Large and ASSOCIATES

ADEQUACY OF THE SIZEWELL A FUEL ELEMENT DEBRIS CONSULTATION DOCUMENTATION AND INFORMATION

CLIENT: SHUTDOWN SIZEWELL CAMPAIGN - REF N^{O} R3093-A1

SUMMARY

This is a review of the adequacy of the information provided to the Shut Down Sizewell Campaign (SDSC) prior to its participation as a consultee in the fuel element debris (FED) consultation process. The objective of the consultation is to select the best practicable environmental option (BPEO) for the future management and/or disposal of the FED arisings held at Sizewell A Magnox power station.

The *options* for managing the radioactive FED waste stream are presented in advance of the consultation meeting in the form of an *issues* paper. The final 4 *options* short listed by Magnox South essentially converge to the two variants of i) dissolution of the FED as a radioactive effluent for discharge to the marine environment, and ii) encapsulation of the FED for retention on site in the interim and, possibly, longer terms as radioactive waste. The *issues* paper presents these *options* to be well understood, tried and proven, low risk technologies that have operated successfully or are being planned for at other decommissioned Magnox power stations.

However, there is fact and evidence that shows Magnox South (and its predecessors) have encountered not inconsiderable difficulties in the management of FED: For example, the Dungeness dissolution plant experienced considerable start-up and nuclear safety case difficulties in the 1990s and is now running much beyond its original target 5 year programme to clear all of the Dungeness FED; the encapsulation campaign at Trawsfynydd has been delayed because of the need to deal with irradiated fuel fragments discovered mixed in with the FED; and the projections for the planned FED schemes at Bradwell and Sizewell reveal quite startling differences in public dose and employee dose exposure, especially when compared to the actuality of FED operations at Dungeness and Trawsfynydd. Yet, none of these difficulties experienced with the dissolution and encapsulation *options* are presented in the *issues* paper which, instead, gives an impression of trouble-free operations at Dungeness and Trawsfynydd, where both dissolution and encapsulation operations are described as *'technically mature'*. On risk to the public, the *issues* paper states that radiation exposure will be entirely negligible or, at the most, equivalent to no more than that received during a 5 second aircraft flight at altitude of 30,000ft; the most significant risk of untoward incident arises not, as it is reasonable to presuppose in these troubled times, from terrorist attack but from accidents involving the additional lorries needed to ship in non-nuclear building materials to construct the on-site ILW store if the encapsulation *option 3* is proceeded with; and there is no mention of the strong incentive for the Nuclear Decommissioning Authority (NDA) to implement the dissolution process with the radioactive discharge *option* prior to the 2020 OSPAR agreement that is to outlaw any further radioactive discharges to the marine environment from existing nuclear sites such as Sizewell A.

Setting aside that the *issues* paper entirely excludes any reference to the difficulties that Magnox South has experienced with its FED programmes elsewhere, the purpose of the *issues* (and other) documentation is to adequately prepare consultees for them to meaningfully and intelligently contribute to the consultation, so does it achieve this purpose?

Originally, in advance of the consultation meeting, consultees were provided with a generic paper supposedly sufficient to prepare consultees for the *issues* to be rated in the consultation meeting. Generally dissatisfied with the content of the generic paper, SDSC instructed Large & Associates to advise it of the adequacy of the generic paper for which Large & Associates sought further information from Magnox South and the Nuclear Decommissioning Authority (NDA), although even when made a month in advance this request could not be satisfied by the NDA within Magnox South's own deadlines for SDSC to respond. Thereafter, Magnox South provided consultees with a new 36 page *issues* paper but leaving only a very limited time (just one or two days in some instances) for consultees to read through, understand and comment upon the much greater Sizewell specific detail contained therein. Because of these difficulties the consultation meeting, originally scheduled for 27 September, has been put back to late-October.

The short period of consultation for feedback originally ventured was too short with SDSC only able to grasp, if at all in a meaningful way, just a part of the information required to understand the FED process and its management options. Moreover, the information provided in the original *issues* paper and documentation was not at all sufficiently comprehensive nor Sizewell FED specific, being in certain respects misleading and when further information was sought for this review on the basis of its inadequacy, the response was at the best uncooperative and, perhaps, obstructive. The subsequently released *issues* paper (which became the main subject of this review) contains much detail, but this is presented clumsily, being beset with nuclear jargon, inappropriate similes, findings that are presented subjectively (*good, marginal*, *significant*, etc) without much factual substantiation, an incomplete range of FED management *options* (just 4 in total) and with key *attributes* that are omitted or entirely disregarded (no *company risk*, *terrorist threat*, *sustainability*, *justification*, etc). Moreover, by not encouraging consultees to explore the full range of viable solutions MS has leapfrogged the stage of carrying out a full and searching consultation on the substantive issue which is how the future management of the FED wastes is to be undertaken.

Thus the process towards the FED consultation and its BPEO decision-making has been not at all clear, transparent and fair with the supporting documentation not providing full information on all of the FED alternatives, costs, safety and other issues that would enable consultees to provide meaningful inputs not just for BPEO, but also on justification and sustainability issues. Put another way, the findings of this review are that the information provided by Magnox South and the NDA was not sufficient, nor was there enough time to enable consultees to make an intelligent response on the issues of principle and detail of FED management

Finally, the review has endeavoured to examine all of the *attributes* as set down seriatim in the *issues* paper. Restraint on time and resource has limited the examination so that not all of the *attributes* have been covered in detail, although much the same findings would apply to these.

JOHN H LARGE
LARGE & ASSOCIATES
CONSULTING ENGINEERS, LONDON

1ST ISSUE	REVISION NO	APPROVED	CURRENT ISSUE DATE
5 OCTOBER 2007	R3093-A1-2		**6 OCTOBER 2007**

ADEQUACY OF THE SIZEWELL A FUEL ELEMENT DEBRIS CONSULTATION DOCUMENTATION AND INFORMATION

INTRODUCTION

For the purposes of this review, the main focus of concern of the Shut Down Sizewell Campaign (SDSC) is on the unsolved problem of radioactive waste management and how this is to be safely and acceptably managed in the immediate, interim and longer terms. The specific radioactive waste stream subject to this consultation exercise is the fuel element debris (FED) radioactive waste that has accumulated during much of the operational lifetime of the now shut down Sizewell A Magnox nuclear power station.

Here the documentation made available to SDSC in its role as consultee prior to the consultation meeting is reviewed for its adequacy.[1]

Although acutely aware of the broader issues involved in the staged decommissioning of a nuclear power plant, the SDSC and/or its individual members should not be considered 'expert' in the pertinent regulatory and technical issues of the decommissioning process overall nor, particularly, in the means of managing the FED radioactive waste. This being so, it is assumed that the amount of regulatory-technical information that could be realistically presented to and understood by the consultees will be very limited during the single day set aside for the consultation meeting (originally scheduled for 27 September), so the adequacy and clarity of the information circulated prior to the consultation meeting is vital to enable the consultees to make a meaningful and intelligent contribution to the FED consultation.[2]

A) CONSULTATION PROCESS

The consultation process is outlined in the Magnox South (MS) *Sizewell A FED Management Assessment*.[3,4]

On the conduct and presentation of consultation processes, the yardstick specified in the government's *2002 Consultation Document*[5] is that

> *" . . the consultation process should be as open and inclusive as possible . . . ".*

It follows, that openness and inclusivity are the salient principles that should equally apply to the Sizewell FED consultation process.

The aim of the FED consultation is to determine a first preference for the best practical environmental option (BPEO).[6]

---

1 At the time of Large & Associates instruction to undertake this review (20 August 2007), the Shutdown Sizewell Campaign had received the *issues* paper (Footnote 15) which was clearly insufficient for a full and meaningful involvement of lay consultees in the consultation process. Following a Freedom of Information Act request to the Nuclear Decommissioning Authority, and not without some difficulty and delay, further documents has been made available to the consultees – it is this later information provided by Magnox South that is reviewed here. The FoI request was not fully responded to within the 20 working days prescribed by the Act and, upon Appeal (Ref N° L02Oct01Large), the NDA found that its contractor (Magnox South) had failed in a number of respects.

2 The United Kingdom Government is a signatory to the *Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters* (Aarhus Convention). This convention requires to the extent appropriate, that there shall be opportunities for public participation in the preparation of policies etc., relating to the environment and that this consultation process must be carried out properly. To be proper, consultation must be undertaken at a time when proposals are still at a formative stage; it must include sufficient reasons for particular proposals to allow those consulted to give intelligent consideration and an intelligent response; adequate time must be given for this purpose; and the product of consultation must be conscientiously taken into account when the ultimate decision is taken.

3 In these footnotes references that have not been made available, or requested for this Review, are highlighted thus.

4 It is assumed that this shortened paper title relates to the paper entitled in the text to be the *Assessment of Short-Listed Options for the Management of Fuel Element Debris at Sizewell A Site, Magnox South* for which a separate title page is provided in the document bundle – it is not at all clear why this document carries a separate title page which is undated.

5 *Energy Policy — Key Issues for Consultation (2002 Consultation Document),* HMG of which S2 identifies the *"main themes for consultation"*

6 The Environmental Protection Act 1990 (EPA90) requires the regulatory body (originally HM Inspectorate of Pollution (HMIP), later to become the Environment Agency (EA) in England and Wales, and the Scottish Environment Protection Agency (SEPA)) to have regard to BPEO in setting conditions on Authorisations. In 1996 the regulator defined the BPEO as

Recommendation:

1) It is not that clear from the *issues* paper that the driving objective of the FED consultation is to determine the BPEO management solution[7] so i) consultees might benefit from an introductory explanation of BPEO, ALARP, etc., prior to the consultation process; and, similarly, it is unclear how the outcome of the consultation meeting is to be conscientiously taken into account when the ultimate decision is taken so ii) this should be explained to consultees.

2) A previous BPEO study has been undertaken for FED management at Sizewell A (along with Oldbury, Hinkley Point and Bradwell)[8] which, together with a strategy and updating papers,[9,10,11,12] should be made available to consultees for information.

3) Consultees should be made aware that in 2001 Magnox Generation (now MS) stated that *'the dissolution option should be maintained as the preferred option for management of all of the FED wastes at Dungeness A and as the fallback option for the remaining sites'*.

MULTI-ATTRIBUTE UTILITY ANALYSIS

Essentially, MS propose to centre the consultation on a *multi-attribute utility analysis* (MAUA).[13]

In application the MS approach relies upon four main stages: *attribute* selection, for which 22 supposedly key *attributes* of waste management have been pre-selected by earlier MS work;[14] *attribute* rating, in which a quantitative assessment is made of the relative importance of each of the *attributes*; *option* evaluation, in which consultees are required to score each *attribute* against each of four *options* of how the FED might be best managed; and it seems that there will be a rounding off session for which each consultee will be asked to *weigh* each of the *attributes* to enable a sensitivity analysis to be completed following the consultation. Those consultees new to the subject (ie the likes of the SDSC, Women's Institute, etc) will need to refer to the information or *issues* papers[4,15] that have been prepared by MS and made available to consultees.

MAUA is quite extensively used in engineering applications, such a material selection problems, where there is certainty regarding the values assigned to each *attribute* for each *option*. Where there is uncertainty or inconsistency with the values of the *attributes*, that is between unweighted *attributes*, unreliability might arise unless it is possible to develop a distribution of *attribute* levels in terms of probabilities of occurrence.

". . . the option which, for a given objective, provides the most benefit or least damage to the environment as a whole, at acceptable cost, in the long term as well as the short term as a result of releases of substances from an IPC process".

7 The concept of *Best Practicable* (sometimes *Practical*) *Environmental Option* (BPEO) was first introduced in 1976 by the Royal Commission on Environmental Pollution (RCEP). Cautioning that removal of pollution from air could result in increased pollution of land and water, the RCEP advocated an *"optimum combination of available methods of disposal so as to limit damage to the environment [as a whole] to the greatest extent achievable for a reasonable and acceptable ... cost]"*. The RCEP's 12th Report (1988) proposed a formal definition and procedure for BPEO, as *"the outcome of a systematic and consultative decision-making procedure …. the option that provides the most benefit and the least damage to the environment [across air, water and land] as a whole, at acceptable cost, in the long term as well as in the short term"*. BPEO was included in Part 1 of the Environmental Protection Act 1990 as a basis for the authorisation of processes under the Integrated Pollution Control (IPC) regime. A useful introduction to BPEO is *BPEO – Decision Maker's Guide*, Department of the Environment, Environment & Heritage Service, undated c2000, http://www.ehsni.gov.uk/ni_bpeo_guidance.pdf - this recommends a much simplified approach to the multi-attribute value analysis (MAUA) that it is assumed will be deployed for the FED consultation, but see later.

8 *Best Practicable Environmental Option for Management of Fuel Element Debris at Bradwell, Hinkley Point A, Oldbury and Sizewell A*, M Chandler, (TE/GEN/REP/0153/96), July 1997

9 *Strategy for the Management of Fuel Element Debris as Bradwell, Hinkley Point A, Oldbury and Sizewell A Power Stations*, S C Hall et al, (RDU/S&A/GEN/REP/0037/00), April 2001.

10 *Updated Review of Options for Management of FED at Sizewell A*, M T Yeung, M J Wilding, LS/SZA/REP/0001/05 Issue 2, August 2005

11 *The effect of (1) unavailability of Drigg disposal (2) Nirex proposed opening date 2040 (3) Varying discount rate on the BPEO for Management of FED at Bradwell, Hinkley point A, Oldbury and Sizewell A Power Stations*, M A Pearce, M/TE/GEN/EAN/0047/98, June 1998

12 *Nirex Assessment Report, Magnox Fuel Element Debris at Sizewell A Decommissioning Site (Conceptual)*, N Carr, NXA/498741, May 2006

13 Sometimes referred to as and/or confused with MADA (Multi Attribute Decision Analysis).

14 *Fuel Element Debris Disposition Technical Optioneering Report* MES/EST/BNA/REP/0009/07, Issue 1, March 2007 – British Nuclear Group.

15 *Arrangements for the Development of Waste Management and Decommissioning Strategies for Magnox Reactor Sites*, British Nuclear Group, RS/E&TS/MI/004, May 2006

For the FED MAUA, MS's *options* are quite diverse, and it may not be possible to entirely resolve the weighting or probabilistic distribution across the *attributes* for some of the more speculative topics (ie the possibility of inclusion of fuel particles, etc), certain aspects of the technology to be adopted may be unproven (the extent if any of dissolution of the nimonic springs, the spiders, element thermocouples, etc), and important end-points of the process may yet to be determined (the final means of disposal of the packaged wastes). A significant weakness of MAUA is the approach inability to exclude subjectivity in the *attribute* rating, particularly where a number of the consultees are lay and/or have only recently been introduced to the detail of the subject matter, or who might come to the MAUA consultation with a predetermined stance.

MAUA as practised in engineering and science applications can be a sophisticated process that involves complex mathematical and probabilistic means to yield reliable and robust results. On the other hand, sometimes the MAUA process is undertaken in the absence of scientific rigour and, in this form, it has attracted criticism and charges that the outcome is highly relativist rather than being drawn from a science or fact basis.[16]

Recommendation:

4) Consultees would benefit from further explanation of the MAUA process, perhaps running through a straightforward illustrative example prior to their engagement in the FED process, together with an outline of the rigour of analysis that is to be adopted by the facilitator in the post-meeting processing of the FED consultation inputs.

5) The independence of the MAUA facilitator should be established, particularly if NNC is to provide this service noting that its holding parent is the construction company AMEC which has a strong commercial interest in nuclear decommissioning works.

OPTIONS

Four *Options*[17] are listed in the MS *issues* paper but there is no description of a greater number of possible FED management solutions previously considered by MS and, particularly, how the MS short list of *options* has been determined. In this respect, consultees are being presented with a short list of pre-ordained solutions or *options*, the selection of which they have not been involved with or, indeed, have no detailed knowledge of.

In other words, a stage of the decision making process has been denied to consultees. This stage might have included *'do nothing'*, *'delay and decay'* and other strategies[18] for managing the FED. Moreover, the absence of encouraging consultees to explore the full range of viable solutions leapfrogs the stage of carrying out a full and searching consultation on the substantive issue which is how the future management of the FED wastes is to be undertaken and not, as proposed by MS, with the consultees being limited to choosing from a short listed *options* range predetermined by MS, one of which is clearly preferred by MS (*option 1* – dissolution).

Recommendation:

6) The *issues* paper should have included, at least, i) a listing of all of the *options* considered by MS prior to the 4 *option* short list being settled, and ii) the methodology of how the range of solutions had been reduced to the *options* short list should have been explained.

7) Consultees might wish to explore the *'do nothing'* FED management option, particularly with reference to the OSPAR agreement requiring a reduction of discharges by 2020.[see 23]

---

16 Large J H, *Carry On at CoRWM - Critical Review of the Deliberations of the Committee on Radioactive Waste Management*, Nuclear Engineering International, April 2005, http://www.largeassociates.com/CoRWM%20Review.pdf

17 In effect, the 4 options converge to 2, these being *dissolution* to off-site and *waste encapsulation* remaining on site.

18 It is not the role of this review to identify other possible strategies or *options* but, that said, these might 1) include transport FED away for dissolution at Dungeness, similarly 2) transport away for encapsulation elsewhere, 3) continued vault storage; 4) on site high temperature treatment; 5) recycling; 6) export abroad, and there are a number of abatement technologies, such as crystallisation and precipitation, and so on.

8) Consultees might wish to consider if the *'operational restraints'* referred to in the *issues* paper (p2) leading to the cessation of desplittering at Sizewell in or about 1994 had any material bearing on the final short listed *options*.

9) The *issues* paper (p26) refers to the *'regulators nor the NDA's favoured option'* so it might be useful for the consultees to be informed of this *'favoured option'*.

ATTRIBUTES

MS has also pre-ordained 22 relevant *attributes* to be rated and which, collectively, will rank the preferences of the *options*.

Certain *attributes* might be determined by good practice, for example minimisation of environmental impact, limitation of radiation dose, etc., but some *attributes* might be strongly influenced by MS's own company *objective* and *principles*[19] and, quite separately, by the directives of the nuclear safety and security regulators, the Nuclear Installations Inspectorate (NII)[20] and the Office of Civil Nuclear Security (OCNS) respectively, and there are government policy directives relating to radioactive wastes.[21]

Recommendation: 10) For and prior to the stage of the process at which consultees are expected to agree the *attributes* list, the consultees should have reference to MS's *objectives and principles*, the NII regulatory requirements, and government policy directives for radioactive waste.[21,22]

11) An *attribute* covering *company* or *corporate risk* should be included in the MAUA.

The 1998 OSPAR[23] convention includes international agreement that radioactive discharges will be reduced by 2020. The discharges are to be reduced to levels where additional concentrations of radionuclides in the marine environment are to be close to zero which will require, for processes like the proposed FED dissolution and discharge option, a need to use abatement technology to contain rather than continue with the practice of dilute and disperse (as at Dungeness – see later). In other words, the implementation and restrictions of OSPAR in the years leading to 2020 may be a strong incentive to MS to bring forward any discharging waste treatment process, such as the FED dissolution *option* at Sizewell, so as not to have it outlawed if it was to be delayed into the next decade.

Recommendation: 12) It will also be necessary to make consultees aware of any discharge (both marine and atmospheric) authorisations that may be required, depending on the particular *option* and the time and (radio)activity limitations imposed by international treaty, such as OSPAR and/or local classifications such as RAMSAR (Wetlands Convention), along with progress on the Environmental Impact Assessment for the site and the final *option*.[24]

13) The existing nominated *attributes* do not include for a number of important issue, for example i) malevolent acts (terrorist, sabotage, etc), ii) extension of the overall operating time for the FED management process at the Sizewell site, iii)

---

19 *Arrangements for the Development of Waste Management and Decommissioning Strategies for Magnox Reactor Sites*, RS/E&TS/MI004, British Nuclear Group, May 2006

20 *Guidance to Inspectors on Decommissioning on Nuclear Sites*, HSE Nuclear Safety Directorate, March 2001

21 *The Decommissioning of the UK Nuclear Industry's Facilities*, Government Policy Statement, 2004

22 It may also be necessary to refer to a number of the recommendations of the Committee on Radioactive Waste Management (CoRWM).

23 OSPAR – the Oslo and Paris Commissions, ie Ospar Convention for the Protection of the Marine Environment of the North-East Atlantic – see also the *Sintra Declaration* – the OSPAR agreement requires a reduction in radioactive discharges to be achieved by 2020 which might be a strong reason that MS is considering the dissolution option now rather than to delay and have its discharges outlawed by OSPAR.

24 The EIADR99 Regulations require an Environmental Impact Assessment (EIA) to be carried out by the licensee before NII considers granting consent for a dismantling or decommissioning project for a nuclear reactor or nuclear power station to commence. NII must ensure that an adequate EIA is carried out. This it does by consulting relevant bodies and the public on an Environmental Statement (ES) provided by the licensee (MS) wit the EIA also be subject to a consultation process. *The Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999* also apply the final FED process

storage of processed products in the longer term, and iv) the justification and sustainability of the process and its outcome.[25]

Some would consider that far too many *attributes* have been nominated for the MAUA to be effective, especially when the time constraints of a single afternoon for the scoring is considered. For example, *options* x *attributes* require (4 x 22=) 88 ratings or scores graduated 1 to 10 to be made in a few hours, which may be particularly testing for the lay consultees.[26] In terms of mathematically mapping,[27] the reliability of the overall result in probabilities of occurrence will be extremely difficult to determine, particularly so where individual consultees may be required to make a choice or rate an attribute under uncertainty.[28] The MS list of *attributes* needs to be reviewed with certain *attributes* being defined as *binary*, that is those that do not require the exactness of numerical rating that a quantitative MAUA requires to obtain a robust choice result – in this respect, limiting the number of *primary attributes* to six for four *options* will be more suited to the time allocated for the FED MAUA process.

Calculations	Option 1	Option 2	Option 3	Option 4
1.1 Public Dose	0.003 µSv /yr	~ 0 µSv /yr	~ 0 µSv /yr	~ 0 µSv /yr
1.2 Operator Dose	13 mSv	18 mSv	31.6 mSv	36 mSv
1.3 Radiological Safety (Accident conditions)	Marginal	Marginal	Marginal	Marginal
1.4 Conventional Safety	Negligible	Marginal	Marginal	Marginal
1.5 Transport Safety	Negligible	Marginal	Significant	Marginal
2.1Hazard Reduction	Good	Good	Moderate	Good
2.2 Long Term Impacts	Negligible	Marginal	Marginal	Negligible
2.3 Decommissioning	Moderate	Poor	Good	Good
3.1 Primary Radioactive Waste Volume	16 Packages	49 Packages	112 Pack's	15 Packages
3.2 Secondary Radioactive Waste	2 HHISOs	3 HHISOs	2 HHISOs	2 HHISOs
3.3 Radioactive Discharges	Moderate	Good	Good	Good
3.4 Non-radiological discharges	127.000 m^3	254.000 m3	81.400 m^3	0 m^3
3.5 Transport	20	54	78	34
3.6 Resource Usage	Moderate	Poor	Moderate	Moderate
3.7 Nuisances	Negligible	Negligible	Negligible	Marginal
4.1 Technical Maturity	Good	Poor	Good	Good
4.2 Technical Reliability	Good	Moderate	Good	Good
4.3 Timescale (Implementation / Processing)	Moderate	Poor	Good	Good
4.4 Interface with Site Operations	Good	Moderate	Moderate	Moderate
4.5 Disposability	Good	Good	Good	Moderate
5.1 Capital Costs	£8.7M	£25M	£33.6M	£13.3M
5.2 Stakeholder Acceptability	Moderate	Good	Good	Good

SUMMARY TABLE OF MS *ISSUES* PAPER (p36)

Recommendation

14) The MS list of *attributes* needs to be reviewed with certain *attributes* being defined as *binary*, that is those that do not require the extensive assessment that a quantitative MAUA requires to obtain a robust choice result – in this respect, limiting the number of *primary attributes* to six for four *options* will be more suited to the time allocated for the FED MAUA process.

B) ADEQUACY OF ATTRIBUTE INFORMATION

MS identifies the *attributes* in PART I of the *issues* paper.[4] PARTS 4, 5, 6 and 7 address each of the four *options* and a summary of MS's analysis is given on p36 of the *issues* paper.

Setting aside the *attributes* that are described in terms of numerical values (eg *Public Dose*, *Operator Dose*, etc), the summary table (above right) allocates several of the *attributes* with subjective or judgmental entries (eg *Decommissioning* rated as *Moderate*, *Poor*, *Good* etc).

These entries derive from sections of the *issues* paper entitled *'BPEO Supporting Information'* but which tends to be somewhat opinionated, particularly when comparing *Option 2* to *Option 1*, and *Option 4* to *Option 3*. These judgements and ratings could, effectively, pre-empt the rating made by the consultees during and as a result of the FED consultation process.

---

25 For sustainability requirements for example see *White Paper on Radioactive Waste Management* (Cm2919)

26 Difficulties of consultees in tackling and scoring, etc., on complex problems new to themselves are given in *Cognitive Modeling of Consultation Processes: A Means for Improving Consultees' Problem Definition Skills*, Cleven C, et al, J School Psychology, v26 n4 Win 1988

27 Here it is assumed that the Facilitator will process a mathematical outcome of the FED consultation process although, that said, the description of the sensitivity analysis of consultation inputs (Step 6) suggests a somewhat rudimentary if not superficial sensitivity analysis.

28 For the mathematically minded, the outcome or utility value *U* this can be quantified in terms of a probability distribution describing the likelihood of achieving the entire spectrum of attribute levels for each material. Integrating the product of the utility at a given point and its probability over the entire range of values of the attribute yields a corrected single attribute utility value:

$$U(i) = \int U(x)p(x)dx$$

where $U(i)$ = the utility of attribute i

$U(x)$ = the utility of level x of attribute i

$p(x)$ = the probability density function

Recommendation 15) Consultees should be cautioned about prejudging the *attribute* rating by reference to certain of the entries of the MS *issues* paper, although note the caveat in PART 3 of the *issues* paper.[29]

Notwithstanding that the rating of the attributes in the *issues* paper might be best disregarded by consultees, the risk and performance criteria are expressed by MS in subjective terms, viz

> *" . . .These risks are rated using a risk sensitivity level, being:*
>
> - *Negligible*
> - *Marginal*
> - *Significant*
> - *Critical*
> - *Crisis*
>
> *Similarly, for the performance of an option for an attribute, these have been ranked using:*
>
> - *Poor*
> - *Moderate*
> - *Good . . ."*

For risk and hazard assessment the nuclear industry adopts a numeric system of the acceptability of event occurrence (failure, success, etc) in terms of probability so, on this basis alone, the subjectivity of *significant, critical* etc., is difficult to gauge and not at all akin the numeric basis of assessment in the risk and hazard adopted, nor are such compatible with the NII Safety Assessment Principles (SAPs).[30]

Recommendation 16) If the *issues* paper *attribute* ratings (ie *Negligible*, *Marginal* etc) are to be relied upon then further explanation and definition should be provided to the consultees.

Now referring to the *attributes* listed in the issues paper – the MS issues paper text is shown *italicised* and the tabulated entry is taken from the MS summary table (above right):

1. General Safety

1.1 Public Dose *– is the collective dose and the dose to the critical group arising from operations relating to each option. This includes exposure due to discharges and waste disposal.*

CALCULATIONS	OPTION 1 DISSOLUTION WITH DISCHARGES	OPTION 2 DISSOLUTION ZERO DISCHARGE	OPTION 3 SOLID ILW	OPTION 4 SOLID ILW/LLW
Public Dose	*0.003 μSv /yr*	*~ 0 μSv /yr*	*~ 0 μSv /yr*	*~ 0 μSv /yr*

The *issues* paper projects an annual radiation dose of *0.003 μSv/yr* for *Option 1* assuming that the total activity of all of the dissolved FED that passes through the sand bed filter will be discharged to the Sizewell marine environment over a 5 year period. Moreover, the *issues* paper compares the hypothetical maximum authorised discharges of Sizewell A and the not that dissimilar Magnox reactors at Dungeness A in Kent, claiming that the radiological impact and resulting critical group dose (ie public dose) at Sizewell for about the same level of overall discharges is about one-sixth of that at Dungeness.[31] Although the claimed favourable comparison between the Sizewell and Dungeness Magnox plants is of interest, its usefulness peters out in the *issues* paper, with no further reference being made to it.[32]

---

29 The 1st paragraph of Part 3 of the issues paper states *"This assessment is the view of the author of this paper and are (sic) meant to act as a guide as to how each option performs and are not intended to preclude or reduce discussion and arrival at independent stakeholder views. These will be discussed at the Optioneering Review to allow consensus to be reached for each option and attribute"* – which as a caveat is all very well, but there remains the risk that these leading ratings of the *attribute* could unduly influence the consultees..

30 *Safety Assessment Principles for Nuclear Facilities*, 2006 Edition, HSE, 2006

31 The one-sixth claim is not substantiated in the *issues* paper.

32 Other than the sand filter bed efficiency for the Dungeness dissolution plant is adopted for the Sizewell calculation.

In fact in 1986 prior to first operation of the Dungeness A FED dissolution plant, the discharges from FED dissolution operation for Dungeness A[33] were then projected to give rise to an annual radiation dose of 1.34 μSv/yr.[34] Using this projected dose the adjusted[35] equivalent Sizewell FED dose is 0.05 μSv/yr for each year of a 5 year FED campaign period, that is about x16 higher than the *issue* paper dose at 0.003 μSv/yr. Another study, applied to Bradwell Magnox nuclear power station indicated a maximum FED dissolution dose of ~30 μSv/yr and the range of doses from a study applied to Bradwell[36] where *Cases 1a*, *1c* and *2a* are much the same as the *issues* paper *options* 1, 2 and 3:

Table 2: Summary of Estimated Public Doses

		1a. Dissolution at Bradwell;	1b. Transportation and Dissolution at Dungeness A;	1c. Dissolution at Bradwell Using Zero Liquid Discharge Option	2a. Prompt Encapsulation on-site, manage as ILW for disposal	2b. Prompt Encapsulation off-site, manage as ILW for disposal	3a. Containerisation and Encapsulation (Bradwell)	3b. Containerisation And Deferred Dissolution Using Zero Liquid Discharge Option
Off Site Dose (Public)	Waste Processing (Discharge)	~30 μSv/yr 0.015 man-Sv	<1.0 μSv/yr based on Dungeness A figures	<1.0 μSv/yr	<1.0 μSv/yr	<1.0 μSv/yr	<1.0 μSv/yr	<1.0 μSv/yr
Off Site Dose (Public) Revised estimate (Ref. 56)	Waste Processing (Discharge)	~0.9 μSv/yr 0.0005 man-Sv						

Another interesting outcome is the comparison of the Dungeness FED dissolution plant as projected prior to operation in 1986 to the actual operational discharges, as presented in TABLE 6 of the *issues* paper. This comparison of FED discharges is about 0.08 TBq/year projected to 0.113 TBq/year actual so, it might be reasoned, that a similar increase in actual FED discharges over that predicted might occur at Sizewell with a corresponding increase in the critical group dose.[37]

Recommendation

17) None of the four *options* seem to give account to the gaseous discharges of tritium and C^{14} that are likely to arise in the FED handling and processing for all options, albeit in different amounts.

18) Rather than make a comparison with a commercial aircraft flight (ie the claimed dose equivalence of 5 seconds at 30,000 ft), the consultees might prefer to consider the proportion that the FED discharges represent to i) other decommissioning discharges and ii) to the Sizewell site overall[38] - the comparison

33 *Predictions of the Radioactive Discharges from the Dungeness A Magnox Dissolution Plant*, PED/MAT/(86)13, CEGB, September 1986.

34 *Assessment of the Radiological Impact of the Proposed Magnox Dissolution Plant at Dungeness A Power Station*, CD/PE-NW/0009, CEGB, October 1986

35 To compare this Dungeness dose to that projected in the *issues* paper for Sizewell requires an adjustment in account of the total differences in the amount of FED about 60t compared 135t, and number of years allocated to the overall FED campaign, 3 compared to 5 years at Dungeness and Sizewell respectively so, it follows, if the five-fifths reduction is adopted, the critical group individual dose at Sizewell should not exceed 0.35 μSv/yr for each year of a 5 year FED campaign period - even by this rule of thumb approximation, this is a significantly higher critical group dose than the 0.003 μSv/yr of the *issues* paper. A major factor determining difference is that for the Dungeness FED about 0.08TBq (excluding tritium and C^{14}) is discharged past the sand filter (SPF) per year compared to 0.011 TBq/year projected for Sizewell, although if this is factored in the Sizewell critical dose projection is still about x16 higher than the *issue* paper dose at 0.05 μSv/yr.

36 *Best Practicable Environmental Option (BPEO) Study for the Management of Magnox FED at Bradwell Nuclear Power Station*, Nuclear Technologies, NT/P434/R194/Issue 1, September 2006

37 That said, it is not the purpose of this review to check either the accuracy or applicability of the information provided in the *issues* paper and, indeed, in the comparisons drawn between the early Dungeness papers[footnote 33,34] there may have occurred significant changes, modifications, etc to render the comparison void.

38 At Dungeness the FED discharges represented about one-half again of the routine radioactive discharges from the Dungeness A Magnox station when operational.

of FED dissolution discharges to normal discharges over the entire site (penultimate para p19 *issues* paper) at a rate of 2% is at odds with the projections given for Dungeness FED.

19) There is some confusion about the applicability of the *issues* paper 0.003 µSv/yr public dose for Sizewell A, particularly when compared to similar projections for Dungeness A, Bradwell[39] and an earlier analysis for Sizewell A,[40] with the *issues* paper critical group dose for the FED dissolution process being uncharacteristically low at 0.003 µSv/yr.

20) It would assist the comparison between the different Magnox stations if the FED tonnage, public critical groups and dominant dose uptake paths for each location is provided to the consultees.

21) It would be useful for the consultees to know if the dose predictions of *options 1* and *2* include for any additional campaign to deal with the Magnox lugs (if stored separately at Sizewell as at Dungeness).

22) It would be useful if consultees were able to compare the monetary worth per man-Sv for the 4 *options* examined applied to operator collective dose.

1.2 Operator Dose *– is the dose received by workers for all operations relating to each option; for example, the doses associated with processing, transport and disposal.*

CALCULATIONS	OPTION 1 DISSOLUTION WITH DISCHARGES	OPTION 2 DISSOLUTION ZERO DISCHARGE	OPTION 3 SOLID ILW	OPTION 4 SOLID ILW/LLW
Operator Dose	*13 mSv /yr*	*~ 18 mSv /yr*	*~ 31.6 mSv /yr*	*~ 36 mSv /yr*

However, the operator doses projected for the Sizewell FED *options* are considerably higher than those predicted by Bradwell study:

Table 1: Summary of Estimated Operator Doses – Total Collective Dose per Annum (man-mSv/year)

		1a. Dissolution at Bradwell;	1b. Transportation and Dissolution at Dungeness A;	1c. Dissolution at Bradwell Using Zero Liquid Discharge Option	2a. Prompt Encapsulation on-site, manage as ILW for disposal	2b. Prompt Encapsulation off-site, manage as ILW for disposal	3a. Containerisation and Encapsulation (Bradwell)	3b. Containerisation And Deferred Dissolution Using Zero Liquid Discharge Option
On-Site Dose (Operator)	Waste Processing	~2.0	~2.0	~2.0	~10.0	~10.0	~10.0	~10.0
	Movements	-	~12.0	-	~12.0	~24.0	~12.0	~12.0
	Transport	-	~0.25	-	-	2.0	-	
Total (man-mSv/year)		~2.0	~14.0	~2.0	~22.0	~36.0	~17.0	~17.0

As before, where *Cases 1a*, *1c* and *2a* are much the same as the *issues* paper *options 1*, *2* and *3* and at Bradwell about 155 tonnes of FED await management compared to up to 170 tonnes of FED at Sizewell.

[39] Zero Liquid Discharge Magnox Dissolution Process, Option Study Datapack, TR/892217/003, NUKEM January 2007

[40] *Assessment of public doses arising from discharges from a Magnox dissolution plant at Sizewell 'A' Power station*, JM Chandler, November 1996, TE/MAG/REP/0030/96 Issue 2

Recommendation

23) Explanation of the reasons for the differences in the operator doses for different Magnox power stations might be helpful to the consultees

24) A copy of the MS paper *Technical Specification for a Fuel Element Debris Retrieval and Processing Facility*[41] might assist the understanding of the consultees as to why these significant operator dose differences arise from station to station.

A potential source of increasing the operator dose is exposure to undesirable radioactive components in the FED during handling from the silos and sorting for all four *options* and, if these components were to pass through to the dissolution process of *options 1* and *2* higher dose rates of the dissolved liquor.

Handling doses have been taken into account for exposure of operatives to an assumed number of components, particularly any fuel element spiders and nimonic springs that were inadvertently disposed of to the silos at the time of the original stripping of the fuel elements. If, however, some of these components are not separated from the batch entering the dissolvers then the operator dose exposure could be higher, particularly if components are themselves subject to dissolution, Previously, work[42] was undertaken to determine the extent of weight loss to the spring and spider components (nimonic 80A and 321 stainless steel) into the liquor under the dissolution chloride reaction at high temperature. Also research[43] was scheduled to determine the cobolt-60 loss from the irradiated nimonic springs. There is apparently nothing published on the corrosion rate of irradiated uranium (ie spent fuel) under carbonate dissolution chemistry with this applying to any fuel debris[44] that could have been inadvertently placed in the FED silos during the desplittering stripping process.

Recommendation

25) Explanation of the reasons for the significant differences in the projected operator doses for over the Magnox power stations might be helpful to the consultees.

26) For both critical group (public) and operator (on-site) dose assessments it might be useful for consultees to have reference to the pertinent collective doses (man Sv).

> ***1.3 Radiological Safety*** *– this addresses the radiological consequences of an accident for each option during implementation and operation. The radiological consequences would include public and operator dose, and any unforeseen breakdowns of equipment or process.*

The previous BPEO consultation for Bradwell defines radiological accidents to be:

> *". . . 1.3 Radiological Accident*
>
> *This is the deterministic and probabilistic (where data exists) risk associated with an accident or abnormal occurrence attributable to the implementation of the option. The relative hazards presented by each option in a credible fault situation are judged to be a significant discriminator between the options.*
>
> *. . ."*

Contrary to this requirement to rank untoward radiological events by the hazard, the *issues* paper describes each of a number of relatively minor and 'contained' accidents as *marginal*. However, Appendix 8[45] covering the dissolution *options 1* and *2* outlines a number of accidents and incidents within the FED plant in terms of (radio)activity release and area spread. Possible accidents during the encapsulation processes relating to *options 3* and *4*, these may be covered by the *2nd BPEO Conference* referred to in Appendix 4.

Recommendation

27) Very little detail or explanation is provided in the *issues* paper on accidents and the risks and radiological impacts arising therefrom. For this information the

---

41 *Technical Specification for a Fuel Element Debris Retrieval and Processing Facility* SZA/00975 Part 2 Issue 2, June 2006 – Magnox Electric Ltd

42 *Conditioning of Metallic Magnox Fuel Element Debris*, CEGB NWR/SSD/82/0098/R, 1982

43 Work scheduled by R N Newman of the CEGB about 1982 but which may have not been reported.

44 The general assumption is that any fuel particles would be passivated by an oxide film formed after dissolution.

45 *Zero Liquid Discharge Magnox Dissolution Process*, TR/8921/003 Issue 1, NUKEM, January 2007

consultees will need to refer to further information given in other documentation that has not been provided in advance of the consultation.[45,36]

28) Accident probability and severity should be expressed in terms compatible with the SAPs, which should also be made familiar to consultees.

Surface hydrides[46] can form on the Magnox FED and on the surfaces of any uranium fuel fragments that may have inadvertently passed into the FED storage silos following the desplittering operation. The formation of hydrides is accelerated in moist conditions and, under certain circumstances, can render the parent metal pyrophoric giving rise to explosions and fires, with the self-ignition temperature of uranium metal, normally at about 220°C reducing to ambient temperatures. Pyrophoricity of reactive metals is usually associated with the material being in a finely divided form, such as swarf or a dried sludge,[47] and may be induced by subjecting the material to an energetic (adiabatic) process, such a crushing.

Although an established risk,[48] pyrophoric reactions of Magnox FED and uranium metal fuel fragments are not identified in the *issues* paper, other than a passing reference to possible fire risk during the compaction of FED for encapsulation. Moreover, the *issues* paper discounts the presence of irradiated uranium fuel in the FED in that there will be *'very little, if any, fuel within the cells [FED silos]'* although this seems to be based entirely on the rationale that *'Due to the complex route that the FED took to be placed in the vault, opportunities for such items to be added were significantly reduced*'. However, FED processing for encapsulation at Trawsfynydd Magnox nuclear power station encountered irradiated uranium fragments mixed in the FED requiring extraction before further processing (encapsulation) could take place.[49]

Recommendation

29) Further consideration should be given to the risk of pyrophoricity for all *4 options* of FED management.

30) Consultees might wish to consider the possibility of irradiated uranium being present in the Sizewell FED and the accompanying risk of ignition (and caesium leaching into the FED).

31) Consultees should have access to the *Reactor Decommissioning Unit Risk Register* that includes risks associated with the FED *options* of dissolution and encapsulation.

***1.4 Conventional Safety** – involves the risk to operators and to the public from accidents, during implementation and operation, and is related to the complexity of the plant and the manpower requirements.*

Generally, the previous recommendations equally apply to conventional accidents and incidents.

***1.5 Transport Safety** – involves transport related safety and is therefore related to the number of journeys which may be required for the transportation of materials and the disposal of waste.*

CALCULATIONS	***OPTION 1 DISSOLUTION WITH DISCHARGES***	***OPTION 2 DISSOLUTION ZERO DISCHARGE***	***OPTION 3 SOLID ILW***	***OPTION 4 SOLID ILW/LLW***
1.5 Transport Safety	*Negligible*	*Marginal*	*Significant*	*Marginal*

The above *issues* paper table gives MS's somewhat subjective assessment of the risk of accident. With its requirement for expanded ILW storage on site, *Option 3* is reckoned by MS to bear a *significant* safety risk of

46 *Hydride* is the name given to the negative ion of hydrogen, H^- and the term hydride is widely applied to describe compounds of hydrogen with other elements.

47 It is not clear if the FED in the silos at Sizewell has been treated with sodium chloride (common salt) as at Dungeness.

48 In the head-end stage of Magnox fuel reprocessing at Sellafield, there is a significant fire risk as the remaining Magnox cladding is stripped from the fuel elements prior to fuel dissolution.

49 *Handling Legacy Waste Streams at Trawsfynydd*, Parsons S, Radwaste Solutions, July 2007

accident from the increased number of construction vehicle shipping in (non nuclear) materials for the construction of the expanded ILW store. It is somewhat doubtful that the increased risk for construction traffic[50] alone would be as *significant* as claimed by MS.

Recommendation 32) Construction traffic data for *option 3* should be provided to substantiate that the risk of accident is significant.

Although not included in the *issues* paper as one of the *options*, other FED BPEO consultations have included consideration of transporting the unprocessed FED from Bradwell to Dungeness for dissolution – this option was probably rejected prior to selection of the final 4 Sizewell *options* of the *issues* paper. Also for all *options* and unless the retained radioactive wastes (either the sand filter residues and spent ion-exchange resins for the dissolution options, or the ILW/LLW drummed wastes from the encapsulation options) are ultimately disposed of on the Sizewell site, then there will be a transportation phase to an off-site repository at a location and time that are yet to be specified.

On transport (beyond the Sizewell site) and also to the FED processes and storage or radioactive wastes arising therefrom, the *issues* paper gives no account whatsoever of malevolent acts, including terrorism. The International Atomic Energy Agency (IAEA) considers transportation of radioactive materials to be particularly vulnerable to terrorist act[51] and decommissioning and, particularly, decommissioning waste transportation has been identified to be potential target of terrorism.[52]

The argument now often presented on terrorism is that publishing any details would reveal vulnerabilities of the plant and its processes, so much so that it would not be in the public interest to do so. Another counter is that, so it is claimed, because of the robustness of the *defence-in-depth* design of the plant and processes, any reasonably foreseeable terrorist action would not result radiological consequences any greater than that predicted for and arising from any credible accident. Interestingly the *issues* paper makes no reference whatsoever to either of these arguments, so it is not at all clear if the FED processes associated with the *4 options* are robust in this respect.

Recommendation 33) The vulnerability to terrorist acts, etc., of the plants and processes used for the options should included as an *attribute* applied to transport and all other activities associated with the FED *options*.

Because of resource and time limitations, the following MS *attributes* have not been examined in any detail:

> ***2. Nuclear Safety***
>
> ***2.1 Hazard Reduction*** *– is the reduction of the mobility of the waste stream on site. Encapsulation makes the waste immobile, but it remains on site, whereas dissolution remove the waste from site, totally removing its hazard.*
>
> ***2.2 Long Term Impacts*** *– is the consideration of the long term impacts of the option, on the site, and on flora and fauna.*
>
> ***2.3 Decommissioning*** *– involves consideration of the future decommissioning program and following uses of the land.*
>
> ***3. Environmental Impacts***
>
> ***3.1 Primary Radioactive Waste Volume*** *– involves the potential advantages of minimising waste volumes at source and for future storage on the sites as ILW.*

---

50 *The Safe Use of Vehicles on Construction Sites HSG 144 - A guide for clients, designers, contractors, managers and workers involved with construction transport*, HSE, 1998 – includes construction vehicle accident statistics.

51 *The Physical Protection of Nuclear Material and Nuclear Facilities*, IAEA INFCIRC/225 Rev b.

52 *Decommissioning Nuclear Plants - Openings for the Terrorist Threat*, 10th Global Conference & Exhibition on Decommissioning Nuclear - Taking Experience Forward, Large J H London, November 2006, http://www.largeassociates.com/ibc%20decommr/IBCpaperFINAL%2014%2011%2006.pdf

3.2 Secondary Radioactive Waste *– the amount of secondary waste which will arise from installing, operation and decommissioning of the facility.*

3.3 Radioactive Discharges – *this involves evaluation of the performance of each option in relation to radiological discharges, be it airborne, liquid or solid.*

3.4 Non-radiological Discharges *– involves evaluation of the performance of each option in relation to chemical discharges, be it airborne, liquid or solid.*

3.5 Transport *– involves consideration of the environmental and social impacts of transport during construction and over the operational period of the facility, and final disposal of the waste. The impact should be scaled relative to the amount transported and include impacts encompassing nuisance, noise, vibration and air quality. It does not include safety, addressed in 1.5 above.*

3.6 Resource Usage *– involves evaluation of the performance of each option in relation to material and energy use, including water and energy. Sizewell A FED Management Assessment Page 7 of 36*

3.7 Nuisances *– involves consideration of each option in relation to disturbance / nuisance to the environment, be it noise, odour or visual but excludes transport.*

4. Technical Feasibility

4.1 Technical Maturity *– involves consideration of the technical feasibility, proven technology, and physical feasibility. It includes considering the strategic disadvantages to adopting plant designs or ideas which require further development work before they can be implemented.*

4.2 Technical Reliability *– this is related to the ability of an option to process wastes etc. If the condition of the waste and its composition vary significantly from that predicted, and involves consideration of the plant and equipment types, and which would be easier to maintain over the operational lifetime of that plant to keep the plant in operating condition.*

4.3 Timescale (Implementation / Processing) *– is in relation to the anticipated implementation and project time. For example, the time for option development and design; for authorisation and Regulatory consultation; for construction and commissioning etc.*

4.4 Interface with Site Operations *– dependencies with site operations or dependency of a particular option on external factors is perceived to be a disadvantage. This involves consideration of the performance of each option in relation to its compatibility with existing and future systems, whilst minimising disruption to other site operations.*

4.5 Disposability *– is related to the waste being in an acceptable state to be finally disposed to meet disposal criteria.*

5. Cost

5.1 Capital Costs *– is the total cost, in current monetary values, of each option and includes capital, operating, decommissioning, storage and waste disposal.*

5.2 Stakeholder Acceptability *– stakeholder views are taken into account through the BPEO process but this includes wider consideration, including that of regulatory permissions that may be required to implement an option. For example, this can include the time, trouble and cost involved in securing new RSA93 authorisations, EIADR99 consents, planning permissions, etc.*