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International Peer Review for

The Decommissioning Programme of Magnox Limited, United Kingdom

With Bradwell as the Reference Site

International Atomic Energy Agency

REPORT OF THE PEER REVIEW FOR

THE DECOMMISSIONING PROGRAMME OF MAGNOX LIMITED, UNITED KINGDOM
(With Bradwell as the reference site)

Mission dates:	29 June to 7 July 2008, Initial Review 12 to 17 June 2011, Follow Up and Close-out Review
Owner:	Nuclear Decommissioning Authority (NDA)
Site Licence Company:	Magnox Limited Ltd
Location:	Bradwell Power Station Bradwell-on-Sea Southminster Essex CM0 7HP
Facility:	Bradwell Site
Organised by:	IAEA

International Atomic Energy Agency
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PREFACE

In 2008, Magnox Limited (then Magnox South Limited) requested that the International Atomic Energy Agency (IAEA) develop and conduct an international peer review of Magnox South's decommissioning activities, using Bradwell Nuclear Power Plant (NPP) as a reference site. The "reference site" serves as a model for the decommissioning of the other 9 reactor sites in the Company's fleet. As is customary with peer reviews, there was also a commitment to invite the IAEA to follow up the initial review after a suitable interval. The initial peer review meeting took place from 29 June to 7 July 2008. In January 2011, Magnox Limited requested the IAEA to organise the follow up review, which took place from 12-17 June 2011.

This present report provides a summary of the findings and recommendations of the follow up review meeting in 2011 and thereby completes the review process. A summary of the findings and recommendations of the initial review meeting in 2008 is provided in Annex A. Both review meetings are reported as they were formulated at the close of the respective review meetings ─ they were not revised to reflect intervening developments.

The objective of the peer review was to provide—on the basis of international safety standards and international good practice—an independent assessment of activities associated with the planning and implementation of decommissioning of Magnox Limited's Bradwell NPP site in the United Kingdom. The peer review set out to inform Magnox Limited whether its decommissioning programme at the Bradwell site is in accordance with international safety standards and whether it reflects good practice when measured against other national decommissioning programmes. It also aimed to assist Magnox Ltd to identify opportunities for improvement in the planning and execution of their decommissioning projects. It should be noted that peer reviews fulfil an IAEA statutory obligation to provide for the application of international standards of safety, and exchange of information among its Member States.

The peer review included the following topics:

- The national policy and legal framework for decommissioning
- General requirement for a Decommissioning Plan
- Decommissioning strategy
- Transition from operations to decommissioning
- Radiological characterisation
- Funding
- Decommissioning approach, technologies and techniques
- Materials management during decommissioning
- Management for safety and environment
- Surveillance and maintenance

The follow up mission in 2011 was focussed on the progress against the findings and recommendations of the 2008 peer review but in light of developments between 2008 and 2011, also touched upon many of the themes listed above.

The follow up review was based primarily on observations made during site visits supported by interviews, documentation and presentations provided by Magnox Limited. The experts selected for this peer review exercised broad professional judgement, supported by requirements and guidance

from the applicable of IAEA safety standards (see Annex B). Off-site management of radioactive waste (e.g. disposal) was not evaluated *per se*; however, it was considered during the review in so far as it had an impact on the decommissioning process.

The IAEA selected review teams comprised of decommissioning specialists and IAEA staff. The specialists, selected from IAEA Member States, were knowledgeable on IAEA safety standards and had broad professional experience in their respective disciplines. The names and affiliations of the specialists who served on the review teams in 2008 and 2011 are listed in Annex C. To avoid conflicts of interest, the IAEA consulted with Magnox Limited regarding the composition of the review team prior to the review meetings. The final decision with regard to the selection of review team members rested with the IAEA.

The review team noted several substantial changes between the July 2008 and June 2011 site visits. In particular, it was clear in 2008 that the level of funding available for decommissioning activities had been a significant barrier to progress. The review team observed then that this was resulting in inefficient use of the available workforce, a planned protracted C&M preparation phase, and associated increases in the total project cost. In 2011, the review team encountered an entirely different situation, with sufficient funding having been allocated by the Nuclear Decommissioning Authority (NDA) to facilitate an accelerated C&M preparations phase at both the Bradwell and Trawsfynydd sites. As a result of this and other initiatives the estimated total project cost had been substantially reduced, C&M preparations were proceeding rapidly, and the contractor workforce had been expanded considerably to support the work being undertaken.

Since the previous site visit there had been significant progress in several dismantling areas. The fuel ponds were in a stabilised state, which will allow the concrete structure to remain during the C&M phase. Demolition of the turbine hall was progressing well and detailed sampling had shown no contamination and the material can be conventionally recycled. Furthermore, one of the gas circulator halls had been completely dismantled and could be used as a temporary waste storage.

The review team found that Magnox had adopted a well-coordinated corporate-wide approach to decommissioning projects, using accelerated entry into C&M at Bradwell and Trawsfynydd as models for decommissioning of the remaining sites. Future major projects will be implemented by teams that move from site to site, making best use of experience gained at sites decommissioned earlier. Review of design changes and underpinning safety cases by an independent review committee, made up of Magnox and external experts, reflects good international practice. A systematic analysis of when and where skills will be needed across the fleet, and linking this with retraining and mobility programmes, demonstrates positive innovation in the management of human resources.

The review team noted that issues such as the use of MiniStores for storage of ILW may have implications beyond Magnox's programme and therefore it was recommended that greater coordination in initiating and assessing such innovations should be established that would engage other waste generators, the NDA and the regulators. The team also recommended that efforts to develop disposal solutions for graphite waste, which represent an impediment to shortening the total duration of the C&M period (currently envisaged to be at least 85 years) should continue to be pursued rigorously.

FINDINGS AND RECOMMENDATIONS AT THE CLOSE OF THE 2011 FOLLOW UP REVIEW MEETING

1. Background and Introduction

In 2008, Magnox Limited (then Magnox South Limited) requested that the International Atomic Energy Agency (IAEA) develop and conduct an international peer review of Magnox South's decommissioning activities, using the Bradwell Nuclear Power Plant (NPP) site as a reference site. The Bradwell site is located near Bradwell-on-Sea, Essex County in the United Kingdom. Decommissioning solutions demonstrated at the Bradwell site will be applied for decommissioning of other Magnox Stations, hence it is designated as a "reference site".

The objective of the peer review was to provide an independent assessment of activities associated with the planning and implementation of decommissioning of Magnox Limited's Bradwell site. In particular, it was intended to:

- inform Magnox Limited whether its decommissioning programme is in accordance with international safety standards and reflects good practice from other national decommissioning programmes,
- assist Magnox Ltd to identify opportunities for improvement to their decommissioning project planning and execution, and
- facilitate the sharing of good practices identified during the review.

The review team was concerned mainly with the preparatory activities required for entry of the Bradwell site into a long-term Care and Maintenance (C&M) phase. Some consideration was given to activities that will be carried out during the C&M period, and to decommissioning activities required to achieve final site clearance post C&M. The scope of the peer review included strategic considerations and technical areas central to decommissioning. The technical areas considered included those being developed by Magnox project teams that are scheduled for implementation at Bradwell (e.g., ILW MiniStores (Ductile Cast Iron Containers) and the Fuel Element Debris (FED) treatment programme). Off-site management of radioactive waste disposal was considered only in so far as it has an impact on the decommissioning programme.

The review process was built around two review meetings: an initial review meeting and a follow up review meeting to close the process. The initial review meeting took place from 29 June to 7 July 2008, and the follow up review meeting took place from 12-17 June 2011. The follow up meeting provided an opportunity to review how preliminary recommendations and suggestions from the first review meeting had been addressed, and to review other progress and change during the intervening three-year period between the review meetings.

The review process included: pre-meetings to plan the international peer review, questionnaires, site visits, examination of Magnox documentation (e.g., the Magnox South Integrated Waste Strategy, and various safety case reports), formal presentations from Magnox Limited, interviews, and roundtable discussions. The specialists who were members of the peer review team were selected by the IAEA; their names and affiliations are listed in Annex C of this document.

There are several international standards applicable to decommissioning of nuclear power plants and related activities, the principal one being: Decommissioning of Facilities Using Radioactive Material,

Safety, IAEA Safety Standards Series No. WS-R-5 (2006). The observations, findings and recommendations of the specialists were based upon the IAEA safety requirements and guidance, and their professional experience and knowledge.

The review team noted several substantial changes between the July 2008 and June 2011 site visits.

In 2008, it was clear that the level of funding available for decommissioning activities was a significant barrier to progress. The review team observed that this was resulting in inefficient use of the available workforce, a planned protracted C&M preparations phase, and associated increases in the total project cost. In 2011, the review team encountered an entirely different situation. Funding had been provided to undertake an accelerated C&M preparations phase at the Bradwell and Trawsfynydd site. As a result of this and other initiatives the estimated total project cost had been substantially reduced, C&M preparations were proceeding rapidly, and the contractor workforce had been expanded considerably to support the work being undertaken.

In 2008, Magnox North and Magnox South had recently been created by splitting the previous organisation in two. The review team interacted with Magnox South, responsible for Bradwell site. The split at that time had resulted in the usual administrative difficulties associated with a restructuring. In addition, although it was noted that some lessons learned were being shared between Magnox sites, site-specific approaches were the norm. In June of 2011, Magnox North and Magnox South had recently been re-joined. Although some centralised functions were still in the midst of being formed, it was clear that significant effort had gone into developing corporate-wide approaches, including a common approach to decommissioning that would be applied to all ten sites in the Magnox fleet, and teams that would move from site to site to oversee specific projects.

Another substantial change between July 2008 and June 2011 was that the UK may soon have facilities permitted to accept very low level radioactive waste (VLLW) for disposal i.e. the Lillyhall landfill site in Cumbria and the Augean landfill site in Northamptonshire. The Studsvik facility in Workington for treatment of metals that have low-levels of radioactive contamination also opens up new opportunities for volume reduction and recycling of these types of materials.

Since the previous site visit, progress in several dismantling areas could be observed. The fuel ponds were in a state to take into C&M. The demolishing of the turbine hall was commencing well. Detailed sampling had shown no contamination and the material can be conventionally recycled. Furthermore, one of the gas circulator halls had been completely dismantled and could be used as a temporary waste storage.

During the 2008 review meeting, seven preliminary recommendations were raised relating to: project costing, the length of the C&M phase, characterisation, regulatory interactions, and a comprehensive decommissioning plan. All of these were revisited during the 2011 review meeting. Due to the significant changes and progress since 2008, in most cases it was found that the concerns embodied in these recommendations had been resolved or were no longer relevant. Any remaining concerns are captured in the findings of this report.

2. Oversight and Funding

In the UK, overall responsibility for the decommissioning and cleanup of State-owned nuclear sites rests with the Nuclear Decommissioning Authority (NDA), which acts on behalf of the UK Government. The NDA discharges this responsibility via contracts with the Site Licence Companies (SLCs), including Magnox, which require that the decommissioning work is carried out in accordance with agreed Lifetime Plans (LTPs) for each site. The Parent Body Organisation (Energy Solutions) is incentivised on the basis of achieving key deliverables or milestones, with additional fee being obtained for achieving better performance than anticipated in the LTP. The LTP is broadly equivalent to the "decommissioning plan" that is the cornerstone document for decommissioning as elaborated in WS-R-5 and other IAEA publications.

Since the first visit by the Review Team in 2008, Magnox has obtained broad agreement from the NDA for a significant acceleration of the Phase 1 decommissioning work at Bradwell and Trawsfynydd, with entry into the Care and Maintenance (C&M) period scheduled for 2015 (Bradwell) and 2016 (Trawsfynydd), and with the intention that the lessons learned during this work will then be replicated on the remaining sites. Funding has been obtained which is consistent with the NDA CR10 (Comprehensive Review) financial settlement with Government. This provides funding over the next 4 years, which contrasts with the previous approach of establishing a budget for a 12-month period only. The resulting increased stability given to the programme represents a significant improvement on the situation, which applied in 2008.

The relevant LTPs are currently being updated in accordance with this revised strategy, which is expected to result in lifecycle cost savings of over £1.0bn, of which approximately £152m relates to Bradwell. The most significant contributors to this reduction in cost is the introduction of innovations and more efficient use of personnel on the sites during the Phase 1 activities, i.e. reduction of staff costs related to keeping the site functional before significant decommissioning activities are undertaken and the plan that minimal staff should remain on site during the C&M period. This allows a significant reduction in the numbers of staff employed by Magnox from 2015 onwards.

The review team strongly welcomes the above changes, which result in a much more coherent and efficient overall programme for Phase 1 decommissioning. Magnox's intention that lessons learned from preparing the Bradwell and Trawsfynydd for early entry in C&M can be replicated on the other sites is also supported.

Recommendation

Decommissioning cost estimates for each site should be prepared according to a standardised format, and a process followed whereby real cost data is collected and used to improve the accuracy of future estimates.

3. Regulatory Interface

Each of Magnox's ten sites is licensed as a nuclear site and, accordingly, Magnox is regulated by the Health and Safety Executive, e.g. through its Office of Nuclear Regulation (ONR) for nuclear safety matters. Issues relating to the management of waste also require approval from the Environment Agency for England and Wales (or the Scottish Environmental Protection Agency). Under the UK legal framework, decommissioning is carried out under the same licence as plant operation. One of the licence conditions (LC 35 (1)) requires the "The licensee shall make and implement adequate

arrangements for the decommissioning of any plant that may affect safety". Magnox arrangements include the formulation of a set of 'Regulatory Milestones' agreed with the ONR (usually 5 / 6 per site) which require satisfactory completion to be attained before proceeding. The ONR also require that commencement of a new phase of decommissioning, e.g. entry into Care and Maintenance (C&M) may only occur when formally approved by them.

Significant changes to the baseline decommissioning plan are required to be agreed with the ONR, and also the Environment Agency where there are waste management issues, e.g. the use of MiniStores as opposed to the baseline option of placing cemented waste in stainless steel drums and adoption of the Fuel Element Dissolution (FED) process. In the specific case of MiniStores, a condition for this agreement is that Magnox first obtains a conceptual "Letter of Compliance (LOC)" from the NDA's Radioactive Waste Management Division (RWMD), in effect a statement that the waste package is likely to meet the anticipated acceptance requirements from a future disposal site operator.

To avoid the situation that regulators need to maintain an oversight of the programme at a very detailed level, Magnox have instituted internal review arrangements of safety assessments that underpin design changes and the regulators have full visibility of this process, e.g. through receipt of the minutes of the meetings of this committee. The regulators may always still determine that a formal approval from them is necessary before proceeding to implement a design change. The review team strongly supports this approach, which enables regulators to focus on key issues whilst being satisfied that an independent review process is being applied to safety significant activities.

In light of the above, it is evident that achievement of the accelerated programme for Bradwell is highly reliant on obtaining various regulatory consents. Failure to reach agreement with one or more regulators, or significant delays in reaching agreement will have a significant impact on the programme. The reviewers noted a strong awareness amongst Magnox staff of this risk to the programme and that there were significant contacts with regulatory inspectors at various levels.

Recommendation

The overall coherence of Magnox's management of its interface with the various regulators may be improved by the identification of a senior level manager having overall responsibility for coordination of safety case submissions to the regulators. Agreement should be sought with the regulators on an overall programme of regulatory submissions, including a broad outline of the time anticipated for regulatory reviews.

4. Decommissioning Strategy

As stated in paragraph 4.2 of WS-R-5,

> *"The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered. These factors may include: the availability of waste disposal or long term storage capacity for decommissioning waste; the availability of a trained workforce; the availability of funds; co-location of other facilities on the same site requiring decommissioning; technical feasibility; and optimisation of the radiation protection of workers, the public and the environment. If the deferred dismantling or entombment strategy is chosen, the operating organisation shall provide a justification for the selection. The operating organisation shall also demonstrate that, for the selected strategy, the facility will*

be maintained in a safe configuration at all times and will be adequately decommissioned in the future and that no undue burdens will be imposed on future generations."

C&M preparations are designed to place the Bradwell site into a safe configuration until it is decommissioned nominally 85 years into the future. The review team understands that when more immediate priorities have been dealt with Magnox will make an effort to review options for the duration of the C&M phase and the activities to be undertaken during this phase. The key driver for the duration appears to be the timing of availability of disposal options for graphite and ILW, although cost and national policy issues and the benefits of radioactive decay in place are also considered. The LTP envisages removal of ILW from the ILW store on site to a disposal facility after the geological disposal facility becomes available. Timing for a graphite disposal option is not yet clear. An early solution for graphite disposal should be actively sought, and all reasonable attempts made to move forward the availability of an ILW disposal option, in order to remove these barriers to achieving FSC as soon as possible. This is consistent with the philosophy of preferring to reach FSC as soon as feasible inherent in IAEA standard WS-R-5. This is driven by a desire to remove potential hazards and land use restrictions sooner rather than later, and to avoid passing the burden of decommissioning to future generations to the extent possible.

Important features of the strategy to accelerate the preparation for C&M, as described in the Magnox Optimised Decommissioning Plan [Sept. 2010], include:

- the proposal to place intermediate level waste in MiniStores . During the preparatory phase, this waste will include ion exchangers, sludges, temporary storage of fuel element debris etc.

- the selection of 2 sites, Bradwell and Trawsfynydd for accelerated decommissioning, with lessons learned then being applied to the other sites.

The sequential dismantling approach at the different sites makes it possible to use employees specialised in certain important tasks (e.g. fuel pond clean up, handling and treatment of fuel element debris) for all sites. This approach makes sense from a technical and personnel management point of view and is also part of the Magnox overall human resource management planning (i.e., Transition planning). Development of innovative decommissioning technologies that are to be applied company-wide is also an efficient use of resources, for example, the handling and treatment of Fuel Element Debris.

For Bradwell, Magnox strategy states that the boilers and gas ducts will be left in their current positions and become part of the safestore. Changing this strategy to one of dismantling would require significant characterisation work and the dismantling activity, which would extend the programme for entry into C&M by one year or more, and would add significant cost (diverting funding from other hazard reduction programmes). This position differs to the approach being followed at Berkeley where the boilers were removed and the safestore is limited to the reactors and surrounding bioshields, i.e. the overall size of the safestore is substantially smaller. The removal of the boilers was in part due to the specific plant configuration. One boiler from Berkeley has been sent to a specialist contractor for melting and recycling.

The long-term management of graphite waste remains an important issue for Magnox, as for the advanced gas cooled reactors. The current expectation is that this waste will need to be emplaced in the geological disposal facility, though other solutions are possible in principle, including near surface disposal. This is an issue where a collaborate approach both within the UK and indeed with other

national programmes is strongly recommended. Such collaborations may lead to the development of alternative solutions, e.g. an approach based on near surface disposal is being assessed at the Hunterston A site in Scotland.

Recommendation

Including earlier achievement of final state clearance as a preferred future option, depending on progress with development of the repository, would bring the UK approach more in line with international recommendations and practice in other advanced programmes.

Recommendation

Issues such as the use of MiniStores and the long-term management route for graphite may have wide implications not only for Magnox's programme, e.g. the use of MiniStores as a waste package form for geological disposal requires changes to the existing national disposal concept. It is recommended that a more structured process for coordinating the initiation and assessment of such innovations be established that would engage other waste generators, the NDA and the regulators.

5. Material Management and Characterisation

Characterisation and material management

The basis for the material/waste management is a prudent characterisation of the plant, i.e. materials, masses, geometries and radiological data. When these data are known, a secured basis for the planning of the project is available. Notably the planning of the management of dismantled material can be performed in a transparent manner, including defining the need for new or adapted treatment and handling methods and facilities.

This means that the characterisation is needed for:

- Planning of the dismantling and the flow of dismantled material after dismantling, hereby establishing the basis for decisions on required treatment facilities and management components and tools.
- Establishing the boundary conditions for external acceptance at interim storages and disposal sites, e.g. for the nuclide and material declaration in view of disposal.
- Establishing the basis for the safety analysis of the C&M phase.

The volume inventory of operational waste and components and facilities to be dismantled has recently been updated for all Magnox sites ("smart inventories"). This has resulted in a significant reduction of anticipated future waste volumes for disposal, and hence cost savings. In addition, a detailed sampling and analytical programme has been worked out and is being implemented. When results are available, the two data banks have to be combined, in order to establish a complete data basis for the planning and execution of the dismantling and material management.

Contaminated Land

For the Bradwell site, the "Paper of Intent: Care and Maintenance Safety Case" (DPAF/4286/Issue 1, MS/NSC 1038 Addendum 1, March 2010) indicates that there are a number of contaminated land areas on the site, and that these will remain in situ until final site clearance.

During the first review meeting it was noted that there is an area of contaminated land towards the northern boundary of the site, and that subsurface characteristics of this contaminated land, including the depth profile and hydrogeological conditions, were not well characterised. Without more information it is not possible to exclude the possibility that the contamination may extend beyond the fence line, or may migrate beyond the fence line during the C&M phase.

Recommendation

Contaminated areas, particularly those near site boundaries, should be well characterised with respect to extent, propensity to migrate, and hydrogeological conditions. Although significant safety and environmental impacts are unlikely, the presence of any off-site contamination upon entry into or during the C&M phase should be avoided. Should the detailed characterisation reveal more potential problems than anticipated, Magnox should carefully reconsider the planning assumption that contaminated land will remain in situ until final site clearance. In this event, alternatives such as removal of some contaminated land to disposal or on-site storage should be considered, as well as the possibility of introducing other mitigation measures to minimise the potential for increased volumes or off-site migration through hydrogeological processes.

6. Care and Maintenance Phase

The Magnox Optimised Decommissioning Programme (T1-MS-07-MEL-2687 Issue 6, 30 September 2010) identifies that:

> *A key strategic objective for the UK is to get a Magnox site into 'early' Care and Maintenance (C&M) in order to:*
>
> - *Define and underpin the cost to achieve entry into C&M*
> - *Prove new technologies and methods for entering C&M, allowing roll out across the fleet, the NDA estate and beyond, leading to significant future reductions in the Nuclear Liability Estimate (NLE)*
> - *Provide data which will form the basis for competing and delivering the remaining Magnox sites*
> - *Deliver a significant UK nuclear decommissioning and hazard reduction project which is vital to the country's new build aspirations*

The Bradwell site was selected to move into early C&M to achieve this objective while also demonstrating the viability of a suite of technologies new to the UK, to "remove the majority of the technology risks from the baseline, provide a firm benchmark for competition and allow a significant write down of the NLE."

For the Bradwell site, the C&M Entry State is described in a general way in the "Paper of Intent: Care and Maintenance Safety Case" (DPAF/4286/Issue 1, MS/NSC 1038 Addendum 1, March 2010). This state includes:

- two de-planted reactor buildings within an engineered enclosure;
- an industrial-type warehouse for MiniStores containing intermediate level waste (ILW);
- residual below-ground de-planted structures decontaminated to acceptable levels and active drains capped and/or grouted; and,
- radiologically contaminated land areas retained in-situ.

The C&M Entry State for the Bradwell Site is and will be described in further detail in seven Stage Submissions:

Stage Submission 1 – Reactor Safestores

Stage Submission 2 – Fuel Cooling Ponds (remaining structure)

Stage Submission 3 – Active Waste Vaults (remaining structure)

Stage Submission 4 – Contaminated Land

Stage Submission 5 – ILW Storage

Stage Submission 6 – Site Infrastructure

Stage Submission 7 – Safety Management Arrangements

Formal entry of the Bradwell site into the C&M Phase will be signalled by the Magnox Design Authority giving final approval following completion of all the Safety Case Stage Submissions described in the Paper of Intent and publication of the final report. After approval, these documents together will become the site Reference Safety Case, replacing the current Reference Case.

There is a regulatory requirement under License Condition 35 Milestone 611 for Design Authority approval before entry into C&M. Throughout the process, the various Stage Submissions and other documents are submitted to the regulatory authority "for consideration". It is generally assumed that the regulatory authority is satisfied with these submissions if no objection is raised within thirty days of submission (letters confirming 'no objection' are issued by the regulator for significant milestones). This is aided by regular interactions between Magnox and the regulatory authority in advance of submissions in part to identify areas of potential regulatory concern before documents are submitted for consideration.

During the June 2011 site visit the review team examined the Magnox Optimised Decommissioning Programme, Paper of Intent, and the first two Stage Submissions, and was informed that these documents had been submitted to the regulatory authority. The remaining Stage Submissions had not been completed at that time. The completed Stage Submissions describe the C&M Entry State and appear sufficient to plan C&M preparation works.

The responsibility for defining and seeking approval for the C&M entry state clearly lies with Magnox with regulatory approval only given when satisfactory cases have been made. This can on occasion result in work progressing slower than anticipated with the eventual approved End State differing to that envisaged at the start. However, it would appear that this is common practice in the UK and does provide some advantage in the form of added flexibility for both Magnox and the regulator. In this case, frequent and constructive interactions between Magnox and the regulator at every level is vital. This does appear to be the case.

However, having a series of somewhat independent Stage Submissions, and not yet having completed all of these Stage Submissions, means that the complete proposed C&M Entry State has not been clearly defined prior to initiating substantial C&M preparation work. This introduces other risks, including missing possible opportunities to exploit commonalities between Stage Submissions, and the possibility of conflicts between the work considered under each Stage Submission. Nonetheless, the review team noted evidence that at least the latter has been considered to some extent as it has been recognised that work around the ponds areas, the subject of one Stage Submission, impacts the work in adjacent areas which are the subject of another Stage Submission.

The arrangements for the site during the 85 year period of C&M remain to be elaborated – they will be detailed in the Stage Submission 7 of the Safety Case (titled Safety Management Arrangements). It is noted in the Paper of Intent that a limited electrical supply network, service roads, some drainage systems, fencing, and intruder detection systems are part of the arrangements for the C&M period. An environmental monitoring capability will have to be in place as well. Provided, there are no significant contaminated lands issues, environmental monitoring might be carried out without much presence on the site. Natural degradation by weathering processes and biological intrusion are unavoidable, as are the need to respond to the possibility of inadvertent and deliberate intrusion. Given the appreciable amount of radioactive materials and materials of commercial value left on site during the C&M phase, careful consideration of the necessary level of oversight is needed to ensure safety. This should include assessment of the need for remote monitoring, site inspections, and possibly on-site staff.

7. Summary and Conclusions

This IAEA international peer review examined Magnox decommissioning activities, using the Bradwell site as a reference. It was conducted around two review meetings, in July 2008 and June 2011. During both review meetings, the review team was appreciative of the openness and helpfulness of the Magnox staff.

The review team noted significant progress between the 2008 and 2011 review meetings. At the Bradwell site, Magnox now has a clear focus on achieving entry into the C&M phase by a specific date, with the funding needed to achieve this objective. The more stable funding regime, based on a funding profile over a 4-year period, results in a much more coherent and efficient overall programme for Phase 1 decommissioning.

The overall view of the review team is positive. During the 2011 review meeting, Magnox demonstrated a well-coordinated corporate-wide approach to decommissioning projects, using accelerated entry into C&M at Bradwell and Trawsfynydd as models for decommissioning of the remaining sites. Major projects will be implemented by teams that move from site to site, and project success is reviewed centrally, making best use of experience gained and successful technical and human resources innovation at sites decommissioned earlier. Specifically, these good practices include technical innovation, such as the technology being employed for removal of FED from the ponds, the subsequent treatment of FED and the use of MiniStores, will be deployed across all sites. Review of design changes and underpinning safety cases by an independent review committee, made up of Magnox and external experts, is also a good practice. A systematic analysis of when and where skills will be needed across the fleet, and linking this with retraining and mobility programmes, demonstrates positive innovation in human resources. Changing the culture from a site-focused mindset to a company-wide focus has been a significant achievement as well.

Nonetheless, the review team found several areas with potential opportunities for improvement. Among the most important specific issues highlighted by the review were:

The accelerated programme for entry into C&M at Bradwell is dependent on satisfying the regulatory authorities on several safety issues and failure to achieve this in a timely manner will have a significant impact on the programme.

Issues such as the use of MiniStores and the long-term management route for graphite may have wide implications beyond Magnox's programme. It is recommended that a more structured process for coordinating the initiation and assessment of such innovations be established that would engage other waste generators, the NDA and the regulators.

Current policy is that the C&M period may have a total duration of 85 years or more. An early solution for graphite disposal should be actively sought, and all reasonable attempts made to progress the availability of an ILW disposal option, in order to remove these barriers to achieving FSC as soon as possible.

Contaminated areas, particularly those near site boundaries, should be well characterised with respect to extent, propensity to migrate, and hydrogeological conditions. The result of the characterisation, if found to be different from current expectations, may lead Magnox to carefully reconsider the planning assumption that contaminated land will remain in situ until final site clearance.

ANNEX A:
FINDINGS AND RECOMMENDATIONS FROM THE INITIAL PEER REVIEW MEETING IN 2008

1. Background and Introduction

The review process began with a series of written questions being posed to Magnox South, based primarily on IAEA Safety Standards Series No. WS-R-5 (see list of IAEA Reference Documents in Annex B). The answers were made available to the review team together with supporting documentation. There was also an opportunity to ask supplementary questions. This part of the review was conducted in advance of the review team's visit to the Bradwell site.

The scope of the review addressed five topic areas selected from IAEA Safety Standards Series No. WS-R-5, namely:

- Decommissioning strategy
- Radiological characterisation (expanded to other hazards)
- Decommissioning approach, technologies and techniques
- Materials management during decommissioning
- Surveillance and maintenance

The review team identified five further 'cross-cutting' topic areas that they felt were integral to the review and referred to these as well as other relevant standards and publications to support the team's review objectives. Review activities commenced at Bradwell site on the 30th June 2008 starting with a tour of the site followed by presentations to the review team by members of Magnox South Head Office staff and Bradwell site staff. The review continued for several days, with further presentations, focussed discussions with key site personnel and several one-on-one meetings with management, site, head office and project staff. The review team were aided in their understanding of the Bradwell decommissioning activities and the strategic objectives of the Magnox South decommissioning programme by dialogue with the Magnox coordinators assigned to the review team during the review process.

There was also an opportunity to further review documentation and to visit the workplace to observe some of the decommissioning activities being carried out. Key projects being planned for implementation in the short term (Fuel Element Debris Dissolution, Ponds and Vault Cleanout Projects) were also reviewed.

The strengths and recommended opportunities for improvement identified by the review team are outlined below.

2. Decommissioning Strategy

The current strategy for Magnox Stations was linked at Bradwell to its Technical Baseline and Research and Development (TBRD) document underpinning the Lifetime Plan (LTP). This plan envisages completion of Care and Maintenance Preparations (C&M Preps) by 2027.

The site owner, the Nuclear Decommissioning Authority (NDA), is presently optimising the UK decommissioning programme with particular emphasis on tackling the initial high-hazard legacies. The flexibility that this approach brings inevitably leads to variations in funding, which can lead to uncertainty at the site level because planning boundaries are not always clear. Consequently, the Bradwell Project tends to be one with large planning uncertainties and high fixed costs. High fixed

costs reduce funds available for the execution of the decommissioning works and their timely utilisation.

The management of radioactive waste and dismantled material have a critical influence on the selection of strategy. Uncertainties in regard to the fate of decommissioning materials exist because the UK's waste management policies are under review and there is a possibility for significant change. Any desired acceleration of decommissioning has as one of its major obstacles the management of the reactors' graphite cores.

It was clear early on that Bradwell's decommissioning strategy could not be undertaken in isolation of the Parent Body Organisation (which supplies the overarching management of the site) and the NDA. IAEA Safety Standards Series No. WS-R-5 requires that deviation from immediate dismantling should be justified. Taking all uncertainties into account, notably funding and waste management routes for ILW and graphite, the review team concluded that the selection of a deferred dismantling strategy for Bradwell was justified. However, the review team is of the opinion that opportunities exist to reduce cost and schedule for phase I (preparations) and the schedule for phase II (Care & Maintenance) (C&M) should be reviewed.

In the absence of a settled long-term strategy, short-term planning becomes cumbersome as it needs to take account of several decommissioning options, and the opportunity to examine critically the high fixed cost base (manpower levels of approximately 300) is effectively lost.

Whilst the team respects the value of analysing options in support of safe, timely and cost effective decommissioning, and believes that Bradwell's implementation of the its Best Practicable Environmental Option and Best Practicable Means (BPEO/ BPM) process is a clear strength, the review team views the present level of optioneering was broader and more extensive than needed.

3. Characterisation

Bradwell was not found to have a comprehensive Characterisation Plan. Characterisation work appears to have been done on an "as-needed" basis in support of specific care and maintenance preparation activities. An overarching strategic characterisation plan is essential to conduct an adequate detailed characterisation survey to support decommissioning activities (as referenced in IAEA Safety Standards Series No. WS-R-5 (2006) and IAEA Safety Reports Series No. 45 (2005)). The individual characterisation projects are not within a broader programme and therefore gaps, inconsistencies, and inefficiencies can occur.

For characterisation of buildings and equipment, a waste database has been developed which contains estimates of the volumes, masses, and material types of radioactive waste remaining on site, as well as an indication of whether the material is Low Level Waste, exempt, etc. Waste categorisation is based primarily on operational and initial screening level characterisation surveys, and it is acknowledged to have significant uncertainties (e.g., contamination levels of inner surfaces of structures or components). Similarly, waste amounts are uncertain.

The waste database is a good basis for estimation of rolled-up waste masses and volumes by material type and category, and for projection of approximate amounts of waste likely to arise through the C&M preparations and Final Site Clearance (FSC) phases. It did not include comprehensive information on hazards or waste arising from contaminated land or from the reactor core, both of which are assessed and documented separately. Activation models have been used to estimate reactor contaminant levels and inventories, and analysis of samples is planned to verify the calculations.

The existing waste database is a good starting point for a more comprehensive version of this database. The more comprehensive version should contain radiological and non-radiological contaminant information, hazard identification, and more precise location information including maps

and drawings. Design of the database so that it can be adapted for use in the future by others not familiar with the Bradwell site is desirable.

Information from other Magnox stations and similar projects is being used in planning assumptions to aid in the characterisation of Bradwell. For example, information has been gathered on measured contamination penetration profiles in the walls and floor of the fuel ponds of other stations.

The characterisation of soils and water has been conducted via record reviews and interviews with staff to identify areas of potential concern. Detailed surface and subsurface characterisation has been carried out around areas where contaminated land is known to exist.

The understanding of the hydrogeology near the known contaminated areas (particularly as they are near site boundaries) is limited. Further work is required to be able to demonstrate that contaminants will not migrate off-site prior to the final decommissioning, or to implement earlier remedial measures as appropriate to avoid this possibility. A full analysis including hard-to-detect radionuclides and potential chemical contaminants is ongoing and will be necessary to support final disposition of the site. Relying on material fingerprints (i.e., scaling factors) is not advised as the mix of groundwater and subsurface contaminants may be very different from the source terms due to differing rates at which the chemical forms travel through the subsurface.

Although known subsurface soil and groundwater contamination extend close to the northern fence line, hydrogeological studies do not extend off site (to the shoreline) in this direction. Groundwater and soil have been sampled off site in this direction to verify the potential existence and/or extent of off-site contamination. This information is vital for the purposes of planning remedial actions (short or long-term) and more accurately assessing waste volumes. This same principle applies to other areas where contamination or groundwater plumes may extend beyond the site boundaries.

Early subsurface investigations of presumed clean areas are insufficient to assure that no major unexpected volumes of subsurface contamination are present e.g. from undetected leaks, or spills, or unexpected groundwater movement from known releases to the environment. There are significant planning advantages to knowing this in advance of decommissioning work, rather than encountering potential surprises during decommissioning of sub-surface features.

It appeared that some characterisation efforts may have overlooked chemical contaminants and other hazards (for example, lead and Polychlorinated Biphenyls PCBs in paint, and some hazards with respect to buildings).

The level of detail of the characterisation carried out to date and resulting reports are not fully consistent with a detailed characterisation survey as per IAEA Safety Standards Series No. WS-G-2.1. Elements which appear to be missing or weak include: contamination levels of inner surfaces of structures or components, and location information (e.g. drawings) specific enough for planning the dismantling and demolition work (beyond a very generic level). Hazards should also be well characterised and included on drawings for use while carrying out dismantling and demolition.

4. Decommissioning Approach, Technologies and Techniques

The international approach in this area is to use well understood, tried and tested methods in combination with appropriate decontamination and continuing use of containment systems. The status of Bradwell's decommissioning and dismantling was not sufficiently advanced at the time of the review to allow more than a general overview of this area.

The use of a scoring system to identify the suitability of various techniques for particular projects was commendable, as was the consideration of options to achieve a range of strategic alternatives being considered. However, the possibility for confusion of options with strategy and plans had the capability of diverting attention from the stated mission.

In addition, selection of appropriate technologies was difficult because characterisation and end-state projections appeared uncertain. The team recommended access to basic analytical facilities to assist the work of the characterisation phase.

5. Materials Management during Decommissioning

The Integrated Waste Strategy for Bradwell was found to be a useful document and contains many of the elements of a Waste Management Plan. It was thought that an extension of the effort already applied in waste characterisation would be of value in reducing the variability of waste information.

The Team recommends implementation of a waste tracking system and better volume reduction of waste through improvements in segregation and size reduction methods. They noted that there was currently no disposal route for ILW and that this was beyond the control of the Bradwell team. The review team also advised that consideration be given to development of a Very Low Level Waste (VLLW) route; one option for which was development of an on-site disposal facility.

Clearance of some material as non-radioactive was occurring in line with national regulations, although the Review Team noted that these were not consistent with international standards such as IAEA Safety Series No. 115 and IAEA Safety Standards Series No. RS-G-1.7.

The provision of buffer storage facilities, though not currently envisaged in the UK, could be useful in making decommissioning operations independent of the disposal process. In certain circumstances, for example, they could also be used as temporary waste stores for storage of metal waste pending introduction of a national melting facility.

6. Surveillance and Maintenance

The requirements for surveillance and maintenance are well understood by the Bradwell team, including the need to monitor plant condition at different stages of decommissioning and over differing timescales, some of which could be quite long (e.g., if associated with deferred dismantling). The site would meet all the requirements of WS-R-5, with the proviso that the preparations phase for C&M is still ongoing.

As decommissioning and dismantling advances, it will be important to define precisely the boundaries associated with C&M. For the physical state - to identify these on drawings; for radioactive content - to accurately establish this e.g. by defining what remains in the reactors, as well as to have made clear decisions on the final status of such e.g. ponds, vaults and boilers. Effort should be made during the preparations for C&M phase to clarify uncertainties e.g. in condition and status of underground pipework. Perhaps by undertaking an early Safety Case for C&M, missing data, missing documents, and other potential difficulties could all be identified. Similarly conducting early basic design studies for reactor dismantling would enhance cost estimation and waste management even if FSC did not take place for several decades.

The provision of a new electrical overlay system with associated rewiring of essential electrical equipment was welcome and should significantly reduce the risk of electrical accidents during dismantling.

7. Underpinning Topic Areas

The team also reviewed the areas of funding, management, planning of decommissioning and hazard management.

Throughout the review process, the team identified several project constraints such as policies, funding and waste disposal routes that were often beyond the direct control of the site or the Magnox

South. These constraints were seen to have profound effects on the overall performance of the decommissioning project at Bradwell with several of the individual constraints being interconnected at various levels, with one often having a causal link to the other.

A number of external factors were observed to be affecting the Magnox South and Bradwell decommissioning programme, namely:

i. The project is presently experiencing a significant level of changes in policy, strategy and bounding conditions. Such changes have impacted on the ability to focus on short term plans and objectives and make it difficult to establish a consolidated and stable multi-year programme.

ii. The project has received, and is expected to continue to receive, reduced and limited funding;

iii. The project has limited, or no options for disposal of some of the waste generated during decommissioning (some disposal routes are still to be decided at UK Government level);

iv. The project has not yet optimised the level or composition of human resources with the present plan for the Care and Maintenance (C&M) preparation phase;

v. The regulatory and customer reporting and approval processes are a significant work load for the site staff; and

vi. The project's strategy for the overall Baseline for Decommissioning (Lifetime Plan-08) is work in progress, which is not fully justified and has not yet received full approval of key regulators and customers.

Despite their work being affected in this way, Bradwell is commended for succeeding in applying good practice and in maintaining a safe and secure environment as work has progressed. However, whilst the team acknowledged that the areas of constraint mentioned above may not be under the direct control of Bradwell Site or Magnox South, it is believed that each has the ability to positively affect these constraints and to continue to provide advancement of the decommissioning mission in the near term.

The review team's key conclusions and recommendations for consideration by the Magnox South and Bradwell Site personnel were:

1. A plan should be developed that:

   i. reduces the C&M preparation phase through optimisation of resources and work processes that will allow more physical decommissioning work to be performed within the current funding projections;

   ii. shortens the C&M phase by incorporating more timely disposition of graphite once a national disposal option is available.

2. The process for analysing options and approaches for the work is and should continue to be performed with due care and consideration; however, more timely decisions need to be made. Preference should be given to proven techniques, rather than research and development of innovative techniques.

3. In further developing the overall characterisation plan for the site and the various systems, structures and components, there needs to be focus not only on the identification and quantification of known contamination, but also the potential for discovery of unknown contamination. This will not only benefit the preparation phase but will serve as a basis of knowledge for those responsible for implementing the Care and Maintenance phase of the decommissioning and eventual dismantlement.

4. Magnox South and the Bradwell site should continue their efforts to positively influence the policy makers and regulators to help ensure that the constraints such as waste disposition routes can be effectively and efficiently dealt with.

It should be clearly acknowledged that the Magnox South Executives, Head Office and Bradwell staff involved all supported an open and transparent review of the project, provided all requested information in a timely and thorough manner and were all extremely professional and courteous during the conduct of this review.

ANNEX B: Applicable IAEA Safety Standards

The findings and recommendations of the international peer review were based upon the international safety standards of the IAEA. The applicable IAEA Safety Standards are:

Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1 (2006).

International Basic Safety Standards for Protection Against Ionising Radiation and for the Safety of Radiation Sources, IAEA Safety Series No. 115 (1996).

Governmental, Legal and Regulatory Framework for Safety, *General Safety Requirements Part 1*, IAEA Safety Standards Series No. GSR Part 1 (2010).

Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series No. WS-R-5 (2006).

Remediation of Areas Contaminated by Past Activities and Accidents, IAEA Safety Standards Series No. WS-R-3 (2003).

Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series No. WS-G-2.1 (1999).

Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7 (2004).

Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5 (2009).

Environmental and Source Monitoring for Purposes of Radiation Protection, IAEA Safety Standards Series No. RS-G-1.8 (2005).

The review teams also drew upon additional IAEA supporting documents to supplement their findings and recommendations.

ANNEX C: Members of the International Peer Review Teams

Initial review meeting: 29 June to 7 July 2008,

BEER, Hans-Frieder	Paul Scherrer Institute, Switzerland
CLEMENT, Christopher H.	Canadian Nuclear Safety Commission, Canada
LARAIA, Michele	IAEA, Department of Nuclear Energy, Austria.
NORTON, Wayne A.	Yankee Atomic Electric Company, United States of America, Team Lead.
O'DONNELL, Patricio	IAEA, Department of Nuclear Safety and Security, Austria.
SANTIAGO, Juan Luis	ENRESA, Spain
STERNER, Hakan	EWN GmbH, Germany
TARDY, Frédéric	EDF/CIDEN Engineering Department, France

Follow up review meeting: 12-17 June 2011

CLEMENT, Christopher H.	International Commission on Radiological Protection, Canada, Team Lead.
O'SULLIVAN, Patrick J.	IAEA, Department of Nuclear Energy, Austria.
ROWAT, John H.	IAEA, Department of Nuclear Safety and Security, Austria.
STERNER, Hakan	EWN GmbH, Germany