EDF Energy

Japanese Earthquake Response Programme

ONR Recommendation Closeout Report

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Glossary

AACP	Alternate Access Control Point
AC	Alternating Current
ACP	Access Control Point
AECC	Alternative Emergency Control Centre
AGR	Advanced Gas-cooled Reactor
AIC	Alternative Indication Centre
ALARP	As Low As Reasonably Practicable
ASR	Auxiliary Shutdown Room (Sizewell B)
AWE	Atomic Weapons Establishment
BCDG	Battery Charging Diesel Generator
BDB	Beyond Design Basis
BGS	British Geological Survey
BLP	Bottom Line Plant
BUCESC	Back-Up Central Emergency Support Centre
BUCS	Back-Up Cooling System
BUECC	Back-Up Emergency Control Centre
BUFS	Back-Up Feed System
BWR	Boiling Water Reactor
CATS	Clean Air Train System
CCR	Central Control Room
CEEHG	Civil Engineering External Hazard Group
CEMS	Continuous Emergency Monitoring System
CESC	Central Emergency Support Centre
CO	Carbon Monoxide
COBR	Cabinet Office Briefing Room
COTS	Commercial Off the Shelf
CR	Condition Report
CSA	Comprehensive Safety Assessment/Stress Test Consideration
CTO	Central Technical Organisation
CTS	Company Technical Standard
CW	Cooling Water
CWI	Containment Water Injection
DA	Design Authority
DB	Design Basis
DBE	Design Basis Event
DBUE	Deployable Back-Up Equipment
DBUEERT	Deployable Back-Up Equipment Emergency Response Team
DBUEG	Deployable Back-Up Equipment Guideline
DC	Direct Current
DCIS	Deployable Communications and Information System
DCS	Diverse Cooling System
DECC	Department for Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DEPZ	Detailed Emergency Planning Zone
DG	Diesel Generator
DNB	Dungeness B (AGR)
DNO	Distribution Network Operators
DRT	Damage Repair Tools

EAN	Engineering Advice Note
EC	Engineering Change
ECC	Emergency Control Centre
EDF SA	Electricité de France Société Anonyme
EDG	Essential Diesel Generator
EEFIT	Earthquake Engineering Field Investigation Team
EES	Essential Electrical System
EHV	Extra High Voltage
EIC	Emergency Indication Centre
EMIT	Equipment Maintenance, Inspection and Testing
ENSREG	European Nuclear Safety Regulators Group
ENTSO-E	European Network of Transmission System Operators for Electricity
EOS	Electrical Overlay System
EPG	Emergency Planning Group
ERC	Emergency Response Centre
EU	European Union
EVA	Extreme Value Analyses
FCP	Forward Control Point
FCV	Filtered Containment Venting
FDS	Forward Deployment Service
FJFP	Fixed Jet Fire Pump
FR	Final Recommendation
GIS	General Instrument Supplies
GMC	Ground Motion Characterisation
GMPE	Ground Motion Prediction Equations
GT	Gas Turbine
HF	Human Factors
HNB	Hunterston B (AGR)
HP	High Pressure
HPA	Health Protection Agency
HPB	Hinkley Point B (AGR)
HPBUCS	High Pressure Back-Up Cooling System
HPC	Hinkley Point C
HR	Human Resources
HRA	Hartlepool (AGR)
HV	High Voltage
HVAC	Heating Ventilation and Air Conditioning
HYA	Heysham 1 (AGR)
HYB	Heysham 2 (AGR)
IAEA	International Atomic Energy Agency
ICP	Integrated Company Practice
INA	Independent Nuclear Assurance
INES	International Nuclear Event Scale
INPO	Institute of Nuclear Power Operations
INSAG	International Nuclear Safety Group
IR	Interim Recommendation
JER	Japanese Earthquake Response
LAN	Local Area Network
LC	Licence Condition
LOOP	Loss of Off-site Power

LP	Low Pressure
LPBUCS	Low Pressure Back-Up Cooling System
LV	Low Voltage
LWR	Light Water Reactor
MCCI	Molten Core Cooling Interaction
MCR	Main Control Room
MHWS	Mean High-Water Spring
MIRA	Motor Industry Research Association
MITS	Maintenance Inspection and Testing Schedule
MSM	Management System Manual
MUS	Make-Up Shield
M_w	Moment Magnitude
NDA	Nuclear Decommissioning Authority
NEAF	Nuclear Emergency Arrangements Forum
NEPDC	Nuclear Emergency Planning Delivery Committee
NEPLG	Nuclear Emergency Planning Liaison Group
NG	Nuclear Generation
NG Exec	Nuclear Generation Executive
NGA	New Generation Attenuation
NGET	National Grid Electricity Transmission
NII	Nuclear Installations Inspectorate
NNB GenCo	Nuclear New Build Generation Company
NP	Nuclear Power
NSAN	National Skills Academy for Nuclear
NSC	Nuclear Safety Committee
NSLPA	Nuclear Site Licence Provisions Agreement
NSP	Nuclear Safety Principles
OH	Occupational Health
ONR	Office for Nuclear Regulation
OPEX	Operating Experience
PAR	Passive Autocatalytic Hydrogen Recombiner
PCPV	Pre-stressed Concrete Pressure Vessel
PGA	Peak Ground Acceleration
PHE	Public Health England
PICA	Periodic Safety Review Identified Corrective Action
POC	Proof of Concept
POI	Plant Operating Instruction
PPE	Personal Protective Equipment
PSA	Probabilistic Safety Analysis
PSHA	Probabilistic Seismic Hazard Assessment
PSR	Periodic Safety Review
PTC	Post Trip Cooling
PVCS	Pressure Vessel Cooling System
PVCW	Pressure Vessel Cooling Water System
PWR	Pressurised Water Reactor
RCS	Reactor Coolant System
REPPIR	Radiation Emergency Preparedness & Public Information Regulations 2001
REVL	Routine Evaluation
RIMNET	Radioactive Incident Monitoring Network
RPS	Reactor Protection System

RPV	Reactor Pressure Vessel (PWR)
RTS	Return To Service
RWST	Reserve Feedwater Storage Tank
SAG	Severe Accident Guideline
SAMG	Severe Accident Management Guidelines
SAP	Safety Assessment Principle
SBERG	Symptom Based Emergency Response Guideline
SBO	Station Black Out
SCS	Satellite Communication System
SDF	Station Director Forum
SHWP	Seismic Hazard Working Party
SOER	Significant Operating Experience Report
SOI	Station Operating Instruction
SP	Scottish Power
SPOS	Safe Place On Site
SQEP	Suitably Qualified and Experienced Personnel
SQUG	Seismic Qualification Utility Group
SSC	Seismic Source Characterisation
SSC	Structures, Systems and Components
SSHAC	Senior Seismic Hazard Analysis Committee
STF	Stress Test Finding
SZB	Sizewell B (PWR)
TAG	Technical Assessment Guidelines
TEPCO	Tokyo Electric Power Company
TiiMs	The incident information Management System
TLMP	Through Life Management Partner
TOR	Torness (AGR)
UPS	Uninterruptible Power Supply
URS	Uniform Risk Spectrum
VCS	Vessel Cooling System (see PVCS)
VOIP	Voice Over Internet Protocol
VOPE	Vessel Over-Pressure Protection Equipment
WANO	World Association of Nuclear Operators
WCHF	Watchet Cothelstone Hatchet Fault

Executive Summary

This report describes how EDF Energy is enhancing the resilience of its fleet of nuclear power stations to mitigate against extremely unlikely but potentially high impact natural environmental events. This enhancement is being delivered by modifications to each of EDF Energy's nuclear sites, combined with the provision of an array of back-up equipment, enhanced procedures and additional training of emergency responders.

The purpose of this document is to provide close-out reports on each of the UK's Office for Nuclear Regulation's (ONR) Interim and Final Recommendations and Stress Test Findings, representing three years' work.

EDF Energy, part of the EDF Group, is one of the UK's largest energy companies and the largest producer of low-carbon electricity, generating around one fifth of the UK's electricity and employing around 15,000 people. The Generation business operates a fleet of eight nuclear power stations (comprising 15 reactors) in the UK with a combined capacity of almost 9,000 megawatts – electricity that is vital to the UK economy.

EDF Energy established the Japanese Earthquake Response (JER) programme in March 2011, in response to the International Nuclear Event Scale 7, 'Major accident', at the Fukushima Dai-ichi Nuclear Power Plant on the East Coast of Japan. In the days and weeks following the accident, nuclear operators and regulators around the world worked to understand the sequence of events and determine the factors leading to its severity, amongst the devastation of the earthquake and tsunami.

The JER programme objective was to process the information from Japan, review the safety of EDF Energy's fleet of nuclear power stations in the UK and to ascertain the possible safety implications and implement any improvements, based on natural hazards relevant to the UK. The programme also proactively responded to regulator requests for information, both nationally and internationally, and responded promptly to recommendations from regulators and peer groups such as World Association of Nuclear Operators (WANO).

The principal outcome of the JER programme has been to improve the resilience of EDF Energy's nuclear plants to extremely unlikely but potentially high impact events, through a combination of reasonable and practical improvements to improve a station's ability to withstand, deal with and recover from an extremely unlikely but high impact event up to and beyond a 72 hour mission time. At the same time, EDF Energy has ensured the continued adequacy of existing safety cases with respect to external natural hazards coverage, in the context of what has been learned from Fukushima. This assessment of resilience implicitly incorporates a demonstration of the absence of "cliff-edge" effects at the design basis boundary, via the existence of margins.

Recognising that nuclear events have a global impact, EDF Energy fully supports the recommendations and findings from the ONR and international organisations such as European Nuclear Safety Regulators Group (ENSREG) and WANO. Furthermore, in developing the programme of work, EDF Energy has worked closely with both national and international licensees including the wider French EDF Group, operators in the US and other UK licensees, ensuring that the international response is understood and that EDF Energy's approach is in line with best practice whilst appropriate for the natural hazards faced in the UK.

The three year JER programme has ensured the continued adequacy of existing safety cases with respect to external hazards, in the context of what has been learned from Fukushima. In addition, the demonstration of the existence of margins beyond the design basis gives confidence in the ability to withstand extremely unlikely but severe natural hazards. This work informed an extensive programme of resilience enhancements across the fleet of eight nuclear power stations, in addition to the procurement of a large quantity of Deployable Back-Up Equipment that is in a continuous state of readiness with emergency responders trained and procedures developed to allow the deployment and use of this enhanced capability should it be required in support of any event.

1 Introduction

1.1 The Events at Fukushima Dai-ichi Nuclear Power Plant

On 11th March 2011, a 9.0M_w earthquake struck at 14.46 Japan Standard Time, with the epicentre approximately 43 miles off the east coast of Japan. Approximately forty-one minutes later the first of a series of tsunamis struck the coast of Japan, resulting in the deaths of 19,000 people and an International Nuclear Event Scale 7, 'Major accident', at the Fukushima Dai-ichi nuclear plant.

Leading up to the tsunami and immediately following the earthquake, eleven operating reactor units in the region were shutdown automatically due to seismic Reactor Protection System (RPS) trips.

At the Fukushima Dai-ichi Nuclear Power Plant, operated by Tokyo Electric Power Company (TEPCO), units 1, 2, and 3 were tripped by the seismic RPS; units 4, 5 and 6 were out of service for refuelling and maintenance. The earthquake damaged power distribution towers and electrical circuit breakers, causing loss of all off-site power to the site. This led to the automatic start up of the on-site emergency diesel generators, which provide Alternating Current (AC) power to emergency systems, and successfully initiated post-shutdown core cooling and spent fuel pond cooling.

The first of a series of seven tsunamis arrived at site, with a maximum height impacting the site estimated to be between 14 and 15m. This exceeded the Design Basis (DB) tsunami height of 6.1m and was above the site ordnance datum levels of 10m at units 1-4. All AC power for units 1-5 was lost when emergency diesel generators and switchgear rooms were flooded. All Direct Current (DC) power was lost on units 1, 2 and 4, whilst on unit 3 limited DC power was available as some of its battery banks had not been flooded. One air-cooled diesel generator remained and provided electrical power to unit 6, and later to unit 5.

With no core cooling to remove decay heat, core damage began on unit 1 on the day of the event. Steam-driven injection pumps were used to provide cooling water to the reactors on units 2 and 3, but these pumps eventually stopped working, resulting in fuel damage in these units. After debris caused by the tsunami was removed, fire engines were moved into position and connected to plant systems to restore water injection. Connection points had been installed previously to support fire protection procedures, but the plant staff had difficulty locating them initially because of the debris and because drawings had not been updated to show their locations.

During the event, containment pressure remained high for an extended time, contributing to hydrogen leakage from the primary containment vessel and inhibiting injection of water to the reactors using low-pressure sources.

Hydrogen generated from the damaged fuel in the reactors then accumulated in the reactor buildings and ignited, producing explosions in the unit 1 and unit 3 reactor buildings and significantly complicating the response. The hydrogen generated in unit 3 likely migrated into the unit 4 reactor building, resulting in a subsequent explosion and damage. The loss of primary and secondary containment integrity resulted in ground-level releases of radioactive material. Following the explosion in unit 4 and the abnormal indications on unit 2 on the fourth day of the event, the site superintendent directed that all non-essential personnel temporarily evacuate for their safety, leaving approximately 70 people on site to manage the event.

Over the following weeks and months the situation at Fukushima stabilised, with TEPCO employees, fire-fighters and the Japanese Self-Defence Force working around the clock to clear debris and provide water coolant to the damaged reactors and spent fuel ponds. On 16th December 2011, Japan's Prime Minister Yoshihiko Noda announced that cold shutdown, with fuel rod temperatures below 100°C, had been achieved at all Fukushima Dai-ichi units. Nevertheless, active cooling of the spent fuel in reactors and fuel ponds continues as necessary, in preparation for eventual removal.

1.2 Natural Hazards in the UK

The risk from natural hazards in the UK is different to that experienced in Japan. Geological factors dictate that an earthquake of the severity that caused the Fukushima accident is not credible in the UK and therefore the risk from inundation by tsunamis is lower. However the risk must still be considered in the development of nuclear power facilities, alongside the risk of other natural hazards and external events in the UK. Hazards considered include, amongst others, earthquakes, flooding, weather effects and climate change.

The nature of the event at Fukushima Dai-ichi, and therefore the focus of the subsequent reviews undertaken across the nuclear industry, is based on the natural external hazards which have the potential to damage or disable multiple safety systems across a site. In some cases, such as seen at Fukushima, not only is the plant affected by the initial event, but there are also consequential effects such as flooding from tsunamis.

EDF Energy's Nuclear Safety Principles (NSPs) require consideration of internal and external hazards in safety cases. The NSPs define the DB for external hazards as an event with an annual probability greater than or equal to 10^{-4}, that is a return frequency of less than 0.0001 per year, or in other words may occur less than once in every 10,000 years. Furthermore, the NSPs require the demonstration that there is no disproportionate increase in risk beyond this frequency, i.e. no "cliff-edge" effect.

The equipment that is claimed to provide the essential safety function during and following the hazard is demonstrated to withstand the event through a process of qualification. This can take many different forms but is essentially a thorough assessment of the ability of the claimed equipment or operator action to perform as required, even when the plant has been affected by the external event. Qualification can be through segregation from the challenge, e.g. the equipment is located above the maximum flood level, or demonstration that it can be exposed to the challenge and still function, e.g. the maximum peak ground acceleration from the DB earthquake.

In 1996, the first systematic review of Advanced Gas-cooled Reactor (AGR) safety cases against a list of potential hazards was completed as part of the first Periodic Safety Reviews (PSR1) for Hinkley Point B (HPB) and Hunterston B (HNB). PSR1 considered a wide range of potential internal and external hazards and established the basis for a safety case with respect to these. The list of hazards was further developed as part of PSR2 which confirmed that NSP2.4 was consistent with the International Atomic Energy Agency (IAEA) recommendations current at that time, for the consideration of hazards within nuclear safety cases, with the notable exception that drought, biological fouling, electro-magnetic interference and lightning were not included in the NSP listing. The PSR2, from 2006 onwards, formalised the requirement for these four hazards to be brought into the AGR safety cases. Consequently, these are now considered in AGR safety cases. In 2013, after operational challenges at HNB during previous years because of volcanic activity in Iceland and increasing concern over the potential impact of solar storms, two new hazards were added: Airborne Particulates and Solar Storms.

1.3 The UK and EU Response

Following the events of Fukushima, the UK Secretary of State for Energy and Climate Change requested that Dr Mike Weightman, at the time HM Chief Inspector of Nuclear Installations and Head of ONR, to prepare a report on the implications of the events in Japan and lessons to be learned by the UK nuclear industry. An interim report was requested by mid-May 2011, with a final report to be provided within 6 months. The reports were to be 'comprehensive, wide in scope and based on the best technical advice, consulting nationally and internationally with colleagues and organisations'. The reports included ONR recommendations; Interim (IR) and Final (FR), for the UK nuclear industry to address in responding to events in Fukushima.

In addition, the European Council, on 25th March 2011, requested that the safety of all EU nuclear plants was reviewed, on the basis of a comprehensive and transparent risk and safety assessment ('stress test'). The stress tests were defined as targeted reassessments of the safety margins at nuclear power plants, with the scope developed by the ENSREG and the European Commission. Nuclear operators throughout Europe were given responsibility for delivery of the stress tests, which were to be reviewed and summarised by national regulators, to produce a National Report for peer review across ENSREG member states. Within the UK national report, the ONR incorporated a series of Stress Test Findings (STFs), identifying areas for review and improvement of safety margins against severe events. These were in addition to the Considerations that EDF Energy incorporated in to its stress test reports and that are also reported on to the ONR.

Furthermore, during a series of peer review visits by ENSREG members, a Country Report was issued by ENSREG for each member country, the UK's being issued in April 2012. This report also contained a number of findings and conclusions.

Following this, in December 2012 the ONR issued its National Action Plan which detailed how the regulator would ensure that the scope of work identified via the aforementioned reports and stress tests is followed-up, completed and reported on. The national action plans for all participating countries, including the UK, were peer reviewed at a workshop held by ENSREG in April 2013.

It should also be noted that several neighbouring countries outwith the EU also took part in the stress test process, namely Switzerland, Turkey and Ukraine.

In addition to the UK and European responses, WANO issued Significant Operating Experience Report (SOER) 2011-2, 'Fukushima Daiichi Nuclear Station Fuel Damage Caused by Earthquake and Tsunami', requiring urgent review and response from its members, including EDF Energy. This was followed later in 2011 by Fukushima based SOERs 2011-3 and 2011-4, and then in 2013 by SOER 2013-2.

This document individually addresses and closes out each one of the ONR IRs and FRs from the Dr Weightman reports and the ONR STFs from their National Report on the ENSREG Stress Test process, describing how EDF Energy has taken reasonable and practical steps to enhance the ability of its fleet of power stations to withstand and recover from a severe event beyond the existing robust DB, giving confidence that a 72 hour mission time can be achieved via a combination of on-site and off-site facilities.

The structure of the report aims to give an overview of the scope of work that EDF Energy has undertaken (Section 2), conclusions (Section 3) and close-out reports on each of the Interim and Final Recommendations and Stress Test Findings (Sections 4, 5, and 6).

2 The EDF Energy Response

EDF Energy responded to the events at the Fukushima Dai-ichi nuclear accident by immediately establishing a response team even as the accident unfolded in Japan. This team provided support to the ONR and government with expert analysis on the events in Japan as well as providing information on EDF Energy's fleet of nuclear power stations as requested, to inform government and the public as required. The JER programme subsequently undertook a systematic review of EDF Energy's fleet of nuclear power stations to assess safety and ensure that all existing systems, procedures and training were fit for purpose to deal with DB events. The JER programme has since developed an understanding of where possible improvements could be made for extreme events classed as Beyond Design Basis (BDB). These are events that are more severe than the station safety features were designed to withstand, and have a return frequency of less than 0.0001 per year, or in other words may occur less than once in every 10,000 years.

The JER programme included a wide-reaching (fleet-wide and corporate) review of the operational experience gained following the events in Japan and the resultant reports from the ONR, ENSREG, WANO and International Nuclear Power Operators (INPO). This was followed by the consideration and delivery of a programme of work including physical and organisational modifications, in addition to the provision of equipment required to deal with a severe event based on the reviews and reports.

The principal objective of the JER programme was to improve the resilience of EDF Energy's nuclear plants to severe natural hazards, through a combination of reasonable and practical improvements in the following areas, to improve a stations ability to withstand, deal with and recover from an extremely unlikely but severe natural hazard, up to and beyond a 72 hour mission time:

- On-site Resilience Enhancements – Improve key plant systems and building resilience to severe events and engineer connection points for the additional back-up equipment post event. See Section 2.2.1
- Additional Deployable Back-up Equipment – Procure additional Deployable Back-Up Equipment (DBUE) to prevent fault escalation and allow faster recovery post event. See Section 2.2.2
- Emergency Planning Arrangements – Enhance Emergency Planning Arrangements to address severe events. See Section 2.2.3
- Further Review and Assessment – Deliver and close the issues identified in the stress test reports, including further analyses on extreme weather events, margins and "cliff-edge" effects. See Section 2.2.4
- Openness and Transparency – Improve the openness and transparency of the UK nuclear industry. See Section 2.2.5
- Proof of Concept – Demonstrate EDF Energy's enhanced capability to respond to severe events. See Section 2.2.6

As a responsible nuclear operator, there is significant commitment on the part of EDF Energy to respond in a positive and pro-active manner to any matters concerning nuclear safety, such as the recommendations and Operational Experience (OPEX) arising from the Fukushima nuclear accident. As a nuclear site licence holder, there is also a legal requirement for EDF Energy to consider how the knowledge and learning from OPEX might be applicable to its sites, plant and people, to limit the occurrence or consequences (nuclear, industrial and environmental) of similar adverse events in the UK.

The EDF Energy JER programme can be seen as two distinct phases, which are discussed below. This report then provides a response to each of the ONR IRs, FRs and STFs.

2.1 JER Programme Phase 1

The EDF Energy JER programme initial phase of work, in 2011, involved:

- An initial Board meeting, confirming that ongoing operations were justified, followed by a letter to the ONR confirming that an immediate review of training, emergency preparedness and equipment readiness would be carried out across EDF Energy's fleet of eight nuclear power stations

- Co-ordinating the compilation of the ENSREG stress tests, in accordance with the ENSREG specifications
- Reviewing and responding to Dr Weightman's Interim and Final Reports; ONR required periodic progress updates on their recommendations and the considerations raised by EDF Energy in the stress test reports
- Processing OPEX; to understand the sequence of events in Japan and how the International Nuclear Event Scale (INES) rated 'major nuclear accident' could have been averted
- Considering areas for improvement at UK sites. Subsequent to fleet wide reviews looking at preparedness for both DB and BDB events, initial optioneering exercises were carried out with input from technical experts and nuclear site representatives to determine the most effective way of further protecting EDF Energy's nuclear sites.

Simultaneous to this, a significant quantity of work was delivered by the ONR:

- 18th May 2011 -The Interim Report ("HM Chief Inspector's Interim Fukushima Report") was issued which looked at the initial implications and lessons learned for the UK nuclear industry. As well as 26 recommendations, the Interim report also contained 11 conclusions for the UK nuclear industry, with Conclusion 1 stating:
    - *'In considering the direct causes of the Fukushima accident we see no reason for curtailing the operation of nuclear power plants or other nuclear facilities in the UK. Once further work is completed any proposed improvements will be considered and implemented on a case by case basis, in line with our normal regulatory approach.'*
- September 2011 - The ONR Final Report was issued which looked at the final implications and lessons learnt from Fukushima. This report outlined a number of conclusions in two categories- 'those related to our consideration of the UK nuclear safety philosophy and regulatory regime reflecting on the circumstances and known facts of the Fukushima accident, and those relating to our review of the information in relation to our Interim Report conclusions.'
- 31st October 2011 - The stress tests were completed on time by EDF Energy. Following assessment of their content, ONR confirmed 'that the UK licensees have completed adequate stress test reviews in line with the ENSREG specification'. ONR then prepared the UK National Stress Test report and submitted it to ENSREG at the end of December 2011. In addition the ONR provided the UK nuclear industry with 19 Stress Test Findings, of which 17 were applicable to EDF Energy.

The initial review of information regarding the safety margins and emergency preparedness established that EDF Energy's eight nuclear sites were adequately protected against a DB incident, that is, an event with a 1 in 10,000 year rate of occurrence. However, learning from the 2011 Japan tsunami, which was significantly beyond the plants intended DB, shows that nuclear sites must be prepared for the extreme (a very unlikely but high impact) event and have healthy margins to the DB.

Mitigation against an extremely unlikely but high impact event extends beyond the legal principle which underpins the assessment of required improvements at UK nuclear sites (the As Low As Reasonably Practicable (ALARP) principle). A core part of the strategy following this OPEX has therefore been to examine and enhance the existing 'defence in depth' present at the eight nuclear stations operated by EDF Energy in the UK and implement practicable improvements to increase station resilience to a BDB event, whilst providing additional DBUE to aid in recovery, should there be an extreme natural event.

2.2 JER Programme Phase 2

The analysis conducted in Phase 1 contributed to the development of considerations and action plans to improve the resilience of the plant to BDB external hazards, and so enhance the capability of EDF Energy's fleet of power stations to withstand and recover from a severe accident scenario.

Phase 2 comprised a major programme of fleet-wide modifications, design and procurement of DBUE, and revision of procedures and training in addition to the ongoing work to address ONR questions and recommendations, ENSREG reviews, and ongoing OPEX reviews.

The safety and effectiveness of the existing facilities were assessed against international standards and best practices provided by IAEA Standards, the ENSREG UK report, ONR Recommendations and OPEX learning points from Japan. A comprehensive range of resilience enhancements were identified, such as additional protection to essential buildings, modifications to emergency facilities, the provision of connection points for back-up equipment and the purchase of DBUE for EDF Energy nuclear sites, in addition to associated updates to the training and emergency planning procedures and arrangements.

In addition to the enhancements identified in this response to the ONR report, a significant amount of further analysis has been performed to re-evaluate the company's understanding of natural hazards, ensuring that the DB is accurate, based on the latest data and modelling techniques available, and the BDB hazards are more comprehensively understood. This work is also discussed further in the following sections.

The philosophy behind the development of the JER scope of work was to increase the resilience of the nuclear site to a severe natural event, but also to provide an off-site response capability in the event that there is severe damage and disruption to the nuclear site and the surrounding area.

This capability will ensure that a station is better prepared to withstand a severe natural event, beyond that of the current robust DB, and also in a stronger position to recover should there be an event which renders site power and cooling facilities unavailable, with the correct training, procedures and exercising in place to ensure that the people involved are better placed to respond, up to and beyond 72 hours.

The work was delivered across a number of key areas as described in the following sections.

2.2.1 On-Site Modifications for Resilience

A range of improvements to enable plants to better resist natural hazards, enhance usability of emergency facilities and improve effectiveness of back-up equipment has been largely delivered, with a small number of remaining items in-progress, nearing completion.

These improvements and modifications follow a series of reviews which resulted in a number of proposals for on-site enhancements covering two key areas:

- Providing resilience to external BDB events
- Providing simple, reliable and accessible interfaces for DBUE.

The modifications identified as part of the scope were developed to a level of detail that ensured:

- A consistent level of capability delivered at each station
- Modifications are consistent with, and complementary to, the other enhancements, notably in the areas of back-up equipment and emergency arrangements
- Delivery to plan and within technical constraints with no detriment to existing station functions
- Impact upon other planned work minimised through selection of modifications that, where possible, avoid the need for outage-based work or invasive modifications to plant. However it should be noted that some works, for example certain Sizewell B (SZB) modifications, are outage dependant.

The high level scope was developed and endorsed in conjunction with Station Directors, technical managers, EDF Energy's internal regulator and the ONR.

Following an extensive amount of work across all eight nuclear power stations, the on-site modifications are largely complete, with only a small number of remaining items requiring final connection on site, or commissioning (for example the Continuous Emergency Monitoring System (CEMS)), both of which require outages for completion. The modification process has been conducted in accordance with the normal safety arrangements associated with:

- Licence Condition 11 – Emergency Arrangements
- Licence Condition 14 – Safety Documentation
- Licence Condition 21 – Commissioning
- Licence Condition 22 – Modification or Experiment on Existing Plant.

Elements of the resilience work were grouped into disciplines, covering all, or a sub-set of, stations. The disciplines are listed and described below:

- Mechanical
- Electrical
- Control and Instrumentation
- Civil/Seismic
- Building Flood Protection
- Fuel Route
- Filtered Containment Venting (FCV)/ Passive Autocatalytic Hydrogen Recombiners (PARs) – SZB only
- Emergency Facilities
- SZB Emergency Response Centre (ERC).

Mechanical Tie-In Points and Modifications

Dedicated connection points have been largely installed, with a small number requiring final connection on site, to facilitate the connection of DBUE. The provision of dedicated interfaces gives the following benefits:

- Rapid connection of DBUE on arrival at site
- Known connection points aligned to pre-determined DBUE lay down positions
- Greater awareness of options to the emergency control team
- More focussed training opportunities
- Reduced risk of damage to critical station systems while attempting emergency engineering solutions post BDB event.

The design of the modifications took into consideration the potential additional loading created by the DBUE to ensure the critical post-BDB capability does not compromise the system, and was undertaken on a ‘no detriment basis’. The mechanical connection points enhance accessibility to a number of key systems for recovery of the plant, including primary and secondary circuit feed, water tanks and containment injection for SZB. More information on mechanical and other connection points can be found in the response to STF-8 in Section 6.

Electrical System Connection Points and Modifications

A series of connection points have been largely installed, with a small number requiring final connection on site, allowing rapid connection of on-site and DBUE generators to assist in the recovery operations of the station following a BDB event. The primary focus is to re-energise the Low Voltage (LV) (415V) electrical system, to provide reactor and plant indications to enable operators to take appropriate actions, combined with the ability to energise charge hall cranes, should ‘box-up’ for reactor reseal be required.

The low voltage (415V) connection points will energise boards which are likely to survive a severe event; they are seismically qualified and protected or raised to a level beyond the modelled infrequent very severe flooding event. They will:

- Provide a starting point for routing power to essential reactor instrumentation and displays through the existing distribution network via isolation and circuit selection
- Energise lighting boards where practicable
- Back feed the 415V Pile Cap Services Board for the AGR box-up process, i.e. cranes
- Provide supplies for welding equipment
- Provide 110V AC sockets for portable tools and lighting.

The electrical modifications will be complemented with building flood protection and the provision of DBUE as discussed later in this document.

Specific to SZB, the Battery Charging Diesel Generators (BCDG) have been replaced with new units, mounted in a manner to provide resilience against BDB floods and seismic events. These new units charge the batteries at SZB and have connection points to allow DBUE generators to be connected.

Control and Instrumentation Resilience Enhancements

Knowledge of plant parameters forms a crucial input to the decision-making process of emergency responders; allowing them to understand the plant state and therefore the response actions to be taken, judge the effectiveness of response actions and the potential for accident escalation.

The control and instrumentation strategy provides multiple layers of defence. This includes the permanently installed CEMS system at the AGRs, and the system which will be deployed as part of the AGR DBUE; the Deployable Communications and Information System (DCIS, see Section 2.2.2), both of which have satellite based communications capability.

At SZB, DCIS is permanently installed at the newly constructed Emergency Response Centre, and the CEMS project is in development, taking learning from the AGR installations. It is anticipated to be completed during the next refuelling outage.

When operational, the CEMS will provide a real-time display of key reactor/station parameters located in a Safe Place On Site (SPOS) to facilitate decision-making by operators in the hours following the event. SPOS location is dependent on judgement on the day, where maximum flexibility is given to the local managers given the difficulty is defining accurate scenarios. The number of parameters monitored by the permanently installed CEMS system is kept to a minimum in order to:

- Monitor only those parameters that are required in the first ten to twelve hours following an event, and
- Limit the complexity of the monitoring systems and hence maximise reliability.

The AGR parameters are as follows:

- Reactor top temperature, T2 (two quadrants)
- Reactor pressure (one location)
- Reactor bottom temperature, T1 (two quadrants)
- Boiler outlet temperature or pressure (all boilers)

For SZB, a Pressurised Water Reactor (PWR), a similar but site specific and appropriate set of parameters are being investigated.

Civil/Seismic Resilience Enhancements

A number of civil and seismic enhancements have taken place with the objective to ensure structures that may be necessary to assist in plant recovery, or may cause secondary damage to other areas of the plant, are further protected to better withstand a severe event. Specific work packages include:

- Fire Stations - enhanced seismic resilience giving increased survivability of fire fighting equipment necessary to combat any potential outbreak of fire following a seismic event
- Dry Risers - seismic qualification of dry risers to withstand a 10^{-4} p.a. infrequent event and enable delivery of water to the reactor charge face to provide water for buffer store cooling

- Tritium Tanks at Hartlepool (HRA) and Heysham 1 (HYA) - installation of restraints to ensure that the tanks do not become buoyant and leak contaminants and/or damage surrounding equipment in the eventuality that the basement area becomes flooded. Restraints are not considered necessary at other sites due to the location of the tritium tanks
- Fixed Jet Fire Pump (FJFP) Tanks - installation of restraints to ensure that the tanks do not dislodge in a BDB seismic event and damage the adjacent fire fighting pumps.

Building Flood Protection

The flood resilience of each station has been assessed against newly performed flooding studies which used the latest modelling techniques and took into account climate change predictions and determined that in most cases there is sufficient resilience to the infrequent event.

However, at Dungeness B (DNB), HRA and HYA, the coastal flooding studies demonstrated that there was less resilience to station flooding in a severe event than previous assessments had shown, and as such the site flood defences have been enhanced via the erection of a flood defence wall at DNB, the increasing in height of HRA’s existing defences and further enhancement of additional key affected buildings at the HYA site.

In addition to the revised flooding studies and defences at DNB, HRA and HYA, it was deemed prudent to enhance protection to limit water ingress into a number of essential buildings identified at each station. It was not the intention to fully waterproof the buildings; some level of water ingress is to be expected and unavoidable in an extreme event. The purpose of the measures was to limit the rate of water ingress to a manageable level whilst back-up equipment arrives, in order to protect the facilities against serious water damage. Emergency dewatering equipment may be deployed to critical areas in the event of flood warning.

The first phase consisted of Commercial Off-The-Shelf (COTS) dam boards, similar to those used by the Environment Agency, designed and installed by specialist contractors. They provide protection to doorways, fire exits, large shutter and concertina doors and louvered vents to 1m above adjacent ground level. This level is well in excess of the infrequent event, providing additional margin to extreme events.

The second phase concerns protecting the same buildings against water ingress through other above and below ground penetrations. This includes sealing fuel lines, cables and pipes without compromising their functionality, safety or seismic qualification (where applicable). This phase also includes the provision of covers for air bricks, protection of cavity vents and the fitting of non-return valves to foul and surface water drains in the buildings being flood protected.

The table below gives an overview of the facilities protected and the rationale behind each one. It is worth noting that each station is different and the scope of buildings protected, station by station, was developed following detailed walk downs.

Facility to be Protected	Rationale
Emergency Generation Buildings	To support long term recovery, i.e. minimise damage to plant.
Electrical Distribution / back-up systems (e.g. Batteries, Motor Generators)	To support long term recovery and maintain short term functionality as far as reasonably practicable.
Boiler Feed and Auxiliary Feed	To maintain functionality as long as reasonably practicable, potentially reducing the requirement for DBUE and support recovery efforts by providing source of water feed.
Ground Level Fuel Ponds	To prevent boron dilution and the potential spread of contamination.

Emergency Control Centres (ECCs) and ground floor back-up generation / Heating Ventilation and Air Conditioning (HVAC)	To maintain functionality a long as reasonably practicable.
Alternative / Emergency Indication Centres (AICs/EICs) and ground floor backup generation / HVAC	To maintain functionality a long as reasonably practicable.

Table 1: Facility Protection Rationale

Fuel Route Resilience Enhancements

Fuel Route resilience enhancements involved the seismic qualification of the Make-Up Shield (MUS) Boom at Heysham 2 (HYB) and Torness (TOR) Power Stations, in order to prevent potential collapse of the MUS Booms during a seismic event. The resultant seismic restraints have been included in the Maintenance Inspection and Testing Schedule (MITS).

Filtered Containment Venting (FCV) and Passive Autocatalytic Hydrogen Recombiners (PARs) for Sizewell B – A Pressurised Water Reactor (PWR)

An FCV system is for use in emergency situations as the last barrier to avoid containment building overpressure. FCV would allow the containment atmosphere to be vented into the auxiliary building and subsequently filtered and vented to atmosphere, preventing containment pressures that could challenge containment integrity and potentially result in an uncontrolled airborne release.

Studies into the feasibility of the installation of FCV are now complete. During this feasibility study, consideration was given to outputs from the Probabilistic Safety Analysis (PSA), improvements in filter technology since the original Safety Case, and the potential impact on current safety systems and operation. It was determined that FCV would be feasible to install although there are some outstanding technical risks identified during the concept design phase. The potential benefits to overall risk reduction following a severe accident at SZB are finely balanced against the potential disbenefits associated with DB operation. Given the extended timescales to containment failure, a project is underway to understand the residual risk and whether there are other reasonably practicable ways of reducing this risk. Installation of an FCV remains a potential option with a decision on this project anticipated in 2015.

In addition to this, following feasibility studies, PARs have been installed to reduce hydrogen levels in containment should there be the generation and build-up of hydrogen in a severe event; PARs have the advantage of not requiring a power source to operate, thus providing a diverse and independent means of hydrogen reduction from the currently installed electrically powered hydrogen management system.

More information regarding the consideration for FCV and PARs at SZB can be found in the response to STF-18.

Emergency Facilities Resilience Enhancements

Emergency facilities are present at all EDF Energy sites and would be used in an emergency for event management, reactor and plant monitoring, communications and access control. The objective of the enhancements was to improve the resilience of the Emergency Control Centres (ECC) and Emergency/Alternative Indication Centres (EIC/AIC) to a BDB event. These facilities have a significant role in the management of the station post-event. They must therefore be enhanced as far as reasonably practicable to remain operational post-event. The Barnwood Central Emergency Support Centre (CESC) also supports the response across the fleet of power stations and therefore similar enhancements have been made where appropriate, acknowledging that there is, in addition, both a Back-Up CESC (BUCESC) and an alternate CESC off-site. The fleet-wide enhancements covered the following areas:

- Flooding - Dam boards installed and penetrations sealed
- Electrical - Back-up diesel generators supplied and electrical supply boards protected

- Seismic - Measures taken to strengthen structures and increase resilience of equipment to earthquakes.

The modifications, where practicable, have strengthened the facilities to enhance their usability during station recovery operations following a BDB event. More information on emergency facilities and their functions can be found in the responses to FR-2 and FR-3.

Sizewell B Emergency Response Centre (ERC)

The shorter fault escalation times for accident sequences in PWRs, such as SZB, require a quicker emergency response. To aid this, the ERC has been constructed for SZB. The ERC is situated close to the station in a location determined to be safe from flooding and has been built to be resilient to natural hazards. The facility serves two primary purposes: as a store for DBUE and as a back-up command and control centre. The facility includes dedicated back-up diesel generators and supplies to provide resilience against loss of power. The ERC is being fully integrated into SZB BDB emergency arrangements.

Sizewell B Emergency Response Centre

2.2.2 Deployable Back-Up Equipment (DBUE)

In addition to the resilience modifications discussed in the previous section, the EDF Energy JER programme has developed and procured a comprehensive array of DBUE and a large fleet of emergency response vehicles for people and equipment transportation. These are maintained in secure locations away from the power station sites.

The DBUE is the appropriate equipment to facilitate faster recovery of key functions at any affected plant, in particular back-up cooling and electrical support along with emergency management facilities.

The DBUE response was derived following a review of the OPEX gained from Fukushima and the output from the subsequent reviews, including the ENSREG Stress Tests, ONR Interim, Final and Stress Test National Reports, along with INPO and WANO recommendations. The strategy for an off-site response has been developed by the EDF Energy JER programme based on postulated BDB scenarios and an understanding of the timescales for accident progression.

The DBUE has been designed in a manner that allows operators to intervene by re-instating reactor core and spent fuel cooling and restoring power on site by providing equipment such as high and low pressure water pumps and additional back-up diesel generators. Plant monitoring equipment is intended to be a key part of the response, providing visibility of plant parameters to support decision making. As such, mobile BUECC facilities combined with DCIS will provide command and control functions. For logistical purposes, Land Rovers and JCBs are included to move personnel and clear debris. Mercedes vehicles (Unimogs and Zetros) provide the capability to carry heavy equipment on and off-road. The use of the DBUE post-event is supplemented by the connection points discussed in Section 2.2.1, above.

Sets of DBUE have been situated at each of the 4 strategically selected locations in the UK. One of these is the newly built ERC in close proximity to SZB, and the other three are situated in northern, central, and southern locations in the UK, capable of providing a timely response to each station, should there be the need. The equipment is managed by a Through Life Management Partner (TLMP), a strategy similar to that used by the UK Armed Forces and English and Welsh fire brigades. This ensures that equipment is always prepared for responding to an emergency, with drivers available and trained in the rapid deployment of the vehicles and equipment to a staging post local to the affected site, where a specially trained Forward Deployment Service (FDS) will mobilise it on to site for station emergency responders to connect and operate. The equipment is maintained in a state of readiness by an appropriate Equipment Maintenance, Inspection and Testing (EMIT) programme, outwith Licence Condition (LC) 28.

Details of the availability and instructions for use of this equipment have been incorporated into the newly created Deployable Back-Up Equipment Guidelines (DBUEGs). These guidelines are being incorporated into existing emergency response arrangements, forming part of the training for emergency responders, ensuring that should the equipment be required it can be deployed and used appropriately.

The DBUE will form part of EDF Energy's Emergency Arrangements under LC 11 with the Generic Emergency Plan being updated to reflect the new capability and being approved by the Nuclear Safety Committee (NSC) and the ONR, prior to the sites Emergency Plans being approved by the ONR. A quality plan ensures that all documentation associated with the DBUE has been approved and issued prior to the issue of the LC 11 Plan. Documentation includes the Training Mentor Guides, Generic Emergency Scheme Training modules and material, DBUEGs, Symptom Based Emergency Response Guidelines (SBERGs) and Emergency Handbooks.

Deployable Back-Up Equipment for AGR Stations

A summary of key equipment items and their uses can be found below, split in to the following key systems:

- Reactor Cooling Support
- Spent Fuel Cooling Support
- Water Supply
- Electrical Generation and Supply
- Reactor and Plant Monitoring
- Event Management and Communications.

<u>Reactor Cooling Support</u>

- Back-up high-pressure direct drive diesel boiler feed pumps have been provided to support water injection into one quadrant per reactor, providing adequate supply to maintain boiler and thus reactor cooling
- Assessments of water stocks show that on-site treated and resilient water stocks are available for at least the first 48 hours post-event for all stations
- A water treatment plant is provided and can be deployed and commissioned within 48 hours, using remaining townswater stocks or seawater, to provide additional cooling supplies.

Additional reactor re-sealing equipment has also been provided to support outage periods when the reactor may be depressurised. The following equipment would support the reseal and repressurisation of a reactor to allow natural circulation to take place and provide suitable reactor cooling:

- LV (415V) connection points allow diesel generators to be connected to assist with operating cranes for 'box-up'

- Sufficient nitrogen stocks to pressurise the reactor to a level that supports cooling by natural circulation.

<u>Spent Fuel Cooling Support</u>

Back-up equipment has been provided to supply additional cooling capability to the spent fuel ponds and buffer stores should the existing cooling functions be unavailable. This includes:

- Low Pressure (LP) water pumps to supply water into the buffer store pipework system and for topping up the ponds
- Deployable pond coolers
- All necessary hoses and associated equipment and fuel stocks required for deploying and using the DBUE have been supplied, which will be deployed using pre-determined routes, ensuring that spent fuel does not overheat.

In addition to this equipment, and in line with WANO SOER 2011-3, work has been undertaken to further understand the times for accident progression should existing diverse lines of protection be lost within the spent fuel plant. This has determined that there is sufficient time to deploy the DBUE, using conservative timeframes, before the spent fuel becomes uncovered due to falling water levels.

<u>Water Supply</u>

As part of the site assessment, following the events in Japan, EDF Energy has confirmed that all sites have a minimum supply of water for 48 hours, stored in seismically qualified tanks. However, should it be required, the DBUE water treatment plant can be delivered and commissioned to any site within 48 hours, providing a continuous supply of high quality water up to, and beyond, the 72 hour target mission time. As such, no additional on-site cooling water supplies have been deemed necessary as the DBUE approach is considered to provide a greater degree of resilience. The water treatment plant can use water from any remaining un-claimed tanks, townswater, and seawater, ensuring that cooling supplies are maintained.

<u>Electrical Generation and Supply</u>

New trailer mounted generators have been procured as part of the DBUE strategy. These 180kVA diesel generators will provide power for LV (415V) systems such as lighting and essential instrumentation and are compatible with the on-site connection points. One diesel generator is stored at each AGR, with the exception of HYB and TOR which have received two due to the segregated and quadrantised layout of the stations electrical circuits. The 180kVA diesel generators provide a further line of defence beyond the existing emergency diesel generators, and can be attached to on-site vehicles for transport around site in event of an incident.

The DBUE strategy also includes LV (415V) containerised 200kVA diesel generators and containerised cabling and switchgear which can be deployed from regional stores within required timescales following a BDB event. The 415V systems support the provision of essential instrumentation, heating, ventilation and lighting.

All electrical DBUE is industry-standard and available COTS as used, for example, by the Armed Forces, Environment Agency and emergency services, ensuring that it is proven in the field and should additional capacity be required it will be possible to readily source and connect equipment.

It should be noted that there are DB qualified on-site stocks of fuel that have been confirmed to meet the technical specification of 24 hours of supply, but that in practice there is greater than 48 hours of stocks available on all sites. However the rationale for a BDB response does not rely on these stocks as the DBUE will, as described, have its own stocks of fuel and be available on site in a timely manner.

<u>Reactor and Plant Monitoring</u>

In addition, and complementary, to the CEMS is the Deployable Communications and Information System (DCIS) which will be deployed post-event to monitor any required mechanical instrumentation via deployable cameras and allow the connection to the CEMS instrumentation to monitor the following key indicators:

- Reactor top temperature, T2

- Reactor pressure
- Reactor bottom temperature, T1
- Boiler outlet temperature or pressure.

The DCIS is compatible with, and can be connected to, the CEMS, but is delivered to site as part of the AGR DBUE, transmitting essential plant parameters to the DBUE staging post up to 10 miles from site, and is not reliant on any fixed telecommunication infrastructure.

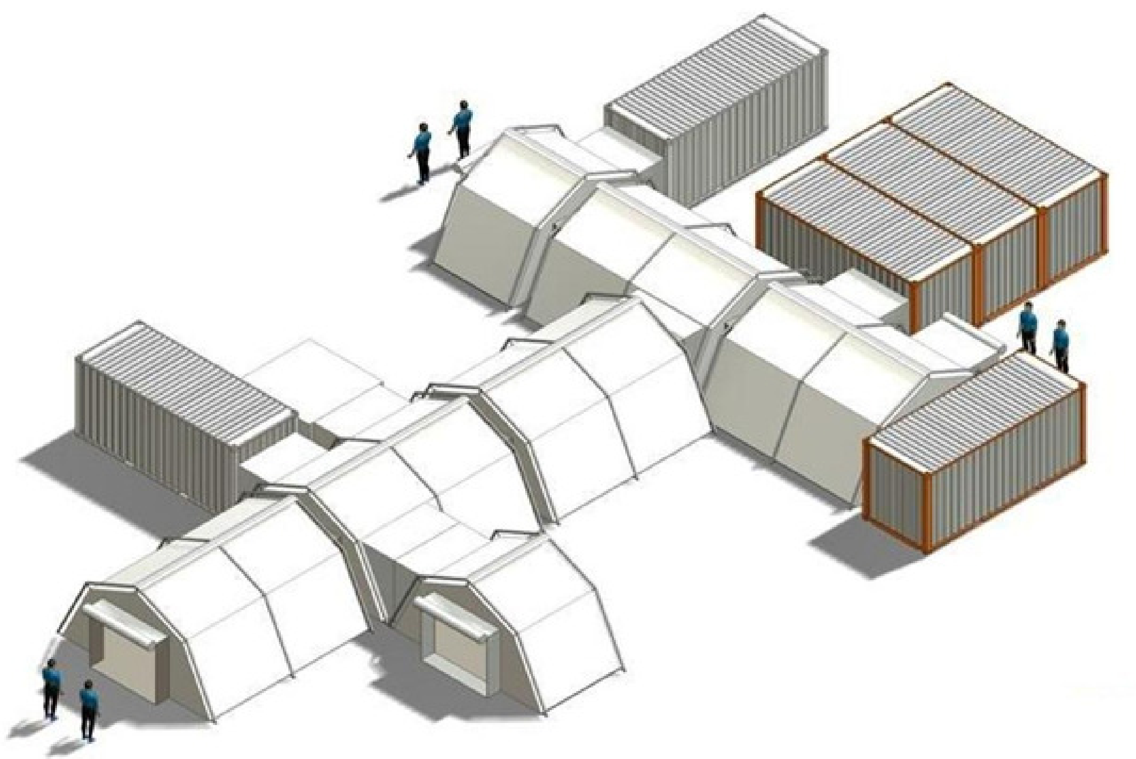
The DCIS provides communications and indications for long term usage in more severe emergency scenarios, and can provide wider situational awareness by allowing access to stored data (e.g. station drawings) and telephony equipment. The information and indications will be available to on-site emergency facilities as well as the CESC and the deployable BUECC.

DCIS has been permanently installed at SZB's ERC, providing a robust facility with independent supplies where the system can be operated from, providing diverse and resilient communications and plant information.

Event Management and Communications

The strategy developed for BDB event management and communications is to replicate as far as possible the existing functions of the on-site emergency facilities and arrangements. This includes mobile ECC and Access Control Point (ACP) facilities, including units with positive pressure air and airborne contamination filtration.

The deployed ACP manages access and egress to a hazardous location from a suitable location. The facility includes communications equipment, Personal Protective Equipment (PPE), radiation monitoring equipment and decontamination showering facilities.



Typical DBUE Mobile Facility

Deployable Back-Up Equipment for Sizewell B (PWR)

The approach assessed what DBUE would be required at SZB following a BDB event. The key systems included are listed below and described thereafter:

- Reactor Cooling Support
- Spent Fuel Cooling Support
- Water Supply
- Electrical Generation and Supply
- Reactor and Plant Monitoring
- Event Management and Communications.

Some of the SZB equipment is housed in the new ERC, providing a shorter response time and support up to 24 hours post event. Support beyond this period, to 72 hours and beyond, will be provided from the other DBUE stores.

Reactor Cooling Support

- A back-up water pump has been provided to feed water into the condensate storage tanks. This will allow any remaining secondary circuit auxiliary feed pumps that remain operating to utilise on-site water stocks
- Back-up nitrogen supplies have been provided for injection into to the Clean Air Train System (CATS) via a new connection point that is scheduled to be completed during the next refuelling outage. This will provide an additional and diverse supply to the CATS nitrogen accumulators, allowing the power operated release valves to continue to function to control temperature and pressure and control the rate of steam fed to the Turbine Driven Auxiliary Feedwater System
- A high pressure water pump has been provided to supply water to the Steam Generators to provide cooling to the reactor in the case that the turbine driven and motor driven auxiliary feed pumps are no longer operational
- Via the installation of a connection point through an existing penetration, Containment Water Injection (CWI) is possible in order to prevent dry-out of the water in the containment floor. This provides a diverse and independent means of water injection from the already installed Reactor Building Spray System and the Fixed Fire Fighting System. CWI remains the first and most effective option for severe accident mitigation and is intended to mitigate the effects of Molten Core Concrete Interaction, helping to minimise gas pressure in the containment. This will also reduce the potential for containment basemat failure, which could result in a radiological release. Back-up water pumps stored at the new ERC will provide the capability to inject water through the modified penetration with water from existing station supplies.

Spent Fuel Cooling Support

- Using the existing seismically qualified dry riser, back-up water pumps can provide pond top-up and cooling. Alternatively, hoses are provided which can be laid out to the pond should the dry riser be unavailable.

Water Supply

As with the AGR sites, within 48 hours, the DBUE water treatment plant can be delivered and commissioned at SZB to provide a continuous supply of suitable quality water up to, and beyond, the 72 hour target mission time. No additional on-site cooling water supplies have been deemed necessary as the DBUE approach is considered to provide a greater degree of resilience in combination with the existing qualified stocks. Cooling water beyond 48 hours will be available from any remaining un-claimed tanks, townswater, and seawater, and will be treated by the DBUE water treatment plant.

Electrical Generation and Supply

The existing BCDGs have been replaced with upgraded units as part of business as usual, however modifications have been implemented which raises the new units to a level that gives additional margin to BDB floods and seismic events. The units are provided on site to charge batteries and support a number of key systems including lighting, heating and plant indications. Connection points are also being provided, allowing additional mobile generators stored at the ERC to be connected.

Reactor and Plant Monitoring

In addition, and similar to the capability described above for the AGR plant, DCIS has been installed and integrated into the ERC and is available for deployment on to site should it be required.

Event Management and Communications

The strategy developed for BDB event management and communications is to replicate as far as possible the existing functions of the on-site emergency facilities and arrangements. At SZB, the ERC will also be available to support an emergency response. The facility serves two primary purposes: as a store for DBUE and as a back-up command and control centre. The facility includes dedicated back-up diesel generators and supplies to provide resilience against loss of power.

Vehicles for Emergency Response

Emergency response vehicles have been purchased to provide resilient logistical support in extreme circumstances, which include capabilities for route clearance, transportation and lifting of heavy machinery, and transporting of response personnel, with the capability to travel both on-road and off-road. The vehicles have been specially chosen and customised to meet the criteria developed by the EDF Energy JER programme. The vehicles have also undergone environmental testing at the Motor Industry Research Association (MIRA) Technology Park, which included testing off-road capabilities and extreme temperature resilience. The fleet of vehicles consists of:

- 44 Land Rovers - providing personnel (such as site responders) movement capabilities across difficult terrain and in adverse conditions
- 17 Mercedes Unimogs with Hook Loader - capable of lifting and moving heavy equipment such as the 5 tonne AGR High Pressure Pumps
- 5 Mercedes Unimog Response Support Vehicles - containing the pre-fitted Damage Repair Tools (DRT), including lighting, axes, electrical equipment, petrol saws, winches, general damage repair equipment and PPE, with capacity to transport 6 responders
- 13 Mercedes Unimog Crane Loaders - increasing flexibility of deployment logistics
- 25 Mercedes Zetros Crane Loaders - capable of carrying heavier loads in an extreme event
- 10 JCB 457's- for a range of activities including route clearance
- 10 JCB 4CX's- which can be fitted with a range of attachments, such as concrete breaker for site clearance.

Integrated Systems Testing

To provide confidence that the equipment and systems provided by the JER programme would provide the intended capability, an Integrated Systems Testing (IST) programme took place. This was carried out in addition to Factory Acceptance Testing (FAT) which provided assurance that the individual components purchased met the requirements of the individual design specification.

The IST programme successfully demonstrated the functionality of the DBUE systems and the practicality of their deployment. By carrying out a series of tests the designed systems were methodically and rigorously tested to provide confidence in the JER response beyond that of individual component FAT testing.

2.2.3 Emergency Planning

EDF Energy has assessed and enhanced the existing emergency arrangements to ensure that physical, communication and human infrastructure are equipped to deal with a serious, BDB, event.

This element of the programme of work enhances emergency response to BDB events, and integrates JER output into the existing emergency arrangements framework. The scope of work has covered:

- Emergency Preparedness review and enhancements
- Updating the AGR specific SBERGs and Severe Accident Guidelines (SAGs) which provide operator guidance under fault conditions
- Developing a new suite of DBUEGs to assist in the use of the new back up equipment capability
- Human Aspects considerations
- On-site and Off-site Communications Capability
- Long term and multi-site response
- Training and Exercising

The emergency response delivery strategy has ensured a flexible and integrated company response to all emergency events, delivered by:

- Oversight of appropriateness of new DBUE
- Resource strategy to maintain, deliver, install and operate the deployable equipment
- Systematic review of all training requirements
- SBERGs reviewed and aligned across the fleet of AGR stations
- DBUEGs, providing guidance on the use of the DBUE
- SAGs have been reviewed and updated in line with current severe accident understanding
- Best practice in Human Aspects established and integrated into the emergency response programme
- Exercise improvements implemented to incorporate learning from Fukushima.

In addition to this, EDF Energy is working with Local and National agencies to contribute to revised emergency arrangements and ensure that EDF Energy's own revised procedures and capability are understood by the appropriate authorities.

2.2.4 Further Review and Assessment

The focus of this workstream has been to ensure the continued adequacy of existing safety cases with respect to external hazards coverage, in the context of what has been learned from Fukushima. This assessment of resilience implicitly incorporates the need to demonstrate the absence of "cliff-edge" effects at the DB boundary, i.e. the existence of margins. It also looks to confirm that the EDF Energy Emergency Response arrangements continue to provide adequate mitigation of the potentially severe effects of unforeseen events. It should be noted however that the DBUE is not claimed as part of EDF Energy Safety Cases.

The following confirms the outline approach which has been followed to deliver the intent of the above review of external hazards resilience, the results, and the arrangements following the closure of the EDF Energy JER programme.

The outline approach defining the Further Review and Assessment approach to the JER work can be summarised as follows:

- Focussing on resilience against the identified key external hazards of coastal flooding, seismic and weather hazards (extreme ambient temperatures, pluvial flooding and wind). This selection is based on the logic that there are no reasonable grounds for challenge on the continuing adequacy of the safety cases with respect to the other external hazards, as a consequence of the learning from Fukushima

- There has been deliberate focus on demonstrating resilience for structures that protect the bottom line plant, the bottom line plant itself and the security of the integrity of the pressure boundary
- Where necessary, the underlying hazards assessment methodologies have been reviewed with the intent on confirming continued acceptability. It is noted that some of these methodologies date back to the 1980s, and whilst there may have been significant developments within the associated discipline areas over the intervening time, this does not necessarily mean that the original approaches do not remain fit for purpose
- Although the demonstration of the absence of a cliff-edge at the DB boundary is important in terms of resilience to severe hazards, and associated uncertainties which may reside within supporting hazards assessment, it is recognised that there is nevertheless a reduced vulnerability to cliff-edges once the DBUE is taken into account
- Confirming the presence of margins at the DB boundary, to support the demonstration of the absence of a "cliff-edge", has been achieved through a mainly qualitative approach. It has been argued that the responses do not need to make reference to highly accurate assessments of margins between the DB hazard and the magnitude/frequency of the BDB hazard which would cause failure of the key safety related plant.

  The key consideration, and the focus of our approach, has been to focus on where margins are judged to be smallest rather than on a comprehensive quantitative assessment of margins which are not worth addressing
- For the postulated external weather hazards the Met Office have been commissioned to deliver a suite of reports across the EDF Energy fleet of 8 power stations, with the intention of reconfirming the severity of the associated climactic conditions for various return frequencies up to and including the DB boundary. It should be noted that there is significant inherent uncertainty associated with the definition of such hazards at the DB boundary of 1 in 10,000 years, due to the nature of extrapolation from weather station records which typically extend for 40-60 years
- Opportunities have also been taken to further enhance the position of EDF Energy's fleet of 8 nuclear power stations with respect to preparedness and real-time decision-making, most notably through the fleetwide deployment of the Met Office's VisualEyes and Safesee tools, which provide detailed meteorological and sea state forecasting, together with the ability to set action/warning levels specific to each site to assist in the preparedness decision-making processes. These web-based tools have been deployed fleetwide, along with the placement of a 10-year contract with the Met Office to provide immediate 24/7 support and ongoing maintenance and upgrade support. Also included is the fleetwide review of the weather preparedness Station Operating Instructions (SOIs) and the ongoing intention to improve the availability of good quality real-time data through local well maintained weather stations
- A pilot study approach has been adopted in some areas, whereby a specific site has been reviewed in detail, to seek site specific learning, and furthermore provide insights for the remainder of the fleet of power stations
- There has been a continuous review of the adequacy of the existing DB assumptions, and the associated security of the safety case, throughout the progression of the JER related tasks. Where potential challenges to the safety cases for continued safe and reliable operation have been identified, EDF Energy normal processes have been applied, and specifically the Safety Case Anomalies Procedure. This has led, in a few instances (i.e. flooding), to the confirmation of safety case anomalies and the subsequent establishment of safety case delivery programmes, within normal business, to reconfirm the security of the existing safety cases.

The Further Review and Assessment activities have resulted in the reconfirmation of security for the existing fleet safety cases, with respect to external hazards coverage. Where shortfalls were identified, normal process has been applied and appropriate recovery work has been progressed. In addition, opportunities have been taken to further enhance the robustness of the external hazards safety cases, particularly for weather hazards. It is recognised that the availability of the DBUE further significantly increases the defence in depth available, albeit noting that this additional resilience is not formally claimed within EDF Energy Safety Cases.

Furthermore, the work undertaken by the Further Review and Assessment workstream has demonstrated that there is inherent margin beyond the design basis boundary, which provides confidence with respect to the difficulty in defining the magnitudes of external hazards at such low beyond design basis return frequencies.

The work has also confirmed confidence with respect to the adequacy of emergency planning arrangements through the support and oversight that has been provided with the development of improved emergency planning arrangements, involving both on and off-site resilience activities.

It is recognised that within the following closure statements reference has been made to ongoing commitments to either complete particular workstreams, or underwrite judgements which have been made.

Lastly, the significance of the events at Fukushima have emphasised the importance for cross-industry collaborative working to ensure that all appropriate learning has been recognised, with the development of standardised improvements, if at all possible. This not only relates to the continued participation by EDF Energy in the relevant cross-industry activities, but also the internal commitment to regularly review the continued adequacy of measures taken, post-Fukushima, on receipt of continued and developing knowledge.

2.2.5 Openness and Transparency

In addition to the programme of work outlined above, EDF Energy is working to improve the nuclear industry's Openness and Transparency in conjunction with Dr Weightman's Interim Recommendation 4 (IR-4). EDF Energy aims to foster a culture of openness and trust, both internally and externally, by creating an open culture and actively engaging with local communities and stakeholders.

Aspects of this drive by EDF Energy include the opening of visitor centres at each of its sites as well as the development of a programme of events aimed at increasing awareness and understanding of the nuclear power generating business in the UK.

The programme of work has included:

<u>Visitor centres</u>

EDF Energy has opened new visitor centres at all its nuclear power stations across the UK. There are visitor centres open at Hartlepool, Hunterston B in North Ayrshire, Torness in East Lothian, Sizewell B in Suffolk, Hinkley Point B in Somerset, Dungeness B in Kent and Heysham in Lancashire. The visitor centres allow the public to find out more about nuclear power station operations, how electricity is generated, and more about EDF Energy.

<u>Site tours</u>

Pre-arranged site tours are available at all EDF Energy nuclear power stations. Groups are able to come on to site and explore electricity generation, seeing first hand how nuclear power is used to provide low carbon electricity for the UK.

<u>Talk Service</u>

The EDF Energy talk service assists employees in giving presentations both at site and in the local community.

<u>Improvements to the way EDF Energy reports its performance internally and externally</u>

From late 2011 EDF Energy has increased the information on policies, strategies and operational results on the company web site.

As part of this action plan, from early July 2011 EDF Energy has been publishing information on "plant status" on the company website. This can be accessed at:

http://www.edfenergy.com/about-us/energy-generation/nuclear-plant-status.shtml

Openness

To further enhance its openness, EDF Energy has also published its Stress Test Reports as well as updates on the ONR recommendations. There have also been a number of presentations given at universities and public events to discuss the events in Japan and how EDF Energy is responding to these events.

The work on openness and transparency will continue to be addressed by a company Steering Group and project boards conducted in line with existing company process. The ONR have been involved in discussions with the Steering Group and are aware of the progress being made.

To ensure that openness and transparency remains a clear focus going forward, EDF Energy embedded a measure into its 2014 business plan. Against the objective 'To be the best and most trusted for customers' is a key performance indicator of 'EDF Energy will be rated as an open and transparent communicator in the vicinity of its power station'. The target for 2014 was for 40% of those surveyed to agree EDF is the best and most trusted for customers, rising by 2% per year over the next three years.

Additionally, and as another driver towards greater transparency, the company set a target of achieving 40,000 people attending its visitor centres during 2014.

2.2.6 The Proof of Concept Demonstrations

The EDF Energy JER programme staged a number of Proof of Concept (POC) demonstrations to provide tangible evidence that the JER programme has delivered the promised improvements in enhanced capability and that these new systems work in practise. The POC demonstrations were endorsed by the EDF Energy Nuclear Generation Executive (NG Exec) and advised to the ONR.

There are parts of the enhanced emergency response capability provided by the JER programme that cannot be practically demonstrated on site due to the invasive nature of the DBUE; as such, practical and theoretical POC demonstrations were devised to illustrate the complete response. These enabled EDF Energy Emergency Response Organisation (Station and CESC) to work with new processes, equipment (DBUE) and organisations (TLMP & FDS) through the activation, deployment and operation of the new capability.

The POC demonstrations were divided into those for response to the AGR and PWR. Each event was subject to independent assessment by an Internal Assessment Team headed by the company's Emergency Planning Fleet Manager and was further reviewed by EDF Energy's internal regulator: Independent Nuclear Assurance (INA). The ONR also witnessed these internal demonstrations as part of their work on regulating the response to the Weightman recommendations. Areas of good practice and areas for improvement were captured and used to inform subsequent demonstrations or future exercise requirements.

Proof of Concept Demonstration AGR

The POC demonstrations for AGR deployment and capability were split into 3 phases.

POC A – A practical 3 day event which demonstrated the activation, logistical deployment of DBUE and establishment of a staging post site by the TLMP. Followed by transfer of DBUE to EDF Energy and the capability of station responders from HYA and HYB to connect and operate the DBUE that would restore Critical Safety Functions.

POC A* - A practical demonstration based at HNB which focused on the interactions between key responders (EDF Energy, FDS and TLMP) in the deployment of DBUE. The exercise illustrated the successfully delivery of DBUE by the FDS and the deployment and laydown/setup of mobile facilities (ECC, ACP & DCIS). These facilities were utilised by the response organisation to respond to an event using existing command and control techniques.

POC B – A simulated BDB long duration emergency scenario involved the CESC and HYA and HYB Central Control Room and Emergency Control Centre teams. The demonstration made use of the updated arrangements, DBUEGs and SBERGs. It demonstrated the capability to understand and manage a multi-site, multi-unit, BDB event, including the benefits of the JER-provided additional measures. The demonstration required real-time decision-making by staff and involved a shift changeover; it also simulated a real emergency through factors such as failures of plant indication systems, communications and lighting.

The internal and external reviews and reports of the AGR POC recorded the successes and captured the lessons learnt from these demonstrations. The continuing improvement process ensures that this learning is embedded within our emergency arrangements.

Proof of Concept Demonstration PWR

POC C - A practical demonstration was performed at Sizewell B (SZB) to evaluate the station's response in activating the Emergency Response Centre (ERC), determine the effectiveness of the Responders in preparing, deploying and operating the back-up equipment, and provide evidence of DCIS's capability in data acquisition, verbal communication and information transfer.

Overall the exercise demonstrated that SZB off-site ERC could be activated in a timely manner. ERC responders demonstrated knowledge and proficiency in the preparation, deployment and operation of back-up equipment. Communication through DCIS was established between responders using hand-held radios and head-sets worn by staff in the off-site ERC, also between the off-site ERC and EDF Energy CESC at Barnwood. Two-way data transfer between the off-site ERC and the CESC was also demonstrated.

Each of the POC demonstrations have been reviewed in detail with the key learning captured in a JER Proof Of Concept Demonstration Report covering A, A*, B and C for future learning as part of the continual improvement process.

3 Conclusions

EDF Energy is determined to be supportive of national and international nuclear regulatory processes and is committed to playing an active role to ensure its nuclear power plants will continue to be operated safely and contribute to making the UK a low carbon economy.

The events at Fukushima will continue to have a profound impact on the way the nuclear industry operates in years to come and as a UK nuclear operator, EDF Energy welcomed the ONR recommendations and findings and has responded accordingly to ensure that the learning from events in Japan provides a positive input to the continued operation of EDF Energy's plant in the UK and that existing resilience measures, training and emergency preparedness are built upon to ensure the continued high levels of safety.

EDF Energy has gained an understanding of the events at Fukushima from a wide range of sources and continues to monitor developments and learning from the recovery operations. EDF Energy has performed extensive reviews based on the available information to date, identifying specific lessons for its fleet of eight nuclear power stations. These lessons have been implemented promptly in the three years since the events at Fukushima, and work continues to seek further lessons from this event.

This on-going process of reviewing experiences, both from the nuclear industry and others, underpins EDF Energy's commitment to learning and recognises the importance of maintaining the very good UK nuclear safety record. This record is maintained by operators being responsible for the safety of their facilities and constantly learning and developing a safety approach that utilises well established standards and principles in the UK and internationally. This ownership of safety by the operators must be within the framework specified by a strong and independent UK regulator who sets high safety standards and ensures all operators comply with these standards. EDF Energy see the HM Chief Inspector's reports as a key step in continuing to support the maintenance of high safety standards and this is an approach EDF Energy wishes to support. EDF Energy applauds the stated intent to conduct this process in an open and transparent manner.

Recognising that nuclear events have a global impact, EDF Energy fully supports the recommendations and findings from the ONR and international organisations such as ENSREG and WANO. Furthermore, in developing the programme of work, EDF Energy has worked closely with both national and international licensees including the wider French EDF Group, operators in the US and other UK licensees, ensuring that the international response is understood and that EDF Energy's approach is inline with best practice whilst appropriate for the hazards faced in the UK.

The three year JER programme has ensured the continued adequacy of existing safety cases with respect to natural hazards, in the context of what has been learned from Fukushima. In addition, the demonstration of the existence of margins beyond the design basis gives confidence in the ability to withstand extremely unlikely but high impact events. This work informed an extensive programme of resilience enhancements across the fleet of eight nuclear power stations as well as the procurement of a large quantity of Deployable Back-Up Equipment that is in a continuous state of readiness with emergency responders trained and procedures developed to allow the deployment and use of this enhanced capability should it be required in support of any event.

EDF Energy firmly believes that the programme of work outlined in this report will further strengthen confidence in its ability to safeguard its fleet of nuclear power stations against an extreme Beyond Design Basis event that it may be faced with, however unlikely, further protecting the public, its employees and the environment.

4 Interim Recommendations

In May 2011, HM Chief Inspector of Nuclear Installations released the Interim Report on the Japanese earthquake and tsunami: Implications for the UK Nuclear Industry. This report aimed to identify implications for the UK nuclear industry in light of events at Fukushima and was welcomed by EDF Energy and the wider nuclear industry.

The report contained 26 Interim Recommendations for which EDF Energy has provided a number of updates and responses to since issue in 2011. Whilst the learning from the events in Fukushima will continue to influence the international nuclear industry as all major incidents do, the following sections aim to close out the recommendations based on the programme of work that has been delivered and discussed in Section 2 since 2011.

4.1 Interim Recommendation 1 Close Out Report

Recommendation IR-1: The Government should approach IAEA, in co-operation with others, to ensure that improved arrangements are in place for the dissemination of timely authoritative information relevant to a nuclear event anywhere in the world.

4.1.1 Overview

As the UK's largest nuclear generation company, EDF Energy has an interest in ensuring that arrangements for the dissemination of timely authoritative information relevant to a nuclear event anywhere in the world are effective. This is necessary to protect workers and the public and to ensure that all nuclear operators receive information that is relevant to the safe operation of their own power stations as quickly as practicably possible. It is also necessary to consider how to take into account the cultural evolution in information technology and digital communications which society relies on more and more.

EDF Energy is a responsible operator which is actively seeking to learn from the Fukushima event and improve safety at its plants. In normal business EDF Energy prepares comprehensive emergency plans for all of its nuclear licensed sites. These are regularly tested, both internally and in conjunction with public authorities and include the effectiveness of communications during an emergency.

4.1.2 Response

This recommendation is essentially a matter for Government. However, EDF Energy supports the development of robust, authoritative and timely arrangements for the dissemination of information relevant to a nuclear event. This has clear linkage from the Nuclear Industry, through all partner bodies and to the Government. It is anticipated that the goal of this recommendation is further strengthening of such event information dissemination arrangements in the UK.

EDF Energy continues to offer support to UK Government in order to progress this recommendation and continues formal communication with the UK Government / Department of Energy and Climate Change (DECC).

In addition, the Safety Director Forum (SDF) Fukushima Sub Group, chaired by EDF Energy, ran until mid-2013 and was established to share learning from the events in Japan and to facilitate the application of common standards and formats in the various responses to regulators. The SDF Fukushima Sub Group had representation from all UK nuclear licensees and also included membership by the Office for Nuclear Regulation (ONR) and DECC.

4.1.3 Recommendation Conclusions

An overall view on 'closure' of this recommendation is essentially a matter for Government. However EDF Energy considers that this recommendation may be moved to normal business since the required links with Government are in place and are active, ensuring that the aims of the recommendation should continue to be achieved.

4.2 Interim Recommendation 2 Close Out Report

Recommendation IR-2: The Government should consider carrying out a review of the Japanese response to the emergency to identify any lessons for UK public contingency planning for widespread emergencies, taking account of any social, cultural and organisational differences.

4.2.1 Overview

As the UK's largest nuclear generation company, EDF Energy has an interest in ensuring that UK public contingency planning for widespread emergencies takes account of any lessons from Japan's response to events at Fukushima, so as to ensure protection of the public. It is necessary to consider how to deal with the personal aspects; this is the physical, emotional, cultural and societal impact for the workers and public as a result of a massive disruption to infrastructure.

EDF Energy is a responsible operator which is actively seeking to learn from the Fukushima event and improve safety at its plants. Through normal business EDF Energy prepares comprehensive emergency plans for all of its nuclear licensed sites and tests these regularly, both internally and in conjunction with public authorities. In preparing these emergency plans EDF Energy seeks to ensure that the UK public contingency planning for widespread emergencies is effectively designed and regularly tested and works in conjunction with EDF Energy's own plans.

Whilst the response to this recommendation is to be led by the Government, EDF Energy welcomes the opportunity to provide a leading and active role in supporting the Government in developing their response.

4.2.2 Response

This recommendation is essentially a matter for Government. However, EDF Energy supports the ongoing development of robust, well-understood and effective emergency response planning. This has clear linkage from the Nuclear Industry, through all partner bodies to the Government.

4.2.3 Recommendation Conclusions

An overall view on 'closure' is essentially a matter for Government. However EDF Energy considers that this recommendation may be moved to 'normal business', as the required links with Government are in place and are active to ensure that any learning from this recommendation is fully benefited from by the industry and wider UK emergency contingency planning bodies.

4.3 Interim Recommendation 3 Close Out Report

Recommendation IR-3: The Nuclear Emergency Planning Liaison Group (NEPLG) should instigate a review of the UK's national nuclear emergency arrangements in light of the experience of dealing with the prolonged Japanese event.

This information should include the practicability and effectiveness of the arrangements for extending countermeasures beyond the Detailed Emergency Planning Zone (DEPZ) in the event of more serious accidents.

4.3.1 Overview

As the UK's largest nuclear generation company, EDF Energy has an interest in ensuring that the UK's national nuclear emergency arrangements take account of the experience of dealing with the prolonged event at Fukushima and will deliver planned measures to protect the public.

EDF Energy is a responsible operator which is actively seeking to learn from the Fukushima event and improve safety at its plants. As part of normal business EDF Energy prepares comprehensive emergency plans for all of its nuclear licensed sites and tests these regularly, both internally and in conjunction with public authorities. As a responsible operator, EDF Energy want the NEPLG to implement a review which ensures that all necessary learning applicable to the UK's national nuclear emergency arrangements is identified and responded to effectively.

Whilst the response to this recommendation is to be led by the NEPLG, EDF Energy welcomes the opportunity to provide a leading and active role in supporting the NEPLG in developing their response.

4.3.2 Response

The Department of Energy and Climate Change (DECC) leads on the NEPLG and has established a revised National Strategic Framework to oversee and deliver improvements in the UK's national nuclear arrangements in respond to this Weightman report action.

EDF Energy utilises the Safety Director Forum (SDF) working group Nuclear Emergency Arrangements Forum (NEAF) Chairman to provide advice to DECC's Emergency Planning Delivery Committee (NEPDC) and, where invited, EDF Energy actively participates in the NEPDC subgroups.

4.3.3 Recommendation Conclusions

An overall view on 'closure' is essentially a matter for the NEPLG. However, EDF Energy considers that this recommendation may be moved to 'normal business', as the required links with the NEPLG and Government are in place and are active.

4.4 Interim Recommendation 4 Close Out Report

Recommendation IR-4: Both the UK nuclear industry and ONR should consider ways of enhancing the drive to ensure more open, transparent and trusted communications, and relationships, with the public and other stakeholders.

4.4.1 Overview

In the immediate aftermath of the Fukushima event there were concerns regarding the accuracy and speed of information being provided. When accidents occur it is important that people have timely and reliable information they can trust. However, it is also necessary to build that openness and transparency into everyday work so that people can develop a trusting relationship with the Nuclear Industry.

EDF Energy is committed to delivering on its sustainability commitment: "we will be open and transparent in our nuclear businesses, demonstrating that we can be trusted to act in the highest professional standards in relation to nuclear security issues."

EDF Energy continues to work to formalise and expand its approach to openness and transparency, ensuring the information communicated is reliable, factual, clear and responsive and that the various stakeholder engagement mechanisms are aligned and managed appropriately.

EDF Energy believes in openness and transparency and is looking to take a lead in this area through dialogue and engagement in order to build up public trust. EDF Energy already enjoys an open reporting culture and works closely with the safety, environmental and security regulators, and the communities around its sites. However recent events at Fukushima in Japan have shined a spotlight on the nuclear industry, and it is clear that more must be done in this area.

4.4.2 Response

An EDF Energy Nuclear Communications Programme Steering Group was established to oversee the implementation of a new action plan. This was developed through a number of project boards across the business, including the Openness and Transparency Project Board and the Nuclear Engagement Programme Project Board. The aims were to improve communications both internally and externally to increase the openness and transparency of the nuclear industry.

It is probable that the list of actions will change over the course of time as new initiatives are identified and others are delivered. The initial focus was in the following areas:

- The reopening of visitor centres, which is now complete
- A co-ordinated visitor tour programme, which is now available at each nuclear power station
- Revitalisation of EDF Energy's 'talk service' offer to better inform the public
- Further enhancement to education programmes
- More work on open reporting and how EDF Energy can build on what has been done.

As part of this action plan, in July 2011 EDF Energy began publishing information on "plant status" on the company website. EDF Energy also now provides increased information on policies, strategies and operational results on the company website.

To further enhance its openness, EDF Energy published its 2011 Stress Test Reports as well as updates on the Office for Nuclear Regulation's (ONR) recommendations. There have also been a number of presentations given at universities and public events to discuss the events in Japan and how EDF Energy is responding.

The work on this recommendation will continue to be addressed by the appropriate steering groups and project boards and will be performed in line with existing company process. The ONR have been involved with discussions throughout the programme and are aware of the progress being made.

To ensure that openness and transparency remains a clear focus going forward, EDF Energy embedded a measure into its 2014 business plan. Against the objective 'To be the best and most trusted for customers' is a key performance indicator of 'EDF Energy will be rated as an open and transparent communicator in the vicinity of its power station' the target for 2014 was for 40% of those surveyed to agree EDF is the best and most trusted for customers, rising by 2% per year over the next three years.

Additionally, and as another driver towards greater transparency, the company set a target of achieving 40,000 people attending one of the visitor centres during 2014, with 41,000 achieved and a target of 45,000 visitors set for 2015.

4.4.3 Recommendation Conclusions

EDF Energy considers that this recommendation has been moved to 'normal business', as the work on this recommendation will continue to be addressed by the appropriate steering groups and project boards and will be performed in line with existing company process, and as such this recommendation is now deemed closed.

4.5 Interim Recommendation 5 Close Out Report

Recommendation IR-5: Once further detailed information is available and studies are completed, ONR should undertake a formal review of the Safety Assessment Principles to determine whether any additional guidance is necessary in the light of the Fukushima accident, particularly for "cliff-edge" effects.

The review of ONR's Safety Assessment Principles (SAP) should also cover ONR's Technical Assessment Guides (TAG), including external hazards.

4.5.1 Overview

As the UK's largest nuclear generation company, EDF Energy has an interest in ensuring that the Office for Nuclear Regulation's (ONR) Safety Assessment Principles (SAPs) and Technical Assessment Guides (TAGs) reflect any additional learning from the events in Japan.

Whilst the response to this recommendation is to be led by the ONR, EDF Energy welcomes the opportunity to provide a leading and active role in supporting the development of this response.

4.5.2 Response

EDF Energy has continued to offer support to the ONR on the development of this topic area and will continue to do so, ensuring that the ONR's SAPs and TAGs reflect any additional learning from the events in Japan, re-evaluating any requirement to address "cliff-edge" effects.

4.5.3 Recommendation Conclusions

An overall view on 'closure' of this recommendation is essentially a matter for the ONR. However, EDF Energy considers that this recommendation may be moved to 'normal business', as the required processes are in place, ensuring that the aims of the recommendation will be achieved.

4.6 Interim Recommendation 6 Close Out Report

Recommendation IR-6: ONR should consider to what extent long-term severe accidents can and should be covered by the programme of emergency exercises overseen by the regulator.

This should include:

a) evaluation of how changes to exercise scenarios supported by longer exercise duration will permit exercising in real time such matters as hand-over arrangements, etc.

b) how automatic decisions taken to protect the public can be confirmed and supported by plant damage control data and

c) recommendations on what should be included in an appropriate UK exercise programme for testing nuclear emergency plans, with relevant guidance provided to Radiation Emergency Preparedness and Public Information Regulations 2001 (REPPIR) duty holders.

4.6.1 Overview

EDF Energy focuses considerable attention on preparing comprehensive emergency plans for all of its nuclear licensed sites. These are regularly tested and exercised both internally and in conjunction with public authorities. EDF Energy recognises the importance that these emergency exercises, overseen by the regulator, should consider longer-term severe accidents, to the extent that this is possible.

Whilst the response to this recommendation is to be led by the Office for Nuclear Regulation (ONR), EDF Energy welcomes the opportunity to provide a leading and active role in supporting them in developing their response.

4.6.2 Response

It is important that emergency exercises overseen by the regulator should consider the challenges associated with responding to long-term severe accidents to test procedures and arrangements. This would increase understanding and knowledge and thus lead to improved response arrangements and procedures.

EDF Energy has continued to offer support to the ONR on the development of this topic area and will continue to work closely with the regulator to ensure appropriate reviews and revisions are derived.

EDF Energy continues to hold regular meetings with the ONR to discuss this recommendation and the scope of the EDF Energy programme of work, including the Proof of Concept exercises which demonstrated longer-term accident management and which were discussed in Section 2.2.6 of this report and witnessed by the ONR.

4.6.3 Recommendation Conclusions

An overall view on ‘closure’ of this recommendation is essentially a matter for ONR. However EDF Energy considers that this recommendation may be moved to ‘normal business’, as the required links with ONR are in place and are active, ensuring that the aims of the recommendation are achieved.

4.7 Interim Recommendation 7 Close Out Report

Recommendation IR-7: ONR should review the arrangements for regulatory response to potential severe accidents in the UK to see whether more should be done to prepare for such very remote events.

This should include:

a) enhancing access during an accident to relevant, current plant data on the status of critical safety functions, i.e. the control of criticality, cooling and containment, and releases of radioactivity to the environment, as it would greatly improve ONR's capability to provide independent advice to the authorities in the event of a severe accident; and

b) review of the basic plant data needed by ONR – this has much in common with what we suggest should be held by an international organisation under Recommendation IR-1.

4.7.1 Overview

EDF Energy has an interest in ensuring that arrangements for regulatory response to potential severe accidents in the UK are robust and tested and will deliver the planned measures to protect the public. EDF Energy prepares comprehensive emergency plans for all of its nuclear licensed sites and tests these regularly, both internally and in conjunction with public authorities. EDF Energy is a responsible operator which is proactively learning from the Fukushima event and improving safety at its plants. In addition EDF Energy wants to ensure that any response by regulators and operators to a potential severe event is appropriately co-ordinated and practised.

Whilst the response to this recommendation is to be led by the Office for Nuclear Regulation (ONR), EDF Energy welcomes the opportunity to provide a leading and active role in supporting them in developing their response.

4.7.2 Response

It is important that comprehensive emergency response plans for severe accidents are in place. This will increase internal and external event response confidence and in conjunction with testing lead to improved regulatory response arrangements and procedures.

EDF Energy has continued to offer support to the ONR on the development of this topic area and will continue to do so. EDF Energy continues to hold regular meetings with the ONR to discuss this recommendation and the scope of the Japanese Earthquake Response programme.

4.7.3 Recommendation Conclusions

An overall view on 'closure' of this recommendation is essentially a matter for the ONR. However, EDF Energy considers that this recommendation may be moved to 'normal business', as the required processes are in place and are active, ensuring that the aims of the recommendation should continue to be achieved.

4.8 Interim Recommendation 8 Close Out Report

Recommendation IR-8: The UK nuclear industry should review the dependency of nuclear safety on off-site infrastructure in extreme conditions, and consider whether enhancements are necessary to sites' self sufficiency given for the reliability of the grid under such extreme circumstances.

This should include:

a) essential supplies such as food, water, conventional fuels, compressed gases and staff, as well as the safe off-site storage of any equipment that may be needed to support the site response to an accident; and

b) timescales required to transfer supplies or equipment to site.

4.8.1 Overview

The accident at Fukushima Dai-ichi was exacerbated by a prolonged loss of grid supply and all other on-site electrical supplies. This situation resulted in the complete loss of the cooling Essential Safety Function to the reactors and spent fuel cooling ponds. As well as the loss of off-site power, other essential supplies such as food, water, fuel and compressed gases were difficult to obtain.

The severe disruption lasted for several days at Fukushima and the surrounding area. This led to the delay in restoring the on-site power supplies, off-site communications and transport, and was a significant contributor to the impact of the event. Arrangements to provide emergency external support and back-up equipment to the site response teams were also overwhelmed by the extent of the disruption.

A post-Fukushima review of EDF Energy sites' self sufficiency was necessary to ensure the appropriate learning is applied and the reliance on the off-site services is reduced.

Extreme conditions are considered in the severe accident management provisions for the UK nuclear plants and these have been enhanced over the past years. Fukushima provides another opportunity to review these provisions to determine if further enhancement is required to reduce dependency on off-site infrastructure. Essential stocks and supplies are also considered under STF-9. Off-site provisions are also covered in IR-19 and IR-23.

4.8.2 Response

EDF Energy has completed a series of reviews of systems, processes and procedures across all 8 station sites:

- During the reviews attention was paid to the effects relating to the self sufficiency and dependence on off-site power
- A review of bulk oil fuel tanks on site showed that in general, the tanks have sufficient capacity to support the associated safety systems for longer than 72 hours, with the exception of Dungeness B (48 hours)
- A similar review showed that sufficient treated and robust water stocks are available on-site to support cooling functions for 48 hours for all sites. Stocks are located in tanks across each site and are protected to the infrequent seismic and flooding event. Further treated water is available in tanks that are not protected to these events and untreated water is available from further protected and unprotected sources. The water requirements and strategy for 72 hours, based on deployable water treatment equipment, are discussed further in IR-19
- Whilst it was recognised that fuel and water supplies are sufficient to support the stations' stated safety case mission time, the reviews conducted also allowed EDF Energy to determine areas where further enhancements to resilience could be made. Several resilience enhancements have been implemented on a station by station basis. The changes to site and procedures have been performed in line with existing company Engineering Change processes.

The scope of work subsequently carried out by the EDF Energy JER programme is discussed below, focusing on on-site resilience enhancements, Deployable Back-Up Equipment (DBUE) and Emergency Planning aspects.

Resilience Enhancements

The resilience work carried out on site has increased the survivability of the on-site infrastructure and supplies, reducing potential dependency on off-site infrastructure. Specific improvements have been made to flood protection, seismic resilience and other potential hazards:

- Resilience of on-site low voltage power, essential for key control and instrumentation, has been increased by provision of additional low voltage alternative diesel generators, in addition to further protecting existing back-up diesel generators where practicable
- High voltage Gas Turbine or Essential Diesel Generator backed supplies are available to support cooling functions following loss of grid. These are qualified against the 10^{-4} pa flooding and seismic event. To increase resilience of these functions to a Beyond Design Basis (BDB) on-site flood, where deemed appropriate, dam boards have been installed, and above and below ground building penetrations sealed
- Flood barriers have been installed at all sites to further protect key buildings and equipment in a BDB event
- Connection points, discussed further in STF-8, have been largely installed, with a small number requiring final connection on site, for ease of access to supplies and affected plant, including:
    - Mechanical DBUE interfaces to provide the capability to inject primary and secondary coolant in to the reactor systems and the fuel ponds and buffer stores – this includes main boiler feed connection to top-up water and pressure support connection points for injection of nitrogen if required at the Advanced Gas-cooled Reactors (AGRs) and the provision of connection points to the primary and auxiliary systems at Sizewell B (SZB), a Pressurised Water Reactor (PWR)
    - Electrical interfaces; low voltage connection points to enable the electrical connection of DBUE generation equipment to restore power and instrumentation to key systems following a BDB event as well as high voltage connection points for the longer term recovery operations at the AGRs.

Deployable Back-Up Equipment

EDF Energy has developed an array of off-site DBUE, and response strategies, to assist in an emergency event. The use of DBUE to support a response to a prolonged event is deemed appropriate considering the potential for severe disruption to occur on-site. Measures have been taken to ensure the strategy for using the DBUE is robust, and will be effective in supporting the station response.

On declaration of a nuclear emergency, EDF Energy's Through Life Management Partner (TLMP) will be contacted and mobilised and delivery of a comprehensive set of DBUE, from the most appropriate regional store, will begin. The DBUE will reach a staging post, within a short distance of the nuclear site, from which transfer of equipment to site will be co-ordinated. The TLMP and the staging post will have a continuing line of communication with the corporate Central Emergency Support Centre (CESC).

The strategy involves three off-site regional stores, located to ensure that any affected station can be supported before safety limits are exceeded. The timescales to safety limits, following loss of all forced cooling, boiler feed and the Pressure Vessel Cooling System (PVCS), have been reassessed using thermal analysis to determine temperature transients.

The deployment strategy has also identified a number of alternate transport routes, and staging posts, for each site. These consider possible disruption from various hazards, such as collapsed bridges, traffic congestion and flooding. Conservative calculations have developed estimates for delivery times, again taking into account the potential for severe disruption off-site. All DBUE has its own fuel stocks and is self sufficient for 72 hours post event.

There is also an additional DBUE store at the newly built SZB Emergency Response Centre (ERC), close to site, to reflect the shorter event escalation times for PWRs.

The stores contain vehicles for transporting equipment and personnel to site under hostile environmental conditions and potential infrastructure disruption, as well as the equipment that would be required on site to establish power and cooling.

The stores contain the following:

- Off-road personnel transport vehicles
- Off-road heavy lifting vehicles
- Debris moving vehicles (route clearance for example)
- Personal protective equipment
- Electricity generators for low voltage (415V) systems
- Water pumps – for reactor and fuel cooling
- Water treatment plant including reverse osmosis kit (it should be noted that this equipment can be deployed to site and operational within 48 hours, that is, prior to any site exhausting its existing treated stocks)
- Pond cooling equipment
- Damage repair equipment
- Dewatering pumps
- Temporary structures for response co-ordination and staff welfare
- Mobile communications equipment, including deployable instrumentation facilities
- Nitrogen gas supplies to support AGR Pressure Vessel repressurisation
- Nitrogen gas supplies for SZB Clean Air Train System (CATS) to support long term valve operations
- All necessary ancillary equipment required to use these facilities, including fuel stocks.

The off-site equipment is stored and maintained by the TLMP whilst in storage. This is an integral part of the BDB deployment strategy that EDF Energy has introduced across the fleet. The TLMP provides three services to the fleet: storage, maintenance and delivery. This strategy brings together logistical expertise from other industries and creates a flexible and timely emergency response capability.

Each station has a site specific deployment plan to provide guidance to the TLMP about delivery of equipment to pre-defined staging posts. From here, a specially trained forward deployment team will transport equipment to site and support logistics as and when required.

Emergency Planning

Emergency exercises at nuclear licensed sites and support centres are used to demonstrate and test the adequacy of the company's response to potential site incidents and nuclear emergencies. This is detailed in each site's Emergency Plan, to comply with nuclear site Licence Condition 11, Radiation Emergency Preparedness & Public Information Regulations 2001(REPPIR) and relevant nuclear security regulations.

As part of the JER programme, demonstrations have taken place similar to regulatory exercises, which validate and prove the concept of response for extreme events. Continuing demonstrations of capability have been embedded into the existing exercise regime.

Using Operational Experience (OPEX) from Fukushima and other industrial incidents, EDF Energy has assessed the needs of emergency responders with Human Aspects and Emergency Arrangements specialists. The work resulted in a number of changes to processes, roles and training packages, which have been incorporated into the emergency handbooks. Emergency roles have been reassessed and enhanced; the Emergency Welfare and Administrative Officer will advise the Emergency Controller on all welfare and administrative matters. This includes monitoring shift lengths, rest breaks and debriefing/ defusing. The increase in capabilities includes the assurance that for longer duration events greater emphasis is placed on staff welfare; for example that accommodation is secured away from site.

Provision of food and water is a key factor in sustaining responders during an emergency response. The TLMP store delivers rations along with water to the staging post. Stocks will sustain the staging post for the first 72 hours. During this time the Emergency Controller can make arrangements through either the CESC or TLMP to supply further supplies as required.

EDF Energy has taken into consideration re-supply of consumables for a prolonged event. Suppliers have been reviewed to ensure that during times of severe disruption robust mechanisms are in place to ensure security of supply. Updated contingency plans are also provided to the CESC Support Team to assist with administrative support to manage the procurement of facilities and supplies during response to events.

4.8.3 Recommendation Conclusions

Dependence on off-site infrastructure, and potential difficulties caused by severe disruption, has been considered. On-site resilience to a severe event has been increased by enhancing defences of key infrastructure, facilities and equipment on-site, thus reducing dependence on off-site infrastructure.

The capabilities of the off-site response have been increased, by provision of off-site DBUE with heavy lifting and personnel transportation vehicles capable of traversing off-road terrain and damaged infrastructure.

Resilience measures and DBUE provision have been built into training regimes which will continue to be demonstrated and reviewed as part of normal continuous improvement. As such, this recommendation is considered closed out.

4.9 Interim Recommendation 9 Close Out Report

Recommendation IR-9: Once further relevant information becomes available, the UK nuclear industry should review what lessons can be learnt from the comparison of the events at the Fukushima-1 (Fukushima Dai-ichi) and Fukushima-2 (Fukushima Dai-ni) sites.

4.9.1 Overview

One of the particular aspects of the Fukushima event was the severe disruption of the electrical grid, communications and transport systems. This lasted for several days and was a significant contributory factor in hindering recovery. Other nuclear power stations were similarly affected by such disruption of the infrastructure, in particular the Fukushima-2 (Fukushima Dai-ni) nuclear power site located some 11km away from the Fukushima-1 site, but while having problems these did not escalate into the problems experienced at Fukushima-1.

This raised the question as to what extent the nuclear safety of a site is reliant on the resilience of the local infrastructure in circumstances of extreme events affecting both the nuclear site itself and the surrounding area.

IR-9 was specifically raised to understand the particular elements that determined the ability of the reactors at the Fukushima-2 site to remain safe while the Fukushima-1 site had great difficulties. This may reveal some particular elements that merit consideration for UK nuclear facilities.

It is noted that this IR-9 is very closely related to IR-8 which provides a more general review of the dependency of nuclear safety on off-site infrastructure in extreme conditions, and considers whether enhancements are necessary to sites' self sufficiency given the reliability of the grid under such extreme circumstances.

4.9.2 Response

The EDF Energy approach to this recommendation has been to work jointly with Sellafield Limited and Magnox Ltd. A group of technical specialists in Civil Engineering and External Hazards has been established to review and analyse performance feedback and lessons learned from the Great East Japan earthquake and tsunami events relevant to the response of structures, systems and components to seismic and flooding hazards. This group has met on a number of occasions.

The group has the following terms of reference:

Title: **Civil Engineering and External Hazards Group**

Function: The purpose of this group is to review external hazards and the design of safety-related nuclear civil engineering structures. This includes performance feedback and lessons learned from the Great East Japan earthquake and tsunami events relevant to the response of structures, systems and components to seismic and flooding hazards. Particular attention is paid to comparison of events at the Fukushima Dai-ichi and Dai-ni sites (Interim Recommendation IR-9) and to information regarding the performance of structures and equipment relevant to the UK nuclear industry (IR-15). Such information is derived directly from Japanese sources and via projects run by international bodies such as: the International Atomic Energy Agency (and its International Seismic Safety Centre); the Nuclear Energy Agency (within the Organisation for Economic Co-operation and Development); the World Association of Nuclear Operators and the Institute of Nuclear Power Operations; as well as learned societies, institutions and other organisations. The aim is to ensure that implications are distilled, understood, shared and made available to inform future design, assessment and safety case work undertaken by the UK nuclear industry.

Membership: The group comprises Civil Engineering and External Hazards specialists nominated by interested UK licensees.

Meetings: Meetings are held as necessary to consider emerging information or matters of common interest arising. Ten meetings have been held in the period August 2011 to

December 2013. It is expected that in future the meetings will occur approximately four times a year.

Reporting: Minutes are kept for internal dissemination within licensees.

Key output from the Group, of relevance to this IR, taking account of meetings held up to and including the issue of this Close-Out Report, is summarised as follows:

(i) EDF Energy, Magnox and Sellafield Ltd believe that Fukushima Dai-ni was significantly less affected in that the Fukushima Dai-ni site was not inundated by the tsunami to the extent that was the Fukushima-Dai-ichi site. According to information from Tokyo Electric Power Company (TEPCO) this is because the peaks of successive tsunami surges coincided at Fukushima Dai-ichi, but not at Fukushima Dai-ni, giving a greater depth of water at Fukushima Dai-ichi.

(ii) The key difference between these two Japanese sites was that at Fukushima Dai-ni one off-site power line was maintained, and a further line that was initially shut-down was restored the following day. In the UK loss of off-site power is considered to be a frequent fault and as such, there are multiple back-up generators in place.

(iii) There was evidence of better leadership at Fukushima Dai-ni by the laying of more than 9km of temporary power cables in 16 hours and the use of mobile power trucks to restore electrical supplies to essential plant; similar attempts at Fukushima Dai-ichi failed because by the time they were made, the hazard had become too great. Similarly, according to TEPCO misjudgement of the operational situation on Fukushima Dai-ichi Units 1 and 3 delayed the injection of alternative water.

(iv) EDF Energy has taken account of lessons learned from the events at Fukushima Dai-ichi and Fukushima Dai-ni in identifying potential enhancements to the resilience of all sites in responding to extreme hazard events.

The delivery of specific additional site resilience measures is covered in more detail within other sections of this report.

This recommendation is considered as having been moved in to normal business as future emerging information will be dealt with as normal business by the Working Group that has been established. It is planned that meetings of technical specialists will continue and be extended to include appropriate representatives from other interested licensees.

4.9.3 Recommendation Conclusions

Adequate arrangements are in place which have ensured review and understanding of the particular elements that determined the ability of the reactors at the Fukushima-2 site to remain safe while the Fukushima-1 site had great difficulties. There will be continual review of learning, not just as a consequence of Fukushima, but through the collaborative discussions now taking place as part of the Civil Engineering and External Hazards Group meetings.

This Recommendation is considered as having been moved in to normal business as future emerging information will be dealt with as normal business by the Working Group that has been established.

4.10 Interim Recommendation 10 Close Out Report

Recommendation IR-10: The UK nuclear industry should initiate a review of flooding studies, including from tsunamis, in light of the Japanese experience, to confirm the design basis and margins for flooding at UK nuclear sites, and whether there is a need to improve further site-specific flood risk assessments as part of the periodic safety review programme, and for any new reactors. This should include sea-level protection.

4.10.1 Overview

The flooding hazard from coastal flooding and rainfall flooding has been addressed in detail by new studies for all sites and is being acted upon to remedy identified weaknesses, as described in more detail in the response to STF-7. As part of Japanese Earthquake Response (JER) programme, EDF Energy is implementing a fleet-wide programme of improved flood resilience to many essential plant buildings, involving provision of new dam board protection, sealing of low-level ingress routes and installing measures to prevent back-flow through drains. The rest of the IR-10 response specifically addresses the tsunami hazard.

Flooding of the site and its effects on plant was central to the events at Fukushima and was caused by a tsunami. This is relevant to EDF Energy as all its sites are coastal or estuarial and so could in principle be vulnerable to flooding from tsunamis; hence it is appropriate to review the hazard with current knowledge to confirm the Design Basis (DB) and margins at EDF Energy stations.

EDF Energy has undertaken a new review of the tsunami hazard to its station sites, based on up-to-date information. The review has made a balanced assessment, recognising that there is a variety of possible causes of tsunamis (tsunamigenic events) and that the views taken of them and the risks they pose vary between different studies. The studies used as the main reference point are the DEFRA 2005 and 2006 reports.

Tsunamis are considered in combination with high water levels - generally, Mean High-Water Spring (MHWS) tide levels – but not combined with worst-case storm surge events, on probabilistic grounds.

4.10.2 Response

EDF Energy has undertaken a new review of the tsunami hazard to EDF Energy's UK nuclear power station sites, presented in an Engineering Advice Note (EAN).

The new tsunami study uses, as its principal reference source on the tsunami hazard, DEFRA's 2005 and 2006 reports, though it also acknowledges and considers different views taken by other studies. These studies consider possible tsunamigenic events, in geographical locations from UK coastal waters to as far as the Canary Islands and the Caribbean, and what tsunamis they could cause to arrive at the UK coast. They do not specifically consider EDF Energy station sites, though these are to some extent considered in a later (2009) paper that considered the tsunami hazard to proposed nuclear new-build sites.

The DEFRA 2005 and 2006 studies are confirmed as still being valid main reference points: notwithstanding that there has been subsequent work on refining tsunami modelling, and some studies have taken different views of particular tsunami hazard sources.

The tsunami review EAN identifies the credible, significant tsunami hazards to EDF Energy stations. Some postulated cases are discounted as not credible (that is, of very low probability), notably the scenario of a single massive collapse at La Palma (Canary Islands) causing a large tsunami.

The review also recognises some historical events over which there is debate but it is concluded that they were not in fact tsunamis, such as the Dover Straits floods of 1580 and the Bristol Channel Floods of 1607; the latter is considered at some length.

The review's findings with respect to each station site are summarised in the following paragraphs. Where there is a tsunami hazard, the study compares it with storm surge scenarios considered as Design Basis events in station safety case, and with 1 in 10,000 year sea water levels (Infrequent hazards, in safety case terms) considered in recent JER flooding assessments. The predicted tsunami water levels are considered with reference not only to MHWS tide levels as considered in safety case documents, but also current information on MHWS for 2008-2026 as published by the National Tide and Sea Level Facility.

For Hartlepool (HRA), tsunamis could be generated by a large undersea slide of a similar type to the prehistoric Storegga event, however this may be largely discounted on probabilistic grounds, and if it were to occur then the effect at HRA would be small. A tsunami could also be generated by a near-field North Sea event, but the effect of events considered in the source literature would be small at HRA. The effects of the tsunamis considered at HRA would be a water elevation increase of less than 1m, and less than effects from storm surge events. The margin compared to storm surge values is less at HRA than at other sites (~0.7m), however this is still a considerable margin.

For Torness (TOR), a near-field event such as that considered for HRA is also relevant, but with similarly small tsunami effects at the station and a greater level of margin due to the sites topography. The proximity of TOR to a Storegga-type large slide event is greater, and hence the tsunami effects may be greater than at HRA, however DEFRA's research concludes that the event would be "a relatively small event if it occurred (less than the Storegga event)" and this suggests a potential tsunami height at TOR up to in the order of 1m. In terms of water levels, this is bounded with some margin by storm surge scenarios. Torness is also a relatively high site, affording reduced vulnerability to tsunami hazards.

Tsunami hazards to Hinkley Point B (HPB) could arise from events in the Celtic Sea or further afield in the Atlantic, west of Gibraltar or in the Canary Islands. Other identified tsunami sources would not be expected to have any significant effects at HPB's location. The maximum water level increase from a tsunami at HPB, from the events considered, would be around 0.4m according to DEFRA's reports, hence considerably less than those in the current Safety Case predicted from a 10,000 year storm surge event.

The new tsunami review considers the 1607 Bristol Channel Floods, as this event is discussed in other literature under the heading of tsunami hazards, including in the DEFRA 2005 report. There is debate over whether or not the floods actually involved a tsunami, and the review EAN notes (a) that the weight of evidence and opinion tends to the view that it was not a tsunami, and (b) that the HPB safety case takes into account the 1607 floods in its consideration of storm surge scenarios.

For Hunterston B (HNB) no credible, significant tsunami hazards are identified in the DEFRA 2005 and 2006 reports, or in the 2009 review of proposed new build sites. The conclusion is therefore that there is no credible, significant tsunami hazard to HNB.

Similarly, for Heysham 1 and 2 (HYA and HYB) neither the DEFRA 2005 and 2006 studies nor the 2009 review of proposed new build sites indicates that the Heysham site or the wider North West of England are at risk of any credible, significant tsunamis. Any tsunami hazard to HYA and HYB is therefore concluded to be minimal, and to be bounded in terms of water levels by storm surge scenarios, with considerable margins.

For Sizewell B (SZB), studies including DEFRA 2005 conclude that the potential for a tsunami hazard should not be considered negligible but also that significant tsunami events should be considered to be very unlikely. The tsunami review notes that SZB could be affected by similar North Sea events to those considered for HRA, if they were to occur further south, however the tsunami water elevation would be estimated as still less than 1m. The SZB tsunami hazard may therefore be considered to be small, and in terms of water levels bounded with a considerable margin by storm surge scenarios, which pose no threat to the station.

At Dungeness B (DNB), neither DEFRA 2005, DEFRA 2006 nor the 2009 review of proposed new build sites indicates that the Dungeness site is at risk of any significant tsunamis. Tsunamis from the potential source area west of Gibraltar are unlikely to penetrate as far as Dungeness, and tsunamis initiated at the northern limit of the North Sea would be unlikely to penetrate into the English Channel. The review EAN considers the possibility of a tsunami generated by rockfall (cliff collapse) but discounts this as a significant hazard.

4.10.3 Recommendation Conclusions

EDF Energy has reviewed the tsunami hazard to its station sites, using up-to-date information from a number of sources, centred on the 2005 and 2006 DEFRA reports. The review concludes that the EDF Energy stations are not vulnerable to the tsunami hazard. Recommendations have been made to capture the requirement for ongoing review in the field of the tsunami hazard, and to consolidate the judgements presented. These Recommendations will be owned by EDF Energy's Design Authority, as part of the ongoing JER legacy delivery programme. This recommendation is therefore considered to be closed.

4.11 Interim Recommendation 11 Close Out Report

Recommendation IR-11: The UK nuclear industry should ensure that safety cases for new sites for multiple reactors adequately demonstrate the capability for dealing with multiple serious concurrent events induced by extreme off-site hazards.

4.11.1 Overview

This recommendation is relevant to EDF Energy's Hinkley Point B (HPB) and Sizewell B (SZB) sites which are adjacent to sites proposed for new reactors.

The issue of adjacent reactor sites is not generally relevant to EDF Energy twin unit Advanced Gas-cooled Reactor (AGR) sites since they are either isolated sites or are adjacent to Magnox Limited reactors which are long cooled and depressurised and, with the exception of Sizewell A, defuelled. It is acknowledged that the two twin unit AGRs at Heysham (Heysham 1 and Heysham 2) do not fall into this category. However, the adequacy of the emergency arrangements at the Heysham sites is being specifically considered in the responses to our own stress test Considerations CSA-81, CSA-82 and CSA-83. Therefore the response to IR-11 excludes consideration of the Heysham sites.

The events at Fukushima clearly demonstrated the requirement to be able to successfully manage reactor accidents at multiple reactors located in close proximity. The issues may have been compounded had the response to multiple reactor events not been coordinated. For the current EDF Energy reactors HPB and SZB, the issue is relevant to the overall accident management arrangements that will be required when nuclear material is introduced onto the new adjacent reactor sites by licensee Nuclear New Build Generation Company (NNB GenCo).

4.11.2 Response

Since the full details of the proposed plant and operations at the sites adjacent to HPB and SZB are only at a preparatory stage there are currently no plans to develop detailed and coordinated accident and emergency arrangements addressing coincident or consequential site events in the near future.

A thorough review of existing EDF Energy emergency arrangements has been undertaken in addressing Recommendations IR-22, IR-23 and FR-2. The Proof of Concept training exercise based on the Heysham site demonstrated adequacy of the post Fukushima provisions at a multi-station site against multiple concurrent events.

EDF Energy has experience in coordinating with Magnox where their sites are located adjacent to our own stations. Where appropriate, existing emergency arrangements take into account adjacent sites and in the event of an incident, full musters of staff on both sites take place under the leadership of the affected site in a single-site driven scenario. Such coordination would also occur in a multi-site event. Should an incident requiring off-site emergency support occur, agreements are in place between licensees for mutual strategic cooperation and assistance at both local and corporate levels, including use of the Central Emergency Support Centre located at Barnwood.

Such coordination would continue and extend to the licensees of new reactor sites including the continuation of regular exercises and demonstrations as part of the national emergency exercise programme.

EDF Energy already actively shares Operating Experience (OPEX) and Suitably Qualified and Experienced Personnel expertise with NNB GenCo and will continue to do so when emergency arrangements for the new stations are in development.

4.11.3 Recommendation Conclusions

EDF Energy will endeavour to share knowledge and guidance with the licensee of any new adjacent site using OPEX gained through collaboration with existing licensees. Such coordinated arrangements will be developed in due course, with full oversight from the regulator, well in advance of nuclear material being introduced onto the adjacent site. Detailed timescales for this are not yet finalised, however EDF Energy considers this to be part of normal business and closed in context of the EDF Energy Japanese Earthquake Response programme.

4.12 Interim Recommendation 12 Close Out Report

Recommendation IR-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.

Existing licensees are expected to review their current spent fuel strategies as part of their periodic review processes and make any reasonably practicable improvements, noting that any intended changes need to take account of wider strategic factors including the implications for the nuclear fuel cycle.

4.12.1 Overview

This is directly relevant to the EDF Energy Sizewell B (SZB) site.

SZB is a Pressurised Water Reactor (PWR) and EDF Energy is currently developing a new strategy for spent fuel at this site which is compliant with Safety Assessment Principles (SAPs). This strategy includes a proposal for an on-site dry cask fuel store.

For the Advanced Gas-cooled Reactor (AGR) fleet of power stations, the existing AGR spent fuel management activities are already aligned with ONR's SAPs; however they have been reviewed in light of the events in Fukushima.

For information on resilience and improvements to existing spent fuel arrangements, see IR-20.

4.12.2 Response

EDF Energy has the responsibility for managing SZB and the AGR fleet spent fuel lifetime arisings. The spent fuel strategies have been reviewed with confirmation that existing AGR spent fuel management activities are already aligned with SAPs. As part of continuous improvement, strategies will continue to be reviewed as part of normal business in Periodic Safety Reviews (see FR-4 for more detail).

The AGR strategy is discussed more fully in the document 'Spent Fuel Endurance Strategy for AGRs: Review following the events of Fukushima Japan', which determined that minimising the storage of spent fuel on-site continues to be the most appropriate strategy, and ties in with national policy.

The Sizewell B Spent Fuel Management – 2011 Strategy Position Report discusses how in 2008 the lifetime strategy for managing the SZB spent fuel was approved by the Nuclear Decommissioning Authority (NDA), and EDF Energy initiated a project to manage the necessary works.

The approved strategy requires the building of a dry fuel store on the SZB site and requires the continued storage of spent fuel on site for an extended period until a long-term storage solution is available to ultimately dispose of the fuel.

The dry fuel store project has discussed the implications of the events in Japan with the ONR, demonstrating that the project has taken due cognisance of the events and that the store has adequate margins against severe events due largely to its inherent passive safety features, and that these margins have been further assessed in light of the events in Japan and found to be appropriate. The dry fuel store safety case will include a description of the resilience of the facility to extreme events and the steps taken in mitigation of these effects.

4.12.3 Recommendation Conclusions

There is no further work required as part of the EDF Energy Japanese Earthquake Response programme. Work is ongoing as part of EDF Energy normal business.

It is noted that the dry fuel store at SZB is incorporating learning from the events in Japan and will demonstrate its resilience to extreme events in its safety case.

This recommendation is therefore considered to be closed.

4.13 Interim Recommendation 13 Close Out Report

Recommendation IR-13: The UK nuclear industry should review the plant and site layouts of existing plants and any proposed new designs to ensure that safety systems and their essential supplies and controls have adequate robustness against severe flooding and other extreme external events. This recommendation is related to Recommendation IR-25 and should be considered along with the provisions put in place under that recommendation. It should include, for example, the operator's capability to undertake repairs and the availability of spare parts and components.

4.13.1 Overview

This recommendation has been linked to IR-25. This response to IR-13 principally addresses layout aspects and access to the site. The response to IR-25 addresses aspects related to arrangements for dealing with severe accident scenarios on-site, in particular external hazards.

The events on the Fukushima 1 site following the impact of the tsunami highlighted the potential for damage to essential safety systems from extreme natural events. It is appropriate for EDF Energy to review site and plant layouts for its nuclear power stations in the UK, to assess how they affect the robustness and resilience of safety systems and their essential supplies and controls in the event of flooding and other extreme external events.

Consideration of site and plant layout has been an essential part of EDF Energy's reviews (under the Japanese Earthquake Response (JER) programme) of external hazards, particularly flooding and including also severe weather and seismic hazards. These have been investigated through a range of new studies, leading where appropriate to additional measures to ensure robust safety cases and adequate margins for safety.

EDF Energy's response to this recommendation is supported strongly by the response to other findings and recommendations, in particular STF-5.

4.13.2 Response

The need to consider plant and site layout against flooding and other external hazards is acknowledged as important in the assessment of new designs, and in the assessment of those hazards for existing plant.

In relation to the existing stations, the external hazards reviews and analyses, including those undertaken under JER relating to flooding, seismic hazards and extreme weather including the ENSREG stress tests and independent flooding reviews, have taken full account of layout when considering aspects such as the hazards' effect on different building and plant, and operator actions in the context of the hazard and the plant/site layout.

Layout is a significant element of flooding scenarios, and the new flooding assessments have modelled the actual layout of each station and the buildings and plant within it; the further-refined flood modelling already undertaken for Dungeness B (DNB), Heysham 1 (HYA) and Heysham 2 (HYB) has more accurately modelled site topography. Such detail will also be considered in any further analyses for the remaining stations.

Whilst existing sites' layout is not being re-arranged, the improvements to flood defences at certain stations (DNB, HYA and Hartlepool (HRA)) and the fleet-wide improvements to building flood protection are effectively remedial action against possible weaknesses of site layout and location with regard to flooding. The flood protection measures being applied to buildings are a major element of the JER on-site resilience improvements. These flood protection measures provide improved defence in depth for the bottom line plant, by limiting water ingress. From a layout viewpoint, they therefore protect the segregation gained by locating plant in different buildings. The JER flood protection consists principally of (a) new facilities to place dam boards around entrances to buildings (or in some cases flood barriers within buildings); (b) sealing of penetrations into the building; (c) fitting non-return valves in building drains. Advance warning of potential weather and external flood conditions has also been improved by provision of the Met Office VisualEyes and Safesee systems, aiding the timely deployment of measures such as dam boards in advance of threats. These measures are described at more length in the response to STF-7.

In relation to seismic hazards, layout is already considered in site safety cases, which recognise buildings/structures ability to collapse onto essential plant. Seismic assessments also recognise the potential for structures/buildings and systems that are themselves seismically qualified to be damaged by the collapse or fall of other, unqualified, structures. EDF Energy's responses relating to seismic hazards are described under STF-2, STF-4, STF-5 and STF-6.

In relation to weather hazards other than rain (which is an aspect of flooding), these hazards do not relate strongly to site layout, as all parts of the site will be affected similarly by the weather conditions. Site layout has some influence on how much high winds may affect nearby facilities (such as by wind-blown debris or failed structures falling onto them, also building/site design can lead to wind corridors), however this will vary with wind direction and station safety cases make no claims on, for example, one building shielding another from wind – in general, buildings/structures are required to be suitably qualified against wind regardless of direction and without assuming protection from other structures. Again, improved weather forewarning from the VisualEyes and Safesee systems will aid site preparedness for severe weather events.

A more complete confirmation of available margins against external hazards, with respect to beyond design basis considerations, is provided through the response to STF-5.

Regarding layout of equipment within buildings (and flooding), a tabulation of buildings containing essential plant together with water levels which might cause essential equipment to fail is not considered useful given that the emphasis under JER has been on preventing flood water entering buildings at all, as described above and in the response to STF-7.

Assessment of severe weather hazards, including wind, rain, snow and flooding, has taken account of the potential for the hazards to affect access routes (though this is a lower priority than protection of essential plant). There is potential for flooding to render some roads impassable, to ordinary vehicles at least, and debris due to damage to buildings and other structures from other external hazards could also affect access routes. The Deployable Back-Up Equipment (DBUE) procured by the JER programme includes Land Rovers (with wading ability) to transport people, all-terrain Unimog and Zetros trucks to transport equipment, and JCBs to clear debris.

Functional integrity will be additionally supported by the EDF Energy JER DBUE, which can restore a variety of essential plant functions and is located externally to the site, to be deployed to the site when needed in an emergency, or potential emergency, scenario. The physical separation of the DBUE from the station sites means that it is likely to be segregated from the effects of severe natural hazard events which create an emergency at the site; this applies to the AGR stations, for which DBUE is stored at a number of locations distributed around the country and typically some hours' travel by road from the stations, and also SZB for which the DBUE (which is specific to SZB) is stored much closer to the site but is still separate from it and so segregated by its location. Note that development of the DBUE's Forward Deployment Strategy has included scenario planning which confirms the ability to deploy the DBUE to each site within the required response timescales, taking account of a variety of issues which may challenge access to site. The JER DBUE is described at more length in the response to IR-25.

The existence of appropriate protection for both second line and bottom line flooding events (with bottom line margins) is the key safety question which is relevant to this recommendation – and the responses to STF-5 and IR-10 are considered sufficient to address this subject. The response to STF-5, in particular, provides assurance of margins for bottom line essential plant against extreme external events (within the scope of JER). Instances of weakness (which may be as a result of poor plant layout) have been identified through a variety of review exercises, with the subsequent application of the safety case anomalies process, as required.

The response to STF-7 also details further how safety systems and their supporting systems and services have been assessed to ensure adequate robustness against flooding.

The last part of IR-13, relating to repairs and the availability of spare parts and components, is addressed principally under IR-25 together with information and justification of DBUE.

4.13.3 Recommendation Conclusions

EDF Energy has undertaken, under the JER programme, a variety of reviews and analyses of external hazards, including the ENSREG stress tests, which have included suitable consideration of site and plant layouts. Where appropriate, measures are being taken to improve safety, notably with respect to flooding safety. Whilst the basic layout of stations has not been changed, measures taken to improve integrity against flooding protect the segregation of plant and related key safety functions. In addition to these on-site modifications which also include connection points, EDF Energy has developed a layered back-up capability based on DBUE and enhanced emergency arrangements allowing the deployment of equipment to site and the connection to systems via newly installed connection points as discussed in STF-8.

EDF Energy's response to this recommendation is supported strongly by the response to other findings and recommendations, in particular STF-5 and also STF-7 and IR-10.

The lessons learned from the JER reviews will be reflected in the layout of future designs, and the reviews of those designs, to ensure future plant with robust safety cases and margins of safety in relation to external hazard events.

Subject to completion and closure of remaining specific activities as documented in responses to other findings and recommendations, this recommendation is considered to be closed.

4.14 Interim Recommendation 14 Close Out Report

Recommendation IR-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.

4.14.1 Overview

The work performed under the ENSREG Stress Test response included a comprehensive review of loss of power, loss of heat sink and the impact of external natural hazards on the safety cases for resilience and recovery for all of EDF Energy existing fuel route areas. This specifically included bottom siphoning faults on fuel ponds. This will therefore ensure that existing bottom penetrations have adequate and operable anti-siphoning features installed. This recommendation is closely related to IR-12 and WANO SOER 2011-3.

4.14.2 Response

All irradiated fuel storage pond safety cases explicitly detail anti-siphon design features and justify acceptable maximum coolant loss due to pipework failures. In addition, an extensive review of pond cooling functionality with a focus on the adequacy of siphon breakers has been carried out fleet wide as per WANO SOER 2011-3, and provided to the Office for Nuclear Regulation (ONR).

The majority of EDF Energy stations have some form of passive anti-siphon measures to protect against the risk of siphoning. These measures include: weir extract systems, high level returns, anti-siphon pipework and anti-siphon vent holes. Further protection is gained from active anti-siphon measures consisting of automatic and manually operated isolation valves, the prompt closure of which would further limit water loss in the event of a pipework breach. Across the fleet of EDF Energy power stations, both the Advanced Gas-cooled Reactors (AGRs) and the Pressurised Water Reactor (PWR), stainless steel pipework is used to ensure the risk of mechanical damage resulting in a breach is sufficiently low.

An action is in place to implement additional protection against siphoning faults at Hinkley Point B (HPB) where there are currently no passive anti-siphon features. Across the fleet, work is in progress to confirm the adequacy of functional checks on the installed passive anti-siphon and pond isolation measures.

Testing carried out to substantiate the installation of anti-siphon pipework at Dungeness B (DNB) Power Station has identified that siphoning can continue to occur after air is first drawn into the system. For the anti-siphon pipework installed at DNB, the siphon is broken at a water level 1.08 metres below the point at which air is first drawn into the pipework. This is judged to be bounding for other stations on the basis of the larger ratio of the anti-siphon measure cross sectional area to that of the system pipework at these stations and the comparable hydrostatic head. Across the fleet, the loss of pond water due to siphoning is therefore not sufficient to expose stored fuel. The drop in level could however expose a travelling skip at Hartlepool, Heysham 1 and HPB Power Stations. The off-site radiological consequences of exposing a single skip of irradiated fuel have been assessed as low, lying within dose band 1.

The fuel element wash systems are a potential siphoning route at all stations. The systems are normally isolated when fuel element disposals are not in progress. This limits the time at risk during which a pipework breach in these systems could give rise to a loss of pond water. Reduction in pond level via the element wash system would be slow as the pipework is small bore. This would give adequate time for the operator to isolate the breach and prevent a significant reduction in pond water level.

Across the fleet, intentional pond drainage is not a routine operation covered by the safety cases. As such pond drainage lines are generally isolated at all times with the operation of the valves precluded by interlocks and administrative controls. An Engineering Change and implementation of additional administrative controls would be necessary should drainage be required.

An action is in place at all stations to confirm the adequacy of controls on the isolation of systems not in constant use, such as the element wash systems and pond drain lines.

For pond operations including fuel handling, element wash and pond drainage, station operators would be present enabling an immediate response to curtail the fault. Across the fleet, a series of diverse alarms and instrumentation provide condition monitoring such that loss of pond water level should be revealed with adequate time for operator response.

It has been found that siphoning faults at irradiated fuel storage ponds do not directly result in the exposure of stored fuel. Work is ongoing to establish timescales to restore cooling at the reduced water level caused by worst case siphoning faults and to confirm that these do not undermine safety case claims on operator response. Due to the large pond water volume and limits on the decay heat of stored fuel, loss of pond cooling events are generally slow progressing faults allowing sufficient time for operator intervention.

Across the fleet there are multiple potential sources of pond make-up water to restore pond level and provide additional cooling in the event of a significant siphoning fault. In addition to diverse pond cooing and make-up water availability at each individual station, the Deployable Back-Up Equipment (DBUE) provision contains pond top-up capability for all stations, and pond cooling capability for the AGR fleet. For further discussion on spent fuel strategies and DBUE capability pertaining to pond water makeup, please see IR-12 and IR-20.

4.14.3 Recommendation Conclusions

An extensive review has been carried out to evaluate the anti-siphon measures in place and their role in preventing a significant loss of water from the irradiated fuel storage ponds following a pipework breach. Potential improvements to further reduce the risk associated with loss of pond water faults have been discussed in an As Low As Reasonably Practicable meeting with key stakeholders to determine the most appropriate course of action. Actions from this review have been incorporated into normal business as part of EDF Energy’s corrective action programme and will be tracked, monitored and progressed accordingly. Therefore, no further work is required as part of the EDF Energy Japanese Earthquake Response programme and this recommendation is considered to be closed.

4.15 Interim Recommendation 15 Close Out Report

Recommendation IR-15: Once detailed information becomes available on the performance of concrete, other structures and equipment, the UK nuclear industry should consider any implications for improved understanding of the relevant design and analyses. The industry focus on this recommendation should be on future studies regarding the continuing validation of methodologies for analysing the seismic performance of structures, systems and components important to safety. This should include concrete structures and those fabricated from other materials.

4.15.1 Overview

It is recognised that the Fukushima reactor shut down systems operated effectively in response to the level 9 earthquake as did the secondary cooling systems. This indicates the robustness of seismic design approaches adopted for these Japanese plants.

In due course, important insights may be gained from detailed observations of the performance of the reinforced concrete reactor building and containment structures, under the seismic loading. This will allow for comparison of actual structural behaviours with analysis and code expectations, and may provide valuable insights into design/analysis for such structures in the future.

This recommendation therefore notes the opportunity to review such learning, as applicable to the UK nuclear industry.

4.15.2 Response

Recommendation IR-15 relates to the need for industry focus on the continuing validation of methodologies for analysing the seismic performance of structures, systems and components important to safety, implicitly given a robust assessment of the hazard.

It is noted that the Close-Out report for Stress Test Finding STF-2 concludes that whilst there have been advances in modern techniques for the assessment of the seismic hazard this does not mean that the existing Seismic Hazard Working Party (SHWP) hazards assessments are no longer fit for purpose. The SHWP studies are judged to remain robust and defendable against modern practice.

The approach for the response to the recommendation has been for EDF Energy to work jointly with Sellafield Limited and Magnox Limited. A group of technical specialists in External Hazards and Civil Engineering has been established to review the events of the Great East Japan Earthquake and to consider the lessons learned in respect of the response of systems, structures and components to seismic and flooding hazards. This group has met on a number of occasions.

The group has the following terms of reference:

Title: **Civil Engineering and External Hazards Group**

Function: The purpose of this group is to review external hazards and the design of safety-related nuclear civil engineering structures. This includes performance feedback and lessons learned from the Great East Japan earthquake and tsunami events relevant to the response of structures, systems and components to seismic and flooding hazards. Particular attention is paid to comparison of events at the Fukushima Dai-ichi and Dai-ni sites (Interim Recommendation IR-9) and to information regarding the performance of structures and equipment relevant to the UK nuclear industry (IR-15). Such information is derived directly from Japanese sources and via projects run by international bodies such as: the International Atomic Energy Agency (and its International Seismic Safety Centre); the Nuclear Energy Agency (within the Organisation for Economic Co-operation and Development); the World Association of Nuclear Operators and the Institute of Nuclear Power Operations, as well as learned societies, institutions and other organisations. The aim is to ensure that implications are distilled, understood, shared and made available to inform future design, assessment and safety case work undertaken by the UK nuclear industry.

Membership: External Hazards and Civil Engineering specialists nominated by interested UK licensees.

Meetings: When necessary to consider emerging information or matters of common interest. Ten meetings have been held in the period August 2011 to December 2013. It is expected that in future the meetings will occur approximately four times a year.

Reporting: Minutes are kept for internal dissemination between relevant UK licensees.

Key output from the Group, taking account of meetings held up to and including the issue of this Close-Out Report, is summarised as follows:

- The UK nuclear industry learns continuously from earthquakes all over the world. It was particularly noted that the Great East Japan earthquake released about 30,000 times more energy than that expected of a UK design basis earthquake.
- Following events in Japan EDF Energy, Magnox and Sellafield Ltd recognised a need to more explicitly account for the risk from beyond design basis natural hazards, and to plan the emergency response to such severe events.
- Sellafield Ltd sent one of its civil engineers as part of the UK's Earthquake Engineering Field Investigation Team to Japan to study at first hand the effects of the Great East Japan earthquake. However, most of the evidence of direct shaking induced damage had been destroyed by the subsequent tsunami.
- Most of the industry's design is in compliance with design standards. The Fukushima Dai-ichi Nuclear Power Plant may have been designed to early USA standards, since the designs originated in the USA. Parts of the UK nuclear industry use current versions of some of these USA standards. The seismic provisions of such design standards are revised and updated in response to lessons learned from earthquakes. Any lessons that emerge from the Great East Japan earthquake may in future be incorporated into these standards by the drafting committees, on which some members of the UK nuclear industry serve.
- A lesson from events in Japan is to reinforce the need to conduct a Periodic Review of the safety of nuclear facilities, including the ability to withstand external hazards, as the UK industry has done since the early 1990s.
- EDF Energy, Magnox Ltd and Sellafield Ltd expect that the Seismic Qualification Utilities Group of which both EDF Energy and Magnox are members, may attempt to obtain data on equipment performance from the Japanese industrial and nuclear plants. The safe shut down of many reactors throughout northern Japan was a success story, in particular the insertion of control rods from below the Boiling Water Reactors.
- Lessons may be learned from Japan concerning soil-structure interaction, given the heavily instrumented nature of the Fukushima plant, when data become available. Even so, smaller ground motions recorded in the downhole arrays at Lotung or Hualian are more relevant to the UK.

Future emerging information will be dealt with as normal business by the Working Group that has been established.

It is planned that meetings of technical specialists will continue and be extended to include appropriate representatives from other interested licensees.

4.15.3 Conclusions

Adequate arrangements are in place, in terms of ongoing involvement in activities associated with the development of methodologies, with respect to seismic performance of structures, systems and components important to safety, taking full cognisance of the significant learning available post-Fukushima.

This Recommendation is considered as having been moved in to normal business as future emerging information will be dealt with as normal business by the Working Group that has been established.

4.16 Interim Recommendation 16 Close Out Report

Recommendation IR-16: When considering the recommendations in this report the UK nuclear industry should consider them in the light of all extreme hazards, particularly for plant layout and design of safety-related plant.

4.16.1 Overview

This Recommendation serves to act as a high level prompt to ensure that the EDF Energy Japanese Earthquake Response (JER) programme takes the opportunity to consider resilience to extreme hazards in general, following the events at Fukushima.

4.16.2 Response

This Recommendation regarding Extreme External Hazards consideration is implicit in the work scope of the JER programme, the details of which have been routinely discussed with ONR over the course of delivery, and are fully represented by the suite of close-out reports issued to the ONR.

There has been a particular focus on the resilience to external natural hazards, noting the specific learning as a consequence of the Fukushima operational experience. Notwithstanding this, the associated enhanced on-site and off-site resilience arrangements will likewise provide improved overall protection and recovery from the wider potential extreme hazards.

4.16.3 Recommendation Conclusions

This Recommendation is judged to be fully closed on the basis of the significant work undertaken post-Fukushima, as part of the JER programme, and the secure transition of outstanding commitments into normal business.

4.17 Interim Recommendation 17 Close Out Report

Recommendation IR-17: The UK nuclear industry should undertake further work with the National Grid to establish the robustness and potential unavailability of off–site electrical supplies under severe hazard conditions.

4.17.1 Overview

It is recognised that the severe disruption lasted for several days at Fukushima and this delay in restoring the on-site power supplies was a significant contributor to the event. Together with National Grid Electricity Transmission (NGET) and Scottish Power (SP) Energy Networks, a review of the electrical supplies from the national grid is necessary to ensure the appropriate learning is applied and to establish if the reliability of the off-site power can be improved. It is also important to review the grid capability to re-build should damage be caused by extreme natural events as happened at Fukushima

EDF Energy has a strong existing relationship with both NGET and SP Energy Networks who own and maintain the grid connections for the nuclear sites. This will continue to be kept under continuous review as regards the appropriateness of the connections for the nuclear sites under the auspices of the relevant Nuclear Site Licence Provisions Agreement (NSLPA), not withstanding the additional work that will be carried out for this event.

A Loss of off-site Power (LOOP) event is, not withstanding the above arrangements, still recognised in station safety cases as a frequent event (~1E-1/yr) at all EDF Energy sites, a figure substantiated by the operational histories of the stations, as discussed in the Stress Tests. All sites therefore have on-site emergency back-up generation with built in redundancy and diversity and on-site fuel stocks sufficient to meet the 24 hour standard mission period. The Stress Tests found fuel supplies to be adequate for 72 hours, except Dungeness with 48 hours.

4.17.2 Response

EDF Energy has taken a lead role, in collaboration with National Grid, Scottish Power Transmission, Sellafield Ltd and Magnox Ltd, in performing a review of the grid robustness and reliability under severe hazard conditions. This review has utilised OPEX from Fukushima as well as from Electricité de France Société Anonyme (EDF SA) and other licensees.

Through a series of workshops and correspondence, EDF Energy, National Grid, Scottish Power Transmission, NuGen, Magnox, Horizon and Sellafield have reviewed the current arrangements and standards for transmission system interfacing electrical connections to nuclear facilities.

A number of conclusions were drawn and have been issued by NGET in a report shared across the UK nuclear industry as well as with the ONR. The conclusions of the report are summarised below:

- While the transmission system and transmission plant and apparatus is robust to a standard which supports restoration, no guarantees against risk of disconnection due to severe hazard conditions can be given nor can restoration time be contained within any particular timescale. The Nuclear Site Licence Provisions Agreement (NSLPA) requires that information on system reliability under conditions which have been experienced or that are foreseeable by reference to the industry standards are considered and that a statistical basis for estimation of Loss Of Off-site Power is maintained thereby allowing Nuclear sites to support their existing safety case analyses as far as reliance on Grid connection is concerned. No provisions beyond the current industry standards are considered at present to be required to support the currently experienced high levels of security of Grid supply afforded to the nuclear industry in the UK.
- Transmission companies possess a thorough understanding and experience of the issues associated with transmission plant and system failure and restoration as it impacts users. Emergency exercises focus on the recovery of transmission connections following failures of sections of line or other key items of plant. The current industry arrangements do not however specifically recognise the reconnection of nuclear installations as a priority above other

customer groups in the event of a "Black Start" condition, although individual sites experiencing difficulties would be able to request support.

- Transmission Owners continue to have significant and effective dialogue with Nuclear Licensees using the existing processes in place since privatisation for the consideration of issues, proposed developments, and reflection on the operation and adequacy of existing measures which are specifically focused upon the support of nuclear site safety cases. It was nonetheless recognised that with industry developments there may be a case for the Office of Nuclear Regulation in conjunction with Ofgem to seek to review the existing governance arrangements so that a single consistent framework can exist covering existing interfaces and new build.
- The Review Group felt that nuclear operators may wish to consider engaging Distribution Network Operators (DNO's), and Transmission Owners (TO's) as required, to review the provision of appropriately rated and sourced distribution connections e.g. at 3.3kV on a site-by-site basis to serve essential services.

Considerations

A number of Considerations were raised by the Review Group as discussed below. EDF Energy supports the raising of these Considerations and will endeavour to work with the appropriate bodies to respond in a timely and appropriate manner, ensuring the ONR is involved in the process.

Consideration 1: Further liaison with emergency services may be sought in relation to incidents of heightened sensitivity. Such work may be informed by further emergency planning.

EDF Energy has identified that current arrangements for contacting and organising repairs are embedded in business as usual. During a Beyond design basis event EDF Energy would utilise its existing command lines to influence Police Gold command and the Government Emergency organisation Cabinet Office Briefing Room (COBR), which would be chaired by the Prime Minister, to prioritise the reconnection of a nuclear power station to Grid. EDF Energy will highlight that Department for Energy and Climate Change (DECC) might consider this a valuable addition to its exercising objectives.

Consideration 2: In consultation with Transmission Licensees Nuclear site Licensees may wish to consider external benchmarking of the Industry Standard levels of security and reliability afforded to UK plant to identify any appropriate generic above standard approach to existing or future Nuclear fleet connections via the World Association of Nuclear Operators (WANO) and other appropriate international bodies (for example ENTSO-e).

EDF Energy is, in principle, supportive of benchmarking via an appropriate industry body and will continue to work with both WANO and Transmission Licensees, reporting to ONR as part of business as usual.

Consideration 3: Whether specific considerations of diversity of options for restoration and indeed speed of restoration should be introduced into future reviews of Black Start strategy on the UK transmission system.

EDF Energy supports this consideration, noting that it is aimed at transmission system operators.

Consideration 4: Whether the Review Group, or Nuclear Licensees independent of the Review Group, might wish to initiate site specific assessment of the options between transmission system DNO and Nuclear licensee in the area of alternate voltage connections being established or being made available for rapid installation.

EDF Energy is providing mobile alternative electrical power supplies which can be quickly deployed and connected into the station auxiliary electrical system in the event of loss of the Grid supplies under severe hazard conditions. The use of DNO supplies was considered but subsequently discounted in favour of the portable supplies solution. An important consideration in this decision was the judgement that a severe hazard event leading to a loss of Grid was also likely to impact DNO supplies.

Consideration 5: Whether the Office of Nuclear Regulation should in conjunction with Ofgem seek to clarify nuclear site liaisons across Transmission Owners, Distribution Network Operators, the System

Operator and other parties which impact nuclear safety such that a single consistent framework exists for governance and application of liaison in managing existing interfaces and the approach towards New Nuclear Build projects.

EDF Energy supports this consideration and will work with those parties involved to seek a consistent approach for managing interfaces.

Consideration 6: Whilst it is the Review Group's conclusion that existing arrangements are sufficient, beyond standard developments of nuclear sites could be facilitated subject to specific bilateral engagement to the extent required by the NSPLA in this area between Nuclear Licensees and Transmission Owners on a case by case basis.

EDF Energy agrees with the conclusions reached and will keep the situation under review through the normal interface arrangements with Transmission Owners but at present has no plans for any beyond standard developments at any of our sites.

Consideration 7: If as part of site specific assessment certain options emerge, Nuclear Licensees may seek further clarification as to whether they should fund any generic or site specific spares holding from the Transmission Owner in those areas.

EDF Energy will keep the situation under review through the normal interface arrangements with Transmission Owners but at present has no plans to fund any additional generic or site specific transmission related spares. It should, however, be noted that EDF Energy remain a member of NGET's spares club which provides access to strategic Extra High Voltage (EHV) spares.

Consideration 8: Whilst emergency processes exist across Review Group participants these are company specific arrangements to which appropriate parties are made aware. It may be beneficial to consider joint emergency response exercises to test practical integration and interfacing. The practical experience of such exercises in testing and identifying resilience needs in cross-industry lines of communication could be critical.

Loss of Grid exercises are standard practice within EDF Energy and form part of the Simulator Training, Station shift exercise and Level 1 programme, and will continue to be reviewed as normal business to take on board new learning. However, Station Operations are in direct daily contact with National Grid discussing load profiles for example; these communication channels are used for emergency operational requirements when appropriate, and have been enhanced via the provision of mobile and fixed satellite communications.

The EDF Energy Central Emergency Support Centre (CESC) could also provide interfacing support and as part of the JER programme has reviewed its emergency telephone directory which has details of the National Grid emergency centre as well as that of senior National Grid personnel who could be contacted should it be required.

Consideration 9: Whilst emergency processes and associated exercises inform options of response, the response itself can be precluded by safety issues affecting the site in question. Transmission Owners are able to balance risks and manage safety issues that are anticipated to impact generic sites or installations, however in an extreme event hazards unique to nuclear sites may exist which delay or preclude transmission staff involvement due to the specific skill sets required to respond. It is possible for the Licensees to consider additional training and provision of transmission staff pertinent to such environments should the outcome of emergency exercises conclude value in these areas.

Loss of Grid is considered a frequent event, as such EDF Energy has a number of station systems, including Essential Diesel Generators for example, to provide the necessary power should grid be lost. In addition, the JER programme has procured a range of Deployable Back-Up Equipment (DBUE) capable of providing key electrical and cooling provisions for an extended timeframe should it be required. As such it is deemed that appropriate training could be provided to transmission staff post-event should the need arise.

Consideration 10: That in subsequent industry review; it will be for Nuclear Licensees to consider whether options to increase the flexibility and resilience of Black Start in relation to New Nuclear Build are required, such that Transmission Licensees may seek further regulatory direction as necessary.

EDF Energy Nuclear New Build (NNB) currently has no plans to provide a Black Start service. All on-site generation will be used to support safe station shut down in the event of a loss of Grid supplies.

In addition to this recommendation, the events at Fukushima highlighted the need to further consider EDF Energy's current diverse and robust provisions to ensure that cooling and power are available when required. To this end, back-up diesel generator resilience and fuel stocks availability have been reviewed and enhanced to provide additional on-site electrical provisions for key areas. In addition mobile back-up equipment modules for electrical and cooling functions have been purchased and are available to assist with event recovery should they be required. Please see IR-18 for more information.

4.17.3 Recommendation Conclusions

In conjunction with the UK nuclear industry, EDF Energy has worked with the Transmission Owners and Licensees to review the robustness of the provision of off-site electrical supplies, with the output being a report which includes a number of Considerations. EDF has proactively reviewed and progressed these Considerations as part of normal business; however, in addition, provisions have been made as part of the EDF Energy Japanese Earthquake Response (JER) programme to ensure that there are alternative means of power and cooling available in the event of unavailability of Grid system electrical supplies under severe hazard conditions.

EDF Energy will continue to liaise with Transmission Owners as well as the ONR on this topic and as such, this recommendation is considered closed.

4.18 Interim Recommendation 18 Close Out Report

Recommendation IR-18: The UK nuclear industry should review any need for the provision of additional, diverse means of providing robust sufficiently long-term independent electrical supplies on sites, reflecting the loss of availability of off-site electrical supplies under severe conditions.

This should be considered along with Recommendation IR-8 within the wider context of "on-site resilience".

4.18.1 Overview

EDF Energy nuclear sites have on-site diesel generators, gas turbines, back-up generators and batteries, which provide power to key systems following a Loss of Off-site Power (LOOP). The Fukushima Dai-ichi nuclear plant also had provisions for a LOOP event; however the majority of equipment was overwhelmed by the tsunami. This learning point highlights the necessity of considering the resilience and diversity of supply of on-site power, in the event that the integrity of infrastructure was to be challenged by a severe event.

Diverse and robust electrical provisions are required to ensure that cooling and power are available when required. As such, the resilience of electrical circuit boards, on-site diesel generators and their alternatives, and fuel stocks, have been reviewed and enhanced as required. In addition, mobile back-up equipment modules are available to assist with event recovery.

4.18.2 Response

EDF Energy completed a series of essential plant reviews across all 8 of its nuclear station sites. The reviews considered the essential electrical power provisions for Design Basis (DB) events and margins in the case of a severe event. Particular attention was paid to "cliff-edge" and "non-linear" effects, regarding availability of diverse means of providing on-site power and cooling, in the event of loss of the site electrical and emergency supplies (Essential Diesel Generators (EDGs)/Gas Turbines(GTs)) used for boiler feed and forced circulation.

This is considered in the station safety cases. On loss of grid and emergency supplies (which are robust to infrequent flooding and seismic events) an operating (or above a threshold pressure) Advanced Gas-cooled Reactor (AGR) can sustain cooling with natural convection. This is achieved with the existing boiler back-up feed systems; these are supplied by multiple 100% load diesel generators and operate independently of all other station electrical supplies. For the non-pressurised reactor case, the ability to repressurise the reactor has been enhanced with a connection point and additional nitrogen supplies, see STF-8 and IR-19 for further details.

For Sizewell B (SZB), a Pressurised Water Reactor (PWR), loss of AC power including emergency supplies (comprising four diverse, 100% load EDGs) is also considered in the safety case. For faults where the primary circuit is intact (at power or on hot shutdown) cooling is maintained by systems which derive steam power from Reactor Coolant System (RCS) heat. Where the primary circuit is not intact (in shutdown modes, with lower decay heat), a gravity driven system is used with water from the Refuelling Water Storage Tank (RWST). This is restricted during the short term transient mode (mode 6) where the Reactor Pressure Vessel (RPV) head is in place and the refuelling pool level is reduced. The EDF Energy Japanese Earthquake Response (JER) programme is increasing the capability to cool the reactor core in this state by the installation of a connection point and the provision of a deployable low pressure pump, see STF-8 and IR-19.

Increasing Resilience of Electrical Supply

Assessments for reasonable and practical resilience enhancement options to the electrical systems were conducted during the early stages of the JER programme, which included focussed walk-downs around the sites involving Suitably Qualified and Experienced Personnel (SQEP) and station personnel. Following these walk-downs and further site reviews, protection enhancements were devised to improve the resilience of the existing diesel generators and other electrically significant equipment. Due to the nature and vulnerabilities of the equipment and the plausible events in the UK, these measures are particularly targeted towards protection against flooding and the aiding of the long term recovery of the plant.

Resilience measures are complete for all stations enhancing protection of the existing electrical distribution, feed systems and back-up generation, such as EDGs and GTs, and include the following:

- 1m above ground demountable flood barriers, installed at key buildings and equipment, to further protect in a Beyond Design Basis (BDB) event
- Above and below ground electrical penetrations secured.

To protect the electrical supply to the Emergency Control Centres (ECC) and Alternative/Emergency Indication Centres (A/EIC) the following work packages have been implemented where required on a station by station basis (for more information see FR-2):

- Provision of back-up diesel generators
- Provision or upgrade of anchorage for back-up diesel generator
- Relocation or improvement of anchorage for electrical supply panels
- Provision or upgrade of Uninterruptible Power Supply (UPS) battery rack and restraints
- Isolation of the electrical supply and circuit for the ECC
- Raising of electrical equipment/ services above 1m Level.

Sealing of Electrical Penetrations, Before and After

A resilience work process was also developed for the JER electrical modifications relating to the connection points for Deployable Back-Up Equipment (DBUE). The connection points allow interfacing of the emergency generation DBUE and Box-Up Generation (for AGR reactor re-seal) with existing plant (for more information, see STF-8). This assists the speedy connection of emergency generation to key “essential boards” which have the greatest likelihood of surviving a BDB event. These boards power up some essential instrumentation, indications and essential plant for post trip cooling or for box-up cranes in the case of a shutdown reactor.

To enhance protection against a BDB flood, equipment has been installed above the 1m level or protected by 1m dam boards. For seismic protection, resilience modifications are seismically qualified to a level equivalent to the existing plant that is being permanently connected to, or as a minimum shown that it has no detriment on the existing station plant. In general this is to the DB Event (bottom line or 10^{-4} event).

Providing Additional Electrical Supplies

New alternative trailer mounted generators have been procured; these 180kVA diesel generators will provide power for low voltage (415V) systems such as lighting and essential instrumentation. One diesel generator is stored at each AGR, with the exception of Heysham 2 and Torness which have received two due to the segregated and quadrantised layout of the stations electrical circuits. The 180kVA diesel generators provide a further line of defence beyond the existing back-up diesel generators, and can be attached to on-site vehicles for transport around site in event of a hazard. At SZB two new Battery Charging Diesel Generators (BCDGs) have been installed; these are seismically qualified to the infrequent event and raised above 1m, which is well in excess of the DB on-site flood level, thus giving further margin to BDB events. An array of DBUE is also located at the SZB Emergency Response Centre (ERC) close to plant.

Trailer Mounted 180kVA diesel generator

In addition to the new on-site mobile generators, the off-site DBUE strategy also provides additional emergency mobile low voltage (415V) 200kVA containerised diesel generators and containerised cabling and switchgear which can be deployed from regional stores within required timescales following a BDB event. The 415V systems support the provision of essential instrumentation and are compatible with the site connection points.

To aid in this recovery, 3.3kV connection points have been largely installed, with a small number requiring final connection on site, with the primary intent to underpin the station 415V essential instrumentation and some limited support to electrical infrastructure through the 3.3kV distribution system.

Between them, the on-site and off-site generators will have adequate fuel stocks to provide power up to 72 hours post-event, beyond this time arrangements are in place to allow the replenishment of stocks for longer term recovery.

For SZB, equivalent high power connection points have been deemed inappropriate by SQEPs as they would not provide a significant benefit over the 415V connections already provided.

It should be noted that the on and off-site generators, cables, plugs and on-site connection points are all ‘industry standard’, and as such, should additional generators be required then commercially available equipment would be compatible and readily connectable.

All modifications undertaken have complied with the modification process; this process in turn must satisfy the requirements of Licence Condition 22. Training and exercising schedules have also been updated to include new equipment and procedures.

4.18.3 Recommendation Conclusions

Following site walk downs, including a review of electrical supplies on a site by site basis, EDF Energy has made a number of improvements on-site including resilience enhancements to electrical systems, the provision of connection points and the provision of additional alternative diesel generators both on-site and off. These changes increase station resilience to a severe event, provide extra layers of defence and incorporate the ability to rapidly connect back-up generating equipment.

The changes made to infrastructure, equipment and procedures will now be considered part of ‘normal business’ and aspects such as maintenance and training will be dealt with under normal EDF Energy processes. This recommendation is considered closed.

4.19 Interim Recommendation 19 Close Out Report

Recommendation IR-19: The UK nuclear industry should review the need for, and if required, the ability to provide longer term coolant supplies to nuclear sites in the UK in the event of a severe off-site disruption, considering whether further on-site supplies or greater off-site capability is needed. This relates to both carbon dioxide and fresh water supplies, and for existing and proposed new plants.

4.19.1 Overview

At Fukushima, it was necessary to pump water into the reactor and fuel ponds to cool the fuel. A diverse means of adequate reactor and spent fuel storage cooling is essential in the event that normal means of cooling are lost. The events at Fukushima highlight the need to consider further diversification and protection of coolant supplies.

At EDF Energy's Advanced Gas-cooled Reactor (AGR) stations, the core coolant used during normal operation is carbon dioxide. The unique design of AGR plants with a large heat sink, low power density, and long timescales to component failure allow much longer response times than water reactors. At pressure, natural circulation of the coolant gas is sufficient to maintain a safe temperature providing that there is a heat sink.

In contrast, Sizewell B (SZB), EDF Energy's only Pressurised Water Reactor (PWR), uses water as the coolant. Following loss of cooling to the primary circuit, with no mitigating actions taken, fuel melt and core damage begins to occur much more quickly than it would in an AGR. For this reason it is important to restore cooling on shorter timescales.

4.19.2 Response

EDF Energy completed a fleet wide assessment of the supply and demand of essential on-site stocks. This included walkdowns across all 8 station sites, assessing stocks and resilience for water, fuel oil and gas.

Water Supplies

Analysis has shown that all sites have sufficient treated water on site to support reactor cooling operations for at least 48 hours. EDF Energy has assessed the feasibility of extending the supply time to 72 hours and has found that this can be achieved using existing qualified stocks combined with the deployment of the Deployable Back-Up Equipment (DBUE).

For all sites, within 48 hours, the DBUE water treatment plant can be delivered and commissioned to provide a continuous supply of boiler quality water up to and beyond the 72 hour target mission time. No additional on-site cooling supplies have been deemed necessary as the DBUE approach is considered to provide a greater degree of resilience in that the DBUE is held off-site and so it less likely to be affected by the initiating event. Cooling water beyond 48 hours will be available from any remaining un-claimed tanks, townswater, and seawater. This water will be treated by the DBUE water treatment plant.

To ensure quick and simple usability of essential stocks in a severe event, EDF Energy identified and has largely installed, with a small number requiring final completion on site, connection points enabling the connection of hoses to low and high pressure pumps to ensure an effective and flexible supply of water for an extended period. The installed connection points, or 'connections', consist of permanent modifications or non-permanent modifications (but which can rapidly be installed on the day should it be required) dependant on station by station requirements. For cooling functions, they include:

- Water tank connections
- Buffer Store connections
- SZB Primary and Auxiliary Coolant connections

- AGR Pressure Support connections
- AGR Boiler Feed connections.

The provision of event qualified connection points to essential supplies is further discussed in the response to STF-8.

Gas Supplies

The core cooling requirement for AGRs is to maintain, or restore, gas pressure in the reactor. Whilst there will be off-site damage repair equipment provided with the DBUE, it is not considered practicable to rely on a plan to re-commission the AGR CO_2 vaporisers within an acceptable timeframe following a Beyond Design Basis (BDB) event. No feasible resilience enhancements to on-site stocks of carbon dioxide could be identified and accordingly a different approach was adopted. It was recognised that to repressurise a reactor, gas pressure support equipment (including gas stocks) may be required; particularly during outage conditions. Off-site DBUE therefore includes sufficient nitrogen stocks to suitably repressurise a reactor and thus promote cooling by natural circulation. Nitrogen is used as it is gaseous at standard air temperature and pressure, therefore a vaporiser is not required. The equipment supplied also includes an appropriate means of delivering the gas to the reactor. The timescales required for this response have been re-evaluated against thermal analysis, and found to be adequate.

Deployable Back-Up Equipment

The JER programme has developed a response strategy that utilises a DBUE portfolio capable of restoring plant cooling capabilities. Full sets of DBUE are stored in strategic regional locations to minimise transport time to site. Recognising the shorter required response timescales for PWRs, SZB has its own DBUE storage located closer to site at the newly constructed Emergency Response Centre (ERC). The availability of road clearance and off road vehicles ensures access to site in the event of severe off-site disruption to infrastructure.

The DBUE includes resources for providing cooling functions for the core and spent fuel:

- Capability to repressurise the AGR pressure vessel to support natural circulation in a scenario where the reactor was on an outage or a leakage has occurred. This will be achieved with the provision of 15 tonnes of nitrogen capable of being injected into the reactor and connection points to allow the connection of generating equipment to support the resealing of the pressure vessel at the pilecap.
- Ability to provide primary circuit feed to the SZB PWR Reactor Pressure Vessel (RPV) during Mode 6, refuelling outage, achieved through additional connection points and low pressure pumps.
- Provision of water to the Secondary Circuit. The DBUE includes high pressure pumps for water injection to the secondary circuit for AGRs and the PWR. Sufficient water sources are on-site and seismically qualified to support functions for over 48 hours. Also available for water accessibility are:

  - Low Pressure transfer pumps (for pumping between tanks and from seawater source)

  - Water treatment plant to provide the required quantity of treated water from townswater/seawater source, ensuring water supplies up to and beyond 72 hours
- DBUE pumps will be available to provide AGR buffer store feed and AGR/PWR spent fuel pond top-up capability.
- For AGRs, pond cooling equipment can circulate pond water through a heat exchanger to cool pond water.

The approach proposed for classification of mobile equipment intended for mitigation of BDB events is for this to be non-safety classified. This is on the basis of allowing maximum flexibility during any postulated BDB accident, such that additional or replacement pumps and generators can be obtained from off-site suppliers with minimum delay and that aspects such as equipment safety classification are not a consideration when sourcing such equipment at extremely short notice and under strenuous conditions. So long as a match is made for the significant performance criteria i.e. flow rate and discharge pressure for pumps and rating and supply voltage for generators, then mobile equipment should be readily available from a wide variety of off-site sources. It should be noted that the mobile equipment intended for mitigation of BDB events will be subject to testing and maintenance as defined in the Examination Maintenance Inspection and Testing (EMIT) Schedule, outwith Licence Condition (LC) 28.

A Through Life Management Partner (TLMP) has been assigned to manage the off-site equipment through its lifetime, to include the delivery of an approved EMIT. The TLMP ensures that the equipment is regularly checked and tested and always ready to be deployed within the required timescales.

As part of the JER programme, new training schedules have been developed to take account of new procedures and equipment for responding to an emergency. The training will be fast tracked for all emergency responders. Proof of Concept exercises have proven response capabilities and provided a level of OPEX for training.

4.19.3 Recommendation Conclusions

The JER programme has reviewed water stocks and cooling requirements, and potential vulnerabilities following OPEX from Fukushima. The reviews found that EDF Energy sites are generally well prepared for a severe external event. However a strategy to increase emergency response cooling capability has been implemented for the fleet. This involves providing diverse and flexible cooling capabilities using off-site independent back-up equipment and pre-installed connection points to key water supplies and plant systems.

This recommendation is therefore considered closed, with no further work required to satisfy its requirements. The changes made to infrastructure, equipment and procedures will now be considered part of 'normal business' and aspects such as maintenance and training will be dealt with under normal EDF Energy processes.

4.20 Interim Recommendation 20 Close Out Report

Recommendation IR-20: The UK nuclear industry should review the 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.

4.20.1 Overview

Following the earthquake and tsunami at Fukushima it was necessary to pump additional water into the reactor fuel ponds to cool the fuel, due to loss of the normal cooling mechanisms. Given the difficulties encountered in performing this action, it is appropriate to review the current situation across the fleet and develop a robust strategy for providing make-up water following a severe event.

This is a key piece of learning from events in Japan as spent fuel cooling is a prerequisite for maintaining control over this plant area, with each EDF Energy site having a fuel storage pond which is required to be cooled.

Spent fuel from the EDF Energy Advanced Gas-cooled Reactors (AGRs) is held for an initial cooling period in the buffer store, before being transferred to the on-site cooling ponds, and then transported to Sellafield as part of the normal fuel cycle. Spent fuel from Sizewell B (SZB), a Pressurised Water Reactor (PWR), is transferred immediately to the cooling ponds and remains on site.

Timescales to reach boiling for cooling ponds (and buffer stores for the AGRs) have been assessed for all stations, including SZB, for the most onerous heat loading scenarios. The conclusion of AGR thermal analysis is that the pond temperatures remain below 60°C for more than 24 hours following the loss of normal cooling to the ponds. This timescale is bounded by the timescale for buffer store and reactor intervention where, assuming that no cooling is supplied, time to acceptable temperatures being exceeded is less.

For SZB pond boiling times are shorter, although a review of station safety cases show that in the most onerous case loss of active cooling will not lead to uncovering of the fuel storage racks within 24 hours. To ensure that minimum fuel coverage for adequate shielding is maintained, pond water make-up and cooling provisions are required on shorter timescales for SZB. New Deployable Back-Up Equipment (DBUE) provision will support this.

EDF Energy is also currently developing a new strategy for spent fuel at SZB, which is compliant with our Nuclear Safety Assessment Principles. This strategy includes an on-site dry cask fuel store with passive cooling during normal operation and following design basis (DB) events, with considerable margin against Beyond Design Basis (BDB) events.

It should be noted that this recommendation is similar to recommendations raised in the World Association of Nuclear Operators (WANO) Significant Operating Experience Report (SOER) 2011-3 which EDF Energy has responded to and is committed to closing out in a timely manner.

4.20.2 Response

In the event that the normal means of providing cooling to the ponds is not available, it is important to ensure that pond water temperatures remain low enough to prevent the uncovering of irradiated fuel and loss of shielding through excessive evaporation. If the pond level does begin to drop, it can be mitigated by the DBUE pond top-up capability at both the AGRs and SZB. In addition it is preferable, but not essential, to maintain cool temperatures in the ponds (<60°C for AGRs) to ensure that the pond walls do not suffer from micro-cracking. This is provided by the DBUE pond cooling capability.

EDF Energy undertook a programme of work to enhance contingency plans for pond water cooling and pond water make up under severe accident conditions, including further analyses, on-site resilience modifications, the provision of DBUE and also the updating and revision of training and procedures to support these provisions, as discussed below.

Further Reviews and Analysis

A review of site contingency plans for pond water make-up under severe accident conditions was completed. Various options were identified which would allow operators to deliver pond water make-up in a severe event based on the EDF Energy Japanese Earthquake Response (JER) programme assumption that normal water supplies and pumps were not available. If normal supplies are available then they would be used.

Further thermal analysis of spent fuel storage areas was also completed to give a more accurate indication of the heating timescales in the AGR buffer stores and AGR/PWR ponds. Pond cracking analysis was also undertaken for the AGRs to determine timescales to failure of the pond structure.

A review of existing water stocks across the fleet was also undertaken; it was found that for all sites robust water stocks qualified up to the infrequent event are available in sufficient quantities to provide cooling capability (boiler feed, buffer store feed, and pond top-up) for at least 48 hours. The DBUE will be used to supplement this endurance with the provision of water treatment equipment from 48 hours post-event, which will supply boiler quality water above the rates required by the combined water demands of Boiler Feed, Buffer Store Cooling and Pond Cooling/Top-Up. This strategy includes the use of sea water if necessary, which has been found to be suitable for pond top-up and buffer store cooling in severe events, but which can also be used by the water treatment equipment to provide boiler quality water also.

On-site Resilience Modifications

Resilience modifications have provided increased flood protection of pond buildings in BDB events, with 1m flood barriers around ground floor fuel ponds to protect further against ingress/egress of flood water.

The use of the DBUE under severe accident conditions is aided by the installation of targeted connection points. The connection points will provide easy access to key systems for the transfer and injection of water and are discussed further in STF-8.

In addition, existing dry risers have been qualified to withstand a 10^{-4} infrequent seismic event and enable delivery of water to the charge face to provide water for cooling purposes to the Buffer store.

Deployable Back-Up Equipment

DBUE which can be deployed following a severe accident has been purchased. The equipment is stored at secure regional off-site locations and includes vehicles capable of off-road personnel and heavy equipment transportation.

To enhance spent fuel cooling capability, the equipment will prolong the supply of water available for cooling via a water treatment facility, offer a pond water cooling capability and increase the capability of delivering water to the required location in the required timescale via pumps and connection points. To enable these cooling functions, and also the monitoring of pond levels and temperatures, the equipment includes:

- Low pressure water pumps to transfer water between tanks and feed water into spent fuel ponds and through buffer/ decay store tube water jackets.
- Pond cooler package for AGRs, to extract water from the cooling ponds and feed through a coolant loop, before returning cooled water to ponds.
- Water treatment plant to treat water from additional sources such as untreated water tanks or the sea, therefore providing further diversity of non-corrosive water supply. It should be noted that this equipment can be mobilised and running within 48 hours, ensuring that additional make-up water is available before the protected on-site stocks are depleted.
- Small Submersible dewatering pumps to extract water from on-site water tanks (treated and un-treated water), other water reserves or the sea.
- All necessary hoses and connectors to enable use of dry risers, or should it be necessary, simple laying of hoses to the required area to provide cooling water.

- Instrumentation devices to allow the monitoring of pond levels from remote locations.
- Electricity generators to supply an additional diverse means of power supply. These are stored on-site and also with the off-site DBUE. All DBUE will have its own power with back-up fuel reserves.

It should be noted that for SZB most of the above functions remain the same, however due to the timescales involved in Reactor Pressure Vessel (RPV) temperature transients, SZB has had its own Emergency Response Centre (ERC) constructed local to site. This gives capability to mobilise equipment in the short timescales required to restore cooling to both the spent fuel ponds and the reactor.

The use of a DBUE pond cooler is not appropriate at SZB due to the location of the pond above the ground floor; a malfunction of the pond cooler coolant loop could lead to siphoning of water from the cooling pond. The decay heat is also much greater in the SZB pond; up to 15MW in comparison to approximately 400kW maximum in the AGR ponds. However, the stainless steel lining of the SZB pond allows greater water temperatures to be reached without loss of water through cracking becoming an issue. Pond water may reach boiling temperatures, but the primary concern remains in ensuring the fuel does not become uncovered; thus the strategy is to pump water into the cooling pond if adequate coverage level is threatened, using the DBUE.

Further information regarding DBUE deployment strategy can be found in IR-8 and FR-3.

Chemistry and Criticality in Fuel Ponds

A key ONR expectation of this response was the consideration of the effect of alternative water supplies on the chemistry and criticality of the ponds.

The storage of spent fuel at AGR and PWR stations is typically done under highly controlled conditions, to achieve the correct chemical balance to minimise corrosion and prevent a criticality incident. The normal chemical composition of the pond water includes boron, sodium hydroxide and otherwise demineralised water.

Following a BDB event the availability of treated water may be limited, and the use of fresh water (from townswater or other sources) and ultimately sea water may be necessary to keep the ponds topped up or to reduce the bulk fuel pond temperature. The effects of adding water from alternative sources to the fuel ponds have been considered. Suitably Qualified and Experienced Personnel (SQEP) for pond chemistry and criticality have advised on the consequences.

From a chemistry perspective, addition to the ponds of untreated seawater could cause severe corrosion of the stainless steel AGR fuel cladding and subsequent failure in the long term. Addition of townswater leads to a slower rate of corrosion, but would eventually cause fuel cladding failure via the same mechanisms. PWR fuel cladding used at Sizewell B is zirconium, which is considerably more resilient to seawater than stainless steel. Failure of fuel cladding would lead to more debris being in the ponds, but would not cause a radiological release which would be of greatest concern.

Boron is used during normal operation as a solute in the pond water. This has the effect of absorbing neutrons, which helps to ensure that criticality is avoided in elements which are being cooled in the ponds. There is significant margin in the boron concentration and sub-criticality can be maintained even in fresh water for AGR and PWR ponds. Boron will also not evaporate out during pond boiling; therefore the risk of loss of boron concentration is from significant pond cracking and pond water leakage.

Should a criticality incident occur following a BDB event, potentially as a result of loss of boron combined with severe damage or geometrical disruption to the fuel, then the radiological consequence would be far lower than that caused by exposed fuel providing the pond level is above the minimum.

Thus, preventing fuel exposure and radiological release are the main priorities for the short term response and it is therefore appropriate to consider all necessary measures to keep the pond levels topped up above the minimum level. The strategy preferentially uses treated water from on-site stores or the DBUE water treatment plant, to minimise the effects of corrosion on the spent fuel. However, should these sources be unavailable another freshwater source should be used or, as a last resort, seawater.

A review of the AGR buffer store tubes judged that sea water could be used for some short period of time (~1 month) without being a great concern to the buffer storage tubes. Levels of corrosion would be expected to be low, and hence any sludge or particulate generated would not be expected to be of great concern. However, as with the cooling ponds, water from a townswater source should preferentially be implemented ahead of seawater.

Emergency Arrangements

The AGR Symptom Based Emergency Response Guidelines (SBERGs) have been updated to increase usability and include changes to emergency capability and new strategies, including for spent fuel cooling. Training regimes for emergency responders have incorporated the latest capabilities and include an introduction to the equipment and the connection points on site. The SZB equivalent, Station Operating Instruction (SOI) 8.8, will be updated following completion of proposed installations, for more information see STF-18.

In addition to the SBERGs a new suite of guidelines have been developed to incorporate the DBUE provision. These new guidelines are known as Deployable Back-Up Equipment Guidelines (DBUEGs) and detail the availability of the DBUE (which can also be used in the context of within design basis events), with particular reference to equipment System Level Reports and operating documentation for equipment used for plant intervention. The DBUEGs also refer the user to the lower level items of DBUE and the associated documentation which provides more detailed description of the operability of the individual pieces of DBUE.

The development of modifications, equipment and procedures has also received appropriate input from Human Factors specialists, ensuring that the enhanced systems are fit for purpose in what could be a challenging environment.

4.20.3 Recommendation Conclusions

EDF Energy’s capability to cool spent fuel in a severe event has been thoroughly reviewed following the learning from Fukushima. Improvements to station resilience and the provision of response equipment and strategies will enhance ability to cool spent fuel and prevent radiological release. This recommendation is therefore considered closed.

4.21 Interim Recommendation 21 Close Out Report

Recommendation IR-21: The UK nuclear industry should review the ventilation and venting routes for nuclear facilities where significant concentrations of combustible gases may be flowing or accumulating to determine whether more should be done to protect them**.**

4.21.1 Overview

Following events in Fukushima, EDF Energy's conducted a review into the impact of combustible gases and associated venting routes for its Advanced Gas-cooled Reactors (AGRs). As noted in the ONR Interim Report, gas cooled reactors cannot generate hydrogen in the same way as occurred at Fukushima Dai-ichi. However, there is potential for other combustible gases such as carbon monoxide (CO) to be generated in the AGRs.

For EDF Energy's only Pressurised Water Reactor (PWR), Sizewell B (SZB), hydrogen generation from overheated Zircaloy fuel cladding and steam reaction is possible in a severe event and could cause significant issues, as experienced at Fukushima. This chemical reaction has long been understood and therefore SZB has been designed with venting routes and safety systems to mitigate against this. However, in light of Fukushima the EDF Energy JER programme has further reviewed the venting management systems at Sizewell B; this is discussed in STF-18.

4.21.2 Response

AGR Fleet

The unique design of AGR systems mitigates the requirement for additional filtration or hydrogen recombination equipment. The final containment barrier on an AGR is the Pre-stressed Concrete Pressure Vessel (PCPV), which is the main pressure retaining part of the reactor. The primary design provision on the PCPV to prevent over-pressurisation is the Safety Release Valves (SRVs), which automatically vent reactor gas to atmosphere when a threshold pressure is reached. However in some circumstances, prior to this threshold being reached, the Symptom Based Emergency Response Guidelines (SBERGs) can be used to give guidance on the use of the operator controlled reactor gas blowdown system. This system has multiple uses during normal operations and can be used for lowering the vessel pressure and directing gas through the particulate filters and the main iodine adsorption plant, before discharging to atmosphere via the main exhaust.

The blowdown system venting routes were considered during the stress test process and it was determined that existing systems are suitable to allow prevention of potentially contaminated/ combustible gases being vented from one reactor to the other.

In response to the OPEX from Fukushima and this recommendation, a study was undertaken into the production and implications of combustible gases at AGR sites.

The study concluded that for AGRs there are no recognised mechanisms for hydrogen production on a significant scale. However, at high enough temperature, the graphite moderator will reduce carbon dioxide, the AGR primary coolant, to carbon monoxide which can burn in air and potentially explode. Post-Fukushima studies have shown that normal operation and Design Basis (DB) accidents are very unlikely to generate flammability hazards from carbon monoxide.

Beyond Design Basis (BDB) Loss of Cooling Accidents (LOCAs) affecting pressurised reactors are also very unlikely to generate flammable mixtures. BDB LOCAs affecting depressurised reactors for over 1 day have the potential to generate flammable mixtures. However measures currently advised in the Severe Accident Guidelines (SAGs) would significantly reduce the risk of hazard from flammable gases.

With carbon monoxide, there is a known risk of toxicity. Since any risk to the general public due to carbon monoxide emissions would also be accompanied by a radiological hazard, the evacuation procedures in place to protect the public from radioactive release would also protect from toxicity. As such, EDF Energy would follow its existing procedures to provide advice to the Police Chief Officer who leads Gold command to allow the police to evacuate the public. Therefore those principally at risk from toxicity would be the staff managing the incident.

An Engineering Advice Note (EAN) was produced to estimate carbon monoxide concentrations downwind of the station to enable the emergency controller to assess the magnitude and nature of the risk in such a scenario.

In a severe accident where circumstances lead to higher than predicted CO concentrations, the Emergency Controller would deploy mobile personal CO-measuring instruments and personal protection equipment for accident management staff.

Sizewell B

Following the OPEX from Fukushima, a review of venting strategies was carried out for SZB and new strategies have been developed to control hydrogen levels and options considered to reduce pressure in the secondary containment:

- Following feasibility studies Passive Autocatalytic Recombiners (PARs) have been installed to reduce hydrogen levels; these units have the advantage of not requiring a power source, thus providing a diverse and independent means of hydrogen reduction from the currently installed electrically powered hydrogen management system. Installation of the first consignment is now complete.
- Studies into the feasibility of installation of Filtered Containment Venting (FCV) are now complete. During this feasibility study, consideration was given to outputs from the Probabilistic Safety Analysis (PSA), improvements in filter technology since the original Safety Case, and potential impact on current safety systems and operation. It was determined that FCV would be feasible to install, although there are some outstanding technical risks identified during the concept design phase. The potential benefits to overall risk reduction following a severe accident at SZB is finely balanced against the potential disbenefits associated with design basis operation. Given the extended timescales to containment failure, a project is underway to understand the residual risk and whether there are other reasonably practicable ways of reducing this risk. Installation of an FCV remains a potential option with a final decision on this project anticipated in 2015.
- Please see STF-18 for more information on PARs and FCV.

4.21.3 Recommendation Conclusions

Combustible gases have been reviewed at both the AGR and PWR stations, with PARs installed at SZB and the requirement to implement FCV currently under review, discussed further in STF-18.

The blowdown system venting routes of the AGRs were considered during the stress test process and it was determined that existing systems are suitable to allow prevention of potentially contaminated/ combustible gases being vented from one reactor to the other.

The risk of carbon monoxide and the associated toxicity at the AGRs is now better understood as a result of actions relating to this recommendation, with results being built in to procedures as required which will aid in recovery operations should there be a severe event; therefore this recommendation is considered to be closed.

4.22 Interim Recommendation 22 Close Out Report

Recommendation IR-22: The UK nuclear industry should review the provision on-site of emergency control, instrumentation and communications in light of the circumstances of the Fukushima accident including long timescales, wide spread on and off-site disruption, and the environment on-site associated with a severe accident.

In particular, the review should consider that the Fukushima-1 site was equipped with a seismically robust building housing the site emergency response centre which had: adequate provisions to ensure its habitability in the event of a radiological release; and communication facilities with on-site plant control rooms and external agencies, such as TEPCO headquarters in Tokyo.

4.22.1 Overview

The OPEX from Fukushima suggests that emergency control, normal instrumentation and communications were not robust and that there may have been limitations and uncertainty on the indications available at alternative emergency control centres. However, it should be acknowledged that the emergency response structure remained intact and partially functional, allowing operators to mitigate against a potentially more severe event.

All EDF Energy nuclear sites have facilities and procedures in place for managing an on-site incident or off-site nuclear emergency, enabling control, instrumentation and communication. The suitability of these facilities and procedures was challenged in the ENSREG Stress Tests which EDF Energy fully complied with. It was found that emergency control, instrumentation and communications were adequate in their function and, where applicable, resilient to Design Basis (DB) events. These facilities were also assessed against the postulated severe event and different stations and facilities were found to have varying levels of resilience, layers of defence, and back-up provisions.

To best ensure that all sites have protection to mitigate the effects of a Beyond Design Basis (BDB) event as far as reasonably practicable, it was deemed appropriate to provide a series of resilience enhancements to further protect the functions required to maintain the plant in a safe state. Regardless of these significant improvements, the overall EDF Energy approach assumes that all power and cooling is lost, including installed back-up systems, and that severe disruption has occurred on-site. This demonstrates a need for a response capability from off-site which has been met by a considerable Deployable Back-Up Equipment (DBUE) capability which ensures equipment reaches site within timescales assessed against thermal fault escalation requirements.

EDF Energy's Japanese Earthquake Response (JER) programme strategy enhances the capability of EDF Energy nuclear power plants to withstand and recover from BDB events. The flexible and diverse BDB capability provides enhanced protection and defence in depth to key indications and communications; essential for maintaining control of the plant.

This IR is closely linked to FRs 2 and 3, and should be considered alongside them. This recommendation is also linked to STF-9.

4.22.2 Response

To increase the reliability of continuous plant indications and emergency control capability, the JER programme has delivered a comprehensive range of resilience enhancements, further protecting existing key facilities against flooding, seismic and other severe hazards. Where necessary, the functions of Emergency Control Centres (ECCs) and the Alternative/ Emergency Indication Centres (A/EICs) have been made more resilient.

Enhancements include:

Resilience Enhancement	Protection Provided
Flood protection to the greater building to 1m above ground level	Flooding
Raise or flood protect external air conditioning condenser units	Flooding
Provision of watertight seal to cable tunnels/penetrations	Flooding
Provision of enhanced flood protection enclosures for external equipment	Flooding
Relocation/improvement of anchorage of electrical supply panels	Electrical
Provision/upgrade of UPS battery rack and restraints	Electrical
Provision of a back-up diesel generator where not currently provided	Electrical
Isolation of the electrical supply and circuit for the ECC	Electrical
Raising of electrical equipment/services above 1m level	Electrical
Upgrades to existing external modules	Electrical
Strengthening raised floors	Civil /Seismic
Strengthening suspended ceilings and lighting	Civil /Seismic
Strengthening partition walls	Civil /Seismic
Construction of waterproof porch	Civil /Seismic
Blast film and attachment system to windows	Civil /Seismic
Provision/upgrade of back-up diesel generator anchorage	Civil /Seismic
Restraint of loose items/furniture and general housekeeping	Civil /Seismic
Provision of restraint to glass worktops	Civil /Seismic
Widening of ceiling mounted projector aperture	Civil /Seismic
Improvements to cable support arrangements	Civil /Seismic
Removal of redundant HVAC	Building Services
Protection of the air conditioning condenser units	Building Services

To improve the survivability of communications, EDF Energy has assessed the existing communication methods and identified areas to enhance resilience based on learning from the Fukushima event. Work included:

- Establishing vulnerabilities of existing communication systems against on-site and off-site power loss and disruption to infrastructure for BDB assumptions
- Identification of resilience and DBUE enhancement options and alternative communication systems that would increase communication resilience and diversity
- Procurement of mobile satellite telephones for 'last line defence communications', that have been distributed across the fleet and incorporated into emergency procedures
- Installation of fixed satellite capability in all Central Control Room (CCRs), ECCs and AIC/EICs.

The resilience programme of work also included the installation of the Continuous Emergency Monitoring System (CEMS) at the Advanced Gas cooled Reactors (AGRs) to provide a real-time display of key reactor/station parameters, located in a Safe Place On Site (SPOS) and facilitating decision making by operators in the hours following the event.

When operational, the CEMS will provide indications of key parameters for the reactor facilities, immediately pre and post fault through to event response. The key parameters will be provided to the Duly Authorised Persons (DAPs), ECC and Central Emergency Support Centre (CESC), giving a more informed decision making process. The CEMS will monitor the following parameters for the AGR stations:

- Reactor top temperature, T2 (two quadrants)
- Reactor bottom temperature, T1 (two quadrants)
- Reactor pressure (one location)
- Main Boiler outlet (steam) temperature or pressure (all four quadrants).

For Sizewell B (SZB), a Pressurised Water Reactor, a similar but station specific set of parameters are being investigated.

The CEMS has been installed on AGR sites and is scheduled to be commissioned in 2015. It is engineered to survive any credible series of events as far as reasonably practicable. When operational, the CEMS will use existing station supplies for normal operation, but will be self sufficient in the event of a complete loss of station supplies. Power to the CEMS is provided by existing battery and/or generator backed power supplies that are resilient up to BDB hazards. Where such supplies are not available the CEMS will typically be provided with its own Uninterruptible Power Supply (UPS) to provide power to the system for the requisite period, however where this is not the case EDF commits to review the situation.

As well as providing enhanced plant monitoring, additional means of tripping a reactor were reviewed and it was deemed that the numerous existing trip functions are adequate. This includes reactor trip buttons in two locations and a number of other system trips that would automatically cause the reactor to be tripped, such as the turbines. It should also be noted that on evacuating the Central Control Room (CCR) there is the requirement for the operator to trip the reactor.

The low voltage electrical supplies on-site are further supported by new alternative trailer mounted generators. 180kVA diesel generators will provide power for the low voltage 415V system to power essential indications. One diesel generator is stored at each AGR, with the exception of Heysham 2 and Torness which have received two due to the segregated and quadrantised layout of the stations electrical circuits. The 180kVA diesel generators provide a further line of defence beyond the existing emergency diesel generators, and can be attached to on-site vehicles for transport around site in event of a hazard. At SZB two new Battery Charging Diesel Generators (BCDGs) have been installed; these are seismically qualified to the infrequent event and raised above the 1m BDB on-site flood level. The connection of new electrical equipment will be supported by new connection points providing simple installation post-event. For more information on connection points see STF-8.

Learning from Japan shows that sites should have preparations for severe loss or damage to site infrastructure. This is the basis for the JER programme Deployable Back-Up Equipment (DBUE) strategy; the DBUE communicates real time plant indications via communication systems, supplied by a Deployable Communications and Information System (DCIS) that includes satellite communications equipment. The DCIS is compatible with, and can be connected to, the CEMS, but is delivered to site as part of the AGR DBUE, transmitting essential plant parameters to the DBUE staging post up to 10 miles from site, and is not reliant on any fixed telecommunication infrastructure. The DCIS provides communications and indications for long term usage, in more severe emergency scenarios, and can provide wider situational awareness by allowing access to stored data (e.g. station drawings) and telephony equipment allowing communications with the CESC and also other organisations.

DCIS is permanently installed at SZB's newly constructed Emergency Response Centre, providing a robust facility with independent supplies where the system can be operated from, providing diverse and resilient communications and plant information.

A significant part of the DBUE programme includes the provision of back-up emergency response facilities. This includes mobile ECC and ACP command facilities, some of which have positive pressure air and radiological particulate filtration systems. With the commissioned CEMS/DCIS capability, these facilities are able to replicate the functions of the emergency facilities on-site should they become untenable. This gives reliable communications and indications, allowing the operators to make the necessary decisions to manage the incident.

It is the EDF Energy JER assumption that in an extreme event complete loss of back-up power and cooling functions has occurred and that responders may be required to take actions local to plant in difficult conditions. This has been considered by the JER programme, as well as operator actions required in DB and BDB scenarios. These activities have considered:

- Personal Protective Equipment (PPE) and dosimeters; these are provided on-site to protect responders from possible exposure to radioactive materials or poisonous gases as existing measures, however are now further supported with the provision of PPE and monitoring equipment as part of the DBUE
- Access to areas required for responders taking local to plant actions. Routes have been assessed and selected based on a combination of the shortest routes, and routes where the plant is seismically qualified and is therefore less likely to be blocked
- The procedures and guidance for operators in emergency situations; work has been undertaken on:
  - The style and presentation of these documents, from a Human Factors viewpoint, to aid their intelligibility and usefulness to operators
  - Reactor and fuel route Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs) have been updated following a review required actions and new analysis
  - Deployable Back-Up Equipment Guidelines (DBUEGs) have been produced to aid responders using the DBUE.

Work on this recommendation has taken note of STF-3 regarding Human Factors.

4.22.3 Recommendation Conclusions

EDF Energy has reviewed its existing facilities for control, instrumentation and communications in a severe event and delivered a programme of improvements based on qualified and experienced engineering judgement.

The approach of the EDF Energy JER programme has been to provide enhanced resilience and additional layers of defence to improve its capabilities for gathering instrumentation and communicating it to emergency responders, whether this is via on-site enhancements or the provision of DBUE and facilities.

EDF Energy will continue to liaise with ONR and commits to further assess the resilience of the CEMS, with a focus on robustness, functionality and capability.

As such EDF Energy has an enhanced, extendable, capability for dealing with severe events and subject to the commissioning of the CEMS across the fleet, deems this recommendation to be closed.

4.23 Interim Recommendation 23 Close Out Report

Recommendation IR-23: The UK nuclear industry, in conjunction with other organisations as necessary, should review the robustness of necessary off-site communications for severe accidents involving widespread disruption.

In addition to impacting communications, it is possible that external events could also affect off-site centres used to support at site in an emergency. Alternative locations should be available and they should be capable of being commissioned in an appropriate timescale.

4.23.1 Overview

Off-site support during extreme events is very important in supplementing capability on-site. Recognising the level of off-site disruption at Fukushima, it is important to review communication provisions to ensure that they are secure under extreme events.

This recommendation is linked with IR-2 and IR-3 which support the wider review of off-site emergency planning external to EDF Energy's own equipment and processes. EDF Energy will take a proactive role in supporting this work which complements this recommendation.

This recommendation also links closely to IR-22 (provision of on-site emergency control, instrumentation and communications) and IR-8 (off-site infrastructure in extreme conditions) and FR-3 (managing & controlling actions in response to an accident, including on and off-site emergency control centres) and should be seen in this context.

4.23.2 Response

EDF Energy has taken a lead role, in collaboration with Sellafield Ltd, Magnox Ltd and the wider nuclear industry and emergency arrangement groups, in performing a review of the Fukushima event in relation to lessons learned, ensuring these are incorporated in to normal business; this included the availability of off-site communications.

Adequate, robust and functioning emergency facilities as well as redundant and diverse systems are required to manage communications following a severe event. As such, EDF Energy carried out a review of existing communication systems in conjunction with the Emergency Planning Group (EPG) and telecommunications Suitably Qualified and Experienced Personnel (SQEP), against on-site and off-site power loss and disruption to infrastructure following a Beyond Design Basis (BDB) event, identifying areas for enhancement.

Whilst the telephone exchange systems at EDF Energy nuclear plants have independent battery backed power supplies and are considered to be resilient, a feasibility study was conducted on enhancing these supplies and identified upgrades will be implemented during the Voice Over Internet Protocol (VOIP) telephony upgrade that is taking place as normal investment business.

To further improve the availability of communications, EDF Energy is providing fixed satellite telephones for improved resilience to communications across the fleet of stations as well as the Central Emergency Support Centre (CESC). All Central Control Rooms (CCRs), Emergency Control Centres (ECCs) and Emergency/ Alternate Indication Centres (EIC/AICs) will have a fixed satellite capability including antenna outside, allowing the phone to be used without leaving the facility.

At Sizewell B (SZB) a new hardened Emergency Response Centre (ERC) has been provided with command and control capabilities, should the ECC on-site become untenable. Facilities at SZB are unique amongst the EDF Energy fleet of power stations, reflecting the shorter event escalation times of a Pressurised Water Reactor (PWR). The ERC is situated off-site, in a location considered safe from flooding and other hazards. The facility is robust to survive a severe event, and includes dedicated back-up diesel generators and supplies to provide resilience against loss of power and site access for 72 hours. The ERC is being fully integrated into SZB emergency arrangements.

A Continuous Emergency Monitoring System (CEMS) has been installed at the Advanced Gas-cooled Reactors (AGRs) and is scheduled to be commissioned in 2015. It is engineered to survive any credible series of events as far as reasonably practicable, providing a real-time display of key reactor/station parameters, located in a Safe Place On Site (SPOS), to facilitate decision making by operators in the hours following the event. When operational, the CEMS will provide indications of key parameters for the reactor, immediately pre and post fault through to event response. The key parameters (reactor top and bottom temperature, reactor pressure, and boiler outlet temperature or pressure for the AGRs, with the equivalent being investigated for SZB) will be provided to the Duly Authorised Persons (DAPs), ECC and CESC, allowing a more informed decision making process. For SZB a CEMS project is in development, taking learning from the AGR installations, and is anticipated to be completed during the next refuelling outage.

Power to the CEMS is provided by existing battery and/or generator backed power supplies that are resilient up to the infrequent event; where such supplies are not available the CEMS will typically be provided its own Uninterruptible Power Supply (UPS) to provide power to the system for the requisite period, however where this is not the case EDF commits to review the situation.

The Deployable Back-Up Equipment (DBUE) also has the capability to provide real time plant indications and communication systems, supplied by a Deployable Communications and Information System (DCIS) that includes satellite communications equipment. The DCIS is compatible with, and can be connected to, the CEMS, but is delivered to site as part of the AGR DBUE, transmitting essential plant parameters to the Mobile ACP, ACP and DBUE staging post. The DCIS is not reliant on any fixed telecommunication infrastructure and provides communications and indications for long term usage in more severe emergency scenarios, and can provide wider situational awareness by allowing access to stored data (e.g. station drawings) and telephony equipment allowing communications with the CESC.

A significant part of the DBUE programme includes the provision of deployable emergency response facilities, where the DCIS data and communications equipment will be available. This includes mobile ECC/ACP command facilities, some of which have positive pressure air and airborne contamination filtration systems. The facilities provide a base from which the wider DBUE response can be organised with assistance from the CESC.

DCIS is installed at SZB’s newly constructed ERC, providing a robust facility with independent supplies where the system can be operated from, providing diverse and resilient communications and plant information.

The DBUE can be deployed from one of four regional locations in a timely manner and includes an ACP which manages access and egress to a hazardous location from a suitable off-site position. The ACP includes Personnel Protective Equipment (PPE), communications equipment, radiation monitoring equipment and decontamination showering facilities.

4.23.3 Recommendation Conclusions

EDF Energy has reviewed its communications and emergency control facilities, both on and off-site to ensure an adequate ability to communicate off-site. These facilities have been enhanced via the provision of satellite communications equipment, the installations of the CEMS capability, DCIS at the SZB ERC, and ability to deploy DBUE emergency facilities and communications equipment in a timely manner, should they be required. EDF Energy will continue to liaise with ONR and commits to further assess the resilience of the CEMS, including a demonstration of its compatibility with DCIS.

These facilities are being fully incorporated into normal business, and subject to the commissioning of the CEMS across the fleet, this recommendation is considered to be closed.

4.24 Interim Recommendation 24 Close Out Report

Recommendation IR-24: The UK nuclear industry should review existing severe accident contingency arrangements and training, giving particular consideration to the physical, organisational, behavioural, emotional and cultural aspects for workers having to take actions on-site, especially over long periods. This should take account of the impact of using contractors for some aspects on-site such as maintenance and their possible response.

This is a wide ranging recommendation and there are a number of aspects that need to be included.

a) the reviews need to acknowledge design differences between individual nuclear facilities and consider whether corporate Severe Accident Guidelines need to be customised;

b) adequacy of trained personnel numbers for long-term emergencies, particularly for multi-unit sites, and taking into account the potential impact of infrastructure damage and societal issues on the ability to mobilise large numbers of personnel;

c) the time windows for availability of off-site support may be challenged hence the role of on-site personnel may change, which has implications for procedures and training;

d) the review of Severe Accident Management Guidelines (SAMG) should consider not only critical safety function prioritisation but also whether and how SAMGs support and dynamic reprioritisation based on emerging information;

e) consideration should also be given to operator support requirements relating to tactical and strategic decision making; and

f) in addition to the acute phase of a severe accident, consideration also needs to be given to stabilisation, recovery and clean-up, and the personnel involved from the many organisations involved.

4.24.1 Overview

EDF Energy has carried out a variety of reviews and analyses relating to demands on operators in event of emergency scenarios, to ensure that they are adequately identified and assessed and to confirm that the actions required of operators can be carried out, including under the conditions created by external hazards.

Complementary activities have been undertaken to revise procedures and guidance in event of emergencies. The revised emergency planning includes the use of the new EDF Energy Deployable Back-Up Equipment (DBUE) and its interaction with site plant. Improved guidance and training is being rolled-out to aid the management and support of staff involved in emergency situations.

This response details EDF Energy’s activities and shows that, in combination, they address all the aspects raised by IR-24.

The ability of staff to respond to a major incident in a calm and measured way is integral to the successful implementation of an emergency response. The learning from Fukushima is highly relevant to understanding and potentially improving our current arrangements.

Whilst arrangements already existed for dealing with severe accidents at all of our sites, Fukushima highlighted that the event may go on for a prolonged duration and that people can be required to perform difficult duties against a background of widespread disruption to the site and the people in the surrounding area.

EDF Energy has accordingly undertaken activities to better prepare and support all involved response workers for a longer timescale severe accident.

This recommendation is covered by different parts of EDF Energy’s response programme, including:

- Reviews of operator actions required in emergency and severe accident scenarios, and Human Factors (HF) review and assessment to ensure that operators are able to carry out the required activities, including tasks involving the new DBUE

- Improvement and extension of Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs) for Advanced Gas-cooled Reactors (AGRs) (and amendment of Station Operating Instruction (SOI) 8.8 at Sizewell B (SZB))
- Human Aspects work contributing to amended procedures and reference material in emergency handbooks, and additional and improved training for staff involved in emergency and accident scenarios
- DBUE procedures and training, including those for the Through Life Management Partner (TLMP) personnel carrying out the deployment and the Forward Deployment Service (FDS) personnel bringing the DBUE onto site.

4.24.2 Response

Studies of Operator Actions

EDF Energy has carried out, under the JER programme, reviews and analyses relating to operator actions required in the safety case and in emergency and accident scenarios. This work has considered different aspects in varying ways, to enable confidence that operator actions have been adequately identified and assessed such that they can be carried out if required, including under the conditions created by the hazard. The work has included reviews of:

- Operator actions claimed in safety cases and SOIs, and additional HF assessments where needed. This has confirmed that for actions formally claimed in the Safety Case, HF assessments have already been carried out to confirm that they can be undertaken as intended; additional HF assessments have similarly been undertaken for other operator actions identified through the reviews
- Operator actions required in response to seismic events, as a specific new study
- Review of the operability of the new DBUE
- Operator actions required in response to severe weather, and preparedness for it. Action is being taken to ensure that all stations have up-to-date procedures and guidance.

These HF reviews have found that the tasks intended to be carried out by operators in emergency, accident and external hazards scenarios can reasonably be expected to be carried out, including in Beyond Design Basis (BDB) scenarios insofar as these are considered in relevant SOIs, in the workshops and in respect of the DBUE which is intended to be deployed to support stations in the event of BDB hazards.

(Operator actions and Human Factors are considered in more detail under STF-3).

Review, Improvement of SBERGs and SAGs

The AGR stations' SBERGs for all AGR stations have been revised, to (1) add new SBERGs covering fuel route facilities; (2) improve their general technical content, and (3) better present information, from a human factors viewpoint.

The SBERGs suitably reflect variations between stations, such as differences regarding Vessel Over-Pressure Protection Equipment and differences such as the Boiler Closure Units at Hartlepool and Heysham1 and associated issues relating to faults affecting Pressure Vessel cooling.

This programme of review and update has also been founded on the work undertaken as part of FR-4, which confirms the ongoing commitments.

Furthermore, the revisions to the SBERGs are being supported by training in their use, as part of the ongoing programme of work.

The AGRs' SAGs have also been updated to be more useful to staff, concisely presenting key information "up-front" and more clearly focussing on what to do in the event of an accident. The new SAGs provide better clarity on key recovery actions, concisely and in relation to the main strategic objectives for emergency planning. The new SAGs also include interfaces with the DBUE that can help to manage a severe accident if one does occur. The SAGs are written at a sufficiently high level that they are applicable generically across the AGR fleet, and do not need to include variations between stations. Note also that the scope of the SAGs does not extend to recovery and clean-up activities following a severe accident.

The SAGs are focussed on the strategic objectives which would need to be met to regain control of the core. Production of SAGs for the fuel route has been considered by EDF Energy. However, recognising that there are no fuel route accidents with comparable complexity of physical phenomena, or the potential for major escalation, as accidents that compromise the key safety functions for the core, specific SAGs for Fuel Route have not been developed. Notwithstanding this, improved accident management advice for the buffer stores and the fuel ponds has been incorporated in the updated SBERGs, based on relatively simple concepts about what is needed to provide cooling. There is therefore enough guidance on response to Fuel Route faults in the updated SBERGs. This approach has not been invalidated by events at Fukushima.

At SZB, SOI8 deals with Critical Safety Functions, and within this SOI8.8 addresses Severe Accident Mitigation. SZB does not use Westinghouse's Severe Accident Management Guidelines.

SOI8.8 will be updated and benchmarked against international practice for Pressurised Water Reactors (PWRs), with particular reference to French PWRs, together with other related SOIs, POIs (Plant Operating Instructions) and Emergency Arrangements.

SOI8.8 will also require amendment to incorporate the addition at SZB of FCV (Filtered Containment Venting) if this modification is implemented; to avoid amending SOI8.8 twice, both the "best international practice" update and the FCV amendment will be done in a single round of change. Inputs to updating SOI8.8 include HF assessment of operator actions. Further work is also to be undertaken at SZB on the "human aspects" of emergency procedures, including staff numbers/availability and training.

Beyond Design Basis Events in Probabilistic Safety Assessments (PSAs)

BDB events have also been included in a Level 2 PSA for Hunterston B as a pilot AGR, including transient analyses extended to cover longer fault timescales than hitherto, noting that SZB already had a Level 2 PSA. This work has highlighted the importance of particular mitigating actions in certain scenarios, and clarified timescales for their implementation. This learning has contributed to refinement of the SAGs and will be fed into further improvements to the SBERGs. (This subject is addressed in more detail in EDF Energy's response to FR-4.)

Deployable Back-Up Equipment

Many aspects of emergency response will be improved by the new DBUE, which can be deployed from storage centres to EDF Energy stations that require assistance, providing back-up to essential safety functions, in particular electrical generation and plant cooling. DBUE deployment will be implemented through a planned, contracted and exercised DBUE deployment strategy, deploying the equipment along pre-planned routes to staging areas from where equipment will be deployed to site following site-specific Forward Deployment Plans, by the FDS.

The Through-Life Management Strategy for the DBUE includes a long-term contract partner, required to maintain a competent workforce to deliver DBUE maintenance and deployment. This includes:

- "No notice" delivery of fully operational DBUE to staging areas in response to an emergency, leaving storage facilities within 2 hours of call-out
- "With notice" support to exercises and training.

The TLMP operates a SQEP process for all members discharging activities under the contract, involving assessment of activities to identify required specialist knowledge & training and ensuring that personnel are suitably trained and competent. SQEP records are kept for personnel performing maintenance activities.

The FDS consists of members of the Turbine Support Group who are being trained in forward deployment aspects, such as driving the vehicles and deploying the equipment. The DBUE will be taken by the FDS to pre-determined lay down points where suitably trained EDF Energy response teams will connect and operate the DBUE in line with the Deployable Back-Up Equipment Guidelines

(DBUEGs). There is also some flexibility with respect to the exact location of DBUE, as the equipment provides the capability to run extended water pipes and electrical power cables if required. The FDS will also provide transport for EDF Energy response teams and logistical support to the site.

The DBUE strategy for AGRs involves three off-site regional stores, located to ensure that any affected station can be supported before safety limits are exceeded, and two concurrent events can be managed. The deployment strategy has identified alternative transport routes and staging posts for each site, considering possible disruption from various hazards such as collapsed bridges, traffic congestion and flooding. Delivery times have been conservatively calculated, taking into account the potential for disruption, to confirm the ability to deploy the DBUE to each site within the required timescales. DBUE for SZB is stored at the newly-built Emergency Response Centre (ERC), close to site, to reflect the shorter event escalation times for PWRs.

The DBUE itself includes Land Rover vehicles to aid movement of site personnel onto and around the site, to ensure that they can still be deployed to carry out necessary tasks in the conditions created by weather or flood hazards. The DBUE also includes JCBs to clear obstacles and ensure access to key plant areas.

A major part of DBUE is also the mobile facility to support personnel working on-site in an emergency situation, containing not only emergency command and control facilities but also personnel support and medical units.

The DBUE and its deployment are described in more depth in EDF Energy's response to IR-25.

The DBUE will be deployed, installed and operated using the DBUEGs, which include:

- An Overview containing generic information on DBUE equipment and systems (or functions), answering questions such as "What is it?", "When does it arrive?", What does it do for me?" and specifying requirements for operation (including people requirements)
- Appendices containing technical information on plant intervention equipment, including station-specific laydown and connection details, also full details on ancillary equipment, and lower-level operating instructions.

The DBUEGs cover all DBUE, and set out equipment configurations and activities required to implement whole systems/functions, e.g. the configuration of multiple DBUE equipment to provide boiler feed water. The DBUEGS will be maintained and configuration-controlled.

<u>Demonstration of Emergency Management Capabilities</u>

The EDF Energy JER programme has staged a number of Proof of Concept (POC) demonstrations that provide tangible evidence that the JER programme has delivered the promised improvements in enhanced capability. The POC demonstrations were endorsed by the EDF Energy Nuclear Generation Executive (NG Exec) and advised to the ONR.

A significant part of the enhanced emergency response capability provided by the JER programme cannot be practically demonstrated on site due to the invasive nature of the DBUE; as such, the POC exercises demonstrated the practicality of the deployment of equipment and personnel, and the ability of stations and the Central Emergency Support Centre (CESC) to respond to, and deal with, beyond design basis events over an extended period of time.

Four POC demonstrations have been undertaken, to demonstrate to EDF Energy that the DBUE, activation and deployment processes, operational procedures and training, all work together to deliver an enhanced BDB emergency response capability.

Each demonstration has undergone independent assessment by an Internal Assessment Team headed by the company's Emergency Planning Fleet manager and has been further reviewed by EDF Energy's internal regulator, INA. The ONR has also witnessed these internal demonstrations as part of their work on assessing the response to the Weightman recommendations. Areas of good practice and areas for improvement have been captured and will be used to inform subsequent demonstrations or future exercise requirements.

Proof of Concept Demonstration AGR

The POC demonstrations for AGR deployment and capability were split into 3 phases.

POC A – A practical 3 day event which demonstrated the activation, logistical deployment of DBUE and establishment of a staging post site by the TLMP. Followed by transfer of DBUE to EDF Energy and the capability of station responders from Heysham 1 and 2 to connect and operate the DBUE that would restore Critical Safety Functions.

POC A* - A practical demonstration based at HNB which focused on the interactions between key responders (EDF Energy, FDS and TLMP) in the deployment of DBUE. The exercise illustrated the successfully delivery of DBUE by the FDS and the deployment and laydown/setup of mobile facilities (Emergency Control Centre (ECC), Access Control Point & DCIS (Deployable Communications and Information System). These facilities were utilised by the response organisation to respond to an event using existing command and control techniques.

POC B – A simulated BDB long duration emergency scenario involved the CESC and Heysham 1 and 2 Central Control Room and ECC teams. The demonstration made use of the updated arrangements, DBUEGs and SBERGs. It demonstrated the capability to understand and manage a multi-site, multi-unit, BDB event, including the benefits of the JER-provided additional measures. The demonstration required real-time decision-making by staff and involved a shift changeover; it also simulated a real emergency through factors such as failures of plant indication systems, communications and lighting.

The internal and external reviews and reports of the AGR POC recorded the successes and captured the lessons learnt from these demonstrations. The continuing improvement process ensures that this learning is embedded within our emergency arrangements.

Proof of Concept Demonstration PWR

POC C - A practical demonstration was performed at SZB to evaluate the station's response in activating the ERC, determine the effectiveness of the Responders in preparing, deploying and operating the back-up equipment, and provide evidence of DCIS's capability in data acquisition, verbal communication and information transfer.

Overall the exercise demonstrated that SZB off-site ERC could be activated in a timely manner. ERC responders demonstrated knowledge and proficiency in the preparation, deployment and operation of back-up equipment. Communication through DCIS was established between responders using hand-held radios and head-sets worn by staff in the off-site ERC, also between the off-site ERC and EDF Energy's CESC at Barnwood. Two-way data transfer between the off-site ERC and the CESC was also demonstrated.

Each of the POC demonstrations have been reviewed in detail with the key learning captured in a JER Proof Of Concept Demonstration Report covering A, A*, B and C for future learning as part of the continual improvement process.

<u>Expanded Emergency Training</u>

EDF Energy has a Generic Emergency Scheme Training programme which is being improved and extended as a result of JER's reviews. Additional training elements are being provided for staff including (amongst others) Emergency Controllers, Shift Managers, ECC staff, Reactor Desk Engineers, all Emergency Response Team staff, CESC Controllers and Technical Support Team leaders. The additional JER training inputs are being co-ordinated through an overall JER "Task to Training" matrix.

Improved emergency response training includes, amongst other things:

- Training in dynamic risk assessment for emergency teams, as required in real-time emergency situations
- Decision-making in emergency scenarios, using a number of scenarios as part of the training to provide assistance on decision making.

A key principle is that all of the new and improved training being introduced under JER has a place in the permanent EDF Energy training structure.

Improved Human Aspects for Management in Emergencies and Accidents

EDF Energy has progressed a Human Aspects workstream to address the central issues raised under IR-24 and is implementing the outputs that have come from it. This is reported in "Japan Earthquake Response Programme: Close Out Report – Human Aspects Workstream".

Human Aspects findings and themes are reflected in, and have been integrated into: emergency documentation and procedures (emergency plans; handbooks), training (roles; competences; content; resource material), exercises (assessment criteria and guidance notes); and new policies Human Resources (HR)/Occupational Health (OH), with supported training and guidance material), as illustrated below:

Objectives /Deliverables	Outputs
• Enhanced staff willingness to respond to emergency events, with particular ref to reviewed/BDB emergency arrangements.	• Specific enhancements to emergency plans, emergency handbooks. • Additions and enhancements to design, delivery and review of training and exercises.
• Enhanced staff availability to respond to emergency events, with particular ref to BDB/prolonged emergency response.	• Specific enhancements to emergency plans, emergency handbooks. • Additions and enhancements to design, delivery and review of training and exercises.
• Enhanced staff preparedness and resilience, for dealing with critical, traumatic and major emergencies.	• Enhanced welfare arrangements and adoption of new trauma management policy and procedures; linked to new training and exercise elements.
• More resilient staff support and family liaison arrangements, with particular reference to incidents involving casualties and fatalities.	• Specific enhancements to emergency plans, emergency handbooks and other relevant company procedures; linked with relevant enhancements in training.

The emergency handbooks include the Generic Emergency Handbook, station-specific Emergency Handbooks (local handbooks based on the generic handbook), and the CESC Handbook for response at the CESC at Barnwood (and alternative locations).

To improve management and support of personnel in emergency/accident scenarios, EDF Energy is introducing a Trauma Management pilot scheme and a range of related policies, procedures and training courses. New training for Human Resources (HR)/ Occupational Health (OH) staff is being provided by Trauma Risk Manager and Practitioner courses (referred to as TRiM courses). Training tools and resources now include the CESC Emergency Leader Briefing Pack, which contains a series of checklists on Resilience: Supporting People in Emergencies.

To incorporate the benefits of the human aspects work, emergency plans/handbooks now include the following:

- Reference to early activation of Trauma management arrangements
- Guidance on supporting staff/relatives on-site in incidents involving casualties/fatalities
- Informing/updating HR early where appropriate for information, staff records and additional admin support
- Higher profile for welfare function, e.g. through renamed Welfare and Administrative Officer/Support Team
- Clarification of welfare responsibilities at different locations – (who, where, what)
- Proactive management of staff welfare, e.g. tasking the monitoring of shift lengths and rest breaks, stress/fatigue risk assessment and defusing

- Further consideration of staff at muster points, e.g. welfare needs and/or to bolster station emergency response
- Opportunities for staff engaged in prolonged response to make brief family contact.

Other significant documents produced in this area include:

- Dealing with a Critical Incident/Traumatic Event: Trauma Management Policy and Procedures
- Critical Incident Policy and Guidance: HR/OH Role in Supporting Staff and Families in the event of Critical Incidents
- Report: Supporting Staff Welfare and Resilience: Information and guidance for enhancing staff resilience, welfare and support during and after critical and major incidents (resource pack available to be used in and beyond emergency response).

4.24.3 Recommendation Conclusions

This response has described how EDF Energy has identified and reviewed the activities required of operators in emergency and accident scenarios.

It has been confirmed that suitable human factors assessments have been carried out to ensure that operators will be able to undertake the required actions, including under the conditions created by incidents and hazards. Where necessary, new analyses have been undertaken.

Procedures to be followed in hazard and emergency scenario have been, or are being, updated to reflect learning from Fukushima and related JER studies. These include new and updated SBERGs and SAGs; SOI8.8 at SZB is also being reviewed and will be up-issued.

The updated emergency procedures include deployment and use of the new JER DBUE, which is the subject of a new suite of guidelines (the DBUEGs). The DBUE will greatly help stations deal with BDB hazards and extended time period emergency situations.

To aid station staff in severe accident and extended emergency scenarios, a range of management improvements have been made through “human aspects” work that has led to additional elements in emergency handbooks and related guidance and training.

Emergency training has been reviewed and improved through JER activities and is now the subject of an improved and extended suite of training courses, all of which will become part of EDF Energy’s permanent training structure.

These additional and improved measures were used and tested in the POC demonstrations, which deployed emergency arrangements including DBUE in a series of simulated emergency situations. All 4 POCs were completed successfully.

This response shows that EDF Energy has made a thorough and in-depth response to IR-24, with major activities having been undertaken to ensure that personnel involved in emergency and severe accident scenarios at EDF Energy stations will be able to undertake the actions required of them and will be suitably trained, will have suitable procedures and guidance to inform their actions, and will be suitably supported and managed, including measures to provide for their personal needs and welfare.

This response draws on a variety of the EDF Energy JER work and overlaps extensively with other Recommendations and Findings, notably STF-3, IR-25 and IR-13, and as such is considered closed.

4.25 Interim Recommendation 25 Close Out Report

Recommendation IR-25: The UK nuclear industry should review, and if necessary extend, analysis of accident sequences for long-term severe accidents. This should identify appropriate repair and recovery strategies to the point at which a stable state is achieved, identifying any enhanced requirements for central stocks of equipment and logistical support. Recommendation IR-25 is linked with Recommendation IR-13. Combining these two recommendations means that we would expect industry to:

a) identify potential strategies and contingency measures for dealing with situations in which the main lines of defence are lost. Considerations might include, for example, the operator's capability to undertake repairs and the availability of spares (capability includes the availability of personnel trained in the use of emergency equipment along with necessary supporting resources;

b) consider the optimum location for emergency equipment, so as to limit the likelihood of it being damaged by any external event or the effects of a severe nuclear accident;

c) consider the impact of potential initiating events on the utilisation of such equipment.

4.25.1 Overview

The events on the Fukushima site following the impact of the tsunami highlighted the potential for damage to essential safety systems from extreme natural events. It is therefore appropriate to review the transient analyses addressing severe accident sequences which will serve to reconfirm their continued adequacy, as well as reconfirming the key recovery activities to control, mitigate or prevent the consequences of a severe natural hazard. Remedial actions may need to be taken by the workforce and emergency response teams to control, mitigate, or prevent the consequences of a severe natural hazard. Therefore the ability of the workforce to recover under the prevailing hazard conditions and consequences is relevant.

This item has been linked to IR-13; the response to IR-13 will principally address layout aspects and access to the site. This response to IR-25 addresses aspects related to arrangements for dealing with severe accident scenarios on-site, in particular external hazards.

Many aspects of IR-25 are also addressed under Stress Test Finding STF-3 in relation to Human Factors and the ability of personnel to carry out activities required of them in an emergency or severe accident scenario. Other aspects are addressed in more detail under Final Recommendation FR-3, including fuller descriptions of the Deployable Back-Up Equipment (DBUE) and its use.

The overall intention is that improvements to functional integrity of essential functions is achieved through better understanding of external hazards, their potential consequences, and required recovery and accident management actions. Two complementary approaches are being followed:

- A programme of plant and equipment enhancements to improve the ability to deal with external hazards and their possible consequences; these principally comprise on-site resilience modifications and the provision of DBUE.
- Analytical work to better understand external hazards and their effects, and the actions required in response to them; the results of these analyses have contributed to development of improved management arrangements, procedures and training for emergency and severe accident scenarios. The analyses have also contributed to reviews of safety case claims with respect to design basis accidents, and to the identification of remedial actions where appropriate.

4.25.2 Response

<u>New Analyses</u>

In response to this Interim Recommendation, EDF Energy has undertaken a variety of new analyses to achieve an improved understanding of the situation in which lines of defence are lost and/or there are significant effects of external hazards (including Beyond Design Basis scenarios (BDB)), leading to emergency situations and potentially severe accidents.

Relevant new analyses have been undertaken as summarised below.

- Level 2 Probabilistic Safety Assessment (PSA) for the Advanced Gas-cooled Reactors (AGRs):

  EDF Energy has undertaken a Level 2 PSA for Hunterston B (HNB) as a pilot AGR, including BDB events and transient analyses extended to cover longer fault timescales than hitherto. (Sizewell B (SZB) already had a Level 2 PSA). This work has highlighted the importance of particular mitigative actions in certain scenarios, and clarified timescales for their implementation. This learning has contributed to refinement of the Severe Accident Guidelines (SAGs) and will be fed into further improvements to the Symptom Based Emergency Response Guidelines (SBERGs). This subject is addressed in more detail in EDF Energy's response to FR-4.

New analyses of the external hazards within the EDF Energy JER programme scope:

- Severe Weather

  Workshops have been undertaken across all the EDF Energy station sites to specifically review the adequacy of arrangements in response to extreme weather scenarios. In conjunction with a fleet-wide review of the extreme weather preparedness procedures, and the fleet-wide deployment of VisualEyes and Safesee forecasting tools, this has confirmed good readiness and resilience to extreme weather hazards. Furthermore, the Met Office has been commissioned to carry out updated Extreme Value Analyses (EVA) in order to reconfirm the continued security of the design basis boundary, for weather hazards of return frequencies of 1 in 10,000 years, or greater. These work areas are described in more detail under STF-5.

- Flooding

  EDF Energy has commissioned new flooding assessments for all station sites, considering possible coastal flooding; rainfall (pluvial) flooding, and flooding from rivers (fluvial) with reference to a 1 in 10,000 year (infrequent) flooding event. Further-refined modelling has been undertaken for Dungeness B (DNB), Heysham 1 (HYA) and Heysham 2 (HYB). The flood modelling has led to improvements being undertaken at DNB, the Heysham stations and Hartlepool (HRA). Flooding was also considered in the severe weather workshops, and rainfall in the Met Office EVA studies. Flooding is considered in more detail under STF-7.

- Seismic

  A significant single station study was undertaken at Hinkley Point B (HPB), which did not identify any unexpected results, nor did it identify any new significant vulnerable features. There were a number of issues requiring further investigation, housekeeping etc. but nothing that compromises the existing safety cases fleet-wide. For SZB, the existing safety case was found to adequately address seismic hazards and so new studies have not been needed. Seismic hazards are considered more specifically in EDF Energy's responses to STF-2, STF-4, STF-5, STF-6 and IR-15.

- Operator Actions and Human Factors (HF)

  EDF Energy has carried out a variety of reviews and analyses relating to operator actions in the event of external hazards, to ensure that they are adequately identified and assessed such that they can be carried out if required, including under the conditions created by the hazard. This has included reviews of:

  - Operator actions claimed in safety cases and Station Operating Instructions (SOIs), and additional HF assessments where needed
  - Operator actions required in response to seismic events
  - Operator actions required in response to severe weather, or preparedness for it
  - Review of the operability of the new DBUE.

  Operator actions and Human Factors are considered in more detail under STF-3 and IR-24.

Improved and New Arrangements – On-Site Resilience

On-site resilience modifications are described in more depth in EDF Energy's response to STF-14, and are summarised here. EDF Energy has undertaken a programme of work to increase the resilience of key existing systems and structures to severe events and BDB events. Significant improvement has been achieved through relatively simple but effective resilience enhancements to structures and equipment.

The modifications/enhancements encompass:

- Flood protection (as described under STF-7), including provision of dam boards; building penetrations sealing; construction of new or improved flood defence walls; flood protection of ponds; and dewatering (pumpout) capabilities. The systems protected include back-up electrical generation and back-up feed water
- Resilience to seismic events, including access to key plant areas; ensuring qualification of water stocks; seismic qualification of dry risers; and mobile fire fighting equipment
- Resilience of infrastructure such as Alternative/ Emergency Indication Centres (A/EICs) and the Emergency Control Centres (ECCs), against extreme external events (not required at SZB)
- New systems have been added to SZB, including Passive Autocatalytic Recombiners and a connection for Containment Water Injection
- A programme is also ongoing reviewing installation of Filtered Containment Venting (FCV) at SZB, on which a final decision has not yet been made; development/design work is continuing and a final decision on whether to proceed will depend on the outcome of that work as it will establish sufficient information to make the decision, considering all benefits and disbenefits
- EDF Energy is also providing connection points such that cooling and essential electrical supplies can be established using back-up equipment should a station require this.

These enhancements have not impacted upon normal safety processes, but have given enhanced protection to severe events.

Deployable Back-Up Equipment

The EDF Energy JER programme has developed a response strategy using a DBUE portfolio capable of restoring plant cooling capabilities. The use of the DBUE is supported by the provision of accessible connection points, as described in EDF Energy's response to STF-8. The DBUE provides the following capabilities on site.

- Cooling Capabilities

  The DBUE includes resources to provide cooling functions for the core and spent fuel, by:

  - Repressurising an AGR reactor, where required, injecting nitrogen into the reactor to create sufficient pressure for natural circulation; DBUE Diesel Generators (DG) can power equipment to support resealing of the pressure vessel, if required
  - Providing primary circuit feed to the SZB Reactor Pressure Vessel in Mode 6, outage mode, using Low Pressure (LP) pumps and an additional connection point
  - Providing water to the AGR Secondary Circuit, using High Pressure (HP) pumps (sufficient water sources are on-site and seismically qualified to support functions for over 48 hours). Also available are LP transfer pumps (for pumping between tanks), and water treatment equipment to provide treated water from townswater/seawater sources
  - Providing water to the SZB (a Pressurised Water Reactor (PWR)) Steam Generators, by an HP pump stored at the new SZB Emergency Response Centre (ERC)
  - Providing AGR buffer (decay) store feed and AGR/PWR spent fuel cooling and pond top-up capability, via pumps and treated water
  - Pond coolers for AGR pond water cooling.

- Electrical Generation

  The DBUE strategy includes:

  The low power approach comprises 415V 200kVA DG units that will be deployed and commissioned at the station within 24 hours to power essential reactor instrumentation. The DGs are compatible with station 415V connection points and are supplied with necessary fuel and ancillary equipment. (Additional, new,180kVA units are held on AGR sites to provide support should they survive the BDB event.)

  3.3kV connection points at AGRs underpin 415V essential instrumentation and provide limited support to electrical infrastructure through the 3.3kV distribution system.

  The generators, cables, plugs and on-site connection points are all 'industry standard', and so should additional generators be required then commercially available equipment would be compatible and readily connectable.

- Control and Communication

  The DBUE provides back-up emergency response control and communication facilities. This includes mobile ECC/ACP (Access Control Point) command facilities, some of which have positive pressure air and radiological particulate filtration systems. The deployed ACP manages access and egress to a hazardous location from a suitable off-site position. The ACP includes Personal Protection Equipment (PPE), radiation monitoring equipment and decontamination showering facilities.

  To support emergency response, the DBUE also provides real time plant indications and communication systems, supplied by a Deployable Communications and Information System (DCIS) that includes satellite communications equipment. The DCIS is compatible with, and can be connected to, the site-based Continuous Emergency Monitoring System, but is delivered to site as part of the AGR DBUE, transmitting essential plant parameters to a mobile ECC, ACP and DBUE staging post, and is not reliant on any fixed telecommunication infrastructure. The DCIS can provide wider situational awareness by allowing access to stored data (e.g. station drawings) and telephony equipment allowing communications with the Central Emergency Support Centre (CESC).

  At SZB DCIS has been permanently installed at the newly constructed ERC, providing a robust facility with independent supplies where the system can be operated from, providing diverse and resilient communications and plant information.

- Fuel Supplies

  All equipment brought to site will have its own fuel supplies delivered with it.

- Storage and Deployment:

  On declaration of a nuclear emergency, EDF Energy's Through Life Management Partner (TLMP) will be contacted to begin the delivery of a comprehensive set of DBUE from the most appropriate regional store. The DBUE will reach a staging post from which transfer of equipment to site will be co-ordinated. The TLMP and the staging post will have a dedicated line of communication with the CESC.

  The DBUE will then be transported from the staging post to site by the Forward Deployment Service (FDS), who have been trained in forward deployment aspects, such as driving the vehicles and deploying the equipment. The DBUE will be taken by the FDS to pre-determined lay down points where suitably trained EDF Energy response teams will connect and operate the DBUE in line with specially prepared operating instructions. There is also some flexibility with respect to the exact location of DBUE, as the equipment provides the capability to run extended water pipes and electrical power cables if required. Connections will be to the engineered locations or if necessary, to ad-hoc connections. The FDS will also provide transport for EDF Energy response teams and logistical support. The DBUE is self sufficient for 72 hours post event.

  The DBUE strategy for AGRs involves three fully stocked off-site regional stores, located to ensure that any affected station can be supported before safety limits are exceeded, and two concurrent events can be managed. The deployment strategy has identified alternative transport routes and staging posts for each site, considering possible disruption from various hazards such as collapsed bridges, traffic congestion and flooding. Conservative calculations have developed estimates for delivery times, again taking into account the potential for severe disruption off-site.

With respect to HYA and HRA, there has been significant focus on the review and update of transient analyses, and deployment arrangements, to ensure that the forward deployment strategies can deliver DBUE to site to provide effective plant recovery.

DBUE for SZB is stored at the newly built SZB ERC, close to site, to reflect the shorter event escalation times for PWRs.

- Maintenance, Exercising

  All DBUE will be stored, maintained and exercised appropriately, ensuring that it is fit for purpose and ready to be deployed should it be required.

- Procedures for Use

  Deployable Back-Up Equipment Guidelines (DBUEGs) have been produced, providing technical detail on use and operation of a range of back-up systems/equipment that the JER programme has procured. The Generic Emergency Handbook has been suitably updated to include the deployment and use of the DBUE, as are site-specific Emergency Handbooks.

  The CESC staffing will include a TLMP liaison officer to aid co-ordination of the DBUE's deployment with EDF Energy activities and planning.

Improved and New Arrangements - Procedural

- Improved and Extended SBERGs

  The SBERGs for all AGR stations have been revised.

  The SBERG changes have been contributed to by three separate studies: (1) reviewing human factors aspects of the documents and how they present information; (2) a review of their technical content, and (3) addition of new SBERGs covering fuel route facilities.

  The updated, new-format SBERGs were produced and implemented at HYA and HYB, and used in the Proof of Concept Demonstration (POC) B. They were then progressively produced and implemented across all other AGRs; an over-arching Engineering Change (EC) for update of all stations' ECs was produced, and ECs for updating the SBERGs for all other stations has been issued with completion in 2014, with a final overall close-out report anticipated in early 2015. This has been supported by training in their use; the courses have been formulated and delivery - initially focussed on HYA and HYB – continued to support the SBERGs' roll-out through 2014, with completion expected in Q2 2015.

  At SZB, which does not use SBERGs, relevant SOIs will be updated in accordance with international best practice for PWRs, with particular reference to French PWRs, together with other related SOIs, POIs (Plant Operating Instructions) and Emergency Arrangements. SOI8.8 (Severe Accident Mitigation) includes equivalents to parts of the AGR SBERGs and to the SAGs. The programme for this revision of SOI8.8 is currently not determined – it will be undertaken together with the revision to incorporate procedures relating to FCV, if FCV is implemented (a final decision has not yet been taken) – otherwise, this revision of SOI8.8 will proceed as a separate activity.

- Improved SAGs

  The AGR SAGs have been updated to be more useful to staff, concisely presenting key information "up-front" and more clearly focussing on what to do in the event of an accident (overlap with the SBERGs and accident prevention has been removed). The new SAGs also include interfaces with DBUE that can help to manage a severe accident if one does occur (e.g. DCIS, mobile command facilities). This has been done without losing useful information from the previous SAGs. The equivalent procedures and guidance to SAGs at SZB is in SOI8.8, as described above.

- Management of Personnel in Emergency or Severe Accident Scenarios

  The JER programme has sought to improve training, procedures, and administrative functions when responders are required to work for extended periods in a severe event. Human Factors and Human Aspects specialists have had appropriate input and assessed the requirements of emergency responders, and made inputs to their training accordingly, also for training to those managing them in an emergency.

  Human Aspects work has also considered physical requirements on-site and off-site, welfare during prolonged events, and developed processes required to support staff and their families during an emergency.

  Facilities provided to support emergency response personnel include the DBUE's deployed Command and Control centre with its facilities including decontamination showers, toilets, briefing and rest areas, and similar facilities at the DBUE staging post.

  Improved processes, and awareness, for management and administrative support to personnel in an emergency have been incorporated accordingly into the generic Emergency Handbook. They are similarly reflected in the planning and preparation of the CESC Support Team, and incorporated in the CESC Handbook.

Proof of Concept Demonstrations AGR

The POC demonstrations for AGR deployment and capability were split into 3 phases.

POC A – A practical 3 day event which demonstrated the activation, logistical deployment of DBUE and establishment of a staging post site by the TLMP. Followed by transfer of DBUE to EDF Energy and the capability of station responders from HYA and HYB to connect and operate the DBUE that would restore Critical Safety Functions.

POC A* - A practical demonstration based at HNB which focused on the interactions between key responders (EDF Energy, FDS and TLMP) in the deployment of DBUE. The exercise illustrated the successfully delivery of DBUE by the FDS and the deployment and laydown/setup of mobile facilities (ECC, ACP & DCIS). These facilities were utilised by the response organisation to respond to an event using existing command and control techniques.

POC B – A simulated BDB long duration emergency scenario involved the CESC and HYA and HYB Central Control Rooms and ECC teams. The demonstration made use of the updated arrangements, DBUEGs and SBERGs. It demonstrated the capability to understand and manage a multi-site, multi-unit, BDB event, including the benefits of the JER-provided additional measures. The demonstration required real-time decision-making by staff and involved a shift changeover; it also simulated a real emergency through factors such as failures of plant indication systems, communications and lighting.

The internal and external reviews and reports of the AGR POC recorded the successes and captured the lessons learnt from these demonstrations. The continuing improvement process ensures that this learning is embedded within our emergency arrangements.

Proof of Concept Demonstration PWR

POC C - A practical demonstration was performed at SZB to evaluate the station's response in activating the ERC, determine the effectiveness of the Responders in preparing, deploying and operating the back-up equipment, and provide evidence of DCIS's capability in data acquisition, verbal communication and information transfer.

Overall the exercise demonstrated that SZB off-site ERC could be activated in a timely manner. ERC responders demonstrated knowledge and proficiency in the preparation, deployment and operation of back-up equipment. Communication through DCIS was established between responders using hand-held radios and head-sets worn by staff in the off-site ERC, also between the off-site ERC and EDF Energy's CESC at Barnwood. Two-way data transfer between the off-site ERC and the CESC was also demonstrated.

Each of the POC demonstrations have been reviewed in detail with the key learning captured in a JER Proof Of Concept Demonstration Report covering A, A*, B and C for future learning as part of the continual improvement process.

4.25.3 Recommendation Conclusions

This response has described how EDF Energy has undertaken new analyses of potential emergency and severe accident scenarios, encompassing a new Level 2 PSA for a representative AGR station (learning from which will be applied across the fleet of power stations), considering fault sequences extended for longer timescales and external hazards including BDB events, and also a variety of external hazard analyses considering weather, seismic and flood hazards.

The understanding gained from these analyses has contributed to improved procedures and training for emergency and severe accident response; EDF Energy has reviewed and extended these, including new elements dealing with additional plant and equipment introduced under JER.

JER has implemented an extensive programme of on-site engineered improvements to aid resilience of essential functions in emergency and severe accident scenarios, described in this and other recommendation responses. Many of these measures relate to the DBUE which may be rapidly deployed from its remote storage locations to any EDF Energy station. The DBUE will support or recover essential functions, principally electrical generation and post-trip cooling, with a variety of supporting elements including deployable command and control facilities. The deployment and use of the DBUE, including its interfacing with resilience modifications on-site, has been demonstrated successfully through a series of POC Demonstrations.

EDF Energy has reviewed and improved emergency and severe accident response procedures and training, including extensions of the scope of SBERGs to include Fuel Route and a general update and improved presentation for the SBERGs and SAGs; the equivalent SOIs at SZB will also be revised. The operation of the CESC has also been updated and improved with respect to communications and data inputs, procedures, staffing and management arrangements.

This response shows that EDF Energy has made a thorough and in-depth response to IR-25, with major activities having been undertaken to improve EDF Energy's understanding of, and response to, emergency and severe accident scenarios in relation to external hazards.

This response draws on a wide variety of the EDF Energy JER work and overlaps extensively with other Recommendations and Findings, notably FR-3, STF-2, STF-3, STF-5, STF-6, STF-7, STF-8, IR-15 and IR-24.

EDF Energy's responses to these items identify ongoing work in some areas, which will be progressed following the identified processes and programmes.

At a higher level, this IR-25 response shows how EDF Energy has responded strongly to address this recommendation, conduct analyses, learn lessons and implement measures to improve preparation for emergency and severe accident scenarios; as such this recommendation is considered closed.

4.26 Interim Recommendation 26 Close Out Report

Recommendation IR-26: A response to the various recommendations in the interim report should be made available within one month of it being published. These should include appropriate plans for addressing the recommendations. Any responses provided will be compiled on the ONR website.

4.26.1 Overview

Fukushima has demonstrated the nuclear industry must continue to improve safety as well as openness and transparency. Regular communications with the national regulator assist in achieving these objectives.

4.26.2 Response

As the UK's largest nuclear generation company EDF Energy wishes to make full use of the learning from the Fukushima event and ensure that this informs improvements to safety and systems at its nuclear power plants.

EDF Energy provided initial responses to the Recommendations from the Interim Report in 2011 within one month of issue, which were published both on the EDF Energy and ONR websites.

Communications between EDF Energy and the ONR, regarding the Interim Report recommendations and others relating to Fukushima, have been regular and productive, ensuring that the programme of work being undertaken by both EDF Energy and the ONR is well understood by both organisations.

4.26.3 Recommendation Conclusions

EDF Energy considers this recommendation closed, as per the ONR's Final Report from September 2011.

5 Final Recommendations

In September 2011 HM Chief Inspector of Nuclear Installations released the Final Report on the Japanese earthquake and tsunami: Implications for the UK Nuclear Industry. This report considered further the assessments and analyses that had become available subsequent to the issue of the Interim Report, identifying areas where the UK nuclear industry should investigate further in light of events at Fukushima and was again welcomed by EDF Energy and the wider nuclear industry.

The report contained 12 Final Recommendations, in addition to the 26 Interim Recommendations from the Interim Report, which EDF Energy has provided a number of updates and responses to since issue in 2011.

The following sections aim to close out the recommendations based on the programme of work that has been delivered and discussed in Section 2 since 2011.

5.1 Final Recommendation 1 Close Out Report

Recommendation FR-1: All nuclear site licensees should give appropriate & consistent priority to completing Periodic Reviews (PSRs) to the required standards and timescales, & to implementing identified reasonably practicable plant improvements.

5.1.1 Overview

EDF Energy's arrangements for complying with the requirements of Licence Condition 15 result in routine Periodic Safety Reviews (PSRs) being carried out at each of its licensed sites on a ten year cycle, as agreed with the regulator. Potential improvements to safety are identified through considerations of ageing, operational performance reviews and comparisons with contemporary standards.

5.1.2 Response

The 7 Advanced Gas-cooled Reactor (AGR) sites have successfully completed their second round of PSRs (PSR2), whilst Sizewell B is currently undergoing its PSR2 ahead of completion in early 2015. A programme of corrective actions (aimed to enhance nuclear safety) at each site has been or is being executed to timescales appropriate to the safety significance.

The PSR3 Strategy paper has been agreed with the ONR following a comprehensive review of national and international operating experience, in order to continuously improve the PSR process. This has involved active participation in the development of new IAEA (International Atomic Energy Agency) PSR guidance (now in the final approval stages), which has been used to develop the PSR3 Strategy and is currently being used to develop the detailed PSR3 scope.

5.1.3 Recommendation Conclusions

It is considered that no further action is required on this issue; the PSR process at all sites is carried out with full visibility to, and scrutiny by, the ONR. EDF Energy's approach to the next round of PSRs is one of continual improvement; the scope of which is also subject to regulatory scrutiny. EDF Energy remains committed to addressing the safety issues identified in the PSRs in a timely manner, commensurate with the nuclear safety significance of each identified issue.

EDF Energy considers that the issue of PSR execution and completion is appropriately addressed as continuing 'normal regulatory business'. Therefore, this recommendation is considered to be closed.

5.2 Final Recommendation 2 Close Out Report

Recommendation FR-2: The UK nuclear industry should ensure that structures, systems & components needed for managing & controlling actions in response to an accident, including plant control rooms, on-site emergency control centres & off-site emergency centres, are adequately protected against hazards that could affect several simultaneously.

5.2.1 Overview

According to international guidance and best practice, emergency response facilities should be available to provide command and control functions and plant parameters, to organise and direct an emergency response.

The ENSREG UK country report and the IAEA (International Atomic Energy Agency) Standards Report outline the minimum provision of emergency facilities required relating to an off-site nuclear emergency within the Design Basis (DB). Guidance can also been found in the form of significant Operating Experience (OPEX) from the events of the Fukushima nuclear accident in Japan.

EDF Energy has reviewed the functions needed to take command of and manage a nuclear emergency at its sites, and assessed their protection against external hazards. The requirements for each emergency management function were drawn from ONR guidance, international best practice, and OPEX.

5.2.2 Response

EDF Energy nuclear sites have existing facilities to co-ordinate an emergency response should there have been an event, these are as follows:

- Central Control Room (CCR) - used to monitor and control the plant (or to direct trained operators local to the plant[1])
- Emergency Control Centre (ECC) - used to manage the on-site aspects of an event and take overall command of the incident
- Access Control Point (ACP) - used to oversee deployment of personnel into the damaged area
- Forward Control Point (FCP) - if information from the event indicates acceptable conditions exist closer to the area of damage where access is required a FCP can be set up in addition to an ACP and can help in:
    - Reducing the spread of any contamination
    - Reducing radiation doses
    - Conserving breathing apparatus supplies
- Central Emergency Support Centre (CESC) - situated at the EDF Energy headquarters, the CESC is in communication with the ECC, co-ordinating the movement to site of emergency responders, and the operating strategy. The CESC also manages the wider response providing information to the public, government agencies such as the police, as well as the nuclear regulator the ONR.

Alternative emergency facilities also exist on and off-site to increase defence in depth; as part of the normal response strategy these are used in case emergency facilities become untenable or damaged:

- Alternative/ Emergency Indication Centre (A/EIC) - used in case the CCR becomes untenable due to radiation, fire or release of gas. The primary use of the AIC is to monitor the reactor, pond cooling and buffer store status with plant control being carried out by trained operators local to plant, deployed from the ACP or under radio control. The EIC (at Heysham 2 (HYB) and

[1] In this document, 'local to plant' refers to any responder actions that are taken on-site, but outside of the normal Central Control Room.

Torness (TOR)) has additional capability to directly trip the reactor from the primary and secondary systems

It should be noted that at Sizewell B (SZB) the equivalent facility to be used in the event that the Main Control Room (MCR) becomes untenable is the Auxiliary Shutdown Room (ASR) which would be used to shutdown the reactor and control and monitor the plant systems

- Alternative ECC (AECC) – used in case the ECC becomes untenable due to radiation, fire or release of gas
- Alternative ACP (AACP) - used in case the ACP becomes untenable due to radiation, fire or release of gas
- Back-Up CESC (BUCESC) and Alternate CESC – BUCESC in a different area of the building to the CESC, Alternate CESC located 30 miles away, used in case the CESC becomes untenable due to fire or other hazard.

The UK stress tests found these facilities to be adequate in their function and, where applicable, resilient to DB events. These facilities were assessed against a postulated severe event and different stations and facilities were found to have varying levels of resilience, layers of defence, and back-up provisions.

As part of the EDF Energy Japanese Earthquake Response programme resilience process, site walkdowns were carried out to assess the level of resilience across all the emergency facilities, with the objective of raising all facilities up to a suitable and more consistent standard. The resultant programme of work was reached following interactions with stakeholders including on-site personnel and other relevant Suitably Qualified and Experienced Personnel (SQEP).

The enhancements will increase the resilience and usability of emergency facilities against the effects of severe and simultaneous natural hazards. The delivered enhancements provide a consistent level of resilience across the sites, whilst having minimal impact on plant operations.

Enhancements to the emergency control facilities across EDF Energy sites include, but are not limited to, the following:

Resilience Enhancement	Protection Provided
Flood protection to the greater building to 1m above ground level	Flooding
Raise or flood protect external air conditioning condenser units	Flooding
Provision of watertight seal to cable tunnels/penetrations	Flooding
Provision of enhanced flood protection enclosures for external equipment	Flooding
Relocation/improve anchorage of electrical supply panels	Electrical
Provision/upgrade of UPS battery rack and restraints	Electrical
Provision of a back-up diesel generator where not currently provided	Electrical
Isolation of the electrical supply and circuit for the ECC	Electrical
Raising of electrical equipment/services above 1m level	Electrical
Upgrades to existing external modules	Electrical
Strengthening raised floor	Civil /Seismic

Strengthening suspended ceiling and lighting	Civil /Seismic
Strengthening partition walls	Civil /Seismic
Construction of waterproof porch	Civil /Seismic
Blast film and attachment system to windows	Civil /Seismic
Provision/upgrade of back-up diesel generator anchorage	Civil /Seismic
Restraint of loose items/furniture and general housekeeping	Civil /Seismic
Provision of restraint to glass worktops	Civil /Seismic
Widening of ceiling mounted projector aperture	Civil /Seismic
Improvements to cable support arrangements	Civil /Seismic
Removal of redundant HVAC	Building Services
Protection of the air conditioning condenser units	Building Services

In addition to enhancements to the physical protection of structures, a new Continuous Emergency Monitoring System (CEMS) has been installed at the Advanced Gas cooled Reactors (AGRs), and is scheduled to be commissioned in 2015, to provide a real-time display of key reactor/station parameters, located in a Safe Place On Site (SPOS), to facilitate decision making by operators in the hours following the event.

The fundamental safety requirement for the CEMS is to provide indications of key parameters for the reactor facilities, immediately pre and post fault through to event response. The key parameters will be provided to the Duly Authorised Persons (DAPs), ECC and the CESC, giving a more informed decision making process.

The CEMS utilises existing instrumentation loops that are qualified against design basis hazards. Where this is not practicable, new or existing spare instrumentation will be used to obtain the CEMS measurement signals. Break-ins to existing instrumentation loops incorporate galvanic isolation at the point of signal acquisition to ensure no detriment to existing Control & Instrumentation infrastructure in the event of failure of the CEMS.

The CEMS signals are routed to a data logger housed in a seismically robust cubicle located in an area protected from Beyond Design Basis (BDB) hazards as far as practicable, but as close as practicable to the point of signal break-in (i.e. the existing signal marshalling cubicles).

The CEMS cubicle provides a number of on-site displays including a panel mounted display, as well as laptops at strategic locations around the station along with a mobile display via a portable Satellite Communication System (SCS). There are diverse methods of transmitting the indications off site via a connection to the existing EDF Energy Local Area Network (LAN) and the SCS. The CEMS also provides an interface to Deployable Communication and Information System (DCIS) via a dedicated network connection point on the CEMS panel.

EDF Energy will continue to liaise with ONR and commits to demonstrate the CEMS, including its compatibility with DCIS, after the CEMS commissioning.

Power to the CEMS is provided by existing battery and/or generator backed power supplies that are resilient to BDB hazards. Where such supplies are not available the CEMS will typically be provided with its own Uninterruptible Power Supply (UPS) to provide power to the system until Deployable Back-Up Equipment (DBUE) can be supplied.

Surveys were undertaken at all sites, together with an optioneering exercise, establishing the most appropriate architecture and layout for the CEMS to achieve the stated objectives and is reasonable and practicable to implement. For the AGR stations it is intended that the CEMS will be implemented in two ‘variants’:

- at Heysham 1 (HYA), Hartlepool (HRA), Hinkley Point B (HPB), Hunterston B (HNB) and Dungeness B (DNB), the CEMS measurement signals will be derived from existing AIC systems
- at HYB and TOR, the CEMS is a partially diverse overlay system, utilising a combination of new and existing spare instrumentation to acquire measurement signals

The detailed designs for each station will contain elements that are station specific and are set out through the Engineering Change (EC) process.

This recommendation is linked to more general on-site resilience, such as building flood protection and power supplies. For more information see IR-18.

A similar set of parameters is being investigated at SZB a Pressurised Water Reactor. However, at the newly constructed Emergency Response Centre at SZB DCIS is permanently installed, providing a robust facility with independent supplies where the system can be operated from, providing diverse and resilient communications and plant information.

5.2.3 Recommendation Conclusions

The safety and effectiveness of the existing structures, systems, and components needed for managing & controlling actions in response to an accident have been assessed against criteria provided by IAEA Standards, the ENSREG UK report, ONR Recommendations and OPEX learning points from Japan. Emergency facilities and procedures have been assessed against a postulated severe event, and a series of enhancements have been made to increase robustness, defence in depth, and response capability.

Further to this, the DBUE programme aims to replicate these facilities in the event of severe disruption on-site, and the readiness of staff to respond to a long term severe event has been improved; these aspects are discussed further in FR-3.

EDF Energy is now in a better position to command and manage a nuclear emergency at any of its sites, with appropriate back-up equipment and facilities available should they be required. Therefore this recommendation is considered to be closed.

5.3 Final Recommendation 3 Close Out Report

Recommendation FR-3: Structures, systems & components needed for managing & controlling actions in response to an accident, including plant control rooms, on site emergency control centres & off-site emergency centres, should be capable of operating adequately in the conditions, & for the durations, for which they could be needed, including possible severe accident conditions.

5.3.1 Overview

The assessment of the resilience of existing on-site emergency facilities has been discussed in FR-2 along with the associated modifications to enhance resilience to severe events. This recommendation will cover the event where severe disruption has occurred on-site as a result of a Beyond Design Basis (BDB) event.

There is a requirement for facilities to manage a BDB event and following severe disruption these may not be available on-site. The focus on long term durability leads to human factors considerations including additional provisions in the areas of power for communications, heating and lighting, along with adequate welfare facilities to provide food and rest for an extended period, and the provision of the appropriate Personal Protective Equipment (PPE).

This recommendation considers the provision of emergency facilities and the enabling of emergency responders to act effectively and with assurance should there have been a severe event.

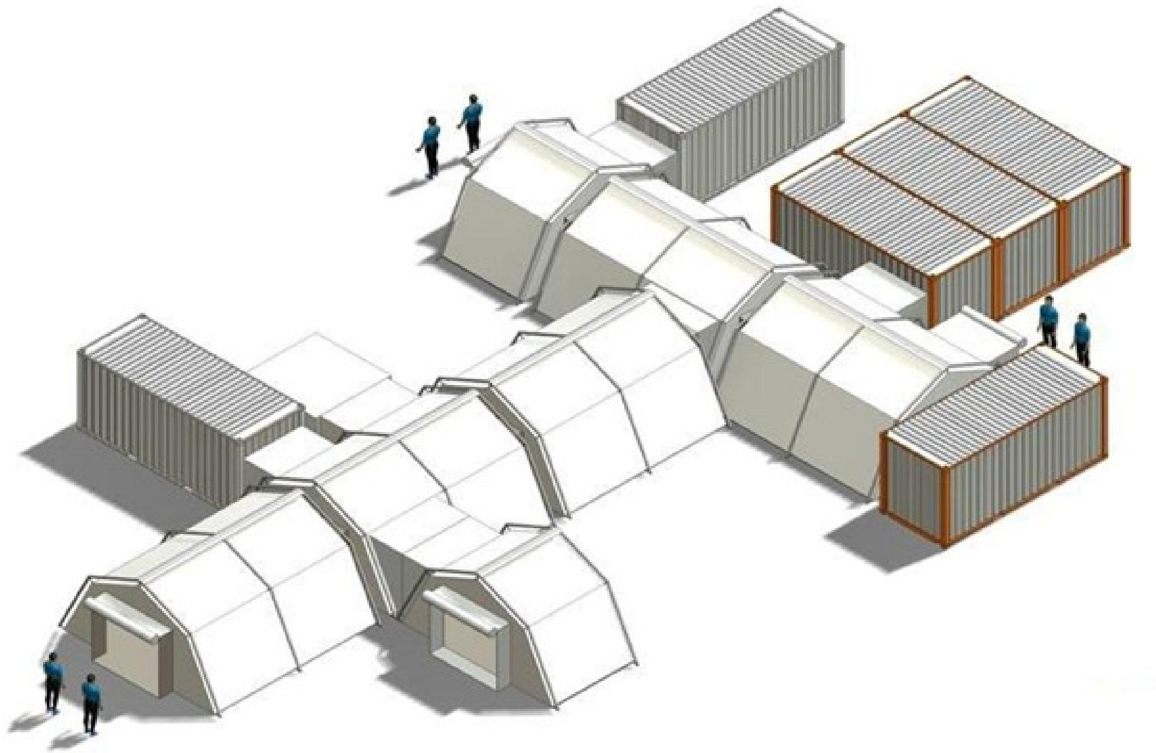
5.3.2 Response

Deployable Back-Up Facilities

EDF Energy has developed an array of mobile Deployable Back-Up Equipment (DBUE) to respond to a severe accident. A significant part of the DBUE programme includes the provision of back-up emergency response facilities. This includes mobile Emergency Control Centre (ECC)/ Access Control Point (ACP) command facilities, some of which have positive pressure air and radiological particulate filtration systems. The intention of these facilities is to replicate the essential functions of the on-site emergency facilities, in the event that they are lost.

The DBUE also provides real time plant indications and communication systems, supplied by a Deployable Communications and Information System (DCIS) that includes satellite communications equipment. The DCIS is compatible with, and can be connected to, the Continuous Emergency Monitoring System (CEMS), but is delivered to site as part of the Advanced Gas-cooled Reactor (AGR) DBUE, transmitting essential plant parameters to the Mobile ECC, ACP and the DBUE staging post; it is not reliant on any fixed telecommunication infrastructure. The DCIS provides communications and indications for long term usage in more severe emergency scenarios, and can provide wider situational awareness by allowing access to stored data (e.g. station drawings) and telephony equipment allowing communications with the Central Emergency Support Centre (CESC) and also other organisations.

The deployed ACP manages access and egress to a hazardous location from a suitable off-site position. The ACP includes PPE, radiation monitoring equipment and decontamination showering facilities.



Depiction of Deployable Back-Up Equipment facility provision

All DBUE will be stored, maintained and exercised appropriately, ensuring that it is fit for purpose and ready to be deployed should it be required. On declaration of a nuclear emergency, EDF Energy's Through Life Management Partner (TLMP) will be contacted to begin the delivery of a comprehensive set of DBUE from the most appropriate regional store. The DBUE will reach a staging post from which transfer of equipment to site will be co-ordinated. The TLMP at the staging post will have a dedicated line of communication with the CESC.

Accident progression times, as well as equipment deployment times, have been assessed allowing the development and implementation of a strategy involving three fully stocked off-site regional stores. These are located to ensure that any affected station can be supported before safety limits are exceeded, and also allow for two concurrent events to be managed should the need arise. This assessment included:

- Using thermal analysis to determine temperature transients and timescales to safety limits being reached following loss of all forced cooling, boiler feed and the Pressure Vessel Cooling System (PVCS)
- Identifying a number of alternate transport routes and staging posts for each site, considering possible disruption from various hazards, such as collapsed bridges, traffic congestion and flooding. Conservative calculations based on Operating Experience (OPEX) have developed estimates for delivery times, taking into account the potential for severe disruption off-site. However, the DBUE includes vehicles to aid transport logistics and clearance of the route, such as Mercedes Unimogs and Zetros vehicles which are capable off-road and JCBs for route clearance.

In addition to these three regional stores there is additional DBUE storage at the newly built Sizewell B Emergency Response Centre (ERC), close to site, to reflect the shorter event escalation times for Pressurised Water Reactors (PWRs). In addition to equipment, this facility includes an alternative ECC, ACP and welfare facilities.

DCIS is being permanently installed at the ERC, providing a robust facility with independent supplies where the system can be operated from, providing diverse and resilient communications and plant information.

The TLMP is an integral part of the BDB deployment strategy that EDF Energy has introduced across the fleet of power stations. The TLMP provides three services to the fleet: storage, maintenance and delivery. This strategy brings together logistical expertise from other industries and creates a flexible and timely emergency response capability. It should be noted that the equipment is owned by EDF Energy, who are also the sole recipient of the TLMP's emergency response services.

Addressing Welfare and Staff Guidance in Severe, Prolonged Emergency Events

Work on this area has taken note of STF-3 and IR-24 regarding Human Factors. The EDF Energy JER programme has sought to improve training, procedures, and administrative functions when responders are required to work for extended periods in a severe event. Human Factors and Human Aspects specialists have had appropriate input and assessed the requirements of emergency responders.

Training schedules have been updated to include the new equipment and procedures; the EDF Energy JER programme is also training emergency responders, ensuring that equipment and procedures can be used when required – providing an enhanced capability. The Proof of Concept (POC) demonstrations proved this capability, which includes assurance that training is adequate for severe events; any learning points arising from these exercises inform future strategy and training requirements.

EDF Energy has developed learning in the areas of shift handover and resourcing from previous events involving the activation of the emergency arrangements. Reviews were carried out in diverse areas such as behaviour in emergency conditions and required operator actions when responding to a severe event. The team also considered physical requirements on-site and off-site, welfare during prolonged events, and developed processes required to support staff and their families during an emergency. Enhancements were made in several areas:

Physical Organisation and Facilities

Physical welfare facilities have been considered, and included in the DBUE response:

- Deployed Command and Control centre - contains facilities such as decontamination showers, toilets, briefing and basic rest areas
- An emergency response staging post - meeting point, briefing and rest area, including kitchenette and toilet facilities
- Away from site - facilities such as local hotels would be used for responders to meet, rest, recuperate etc.

Contingency Planning to Procure Resources

Contingency plans include the CESC Support Team assisting with administrative support to manage the procurement of facilities and supplies during response to events. Enhancements to procedures, handbooks and training programmes include:

- Changes to the CESC Handbook and roles including revised CESC 'Welfare and Support Team' Role
- Enhanced Human Resources role in emergency response including 'representation and assistance at CESC/elsewhere in relation to staffing, team support and sourcing/provision of welfare supplies and management'
- Revision to Generic Emergency Handbook - Emergency Welfare and Administration Officer Role enhanced to ensure it addresses local procurement/prolonged events.

Management Practice during Response: Training and Preparation

Managerial and administrative support to responders has been enhanced through:

- Additional knowledge and guidance on practically addressing individuals' welfare, and organisational resilience in emergency response - addressed through enhanced role definitions, competences and training content
- Additional checklists with tips and reminders on ways of minimising stress for managers and workers, including guidance on debriefing and defusing responders
- Consolidated guidance and procedures on managing communications, liaison and support, to staff and families during incidents involving casualties and fatalities
- Improvements to Symptom Based Emergency Response Guidelines (SBERGs) documentation which support operators identifying unknown faults, enabling return to stable state or escalation to emergency arrangements and supporting equipment. This review has included a review of the technical basis of the SBERGS.

Updates to the Severe Accident Guidelines (SAGs) documents have also taken place along with the creation of the Deployable Back-Up Equipment Guidelines (DBUEGs), which provide technical detail on use and operation of a range of systems/equipment that EDF Energy has procured. These support the principles of maintaining core cooling and containment integrity, and include guidance on use of specialist equipment e.g. High Pressure/Low Pressure pumps.

5.3.3 Recommendation Conclusions

The long term durability of EDF Energy's emergency response capability has been assessed against the effects of severe accidents, and improvements have been implemented to address the long term requirements, including taking account of staff welfare.

The necessary functions of communications, management of personnel in potentially hazardous areas and plant indications have been replicated by the DBUE provisions, which if required can be deployed and operational within the required timescales.

Following a significant portion of work, this recommendation is considered closed out. The changes being made to infrastructure, equipment and procedures are being integrated into emergency arrangements, and aspects such as ongoing maintenance and training will be dealt with under normal EDF Energy processes.

5.4 Final Recommendation 4 Close Out Report

Recommendation FR-4: The nuclear industry should ensure that adequate Level 2 Probabilistic Safety Analyses (PSA) are provided for all nuclear facilities that could have accidents with significant off-site consequences and use the results to inform further consideration of severe accident management measures. The PSAs should consider a full range of external events including "beyond design basis" events and extended mission times.

5.4.1 Overview

The ONR's investigation and report into the 2011 Fukushima accident included the following specific conclusion: "The circumstances of the Fukushima accident have heightened the importance of Level 2 Probabilistic Safety Analysis (PSA) for all nuclear facilities that could have accidents with significant off-site consequences". This led to the FR-4 Recommendation above.

5.4.2 Response

The Level 2 (L2) PSA function is most easily understood in the context of water reactor technology.

For the Pressurised Water Reactor (PWR), L1 PSA considers faults and how they can give rise to core damage, but there is no correlation between core damage and off-site release because of containment. L2 PSA then considers sequences resulting in off-site doses arising due to containment being breached or bypassed. So the frequency of the overall fault sequences leading to significant off-site release is derived from the L1 and L2 PSAs in combination (L3 PSA then goes on to consider the likelihood of various off-site dose outcomes, but is not considered further either in the Weightman Final Report or here).

Sizewell B (SZB) already has a L2 PSA consistent with current international standards. The L2 PSA was reviewed in the SZB PSR2 (Periodic Safety Review 2) and is being updated as a result of that review. It currently does not include modelling of the new Deployable Back-Up Equipment (DBUE). This could be added in a future update but is not currently part of the definite plan, which will be determined when the next round of SZB PSA update is scoped (this will be in 2015, for a 2017 PSA update), also taking account of other accident management proposals such as the installation of Passive Autocatalytic Recombiners and potentially the installation of Filtered Containment Venting. No further actions have been undertaken for the SZB L2 PSA in response to FR-4 and the remainder of this response is therefore applicable to the Advanced Gas-cooled Reactors (AGRs) only.

For the AGRs, the existing PSAs already deal with the frequencies of releases to the environment. Any sequence that involves failure to trip, or to shutdown following a trip signal, or to establish adequate Post Trip Cooling (PTC) is treated as a "failure" sequence and assigned to Dose Band 5: the PSA calculates the frequency of such sequences. The result is dominated by failures of PTC, which themselves are dominated by operator action failures and common cause failures of PTC systems.

What the AGR PSAs do not do, however, is 1) accommodate beyond design basis initiating events, 2) continue the modelling of the failure sequences to cover potential escalated fault outcomes, or 3) include mitigating (accident management) measures. These aspects have all been explored further in the response to FR-4 as described in the following.

<u>Activities undertaken in response to FR-4 - overview</u>

The overview is that a pilot AGR L2 PSA has been developed for Hunterston B (HNB).

The HNB PSA was selected as the starting point because it is one of EDF Energy's benchmarks for a modern standards, fit-for-purpose AGR PSA. The other is the Hinkley Point B (HPB) PSA (the other AGRs' PSAs are currently being worked up to equivalent standards); HPB staff have previously invested significant amounts of effort in supporting other pilot PSA exercises, so the choice was made to focus on HNB purely in the interests of sharing the workload equitably.

For item 1) above, the pilot study has required significant input from a series of "Expert Panels", comprising senior EDF Energy Suitably Qualified and Experienced Personnel (SQEP) staff who have made informed professional judgments on the selection of appropriate Beyond Design Basis (BDB) initiating events and their expected consequences. The selection involved the identification of bounding internal faults and external hazards to be addressed.

For item 2), it has involved transient analyses extended to cover longer fault timescales than hitherto, and judgments about the likelihood of the various fault escalation phenomena already described in the Severe Accident Guidelines (SAGs).

For item 3) above, it has involved considerable technical innovation to develop a means of building accident management (mitigation) measures into a logical model structure which extends, and is consistent with, the existing PSA, in particular in respect of the relationship between the human reliability claims already made in the existing PSA and the new ones needed. The mitigation activities modelled reflected implementation of existing (or improved) accident management advice (based on Symptom Based Emergency Response Guidelines (SBERGs), SAGs, or the new DBUE Guidelines (DBUEGs)). The remit of the Expert Panels also included judgments on the effectiveness and feasibility of the accident management measures to be included quantitatively within the PSA model, taking account of the extended transient analyses from 2) above, and this was the aspect which also involved significant input from HNB staff.

It is to be noted that no equivalent extension of the separate Fuel Route PSA has been carried out in response to FR-4. Further discussion of this is given below.

<u>Specific learning taken from the HNB pilot L2 PSA results</u>

The extended PSA model includes mitigation actions to recover from faults previously simply identified as “failure” sequences and allocated to Dose Band 5. The structure and discipline imposed by PSA methodology has clarified the relative importance of the potential mitigation actions and the timescales on which they are required, including the following examples:

- Deployment of DBUE to restore boiler feed when all installed plant has failed
- Management of the reactor circuit e.g. by closure of gas circulator domes and controlled blowdown of a pressurised but uncooled reactor to protect the integrity of the reactor structures, and hence extend the timescales on which deployment of DBUE will allow recovery
- Water injection directly into the core as the ultimate means of prevention of core damage escalation
- Sealing of circuit breaches if the initial event is a depressurisation fault to confine radioactivity and (if possible) allow restoration of cooling via boiler feed.

Advice on all these actions is either to some extent already in place (in the SBERGs or SAGs), or under development (in the DBUEGs). The relationship between the guidance and the development of the pilot L2 PSA is as follows.

- The provision of the DBUE, with the documentation that is required to control its storage, maintenance, deployment and operation, and with some supporting plant modifications, is the most significant new aspect of the EDF Energy arrangements for the management of potential accidents that has been adopted and implemented in response to Fukushima. It was determined as beneficial independently of the development of the L2 PSA; the latter has simply reflected the intended role of the DBUE in helping to maintain/regain control under challenging accident conditions
- Nevertheless, the clarity provided by the L2 PSA work has enabled the identification of further improvements to the content of the SBERGs, which have been in place for ~20 years. This is over and above the re-casting exercise that has been pursued in parallel since Fukushima to improve the usability of the document suite and to extend coverage to loss of cooling faults in the fuel route (buffer stores and ponds). The workstream issuing re-cast reactor fault SBERGs and introducing fuel route fault SBERGs is in progress. Note that the latter aspect has been identified as worth pursuing without any supporting extension to the risk modelling in the Fuel Route PSAs

- Likewise, the clarity provided by the L2 PSA work has enabled the identification of improvements to the (generic) AGR SAGs which, again, have been in place for ~20 years. The improvements have been to simplify, to remove redundant material, to remove impracticable advice, and to focus the advice on the most important strategic objectives. Updated SAGs were issued in January 2014 following a consultation period around the AGR fleet and the Central Technical Organisation. The L2 PSA work has not resulted in further work on development of more detailed technical arrangements for achieving delivery of the Severe Accident Guideline (SAG) strategic objectives. It is an agreed EDF Energy company position (endorsed by the Japanese Earthquake Response Programme Board) that the investment required to pursue such work is disproportionate to the residual risk.

The quantitative outcome of the L2 PSA is that the summated assessed frequency of sequences giving rise to a Dose Band 5 dose has been reduced by a factor of about 5, based on the judgments incorporated about the effectiveness and reliability of the fault mitigation actions.

This overall reduction in the summated assessed frequency is as expected, because of the inclusion of fault mitigation measures into the model (reducing assessed risk) and the very low frequencies of BDB initiating faults (increasing assessed risk).

About a third of the residual Dose Band 5 risk is attributable to BDB seismic events, where all the mitigation actions are judged to be less effective because of the potentially more extensive plant damage. It is judged that there are few measures that could practicably be adopted to reduce this contribution given the safety management approach adopted over the last ~25 years to underwrite a deterministic safety case against a bottom line 10^{-4} pa seismic event.

While the structured/disciplined approach to the analysis is judged to have been very valuable in order to enhance clarity as described above, the actual development of the L2 PSA model in order to be able to produce a quantified output is judged to have been much less so; the additional resource investment in developing the model and populating it with judgment-based data is judged to have been disproportionate to the incremental safety benefit/insight obtained.

<u>Read-across of the learning from the HNB pilot L2 PSA to the rest of the AGR fleet of stations</u>

The nature of the specific learning derived from the HNB pilot summarised above makes it clear that the insights are directly transferable to the other AGRs provided that due account is taken of differences in plant design, including confirmation that the recommended actions are achievable under the postulated fault conditions. These insights are not dependent on the output from the L2 PSA, but rather from the thinking, judgments and transient analyses that have been used as inputs to it.

This observation supports the decision to incorporate sensible fault mitigation measures for Fuel Route faults and to add them to the SBERG suite without extending the Fuel Route PSA; there is an analogous logic.

There is a specific (known) issue to be addressed here for Hartlepool/Heysham, because of the lower robustness of this reactor design to total loss of Pressure Vessel Cooling. While it may be necessary to carry out further transient analyses to develop improved SBERGs for this fault, this is no strong driver for the production of a L2 PSA for these stations.

5.4.3 Recommendation Conclusions

The review on the HNB L2 PSA arrives at the following proposals for follow-on work:

a) Update SAGs, to improve focus (complete).

b) Update the HNB SBERGs to reflect mitigating actions modelled in the L2 PSA.

c) Consider the arguments regarding transferability to other sites and consider carrying out station visits to confirm operator action feasibility and update SBERGs for all other AGRs.

d) Consider carrying out further transient analysis for Heysham 1 (HYA) and Hartlepool (HRA) to better define recovery timescales.

It has also been identified that the HYA and HRA SBERGs should be reviewed to ensure that they most effectively reflect the current understanding of possible scenarios involving loss of Pressure Vessel Cooling.

There is a logical sequence to further reviews, decision-making and activities, and accordingly EDF Energy will do the following:

1. Revise the SBERGs for HNB to incorporate the learning described above.
2. Review the SBERGs for the other AGR stations with regard to possible amendments to reflect learning from the HNB L2 PSA study. This is likely to include discussions with station staff to discuss the learning from the L2 PSA and its implications for what should be done in some emergency scenarios.
3. Review the HYA/HRA SBERGs with a view to amending them to better incorporate current understanding of failure scenarios involving loss of Pressure Vessel Cooling.
4. Consideration of the need for further transient analyses for HYA/HRA SBERGs. This will be informed by 2. and 3. above.

A programme is being developed, taking account of the above drivers, with resource being secured as part of EDF Energy business planning process. The intention is to develop an associated fully resourced and baselined programme, by the end of Q2 2015.

The ongoing programme will be owned by Design Authority, with the ongoing activities considered to be part of normal business. At this point, it is concluded that EDF Energy has satisfied the requirements of FR-4, and this recommendation can be closed.

5.5 Final Recommendation 5 Close Out Report

Recommendation FR-5: The relevant Government departments in England, Wales & Scotland should examine the adequacy of the existing system of planning controls for commercial & residential development off the nuclear licensed site.

5.5.1 Overview

This recommendation does not apply to EDF Energy. However, EDF Energy do, and will continue to, respond appropriately to any requests from the relevant Government departments and offer support as required.

5.5.2 Recommendation Conclusions

Aimed at Government authorities, EDF Energy is not in a position to determine if this recommendation is considered closed by the ONR.

5.6 Final Recommendation 6 Close Out Report

Recommendation FR-6: The nuclear industry with others should review available techniques for estimating radioactive source terms & undertake research to test the practicability of providing real-time information on the basic characteristics of radioactive releases to the environment to the responsible off-site authorities, taking account of the range of conditions that may exist on and off the site.

5.6.1 Overview

As a licensed operator of 15 reactors, this recommendation applies to all EDF Energy power station sites.

Following discussion with the Office for Nuclear Regulation (ONR), the expectations have been identified as follows:

The nuclear industry with others should:

- Review available techniques for estimating Source Terms (ST)
- Engage in research on practicability of real time information and the technical approaches required to identify any reasonably practicable improvements.

5.6.2 Response

EDF Energy has existing procedures which are used to estimate surface and airborne radioactivity based on environmental measurements of dose rate and airborne concentration. These estimations are calculated using current weather data provided by site instrumentation or the UK Meteorological Office, and also a library of default radiological ST which can be used to identify radioactive nuclides expected for potential faults until environmental measurements are obtained. This information can then be used to best deploy countermeasures promptly.

Each of EDF Energy's nuclear sites has a system of radiation detectors which together provide information on the magnitude of any off-site aerial release of activity from the site. In the event of such a release, mobile units are sent to determine the airborne concentrations of activity and isotropic at specific locations. These measurements can be used to modify the initial ST data to provide a better estimate of the activity release from the site and better estimates of the doses which would be received by people in the surrounding areas.

As part of EDF Energy's emergency procedures, in the event of a possible off-site release, radiation assessments taken from the surrounding area would be transmitted to the Suitably Qualified and Experiences Personnel (SQEP) at the station and also to the Central Emergency Support Centre (CESC) at Barnwood. The information would be communicated to responsible off-site authorities and Radioactive Incident Monitoring Network (RIMNET) both by The incident information Management System (TiiMS), and in-person since representatives from appropriate external organisations are sent to the CESC to facilitate communications.

It was proposed and agreed that the Nuclear Emergency Arrangements Forum (NEAF) shall coordinate the review of techniques, share best practice across operators and confirm details of findings to ONR on behalf of the industry. EDF Energy will provide NEAF with the results of the ongoing project to determine current practice for mobile counting techniques and equipment arrangements for reliable airborne analysis and the evaluation of current standards in source term modelling.

5.6.3 Recommendation Conclusions

EDF Energy will submit to NEAF, the results from an existing project to determine the best mobile counting equipment arrangement for reliable airborne analysis to replace current probes and scalars. NEAF will review the different operator responses, declare the justification of adequacy to ONR, then maintain a review of best practice. ONR are expected to take any follow up action through normal regulatory processes with EDF Energy.

As such, EDF Energy considers this recommendation as closed, with any remaining ST integration work moved to normal business using the existing communication channels with ONR and Government Agencies.

5.7 Final Recommendation 7 Close Out Report

Recommendation FR-7: The Government should review the adequacy of arrangements for environmental dose measurements & for predicting dispersion & public doses & environmental impacts, & to ensure that adequate up to date information is available to support decisions on emergency countermeasures

5.7.1 Overview

This recommendation is not directed at EDF Energy. However, EDF Energy will continue to proactively support and respond appropriately to any requests from the relevant Government departments as required, noting that this subject is directly related to the events in Fukushima as well as the ONR's Final Recommendation 6.

5.7.2 Response

As the UK's largest nuclear generation company, EDF Energy has an interest in ensuring that UK arrangements for dose prediction, dispersion and measurement for both public doses and environmental impact are adequate and take account of any lessons from Japan's response to events at Fukushima, so as to ensure protection of the public and environment.

EDF Energy has a system in place at all of its power station locations which would, in a severe accident, be able to monitor any radioactive release. EDF Energy's response to the ONR's Final Recommendation, FR-6, provides further details of how, as an industry, this topic is being further reviewed and enhancements dealt with to provide additional arrangements for dose prediction and dispersion, should the existing system be rendered inoperable.

5.7.3 Recommendation Conclusions

EDF Energy is not in a position to determine if this recommendation is considered closed by the ONR as it is aimed at Government authorities, however EDF Energy does note that it is directly related to FR-6.

5.8 Final Recommendation 8 Close Out Report

Recommendation FR-8: The Government should consider ensuring that the legislation for the new statutory body requires ONR to be open & transparent about its decision-making, so that it may clearly demonstrate to stakeholders its effective independence from bodies or organisations concerned with the promotion or utilisation of nuclear energy.

5.8.1 Overview

This recommendation does not apply to EDF Energy. However, EDF Energy does, and will continue to, respond appropriately to any requests from the relevant Government departments and offer support as required.

EDF Energy agrees with the aim of this recommendation, that as an independent body, the ONR is required to be open and transparent and able to demonstrate independence from those with a vested interest in nuclear energy.

5.8.2 Recommendation Conclusions

Aimed at Government authorities, EDF Energy is not in a position to determine if this recommendation is considered closed by the ONR, but supports the openness, transparency and independence of the ONR from external bodies.

5.9 Final Recommendation 9 Close Out Report

Recommendation FR-9: The UK Government, nuclear industry & ONR should support international efforts to improve the process of review & implementation of IAEA & other relevant nuclear safety standards & initiatives in the light of the Fukushima-1 (Fukushima Dai-ichi) accident

5.9.1 Overview

EDF Energy takes proactive roles in these international nuclear organisations: (International Atomic Energy Agency (IAEA)/ World Association of Nuclear Operators (WANO)/ Institute of Nuclear Power Operations (INPO)) since EDF Energy is a learning organisation and as such looks to national and international operating experience to learn from, and enhance, the safety and operational aspects of its plants.

EDF Energy has, and will continue to, take part in formal review panels for the IAEA and other bodies, implementing IAEA and other relevant nuclear safety standards and initiatives where applicable, as a matter of normal business as well as in the light of the Fukushima Dai-ichi accident. Furthermore, in the aftermath of Fukushima, EDF Energy set up a specific Japanese Earthquake Response (JER) programme, with a 'governance board', to ensure implementation of recommendations from such bodies were suitably dealt with and incorporated into the business.

EDF Energy will also continue to fully engage with WANO in a proactive manner, ensuring that all recommendations are responded to in a positive and timely manner. Similarly, when there is additional learning from INPO, EDF Energy will ensure that this is taken on board.

EDF Energy will also continue to respond appropriately to any requests from the relevant Government departments and offer support as required.

5.9.2 Response

There has been a number of Significant Operating Experience Reports (SOERs) which have been issued by WANO in light of the Fukushima Dai-ichi nuclear accident. EDF Energy has submitted responses to the following Fukushima specific WANO SOERs:

- 2011-2: Fuel Damage Caused by Earthquake and Tsunami
- 2011-3: Spent Fuel Pool/Pond Loss of Cooling and Makeup
- 2011-4: Extended loss of all AC power
- 2013-2: Post-Fukushima Daiichi Nuclear Accident Lessons Learned.

In responding to these SOERs there have been a number of recommendations and actions identified which are being tracked and progressed as part of the EDF Energy JER programme.

A number of international conventions, hosted by WANO and other agencies, in the aftermath of Fukushima have also been attended by EDF Energy, however it should be noted that events of this nature were attended before the events in Fukushima and will continue to be attended as they offer valuable opportunities to share EDF Energy's experiences and learn from other operators.

EDF Energy staff have also reviewed plant modifications and emergency response changes that have been, or are being, enacted in a number of countries, including Taiwan, Japan and Switzerland. Proposed modifications have also been reviewed for a number of French and German stations.

EDF Energy also takes part in WANO Peer Reviews; visiting stations around the world to monitor closure of recommendations and offer advice on improvements. These reviews provide an opportunity for both EDF Energy and the host to learn from the experience of others, as well as enhancing the process of how recommendations and initiatives are implemented as and when areas for improvement are identified.

5.9.3 Recommendation Conclusions

As a learning organisation, EDF Energy continuously looks to national and international operating experience to learn from and enhance the safety and operational aspects of its plants, and will continue to review and enhance safety in light of further Operating Experience as part of normal business.

Fukushima related actions identified as part of the WANO SOER review process have been captured through EDF Energy's normal action tracking processes and will continue to be addressed as part of normal business.

EDF Energy also proactively takes part in various organisations' efforts to ensure the initiatives and recommendations are adopted, looking to enhance this process when areas for improvement are identified.

As such, this recommendation is considered to be closed.

5.10 Final Recommendation 10 Close Out Report

Recommendation FR-10: ONR should expand its oversight of nuclear safety-related research to provide a strategic oversight of its availability in the UK as well as the availability of national expertise, in particular that needed to take forward lessons from Fukushima. Part of this will be to ensure that ONR has access to sufficient relevant expertise to fulfil its duties in relation to a major incident anywhere in the world.

5.10.1 Overview

As the UK's largest nuclear generation company, EDF Energy has an interest in nuclear safety-related research, and availability of national expertise in the UK, and also recognises the importance of carrying forward lessons learnt from Fukushima. EDF Energy therefore supports the expansion of the Office for Nuclear Regulation's (ONR) oversight in this area.

Whilst the response to this recommendation is to be led by the ONR, EDF Energy welcomes the opportunity to provide a leading and active role in supporting the development of this response.

5.10.2 Response

EDF Energy has continued to offer support to the ONR on the development of this topic area and will continue to do so, ensuring ONR is aware of the safety related research undertaken by EDF Energy and the commitment to the development of its nuclear professionals to achieve Suitably Qualified and Experienced Personnel (SQEP) status.

5.10.3 Recommendation Conclusions

EDF Energy is committed to learning from the events in Fukushima and will proactively share any learning with the ONR as appropriate. However, it is noted that this particular recommendation is aimed at the ONR and as such EDF Energy is not in a position to determine if this recommendation is considered closed.

5.11 Final Recommendation 11 Close Out Report

Recommendation FR-11: The UK nuclear industry should continue to promote sustained high levels of safety culture amongst all its employees, making use of the National Skills Academy for Nuclear & other schemes that promote "nuclear professionalism".

5.11.1 Overview

EDF Energy recognises that high levels of safety culture are fundamental to the operation of its business. Therefore, the promotion of safety culture is an integral part of the EDF Energy Nuclear Professionalism programme and is an input to the company safety and business targets.

Engagement with external organisations, for example National Skills Academy for Nuclear (NSAN), Cogent Sector Skills Council, World Association of Nuclear Operators (WANO), Institute of Nuclear Power Operations (INPO) and other Nuclear Licensees, is considered a key enabler in enhancing and improving EDF Energy's approach to Nuclear Safety Culture.

5.11.2 Response

The Policies and approaches to Nuclear Safety Culture and Nuclear Professionalism stem from the Company's Management System as detailed in the Management System Manual (MSM).

The management system supports the achievement of the two general aims of a management system, as stated by the International Nuclear Safety Group (INSAG) on 'Management of Operational Safety in Nuclear Power Plants' INSAG-13:

- To improve the safety performance of the organisation through the planning, control and supervision of safety related activities in normal, transient and emergency situations
- To foster and support a strong safety culture through the development and reinforcement of good safety attitudes, values and behaviour in individuals and teams so as to allow them to carry out their tasks safely

The MSM also details the standards and expectations for the organisation and the responsibilities of the Board. The Nuclear Safety Policy Document and Nuclear Professionalism Integrated Company Practice (ICP) set out the approaches to promoting and sustaining high levels of safety culture and nuclear professionalism amongst all employees. The supporting programmes and strategy include contractors, as well as staff, to ensure that they are also imbued with an appropriate safety culture. This is addressed via the Step Up to Quality programme.

Activities

A Company level Nuclear Safety Working group is chaired by a member of the Executive (Continuous Improvement and Operational Support Director) and provides direction, support and oversight of the overall implementation of improvements in the area of safety culture.

EDF Energy has embedded safety culture at the heart of its operations and continues to focus on how to ensure continuous improvement in safety culture via ongoing self assessments which include company-wide surveys and focus groups. These also include long term contract partners.

The nuclear safety culture surveys have been taking place on a biannual basis since 2005. The results from the surveys are analysed and detailed improvement programmes are developed for implementation across the fleet. The fourth such survey was completed in 2012, with the results analysed to focus ongoing improvement plans and ensure strategies are effective in delivering the required results. Other key elements include safety culture training and ongoing communications to ensure nuclear safety is promoted as the overriding priority in word and deed.

Promotion and assurance of effective safety leadership at all levels within the organisation is undertaken in a number of ways. The Leadership Academy includes programmes for all levels of leadership. In addition, leaders' behaviours to promote and improve safety are a key element of the nuclear professionalism programme and include a 'Nuclear Professionalism Leader'. This has recently been reviewed and updated to take account of ongoing improvements to the overall nuclear professionalism programme.

EDF Energy is also a member of the UK Human Performance Forum which includes members of all the major UK Licensees, NSAN and Cogent. The group is sponsored by the Safety Directors Forum (SDF) and has members of the Office for Nuclear Regulation (ONR) in attendance for information and support at least once per year. Through this group EDF Energy continually work with these bodies to identify best practice in human performance and develop national improvements in the area. The most recent development has been on national standards for personnel working in the field of human performance, which has a specific requirement to have detailed knowledge of safety culture and the ability to implement programmes to drive improvement.

The UK Forum work to develop the Human Performance standards and has been led by EDF Energy personnel in conjunction with NSAN and Cogent. EDF Energy has supported personnel visiting and working with INPO to obtain international best practice to further enhance the UK standards.

EDF Energy also maximises other learning opportunities provided internationally, and regularly attends both WANO and International Atomic Energy Agency (IAEA) conferences to identify best practice and share learning to improve internally and support the broader industry development of Nuclear Safety Culture.

5.11.3 Recommendation Conclusions

The work to enhance and further improve EDF Energy’s safety culture is an ongoing commitment as part of normal business. As such, the work in this area will continue to make and drive internal improvements. EDF Energy will also continue to engage with and support the wider nuclear community in this area of expertise. Therefore, this recommendation is considered to be closed.

5.12 Final Recommendation 12 Close Out Report

Recommendation FR-12: Reports on the progress that has been made in responding to the recommendations in this report should be made available to ONR by June 2012. These should include the status of the plans, together with details of improvements that have been implemented by that time.

5.12.1 Overview

This applied to EDF Energy as an operator of 15 reactors at 8 locations within the UK. As part of normal business, EDF Energy strives to be open and transparent, demonstrating the rationale and decision making process behind the response to the events in Fukushima with the Office for Nuclear Regulation (ONR). Therefore this finding is highly relevant.

5.12.2 Response

EDF Energy reported on the progress that had been made in responding to the recommendations in the ONR's Final report as part of the June 2012 response.

The June 2012 response included updates on the Interim and Final Recommendations as well as EDF Energy's Considerations from its Stress Tests and a future programme of work, demonstrating EDF Energy's commitment to learn from the events in Fukushima.

As with the June 2012 submission, this report addresses all ONR Interim and Final Recommendations and includes an explanation of the delivered EDF Energy scope of work. This demonstrates to the public and the ONR how these recommendations have been dealt with in a responsible and timely fashion to a satisfactory conclusion by EDF Energy.

5.12.3 Recommendation Conclusions

Based on the June 2012 submission of material to the ONR, responding to all ONR recommendations and findings as well as EDF Energy's own Considerations and including a proposed programme of work, EDF Energy considers this recommendation closed.

6 Stress Test Findings

Following the issue by EDF Energy and other UK licensees of the ENSREG Stress Test Reports in October 2011, the ONR issued its National Final Report on the Stress Tests for UK nuclear power plants in December 2011.

In addition to the Interim and Final Recommendations, this national report contained 19 Stress Test Findings which EDF Energy incorporated into its programme of work. In line with the previous recommendations, EDF Energy has kept the ONR updated on progress and have also provided a number of updates. The following section will now demonstrate how EDF Energy has closed these findings.

6.1 Stress Test Finding 1 Close Out Report

Finding STF-1: Licensees should provide ONR with the decision-making process to be applied to their Considerations along with a report which describes the sentencing of all their Considerations. The report will need to demonstrate to ONR that the conclusions reached are appropriate.

6.1.1 Overview

EDF Energy developed and delivered a programme of work in the aftermath of the events in Fukushima in 2011.

The programme of work was wide ranging and was based on the Operating Experience (OPEX) from Fukushima, the ONR Interim and Final Recommendations and Stress Test Findings along with EDF Energy's own Considerations arising from the stress test process as well as input from station walkdowns and reviews.

6.1.2 Response

EDF Energy's programme of work followed a decision making process as supplied to the ONR in June 2012.

The process outlined the sources of information and actions, how these were tracked and then how EDF Energy, through workshops and a specially convened Programme Board, decided upon a course of action that would enhance understanding of severe events and accident progression, and what modifications and back-up equipment would further develop preparedness and ability to mitigate against a severe accident and allow the company to deal with one should it occur.

EDF Energy also supplied a full update of what stage each Consideration was at, along with a plan demonstrating how each would be closed out. It should also be noted that throughout the life of the programme of work, the ONR has been kept abreast of what decisions have been made and how the work has progressed.

6.1.3 Finding Conclusions

This recommendation is considered to be closed by EDF Energy as the decision making process was issued along with a full update on all Considerations in June 2012.

Furthermore, an update on the status of all Considerations and how they have been closed has been supplied to the ONR.

6.2 Stress Test Finding 2 Close Out Report

Finding STF-2: The nuclear industry should establish a research programme to review the Seismic Hazard Working Party (SHWP) methodology against the latest approaches. This should include a gap analysis comparing the SHWP methodology with more recent approaches such as those developed by the Senior Seismic Hazard Analysis Committee (SSHAC).

6.2.1 Overview

Seismic hazard studies in the UK for nuclear facilities in the 1980s and 1990s were largely undertaken by a consortium of individuals who operated under the name "Seismic Hazard Working Party" (SHWP). In those studies that the SHWP completed for British nuclear sites, they followed a consistent set of practices over the roughly fifteen year period in which they were active (c. 1983-1998). The Office for Nuclear Regulation's (ONR) STF-2 confirmed the need to reassess the status of these studies, and how they compare with modern practice.

6.2.2 Response

EDF Energy commissioned the British Geological Survey (BGS) to review the SHWP Probabilistic Seismic Hazard Assessment (PSHA) methodology using the original references for the Hinkley Point B (HPB) seismic hazard as a specific example and judged to be an illustrative sample of the SHWP studies across the fleet of power stations.

The purpose of the study was to identify any gaps and whether or not these would significantly affect the existing seismic hazard estimate for the 10^{-4} pa event. The focus of the study was the approach adopted to calculate the ground motion hazard.

A gap analysis report was produced [Ref.1] which considered the extent to which the original HPB seismic hazard studies remain valid, given the improvements in knowledge and advances in available techniques and including updates and key references plus the approach developed by the Senior Seismic Hazard Analysis Committee (SSHAC). The scope of the study was then enhanced [Ref.2] to address review comments and consider the SHWP approach adopted elsewhere across the EDF Energy nuclear sites including consideration of the complete Design Basis Event (DBE) definition (attenuation model for pga and ground motion spectrum).

The analysis examined, topic by topic, the elements of the seismic hazard methodology and compared the SHWP's 1987 practices with the typical approach that would be expected from a modern study and considered best practice today by the wider seismic hazard community. A subjective gap analysis was produced showing the likely significance of the each topic area on the final hazard results.

The report was shared with the cross-industry Civil Engineering & External Hazard Group (CEEHG) Industry Working Group on seismic hazards to ensure consistency of approach across the UK and incorporate the expert views of the wider nuclear community.

Refs. 1 & 2 present the findings of the gap analyses within broad topic areas, along with a provisional sentencing of potential significance. This is represented in Table 1.

6.2.3 Discussion

Ref.1 was updated and expanded via [Ref.2] to take account of comments received from EDF Energy, the CEEHG cross-industry forum and the ONR as follows:

- consideration of the complete DBE definition
- further discussion on the use of geometric mean in modern PSHA & implications when comparing against SHWP studies
- further discussion on the use of the surface magnitude scale Ms20 conversion issue & potential reduction in the SHWP hazard estimation
- include scoping quantified estimates of the significance of each gap

- addressed the Horizon-Hitachi review comments
- addressed the Sellafield Ltd review comments
- addressed the Horizon review comments

A draft copy of Ref.1 was provided to the ONR and preliminary comments were received from their technical consultant who requested copies of some SHWP supporting references. These documents were provided to the ONR in September 2013.

Gap Analysis

It is noted that the SHWP studies perhaps lack the degree of peer review that would be expected via a modern study (e.g. a SSHAC type approach to address independent expert elicitation and treatment of uncertainties). However, this aspect is more a reflection of the period when the seismic community was generally a smaller population from which to draw expertise. Notwithstanding this, the ONR (Nuclear Installations Inspectorate (NII) at the time) commissioned their own independent review as part of the regulatory decision making and the SHWP made best use of the collective UK seismic expertise available at the time.

In summary, the main challenges to the SHWP methodology, as a consequence of the gap analysis, can generally be identified as:

(i) Gaps associated with the Seismic Source Characterisation (SSC) model – e.g. uncertainty in magnitude definition, choice of b value & effect on activity rate

(ii) Gaps associated with the choice and application of Ground Motion Characterisation (GMC) model – e.g. consideration of modern Ground Motion Prediction Equations (GMPEs)

The majority of the significant gaps identified in Table 1 were incorporated into a recent PSHA at the Wylfa site, North Wales and the results showed no significant change from previous hazard estimates for the site.

SSC Model

Magnitude uncertainty

The SHWP studies adopted the surface magnitude Ms scale for magnitude definition in the expectation that they could avoid uncertainty from magnitude conversion to other scales. The choice of magnitude scale would not be an option for a modern study where M_w (Moment Magnitude) would generally be the preferred method but it is noted that using M_w rather than Ms does not of itself change the hazard results; it is simply a prerequisite for using recent data and models.

However, in the SHWP model, it is noted that most of the magnitude values were converted from macroseismic data using least squares regression on the isoseismal records - where as current best practice would ideally correct the magnitude values on a per-event basis. In more recent studies the effect of this conversion has been modelled and any differences can be duly compensated. In the SHWP's case, the effect of not compensating is to underestimate the original hazard by ~3%, if considered in isolation of all other effects.

A potential conservatism inherent within the original SHWP methodology relates to the inconsistent interpretation of the Ms scale. Historically, the Ms scale was intended for larger earthquakes and calculated from seismogram surface wave amplitudes at 20s period. For smaller earthquakes, it is noted that continuing to choose amplitudes at 20s irrespective of the event size progressively leads to an underestimation of the Ms value as the magnitude decreases.

By comparison, current best practice would ideally be based upon the correct interpretation of the Prague formula (1962) which does not restrict the use of the scale to 20s amplitudes but rather allows the highest amplitude to be chosen irrespective of period or at a distance related period as appropriate.

The Ms surface magnitude can be identified by two scales as distinguished by Ms (BB) to represent the correctly interpreted "broadband" approach as opposed to the Ms20 definition from the historical interpretation. This difference was not previously realised during the SHWP era. It is judged that the effect of SHWP underestimating the influence of lower magnitude events has led to an overestimation of the hazard estimate of ~12% if considered in isolation of all other effects.

b value

The b value controls the ratio of large to small earthquakes in the seismic source model and represents the slope of the relationship between Magnitude (M) and log N (where N is the number of events per year greater than magnitude M) based upon the Gutenberg-Richter relationship.

Modern PSHA experience shows that the b value is typically close to unity and this was generally confirmed by studies supporting the Eurocode 8 UK Seismic Hazard Zoning Maps 2007.

The SHWP studies adopted a high b value of 1.28 with a small range 1.25-1.30 to allow for epistemic uncertainty. High b values imply a lower activity rate for higher magnitude events and vice versa.

This can be illustrated by reference to the SHWP activity rates for South Wales Zone 1 of the original SSC model, it can be shown that for events ≥2.5 M_w, the SHWP model would on average predict an activity rate of about 2.35 events per year. However, in the period 1992-2012 (during which there is a complete earthquake record for this threshold) the total recorded number of events ≥2.5 M_w was 9 (of which 3 are very likely to be mining related). Whilst it is noted that the model was not designed to be extended to magnitudes lower than 4.0 Ms, there is no seismological reason for a sharp discontinuity between magnitudes 2.5 and 4.0.

The high b value adopted by SHWP underestimates the activity of higher magnitude events of greater significance to engineering structures and is accepted to be non-conservative. If a lower b-value (~unity) was introduced to the SHWP model in isolation of all other effects, it is judged that the hazard estimate would increase by ~6%.

Activity rate

It is also noted that an alternative method is available to a modern PSHA to address the joint distribution of b value & activity rate whereby the Penalised Maximum Likelihood method could be adopted. This method captures the uncertainty in both the b value and activity rate parameters.

It is judged that if such a technique was adopted as part of a modern PSHA, in lieu of the traditional “b value & activity rate" combination, it would give rise to a 14% increase to hazard estimate if treated in isolation of all other effects.

In addition, a modern PSHA would ideally include a formal assessment of the probability of fault activity (where such features are considered and assigned as a specific source in the model), which would likely reduce the hazard. By example, the Watchet Cothelstone Hatchet Fault (WCHF) was assessed as part of the SHWP Hinkley Point B (HPB) site specific study and, by reference to further fault studies undertaken post SHWP, a reduction in the fault activity rate from 0.5 (as assumed by SHWP) to 0.05 can now be proposed [Ref.4]. This would imply a reduction in overall contribution of this fault to the hazard and an overestimation of ~7% in the original SHWP hazard estimate, if treated in isolation of all other effects.

GMC Model

Modern GMPEs

A previous sensitivity study [Ref.3] was commissioned by EDF Energy to consider the effect on the HPB site seismic hazard by applying a series of modern GMPEs to a replication of the original SHWP model.

The following New Generation Attenuation (NGA) 2008 relationships were considered:

- Boore & Atkinson (2008)
- Campbell & Bozorgnia (2008)
- Chiou & Youngs (2008)
- Idriss (2008)
- Abrahamson & Silva (2008).

In addition, the following relationship was also included in the study scope:

- Akkar & Bommer (2010).

Table 2 presents the Peak Ground Acceleration (PGA) estimates from each of the above for comparison against SHWP and other recent PSHA studies of interest.

The Figures in Section 6.2.6 illustrate the predicted 10^{-4} pa Uniform Risk Spectrum (URS) spectral shape for each and comparison against the SHWP 10^{-4} pa URS and the 10^{-4} pa Principia spectrum anchored at 0.14g (the latter represents the safety case DBE for HPB, Ref.5).

The results from all the modern Ground Motion Prediction Equations (GMPE) were scaled up by 1.15 to 1.20 depending upon the period to accommodate the differences in definition between geometric mean and max component methodology and thus allow a 'like-for-like' comparison.

If a modern PSHA study was undertaken, with the appropriate justified choice of GMPEs and appropriate weighting in the logic tree, then the results would be defined based upon the geometric mean and hence lower by ~15% than presented here.

The sensitivity study produced two categories of results:

(a) Models that gave hazard results significantly lower than those obtained by SHWP. These are Akkar & Bommer (2010), Boore & Atkinson (2008) and Campbell & Bozorgnia (2008)

(b) Models that gave results comparable to those obtained by SHWP, or slightly higher. These are Abrahamson & Silva (2008) Chiou & Youngs (2008) and Idriss (2008).

The distinction between groups (a) and (b) is a combination of differences in expected (median) ground motions and the handling of aleatory variability. It is notable that the magnitude-dependent sigma is used by all GMPEs in group (b) and none in group (a).

The URS curves calculated do not predict significantly higher spectral hazard than the values previously adopted for HPB, with the exception of Abrahamson & Silva.

For the Abrahamson & Silva attenuation relationship, it was subsequently noted that restricting the minimum magnitude to 5 M_w (within its range of recommended applicability) approximately halved the peak of the hazard. In addition, it is judged that this equation generally produces consistently higher results in comparison to the other relationships.

Minimum Magnitude

The choice of minimum magnitude could be potentially significant (depending upon the value chosen by a modern PSHA) but is really a procedural issue rather than a scientific one. However, its effect has been considered for completeness in the gap analysis.

Modern PSHA practice tends towards a 5 M_w minimum magnitude value, whilst the Eurocode 8 Seismic Zoning Maps for the UK adopted a lower 4.5 M_w value. It is noted that most modern GMPEs have applicable ranges of use typically between 5.0-8.0 M_w, which therefore requires their extrapolation to capture lower Mmin cut-off values e.g. 4.0 Ms used in the SHWP studies.

This effect can artificially inflate the 10^{-4} pa hazard estimate (in a similar manner to Abrahamson & Silva discussed above due to the increasing sigma value for lower magnitudes) and would present a issue for consideration in a modern PSHA if a Mmin value of <5.0 M_w was to be adopted.

The effect of a higher minimum magnitude cut-off value than adopted by SHWP would reduce the hazard estimate whilst the adoption of a lower value, say 4.0 M_w, would generally lead to similar hazard values (if treated in isolation of all other gaps and issues). The original SHWP studies adopted a Mmin value of 4.0 Ms (broadly equivalent ~4.0 M_w).

Other Issues

Ref.2 also discussed some issues which are not strictly gaps, as the SHWP methods are valid, but where differences due to newer information or opinions as expressed in later studies could affect the hazard.

- Focal depth distribution (whereby weighting more heavily in favour of lower depth events, as expected for the UK, reduces the hazard). This would have no effect on the mean SHWP hazard but would affect the spread of fractile hazard curves. For interest, to assess the significance of this parameter, the hazard was recalculated with the only change in the SHWP model being the replacement of the original focus depth distribution in Zones 1 & 2 with the weightings adopted for the Eurocode 8 UK Seismic Hazard Zoning Maps 2007. This predicted a 12% reduction in the SHWP hazard
- Earthquake catalogue completeness (whereby modern UK PSHA would use the BGS catalogue which differs from the original SHWP listing – Figure 6.2.7. Activity rates would likely increase due to the greater number of events in the more complete BGS catalogue. A pessimistic view for the HPB studies could imply a possible 5% increase in the hazard. However, this is misleading, in terms of the actual significance, since the effect on the HPB model increases the activity rates in Zone 1 and decreases them in Zone 2 (since some earthquakes drop out the analysis altogether) to the extent that there would no longer be any earthquakes in Zone 2 above 4.0 Ms in the new completeness windows. The significance at other sites will vary depending upon seismic source zone geometry and the distribution of events in the more complete catalogue.
- Maximum magnitude – the lack of conservatism in the SHWP approach is negligible and has been assessed to have a ~1% increase in the hazard.

6.2.4 Finding Conclusions

In response to ONR's STF-2, EDF Energy has reviewed the SHWP methodology using the references from HPB as an illustrative example for the UK sites. A study by BGS [Refs.1&2] has identified a number of topics from the original SHWP approach for comparison against modern practice.

A subjective gap analysis has been produced assessing the likely significance of each topic area on the final hazard results. The significant gaps have been considered further by EDF Energy company experts and it is judged that the SHWP methodology and results remain defendable against modern PSHA practices in terms of providing a safe and conservative estimate of the seismic hazard that is plausible for the UK sites.

The scope of the study was enhanced to assess whether the other EDF Energy nuclear sites adopted the same methodology as per the HPB pilot study to secure a fleet-wide position, and this has been confirmed. The approach adopted by SHWP was generally consistent with little deviation of significance in the approach between UK sites.

Where possible, and to serve as an aid to judgement, the more significant gaps and issues identified in Table 1 have been assigned a scoping value in terms of their likely effect on the SHWP hazard, if treated in isolation. This provides a simple quantified estimate to assist overall judgement on the robustness to modern change. In addition, the results from a sensitivity study to review the effect of considering a series of modern ground motion models on the original SHWP model and hazard estimate for HPB are presented to assist the review (Table 2).

The issue of the SHWP adopting a single attenuation relationship is a long standing challenge and has been generally recognised as potentially constituting the single most critical gap, in comparison to modern best practice. The sensitivity study was not intended to derive a modern 10^{-4} pa URS for the HPB site, rather it was intended purely to assess the significance of modern GMPEs. However, it does support the overall aid to judgement here-in to review the collective significance of the gap analysis

It is EDF Energy expert opinion that the combined consideration of all the gaps and issues imply that the overall net effect would yield generally similar (within an acceptable +/- range) or lower results to the SHWP studies – albeit the caveat being that each topic area has been considered here in isolation and the overall hazard estimate is dependent upon the combination and correlation between many parameters, assumptions and uncertainties. Notwithstanding, based upon the best information available and supported via Refs.1 & 2, the key implication is that there is no significant expectation that the SHWP estimates are unsafe.

It is worth noting that PSHA is a rapidly changing discipline and the hazard derivation is very subjective on the assessment and choice of parameters. Inevitably, there will be varying opinions and future developments will need to be considered but EDF Energy has consulted widely and is content that current safety case positions, where based upon the SHWP studies, remain secure.

The accuracy of any method of analysis is difficult to predict (or even verify) and depends upon the model to represent a combination of very complex characters with innumerable variations. Difference in outcome and divergence of view on the final result are likely whatever methods are used. Importantly, the EDF Energy approach to seismic assessment includes informed consideration of the physical behaviour of the plant and structures during earthquake loading to balance the overall safety case position.

EDF Energy will continue to review the continued validity of the seismic hazard across the fleet as part of Periodic Safety Review (PSR) activities in accordance with Licence Condition (LC) 15 and via continuation of the post-Fukushima CEEHG programme to ensure consistency across the UK nuclear Licensees. This includes taking cognisance of changes to current PSHA best practice.

In addition, as existing Licensees located on adjacent sites to proposed new nuclear build developments (at Hinkley Point C and Sizewell C) it should be noted that EDF Energy are direct stakeholders in the development of any new seismic hazard studies via PSHA which may be forthcoming from the EDF Nuclear new build licensee, Nuclear New Build Generation Company (NNB Genco). Current dialogue and synergy across the EDF Energy Generation and NNB GenCo business units and licensees will continue in this area.

The SHWP studies were intended to present a conservative estimate of the 10^{-4} pa URS to support and inform the overall site specific seismic assessments associated with the DBE and safety cases. For Beyond Design Basis (BDB) events, the emphasis shifts towards demonstrating suitable resilience for events larger than the DBE envelope such that cliff-edge effects may be present.

For EDF Energy sites, this aspect is generally addressed by considering the seismic performance of the engineering structures and plant based upon inherent structural ductility; conservatism of elastic code based design assumptions and developing acceptable performance criteria, as opposed to extrapolating the seismic hazard estimate to lower probabilities or artificially factoring the 10^{-4} pa hazard estimate to account for BDB events which would not serve as a suitable means of addressing the disproportionate increase in risk.

6.2.5 Tables

Table 1 Summary of Reference 1 Gap Analysis

Topic	*Issue*	*Modern practice*	*Conservative*	*Significance*
Construction of source zone model	Simplistic, over-geometrical zones, possibly due to limitations of software	Detailed source model	Varies	Probably low
SSZ modelling	Earthquakes treated as point sources	Use of virtual ruptures	Unconservative	Probably very low (~ 1%)
Choice of *b* value	Too high, too limited, wrongly calculated, no regional variation	Penalised maximum likelihood to capture epistemic range	Unconservative	Significant (~ 6%)
Calculation of activity rate	Correlation of activity rate and *b* value ignored	Joint determination of parameters by penalised maximum likelihood to capture epistemic range	Unconservative	Significant (~ 14%)
Magnitude uncertainty from conversion (from macroseismic data)	Uncertainty ignored	Uncertainly modelled using "M*" approach	Unconservative	Low (3%)
Depth distribution	Incorrectly used in logic tree	Logic tree branches used only for epistemic uncertainty.	Neither	No effect on median hazard, significantly affects fractiles
Maximum magnitude	Range not conservative (this does not mean it is wrong)	Mmax not below 6.5 Mw	Unconservative	Very low (~ 1%)
Ground motion model	Only one used; epistemic uncertainty not addressed	Multiple models used	Depends on which modern models used, but likely to be conservative	High

Table 1 (continued)

Ground motion model	Model is unrealistic	Newer models are based on more data and better formulated	Depends on which modern models used, but likely to be conservative	High
Ground motion model	Inconsistent modelling of near-field motions	Newer models cover distance range better	Depends on which modern models used, but likely to be conservative	Unclear
Use of Ms	Inconsistent versions of the scale used	Modern studies would use Mw	Conservative	Significant (12%)
Fault model	Characteristic earthquakes implied but not modelled	Characteristic earthquakes modelled	Depends on modelling decisions	Probably low
Documentation	Inadequate justification of decisions, weights, etc	Documentation vetted by PPRP	Neither	Unquantifiable
Consultation	Procedure unclear	Structured workshops	Neither	Unquantifiable

<u>EDF Energy Technical Review Note.</u>

This close out report summarises the results of the review of the SHWP methodology and gap analysis to modern methods and concludes that the site specific seismic hazard estimates are still conservative and defensible for UK nuclear power plant sites.

The temptation to summarise the estimated differences in isolation should be treated with caution as, for example in Table 1, the 'b value' in isolation gives one value, the 'b value plus activity rate' gives another and these are not additive, but rather relate to alternative options available to a modern PSHA in comparison to SHWP methods.

Similarly, within the text other changes to the hazard estimate and definition have been identified including use of geometric mean to define the hazard; influence of minimum magnitude, formal fault activity assessment, earthquake catalogue completeness & focal depth distribution. Table 2 indicates the range of possible changes and average effects that could be yielded from modern GMPEs albeit applied to the original HPB model. The scoping values in Tables 1 & 2 are provided to assist overall judgement.

The full scope of the combined references needs to be read to inform an overall judgement on the SHWP resilience to modern change.

Chief Civil Engineer, EDF Energy, March 2014

Fleet Lead Civil Engineer, EDF Energy March 2014

Table 2 Comparison of Results for 10^{-4} pa PGA

Ground Motion relationship	PGA (g)	Comparison to SHWP	Comments
SHWP Principia (1982)	0.225	-	HPB 10^{-4} pa URS
Abrahamson & Silva (2008)	0.243	108%	PGA reduced to ~0.15g when applied within recommended range 5.0-8.0 M_w
Boore & Atkinson (2008)	0.117	52%	
Campbell & Borzognia (2008)	0.132	59%	Used in EC8 Seismic Zoning Maps for UK (equal weighting with Bommer et al 2007 relationship)
Chiou & Youngs (2008)	0.175	78%	
Idriss (2008)	0.186	83%	
Akkar & Bommer (2010)	0.146	65%	
AMEC PSHA Study for Hinkley Point C (2009)	0.116	51%	Shown for comparable interest only
Eurocode 8	0.04-0.06	n/a	Based upon 2500 yr return period, non site specific study

Average of 74% for the 6 models used in Ref.3

The above results are based upon the New Generation Attenuation (NGA) relationships 2008 and consider the effect on the 10^{-4} pa URS, using the original SHWP model and treated in isolation of all other effects.

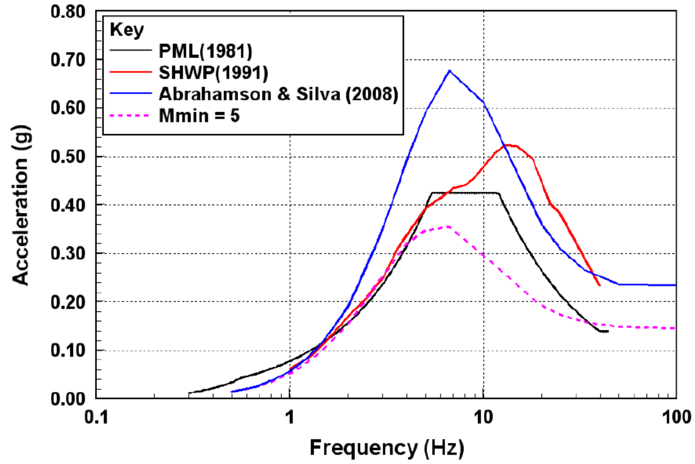
Recently, some of these have been updated to present a 'NGA 2013' revision.

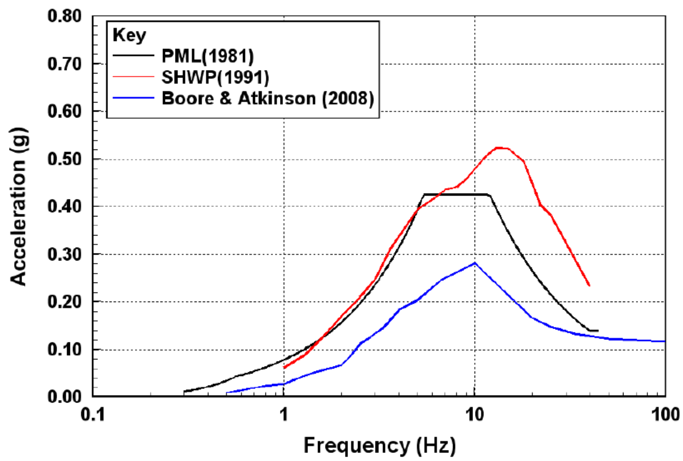
To support aid to judgement, simple scoping calculations have been undertaken as a further sensitivity check:

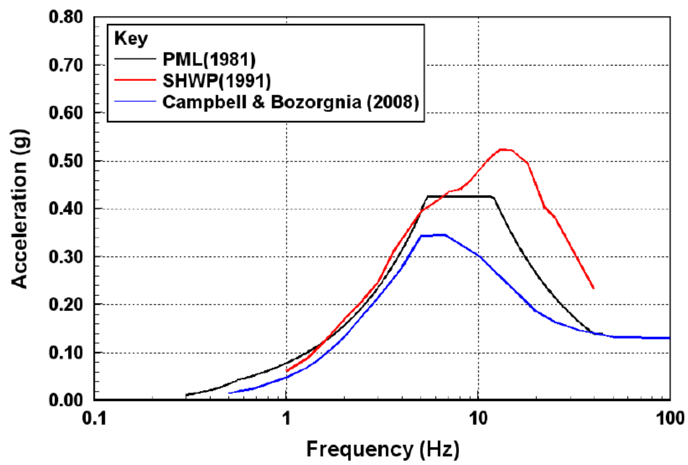
Ground Motion relationship	Comparison of NGA 2013 : 2008	NGA 2013 Comparison to SHWP
Abrahamson & Silva (2013)	Stays about same	~108%
Boore & Atkinson (2013)	~125%	~65%
Campbell & Bozorgnia (2103)	~200%	~117%
Chiou & Youngs (2013)	~60%	~47%

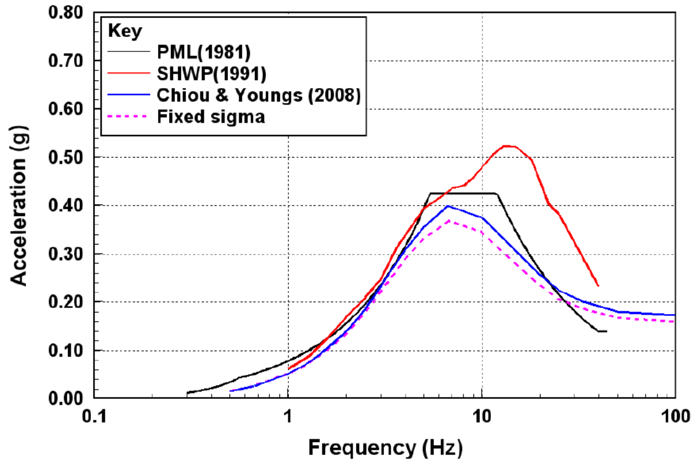
Average of ~84%

6.2.6 Figures of Modern GMPE 10^{-4} pa Hazard Curves for HPB





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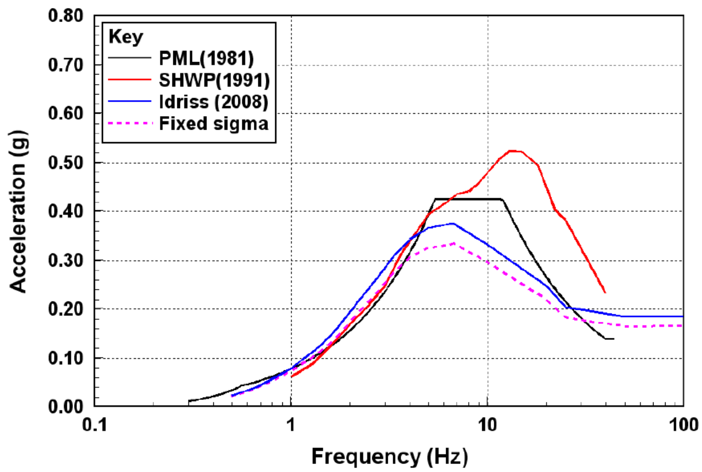
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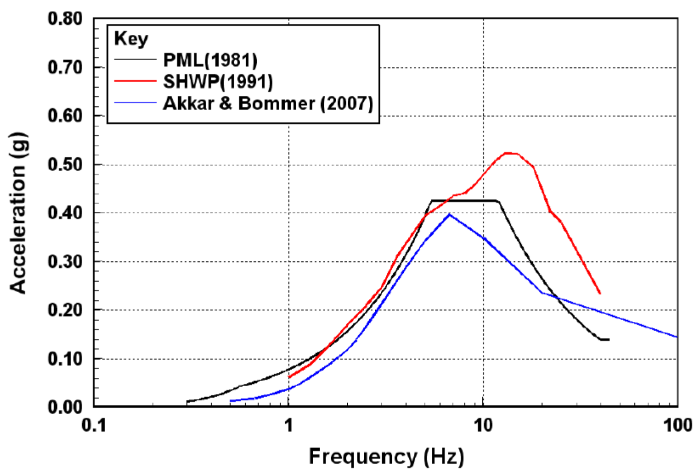
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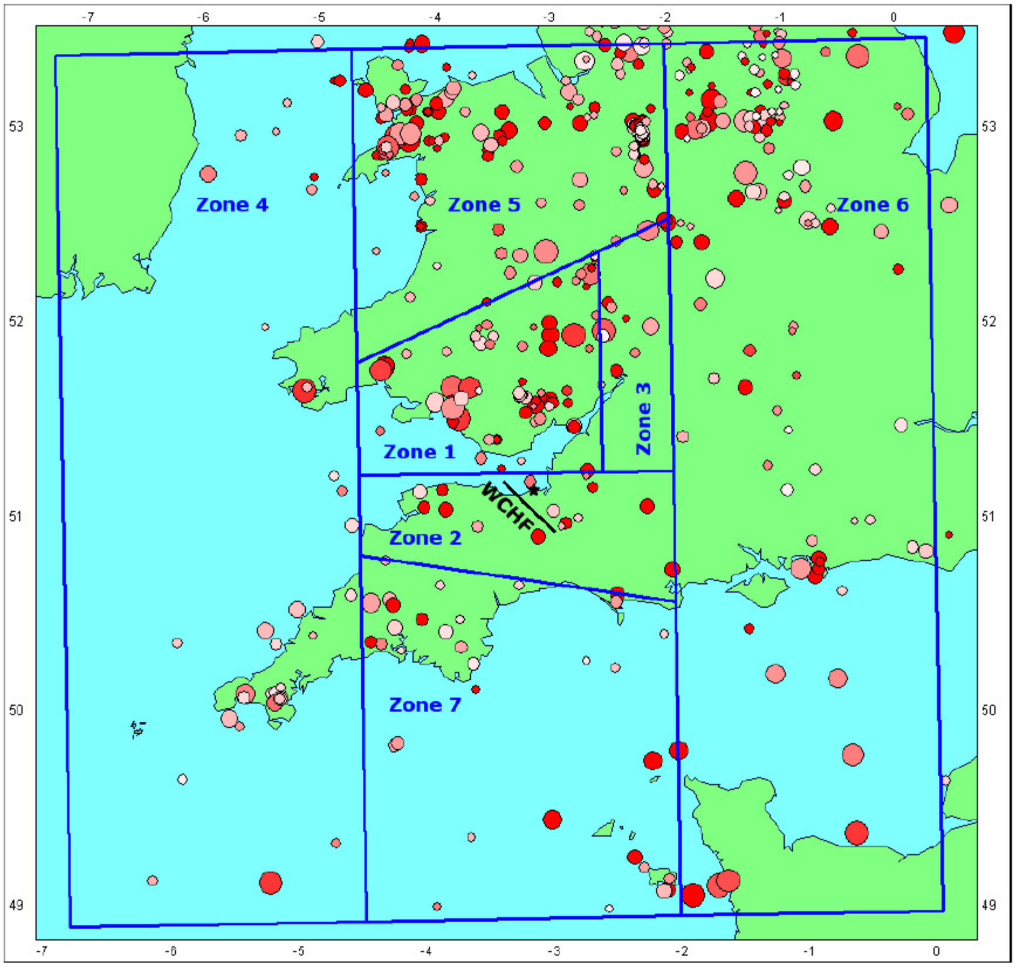
6.2.7 Full Seismic Source Model from SHWP HPB (1987), replotted in latitude and longitude and with BGS earthquake data



6.3 Stress Test Finding 3 Close Out Report

Finding STF-3: Licensees should undertake a further review of the totality of the required actions from operators when they are claimed in mitigation within external hazards safety cases. This should also extend into beyond design basis events as appropriate.

6.3.1 Overview

This finding applies to external hazard safety cases across the fleet, where "external hazards" means the scope agreed for the Japanese Earthquake Response (JER) programme to be external flooding, seismic and weather hazards (extreme ambient temperatures, rainfall, wind), as set out in the response to STF-5.

EDF Energy has carried out a variety of reviews and analyses relating to operator actions in event of these external hazards. The aim has been to ensure that they are adequately identified and assessed, in order to have confidence that they can be reliably carried out if required, including under the conditions created by the hazard.

This response describes a range of activities undertaken by EDF Energy. The scope of the reviews and analyses goes beyond considering the operator actions formally claimed in existing safety cases, to consider also:

- Operator actions required by current Station Operating Instructions (SOIs) and Emergency Procedures;
- The operability of Deployable Back-Up Equipment (DBUE);
- Operator actions in Beyond Design Basis (BDB) scenarios.

Operator actions claimed by the safety case in response to seismic events have been identified and reviewed in a specific, separate study.

Measures are being, or have been, implemented that will also aid operators' ability to successfully carry out activities in the timescales required in emergency or severe accident scenarios. These include, as outlined in this STF-3 response:

- Provision of the Met Office VisualEyes and Safesee information and warning systems at stations;
- Introduction of DBUE, to support essential functions;
- Addition of on-site resilience measures to support essential functions, including connections to the new DBUE.

These activities, in combination, show how operator actions have been identified and assessed for all external hazards within the scope of the EDF Energy JER programme, including BDB hazards.

6.3.2 Response

<u>Review of Operator Actions in Existing Safety Cases, SOIs and Emergency Procedures</u>

<u>Assessment Method</u>

The main activity that directly addresses STF-3 is a Human Factors (HF) review of operator actions claimed in external hazards safety cases.

This has been done primarily as a pilot study on Heysham 1 (HYA) and Hartlepool (HRA) stations, accompanied by a subsequent fleetwide review of extreme weather-related actions at other stations, taking account of the learning accrued as part of the Pilot studies undertaken.

<u>Findings and Recommendations of the HF Review</u>

The review of HYA and HRA station documentation found that the operator actions specific to external flooding, high wind loading and extreme ambient temperature hazards were all described in the SOIs, Conduct of Operations and Emergency Handbook. These actions were not explicitly cited in the station safety case documents; the operator actions cited in the extreme weather Living Safety Case Documentation are limited to those relating directly to spurious trip and/or loss of grid, with extreme weather hazard-specific operator actions stated as being within station procedures.

Whilst this might suggest that operator actions related to extreme weather do not support any safety case claims, the station workshops identified a number of operator actions as the equivalent of "claimed" actions, notwithstanding that they were not explicitly cited in the relevant HYA and HRA safety cases:

- Fitting dam boards around the Cooling Water (CW) pumphouse;
- Operating the sump pumps within the CW pump house;
- Clearing the air intake screens of snow on top of the Gas Turbine (GT) building;
- Cleaning the drum screens.

These actions were the subject of subsequent HF assessments (including on-site walkdowns) which analysed the ability of operators to perform these tasks in challenging environments:

- Fitting of dam boards: fitting of dam boards should be a task that would be carried out with high reliability. This is subject to the station receiving sufficient weather warnings (~24 hours); the review also recommends independent checks on dam boards after installation.
- Starting of sump pumps should be an action that would be carried out with high reliability. The review makes recommendations to aid this by improved labelling at the CW pump house, and possible refinement of procedures to position operators at the pump house in severe weather.
- Clearing the GT air intake route is straightforward, though the action of manually opening the bypass louvres will not be familiar to most operators and the review recommends improved guidance to operators on this action.
- Clearing the drum screens is a straightforward task under normal environmental conditions. The review however identified that the differential pressure gauges that indicate fouling are considered unreliable (hence could be improved), also that operator intervention the drum screens could be difficult in some severe weather conditions.

The HF review makes a number of recommendations regarding aspects noted above and other items. Some of these relate to forecasting of severe hazards and decision-making with respect to taking actions.

Further work is being considered in some areas, to ensure that the review of operator actions can be shown to be comprehensive:

- The HF review has been focussed on HYA (an Advanced Gas-cooled Reactor (AGR) station), so it has not considered external hazard operator actions that may be specific to Sizewell B (SZB) as a Pressurised Water Reactor (PWR) station.
- Notwithstanding the fleet-wide elements of the HF review, further activities may be undertaken to ensure a complete assessment of the other AGR stations.
- Local to plant operator actions in the event of loss of grid connection have not been reviewed. Further work may be undertaken in relation to these actions, identifying and reviewing actions that may relate to external hazards, or be affected by external hazards.

These subjects are currently being reviewed by EDF Energy (see Finding Conclusions below).

<u>Beyond Design Basis Events</u>

The BDB aspects of STF-3 have been addressed by EDF Energy through specific work considering such scenarios, as described in the responses to other recommendations:

- The work on the Level 2 Probabilistic Safety Analysis (PSA), as summarised below and presented in EDF Energy's response to FR-4;

- The updated Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs), as described in EDF Energy's response to IR-24.

In addition, the nature of external hazards and the operator actions required in their event can reasonably be considered not to have sharp "cliff-edge" changes when moving from design basis to BDB scenarios. Therefore the HF review centred on operator actions identified in safety case documents, SOIs, Plant Operating Instructions (POIs) etc. also provides assurance of some reliability of operators' being able to perform the actions in BDB scenarios, albeit with some difficulties increasing in more severe conditions.

Operator Actions Required In Response to Seismic Events

A separate review has been carried out of operator actions required following a seismic event, presented in a separate report. This has been undertaken with reference to HYA and HRA, selected as the stations for which operator actions following a seismic event are considered to be the most important. The start-point for the review was the HYA/HRA consolidated seismic safety case, which considers the station at power and at shutdown and makes claims on various operator actions. These actions align with those identified in the visible safety case, and to a large extent those in the PSA. The operator actions have been reviewed to confirm their realistic achievability. The analyses included on-site walk-through, and a qualitative theoretical analysis, and reached qualitative assessments of whether the actions could reliably be carried out.

The review has concluded that:

- Clear and unambiguous guidance is provided in the procedures regarding the required actions and timescales;
- The Human Machine Interfaces used are appropriate from a HF perspective;
- Performance Shaping Factors that could undermine reliable task performance are adequately controlled;
- There is adequate time available to complete the actions.

These findings confirm the deterministic claims on operator action. Some recommendations have been made to improve procedures and the details of how action are undertaken, and will be progressed through normal EDF Energy business.

Operator Actions in Beyond Design Basis Scenarios

Through the activities below, operator actions in BDB scenarios have been identified, assessed from an HF/operability viewpoint, and steps taken to suitably reflect them in relevant procedural and guidance documents. Some of these activities have been undertaken through normal EDF Energy business activities, others have been undertaken under the EDF Energy JER programme:

- HF assessments within the new Level 2 (AGR) PSA pilot study at Hunterston B (HNB), which also takes into account the extended timescales of some sequences (longer than modelled in previous studies). (This is described in more detail in EDF's response to FR-4);
- For AGRs, review of the procedures and guidance in SBERGs, following review with station staff of the current SBERGs and their contents. (Update and extension of the SBERGs is described in more detail in IR-25, and STF-16);
- For SZB, through a different process, emergency and severe accident guidance in SOI8.8 is to be updated – this will involve improvement by "benchmarking" against international practice for PWRs.

Operability of Deployable Back-Up Equipment

A study has reviewed DBUE equipment from the angle of considering its intended use in emergency response, including in BDB and external hazards scenarios, and reviewing the equipment's design and operation. The review included physical examination of the equipment. The reviews have led to detailed amendments to equipment and how it will be used, but generally have confirmed its operability and suitability for purpose.

Provision of VisualEyes and Safesee Information and Warning Systems at Stations

Additional severe weather forewarning systems have now been provided to all EDF Energy stations (the Met Office's VisualEyes and Safesee systems) to ensure that station staff are aware of severe weather, such as that which could cause or exacerbate flooding hazards; this will aid staffs' ability to ensure that suitable preparations are made, including placement of dam boards if appropriate. The two Met Office products are seen as best practice in terms of local forecasting technology. (This is described in more detail in EDF Energy's response to STF-5).

Severe Weather Preparedness

EDF Energy has compared and reviewed station SOIs related to seasonal preparedness, severe weather and other external hazards against the requirements and guidance in BEG/SPEC/062 (Company Specification: Seasonal, Severe Weather and Marine Impact Preparations). Learning has been gained from the fleet-wide review of these SOIs, which will inform bringing all stations' SOIs to a common, improved, level.

Revision to these SOIs will also include changes to reflect work done to improve EDF Energy's understanding of these external hazards, identify revised or clarified "triggers" for action, and provide additional risk mitigation measures, notably the VisualEyes and Safesee warning systems and resilience measures that can be taken, such as deployment of dam boards and possibly early deployment of back-up equipment. SOI revisions which address some of the improvements have been implemented at a number of stations. Further improvements which address all identified aspects will continue as normal business under EDF Energy's commitment to continuous improvement. A programme will be confirmed in 2015.

Introduction of JER Deployable Back-Up Equipment, To Support Essential Functions

In the event of an emergency, severe accident or severe external hazard conditions, operators' ability to take actions to reduce risks and/or restore essential functions will be increased by the provision of the new DBUE. The JER DBUE is described at more length in the responses to IR-25 and STF-5; below is a summary description.

The DBUE, which can restore a variety of essential plant functions and is located externally to the site, is to be deployed to the site when needed in an emergency, or potential emergency, scenario. The physical separation of the DBUE from the station sites means that it is likely to be segregated from the effects of severe natural hazard events which create an emergency at the site; this applies to the AGR stations, for which DBUE is stored at a number of locations distributed around the country and typically some hours' travel by road from the stations, and also SZB for which the DBUE (which is specific to SZB) is stored much closer to the site but is still separate from it and so segregated by its location. Use of the DBUE is supported by a full suite of documentation, including detailed instructions for installation and use on-site (centred on the DBUE Guidelines (DBUEGs)), and training for emergency response staff. The DBUE deployment strategy includes pre-planned alternative transport routes.

Much of the DBUE interfaces with permanent plant systems via connections which have been introduced or improved as part of on-site resilience work. This is also described further in the responses to IR-25, STF-5 and STF-8.

Added On-Site Resilience Measures

EDF Energy has undertaken a programme of work to increase the resilience of key existing systems and structures to severe events and BDB events. The modifications/enhancements include:

- Flood protection (as described under STF-7), including provision of dam boards; sealing building penetrations; new or improved flood defence walls; flood protection of ponds; dewatering (pumpout) capabilities. Systems protected include back-up electrical generation and back-up feed water;
- Resilience to seismic events, including access to key plant areas; qualification of water stocks and dry risers; mobile fire fighting equipment;

- Connection points such that cooling and essential electrical supplies can be established using the DBUE;
- Resilience of infrastructure such as Alternative/ Emergency Indication Centres (A/ EIC) and Emergency Control Centres (ECC) against extreme external events (not required at SZB);
- New systems have been added to SZB, including Passive Autocatalytic Recombiners (PARs) and a connection for Containment Water Injection (CWI);
- A programme is ongoing reviewing installation of Filtered Containment Venting (FCV) at SZB, on which a final decision has not yet been made and will depend on the outcome of continuing development/design work.

On-site resilience modifications are described in more depth in EDF Energy's response to STF-14 and IR-25.

The EDF Energy JER programme staged a number of Proof of Concept (POC) demonstrations to provide tangible evidence that the JER programme has delivered the promised improvements in enhanced capability and that these new systems work in practise. The POC demonstrations were endorsed by the EDF Energy Nuclear Generation Executive (NG Exec) and advised to the ONR.

There are parts of the enhanced emergency response capability provided by the JER programme that cannot be practically demonstrated on site due to the invasive nature of the DBUE; as such, practical and theoretical POC demonstrations were devised to illustrate the complete response. These enabled EDF Energy Emergency Response Organisation (Station and Central Emergency Support Centre (CESC)) to work with new processes, equipment (DBUE) and organisations (Through Life Management Partner (TLMP) & Forward Deployment Service (FDS)) through the activation, deployment and operation of the new capability.

The POC demonstrations were divided into those for response to the AGR and PWR. Each event was subject to independent assessment by an Internal Assessment Team headed by the company's Emergency Planning Fleet manager and was further reviewed by EDF Energy's internal regulator, INA. The ONR also witnessed these internal demonstrations as part of their work on regulating the response to the Weightman recommendations. Areas of good practice and areas for improvement were captured and used to inform subsequent demonstrations or future exercise requirements.

Proof of Concept Demonstration AGR

The POC demonstrations for AGR deployment and capability were split into 3 phases.

POC A – A practical 3 day event which demonstrated the activation, logistical deployment of DBUE and establishment of a staging post site by the TLMP. Followed by transfer of DBUE to EDF Energy and the capability of station responders from Heysham 1 and 2 to connect and operate the DBUE that would restore Critical Safety Functions.

POC A* - A practical demonstration based at HNB which focused on the interactions between key responders (EDF Energy, FDS and TLMP) in the deployment of DBUE. The exercise illustrated the successfully delivery of DBUE by the FDS and the deployment and laydown/setup of mobile facilities (ECC, Access Control Point & DCIS (Deployable Communications and Information System)). These facilities were utilised by the response organisation to respond to an event using existing command and control techniques.

POC B – A simulated BDB long duration emergency scenario involved the CESC and Heysham 1 and 2 Central Control Room's and ECC teams. The demonstration made use of the updated arrangements, DBUEGs and SBERGs. It demonstrated the capability to understand and manage a multi-site, multi-unit, BDB event, including the benefits of the JER-provided additional measures. The demonstration required real-time decision-making by staff and involved a shift changeover; it also simulated a real emergency through factors such as failures of plant indication systems, communications and lighting.

The internal and external reviews and reports of the AGR POC recorded the successes and captured the lessons learnt from these demonstrations. The continuing improvement process ensures that this learning is embedded within EDF Energy's emergency arrangements.

Proof of Concept Demonstration PWR

POC C - A practical demonstration was performed at SZB to evaluate the station's response in activating the Emergency Response Centre (ERC), determine the effectiveness of the Responders in preparing, deploying and operating the back-up equipment, and provide evidence of DCIS's capability in data acquisition, verbal communication and information transfer.

Overall the exercise demonstrated that SZB's new off-site ERC could be activated in a timely manner. ERC responders demonstrated knowledge and proficiency in the preparation, deployment and operation of back-up equipment. Communication through DCIS was established between responders using hand-held radios and head-sets worn by staff in the off-site ERC, also between the off-site ERC and EDF Energy's CESC at Barnwood. Two-way data transfer between the off-site ERC and the CESC was also demonstrated.

Each of the POC demonstrations have been reviewed in detail with the key learning captured in a JER Proof Of Concept Demonstration Report covering A, A*, B and C for future learning as part of the continual improvement process.

6.3.3 Finding Conclusions

This response to STF-3 has described a range of relevant activities, centred on human factors assessment of operator actions in event of external hazards at HYA together with a review of operator actions across other stations. The findings from these activities are generally positive and provide assurance that operator actions required in the event of external hazards could be carried out reliably.

BDB events have also been considered in the Level 2 PSA and in the revised SAGs and SBERGs which will improve guidance to staff in taking the best courses of action should such scenarios occur. Whilst the main review activities have focussed on operator actions that are cited in safety case and station SOIs, POIs etc and so are considered in the context of design basis scenarios, their positive conclusions also provide some assurance of operators' ability to carry out these actions in BDB events.

The response has also described the measures being implemented to aid the ability to successfully carry out activities in the timescales required in emergency or severe accident scenarios, including improved weather forecasting and warning systems to ensure that station staff have time to take required preparatory actions; in the event that recovery actions are needed, the provision of JER DBUE and on-site resilience modifications will greatly improve the ability to take effective action to support essential functions.

A forward programme of work, as part of continuous improvement in normal business, will address any recommendations arising from the significant work undertaken.

In conclusion, this response shows that EDF Energy has made a broad-ranging and in-depth response to STF-3, which has extended beyond consideration of actions explicitly claimed in the safety case in relation to external hazards, and has included new human factors analyses where appropriate. It is supported by specific work into BDB events as detailed in our responses to FR-4 and IR-24.

Whilst there will be some further activities to ensure that a comprehensive assessment is completed, the results of the work done in response to STF-3 provides confidence that any significant issues that could affect station safety cases or indicate a lack of margin with respect to BDB events will not be identified.

6.4 Stress Test Finding 4 Close Out Report

Finding STF-4: Licensees should undertake a further systematic review of the potential for seismically-induced fire which may disrupt the availability of safety-significant structures, systems and components (SSC) in the seismic safety case and access to plant areas.

6.4.1 Overview

The ONR raised the above finding in its National Stress Test report at the same time as noting the importance of EDF Energy's own stress test considerations CSA003 and CSA004 which are:

- CSA003 – 'EDF Energy will consider reviewing the probability of consequential fire as a result of an earthquake';
- CSA004 – 'Consideration should be given to the feasibility of enhancing the seismic capability of appropriate unqualified fire systems'.

Both considerations were raised in the context of the EDF Energy's Advanced Gas-cooled Reactors (AGRs). The same considerations were not identified in the Sizewell B (SZB) stress test which concluded: 'The potential indirect effects (of an earthquake) have been considered as part of the safety case and, where considered necessary to protect essential plant, interactions have been qualified against the appropriate Design Basis Event (DBE).'

The ONR also provided supplementary material to their National Stress Test report which provided further guidance on their expectation for the response. Specifically for STF-4, ONR expected that a more comprehensive and structured review of the potential for this secondary hazard (fire) should be undertaken.

EDF Energy's response to STF-4 takes cognisance of all of the above. EDF Energy's approach to addressing STF-4 has been to carry out a detailed study at a single nominated site (Hinkley Point B (HPB)); chosen because it is considered to be suitably representative of the older AGRs which did not explicitly address the potential for seismically induced fires in their original design. The expectation was that a single station study might reveal both generic and station-specific issues; the balance between the two would influence the manner in which the Stress Test Finding was to be addressed for other stations. The outcome of the HPB study is summarised below together with the implications for the rest of the AGR fleet of power stations.

6.4.2 Response

6.4.2.1 Scope of the Hinkley Point B Study

The scope of the HPB seismic/fire hazard study centred upon systems, structures and components which had been previously qualified to bottom line i.e. capability of withstanding the seismic hazard with a severity appropriate to 10^{-4} per annum return frequency. This included both reactor and fuel route systems. Consideration was also given to the potential for fire affecting access routes associated with the potential deployment of EDF Energy's Japanese Earthquake Response (JER) programme Deployable Back-up Equipment (DBUE). The scope of the study was shared with ONR prior to commencing the work.

EDF Energy commissioned Atkins and ABS Consulting to carry out the HPB study. The work consisted of background research, reviewing the fire and seismic safety cases, as well as performing seismic walkdowns at Hinkley. These walkdowns were carried out by experienced Seismic Qualification Utility Group (SQUG) engineers (ABS) supported by Atkins. Suitably Qualified and Experienced (SQEP) fire engineers within EDF Energy were also utilised in support of the review report production and in its subsequent appraisal.

The outcome of the review has identified and assessed areas which are potentially vulnerable to credible seismically-induced fire hazards and which could pose a significant risk to any of the following:

- Seismic Bottom Line Plant (BLP) claimed for the Reactors at full power
- Fuel Route plant claimed following a seismic event
- Access routes to claimed plant
- JER DBUE deployment.

To ensure that the above plant and access routes were not prejudiced by the escalation of a fire from a neighbouring area, the walkdown team also reviewed the potential for seismically-induced fires in such adjoining areas, even if they contained no essential systems.

The review considered the following:

- Potential causes and sources of fire following a seismic event
- Potential for fire spread as a result of damage to fire barriers
- Potential for consequential damage to Bottom Line structures, systems and components as a result of fire
- Availability of fire detection, suppression and fire fighting systems
- Potential to compromise operator and/or JER emergency response plant.

The potential for a seismically-induced fire hazard in each of the areas described above has been evaluated and given a rating of High, Medium or Low. It is important to stress that these ratings allocated to each of the surveyed zones are an initial assessment of the potential for fire based on the presence of fire pre-cursors and the assessed seismic resilience of local essential plant and fire protection equipment. They should not be interpreted as a surrogate for the likelihood of fire, nor should they be associated with the likelihood of failure to provide essential safety functions. A substantial number of the areas reviewed have a ‘Low’ rating due to the lack of credible fuel or ignition sources, or interaction of the two. However, some areas have been given a rating of ‘Medium’ or ‘High’. The areas and equipment potentially affected are described below together with judgements on the overall safety significance based on a subsequent appraisal by fire and safety case SQEPs.

6.4.2.2 Outcomes of the Hinkley Point B Study

The review has highlighted a number of potential seismically-induced fire hazards that could affect claimed plant or JER access routes at HPB.

1. A number of high voltage (3.3kV and above) electrical cubicles and panels were noted as not being seismically qualified during the walkdown. These cubicles were assessed to be vulnerable to sliding and/or rocking during a seismic event. Such movement was assumed to be a potential cause of arcing with subsequent ignition of the cable insulation or other flammable inventory within the vicinity being a threat to claimed plant. The potential for fire (based on the presence of fire pre-cursors) was rated as “Medium” (as a threat) to bottom line plant, fuel route plant and access routes.

   The EDF Energy fire SQEPs’ subsequent judgement was that the likelihood of ignition in the manner described above is low. Even if a fire were to be initiated, operational experience suggests that the likelihood of fire spread is also low. It should be noted that the ‘Medium’ rating applies only to high voltage electrical cubicles which are not already seismically qualified i.e. a seismically-induced fire arising in an essential high voltage electrical system cubicle is not considered credible. Moreover, one of the factors leading to the ‘Medium’ rating of the non-qualified high voltage cubicles identified was a lack of access for visible inspection of the cubicle anchorages. Although the likelihood of ignition is low, confirmation of the adequacy of the non-qualified high voltage cubicle anchorages will be sought.

2. A number of flammable liquid storage cabinets were noted at various locations on site, within claimed plant areas or within areas affecting the JER access routes. These cabinets are susceptible to sliding and/or rocking during a seismic event with potential leakage of the

unsecured flammable contents, within the vicinity of various ignition sources such as electrical equipment, lighting and hot surfaces. These hazards have been rated as “Medium” (as a threat) to the bottom line plant, fuel route plant and access routes.

The likelihood of fire initiation in the above scenario cannot be judged to be low. However, it is considered that the likelihood of fire spread is relatively low since the combustible loading in such cabinets is small. It is therefore considered appropriate to carry out a nuclear safety/ fire safety/ industrial safety inspection of each flammable store which will include the anchorage arrangements. Resulting recommendations to secure/remove/relocate/implement best practice will be addressed as normal business.

3. Two highly flammable stores and the oil drum store (with adjacent oil tanks) external to the Reactor Building and Turbine Hall, along the JER access route, were identified as not being seismically qualified, or having potentially inadequately restrained ignition sources. There is potential for spillage/leakage of large amounts of highly flammable materials within the vicinity of ignition sources, which poses a significant risk of seismically induced fire. These have been rated as “High” (as a threat) to the JER access routes.

   It should be noted that the threat here is to the JER access routes rather than to bottom line plant. Particular considerations relevant to the overall effect on safety are applicable in this instance e.g. the JER DBUE is designed for application many hours following a significant hazard event after which the effects of a major fire may be expected to be diminished. It may also be noted that the JER DBUE includes vehicles designed to clear debris and re-open blocked access ways and, for many of the JER DBUE connection points, alternative access routes are available. However, similar to the item (2) above, it is considered appropriate to carry out a nuclear safety/ fire safety/ industrial safety inspection of the buildings identified above. Reasonably practicable recommendations to enhance the seismic resilience and implement best practice will be considered under normal business.

4. A number of High Voltage (HV) Transformers were identified as having no visible anchorage. These could be susceptible to sliding and/or rocking during a seismic event, resulting in leakage of oil and potential ignition through arcing or interaction with adjacent electrical equipment. These have been given a rating of “High” (as a threat) to the JER access routes.

   As is the case for item (3) above, the identified threat is to JER access routes rather than to bottom line plant. Operational experience suggests that the likelihood of ignition is low. Considerations listed above for item (3) regarding the deployment of JER DBUE are applicable in this instance. The anchorages of the relevant transformers will be assessed to determine whether steps to enhance the seismic resilience of this equipment are reasonably practicable.

5. Concerns were raised regarding the restraint provided to a large number of hydrogen bottles stored within a compound along the JER access route which are adjacent to essential plant. The hydrogen bottles were considered to be susceptible to toppling during seismic excitation and due to potential release of significant amounts of hydrogen gas, all potential ignition sources could not be readily dismissed. These have been given a rating of “Medium” (as a threat) to the JER access routes.

   As is the case for items (3) and (4) above, the identified threat is to JER access routes rather than to bottom line plant. Considerations listed above for items (3) and (4) regarding the deployment of JER DBUE are applicable in this instance. The hydrogen bottle restraint arrangements will be assessed to determine whether steps to enhance the seismic resilience are reasonably practicable.

6. The Turbine Generators 7 and 8 are not seismically qualified. There is potential for damage to the hydrogen lines and spillage/leakage of large amounts of lubricating oil (also not seismically qualified) within the vicinity of hot surfaces, which poses a significant risk of seismically induced fire.

   The general view of the subsequent expert panel (see below) was that a large turbine hall fire was not a credible scenario (some support from OPEX). Notwithstanding this view, essential plant located away from the turbine hall would be able to provide sufficient reactor cooling. Defence in depth for the key essential safety function (reactor cooling) remains available via the Back-up Feed System (BUFS) which is external to the turbine hall. Considerations in respect of JER access routes raised for other items above are applicable here also.

6.4.2.3 Implications of the Hinkley Point B Study on the rest of the fleet.

An 'expert panel' comprising seismic, fire and safety case SQEPs was convened in late January 2014 to assess the implications of the HPB study on the rest of the fleet of power stations.

The panel's view was that the HPB review had not identified any fleet-wide issues of significance which were not already recognised by the EDF Energy fire SQEPs or were not in the process of being addressed under normal business. Specific examples include the revision of the fire safety case for Hartlepool (HRA) and Heysham 1 (HYA) which is now considered normal business. The significance of the seismic/fire interactions is recognised and will be incorporated in the safety case scope. Similarly, the Dungeness B (DNB) fire safety case has been revised, with an interim case issued in March 2014: the long term case will include appropriate consideration of seismic/fire hazard interaction and is scheduled for issue in Q4 2015. In the short term, however, the panel recommended that a desktop review should be undertaken to further consider the following potential seismic/fire issues at DNB to assist in the development of the longer term safety case:

- Seismic resilience of bulk oil storage in circulator hall
- Seismic qualification of oil bulk storage in boiler house (likely to be a relatively insignificant issue since the loss of boiler house from fire is addressed within the current safety case as a frequent event)
- Exposed tendon ends
- Hydraulically actuated Main Steam Valves (reactor side)
- Lack of Fire Retardant Fluid in steam valves (turbine side)
- Oil spills
- Electrical Overlay System (EOS) cabling passes over/close to transformers. Vulnerability to a transformer fire may be a potential issue.

It was also considered that the HPB study outcomes were broadly applicable to Hunterston B (HNB), noting that an additional review of particular plant differences (Diverse Cooling System (DCS) and Back-up Cooling System (BUCS)) would be worthwhile. Localised and 'concentrated' fire hazards at HNB were already receiving attention under normal business. (The nitrogen plant refurbishment already in progress will result in the removal of the propane store as a significant fire/explosion hazard.) The panel noted the recent revisions to both the fire and seismic hazard safety cases at HNB. Their completion provides assurance that significant seismic/fire shortfalls are unlikely to be present.

The safety cases of most recent AGRs (Heysham 2 (HYB) and Torness (TOR)) together with SZB were considered to be robust against the seismic/fire interaction hazards since the original design of HYB/TOR/SZB took into account both seismic and fire events. Fire protection at these sites relies on segregation and provision of passive fire barriers (including fire doors). Although regular fire surveys at these sites have identified some weaknesses - both physical (shortfall in barrier integrity) and cultural (fire door closure) – these have been / are being closed as normal business. No specific actions in the context of Stress Test Finding 4 (other than the two generic issues outlined immediately below) are considered appropriate at these stations.

Generic Issues:

1. Fire concerns have arisen from the potential for seismically induced failure of flammable liquid storage tanks. The potential for degradation of seismic margins in liquid (fuel oil, feed water) storage tanks which have been subject to corrosion is recognised across the fleet and action is in hand to address the issue. The issue was initiated by observation of excessive corrosion in SZB condensate storage tank (CR 771481). Subsequent Routine Evaluations (REVL) 796196

across the fleet have identified all safety-related liquid storage tanks. Maintenance and inspection practices have been found to be inconsistent and in need of improvement. A new Company Technical Standard (CTS) addressing corrosion is in preparation, and will provide mandatory measures aiming to support maintenance of satisfactory material condition of such storage tanks, thereby maintaining the seismic withstand capability (and seismic margins). This aspect is continuing as normal business with ONR being informed of progress at Level 4 meetings.

2. The expert panel considered that the HPB study had confirmed the significance of 'good housekeeping' as a key contributor to the maintenance of the seismic/fire safety case integrity. It was also recognised that this was an issue which applied across the fleet. Recent initiatives such as periodic 'zonal hazards walkdowns' (currently supporting Periodic Safety Review (PSR) 3) are already assisting in this aspect – and are considered to be a major contributor to the future security of the hazards safety cases. Similarly, better control of combustible materials is currently being addressed across the AGR fleet as part of the LC 23 update programme. It is therefore considered that these 'normal business' processes are appropriate measures to address this generic 'housekeeping' issue.
3. In addition to the 'normal business' activities described in 1. and 2. above, it is intended that a separate learning brief will be produced by EDF Energy's Design Authority to summarise all aspects identified in the complete set of EDF Energy JER workstreams which are relevant to improving the maintenance of the hazards safety case integrity. It is intended that this will be communicated to all stations and shared within Design Authority.

6.4.3 Finding Conclusions

The HPB seismic/fire study has been completed. While it identified a small number of areas of potential concern purely from potential co-location of combustible material and a source of ignition, further consideration by fire and safety case SQEPs has resulted in the judgement that the safety cases are adequately secure at all EDF Energy sites.

Nevertheless, it is recognised that further activities are required to consolidate the security of the safety cases for seismically-induced fire at a number of stations which have been identified directly from the HPB study and from the subsequent expert panel assessment. These are outlined below.

Hinkley Point B:

- Seek confirmation of the seismic adequacy of the non-qualified high voltage (3.3kV) cubicle anchorages;
- Identify unsecured flammable materials storage cabinets in bottom line plant areas and implement appropriate measures to prevent cabinet toppling or spillage of contents. Alternatively, remove such storage cabinet(s) from bottom line plant areas;
- Assess the anchorages of the relevant transformers to determine whether steps to enhance the seismic resilience of this equipment are reasonably practicable. (The potential threat is to JER DBUE access routes rather than bottom line plant);
- Assess the hydrogen bottle restraint arrangements to determine whether steps to enhance the seismic resilience are reasonably practicable. (The potential threat is to JER DBUE access routes rather than bottom line plant);
- Carry out a nuclear/fire/industrial safety inspection of the two highly flammable stores and the oil drum store external to the reactor building. Reasonably practicable recommendations to enhance the seismic resilience will be considered under normal business. (The potential threat is to JER DBUE access routes rather than bottom line plant).

The above items have been included on a 'PSR3/JER Hazard Issues Database' at HPB which also includes recommendations arising from the STF-5 and 6 seismic walkdowns. Database entries have been actioned or allocated to Condition Reports which will be addressed under normal business. The process mirrors that being followed for the zonal hazards walkdowns which are currently supporting PSR3.

Dungeness B:

- Carry out desktop review of specific potential seismic/fire issues identified by the expert panel including bulk oil storage arrangements, tendon ends, steam valves, oil spills and EOS cabling near external transformers.

  Subsequent to the Expert Panel, continued support has been provided to the ongoing programme of work delivering the interim (NP/SC 7673 EC 348182) and the longer term fire safety case. This has ensured that the scope of this safety justification remains robust, with particular focus on securing additional resource for the purposes of undertaking seismic qualification walkdowns.

Hunterston B:

- Carry out desktop review of seismic/fire resilience of DCS and BUCS.

All Sites:

- Design Authority 'learning brief' is being produced to communicate key 'housekeeping' aspects identified by the JER workstreams which are significant to the maintenance of design integrity. This 'learning brief' will be formally issued in 2015; however key aspects have already been discussed and disseminated through the establishing EDF Energy hazard governance arrangements.
- Implement appropriate periodic inspections in accordance with the Company Technical Standard (CTS) requirements.

  Interim guidance has been issued to all sites in July 2014, to augment the existing Technical Guidance Note (TGN) 130 in terms of scope of surveillance for tanks and vessels potentially subject to environmental conditions conducive to corrosion, in advance of a full revision of this TGN in 2015. Furthermore, CTS/031 Corrosion Management has been developed to formalise the requirement for all Sites to have robust arrangements in place to manage the threat to plant integrity and functionality, as a consequence of corrosion. CTS/031 was issued in late 2014 with the key aspects being discussed with each station.
- Continue zonal hazards walkdowns across the fleet in order to identify and address nuclear safety issues arising from 'housekeeping failures' and instances of degraded material condition in areas containing essential systems.

This is now fully embedded within normal business and is therefore considered closed.

6.5 Stress Test Finding 5 Close Out Report

Finding STF-5: Licensees should further review the margins for all safety-significant structures, systems and components (SSC), including cooling ponds, in a structured systematic and comprehensive manner to understand the beyond design basis sequence of failure and any cliff-edges that apply for all external hazards

6.5.1 Overview

The Stress Test specification requested the determination of margins associated with Beyond Design Basis (BDB) hazards. In response, the EDF Energy submissions make general statements regarding margins inherent in the design. The Office for Nuclear Regulation (ONR) recognised that there are unquantified margins present in the current safety cases, but made a challenge on the adequacy of the submission with respect to retained confidence beyond design basis. Therefore, ONR requested, through STF-5, that the margins against external hazards should be determined for all Systems, Structures and Components (SSCs), to demonstrate the absence of cliff-edges beyond design basis, and also confirm additional resilience measures for limiting plant, as required.

It is understood that ONR's view was that the determination of margins should be used to identify the most vulnerable plant to a given hazard, leading on to decisions on whether realistic enhancement options are feasible, and confirmation of the level to which this will increase the overall protection of the system as a whole.

Noting the very broad potential interpretation of this Finding, which could lead to very large numbers of SSCs that would need to be assessed, and very significant resource demands which could be grossly disproportionate in relation to the benefits realised in terms of demonstrating the requisite resilience to external hazards, post-Fukushima, a number of further discussions were held between EDF Energy and ONR to confirm and agree the scope for this STF.

Following these discussions, for the purposes of this Closure Statement, the following specific aspects are highlighted as being of most significance with respect to the delivery of this close-out report:

- The overall response will be proportionate and based on a good and clear understanding of the plant vulnerabilities and importance within the safety case, e.g. where the hazard cannot credibly threaten the vulnerable plant under consideration, then a judgement-based response is appropriate
- This close-out response will cover both the Advanced Gas-cooled Reactors (AGRs) and Sizewell B (SZB), a Pressurised Water Reactor (PWR). The AGRs are qualitatively different to water reactors because the timescales for fault escalation (even if all Post Trip Cooling (PTC) safety function has been lost) are so much more extended
- The response will not provide highly accurate assessments of margins between the design basis hazard and the magnitude /frequency of the BDB hazard which would cause failure of the plant under consideration. It will, however, provide sufficient confidence through qualitative /semi-quantitative means to address the challenges reflected within the STF
- The scope of work on external hazards resilience will focus on external flooding, seismic and weather hazards (extreme ambient temperatures, rainfall, wind, noting that these can occur in combination). It was agreed that no other external hazards (aircraft impact, non-weather related aspects of bio-fouling, drought, external Electro-Magnetic Interference (EMI)/ Radio Frequency Interference (RFI), industrial hazards, space weather) would be within scope. This is consistent with the over-arching intent to take full account of the events and learning from Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident
- There are three aspects of the margins that would be the focus of the response, namely structures that protect the bottom line plant, the bottom line plant itself, and the security of the integrity of the pressure boundary

- It was agreed that other aspects of the EDF Energy approach to hazards safety cases (margins for second line plant, the role of hazards sequence analysis, hazards Probabilistic Safety Analysis (PSA)) will not be included in the scope of this response
- A key component part of the response will be the confirmation that the hazards assessment methodologies are confirmed to be acceptable, in light of current knowledge, standards and best practice
- There is no requirement for Deployable Back-Up Equipment (DBUE) to be treated as essential plant, noting that DBUE is not claimed as part of design basis protection. Clearly, if DBUE does become part of a claimed Line of Protection, then it will have to be considered as essential plant.

Noting the above agreed framework, the following sub-sections provide the detail in relation to the proposed responses on the hazards within the scope of this STF, namely seismic, external flooding and weather; with margins of safety having been quantified as appropriate.

The above scope continues to fully satisfy the intent of the European Nuclear Safety Regulators Group (ENSREG), and the requirements of the “stress tests”, in terms of reconfirming the safety margins of the EDF Energy nuclear power plants in light of the events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident.

6.5.2 Response

Noting the above agreed scope, and the focus of this response on seismic, external flooding and weather hazards, there are specific sub-sections below which consider each of these in turn.

However, there are a number of generic claims which can be made with respect to the continued resilience of the EDF Energy safety cases to these hazards, irrespective of the specifics relevant to each individual hazard:

- The Nuclear Safety Principles (NSPs) require consideration of internal and external hazards within the EDF Energy safety cases
- The systematic reviews undertaken as part of the Periodic Safety Review (PSR), together with improved mitigation through design (separation and segregation) for the later stations (Heysham 2 (HYB) /Torness (TOR) / SZB), and improving Governance Arrangements within EDF Energy, confirm robust arrangements within normal business with respect to ongoing resilience to hazards in general
- The NSPs define the design basis for external hazards as an event with an annual probability of exceedance of 10^{-4}. Noting the associated difficulties with respect to determining the severity of such low frequency hazards, the NSPs further require the demonstration that there is no disproportionate increase in risk beyond this frequency, i.e. no “cliff-edge” effect where the consequence significantly increases with a slight increase in the challenge. Therefore, the existing safety cases inherently demonstrate margin beyond the design basis
- There was a robust approach undertaken to qualify essential SSCs claimed during and following the hazards postulated. This qualification can take many forms but is essentially a thorough assessment of the ability of the claimed equipment, or operator action to perform as required, even when the SSC has been affected by the external event. Qualification can be though segregation from the challenge or demonstration that the SSC can be exposed to the challenge and still carry out its safety function (or not fail in such a manner as to prevent other systems from carrying out their safety functions)
- Notwithstanding the inherent confidence provided by the above bullets, additional margin has been secured through the EDF Energy Japanese Earthquake Response (JER) programme, through the provision of increased on-site resilience, DBUE and improved arrangements to ensure that personnel involved in emergency and severe accident scenarios at EDF Energy stations will be able to undertake the actions required of them

- The AGRs are qualitatively different to water reactors because the timescales for fault escalation (even if all PTC safety function has been lost) are so much more extended. The JER programme has taken full account of this through the specific additional measures taken for SZB, most notably through the provision of a local Emergency Response Centre, and on-site resilience through the installation of Passive Autocatalytic Recombiners (PARs), and potentially Filtered Containment Venting (FCV), noting that a formal decision on this significant modification is still outstanding at the time of this close-out report. These additional measures will reduce the likelihood of sequences that include core damage and containment disruption
- Of the hazards covered in this response, it is taken that only the seismic hazard has the potential to adversely affect pond integrity and hence cooling of spent fuel.

The remainder of this response is structured as follows. Sub-section 6.5.2.1 deals with the seismic aspects of STF-5, and while making links to the responses to other Recommendations and Findings it is self-contained in respect of this response. Sub-section 6.5.2.2 deals with flooding, and sub-section 6.5.2.3 deals with weather. There is clearly an overlap here, in that external flooding can be a consequential effect of an overall severe weather event. The external flooding hazard encompasses pluvial (rainfall), fluvial (river-sourced) and coastal (sea-water). For the latter, the objective is to ensure that there is no significant sea-water ingress to site (i.e. maintaining a "dry site") and this is the focus of sub-section 6.5.2.2. *Minor* sea-water ingress is more equivalent to the pluvial hazard than a general inundation of the site, and this aspect is therefore covered along with the other weather-related hazards in sub-section 6.5.2.3.

In all three sub-sections, however, the approach to analytical identification of margins, as discussed in Section 6.5.1, will also be put into the context of how additional measures have also been taken to reduce reliance on the analysis by describing the real measures which have been taken to increase resilience, where appropriate.

6.5.2.1 Seismic Hazard

EDF Energy's approach to addressing STF-5 for the seismic hazard has been to carry out a detailed study at a single nominated site (Hinkley Point B (HPB)); chosen because it is considered to be suitably representative of the older AGRs which did not explicitly address the seismic hazard in their original design. The expectation was that a single station study might reveal both generic and station-specific issues; the balance between the two would influence the manner in which the Stress Test Finding was to be addressed for other stations. The outcome of the HPB study is summarised below together with the implications for the rest of the AGR fleet.

6.5.2.1.1 Scope of the Hinkley Point B Seismic Study

The scope of the HPB seismic study centred upon SSCs which had been previously qualified to bottom line i.e. capable of withstanding the seismic hazard with a severity appropriate to 10^{-4} per annum return frequency. This included both reactor and fuel route systems. The scope of the study was shared with ONR prior to commencing the work, noting that further discussion and clarification of the approach was subsequently undertaken as outlined in the above overview. It may also be noted that the scope of the study addressed not only the seismic aspects of STF-5 but also covered those relating to STF-6. The latter may be viewed as a sub-set of STF-5, focussing on the beyond design basis resilience of components of the primary circuit pressure boundary. A separate response to STF-6 is provided, although some of the information presented in this response to STF-5 is relevant.

EDF Energy commissioned Atkins and ABS Consulting to carry out the HPB study. The work consisted of background research, reviewing the current seismic safety case, as well as performing seismic walkdowns at HPB. These walkdowns were carried out by experienced Seismic Qualification Utility Group (SQUG) engineers.

The assessment employed the principles of the Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure (GIP), the Department of Energy (DOE) Seismic Evaluation Procedure, the EDF Energy Seismic Design Guidelines and other SQUG guidance consistent with seismic experience data. It also relied heavily on existing calculations and safety case work for the seismic assessment of HPB as well as PSR findings.

Bottom line reactor shut-down and hold-down systems are failsafe and, provided that reactor core geometry is maintained, these safety functions will not be threatened. These systems have therefore not been considered as part of the seismic assessment.

6.5.2.1.2 Outcomes of the Hinkley Point B Seismic Study

The key findings for structures and systems are summarised separately below reflecting the different approaches to assessing seismic resilience; analytical methods are generally employed in the assessment of structures whilst the evaluation of the presence of seismic margins in systems is supported by seismic experience and walkdown techniques.

Structures:

The assessment concluded that foundation failure is not credible for most of the structures because they are founded on rock type material. Single storey buildings are founded on shallow foundations, and failure remains unlikely.

The Reactor Building structures have varying degrees of vulnerability. It has been judged that the Pre-stressed Concrete Pressure Vessel (PCPV), Central Block, Reactor Services Building, Circulator Hall primary steelwork and Charge Hall primary steelwork structures are robust and either have ductility or have sufficient beyond design basis margin and are therefore considered not susceptible to cliff-edge effects near to the design basis boundary.

The Turbine Hall and Gas Turbine buildings are judged to have ductility or margin before cliff-edge behaviour.

The Back-Up Feed System (BUFS) / Alternative Indication Centre (AIC) and the Switchrooms are principally masonry structures and the DB analysis only demonstrates limited margins before masonry collapse.

The HPB Control Building is potentially the most susceptible structure and the low design code margin (0.8) is a known issue. The HPB Long Term Seismic Safety Case argues that building collapse at the design basis boundary is unlikely due to load transfer from highly stressed shear walls into adjacent lower stressed column supports. Further conservatisms exist when considering a BDB earthquake affecting this structure e.g.

- In the event of seismic movements across the movement joints between the Control Building and adjacent robust Central Block, seismic energy would be dissipated due to sliding and the frequency of response will reduce – leading to a lower overall demand. Movement joints were not included in the original finite element analytical model
- Modal participation results imply the main response occurs in the region of 2-3Hz – with lower seismic demand
- Conservatism exists in the linear elastic assessment approach with respect to modelled load paths vs. real load paths
- Current force-based analysis is based upon gross section properties: a more realistic representation would consider cracked concrete section properties with reduced stiffness and hence lower seismic demand
- The control building is located between two robust structures and collapse is mitigated by existing geometry.

Gross failure of the fuel cooling/storage ponds is not expected, so pond leakage caused by significant cracking becomes the significant potential cliff-edge effect. The analysis reviewed made use of the tensile strength of the concrete to demonstrate a margin, rather than seeking to demonstrate ductility. The beyond design basis performance is limited by the margin of 1.25.

For structures within the pressure vessel, the seismic integrity of the boilers and penetrations has been assessed as part of the safety case. This work used a method that is judged to include margin for beyond design basis events. The presence of seismic margins for the reactor core and its support/restraint arrangements remains under regular review as part of normal business. The current position is secure.

Consideration of the seismic margins associated with the PCPV structure, liner, penetrations through the structure and the reactor pressure boundary is addressed separately in the close-out statement for STF-6.

Systems:

A walkdown review of the essential systems and components that form the Bottom Line Plant at HPB was undertaken. The review has established the seismic ruggedness of the systems and components and is presented in detail in the review report. No single system or component has been identified with a ruggedness rating of ‘Low’. However, a number of systems and components have been assessed to have a ‘Medium’ ruggedness rating, resulting in a number of minor recommendations being included in the review report. These are typically associated with defective or missing equipment/pipework anchorages although there were also a number of recommendations which may be considered to be associated with ‘housekeeping’ lapses. It should be noted that none of the identified recommendations were considered to pose an immediate threat to nuclear safety. The review recommendations have been included on a ‘PSR3/JER Hazard Issues Database’ at HPB which also includes recommendations arising from the STF-4 seismic/fire walkdowns. Database entries have been actioned or allocated to Condition Reports which will be addressed under normal business. The process mirrors that being followed for the zonal hazards walkdowns which are currently supporting PSR3. It may be noted that some of the recommendations identified in the ‘JER’ review had been addressed prior to the PSR3 zonal hazards walkdowns were undertaken.

The claimed Bottom Line systems that contribute directly to reactor trip, post-trip reactor cooling and monitoring functions at HPB were demonstrated to possess sufficient capacity to accommodate beyond design basis event seismic loadings.

Conclusions of the Hinkley Point B Seismic Study:

The seismic study at HPB did not reveal any unexpected results nor did it identify any features more vulnerable than those already known.

The overall conclusion of the review is that, subject to the continual rectification of small defects which were identified in this review together with further defects which may arise over time, seismically qualified plant, systems and structures should all possess margins against “cliff-edge” effects at the design basis boundary. The review confirms once again the importance of maintaining consistency between the management of the plant and the requirements of the seismic safety case: while this is very much a normal business driver, it does underwrite the identified margins of safety for beyond design basis events. The review has not identified any major shortfall(s) which might suggest that ‘normal business’ is not an appropriate approach to address such issues.

6.5.2.1.3 Implications of the Hinkley Point B Seismic Study for the Rest of the Fleet

An ‘expert panel’ comprising seismic and safety case Suitably Qualified and Experienced Personnel (SQEP) was convened in late January 2014 to assess the implications of the HPB study for the rest of the fleet. The main observations made by the expert panel are summarised below for both station-specific and generic aspects. It should be noted that resilience of the primary circuit pressure boundary for the AGRs is addressed separately in the response to STF-6.

Sizewell B

The Safe Shutdown Earthquake (SSE) for SZB has been defined as having a peak horizontal ground acceleration (pga) of 0.14g. However, the majority of the SZB structures and equipment have actually been designed to a pga of 0.25g. Furthermore, qualification to 0.25g included an additional 40% (i.e. 0.35g) to demonstrate the absence of a cliff-edge. Those SSCs not qualified to 0.25g but only 0.14g were supported by additional work based on 0.20g claiming ductility.

No further general analytical assessment work on margins is considered appropriate for SZB except on a case by case basis to address material degradation (normal business).

Heysham 2 and Torness

In comparison to the site-specific Uniform Risk Spectrum, the design spectrum has been confirmed to be exceptionally onerous in the frequency range from 1 to 4 Hz, by a factor of up to 7 for TOR and up to 5 for HYB. This frequency range dominates the response of the major building structures. The spectral acceleration at 2.5 Hz in the design spectrum corresponds to an annual probability of exceedance of between 10^{-7} and 10^{-8} for TOR and between 10^{-6} and 10^{-7} for HYB.

It may be concluded that at HYB and TOR, no further general analytical assessment work on margins is considered appropriate except on a case by case basis to address material degradation (normal business).

Hunterston B

The main messages from the HPB seismic study are generally applicable to HNB: e.g. the control building shows similar low margins against code compliance. The assessment of bottom-line seismic capability at HNB has generally been carried out against the 0.14g PML spectra, consistent with HPB. However, the location and ground conditions at Hunterston are such that the 0.1g PML spectrum is a very good surrogate for the expected infrequent event with a return frequency of 10^{-4} per annum. There is, therefore, a large built-in margin to cope with a seismic event with a return frequency of less than 10^{-4} p.a.

The seismic margin applicable to the fuel pond as reported in the stress test for HNB is low (1.05) in comparison to other stations. The panel noted that the consequences of potential pond cracking were unlikely to be significant at HNB, since the bottom of the pond is below ground level.

Dungeness B, Hartlepool and Heysham 1

The expert panel raised no specific concerns in respect of calculated structural seismic margins at these stations being significantly better (or worse) than those at HPB. The generic observations presented below on robustness and conservative methodology are applicable.

Since systems are generally qualified by walkdown techniques, the SQUG walkdown methodology provides confidence that the magnitude of seismic event required to cause system failure is normally well in excess of that likely to be experienced at any location in the UK.

Generic Observations

While findings of the HPB assessment are not individually applicable to the rest of the fleet, the expert panel considered that similar issues may be expected to arise at other stations. Ongoing LC28 inspections (supported by EDF Energy Civil Design Group) are considered satisfactory in maintaining confidence in the continued seismic withstand capability of civil structures. Continued confidence in the seismic resilience of systems is reliant on a variety of station personnel in the maintenance of good housekeeping, satisfactory equipment reinstatement following maintenance, and the addressing of plant degradation issues such as corrosion: as above these are very much normal business drivers, but they do underwrite the identified margins of safety for beyond design basis events. The expert panel review has not identified any major shortfall(s) which might suggest that ‘normal business’ is not an appropriate approach to address such issues.

It should be acknowledged that the discovery and sentencing of defects or abnormal conditions (in some cases by the safety case anomalies process – when appropriate) continues to occur as ‘normal business’ across the sites. However, the first phase of triennial ‘zonal hazards walkdowns’ in support of PSR3 is already underway as a ‘normal business’ process and aims to enhance the awareness and rectification of identified defects and issues which are likely to degrade nuclear safety.

The potential for degradation of seismic margins in liquid (fuel oil, feed water) storage tanks which have been subject to corrosion is recognised across the fleet and action is in hand to address the issue. The issue was initiated by observation of excessive corrosion in a condensate storage tank at SZB (CR 771481). Subsequent routine evaluations (REVL 796196) across the fleet have identified all safety-related liquid storage tanks. Maintenance and inspection practices have been found to be inconsistent and in need of improvement. A new Company Technical Standard (CTS) addressing corrosion is in preparation, and will provide mandatory measures aiming to support maintenance of satisfactory material condition of such storage tanks, thereby maintaining the seismic withstand capability (and seismic margins). This aspect is continuing as normal business with ONR being informed of progress at Level 4.

The seismic integrity of the AGR graphite cores remains an issue which is handled under normal business and takes specific account of ageing effects which have the potential to modify the seismic resilience of the graphite core and core restraint. The existing core and core restraint safety cases for the AGRs seek to demonstrate the absence of a cliff-edge at the design basis boundary not by quantifying a margin, but by demonstrating that some degree of failure is tolerable before adequate control rod entry and PTC of both core and fuel would become ineffective. The cases are supported by inspections which seek to support their continuing validity.

The expert panel seismic SQEP judgement is that the approach to seismic safety cases across the fleet is conservative - i.e. compliance with design codes implies the presence of margins and the seismic hazards used for bottom line assessment are considered to be conservative compared to 'best estimate' site-specific 10^{-4} pa seismic hazard. SQEP judgement (based in part on the work to support STF-2) is that around a 15% margin is likely to be present in respect of the seismic hazard assessment level vs. site specific seismic hazard.

6.5.2.1.4 Seismic Hazard Resilience Conclusions

The overall conclusion is that the seismic design bases of the fleet are generally sound. As may be expected, for the more recent sites, in which the seismic hazard has been integrated into the plant design, there are judged to be significant margins against the 10^{-4} pa seismic event. The position at the older stations is less robust but nevertheless acceptable in terms of risk. Margins against the 10^{-4} pa seismic event are considered to be most limited in respect of structures - and in such cases, arguments made in the relevant seismic safety cases have claimed conservatism in respect of the seismic hazard analysis together with structure ductility. ALARP arguments, presented in the seismic safety cases for the older sites are considered to remain valid. While there are a number of individual items which are identified and addressed as part of normal business, including PSR, the key systematic shortfall identified in the HPB pilot relates to 'housekeeping' i.e. the maintenance of consistency between day-to-day management of the plant configuration with the requirements of the safety case. As the stations age, so the significance of maintenance of adequate material condition increases.

It is intended that a separate learning brief will be produced by EDF Energy to summarise all aspects identified in the complete set of EDF Energy JER workstreams which are relevant to improving the maintenance of the hazards safety case integrity. It is intended that this will be communicated to all stations in 2015, however key aspects have been discussed and disseminated through the newly established EDF Energy hazard governance arrangements.

6.5.2.2 External Flooding

As described above at the end of Section 6.5.2, this sub-section focuses entirely on the coastal flooding aspects of the overall External Flooding Hazard, while pluvial and fluvial flooding are dealt with in the generalised Weather Hazard as discussed in sub-section 6.5.2.3. For all stations, a clear margin of safety has been quantified between the coastal flooding hazard water levels and the key safety related plant.

Updated Hazard Assessments

New coastal flooding assessment studies have been undertaken (by AMEC/Royal Haskoning) for all EDF Energy stations, considering the effects of 1 in 10,000 year flooding scenarios. The initial round of reports included a variety of approximations and conservatisms, as the intent was to provide a relatively quick updated assessment of the hazard magnitude.

This initial round of reports confirmed that the existing design basis remained secure for HNB, TOR, HPB and SZB.

The remaining stations are each covered in more detail below.

Dungeness B

For DNB, the initial analyses confirmed a within design basis safety case challenge, and the safety case anomalies procedure was applied in Dec 2012 which confirmed that the case for continued operation was apparent and ALARP. This was based on a confirmed line of protection for post-trip cooling, improved focus on forewarning and a committed programme of work to further mitigate the threat. This ongoing programme included more detailed analyses of the coastal flooding hazard, physical simulations of the behaviour of the shingle bank sea defence which fronts the station site, along with optioneering and implementation of additional flood protection measures.

The additional more detailed analyses reconfirmed the challenge to the design basis assumptions, for the frequent coastal flooding hazard, and subsequently the operational decision was taken to shut down both Units to remain in positive control. It is noteworthy that the more developed analyses confirmed an increased level of threat from outflanking, as compared to over-topping of the sea defence offered by the shingle bank.

A project was then established to support the recovery through the delivery of a significant programme of improvements to the coastal flooding protection measures. The work includes:

- Construction of a new flood defence wall around the site, which has now been completed and which will also be qualified to maintain a dry site (with margin) during the most onerous 1 in 10,000 year coastal flooding challenge;
- Improvements to be undertaken to provide reinforcement to the shingle bank to enhance its physical resilience to a prolonged severe sea state (1 in 10,000 year coastal flooding challenge);
- Flood-proofing features such as sealing of low-level building penetrations and the addition of non-return valves to building drains to prevent water ingress through them thus bypassing the wall;
- Provision of dam boards to provide additional resilience together with enclosures for some equipment. Installation of plinths to raise the level of some equipment to preserve operability in the event of localised pooling of water on the site (see sub-section 6.5.2.2).

Heysham Site (Heysham 1 and Heysham 2)

The initial analyses confirmed a within design basis safety case challenge (albeit to a much lesser extent than at Dungeness), and the safety case anomalies procedure was applied in Dec 2012 which confirmed that the case for continued operation was apparent and ALARP and also that the analyses contained significant conservatisms with respect to predicted over-topping, and that with a more representative approach the justification for continued operation remained secure. A commitment was made to develop the flooding analyses to provide a more representative assessment. These more detailed analyses have now been delivered, confirming a level of design basis safety case challenge. As such, the safety case anomalies procedure was again applied which confirmed that the cases for continued operation remained apparent and ALARP. The basis of this justification was the demonstration of the operability of the requisite lines of PTC protection for the frequent and infrequent hazards, along with enhanced preparedness arrangements. It is again noteworthy that the more developed analyses confirmed an increased level of threat from outflanking rather than over-topping of the seaward sea wall defences.

At HYA, the challenges are to the main CW pumphouse and the Low Pressure Back-Up Cooling System (LPBUCS) building. A flood wall has been constructed around the LPBUCS compound and localised improvements are being made to the CW pumphouse with expected completion in Q2 2015.

For HYB the level of design basis safety case challenge was low, with refined flood analysis not identifying any significant on site flooding, however improvements already being implemented under JER have enhanced margin and optioneering is being carried out to determine the extent of additional flood protection measures to be implemented for some plant areas.

Hartlepool

The initial suite of flooding assessment studies demonstrated that the position with respect to wave overtopping and resultant flooding was acceptable but with little margin to widespread but shallow flooding in the most extreme 1 in 10,000 year event. As a prudent and practicable measure, EDF Energy committed to a small increase in the height of the secondary flood barrier wall to increase resilience; this modification was completed in 2014.

In addition, it was identified that further flooding analysis should be commissioned, making use of understanding gained from the work on DNB and HYA/B, to reconfirm the margins afforded by the improved sea defences. However, it has been decided to review specific areas of development and learning relevant to the initial modelling undertaken, to allow a more risk-informed decision to be made, prior to commissioning further resource intensive work. This additional commitment will ensure that EDF Energy allocates resource in a risk-informed manner, and the subsequent decision and supporting rationale will be reported to the ONR as part of routine and ongoing discussions during the first half of 2015.

HNB, TOR, HPB and SZB

Notwithstanding the focus on DNB, HYA, HYB and HRA described above, consideration will be given to further flood analyses for the rest of the fleet, recognising the learning from work undertaken on the other stations and also the significant margins already evident against the flooding hazard i.e. decisions on whether or not to progress additional potentially resource intensive and expensive work will be founded on consideration of dynamic ALARP. Following the definition of the programme for the additional HRA flooding studies, EDF Energy will hold a review and decision-making workshop to consider the flooding assessments, flooding safety cases and measures taken to improve flood defences as a whole, and determine whether further studies are required. If further analyses are to be undertaken, the timescales for them and any follow-up work may be lengthy e.g. 2015 or later. This is judged acceptable because these studies would be of benefit from the viewpoint of making the coastal flooding safety case analyses consistent across the EDF Energy fleet rather than to address any shortfall in the current safety case position.

Forewarning of Coastal Flooding Risk

Additional severe weather forewarning systems have been provided to all EDF Energy stations (the Met Office's VisualEyes and Safesee systems) to ensure that station staff are aware of approaching severe weather, such as that which could cause or exacerbate flooding hazards. This will aid staffs' ability to ensure that suitable preparations are made, including placement of dam boards if appropriate.

In addition, there has been a focus on the adequacy of fleetwide preparedness procedures. A review of such procedures has been undertaken and is described in the weather hazards sub-section below.

Tsunami

For completeness, it should be noted that the tsunami hazard is specifically addressed in the response to IR-10. This refers to a new review of tsunami risks to EDF Energy sites which shows that the credible tsunami hazard to EDF Energy stations is limited, and is bounded by the storm surge scenarios considered in the station safety cases' design bases.

6.5.2.3 Weather

The approach taken to other natural hazards of relevance to this response is to consider them under the heading of "Weather Hazards". Traditionally, the safety cases for the EDF Energy sites have treated external hazards individually, but in the case of extreme wind, extreme ambient temperatures or extreme rainfall giving rise to the pluvial external hazard, there is likely to be a causal link such that the hazards may occur concurrently to some extent. Indeed this is also true for the external coastal flooding hazard discussed in sub-section 6.5.2.2 above, because the biggest coastal flooding challenge is likely to be associated with extreme low barometric pressures and high winds (large storm surges and large waves) which themselves give rise to severe storm conditions. Unlike the approach to coastal flooding, however, where the objective is to maintain a "dry site" for the other weather-related hazards their effect on the site cannot be prevented and safety has to be assured by confidence in dealing with the outcomes/consequences. The causal link means that a design basis (1 in 10,000 year) storm will not present individual hazards as large as in the individual hazard design basis safety cases. This offers a margin of safety which has been appropriately quantified.

Extreme weather-related events are, however, forecastable. This means that there is an opportunity to reduce the effects and consequences of the hazard by preparing for its arrival and managing the plant in such a way as to increase resilience against the challenge presented by the hazard.

This sub-section describes in turn the main safety-driven developments in mitigating the potential consequences from severe weather hazards, with a particular focus on improving preparedness to deal with them. It then describes analytical work which is being progressed to confirm that our understanding of the weather hazard magnitudes is adequate to inform both the design and preparedness defences against their potential consequences.

Preparedness

As per the above, the main focus in relation to reviewing the existing EDF Energy arrangements with respect to extreme weather has been on the adequacy of such preparedness activities. Three specific workstreams have been progressed:

(1) Fleetwide site-specific workshops reviewing the adequacy of on-site arrangements in response to extreme weather and raising awareness of their importance (which was reinforced to very good effect by the meteorological conditions late 2013/early 2014);

(2) Fleetwide deployment of improved forecasting systems VisualEyes and Safesee;

(3) Fleetwide review of extreme weather preparedness procedures.

Activities (2) and (3) were initiated following identification during the fleetwide workshops of (1). Each of these workstreams is described in more detail below.

(1) Fleetwide site-specific workshops reviewing the adequacy of on-site arrangements in response to extreme weather

The intention of these workshops was to present some scenarios where sites would be challenged in terms of both a summer storm (sudden thunder storms with significant rainfall) and winter storm (sea surge, driving winds and rainfall). The workshop attendees, comprising the role holders with the key responsibilities for preparation and direct response to these weather-related challenges, both on-site and off-site, were then taken through some indicative timelines and challenged with respect to the adequacy of the site arrangements. This challenge deliberately started at a level seeking to confirm resilience to within design basis events, greatly aided by direct OPEX and personal testimony, and then incrementally increased the level of challenge in terms of the hypothetical scenarios which may be faced during extreme weather events.

This fleetwide study concludes that in general our arrangements on site are robust. Where opportunities for further enhancement have been identified, these have been delivered as part of the JER programme. Three such examples include the fleetwide deployment of VisualEyes and Safesee, the fleetwide review of weather preparedness procedures to confirm and share best practices, and the review of weather stations, all of which are described further below.

(2) Fleetwide deployment of improved forecasting systems VisualEyes and Safesee

Following the workshops described above, a review was undertaken to identify current industry best practice with respect to weather and sea-state forecasting technology. This led to the identification of the Met Office forecasting tools VisualEyes and Safesee, which provide detailed meteorological and sea state forecasting, together with the ability to set action / warning levels specific to each site to assist in the preparedness decision-making processes. These web-based tools have been deployed fleetwide, along with the placement of a 10-year contract with the Met Office to provide immediate 24/7 support and ongoing maintenance and upgrade support.

Initial feedback from the EDF Energy sites confirms that these enhanced tools have proven effective during late 2013 and early 2014 storms encountered around the UK.

(3) Fleetwide review of extreme weather preparedness procedures

In addition to the importance of securing good quality forecasting data, it is equally important to have clear procedures which make use of this data to effectively support decision-making in readiness of severe weather. Such effective decision-making will greatly reduce the level of threat posed by the weather hazard, both from a nuclear and industrial safety perspective. Therefore, a fleetwide review of extreme weather preparedness operational procedures has been undertaken, with the intention of confirming and sharing best practices.

The key aspects addressed include securing buildings, ensuring good supplies of consumables etc. when the forecasting systems give the alert that a significant weather hazard is likely to affect the site, including additional provisions made as part of the overall JER programme (see below). Whilst recommendations have been made to enhance the effectiveness of the site-specific procedures, along with higher level governance improvements, the overall conclusion reached is that the current preparedness procedures are adequate. The recommendations identified will be taken forward as part of normal business, and a programme will be confirmed within 6 months of this close-out report.

Existing Safety Case Resilience

The design basis for weather hazards has been defined with the specific requirement to consider the following external weather hazards; external flooding (including rainfall), extreme wind, extreme ambient temperature, lightning and drought. It is noted that lightning and drought hazards are currently being considered as part of the ongoing PSR2 Periodic Safety Review Identified Corrective Action (PICA) programme of commitments, and noting the agreed scope of response to this STF as set out in Section 6.5.1, are not considered further here.

The safety case for external flooding is based on assessment of the hazards presented by coastal, pluvial and fluvial flooding. Coastal flooding has been considered comprehensively in sub-section 6.5.2.2 above. Fluvial flooding is not a significant threat for EDF Energy sites. The pluvial flooding safety case is based on estimates of extreme rainfall, which are being revisited as described below, but additional resilience measures have also been taken: these are partly associated with the short-term preparedness arrangements, and partly associated with improved standing arrangements to reduce the risk arising from the hazard.

The design basis for extreme winds is based on adherence to standards and codes, with continuous review and oversight through well established process within EDF Energy, and supported by SQEP resource. The application of codes and standards ensures the provision of margins to provide confidence with respect to uncertainties at the design basis, i.e. 1 in 10,000 year return frequencies.

Resilience to extreme ambient temperature is demonstrated through equipment qualification, and ensuring robust procedures which provide forewarning and ongoing protection as the temperatures (high or low) become more challenging. The associated timescales over which temperatures become potentially challenging affords the opportunity to “manage” the increasing threat through ongoing surveillance and associated real-time decision-making, e.g. antifreeze addition, pre-warming, embargoing lifting activities etc. As such the preparedness workstreams described above provide continued confidence in the adequacy of these arrangements in confirming resilience to both design and beyond design basis events.

Improved Resilience Provided against External Flooding Hazards

At all EDF Energy sites, the JER programme is providing permanent and deployable flood resilience measures to key buildings in order to protect systems and plant against some degree of on-site flooding and is described in the following paragraphs. The JER flood resilience measures provide resilience against BDB flood events by limiting water ingress as far as is reasonably practicable. It is not formally claimed as a line of protection in the safety case. It is particularly noted that, for the DNB updated safety case, equivalent additional resilience measures have been procured and deployed, but this has been done outside of JER, under normal arrangements appropriate for claimed lines of protection.

The JER flood resilience measures consist principally of (a) new facilities to place dam boards around entrances to buildings (or in some cases flood barriers within buildings), to hold back flood water; (b) sealing of penetrations into the building, to prevent water ingress; (c) fitting non-return valves in building drains to prevent water coming up through them into the building. The flood resilience measures are designed to preserve equipment operability in the presence of static flood water up to approximately 1m depth.

The rationale for applying the JER flood resilience measures has been to add them to particular facilities (that is, buildings containing plant that is part of particular systems/functions), broadly categorised as:

A: Emergency Generation Buildings

B: Electrical Distribution / back-up systems (e.g. Batteries, Motor Generators)

C: Boiler Feed and Auxiliary Feed

D: Ground Level Fuel Ponds

E: Emergency Control Centres (ECCs) and ground floor back-up generation / Heating Ventilation and Air Conditioning (HVAC)

F: Alternative / Emergency Indication Centres (AICs /EICs) and ground floor back-up generation / HVAC

Based on the philosophy of maintaining operability of such facilities, for each station a set of buildings has been selected to have the JER flood protection added; the buildings have been identified through consultation with station staff and detailed on-site walkdowns. Some buildings which could have been included amongst those to receive the flood protection, on the basis of the rationale above, have not been included for reasons such as the buildings being at no significant risk from flooding, or the plant in the building not being bottom-line for the station concerned.

JER resilience measures also include the provision of pumps for de-watering of flooded areas and buildings in the event that some flood water does ingress.

The continued importance of maintaining good drainage routes on-site has also been identified within the weather workshops, described above.

Resilience against Combinations of Weather Hazards

The above assessment deals with the identified weather hazards individually, but clearly there are causal links which need to be taken into account, such that these individual hazards can act in unison, within associated storm scenarios. The reviews undertaken post-Fukushima have confirmed that allowance has been made of such weather combinations, but that this has not been to a common standard across the fleet. In recognition of this, Hazards Governance activities have better defined the weather combinations which should be considered within safety cases supporting operation across the EDF Energy stations.

It is also worth noting that the considerations provided within the existing safety justifications of each of the individual hazards, at the design basis boundary return frequency of 1 in 10,000 years, will most likely bound the combinations of individual hazards, representative of an equivalent 1 in 10,000 years storm. Therefore, the consideration of these individual hazards provides confidence with respect to resilience against combinations. The margins between the most likely design basis storm combinations and the individual design basis hazard magnitudes addressed by the safety case have been quantified as appropriate.

Lastly, further confidence can also be taken from the fleetwide weather workshops undertaken, and described above.

Re-confirmation of design basis weather hazard magnitudes

Notwithstanding the above confidence with respect to the existing design basis resilience to weather hazards, a further significant workstream was initiated whereby the Met Office was commissioned to undertake fleetwide Extreme Value Analysis (EVA) for each individual site. These EVAs have used the latest methodologies, as recommended by the Met Office, along with the latest data available. Wind speed, rainfall and extreme ambient temperature magnitudes have been predicted, representative of hazard return frequencies of 1 in 50 years, 1 in 100 years, 1 in 1000 years, and 1 in 10,000 years.

There has been no attempt to derive predictions beyond the design basis, noting that at the 1 in 10,000 years return frequency there is already inherent significant uncertainty. This level of uncertainty would not lead to a credible assessment of margin beyond the design basis boundary. Instead, confidence with respect to the absence of a cliff-edge will be assured through the appropriate consideration of the bandwidth of predictions for the 1 in 10,000 years events.

Technical Review of the suite of EVA reports is still ongoing at the time of issue of this close-out report. A key aspect of this ongoing Technical Review is the review and comparison of the Met Office approach and supporting methodologies against the other ongoing activities within this area of significant scientific interest and development. These other relevant activities include EDF R&D activities, Nuclear New Build studies, and collaborative industry-wide R&D programmes. Awareness of these other activities is an integral part of the review and acceptance of the Met Office work. A commitment is therefore made to conclude the review of available methodologies, for the prediction of weather hazard magnitudes, such that an EDF Energy agreed position is reached by end of Q2 2015.

This overall work programme will be overseen by the newly established EDF Energy Hazards Governance Board, which will ensure an effective transition into normal business. If, upon agreement of the most appropriate methodology, the design basis is challenged for any of the sites, normal business process will be applied through the application of the safety case anomalies procedure. Whilst this will delay the ability of EDF Energy to present an updated position with respect to confirmed margins for the weather hazards, this is judged to be the appropriate way forward, noting the importance of ensuring that the weather hazards being considered are truly representative for each of our sites, making full use of the current accrued scientific knowledge and understanding.

6.5.3 Finding Conclusions

This STF requested that the Licensees should further review the margins for all safety-significant SSC, including cooling ponds, in a structured systematic and comprehensive manner to understand the beyond design basis sequence of failure and any cliff-edges that apply for all external hazards.

Noting the very broad potential interpretation of this Finding, which could lead to very large numbers of Systems, Structures and Components that would need to be assessed, and very significant resource demands which could be grossly disproportionate in relation to the benefits realised in terms of demonstrating the requisite resilience to external hazards, post-Fukushima, a number of further discussions were held between EDF Energy and ONR to confirm and agree the scope for this STF. This scope is defined in 6.5.1 above, confirming a focus on a detailed consideration of the external flooding, seismic and weather external hazards.

It is judged that this approach continues to fully satisfy the intent of ENSREG, and the requirements of the "stress tests", in terms of reconfirming the safety margins of the EDF Energy nuclear power plants in light of the events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident. These margins have been appropriately quantified.

The key conclusions reached, supporting closure of this STF are:

- The existing design basis remains secure, with demonstrable margins to accommodate beyond design basis scenarios
- Opportunities have been taken to further improve resilience to hazards, and robustness of arrangements both within and beyond the design basis
- Where there are identified areas for continued focus, to underwrite existing judgements and further improve EDF Energy arrangements, these are considered to be secure within normal business.

6.6 Stress Test Finding 6 Close Out Report

Finding STF-6: Licensees should review further the margin to failure of the containment boundary and the point at which containment pressure boundary integrity is lost should be clearly established for the advanced gas-cooled reactors (AGR) and Magnox stations.

6.6.1 Overview

It may be appreciated that STF-6 is effectively a subset of STF-5. Whereas the latter has been taken to apply to all systems structures and components which comprise the 'bottom line' of protection, STF-6 applies specifically to those structures and components which are required to maintain the integrity of the primary circuit pressure boundary in the event of severe natural hazards.

The overview presented in the response to STF-5 is generally applicable to STF-6 and is not repeated here. However, it may be noted that while STF-6 is specifically applicable to the Advanced Gas-cooled Reactors (AGR), STF-5 is also applicable to Sizewell B.

The ONR also provided supplementary material to its National Stress Test report which provided further guidance on its expectation for the response. Specifically for STF-6, ONR expected that any review should consider components required to sustain vessel pressure following a severe event, particularly in respect of information regarding the survivability of the vessel and its penetrations.

It is also important to recognise the link between this stress test finding (STF-6) and STF-17. The response to STF-17 considers supporting systems which cool the pre-stressed concrete pressure vessel and addresses their resilience to hazards within and beyond the Design Basis (DB). In contrast, the response to STF-6 applies to the structures and components which directly resist primary circuit gas pressure.

6.6.2 Response

In view of the above distinction between STF-6 and STF-17, it may be appreciated that the response to STF-6 needs to address only the pressure vessel, penetrations and unisolatable sections of pipework which run externally to the vessel. These are essentially 'passive' items. The resilience of the systems associated with cooling the pressure vessel is addressed separately in the response to STF-17 and is not considered in the response to STF-6.

It may also be appreciated that the range of natural hazards which require detailed consideration is also different between STF-6 and STF-17. For all AGRs the pressure vessel, penetrations and unisolatable sections of primary coolant pipework are each located within the reactor building. Also (with the exception of the vessel cooling system which is addressed separately in the response to STF-17) these structures and components do not require support from other systems i.e. they are essentially 'passive' in providing their pressure boundary safety function. In the context of providing a response to STF-6 it may therefore be argued that natural 'weather-related' hazards do not present a credible challenge to the integrity of the primary circuit boundary. It follows that the only natural hazard that requires consideration in the response to STF-6 is the seismic hazard – and this is discussed further below.

6.6.2.1 Hinkley Point B Single Station Seismic Study

EDF Energy's approach to addressing STF-6 has been to carry out a detailed study at a single nominated site (Hinkley Point B, HPB); chosen because it is considered to be suitably representative of the older AGRs which did not explicitly address the potential for natural hazards in their original design. The expectation was that single station study might reveal both generic and station-specific issues; the balance between the two would influence the manner in which the Stress Test Finding was to be addressed for other AGRs. The outcome of the HPB study is summarised below together with the implications for the rest of the AGR fleet. Because of the overlap with the requirements of STF-5, the scope of the study covers both STF-5 and STF-6 and the output has been reported in a single document. The scope of the study was shared with ONR prior to commencing the work.

EDF Energy commissioned Atkins and ABS Consulting to carry out the HPB study. The work consisted of background research, reviewing the HPB seismic safety case, as well as performing seismic walkdowns at HPB. These walkdowns were carried out by experienced Seismic Qualification Utility Group (SQUG) engineers.

6.6.2.2 Outcomes of the Hinkley Point B Study

In respect of items which comprising the primary circuit pressure boundary or structures whose failure could challenge the integrity of the pressure boundary, it has been judged that the Pre-stressed Concrete Pressure Vessel (PCPV), Central Block, Reactor Services Building, Circulator Hall primary steelwork and Charge Hall primary steelwork structures are robust and either have ductility or have sufficient Beyond Design Basis (BDB) margin and are therefore considered not susceptible to cliff-edge effects near to the DB boundary.

Gas by-pass penetrations and the stand-by filling penetration are the only penetrations where the seismic case is stated to be bounding. A BDB event could increase the seismic loading significantly and erode the margins. However, the limiting defect sizes that would weaken these penetrations such that a failure might occur are detectable. In an assumed defect free condition of these penetrations, there is a large margin for BDB behaviour.

The resilience of small bore pipework included in the primary circuit pressure boundary review has been assessed via seismic walkdown – and the general observation made in the response to STF-5 is applicable to this particular aspect of the STF-6 response. The walkdowns established the seismic ruggedness of the bottom line systems and components (including small bore primary circuit pressure boundary pipework) and is presented in detail in the review report. No single system or component has been identified with a ruggedness rating of 'Low'. However, a number of systems and components have been assessed to have a 'Medium' ruggedness rating, resulting in a number of minor recommendations being included in the review report. These are typically associated with defective or missing equipment/pipework anchorages although there were also a number of recommendations which may be considered to be associated with 'housekeeping' lapses. It should be noted that none of the identified recommendations were considered to pose an immediate threat to nuclear safety. The review recommendations have been included on a 'PSR3/JER Hazard Issues Database' at HPB which also includes recommendations arising from the STF-4 seismic/fire walkdowns. Database entries have been actioned or allocated to Condition Reports which will be addressed under normal business. The process mirrors that being followed for the zonal hazards walkdowns which are currently supporting PSR3.

When the charge machine is connected to the reactor, forming part of the pressure boundary, there is a known reduction in the seismic margin. Increasing the margin is the subject of ongoing modifications and safety case development under 'normal business'.

6.6.2.3 Implications of the Hinkley Point B Study for the rest of the fleet

An 'expert panel' comprising seismic and safety case SQEPs was convened in late January 2014 to assess the implications of the HPB study for the rest of the fleet. The expert panel considered the HPB study in the context of STF-5 and STF-6 concurrently. The main observations made by the expert panel are summarised below for both station-specific and generic aspects (AGR only) relevant to STF-6.

Heysham 2 and Torness

Heysham 2 and Torness were designed with a seismic event withstand capability significantly greater than that appropriate for the 10^{-4} per annum site-specific seismic hazard at these locations. (Further information is presented in the response to STF-5.) It may be concluded that at HYB and TOR, no further general analytical assessment work on margins is considered appropriate except on a case by case basis to address material degradation (normal business).

Hunterston B

While there are some differences in bottom line post trip cooling plant, the primary coolant pressure boundary structures and pipework are similar between HNB and HPB. The expert panel considered that the outcomes of the HPB review were broadly applicable to HNB, noting that the 10^{-4} per annum site-specific seismic hazard at HPB bounds that at HNB.

Hartlepool and Heysham 1

Seismic resilience of the pressure vessel is receiving specific attention as a follow on action from NP/SC 7676 (ECs 334463/335739 – October 2013 NSC). Revised seismic analysis indicates that peak loadings in the radial keys between the PCPV and support structure could be higher than previously assessed, and that damage to the radial keys cannot be ruled out. This is judged to be acceptable based on the conservatisms in the seismic event characterisation and the acceptable consequences of such damage. The increased radial key loadings are transferred into the PCPV support walls, and are greater than those for which the support walls have been previously qualified. A simplified code based assessment has been undertaken and it is judged from this initial result that the skirt is likely to be able to withstand the seismic loads. However, it has been recommended that a detailed analysis of the support wall under these loadings should be completed. This will be progressed as normal business.

The expert panel did not identify any additional items of significance in relation to the seismic integrity of the pressure boundary. The responses to STF-17 (and FR-4) may be noted to be of particular relevance to the resilience of systems supporting pressure vessel cooling at HYA and HRA.

Dungeness B

In respect of primary circuit pressure boundary for Dungeness B, the expert panel noted that the issue discussed above for HYA/HRA (radial key failure) was potentially relevant to DNB since the PCPV is similarly located upon support walls. A subsequent review of the safety case revealed that the central pillar and keyed torsional restraints are predicted to fail in the bottom line seismic event and no credit for them is taken in the DNB dynamic analysis. While the analysis supporting the current safety case identifies that a significant margin is attributable to the PCPV, it allocates a factor of safety equal to unity with the castellated PCPV supports. It is therefore judged that it is unlikely that significant analytical margins are or will be demonstrable against the bottom line assessment standard adopted for DNB. However, this must be balanced against the SQEP judgements that the approach to the seismic safety cases across the fleet is conservative - i.e. compliance with design codes implies the presence of margins and the seismic hazards used for bottom line assessment are conservative compared to 'best estimate' site-specific 10^{-4} pa seismic hazard.

Generic Observations

The HPB study identified that continued confidence in the seismic resilience of systems is reliant on a variety of station personnel in the maintenance of good housekeeping, satisfactory equipment reinstatement following maintenance, and the addressing of plant degradation issues such as corrosion. In the context of the components comprising the primary circuit pressure boundaries of the AGRs, this observation is directed at primarily at the penetrations and pipework external to the vessel rather than the PCPV itself. While the above are very much normal business drivers, they nevertheless underwrite the identified margins of safety for BDB events. The expert panel review has not identified any major shortfall(s) which might suggest that 'normal business' is not an appropriate approach to address such issues.

6.6.3 Finding Conclusions

The overall conclusion is that in respect of the primary circuit pressure boundary the seismic design bases of the AGR fleet are generally sound. As may be expected, for the more recent sites, in which the seismic hazard has been integrated into the plant design, there are judged to be significant margins against the 10^{-4} pa seismic event. The position at the older stations is less robust but nevertheless acceptable in terms of risk. ALARP arguments, presented in the seismic safety cases for the older sites are considered to remain valid.

6.7 Stress Test Finding 7 Close Out Report

Finding STF-7: Licensees should undertake a more structured and systematic study of the potential for floodwater entry to buildings containing safety-significant structures, systems and components (SSC) from extreme rainfall and / or overtopping of sea defences.

6.7.1 Overview

Flooding of the site and its effects on plant was central to the events at Fukushima. Whilst flooding at Fukushima was specifically due to a tsunami, which is considered in EDF Energy's response to IR-10, this response to STF-7 considers flooding hazards in general. EDF Energy has undertaken a thorough review of external flooding, its effects and the robustness of safety cases and defence in depth against it, and is taking all action appropriate to ensure adequate safety against flooding. It is considered that this satisfies the intended outcomes of the Finding as written; that is, a more robust safety position in respect of floodwater affecting essential safety functions.

EDF Energy has commissioned, from independent specialist suppliers, new flooding assessments for all station sites, considering possible coastal flooding (from the sea); rainfall (pluvial) flooding, and flooding from rivers (fluvial) with reference to 1 in 10,000 year (infrequent) flooding events. The initial assessments included a variety of simplifications and conservatisms; where the initial assessments have identified that flooding may occur that could threaten essential plant, further assessments have been undertaken.

EDF Energy is also undertaking a programme of adding flood defences to buildings containing key plant, principally (a) the addition of deployable dam boards and the permanent fixing structures to enable mounting of the boards, and (b) the addition of protection for the same buildings against water ingress through other above and below ground penetrations, such as trenches and ducts; this includes sealing cables and pipe penetrations, and fitting of non-return valves to building drains. These measures are generally intended as risk mitigation measures against Beyond Design Basis (BDB) events rather than to be claimed as lines of protection in nuclear safety cases.

Additional flood protection measures have been and are being added at some stations in response to the EDF Energy Japanese Earthquake Response (JER) programme flood assessments. The most work is being undertaken at Dungeness B (DNB), notably including the building of a new sea defence wall around the site and reinforcement of the shingle bank; work is also being undertaken at Heysham 1 (HYA) and also at Hartlepool (HRA), where the existing wall has been raised in height and openings and penetrations sealed.

The review of flooding has also included consideration of rainfall flooding and combined rain and wind events in the JER extreme weather workshops and in the Extreme Value Analysis work undertaken by the Met Office.

Other specific aspects are also addressed by EDF Energy under CSA-018 (drainage in general), and CSA-013 (drainage and rainfall at DNB).

6.7.2 Response

6.7.2.1 Coastal Flooding

New flooding assessment studies have undertaken (by AMEC/Royal Haskoning) for all EDF Energy stations, considering the effects of 1 in 10,000 year flooding scenarios in 2035. The initial round of reports included a variety of approximations and conservatisms.

With regard to coastal flooding, from EDF Energy's review of the initial reports some stations (Hunterston B (HNB), Torness (TOR), Hinkley Point B (HPB) and Sizewell B (SZB)) were assessed as low-risk insofar as the studies showed significant margin to any effects on buildings and plant based on the 1 in 10,000 year event. Other stations (DNB, HYA/B and HRA) were identified as requiring further work, as described in the following paragraphs. For DNB and HYA/B, more refined studies have been undertaken and have indicated needs for improved flood defences, which are being provided. For HRA flood defence improvements have been implemented to provide adequate margin.

The initial assessment at DNB was followed by a more refined second study which took greater account of the details of local topography and indicated extensive flooding in worst-case (infrequent) events. The station at one stage ceased operation; a Return To Service (RTS) Safety Case has been produced followed by a revised long-term Safety Case for flooding. A programme of work was implemented by EDF Energy, to resolve the issue and provide additional margin. DNB's site defences against coastal flooding have been improved and additional protection provided for specific buildings and essential plant. The work included; construction of a new flood defence wall around the site; provision of dam boards and flood-proofing features such as sealing of low-level building penetrations and addition of non-return valves to building drains to prevent water ingress through them; enclosures for some equipment or plinths to raise equipment's level. The new perimeter wall is qualified to maintain a dry site (with margin) during the most onerous 1 in 10,000 year external flooding event. In addition, further work is planned to provide reinforcement of the existing shingle bank, with completion expected in Q2 2015. Rainfall and drainage at DNB are also considered in more detail under CSA-013.

At HYA, the outcome of the refined flood analysis was broadly positive, in that the predicted water levels on site were much lower than those predicted by the initial assessment. However, the revised results did indicate localised flooding to the north side of the site resulting in an increased threat to the Low Pressure Back-Up Cooling System (LPBUCS) and Cooling Water (CW) pumphouse. As the existing safety case claims both systems an Interim Justification for Continued Operation (IJCO) was put in place whilst a flood wall was constructed around the LPBUCS compound and localised improvements are made to the CW pumphouse; these improvements are expected to be completed in Q2 2015.

For HYB refined flood analysis has not identified any significant on site flooding, however improvements already being implemented under JER will enhance margin and optioneering is being carried out to determine the extent of additional flood protection measures to be implemented for some plant areas. The analysis has shown that the extent of flooding will increase in the future due to climate change and further protection may ultimately be required. Noting that climate change is a gradual process further analysis is being undertaken to indicate the approximate time frame over which any change would occur. Any additional protection required will be identified and provided within normal business processes on an appropriate and conservative timescale.

At HRA, the results of the initial AMEC/Royal Haskoning study raised possible risks from coastal flooding (in 2035); the position with respect to wave overtopping and resultant flooding was marginal, and to be prudent EDF Energy has proactively progressed a programme to increase the height of the sea wall and restore margins, and to ensure the integrity of the wall, sealing openings/penetrations and ensuring that openings can be sealed closed. EDF Energy has also undertaken a programme of work to close building penetrations that could become water ingress routes and to provide dam boards, to protect buildings and their plant against external flood water. Further analysis may be commissioned, making use of understanding gained from the work on DNB and HYA/B, to reconfirm the margins afforded by the improved sea defences. (This will be undertaken in accordance with the scope agreed for STF-5, and will be reviewed and acted on in accordance with EDF Energy's normal due process).

For the stations not considered above (HNB, TOR, HPB and SZB), the need for any further flood analyses will be considered as part of normal business, but the risk is considered to be low.

6.7.2.2 Pluvial Flooding

Pluvial (rainfall) flooding has also been assessed in the AMEC/Royal Haskoning flooding reports, considering a 1 in 10,000 year maximum rainfall event. Whilst pluvial flooding could cause some flooding on-site (e.g. on site access routes), and around some buildings, it would not be sufficient to threaten essential plant. Also, JER Resilience work will provide additional protection to buildings against pluvial flooding. Rainfall is also included in the Met Office's Extreme Value Analysis (EVA) studies, which have used the best available information to predict maximum unlikely (1 in 10,000 year) rainfall events based on historical data.

6.7.2.3 Combined Severe Weather Scenarios

EDF Energy has researched combined weather hazard scenarios and identified particular combinations as credible and potentially capable of impacting EDF Energy stations; the weather combination most obviously relevant to flooding is the combination of wind and rain; wind damage to buildings can allow rain water to internally flood them and/or directly affect plant. (Note that storm surge flood modelling includes consideration of wind-driven waves above the still water level, according to recognised modelling norms which do not require a combination of both worst case storm surge and maximum wind-driven waves). EDF Energy's study is supported by Met Office research, including some station-specific studies - the most relevant to flooding considered high wind and heavy rainfall at HNB, concluding that these are mutually exclusive at high values, including high wind followed by heavy rain within 7 days; also that the results would be similar or (in hazard terms) less significant at other EDF Energy sites. The possibility of more significant combined wind and rain is noted as possible due to tornadoes, which have been considered in EDF Energy's severe weather workshops and in a specific tornado report albeit with a focus to date on wind loads on buildings.

As part of JER, workshops have been undertaken at all EDF Energy's station sites addressing severe weather hazards, their possible effects and the actions required of station staff in response; these considered flooding as a possible effect and identified some flood-related issues. The issues have been reviewed and sentenced (prioritised) within the EDF Energy's Design Authority workshops report, and all significant issues will be suitably actioned and resolved. All issues will be assigned to the most appropriate owners to progress their resolution.

The integrity of many buildings is also to be improved by JER flood-proofing measures (below).

Severe weather, including combined scenarios, is addressed more generally in EDF Energy's response to STF-5.

6.7.2.4 Flooding Resilience Measures Adopted at All Sites

At all EDF Energy sites, the JER on-site resilience programme is providing permanent and deployable flood protection measures to key buildings, to protect systems and plant against some degree of on-site flooding, as described in the following paragraphs. The JER flood protection is to provide resilience against BDB flood events by limiting water ingress as far as is reasonably practicable. It is not formally claimed as a line of protection in the safety case (though very similar measures at DNB to reduce risks from flooding, by providing defence in depth, are to be claimed in DNB's new flooding safety case).

The JER flood protection consists principally of (a) new facilities to place dam boards around entrances to buildings (or in some cases flood barriers within buildings), to hold back flood water; (b) sealing of penetrations into the building, to prevent water ingress; (c) fitting non-return valves in building drains to prevent water coming up through them into the building. The flood protection measures are to protect against static flood water up to approximately 1m depth. An exception is TOR, where coastal flooding has been assessed as not being a credible threat; to protect against limited local flooding due to rainfall, flood barriers have been provided for key buildings against a water depth of 0.3m, and it has been assessed that additional penetration sealing is not required.

The rationale for applying the JER flood protection has been to add it to particular facilities (that is, buildings containing plant that is part of particular systems/functions), broadly categorised as:

A: Emergency Generation Buildings

B: Electrical Distribution / back-up systems (e.g. Batteries, Motor Generators)

C: Boiler Feed and Auxiliary Feed

D: Ground Level Fuel Ponds

E: Emergency Control Centres (ECCs) and ground floor back-up generation / Heating Ventilation and Air Conditioning (HVAC)

F: Alternative / Emergency Indication Centres (AICs /EICs) and ground floor backup generation/ HVAC.

Based on the philosophy of protecting these facilities, for each station a set of buildings has been selected to have the JER flood protection added; the buildings have been identified through consultation with station staff and detailed on-site walkdowns. Some buildings which could have been included amongst those to receive the flood protection, on the basis of the rationale above (A-E), have not been included for reasons such as the buildings being already not at significant risk from flooding, or the plant in the building not being bottom-line for the station concerned.

JER has also provided pumps for de-watering of flooded areas and buildings in the event that some flood water does ingress.

6.7.2.5 Forewarning of Severe Weather

Additional severe weather forewarning systems have been provided to all EDF Energy stations (the Met Office's VisualEyes and Safesee systems) to ensure that station staff are aware of approaching severe weather, such as that which could cause or exacerbate flooding hazards; this will aid staffs' ability to ensure that suitable preparations are made, including placement of dam boards if appropriate.

6.7.2.6 Tsunami

The tsunami hazard is specifically addressed under IR-10. This refers to a new review of tsunami risks to EDF Energy sites. This shows that the credible tsunami hazard to EDF Energy stations is limited, and is bounded by the storm surge scenarios considered in station safety cases' design basis.

6.7.2.7 Drainage

Though station safety cases do not make formal claims on site drainage, the condition of drain systems is being addressed, as described under CSA-18. Site drains have been inspected and remedial action is being undertaken where necessary; it is also being ensured that site drain inspections are periodically undertaken in the future. Building drainage (including building roofs) has been considered in the severe weather workshops and identified issues are being addressed under appropriate business processes.

6.7.3 Finding Conclusions

Varied and substantial actions have been taken with respect to the flooding hazard. New flooding assessments have been produced, with further assessments where needed, and remedial action is being taken as necessary, with significant improvement implemented as high-priority activities. Follow-on work remains ongoing in some areas.

EDF Energy has pro-actively designed and implemented JER flood protection measures across the station fleet to add resilience in the event of on-site flooding and hence margin in event of BDB events.

The new Safesee and VisualEyes warning systems will provide stations with improved warning of severe weather and possible flood events, and hence aid their taking prompt mitigative action.

EDF Energy has also reviewed other angles such as severe weather as a cause of flooding, combined weather hazards, and tsunamis; further work is ongoing into the weather hazards, and all issues identified are being suitably managed. This is also the case with surveys and reviews of site drainage.

Hence EDF Energy has made a strong response to STF-7, undertaking not only new analyses but also significant work to ensure robust safety cases with respect to the flood hazard and to add resilience to beyond BDB that might cause flooding to occur. The JER resilience measures also add defence in depth against design basis events, and potentially against currently-unforeseen events. Regarding weather-related hazards, resilience measures may be deployed in advance of a severe weather scenario, whether or not the hazard is forecast to be beyond the design basis.

The following areas of work are currently ongoing (in summary):

- HYA: optioneering is ongoing in relation to possible additional flood protection measures, as part of the ongoing programmes delivering updated coastal flooding safety cases;
- Reviews are ongoing to assess the need for additional coastal flooding analyses for HRA, HPB, HNB, TOR, and SZB, taking account of learning from work undertaken in support of DNB, HYA and HYB;
- Flooding is an aspect of continuing work into extreme weather, including single-parameter Extreme Value Analysis and combined hazard scenarios, based principally on Met Office studies. It is similarly an aspect of the severe weather workshops and the issues that have been identified from those, all of which will be progressed to resolution either through normal business processes or other suitably-owned programmes.

Therefore, all aspects of STF-7 are either closed or transferred into normal business processes, as such this consideration is considered closed.

6.8 Stress Test Finding 8 Close Out Report

Finding STF-8: Licensees should further investigate the provision of suitable event-qualified connection points to facilitate the reconnection of supplies to essential equipment for beyond design basis events.

6.8.1 Overview

Event qualified connection points allow quick connection of essential supplies following a severe event. Learning from Fukushima demonstrates that following loss of on-site infrastructure, with the correct equipment and resources, plants can successfully reach cold shutdown. This can be achieved by restoring key functions such as power supply for control, instrumentation and essential electrics, and providing self contained skids for reactor core and fuel store cooling.

This Stress Test Finding (STF) relates closely to Interim Recommendations (IR) 18 and 19, regarding the need to review the provision of additional, diverse means of providing robust sufficiently long term independent electrical supplies and also coolant supplies on sites. This recommendation was also raised by EDF Energy's Japanese Earthquake Response (JER) programme as a Stress Test Consideration (CSA), following the ENSREG Stress Test.

6.8.2 Response

A number of site walkdowns were carried out to review the practicability of providing connection points to facilitate the reconnection of supplies to essential equipment for Beyond Design Basis (BDB) events. The findings from the walkdowns were discussed in workshops with representatives from each station and the Central Technical Organisation (CTO). Optioneering studies identified the most effective solutions to enable the quick and simple connection of off-site Deployable Back-Up Equipment (DBUE) to mechanical and electrical systems, to assist in the response operation of the Station following a BDB event.

A work package was developed which covered two main areas:

- Mechanical JER DBUE interfaces providing the capability to inject coolant into the primary and secondary circuits, reactor systems and fuel stores
- Electrical interfaces enabling the connection of DBUE generation equipment to restore power to instrumentation and key systems following a BDB event, energising boards likely to survive both seismic and flooding events.

The strategy to provide connection points for DBUE, provides:

- Rapid connection of JER DBUE on arrival at site
- Known connection points aligned to pre-determined DBUE lay down positions
- Greater awareness of options to the emergency control team
- Facilitates more focussed training opportunities
- Reduced operator resource requirements post BDB event
- Reduced risk of damage to critical station systems while attempting emergency engineering solutions post BDB event
- Connection points are seismically qualified for the infrequent event or to the equivalent level of existing plant and flood protected to, or raised above, the 1m level local to plant, which is well above the projected 10^{-4} flood level.

The connection points were identified and have been largely installed across the 8 UK reactor sites, with a small number requiring final connection on site, and provide the necessary points to connect the DBUE to support response actions. Fleet wide connection points and modifications include:

- Provision of connection points for the connection of cooling supplies to the Main Boilers at all Advanced Gas-cooled Reactor (AGR) sites, with permanent modifications completed at Torness, Hartlepool/Heysham 1 and Dungeness B. Modifications are ongoing at Heysham 2. At the other locations additional on-site apparatus is provided, enabling the connection to existing plant, post event
- Water tank connections providing quick hook up access and isolation to ensure desired control and use of water stocks, including supplying boiler feed and allowing header tanks to be refilled from other on-site townswater stocks and from the DBUE water treatment plant
- Pressure support connections to enable injection of off-site supplies of nitrogen to support repressurisation and natural circulation at the AGRs
- Plug in for low voltage (415V) electrical systems to support re-energising essential instrumentation and indicators and to support resealing operations at all sites
- 3.3kV connection points provided at all AGR stations with the primary intent to underpin the station 415V essential instrumentation and some limited support to electrical infrastructure through the 3.3kV distribution system, as part of a longer-term (post 72 hour) response strategy
- Both high and low voltage connection points include switchover boxes and cabling with connection to switchboards to be made on the day, post event. All electrical connection points and associated DBUE equipment are 'industry standard' and as such compatible with equipment readily available from commercial suppliers, giving further flexibility should it be required in a severe event
- Control and instrumentation connection points; the pre-installed Continuous Emergency Monitoring Systems (CEMS) and compatible DBUE Deployable Communications and Information System (DCIS) give resilience and diversity of information networking at all sites and which is permanently installed at Sizewell B's (SZB) newly constructed Emergency Response Centre
- Seismic enhancement of dry risers will enable delivery of water to the charge face to provide water for cooling purposes to the Buffer Store at AGR sites, other than Dungeness B which does not have dry risers
- Buffer store connections to support cooling operations have been installed where required, at Dungeness B, Hunterston B and Hinkley Point B.

The unique nature of EDF Energy's SZB Pressurised Water Reactor (PWR) requires a slightly different approach from the AGRs, with the following connection points being installed:

- Auxiliary Feed system - enables connection of the DBUE high pressure pump, capable of supplying cooling water (treated or sea water) directly to the secondary circuit
- Containment water injection - a connection point has been provided to connect the DBUE pump, capable of supplying water (treated or sea water) directly to the containment building to prevent the dry-out of water in the containment floor and provide corium cooling
- Clean Air Train System (CATS) connection will be completed during the next planned refuelling outage in RO14 – and will enable connection of back-up nitrogen supplies, sufficient to maintain adequate pressure in the system to allow long term operation of the valves
- Primary Coolant Connection will be completed during the next planned refuelling outage RO14 – and will enable the low pressure DBUE pump to feed water into the Primary circuit to provide borated water from the Reserve Feedwater Storage Tank (RWST) during the outage phase Mode 6 condition.

EDF Energy has ensured that off-site DBUE is fully compatible with station systems and that operator actions have been assessed appropriately. All modifications undertaken within EDF Energy have to comply with the modification process; this process in turn must satisfy the requirements of Licence Condition 22.

As well as the installation of connections and procurement of DBUE, it was important to consider the use of the equipment and required responder actions in an emergency, as such:

- Training regimes for emergency responders have been enhanced and updated to include the required actions, and locations, regarding the provision of back-up equipment and connection points
- Work on this Finding has taken note of STF-3 regarding human factors. Please see the closeout report for STF-3 for more detail on the work in this area.

6.8.3 Finding Conclusions

The installation of connection points and provision of DBUE will greatly increase the ability of EDF Energy to access key plant systems in a severe event and restore the supply, whether this be for essential electrical systems or for cooling purposes.

With equipment and procedure changes having been incorporated into normal business, this recommendation is now considered closed.

6.9 Stress Test Finding 9 Close Out Report

Finding STF-9: Licensees should further investigate the enhancement of stocks of essential supplies (cooling water, fuel, carbon dioxide, etc.) and extending the autonomy time of support systems (e.g. battery systems) that either provide essential safety functions or support emergency arrangements.

6.9.1 Overview

Following a severe event, all nuclear power stations require sufficient stocks of essential supplies to provide cooling and power. The learning from Fukushima highlights the implications of widespread damage to on-site and off-site infrastructure in terms of the difficulty faced in replenishing stocks of fuel and water.

At Fukushima, water supplies were required to be pumped into the reactor and fuel ponds to cool the fuel. For all EDF Energy stations, a diverse means of adequate reactor and spent fuel storage cooling is an important consideration in the event that normal means of cooling are lost. The events at Fukushima highlight the need to consider further diversification and protection of coolant supplies.

At the Advanced Gas-cooled Reactor (AGR) stations, the core coolant used during normal operation is carbon dioxide. Should normal cooling be lost, the unique design of AGR plants with large graphite core and low power density allows much greater response times than water reactors. Recent thermal analysis has calculated the pressure at which natural circulation of the coolant gas is sufficient to maintain a safe temperature, and the time operators have in which to restore this pressure.

Following loss of the water coolant in the primary circuit of the Sizewell B (SZB) a Pressurised Water Reactor (PWR), fuel melt and core damage begins to occur much quicker. For this reason it is important to restore cooling in shorter timescales.

Fuel supplies are required to power on-site electrical generation in the event of Loss of Off-site Power (LOOP). Existing alternative electrical supplies at EDF Energy stations provide power to emergency control and instrumentation systems and, following a loss of power, a combination of battery supplies, diesel generators, and Uninterruptible Power Supply (UPS) systems are designed to ensure critical systems continue to function.

6.9.2 Response

EDF Energy completed a fleet wide assessment, through the ENSREG stress test process, of the supply and demand of essential on-site stocks. The reviews across all 8 of its station sites reported on stocks and resilience for water, fuel oil and gas.

Water Supplies

EDF Energy has assessed the feasibility of extending the supply time to 72 hours and has found that this can be achieved using existing qualified stocks combined with the use of Deployable Back-Up Equipment (DBUE). Analysis has shown that all sites have sufficient treated water on-site to support operations for at least 48 hours. These are qualified up to the infrequent event.

For all sites, within 48 hours, the DBUE water treatment plant can be delivered and commissioned to provide a continuous supply of water of sufficient quality, up to and beyond 72 hours. No additional on-site cooling supplies have been deemed necessary as the DBUE approach is considered to provide a greater degree of resilience, as it is unlikely that the water treatment plant, stored off-site will be affected by the same event as the station. Cooling water beyond 48 hours will be available from any remaining un-claimed tanks, townswater and seawater, treated as necessary by the DBUE water treatment plant.

To ensure quick and simple access and use of essential stocks in a severe event, EDF Energy has identified and largely installed, with a small number requiring final completion on site, connection points which will allow the connection of low and high pressure pumps and hoses. The installed connection points consist of permanent or non-permanent modifications dependant on station by station requirements including:

- Water Tank connections
- AGR Buffer Store connections
- SZB Primary Circuit Mode 6 connection
- SZB Steam Generator Auxiliary Feed connection
- AGR Pressure Support connections
- AGR Boiler Feed connections.

The provision of event qualified connection points to essential supplies is discussed in the response to STF-8.

Gas Supplies

The core cooling requirement for AGRs is to maintain, or restore, gas pressure in the reactor. Whilst there will be off-site damage repair team equipment provided with the back-up equipment, it is not considered practicable to rely on a plan to re-commission the AGR CO_2 vaporisers within an acceptable time frame following a severe event. No feasible resilience enhancements to on-site stocks of carbon dioxide could be identified and accordingly a different approach was required. It was recognised that to repressurise a reactor, gas pressure support equipment (including gas stocks) may be required, particularly during outage conditions. Off-site DBUE therefore includes sufficient nitrogen stocks to adequately repressurise a reactor and thus promote cooling by natural circulation. Nitrogen is used as it is gaseous at standard air temperature and pressure and therefore a vaporiser is not required. The equipment supplied also includes an appropriate means of delivering the gas to the reactor. The timescales required for this response have been re-evaluated against thermal analysis fault escalation times and found to be adequate.

Fuel Supplies

Bulk fuel tanks have sufficient capacity to support the associated safety systems for much longer than 24 hour mission time. Stations were found to have greater than 72 hours worth of fuel storage, seismically qualified up to the infrequent event. The only exception is bulk fuel oil for the auxiliary steam boilers at Dungeness B, for which the maximum endurance is 48 hours by which time DBUE, with its associated fuel stocks, will have arrived on site. As such this is deemed adequate.

A review into the resilience of the supply chain was also carried out and the current arrangements for procuring fuel were deemed to be robust following a severe event.

Battery supplies

Battery supplies are used in the short term to provide ‘No Break’ supplies for plant functions such as controls and indications, start-up of standby plant such as Essential Diesel Generators (EDGs) and Gas Turbines (GTs), and essential heating and lighting. For the AGR systems the batteries are designed only for short term functions, and become redundant on start-up of the back-up generation. At SZB, Battery Charging Diesel Generators (BCDGs) are available to keep the batteries charged beyond 24 hours, with the replacement of the existing BCDGs by two new 100% load units completed; the new units are seismically qualified and raised above the 1m Beyond Design Basis (BDB) flood level.

Battery discharge only becomes an issue should EDGs or GTs fail to start. Although it is possible for operator actions to reduce the electrical load on plant equipment deployed following reactor trip (and thereby reduce battery usage), however the role of the operator is focused on establishment of adequate reactor cooling. The operator’s main priority, the initiation of back-up reactor cooling systems, does not depend on battery systems likely to become drained. It is considered that the specification of operator actions to reduce battery discharge is likely to be incompatible (in the short post trip period) with the operator's priority to establish adequate post-trip cooling.

Options were reviewed by Suitably Qualified and Experienced Personnel (SQEP) to increase battery capacity at AGRs but have been assessed and judged as not being appropriate. This is based on the practicability of installing new battery systems combined with the availability of DBUE which, as described below, includes both on-site and off-site low voltage mobile Diesel Generators (DG). Connection points for these low voltage (415V) generators to support re-energising essential instrumentation and indicators have been largely installed, with a small number requiring final completion on site, to provide easy and quick connection of the mobile generators; STF-8 discusses these points further.

Battery supplies are also used in the UPS systems which support continuous operation of Emergency Control Centres (ECCs) and Alternative Indication Centre (AIC)/ Emergency Indication Centres (EIC) during Station Black Out (SBO), and are backed by independent DGs. The resilience of the UPS has been increased where necessary by the provision or upgrade of the battery racks and restraints. These systems support the new Continuous Emergency Monitoring System (CEMS) operation at the AGRs (see FR-2) where architecture and layout permits, otherwise the CEMS will typically be supported by its own UPS system. EDF Energy will continue to liaise with ONR and commits to further assess the resilience of the CEMS, including a demonstration of its compatibility with DCIS (Deployable Communications and Information System).

Enhanced Resilience

Site resilience walkdowns were carried out at all stations to provide firm site specific resilience enhancement plans. These site specific reviews addressed flood, seismic and hazard resilience plans and provision of DBUE interfaces. Based on these reviews a number of enhancements to the resilience of key supplies have been made.

Resilience measures for back-up generation, electrical distribution, feed systems and water stocks include:

- Demountable flood barriers (1m) and protection of above and below ground penetrations for emergency generation buildings, electrical distribution and back-up systems
- For communication and indications at emergency response facilities (see FR-2):
  - Provision of back-up DGs
  - Provision or upgrade of anchorage for back-up DG
  - Relocate or improve anchorage of electrical supply panels
  - Provision/upgrade of UPS battery rack and restraints
  - Isolate the electrical supply and circuit for the ECCs
  - Raising of electrical equipment / services above 1m Level
  - Restraining equipment to reduce the likelihood of collateral damage.

As well as resilience measures to existing equipment, new trailer mounted generators have been procured. These 180kVA DGs will provide power for low voltage systems such as lighting and essential instrumentation. One diesel generator is stored at each AGR, with the exception of Heysham 2 (HYB) and Torness (TOR) which have received two due to the segregated and quadrantised layout of the stations electrical circuits. The 180kVA DGs provide a further line of defence beyond the existing DGs, and can be attached to on-site vehicles for transport around site in event of a hazard. At SZB two new 100% load BCDGs have been installed; these are seismically qualified to the infrequent event and raised above the 1m level – which is in excess of the design basis on-site flood level, giving enhanced margin.

Deployable Back-Up Equipment

The EDF Energy Japanese Earthquake Response programme has developed a response strategy that utilises a DBUE portfolio capable of restoring plant cooling capabilities. Full sets of DBUE are stored in strategic regional locations to minimise transport time to site. Recognising the shorter required response timescales for PWRs, SZB has its own DBUE storage facility located close to site at the new SZB Emergency Response Centre (ERC).

The availability of road clearance and off road vehicles ensures access to site in the event of severe off-site disruption to infrastructure. This equipment is to be managed and stored by the Through Life Management Partner (TLMP). The TLMP will ensure that the equipment is regularly checked, maintained and tested and always ready to be deployed within the required timescales.

The use of the DBUE is supported by installation of accessible connection points, for more information see STF-8. The DBUE provides the following capabilities on site.

Cooling Capabilities

The DBUE includes resources for providing cooling functions for the core and spent fuel:

- Repressurise the AGR reactor in the scenario where the reactor was on an outage or a leakage has occurred. This will be achieved with:

  - Provision of 15 tonnes of nitrogen for injection into the reactor to create sufficient pressure to promote natural circulation

  - Connection points to allow DGs to be connected and power equipment to support the resealing of the pressure vessel at the pilecap, should it be required during outage operations

- Provide primary circuit feed to the SZB PWR Reactor Pressure Vessel during Mode 6, outage mode, achieved through an additional connection point and low pressure pumps
- Provide water to the AGR Main Boilers - DBUE includes high pressure pumps for water injection to the boilers. Conservative transit times demonstrate that the pumps could be deployed and connected in sufficient timescales to meet the needs of the stations as demonstrated via recent thermal analysis on fault escalation times. Sufficient water sources are on-site and seismically qualified to support functions for over 48 hours. The following is also available to ensure supply of water:

  - Low pressure transfer pumps (pumping between tanks)

  - Water Treatment Equipment, mobilised and commissioned within 48 hours, providing sufficient quantities of treated water from townswater/seawater source, ensuring supply up to and beyond 72 hours

- Provide water to the PWR Steam Generators - a high pressure pump is stored at the ERC for rapid deployment
- DBUE pumps and additional treated water will also be available to provide AGR buffer (decay) store feed and AGR/PWR spent fuel cooling and pond top-up capability
- Pond cooling kits will circulate AGR cooling pond water through a coolant loop.

Electrical Generation

The JER programme off-site DBUE strategy includes a low power capability deployable from the regional storage locations in self contained, stand alone units.

The low power approach comprises 415V 200kVA DG units that can be deployed and commissioned ready for use at the station within 24 hours to support powering essential reactor instrumentation. The DG units are compatible with the station 415V connection points and are supplied with fuel stocks and the necessary ancillary equipment to allow connection and use. 180kVA units are also held on AGR sites to provide support should they survive a BDB event.

3.3kV connection points are being provided at all AGR stations with the primary intent to underpin the station 415V essential instrumentation and some limited support to electrical infrastructure through the 3.3kV distribution system.

For SZB, equivalent high power connections have been deemed inappropriate by SQEPs as they would not provide a significant benefit over the 415V connections already provided.

It should be noted that the on and off-site generators, cables, plugs and on-site connection points are all 'industry standard', and as such should additional generators be required then commercially available equipment would be compatible and readily connectable.

Fuel Supplies

All equipment brought to site will have its own independent fuel supplies delivered to site in the event of a BDB event. A review into procurement of essential supplies, including fuel, found arrangements to be robust, ensuring supplies will be maintained beyond 72 hours.

6.9.3 Finding Conclusions

After a substantial review and site walkdown process, stocks of essential supplies have been assessed. Protected stocks were found to meet the existing 24 hours mission time, and for a number of resources the supply time extended up to and beyond 72 hours.

In all cases sufficient essential stocks are available for a minimum of 48 hours, by which time the DBUE will have been deployed, be operational and connected to key systems via the newly installed connection points.

Connection points are fully compatible with all DBUE and the required hoses, fuel stocks and ancillary equipment has been provided to ensure that should it be required a complete system is available which has been through testing and commissioning.

As such, this recommendation is considered closed, based on the availability of protected stocks on site, the provision of connection points and the delivery of DBUE within suitable timeframes.

6.10 Stress Test Finding 10 Close Out Report

Finding STF-10: Licensees should identify safety-significant prime mover-driven generators and pumps that use shared support systems (including batteries, fuel, water and oil) and should consider modifying those prime mover systems to ensure they are capable of being self-sufficient.

6.10.1 Overview

STF-10 is taken to apply to those essential systems (and their supporting systems) which enable cooling and monitoring of a shutdown reactor and which use any form of on-site stored energy source. Reactor trip and shutdown, which would be expected in an extreme initiating event, do not rely on shared systems and are not considered further in the context of the response to STF-10. ONR's supplementary material to its National Stress Test report provides further insight to the finding: the concern is the potential vulnerability of essential electrical generation or reactor cooling systems (generally provided with redundancy) to hazard-related common cause failures in shared supporting systems.

EDF Energy's approach to addressing STF-10 has been to carry out a detailed study at a single nominated site (Heysham 1 (HYA)); chosen because it is considered to be suitably representative of the older Advanced Gas-cooled Reactors (AGRs) which did not comprehensively address the potential for hazard-related common cause failures in their original design. The expectation was that this single station study might reveal both generic and station-specific issues; the balance between the two would influence the manner in which the Stress Test Finding was to be addressed for other stations. The outcome of the HYA study is summarised below together with the approach adopted to address any potential implications for the rest of the AGR fleet.

6.10.2 Response

6.10.2.1 Scope of the Heysham 1 Study

The HYA study identified and investigated the following prime mover systems having a safety-significant role in reactor cooling and monitoring:

- Four Gas Turbines (GTs), (GT3, GT4, GT5, GT6), for electrical supplies to essential post-trip cooling plant
- Three diesel driven pumps for the Low Pressure Back Up Cooling System (LPBUCS 1, 2 & 3) to provide cooling to essential plant in the event of low probability faults associated with pressurised and depressurised reactor shutdown
- Three diesel driven pumps for the High Pressure Back-Up Cooling System (HPBUCS 1, 2 & 3) for diverse supply of feedwater to the boilers for post trip cooling
- Two Diesel Generators (DGs) for Alternative Indication Centre (AIC) electrical supplies
- Five motor-alternator units [1A, 1B, 1C (2C), 2A, 2B] to provide 415V ac supplies to essential equipment including the 110V 3 phase General Instrument Supplies (GIS) during the start-up and connection period of a GT.

Each of these systems has been reviewed (desktop study) to identify and assess the relevant supporting systems. A walkdown of the systems at HYA has also been undertaken to validate the desktop study. The review has considered the extent to which prime mover supporting systems are shared and has also considered the location of supporting systems; an aspect which is potentially relevant to hazard events.

The adequacy of each identified prime mover system was considered in a range of scenarios and for operation over a 24 hour period. It may be noted that EDF Energy Japanese Earthquake Response (JER) Deployable Back-up Equipment (DBUE) would be expected to be available on site following a severe hazard event within a 24 hour timescale.

The scope of the HYA study was originally focussed on the systems supporting the identified prime mover systems. However, the study also takes account of a particular event which occurred at HYA and is relevant to common cause failure of supporting systems i.e. CR 832190 – Gas Turbine 5 (GT5) fire deluge system operation and subsequent water ingress into GT4 and GT6 plant areas.

6.10.2.2 Outcomes of the Heysham 1 Study

The review of the prime mover support systems at HYA did not identify any significant opportunities for enhancing the existing design of LPBUCS, HPBUCS, and motor alternators in respect of increasing resilience against hazard-related common cause failures.

Both LPBUCS and HPBUCS systems are based on 3-fold redundant diesel driven pumps and the few supporting systems (e.g. starting battery, fuel tank, cooling radiator, control system) are not shared. While pumps 1 and 2 on both LP and HP BUCS systems are located in the same building, pump 3 is located in an adjacent building and is considered to provide adequate resilience against location-specific hazards.

The motor alternators have a single support system which is not shared (each alternator is supported by a single 440V battery). The motor alternator system’s purpose is to support the 415V essential no-break electrical system for a period of up to 15 minutes, by which time the back-up electrical generation systems are required to be running. The alternators are normally running when the reactor is operational. Protection against localised common cause hazards is delivered by segregation: pairs of alternators/batteries are located in separate rooms.

The review did identify some aspects relevant to the resilience to hazard-based common cause failure for the AIC electrical supplies and GTs which are outlined below:

AIC diesel generator electrical supplies

Although each of the two 100% duty AIC DGs can be started from its own independent battery supply (and is fed by an independent fuel oil supply) the review identified that the two generators are in adjacent rooms (OM4 and OM5) with an interconnecting door. The review recommends that the adequacy of segregation between rooms OM 4 & 5 with respect to fire and flooding should be confirmed.

Gas Turbines

The most onerous demand on back-up electrical supplies is associated with a coincident depressurisation event on both reactors combined with a loss of off-site power together with assumed damage to the essential electrical system. This unlikely scenario requires two GTs to operate simultaneously and requires the fuel oil day tanks to be replenished after approximately 14 hours. The transfer of fuel oil from the bulk tank to any of the day tanks requires the operation of one of centrifuges 1, 2 or 3, with power supplied from the 415V Short Break GT Boards 3, 4 and 5 respectively. These boards are normally supplied from the Essential Electrical System.

Only one centrifuge, working at its minimum capacity, is required to replenish the fuel oil day tanks for two operating GTs. In the event of unavailability of part of the essential electrical system (such as may be postulated in a turbine disintegration event, for example) supplies to one or more of the 415V Short Break GT Boards may be unavailable; disabling the associated centrifuges. Consideration of the turbine disintegration event led to the installation of separate 11kV/415V standby supply transformers to GT 4 and GT 6, connected directly to the GT 11kV output terminals. These standby supply transformers can provide power to the relevant 415V Short Break GT Board. Notwithstanding the general difficulties associated with postulated unavailability of parts of the essential electrical system, it may be appreciated that under such circumstances, fuel oil transfer from the bulk tanks to support extended running of the GTs would be reliant on the successful operation of GT 4 and centrifuge 2. The review suggests that the provision of “splitter boxes” would provide flexibility on electrical supplies to the centrifuges. The review also notes that the 3 centrifuges are located adjacent to each other in a single centrifuge house and that the discharge from the centrifuges to the day tanks is via a single ring main. These two observations suggest potential vulnerabilities to common cause failure.

It is clear that further consideration should be given to assessing whether additional 'on site' measures should be adopted to enhance the resilience of fuel oil transfer from the bulk storage tanks to the GT day tanks. Given the extended timescales before which such a transfer may be required, such measures could include portable pumps and hoses – and it may be noted that such equipment is already included in the JER off-site DBUE.

The review also notes an event which occurred at HYA in 2013, in which GT 5 fire deluge water flooded the adjacent GT 4 and GT 6 lube oil pits and associated alternator air intakes (CR 832190). Initial understanding of how the water accessed the oil pits and alternator air intakes on the two adjacent GTs enabled some temporary mitigation to be made including additional dewatering pumps, sealing of floor slabs in the GT house and temporary dwarf walls between GTs. Longer term actions to mitigate against common mode failure from this source (and at other site locations) are identified in CR 832190 and are being addressed under normal business.

6.10.2.3 Implications of the Heysham 1 Study on the rest of the fleet

The HYA study was completed in Q1 2014 and the findings of the review have been assessed by an expert panel, which comprised Suitably Qualified and Experienced engineers representing each of EDF Energy's power stations, to determine whether follow-up actions are required to address the potential common cause failure issues associated with AIC diesel segregation and potential reinforcement of long term bulk fuel oil transfer to the GTs. The panel also considered the implications for the remaining EDF Energy sites.

The HYA review did not identify any common cause vulnerabilities associated with the prime movers and their supporting systems which would challenge the short term provision of essential safety functions. This is not an unexpected result since HYA has a Probabilistic Safety Assessment (PSA) model in which common cause failures are modelled in most of the prime mover systems considered in the review. The same observation is judged appropriate for the remaining EDF Energy sites. It follows that any potential vulnerabilities to hazard-related common cause failures are likely to be associated with systems not modelled in the PSAs such as those associated with long term transfer of essential consumables. These aspects were discussed in the expert panel.

No significant shortfalls were identified by the Expert Panel, with respect to the dependence of prime mover systems upon shared systems. Recommendations were made to further underwrite the position and these are now part of normal business. The deliverable summarising the findings of the Expert Panel also made reference to the EDF Energy response in relation to WANO SOER 2002-2, noting the equivalence in terms of review, challenge and findings.

6.10.3 Finding Conclusions

A review of prime mover systems (and their supporting systems) at HYA has been completed and did not identify any weaknesses in the short term capabilities of essential prime mover systems (including their supporting systems) in respect of their resilience to hazard-related common cause failures. However, two aspects worthy of further consideration were identified:

1. confirmation of the adequacy of segregation of the two AIC diesels from potential fire & flooding events;
2. assessment of potential reinforcement measures to enhance long term bulk fuel oil transfer to the GTs.

The review noted the follow up actions arising from an event at HYA in which the GT 5 fire deluge system had led to flooding of supporting systems on GT 4 and GT 6. Normal business processes are being followed which will address the 'common cause' aspects of this event.

The findings of the HYA review have been assessed by an expert panel to consider whether additional fleetwide measures are warranted to enhance resilience against the potential common mode failure modes identified above. The findings of the Panel, along with any identified follow up actions, have been formally issued. Ongoing commitments will be captured in a baselined programme, to be owned by Design Authority within EDF Energy.

No significant shortfalls were identified by the Expert Panel, with respect to the dependence of prime mover systems upon shared systems. Recommendations were made to further underwrite the position and these are now part of normal business.

In conclusion, it is judged that the intent of STF-10 has been fully satisfied and as such is considered closed.

6.11 Stress Test Finding 11 Close Out Report

Finding STF-11: Licensees should further consider resilience improvements to equipment associated with the connection of the transmission system to the essential electrical systems (EES) for severe events.

6.11.1 Overview

This applies to EDF Energy as an operator of 15 reactors at 8 locations within the UK. The opportunity to further consider whether resilience improvements are required for the Essential Electrical Systems (EES) is welcomed. The desired outcome of this finding is an assessment of the practicability for resilience improvements of the equipment associated with the connection of the transmission system to the EES, since it is desirable to restore the normal electrical supply route as soon as possible after a severe event.

6.11.2 Response

It is recognised that it is highly desirable to maintain the grid connection. However, it should be noted that reactor shutdown and cooling is not reliant on off-site power, and the EES has existing back-up power provisions. These are derived from the back-up 11kV, or 3.3kV systems depending on the stations, supplied by the Gas Turbines (GT) or Essential Diesel Generators (EDG) which are qualified to infrequent seismic and flooding events. Enhancements to these systems has included flood protection to 1m local to plant, shown to be well beyond the 10^{-4} pa event, that is Beyond Design Basis (BDB).

After considering credible hazards, walkdowns and surveys have shown that generally the grid supplies may be lost due to the 11kV switchgear being located at ground level and not being seismically qualified. It is worth noting that a Loss of Off-site Power (LOOP) event is recognised in station safety cases as a frequent event (~10^{-1} pa), a figure substantiated by the operational histories of the stations, as discussed in the Stress Tests.

As such, after considering enhancements to grid connecting equipment combined with the potential for national grid infrastructure to be damaged, it was concluded, based on Suitably Qualified and Experienced Personnel (SQEP) engineering judgement, that it is not appropriate to implement changes to the grid connection. Therefore this did not form part of the EDF Energy Japanese Earthquake Response (JER) programme strategy.

The programme has assessed the required electrical systems and determined that in the first 72 hours the most important system is the 415V which provides power for essential plant indications. The strategy has concentrated on enhancing on-site generating capability via resilience enhancements (see IR-18) and the provision of appropriate connection points for 415V and 3.3kV systems (see STF-8). This is combined with the addition of on-site and off-site generating equipment that can be deployed and connected should it be required.

The development and specification of the connection points provides confidence that the connection points, internal link switch boxes and hardwired cabling would survive a seismic event and flooding event, as assessed on a station–by-station basis.

To protect against a BDB flood, equipment has been installed above the 1m level or protected by 1m dam boards, this gives enhanced margin to a BDB event. For seismic qualification, resilience modifications are qualified to a level equivalent to the existing plant, or as a minimum, shown to have no detriment on the existing station plant. In general this qualification is to the DB Event (bottom line or 10^{-4} pa event). In addition, to increase availability of the connections, a recommissioning ‘pod’ has been provided with spares and drying out equipment. All modifications undertaken have complied with the modification process; this process in turn must satisfy the requirements of Licence Condition 22.

New alternative trailer mounted generators have been procured, these 180kVA diesel generators will provide power for low voltage (415V) systems such as lighting and essential instrumentation. One diesel generator is stored at each Advanced Gas-cooled Reactors (AGRs), with the exception of

Heysham 2 (HYB) and Torness (TOR) which have received two due to the segregated layout of the stations' electrical circuits. The 180kVA diesel generators provide a further line of defence beyond the existing EDGs/ GTs, and can be attached to on-site vehicles for transport around site in event of a hazard.

Trailer Mounted 180kVA diesel generator

At Sizewell B (SZB) two new Battery Charging Diesel Generators (BCDGs) have been installed; these are seismically qualified to the infrequent event and raised above 1m, which is in excess of the Design Basis on-site flood level, giving margin to a BDB event. A full array of back-up electrical equipment is also available at the Emergency Response Centre (ERC) close to plant.

External Connections box for SZB battery charging diesel generator

The JER Deployable Back-Up Equipment (DBUE) strategy includes low power capability deployable from the regional storage locations in self contained, stand alone units.

The DBUE low power approach comprises of 415V 200kVA diesel generator units that can be deployed and commissioned ready for use at the station within 24 hours to support powering essential reactor instrumentation. The units are compatible with the station 415V connection points and are supplied with fuel stocks and the necessary ancillary equipment to allow connection and use.

3.3kV connection points are being provided at all AGR stations with the primary intent to underpin the station 415V essential instrumentation and some limited support to electrical infrastructure through the 3.3kV distribution system.

6.11.3 Finding Conclusions

EDF Energy has concluded based on SQEP engineering judgement that it is not appropriate to implement changes to the grid connection and therefore this did not form part of the EDF Energy JER programme strategy. This is partly due to the difficulty of enhancements combined with the potential for severe disruption to have affected the national grid.

The EES is supplied by on-site generation capability, which is protected up to infrequent seismic and flooding events. Furthermore flood protection levels have been increased to further protect EES supplies against a BDB flood.

It has been deemed that the most important electrical system in the short term is the 415V which provides essential instrumentation to inform operators of plant status. Modifications have therefore been provided by the JER programme including connections for the use of the on and off-site generating equipment that has been supplied, as well as the further protection of key systems to severe events. The modifications and provision of equipment have been incorporated into appropriate operating procedures and relevant training.

It should also be noted that the focus of the Further Review and Assessment stream to the findings raised has been on resilience against the identified key external hazards of coastal flooding, seismic and weather hazards (extreme ambient temperatures, pluvial flooding and wind) and that there has been deliberate focus on demonstrating resilience for structures that protect the bottom line plant, the bottom line plant itself and the security of the integrity of the pressure boundary, as discussed in a number of recommendations and findings.

As such, this recommendation is considered to be closed.

6.12 Stress Test Finding 12 Close Out Report

Finding STF-12: Magnox Ltd should assess the progressive loss of electrical systems on all aspects of the fuel route and address any implications.

6.12.1 Overview

This finding is not specifically directed at EDF Energy. However, EDF Energy recognises the value in sharing experience with other operators and through the Safety Directors Forum, for example, will keep updated to ensure that EDF Energy understands any implications for Magnox and if there is any cross-over to EDF Energy.

The loss of electrical systems at Fukushima was a key part of the accident progression and EDF Energy is learning from this; a number of recommendations apply to this topic, in particular Interim Recommendations 18, 19 and 20. Updates to the ONR on the progress with of these recommendations has been via a number of meetings and updates and finally with the submission of this suite of close-out reports.

6.12.2 Response

Whilst not directed specifically to EDF Energy, resilience enhancements have been identified and implemented, and mobile back-up equipment modules, which will ensure power and cooling capabilities for the fuel route are maintained, have been provided.

Details of these modifications can be seen in responses to Interim Recommendations 18, 19 and 20.

6.12.3 Finding Conclusions

Whilst this Finding is not directed at EDF Energy, a programme of work has been delivered which ensures that both power and cooling can be maintained for the fuel route following a severe event, and as such, this Finding is considered closed.

6.13 Stress Test Finding 13 Close Out Report

Finding STF-13: Magnox Ltd should demonstrate that all reasonably practical means have been taken to ensure integrity of the fuel within the dry fuel stores in the extremely unlikely event of the natural draft air ducting becoming blocked.

6.13.1 Overview

This finding is not specifically directed at EDF Energy. However, EDF Energy recognises the value of this Finding and the importance of maintaining integrity of spent fuel in dry store.

6.13.2 Response

Whilst not directed specifically at EDF Energy and although EDF Energy does not currently have a dry fuel store, plans are in place to build one at Sizewell B (SZB), at which time the intent of this Finding will become applicable.

The dry fuel store at SZB will be robust to severe events and will be built to ensure that even if the vents are fully blocked for an extended duration that there will be no cliff-edge effect.

The dry fuel store will be built in compliance with Licence Conditions and the ONR will be involved throughout.

It should be noted that the dry fuel store in Fukushima which was subjected to the severe seismic event followed by exposure to sea water was not adversely affected by these conditions. However EDF Energy is taking steps to add further resilience to the dry fuel store, ensuring that the learning from Fukushima is incorporated into the design of the facility.

6.13.3 Finding Conclusions

Whilst this Finding is not directed at EDF Energy, learning from Fukushima is being incorporated in to the new dry fuel store at SZB and the ONR have been and will continue to be involved with the design and build as per normal regulatory business, as such, this Finding is considered closed.

6.14 Stress Test Finding 14 Close Out Report

Finding STF-14: Licensees should confirm the extent to which resilience enhancements are to be made to existing equipment and systems that are currently installed at nuclear power plants. Information should be provided on the equipment and systems that may be affected and the nature of the resilience enhancements, including interconnectivity with mobile back-up equipment.

6.14.1 Overview

EDF Energy has undertaken a programme of work aimed at increasing the robustness of key existing systems to severe events and provided connection points such that cooling and essential electrical supplies can be established using back-up equipment should a station experience difficulty during such an event.

Relatively simple but effective resilience enhancements have been made to structures and equipment in order to increase protection against Beyond Design Basis (BDB) events. These enhancements have not impacted upon normal safety processes, but have given enhanced protection to severe events.

Communication with the Office for Nuclear Regulation (ONR) regarding the extent and nature of these enhancements, as well as the engineering judgement supporting them, is important for the ONR's understanding of the overall safety picture.

6.14.2 Response

How we have chosen what to protect:

Preliminary engineering assessments were carried out on selected areas, in which potential enhancements to on-site equipment, or provision of back-up capability, were assessed via primarily desk-based assessments and station walkdowns.

The development of these assessments included engagement with key qualified and experienced stakeholders such as System Health representatives from stations, and Design Authority (DA) and Emergency Planning representatives from Barnwood, to ensure practicability of each proposed enhancement that was identified.

Workshops were held for on-site resilience modifications and back-up equipment respectively, at which viable enhancements were accepted for further evaluation and impracticable/low benefit proposals were rejected.

A further workshop was held where the feasible and practicable capability enhancements were evaluated for inclusion within the execution programme.

At all stages, the assessments considered a set of criteria including the following:

- Minimisation of disruption to normal operations including management of nuclear safety
- Greatest increase in resilience/ back-up capability achieved
- Time and practicability to deliver benefit

A set of conceptual enhancements designed to enhance recovery capability in the event of loss of key nuclear safety related functions were defined and agreed with appropriate stakeholders throughout EDF Energy as being worthy of further consideration. These are discussed below.

What we are protecting:

The EDF Energy Japanese Earthquake Response (JER) programme has installed a number of modifications/enhancements across the 8 reactor sites in the UK, with the focus on seismic and flooding resilience enhancements. Modifications/enhancements have been constructed to varying extents as considered necessary on a station-by-station basis. Resilience measures have been identified with the vast majority now delivered.

Flooding

Site specific basic flood protection measures have been provided to enhance survivability of plant in BDB flooding and severe weather events. This has been achieved by the installation of dam boards around a number of key facility entry/exit points and the sealing of above and below ground penetrations. Additional sea wall protection has also been constructed at Dungeness B and Hartlepool.

Measures include:

- Increased flood protection of back-up generation system buildings
- Increased flood protection of back-up feed system buildings
- Increased flood protection of ponds to prevent the potential spread of contamination
- Dewatering capabilities supplied from off-site, to be deployed following severe weather warning or a BDB event.

Seismic

The main focus of the seismic work was:

- Seismic Qualification Utility Group (SQUG) assessments found that access to key plant areas can be provided following the infrequent event
- Water Stocks assessments which found appropriate levels of qualification across all sites
- Seismic qualification of dry risers to support buffer store recovery actions.

A judgment, based on appropriate engineering experience, concerning the hardening of fixed fire fighting equipment deemed modifications to be impractical due to multiple vulnerabilities; therefore focus was placed on protection of mobile fire fighting equipment including the modification of fire station buildings to increase likelihood of surviving a seismic event across the AGR fleet. For more information on seismically induced fire, see STF-4.

Infrastructure

Modifications have increased the resilience of emergency facilities, such as the Alternative/ Emergency Indication Centres (A/EICs) and the Emergency Control Centres (ECCs), against extreme external events. Modifications were not necessary at the Sizewell B (SZB) equivalent, the Auxiliary Shutdown Room (ASR), as this was designed with a greater level of resilience

The modifications, implemented on a station-by-station basis where appropriate, include:

- Removal/strengthening of suspended ceilings
- Ensuring fixtures and fittings are sufficiently robust
- Windows removed and replaced with protection to reduce the hazard posed by airborne debris in extreme winds
- Increased boundary flood protection
- Flood protection of existing back-up diesel generators
- Independent Heating Ventilation and Air Conditioning (HVAC)
- Ensuring all ECCs/AICs have back-up electrical generation.

Connection points:

To support the quick and simple use of back-up equipment, interface and connection points are being enhanced and installed with a strategy developed around four key considerations:

- Access (i.e. distance from reactor/ability to access in a severe event)
- Flexibility
- Vulnerability of any performed modifications

- Human Factors.

As a result of these considerations, and following significant reviews and site walkdowns, the following back-up interface enhancements were identified and judged to be appropriate:

- Connection points for the connection of cooling supplies to the main boiler at all Advanced Gas-cooled Reactor (AGR) sites, with permanent modifications at Heysham 2 / Torness, Heysham 1 / Hartlepool and Dungeness B. Where there have not been permanent modifications due to reasons of practicability, additional on-site apparatus is provided enabling the connection to existing plant post event
- Plug in for low voltage (415V) supplies to support re-energising basic instrumentation and indicators and to support recovery operations
- Connection points for high voltage (3.3kV) AGR electrical systems to aid the recovery of installed plant systems, as part of a longer-term (post 72 hour) response strategy
- Both high and low voltage plug in points include connection points, switchover boxes, cabling and ability to connect to switchboards
- Water tank connections providing quick hook-up access and isolation to ensure desired control and use of water stocks, including supplying boiler feed and allowing header tanks to be refilled from other sources, including the Deployable Back-Up Equipment (DBUE) water treatment plant (see IR-19).

SZB specific connection points include:

- Auxiliary Feed system which enables connection of a DBUE high pressure pump capable of supplying cooling water (treated or sea water) directly to the secondary circuit
- Containment water injection - a connection point has been provided to connect a back-up equipment pump capable of supplying water (treated or seawater) directly to the containment building to prevent dry-out of the water in the containment floor and provide corium cooling
- Clean Air Train System connection will be completed during the next planned refuelling outage RO14 – and will enable connection of back-up nitrogen supplies, sufficient to maintain adequate pressure in the system to allow long term operation of the valves
- Primary Coolant Connection will be completed during the next planned refuelling outage RO14 – and will enable the low pressure DBUE pump to feed water into the primary circuit to provide borated water from the Reserve Feedwater Storage Tank during the outage phase Mode 6 condition
- Electrical connection points to the new replacement battery charging diesel generators.

Connection points are discussed in further detail in STF-8. Rationale and Human Factors assessments, which fed into the modifications, are discussed in STF-1 and STF-3 respectively.

What we are not protecting:

A number of proposed enhancements were discounted from further consideration due to inability to deliver benefits in an appropriate timescale, disruption to normal operations including management and maintenance of the operational nuclear safety case margins, or disproportionate cost incurred to the capability enhancement achieved. A number of procedures were implemented to ensure removal from scope was appropriate, including use of change controls, programme board papers, initial workshops and Suitably Qualified and Experienced Personnel (SQEP) input.

In some instances it was deemed more appropriate to supply (DBUE) than to perform site modifications. For example, rather than providing additional on-site qualified water stocks that a deployable water treatment plant would offer more diversity as it would be less likely to be affected by the event affecting the stations. For more information see IR-8.

6.14.3 Finding Conclusions

Following an extensive review process, with the involvement of the ONR throughout, resilience enhancements have been implemented across EDF Energy sites. The resilience enhancements provide a consistent level of protection, increasing chances of availability should there be a BDB event, and were selected following input from various stakeholders.

A number of connection points for back-up equipment have been largely installed, with a small number of remaining items nearing completion, across EDF Energy nuclear power stations in response to findings from Fukushima. Connection points have been designed to have minimal impact on existing equipment and systems, and were selected following discussion with stakeholders including the ONR and SQEP station representatives. All modifications are completed using normal EDF Energy Engineering Change (EC) processes and in conjunction with the relevant licence conditions.

The programme of work for this recommendation is largely complete with all remaining work fully planned and resourced, and maintenance and training incorporated into normal operations. As such this recommendation is considered closed.

6.15 Stress Test Finding 15 Close Out Report

Finding STF-15: Licensees should complete the various reviews that they have highlighted so that ONR can assess their proposals and associated timescales. These reviews should look in detail at on-site emergency facilities and arrangements, off-site facilities, facilities for remote indication of plant status, communication systems, contents and location of beyond design basis containers and the adequacy of any arrangements necessary to get people and equipment on to and around site under severe accident conditions. Any changes to arrangements and equipment will require appropriate training and exercising.

6.15.1 Overview

Following the events at Fukushima, EDF Energy reviewed the capability of its stations to withstand a Beyond Design Basis (BDB) event. This work has led to a comprehensive scope of work to enhance the resilience of on-site structures, components, and systems and to provide a Deployable Back-Up Equipment (DBUE) capability which can be deployed to further support station response.

6.15.2 Response

A number of reviews and strategy reports have been written to understand and enhance EDF Energy's BDB capability. This has included workshops and station walk downs with Suitably Qualified and Experienced Personnel (SQEP), as well as specific detailed reviews undertaken by EDF Energy's contract partners, for example the Royal Haskoning flooding studies. The result has been a scope of work planned and implemented using appropriately qualified SQEP engineering judgement.

There has been a schedule of Level 4 meetings between the EDF Energy Japanese Earthquake Response (JER) programme and ONR to discuss the work programme, timescales, and approach taken. EDF Energy's initial responses to ONR's Interim and Final Report Recommendations as well as Stress Test Findings were submitted to ONR in June 2012, and received substantial feedback. Source documents covering the technical and strategic basis of the JER programme of work have been, and will continue to be, shared with the ONR for assessment and feedback. These processes have helped to shape the nature of the programme.

Resilience Enhancements

To increase the reliability of on-site emergency control capability, EDF Energy has implemented a comprehensive range of resilience enhancements to protect existing key facilities against flooding, seismic and other severe hazards. Where necessary, the functions of Emergency Control Centres (ECCs) and the Alternative/ Emergency Indication Centres (A/EICs) have been made more resilient, including:

- Increased resilience to flooding on a site specific basis (including 1m dam boards and securing of below ground penetrations)
- Provided basic protection against high winds (installation of shutters, bricking up windows or installation of other protection measures, on a site specific basis)
- Increased resilience to a seismic event (false ceilings/walls secured or removed, equipment secured)
- Provided secure back-up power (emergency generation units installed, replaced, or secured against hazards)
- Improved the Heating Ventilation and Air Conditioning (HVAC) systems where practicable
- Newly installed low voltage (415V) electrical connection points, and additional generators on and off-site, will help secure power supply for key indications and communications
- New robust Emergency Response Centre (ERC) constructed at Sizewell B (SZB) in a location close to site, providing alternative command and control capabilities and housing DBUE, reflecting the shorter fault escalation times for Pressurised Water Reactors (PWRs)

- Work has been carried out to assess the resilience of both the Barnwood Central Emergency Support Centre (CESC) and the alternative CESC in Bristol to extreme natural events, and to implement enhancements to these facilities that would increase resilience to such events.

To improve the survivability of communications, EDF Energy has assessed the existing communication methods and identified areas to enhance resilience based on learning from the Fukushima event. Work included:

- Establishing vulnerabilities of existing communication systems against on-site and off-site power loss and disruption to infrastructure for BDB assumptions
- Identification of resilience and DBUE enhancement options and alternative communication systems that would increase communication resilience and diversity
- Procurement of mobile and fixed satellite telephones for 'last line defence communications', which have been largely distributed across the fleet of stations and incorporated into emergency procedures.

The resilience programme of work also included the installation of the Continuous Emergency Monitoring System (CEMS) at the Advanced Gas-cooled Reactors (AGR) to provide a real-time display of key reactor/station parameters, located in a Safe Place On Site and facilitating decision making by operators in the hours following the event. For SZB a CEMS project is in development, taking learning from the AGR installations, and is anticipated to be completed during the next refuelling outage.

When operational, the CEMS will provide indications of key parameters for the reactor facilities, immediately pre and post fault through to event response. The key parameters will be provided to the Duly Authorised Persons, ECC and CESC, giving a more informed decision making process.

The CEMS has been installed on AGR sites with commissioning in 2015, and is engineered to survive any credible series of events as far as reasonable. Power to the CEMS is provided by existing battery and/or generator backed power supplies that are resilient up to the infrequent event. Where such supplies are not available, the CEMS will typically be provided its own Uninterruptible Power Supply (UPS) to provide power to the system for the requisite period. EDF Energy will continue to liaise with ONR and commits to further assess the resilience of the CEMS, including a demonstration of its compatibility with the Deployable Communications and Information System (DCIS).

Investigation is ongoing into a similar capability at SZB, noting that DCIS as discussed below is permanently installed at the ERC.

Deployable Back-Up Equipment

EDF Energy has developed an array of mobile DBUE to respond to a severe accident. A significant part of the DBUE programme includes the provision of back-up emergency response facilities. This includes mobile ECC/ACP (Access Control Point) command facilities, some of which have positive pressure air and filtration systems to reduce the risk from airborne contamination.

The DBUE also provides real time plant indications and communication systems, supplied by the DCIS that includes satellite communications equipment. The DCIS is compatible with, and can be connected to, the CEMS system, but is delivered to site as part of the AGR DBUE, transmitting essential plant parameters to the mobile ECC, ACP and DBUE staging post, and is not reliant on any fixed telecommunication infrastructure. The DCIS provides communications and indications for long term usage, in more severe emergency scenarios, and can provide wider situational awareness by allowing access to stored data (e.g. station drawings) and telephony equipment allowing communications with the CESC.

The deployed ACP manages access and egress to a hazardous location from a suitable off-site position. The ACP includes Personal Protective Equipment, radiation monitoring equipment and showering facilities.

All DBUE will be stored, maintained and exercised appropriately, ensuring that it is fit for purpose and ready to be deployed should it be required. Once contacted, EDF Energy's Through Life Management Partner (TLMP) will begin the delivery of a comprehensive set of DBUE from the most appropriate regional store. The DBUE will reach a staging post at a safe point near the nuclear site from which transfer of equipment to site will be co-ordinated. The TLMP and the staging post will have continuous communication with the CESC.

The strategy involves three fully stocked off-site regional stores, located to ensure that any affected station can be supported before safety limits are exceeded leading to possible accident progression, and allows two concurrent events can be managed. The timescales to safety limits, following loss of all forced cooling, boiler feed and the Pressure Vessel Cooling System, have been reassessed using thermal analysis to determine temperature transients. The deployment strategy has identified a number of alternate transport routes and staging posts for each site. These consider possible disruption from various hazards, such as collapsed bridges, traffic congestion and flooding. Conservative calculations have developed estimates for delivery times, again taking into account the potential for severe disruption off-site. The DBUE includes vehicles to aid transport logistics and clearance of the route, such as Mercedes Unimogs and JCBs, and is self sufficient for 72 hours post event.

There is additional DBUE storage at the newly built SZB ERC, close to site, to reflect the shorter event escalation times for PWRs.

The TLMP is an integral part of the BDB deployment strategy that EDF Energy has introduced across the fleet. The TLMP provides three services to the fleet: storage, maintenance and delivery. This strategy brings together logistical expertise from other industries and creates a flexible and timely emergency response capability. It should be noted that the equipment is owned by EDF Energy, who are also the sole recipient of the TLMP’s emergency response services.

The DBUE will be taken by the Forward Deployment Service to the pre-determined lay down points on site, where suitably trained EDF Energy response teams will connect and operate the DBUE in line with the DBUE Guidelines (DBUEGs).

Emergency Arrangements and Procedures

EDF Energy has updated and improved the AGR Symptom Based Emergency Response Guidelines and Severe Accident Guidelines to enhance usability, STF-16 has further information on this topic. For the SZB PWR, the updates to the equivalent documentation, such as Station Operating Instruction 8.8, Severe Accident Mitigation, will take place to outline how the JER equipment and tie-ins could be deployed alongside other mitigation measures following a severe event, for further information see STF-18.

In addition to these reviews and updates is the development of DBUEGs, providing details of the back-up equipment and how and where it is used.

Furthermore, exercising and training schedules have been updated to include the new equipment and procedures; the JER programme is also training emergency responders, ensuring that equipment and procedures can be used when required – providing an enhanced capability. The Proof of Concept demonstrations as discussed in section 2.2.6 exhibited this capability, which included proving that training is adequate for severe events and that procedures and equipment are adequate and fit for purpose. Learning points arising from these exercises has helped to inform strategy and training requirements, ensuring that the learning is incorporated into normal business.

6.15.3 Finding Conclusions

Following a review process, resilience enhancements have been implemented across EDF Energy sites. The resilience enhancements provide a level of protection against BDB events, increasing the chances of key buildings and systems surviving and providing enhanced communications to what is already present. In addition the provision of DBUE along with enhanced procedures and training will enhance EDF Energy’s response capability to a severe event.

The programme of work is largely complete, with maintenance incorporated into normal business and training will continue to be delivered in 2015.

EDF Energy will continue to liaise with ONR to discuss the delivered programme of work and approach taken and will continue to share information with the ONR for assessment and feedback as part of normal business, as such this recommendation is considered closed out.

6.16 Stress Test Finding 16 Close Out Report

Finding STF-16: Licensees should review the symptom-based emergency response guidelines (SBERG) and severe accident guidelines (SAG) taking into account improvements to the understanding of severe accident progression, phenomena and the equipment available to mitigate severe accident. This review should also take into account the fuel route. Once completed, appropriate training and exercising should be arranged**.**

6.16.1 Overview

In the aftermath of the events in Japan, it is important that EDF Energy, as a nuclear licensee, reviews it's emergency response guidelines to incorporate learning from Fukushima as well as new information gained from further reviews and assessments carried out since March 2011.

In responding to and closing out this finding, EDF Energy understands that the aim of this STF was to:

- Review, modify (where appropriate) and update the Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs), also taking into account fuel route and new back-up equipment
- Develop appropriate SBERG/SAG training and exercising once the above was completed.

It should be noted that Sizewell B (SZB) does not have SBERGs and SAGs, instead it has Station Operating Instructions (SOI) from which Series 8 provides specific guidance for emergency operations. These will be reviewed separately following any major plant modifications (see STF-18).

6.16.2 Response

The EDF Energy Japanese Earthquake Response (JER) programme has reviewed the SBERGs and SAGs using additional analysis work on accident progression and incorporating learning from Fukushima and internal reviews.

The main output from this work was:

- Revised SBERGs
- Revised SAGs
- Development of Deployable Back-Up Equipment Guidelines (DBUEGs).

The review ensured that existing emergency response procedures were updated to include input from updated analysis as well as from Human Factors experts, and that the changes were incorporated into the appropriate training.

Furthermore, the development of the DBUEGs, along with a training package, ensures that the Deployable Back-Up Equipment (DBUE) is fully incorporated into company processes with the appropriate level of training given.

SBERGs

The Technical Basis of the reactor SBERGs was reviewed through a number of stages including the identification of current Periodic Safety Review (PSR) - Identified Corrective Action (PICA) requirements and station feedback on the current reactor SBERGs regarding the feasibility of actions and technical accuracy of each step.

In addition, the review examined Safety Case changes since the last update at Periodic Safety Review 2 (PSR2) and ensured that the structural values were consistent with current expectations.

The preparation of the Technical Basis for the Fuel Route SBERGs included work to define the Fuel Route Critical Safety Functions which incorporated station engagement and input to define the entry and exit conditions. It also incorporated additional analysis work being undertaken on accident progression for all stations. Analysis has also been undertaken to establish the estimated times to boil for the Buffer Stores and Ponds, and to provide advice on maximum temperatures which maintain the structural integrity of the concrete.

Scenario workshops were also held with Human Factors specialists to identify opportunities for improvement in the existing SBERGs, the findings of which were incorporated into the updates. A 'Style Guide' was developed in conjunction with a Human Factors specialist with procedural writing experience, which was then reviewed by the relevant station Responsible Engineers. This style guide, supplied as an appendix to the Paper of Intent, provided a consistent guide on how a model SBERG should be formatted and presented. Updates were then incorporated into the SBERGs by authors following this guide.

The work has culminated in a set of updated, verified and approved SBERG documents for all of the AGR fleet and the production of new Fuel Route SBERGs (covering Decay/Buffer Stores, Fuel Ponds and Fuel Storage Flasks).

SAGs

The AGR SAGs have been reviewed and updated to remove overlaps between advice/instructions given elsewhere (such as in the SOIs, SBERGS or DBUEGs) and now provide guidance on the prevention of further accident progression. The changes take account of JER programme developments and have a strong interface with the document structure developed for the DBUEGs. Furthermore, the changes ensure that any previous information in the SAGs is not lost, but is available should it be required. The revised SAGs put across the main points upfront in a clear manner, leaving the scientific logic underpinning the guidelines to other areas of the documentation. The format of the new guidelines also facilitates the incorporation of additional information so that the SAGs can be more easily revised should it be deemed necessary in the future.

DBUEGs

In addition to the SBERGs and SAGs a new suite of guidelines, the DBUEGs, have been developed to incorporate the DBUE provision. These new guidelines include the purpose for the use of the DBUE capability (which can also be used in the context of design basis events), with particular reference to System Level Reports and operating documentation for equipment used for plant intervention. The DBUEGs also refer the user out to the lower level items of DBUE and the associated documentation which provide a more detailed description of the operability of the individual pieces of DBUE.

Sizewell B

In addition to the SZB specific DBUEGs, an update to station procedures such as SOI 8.8 will take place to outline how the JER equipment and tie-ins could be deployed alongside other mitigation measures following a severe event. In doing so, it is intended to incorporate any appropriate best practice drawn from international severe accident management guidelines. Please see STF-18 for more detailed information.

Training and Exercising

Work on this Finding has taken note of STF-3 and IR-24 regarding Human Factors, ensuring that any modifications are adequately assessed for any required operator actions and that any actions are suitably covered by training and emergency procedures.

Training for operators in DBUE decision making, use of SBERGs, and emergency leadership is under development and will be delivered to Central Control Room staff. This training incorporates the use of the revised and new procedures. These procedures, along with the equipment and training, have been demonstrated via Proof of Concept (POC) exercises, and will be built in to normal exercise regimes within EDF Energy going forward.

6.16.3 Finding Conclusions

There are two aspects to this recommendation; the review of SBERGs and SAGs, and the arrangement of appropriate training and exercising of the updated documents and DBUEGs.

A new suite of SBERGs and SAGs have been authored, verified and issued, and DBUEGs are in development. They have been used during POC exercises, demonstrating their fitness for purpose and that operators are trained in their use. Further training of operators in the updated procedures will be conducted as part of EDF Energy normal business.

Updates to SZB procedures will be implemented following installation of any major modification. Therefore this work, if necessary, will be overseen by the EDF Energy SZB project team.

Therefore the review aspect of this recommendation is considered to be closed, however the arrangement of appropriate training and exercising will remain open as part of EDF Energy normal business until fully incorporated into existing practice.

6.17 Stress Test Finding 17 Close Out Report

Finding STF-17: Licensees should further review the systems required to support long-term claims on the pre-stressed concrete pressure vessel containment capability in severe accident conditions.

6.17.1 Overview

The ONR raised the above finding in its final 'Stress Test' report to take account of a particular aspect of the European Nuclear Safety Regulators Group (ENSREG) Stress Test specification directed at the dependence of Light Water Reactor containment building integrity upon electrical supplies, particularly in the context of potential containment overpressure in the later stages of a severe accident. The equivalent 'stress test' challenge in respect of the UK's gas-cooled reactors is taken to apply to the dependency of the pre-stressed concrete pressure vessel containment upon its cooling system(s) following a Beyond Design Basis (BDB) event.

The response to this finding is therefore relevant to the Advanced Gas-cooled Reactors (AGRs) only.

6.17.2 Response

Pressure boundary integrity and the Pressure Vessel Cooling System

For an AGR, and in common with all designs of oxide-fuelled reactor, the first barrier to potential fission product release is the UO_2 matrix, which retains a large majority of the fission products generated unless the fuel approaches melting point. The second barrier is the cladding which contains the reactor fuel. The third and final barrier is the primary circuit pressure boundary.

In the case of the AGR, the major component of primary circuit pressure boundary is the pre-stressed concrete pressure vessel (PCPV), which is a massive, highly redundant structure: failure of significant numbers of pre-stressing tendons, for example, is assessed as being acceptable before there is any risk of failure under normal operating conditions. Additional components of the pressure boundary include welds and seals on vessel penetrations together with portions of pipework which run externally to the vessel. The 'long term' primary circuit pressure boundary may therefore be viewed as a 'passive' combination of structures/components.

The primary system claimed to support long-term claims on the PCPV capability, as per the wording of the recommendation, is the Pressure Vessel Cooling Water System, which is variously called the PVCS, the VCS, or the PVCW system at the different sites, but all with the same underlying meaning.

These systems are specifically designed to control concrete temperatures, concrete temperature gradients, and penetration/seal temperatures to within acceptable levels under normal operating conditions and Design Basis (DB) fault conditions.

PVCW systems are installed on all AGRs and are typically dual closed water circuits with redundant electrical pumps. The PVCW pipework is cast into the concrete of the pressure vessel and transfers heat from the concrete to heat exchangers which, in turn, reject heat to a pumped seawater cooling system. The PVCW pipework is routed so as also to cool all the major penetrations with a high degree of redundancy.

Challenges to PCPV integrity

Initiating events which involve an immediate loss of pressure boundary integrity are covered by the safety case for DB events: BDB initiating events falling into this category are considered further in the response to FR-4. They are not discussed further here because STF-17 focuses on long-term claims on pressure boundary security, i.e. where the pressure boundary is initially secure but may be threatened by degradation during the evolution of the fault sequence.

Long-term challenges to integrity of the PCPV or the penetrations etc. are always minimal provided that the concrete and the penetrations are adequately cooled.

If this is not the case, then there is a range of potential challenges that may arise depending on the circumstances: these are summarised below, in increasing order of challenge.

- Total loss of PVCW while reactors are at power (or blockage of some circuits) is not a BDB event and is addressed within the plant safety cases by claiming detection of the fault, and/or redundancy in the system design, in the pumping arrangements and in the water source arrangements. No further review or actions relating to the PVCW systems are therefore considered necessary.

- Loss of PVCW systems post-trip, while full reactor cooling remains available, is also covered by the safety case. If loss of PVCW poses a threat to pressure boundary integrity, then this remains a safe configuration provided that boiler feed with forced gas circulation remains available. Again, this sequence does not lead to any requirement for further review or actions relating to the PVCW systems.

- Loss of PVCW systems post-trip in combination with concurrent loss of forced gas circulation is also considered by the safety case i.e. the loss of PVCW/natural circulation case.

  At Dungeness B (DNB), Hinkley Point B (HPB), Hunterson B (HNB), Heysham 2 (HYB) and Torness (TOR), the safety case demonstrates that total loss of PVCW cooling following a reactor trip is unlikely to lead to a failure of the pressure boundary of sufficient magnitude to disable successful primary coolant natural circulation (which requires a retained pressure of order 10bar/1MPa). A general summary of the position is that the case is shown to be acceptable on probabilistic grounds provided that that the frequency of sequence is less than about 10^{-5} pry, which reduces the claim on the continued integrity of the pressure boundary to a relatively modest 10^{-2} failures per demand. This is a sustainable claim because of the overall reliability of the various sources of Post Trip Cooling (PTC) and PVCW feed. In the event of a prolonged event with natural circulation with no pressure vessel cooling, sustained damage to the pressure vessel may preclude subsequent power operation, but the vessels are sufficiently robust to take a 'one-off' challenge of long term PVCW loss. It is emphasised that this scenario is very much a worst case position: any pressure vessel cooling achieved in the short term immediately following a reactor trip lengthens the time for which any subsequent total cooling loss may be tolerated without economic damage. On this basis, it is judged that these fault sequences do not lead to any requirement for further review or actions relating to the PVCW systems.

  The position at the two remaining AGRs, Heysham 1 (HYA) and Hartlepool (HRA), is comparatively less robust because the reliability of pressure boundary survival here is less assured, and the backup sources of PVCW supply (via automatic initiation of the Low Pressure Back-Up Cooling System feed into the PVCW system) can only be claimed with moderate reliability. The threat to the pressure boundary integrity here is not only due to effects on concrete temperatures, but also on the structural integrity of welds in the superheater headers in the vicinity of the Boiler Closure Units.

  This was recognised many years ago as an issue within the DB and led to reinforcement of PVCW back-up cooling in the form of a tertiary cooling water supply to the PVCW pipework at the Boiler Closure Units. This system is gravity fed with longer term make-up taken from pumped townswater supplies. It is initiated on detection of loss of PVCW system pressure, so is principally effective as protecting against breaches in the PVCW system pipework.

  The safety case for loss of PVCW relies on the availability of forced gas circulation and boiler feed to achieve a rapid cooldown of the circuit in the event of loss of PVCW. Failure of the safety case requirements is a dominant risk in the HRA/HYA Probabilistic Risk Assessment (at ~$4x10^{-6}$ for a Dose Band 5 release), and would be a potential initiator for a severe accident. The appropriate future actions to address this risk, subject to ALARP considerations, are referenced out from the response to FR-4, and not repeated here, but do include a potential review of the reliability of the back-up PVCW feed systems.

- Loss of PVCW systems concurrent with loss of all core PTC, as in the risk discussed above for HRA/HYA, has also been addressed for other stations initially via the work carried out in response to FR-4. In particular, this has embraced consideration of the most effective accident management actions in a pilot study for HNB *assuming* that both core PTC and PVCW systems have been lost in order to protect the reactor system until such time as the Deployable Back-Up Equipment (DBUE) can be deployed in order effectively to remove heat from the primary circuit. This requires both boiler integrity and pressure circuit integrity to be maintained, because the DBUE model is for heat removal from the core via natural circulation supported by boiler feed. No specific review or actions relating to the PVCW systems are therefore considered necessary, because operation of the PVCW system on its own, while offering overall benefit in terms of heat removal from the circuit, is not adequate to prevent damage escalation in the core in the absence of any other heat sink.

The pilot study for HNB described in the response to FR-4 is considered to be able to be read across to the other AGRs subject to considerations which are also described in that response, and which are not repeated here. Implementation of the findings from the pilot, subject to the same considerations, would be via updates to the station-specific Symptom Based Emergency Response Guidelines (SBERGs).

6.17.3 Finding Conclusions

No drivers for further review or action have been identified to address improvements to the PVCW systems have been identified for the AGRs at DNB, HPB, HNB, HYB or TOR.

It is considered that provision of further defence in depth against vessel cooling failure via plant modifications is likely to be of little benefit. Reasonably practicable improvements are more likely to be derived from procedural enhancements - specifically SBERGs – and this area is the focus of follow-on work as described in the response to FR-4.

The reactor pressure vessel designs at HRA and HYA, based on the existing safety case and supporting transient analysis, are considered to offer lower robustness against a total loss of pressure vessel cooling. Further consideration of the adequacy of defence in depth at these stations is considered worthwhile, subject to ALARP considerations, but this is not driven by severe accident studies. Again, the required considerations for further work are described in the response to FR-4. As such, this recommendation is considered closed.

6.18 Stress Test Finding 18 Close Out Report

Finding STF-18: EDF Energy Nuclear Generation Ltd should complete its feasibility study into the installation of filtered containment venting, installation of passive autocatalytic hydrogen recombiners and flexible means of injecting water into the Sizewell B containment.

6.18.1 Overview

The severity of the Fukushima Dai-ichi event was greatly increased by a series of explosions that occurred in units 1, 2, and 4. The resultant loss of primary and secondary containment integrity led to the release of radioactive materials and complicated the recovery efforts.

In the immediate aftermath of the tsunami at Fukushima, operators faced difficulties with loss of control and instrumentation, collateral damage to the site, and high levels of radiation in some of the reactor buildings. This hindered both the decision making process and necessary actions that needed to be taken to safely reduce pressure in the reactor pressure vessels and primary containment. The high pressure in the containment also caused difficulties for coolant injection, since only low pressure pumps were available.

The explosions were ultimately a result of a build up of hydrogen in the containment buildings; hydrogen generated from the damaged fuel in the reactors accumulated during venting operations or from leaks, and ignited.

The learning from Fukushima therefore highlights the requirement for a well considered strategy for maintaining containment integrity at EDF Energy's Sizewell B (SZB). Consideration also needs to be given to the control of hydrogen and to support coolant injection with low pressure systems. It is also noteworthy that the venting operation at Fukushima might have been more successful had more real time information about the condition of the reactors and containment been available; this issue is covered in greater detail in Interim Recommendation 22.

6.18.2 Response

The reactors in operation at Fukushima Dai-ichi were Boiling Water Reactors (BWR), of which none are operated by EDF Energy or any other licensee in the UK. However, certain similarities exist that indicate a similar hydrogen generating event could occur in a Pressurised Water Reactor (PWR) severe event, such as the presence of zircaloy cladding and water coolant.

EDF Energy has only one PWR unit, at SZB, and strategies have been developed to consider a number of options to reduce pressure and hydrogen levels in the SZB containment:

- Following feasibility studies, Passive Autocatalytic Recombiners (PARs) have been installed to reduce hydrogen levels; these units have the advantage of not requiring a power source, thus providing a diverse and independent means of hydrogen reduction from the currently installed electrically powered hydrogen management system.
- Connection points, or 'tie-ins' have been installed for Containment Water Injection (CWI) to be supplied through an existing penetration in the containment in order to prevent dry-out of the water in the containment wet well. This provides a diverse and independent means of water injection from the already installed Reactor Building Spray System and the Fixed Fire Fighting System. Water injection into containment remains the primary action for severe accident mitigation involving core melt and is intended to help minimise gas pressure in the containment and to mitigate the effects of Molten Core Concrete Interaction; reducing the potential for containment basemat failure, which would result in a radiological release. Back-up mobile water pumps stored on-site and at the new Emergency Response Centre will provide the capability to inject water through this modified penetration with water from existing station supplies. By injecting further water supplies through the engineered CWI point, it is judged possible to further extend the timescales to containment failure.
- Studies into the feasibility of the installation of Filtered Containment Venting (FCV) are now complete. During this feasibility study, consideration was given to outputs from the

Probabilistic Safety Analysis, improvements in filter technology since the original Safety Case, and the potential impact on current safety systems and operation. It was determined that FCV would be feasible to install although there are some outstanding technical risks identified during the concept design phase. The potential benefits to overall risk reduction following a severe accident at SZB is finely balanced against the potential disbenefits associated with design basis operation. Given the extended timescales to containment failure, a project is underway to understand the residual risk and whether there are other reasonably practicable ways of addressing the risk. Installation of an FCV remains a potential option with a final decision on this project expected in 2015.

- Whilst this finding is directed at SZB, it should be noted that the Advanced Gas-cooled Reactor (AGR) fleet has been assessed for any similar issues. It was determined that the unique design of AGR systems mitigates the requirement for additional filtration and that there are no recognised mechanisms for hydrogen production on a significant scale. The ventilation routes are also different to a PWR; the final containment barrier on an AGR is the Pre-stressed Concrete Pressure Vessel (PCPV), which is the main pressure retaining part of the reactor. The primary design provision on the PCPV to prevent over-pressurisation is the Safety Release Valves (SRVs). In addition there are blowdown routes for lowering the vessel pressure. All discharge routes are fitted with filters, including particulate filters on the SRVs. See IR-21 for further details.

EDF Energy emergency arrangements will be updated to incorporate any changes to procedures as a result of the modifications made relating to this recommendation. Training regimes for emergency responders will incorporate the latest capabilities and include an introduction to the equipment and the connection points on site.

The development of modifications, equipment and procedures will have appropriate input from Human Factors specialists, ensuring that the enhanced systems are fit for purpose in what could be a challenging environment. The maintenance of on-site equipment and plant modifications will be managed under normal licence conditions.

6.18.3 Finding Conclusions

Through the delivery of the EDF Energy Japanese Earthquake Response (JER) programme of work, SZB will be more resilient to a severe event. The effects of hydrogen generation in the reactor have been mitigated by the installation of PARs, and studies into the feasibility of FCV have been completed. A pre-engineered hook-up point will also increase the ability of emergency responders to provide cooling water into the containment building.

Following an extensive programme of work, this recommendation is considered closed. The management of modifications and installations has been moved to normal business.

Furthermore, IR-19 discusses additional cooling provisions and STF-8 the provision of connections which will provide additional defences in a severe event.

6.19 Stress Test Finding 19 Close Out Report

Finding STF-19: Reports on the progress made in addressing the conclusions of the licensees Considerations and the ONR findings should be made available to ONR on the same timescale as that for HM Chief Inspector's recommendations (June 2012). These should include the status of plans and details of improvements that have been implemented.

6.19.1 Overview

This applies to EDF Energy as an operator of 15 reactors at 8 locations within the UK. It is standard practice for EDF Energy to be open and transparent, demonstrating the rationale and decision making process behind the response to the events in Fukushima with the Office for Nuclear Regulation (ONR), therefore this finding is highly relevant.

EDF Energy issued, as part of the ENSREG Stress Test process, a number of Considerations relating to the conclusions from the Stress Tests, which the ONR is interested in understanding and having appropriate oversight of how the company intends to adequately close out.

6.19.2 Response

In June 2011 EDF Energy submitted, and published, a package of reports including both responses to the ONR's Recommendations and Findings as well as an update on EDF Energy's own Considerations.

The update demonstrated the current status of all Considerations and also a plan of how and when each would be closed out.

It is also of note that an action tracking, decision making and closure process was developed and approved within the EDF Energy Japanese Earthquake Response (JER) programme. The process covers the tracking of all actions, including: ONR Interim Recommendations; ONR Final Recommendations; ONR Stress Test Findings as well as EDF Energy's own Considerations.

The action tracker also includes many other actions from international organisations such as The World Association of Nuclear Operators (WANO) and International Nuclear Plant Operators (INPO)

This action tracker has also been reviewed by the EDF Energy Independent Nuclear Assurance division (INA).

This process has been used for all Considerations and allows EDF Energy to demonstrate that there is a clear decision making process in place for all considerations.

The process demonstrates that any decisions made are appropriate and consistent and will also link to the overall programme of work, demonstrating the programme of work clearly.

This process will also demonstrate that all other actions, as discussed above, have been sentenced accordingly.

6.19.3 Finding Conclusions

EDF Energy issued to the ONR, as part of the June 2012 submission, an update giving further detail on all of its Considerations as well as the ONR Recommendation and Findings and the decision making process which governs the programme of work. EDF Energy also supplied an update on how all Considerations were being closed to the ONR in April 2014. As such, this recommendation is considered to be closed.

7 Source documentation

The following documents were used to support the development of this report, are available in the public domain and can be consulted for further detail on their respective subject matter.

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[Ref. 2] CR/14/034 - PSHA Methodology for Nuclear Facilities in the UK: Gap Analysis (Revised and Expanded), R.Musson, BGS

[Ref. 3] CR/10/060 Hazard sensitivity to developments in strong ground motion modelling at Hinkley Point, R.Musson BGS

[Ref. 4] EDF NNB Report 17196-000-HPC-RPT-0005 Hinkley Point Site Seismic Hazard. Fault Capability Study: Application of PFDHA Methodology to Hinkley Point C

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WANO SOER 2011-2: Fuel Damage Caused by Earthquake and Tsunami

WANO SOER 2011-3: Spent Fuel Pool/Pond Loss of Cooling and Makeup

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IJCO – Interim Justification for Continued Operation of the Reactors at Heysham 1 in Light of the Reassessment of the External Flooding Risk; EC No 350931