- For clarification, diversion of PuO_2 by sea is not necessarily more likely. Agree that diversion of PuO_2 more likely than of Mox (given equal availability).

  Noted and agreed.

- When considering costs SFMO should address the liabilities regime (company and conventions) and those costs not covered (i.e. the financial impact on society) by these regimes.

  We did look at catastrophic accidents, including transport, under the 'risks' category – but we feel that the consideration of liability regimes is outside our terms of reference.

- Has air transport been discounted or just not considered?

  As far as we are aware air transport is not part of the current scenarios. As previously mentioned, we will include the possibility of PuO2 or MOX in the list.

- Some members of the group cannot accept the assumption that the risk of flask breach is small.

  This has been noted.

Appendix 7

Terms of reference for technical advisors to green stakeholders in Spent Fuel Management Options working group.

1. To form, with other experts & contributors, a technical sub-group to the SFMO WG.
2. To provide technical and scientific scrutiny and challenges to the assumptions and outcomes attending various spent fuel management options being explored by the working group.
3. To attend SFMO WG meetings as required at the invitation of the working group to offer in-situ peer review of technical matters.
4. To advise green stakeholders involved in SFMO WG as a primary task but to make their advice available to the entire WG as requested.

30th August 2000

Appendix 8

The Environment Council

Magnox Task Group – Draft Working Paper

Magnox Station Lifetimes and Reprocessing Throughput

1. The announcement made by BNFL on 23 May 2000 (attached as Annex 1) relating to the expected lifetimes of Magnox stations and the closure of B205, caused the dialogue process to experience its most critical period of uncertainty about its future since it began. Green stakeholders saw the announcement of the 2012 closure date for B205 as having ignored the work carried out in the Waste and Discharges Working Groups. The programme announced, while within the envelope defined by both groups, was near the 'blue sky' end of the spectrum and certainly did not seem to have placed any weight on green aspirations to move to the other end of the envelope.

2. In light of the announcement both WWG and DWG have reconvened to examine how the announcement has affected their respective reports. Also, the announcement introduced the little-discussed Magrox fuel issue (which had already caused controversy in the earlier groups) for introduction into the cores of Oldbury and Wylfa. The announcement also extended the lifetimes of some Magnox stations – including these two – beyond the point where some felt safety cases could be expected to be made. Finally, the closing date for B205 was predicated on a major improvement in throughput compared to actual recent performance.

3. The company, for their part, believed that the announcement had been influenced by the dialogue in that it did not go to the extremes of the company's 'blue sky' scenario for Magnox. Rather, by clarifying the position on Magnox lifetimes, it removed much of the doubt which had concerned the communities, the workforce, local authorities and regulatory bodies involved with operating and regulating these plants. The company also believes that B205 throughput can be rapidly increased and stated its aim as maximising the revenue-earning lifetime of the Magnox Stations while de-coupling their operation as quickly as possible from B205. Thus the introduction of Magrox fuel into the concrete pressure vessels of Oldbury and Wylfa would allow this fuel to be stored or reprocessed through Thorp while allowing the last of the Magnox fuel to pass through B205 by 2012.

4. The controversy caused by the announcement was so marked that it was agreed by the co-ordinating committee to establish what became known as the 'bridge mechanism'. This is a hot-line communication which will allow the company to discuss upcoming announcements with the green stakeholders, giving sufficient pre-warning to allow the underlying reasons for the announcement to be discussed with the company. The green stakeholders would hear directly from the company the justification for the announcement and to what extent the dialogue had - or had not - influenced it. This is standard practice with the company's other stakeholder groups such as the unions, the regulators, customers and local authorities. Since the establishment of the 'bridge mechanism', it has been used only once, but with some positive effect. When the company released it's accounts, the greens were given prior notice and a

conference call too place between representatives of BNFL, Friends of the Earth, Greenpeace and CND which allowed the greens to hear first hand why the accounts showed such poor performance.

5. At subsequent meetings of the working groups and of individual stakeholder groupings, the issues were again debated. However, despite additional information being provided by BNFL (attached as Appendices 2 and 3), some uncertainties remained. A Task Group was set up to address the issues which, in broad terms, addressed the perceived lack of information about the assumptions inherent in BNFL's Magnox closure plan and a lack of clarity as to how the dates suggested for closure of the power stations and B205 had been arrived at and how they would be implemented.

6. Specifically, there were green concerns that at current stock levels and reprocessing performance, the 2012 closure date for B205 was highly optimistic and unlikely to be met. This would not only extend the overall discharge period for B205 but would be hard to reconcile with meeting OSPAR requirements. It was also noted that the proposed doubling of reprocessing rate in B205 would lead to increased discharges – again with implications for the OSPAR agreement. Other concerns included the possible use of Magrox fuel via initial trials at Calder Hall and subsequent trials and full loading at Wylfa and Oldbury, the go/no go decision date for the commercial use of Magrox and information on the safety cases for its use at the two latter stations.

7. The new Task Group, which met on 1 November, was tasked to identify the uncertainties and assumptions contained in BNFL's Magnox Stations/B205 closure programme. The membership of the Task Group is attached as Annex 4. Issues raised, and clarifications sought, by members of both current working groups were addressed by the Task Group with the aim of 'fleshing-out' and making transparent the full implications of BNFL's Magnox closure programme. . It should be noted that all dates discussed are indicative. The rest of this report summarises these discussions.

Magnox Stations

8. Magnox station lifetimes are dependent on a number of issues.

- Every Magnox station must maintain a valid safety case which is a requirement of the Site Licence from the NII. These safety cases evolve to take account of operational developments at the station, graphite degradation and other ageing effects, unforeseen occurrences and the normal cycle of maintenance, fuel loading etc. Major Periodic Safety Reviews are undertaken at ten yearly intervals. These are in themselves expensive and can actually bound a station lifetime as in the case of the early closure of Hinkley A in May 2000. Oldbury and Wylfa are due to undergo PSR's in 2008 and 2004 respectively. In addition any full loading of Magrox would be the object of a specific safety case submission and approval by the NII.

- Every station must also have a valid Discharge Authorisation from the Environment Agency, and these will be influenced by factors such as OSPAR interpreted via the UK National Discharge Strategy.

- Plant must be able to generate income by selling electricity. However, the economic balance of each station in the Magnox fleet has to be considered in the context of the performance of the overall Magnox cycle from fuel fabrication, plant operation, spent fuel management and overall liability exposure.

- The economic performance of the Magnox stations depends strongly on their availability and the coming back on stream of Wylfa is clearly important in this respect.

- The price of electricity is also an important determining factor, and the 'New Electricity Trading Arrangement (NETA) could significantly affect market prices.

- Wylfa and Oldbury have sufficient projected life to consider loading of Magrox fuel. This fuel has similar characteristics to AGR fuel, and after discharge from the reactors could be stored or reprocessed through Thorp. This would decouple the operation of these stations from B205, which is scheduled to close "around 2012 although this could be later depending on throughput schedules achieved".

- If Magrox is not adopted for these stations then their closure dates would need to be advanced unless a satisfactory alternative management for Magnox fuel could be identified. Options include temporary dry storage pending reprocessing through a modified Thorp or some other treatment yet to be identified.

- Ability to load Magrox fuel depends on:

  - Successful trial loadings in Calder and Wylfa
  - The availability of safety cases
  - The economic viability of the Magrox fuel cycle

- In order to meet a date of 2012 for full core transition from Magnox to Magrox a decision will be necessary 9-10 years earlier because:

  - It will take about 3 years to build and commission a fuel assembly line at Springfields
  - It will take 1-2 years to make sufficient Magrox fuel for smooth transition to begin.
  - It will take about 5 years for full Magnox to Magrox transition at the station(s).

- Reactor operation also depends on an adequate transport infrastructure, including flasks, to keep pond stocks at the stations at acceptable levels and/or enable adequate throughput through B205.

B205 Throughput

9. It is in BNFL's commercial interests to close B205 as soon as possible after the closure (and subsequent loss of income from) the Magnox power stations. The current proposed closure date for B205 is 2012 but, should the Magnox stations fail to achieve the lifetimes announced by BNFL because of economic or safety consideration, the timeframe for B205 closure would obviously be affected. Similarly, if B205 throughputs cannot be sustained, BNFL would have to re-evaluate its Magnox generation strategy given it's announcement about predicated lifetime dates.

10. As well as the technical issues associated with the B205 plant, achieving the projected throughput depends on being able to transport used fuel to Sellafield (number of flasks and fuel in flasks) at the rate required by B205 and the ability to feed that fuel through the Sellafield system into the plant.

11. Noting that the total discharge from B205 is finite, and linked solely to the quantity of fuel reprocessed:

   - Throughput rate links directly to changes in discharge rate
   - Tc99 discharges and some other aerial and gaseous discharges will continue for up to 5 years after the shutdown of B205.

12. If B205 throughput, currently planned to exceed 1000 tonnes per annum, is not achieved the options open to the company include:

   - Reprocessing through new Thorp head end
   - Dry store pending some other treatment yet to be identified
   - Close Magnox stations earlier than planned.

13. Currently B205 is closed for refurbishment, it is expected to reopen towards the end of the year. Given that:

   a) BNFL want to close B205 by 2012 or not too long after
   b) There is a current stock (as at 1/04/00) of 7560 tonnes of spent Magnox fuel
   c) All other variables meet expectations

14. Then if the planned B205 throughput increases are not achieved, it can be seen that at some time over the next 2 to 4 years decisions will have to be made about closing Magnox power stations earlier than planned or finding an alternative route for Magnox spent fuel.

15. The existing Magnox reprocessing plant has demonstrated its capability to achieve well in excess of 1000 tonnes annual throughput on a regular basis. Some NGO's retain doubts about this achievement. The only obstacles to a return to those kinds of throughput volumes are the levels of manning on the plant and increased availability. Manning levels within the Magnox Reprocessing area are now being increased. An increase of 15% is now in progress with particular focus on key production areas, such as fuel decanning, B205 charge

machines and also on larger production support groups. The scheduled biannual maintenance shutdown began in September and will see the start of a refurbishment programme the aim of which will be to improve the availability and reliability of the key components of the plant.

Annex 1. BNFL Statement of 23 May 2000

BNFL/1566/00

BNFL confirms Magnox station lifetimes

BNFL is today announcing a lifetime strategy for its fleet of Magnox nuclear power stations. The strategy provides a phased programme for the cessation of electricity generation at the eight stations, most of which began operating in the 1950s and 1960s.

The reactors are licensed to operate for between 33 and 50 years and this early announcement of the Company's strategy for the lifetimes of the stations will allow operational plans to be optimised. For business reasons, Hinkley Point A will not be brought back into service from its current shutdown.

With today's announcement the Magnox station lifetimes will be planned as follows:

Station	Licensed lifetime	Age at Cessation of Generation	Latest date for end of Generation
Calder Hall	50	50	2006 – 2008
Chapelcross	50	50	2008 – 2010
Bradwell	40	40	2002
Hinkley Point A	40	35	2000
Dungeness A	40	40	2006
Sizewell A	40	40	2006
Oldbury*	40	45	2013
Wylfa*	33	45 / 50	2016 / 2021

* Continuing to run Oldbury and Wylfa to these dates depends upon the development and use of Magrox fuel. Magrox is a fuel in which uranium is used in ceramic oxide rather than metal form. A decision on the use of Magrox fuel will be taken in around 2003. Oldbury and Wylfa will also need to undergo a Periodic Safety Review in order to secure operation to these dates.

BNFL's Chief Executive Norman Askew said: "Everyone knows that these stations have a finite life and there has been speculation as to our intention regarding their operating lives.

The reason we are making this announcement today, well ahead of time, is to provide certainty about the future for all concerned. It will bring clarity to the Company's business plans, explains our plans to our employees and provides us with time to work with the communities around our stations on plans for decommissioning.

"These stations were pioneers in the nuclear industry and have made, and are continuing to make, a huge carbon-free contribution to the electricity generating industry. This decision will mean that the reactors will not be run beyond the dates announced. However, both market conditions and technical issues could result in earlier closure."

The lifetime strategy announcement means that the Magnox reprocessing plant (B205) at Sellafield will close once all Magnox fuel has been reprocessed. It is expected that this will be around 2012 although this could be later depending on throughput schedules achieved. Based on the same programme, Magnox fuel production, which is carried out at the Company's fuel manufacturing site at Springfields, near Preston, will cease by 2010.

The end of Magnox reprocessing at Sellafield will significantly reduce discharges even further and virtually eliminate the already low discharges of Technetium. Total liquid discharge impact, which is already minute, will further reduce by more than 80 per cent. In the meantime BNFL will continue to work on abatement technology for Technetium and, if successful, will reduce discharges even sooner.

-ends-

Notes to Editors

BNFL took over responsibility for the UK's Magnox power stations in January 1998 when the former Magnox Electric plc was merged into BNFL.

There are three other stations in the Magnox fleet which are currently undergoing decommissioning – Berkeley (which closed in 1989), Hunterston A (1990) and Trawsfynydd (1993).

In December 1999, BNFL announced that the Bradwell Power station in Essex will close in 2002 when it reaches its 40th birthday.

The stations employ on average around 350 people each and we expect job numbers to remain fairly constant for up to a year after cessation of generation. From experience at other Magnox sites, we would expect to retrain around 250 staff for the next phase, defuelling, which usually takes 3-4 years. After this phase we would expect numbers employed at the sites to fall gradually to around 50 people.

B205 is the plant built in 1964 to reprocess fuel from the UK's Magnox power stations. Overseas and UK oxide fuel is reprocessed in the separate, more modern, thermal oxide reprocessing plant (Thorp) at Sellafield.

Annex 2. BNFL Statement of 9 August 2000

The existing Magnox reprocessing plant has demonstrated its capability to achieve well in excess of 1000 tonne annual throughput on a regular basis. The only obstacles to a return to those levels are the levels of manning on the plant and increased availability. Manning levels within the Magnox reprocessing area are now being increased. An increase of 15% is now in progress with particular focus on key production areas, such as fuel decanning, B205 charge machines and also on larger production support groups. The scheduled biennial maintenance shutdown, due to begin in September, will also see the start of a refurbishment programme, the aim of which will be to improve availability and reliability of the key components of the plant.

BNFL's announcement about the predicted lifetimes of the Magnox fleet means that the reprocessing plant will close once all Magnox fuel has been reprocessed. It is expected that this will be around 2012 although we prudently stated at the time of our announcement that this timeframe would obviously depend upon B 205 throughputs being satisfactorily achieved.

Annex 3. BNFL Statement on B205 throughput, 25 August 2000

Following the announcement about Magnox Station lifetimes, there was concern expressed by some NGOs about the throughput in B205. This note provides some information about what actions BNFL are undertaking to improve reliability in throughput rates.

The major refurbishment of B205, which took place in 1995/96, involved the installation of the new South Dissolver. This shutdown lasted 38 weeks and achieving the installation within time and budget attracted media coverage. It was this media coverage which stated that the new dissolver would allow B205 to operate up to 2016.

During this major shutdown, BNFL commissioned over £100M of new plant. This included the new dissolver, a plutonium evaporator and other projects. Separately, B205 is required to undertake statutory shutdowns every 2 years as an NII requirement under the site licence. These shutdowns, typically lasting 3 months, cover for example plant washout, inspection and maintenance of vessels and pipe work. During these statutory shutdowns, we obviously take the opportunity to carry out any minor projects and improvements needed to maintain plant efficiency.

We have a forward programme of about £5M-£10M per year to keep the plant up to date and to replace any equipment. This year's statutory shutdown, scheduled to begin in September, will involve a capital cost of about £5M. Projects due to be implemented during this shutdown relate to safety and reliability improvements to increase throughput.

These include improvements to the fuel charge machine, crane hoist replacement, improvements to containment in certain areas, pump replacements and instrumentation upgrades.

Manpower levels within the plant are also being increased by some 15%. As part of progressively implementing the new contract in partnership with the Trades Unions, we expect additional skills training to lead to improved efficiency and productivity.

The Magnox station lifetime announcement gave 2012 as the projected B205 shutdown date, subject to our achieving the necessary throughput levels. It remains our intent to achieve this date since it will significantly reduce the value of the Magnox Generation business to operate B205 beyond the station shutdown dates. The performance of B205 is critical to the achievement of the station lifetimes so it is BNFL's business interest to achieve the throughputs necessary in B205. Achieving higher throughputs is essential to deliver maximum business value and to minimise liabilities.

Should the Magnox stations fail to achieve the lifetimes we have announced because of economic or safety considerations, the timeframe for B205 closure would obviously be affected. Similarly, if B205 throughputs cannot be sustained, BNFL would have to re-evaluate its Magnox generation strategy given the announcement about predicted lifetime dates.

Annex 4. Magnox Task Group Membership

Peter Addison	Nuclear Installations Inspectorate
Gregg Butler	Westlakes Research Institute
Mark Drulia	BNFL
Martin Forewood	CORE
Peter Maher	BNFL
Grace McGlynn	BNFL
Richard Mrowicki	BNFL
Pete Roche	Greenpeace UK
Pete Wilkinson	Wilkinson Environmental Consulting

Appendix 9

Magnox Task Group Update

January 2002

On the 8th November 2001, the Magnox Task Group reconvened to review developments to the issue of Magnox station operation, planned closure dates and, in particular, spent Magnox fuel management. These issues relate to the work of the Waste Working Group (WWG) and are of critical importance to the work of the Spent Fuel Management Options Working Group (SFMO WG). This brief paper is designed to bring the Magnox Task Group report up-to-date for presentation to the March 2002 main stakeholder dialogue meeting.

Station operations: Wylfa came back on line in October 2001. Its safety case and discharge authorisations have not changed. Magrox as a substitute fuel for Magnox has been abandoned and Wylfa and Oldbury therefore revert to their originally announced closure dates of 2009 and 2008 respectively.

Fuel stocks: April 2001 estimates were for 11600 tonnes fuel requiring reprocessing over 11.75 years to the end of 2012.

Delivery of spent fuel: Concern had been expressed previously that the transport infrastructure was not well enough equipped to enable sufficient fuel to be delivered to Sellafield for reprocessing, regardless of the performance of B205. The company reported that the current rate of delivery is 10-11 flasks per week with a payload of 1.35 tonnes of fuel per cask delivering 700 tonnes. This compared with an average payload in the 2000/2001 period of 1.1 tonnes per cask which delivered 450 tonnes. The target for 2002/3 is 1.5 tonnes per cask with a delivery rate rising to 880 tonnes from 12 flask arrivals per week. While the company remain confident of meeting this requirement, to meet the 2012 deadline for the closure of B205, a further improvement to the 1000 tonnes per annum is required. This key assumption was referred to the SFMO WG.

Reprocessing throughputs: The target for the 2001/2 operating year is 725 tonnes of spent Magnox fuel reprocessed, with 429 tonnes reprocessed by the 7th November 2001 from 1st April 2001. Projections for the 2001/2 year predict a shortfall of 25 tonnes. This must be set against the 2000/1 outurn of 368 tonnes, though the plant was closed for 3 months of this period. The provisional target for 2002/3 is 900 tonnes. After taking account of planned plant shutdowns, a throughput rate of 100 tonnes a month is required to meet the 2012 closure date. The intention is to get as close as possible to this target during2002/3. This leaves the decision 'window' at 2002 – 2004 and this assumption was passed to the SFMO WG. Other issues affecting the B205 performance statistics were manning level and plant availability. The reprocessing workforce has been increased by 15% through the recruitment of an extra 110 persons and is increasing at some tens of people a month. With respect to plant downtime, there has been none since May 2001 although minor breakdowns and losses have continued at a significant rate.

The Group agreed to pass all relevant information and recommendations over to the SFMO WG and to consider its work as a sub-group of the WWG completed in all aspects. A key recommendation was that the B205 throughput review 'window' should be represented in diagrammatic form as a performance graph or operational envelope. This was subsequently supplied by the Company and is seen below (Figure A9). This shows the required lifetime performance of the Magnox spent fuel management system. On current projections some 11,000 te of spent fuel will need to be reprocessed to achieve closure of B205 by the end of 2012. If achievement at any time falls below the curve, action will need to be considered to reduce spent fuel arisings over the remaining programme lifetime.

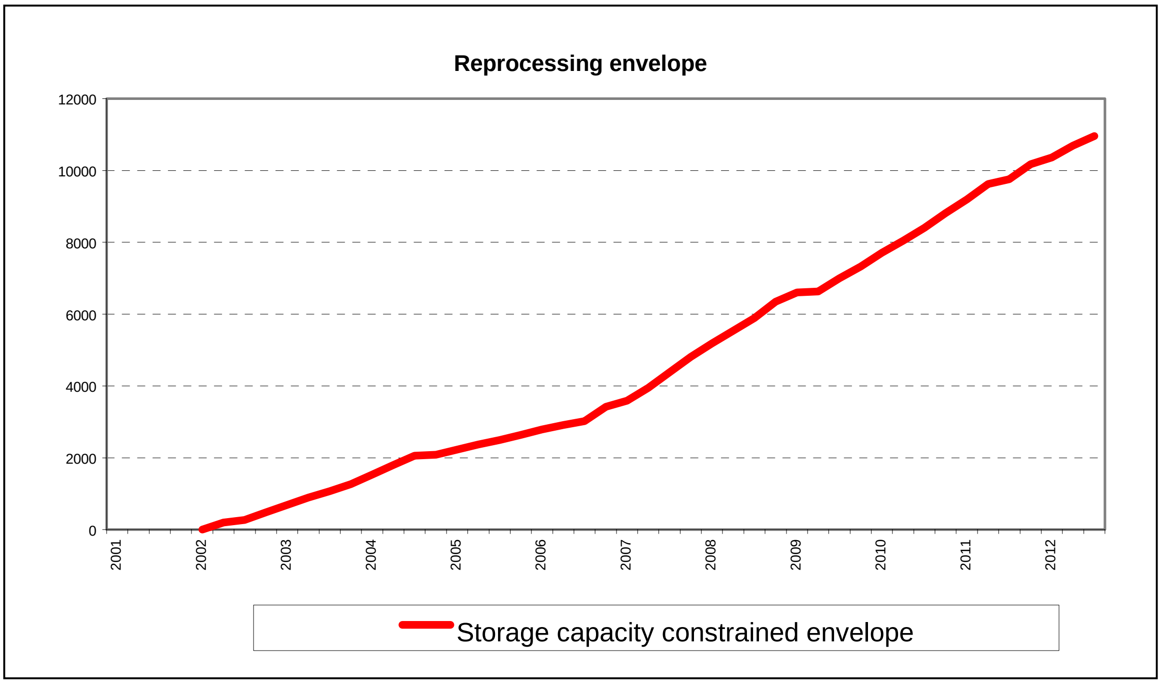


Figure A9

Gregg Butler
Pete Wilkinson

January 2002

Appendix 10 - Scenario Benefits and Detriments - Range of Views

Introduction

The data obtained from BNFL or through the ERM Socio-economic study contains four elements which are important in the judgement between scenarios but are also controversial and subject to very different interpretation by different stakeholders. These are:

- the public health detriment from Sellafield discharges
- the public health detriment associated with any increase in unemployment levels in West Cumbria
- the detriment or benefit of changes in Magnox generation, particularly as expressed in changes in carbon dioxide emissions

This Appendix attempts to outline the range of arguments and interpretations which to a great extent underpinned the two bounding views on scenarios arrived at by the Spent Fuel Management Options Working Group.

Sellafield Discharges – Public Health Detriment

The discharges from Sellafield were extensively studied by the Discharges Working Group[1]. They can affect human health by giving radiation doses to the public either directly (by direct radiation, inhalation etc.) or via food and drink. The doses to individuals may be modelled. The doses to the most exposed individuals over a set period (normally a year) is termed the Critical Group Dose, with a unit of Sieverts, while the total effect on whole populations may be measured by adding together all the modelled exposures to all individuals in any given area over a stated time. This is termed Collective Dose, and has a unit of man Sieverts.

Collective dose models therefore calculate the dose received by the public from site discharges in any given geographical area over any assumed timescale. There are four main areas of debate which can give very different answers in collective dose calculations and give rise to considerable, and considerably polarised, debate.

1. The calculations all assume that risks reduce linearly as doses reduce – with even extremely small doses still producing calculable risks.
2. While some argue that any dose, however small, must be taken account of, others argue that if the dose (and therefore risk) to an individual is trivial, then the sum of many such dose/risks is itself trivial.
3. Some radionuclides are very long lived, and so deliver doses over very long times, and these can give large overall collective doses. There is controversy about the length of time over which doses should be calculated – with some advice that 500 years should be used as a cut-off, while other opinion is that doses should be summed over all time.
4. The geographical area over which the dose is summed is significant. Higher doses (and hence risks) tend to occur near the discharge source, so while significant increases in calculated dose can occur by, for example, increasing the calculation area from UK to Europe to the whole world, the significance of

[1] Discharges Working Group: Interim Report 28 Feb 2000. The report can be found at: www.the-environment-council.org.uk/PdFFolder/DWG.pdf

these increases depends very markedly on the opinion taken on question (2) and to some extent (3).

The calculation of collective dose is based on modelling. There is little opportunity to verify the calculations by measurement except at high doses. At low doses the concentrations in foodstuffs etc are generally simply too small to be directly measured. There is also no chance of ever measuring the actual mortality produced, as the doses delivered are in all cases very small compared to the natural radiation background, and the effects will not be statistically detectable[2].

In short, by varying the assumptions used very large variations in the calculated dose occur, and the view of the results will be affected by the opinions and values of individual stakeholders and stakeholder groups. There is very considerable literature on this subject, and some key papers have been distributed to the members of SFMOWG. The following sections are meant to be illustrative and to encourage debate.

UK Doses from Sellafield Discharges

The most highly exposed group from Sellafield discharges, the critical group, receives around 100 microsieverts per annum from all Sellafield discharges to date, largely by eating large quantities of locally caught fish and other seafood. As the bulk of the UK population do not eat significant quantities of seafood from the Cumbrian coastal area, and as future discharges will be much lower than those in the past, the average dose from future discharges to the UK population is very small, and the collective dose predicted is largely made up of a large number (i.e. the UK population) of very small doses.

A typical distribution of doses is illustrated in the table below, taken in this case from the discharges predicted for the SF3 business scenario. Full references are given in Attachment 1 to this Appendix.

Table 1Collective dose (manSv) delivered in dose range indicated

Individual dose range (microSv per annum)					
<0.015	0.015-0.15	0.15-1.5	1.5-10	>10	Total
3500 95.8%	110 2.9%	17 0.5%	20 0.5%	12 0.3%	3700

Using a risk factor of 0.06 of a fatality per sievert, (see Attachment 1) these figures can be converted into statistical fatalities, and the dose ranges into ranges of risk. This is illustrated by the table below.

Table 2Number of statistical fatalities occurring from the risk range indicated

less than 1 in 1,100 million per annum	1 in 1,100 million to 1 in 110 million per annum	1 in 110 million to 1 in 11 million per annum	1 in 11 million to 1 in 1.7 million per annum	greater than 1 in 1.7 million per annum	Total
210 95.5%	6.6 3.0%	1 0.5%	1.2 0.5%	0.72 0.3%	220

[2] Note that at 2200µSv/a UK average the annual risk of death is about one in 10,000 – so in a population of 55 million there will be 5,500 predicted deaths per annum from natural radiation.

Clearly anyone holding the opinion that there is some threshold of risk below which the risk should be deemed trivial will see a very different picture to someone believing that all risks, however small, should be added.

An ethical element exists which centres on the acceptability or otherwise of the involuntary imposition of an additional risk - no matter how small - on a population without their approval or sanction. This view is complicated by the detriment/benefit argument where some will hold the view that no benefit accrues from the polluting activity to those receiving the additional dose, while others will point out that 'risk exchange' at low risk levels is inherent in any society which makes discharges of any sort. Yet a further complication arises when examining this issue as the health cost detriment visited upon a population should be taken into consideration when weighing the detriment/benefit balance, and this would apply equally to heath effects relating to socio-economic changes (see below).

Geographical Spread of Collective Dose

Increasing the geographical area over which the collective dose is calculated increases the collective dose. This is very much at the low dose end of the spectrum as, for example, the Irish critical group dose from Sellafield discharges is about 50 times lower than that in West Cumbria, and the critical group dose in, say, Denmark, is ten times lower still.

Timescale of Collective Dose Calculation

The figures for UK quoted above are limited to doses received in 500 years. Radionuclides such as Carbon 14 and Technetium 99 have half lives much longer than this, and will give considerably greater collective doses. For example the UK critical group for Carbon 14 is relatively close to the Sellafield site and is calculated to receive 4.3µSv per annum from this radionuclide – indicating maximum risk levels from this radionuclide of around one in 5 million per annum.

The combined effects of removing time and geography constraints are illustrated in the table below, which considers the two SFMOWG scenarios SF1a and SF3:

Table 3 Collective doses resulting from business scenarios SF1a and SF3 (manSv)

Population	Integration time	Business scenario		
		SF1a	SF3	SF3-SF1a
min. 10 µSv individual dose	500 y[3]	5.6	12	6.6
UK	500 y	26	120	94
	infinity	50	330	280
EU	500 y	100	520	420
	infinity	300	1900	1600
World	500 y	510	3700	3200
	infinity	3700	29000	26000

[3] Doses at times greater than 500y will be lower than 10 microSieverts per year, so the dose integrated to infinity in this category would be no greater.

Converting this table to statistical deaths using 6% per man Sievert factor gives:

Table 4 Statistical fatalities resulting from business scenarios SF1a and SF3

Population	Integration time	Business scenario		
		SF1a	SF3	SF3-SF1a
min. 10 µSv individual dose	500y	0.34	0.72	0.4
UK	500y	1.6	7.2	5.6
	infinity	3	20	17
EU	500y	6	31	25
	infinity	18	110	96
World	500y	31	220	190
	infinity	220	1700	1600

Note that since no individual doses over 10 µSv per annum are ever delivered outside the UK, or at times greater than 500 years after discharges have ceased, the collective dose delivered at individual dose rates above this level does not change as the geographic boundary is extended beyond the UK, or the integration time increased beyond 500 years.

The distribution of radionuclides causing the increase at low doses and long times is illustrated in the table below:

Table 5Breakdown of collective dose per radionuclide
for scenario SF3 and world population (manSv)

Radionuclide	Integration time	
	500 y	infinity
C-14	2000	15000
I-129	260	13000
Kr-85	1400	1400
H-3	16	16
Cs-137	14	14
Tc-99	3.4	12
Ru-106	5.4	5.4
Pu-alpha	2.9	3
Cs-134	2.5	2.5
Am-241	2.5	2.5
Np-237	0.16	2
Ar-41	1.5	1.5
Sr-90	1.3	1.3
Co-60	1.2	1.2
S-35	1	1
Pu-241	0.5	0.5
Sb-125	0.35	0.35
I-131	0.072	0.072
Ce-144	0.0038	0.0038
Zr-95	0.0034	0.0034
Cm-243/244	0.003	0.003
Ru-103	0.0021	0.0021
Nb-95	0.00087	0.00087
Total	3700	29000

Note that 50% of the dose is delivered by Carbon 14. It has already been mentioned that the critical group dose for this nuclide is 4.3µSv/a. Carbon 14 occurs in nature, and Attachment 2 provides some comparison with doses from this naturally occurring isotope. The world dose to people from naturally occurring Carbon 14 is 72,000 man Sieverts per annum – so the figure to compare with the 2,000 man Sieverts from the 500 year case above is 36,000,000, or 0.006%. At infinite time the proportion from Sellafield is infinitely small.

It is clear from all the above that radiological detriment from discharges can be viewed as a very small problem if low risks are neglected, but may be seen as significant if this is not the case.

National and International Policy and Guidance

There are various elements of UK and international policy and guidance which should be borne in mind during the evaluation of the detriment figures. They are not necessarily ‘right’ but do give insights into 'official' views, and will of course provide a significant part of the regulatory and policy background against which BNFL must conduct its business.

Dose / Risk Levels

The UK Tolerability of Risk methodology[4] generally considers risks of less than about one in a million per annum to be generally acceptable. A corresponding level (variously quoted as 10, 20 and 30 µSv per annum) is considered below regulatory concern in the existing UK Radioactive Waste Policy[5] (Cm2919) and the recent draft statutory guidance to the Environment Agency[6]. A *de minimis* level of 10 µSv per annum also underpins the EC Basic Safety Standards, ratified by the UK in 2000.

A recent report on progress towards new recommendations on radiological protection from the International Commission on Radiological Protection illustrates current trends.[7]

Timescales

Perhaps the most coherent discussion of collective dose timescales is found in NRPB Report M453. The relevant paragraph states:

" A risk factor may be applied to collective dose figures in order to obtain an index of radiological detriment. Values for risk factors have been proposed by the International Commission on Radiological Protection (ICRP) and, for application in the UK, by NRPB. These risk factors are based on current experiences and in their derivation various assumptions are made including the best approach in transferring risks from one population to another. Clearly it is questionable to apply such risk factors to possible exposures delivered to populations over thousands of years into the future: for example, base-line cancer rates could be substantially different. Furthermore, in calculating collective doses, assumptions are made about the size and habits of populations and these become increasingly uncertain as the time period under consideration increases. For these reasons, estimating radiological detriments to populations who may exist in the far future has little scientific justification, particularly when the values are to be used as an input to current decision making and resource allocation. Estimates of detriment derived from truncated doses may have more validity; collective dose commitments truncated at 500 years are particularly significant in this respect."

The 500 year period is recommended in the recent draft statutory guidance to the Environment Agency.

Health Detriment from Reduced Employment levels in West Cumbria

That health is affected by economic circumstances, including unemployment is well known. The study for the BNFL National Stakeholder Dialogue by ERM[8] has given figures for the expected health effects in terms of increased mortality rates. The studies on which the

[4] The Tolerability of Risk from Nuclear Power Stations, Health and Safety Executive, 1988
[5] Review of Radioactive Waste Management Policy, Cm2919, HMSO, 1995
[6] "Statutory Guidance on the Regulation of Radioactive Discharges into the Environment from Nuclear Licensed Sites – Consultation Paper", DETR, November 2000
[7] A report on progress towards new recommendations: A communication from the International Commission on Radiological Protection, J. Radiol. Prot. 21(2000) 113-123.
[8] The Environment Council: BNFL National Stakeholder Dialogue. "Socio-economic Study West Cumbria: Visions for West Cumbria", May 2001

excess mortality rates are based show significant variability, so the figures derived for West Cumbria are also variable. The extremes of the estimates are indicated in the table below:

Table 7 Possible range of impacts on Mortality by scenario: compared Minimum case[9].

Scenario	Impact with 21% increase in mortality	Impact with 111% increase in mortality
Blue Sky (SF3)	-100	-525
BNFL Business Case	0	0
Stop ASAP (SF1b plus increased cleanup)	+35	+193
Minimum (SF1b)	+78	+405
Total effect of possible non-BNFL employment schemes	-130	-683

Compared to the business case scheme SF, the minimum case would give an increase in mortality of between 3 and 16 per annum – or between 78 and 405 for the 25 year period. It is clear that new non-BNFL employment schemes can reduce these figures, but their 'success' is not linked to BNFL 'failure' so the relative detriment generated by the BNFL cases should remain, though somewhat reduced if all the new non-BNFL schemes are successful.

A key comparison is therefore that between the 'economic' detriment of losing Sellafield jobs (78-405 statistical deaths) and the 'discharges' detriment (0.25 – 1578 deaths). The huge variation in discharges detriment, which depends on the views on collective dose already discussed, made agreement across the group impossible, but did give some underpinning data for the bounding views which emerged.

Alternative Generation

The SFMOWG scenarios deal with varying amounts of Magnox fuel, different Magnox reactor closure scenarios and hence varying amounts of Magnox generation. This is captured in the initial figure of this note as an increase of 90 million tons of CO2 if the generation is replaced by a mixture of fossil fuel burn.

In fact the picture is more complex. The increased reactor operation will itself give rise to discharges from the stations, and the replacement generation will also have SOx, Nox, particulates, transport and industrial safety etc. effects.

There is an argument that this replacement generation effect is outwith the spent fuel area per se and therefore should not be considered. This argument contends that it is the spent fuel management scenarios which are being compared in terms of their individual environmental characteristics rather than the method by which electricity is generated which is under scrutiny. The counter-argument is that as the reduction of Magnox generation is a direct result of a decision to curtail Magnox reprocessing, replacement generation is an essential component of the environmental consequences of this decision, and should be included.

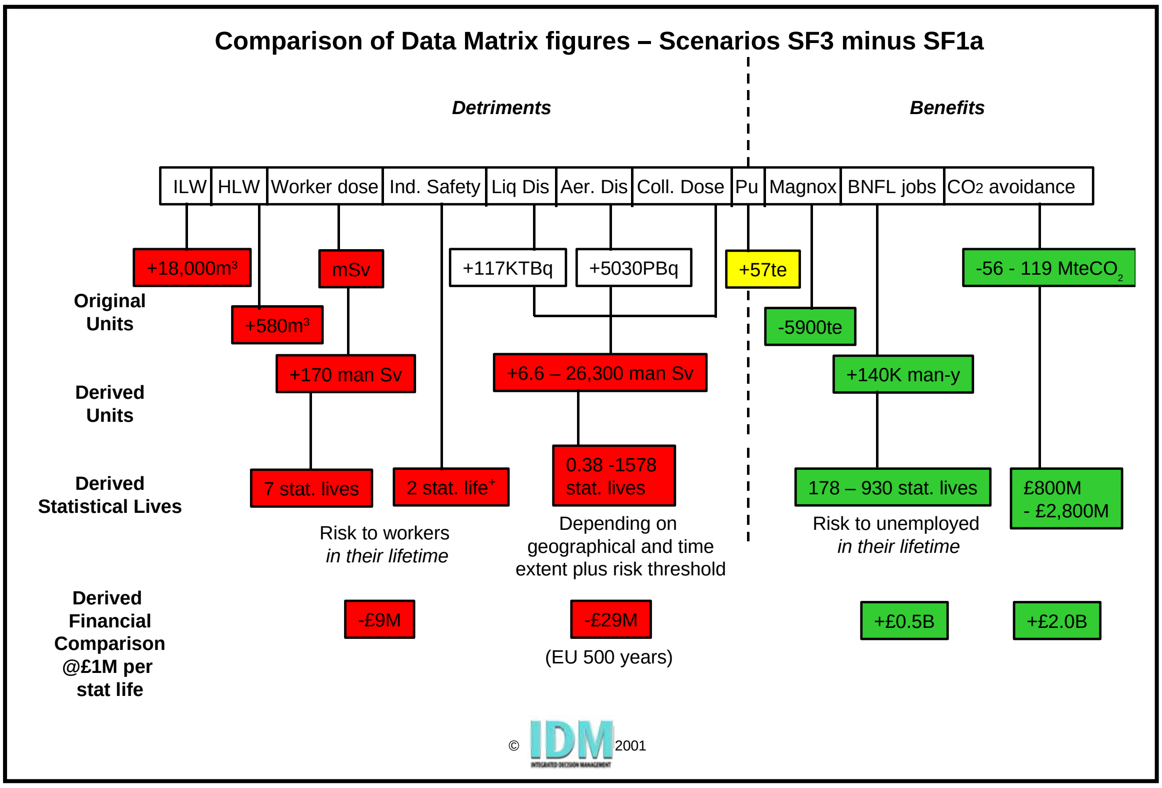
In fact, if replacement generation is considered to be relevant, the 'environmental adders' which value fossil fuel emissions are based involve calculations of health and socio-

[9] Calculated from Table 1.2 of reference 2. Figures are multiplied up to get 25 year totals.

economic brought on either directly by the emissions (e.g. particulates) or by indirect effects (e.g. global warming). This includes such things as deaths from extreme weather and by flooding. Effects from uranium mining and transport would also need to be included in the Magnox case. A direct comparison of global effects could therefore be attempted, but probably not within the timescale or effort available for the SFMOWG study. It would however make an essential unit of any future study of new nuclear build.

Overall Comparison

The overall comparison being made by the Group was illustrated by the figure below. In this figure the quantified elements generally regarded as detriments are on the left, with the two elements regarded as benefits on the right.



This figure includes a range of monetary values for carbon dioxide avoidance derived from published data[10]. These were not discussed at any length by the Group, but the judgement of the importance or otherwise of this factor underpinned the marked difference in weightings given to this criterion in the bounding profiles.

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[10] Study on Economic Prospects for Nuclear
Presented to Lionel Jospin by Messrs Charpin, Dessus, Pellat, 28 July 2000

Attachment 1 to Appendix 10

Collective dose calculations for SF1a and SF3 scenarios

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Project: Stakeholder technical support			
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Method

Collective doses resulting from aerial and marine discharges according to two business scenarios, SF1a and SF3, at BNFL Sellafield were calculated. Cumulative discharges between 2001 and 2028 were used. Integration times of 500 years and 'infinity' were applied. The following populations were considered:

- UK;
- EU (membership countries of the European Union, including the UK);
- World; and
- population receiving individual doses greater than 10 μSv per year.

Discharge data from 2001-2028 resulting from 2 business scenarios, SF1a and SF3, were provided from BNFL (Chamberlain, pers. comm.). Collective dose factors for UK, EU and world populations were taken from Lambers (2001). Doses were only calculated for radionuclides for which previous collective dose calculations had been carried out, to maintain consistency (Chamberlain, pers. comm.). Cumulative discharge data used is listed in Table 1 for liquid discharges and Table 2 for aerial discharges.

To calculate the collective doses received by the members of the population exposed to individual doses greater than 10 μSv per year the method described previously in Jones (2002) was adapted. Collective doses for a number of individual dose bands are shown in Table 3.

The collective doses in Table 3 have been converted to statistical fatalities using a risk factor of 0.06 per Sv in Table 4. The following is copied from Simmonds *et al*. (1995):

> *'Assuming linearity between dose and effect, at the levels of dose typical of routine discharges of radionuclides, the relationships between dose and effect given by ICRP in Publication 60 can be used to estimate the incidence of particular health effects. ICRP have recommended a risk factor of 0.05 per Sv for fatal radiation-induced cancers for radiation protection purposes. This value is appropriate for the general population, assuming a mix of ages. It is calculated as an average value for five populations (Japan, UK, USA, Puerto Rico and China) based on transferring both absolute and relative risks across populations.'*
>
> *'ICRP have also recommended a risk factor for hereditary disorders for exposure of the whole population of 0.01 per Sv. This is based on a risk following exposure of either parent of hereditary disorders of 0.024 per Sv expressed over all generations. However, the genetically significant exposure in a population and hence the risk, will be less than this because a proportion of the population are older than child bearing age. If the mean age of child bearing is 30 years and average life expectancy is 75 years then the probability of genetic harm resulting from exposure of the entire populations is 30/75*0.024=0.01'*

The two risk factors, 0.05 per Sv for fatal radiation-induced cancers and 0.01 per Sv for hereditary disease, are commonly added to give a total risk factor of 0.06 per Sv. The total collective doses received from each business scenario and the difference between them are presented in Table 5. Table 6 shows a breakdown between individual radionuclides for the SF3 business scenario and world populations. From this table it can be seen that C-14 and I-129 contribute by far the largest part to the collective dose at 'infinity', 15,000 manSv and 13,000 manSv respectively, followed by Kr-85 at 1,300 manSv.

H-3, C-14, Kr-85 and I-129 are assumed to become globally circulated due to their relatively long half-lives and behaviour in the environment. Globally dispersed radionuclides act as a long term source of irradiation of both regional and world populations. This is in addition to the irradiation of the population exposed during the initial dispersion of these radionuclides from their points of discharge (Simmonds *et al.* 1995). Individual doses arising from the global circulation of these radionuclides are very small, much below 10 μSv per annum.

References

Chamberlain Rachael, BNFL, personal communication, 08.05.2001.

Jones (2002). Collective doses arising from discharges to the environment from BNFL Sellafield on differing assumed business scenarios. Westlakes Scientific Consulting report no 000079/06 First Issue.

Lambers (2001). Collective dose per unit release factors for BNFL sites. Westlakes Scientific Consulting report no 000167/03 First Draft.

Mayall A, Cabianca T, Attwood CA, Fayers CA, Smith JG, Penfold J, Steadman D, Martin G, Morris TP and Simmonds JR (1997). PC-CREAM 1997: Consequences of Releases to the Environment Assessment Methodology. NRPB-SR296 (EUR 17791 EN), National Radiological Protection Board, Chilton, UK.

Simmonds J R, Lawson G and Mayall A, 1995. Methodology for assessing the consequences of routine releases of radionuclides to the environment. EUR 15670, European Commission, Luxembourg.

Table 1 Atmospheric discharges (TBq), cumulative 2001-2028

Radionuclide	SF1a	SF3
H-3	7.6E+02	5.8E+03
C-14	1.2E+01	2.2E+01
S-35	2.1E-02	1.2E+00
Ar-41	1.5E+01	1.9E+04
Co-60	4.0E-05	1.1E-03
Kr-85	1.0E+05	5.1E+06
Sr-90	2.5E-03	2.5E-03
Ru-106	8.4E-02	1.00E-01
Sb-125	2.6E-01	2.6E-01
I-129	1.7E-01	8.3E-01
I-131	2.1E-02	8.3E-02
Cs-137	1.6E-02	1.6E-02
Pu-alpha	2.3E-03	2.3E-03
Pu-241	1.5E-02	1.5E-02
Am-241	1.7E-03	1.7E-03

Table 2 Marine discharges (TBq), cumulative 2001-2028

Radionuclide	SF1a	SF3
H-3	2.6E+03	1.2E+05
C-14	1.6E+01	1.3E+02
Co-60	3.3E+01	7.3E+01
Sr-90	5.3E+02	5.8E+02
Zr-95	1.6E+00	6.2E+00
Nb-95	1.6E+00	6.2E+00
Tc-99	4.8E+02	6.4E+02
Ru-103	4.8E-01	3.6E+00
Ru-106	8.9E+01	2.7E+02
Sb-125	1.3E+01	1.3E+01
I-129	1.1E+00	2.5E+01
Cs-134	4.4E+01	7.8E+01
Cs-137	2.9E+02	3.2E+02
Ce-144	2.2E+00	1.6E+01
Np-237	1.3E-01	9.9E-01
Pu-alpha	8.9E+00	1.5E+01
Pu-241	1.6E+02	1.9E+02
Am-241	7.9E+01	8.3E+01
Cm-243/244	1.1E-01	1.1E-01

Table 3Collective dose (manSv) delivered in dose range indicated

Individual dose range (microSv per annum)					
<0.015	0.015-0.15	0.15-1.5	1.5-10	>10	Total
3500 95.4%	120 3.3%	17 0.5%	20 0.5%	12 0.3%	3700

Table 4Number of statistical fatalities occurring from the risk range indicated

less than 1 in 1,100 million per annum	1 in 1,100 million to 1 in 110 million per annum	1 in 110 million to 1 in 11 million per annum	1 in 11 million to 1 in 1.7 million per annum	greater than 1 in 1.7 million per annum	Total
210 95.5%	7.2 3.3%	1 0.5%	1.2 0.5%	0.72 0.3%	220

Notes to Tables 3 and 4:
- discharge scenario 'SF3'
- doses from aerial and liquid discharges are summed
- integration time: 500 y
- population: world

Table 5 Collective doses resulting from business scenarios SF1a and SF3 (manSv)

Population	Integration time	Business scenario		
		SF1a	SF3	SF3-SF1a
min. 10 μSv individual dose	500 y[11]	5.6	12	6.6
UK	500 y	26	120	94
	infinity	50	330	280
EU	500 y	100	520	420
	infinity	300	1900	1600
World	500 y	510	3700	3200
	infinity	3700	29000	26000

[11] Doses at times greater than 500y will be lower than 10 microSieverts per year, so the dose integrated to infinity in this category would be no greater.

Table 6 Breakdown of collective dose per radionuclide for scenario SF3 and world population (manSv)

Radionuclide	Integration time	
	500 y	infinity
C-14	2000	15000
I-129	260	13000
Kr-85	1400	1400
H-3	16	16
Cs-137	14	14
Tc-99	3.4	12
Ru-106	5.4	5.4
Pu-alpha	2.9	3
Cs-134	2.5	2.5
Am-241	2.5	2.5
Np-237	0.16	2
Ar-41	1.5	1.5
Sr-90	1.3	1.3
Co-60	1.2	1.2
S-35	1	1
Pu-241	0.5	0.5
Sb-125	0.35	0.35
I-131	0.072	0.072
Ce-144	0.0038	0.0038
Zr-95	0.0034	0.0034
Cm-243/244	0.003	0.003
Ru-103	0.0021	0.0021
Nb-95	0.00087	0.00087
Total	3700	29000

Attachment 2 to Appendix 10 Collective Dose from natural radiation, 500 years integration time

This is taken from the BNFL Annual discharge report 2000, page 56 (para 61 and Table 26):
'Atmospheric concentrations of C-14 attributable to Sellafield are indistinguishable from naturally occurring background concentrations at distances exceeding 100 km. The natural background results in collective doses that are many orders of magnitude higher than the doses resulting from Sellafield's discharges of C-14 (Table 26). This reflects the fact that natural sources of radiation constitute the largest source of public radiation exposure on a national or global scale (Hughes 1999).'
Hughes JS (1999). Ionising radiation exposure of the UK population: 1999 Review. NRPB-R311, HMSO, London.

Table 26. Annual collective dose commitments from natural radiation

Source of collective dose	Collective dose commitment (manSv per year)		
	UK population	European population	World population
Natural C-14 All sources of natural radiation	660 120,000	8,400 1,600,000	72,000 13,000,000

In this context, Europe includes Greenland, Iceland, Scandinavia, and Western Russia up to 50°E. This represents a total European population of 700 million, including 55 million in the UK. The world population is taken to be six billion.

Since radiation exposure from natural sources and hence individual dose can be assumed to remain constant over time the collective dose integrated over a set time period (500 years) is given by the annual dose multiplied by the years.

Collective doses from natural radiation over 500 years

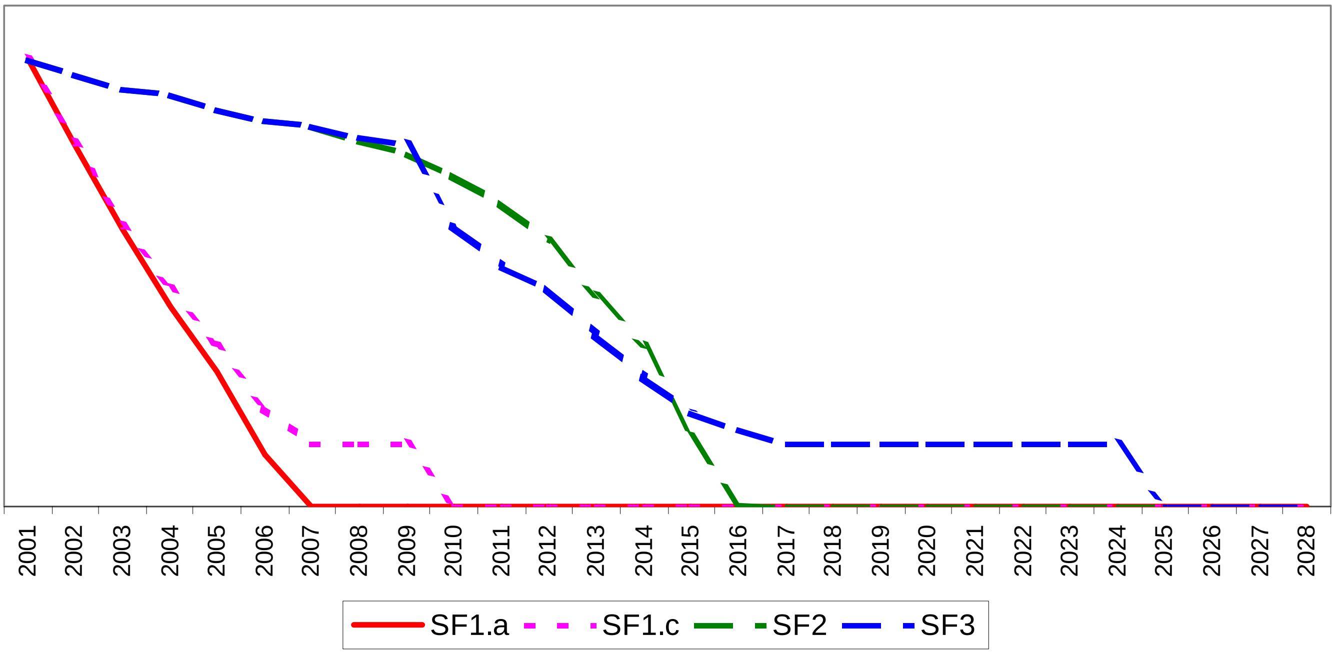
Source of collective dose	**Collective dose commitment over 500 years (manSv)**		
	UK population	**European population**	**World population**
Natural C-14 **All sources of natural radiation**	330,000 60,000,000	4,200,000 800,000,000	36,000,000 6,500,000,000

Appendix 11

Variation of key variables with time

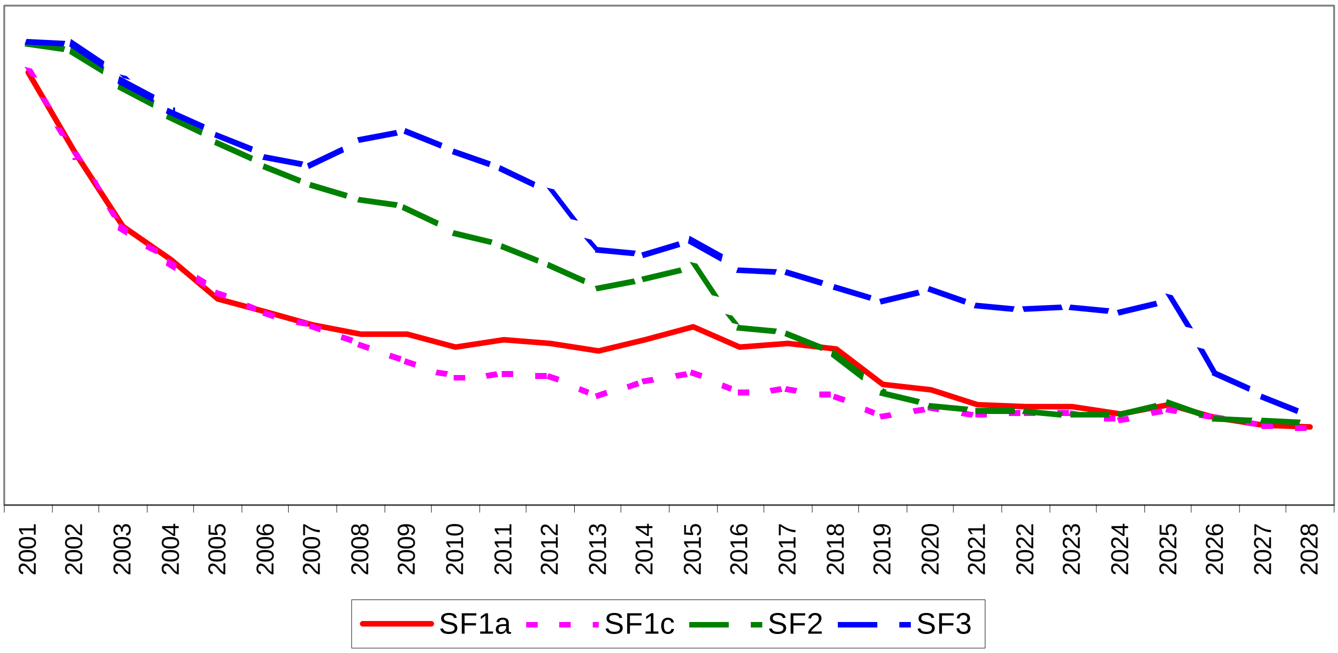
Indicative Highly Active Liquid Waste stocks at Sellafield (m^3)

Note that scenario SF3 assumes that an additional vitrification plant for processing HAL is available from 2010



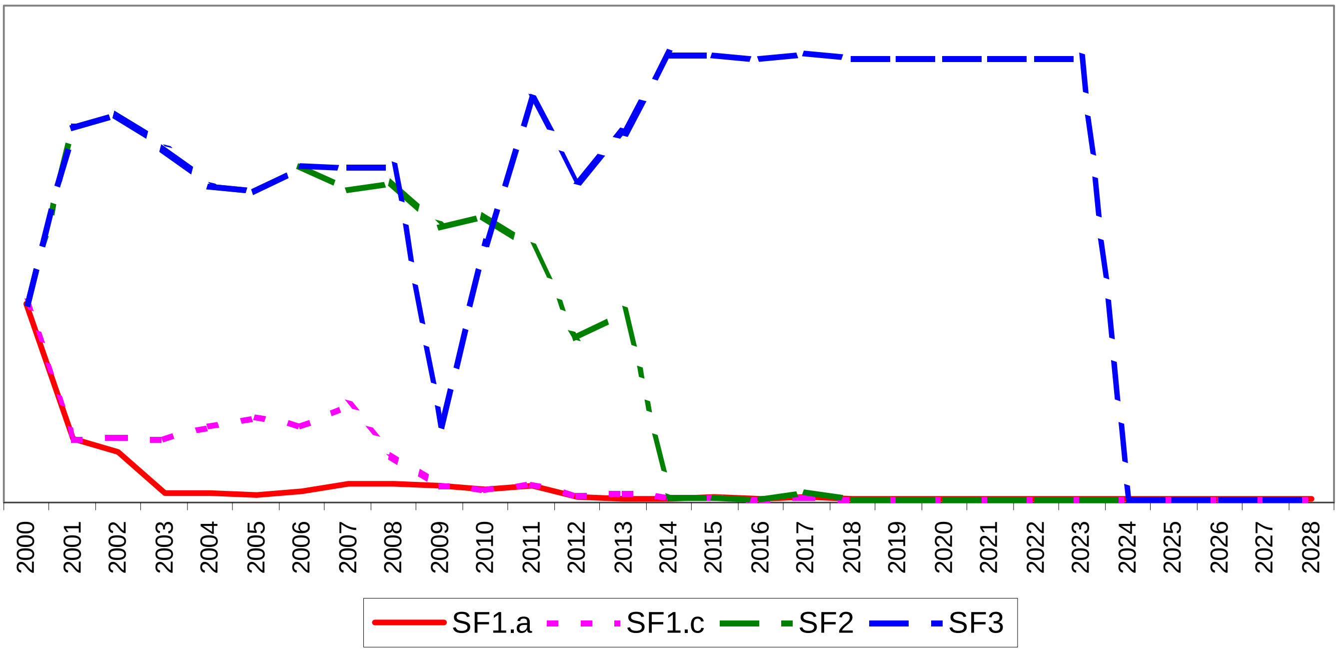
Indicative BNFL employment forecasts

Profiles shown for direct employment on operating sites only, including agency workers and contractors at all sites, together with construction workers at Sellafield. Operating sites include Sellafield, Springfields and Magnox reactor sites



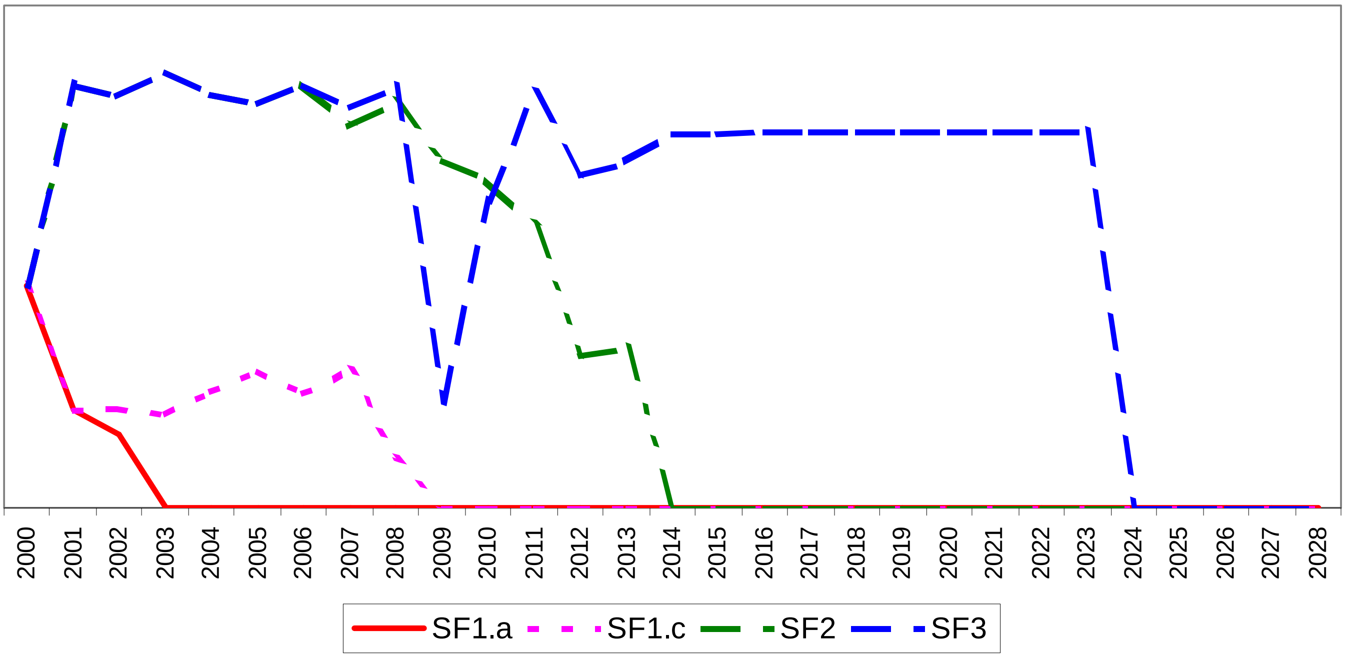
Indicative activity from Sellafield liquid discharges (TBq)

Profiles exclude discharges associated with future decommissioning operations. No reductions due to additional abatement are assumed.



Indicative activity from Sellafield aerial discharges (TBq)

Profiles exclude discharges associated with future decommissioning operations. No reductions due to additional abatement are assumed.



Appendix 12

Strategic Action Planning

Original by Allen Hickling: 29th April 2001, extended by Richard Harris with additional material "Definitions and Practicalities": 22nd January 2002

The aim of this paper is to explain how strategic planning can be combined with the management of uncertainty to provide a way forward for the SFMO WG. In it the following definitions are used:

1) A scenario is a sequence of activities leading to a particular long-term future.
2) An action plan is a package of relatively short-term actions.

A Conventional Strategy

A conventional strategy is a scenario combined with an action plan designed to achieve a selected best future. (See Figure 1.)

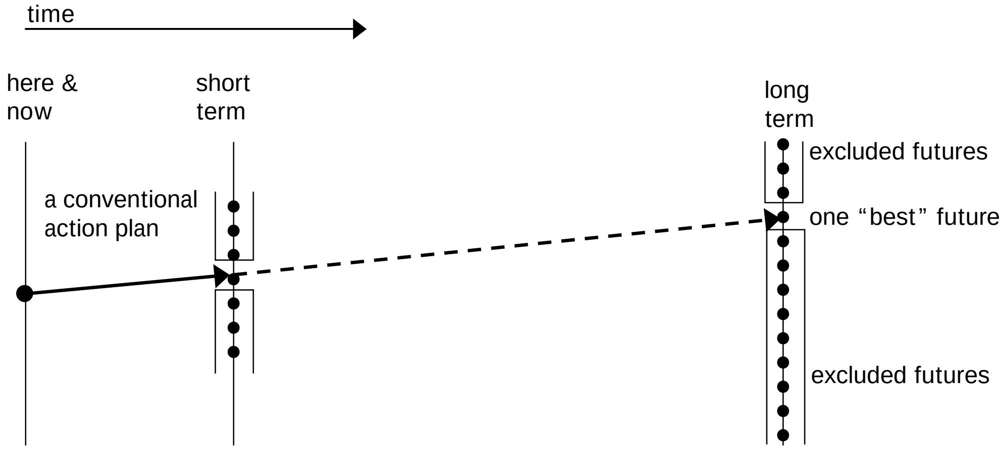


Figure No 1: A conventional strategy

This may sound simple, but the truth of the matter is that it is very difficult, especially where there are many uncertainties and many stakeholders. Even if it is possible to get agreement about which scenario to choose – and often it is not – there is usually a wide range of opinion on how best to achieve it.

This is for two reasons.

- There is always considerable uncertainty to be faced – not only about how the various short-term actions could work out, but also about possible future events, and about the way others might behave.
- The stakeholders have very different values - expressed in their perceptions; the assumptions they make; and the priorities they choose to set - which underlie all their efforts to overcome the uncertainty.

Most often this makes it all so difficult that the search for agreement has to be abandoned, and the way forward is chosen by individuals who are in a position of power of some sort.

A Strategy with Management of Uncertainty

However, there is another way. In this a strategy is developed by selecting a range of good scenarios excluding only those that are not feasible or are clearly less desirable than others. These are then combined with a strategic action plan comprised of a set of short-term actions selected so as to keep the widest range of good futures open. (See Figure 2.)

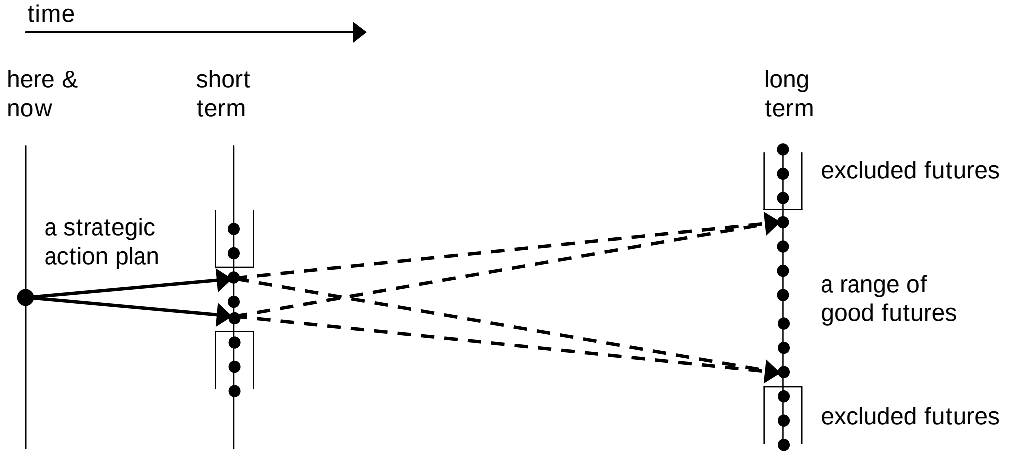


Figure No 2: A strategy with management of uncertainty

In this case the search for just one most desirable long term future can be put aside. Not only is such a search extremely difficult – maybe impossible in a multi-stakeholder situation – but, in any case, there are so many uncertainties along the way that it is most unlikely that the chosen one will be achieved anyway. In its place a more effective approach is to develop a strategy in which the uncertainty about how things will work out has to be acknowledged as something to be managed openly and creatively – not suppressed or ignored.

In this the strategic action plan will contain

- robust and adaptable short-term actions,
- explorations to reduce the most significant uncertainties,
- and contingency plans in case unavoidable assumptions turn out to be wrong.

Where a variety of stakeholders are involved, consideration may also have to be given to actions designed to alleviate the negative impacts of the strategy which are likely to affect some of them.

STRATEGIC ACTION PLANNING: DEFINITIONS AND PRACTICALITIES

USING SCENARIOS:

SAP work can be carried out following the development of a number of "scenarios". A scenario is defined above as "*a sequence of activities leading to a particular long term future*"; in this case the scenarios effectively describe all or part of the route to a number of possible future states.

"Interrogating" a set of varied, and often opposed, scenarios in the SAP framework enables a group to explore the range of possible futures which exist, along with all the inherent uncertainties associated with them. SAP helps the group to undertake a full exploration because it explicitly avoids the anxiety associated with the search for one "best" option.

THE SAP FRAMEWORK:

A typical Strategic Action Planning table will look like this:

ASSUMPTION	ACTIONS	EXPLORATIONS	DEFERRED ACTIONS (OR DECISIONS)	CONTINGENCY

ASSUMPTIONS:

Assumptions are used in strategic action planning where an uncertainty cannot be easily or quickly reduced. These are made explicit and then clearly stated. Each assumption (or group of related assumptions under an "Issue" heading) then starts a row of the table.

Typical Question(s) (TQ) - What assumptions are being made in order that this scenario can work?

ACTIONS:

What is to be done in the short term. These tend to be actions about which there is little or no uncertainty, especially with regard to their relevance or impact.
TQ – What short term action is required in order that this scenario is to be pursued?

EXPLORATIONS:

Those areas of uncertainty to be researched or investigated, starting in the short term. Explorations are aimed at reducing the uncertainty relevant to the assumption and often are intended to support decisions which can safely be put off to a future date (or deferred - see below).

TQ – What needs to be known in order that the uncertainty can be reduced? How can we find out?

DEFERRED DECISIONS OR ACTIONS:
Decisions, or actions, which can be safely deferred – often pending the outcome of explorations when the uncertainty has been reduced. These are usually decisions which present a risk if they are taken now (based on an assumption) and are better deferred till more is known and the associated risk can be reduced.

TQ – What decision/action can be deferred? When does the decision have to be made or implemented?

CONTINGENCY:
What will be done in the event that the assumption turns out to be wrong? N.B. When a number of scenarios are being considered it is common for one scenario to be the ultimate contingency for another.

TQ – e.g. What will be done if the plant suffers a catastrophic failure?

RESULTS AND CONCLUSIONS:
A completed SAP table may be a result in itself as it will, for example, provide strategic direction, including adaptable critical path and milestones information. However, when a number of scenarios have been explored it is necessary to bring them together and develop a single strategy (which, of course, need not be exclusive to one scenario or another). This may be done in at least two different ways:

(i) Producing a single SAP
This is based on applying the accumulated learning derived from the scenario based SAP's done to date. This will usually start with a look at the SAP's to see what commonality exists between them and then resolving outstanding differences.

(ii) Developing Conclusions and Recommendation
This is also based on applying the accumulated learning to date. With reference to the scenario SAP's it should be possible to identify areas of convergence where, for example, no matter which feasible scenario is used similar actions, explorations etc are required. These then form the basis of derived conclusions and recommendations.

CYCLIC WORKING:
It is critical to note that working with SAP is a cyclic activity in two senses:

(i) moving from one part of the table to another is not constrained by vertical or horizontal one step shifts; indeed, trying to work with the SAP table with such a linear approach is unlikely to be successful.
(ii) A number of "passes" is usually required before a group becomes comfortable with the content in the table. On each pass the group is likely to alter its earlier work as they learn more about the scenario, the concept of uncertainty and its management through SAP. At each pass the work will be improved and will eventually become "firm".

AN EVERYDAY EXAMPLE:
Imagine you are expecting a child and need an additional bedroom. Your preference is to buy a new house which will provide the space you need. An alternative scenario is to convert

your existing loft space to provide a bedroom. Of course, at the outset you cannot know everything you possibly need to know, so you make certain assumptions, for example:

(a) A desirable property can be found
(b) Your own property can be sold
(b) The purchase can be financed
etc

ASSUMP-TION	**ACTIONS** ***(Now)***	**EXPLORATIONS** ***(Now)***	**DEFERRED ACTIONS OR DECISIONS** ***(Later)***	**CONTINGENCY** ***(Later)***
(a) A desirable property can be found	*Contact estate agents covering the desired area.* *Develop criteria to enable short listing of options.*	*View a number of properties and draw up short list.* *Establish the cost and other implications of renting a property (see contingency).*	*Choice of house to buy.* *Decide whether short term renting is acceptable Contingency.*	*In the event that a desirable property cannot be found – (i) abandon moving plans and consider converting the loft or (ii) sell own property and move into a rented property.*
***(b)* Your own property can be sold**	*Contact estate agents and seek at least 3 evaluations*	*Research market to determine minimum acceptable selling price.*	*Choose estate agent and place property on the market.* *Decide whether or not to sell.*	*In the event that your property cannot be sold-convert the loft.*

***(c)* The move can be financed**	*Determine the likely amount required.*	*Contact a number of lenders to establish interest rates, packages etc.* *Establish likely cost and other implications of loft conversion option.*	*Choice of lender.*	*In the event that the move cannot be financed – convert the loft.*

Note
This simple example is definitely not exhaustive - as anyone who has ever bought a house knows full well! The example is intended to help the reader understand how the components of a SAP may interrelate; of course, you may not bother doing a SAP for such an everyday exercise! But there again...

Appendix 13

Multi Attribute Decision Analysis

Background

A15.1 The SFMO WG considered how MADA works by taking steps to define more precisely the context of the analysis; by looking at questions such as who are the decision makers and key stakeholders, and by reviewing the options available. The key steps in a MADA are to:

- Establish the context (identifying decision makers and key stakeholder);
- Define what “options” are available;
- Agree which (non overlapping) attributes may distinguish better from poorer options, by identifying “values” to facilitate checking and weighting
- Assess expected performance – producing a table of “options” by “performance” values;
- Assign weights to attributes – with careful discussion amongst “stakeholders” – with weightings agreed adding up to 1;
- Combining weights and scores for each option (usually facilitated by specialised computer software) but only introducing aspects such as cost or public acceptability after that stage;
- All this leading to the identification of a provisional choice (or choices);
- Applying sensitivity testing.

Throughout the analysis the MADA technique required extensive discussion amongst the participants and is by its very nature cyclic.

Develop Scenarios

A15.2 13 scenarios were considered, with 8 being carried forward into the MADA:

- SF1a ‘stop now’ – immediate Magnox reactor and THORP closure. Leave final Magnox fuel loading in the reactor and reprocess wetted fuel in B205.
- SF1c immediate Magnox reactor and THORP closure but reprocess all current Magnox fuel through B205.
- SF1T as SF1a, including reprocessing of wetted fuel in B205, but final Magnox fuel loading is reprocessed in a new THORP head end plant when available.
- SF2 current business plan
- SF2T current business, but Magnox fuel reprocessed through a new THORP head end plant when available.
- SF3 ‘blue sky’
- SF3T ‘blue sky’, but Magnox fuel reprocessed through a new THORP head end plant when available.
- SF3T+ hybrid – As SF3T, but the availability of the new THORP head end plant enables Wylfa and Oldbury Magnox stations to operate on Magnox fuel to dates as in Appendix 4.

Scenarios	Attributes			
SF1a				
SF1c				
SF1T				
SF2				
SF2T				
SF3				
SF3T				
SF3T+				

Figure A15.1

Develop Criteria

A15.3 The description of how the SFMO WG developed the attributes, or 'criteria' as they were described within the group, to be considered in the MADA is addressed in Section 4. These criteria form another axis of the MADA table, as shown in Figure A15.2 below.

The criteria are:

1 Lifetime Arisings
2 Magnox Storage
3 AGR storage
4 CO^2 avoidance
5 Worker deaths
6 Environmental discharges
7 BNFL jobs
8 Rail miles
9 Sea Miles
10 Environmental Impact
11 Hazard
12 Risk
13 Transport Risk

	Criteria												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Scenarios													
SF1a													
SF1c													
SF1T													
SF2													
SF2T													
SF3													
SF3T													
SF3T+													

Figure A15.2

Scoring Scenarios

A15.4 The SFMO WG developed its list of criteria and confirmed that, as is commonly used in the MADA technique, it would score them between 0 (‘worst’) and 10 (‘best’). Figure A15.3 [below] was the outcome of several passes at agreeing a set of basic scores for each criterion. This was a relatively straightforward exercise where the Group was dealing with measured data. But in those cases where the criterion was less easily quantified (for example Risks) the group carried out a quite detailed assessment of the data to make the necessary comparison between the scenarios. All of which took a significant time, as the Group needed to ensure that it was scaling appropriately

	Criteria												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Scenarios													
SF1a	10	0	0	0	9	10	3	10	10	4	10	0	0
SF1c	8	10	0	0	10	9	0	10	10	10	10	10	0
SF1T	8	10	0	0	7	10	4	10	10	4	10	0	0
SF2	1	10	10	6	5	2	4	4	9	9	3	3	10
SF2T	1	10	10	6	5	3	5	4	9	4	3	3	10
SF3	1	10	10	6	2	1	8	4	0	4	3	3	8
SF3T	1	10	10	6	2	1	8	4	0	0	3	3	8
SF3T+	0	10	10	10	0	0	10	0	0	0	0	2	8

Figure A15.3

Weighting Criteria

A15.5 The SFMO WG noted that there were no obviously stronger scenarios without weighting the criteria, so it progressed into the application of weightings. The group recognised a number of key issues in undertaking this task:

- weights must take into account the length of the scale
- some criteria carry proxies having different scales
- how important to environmental performance is a move from worst to best in the scale of the criteria
- the need to consider “sustainability” in its widest sense, including socio-economic effects when considering weighting

A15.6 This work led, after a number of iterations, to a set of weightings as shown below in Figure A15.4. The SFMO WG noted a potential ‘weakness of the MADA process insofar as there can be a tendency for each stakeholder group to manipulate the weightings to give an undue significance to one criterion – i.e. employment or discharges – to produce an intended or unconscious outcome. However, the explicit nature of the MADA process means that any manipulation is open to direct scrutiny by others.

	Criteria												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Scenarios													
SF1a													
SF1c													
SF1T													
SF2													
SF2T													
SF3													
SF3T													
SF3T+													
Weighting 1	0.16	0.13	0.03	0.04	0.09	0.1	0.09	0.05	0.05	0.04	0.08	0.06	0.08
Weighting 2	0.05	0.15	0.03	0.14	0.11	0.03	0.38	0.01	0.01	0.02	0.02	0.03	0.02

Figure A15.4

Analysis / Output

A15.7 The SFMO WG collectively assessed the effects of the weightings and looked at where it thought that unjustifiable weight had been applied and collectively re-assessed the weights using the spreadsheet with support from Professor Pearman. Following discussion it was realised that two criteria were dominant – and seemed to reflect the significance attached to jobs and to the impact of environmental discharges. The Group collectively developed two weighting sets, which acknowledged the role of these two key emphases – and concluded that these need to be fully reported as an outcome from the work of the SFMO WG. This is more fully discussed below.

A15.8 Figure A15.5 shows the scores for each scenario on each criterion, plus (bottom two rows) the weights agreed for the two representative weight profiles. The final two columns show the total weighted scores achieved by the 8 scenarios using each weight set.

	Attributes													Profiles	
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2
Scenarios															
SF1a	10	0	0	0	9	10	3	10	10	4	10	0	0	5.64	3.41
SF1c	8	10	0	0	10	9	0	10	10	10	10	10	0	7.18	4.17
SF1T	8	10	0	0	7	10	4	10	10	4	10	0	0	6.53	4.97
SF2	1	10	10	6	5	2	4	4	9	9	3	3	10	5.24	5.48
SF2T	1	10	10	6	5	3	5	4	9	4	3	3	10	5.23	5.79
SF3	1	10	10	6	2	1	8	4	0	4	3	3	8	4.42	6.41
SF3T	1	10	10	6	2	1	8	4	0	0	3	3	8	4.26	6.33
SF3T+	0	10	10	10	0	0	10	0	0	0	0	2	8	3.66	7.22
Weighting 1	0.16	0.13	0.03	0.04	0.09	0.1	0.09	0.05	0.05	0.04	0.08	0.06	0.08		
Weighting 2	0.05	0.15	0.03	0.14	0.11	0.03	0.38	0.01	0.01	0.02	0.02	0.03	0.02		

Figure A15.5

A15.9 The diagrams below (Figures A15.6 and A15.7) show this information pictorially. The width of each bar shows the contribution to overall score made by each of the 13 criteria.

[Note that the software converts all aggregate scores to a 0 → 1 “Utility” scale, i.e. divides the above scores by 10.]

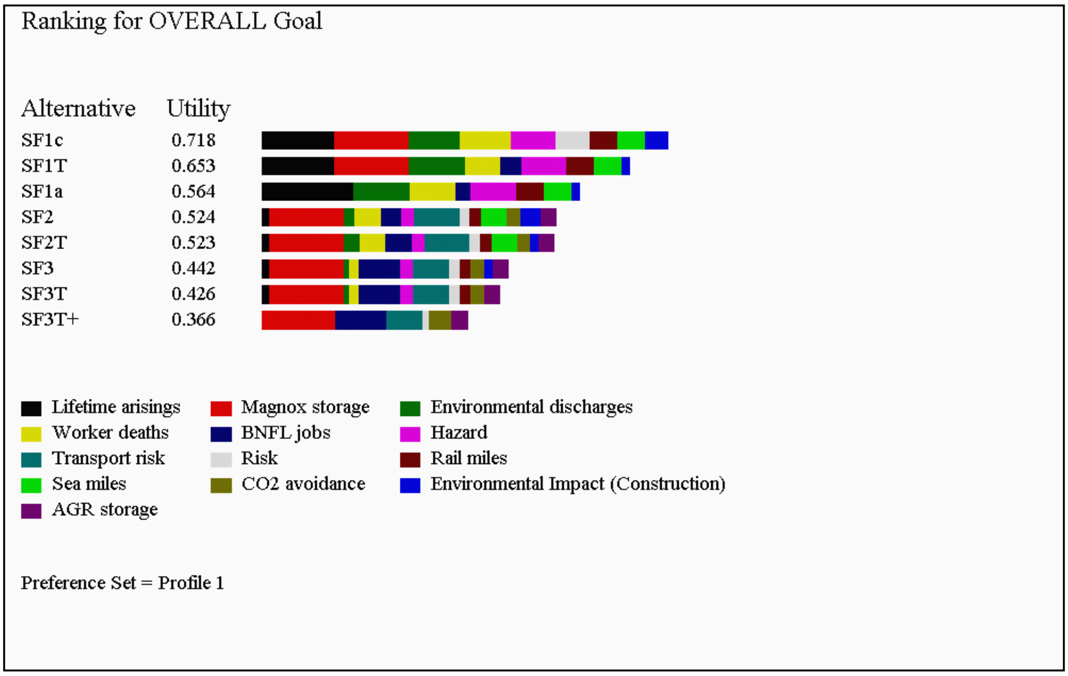


Figure A15.6 Ranking for Profile 1 - Environmental

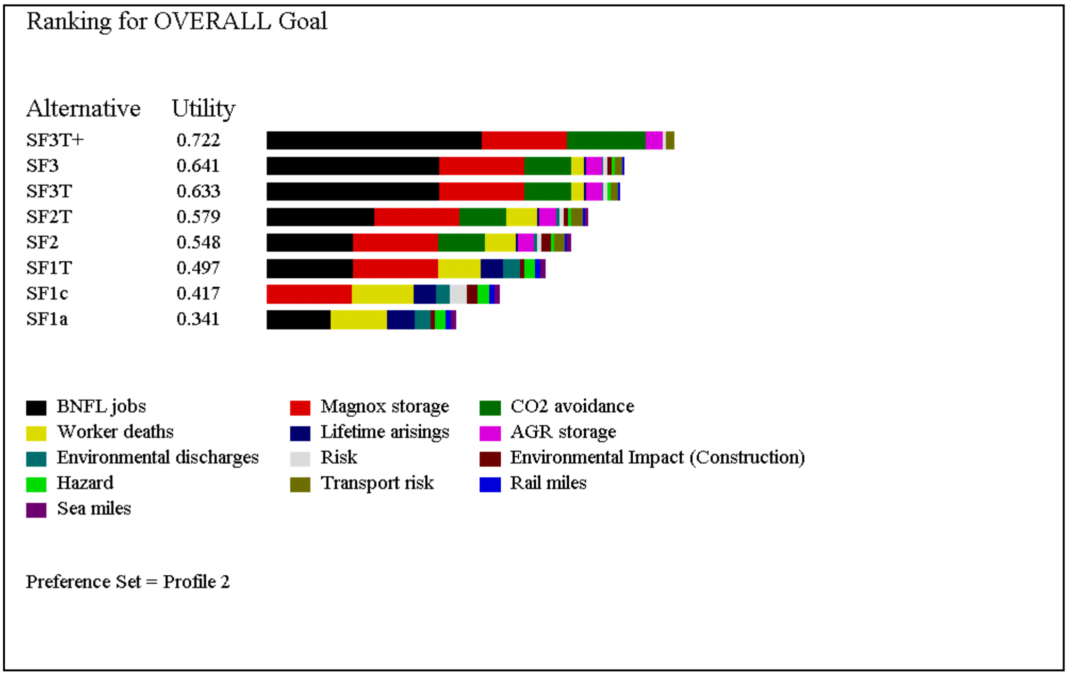


Figure A15.7 Ranking for Profile 2 – Socio-economic

Appendix 14

BNFL NATIONAL STAKEHOLDER DIALOGUE
SPENT FUEL MANAGEMENT OPTIONS WORKING GROUP (SFMO WG)

DRAFT TECHNICAL EXPERTS' APPENDIX
COSTING OF THE SCENARIOS DEVELOPED BY THE SFMO WG

12 November 2001

This paper reports work from the Technical Experts (TX) for the SFMO WG, and is prepared for the SFMO WG meeting of 13/14 November 2001. It is drafted as an Appendix to the main SFMO WG report.

The Technical Experts have comprised:

BNFL Experts (BX):

Peter Wiley
Jeff Ferguson

Green Experts (GX):

Ian Fairlie (October 2000 – November 2001)
Gordon MacKerron (October 2000 – May 2001)
Mike Sadnicki (October 2000 – December 2000; May 2001 onwards)

This TX Report has the following Sections:

1. Introductory Comments
2. Scenarios and Activities
3. Income and Costs: Data Assumptions and Methodology
4. Overview of Results; TX Commentary and Conclusions
5. BX Commentary
6. GX Commentary

Annex A gives a full definition of each Scenario.
Annex B gives the detailed assumptions in each Scenario, listed by facility.
Annex C gives model output of activity timings for each Scenario.
Annex D documents the total results for each Scenario, by activity.
Annex E graphs year by year undiscounted and discounted costs for each Scenario.
Annex F documents the GX view of long-term reprocessing and MOX prices.

The Report is jointly written by the TX, with the exception of Section 5 by the BX, and Section 6 and Annex F by the GX.

1. INTRODUCTORY COMMENTS

Time periods covered

1.1 The analysis in this TX Report estimates the future cash flows of a number of possible spent fuel management Scenarios defined by the SFMO WG. The cash flows are measured from a start date of 1 April 2001. For most activities, only cash flows (income and outflow) up to 2030 are included. This is a completely arbitrary cut-off defined early on by the SFMO WG. The only exception to the 2030 cut-off is "optional investment" activities, which arise where major new capital investment is included for some Scenarios and not for others (see Section 3 below).

Sector being analysed

1.2 Most of the cash flows occur at Sellafield, and the activities comprise most of the Sellafield site. However, the entity being analysed must not be construed as being BNFL Parent, or BNFL Group, or the Sellafield site, or e.g. the BNFL "Spent Fuel and Engineering Business Group" as defined in the BNFL 2001 Annual Report and Accounts (ARA). "The SFMO WG Sector" under consideration comprises the totality of the set of activities defined by the SFMO WG, and described below in Section 2, and then in more detail in Annex B.

1.3 It should be understood that there are many Sellafield and BNFL cash flows which are specifically not included in the SFMO WG Sector. These are usually cash outflows. Two examples of items not included are:

- the Post-operational Cleanout (POCO) (if any) and the decommissioning of all of the plant, connected with spent fuel management, which currently exists at Sellafield. Such plant has an asset value of several billions of pounds, and its POCO and decommissioning costs will be considerable.

- any cash costs of Magnox generation not included in the avoidable cost of generation defined in Annex B to be 1.4 p/kWh.

Net cash flows versus profitability

1.4 Nevertheless the SFMO WG Sector represents most of the Sellafield site. The analysis allows the SFMO WG to investigate the business opportunities and threats faced by BNFL, and to compare the economic performance of the different options for spent fuel management. *However, it must be noted that "economic performance" is measured by net cash flow from now – the difference between total cash inflows and total cash outflows. The estimates produced by this analysis are not estimates of accounting profitability.*

1.5 In particular, the analysis in this TX Report allows no conclusion to be drawn about the underlying profitability of reprocessing. This is particularly so since the history of reprocessing contracts involved a large element of early prepayments by customers. BNFL is now entering the tail-end of the reprocessing arrangement; it has reaped much of the income, but is faced by continuing costs.

1.6 There are two alternative views as to the judgement that will ultimately be made of reprocessing, when all accounts are known and settled:

- the BNFL view is that reprocessing will ultimately be shown to have generated significant profits for the UK and Cumbria. Income earned, and the benefit of being able to invest that income when prepaid, outweighed the later costs;

- the "opposing" view is that when setting reprocessing prices, BNFL significantly underestimated future costs of waste management and discharge abatement, and its customers overestimated the value of separated plutonium and reprocessed uranium. Reprocessing will ultimately be shown to have been a costly error.

Objectives of this TX Report

1.7 The analysis in this TX Report does not allow a judgement to be made as to which of the above two views is correct. Instead, the analysis is simply concerned with helping to identify the best spent fuel management option for the UK from here on in.

What is par?

1.8 Great care has been taken by the SFMO WG in general, and by the TX in particular, to try to ensure that all Scenarios have been costed on a like for like basis. The TX are confident that this objective has by and large been achieved, and that Scenarios can be ranked and compared in terms of their net cash flow.

1.9 However, the question arises: what is a good result? Clearly, a net cash *inflow* is better than a net cash *outflow*. However, in the nature of things, because of the prepayments described above, the situation is usually one of net cash *outflow*. Only a couple of Scenarios ever produce a net cash inflow from 1 April 2001, and then only under specific sets of assumptions. Net cash outflows so predominate that Scenarios are documented under the convention that costs are shown positive. Income, and net cash inflows are shown negative.

1.10 The question still arises: what is par for the course? The best answer to this question is: the net cash outflow estimated for BNFL's current business plan for the "the SFMO WG sector." In the case of reprocessing and MOX production, "current business plan" is best interpreted as "under existing arrangements with firm contracts."

1.11 Unfortunately, this "current business plan" is not one of the Scenarios defined by the SFMO WG – the Scenario 1's involve less reprocessing and MOX production than the current business plan, and the Scenario 2's involve more. However, a rough answer can be inferred from some of our results in Section 4. A broad estimate might be that the current business plan involves a net cash outflow to BNFL of several billion from now onwards. The objective of this exercise is therefore to improve on this, or alternatively to reduce any risk that the net cash outflow of the selected spent fuel management option might exceed this.

Investment appraisal and sensitivities

1.12 Conventional investment appraisal also uses cash flow analysis. Therefore, although the analysis in this Report makes no statement on underlying accounting profitability of overall BNFL programmes, paradoxically the analysis in this Report can be used for investment appraisal of specific investment projects, if the project is separated out from all other activities.

1.13 Some analysis of this type is included in later Sections, including typical sensitivity testing of "breakeven" prices or throughputs. Specific examples include:

- the possibility of a second Sellafield MOX Plant, SMP2;
- the possibility of adding lines 4 and 5 for HLW vitrification as WVP2.

1.14 However, it is not realistic to talk of breakeven prices for the whole "SFMO WG sector", specifically because as described above there is no particular reason why the sector should break even, given the historical context.

View LNC and View HNC

1.15 For cost and income, the assumptions reflect the TX dialogue between GX and BX over the period December 2000 to October 2001. Wherever possible, one single assumption is specified for the activity in each Scenario. Where the dialogue has not produced consensus (and indeed often could not be expected to), cost and income assumptions are given as Views Lower Net Cost (LNC) and Higher Net Cost (HNC).

1.16 The differences between LNC and HNC for some parameters reflect both the range of uncertainty in estimating the future, and genuine differences between the GX and the BX.

- **View LNC** reflects expectations of lower capital and operating costs for activities, and also expectations of higher income levels from activities such as reprocessing and MOX production.
- Conversely, **View HNC** reflects expectations of higher capital and operating costs for activities, and expectations of lower income levels from activities such as reprocessing and MOX production.

1.17 In most cases the GX view will tend to be represented by the Lower Net Cost View in Scenario 1's, and the Higher Net Cost View in Scenario 2's and 3's[1]. Conversely, the BX view will tend to be represented by the Higher Net Cost View in Scenario 1's, and the Lower Net Cost View in Scenario 2's and 3's.

1.18 However, because of the difficulties described in Section 3 with respect to BNFL disclosure of information, in many cases the BX were not able to disclose specific assumptions for either LNC or HNC. In such cases the GX have had to infer "likely" assumptions, which the GX would expect the BX to have made. Because of the good working relationships established between GX and BX since November 2000, the GX are hopeful that the assumptions made broadly reflect BNFL views. However, this must not be construed as an attempt to trap either the BX or BNFL into "ownership" of any assumptions.

[1] There are some activities which are an exception to this rule.

1.19 For many individual activities in individual Scenarios, the LNC and HNC Views are the same. Where they differ, it would be misleading to infer a measure of central or average tendency between them.

Traps in interpreting results: "BNFL would not invest unreasonably"

1.20 A first set of trial results was presented to the SFMO WG on 11 June 2001. Several members of the SFMO WG were uneasy with the method of presentation. In some Scenarios and some Views, net cash outflows were very large. This caused uneasiness, with typical comments being that such results should not be presented because: "BNFL is a sensible prudent company – it would not allow itself to get into such a position"; or "if SMP2 were going to be that unprofitable, BNFL would not build it in the first place".

1.21 Such logic is incorrect. The process the SFMO WG is going through is precisely that of replicating the *decision-making process.* The presentation of a poor outturn for a particular Scenario is part of the decision-making process of rejecting that Scenario. To edit out results of this type would mean that the ultimate SFMO WG Report would not be systematically representing all the possible outcomes.

Traps in interpreting results: Specification of cumulative throughput

1.22 The SFMO WG defined the total throughputs of all Scenarios (in terms of tonnes reprocessed, tonnes MOX produced etc) as an inherent part of each Scenario definition. This has unfortunately introduced an unforeseen constraint. By making the throughputs part of the definitions, the capability of expressing a major component of *estimation uncertainty* has been eliminated. There is no way of reflecting the fact that the throughput itself may not be achieved.

1.23 What is worse is that this problem does not act uniformly in all Scenarios:

- **The 1's Scenarios** do not contain throughputs of AGR/PWR reprocessing, or MOX. If BNFL decides to adopt such a Scenario within its corporate plan, then the number of parties involved is relatively few, mainly BNFL, regulatory bodies, and BNFL's shareholder (currently Government). There is estimation uncertainty on costs and impacts, but there is relatively little inherent uncertainty as to whether the policy can be implemented, if the decision is taken to adopt it.

- **The 3's Scenarios**, in contrast, will involve many more participants, especially overseas. These participants will be making increasingly market-based decisions which are inherently more uncertain. There is still the estimation uncertainty on costs and impacts, but there is also considerable "market-based" uncertainty as to the *extent to which the throughputs can be achieved, including the possibility that they may not be achieved at all*[2]*.*

1.24 From the public domain information available, there seems *considerably* more uncertainty as to what levels of throughput may be achieved in the 3's Scenarios than in the 1's Scenarios. As such it gives a misleading impression to give the Scenario 3's the same status as that given to the 1's and 2's Scenarios. Further comments on Scenario interpretation can be found in Sections 4, 5 and 6.

[2] The counter-argument against this "throughput uncertainty" argument is that there is considerable regulatory and "customer compensation uncertainty" with respect to the Scenario 1's (see Section 5).

Accuracy and precision

1.25 All assumptions, intermediate calculations, and results are given to the nearest £ million. This convention is adopted purely to help the reader check calculations and establish audit trails. It does not imply that the resulting estimates are in any way accurate to the nearest million.

2. SCENARIOS

Timings and Throughputs

2.1 The key Scenario assumptions as agreed by the SFMO WG are as given in Table 2.1.

TABLE 2.1: KEY SCENARIO ASSUMPTIONS

			End date			**Overall throughput**			
	Reactor policy	Magnox fuel route	B205	THORP	SMP	Magnox te	AGR te	Foreign LWR te	MOX tHM
SF1a	Stop	B205/ dry store	2003	2001	n/a	1500	0	0	0
SF1a~	Stop	B205/ dry store	2003	2001	n/a	1500	0	0	0
SF1c	Stop	B205	2008	2001	n/a	7400	0	0	0
SF1T	Stop	B205/ Thorp	2003	2017	n/a	7600	0	0	0
SF2	Cont-inue	B205	2012	2014	2015	11100	4300	4900	910
SF2T	Cont-inue	B205/ Thorp	2010	2017	2015	11100	4300	4900	910
SF3	Extend	B205	2012	2024	2024	11100	4300	15300	3500
SF3T	Extend	B205/ Thorp	2010	2027	2027	11100	4300	15300	3500
SF3T+	Extend	B205/ Thorp	2010	2029	2029	13500	4300	15300	3500

2.2 The above are as presented at the SFMO WG meeting of 14/15/16 March 2001, with the addition of SF1a~, which was added at the suggestion of the GX in order to investigate savings from dry storage of AGR spent fuel.

2.3 The Scenario nomenclature is ordered under the following broad schema:

prefix “1”: stop all AGR and LWR reprocessing immediately; no MOX production;

prefix “1a”: stop all Magnox reprocessing immediately with the exception of spent fuel currently wet-stored;

in all other cases: reprocess all Magnox in B205 until the end of reactor lives; unless

suffix “T”: install a new head-end at Thorp which will enable THORP to reprocess any Magnox spent fuel requiring reprocessing beyond the planned life of B205;

prefix “2”: continue AGR/LWR reprocessing until 2010 or 2012 (baseload and some post-baseload). Return all LWR plutonium as MOX;

prefix “3”: substantial extra Thorp reprocessing of AGR/LWR until at least 2024, with corresponding increase in MOX production.

2.4 Another way of thinking about the Scenarios is that under the Scenario 1’s all reprocessing finishes in the first decade of the 21st century; in the Scenario 2’s reprocessing continues into the second decade; and in the Scenario 3's reprocessing continues into the third decade.

Major New Capital Requirements by Scenario

2.5 Table 2.5 summarises non-quantitatively the major variations in new plant and refurbishment requirements, in the different Scenarios defined in Table 2.1.

TABLE 2.5: NEW PLANT AND REFURBISHMENT REQUIREMENTS in different Scenarios

	1a	1a~	1c	1T	2	2T	3	3T	3T+
SMP start-up (& decommissioning)					YES	YES	YES	YES	YES
SMP2							YES	YES	YES
Magnox dry store	YES	YES							
Magnox drying facility	YES	YES							
AGR dry store		YES							
AGR drying facility		YES							
Refurbishment: reactor life extension									YES
Magnox route to THORP				YES		YES		YES	YES
Thorp enhancement, refurbishment					yes	yes	YES	YES	YES
Waste treatment plant refurbishment							YES	YES	YES
Abatement					YES	YES	YES	YES	YES
WVP Line 4							YES	YES	YES
Additional product & waste stores					yes	yes	YES	YES	YES
LWR return	YES	YES	YES	YES					
Overseas Pu powder export route	(Y)	(Y)	(Y)	(Y)					

Key:
YES = major new capital investment/refurbishment required;
(Y) =BX believe major expenditure required; GX do not;
yes = significant new capital investment/refurbishment required, but not of the same order as the above two categories.

Activities

2.6 For the 9 Scenarios under consideration, BNFL have provided a list of 27 possible activities which will occupy various periods to 2030.

TABLE 2.6 ACTIVITIES DEFINED BY BNFL	
1	Magnox generation net income: 2001 - 2007
2	Magnox generation net income: 2008 - 2020
3	Magnox wet storage at reactors
4	Magnox wet storage at Sellafield
5	Magnox storage in reactor cores
6	Removal of fuel from Magnox cores
7	Magnox drying facility at Sellafield
8	Magnox dry store at Sellafield
9	Magnox reprocessing (2 years only)
10	Magnox reprocessing (8 or more years)
11	THORP oxide reprocessing: 2001 - 2013
12	THORP oxide reprocessing: 2014 – 2020's
13	Magnox to THORP: new head-end plant
14	LWR wet storage
15	LWR return to foreign customers
16	AGR wet storage
17	AGR drying facility
18	AGR dry store
19	SMP 1: 2001 – 2010's or 2020's
20	SMP 2: 2013 - 2030
21	Waste management: HLW: Lines 1 - 3
22	Waste management: HLW: Lines 4 - 5
23	Waste management: ILW
24	Sellafield site infrastructure: Full
25	Sellafield site infrastructure: Half
26	Pu returns (1's); Abatement (2's, 3's)
27	THORP repayments

2.7 It will be seen that in some cases - (e.g. 2, 10, 12, 25) - an activity is essentially the same as the preceding activity, but represents a different level of throughput and/or capacity and/or operating cost. In other cases (e.g. 20, 22) the activity is essentially the same as the preceding activity, but represents an optional level of increased investment.

2.8 For each Scenario, the first and last date of operation of each activity has been defined by the TX. These are all documented in Annex B.

3. COSTS AND INCOME: DATA ASSUMPTIONS AND METHODOLOGY

Problems encountered

Commercial confidentiality

3.1 In principle, most operating cost and current price data are already available, because most of the Scenario activities are already undertaken by BNFL, and are therefore already somewhere in the company's accounts.

3.2 However, the data needed for the SFMO WG Scenario modelling are mostly for specific, individual activities (e.g. the costs of Magnox wet storage or the costs of Magnox reprocessing). BNFL generally regards these specific data as commercially confidential and they are not on the public record.

The Financial Services Act

3.3 The BX were unable to participate directly in this costing exercise because of restrictions placed by the Financial Services Act (in the context of the possible PPP) on BNFL's ability to put specific financial data on any sort of record, including the Stakeholder Dialogue. Consequently, the onus has been on the GX to derive cost data from limited material on the public record, and to use their own knowledge and capacity for intelligent inference to find approximations to the numbers needed. This is clearly not as satisfactory as it might be.

The ERM data

3.4 After the March SFMO WG, a meeting was held between Gordon MacKerron, and David Elliott and Jon Samuel of the ERM team responsible for the socio-economic study. It became clear during that meeting that ERM holds a great deal of data, originally provided by BNFL, on precisely the cost categories that we need in order to undertake the present Scenario costing exercise. It would obviously have saved both time and money, and lead to more accurate Scenario costing work, if the SFMO WG TX had access to this cost data.

3.5 The GX consequently requested access to this data via the Environment Council. At the May meeting of the SFMO WG, BNFL announced:

- that the BNFL data held by ERM would not be made available to the GX;
- that in the opinion of BNFL, the SFMO WG exercise would not benefit from access to the ERM data.

Capital and Operating Costs

3.6 Detailed cost assumptions, for all activities and Scenarios, are in Annex B.

Capital costs and Refurbishment

3.7 All Scenarios require some new capital expenditure on some activities. In addition, for activities extending for some considerable time beyond 2001, some annual level of refurbishment may be required. BNFL have been helpful in indicating the broad orders of magnitude of costs that they would expect to incur for various capital items, and broad consensus has been reached between GX and BX on a sensible *range* of future costs of construction, and corresponding assumptions for View LNC and View HNC.

Operating costs

3.8 In any Scenario, for each activity specified, the operating cost is calculated as being incurred in each year for which that activity is specified in the Scenario definition. The calculations follow directly from assumptions on timings and annual operating costs.

3.9 In many cases, history and current activity are only useful as broad guides in estimating operating costs. This is either because a particular facility may not previously have been constructed (e.g. a dry store) or because regulatory and technical considerations may have substantially moved on since the last construction was undertaken (e.g. a new WVP line).

3.10 This is therefore an area where in many cases it is meaningful to talk in terms of a range of future costs. However, in cases where the activity is one currently operating at Sellafield, the confidentiality restrictions described above have generally applied, and the GX have had to estimate the assumptions for both Views LNC and HNC.

Income-generating Activities

3.11 Activities 1, 2 (Magnox generation), 11, 12 (THORP reprocessing), and 19 and 20 (SMP production) generate income for BNFL. In any Scenario, for each income-generating activity defined in that Scenario, the income is calculated for each year that the activity is defined as operating. The prices charged by BNFL will reflect market conditions, and the relative power of producer and consumer.

3.12 Again detailed assumptions, for all activities and Scenarios, are given in Annex B. However, expected average prices have, in the nature of things, proved particularly difficult issues for the GX and BX to achieve consensus, and so a fuller account is given here than for costs.

3.13 Where Scenarios involve continued use of facilities such as Magnox generation, THORP, SMP (and the notional SMP2), BNFL clearly expect to make a financial return on these operations, including new investment. Such profits would clearly reduce the net costs of Scenarios from 2 onwards, and lead to a BNFL expectation that variants of Scenarios 2 and 3 will be cheaper than variants of Scenario 1, where income streams stop quickly. However, the question of the profitability of such activities is clearly a point of disagreement between the company and some other stakeholders, requiring the use of Views LNC and HNC.

Magnox generation

3.14 Fuel fabrication and generation are combined, as there is no need, for cost purposes, to treat fuel fabrication separately. The required annual sums here are the revenue from selling Magnox electricity minus all ‘front end’ costs.

Electricity selling price

3.15 The Magnox selling price is assumed to be **2.1p in View LNC and 1.9p/kWh in View HNC.** This is lower than the historical average but in line with current expectations in the electricity industry as a whole. Increasing competition and the new market NETA have pushed prices below 2p/kWh but rises in underlying fossil fuel prices may prevent further price collapses.

Operating costs (front end fuel plus O&M only)

3.16 **An estimate of 1.4p/kWh is derived in Annex B.** This seems roughly consistent with the average of the 1997 figures produced for each station for the justification exercise. No refurbishment expenditure is assumed, which may be optimistic.

Net revenue

3.17 The result is that we have a range of net revenues of **0.7p/kWh in View LNC** to **0.5p/kWh in View HNC**, over 125 TWh for Scenarios 2, 2T, 3, 3T and over 220 TWh for Scenario 3T+.

THORP

3.18 In the *short run* – say the next 5 years - reprocessing prices are predominantly already contracted.

3.19 In the *long run* – say beyond 15 years - the GX View is that average reprocessing price will be determined by the cost of the significant competing alternative, which in this case is storage of the spent fuel for perhaps a prolonged period, before ultimate direct disposal of the spent fuel in a deep repository. Bearing in mind that this fuel will almost all be LWR, and LWR (dry) storage is in principle cheaper than AGR storage, this 'limit' price is unlikely to be above **£200/kg** [3]. To estimate the LNC View, the GX inferred a position roughly half-way between current prices and the above GX View.

SMP operation

3.20 BNFL would clearly not run SMP or build and run SMP2 unless they expected to make money from these activities. In this respect, the views of BNFL and other stakeholders may differ considerably. Again, the full details of these differences are given in Annex B.

Optional Investment Activities

3.21 Some activities represent new activities which are only undertaken in certain Scenarios. In such cases, to preserve a fair comparison between Scenarios, the Post-operational Clean-out (POCO) and decommissioning costs are also estimated. POCO is usually costed as one further year's operating cost in the year following termination of operations. Decommissioning cost varies between 10% and 30% of the capital cost of the plant, depending on the activity in question, and is usually initiated 5 years after termination of operations, lasting for a further 5 years. Full details are given at Annex B.

[3] This figure derives from a GX calculation based on BX and BNFL data. See Annex F.

Repository costs

3.22 From very early on in the SFMO WG dialogue process in 2000, it has been (tacitly) agreed that the costs and timing of such a repository are so radically uncertain that they will be ignored, across all Scenarios, in the present round of costings.

Value basis of income and cost estimates

3.23 All income and costs are presented on the basis of prices of the year 2001, thus ignoring any potential future inflation.

Discount Rates

3.24 BNFL and other companies routinely use discount rates to assess projects and policies, and we would expect them to do so in relation to spent fuel management options - clearly an early capital expenditure will seem more onerous than one that is postponed for say 20 years. There are two discounting practices appropriate to the economic analyses, described as follows[4].

Commercial case analysis

3.25 This will nearly always involve a capital investment and/or income stream. The purpose of discounting is to compare alternative investment options (including an implied alternative of doing nothing). The appropriate discount rate is the *cost of capital discount rate*.

- BNFL currently uses 8% (e.g. in the current round of SMP consultation). This represents the rate that the Treasury wishes State-owned enterprises to apply, appropriate to appraising new income-earning activities in the public sector.

- It can be argued that 11%, or even higher, is more appropriate for BNFL preparing for a possible PPP. This more nearly reflects conditions applying to income-generating activities for a private company (it is the rate recommended to Nuclear Electric in 1994 when that company prepared investment plans that would have been implemented in the private sector).

Resource cost analysis

3.26 In many "pure waste management" projects, there is little or no income stream, and doing nothing is not an option (although different periods of delay might be associated with different options). The more appropriate discount rate is now the *financing or funding rate.* If there are several options, the purpose of discounting is to investigate whether their ranking differs significantly from that based on undiscounted costs. If there is just one option, the purpose of discounting is to discover what the funding implications are.

3.27 In such cases the rate applied is 2.5%, already used by BNFL as a long-term 'liability' rate for costing waste management options.

[4] F Barker, M J Sadnicki, *The Disposition of Civil Plutonium in the UK*, April 2001, Section 8.6, pp 108-110.

Conclusion on discount rate

3.28 Since the SFMO WG task, taken it its entirety, is essentially a project which must be carried out, with a large number of "pure waste management" components, it can be argued that 2.5% is the most appropriate rate for discounting a full Scenario. This in no way rules out using cost of capital rates for separate investment appraisals of individual activities, such as building a new SMP, within the overall exercise. An example of such an investment appraisal is given in Section 6 below[5].

Spreadsheet model

3.29 To facilitate the calculations, a spreadsheet model has been developed which incorporates all Scenarios, all activities, and all the years in question. The spreadsheet format makes it easy to supply our results in discounted as well as undiscounted forms.

5 Indeed, the development of the spreadsheet model means that different discount rates can be used for different activities within the same discounting calculation. This may intuitively seem awkward, but there is no theoretical reason why it should not be done.

4. SUMMARY OF RESULTS AND TX COMMENTARY

Introduction

4.1 This Section 4 includes the following sub-Sections:

paras 4.2 – 4.4	Results for all Scenarios, Views LNC and HNC
paras 4.5 – 4.8	Validation of Spreadsheet Model
paras 4.9 – 4.19	TX Commentary on Results
paras 4.20 – 4.22	BNFL Long-term Strategy Options

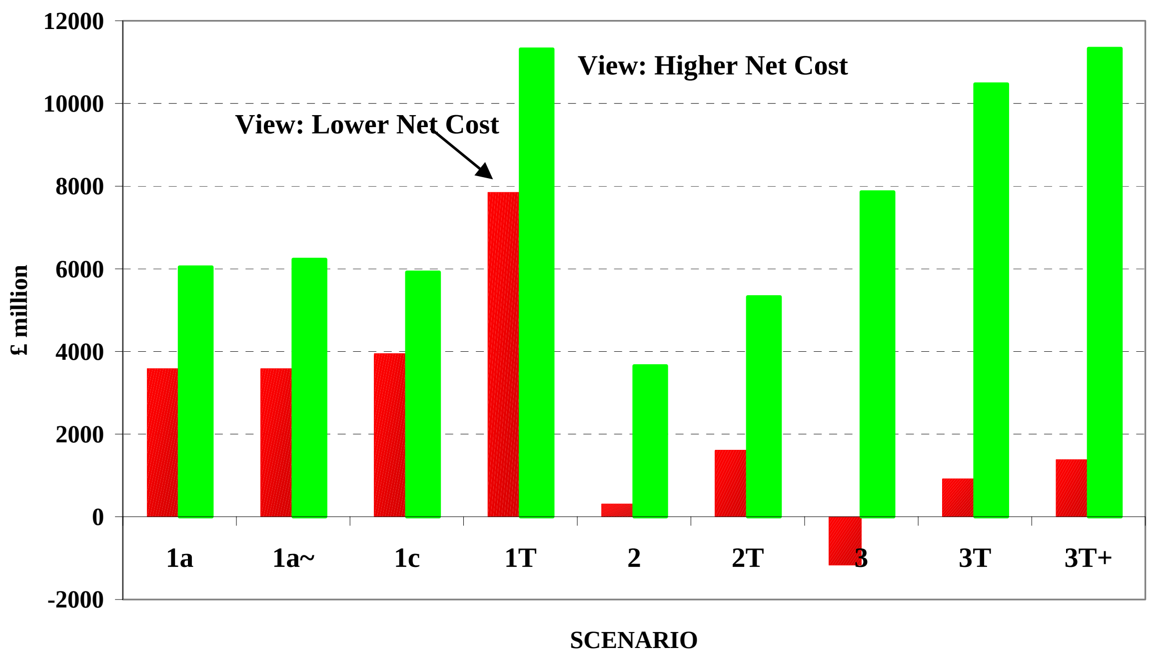
Undiscounted Scenario net costs

4.2 The Table and Figure 4.2 below give the total net *undiscounted* costs for each of the 9 Scenarios. Note the convention that *net costs* are shown positive; a figure in brackets is a *net revenue* or income stream to BNFL.

TABLE 4.2: UNDISCOUNTED SCENARIO COSTS
Results for View LNC and View HNC for input to MADA
£ million; net cost positive; net income ( )

Scenario	Lower Net Cost	Higher Net Cost
1a	3586	6043
1a~	3584	6225
1c	3949	5917
1T	7851	11312
2	312	3652
2T	1614	5322
3	(1167)	7860
3T	919	10470
3T+	1386	11329

FIGURE 4.2: SCENARIO TOTAL NET COSTS: UNDISCOUNTED
(net costs shown positive)

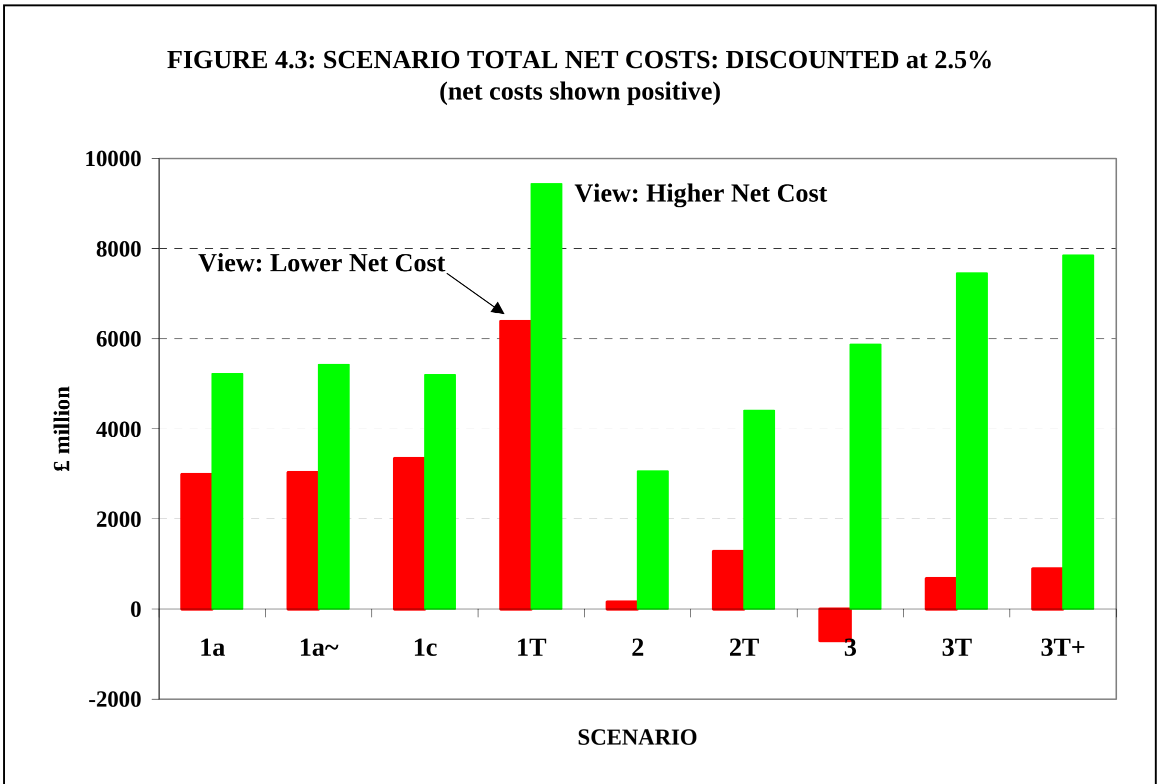


Discounted Scenario net costs at 2.5%

4.3 Table 4.3 and Figure 4.3 below give the total net costs, *discounted @ 2.5 %* for each of the 9 Scenarios. Again, the convention is that *net costs* are shown positive; a figure in brackets is a *net revenue* or income stream to BNFL.

TABLE 4.3: DISCOUNTED SCENARIO COSTS
at "FINANCING" or "FUNDING" DISCOUNT RATE OF 2.5%
Results for View LNC and View HNC for input to MADA
£ million; net cost positive; net income ( )

Scenario	Lower Net Cost	Higher Net Cost
1a	2986	5222
1a~	3028	5426
1c	3339	5196
1T	6386	9437
2	158	3062
2T	1278	4408
3	(704)	5874
3T	676	7454
3T+	892	7853



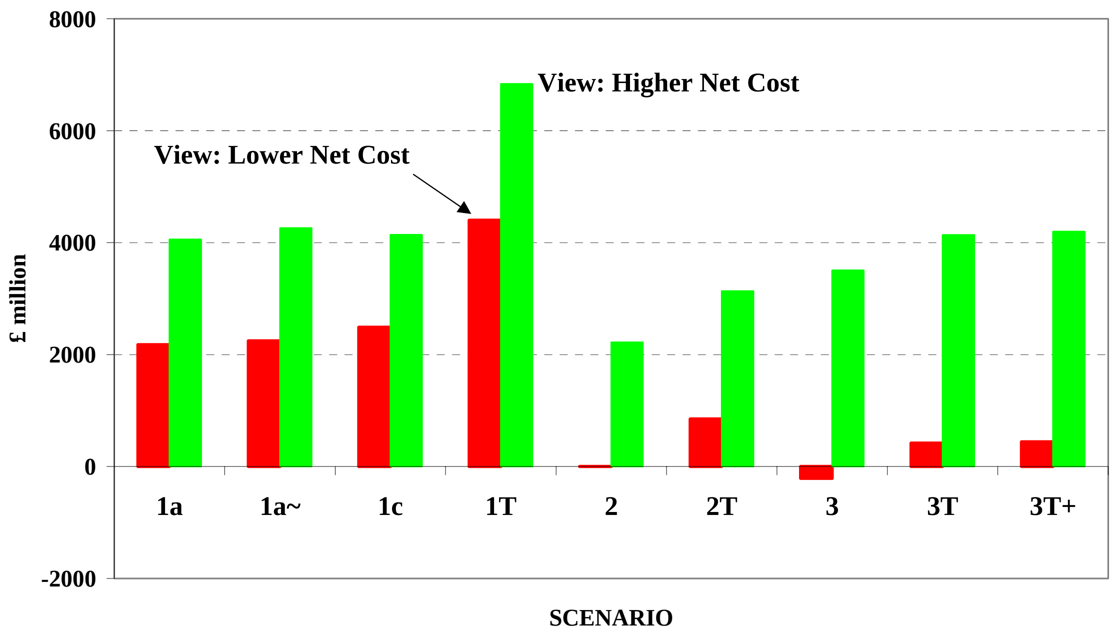
Discounted Scenario net costs at 8.0%

4.4 Table 4.4 and Figure 4.4 below give the total net costs, *discounted @ 8 %* for each of the 9 Scenarios. Again, the convention is that *net costs* are shown positive; a figure in brackets is a *net revenue* or income stream to BNFL.

TABLE 4.3: DISCOUNTED SCENARIO COSTS
AT "FINANCING" or "FUNDING" DISCOUNT RATE OF 8.0%
Results for View LNC and View HNC for input to MADA
£ million; net cost positive; net income ( )

Scenario	Lower Net Cost	Higher Net Cost
1a	2177	4060
1a~	2247	4260
1c	2489	4141
1T	4400	6838
2	2	2221
2T	853	3135
3	(208)	3508
3T	419	4137
3T+	441	4198

FIGURE 4.4: SCENARIO TOTAL NET COSTS: DISCOUNTED at 8%
(net costs shown positive)



Validation of Spreadsheet Model

4.5 A simple method of validating the spreadsheet model is to compare the operating cost of a full program (either Scenario 2 or Scenario 3) with the total operating costs as shown for 2000/01 in the BNFL 2001 Annual Report and Accounts (ARA 2001).

4.6 The comparison cannot be too explicit because the ARA 2001 shows Profit/Loss costs rather than cash outflows, and will thus include non-cash costs such as depreciation. To balance this, there will be some cash costs which will not be included in the ARA Profit & Loss operating costs. However, in general the ARA Profit & Loss operating costs would be expected to be higher than the cash operating costs.

4.7 Relevant statistics for annual operating costs are:

BNFL ARA 2001[6]:	Magnox generation	£332 million
	Spent fuel & engineering	£617 million
	Total	£921 million
Spreadsheet model	LNC View	£700 million
Spreadsheet model	HNC View	£790 million

4.8 The comparison gives some reassurance that the majority of the relevant costs are correctly included in the spreadsheet model.

TX Commentary on Scenario net costs

Scenario 1's:

4.9 As would be expected, the Scenario 1's are all characterised by significant net costs. In undiscounted terms, (ignoring 1T as a special case) the Scenario 1's are broadly equal, hovering around £3.75 billion in the Lower Net Cost (LNC) View, and £6.0 billion in the HNC View (see Figure 4.2).

4.10 Discounting the Scenario 1's at 2.5% brings the LNC View down to below £3 billion, and the HNC View down to around £5.25 billion (see Figure 4.3).

Scenario 2's:

4.11 The Scenario 2's represent an improvement in terms of net cost over the Scenario 1's, but not to the extent of generating a net positive cash flow. In undiscounted terms, the two Scenario 2's are at a net cost of £0.3 to £1.6 billion in the Lower Net Cost (LNC) View, and £3.7 to £5.3 billion in the HNC View (see Figure 4.2).

4.12 Discounting at 2.5% brings the LNC View down to £0.2 to £1.3 billion, and the HNC View down to £3.1 to £4.4 billion (see Figure 4.3).

[6] The values shown are inferred from BNFL ARA 2001, p51.

Scenario 3's:

Lower Net Cost (LNC) View

4.13 For the Scenario 3's, even in the LNC View, a *net income* is generated only in one case (Scenario 3 at £1.2 billion). The other two Scenario 3's (3T and 3T+) have a net cost in the LNC of between £0.9 billion and £1.4 billion (see Figure 4.2).

4.14 Discounting at 2.5% brings the Scenario 3 LNC View down to a *net income* of £0.7 billion. Discounting also brings the other two Scenarios 3's down to a net cost of between £0.65 billion and £0.9 billion (see Figure 4.3).

Higher Net Cost (HNC) View

4.15 The HNC View damages all Scenario 3's severely. The increases in operating cost, and decreases in income, mean that the undiscounted HNC net cost rises to nearly £8 billion in Scenario 3 to over £11 billion in Scenario 3T+ (Figure 4.2).

4.16 Similarly, the discounted HNC net cost rises to nearly £6 billion in Scenario 3 to nearly £8 billion in Scenario 3T+ (Figure 4.3).

4.17 In general the uncertainty in the Scenario 3's, as shown in the differences between LNC and HNC Views, is much greater than the differences between LNC and HNC Views in Scenario 1's and Scenario 2's. The Scenario 3's appear to be *higher risk Scenarios* - balancing the chance of very large HNC net costs against the chance of relatively small LNC net costs or net incomes.

New THORP Head-end for Magnox Spent Fuel: the Scenario T's

4.18 In all cases, the T Scenarios emerge as significantly more expensive than their nearest comparators. Table 4.18 shows the differences for the LNC View. Depending on the Scenario, the T Scenario is always more expensive than its nearest comparator by between £1.3 billion and nearly £3.9 billion. The difference is particularly significant in Scenario 1 because of the number of years that THORP has to tick over before the new head-end for Magnox spent fuel is commissioned.

TABLE 4.18 T SCENARIOS
COMPARISON OF TOTAL NET COST WITH NEAREST COMPARATOR
LNC View (£ million undiscounted)

T Scenario Net cost		Nearest Comparator Net cost		Net amount by which T is costlier
Scenario 1T	7851	Scenario 1c	3949	3902
Scenario 2T	1614	Scenario 2	312	1302
Scenario 3T	919	Scenario 3	(1167)	2086
Scenario 3T+	1386	Scenario 3	(1167)	2553

4.19 Table 4.19 shows the differences for the HNC View. Depending on the Scenario, the T Scenario is always more expensive than its nearest comparator by between £1.7 billion and nearly £5.4 billion. Again, the difference is particularly significant in Scenario 1, because of THORP tick-over years.

TABLE 4.19 T SCENARIOS
COMPARISON OF TOTAL NET COST WITH NEAREST COMPARATOR
HNC View (£ million undiscounted)

T Scenario Net cost		Nearest Comparator Net cost		Net amount by which T is costlier
Scenario 1T	11312	Scenario 1c	5917	5395
Scenario 2T	5322	Scenario 2	3652	1670
Scenario 3T	10470	Scenario 3	7860	2610
Scenario 3T+	11329	Scenario 3	7860	3469

BNFL Long-term Strategy Options

4.20 One of the main reasons why BNFL might prefer the Scenario 2's to the scenario 1's is to "keep options open", so that if at the end of the current decade (around 2010) prospects for reprocessing and MOX utilisation move to the more optimistic end of the range, BNFL will have maintained both operating plant and expertise, and so be in a position to respond positively and rapidly.

4.21 Thus there are two possible cases with respect to "keeping options open"[7]:

- Scenario 2's are expected to have *less* net costs than Scenario 1's. In such a case there is an economic *benefit* in keeping options open, and so the economic thrust from economic and socio-economic factors would clearly be to continue operations until later in the current decade. The MADA will then inform the SFMO WG if this thrust is supported or counterbalanced by environmental factors.

- Scenario 2's have broadly *equal* net costs to Scenario 1's. In such a case, the MADA will then inform the SFMO WG if this economic equality is increased or mitigated by environmental and socio-economic factors. Even if the MADA counts against Scenario 2's, any eventual probability of high gains in Scenario 3's might still make it worthwhile to maintain the Scenario 2's.

4.22 In either case, it is necessary to obtain a greater understanding for the likelihood of various levels of profitability in the Scenario 3's. One way of improving this understanding is by performing sensitivity tests. Results of sensitivity analyses are shown in Section 6, paragraphs 6.24 to 6.39.

[7] Note that in comparing Scenario 2's with Scenario 1's, one does not necessarily compare LNC with LNC, or HNC with HNC. It is legitimate for a "BX Viewer" to compare Scenario 1 HNC with Scenario 2 LNC, and for a "GX Viewer" to compare Scenario 1 LNC with Scenario 2 HNC.

5. BX COMMENTARY

Summary

5.1 The assessment carried out by the GX has been thorough and, with respect to the process used, objective. The GX have been hampered by the unavailability of financial data, but the BX have sought to offset this by supporting the GX as far as possible in their understanding of the scenarios and their consequences. The purpose of using the GX to carry out the financial assessment was to achieve an independent result, and the BX believe that this has been achieved.

5.2 The BX believe that the reader should bear the following points in mind when interpreting the results presented in this report:

- Precision does not mean accuracy;
- The avoidable costs presented are the BNFL impact, not the "UK plc" impact;
- The assessment is one based on cashflow, and does not reflect the profitability of BNFL's business;
- The end points of the scenarios are different, leaving different scales of financial liabilities and risks to future generations.
- The analysis has been carried out to support the work of the Spent Fuel Management Options Working Group within the BNFL Stakeholder Dialogue, and BNFL has judged the level of its support to the rigour of the analysis in that context.

Introduction

5.3 The analysis presented in this report is the work of the Green Experts ("GX") appointed to support the work of the Spent Fuel Management Options Working Group ("SFMO WG") within the BNFL Stakeholder Dialogue. The BNFL Experts ("BX") have sought to support the GX as far as possible within the constraints of commercial confidentiality and the possibility of a PPP for BNFL.

5.4 Although the Technical Experts ("TX") have worked closely together to avoid gross errors of fact and to seek results and conclusions that are mutually agreed, inevitably there will be some differences in the interpretation of the results. This section presents the BXs' views on these areas of difference and also reinforces the comments and conclusions that the BX consider to be particularly significant.

5.5 The BX have assisted the GX in understanding the different scenarios that the SFMO WG have identified, in interpreting the operational consequences of those scenarios, and in assessing the scope of the costs and incomes that might result. The actual monetary figures used by the GX have not been provided by the BX nor have the BX independently confirmed the calculations that the GX have carried out. The comments that follow should not be taken to imply BNFL endorsement of the results that the GX have calculated.

<u>Precision and accuracy</u>

5.6 The BX welcome the caveat in paragraph 1.25 of this report that the precision of the numbers should not be taken to imply accuracy.

5.7 Throughout the exercise the BX have sought to help the GX in understanding the scenarios and their consequences, in accessing public domain information on costs and, where this is not available, in making estimates for costs using simple algorithms or by extrapolating from known information. As a result of this approach, and through the GX's desire to maintain rigour and an "audit trail" through their financial analysis, the reader could be mislead into thinking that the precision of the numbers presented in Appendices B and C and in Section 4 of this report reflects accuracy. It is the view of the BX that the results presented in this analysis should be considered indicative to the nearest £1Bn.

5.8 The accuracy of the numbers must be "fit for purpose", and the BX have always understood that the purpose of this analysis has been to provide a cost dimension to the SFMO WG's MADA exercise which itself contains much subjective and qualitative data (for example in the criteria of hazard, environmental impact, and risk/accident). The absence of a cost range for any of the cost components in Annex B should not be taken to mean that the BX wholly agree with the single number used, but merely that in the context of an overall accuracy of even $^{+}$/-£½Bn it was not worth the GX/BX's time to define a range.

Cashflow and profitability

5.9 The BX appreciate the importance that the GX place on highlighting that this analysis addresses cashflows, not profitability (Section 1.4). Any attempt to convert this avoidable cost analysis into a profit and loss assessment of BNFL's activities is fundamentally flawed for a number of reasons.

5.10 The assessment that has been carried out has been based on the GX's understanding of the costs of the various alternative strategies and scenarios. For commercial and legal reasons, very little information on income (past or future) can be made available to the GX.

5.11 The nuclear industry carries out complex provisioning in its accounts to allow for future costs relating to income already received. In the scenarios considered here, this particularly applies to both Magnox Generation where fuel to be reprocessed in the future has already generated electricity and revenue in past years, and to Thorp where customers have made advance payments against future reprocessing operations.

5.12 The cashflow estimates ignore certain aspects of BNFL's business at Sellafield, and the contribution that the income from these businesses makes to offsetting the cost base. These operations, although not explicitly addressed here, reduce the share of BNFL's costs that are allocated to spent fuel management operations, and hence impact on the profitability of those operations.
Investment appraisals

5.13 The remit of the TX has been to consider the costs of the various scenarios created by the SFMO WG, to allow that group to consider how the financial benefit or detriment of those scenarios might be balanced against their environmental impacts. Against that background the consideration of the business case for individual plants such as an "SMP2" is irrelevant. If the SFMO WG were to recommend that BNFL adopts a strategy which is less financially attractive that its current one, then the whole business case would fail, let alone a single plant.

5.14 Considering the role of an "SMP2" within one of the scenario 3s, it provides a key part of the overall business strategy. Without the ability to return Pu as Mox fuel, it is unlikely that BNFL would ever be able to win the volumes of business that the scenario 3s assume (against a background of a resurgence of interest in recycling). An SMP2 would be just as necessary as a WVP Line 4 (which would have no income at all and so an even worse business case if considered in isolation!).

Avoidable costs – BNFL or "UK plc" view

5.15 The assessment that has been carried out addresses the impact on BNFL of the alternative spent fuel management strategies and scenarios. Unlike the SFMO WG MADA assessment of the environmental impact of various scenarios which takes a UK view of the impact, the avoidable cost assessment is limited to the internal impact on BNFL.

5.16 By taking a "BNFL" view, the assessment ignores genuine costs to the UK of the different scenarios, such as unemployment costs, the costs of providing alternative forms of generation and the costs of reducing the UK contribution to CO_2 emissions.
The assessment also includes as a cost the profit component in the charges made to BNFL by its UK-based suppliers and contractors.

End points and future liabilities

5.17 The different strategies result in different end points for the fuel. In some cases (e.g. scenario 1a) the Magnox fuel is to be stored, leaving future generations with spent fuel to be managed and disposed of. In other cases all the fuel is reprocessed and the resultant waste is processed for storage and disposal.

5.18 The report reflects a divergence of views on the costs of carrying out BNFL's operations in the short-term. Many of these operations are carried out today and the actual costs are known within BNFL. Compared to the range in these existing costs, the uncertainty in the costs for treating and disposing of metal fuel following long term storage must be far greater. Routes are not known, safety cases have not been established and the timing of operations is extremely uncertain. Some of these issues also apply to the disposal of ILW and HLW, but BNFL and the nation are already committed to resolving them as the wastes forms already exist. However, creating new waste forms for the future creates additional liabilities.

5.19 It should also be remembered that the financial analysis does not include costs after 2030, and so incremental long term storage, treatment and disposal costs are not fully addressed (see paragraph 1.1).

Stakeholder issues and risks

5.20 In Section 1.23 a comparison is made between the stakeholder interests in the scenario 1s and the scenarios 3s. Although the scenario 3s would require more positive decisions by customers in favour of reprocessing, the scenarios 1s also require a high deal of stakeholder support. Customers would have to agree to Thorp contracts being cancelled; international stakeholders would have to support the return of plutonium powder; HMG and regulators would have to act speedily and supportively to allow alternative spent fuel management strategies to be implemented on extremely short timescales; and local authorities and the public in West Cumbria would have to support new strategies at Sellafield that would generate far fewer jobs. The BX therefore view the risks associated with aspects of the scenarios 1s to be different to those in the scenario 3s but equally significant and fundamental.

Use of LNC and HNC data

5.21 The reader should note that the Higher Net Cost (HNC) and Lower Net Cost (LNC) results assume that where the TX have agreed upon a range of cost or income uncertainty, the HNC result assumes that all the costs are at the higher end of the range and all the income is at the low end. Similarly the LNC results are based on all the low costs and high income assumptions.

5.22 These extremes of the cost ranges do not automatically reflect either a BX or GX position. For example, the early closure cases (SF1's) require some Magnox reprocessing as well as the introduction of alternative spent fuel management processes. The LNC view uses the low reprocessing cost (which might be considered to be the BX estimate) alongside the low cost for providing the new spent fuel management process (which might be considered to be the GX estimate).

Additional comments on results tables

5.23 The following comments are made on the basis of the financial results presented in Tables 4.2-.4.4 and Figures 4.2-4.4, ignoring any environmental benefits or detriments associated with the scenarios.

5.24 Scenario 2 is some £2.5Bn (View HNC, undiscounted) or even £3-3.5Bn (LNC views, undiscounted) more attractive than the early closure cases 1a, 1a~ and 1c. Even taking the extreme comparison of assuming the high costs in all cases for scenario 2, and the low costs for all the scenario 1s, the values are almost the same (given the accuracy of the numbers being used). This comparison is flawed, however, as it assumes a low cost for Magnox reprocessing and vitrification operations required in the scenario 1's and a high cost for the same operations in scenario 2. If consistent assumptions are used then scenario 2 becomes the most financially attractive.

5.25 Scenario 1a~ is more costly than scenario 1a. Dry storage of AGR fuel, even when Magnox fuel is being dry stored, is shown to be more expensive than wet storage. Only in view LNC, undiscounted, does dry storage break even with wet storage.

6. GX COMMENTARY

Introduction

6.1 This Section 6 includes the following sub-Sections:

paras 6.3 – 6.8	The GX viewpoint
paras 6.9 – 6.19	TX conclusions as in 4.23 to 4.29, adjusted for a GX perspective
paras 6.20 – 6.23	BNFL Long-term Strategy Options, Investment Appraisal and Sensitivity Testing
paras 6.24 – 6.33	Sensitivity analysis: Investment Appraisal of SMP2
paras 6.34 – 6.39	Sensitivity analysis: Investment Appraisal of Scenario 3
paras 6.40 – 6.41	GX Recommendations

6.2 Thus this Section 6 contains two types of material:

- paras 6.3 to 6.19; paras 6.40 to 6.41: material written from the GX viewpoint, which arises because it would never be possible to reconcile the GX and BX viewpoints completely;

- paras 6.20 – 6.39: sensitivity analysis and cut-off analysis as requested by the SFMO WG. This material is not written from a GX Viewpoint. Instead it is included in this Section 6 because the BX could not wholly "buy in" to its appearing in Section 4, before the reader had seen the BX caveats in Section 5.

The GX viewpoint

6.3 The GX position arises from the considerations of long-term trends in treatment of spent fuel. In world-wide terms, reprocessing is a declining technology within the "market" for spent fuel management. The dry storage of LWR spent fuel is significantly cheaper. Plutonium recycle is also not going to be economic for some considerable time to come, if at all, and so there is no plutonium recycle driver for reprocessing. These considerations are set out more fully in the GX Annex F, which reports the GX analysis of long-term costs of alternative technologies:

- long-term storage of spent fuel as the alternative to reprocessing;
- conventional LEU fuel as the alternative to MOX use in existing PWR's;
- plutonium immobilisation as the alternative to MOX use in new reactors.

6.4 Overall, only nations with a strong historical and geo-political commitment to plutonium recycle will continue to reprocess. One can list here Japan, Russia and France. Such commitment to plutonium recycle will require considerable state subsidy. In any case such commitment will not necessarily lead to market opportunities for BNFL - in France, and within 10 years in Japan, there will be competing national reprocessing and MOX production facilities.

6.5 In nations with more open competitive electricity sectors, such as the UK, the prospects for reprocessing are not encouraging. This line of thinking is supported by recent statements from British Energy, and by BE's present pressure on the UK Government to renegotiate its reprocessing contracts, which BE states are a considerable drain on its resources.

6.6 Of course, the structures of existing contracts arrangements will take time to unravel, and BNFL may continue reprocessing for several years to come. But in the opinion of the GX, there is almost no probability of new post-baseload contracts beyond existing agreements, and ideas of MOX production in the second and third decade of this century are far fetched.

6.7 Thus, the GX regard the probability of achieving the throughputs specified by the SFMO WG in the Scenario 3's as close to zero. In addition, the GX regard the probability of achieving any significant throughput in the Scenario 3's as very small indeed.

6.8 With these initial comments on the Scenario 3's in mind, it is possible to restate the TX Conclusions as set out in paragraphs 4.43 to 4.49, but from a GX perspective.

Scenario 3's

6.9 The Scenario 3's all emerge as Scenarios with vast uncertainties in net cost, within and between the LNC and HNC Views. Even if throughputs were achievable, there is a high probability of net cash outflows between £5 billion and £10 billion. In other words, there is a high probability that when the time for new investment came (major THORP refurbishment, SMP2, WVP Lines 4 and 5), BNFL would decide not to make such investment.

6.10 Investment appraisal of the incremental components of Scenario 3's confirms this. There are many combinations of reprocessing price and MOX price where returns on investment might be negative. When added to uncertainty on achievable throughputs, the probability of a negative return is very large.

6.11 Investment appraisal within a Scenario 3 context shows no case whatsoever for individual plants such as SMP2. This comes as no surprise given the economic actuality of SMP1.

6.12 The GX recommend that the SFMO WG abandon the Scenario 3's altogether, or possibly just reduce them to one, to represent a sample illustration of a very unlikely future world.

6.13 On this basis, there is no case for justifying the Scenario 2's in terms of keeping options open. Scenario 2's can only be preferred over Scenario 1's if there is a genuine expectation of net economic and socio-economic benefit from Scenario 2's alone, sufficient to outweigh any counterbalancing from environmental effects.

6.14 Again, there is significant uncertainty in Scenario 2 and Scenario 1 net costs between LNC and HNC Views, and there is a significant probability that the Scenario 2's do not bring a reduction in net cash outflows from the Scenario 1's.

6.15 BNFL's best strategy would seem to be to find the best solution for exiting from reprocessing, taking into account the trade-off between economic, environmental and socio-economic factors. Although the GX believe there is scope to renegotiate current contracts to the net advantage of all contracting parties through dry storage, the BX view is that there is a high probability that significant compensation payments might arise. Thus, the least cost solution might be one of the Scenario 1's or one of the Scenario 2's, or may prove to lie somewhere in between.

6.16 An obvious possibility is that the least cost solution might lie at the point where all existing contracts are fulfilled, but no new ones are sought. In this context the Scenario 2's total throughput of 9200 tonnes (Table 2.1) are somewhat higher than the current total "contracted", which is about 7700 tHM[8]. In addition, foreign LWR contracts are nearly all baseload[9], and will therefore finish around 2004 or 2005. MOX production in Scenario 2's is much higher than current contracts, and at a greater throughput than the BNFL "Reference Case" in the recent SMP Justification.

6.17 The "fulfill existing contracts" Scenario could be designated as Scenario 1.5, since LWR reprocessing would cease in about 2005/06, half way between the Scenario 1's and the Scenario 2's. The broad characteristics of Scenario 1.5 would be:

- existing LWR contracts are fulfilled but no new LWR reprocessing contracts are sought. Thus LWR reprocessing ceases somewhere in 2004 or 2005;
- BNFL and BE negotiate to phase out AGR reprocessing by the above time limit at the latest;

6.18 While the SFMO WG may have had sound reasons in 2000 for rejecting such "1.5 Scenarios", the results reported in Section 4 indicate strongly that such rejection should be reconsidered.

T Scenarios

6.19 In all cases, the T Scenarios (with Magnox spent fuel going through a new THORP head-end) emerge as significantly more expensive than their nearest comparators. The difference is particularly significant between Scenario 1 and Scenario 1T because of the number of years that THORP has to tick-over before the new head-end for Magnox spent fuel is commissioned. There would have to be very strong non-financial arguments for any T Scenario, if it were to overcome the cost disadvantage.

BNFL Strategy Options, Investment Appraisal and Sensitivity Testing

6.20 It is possible to use the SFMO WG assumptions and spreadsheet model to perform a conventional investment appraisal of particular subsets of the SFMO WG sector in the Scenario 3's.

6.21 The target for such an investment appraisal is that the Internal Rate of Return (IRR) of the project cash flows should be at least 8%[10], the Treasury rate for public sector projects which are competing with other companies in the private sector. A slightly harder view would be to say that since BNFL is charged by the Government with behaving as if it were in the private sector (partly in preparation for any possible PPP), then the IRR achieved by the project should be 11%.

6.22 We have already noted that probably the main driver in all such sensitivity tests and investment appraisals is the cumulative throughputs achieved for reprocessing and MOX

[8] RWMAC, *The Radioactive Waste Management Advisory Committee's Advice to Ministers on the Radioactive Waste Implications of Reprocessing*, Table 3, p20, gives 8000 tHM from 1 April 2000, from which perhaps 300 tHM in 2000/01 should be subtracted.
[9] From 1 April 2000, "contracted" LWR was 3600 tHM, of which 3200 tHM was baseload. RWMAC, as above.
[10] This is the same as saying that the Net Present Value (NPV) of the cash flow stream should be greater than zero, if all the cash flows are discounted at 8%.

production. We have also noted that it is not really possible to vary such throughputs in a systematic manner, since the throughputs and durations of all consequent activities would also need adjusting.

6.23 For such sensitivity tests and investment appraisals, the next two main drivers are long-term reprocessing price, and long-term MOX prices. Table 6.23 reviews the main assumptions documented in Annex B.

TABLE 6.23: LONG-TERM REPROCESSING AND MOX PRICES
as used in SFMO WG analyses

	Reprocessing price (£/kgHM)	**MOX price (£/kg MOX)**
Long-term "limit price" as driven by alternative technology (GX analysis: Annex F)	200	269
THORP beyond 2014/SMP2 View LNC assumption (as given in Annex B)	550	750
THORP beyond 2014/SMP2 View HNC assumption (as given in Annex B)	200	500

Investment appraisal: SMP2

6.24 An obvious candidate for a conventional investment appraisal is the new MOX Plant, SMP2, which appears in all Scenario 3's.

Restatement of throughput assumptions

6.25 The basic SFMO WG (and BNFL) assumption is as in Scenario 3. The SMP2 commences production in 2013, and produces a cumulative 1820 tonnes of MOX from 2013 to 2030, an average of just over 100 tonnes a year.

6.26 Sensitivity tests will be performed on cumulative throughputs from 500 tonnes MOX to 2000 tonnes a year, in steps of 500 tonnes a year.

Price assumptions

6.27 Sensitivity tests will be performed for annual prices from £250/kg to £1250/kg MOX, in steps of 250 £/kg MOX. Note that in practice, there will be a degree of correlation between low prices and high throughputs, and high prices and low throughputs.

Operating cost assumptions

6.28 Operating cost assumptions are set between the LNC View and the HNC View, as described in Annex B, Activities 19 and 20. In practice, this means that SMP2 operating costs are predicted to be about £30 million a year, although the precise figure depends on throughput.

Results of sensitivity analysis

6.29 Table 6.29 shows the results of a conventional investment appraisal of the IRR of the SMP2 project.

TABLE 6.29: SMP2: INTERNAL RATE OF RETURN (IRR)
Scenario 3 assumptions: but varying cumulative throughput and price

SMP Cum. throughput (t MOX)	**MOX price (£/kg MOX)**				
	250	**500**	**750**	**1000**	**1250**
500	x	x	x	x	x
1000	x	x	x	-1.4%	7.2%
1500	x	x	x	6.3%	11.5%
1820	x	x	0.9%	8.1%	12.7%
2000	x	x	2.0%	8.5%	12.9%

Other SMP parameters set mid-way between LNC and HNC values.

Target IRR: Treasury rate for public sector projects = 8%
Target IRR: Minimum commercial rate for nuclear utilities = 11%
x = the project returns are so negative that the Microsoft spreadsheet algorithm fails to compute any value at all.

6.30 From Table 6.29, it can be seen that the desired IRR of 8% or even 11% is only achievable towards the bottom right-hand corner of the Table, with a combination of high cumulative throughputs and high prices. Such combinations are not very probable. Over most plausible combinations, the IRR is not only less than 8%, but is often negative, in other words it makes negative returns. In combinations marked “x” – more than half Table 6.29 - the project returns are so negative that the Microsoft spreadsheet algorithm fails to compute any value at all.

6.31 The values shown in bold are the cells which correspond most closely to the LNC and HNC Views for Scenario 3:

- [Throughput 1820: price = £750/kg] = Scenario 3 View LNC; The IRR is only 0.9% compared with the desired 8%. To put the result another way, the Net Present Value (NPV) at 8% discount rate is *minus* £186 million.

- [Throughput 1820: price = £500/kg] = Scenario 3 View HNC; the returns are so negative that it is not possible to compute an IRR. To put the result another way, the Net Present Value (NPV) at 8% discount rate is *minus* £374 million.

6.32 On the above basis, SMP2 would not go ahead. Of course, the decision on whether or not to commence the investment does not have to be taken until about 2008. By that time BNFL will have a far clearer idea as to what combination of throughput and prices might be expected. But it is apparent, looking from the year 2001, that there appears to be small probability of ultimate acceptable returns. This means that there is little or no apparent value in “keeping options open” so as to facilitate later possible activation of SMP2.

6.33 The above results are entirely consistent with current data for SMP1. BNFL 2001 Report and Accounts show a "carrying value" for SMP1 of £473 million[11]. It is not disputed that, over its entire lifetime, SMP1 will have been a loss-making investment. The maximum Net Present Value (NPV) from future cash flows is estimated by ADL at £199 million[12]. Even with permission to operate, an immediate write-off in the Balance Sheet – "or impairment" - of at least £274 million will be required to reflect the fact that this NPV of future cash flows is less than the carrying value of £473 million. Further write-downs may be necessary, if any of ADL's "Downside Risks" occur.

Investment Appraisal of Scenario 3 compared with Scenario 2

6.34 A more complex sensitivity analysis can be framed around an *incremental* investment appraisal. This is a standard exercise in investment appraisal, in which the series of total cash flows associated with Option A are subtracted from the total cash flows associated with Option B. The resultant series of *incremental* cash flows can themselves be subjected to conventional IRR and NPV analysis, where the project being analysed is the set of investments represented by Option B, compared with the reference Option A.

6.35 In this case, Option A is Scenario 2, and Option B is Scenario 3. We wish to appraise the set of investments represented by Option B, compared with the reference Option A.

6.36 Over all activities, Scenario 2 involves no new capital expenditure, and refurbishment expenditure of £950 million. Scenario 3 involves new capital expenditure of £1000 million, and refurbishment expenditure of £1775 million, a total of £2775 million. Thus the incremental expenditure from Scenario 2 to Scenario 3 is £1875 million. The task is to analyse the returns on this incremental investment of £1875 million.

6.37 Table 6.37 shows the results of the incremental cash flow analysis for [Scenario 3 minus Scenario 2], for varying reprocessing prices and MOX prices.

TABLE 6.37: SCENARIO 3 minus SCENARIO 2
INTERNAL RATE OF RETURN (IRR%)
of INCREMENTAL CASH FLOW ANALYSIS

Reprocessing price (t/kg HM)	MOX price (£/kg MOX)				
	250	500	750	1000	1250
200	x	x	x	x	x
400	x	x	x	x	x
600	x	x	10.0	17.2	23.8
800	14.9	20.2	25.3	30.6	36.4
1000	26.2	30.5	35.0	39.9	45.4

[11] BNFL ARA 2001, p59.
[12] Arthur D Little, *Assessment of BNFL's Business Case for the Sellafield MOX Plant*, July 2001, p3.

All other activities at HNC View assumptions.

Target IRR: Treasury rate for public sector projects = 8%
Target IRR: Minimum commercial rate for nuclear utilities = 11%
x = the project returns are so negative that the Microsoft spreadsheet algorithm fails to compute any value at all.

Interpretation of Table 6.37

6.38 Table 6.37 confirms that there are possible combinations of throughputs, reprocessing price, and MOX price, in which the returns from moving from Scenario 2 to Scenario 3 would be acceptable.

6.39 However, when looked at in the context of the prices shown in Table 4.26 above, it will be seen that the probability of such combinations might be small. This is particularly so given the comments made above: that it has been necessary to stick to the Scenario throughputs as specified by the SFMO WG, and it has not been possible to perform sensitivity analysis on throughputs. The risk of negative returns attached to the investments in Scenario 3 is significant.

GX recommendations

6.40 Ideally, the SFMO WG would initiate one further round of analysis, perhaps comparing Scenario 1, with a suitably defined Scenario 1.5, and Scenario 2. The balancing of costs, environmental factors, and socio-economic factors for three such Scenarios would represent a significant input to BNFL's decision-making process. The spreadsheet model and MADA methodologies are now sufficiently well rehearsed that such a final exercise would not be difficult to carry through. Obviously, time and budgets may be a limitation.

6.41 If such an exercise were undertaken, the SFMO WG might also consider the following:

- include Post-operational Clean-out (POCO) and decommissioning costs for all activities;
- extend the cost boundary beyond 2030, which is an artificial and unnecessary current constraint;
- ask that BNFL reconsider its decision, so that the TX have access to the ERM cost data. If the present situation is allowed to persist, it would seem that the credibility of the SFMO WG Project would be undermined.

Appendix 15

SFMO WG: ANALYSIS OF NET COSTS IN CONJUNCTION WITH MADA SCORES

Introduction

This note takes the MADA scores and the two weight profiles generated at the April 2001 workshop and assesses scenarios in the light of cost estimates finalised following the May workshop. The principal mode of analysis is through "Efficiency Frontiers", which identify scenarios that, relative to others, offer either high overall performance estimates (Existing aggregate MADA scores)[1], or low costs, or some combination of the two.

The data

The basic data used in the analysis is as follows:

MADA scores

Scenario	Environmental Profile - Profile 1	Socio-economic Profile - Profile 2
SF1a	0.560	0.333
SF1c	0.812	0.416
SF1T	0.626	0.473
SF2	0.421	0.535
SF2T	0.437	0.579
SF3	0.366	0.615
SF3T	0.358	0.615
SF3T+	0.276	0.692

Undiscounted costs

These costs are in £ millions. They are net costs; in other words, they incorporate estimates of revenue flows to BNFL where appropriate. No discount factor has been applied. The negative cost for SF3 under the lower cost estimate therefore represents a net revenue. For the cost calculations, one extra scenario was assessed, SF1a~. Since there are no MADA scores assessed for this scenario, it has not been included in the present analysis. The basis for the lower and upper net cost calculations is set out in the June 2001 paper prepared by the Costing team.

[1] "Existing" emphasises that, if weight profiles, for example, were to change, then the aggregate MADA scores would change also.

Scenario	Lower Net Cost	Higher Net Cost
SF1a	3271	5796
SF1c	3467	5412
SF1T	5754	8896
SF2	484	3924
SF2T	1204	4859
SF3	-1376	7754
SF3T	401	9898
SF3T+	546	10383

Analysis

Efficiency frontier diagrams were prepared separately for each of the two weight profiles and for upper and lower cost assessments, a total of four ‘preferred world views’, each with a corresponding efficiency frontier. These are reproduced in the Appendix.

Review of individual efficiency frontiers

Each efficiency frontier highlights those alternatives that are most promising in terms of having low net cost and high performance, the latter as assessed through the aggregate MADA score. It is possible to show mathematically that, in any one diagram and taking the numbers purely at face value, only scenarios that lie on an efficiency frontier are candidates for the most preferred choice. Seeking low cost and high performance means that the efficiency frontier will lie towards the bottom right-hand corner of each diagram.

Points on the frontier can be viewed as representing increasing net cost and increasing performance as one moves from left to right along the frontier. All scenarios on the frontier are in a sense “efficient” and the choice to be made is between low cost/low performance at the left-hand extremity through to progressively higher levels of both cost and performance for each step to the right along the frontier.

There are MADA procedures that would allow a ranking to be made among all points lying on a single efficiency frontier, but this is probably not a fruitful direction to follow here, where there are four separate frontiers, each with a claim to legitimacy.

Review of efficiency frontiers as a group

It is probably more helpful at this stage simply to tabulate which scenarios are on the efficiency frontier in each of the four preferred world views and which scenarios are explicitly dominated[2] by one or more of the other scenarios (and hence probably not serious competitors).

It is important to stress that it is unlikely that any clean and clear single preference for a particular scenario will emerge from such an analysis. The substantial differences in weight profiles and cost assessments almost guarantees this.

World view	Lies on the Efficiency Frontier	Dominated
E/U/L	SF1c, SF3	SF3T+, SF3T, SF1T
S/U/L	SF3T+, SF3	SF1a, SF1c, SF1T, SF2, SF2T, SF3T
E/U/H	SF1c, SF2	SF1a, SF1T, SF3, SF3T, SF3T+
S/U/H	SF3T+, SF2T, SF2	SF1a, SF1T, SF1c

The MADA exercise was based on two profiles – one environmentally biased, the other favouring the socio-economic aspects of each scenario. The cost data against which the outcomes of the MADA were tested for sensitivity were likewise based on two views:
Low Net Costs – where the most favourable market and financial conditions are assumed
High Net Costs – where these conditions are assumed to be least favourable

Thus the outcomes of the sensitivity testing are based on two ‘preferred world views’ and two sets of costs assumptions. While the analysis of the costs, carried out in SFMO WG sessions mitigated against the T variants due to the relative high costs and time considerations required for a new Thorp head end construction, some survived the cost sensitivity test but only by applying the most favourable MADA profile and cost assumptions.

From this table, it might be tentatively concluded that scenarios SF1c, SF2, SF2T, SF3 and SF3T+ are the more promising contenders, whereas SF1a, SF1T and SF3T look to be less attractive. Note that this assessment does *not* address questions such as the flexibility of scenarios (e.g., opportunities for mitigation) or

[2] i.e., both higher in cost and lower in performance

of the uncertainty surrounding cost assessments, and so should be seen simply as a crude tool to provide one way of focusing the next stages in the overall consultation on scenarios.

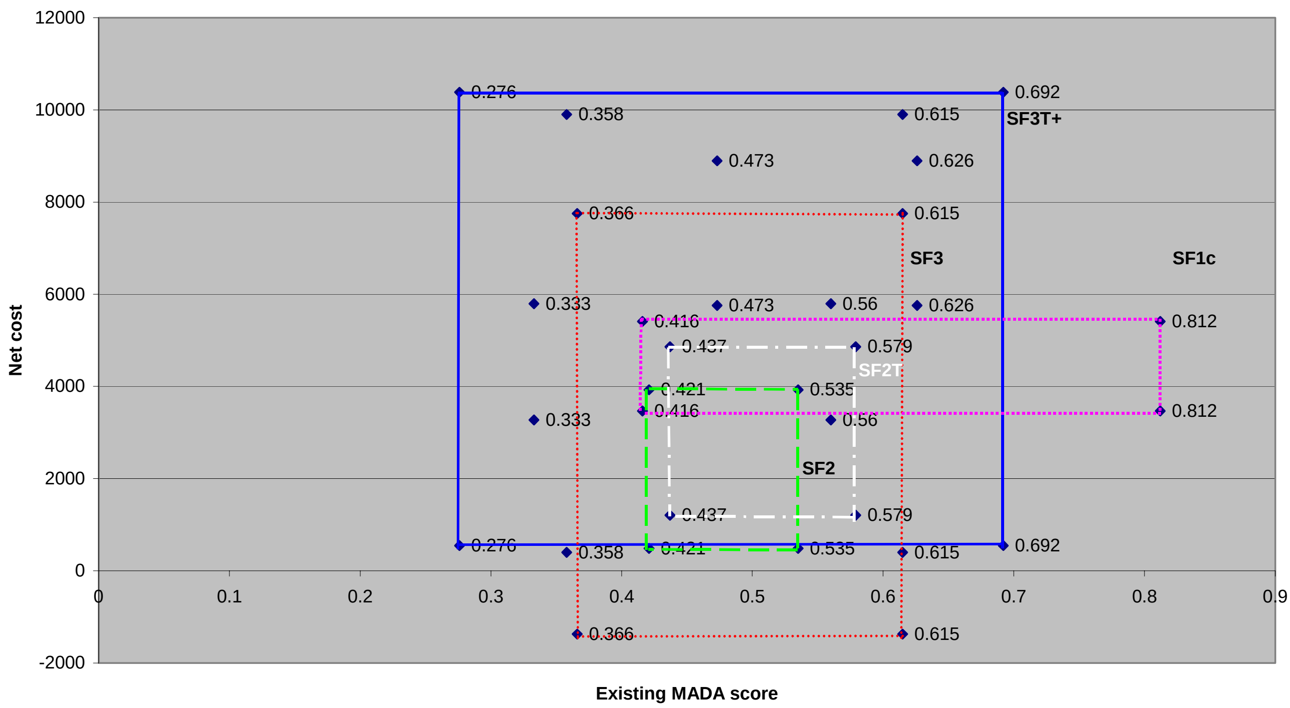
The following diagram sets out each of the four sets of four combinations of cost (upper, lower) and MADA score (environmental, socio-economic) using *undiscounted*[3] costs. Further, to help focus concern on the five more "promising" scenarios, boxes have been drawn to identify the range of assessments associated with each.

In consciously *non-rigorous* terms, what this diagram suggests is that:

- SF1c, SF3 and SF3T+ have the clearest potential to be low net cost, high performance options, but they are the options where the biggest difference of viewpoint exists as to how good their performance can be assessed to be (boxes with big horizontal dimensions)
- SF3 options have very substantial "cost uncertainty"[4]
- SF2 and SF2T have a potentially attractive combination of less divergence in view about performance and relatively narrowly defined cost profiles

[3] Note that there is, in fact, little difference between the *relative* costs of scenarios if discounted, rather than undiscounted, costs are used. For simplicity, only undiscounted cost results are reported here.
[4] It is *particularly* important to appreciate that the costs used throughout this paper are *not* simple upper and lower bounds on cost estimates. Thus the vertical dimension of each box should only be seen as suggestive of uncertainty in a very broad and ill-defined sense.

All undiscounted cost combinations



Thoughts about ways ahead

Creating the set of four efficiency frontiers has added an important new dimension to thinking about the scenarios. It has not “solved” the problem, but it does provide a helpful way of focusing on ways to move ahead. An important consideration in this regard, of course, is the time-scale that is envisaged for the Dialogue as a whole.

(1) There is currently no consensus on performance or costs, or approach to consensus, that looks likely to identify a single preferred case from among the existing scenarios.

(2) One way ahead, which may be especially important in the immediate future, is to seek agreed short-term actions, building on the Strategic Action Planning discussed at the May meeting.

(3) In a similar vein, it may also be appropriate to consider compromise scenarios, or scenarios that explicitly seek to explore mitigation of effects viewed negatively under one or other of the weight profiles. This latter could be either a short-term or a longer-term action.

(4) At some stage, it will be important to understand as fully as possible the uncertainties surrounding the net costs of key scenarios. It is arguable that properly understanding the degree of risk associated with the costings and exploring any links between risks that influence costs and risks that influence MADA scores needs more work.[5] Because some aspects are commercially sensitive, this may not be straightforward.

(5) It would be feasible to explore quite quickly some new scenarios or variations on existing ones in the way that the eight have been analysed in this paper. In the case of new scenarios, a basis for agreeing performance scores would be necessary, however.

(6) If a longer-term continuation of the National Stakeholder Dialogue is agreed, then it could be helpful to repeat the MADA/Efficiency frontier analysis, with any new scenarios and/or more considered assessments of existing scenarios.

(7) Further sensitivity testing could be helpful. In the short term, this might address simply the discount rate question (i.e., variations from the presently used, but not presented, 2.5% figure). In the longer term, it could look more fully at sensitivities in MADA scores, but this can be quite detailed work and is best applied to a smaller number of alternative scenarios that may be beginning to emerge as preferred.

Alan Pearman
January 2002.

[5] For example, if commercial or political considerations lead to lower demand levels for reprocessing services and hence higher net costs on some scenarios, will these same factors also alter some of the impacts of these scenarios, as reflected in the presently assessed MADA scores?

Appendix 16

Record of Documents Circulated to SFMO WG

Circulation Date	Title	Provided By
21/02/00	BNFL National Stakeholder Dialogue Groundrules - 5th Draft	The Environment Council
21/02/00	Working Group Draft Terms of Reference, Spent Fuel Management Options - 1st Draft	The Environment Council
21/02/00	BNFL National Stakeholder Dialogue Groundrules. Attachment. Selection Criteria for Working Groups - 4th Draft	The Environment Council
31/03/00	SFMO WG terms of reference - 2nd draft	The Environment Council
06/04/00	BNFL National Stakeholder Dialogue Groundrules - 6th Draft	The Environment Council
06/04/00	List of Cricklewood Documents	The Environment Council
06/04/00	The Cricklewood Dialogue Process	The Environment Council
25/04/00	Lifting the lid on the Mox box	Pete Roche, Greenpeace
25/04/00	Assessment of CEGB/SSEB reports	Pete Roche, Greenpeace
08/05/00	The management of spent oxide fuel; the environmental and radiological effects of alternative approaches	Pete Wilkinson, WECL
11/05/00	The CEGB/SSEB response to recommendations 17 and 18 in the Environment Committee's report on radioactive waste - An Overview	Patrick van den Bulck, CND
01/06/00	HSE Policy and Strategy on Decommissioning and Radioactive Waste Management at licensed nuclear sites	Hugh Richards, WANA
15/06/00	Proposed Closure Dates (for accounting purposes) for British Energy power stations	Tony Free, BE
15/06/00	Station lifetimes	Tony Free, BE
19/06/00	Long-Term Storage of Spent Nuclear Fuel. Work carried out for the Nuclear Waste Management Division Department of the Environment. Associated Nuclear Services Report No. 206 (June 1980)	Pete Roche, Greenpeace
05/07/00	Suspension of Magnox Reprocessing	Martin Forwood, CORE
05/07/00	Packaging, storage and direct disposal of spent AGR fuel	Martin Forwood, CORE
05/07/00	Technical aspects of spent fuel storage - influence on store design and operation	Martin Forwood, CORE

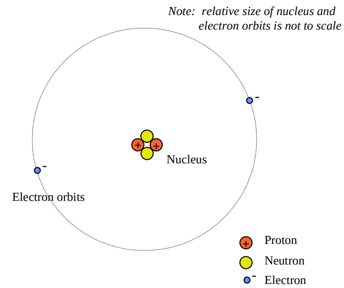
Circulation Date	Title	Provided By
05/07/00	The role of the modular vault dry store in a spent fuel management programme	Martin Forwood, CORE
05/07/00	Success for the NUHOMS dry store	Martin Forwood, CORE
05/07/00	Examining the benefits of dry storage	Martin Forwood, CORE
05/07/00	AGR Fuel Dry Buffer Store - a brief technical description	Martin Forwood, CORE
05/07/00	The Economics of Spent Fuel Dry Storage (Paper for CORE Dry Store conference, Lancaster 30/6/00)	Martin Forwood, CORE
05/07/00	Radiological Effects of Dry Storage of Spent Nuclear Fuel (paper for Core Dry Store Conference, Lancaster) 30/6/00	Martin Forwood, CORE
05/07/00	Core Dry Store Conference, Lancaster 30/6/00 - Lothian Regional Council's repose to the Scottish Nuclear Ltd proposal for dry storage of irradiated fuel at Torness Power Station	Martin Forwood, CORE
11/07/00	BNFL and Kansai Electric Power Company Agree Way Forward - press notice	Grace McGlynn, BNFL
17/07/00	BNFL: National Stakeholder Dialogue groundrules 8th Draft	The Environment Council
06/10/00	West Cumbria Socio-economic Study, Inception Report: Work in Progress, ERM Economics (September 2000)	ERM
09/10/00	Multi Attribute Decision Analysis (MADA), Presentation, Alan Pearman, Centre for Decision Research, University of Leeds	Alan Pearman, Centre for Decision Research, University of Leeds
17/10/00	Summary of the derivation of radiation dose limits and the impact of BNFL's activities – update 2000. D Jackson, K Charles, B Lambers, Westlakes Scientific Consulting (19 June 2000)	Grace McGlynn, BNFL
11/12/00	Radiation dose (and related concepts)	Steve Jones
02/01/01	Scenario Benefits and Detriments - Ranges of Views (App 9 to SFMO report)	Gregg Butler, Westlakes Institute
15/01/01	A regulatory view of the long term passively safe storage of radioactive waste in the uk	HSE Nuclear Installations Inspectorate
12/02/01	HSE enforces waste reductions at Sellafield - HSE press notice	Peter Addison
13/02/01	Study on Economic prospects for nuclear (excerpts)	Gregg Butler, Westlakes Institute

Circulation Date	Title	Provided By
19/02/01	Media response - Magrox - BNFL press notice	BNFL
07/03/01	NOP Solutions market research report on Sellafield	Pete Wilkinson, WECL
29/03/01	BNFL welcomes progress on Sellafield Mox Plant Regulatory Process - press notice	Grace McGlynn, BNFL
03/04/01	SFMO WG photo report of meeting of 14-16 March 2001	The Environment Council
25/04/01	Control of low-level radiation exposure: time for a change	Grace McGlynn, BNFL
25/04/01	In defence of collective dose	Grace McGlynn, BNFL
25/04/01	Editorial: Collective Dose: kill or cure?	Grace McGlynn, BNFL
25/04/01	Letter to the Editor and reply: Comment on 'Collective dose: kill or cure?'	Grace McGlynn, BNFL
30/04/01	Management of radioactive materials and radioactive waste on nuclear licensed sites	Peter Addison, NII
30/04/01	Guidance for inspectors on Decommissioning on nuclear licensed sites	Peter Addison, NII
11/05/01	Strategic Planning (draft)	Allen Hickling
05/07/01	Thorp: the case for contract renegotiation	Mike Sadnicki, Fred Barker, Gordon MacKerron
02/10/01	Michael Meacher announces new review of radiation risk models	The Environment Council

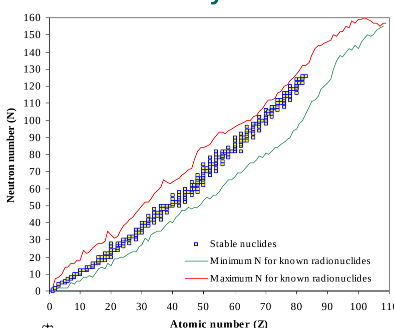
Radiation dose
(and related concepts)

Steve Jones

Nuclear structure



Stability of nuclides



$$^{A}_{Z}X_{N}$$

For example:

$^{12}_{6}C_{6}$ $^{14}_{6}C_{8}$

Or more usually:

^{12}C ^{14}C

Radioactive decay modes

Beta decay: $n \equiv p + e^-$ (beta decay); $p + e^- \equiv n$ (electron capture)

For example: $^{14}_{6}C_8 \rightarrow {}^{14}_{7}N_7 + e^-$

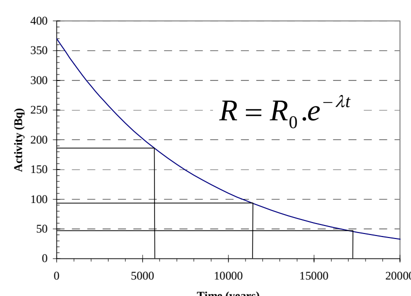
Gamma ray emission: $^{137}_{55}Cs_{82} \rightarrow {}^{137m}_{56}Ba_{82} + e^-$; $^{137m}_{56}Ba_{82} \rightarrow {}^{137}_{56}Ba_{82} + \gamma$

Alpha decay: $^{210}_{84}Po_{126} \rightarrow {}^{206}_{82}Pb_{124} + {}^{4}_{2}He_{2}\,(\alpha)$

Penetrating power of radiation types

- Gamma radiation
  - » Very penetrating
  - » Requires a metre or more of soft tissue for significant absorption
- Beta radiation
  - » Moderately penetrating
  - » Wholly absorbed within a few mm to a cm of soft tissue (depends on energy)
- Alpha radiation
  - » Weakly penetrating
  - » Wholly absorbed by <0.1 mm of soft tissue

Radioactive halflife
Example: ^{14}C

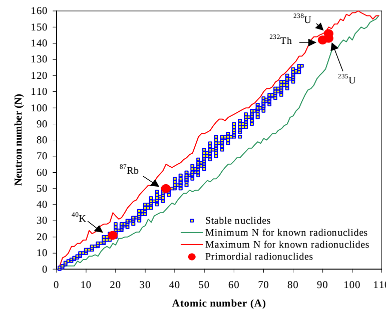


$$R = R_0 . e^{-\lambda t}$$

Naturally occurring radionuclides
Primordial

Nuclide	Symbol	Half-life (y)	Main decay mode	Daughter(s)	Abundance (Bq kg^{-1} in crust)
Potassium-40	^{40}K	1.3×10^{9}	β,γ	^{40}Ca (stable)	850
Rubidium-87	^{87}Rb	4.8×10^{10}	β	^{87}Sr (stable)	70
Thorium-232	^{232}Th	1.4×10^{10}	α	^{228}Ra (active)	44
Uranium-235	^{235}U	7.0×10^{8}	α	^{231}Th (active)	1.7
Uranium-238	^{238}U	4.5×10^{9}	α	^{234}Th (active)	36

Disposition of primordial radionuclides relative to stable nuclides



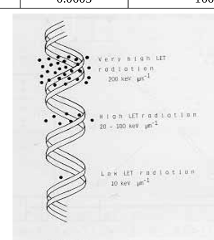
Important anthropogenic ('artificial') radionuclides

Radionuclide	Symbol	Type / origin	Decay mode	Halflife
Tritium (Hydrogen 3)	^{3}H	Ternary fission product	Beta	12.4 years
Carbon 14	^{14}C	Activation product	Beta	5730 years
Argon 41	^{41}Ar	Activation product	Beta-gamma	1.83 hours
Sulphur 35	^{35}S	Activation product	Beta	87.4 days
Cobalt 60	^{60}Co	Activation product	Beta-gamma	5.27 years
Krypton 85	^{85}Kr	Fission product	Beta	10.7 years
Strontium 90	^{90}Sr	Fission product	Beta	29.1 years
Yttrium 90	^{90}Y	^{90}Sr daughter	Beta	2.67 days
Zirconium 95	^{95}Zr	Fission product	Beta-gamma	64.0 days
Niobium 95	^{95}Nb	Fission product*.	Beta-gamma	35.2 days
Technetium 99	^{99}Tc	Fission product	Beta	211,300 years
Ruthenium 106	^{106}Ru	Fission product	Beta	1.02 years
Rhodium 106	^{106}Rh	^{106}Ru daughter	Beta-gamma	29.9 seconds
Iodine 129	^{129}I	Fission product	Beta	15.7 million years
Iodine 131	^{131}I	Fission product	Beta-gamma	8.04 days
Caesium 134	^{134}Cs	Fission product	Beta-gamma	2.06 years
Caesium 137	^{137}Cs	Fission product	Beta	30.2 years
Barium 137m	^{137m}Ba	^{137}Cs daughter	Gamma	2.6 minutes
Cerium 144	^{144}Ce	Fission product	Beta-gamma	284 days
Praseodymium 144	^{144}Pr	^{144}Ce daughter	Beta-gamma	17.3 minutes
Plutonium 238	^{238}Pu	Transuranic	Alpha	87.7 years
Plutonium 239	^{239}Pu	Transuranic	Alpha	24,100 years
Plutonium 240	^{240}Pu	Transuranic	Alpha	6,540 years
Plutonium 241	^{241}Pu	Transuranic	Beta	14.4 years
Americium 241	^{241}Am	Transuranic *	Alpha	432 years

Interaction of radiation with tissue

Radiation type	Typical energy (keV)	Range in water (cm)	Linear energy transfer (keV µm^{-1})
Gamma	100 - 1000	5 - 10	0.2 - 0.5
Beta	100 - 1000	0.2 - 0.5	2 - 3
Alpha	1000 - 7000	0.0005	100

$$H_2O \rightarrow H_2O^+ + e^-$$
$$H_2O + e^- \rightarrow H_2O^-$$
$$H_2O^+ \rightarrow H^+ + OH^\bullet$$
$$H_2O^- \rightarrow H^\bullet + OH^-$$



Absorbed Dose

- Absorbed dose (Grays) = Energy deposited (Joules per kg)
- Only small amounts of deposited energy from ionising radiation are required to produce biological harm - because of the means by which energy is deposited (ionisation and free radical formation)
- For example - drinking a cup of hot coffee transfers about 700 Joules of heat energy per kg to the body.
- To transfer the same amount of energy from ionising radiation would involve a dose of 700 Gy - but doses in the order of 1 Gy are fatal.

Acute effects of radiation exposure

- *'I started in to make a number of these lamps but I soon found that the X-ray had affected poisonously my assistant, Mr. Dally, so that his hair came out and his flesh began to ulcerate. I then concluded that it would not do, and that it would not be a very popular kind of light; so I dropped it.'*
  - » *Thomas Edison, on attempts to make fluorescent light devices involving X-ray tubes*
- Effects of acute radiation exposure on rodents

Dose to whole body (Gy)	Approximate time of death after irradiation	Mode of death
>100	Minutes to 48 hours	Central nervous system syndrome
10-100	3-5 days	Gastrointestinal system syndrome
2-10	10-30 days	Bone marrow syndrome

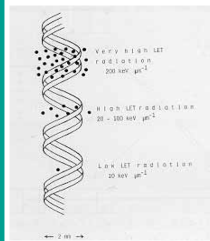
- Effects which occur only above a given threshold of dose are said to be *non-stochastic* or *deterministic*

Late effects and effects of prolonged low dose exposure *(stochastic effects)*

- Ionising radiation can produce sub-lethal cellular effects - particularly, damage to DNA either by free radical attack or direct ionisation 'hits' on DNA itself
- Such effects can lead to cancer or transmissible genetic defects - but rather than their being a 'threshold' dose below which no effect occurs (or above which an effect is certain), the probability of the effect increases with dose
- These effects are termed *stochastic* and are the health effects of main concern in assessing low dose exposure to ionising radiation

Equivalent dose

- Effectiveness of ionising radiation in inducing stochastic effects depends on linear energy transfer:



- Equivalent dose = absorbed dose x radiation weighting factor (w_r)
- Units of equivalent dose are Sieverts (Sv)
- For gamma radiation and beta radiation the recommended value of w_r is 1;
- For alpha radiation the recommended value of w_r is 20.

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Risk of stochastic effects following exposure - sources of epidemiological data

- Survivors of the Hiroshima and Nagasaki A-bomb attacks (cohort of 50,000 followed since 1947)
- Patients treated for ankylosing spondylitis by irradiation of the spine(cohort of 14,000 followed for up to 48 years)
- A number of other radiotherapy cohorts (including patients treated with radium and thorium)
- Uranium and iron ore miners exposed to radon and thoron

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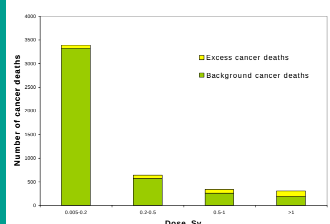
Hiroshima and Nagasaki cohort



- **50,000 in cohort**
- **Average dose about 0.25 Sv**
- **Half still alive**
- **90% of exposed children still alive**

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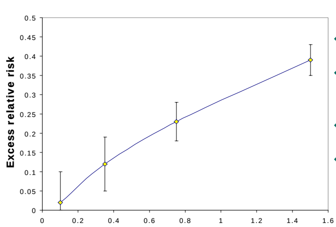
Hiroshima and Nagasaki cohort



- **50,000 in cohort**
- **Average dose about 0.25 Sv**
- **Half still alive**
- **90% of exposed children still alive**

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Sensitivities of different organs to radiation induced cancer (ICRP Publication 60)

Organ	Risk of fatal cancer following a radiation dose of 1 Sv, delivered at a low dose rate
Bladder	3×10^{-3}
Bone marrow	5×10^{-3}
Bone surface	5×10^{-4}
Breast	2×10^{-3}
Colon	8.5×10^{-3}
Liver	1.5×10^{-3}
Lung	8.5×10^{-3}
Oesophagus	3×10^{-3}
Ovary	1×10^{-3}
Skin	2×10^{-4}
Stomach	1.1×10^{-2}
Thyroid	8×10^{-4}
Remainder	5×10^{-3}
All cancers	5×10^{-2}

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Effective dose

$$Absorbed\ dose = \frac{\Delta E_t}{\Delta m_t}$$

$$Equivalent\ dose\ (D_t) = \frac{\Delta E_t}{\Delta m_t} \times w_r$$

$$Effective\ \ dose\ (H) = \sum_t (D_t \times w_t)$$

- *The effective dose is the sum of the equivalent doses in all individual irradiated organs, each organ dose being multiplied by an organ weighting factor (w_t) which reflects the sensitivity of that organ to radiation induced cancer.*
- *The unit of effective dose is the Sievert (Sv).*
- *The risk of fatal radiation induced cancer is directly proportional to the effective dose received (0.05 per Sv).*

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Tissue weighting factors currently recommended by ICRP

Organ or tissue	w_t
Gonads	0.20
Red bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05
Sum of weights	1.00

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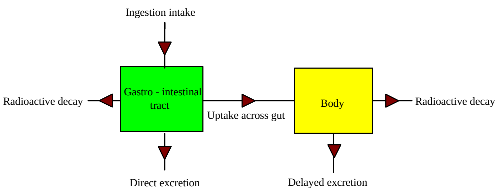
Committed effective dose

- Committed effective dose is used to express the dose resulting from intakes of radionuclides into the body - taking account of the distribution and retention of radionuclides in different organs



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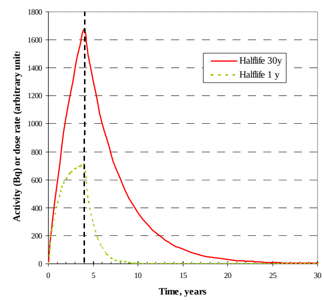
Committed effective dose



- The committed effective dose is the total effective dose received over a defined period (say, for 50 years, or up to age 70) as a result of the intake of radioactivity

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Summary of dose quantities

- The *absorbed dose* is simply the energy absorbed per unit mass of tissue; 1 Gray is 1 joule of energy per kilogram.
- The *equivalent dose* is the absorbed dose modified by a *radiation weighting factor* which depends on the type of radiation involved, and its degree of harmfulness.
- The *effective dose* is the sum of equivalent doses to all the organs in the body, each modified by a *tissue weighting factor* reflecting the sensitivity of the organ to radiation induced cancers.
- The *committed effective dose* is the total effective dose received over a period of time after intake of radionuclides into the body, allowing for the distribution of radionuclides between organs and subsequent retention.
- When doses due to radioactivity in the environment are quoted as millisieverts per year, that usually means *the effective dose received from external sources during the year plus the committed effective dose from radionuclide intakes which have occurred during the year* - but since that's quite a mouthful, the term 'dose' is generally used.

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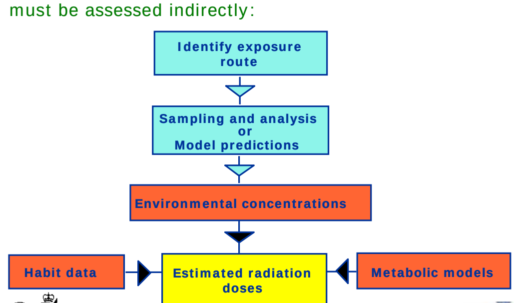
Assessment of dose

- Committed effective dose *cannot be directly measured.* It must be assessed indirectly:



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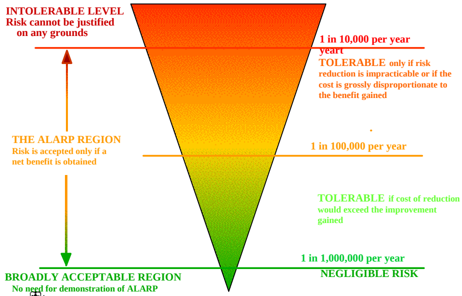
The Tolerability Of Risk (TOR) framework



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Collective dose

- Collective dose is the *total committed effective dose* incurred by a *defined population* within a *specified period of time* as a result of a *specific practice*
- Examples: The collective dose received by all staff employed at Sellafield over a given period; the collective dose which will be received by the population of the European Union over the next 500 years as a consequence of discharges to the environment from Sellafield this year; etc.
- If the risk from radiation dose is linearly proportional to dose at very low doses, collective dose presents a measure of the total health detriment associated with radiation exposure.

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Issues with interpretation of collective dose

- The affected population and the integration time must always be defined - and different choices can give very different values for collective dose.
- In many cases much of the collective dose is incurred at very low individual doses - well below the 'negligible' individual risk of 10^{-6} per year - is it right simply to add up large numbers of very low risks?

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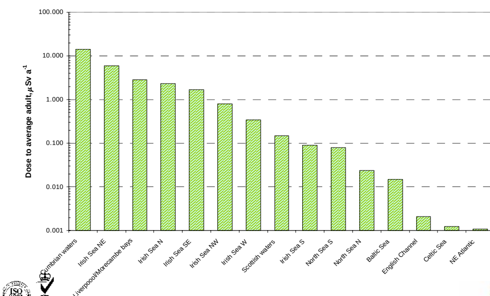
Indicative individual doses to seafood consumers in different regions - future Sellafield liquid discharges

Peak doses from discharge scenarios developed by the Discharges Working Group



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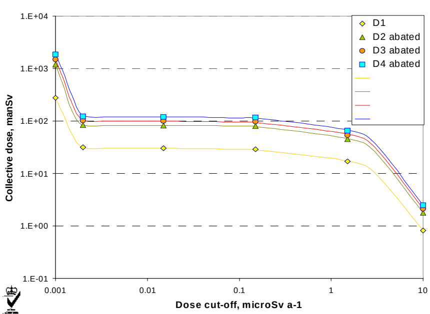
Collective doses from Sellafield liquid discharges - with varying values of 'cut-off' for individual dose

Total collective doses from discharges to 2030, using discharge scenarios developed by the Discharges Working Group



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Radiation dose isn't the only detriment.......

- Chemical emissions
- Accident risks - radiological and non radiological
- Resource usage - raw materials, water, energy
- Land use and visual impact
- Impacts of associated transport infrastructure
- Volume and nature of wastes produced
- Direct and indirect effects on wildlife habitats

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