Generic design assessment

UK EPR™ nuclear power plant design by AREVA NP SAS and Electricité de France SA

Final assessment report

Spent fuel

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Final Assessment report – Spent fuel

Protective status	This document contains no sensitive nuclear information or commercially confidential information.
Process and Information Document (1)	The following sections of Table 1 in our Process and Information document are relevant to this assessment: Section 1.4 A proposed **waste and spent fuel strategy** based on the expected waste generation and management practices throughout the facility lifecycle Section 2.5 A description of **how spent fuel will be managed** and the quantities that will arise throughout the facility's lifecycle
Radioactive Substances Regulation Environmental Principles (2)	The following principles are relevant to this assessment: RSMDP1 – Radioactive Substances Strategy: A strategy should be produced for the management of all radioactive substances RSMDP3 – Use of BAT to minimise waste: The best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity. RSMDP10 – Storage: Radioactive substances should be stored using the best available techniques so that their environmental risk and environmental impact are minimised and that subsequent management, including disposal is facilitated. RSMDP14 – Record Keeping: Sufficient records relating to radioactive substances and associated facilities should be made and managed so as: to facilitate the subsequent management of those substances and facilities; to demonstrate whether compliance with requirements and standards has been achieved; and to provide continuing assurance about the environmental impact and risks of the operations undertaken, including waste disposal. RSMDP15 – Requirements and conditions that properly protect people and the environment shall be set out and imposed for disposal of radioactive waste. Disposal of radioactive waste shall comply with imposed requirements and conditions.
Report author	Grundy, Dr. C. L.

1. Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs, Environment Agency, Jan 2007.

   http://publications.environment-agency.gov.uk/pdf/GEHO0107BLTN-e-e.pdf

2. Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation - Environmental Principles (REPs), 2010.

   http://publications.environment-agency.gov.uk/pdf/GEHO0709BQSB-e-e.pdf

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1 Summary

1 This report presents the findings of our assessment of the proposals made by EDF and AREVA for spent fuel management based on information submitted in their Pre-Construction Environmental Report (PCER) and supporting documents.

2 The Joint Regulators for GDA, the Office for Nuclear Regulation[1] (ONR) and the Environment Agency, have worked together closely to review EDF and AREVA's spent fuel management proposals in GDA. ONR are responsible for regulation of storage of spent fuel and the Environment Agency regulate disposals. Our assessment has involved review of EDF and AREVA's GDA submissions and, in particular their integrated waste strategy (IWS), BAT demonstration report, solid radioactive waste strategy report (SRWSR), their mapping document for the radioactive waste management case (RWMC), and the Nuclear Decommissioning Authority (NDA) Radioactive Waste Management Directorate (RWMD) Disposability Assessments, including an EDF and AREVA Critique of the NDA RWMD findings.

3 This assessment aims to establish that EDF and AREVA have an adequate strategy for spent fuel management, and that spent fuel will be managed so that it will be suitable for disposal at a geological disposal facility.

4 We have examined EDF and AREVA's GDA submissions, and found that they give consideration to operating strategies in regard to spent fuel generation. The strategy proposed by EDF and AREVA for managing spent fuel following its removal from the reactor, is to transfer the spent fuel to the spent fuel pool for storage and initial cooling for some years. The fuel is then proposed to be transferred to an interim storage facility (PCER sc6.2s3.4.2) until such time a geological disposal facility becomes available for direct disposal. EDF and AREVA have provided supporting information on longer term storage.

5 We conclude that in their submission, EDF and AREVA describe how spent fuel will arise, be managed and disposed of throughout the facility's lifecycle. EDF and AREVA provide information on the fuel composition and characteristics, and expected fuel burn up, and quantities of spent fuel that will arise. Information is provided in the submission and supporting documents on short and long-term management proposals for spent fuel. EDF and AREVA have obtained a view from the RWMD of the NDA on the disposability of the fuel and have provided their critique to the Regulators.

6 EDF and AREVA provided detailed responses in regard to storage and disposability in February and March 2010. Their response on disposability was considered in our assessment report on disposability of spent fuel published in June 2010 (Environment Agency, 2010c), and is discussed in this document.

7 At the time of our consultation, when this report was first published, we said that we needed more information on the longer term storage of the fuel to understand whether there is any potential for degradation of the fuel over the longer term that might affect its disposability. This is consistent with the ONR requirement for a satisfactory demonstration that spent fuel can be stored safely for the necessary period of time without significant degradation. At the time of our consultation we said that our conclusion was subject to the potential GDA Issue:

a) Disposability of spent fuel following longer term interim storage pending disposal.

8 Further information was provided by EDF and AREVA in regard to the proposed storage facilities to support the safe long-term storage of the spent fuel and to ensure that the fuel does not degrade over the long storage period. ONR reviewed this information in its Step 4 assessment. We continued to work with ONR on these

[1] The Office for Nuclear Regulation (ONR) was created on 1st April 2011 as an Agency of the Health and Safety Executive (HSE). It was formed from HSE's Nuclear Directorate and has the same role. In this report we therefore generally use the term "ONR", except where we refer back to documents or actions that originated when it was still HSE's Nuclear Directorate.

matters, and this work informed our decision. We are satisfied with the information provided and have closed out the issue on disposability.

9 Our conclusions have been updated since our consultation.

10 **We conclude that EDF and AREVA have:**

a) **demonstrated BAT in the fuel design for the UK EPR in order to minimise the amount of spent fuel for disposal;**

b) **provided sufficient evidence to support the safe short and longer term interim storage of the spent fuel to support the condition of the fuel for disposal.**

11 **We also conclude, based on the further evidence provided on EDF and AREVA's management plans for the fuel including storage, that the UK EPR is not expected to produce spent fuel for which there is no foreseeable disposal route.**

12 As part of our assessment we identified the following assessment findings:

a) The future operator shall, before the commissioning phase, propose techniques for the interim storage of spent fuel following a period of initial cooling in the pool. The future operator shall provide an assessment to show that the techniques proposed are BAT. (UK EPR-AF16)

b) The future operator shall, before the commissioning phase, provide confidence that adequate radioactive waste management cases (RWMCs), supported by appropriate stage Letters of Compliance (LoCs) and taking due account of necessary storage periods, can be developed for spent fuel on the timescales identified in EDF and AREVA's plan for disposability of spent fuel. (UK EPR AF17)

13 Our findings on the wider environmental impacts and waste management arrangements for the UK EPR reactor may be found in our Decision Document (Environment Agency, 2011d).

2 Introduction

14 We originally published this report in June 2010 to support our GDA consultation on the UK EPR design. On 28 June 2010, our consultation began on our preliminary conclusions following our detailed assessment of this submission. This consultation closed on 18 October 2010.

15 We received additional information from EDF and AREVA after June 2010 and also undertook additional assessment in response to consultation responses. This report is an update of our original report covering assessment undertaken between June 2010 and the end of March 2011 when EDF and AREVA published an update of their submission. Where any paragraph has been added or substantially revised it is in a blue font.

16 We set out in our process and information Document (P&ID) the requirements for a Requesting Party to provide a proposed waste and spent fuel strategy based on the expected waste generation and management practices throughout the facility lifecycle. This strategy should have regard to:

a) the UK Government's Sustainable Development Strategy (March 2005) Cm 6467;

b) the objectives of the UK strategy for radioactive discharges (DECC, 2009b);

c) the Review of Radioactive Waste Management Policy, Final Conclusions, Cm2919 July 1995 (DETR, 1995);

d) The Decommissioning of the UK Nuclear Industry's Facilities (DTI, 2004); and

e) our Radioactive Substances Regulation Environmental Principles (REPs) (Environment Agency, 2010c).

17 Our P&ID also requires a description of how spent fuel will be managed and the quantities that will arise throughout the facility's lifecycle. This should include:

a) new fuel composition and characteristics;

b) expected fuel burn up and ratings;

c) short and long term management proposals including any for off site management or disposal.

18 If the management options include direct disposal, the requesting party should obtain, and provide, a view from the Nuclear Decommissioning Authority (NDA) (as the UK authoritative source in providing such advice) on the disposability of the spent fuel.

19 We published our Radioactive Substances Regulation Environmental Principles in 2010 and principles on radioactive substance strategy, use of BAT to minimise waste, storage, record keeping and requirements and conditions that properly protect people and the environment are relevant to this topic.

20 This assessment aims to establish that EDF and AREVA have an adequate strategy for spent fuel management, and that spent fuel will be managed so that it will be suitable for disposal at a geological disposal facility. This assessment considers in detail EDF and AREVA's proposals for spent fuel management.

21 The Joint Regulators have worked closely to review EDF and AREVA's proposals for spent fuel management in GDA. Our assessment is performed on a sampling basis and has involved review of EDF and AREVA's GDA submissions including the PCER and key supporting documents namely the IWS, BAT demonstration report, solid radioactive waste strategy report (SRWSR), and the radioactive waste management case (RWMC) mapping report.

22 We assessed information contained in the PCER but found that while much improved from the original submission it still lacked the detail we require including an IWS for waste and spent fuel, and detailed proposals for spent fuel management. We raised Regulatory Observations (ROs), some jointly with ONR and some were raised directly

by ONR with relevance to this assessment report, on EDF and AREVA that had actions to provide:

a) IWS, BAT case and evidence to support a radioactive waste management case (RO-UKEPR-33);

b) Long Term Storage (RO-UKEPR-39) (ONR);

c) Disposability of Spent Fuel and ILW (RO-UKEPR-48);

23 We raised 33 Technical Queries (TQs) on EDF and AREVA during our assessment. The following TQs, some of which were raised jointly with ONR or directly by ONR, were relevant to this report:

a) TQ-EPR-123 Information on the longer term used fuel storage facility (ONR)

b) TQ-EPR-149 EPR Environment Design Review and Environment Committee

c) TQ-EPR-182 Fuel management regime and proposed liquid and gaseous radioactive waste discharges

d) TQ-EPR-222 EPR Intermediate Level Waste

e) TQ-EPR-231 Discharge of Actinides

f) TQ-EPR-467 Encapsulation of spent fuel prior to disposal (ONR)

g) TQ-EPR-569 Long-term pond storage of spent fuel (ONR)

24 EDF and AREVA responded to all the ROs and TQs. They reviewed and updated the PCER in March 2010 to include relevant information provided by their response to the ROs and TQs.

25 In January 2011, EDF and AREVA provided an updated 'mapping document' that identifies how their existing documentation forms the basis of a RWMC for the UK EPR. This document was updated again in March 2011. They also produced a final response to RO-UKEPR-48 in regard to disposability of waste and spent fuel, where further information was provided on their plan for disposability of spent fuel including the plan for long-term storage, and the work being undertaken by the Radioactive Waste Management Directorate (RWMD). In March 2011, EDF and AREVA provided an updated PCER.

26 Our detailed assessment of EDF and AREVA's proposals for spent fuel management is documented within this assessment report. This is essentially the same as that provided in the first issue of this assessment report but updated, where appropriate, to reflect:

a) Our assessment of any further information provided by EDF and AREVA since the consultation date.

b) Any further work that we said, in the consultation document, that we intended to do.

c) Any matters arising from ONR's GDA Step 4 work that are relevant to our assessment.

d) Our consideration of any consultation responses relevant to this topic.

e) Our consideration of any comments from our 6 July GDA stakeholder seminar relevant to this topic.

27 We have published the consultation responses submitted in regard to our preliminary conclusions for the UK EPR design on our website (see: https://consult.environment-agency.gov.uk/portal/ho/nuclear/gda).

28 The questions raised at our stakeholder seminar have also been published (see: http://www.hse.gov.uk/newreactors/seminar-060710.pdf).

3 Assessment

3.1 Assessment Methodology

29 The basis of our assessment was to:

a) review appropriate sections of the PCER and its supporting documents including the IWS, BAT demonstration report, solid radioactive waste strategy report (SRWSR), and the radioactive waste management case (RWMC) mapping document;

b) hold technical meetings with EDF and AREVA to clarify our understanding of the information presented and explain any concerns we had with that information;

c) raise Regulatory Observations (ROs) and Technical Queries (TQs) where we believed information provided by EDF and AREVA was insufficient;

d) carry out supporting site visits to gain knowledge to inform our decision;

e) consider consultation responses and comments from our stakeholder seminar relevant to this topic;

f) decide on any GDA Issues;

g) identify assessment findings to carry forward from GDA.

30 In undertaking our assessment, we have worked closely with ONR. We have also had discussions with other Regulators; the Radiation and Nuclear Safety Authority of Finland (STUK) and the United States Nuclear Regulatory Commission (NRC).

3.2 Assessment Objectives

31 We started our assessment with some key questions to answer:

a) Do EDF and AREVA provide an adequate integrated waste and spent fuel strategy?

b) Do EDF and AREVA provide information on new fuel composition and characteristics, and proposed fuel burn up?

c) Do EDF and AREVA provide information on spent fuel quantities and give consideration to operating strategies in regard to spent fuel generation?

d) Do EDF and AREVA provide information on the short and long term management proposals for spent fuel?

e) Are the spent fuel arisings from a UK EPR disposable?

32 We expect new nuclear power plant designs to be developed in line with a radioactive waste and spent fuel strategy that seeks to:

a) minimise the production of radioactive waste;

b) manage unavoidable waste and spent fuel to achieve an optimal level of protection for people and the environment.

33 Our radioactive substances regulation environmental principles (REPs) (Environment Agency, 2010c) set out the issues that this type of strategy should take into account. For new nuclear power plant designs, the strategy also needs to be consistent with recent government statements (BERR, 2008) that:

a) the disposal of intermediate level waste (ILW) to a future geological repository, from any new nuclear power stations, is unlikely to occur until late this century;

b) any nuclear power stations that might be built in the UK should proceed on the basis that spent fuel will not be reprocessed.

34 There are currently no final disposal facilities for spent fuel in the UK. However, the Government has stated (BERR, 2008) that it is satisfied that:

a) a geological disposal facility would provide a possible and desirable mechanism for disposing of higher level wastes (both from a new nuclear programme and existing legacy waste);

b) there are feasible and long-term mechanisms through the managing radioactive waste safely (MRWS) (Defra et al 2008) programme for identifying a suitable site and for constructing a geological disposal facility.

35 Although a permit for final disposal may not be required for a considerable time, we expect EDF and AREVA to show now whether spent fuel:

a) is likely to be suitable for disposal in a geological repository;

b) will be appropriately managed in the interim, so as not to prejudice its ultimate disposal.

36 We expect spent fuel storage to be required for around 100 years until a geological disposal facility is available. The Regulators need to see that spent fuel can be safely stored and managed to avoid degradation over time such that it can remain in a form acceptable for transport to, and disposal in, a repository.

3.3 EDF and AREVA documentation

37 We referred to the following documents to produce this report:

Document reference	Title	Version number
UKEPR-0003-64	PCER Sub-Chapter 6.5- Interim storage facilities and disposability for UK EPR	04
NDA TN 11261814	GDA: Summary of Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR	Oct 09
NXA/10747397	GDA: Disposability Assessment of Wastes and Spent Fuel arising from Operation of the UK EPR Part 1 Main Report	Jan 10
NXA/10777960	GDA: Disposability Assessment of Wastes and Spent Fuel arising from Operation of the UK EPR Part 2 Data Sheets and Inventory Tables	Jan 10
UKEPR-0010-001	GDA UK EPR – Integrated Waste Strategy Document	02
ELI0800224	Interim storage facility for spent fuel assemblies coming from an EPR plant	A
NESH-G/2008/en/0123	Solid Radioactive Waste Strategy Report (SRWSR)	A
UKEPR-0009-001	Longer Term Spent Fuel Interim Storage Facility	1
UKEPR-0011-001	GDA UK EPR BAT Demonstration	03
R10-017	The Case for Disposability of Spent Fuel and	

Document reference	Title	Version number
	ILW	
ELIDC0902019	Plan for the development of waste management facilities over the EPR lifetime	B
R10-002 (A)	Management of Records for Long Term Management of Spent Fuel and ILW	3
R10-006 (A)	Human Factors in Long Term Waste Management	2
SGN NT 100330 20 0004A	Maintenance of Interim Storage Facilities	
SGN NT 100330 20 005A	Current French and International Research and Development Programmes for Interim Storage of Spent Fuel	
ELIDC100094	The safety of long-term spent fuel storage in pools	A
NT 100330 20 0003	Technical Note Encapsulation Facilities for Spent Fuel UK-EPR Project	B
UKEPR-0012-001	GDA UK EPR Mapping Document for Radioactive Waste Management Case	02
EPR70238R	RO-UKEPR-48 A.2 – Consolidation of the plan for disposability of waste and spent fuel	14/01/11

38 We use short references in this report, for example:

a) PCER sub-chapter 6.2 section 1.2.1 = PCERsc6.2s1.2.1.

3.4 Spent Fuel Strategy

39 EDF and AREVA present a 'reference case' for solid radioactive waste and spent fuel strategy based on the waste and spent fuel management practices and arrangements of the reference plant for the UK EPR, Flamanville 3. This is supported by a BAT analysis in PCERsc8. EDF and AREVA recognise that UK EPR operators may wish to adopt alternative spent fuel arrangements. Other possible options to the reference case for spent fuel strategy are presented in a solid radioactive waste strategy report (SRWSR). However, the SRWSR does not present respective BAT arguments. EDF and AREVA claim there is a high degree of confidence that such cases can be made by potential EPR operators.

40 Five interim storage solutions are identified in the solid radioactive waste strategy report, SRWSR, including underwater long-term pool storage and four types of dry storage. Wet storage is usual practice in nuclear power plants and is used for initial cooling, and subsequently may be used for interim storage (for example, as in La Hague in France), before final disposal. Dry interim storage for spent fuel is used in Europe and the USA.

41 Of the five options, one wet pool storage, and two dry storage solutions were identified and assessed in more detail for the UK EPR. EDF and AREVA considered the regulatory requirements for interim storage facilities and in particular Environment Agency requirements in relation to BAT and our radioactive substances environmental principles (REPs).

42 EDF and AREVA considered three spent fuel storage technologies, based on available and proven technologies:

a) wet interim pool storage - fuel assemblies stored in a pool;

b) dry interim cask storage - fuel assemblies stored in metal casks;

c) dry interim storage in purpose designed stores - fuel assemblies stored in vault type storage.

43 The dry interim storage facility uses metallic storage flasks technology, such as the TN DUO flask which is designed for both transport and storage. Information is provided on the building layout and safety features in the SRWSR. The storage facility is designed to operate for about 100 years. Visual surveillance is carried out as part of a maintenance programme for flasks in the interim storage facility. A permanent check system is implemented which monitors any pressure drop in the interspace between the primary and secondary lid of the TN-DUO flask.

44 The dry storage vault involves placing fuel assemblies into canisters when they are received. The stainless steel canisters contain aluminium partitions to house fuel assemblies and ensure heat dissipation. Details are provided on the building layout and safety features in the SRWSR.

45 These designs allow for retrieval and inspection of the fuel, and for refurbishment. Further information on wet interim storage is provided later in this report.

46 EDF and AREVA's IWS was produced in response to RO-UKEPR-33. The IWS includes the management of both radioactive and non-radioactive wastes arising from construction, operation and decommissioning of the UK EPR. More information is provided in our IWS assessment report (Environment Agency, 2011b).

47 The IWS states there is a spent fuel interim store to store all spent fuel assemblies generated by the reactor, assuming 60 years operation for the UK EPR, for about 100 years before final disposal. The design of the store is claimed to provide adequate space and handling for safe operation, and monitoring of the condition of the spent fuel. The store is designed to be maintained to last for about 100 years from when spent fuel is first emplaced in the store.

48 Interim storage may be required potentially beyond 100 years to cover the lifetime of reactor operations (including the final emplacement of fuel to interim storage, following an initial cooling period in a pond after reactor operations cease), and the time to reduce the heat generation of the fuel. The potential for refurbishment of the store(s) would be considered if required.

49 The Regulators requested further information about long-term storage initially in TQ-EPR-123, and subsequently in RO-UKEPR-39, see later in this report. EDF and AREVA provided a detailed response report to TQ-EPR-123 which provided information on fuel integrity during storage for both wet and dry storage options.

50 EDF and AREVA provided detailed response information in regard to RO–UKEPR-39 in February and March 2010 which was received too late for us to consider in our public consultation document. We reviewed this information, and continued to liaise with ONR who reviewed this information in its Step 4 assessment, to inform our decision document, see later.

51 The Regulators requested further information about long-term storage, including a plan showing when waste management facilities will be developed and constructed, and the research needed to underpin the plan for longer term storage to ensure the spent fuel can be stored, transported and disposed, see later.

52 EDF and AREVA take account of Government policy in their IWS, noting that spent fuel will be declared as waste and will not be reprocessed, and that therefore spent fuel will be stored on site and then disposed of to the geological disposal facility. The IWS indicates that the UK EPR design allows for spent fuel to be stored in an on-site

fuel store designed to accommodate the lifetime arisings of spent fuel from the nuclear power station. PCERsc6.2s3.4.2 notes one or more options for spent fuel storage, including an on-site interim storage facility and, or, construction and operation of an interim spent fuel storage facility shared between several sites.

53 EDF and AREVA provided information on the measures incorporated in the design and the use of fuel materials, and reactor controls in order to retain activity in the fuel.

54 The IWS is consistent with recent government statements (BERR, 2008) as EDF and AREVA have made the following assumptions:

a) Spent fuel will be declared as waste and will not be reprocessed.

b) Spent fuel will be stored on site followed by disposal to a geological disposal facility (GDF) at the appropriate time.

55 The radioactive waste strategy is a 'reference case' based on the waste and spent fuel management practices and arrangements of the reference plant for the UK EPR, Flamanville 3. The reference case is reasonable, however we expect the future operator shall identify any changes to the 'reference case' for solid radioactive waste and spent fuel strategy, and evidence that the site-specific IWS achieves the same objectives at the detailed design stage (UK EPR-AF01).

56 **We have concluded that:**

a) **EDF and AREVA have provided a reasonable strategy for managing spent fuel that will be produced by the UK EPR.**

b) **The spent fuel strategy is consistent with recent government statements (BERR, 2008), and our REPs (Environment Agency, 2010).**

3.5 Creation of spent fuel

57 The UK EPR reactor core comprises 241 fuel assemblies that contain bundles of fuel rods held in place by space grips and top and bottom fittings. The fuel assembly is a 17x17 square array comprising 265 fuel rods and 24 guide thimbles. The thimbles are joined to the grids and the top and bottom nozzles. The thimbles may also hold rod cluster control assembles (RCCAs) which are used to control the reactivity of the core and power distribution, and for reactor shutdown, and neutron source rods, or in core instrumentation. The fuel is in the form of uranium dioxide (UO_2) pellets that are stacked in a zirconium alloy cladding tube to form fuel rods. Some fuel assemblies also include a neutron poison, gadolinium oxide, which is mixed with the fuel and depletes slowly with burn up. EDF and AREVA claim it is also possible to use mixed oxide (MOX) fuel pellets in the EPR but this is not proposed for the UK EPR in GDA.

58 The initial enrichment of new fuel is up to 5 per cent in weight uranium-235 in order to sustain the nuclear fission reaction. The UK EPR is designed for an operational life of 60 years during which time the operational reactor will contain around 127 tonnes of enriched uranium fuel. Reactor refuelling takes place at the end of each reactor fuel cycle. The UK EPR fuel cycle lasts from 12-22 months depending on the fuel management regime adopted by the future operator. At the end of the fuel cycle, approximately one third of the 241 fuel assemblies are replaced by new fuel assemblies. The isotopic composition of the spent fuel depends on the initial enrichment, the uranium source and the fuel management conditions in the reactor. The average core region fuel burn up is less than 65,000 MWd/tU, which is the maximum burn up proposed.

59 The Regulators requested further information from EDF and AREVA in TQ-EPR-182 on the fuel management regime since this might impact on the radionuclide fingerprint and activity for liquid and gaseous discharges. EDF and AREVA's response confirmed that the fuel management regime will be dependent on the operator. PCSRsc3.1 indicates the possibility for different fuel management techniques has

been left open to allow flexibility for the future operator. The information EDF and AREVA provided suggests that benchmark regimes are based on a uranium oxide core with a cycle of 12, 18 or 22 months. The type of fuel management regime impacts mainly on tritium production through boron concentration, but the differences between the tritium produced for the various fuel management conditions are said to be small. EDF and AREVA claim that the maximum discharges presented in the GDA submission will be applicable for benchmark fuel management regimes that may be implemented by the operator.

60 Both new fuel and spent fuel are stored on the reactor site in the fuel building. PCERsc1.2 describes the fuel building, which includes the spent fuel pool, the loading pit for casks, the transfer station, and storage and inspection compartments for new fuel assemblies. It also includes filtration units to filter air escaping in accident conditions and ventilation systems.

3.6 Management of Spent Fuel

3.6.1 BAT for Fuel Design

61 The BAT demonstration report was prepared by EDF and AREVA to provide evidence that best available techniques have been used to prevent, and where that is not practicable to minimise the production of radioactive waste at source in the EPR design.

62 Carbon-14 is produced by the neutron activation of nitrogen-14 and oxygen-17. The two main sources of nitrogen and oxygen are the coolant and the fuel.

63 The production of carbon-14 in fuel is mainly caused by the oxygen in the fuel and minor sources are nitrogen impurities in the fuel. This carbon-14 is mainly confined in the fuel cladding and is removed from the reactor with the fuel.

64 Carbon-14 from fuel would only usually be discharged during major fuel cladding failure. Increased discharge in fission products such as caesium-137 and noble gases such as krypton and xenon would indicate a problem with fuel cladding. Also the liquid discharge monitoring of carbon-14 would indicate any increase in discharge of carbon-14 into the primary coolant.

65 Tritium may also be produced from fuel as a result of ternary fission reactions. Evidence is that only a small amount is released through the fuel cladding. The Zircaloy cladding provides an effective barrier in preventing the release of tritium such that releases from the fuel are very low compared to other sources. Production of tritium from helium used to pressurise the fuel rods is a small source and less significant than from the fission process.

66 Further information on radionuclide production mechanisms is available in both our Final Assessment Report UK EPR-03 on ‘creation’, and Annex 4 of the UK EPR GDA Consultation Document (Environment Agency, 2010a).

3.6.2 BAT to minimise disposals of spent fuel

67 EDF and AREVA have used a step-by-step approach to apply BAT as described in PCER Chapter 8. The UK EPR reference plant is Flamanville 3, which was designed to take into account experience and feedback from operating PWRs in France and Germany. This allowed improvements to be identified and incorporated as a result of learning from experience. There was an EPR environment design review in France in 2004, and an action plan and task force was set up. The scope and findings of the design review was discussed at the Joint Regulators' inspections in December 2007 and April 2009, and presented in the published Joint Regulators' inspection report in 2009. TQ-EPR-149 was issued by the Environment Agency to request the provision of

documentation from the 2004 design review. TQ-EPR-149 also requested minutes of the Environment Committee referenced in the PCER.

68 It is understood from the TQ response from EDF and AREVA that the aim of the environmental design review meeting was to assess the aspects of the design that had the potential for significant environmental impact that need to be addressed at the design stage, rather than through reliance upon operational management arrangements.

69 The review considered radioactive and non-radioactive solid wastes, liquid and gaseous discharges. This was based on operational experience feedback from the 58 operating EDF plants, the German KONVOI reactors, and the periodic assessment of discharges and releases for operating plants. The review was carried out to define outstanding environmental issues which required further studies, as preparation for the environmental report to be submitted for the construction permit, and to prepare answers for the public debate in France once a site was chosen. The review jury made recommendations which included requirements for further studies. Information regarding implementation of the recommendations was presented at the joint Regulators team Inspection in April 2009, and at a waste topic meeting with the Regulators in March 2009.

70 EDF and AREVA claim the improvements in environmental performance of the UK EPR project with regard to waste and fuel include:

a) a more efficient use of natural uranium resources;

b) a significant reduction in the quantity (volume, mass) of long lived radioactive waste resulting from the fuel and its cladding owing to its:

   i) neutronic design (large core, neutron reflector);

   ii) and the fuel management performance (high burn up).

71 PCERsc8 describes the use of BAT in the UK EPR design with regard to spent fuel, namely the improved overall use of the fuel material compared with existing plants, as a result of increased operating and safety margins and more efficient use of the neutrons produced. EDF and AREVA claim there is less use of nuclear materials to produce the same amount of energy, and that it is possible to reduce both the consumption of natural uranium and the quantity of waste produced by irradiation, for the same amount of energy produced. They also claim that high burn up of the fuel optimises the use of the fuel and saves approximately 7 per cent of the natural uranium resource required compared with current fuel for a given amount of energy produced.

72 EDF and AREVA claim the UK EPR design has three design features which directly contribute to reducing natural uranium consumption and spent fuel production:

a) the use of a large core with 241 fuel assemblies compared to 205 fuel assemblies for the N4 reactor operating units; the N4 is a predecessor design to the EPR. There is a reduction in neutron leakage due to the larger size of the core. Adopting a larger core with a smaller refuelling fraction enables 7 per cent savings in natural uranium;

b) using a solid steel reflector, the heavy reflector. The reduction in radial neutron leakage leads to savings of 2 - 3 per cent natural uranium;

c) the improvement in overall thermal efficiency and the enhanced turbine efficiency, contributes 5 per cent to the reduction in consumption of natural uranium.

73 EDF and AREVA indicate that the reduction of solid waste arising from fuel and its cladding is linked to the UK EPR's neutronic design and the capability for improved burning of the fuel used. EDF and AREVA claim the increased burn up rate leads to a reduction in radiotoxic materials of around 14 per cent and a reduction of high activity long lived waste such as cladding of around 30 per cent.

74 EDF and AREVA note that the improvement in fuel reliability is a major objective for the UK EPR in their response to TQ-EPR-231 Discharge of actinides. This TQ issued by the Regulators required EDF and AREVA to quantify the actinide content of gaseous and liquid discharges and solid wastes arising from reasonably foreseeable events during the lifecycle of the UK EPR. This included the potential for fuel to contain tramp uranium, that is traces of uranium on the outside of the cladding left over from fuel manufacture, and potentially for fuel failure to occur. Information provided indicates that the current UK EPR fuel design is based on improvements in manufacturing and quality, and research and development. There is a worldwide programme of research and development, including manufacturing and human aspects. The current UK EPR fuel AFA 3G assemblies have shown consistent high operational reliability as a result of the improvements in manufacturing and quality as above.

75 EDF and AREVA have not provided detailed information on discharges from spent fuel storage. EDF and AREVA provided some generic information in regard to discharges from the spent fuel pool in their response to TQ-EPR-123 on longer term interim storage of spent fuel in the report 'Spent fuel interim storage facility' (UKEPR-0009-001). Aerial discharges via the ventilation system will be generated under wet and dry interim storage options. In both cases, solid wastes are anticipated from the filtration of these discharges. However, for wet storage, additional wastes are anticipated from the treatment of the spent fuel pool water. Both solid and liquid wastes may be generated. EDF and AREVA confirm no liquid wastes will be released directly to the environment from the storage facility under any option. Any solid or liquid wastes will be transferred to dedicated treatment and assay facilities.

76 EDF and AREVA anticipate that aerial discharges will be very small under normal operating conditions for both dry and wet storage options. Abatement will be provided using HEPA filtration upstream of the discharge point. For wet storage, in regard to liquid effluent discharges, some abatement will be provided by passive filtration. However, chemical treatment such as ion exchange may also be required.

77 We would not expect discharges from interim spent fuel storage to be significant, and would include any discharges within the limits and levels proposed for the reactor in Chapters 8 and 9 of the UK EPR Decision Document (Environment Agency, 2011d).

78 We consider EDF and AREVA have demonstrated BAT in the fuel design and in order to minimise the amount of spent fuel for disposal.

3.6.3 Initial Fuel Cooling in the Pool

79 In PCERsc6.2, EDF and AREVA provide information on radioactive waste and spent fuel produced by the UK EPR. A fuel assembly is spent and must be discharged after producing energy in the reactor for a period of 3 to 5.5 years depending on the fuel cycle adopted by the operator. The fuel assembly is then transferred from the reactor building to the fuel building through the containment penetration formed by the fuel transfer tube. The UK EPR spent fuel reactor pool and transfer facility are described in PCSR chapter 9.1. Decay heat generated from the irradiated fuel assemblies is removed by the fuel pool cooling system.

80 Spent fuel assemblies are discharged from the reactor and placed into the spent fuel pool to cool and decay for some years before being moved to an interim storage facility. The UK EPR design allows a storage capacity in the fuel pool for 10 years electricity generation.

81 The quantities of spent fuel discharged from the reactor during refuelling can be up to 80 spent fuel assemblies each refuelling operation. A bounding value for the total number of spent fuel assemblies produced at the end of reactor life is set to 3400 units based on 60 years operating life.

82 Core components used to control or measure neutron activity such as rod cluster control assemblies (RCCAs) and in core instrumentation (aeroball finger tubes) may be replaced during outages. The components are highly activated when they are removed from the reactor (because of their exposure to neutron radiation in the reactor core) and are transferred to the spent fuel pool where they are left to radioactively decay.

3.6.4 Interim Storage

83 One wet pool storage, and two dry storage solutions were identified and assessed in detail for the UK EPR, based on available and proven technologies. More information on the options is presented in an earlier section on spent fuel strategy.

84 PCERsc6.5s4.1 describes the arrangements for interim storage for spent fuel. An interim wet storage facility is described with supporting review information in a report (ELI0800224).

85 The Regulators issued guidance on the level of design required for waste plants in GDA, recognising the requirements for significant periods of storage for waste, and spent fuel, in particular; 'to give the Regulators the required level of confidence that the operators can safely handle, store and dispose of spent fuel viable options will have to be identified by the Requesting Parties and a strategy / plan developed to show that one of these could be developed and implemented'. More details are below.

86 A UK EPR will generate approximately 3400 assemblies during its 60 year operating life that will require interim storage. The interim wet storage pool facility is designed to be in operation to safely and securely store the spent fuel underwater. The lifetime of the store is about 100 years with stated objectives to maintain shielding, preserve the fuel cladding, minimise contamination, cool the fuel, maintain the sub-criticality, and to protect the fuel assemblies from mechanical damage. Potential refurbishment of the store could be considered if required beyond its 100 year lifetime.

87 The review report of interim wet storage (ELI0800224) is based on more than 30 years experience from EDF in underwater storage of spent fuel. The review also considers international design and operating experience for interim storage facilities in Sweden, Finland, UK (Sellafield Site) and Russian Federation Facilities. EDF and AREVA conclude that long term pool storage of fuel has been successfully used at a large number of sites without significant degradation of the cladding.

88 EDF and AREVA gave a presentation to the Regulators on the UK EPR fuel route in November 2009. The Regulators requested a document providing the evidence and arguments to support the proposals for long-term pond storage in TQ-EPR-569 issued in January 2010. EDF and AREVA provided further information in March 2010,' The safety of long-term spent fuel storage in ponds' (see 3.3 EDF and AREVA documentation). The report detailed arguments to support the safe long-term interim storage of spent fuel in pools, based on preservation of cladding integrity, ease of inspection and monitoring and retrieval of the fuel.

89 The Department of Energy and Climate Change (DECC) considered UK and international experience of managing higher activity waste in developing their preliminary conclusions on new build waste. A range of evidence on the arrangements for the management and disposal of the waste from new nuclear power stations was reviewed and summarised in a paper published by DECC. For example, for interim storage of spent fuel, evidence was reviewed from the Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA), and the US Nuclear Regulatory Commission (NRC). NRC evidence indicates that spent fuel can be stored safely and securely without significant environmental impact for at least 100 years. Evidence from OECD member countries is that spent fuel has been safely and securely stored for several decades and such storage may continue for many more decades with proper control and supervision, as well as repackaging of

some wastes and periodic refurbishment of stores. The NEA also noted that stores of modern design have typically been licensed for periods of decades. The DECC paper also noted that considerable international experience exists for dry fuel stores that give confidence that similar stores can be constructed and licensed for operation in the UK.

90 During GDA, joint Regulator visits were made to sites in France, Germany, Sweden, UK and USA. We observed operation of waste management facilities, training and maintenance facilities, decommissioning activities, spent fuel pool operations and mobile plant during these visits. In particular, with regard to spent fuel we found that there is significant experience of operating spent fuel pools and dry spent fuel stores with techniques well developed.

91 The SRWSR indicates that the design of the wet storage facility for UK EPR spent fuel is based on the latest generation of La Hague complex storage pools, and detailed information is presented in the interim wet storage report on the arrangements for receipt of transport containers, handling and loading of fuel assemblies, cooling of the fuel pool, together with details of the building layout, safety and other relevant features.

92 The interim wet storage facility will be able to receive and store defective fuel assemblies associated with cladding failures. This damage may have been detected in the reactor pool or it may have occurred during spent fuel transfer or during interim storage. Defective assemblies can be inserted into over-packing replacement fuel cylinders and stored in the interim wet store.

93 TQ-EPR-123 was issued by the Regulators requiring further information on interim longer term spent fuel storage. The interim store is required potentially to operate beyond 100 years to cover the lifetime of reactor operations (including the final emplacement of fuel to interim storage, following an initial cooling period in a pool after reactor operations cease), the time to reduce the heat generation of the fuel. The potential for refurbishment of the store(s) would be considered if required.

94 EDF and AREVA prepared a report (UK EPR-0009-001) in response to TQ-EPR-123 containing detailed information on proposals for longer term storage of spent fuel, in addition to information provided in the SRWSR. They assumed that the interim store would have capacity for all spent fuel arising over the 60 year operational life of the UK EPR. The lifetime of the interim storage facility is assumed to be 100 years from receipt of the first spent fuel assembly for storage. The report considered both wet and dry interim storage facilities, as detailed in the SRWSR, and specifically interim wet storage as considered in report ELI0800224.

95 The potential for spent fuel assemblies to degrade over time was considered in response to TQ-EPR-123 and monitoring and mitigation options were provided. Inspection and maintenance activities were considered. Maintenance of integrity during storage was reviewed including potential mechanisms for fuel damage to occur, and the potential for degradation of other containment structures such as stainless steel and concrete structures designed to provide containment of spent fuel. The design philosophy takes into account the extended period for operation of the facility, and the need for maintenance, refurbishment and replacement. For example, the replacement on a periodic basis of equipment.

96 The potential for damaged fuel to occur was considered, and the means for detection of damaged fuel and options for longer term interim storage of damaged fuel were considered.

97 Plans for retrieval and inspection of fuel were considered, with details of an inspection and monitoring regime. Also plans for spent fuel retrieval were set out. Plans for final fuel retrieval prior to final disposal were detailed.

98 The Regulators found the report provided in response to TQ-EPR-123 (UKEPR-0009-001) to be a good quality response. Evidence from operating experience was provided in several parts of the response. However there were some remaining

issues, particularly with regard to longer term wet storage. The Regulators required further information, in particular evidence that fuel will remain robust over the storage period for retrieval, transport and disposal. We also required information on how the future operator will manage and implement arrangements to deal with changes in the size and skills of the workforce over the lifetime of storage, that is the change from operations to a quiescent phase when operations end. This will affect the reliance that can be placed on the workforce. The storage designs and plans for retrieval need to be robust in regard to these changes.

99 The Regulators required the Requesting Parties for GDA to provide information to demonstrate the facility for long-term interim storage of spent fuel can be designed for the total expected lifetime. Long-term interim storage is required until a geological disposal facility is available for direct disposal of spent fuel. The long term provision of services, for example to a storage pond for spent fuel, after a reactor has been shut down is required to be considered. A paper was issued in GDA '*The required level of design of waste plants for new build reactors in the Generic Design Assessment*' (HSE, 2009a). The paper sets out requirements for a Requesting Party to provide sufficient levels of design to justify credibility of the proposed storage options; understanding how waste streams and their packaging evolve during the storage period, the need for data and records management, knowledge of the constraints placed on the wastes by the disposal facility, identification of knowledge gaps and a supporting research programme to address the gaps, and robust estimates of the required capacity.

100 The Regulators issued RO-UKEPR-39 requesting further information on long-term storage. The actions associated with the RO outline the requirement for a plan showing when facilities for long-term storage should be operational, and the research needed to underpin these plans to ensure that spent fuel can be stored transported and disposed of. Other actions required EDF and AREVA to show how they will manage records over the lifecycle of the waste, to show how human factors have been built into longer term waste management plans and to show how facilities will be maintained over an extended storage period. EDF and AREVA provided a number of reports in regard to their response in February and March 2010.

101 The reports provided by EDF and AREVA in response to RO-UKEPR-39 included:

a) 'Plan for the development of waste management facilities over the EPR lifetime' (ELIDC0902019).

b) 'Management of Records for Long Term Management of Spent Fuel and ILW' (R10-002).

c) 'Human Factors in Long Term Waste Management' (R10-006).

d) 'Maintenance of Interim Storage Facilities' (SGN NT 100330 20 0004A).

e) 'Current French and International Research and Development Programmes for Interim Storage of Spent Fuel' (SGN NT 100330 20 005A).

We reviewed this information and we continued to work with ONR on this issue to inform our decision document.

102 The plan for the development of waste management facilities over the UK EPR lifetime report was produced for the interim storage facilities for spent fuel and ILW. The filling and retrieval stages are considered for the spent fuel interim store. Some remaining issues were raised by ONR in discussion with ourselves which were required to be addressed in RO-UKEPR-48 on disposability.

103 The document provided on 'Management of Records for Long Term Management of Spent Fuel and ILW' confirmed that records for waste generated over the lifetime of the plant will be integrated into the British Radwaste Information Management System (BRIMS™). The report indicates the type of records that will need to be retained for

the UK EPR. The BRIMS system is able to manage waste records and is proposed to be used to ensure knowledge retention over time for the UK EPR.

104 EDF and AREVA prepared a report to consider human factors in plans for long-term waste management for spent fuel and ILW. This report considers matters such as workforce requirements over the plant lifecycle including maintaining competence.

105 The report on 'Maintenance of Interim Storage Facilities' was prepared in regard to spent fuel, and considered both wet and dry storage systems for the UK EPR. The need for exceptional access was considered in the report. For example for the complete replacement of a large piece of equipment that is difficult to replace such as an operating crane.

106 'Current French and International Research and Development Programmes for Interim Storage of Spent Fuel' reviewed operating experience, the research and development that has been carried out to determine acceptable storage conditions and identified future research needs. The report is based on the requirement to maintain appropriate storage conditions thereby preserving integrity of the fuel cladding and the assembly structure, allowing safe handling for retrieval. Inspection regimes for wet and dry storage conditions were considered.

107 ONR wrote to EDF and AREVA in 2010 to indicate information on long-term storage was satisfactory, and to close out RO-UKEPR-39, but noting that some issues needed to be addressed as part of the response to RO-UKEPR-48 on disposability.

108 We note that ONR has an assessment finding on knowledge management in regard to records management for spent fuel and waste. Our REP MDLP3 Capability requires an organisation to secure and maintain sufficient knowledge, and competence. For example, requiring effective processes for managing records and documents, and such that sufficient relevant information is available to those who make decisions that might affect environmental protection.

109 The ONR commissioned the National Nuclear Laboratory (NNL) to carry out work to identify mechanisms that could lead to early failure of the fuel cladding or the fuel assembly during storage. This work was reviewed in ONR's Step 4 and the findings were taken into account in our decision.

110 There will be requirements for regular maintenance inspections on the fuel condition over the storage period, to maintain confidence that the fuel remains in a suitable condition. ONR have included a specific assessment finding on this matter in its Step 4 report (ONR, 2011):

111 ONR indicate that NNL found that the fuel should remain in a stable state for about 100 years such that it is suitable for transport and disposal, providing it is adequately cooled once it is removed from the reactor. They recognise that limited information exists on the performance of spent fuel in long-term storage, perhaps for as long as 100 years, after receiving the burn-up likely to be achieved in a UK EPR.

112 The ONR have an assessment finding for the licensee to produce a joint plan with RWMD for the work necessary to reduce the on site storage period for the spent fuel produced by the reactor so that the fuel can be transported as soon as reasonably practical. There is an assessment finding for the licensee to undertake an optimisation process for the long term spent fuel storage facility. The assessment findings for spent fuel are detailed in ONR's Step 4 report (ONR, 2011).

113 ONR asked EDF and AREVA to consider the effects on the operation and decommissioning of the UK EPR of having to cool fuel in the at-reactor spent fuel pool for an assumed period of ten years. The actual period that the fuel has to be cooled before it is placed in long term interim storage will need to be derived by the licensee. ONR has included an associated assessment finding for the licensee on spent fuel storage, transport and disposal strategy. ONR recognise that a licensee's research could indicate a period of cooling before placement into long-term storage different to the ten years assumed. The UK EPR could offer a typical cooling period of some

years up to about 15 years before export to interim storage; this will depend on the operators fuel management and the operator could export fuel earlier than 10-15 years. ONR consider in its Step 4 report there is sufficient flexibility in the at-reactor spent fuel pool design to allow the licensee to meet any cooling constraints imposed by the long-term storage regime to ensure the long-term performance of the spent fuel.

114 For transportation considerations for the transfer of spent fuel offsite, an IAEA type B transport container is required. EDF and AREVA propose to use the TN type transport container. The TN-DUO is proposed as an option for both storage and transport of UK EPR spent fuel if a dry interim storage option is chosen for spent fuel (SRWSR). The UK EPR adopts a proposed fuel assembly burn up of up to 65,000 MWd/tU for the purpose of assessing heat load and the TN container is designed to accommodate this. Suitability of transport containers will be for the Department for Transport to address.

115 ONR has considered different interface arrangements between the at-reactor pond and the long-term spent fuel store. The UK EPR design is based on bottom unloading of the spent fuel in the fuel building, using a TN 13/2 transport container (or similar). EDF and AREVA found until detailed studies of adaptations on the storage containers and/or modifications of the UK EPR spent fuel pool pit loading systems have been performed, an additional Dry Transfer Facility (DTF) will be required for the purpose of spent fuel transfer from the transport container into the storage facility for some of the long-term storage options.

116 The PCERsc5.2 provides information on design aspects in relation to decommissioning; the Environment Agency asks the requesting party to consider the whole lifecycle from design to decommissioning in their waste and spent fuel strategy. Improving the strength of fuel cladding materials significantly impacts the classification of waste by limiting the release of alpha and beta emitters. The SRWSR refers to the improvement of fuel cladding integrity to further reduce the likelihood of fuel leakages which EDF and AREVA claim are low.

117 The NDA revisited the cooling period for spent fuel arising from new nuclear build; it had previously identified a cooling period of the order of about 100 years for high burn up fuel (65 GW/tU). It was identified that the duration of storage, following the end of power station operation could be reduced to the order of 50 years before disposal, for example with the judicious mixing of long-cooled and short-cooled spent fuel. (NDA, 2011). This will help ensure that heat load limits for the individual disposal packages are not exceeded.

118 The designated Nuclear National Policy Statement (NNPS) confirms that the Government is satisfied that effective arrangements will exist to manage and dispose of the waste that will be produced by new nuclear power stations in the UK. We note that CoRWM have said that the Government must judge whether all the arrangements will exist by the time they are needed (CoRWM, 2010). In the NNPS, Government also states that: '*As further evidence of its commitment to the implementation of geological disposal, the Government has reviewed and strengthened the arrangements, to provide oversight of geological disposal implementation and hold the NDA to account as the implementation body responsible for delivery.*' We also note that the Government base case for new build is that a facility for long term storage of high level waste and spent fuel will be available in time to receive the wastes from new reactor build.

119 We are satisfied that EDF and AREVA have demonstrated BAT for storage of spent fuel in the wet and dry interim options they have assessed in detail, so as to ensure that radiation exposure of members of the public from disposals of radioactive waste, including discharges, are as low as reasonably achievable (ALARA).

120 We expect the future operator to address the following assessment finding:

a) the future operator shall, before the commissioning phase, propose techniques for the interim storage of spent fuel following a period of initial cooling in the pool. The

future operator shall provide an assessment to show that the techniques proposed are BAT. (UK EPR-AF16)

3.7 Disposability

121 EDF and AREVA have obtained and provided a view from the Radioactive Waste Management Directorate (RWMD) of the Nuclear Decommissioning Authority (NDA) (as the UK authoritative source) on the disposability of their proposed arisings of spent fuel.

122 RWMD assume that the spent fuel will be delivered to the disposal facility packaged in robust disposal canisters, made from copper or steel which would contain up to 4 spent fuel assemblies in a cast iron inner vessel. It is also assumed that the spent fuel will be delivered to the GDF packaged in the disposal canisters. Comments were made in response to our consultation about disposal canisters. These are discussed in our decision document (Environment Agency, 2011d).

123 RWMD concluded that EDF and AREVA supplied comprehensive inventory data sufficient to provide confidence in the conclusions of the GDA disposability assessment. The principal radionuclides in the wastes and spent fuel are the same as those present in existing UK legacy wastes and spent fuel, in particular, to the anticipated arisings from the existing PWR at Sizewell B. The design of the UK EPR and the PWR at Sizewell are similar and it is expected that the operating regimes will be similar.

124 The comparison of UK EPR and Sizewell B spent fuel inventories compared the UK EPR maximum fuel assembly average burn up inventory with the batch average fuel burn up inventory for Sizewell B. RWMD recognised it would have been more appropriate to compare either the two maximum fuel assembly average burn up or two batch average fuel burn up inventories. The information was not available to do this at the time of the RWMD assessment.

125 RWMD evaluated the implications of constructing a single UK EPR and a fleet of UK EPRs. A fleet of 6 UK EPRs was chosen to represent a generating capacity of approximately 10GW(e), equivalent to the capacity of the existing nuclear reactors in the UK which will cease to be operational over the next 20 years.

126 The disposability assessment for the UK EPR undertaken by RWMD conservatively assumes that 90 fuel assemblies will be generated every 18 months of reactor operation, which, for an assumed 60 year operating life results in a total of 3600 assemblies requiring disposal which is equivalent to 900 canisters.

127 The potential impact of the disposal of UK EPR spent fuel on the size of the geological disposal facility has been assessed. The area required represents approximately 8% of the area required for legacy HLW and spent fuel per UK EPR reactor and approximately 50% for the illustrative fleet of 6 UK EPRs. This is in agreement with previous estimates from Nirex (the predecessor organisation to RWMD) for potential new build reactor designs.

128 RWMD undertook an assessment which considered the spent fuel disposal packages against the waste package standards and specifications developed by RWMD and the supporting safety assessments for a geological disposal facility. The safety of transport operations, handling and emplacement at a geological disposal facility (GDF), and the longer term performance of the system have been considered, together with the implications for the size and design of the GDF. The potential disposability of spent fuel from the UK EPR was considered with existing assessments of RWMD reference disposal concepts. These assessments provide the basis for judging the potential disposability of UK EPR wastes and spent fuel. One important consideration for the assessment of spent fuel from the UK EPR is that increased burn up and irradiation of the fuel will result in an increased concentration of fission

products and higher actinides which causes the fuel assemblies to have a higher thermal output and dose rate.

129 Since our consultation, NDA has published a generic Disposal Systems Safety Case (gDSSC) for a future Geological Disposal Facility (GDF), based on its understanding of the scientific and engineering principles supporting geological disposal (RWMD, 2010). NDA has also provided a report regarding the impact of the gDSSC on its previous new build disposability assessments undertaken for RPs to support GDA submissions (RWMD, 2011). The report concludes:

a) '*The original 2009 GDA Disposability Assessments concluded that ILW and spent fuel from operation and decommissioning of an AP1000 or EPR raised no new disposability issues when compared against legacy wastes and existing spent fuel. These assessments have been reviewed in the light of recent developments to disposal concepts and generic safety assessment methodologies as applied in the generic DSSC.*

Overall, the changes in concept, assessment methodology and assumptions regarding parameter values have only minor impacts on the findings of the original GDA Disposability Assessments. The review therefore confirms that there are no new issues arising from the generic DSSC that would challenge the fundamental disposability of the wastes and spent fuel expected to arise from operation of the AP1000 and EPR. This conclusion is supported by the similarity of the wastes to those expected to arise from the existing PWR at Sizewell B, which are included in the generic DSSC Baseline Inventory and have been found to be acceptable.'

130 A reference disposal concept is used for the disposability assessment based on the KBS-3V concept developed by the Swedish Nuclear Fuel and Waste Management Co. (SKB) for the disposal of spent fuel in Sweden. Spent fuel will be over-packed into durable, corrosion-resistant canisters manufactured from suitable materials that will provide containment for the radionuclides associated with the spent fuel. The assessment has considered the performance of both copper and steel canisters with a cast iron inner vessel used to hold and locate the spent fuel canisters. The canisters would be emplaced in disposal holes lined with a buffer made from compacted bentonite which swells following contact with water.

131 The disposability assessment undertaken by RWMD also considered for spent fuel, estimates of risks from migration of radionuclides to the biosphere following closure of the GDF, with risks considered for the groundwater pathway.

132 Three potential power histories were considered by EDF and AREVA. The power history adopted was one of four short cycles with constant high specific power and considered to be the most challenging.

133 RWMD concluded that compared with legacy waste and existing spent fuel, no new issues arise that challenge the fundamental disposability of the waste and spent fuel expected to arise from operation of the UK EPR. (NDA Document TN 11261814 October 2009)

134 RWMD indicated that the disposal route for rod cluster control assemblies (RCCAs) will need to be clarified. The RWMD assessment indicates they will not represent a major addition to the overall inventory, and that they could be conditioned separately as ILW or disposed of with the rest of the fuel assembly. TQ-EPR-222 EPR Intermediate Level Waste was issued by the Regulators requiring further information from EDF and AREVA in regard to these wastes, including evidence that they will be disposable. Further information is provided in our assessment report on solid radioactive waste (Environment Agency, 2011c).

135 The activated core components are considered intermediate level waste (ILW), although they generate heat when they are removed from the reactor. These include RCCAs, the stationary core component assemblies, and core instrumentation. As they are exposed to radioactivity (neutrons) in the reactor core, the RCCAs are highly

activated by the time they are replaced; they are placed in the spent fuel pool to cool, as is the practice in existing PWR plants. EDF and AREVA claim that these wastes should be accepted for disposal in a Geological Disposal Facility.

136 EDF and AREVA provided the Regulators with a critique of the RWMD disposability assessment, considering the impact of RWMD disposability assessment on their plans for conditioning, storing and dispatching the waste to a repository (GDF). The critique raised a number of issues. EDF and AREVA identified that the principal issues were in relation to fuel burn up, assessment inventories, serious fuel cladding failures, interim storage of spent fuel, the use of supplementary data by RWMD, and the chloride impurity assumption. The Regulators requested further information from EDF and AREVA on how they will address the issues raised in their critique and those issues raised by RWMD in their disposability assessment, see next section.

3.7.1 Plan for Disposability of Spent Fuel including long-term storage

137 The Regulators required the Requesting Parties for GDA to provide information to demonstrate the facility for long-term interim storage of spent fuel can be designed for the total expected lifetime. Long-term interim storage is required until a geological disposal facility is available for direct disposal of spent fuel. The long term provision of services, for example to a storage pool for spent fuel, after a reactor has been shut down is required to be considered. A paper was issued by the Regulators in GDA 'The required level of design of waste plants for new build reactors in the Generic Design Assessment.' (HSE, 2009a). The paper sets out requirements for a Requesting Party to provide sufficient levels of design to justify credibility of the proposed storage options; understanding how waste streams and their packaging evolve during the storage period, plans for data and records management, knowledge of the constraints placed on the wastes by the disposal facility, identification of knowledge gaps and a supporting research programme to address the gaps, and robust estimates of the required capacity.

138 The paper detailed the anticipated outcomes for the Generic Design Assessment (GDA) for radioactive waste proposals. This proposed that for those storage facilities not on the nuclear island, the RP should develop a strategy that included a detailed plan with key milestones. The plans would be underpinned by descriptions of:

a) the types of facility that could be used;

b) when facilities will be developed and constructed; and

c) the research needs that are required to ensure the waste and spent fuel can be safely managed on sites, transported and disposed of.

139 Whilst the plan is a very simple document it is important to EDF and AREVA, future operators and the Regulators as it provides a baseline to the implementation of the proposed waste management strategy. The supporting documentation, identified in the bullets above has to be substantive, logical and plausible for the plan to be considered credible.

140 It would also be acceptable for a future operator to adopt an alternative strategy than that presented in the plan. In this case they would need to show that the baseline they had established in their plan was broadly equivalent to, or better than, that presented here and could be realised in a suitable timescale.

141 Further information was requested from EDF and AREVA in RO-UKEPR-48 to support the case for disposability of spent fuel and ILW. With particular regard to EDF and AREVA's critique of the RWMD disposability assessment, the Regulators needed more detail from EDF and AREVA when considering the impact of the RWMD review on its plans for conditioning, storing and dispatching the waste to a repository (GDF). EDF and AREVA were asked to make a case for the disposability of spent fuel and ILW to ensure it can be stored, transported and disposed of. The case should include consideration of the issues identified in the RWMD disposability assessment, and in

EDF and AREVA's critique of the RWMD assessment, and should include a plan showing how and when the issues will be addressed.

142 In RO-UKEPR-48, EDF and AREVA were asked to make a case for the disposability of spent fuel and ILW, which demonstrates the following:

a) How the issues identified in their critique of RWMD's Disposability Assessment will be addressed.

b) How the issues in Appendix B of RWMD's Disposability Assessment will be addressed.

c) How they will manage any risks associated with these issues.

143 Information was received from EDF and AREVA in late February 2010 in response to RO-UKEPR-48 in a report 'The Case for Disposability of Spent Fuel and ILW' (R10-017). This response was considered in our assessment report on disposability of ILW and spent fuel (Environment Agency, 2010b) published in June 2010 which found that the plans proposed to address outstanding disposability issues to be adequate at this stage. Our report has since been updated with further information, see later.

144 We identified in closing out RO-UKEPR-39 that further work was needed since that response from EDF and AREVA did not address the work necessary to show waste and spent fuel will be disposable. We issued a new Action A2 to RO-UKEPR-48, where EDF and AREVA were asked to consolidate the plan produced in response to RO-UKEPR-48 to include the plan for long-term storage and the work being undertaken by RWMD.

145 EDF and AREVA have developed and submitted a plan to the Regulators for addressing disposability issues and seeking LoC endorsements to support the case for disposability of spent fuel following storage.

146 We note in particular that EDF and AREVA have consulted with RWMD specifically on the stages in the Letter of Compliance (LoC) process at which they would expect issues to be addressed. We recognise that, in most cases, these issues will need to be addressed by future operators of UK EPRs, rather than by EDF and AREVA, and we understand that EDF and AREVA have also discussed the timing of resolution of these issues with a potential UK EPR operator.

147 Our final report on disposability of ILW and spent fuel considers (Environment Agency, 2011a) both EDF and AREVA's critique and the RWMD assessment. It concludes that on the basis of the information provided for GDA there should be no reason at this stage to believe that spent fuel from a fleet of six UK EPRs will not be disposable in a suitably designed and located GDF. Also that the UK EPR is not expected to produce spent fuel for which there is no foreseeable disposal route. Please refer to this report for more information.

148 EDF and AREVA produced a mapping document in response to RO-UKEPR-33 to demonstrate how they could meet regulatory expectations, and identified the information required to produce the radioactive waste management case (RWMC) for spent fuel for the UK EPR. The RWMC demonstrates the longer term safety and environmental performance of waste for the planned management from generation to conditioning to a form which will be suitable for storage and eventual disposal. The mapping document identifies the existing documents that form the basis of the RWMC, states the RWMC requirements and identifies where relevant information is provided in the submission and related documents, and provides a justification that the information meets the requirement. It covers spent fuel generated throughout the reactor lifecycle.

149 The mapping document indicates where the information that will be needed for future RWMCs will come from, and when. EDF and AREVA updated the mapping documents for the RWMCs in January 2011, and again in March 2011. The updated document gives us sufficient assurance for this stage of the GDA stage process that

RWMCs for spent fuel can be complied at relevant stages in the development of a UK EPR fleet.

150 The conclusion of our final report on disposability of ILW and spent fuel (Environment Agency, 2011a) is subject to an assessment finding:

a) The future operator shall, before the commissioning phase, provide confidence that adequate Radioactive Waste Management Cases (RWMCs), supported by appropriate stage Letters of Compliance (LoCs) and taking due account of necessary storage periods, can be developed for spent fuel on the timescales identified in EDF and AREVA's plan for disposability of spent fuel. (UK EPR-AF17).

151 In general, we consider the plans proposed by EDF and AREVA, outlining how and when they and future licensees will address the outstanding disposability issues to be adequate at this stage. We will expect these plans to be periodically refined and updated in future to reflect developments. We will expect prospective licensees to make progress on demonstrating disposability at the earliest reasonable opportunities rather than waiting for dates specified in the plan.

152 On the 13 December 2010 the RWMD presented a briefing on the development of their plans for the disposal of spent fuel to representatives from DECC and the Regulators. This provided assurance that RWMD have in place plans for developing the underpinning needed to validate the more detailed proposals that will come forward from future operators.

153 We continued to work with ONR following our consultation, and this work has informed our final decision. ONR concluded that EDF and AREVA have produced the basis for the development of a credible plan for the implementation of their proposed spent fuel strategy. The plan still has areas that need to be revised or extended; these are identified in assessment findings (ONR, 2011).

154 We are satisfied that EDF and AREVA have a credible plan for long-term management of spent fuel. This was sufficient to close out the potential GDA Issue that was included in our consultation document on disposability of spent fuel following longer term interim storage pending disposal (UK EPR-I2).

155 The Regulators requested further information from EDF and AREVA on the encapsulation process for disposal for spent fuel since this was not considered in the RWMD assessment. As discussed earlier, the RWMD assessment was based on the Swedish KBS-3V concept where spent fuel is encapsulated in a copper steel canister prior to disposal. A final report from EDF and AREVA on the ability to encapsulate spent fuel for disposal was submitted in September 2010. The submission provided a review of international practice, and concluded that encapsulation is a feasible technology.

156 We will need to see evidence that the spent fuel is capable of being packaged and transported safely, and we require the future operators to demonstrate unpackaged spent fuel at a reactor site can safely be turned into packaged spent fuel at a GDF ready for disposal. There is considerable experience internationally to show that packaging could be done safely at the reactor site, the GDF site or a third site if appropriate facilities and operations are put in place. EDF and AREVA considered methods for how spent fuel might be packaged, and reviewed international experience as part of their response.

157 However, we recognise that EDF and AREVA also need to know other organisations' plans in order to take a considered view of the best option – we are aware, for example, that RWMD are considering the feasibility of a centralised spent fuel packaging facility. We note that RWMD's initial feasibility study for NIA identifies and briefly considers options for spent fuel packaging but does not propose a definitive position.

158 We noted in our consultation that ONR was to review this information in its Step 4 assessment. We continued to work closely with ONR on this matter; they reported

that information provided by EDF and AREVA on encapsulation of spent fuel is sufficient to show that packaging for disposal should be feasible.

159 In their submission, EDF and AREVA provide reasonable proposals for how spent fuel will arise, be managed and disposed of throughout the facility's lifecycle. EDF and AREVA provide information on the fuel composition and characteristics, and expected fuel burn up, and quantities of spent fuel that will arise. Information is provided in the submission and supporting documents on short and long-term management proposals for spent fuel. EDF and AREVA have obtained a view from the RWMD of the NDA on the disposability of the fuel and have provided its opinion / critique to the Regulators. EDF and AREVA provided sufficient information and evidence to satisfy our requirements for spent fuel management in GDA.

160 ONR through its Step 4 of GDA continued to work with us to review the information supplied by EDF and AREVA as they finalised the information contained in their submissions on long-term storage and disposability. We now have further information and evidence from EDF and AREVA to support the safe storage and disposal of spent fuel, as detailed above.

161 ONR advised us that the spent fuel can be maintained in a suitable condition during on-site storage such that it will remain acceptable for disposal (ONR, 2011).

162 We conclude that based on EDF and AREVA's plans for management of spent fuel, that the UK EPR is not expected to produce spent fuel for which there is no foreseeable disposal route. However we will expect EDF and AREVA and potential operators to continue to make progress in consultation with RWMD towards confirming the disposability of spent fuel taking account of necessary periods of storage.

163 We stress, however, that we will expect to see before any UK EPRs begin operation further information from EDF and AREVA on the properties of high burn-up spent fuel following long term storage (particularly in relation to Instant Release Fractions (IRFs)). We recognise that detailed and definitive information may not be available until there is direct operational experience (e.g. for the Interim Stage LoC submission), but we will expect much earlier than that to see evidence of sufficient progress to provide reasonable confidence that any issues are likely to be manageable.

4 Public comments

164 Comments on spent fuel received from the public involvement process relating to the UK EPR design by 4 January 2008 were addressed in our preliminary assessment report (Environment Agency, 2008). Public comments on this subject were received during our detailed assessment stage. One comment requested information about the type of spent fuel cask that would be used to transport spent fuel for processing or disposal. The response from EDF and AREVA confirmed that the TN type family of casks such as the transport cask TN24TM or others with comparable characteristics would be used to transport spent fuel in the UK, and EDF and AREVA provided information about the casks in the SRWSR. The TN cask is a dual purpose cask that can be used to store and to transport spent fuel.

165 A public comment was received in regard to storage of spent fuel following the closure of reactor operations, and the need for ongoing secure power supplies to service the spent fuel storage ponds, water treatment systems, waste treatment systems and storage facilities. The comment also queried whether the design of the dry storage casks would take into account the varying enrichment levels of the fuel elements. The response from EDF and AREVA confirmed that the technology for longer term spent fuel management is not chosen although several options are available such as dry cask or dry vault storage, or long-term pool storage. The response also confirmed the design of the storage facilities will take into account the enrichment and residual heat of the spent fuel elements, whatever technology is chosen. With regard to the ongoing availability of electrical power for services following reactor closure, it was confirmed

that it is the aim of the UK national energy policy to ensure security of supply, together with the integrity of back up power supplies to provide power in the event of loss of grid supplies. Back up power supplies are addressed by the ONR, and it is noted that some store technologies utilise passive methods.

166 Comments made in response to our public consultation in regard to spent fuel for the UK EPR design were considered in our decision document (Environment Agency, 2011d).

167 A large number of the consultation responses for both designs considered in GDA were in regard to the issues of waste and spent fuel storage and disposal. Responses were made in regard to issues including the use of high burn up fuel requiring extended storage, the long period of interim storage for spent fuel prior to disposal, the integrity of fuel following storage, the integrity of the fuel store over time, whether centralised stores would be available, whether an encapsulation plant for spent fuel would be required on the reactor site, and about the availability of the GDF in the expected timeframe. These responses have been shared with ONR given its lead regulatory role in regard to safe storage of wastes including spent fuel.

168 Questions were also raised and published from our 6 July GDA stakeholder seminar and are considered in our decision document (Environment Agency, 2011d). http://www.hse.gov.uk/newreactors/seminar-060710.pdf

5 Conclusion

169 We conclude that, in their submission, EDF and AREVA describe how spent fuel will arise, be managed and disposed of throughout the facility's lifecycle. EDF and AREVA provide information on the fuel composition and characteristics, and expected fuel burn up, and quantities of spent fuel that will arise. Information is provided in the submission and supporting documents on short and long-term management proposals for spent fuel. The strategy proposed by EDF and AREVA for managing spent fuel following its removal from the reactor, is to transfer the spent fuel to the spent fuel pool for storage and initial cooling for a period for some years. The fuel is then proposed to be transferred to an interim storage facility (PCER sc6.5) until such time a geological disposal facility becomes available for direct disposal.

170 The strategy is consistent with our REP, RSMDP1 Radioactive Substances Strategy. The evidence provided for BAT for the UK EPR fuel design and to minimise disposals satisfies RSMDP3 use of BAT to minimise waste. Information was provided on record keeping, together with further information on longer term storage. This has been assessed and is considered to be compliant with our REPs, in particular RSMDP14 record keeping, and RSMDP10 storage.

171 EDF and AREVA have obtained a view from the RWMD of the NDA on the disposability of the fuel and have provided their critique to the Regulators.

172 EDF and AREVA's proposals for storage of spent fuel are based on current practice. EDF and AREVA have provided supporting information on longer term wet storage (ELI0800224) based on 30 years operating experience worldwide in underwater storage of spent fuel.

173 At the time of our consultation, when this report was first published, we said that we needed more information on the longer term storage of the fuel to understand whether there is any potential for degradation of the fuel over the longer term that might affect its disposability. This is consistent with the ONR requirement for a satisfactory demonstration that spent fuel can be stored safely for the necessary period of time without significant degradation. At the time of our consultation we said that our conclusion was subject to the potential GDA Issue:

a) Disposability of spent fuel following longer term interim storage pending disposal.

174 Further information was provided by EDF and AREVA in regard to the proposed storage facilities to support the safe long-term storage of the spent fuel and to ensure that the fuel does not degrade over the long storage period. ONR reviewed this information in its Step 4 assessment. We continued to work with ONR on these matters, and this work informed our decision. We are satisfied with the information provided and have closed out the issue on disposability.

175 Our conclusions have been updated since our consultation.

176 **We conclude that EDF and AREVA have:**

a) **demonstrated BAT in the fuel design for the UK EPR in order to minimise the amount of spent fuel for disposal;**

b) **provided sufficient evidence to support the safe short and longer term interim storage of the spent fuel to support the condition of the fuel for disposal.**

177 **We also conclude, based on the further evidence provided on EDF and AREVA's management plans for the fuel including storage, that the UK EPR is not expected to produce spent fuel for which there is no foreseeable disposal route.**

178 As part of our assessment we identified the following assessment findings:

a) The future operator shall, before the commissioning phase, propose techniques for the interim storage of spent fuel following a period of initial cooling in the pool. The

future operator shall provide an assessment to show that the techniques proposed are BAT. (UK EPR-AF16)

b) The future operator shall, before the commissioning phase, provide confidence that adequate Radioactive Waste Management Cases (RWMCs), supported by appropriate stage Letters of Compliance (LoCs) and taking due account of necessary storage periods, can be developed for spent fuel on the timescales identified in EDF and AREVA's plan for disposability of spent fuel. (UK EPR AF17)

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While every effort has been made to ensure the accuracy of the references listed in this report, their future availability cannot be guaranteed.

Abbreviations

AREVA	AREVA NP SAS
ASN	the French Nuclear Safety Authority, Autorité de Sureté Nucléaire
BAT	Best available techniques
CEA	Commissariat à l'énergie atomique
EDF	Electricité de France SA
GDA	Generic design assessment
GDF	Geological Disposal Facility
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
JPO	Joint Programme Office
NDA	Nuclear Decommissioning Authority
NEA	Nuclear Energy Agency (of the OECD)
OECD	Organisation for Economic Cooperation and Development
ONR	Office for Nuclear Regulation, an Agency of the HSE (formerly HSE's Nuclear Directorate)
P&ID	Process and information document
PCER	Pre-Construction Environmental Report
PCERsc3.3s4.1	PCER sub-chapter 3.3 section 4.1 (example reference)
PCSR	Pre-Construction Safety Report
PWR	Pressurised water reactor
RCCAs	Rod cluster control assembles
REPs	Radioactive substances environmental principles
RGN	Regulatory Guidance Note
RGS	Regulatory Guidance Series
RO	Regulatory Observation
RWMC	Radioactive Waste Management Case
RWMD	Radioactive Waste Management Directorate of the Nuclear Decommissioning Authority
SODA	Statement of Design Acceptability
SNF	Spent nuclear fuel. That is fuel that has been irradiated in and permanently removed from a reactor core (IAEA)
SRWRS	Solid Radioactive Waste Strategy Report
TQ	Technical Query
US NRC	United States Nuclear Regulatory Commission

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