Meeting:	NuLeAF Steering Group, 6 July 2011
Agenda Item:	4
Subject:	Fukushima Nuclear Accident: Implications in the UK
Author:	Fred Barker
Purpose:	To report on the steps being taken to consider the implications for the UK

Introduction

This report provides:

- an update on the actions taken as a result of the decisions of the April meeting of the Steering Group (SG);
- a summary of the findings of the Chief Nuclear Inspector's interim report on the implications of the accident for the UK nuclear industry; and
- a summary of the wider implications for the UK, including the proposed new nuclear build programme.

Recommendation

That the Steering Group consider whether there are specific aspects of the review of the implications of the Fukushima accident for the UK nuclear industry that it wishes Mike Weightman to focus on in his presentation to the meeting on 21 October.

Contribution to Achieving Strategic Objectives

NuLeAF does not have any strategic objectives which specifically address major nuclear accidents. However, the outcome of the review initiated in the UK may be relevant to a number of specific strategic objectives about nuclear legacy management.

1 Update on Actions from the April SG Meeting

The update on actions taken following the decisions of the April Meeting is as follows:

- the comments attached as Annex A were sent to Mike Weightman, the Chief Nuclear Inspector, in response to his call for topics to include in his review of the implications of the Fukushima accident for the UK nuclear industry;
- Mike Weightman has provisionally agreed to make a presentation to the SG meeting on 21 October on the outcome of his review; and
- Letters offering sympathy and solidarity were sent from the Chair and Vice Chair to the Japanese Ambassador in London and the Governor of Fukushima Prefecture

2 Findings of the Interim Weightman Review

The Chief Nuclear Inspector's interim report was published on 18 May. It points out that the direct causes of the Fukushima accident, a magnitude 9 earthquake and the associated 14 metre high tsunami, are far beyond the most extreme natural events that the UK would be expected to experience. It adds that the UK is, reassuringly, some 1000 miles from the edge of a tectonic plate – where earthquake activity and severity is greater. Additionally, UK nuclear power plants, both those operational and those planned, are of a significantly different design to the Boiling Water Reactors (BWR) reactors at the Fukushima-1 site. In addition, the interim report explains that the UK approach to design basis events and analysis seems different. In particular, regulators in the UK require designers and operators to ensure that adequate protection is in place for natural events of a remote nature, based on an extrapolation from the historical record. The regulators then look to see that there are no "cliff-edge" increases in risks and that more could not be reasonably done to protect against very remote events.

Against this background, the interim report concludes there is no need to curtail the operations of nuclear plants in the UK but lessons should be learnt. It also concludes that there is no need to change the present siting strategies for new nuclear power stations. It adds that for sites with a flooding risk, detailed considerations may require changes to plant layout and the provision of particular protection against flooding. On the use of MOX fuel, the interim report concludes that there is no evidence to suggest that the presence of MOX fuel in Reactor Unit 3 significantly contributed to the health impact of the accident on or off the site.

The report identifies 25 recommended areas for review - by either industry, the Government or regulators - to determine if "sensible and appropriate measures can further improve safety in the UK nuclear industry". These include reviews of the layout of UK power plants, emergency response arrangements, dealing with prolonged loss of power supplies and the risks associated with flooding. These reviews are relevant to the management of high hazard nuclear legacy facilities, as well as to operating nuclear power stations.

A number of recommendations make specific reference to arrangements for spent fuel management. These recommendations call on the industry to:

- ensure the adequacy of any new spent fuel strategies compared with expectations for passive safety and good engineering practice (recommendation 12);
- ensure that the design of new spent fuel ponds close to reactors minimises the need for bottom penetrations and lines that are prone to siphoning faults (recommendation 14); and

- review site contingency plans for pond water make up under severe accident conditions to see whether they can and should be enhanced given the experience at Fukushima (recommendation 20).

The assessment in the interim Weightman review that leads to these recommendations is set out in Annex B below.

The 10th recommendation is that the UK nuclear industry should initiate a review of flooding studies, including from tsunamis, to confirm the design basis and margins for flooding at UK nuclear sites. This should include consideration of whether there is a need to improve further site-specific flood risk assessments for any new reactors, or as part of the periodic safety review programme for existing reactors. The reviews should address sea-level protection.

The 26th recommendation calls for plans to be published by the middle of June detailing how each of the other 25 recommendations will be addressed. A more comprehensive 'lessons learned' report is to be published in September.

The interim report also refers to the development of "stress tests" for nuclear power stations, which is being undertaken in response to a request from the Council of the European Union. The interim report states that the industry should produce a common plan for responding to the "stress tests" and to the recommendations. More information about the stress tests is available at EU Nuclear Stress Tests.

The interim report is available on the HSE website at Fukushima - Interim 'lessons learnt' report.

3 Wider Implications for the UK

The Secretary of State, Chris Huhne, welcomed publication of the interim review, stating that it "provides us with the basis to continue to remove the barriers to new nuclear build in the UK" (see the statement on DECC website, Huhne welcomes interim report from chief nuclear inspector).

Subsequently, it has been reported that the National Policy Statement (NPS) on nuclear power will be published before the parliamentary recess in July. The publication of the nuclear NPS before summer is seen as vital for allowing progress on the planned nuclear power station at Hinkley in Somerset. It is reported that EDF intend to submit a planning application in October. Any application will not be able to be considered until after publication of the nuclear NPS. See http://www.building.co.uk/sectors/infrastructure/government-set-to-confirm-eight-nuclear-sites/5019854.article.

The regulators have also commented on how they will take forward the Generic Design Assessment process for new nuclear reactors. By June 2011, the regulators would have completed the assessment work necessary to make decisions on whether to provide interim Design Acceptance Confirmations (DACs) and interim Statements of Design Acceptability (SoDAs). This assessment work is also identifying the "GDA Issues" to be addressed by the requesting parties (RP) beyond June 2011. GDA Issues must be resolved to the regulators' satisfaction before they would consider issuing final DACs and SODAs and concluding GDA. In the light of Weightman review, the regulators have stated that they will not now draw conclusions from their assessments in June 2011 as planned. This will allow them to take account of relevant recommendations from the Weightman reports. However, the regulators still intend to publish the GDA Issues they have identified and the RPs' Resolution Plans in the summer. The GDA Issues will include a requirement to address any relevant recommendations from the Weightman review.

The SG may also wish to note that DECC recently completed a consultation on nuclear third party liability (see the press release on the DECC website at Proposals on liabilities for nuclear operators published). The consultation ran from 24 January to 28 April (and started before the Fukushima accident). The consultation proposed a seven-fold increase in liability for nuclear sites. The press release stated:

> Nuclear operators will be expected to take on liability of €1.2 billion for each of their sites, an increase on the current level of £140 million, under proposals outlined by Chris Huhne today.
>
> Chris Huhne, Secretary of State for Energy and Climate Change said:
>
> "The government is determined to provide certainty to low carbon investors, but there will be no public subsidy for nuclear power which is a mature technology. We are taking steps to reduce any risk of the taxpayer having to pick up the tab for new nuclear further down the track. We've already set out how operators will be required to put aside money from day one for their eventual clean up and waste storage, and now we're increasing substantially the liability to be taken on by operators."
>
> The proposal to require operators to take on liability of €1.2 billion for each of their sites follows the changes to the Paris and Brussels Conventions on nuclear third party liability and is a seven-fold increase on the current level of £140 million. It is also more than the €700m minimum required under the revised Conventions.
>
> There will also be an increase in the categories of damage for which operators are liable to include damage related to the environment. The geographical scope of those eligible to claim compensation will be widened, and any liabilities will be channelled automatically to the nuclear operator.

A response to the consultation from DECC is awaited.

Finally, it should be noted that anti-nuclear critics have strongly questioned the Weightman review process, pointing out, for example, that important submissions to the review have been taken off the Office for Nuclear Regulation's website for reasons of confidentiality, and that there has been little involvement of independent experts. Critics also argue that the nuclear NPS should not be finalised, and that various nuclear policy consultations should be suspended, until the outcome of the full review is known. For further details see the NFLA NGO Joint Response to Chris Huhne on the NFLA website.

ANNEX A: COMMENTS ON THE SCOPE OF THE REVIEW

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Dr M Weightman
HM Chief Inspector of Nuclear Installations
Head of ONR

by email

15 April, 2011

Dear Dr Weightman,

I write on behalf of the Nuclear Legacy Advisory Forum (NuLeAF) to welcome the setting up of the review into the implications of the Fukushima accident for nuclear installations in the UK and to make some suggestions for issues that should be included within its scope.

NuLeAF's primary interest in this matter concerns the potential implications for the management of legacy nuclear materials and radioactive wastes. There are several aspects of this management which we would suggest be included within scope.

These include:

- The interim management of spent fuel – for example, might there now be a stronger case for moving away from wet storage of spent fuel to dry storage systems?
- High hazard facilities – for example, is there confidence that sufficient effort and resource is being put into dealing with the legacy ponds and silos at the Sellafield site?
- Moves towards the consolidation of treatment and storage of ILW at a smaller number of sites – do issues arise that strengthen or weaken the case for such consolidation?
- Use of MOX fuel and management of spent MOX fuel – do issues arise that need to be taken into account by the Government when considering its preferred strategic option for managing UK plutonium stockpiles?
- Tolerability of risk – should the accident cause a rethink to the safety regulator's approach to judgements of what constitutes a 'tolerable societal risk'?

Special Interest Group on Nuclear Decommissioning and Radioactive Waste Management

Local Government Association

In general terms, we would like to highlight the importance of a robust and open review process that lays the foundations for developing public confidence that the lessons of the accident have been identified and can be appropriately applied.

We would also like to ask whether in principle you would be prepared to attend a future meeting of our Steering Group to explain the review findings, particularly as they pertain to nuclear legacy management issues.

Yours sincerely,

Fred Barker

ANNEX B: EXTRACTS FROM THE WEIGHTMAN INTERIM REVIEW RELATING TO SPENT FUEL MANAGEMENT

Spent Fuel Pond Factors the Fukushima accident

178 The challenges to the safe storage of spent fuel arose from three sources:

1. The loss of pond water cooling and top up capability. This was especially acute in reactor pond 4 which contained over 1300 irradiated fuel assemblies (around 2.5 cores worth), including a recent core off load from November 2010. The pond will have had the largest decay heat loading of any of the reactor storage ponds.
2. Structural damage to the reactor ponds and containment. The condition of the ponds is unknown, but the need for urgent action early in the event timeline might suggest damage to the ponds or pipes and loss of water. The proximity of the ponds just above the reactors increases the risk of pond degradation and loss of systems. The damage to the outer structure around the fuel ponds and handling areas provides a direct escape route to the environment for any activity released from the spent fuel. It is likely that debris resulting from damage to the building has fallen into the storage ponds, and this may have created local blockages in the fuel storage racks leading to local overheating. However, one positive thing arising from the damage to the outer containment is that it did simplify the process of introducing sea-water into the plant either via helicopter or spray. The situation of the large fuelling crane used to off load fuel is not known.
3. The effects of the earthquake on the spent fuel are not known, but it is likely that the fuel was violently shaken resulting in impacts between the fuel assemblies and the storage racks, and with the pond walls. Fuel rods may have been significantly damaged during this event. Storage racks may have been distorted and their spatial arrangement changed possibly eroding margins to criticality safety. Building debris falling into the ponds may block the water cooling pathways in the fuel leading to local overheating.

179 There was a lot of spent fuel in the ponds. In March 2010 it was reported that the storage facilities on-site were 84 percent full, although most of this was in the common pool which appears to have been unaffected.

180 The site had recently moved to high-density storage racks which further increased the heat loading in the ponds (particularly in reactor 4 pond which contained 2.5 cores worth of fuel).

181 It is easy to speculate on what did or did not happen to the spent fuel during the Fukushima accident, however it may be some time until it is known what really happened. However, one of the root causes was decay heat generation within the spent fuel. In the longer term it may be worthwhile to review the cumulative effects of those factors that may have increased decay heat loading in the fuel above design, in the pond (e.g. accumulations of significant amounts of spent fuel, high density storage racks) alongside the robustness of the pond structures water management systems and the adequacy of the original pond cooling system designs.

182 The spent fuel storage ponds are massive concrete and steel structures which are designed to withstand natural hazards. It is not clear what seismic criteria were applied to the design of the storage ponds, but these may have been less than the massive earthquake that was experienced in Japan on 11 March 2011. It is likely that data from the Fukushima accident may allow a good comparison between design criteria and real plant behaviour during significant seismic events.

183 The possibility of a zirconium fire in the spent fuel storage pools was discussed within ONR and with other nuclear regulators around the world. There does not appear to be a general consensus on the conditions required to cause ignition, or the amount of cooling time that the spent fuel requires to eliminate the possibility of ignition.

184 It is not clear if any significant releases of radioactivity occurred from the storage ponds. However, the fact that the operators undertook a number of difficult and dangerous tasks to deliver sea water to the storage ponds of Reactor Units 1 to 4 indicates that they were concerned about such an event happening. It is likely that these actions prevented further escalation and radioactivity release during the Fukushima accident. The decision to use sea-water was inevitable given the seriousness of the situation and the lack of fresh water supplies. The build up of salt depositions in the storage ponds is likely to have a limited effect given that neither the fuel nor the facilities will be operated in the future. Overall it is considered that the use of sea-water (and more recently freshwater) was essential in preventing a significant escalation of the Fukushima accident.

UK Reactor Site Spent Fuel Storage

272 Keeping the spent fuel ponds filled with water and adequately cooled has been a challenge at Fukushima following the earthquake and tsunami. As has been discussed earlier, the water inventory in the ponds needs to be maintained to protect the fuel from failing, to provide shielding, to prevent hydrogen formation and to avoid fuel fires.

273 None of the operating UK reactors have identical fuel or spent fuel facilities to those at Fukushima. Magnox fuel assemblies are clad in a magnesium alloy whilst the AGR fuel is clad in stainless steel therefore the chemical reactions of the cladding at raised temperatures and when exposed to steam/air are different from those experienced by zirconium alloys. However, the strategy of storing fuel underwater in cooled ponds is one which is utilised at almost all UK operating reactor sites during some of the fuel route cycle after removal from the reactors.

274 It should be noted that in the UK both AGRs and Magnox reactors use batch refuelling, so whole reactor core fuel inventories are not offloaded into the fuel ponds.

275 A summary of the spent fuel storage capabilities in the UK is provided below.

Advanced Gas-cooled Reactors

276 There are a number of design differences between the stations, but the overall fuel storage philosophy is the same. The fuel is discharged from reactor into a refuelling machine which is used to move the fuel to a dry buffer store pressurised with carbon dioxide. The fuel remains in the buffer stores for around 60 days to allow the decay heat to reduce. The spent fuel is then moved to a dismantling facility and then transferred to a water filled storage pond were it continues its storage period. The fuel in the storage pond is held in skips that can accommodate up to 15 fuel elements each. After at least 100 days storage the spent fuel is loaded into a transport flask and moved to Sellafield where it is either reprocessed or continues its storage.

Magnox reactors

277 At Oldbury spent fuel is discharged from the reactors into the refuelling machine which transfers the fuel to a discharge tube connected to the station pond. The spent fuel is stored in skips under water in the pond. The fuel remains in the storage pond for at least 90 days prior to loading into a flask for transport to Sellafield where the fuel is reprocessed.

278 At Wylfa spent fuel is discharged from the reactor into the refuelling machine which transfers the fuel to a dry storage facility. The fuel remains in storage in one of three dry stores which are pressurised with carbon dioxide. Once the spent fuel has cooled sufficiently it can be moved to two other on-site facilities that store the fuel in dry air. The fuel remains in the stores for at least 90 days prior to loading into a flask for transport to Sellafield where the fuel is reprocessed.

Sizewell B

279 Spent fuel is removed from the reactor under water during a station refuelling outage. The fuel is transferred via a water-filled canal to the station pond. The station pond can accommodate up to 1500 fuel assemblies and much of this in high-density stage racks. All of the Sizewell B fuel is stored in the fuel pond, although the station intends to develop a dry storage capability in a few years time.

Generic Design Assessment (UK EPRTM and AP1000*TM*)

280 UK EPRTM and AP1000TM have similar strategies to that currently in place at Sizewell B. Fuel is transferred via an underwater canal, from the reactor to a fuel storage pond located outside the reactor containment in a contiguous building which is part of the nuclear island. Westinghouse and EDF and AREVA are developing plans to move spent fuel, after approximately 15 years of pond cooling, to additional on-site storage facilities for longer term storage.

Magnox Limited

322 This response notes that Magnox Limited run two operating reactor sites, three sites undergoing defueling and five sites undergoing decommissioning. The following responses on spent fuel storage were noted:

- *“Wylfa and Oldbury have irradiated fuel stored on-site in dry stores (Wylfa) and ponds (Oldbury). These will also be considered as part of the company’s safety case review (see below) especially as experience from Fukushima demonstrates the importance of controlling fuel temperatures. This will be important for both Wylfa and Oldbury due to the presence of short cooled fuel in their storage facilities.”*
- *“For sites only undertaking defueling, i.e. Chapelcross, Dungeness and Sizewell, the reactor risk is lower since these sites have been shutdown for over four years and fuel cooling is now achieved passively. Therefore, for these three sites the concern would be events that prejudiced the fuel storage ponds such that there may be a loss of the radiological shielding provided by the water. Although less of an issue in terms of off-site release and dose to members of the public, recovery actions by the operator would be difficult and further operator guidance and/or facilities may be appropriate in response to such an event.”*
- *“Recognising the role of the operator in responding to extreme events it would be prudent to review our* [Magnox Limited] *SBERGs (Symptom Based Emergency Response Guidelines) and SAGs (Severe Accident Guidelines) to determine if any improvements could be made. Training in and practicing of the deployment of these guidelines will also be considered.”*

EDF Energy (Existing Fleet)

324 EDF Energy’s response provides a view on the seven AGR sites and the Sizewell B PWR. Its preliminary response was:

- *“The AGR fuel ponds and buffer stores are water-cooled. For the newer AGRs, there is redundancy and diversity in these systems; for the older AGRs arrangements are in place to provide defence in depth.”*
- *“At Sizewell B fuel is stored in the fuel storage pond with a minimum of eight metres of water above the top of the active fuel. Water can be made up from numerous systems but if these are not available then provision is provided to provide make up water using a fire tender parked outside of the fuel building via an engineered penetration into the fuel building.”*

Spent Fuel Strategies

384 A complicating factor in the Fukushima accident was the spent fuel stored on the site, particularly in fuel ponds inside the reactor buildings. In the case of the Reactor Unit 4 pond, there were at least

two and half cores worth (1,331 elements) of spent fuel held in the pond located very near to the reactor.

385 In addition, around 6,000 spent fuel elements are held in the main storage pond on site, with further quantities in dry storage casks. These facilities do not appear to have contributed to the problems at the Fukushima site.

386 In the reactor building spent fuel ponds, the operators had employed increased packing density of the spent fuel elements due to decreasing spare capacity in the ponds. Before increasing the packing density in any spent fuel pond, consideration has to be given to criticality accidents and to the fuel pond cooling capabilities, both for normal operation and for accident situations. Increased packing density will also shorten the time available after a loss of cooling accident before the fuel pond begins to boil. This therefore puts greater onus on the reliability of the cooling systems and on operator remedial action in the event that normal cooling is lost.

387 The quantities of spent fuel held at the site may well reflect a wider issue of dealing with spent fuel in Japan when the full operation of the new national reprocessing plant is running behind schedule, and with limited availability of alternative fuel reprocessing facilities across the world. We understand that some consideration is being given in Japan to constructing a centralised spent fuel store away from the coast. In the UK, except for Sizewell B, the existing operating reactors send fuel to Sellafield for storage and reprocessing thus minimising spent fuel storage at sites other than at Wylfa where a dry store is located. Even at Wylfa the quantity of spent fuel stored on site is modest, about 25 percent of a reactor core load, and is generally passively cooled.

388 The individual spent fuel storage ponds in the Fukushima plants are located at height, in close proximity to the reactors. This close proximity clearly presents the possibility of an accident in one part of the plant affecting the other. Given this, there would appear to be good safety reasons to minimise (ALARP) the amount of spent fuel in each such pond, especially when a core's worth of hot fuel is unloaded at once. In the case of gas-cooled reactors only relatively small amounts of hot fuel are required to be unloaded at any one time. In the UK, this approach would be reinforced through one of our SAPs (No. ENM.6) states:

"When nuclear matter is to be stored on site for a significant period of time it should be stored in a condition of passive safety and in accordance with good engineering practice."

389 We consider that the UK nuclear industry should consider any new spent fuel strategies employed for its plants to ensure that this principle is fully adopted. There is the possibility that this may enhance the drive for different approaches to spent fuel management in the future with earlier conditioning or treatment into more demonstrably passive safe forms.

Recommendation 12: The UK nuclear industry should ensure the adequacy of any new spent fuel strategies compared with the expectations in the Safety Assessment Principles of passive safety and good engineering practice.

390 This may also be usefully considered in the provision of more spent fuel storage at Sizewell B.

Fuel Pond Design

393 It is not yet known what has caused the reactor ponds, especially Fuel Pond 4, to lose water to the extent that appears to have happened. The amount of water still being pumped into the ponds indicates that at least Reactor Unit 4 Fuel Pond is losing water through some mechanism other than evaporation, e.g. through leakage from structural failure of the pond. The TEPCO roadmap for restoration of the site includes measures to install a supporting structure over the next three months which may indicate concerns about the pond's structural integrity.

394 Examination of some outline process flow drawings for the reactor building pond cooling systems indicates that there are some pipelines penetrate the bottom of the interconnecting structure of the pond. Fractures of these could account for some water loss. There is also the possibility of water loss by siphoning from fractured fully flooded pipes that enter the pond from above.

395 More details are required on the design and condition of the fuel ponds at Fukushima-1 before definitive lessons can be learned in relation to spent fuel pond design. However, we consider it good practice for any new designs of reactor spent fuel ponds for bottom entry penetrations and lines without siphon breaks to be minimised, and any that are necessary are robust to faults to potential faults.

Recommendation 14: The UK nuclear industry should ensure that the design of new spent fuel ponds close to reactors minimises the need for bottom penetrations and lines that are prone to siphoning faults. Any that are necessary should be as robust to faults as are the ponds themselves.

410 For the Fukushima-1 site there was a need to adopt diverse and unplanned means to provide coolant for the fuel ponds given the lack of normal water supplies and heat exchangers, and damage caused by the hydrogen explosions and fires. The use of articulated pumping equipment normally used to deliver concrete appears to have been particularly useful. In the UK, although there are contingency provisions for pond water make up, we consider that these should be reviewed in light of the experience in Japan to determine whether they can and should be enhanced. It is noted that for the UK fleet of AGR and Magnox reactors there is more limited storage of spent fuel on site as it is shipped to Sellafield.

Recommendation 20: The nuclear industry should review site contingency plans for pond water make up under severe accident conditions to see whether they can and should be enhanced given the experience at Fukushima.