JUSTIFICATION APPLICATION

Nuclear Industry Association

UK ABWR NUCLEAR REACTOR

DECEMBER 2013
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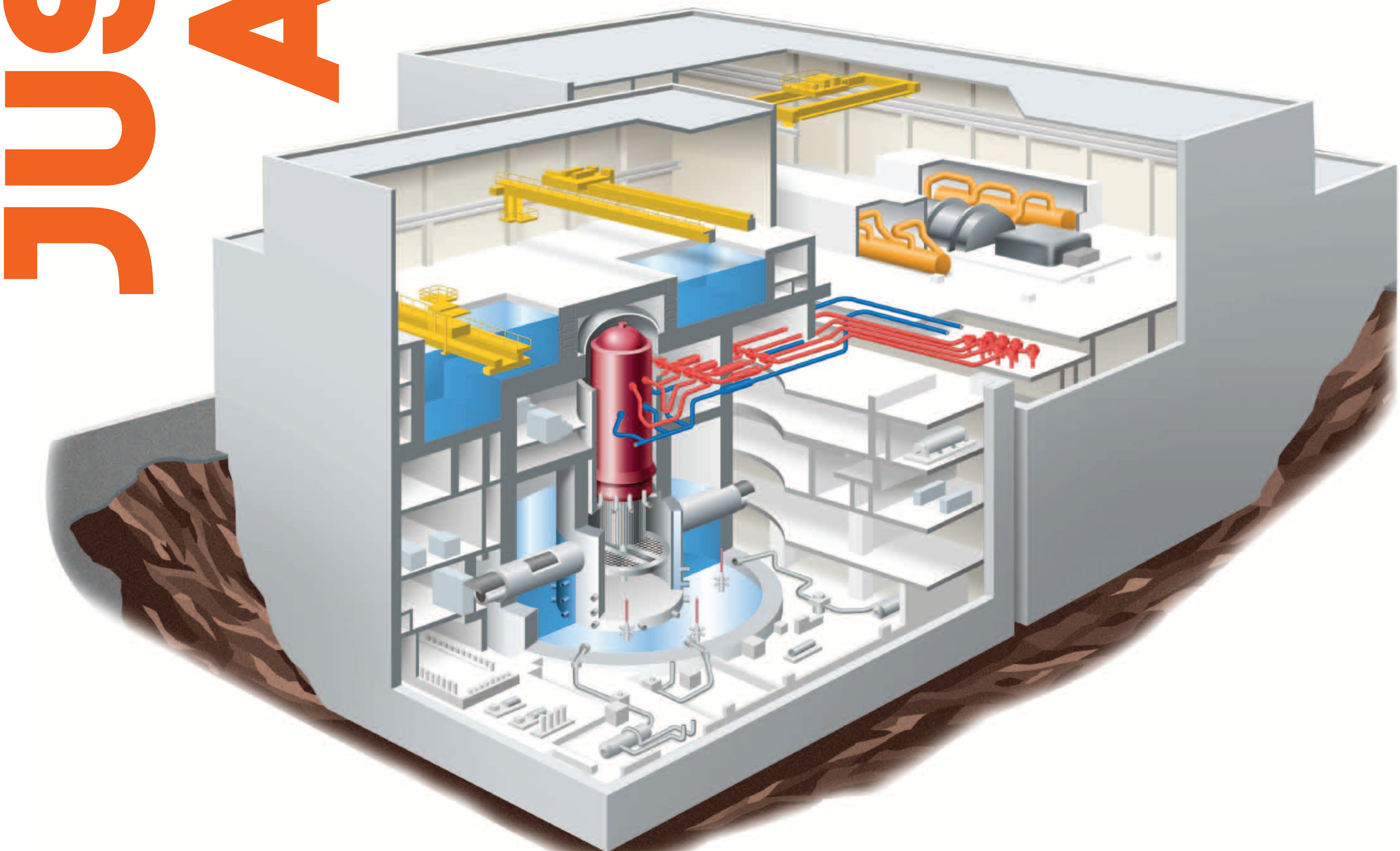

Volume 1
Contents

Introduction and Proposed Practice

Security of Supply and Climate Change Benefits

Economic Assessment

Radiological Health Detriments

Other Potential Detriments

Summary

Volume 2
Annexes

INTRODUCTION

INTRODUCTION AND PROPOSED PRACTICE

INTRODUCTION

Introduction and Proposed Practice
Introduction

Background

0.1 The Government's National Policy Statement[1] states that new nuclear power should play a role in the country's future energy mix alongside other low-carbon sources:

> *"For the UK to meet its energy and climate change objectives, the Government believes that there is an urgent need for new electricity generation plant, including new nuclear power. Nuclear power generation is a low carbon, proven technology, which is anticipated to play an increasingly important role as we move to diversify and decarbonise our sources of electricity."*

The UK ABWR is a nuclear reactor technology designed by Hitachi-GE Nuclear Energy, Ltd ("Hitachi-GE"), which is planned to be built in the UK. One of the steps prior to building a project involving new nuclear power technology in the UK is to submit a Justification application. This Application seeks a decision under regulation 9 of the Justification of Practices Involving Ionising Radiation Regulations 2004 (the "Justification Regulations") that the UK ABWR design is justified.

0.2 The principle of "Justification" is derived from the recommendations[2] of the International Commission on Radiological Protection ("ICRP"). This principle requires that *"any decision that alters the radiation exposure situation should do more good than harm".*

0.3 The requirements of this principle for new sources of radiation have been adopted in the European Union Council Directive 96/29/Euratom (known as the Basic Safety Standards (BSS) Directive) which is derived from the ICRP recommendations. The Directive requires that:

> *Member States shall ensure that all new classes or types of practice resulting in exposure to ionising radiation are justified in advance of being first adopted or first approved by their economic, social or other benefits in relation to the health detriment they may cause.*

0.4 This requirement of the BSS Directive has been implemented in the UK by the Justification Regulations, which came into force in August 2004. For classes and types of practice relating to nuclear energy, the Justifying Authority is the Secretary of State for Energy and Climate Change.

0.5 In 2008, we submitted an application to the Justifying Authority seeking justification of new nuclear power stations in the UK (our "2008 Application").[3] Our 2008 Application sought a justification decision for a "class or type of practice" based on four reactor designs: ACR-1000®; AP1000®; EPR™; and ESBWR. Following the application, the AP1000® and EPR™ designs, being the two designs with vendors who were supporting them through the later stages of Generic Design Assessment, progressed to the next stage of the Justification assessment. On 18th October 2010, the Secretary of State, the "Justifying Authority" for nuclear power under the Justification Regulations, published his decisions that the AP1000® and EPR™ designs were justified. These decisions were then endorsed by both Houses of Parliament (the "2010 Justification Decisions").[4,5]

0.6 This new application seeks Justification of the Proposed Practice defined in Chapter 1, which is a "class or type of practice" specifically relating to the UK ABWR designed by Hitachi-GE, which has not yet been justified in the UK. It should be noted that the Justification of the UK ABWR

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[1] Overarching National Policy Statement for Energy (EN-1), Planning for new energy Infrastructure, July 2011. Quote paragraph 3.5.1 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf.

[2] The most recent recommendations are contained in ICRP Publication 103, Annals of the ICRP, Volume 37 Nos. 2-4, 2007. These latest regulations largely affirm the justification principle set out in earlier recommendations. See for example, the 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60.

[3] Justification Application - New Nuclear Power Stations, Volumes 1 & 2, NIA, November 2008.

[4] The Justification of Practices Involving Ionising Radiation Regulations 2004, The reasons for the Secretary of State's Decision as Justifying Authority on the Regulatory Justification of the Class or Type of Practice being: "The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in a light water cooled, light water moderated thermal reactor currently known as the AP1000 designed by Westinghouse Electric Company LLC".

[5] The Justification of Practices Involving Ionising Radiation Regulations 2004, The reasons for the Secretary of State's Decision as Justifying Authority on the Regulatory Justification of the Class or Type of Practice being: "The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in a light water cooled, light water moderated thermal reactor currently known as the EPR designed by AREVA NP".

is being sought in respect of the same overall UK new nuclear power programme that was the subject of our 2008 Application. If the UK ABWR were justified, this would provide UK nuclear utilities with an additional choice of technology to deploy in pursuance of their development plans. Accordingly, this application would not necessarily translate into a change in the size of the overall UK new nuclear power programme contemplated by our 2008 Application.

0.7 This Application follows a similar structure to our 2008 Application. The arguments from our 2008 Application are valid for the UK ABWR reactor technology, and have been updated in this application to take into account any new information and events since the 2010 Justification Decisions were issued.

0.8 The main changes since our 2008 Application include the following:

- This Application draws on conclusions from the 2010 Justification Decision documents issued in response to our 2008 Application, as well as Government policy statements and publications issued since those decisions, including in particular the National Policy Statements for Overarching Energy (EN-1) and Nuclear Power Generation (EN-6) designated in July 2011.
- This Application includes a more detailed discussion of the causes and effects of severe accidents and extreme events that have occurred in commercially operating nuclear power stations in the form of an annex (Annex 5). In particular, Annex 5 includes an overview of the 2011 accident at Fukushima.
- This Application addresses regulatory developments which have occurred since the 2010 Justification Decisions were issued, including the proposed introduction of electricity market reforms and the Government's recent consultation on revised siting plans for the geological disposal facility for nuclear waste. Since our 2008 Application the Government has been taking steps to ensure that the nuclear regulator is appropriately resourced and responsive for the challenges of the nuclear sector, as well as increasing its transparency and accountability (although the regulatory requirements have not changed). To achieve this, the Office for Nuclear Regulation ("ONR") has been established as an agency of the Health and Safety Executive ("HSE"), and through the Energy Act 2013 will be established as an independent statutory corporation later this year.
- The Application uses updated costs estimates for building nuclear reactors (based on DECC's July 2013 Electricity Generation Costs publication)[6].
- This Application includes information specific to the UK ABWR technology.

0.9 A guidance document on how the Justification process would operate, in respect of new nuclear power stations, including recommendations as to the content of a Justification application, was issued in March 2008[7]. This guidance was followed in our 2008 Application and, whilst the prescribed dates have changed, it is suggested that the guidance and an equivalent time schedule are appropriate for this UK ABWR Application. This Application follows the guidance and is informed by the previous Justification process for new nuclear, particularly the following documents:

[A] Our previous Justification Application for New Nuclear Power Stations – November 2008;
[B] New Nuclear Power Station Designs: Determination on Class or Type of Practice – November 2009; and
[C] The Justifying Authority's documents detailing the reasons for the 2010 Justification Decisions (relating to the EPR™ & AP1000® reactors), published by DECC – October 2010.

Purpose of the Justification Application

0.10 Justification is a high level assessment that is intended to take place early in the series of decision-making processes applicable to a new class or type of practice. It is designed to establish, before a new class or type of practice is introduced, that such practice will provide an overall benefit[8]. The BSS Directive defines the test as being that the benefits (whether economic,

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[6] https://www.gov.uk/government/publications/decc-electricity-generation-costs-2013.

[7] The Justification of Practices Involving Ionising Radiation Regulations 200 Guidance for applications relating to new nuclear power, March 2008 - BERR guidance - BERR was disbanded in June 2009 and the responsibility for energy policy was moved to DECC. DECC advise and assist the Justifying Authority in making their decision.

[8] For convenience, the term "class or type of practice" is abbreviated in this document to "practice".

social or other) should justify the health detriments caused by the exposure to ionising radiation resulting from the class or type of practice. This is the test that has been adopted by the UK in the Justification Regulations which implement the BSS Directive.

0.11 Notwithstanding that the strict legal test set out in the Justification Regulations requires only that the benefits of a practice will outweigh its radiological health detriments, the UK guidance on the process to be followed in applying the BSS Directive and Justification Regulations to new nuclear power stations arguably takes this a stage further, by suggesting that the test requires that the net benefit be weighed against the radiological health detriment of the practice. Although this interpretation arguably goes beyond the requirements of the Regulations, our Application has followed this approach.

0.12 Under such guidance, our 2008 Application not only assessed the potential radiological health detriment associated with the new nuclear power practices that were the subject of that application, but also any other potential detriments that could be significant when considered against the benefit derived from those practices. This Application follows the same approach and provides a wide-ranging review of other potential (non-radiological health) detriments of the Proposed Practice, which are summarised against the benefits in the final chapter, so as to identify the net benefit. This is weighed against the potential radiological health detriment in the final chapter.

0.13 In line with the approach described above, this Application focuses on the potentially very significant benefits to the UK of the Proposed Practice - the delivery of low carbon electricity; and increased security of supply. While there are undoubtedly other potential benefits – including economic benefits to the nuclear supply chain, as well as to wider communities – this Application does not rely on these benefits as part of its demonstration that the Proposed Practice is justified. It is for this reason that all benefits are not, and do not need to be, assessed within this Application.

Regulatory Context

0.14 It is important to note that a conclusion that a practice is justified does not in itself allow installations of that type or class to be constructed or operated. This is because the Justification process is generic, and not project or site-specific. A new nuclear power station could only be constructed and operated once a range of specific consents have been obtained as part of the normal and rigorous process of regulatory scrutiny. These consents would only be forthcoming once the relevant requirements, which include that any potential adverse impacts identified would be either avoided altogether or mitigated to such an extent that they were acceptably low, had been met.

0.15 It is worth emphasising that although this Application relates to new nuclear power station technology, the UK nuclear industry has almost 60 years' experience of operating nuclear power stations within a robust goal setting regulatory regime that places the onus on operators to demonstrate to the regulators high levels of safety and environmental protection. It has an excellent record of safety and looking after the welfare and health of both its workers and the public and environmental protection. The existing regulatory system will continue to evolve in line with technological and societal developments to remain effective.

0.16 Following the accident at Fukushima in March 2011, the then Secretary of State for Energy and Climate Change requested that Dr Mike Weightman, the then HM Chief Inspector of Nuclear Installations, examine the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. The final report was published in September 2011. Conclusions from this report[9] highlighted the positive response of the UK nuclear industry which was described as reacting *"responsibly and appropriately displaying leadership for safety and a strong safety culture in its response to date".* It also highlighted the robustness of the regulatory regime:

> *"Consideration of the accident at Fukushima-1 against the ONR Safety Assessment Principles for design basis fault analysis and internal and external hazards has shown that the UK approach to identifying the design basis for nuclear facilities is sound for such initiating events."*

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[9] Weightman report: http://www.hse.gov.uk/nuclear/fukushima/final-report.pdf.

0.17 In addition to the UK response to Fukushima, Dr Weightman was also asked by the International Atomic Energy Agency ("IAEA") to lead a fact-finding mission with the main aim being to identify lessons so that the worldwide nuclear community could learn from the accident at Fukushima[10]. One of the main outcomes from this mission was an Action Plan on nuclear safety to design a program of work to strengthen the global nuclear safety framework.

0.18 The global industry has a wealth of operating experience (over 14,500 reactor years) and the continuing sharing of best practice will help to improve safety and operational standards throughout the world.

Structure of Application

0.19 The following chapters provide an overview of the benefits and detriments of the Proposed Practice. Chapter 1 includes a description of the Proposed Practice for which a Justification decision is sought. The remainder of the Application is divided into 5 parts:

- A discussion of the potential benefits the practice could bring in terms of security of supply and climate change (Chapters 2 and 3 respectively);
- An assessment of the potential impacts of the Proposed Practice on the UK economy (Chapter 4);
- Identification of the potential radiological health detriments (Chapter 5);
- Identification of the potential detriments associated with the Proposed Practice other than those to do with radiological health. Chapter 6 deals with those linked to radioactive waste and decommissioning, Chapter 7 covers environmental effects not associated with radioactivity and Chapter 8 covers the remaining areas;
- A final section (Chapter 9) that summarises the comparison between the net benefits and the radiological health detriments.

Applicant Details

0.20 This Justification Application is being made by the Nuclear Industry Association ("NIA") of Carlton House, 22a St James's Square, London, SW1Y 4JH ("the Applicant") with the support of Horizon Nuclear Power Services Limited (Company Number 06812099) of 5210 Valiant Court, Gloucester Business Park, Gloucester, GL3 4FE ("Horizon"). The ultimate parent company of Horizon is Hitachi, Ltd. This application includes information on the UK ABWR reactor designed by Hitachi-GE Nuclear Energy, Ltd. ("Hitachi-GE") whose head office is in Hitachi City, Ibaraki Prefecture, Japan.

0.21 Our 2008 Application was actively supported by several utilities who were interested in operating the new nuclear technologies in the UK. This application is actively supported by Horizon, which is currently the only UK utility expressly interested in operating a Hitachi-GE designed UK ABWR reactor. However, like the AP1000® and EPR™ technologies the subject of our 2008 Application, the UK ABWR technology could equally be deployed by any other utility in the UK in the future, including by our other members.

0.22 The NIA is the trade association, information and representative body for the civil nuclear industry in the UK. It represents more than 260 companies operating in all aspects of the nuclear fuel cycle, including the operators of the nuclear power stations, the international designers and vendors of nuclear power stations, and those engaged in decommissioning, waste management and nuclear liabilities management. Members also include nuclear equipment suppliers, engineering and construction firms, nuclear research organisations, and legal, financial and consultancy companies.

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[10] Mission report IAEA International Fact Finding Expert Mission of the Fukushima Dai-chi NPP Accident Following the Great East Japan Earthquake and Tsunami Tokyo, Fukushima Dai-ichi NPP, Fukushima Dai-ni NPP and Tokai Dai-ni NPP, Japan 24 May–2 June 2011.

0.23 The NIA's address is:

Nuclear Industry Association
Carlton House
22a St James's Square
London
SW1Y 4JH

0.24 All questions concerning this Application should be addressed to Mr Keith Parker at the above address and marked "Justification Application".

ONE

INTRODUCTION AND PROPOSED PRACTICE

PROPOSED PRACTICE

1

Proposed Practice

Introduction

1.1 This Application seeks a Justification decision for a new type or class of practice pursuant to regulation 9 (1) of the Justification of Practices Involving Ionising Radiation Regulations 2004 (SI 2004 No. 1769).

1.2 This chapter describes the "class or type of practice" for which Justification is being sought. Annex 1 contains a description of a non-site specific version of the ABWR, that has been developed and built elsewhere in the world. Annex 1 also provides a brief description of how the UK ABWR design will contain the features and characteristics of the ABWR, will incorporate further improvements and enhancements, and will need to take account of UK conditions and regulatory requirements. The annex includes evidence which demonstrates the figures and statistics which support the level of the benefits and detriments identified in the chapters of this Application. A description of the nuclear fuel cycle is provided in Annex 2.

Proposed Practice

1.3 This Application is made to support the construction, operation and, ultimately, the decommissioning of new nuclear power stations in the UK by reference to the UK ABWR technology. The class or type of proposed practice for which justification is sought (the "Proposed Practice") can be summarised as:

> *The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in a light water cooled, light water moderated thermal reactor currently known as the UK ABWR designed by Hitachi-GE Nuclear Energy, Ltd.*

1.4 We have designed this definition of the Proposed Practice by studying the approach taken by the Justifying Authority in determining the "class or type of practice" in response to the options presented in our 2008 Application. Accordingly, the definition of Proposed Practice aligns with the definitions of previously justified new nuclear power station practices.

1.5 We recognise that it is for the Justifying Authority to determine what the "class or type of practice" is, and whether it is capable of being considered as a new class or type of practice for the purpose of the Regulations. We ask the Justifying Authority to consider our Proposed Practice to determine whether he agrees with our proposed definition.

1.6 The main attributes of the Proposed Practice are set out in Table 1.1. The Justifying Authority's determination of the class or type of practice in response to the 2008 Application included a statement that the practice is best defined by reference to a common set of technical characteristics. Table 1.1 also includes some non-technical characteristics, which may not therefore be necessary to define the Proposed Practice. However, we have included non-technical characteristics to provide further explanation of the attributes of the Proposed Practice which are relevant to the assessment of its benefits and detriments.

1.7 The UK ABWR reactor, which is the subject of the Proposed Practice, is designed by Hitachi-GE Nuclear Energy Ltd. The UK ABWR is a direct cycle boiling water reactor ("BWR") type which depends on thermal energy fission and utilises low enriched oxide fuel. Light water is utilised in the design as both a moderator and a coolant and the nominal electrical power output is 1350MWe.

1.8 Most light water reactors being constructed in the world today belong to what are known as Generation III/III+ reactors. These designs have evolved from the PWRs and BWRs that were constructed in the 1980s and that are still in operation today. The UK ABWR, along with the designs in our 2008 application, is considered to be a Generation III+ technology. These evolutionary reactors have incorporated improvements to offer enhanced safety levels and efficiency.

1.9 Justification is a process which involves the initial, high level assessment of the benefits and detriments of the Proposed Practice. It is not intended to substitute more detailed examinations of reactor designs by the regulators. The generic design assessment ("GDA") and later regulatory steps and design development to optimise the design can be expected to introduce design changes; however these modifications will not materially affect the balance of the benefits and detriments described in this Application. As was the case with the 2010 Justification Decisions[11] for the AP1000® and EPR™ reactor designs, these modifications should not require that any Justification decision made in respect of this Application be revisited.

1.10 The benefits of carbon reduction and security of supply described in this Application are relevant to all large, commercial nuclear reactor technologies currently being considered for deployment by UK nuclear utilities (including the UK ABWR, the EPR™ and the AP1000®), and will remain the same regardless of technology developments to optimise the design.

Table 1.1
Main Attributes of the Proposed Practice

Characteristic	Defining Attribute of Proposed Practice	Further Information provided in this application
Basic Nuclear Characteristics		
Fission process	Thermal energy fission	Annex 1
Fuel	Low enriched oxide fuel	Annex 1
Moderator	Light Water	Annex 1
Coolant	Light Water	Annex 1
Radiological Health Detriment		
Normal operation - workers	Effective individual dose in calendar year: • Below legal limit 20mSv/yr averaged over any consecutive 5 years, 50mSv in any one year* • Average for defined groups less than UK regulatory Basic Safety Level (10mSv/yr)**	Chapter 5 & Annex 4
Normal operation - public	Below 1mSv/yr legal dose limit. Maximum individual dose in calendar year complies with Environmental Permitting Regulations: 0.3mSv/y from new plant***	Chapter 5 & Annex 4
Accident risk	Meets UK regulatory Basic Safety Level criteria for accident risk	Chapter 5
Security of Supply		
Origin of fuel	Available from diverse countries	Chapter 2
Readiness for implementation	UK ABWR design commercially available in UK • UK ABWR currently going through GDA process • Utility already lined up to build UK ABWR in the UK	Annex 1

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[11] The Justification Decision (Generation of Electricity by the AP1000 Nuclear Reactor Regulations 2010) – http://www.legislation.gov.uk/ukdsi/2010/9780111502891.

Carbon "Footprint"		
Lifecycle CO_2 emissions	Considered low carbon	Chapter 3
Radioactive Waste & Decommissioning		
Radioactive wastes and spent fuel arisings	Compatible with UK disposal or interim storage plans	Chapter 6 & Annex 3

* Part II paragraph 9, schedule 4 of The Ionising Radiation Regulations 1999, SI 3232. http://www.legislation.gov.uk/uksi/1999/3232/contents/made3232

** Safety Assessment Principles for Nuclear Facilities, HSE, 2006. http://www.hse.gov.uk/nuclear/saps/saps2006.pdf

*** These requirements are included in Schedule 23, Part 4, Section 2(1) of The Environmental Permitting (England and Wales) Regulations 2010. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69503/pb13632-ep-guidance-rsr-110909.pdf

Scope of the Proposed Practice

1.11 The nuclear fuel cycle comprises a series of processes related to the production of electricity from uranium in nuclear power reactors and the management of the resulting radioactive waste products.

1.12 In May 2012 the Department of Energy and Climate Change (DECC), consulted on a potential Justification process relating to the reuse of plutonium in connection with new nuclear power stations in the UK. The practice described in that consultation is not relevant to this Justification Application as the definition of our Proposed Practice is expressly confined to the use of low enriched oxide fuel.

1.13 Annex 2 provides a brief description of the key aspects of the Proposed Practice pertinent to this Justification Application. Information on all aspects of the nuclear fuel cycle related to the current Application is provided, including those that occur outside the UK, or that constitute separate practices in their own right. For completeness, the potential health detriments associated with these aspects are considered later in this Application.

1.14 Table 1.2 presents the activities related to the Proposed Practice, which are considered in this Application. Nuclear power plants need to be supported by facilities for fuel manufacture and for managing spent fuel and radioactive waste. The ICRP recommends that for the purposes of Justification, radioactive waste management, waste disposal operations are treated as part of the practice generating the waste[12].

1.15 A number of activities, namely conversion, enrichment, fuel fabrication and transport of fresh fuel, spent fuel and radioactive wastes are already justified as Existing Practices*. Information on these is included in this Application which shows that UK ABWR technology does not introduce any new material considerations in respect of these activities. Uranium extraction does not take place in the UK but is included for information purposes.

1.16 The current ICRP Recommendations represent an evolution from the original recommendations on which the BSS Directive and the Regulations are based, which had focussed on the assessment of the radiological impacts of a "practice". The current Recommendations instead provides that the radiological impacts of an activity should be assessed by considering doses associated with the "planned exposures situations" and "emergency exposure situations" that the activity can (or may) give rise to. This application addresses the Proposed Practice as a "practice" in accordance with the legal requirements of the Regulations. However, in doing so, and consistent with the current ICRP Recommendations, all potential radiological impacts of all relevant aspects of that "practice" are addressed, including impacts from both planned and emergency situations.

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[12] Radiological Protection in Geological Disposal of Long-lived Solid Radioactive Waste, ICRP publication 122, 2013 http://www.icrp.org/publication.asp?id=ICRP%20Publication%20122.

Table 1.2
Activities Related to the Proposed Practice

Activity	Existing Practice*
Uranium extraction (mining and milling or in-situ leaching)	Takes place outside the UK
Conversion	Yes
Enrichment**	Yes
UK Fuel Fabrication	Yes
Generation of electricity by UK ABWR	No
UK ABWR Spent Fuel Management	No
UK ABWR Radioactive Waste Management	No
Decommissioning of UK ABWR plants	No
Transport of fresh fuel, spent fuel and radioactive wastes	Yes
Final disposal UK ABWR LLW	No
Final disposal UK ABWR ILW & spent fuel	No

*Justified by virtue of being a class or type of practice existing in the UK prior to 13 May 2000[13].

** With respect to enrichment, we note that this is currently undertaken in the UK at Urenco's Capenhurst site. According to Urenco's 2012 annual report, last year the Capenhurst site had a capacity for 5000t separative work. This capacity is more than sufficient to fuel a UK fleet of, for example, 16GWe (which roughly represents the total capacity of new nuclear power stations that UK utilities have announced plans to develop to date). However, the Capenhurst site already has customers for its output, and it is possible that the site would have to expand production capacity to accommodate both current customers and UK new build customers if the existing practice of Enrichment was all undertaken in the UK.

[13] Under paragraph 5 of the regulations, a practice is justified if a practice in that class or type of practice was carried out in the United Kingdom before 13 May 2000. These practices are listed in Annex 3 of Defra guidance. The Justification of Practices Involving Ionising Radiation Regulations 2004 (SI 2004 No 1769); Guidance on their application and administration, Version May 2008.

TWO

SECURITY OF SUPPLY AND CLIMATE CHANGE BENEFITS

SECURITY OF SUPPLY

Security of Supply and Climate Change Benefits

Security of Supply

DECC's Overarching National Policy Statement for Energy (EN-1)[14] made a number of important statements regarding security of supply and nuclear power:

> *"It is critical that the UK continues to have secure and reliable supplies of electricity as we make the transition to a low carbon economy."* [15]

> *"Nuclear power is a proven technology that is able to provide continuous low carbon generation, which will help to reduce the UK's dependence on imports of fossil fuels."* [16]

Sufficient uranium is readily available to fuel existing and potential new nuclear power stations.

Nuclear power stations are relatively invulnerable to short-term fluctuations in the availability of fuel with the ability to stockpile if future supply became uncertain.

The UK ABWR is based upon a design which is proven and successfully operating elsewhere in the world.

The adoption of the Proposed Practice would provide a significant benefit to the UK from a security of supply perspective.

Introduction

2.1 People, businesses, Government and services all depend on the reliable supply of electricity to properly function. Delivering that reliable supply of electricity at an affordable price ensures that the UK remains competitive globally and contributes to the population's quality of life. Interruptions to supply, and the increased costs which would result, would have an adverse social and economic impact.

2.2 This chapter looks at the potential security of supply benefits that would result from the adoption of the Proposed Practice.

What Has Changed Since Our 2008 Application

2.3 The need for secure electricity supplies in the UK, and for new, large-scale infrastructure to be brought forward as soon as possible to meet that need, has been confirmed as firm Government policy in DECC's Overarching National Policy Statement for Energy ("EN-1"). This was approved by the House of Commons and designated in July 2011. It states:

> *"It is critical that the UK continues to have secure and reliable supplies of electricity as we make the transition to a low carbon economy… we need… sufficient electricity capacity to meet demand at all times… and… a diverse mix of technologies and fuels, so that we do not rely on any one technology or fuel."* [17]

> *"In order to secure energy supplies that enable us to meet our obligations for 2050, there is a need for new (and particularly low carbon) energy Nationally Significant Infrastructure Projects (NSIPs) to be brought forward as soon as possible, and certainly in the next 10 to 15 years."* [18]

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[14] DECC. Overarching National Policy Statement for Energy (EN-1). July 2011 – available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf.

[15] EN-1, paragraph 2.2.20.

[16] EN-1, paragraph 3.3.4.

[17] EN-1, paragraph 2.2.20.

[18] EN-1, paragraph 3.3.15.

2.4 EN-1 identifies a growing need for electricity capacity:

> *"The 2050 pathways show that the need to electrify large parts of the industrial and domestic heat and transport sectors could double demand for electricity over the next forty years."* [19]

2.5 EN-1 also makes a number of important statements regarding the contribution that new nuclear power stations can make towards achieving the necessary capacity:

> *"Nuclear power is a proven technology that is able to provide continuous low carbon generation, which will help to reduce the UK's dependence on imports of fossil fuels."* [20]

> *"The Government would like a significant proportion of [the new non-renewable capacity required balance to be filled by new low carbon generation and believes that, in principle, new nuclear power should be free to contribute as much as possible toward meeting the need for around 18 GW of new non-renewable capacity by 2025."* [21]

Benefits of Electricity to UK Society

2.6 Electricity cannot readily be stored, but must be generated to match demand. It is therefore crucial that the UK electricity system is provided with a mix of generating sources that, in aggregate, deliver very high confidence that demand will be met. The Proposed Practice is, first and foremost, an important means of contributing to the generation of reliable, dependable, large-scale quantities of electricity as part of this mix. One 1350MW ABWR unit would be capable of supplying electricity to over 2.5 million homes[22]. Irrespective of the other characteristics of nuclear as a source of generation, this is a substantial benefit when assessing Justification.

2.7 Nuclear generation has characteristics that mean it makes an especially significant contribution to the robustness of the generation mix, and hence to security of supply. This further substantial benefit of the Proposed Practice is set out in the remainder of this chapter.

Security of Electricity Supplies

2.8 In the 2010 Justification Decisions, it was stated that:

> *"Reliable and affordable electricity supplies are essential for the UK. Today and in the future, the UK must be able to count on reliable supplies of energy for electricity, heating and transport."* [23]

> *"The Secretary of State believes that nuclear power can make a significant contribution to our energy mix, alongside other low carbon technologies including renewables and CCS. This will reduce our dependency on imported fossil fuels and help maintain a diverse mix of electricity generating technologies with the flexibility to respond to future developments and therefore make an important contribution to the security of energy supplies."* [24]

2.9 Over the next ten years a fifth of the UK's 2011 capacity must close, and investment is needed if we are to maintain the secure energy supplies that are critical to our economy and our way of life.

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[19] EN-1, paragraph 2.2.22.

[20] EN-1, paragraph 3.3.4.

[21] EN-1, paragraph 3.3.22.

[22] Based on 90% load factor with the average annual household consumption of 4,160kWh (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/170728/et_article_domestic_energy_bills_in_2012.pdf).

[23] DECC, The reasons for the Secertary of State's Decision as Justifying Authority on the Regulatory Justification – for the EPR and AP1000 – October 2010 ("2010 Justification Decisions") paragraph 5.49.

[24] 2010 Justification Decisions, paragraph 5.53.

2.10 In the 2012 Energy Security Strategy[25], four elements of security of supply were considered: adequate capacity; diversity; reliability and demand side responsiveness. Nuclear power stations will help to deliver against the first three of these elements.

2.11 New nuclear power stations will help to ensure a diverse mix of technology and fuel sources, which will increase the resilience of the UK's energy system. They will reduce exposure to the risks of supply interruptions and of sudden and large spikes in electricity prices that can arise when a single technology or fuel dominates electricity generation.

Role of Baseload Plant

2.12 The demand of electricity varies all the time. However, a significant proportion of demand, known as "baseload", is required 24 hours a day. Transport, industry, hospitals, lighting etc. that can be required to operate throughout the night make up most of baseload demand.

2.13 The key attribute of baseload plant is their ability to generate continuously in a reliable and predictable way. Baseload plants are generally operated continuously at high capacity. Fluctuations, including spikes, are handled by more responsive plants on the system which are faster to start/ramp up. New nuclear power stations with their low variable costs, high availability and low carbon emissions (see Chapter 3) are suited to meet future baseload demand.

Availability of Nuclear Fuel

2.14 Nuclear power stations are relatively invulnerable to fluctuations in the availability of fuel. In this respect, they are very different to, for example, gas-fired power stations, which require a continuous supply of new fuel in order to generate electricity. A typical modern nuclear reactor will only be re-fuelled every 12 to 24 months, and in the meantime will operate with high availability at full power. If a refuelling could not take place as scheduled, the reactor could continue to operate for several months although the maximum power output would slowly decline. In addition to contributing to security of supply, this is also part of the reason why the full cost of nuclear generation is relatively insensitive to the price of uranium.

2.15 Several of the most important supply countries for uranium are politically stable, with over 40% of identified resources located in Australia or North America[26]. Risks of fuel supply interruption are considered to be minimal.

2.16 The OECD's Nuclear Energy Agency ("NEA") and the International Atomic Energy Agency ("IAEA") have stated that, regardless of the role that nuclear energy ultimately plays in meeting rising electricity demand, the uranium resource base is more than adequate to meet projected requirements. The joint 2012 report by the OECD NEA and the IAEA, "Uranium 2011 – Resources, production and demand" states:

> *"At 2010 rates of consumption, identified resources are sufficient for over 100 years of supply for the global nuclear power fleet."* [27]

2.17 Unlike fossil fuel power plants, the relatively small volume of nuclear fuel required for electricity generation means that nuclear fuel can be stockpiled. Many years' fuel could be stored in a relatively small area if future supply became uncertain.

2.18 EN-1 confirms the security of supply of nuclear fuel:

> *"Nuclear fuel fabrication is a stable and mature industry with a range of uranium sources. Uranium deposits are predicted to last much longer than oil and gas reserves. Following the review of publications... the Government believes that adequate uranium resources*

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[25] DECC. Energy Security Strategy. November 2012. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65643/7101-energy-security-strategy.pdf.

[26] "Uranium 2011: Resources, production and demand". OECD Nuclear Energy Agency and International Atomic Energy Agency: http://www.oecd-nea.org/ndd/pubs/2012/7059-uranium-2011.pdf.

[27] Uranium 2011 – Resources, Production and Demand.

> *exist to fuel a global expansion of nuclear power, including any new nuclear power stations constructed in the UK.”* [28]
>
> *“The supply chains of nuclear fuel, gas and coal are not interdependent. An interruption in the supply of gas or coal is unlikely to affect the supply of uranium. Consequently, including new nuclear power stations in the generating mix increases the diversity of fuels that we rely on and reduces the risks of interruptions to fuel supply.”* [29]

Reliability

2.19 New nuclear power stations could be expected to deliver high levels of performance. Data from the World Association of Nuclear Operators (“WANO”)[30] shows the performance of over 350 operating nuclear power units, of differing designs, worldwide. As demonstrated in Figures 2.1 and 2.2 below, the most recent data from WANO shows sustained levels of high capacity operation with very small unplanned losses. Based on a proven international design, the UK ABWR would be able to benefit from this worldwide operating experience.

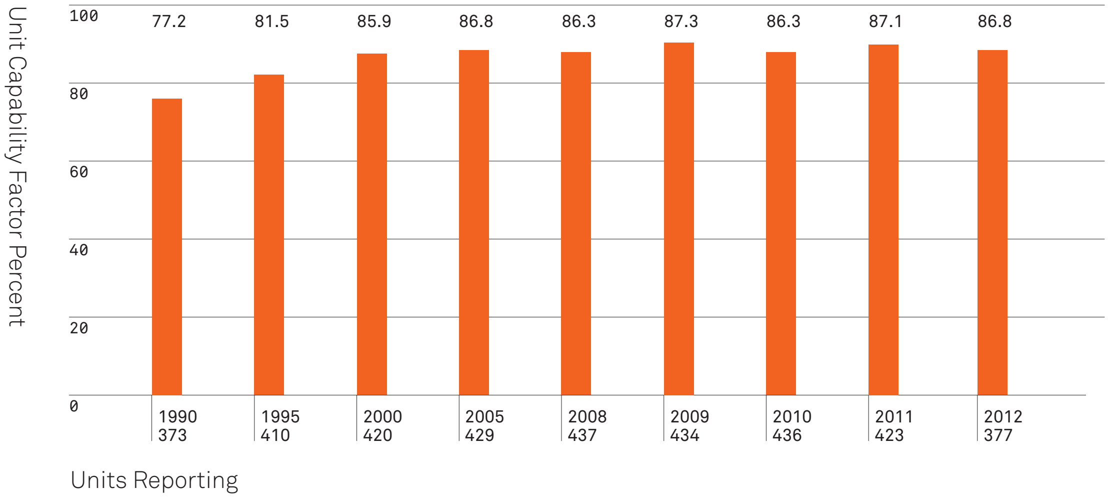

Figure 2.1 Unit Capability factor

2.20 Unit capability factor is the percentage of maximum energy generation that a plant is capable of supplying to the electrical grid, limited only by factors within control of plant management. A high unit capability factor indicates effective plant programmes and practices to minimise unplanned energy losses and to optimise planned outages.

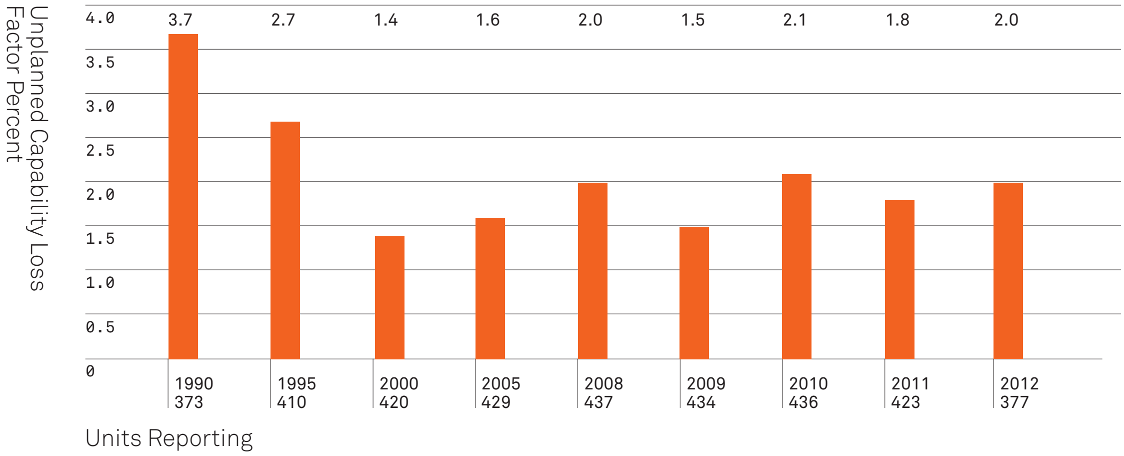

Figure 2.2 Unplanned Capability loss factor

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[28] EN-1, paragraph 3.5.4.

[29] EN-1, paragraph 3.5.4.

[30] WANO Performance Indicators 2012: http://www.wano.info/wp-content/uploads/2012/11/2011-WANO-PI-Trifold.pdf.

2.21 The unplanned capability loss factor is the percentage of maximum energy generation that a plant is not capable of supplying to the electrical grid because of unplanned energy losses, such as unplanned shutdowns or outage extensions. A low value indicates important plant equipment is well maintained and reliably operated and there are few outage extensions.

2.22 The Load Factor of a power plant (also called the capacity factor) is the ratio of the actual energy output over a period of time, to the amount of energy the plant would have produced if operating at full capacity (i.e. at its reference power capacity). Information on the load factor performance for the world's nuclear power plants can be found in the IAEA Power Reactor Information System database,[30a] and has been used to review BWR and ABWR average load factors for the periods of 2001–2005 and 2006–2010.

2.23 The data relating to the load factors of other operating BWRs (including the four operational ABWRs) worldwide can be used to provide an indication of the performance and reliability that could be achieved by the UK ABWR. The fleet of BWRs considered are: the four operational ABWR units, each in Japan; other BWRs in Japan; and BWRs in the US and Europe. Whilst the data indicates lower BWR load factors in Japan than in the US and Europe, as explained below this results from factors that would not be expected to arise in the UK.

2.24 For the period 2001–2005, load factors average at approximately 80% for the first two operating ABWRs;[30b] 60% for other Japanese BWRs; 85% for European BWRs; and 90% for US BWRs. For the period 2006–2010, load factors average at approximately 45% for all four operating ABWRs; 60% for the other Japanese BWRs; 80% for European BWRs; and 90% for US BWRs. At the time of this Application, all operational Japanese BWRs, including the ABWR units, are shutdown for the installation of post-Fukushima countermeasures but applications for restart are now progressively being put forward[30c].

2.25 For the period 2001–2005, ABWRs were among the top-performing Japanese BWRs and their performance was comparable to European BWRs. For the period 2006–2010, all four ABWRs operated below their full capacity for various reasons that are not expected to arise in the UK. Following the 16 July 2007 Chuetsu Oki earthquake (with a magnitude of 6.6), the Kashiwazaki-Kariwa units (including 2 ABWRs) were shutdown for inspection and additional reinforcement. The Shika-2 and Hamaoka-5 ABWRs also had extended shutdowns to address issues arising from now-resolved issues with the deployment of a new turbine design at these plants[30d] which are unrelated to the UK ABWR reactor design.

2.26 The data also shows that Japanese BWRs generally have lower load factors than US and European BWRs. A major reason for this is longer outages[30e, 30f] for inspections under Japanese regulations. A further factor is the shorter (13 month) fuel cycle of Japanese reactors compared to European and US plants which typically have fuel cycles of 18 months or longer[30g]. Since this regulatory approach is unique to Japan, the level of performance achieved by European and US BWRs is a more appropriate benchmark for a UK operator than Japanese ABWR performance, and is the operating experience that a UK ABWR operator would seek to emulate. This is supported by experience from the Sizewell B plant, which has a lifetime load factor of 82.9%, and so demonstrates that a UK operator can match world-wide performance benchmarks with an introduced technology in a UK operating context.

[30a] http://www.iaea.org/PRIS/home.aspx.

[30b] The third and fourth ABWR units at Hamaoka 5 and Shika 2 came into commercial operation in 2005 and 2006 respectively so are not included in the 2001–2005 ABWR load factor averages (see also paragraph A1.126 of Annex1).

[30c] The World Nuclear Association provides a summary of the status of Japanese nuclear reactors at: http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Japan/.

[30d] Paragraph A2.10 explains that nuclear power plant turbines are similar to those for other thermal stations.

[30e] The World Nuclear Association identifies similar factors behind the lower performance of Japan's nuclear power plant compared with other countries (see http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Japan/).

[30f] In Japan outages require several months compared to for example the current average of 40 days in the US (see http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/USA--Nuclear-Power/);

[30g] The selection of fuel cycle length is a matter for the operator (except in Japan where regulatory inspection requirements limit fuel cycle lengths). Annex 1 (in particular paragraphs A1.49 and A1.51) explains the fuel management considerations for the UK ABWR fuel cycle length. The UK ABWR is capable of operating with 13 month and 18 month fuel cycle lengths. As also identified in Annex 1, a 24 month fuel cycle length should be achievable although further work is required to establish specific ABWR management and design provisions.

Technical Failure

2.27 The Government concluded in the Nuclear White Paper[31] that nuclear power is *"dependable – a proven technology with modern reactors capable of producing electricity reliably"*.

2.28 However one potential security of supply risk that has been associated with baseload nuclear plant is that they could be susceptible to technical faults, conceivably resulting in a power station, or a fleet of stations of a particular type, being out of operation for a sustained period of time.

2.29 Although there are examples of the need to respond to specific issues (which are outlined above in relation to ABWR), this is strongly mitigated by worldwide operational capability that has now matured and achieved the increased reliability trends seen over the past 20 years[32]. This increased capability is in part due to the international cooperation on common nuclear technologies and this is a major strength of the industry.

2.30 The Proposed Practice would build on this by deploying the UK ABWR design, which would be able to take advantage of the large pool of experience built up worldwide with other ABWR reactors, other boiling water reactors and the even larger world wide fleet of light water reactors. The UK would be able to benefit from many thousands of years of reactor operating experience worldwide. Furthermore, the Justification of the UK ABWR technology (in addition to the EPR™ and AP1000® reactors which were the subject of the 2010 Justification Decisions) would facilitate the deployment of a more diverse range of reactor types within the UK electricity generation mix. The Justification of the Proposed Practice would, therefore, potentially further diffuse the impact of any technology risks that might arise with respect to a fleet of a particular nuclear reactor design.

Conclusion

2.31 The adoption of the Proposed Practice would provide a significant benefit to the UK from a security of supply perspective. Nuclear energy already provides secure, large-scale, baseload electricity. As part of a diverse energy mix, nuclear energy reduces dependence on imported energy and protects UK supplies in the event of fuel supply interruptions overseas. These benefits would be maintained by the construction of new nuclear stations including the UK ABWR.

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[31] Meeting the Energy Challenge, a White Paper on Nuclear Power, 2008.

[32] An overview of recent trends is provided by the WNA at http://www.world-nuclear.org/info/Current-and-Future-Generation/Nuclear-Power-in-the-World-Today/. The analysis presented by the WNA is drawn from data in the IAEA Power Reactor Information Systems (PRIS) database: http://www.iaea.org/PRIS/CountryStatistics/CountryStatisticsLandingPage.aspx.

THREE

SECURITY OF SUPPLY AND CLIMATE CHANGE BENEFITS

CLIMATE CHANGE BENEFITS

3

Security of Supply and Climate Change Benefits
Carbon Reduction

The Climate Change Act 2008 established a legally binding climate change target for the UK. The Act states that:

> *"It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline"*

The emissions from nuclear power generation are comparable to those from renewable generation The UK's Overarching National Policy Statement for Energy (EN-1) states that:

> *"New nuclear generation would complement renewables and fossil fuels with CCS in ensuring that we meet our legal obligations as it can provide dependable supplies of low carbon electricity."*

Introduction

3.1 There is scientific consensus that human activities are causing global climate change. The burning of fossil fuels, changes in land use, and various industrial processes are adding greenhouse gases, particularly carbon dioxide ("CO_2"), to the atmosphere. CO_2 concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The effects of these additional gases can already be seen (global average temperatures have risen by 0.75°C since about 1990) with consequences for both the environment and people's lives. The Low Carbon Transition Plan ("LCTP")[33], published in 2009, concluded that if climate change continues unchecked, the consequences for the UK will be severe, and that across the world, the consequences of failing to control emissions would be worse still. It also concluded that action on climate change is urgently needed to prevent widespread human suffering, ecological catastrophe, and political and economic instability.

3.2 In the electricity sector, the UK will be able to rely less on gas and coal if it increases the amount of electricity generated through low-carbon technologies such as renewables, carbon capture and storage and nuclear, and if we can reduce our overall consumption of electricity through demand reduction and energy efficiency. However, reducing the carbon content of our heat and transport energy may require an increase in the amount of electricity generation we require overall.

What Has Changed Since Our 2008 Application?

3.3 The Climate Change Act 2008[34] established the world's first legally binding climate change target, requiring an 80% reduction in greenhouse gas emissions from 1990 levels by 2050. Meeting this target will require the UK to drastically reduce its dependence on fossil fuels.

3.4 In order to meet these legally binding targets, the UK will have to make significant progress towards decarbonising the electricity sector: Figure 3.1 shows the development of the electricity generation mix since 1995, showing the growth of renewable generation, particularly from 2007. There is also a clear increase in 2012 of the contribution from coal, gas (non-Combined Cycle Gas Turbine), oil and biomass and a reduction in the electricity from Combined Cycle Gas Turbine (CCGT) stations. The contribution of nuclear to UK electricity generation has decreased from the levels generated in the 1990s, as older nuclear stations have reached the end of their life, although there is a slight increase in nuclear generation from 2010.

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[33] http://webarchive.nationalarchives.gov.uk/20100509134746/http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=White Papers/UK Low Carbon Transition Plan WP09/1_20090724153238_e_@@_lowcarbontransitionplan.pdf&filetype=4.

[34] http://www.legislation.gov.uk/ukpga/2008/27/contents.

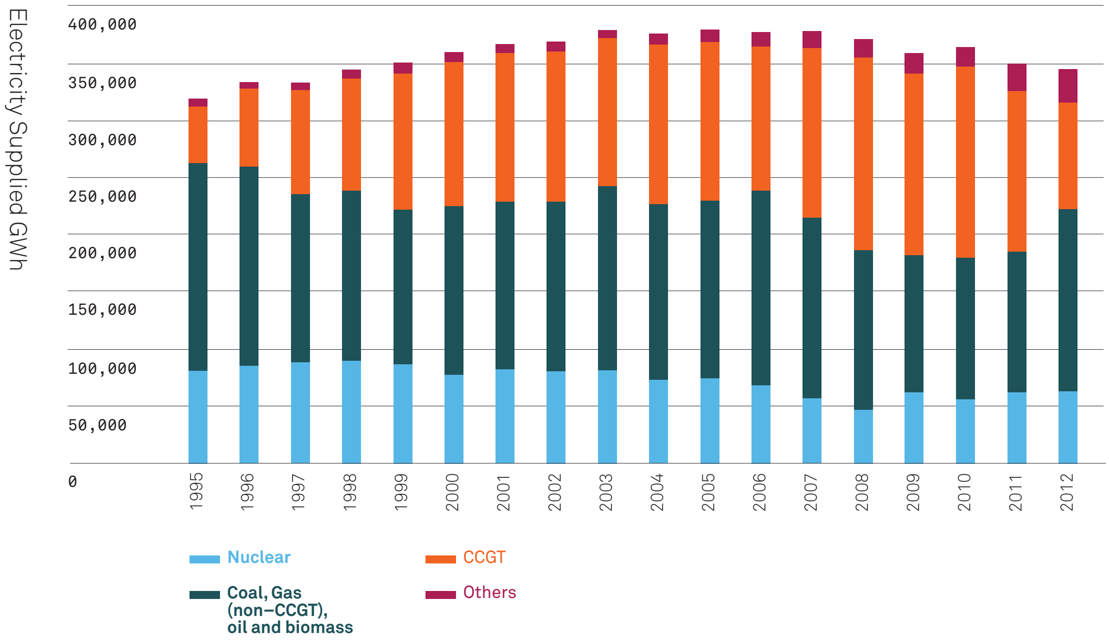

Figure 3.1 GB Generation mix of electricity supplied since 1995, source DECC Historic electricity data[35]

3.5 In considering options for achieving the 2050 carbon target, the Committee on Climate Change ("CCC") said in April 2012, *"all our scenarios [for meeting the 2050 target] involve widespread deployment of energy efficiency measures and decarbonisation of the power sector (through a combination of nuclear, renewables and CCS)"* [36]. Figure 3.2 shows the illustrative mix that the CCC put forward for 2030 generation, which clearly illustrates the switch required from fossil fuels to low-carbon technologies.

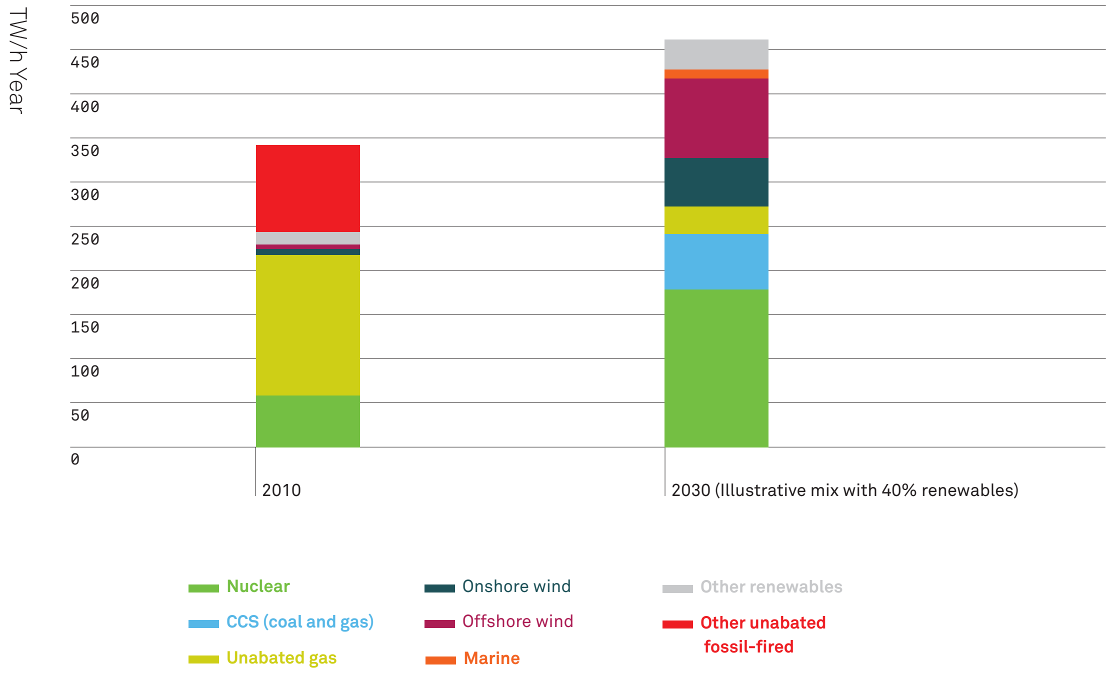

Figure 3.2 Generation Mix

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[35] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224644/electricity_since_1920_historical_data.xls.

[36] Quote from – "The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping", Committee on Climate Change, April 2012: http://archive.theccc.org.uk/aws/IA&S/CCC_IAS_Tech-Rep_2050Target_April2012.pdf.

Comparative Carbon Content of Nuclear Power

3.6 Nuclear power stations produce very few carbon dioxide emissions directly from electricity generation.

3.7 All forms of electricity generation have some carbon dioxide emissions associated with the energy used in the construction, operation and decommissioning of plant. Nuclear (like coal) has carbon dioxide emissions associated with energy use during mining; and also with extraction, enrichment, and the manufacture of its fuel. Like coal, energy is also used in management of the waste products from generation resulting in carbon dioxide emissions.

3.8 In 2011, the Intergovernmental Panel on Climate Change ("IPCC") synthesized evidence from a comprehensive review[37] of published Life Cycle Assessments ("LCAs") covering all regions of the world, to produce a comparison of carbon dioxide emissions from different electricity generation technologies. This showed that emissions from nuclear power stations (median figure of 16gCO_2/kWh) are comparable to those from renewable resources, and significantly lower than those from electricity generated from fossil fuels.

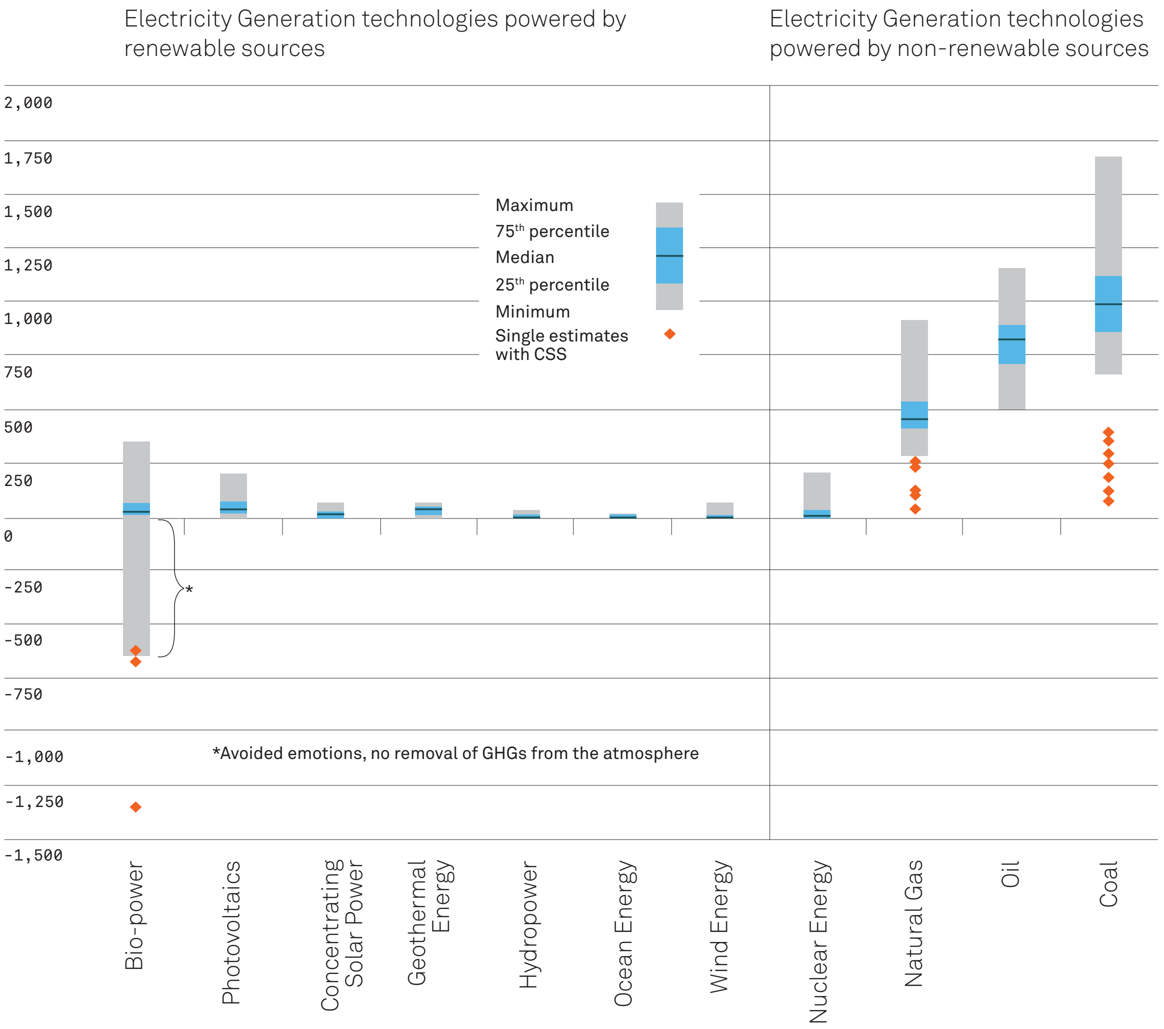

Figure 3.3 Estimates of lifecycle GHG emissions (g CO2eq/kWh) for broad categories of electricity generation technologies, plus some technologies integrated with CCS.[38]

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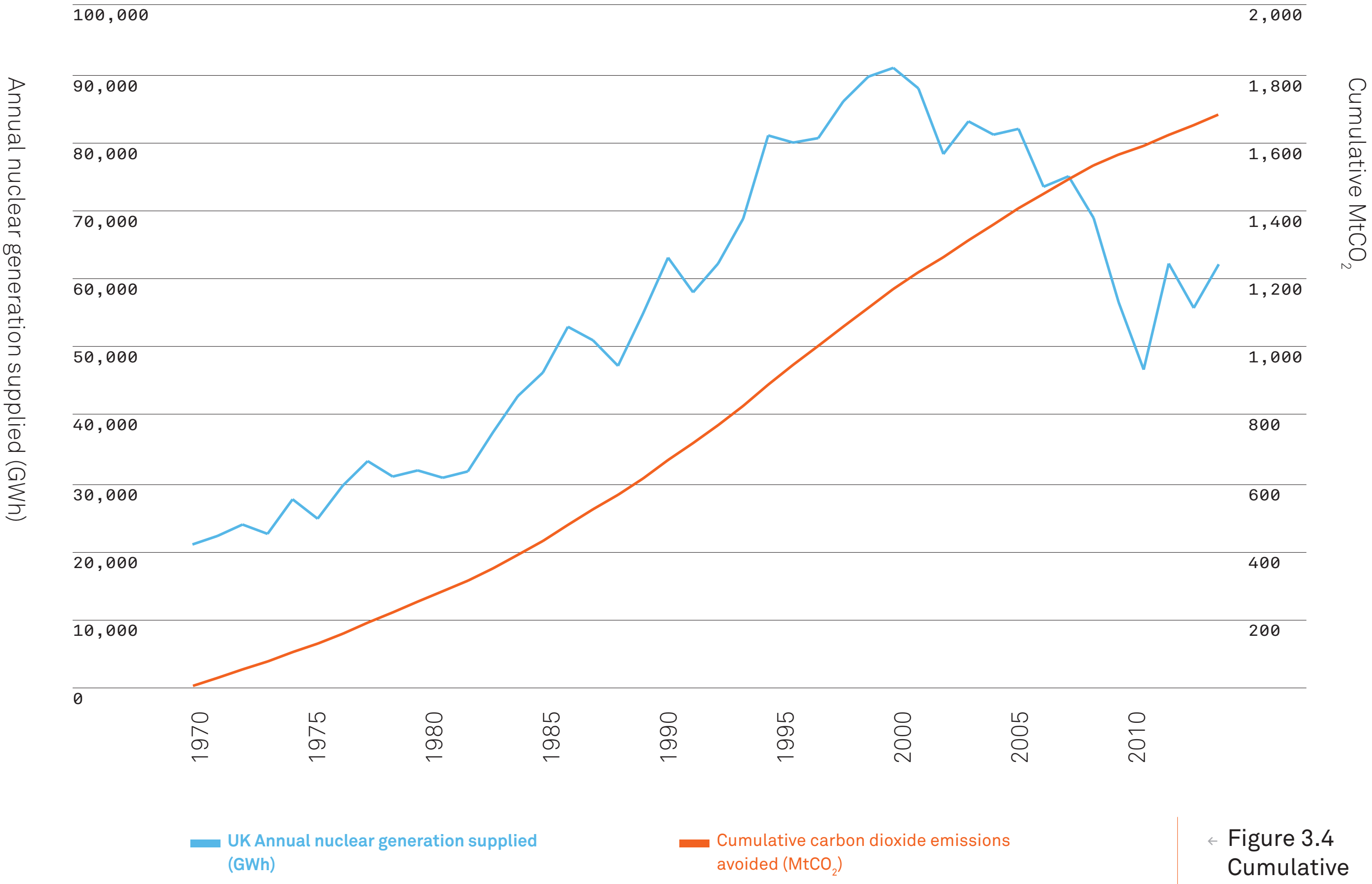
[37] Special report on renewable energy sources and climate change mitigation, IPCC SRREN Full report (2011), see chapter 9: http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch09.pdf.

[38] Source: Sathaye, J., O. Lucon, A. Rahman, J. Christensen, F. Denton, J. Fujino, G. Heath, S. Kadner, M. Mirza, H. Rudnick, A. Schlaepfer, A. Shmakin, 2011: Renewable Energy in the Context of Sustainable Energy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs–Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press. Figure 9.8.

Net Contribution to UK's Overall Emissions

3.9 In 2012, nuclear power stations in the UK supplied just under 64TWh of electricity to the grid.[39] If a series of new nuclear stations were built (including UK ABWRs, whether or not amongst others) to provide the same amount of electricity, the total annual carbon emissions from this electricity generation (using the median figure provided above) would be $1.0MtCO_2$ (million tonnes of carbon dioxide): this is less than 0.25% of the UK's total emissions of $479.1MtCO_2$.[40]



← Figure 3.4 Cumulative emissions avoidance from nuclear generation since 1970. Source, NIA analysis

3.10 Figure 3.4 shows the output from the UK's nuclear plants and CO_2 emissions avoided since 1970. The emissions avoided through this generation are based on the prevailing mix of fossil fuel generation replaced by nuclear in each year. On this basis, nuclear generation in the UK has avoided the emission of over 1.6 billion tonnes of carbon dioxide ($bntCO_2$) since 1970.

3.11 Over a 60-year lifetime, a series of new nuclear reactors providing the same amount of electricity as the existing ones could save 1.5 billion tonnes of carbon dioxide compared with generating the same energy from the UK's current generation mix (excluding nuclear)[41].

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[39] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224644/electricity_since_1920_historical_data.xls.

[40] 2012 UK Greenhouse Gas emissions, provisional figures: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/193414/280313_ghg_national_statistics_release_2012_provisional.pdf.

[41] Based on DECC's 2011 greenhouse gas emissions and historic electricity data, available at: https://www.gov.uk/government/statistical-data-sets/historical-electricity-data-1920-to-2011.

Detriments if Carbon Emissions are not Reduced

3.12 The Stern Review of the Economic Impacts of Climate Change[42] (the "Stern Review") stressed the potential financial cost of climate change, and highlighted the need for an urgent, co-ordinated international response to address this. It suggested that working to mitigate the problems of climate change immediately would cost about 1% of global GDP a year by 2050 with a range of +/-3% to take account of a number of variables. As a comparison, the Stern Review said that it could cost about 5% of global GDP a year in the long term if nothing is done, rising to as much as 20% if a wider range of issues such as health and the environment is taken into account.

3.13 However, the impacts of climate change are not limited to economic effects. Possible global temperature increases could lead to a radical change in the physical geography of the world, which would have powerful implications for the human geography - where people live, and how they live their lives. Impacts on food production, sea levels, water availability and extreme weather events are all considered likely, and as the Overarching National Policy Statement for Energy ("EN-1") stated, *"heat waves, droughts, and floods would affect the UK"*. As the Stern Review summarised, *"the impacts of climate change are not evenly distributed - the poorest countries and people will suffer earliest and most. And if and when the damages appear it will be too late to reverse the process."*

Conclusion

3.14 As the National Policy Statement for Nuclear Power Generation ("EN-6") says:

> *"Any new nuclear power stations ... will play a vitally important role in providing reliable electricity supplies and a secure and diverse energy mix as the UK makes the transition to a low carbon economy."* [43]

3.15 By providing large-scale generation with a low carbon footprint, new nuclear plant, including the UK ABWR, would deliver a substantial benefit to the UK's efforts to tackle global climate change. Nuclear power is a proven, reliable and low carbon generating technology that has made and is making a significant contribution to avoiding the harmful emissions that cause climate change.

3.16 The Overarching National Policy Statement for Energy (EN-1) recognises the role that nuclear power should play as part of the energy mix:

> *"To ensure our future energy is secure, clean and affordable, the UK needs a mix of [renewable, fossil fuels with CCS, and nuclear] electricity generation. The Government believes that new nuclear generation would complement renewables and fossil fuels with CCS in ensuring that we meet our legal obligations as it can provide dependable supplies of low carbon electricity."* [44]

3.17 The UK has made a legal commitment to achieve an ambitious de-carbonisation target by 2050, and the Proposed Practice, as part of a fleet of new nuclear power plants, will be a very important part of the strategy to meet this requirement.

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[42] HM Treasury. Stern Review on the Economics of Climate Change. 30 October 2006 . Available at: http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm.

[43] DECC. National Policy Statement for Nuclear Power Generation (EN-6), Volume I, June 2011.

[44] DECC. Overarching National Policy Statement for Energy (EN-1), June 2011.

FOUR

ECONOMIC ASSESSMENT

Economic Assessment

Economic Assessment

FOUR

Deployment of the Proposed Practice will not result in unreasonable or unacceptable costs being incurred by UK taxpayers or electricity consumers.

The expected costs of nuclear power stations are comparable with the costs of other forms of electricity generation, including other low carbon technologies.

Government will ensure that an appropriate framework exists to ensure that its policy objectives can be delivered. This is expected to include measures to ensure that individual projects do not go forward unless they demonstrate an acceptable cost to the consumer. Currently, through the Government's electricity market reform policy and proposals, long-term contracts will be the key mechanism for encouraging investment in low-carbon generation. This new regime provides a mechanism for the Government to determine whether it considers that a project represents value for money and would be a cost-effective additions to the UK generation mix.

The risk of severe detriment to the UK economy as a result of the impacts of a nuclear accident involving the Proposed Practice is very low. Furthermore, this risk is mitigated by the mandatory insurance protection provided through the international nuclear liability channelling regime to which the UK is a party.

The construction of more nuclear power stations in pursuance of the Proposed Practice would provide short-term socio-economic benefits to local economies. The operation of the stations would also bring long-term, wider socio-economic benefits.

Introduction

4.1 Chapters 2 and 3 of this Application, which relate to security of supply and carbon reduction, identify the need for, and benefits of, the Proposed Practice. This Chapter considers potential impacts of adoption of the Proposed Practice on the UK economy. In doing so, this Chapter makes a distinction between the national economic perspective and the perspective of a private sector developer who may become involved in deployment of the Proposed Practice. From the national viewpoint, it is important to establish that the costs of the Proposed Practice would not be expected to result in unreasonable or unacceptable costs being incurred by UK taxpayers or electricity consumers (i.e. it does not represent an economic detriment).

4.2 As with our 2008 Application, this submission does not rely on demonstrating an economic benefit to conclude that the Proposed Practice is justified.

What Has Changed Since Our 2008 Application?

4.3 Since our 2008 Application, the cost estimates for building nuclear reactors (generally, across all types of technology) have increased: construction experience in this period has demonstrated that previous cost predictions were too low. Real construction experience available today has allowed the industry and analysts to prepare more accurate updates of future cost assumptions. These updated assumptions are presented in this Application.

4.4 Further, since our 2008 Application, the Government has proposed a reform of the UK electricity market. This seeks to incentivise investment in a range of low carbon generating technologies and to facilitate investment in new capacity. As outlined below, this balancing process has as a key aim minimising costs to consumers.[45]

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[45] See, for example, paragraph 8 of "Electricity Market Reform: Consultation on Proposals for Implementation" published in October 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/253385/emr_cons_implementation_proposals.pdf.

Costs

What are levelised costs?

4.5 The Levelised Unit Electricity Cost ("LUEC or levelised costs") is the discounted lifetime cost of the ownership and use of a generation asset. This is converted into an equivalent unit of cost of generation and expressed in £/MWh.

4.6 The "levelised cost" of a particular generation technology is the ratio of the total costs of a generic plant (including both capital and operating costs) to the total amount of electricity expected to be generated over that plant's lifetime. Both figures are expressed in present value terms. This means that future costs and outputs are discounted when compared to current costs and outputs.

4.7 This is sometimes called a "life cycle cost", which emphasises the "cradle to grave" aspect of the concept. The levelised cost estimates do not consider revenue streams available to generators (for example, from sale of electricity or revenues from other sources), with the exception of heat revenues for CHP plant, which are included so that the estimates reflect the cost of electricity generation only.

4.8 As the definition of "levelised costs" relates only to those costs accruing to the owner/operator of the generation asset, it does not cover wider costs that may in part fall to others, such as the full cost of system balancing and network investment, or air quality impacts, nor does it capture other benefits such as those described in Chapter 2 (Security of Supply).

Nuclear Levelised Costs

4.9 There is a wide range of independent external assessments of generation costs for all electricity generation technologies, including nuclear, which can be used to estimate the range of possible costs. These assessments generally estimate the cost of nuclear power to be higher than the figures existing at the time of our 2008 Application. However, nuclear remains cost-competitive relative to other sources of low carbon electricity.

4.10 DECC's July 2013 paper on electricity generation costs[46], which relies on studies undertaken by Parsons Brinckerhoff and was published around the same time[47], forecasts a range of between £83-£108/MWh for nuclear reactors commissioning in 2020, and £70-94/MWh for reactors commissioning in 2030. The Parsons Brinckerhoff study considers the complete life cycle cost, including the costs of decommissioning, waste management and final waste disposal, using a flat 10% discount rate (so that costs across all technologies can be compared). Table 4.1 below indicates a range of assumptions for key cost components to levelised cost calculation for first of a kind ("FOAK") nuclear technology.

Table 4.1

Range of assumptions for key cost components to levelised cost calculation.

Levelised cost of nuclear electricity generation (LCOE) cost component	Units	First of a kind (FOAK)
Pre development costs	£m/MW	0.11—0.47
Construction costs	£m/MW	3.7—4.6
Fixed operating cost	£/kWh/yr	72
Variable operating cost	£/MWh	3
Insurance	£/MW/yr	10,000
Connection and Use of System Charges (CUSC)	£/MW/yr	7.4

[46] 'Electricity Generation Costs', DECC, July 2013: https://www.gov.uk/government/publications/decc-electricity-generation-costs-2013. Parsons Brinkerhoff Electricity Generation Model:2013.

[47] Update of Renewable Technologies, DECC, June2013: https://www.gov.uk/government/publications/parsons-brinkerhoff-electricity-generation-model-2013-update-of-non-renewable-technologies; and Parsons Brinkerhoff Electricity Generation Model: 2013 Update of Non-Renewable Technologies, DECC, April 2013: https://www.gov.uk/government/publications/parsons-brinkerhoff-electricity-generation-model-2013-update-of-non-renewable-technologies.

Table 4.2 below indicates levelised cost estimates for nuclear projects commissioning in 2020, 2025, 2030 with a 10% discount rate for FOAK and nth of a kind ("NOAK").

Table 4.2
*Levelised Cost Estimates for Nuclear Projects (£/MWh)**

Commissioning year	**2020**	**2025**	**2030**
Nuclear FOAK / NOAK – High	108	106	94
Nuclear FOAK / NOAK – Central	93	90	80
Nuclear FOAK / NOAK – Low	83	78	70

*10% discount rate, (highs and lows reflect high and low capital cost estimates). Source: 'Electricity Generation Costs', DECC, July 2013.

4.11 Figure 4.1 shows a comparison of the cost of nuclear power with other generation technologies where projects have a commissioning date in 2025, using data provided in DECC's July 2013 Electricity Generation Costs publication. The graph shows that nuclear is expected to remain a cost competitive form of generation. This is particularly clear when nuclear costs are compared against other low carbon technologies, which will need to be deployed if the UK is to meet its legally binding 2050 carbon reduction targets.[48]

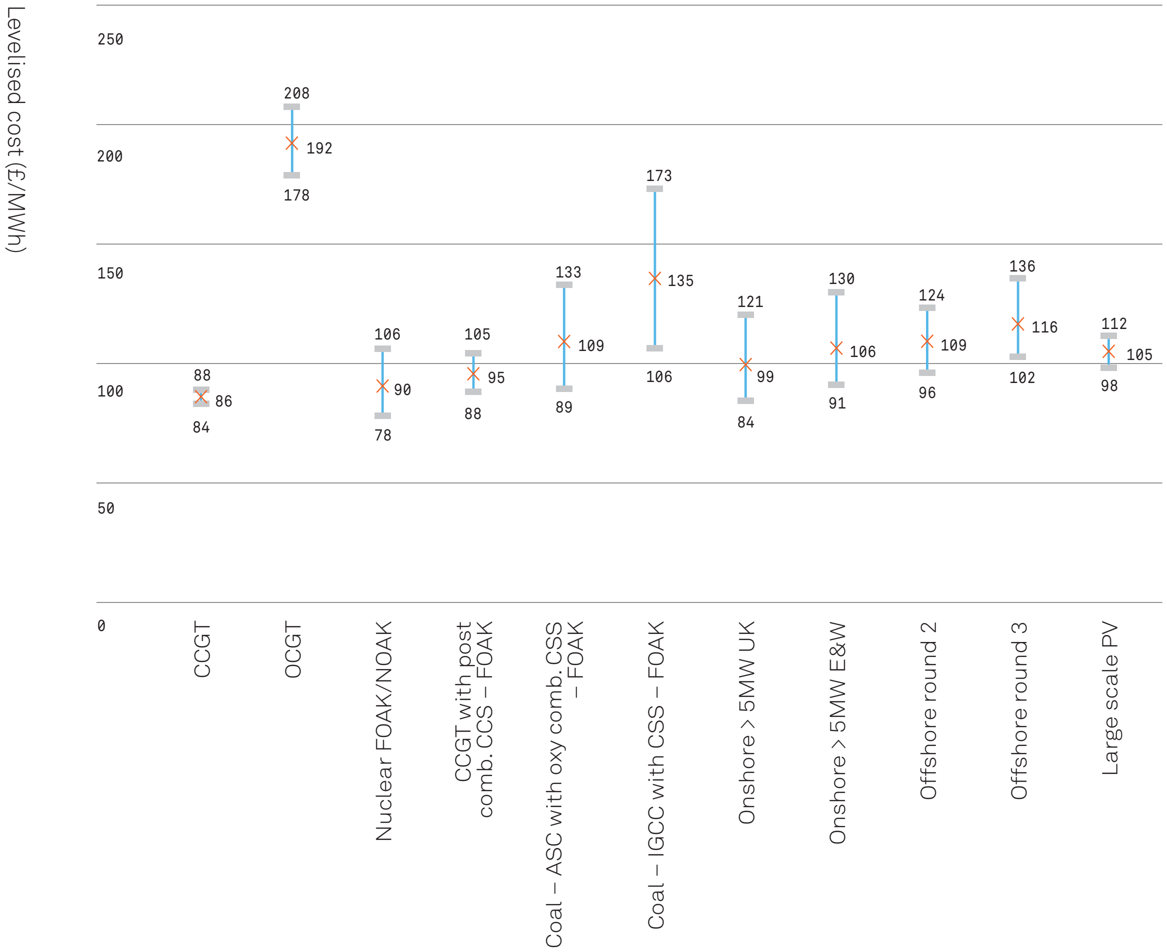

Figure 4.1 Levelised costs of projects commissioning in 2025, high, central and low forecasts. Source, DECC Electricity Generation Costs July 2013, table 6.

4.12 The levelised costs of nuclear generation are broadly comparable with other forms of generation: the range of costs provided in the Parsons Brinckerhoff studies is no greater for nuclear than most other technologies.

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[48] The Climate Change Act 2008 introduced carbon budgets, which place a legally binding restriction on the total amount of greenhouse gases the UK can emit over a 5-year period, and which are designed to help the UK meet its carbon reduction targets.

Electricity Market Reform

Policy background

4.13 The Electricity Market Reform ("EMR") programme is intended to incentivise investment in secure, low-carbon electricity generation, while improving affordability for consumers. The electricity sector is a critical part of the UK economy and is an important driver of growth. EMR is the Government's response to the challenges facing the electricity sector:

- The need for a fifth of 2011 capacity to close over the next ten years;
- The need to transform our generation mix to respond to the challenge of climate change and meet our legally-binding carbon and renewable targets; and
- The expectation that electricity demand will continue to increase over the coming decades.[49]

4.14 This amounts to a significant investment challenge, with an estimated investment of up to £110 billion needed in the sector over the next 10 years. This investment in turn has the potential to support up to 250,000 jobs in low carbon electricity to 2020.[50]

4.15 Minimising costs to consumers is a key aim for the EMR package. EMR will work with the market and encourage competition, minimising costs to consumers to deliver the investment we need. As a result of these reforms, household electricity bills are estimated to be, on average, around 9% – or £63 per annum – lower over the period 2016 to 2030 compared to decarbonising to a level of 100gCO_2/kWh through existing policy instruments. The impact on average bills for businesses and electricity intensive industries will be similar.[51]

The Government's Solution

4.16 The Government has confirmed that one of the mechanisms to incentivise this investment will be long-term contracts with eligible electricity generators by providing increased certainty of long-term revenue for investors. These long-term contracts, also known as Feed-in Tariffs with Contracts for Difference ("FiT CFDs", or simply "CFDs"), are intended to increase the rate of investment and lower the cost of capital in relation to new relevant energy infrastructure development, thereby reducing costs to electricity consumers (compared with a "do nothing" scenario). The Energy Act 2013 provides a statutory basis for CFDs.[52]

4.17 Impact Assessment No DECC0144[53] summarises that Government intervention in the electricity market through CFDs is required because:

> *"Reducing emissions from the power sector will become increasingly important to help us meet wider decarbonisation goals. There are several reasons to believe that the current market arrangements will not deliver power sector decarbonisation at lowest cost to the electricity consumer. Contracts for Difference (CFDs) lead to a more efficient allocation of risk among investors, consumers and Government than under existing policies, thereby resulting in decarbonisation at lower cost to the electricity consumer."*

4.18 The Government's proposal is for CFDs to be available for many low carbon technologies (including nuclear new build). At least in relation to early new build nuclear projects, it is anticipated that these CFDs will be negotiated bilaterally (whereas other technologies will initially be allocated CFDs at pre-set strike prices and on largely pre-set terms).

4.19 The Government has confirmed that it intends for a Government-administered counter-party (with statutory functions and duties) to enter into (and where relevant negotiate) CFDs with

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[49] See paragraphs 3 and 4 of "Electricity Market Reform: Consultation on Proposals for Implementation" published in October 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/253385/emr_cons_implementation_proposals.pdf.

[50] See paragraph 5 of "Electricity Market Reform: Consultation on Proposals for Implementation" published in October 2013.

[51] See paragraph 8 of "Electricity Market Reform: Consultation on Proposals for Implementation" published in October 2013.

[52] Energy Act 2013 available at: http://www.legislation.gov.uk/ukpga/2013/32/contents/enacted.

[53] t.

developers of potential new nuclear projects. In negotiating any CFD, nuclear project developers will share costs data with the Government. It is expected that the Government will scrutinise and analyse such data as part of negotiating a "strike price" with a new nuclear developer.

4.20 After a CFD has been agreed, when power is generated and (irrespective of the price of power actually captured by the generator), under the CFD:

- If the "average reference market price" is less than the negotiated strike price, the generator will receive an additional payment of the difference between the strike price and the higher of zero and the average reference market price (a "Difference Payment"); or

- If the average reference market price is more than the strike price, the operator will return the difference between the strike price and the average reference market price.

The following figure illustrates the operation of a CFD (at least where the reference market price is positive). This is taken from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65634/7090-electricity-market-reform-policy-overview-.pdf.

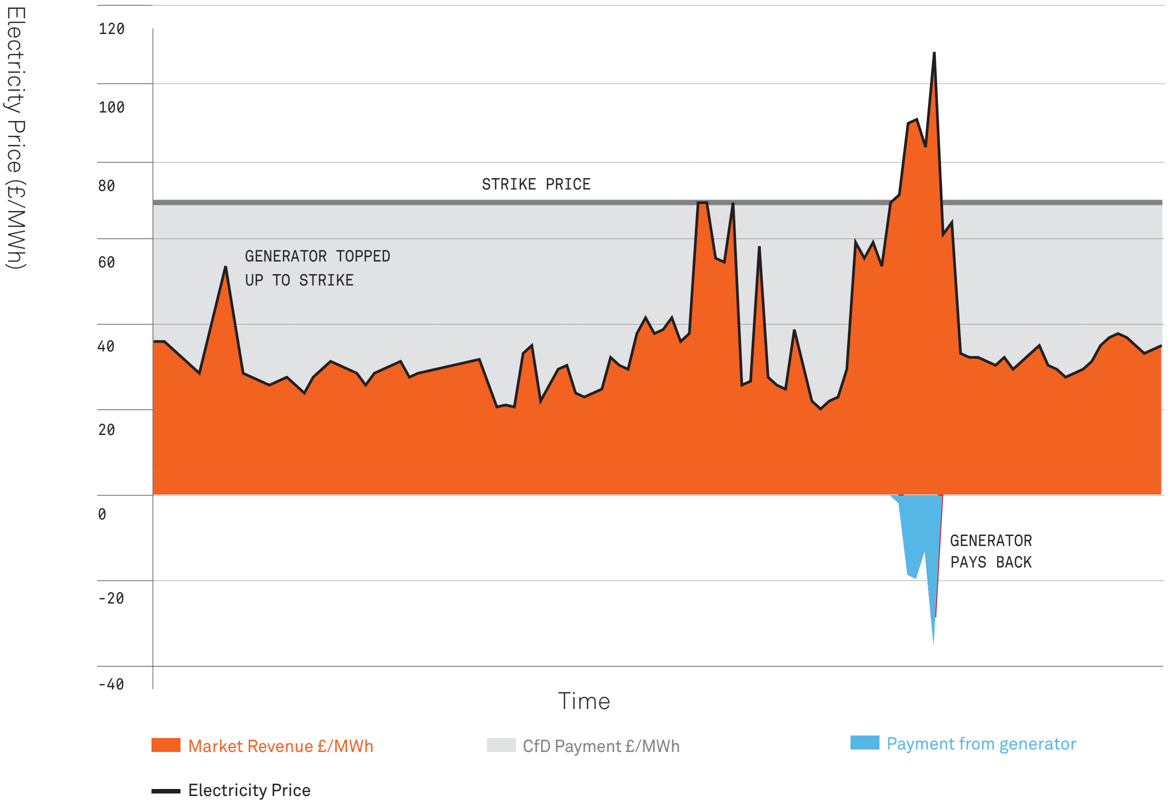

Figure 4.2 Illustration of the operation of a Contract for Difference where the reference market price is positive.

The counter-party will administer the scheme on a portfolio basis across low carbon generation capacity in the UK subject to the CFD regime, and it is intended that the cost of Difference Payments will be met from payments made by generators and through retail electricity pricing (via a compulsory levy on electricity suppliers).

4.21 This mechanism increases certainty and consistency in relation to the net price that a project operator (and its investors and funders) will receive for the electricity generated by the project, thereby increasing confidence around the ability to recoup upfront investment in the project.

4.22 The Government will thus determine whether proposed projects should be allowed to proceed. It would be reasonable to assume that the Government would not enter into a CFD for a project if Government considered it likely to represent, given the available alternatives, an economic detriment to the UK.

4.23 The framework for EMR and CFD is not finalised and may change before such time as it could apply to a specific project to develop a UK ABWR, in which case, the relevance of the EMR and

CFD framework would be limited. However, whilst Government may choose to bring forward an alternative (or additional) mechanism to encourage investment in low carbon generating technology, in all cases it is reasonable to expect Government to exercise its judgment on whether individual projects demonstrate an acceptable cost to the electricity consumer.

Levelised Costs are not Strike Prices

4.24 DECC explained in its paper on electricity generation costs[54] how levelised cost estimates differ from CFD strike prices. DECC explained that levelised cost estimates do not provide an indication of potential future strike prices for a particular technology or plant under the CFDs that are being introduced as part of EMR.

4.25 Generation costs data is one input into setting strike prices. Other inputs may include:

- Revenue assumptions;
- Other costs not included in DECC's definition of levelised cost;
- CFD contract terms, including length and risk allocation;
- Financing costs (reflected in the levelised costs calculated at technology-specific hurdle rates but not in those calculated at a 10% discount rate); and
- Wider policy considerations.

4.26 Where project-specific cost discovery processes are undertaken, as is expected for early nuclear projects, generation costs data used as part of the strike price setting process will be different from cost data used to calculate levelised costs. The strike price process will reflect a site-specific, highly granular assessment of costs, whereas the levelised cost estimates are more high-level and generic. Therefore, as asserted earlier, it is reasonable to expect Government to exercise its judgment on whether an individual project demonstrates an acceptable cost to the electricity consumer.

Other UK Government Measures

4.27 It is possible that other actions by Government could be relevant to the decision to bring a project forward that utilises the Proposed Practice. For example, if a suitable extension were to be made to the UK Guarantee Scheme for Infrastructure Projects, it is highly likely that a project based on the Proposed Practice would apply to be a beneficiary of such scheme. In considering whether to allow a project to be a beneficiary of such a scheme, it would again be reasonable to assume that Government would not allow a project to benefit if, in light of the alternatives, it concluded that the project represented an economic detriment to the UK.[55]

Economic Impacts of Accidents

4.28 If a severe nuclear accident occurred in the UK then there could be an economic detriment to the UK economy. Annex 5 provides a short overview of previous severe accidents involving commercial nuclear power plants around the world.

4.29 The radiological and non-radiological health effects of a severe accident (such as anxiety), are outlined in Chapter 5 and Annex 5. Chapter 5 explains UK regulatory expectations and Annex 5 explains how these expectations are secured and overseen. Major economic impacts could also result from a nuclear accident, including damage to the economy and financial damage to the operator of the reactor.

4.30 Past experience has prompted the development of strong regulatory and corporate governance arrangements which are focused on the overriding priority of nuclear safety, which works to prevent accidents such that the likelihood of them occurring is very low. These arrangements are described in Annex 5 of this application.

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[54] DECC Electricity Generation Costs, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223940/DECC_Electricity_Generation_Costs_for_publication_-_24_07_13.pdf.

[55] For example, Government's latest announcement regarding the National Infrastructure Plan on 4th December 2013 includes nuclear new build at Wylfa in the list of potentially relevant projects: see https://www.gov.uk/government/news/new-infrastructure-plan-published-by-government.

4.31 The UK is a contracting party to the 1960 Paris Convention on Nuclear Third Party Liability and the Brussels Supplementary Convention. Operators in the UK bear a strict and exclusive liability to compensate victims of certain nuclear incidents under the Nuclear Installations Act 1965, which implements these Conventions.

4.32 Operators are required by section 19 of the Nuclear Installations Act 1965 to carry mandatory insurance for these liabilities approved by the Secretary of State and HM Treasury. The effect of this regime will to ensure that victims of a major nuclear accident will be guaranteed compensation, effectively mitigating any potential economic detriment.

4.33 Operator liability for radiological property damage and personal injury is currently capped at £140m per incident [56]. However, the Government has confirmed its intention to substantially increase this figure in line with the 2004 Protocol to Amend the Paris and Brussels Conventions, and is planning to lay the necessary legislation to amend the Nuclear Installations Act 1965 before Parliament in the near future (although it would only enter into force upon other signatory states taking the same steps). The Government's plan is to eventually increase operator liability to €1,200m per incident. This level will be phased in over five years and will start at €700m. The €1,200m limit is €500m more than the minimum limit required under the Protocols to amend the Paris and Brussels Conventions[57].

4.34 For liabilities in excess of the current cap on operator liability, the Brussels Supplementary Convention provides that the operator's home country and the contracting states are to top-up operators' funds to a total of 300m Special Drawing Rights ("SDR" [58]) per incident (currently equivalent to about £285m[59]). As host state for the installation, the UK must make available in public funds the difference between the operator liability of £140m and SDR 175m (£166m[60]). Between SDR 175m (£166m) and SDR 300m (£285m), the compensation is drawn from public funds made available by the contracting states collectively, following a formula established by Article 12 of the Brussels Supplementary Convention. These amounts would be significantly increased if the Amendments to the Brussels Supplementary Convention were ratified[61].

4.35 This nuclear liability channelling regime accordingly provides protection for the UK Government and for victims of the most types of nuclear incidents. The risk of a very severe accident of the type which could result in liabilities in excess of these amounts in the UK is very low as further explained in Chapters 5 and 8.

4.36 It is concluded that, as the likelihood of severe nuclear accidents in the UK is very low, the corresponding risk of severe detriment to the UK economy is also very low.

Socio-economic Benefits

4.37 In addition to the major security of supply and carbon reduction benefits described in Chapters 2 and 3 of this Application, there would also, as with other major infrastructure projects, be significant socio-economic benefits to the local economy resulting from a new nuclear power plant. Depending on operational and contracting practices, a two-unit nuclear power plant would directly employ around 800 workers. Such long-term, high quality and stable employment would be especially valuable in the remote communities that host nuclear power plants. During outages, an additional workforce, expected to consist of around 800 people, would contribute to the local economy. In addition, local businesses and services would benefit, both in terms of providing services to the plant and from the wider economic effect.

[56] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42743/1182-cons-implement-changes-paris-brussels.pdf.

[57] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42743/1182-cons-implement-changes-paris-brussels.pdf.

[58] A unit of account used in the Conventions and defined by the International Monetary Fund, based upon the sum of the values of a basket of key international currencies (the U.S. Dollar, Euro, Japanese Yen, and Pound Sterling).

[59] 1 SDR is the equivalent of approximately GBP£0.95 (US$1.53, as at 22.11.2013, http://www.imf.org/external/np/fin/data/rms_sdrv.aspx).

[60] i.e. the equivalent of about £166m (as at 22.11.2013), therefore the difference to be topped-up by the Government would be about £26m.

[61] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42743/1182-cons-implement-changes-paris-brussels.pdf.

4.38 The construction of a new nuclear power plant would bring major benefits to the UK construction and manufacturing industry. In addition to nuclear-specific engineering and construction work on site, there would also be conventional engineering and construction activities associated with the overall development of any new nuclear site and construction of ancillary infrastructure. Our December 2012 report entitled "Capability of the UK Nuclear New Build Supply Chain"[62] showed that a new-build programme of 16GWe of reactor capacity would increase the UK civil nuclear industry by 66,500 jobs during the peak of the new build period, a figure which would level at 47,000 jobs during the operational period. An Institute for Public Policy Research ("IPPR") report in 2012 estimated that a 16GW new nuclear build programme could boost GDP by up to 0.34 per cent per year for 15 years[63].

Conclusion

4.39 Based on the Government's own analysis, adoption of the Proposed Practice is highly likely to be beneficial for the UK economy when security of supply and carbon reduction benefits are taken into account.

4.40 The risks of significant detriment to the UK economy from the Proposed Practice are very low.

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[62] The report is available at: http://www.niauk.org/uk-capability.

[63] 'Benefits from Infrastructure Investment: A Case Study in Nuclear Energy', an IPPR Trading Limited Report for EDF Energy, June 2012: http://www.edfenergy.com/media-centre/press-news/infrastructure-investment-nuclear_June2012.pdf.

FIVE

RADIOLOGICAL HEALTH DETRIMENTS

POTENTIAL RADIOLOGICAL HEALTH DETRIMENTS

Potential Radiological Health Detriments

Any overall radiological health detriment from deploying the Proposed Practice would be very small. New UK nuclear power stations of the class proposed, and its associated processes, would be capable of meeting all applicable dose limits and constraints; indeed the mature regulatory processes governing this Proposed Practice would lead to radiation doses being well below these levels.

Following optimisation the maximum level of additional dose to any member of the UK public per year would be around the same as the additional dose incurred in a return flight from the UK to New York, or through spending a week in Cornwall instead of somewhere with the UK average level of natural background radioactivity. Ahead of optimisation it is clear maximum doses to the public will certainly be less than 0.3mSv per year, the UK constraint relevant to new facilities: this is taken as a bounding value for the purposes of justification of individual dose to any member of the public from introduction of the Proposed Practice. Doses to the UK population generally will be so low as to be of no health significance.

Workers employed as a result of the Proposed Practice would receive doses comparable with, or lower than those received currently by those employed in the nuclear power industry. Ahead of optimisation it is anticipated that average worker doses will be less than 10mSv per year: this is taken as a bounding value for the average level of dose to any worker in the UK assessed to arise from the Proposed Practice.

The Proposed Practice would meet the UK's stringent requirements to reduce both the likelihood and consequences of accidents and so would result in extremely low additional levels of risk, even to those closest to the site(s).

These conclusions are based on a comprehensive examination of all the areas that could give rise to the potential for radiation doses to workers and members of the public or to accident risks. Although some of these activities would take place outside the UK, all have been considered here to ensure completeness.

In its 2008 White Paper, the Government shared this conclusion noting that *"...the Government continues to believe that new nuclear power stations would pose very small risks to safety, security, health and proliferation."*

This conclusion has been reached by comparing anticipated maximum doses with dose limits and constraints. Here dose is assumed to be a measure of health detriment; the validity of this assumption and the scientific basis for dose limits are considered below. Doses anticipated from this Proposed Practice are also compared with those from natural background radiation and other common activities that might lead to an increased exposure from natural radiation and with those from medical exposure. Finally, to give another indication of the significance of the health detriments being considered here, the doses are equated to a risk of death from induced cancer.

Introduction

5.1 This Chapter outlines the potential radiological health detriment to members of the public and workers from the deployment of the Proposed Practice.

5.2 The high level approach in this Application provides a comprehensive examination of potential radiological health detriment. This chapter presents substantial evidence from analysis of the Proposed Practice, and the other processes required to support the development of nuclear power plants using UK ABWR technology as part of the wider UK nuclear new build programme, that the UK's regulatory radiological dose limits and constraints[64] for workers and the public can be met, and that the required minimum standards for preventing and mitigating potential accidents will be delivered.

5.3 It is also clear that all sources of public radiation exposure that would stem from the Proposed Practice could meet the UK's dose constraint for new facilities. There is also evidence available

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[64] The Ionising Radiations Regulations 1999 Statutory Instrument No. 3232.

from existing nuclear power stations and from other related activities that would be required to support the Proposed Practice to illustrate the impact of UK and international safety and environmental regulation on reducing radiological health detriment below these dose limits and constraints.

5.4 Radiological protection follows principles laid down internationally[65]; these principles are incorporated into the EU Basic Safety Standards Directive which forms a legal obligation in the UK and Europe. Justification is the first of these principles and is, in effect, the first assessment hurdle a practice involving the use of radioactive materials must overcome. Even if a practice is *justified* it may only be implemented when the way it is carried out has also been *optimised* – the second principle underpinning radiological protection.

5.5 *Optimisation* refers to the requirement, within the hierarchy of radiological protection principles, for radiation doses from a practice that is *justified* to be reduced to a level as low as is reasonably achievable ("ALARA") taking account of economic and societal factors. Optimisation involves striking a balance between the efforts (time, cost etc.) required to reduce doses, against the dose reduction these efforts can deliver. In the UK, optimisation is implemented as a requirement within the legal processes through which a design is licensed and permitted. It is these licensing and permitting processes that have the greatest impact in determining what level of radiological health detriment is ultimately permitted. These essential regulatory processes will follow Justification if new nuclear power stations using UK ABWR technology are deployed in the UK and apply to all stages of the life cycle of a station from design, construction, commissioning through to operation, decommissioning and final waste disposal. The application of optimisation means that, in practice, radiological doses from the nuclear industry are very significantly below legal limits.

5.6 It is important to understand that this Application does not address or prejudge the results of optimisation. Instead it presents sufficient evidence to demonstrate that the first hurdle, Justification, is met. To be justified it is sufficient to show that there are Net Benefits of the practice that outweigh any potential radiological health detriment; it is not necessary to demonstrate that the practice has been optimised. If the Net Benefits of a practice are very significant (as this Application shows in Chapters 2 and 3), the first radiological protection principle, justification, can be met by demonstrating that the radiological detriments are by comparison small – for example, by demonstrating that the practice can be carried out within all the relevant dose limits or constraints[66] (since these have been set at levels of health risk that are relatively small). This means it is not necessary to rely on precise estimates of what radiological effects will derive from applying the regulatory processes relevant to optimisation that have yet to be undertaken. Nevertheless, evidence is provided (from similar existing activities) to show that these limits and constraints can not only be met, but can be met by a large margin, and that this would apply equally to the Proposed Practice.

5.7 This chapter summarises the overall scale of the potential radiological health detriment, having first identified and described all potentially significant sources of radiological health detriment associated with the processes required to support the Proposed Practice. An analysis of the potential effects of radiation in general on human health is briefly summarised in the boxes below. In addition, attention is drawn to the more detailed analysis of the effects of radiation on human health contained in Annex 4 to this Application.

Commentary on Our 2008 Application

5.8 This Application follows the same approach as our 2008 Application, but where relevant presents updated data as well as data relevant to the UK ABWR. Although the design differences between the UK ABWR and the already justified AP1000® and EPR™ reactors will lead to differences in safety cases and operational regimes, the UK's mature regulatory processes ensure that radiation doses will be within dose limits and constraints for all activities required to undertake these practices. Supporting activities such as enrichment, fuel fabrication and transport already take place in the UK: utilisation of these supporting activities by the UK ABWR would be expected to result in similar radiation exposures for both the public and for workers.

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[65] Recommendations of the ICRP. ICRP103 December 2007 – this is the latest in a series of publications which has again reaffirmed the principles to be applied in radiological protection.

[66] NB We do NOT seek to argue that the practice is justified simply because it can meet dose limits or constraints; rather that by complying with these, even for those small numbers of people who could be most affected, we can be confident that the radiological health detriment will fall within a level that is small compared to the substantial benefits we demonstrate.

For other activities that would be specific to the UK ABWR such as generation of electricity, this chapter explains how optimisation is expected to result in similar levels of exposure to other already justified practices.

5.9 No material changes have been identified in updating information on potential radiological health detriment.

Dose Measurements
Dose Limits and Constraints

5.10 The UK in common with other countries has not defined a regulatory limit or constraint for the public in terms of collective dose or average individual dose. Instead, consistent with the ICRP recommendations which are embodied in European and UK law, these limits and constraints are framed in relation to the individual who could be most exposed, in the knowledge that this will provide a very high level of protection to all.

5.11 Through a Direction[67], issued by the Secretary of State for the Environment, Transport and the Regions in May 2000 under a provision of the Environment Act 1995, the Environment Agency is tasked with specific requirements in relation to the implementation of the Euratom Basic Safety Standards Directive within England and Wales. An equivalent Direction has been issued by the Scottish Ministers to the Scottish Environment Protection Agency ("SEPA")[68]. These requirements are now included in Schedule 23, Part 4, Section 1(1) of The Environmental Permitting (England and Wales) Regulations 2010[69] ("EPR 2010"); which replaced and repealed the Radioactive Substances Act 1993 in England and Wales. These Directions and Regulations impose a requirement on the Environment Agency and SEPA to:

> *"Have regard to the following maximum doses to individuals which may result from a defined source, for use at the planning stage in radiation protection -*
> [A] *0.3 millisieverts per year from any source from which radioactive discharges are first made on or after 13th May 2000; or*
> [B] *0.5 millisieverts per year from the discharges from any single site."*

On 1 April 2013, Natural Resources Wales ("NRW") took over the functions of the Environment Agency in Wales as well as some functions of the Welsh Government and other bodies in Wales.[70]

5.12 The single source constraint specified above of 0.3mSv per year for facilities established after May 2000 has been adopted in this Application as a useful parameter to describe the maximum individual public dose (and health detriment) from new facilities developed in the UK as part of the Proposed Practice. The Office for Nuclear Regulation ("ONR")[71] states in its Safety Assessment Principles[72] that its view is that a single source should be interpreted as a site under a single dutyholder's control, in that it is an entity for which radiation protection can be optimised as a whole. A public dose of 0.3 mSv/y is therefore a bounding value for the purposes of justification of individual dose to any member of the public from introduction of the Proposed Practice.

5.13 The ONR's Basic Safety Level[72a] for the average annual individual dose to people who work with radiation on a licensed site, which is set at 10mSv, has been adopted, for the purposes of this application, as the maximum average annual dose to workers from the Proposed Practice. This is taken as a bounding value for the average level of dose to any worker assessed to arise from the Proposed Practice.

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[67] The Radioactive Substances (Basic Safety Standards) (England & Wales) Direction 2000.

[68] The Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000.

[69] The Environmental Permitting (England and Wales) Regulations 2010, Statutory Instrument 2010 No. 675.

[70] The National Resources Body for Wales (Functions Order) 2013.

[71] The Office for Nuclear Regulation ("ONR") was formed on 1 April 2011, as an Agency of the Health and Safety Executive ("HSE"), assuming the role formerly served by the Nuclear Installations Inspectorate ("NII"). The Energy Bill 2012-13 includes provisions which, if passed into law, will create the ONR as a statutory corporation independent of the HSE, to regulate the civil nuclear industry.

[72] Safety Assessment Principles for Nuclear Facilities, paragraph 590. HSE 2006.

[72a] Safety Assessment Principles for Nuclear Facilities. HSE 2006 (see paragraph 585 Target 2).

5.14 These limits and constraints afford a high level of protection to workers and the public. This is confirmed in this application through the evidence presented on the level of individual doses that result from existing practices that meet these UK limits or constraints.

5.15 The approach in this chapter is to explain the relevant UK regulatory requirements for each potential source, and to show that any relevant UK radiation dose limit (or where appropriate dose constraint) can be met (see Box 1 below for an explanation of the relevant dose limits). As explained above, we consider that this step should be sufficient to enable the justification principle to be addressed. However, in addition and so as not to mislead those reading this Application, evidence is also presented of the scale of reduction to any radiological impact that is likely to occur as a result of applying the optimisation principle. This is done by drawing on the results of the application of UK and international regulation to similar practices of which there is already actual experience – e.g. reactor operation, transport of fuel etc.

Box 1
How well established are the dose limits for exposure to radiation?

The relationship between exposure to radiation and health detriment has been studied for more than 60 years and is kept under review by international bodies. On the basis of these and other reviews, recommendations for radiological protection are made by the ICRP and various national bodies. This Box summarises the position at the time of this application, which has not materially changed since our 2008 Application.

The health risks associated with exposure to radioactive materials are, in general, better understood than those relating to the chemical and biological toxicity of many everyday materials. While, as in all scientific fields, there remains room for refining theories and for reducing the remaining levels of uncertainty, the level of understanding is certainly sufficient to support conclusions relating to the justification of a new practice.

The advice on dose limits from the ICRP, originally promulgated in their 1990 recommendations (ICRP 60) and which has been embodied in UK regulations, can be summarised as:

Dose Limit for:	**Workers**	**Public**
Effective Dose per person	20 mSv per year (mSv/y) averaged over defined periods of five years, and not greater than 50mSv in any one year	1 mSv per year

The Committee on the Biological Effects of Ionizing Radiations ("BEIR") of the US National Research Council issued its Seventh Report ("BEIR VII") in 2006, and the United Nations Scientific Committee on the Effects of Atomic Radiation ("UNSCEAR") has published a series of reports. These reports examine the latest scientific evidence on adverse health effects. In 2007, the ICRP approved its latest set of Recommendations* for radiological protection, which will form the basic framework of radiological protection for several years to come.

These ICRP Recommendations have been formulated on the basis of the BEIR VII and UNSCEAR reports, together with ICRP's own evaluation of the scientific evidence. It is of note that the ICRP has not recommended any change to the currently advised system of radiation protection or to the system of dose limits used as part of protecting the public and people at work in its most recent report.

* Recommendations of the ICRP. ICRP103 December 2007

Approach to Evaluation of Radiological Health Detriment
Assessment of Detriments from Normal Operation

5.16 For the public, the assessment here focuses on the potential *individual* radiation doses that could arise from the Proposed Practice for those aspects that would routinely take place (e.g. normal operation of the power station). Evidence is provided below from existing nuclear stations that have been justified and subjected to UK regulation to show indicatively what level of individual dose results from this approach. Data on experience overseas is also provided to give evidence on an even larger population of reactors. These values are therefore indicative of the doses that could result from the Proposed Practice. This supports the argument that nuclear stations using the UK ABWR design would result in maximum "representative person" (or critical group[73]) doses well within the 0.3mSv/y constraint, and doses to people other than the representative person would be very much lower. On the basis that UK regulation is framed so as to reduce potential radiological health impacts to the public to a low level and that regulatory constraints can be easily met, this therefore substantiates the argument that any radiological health detriment from the Proposed Practice will be very small.

5.17 For workers, the average individual doses are generally described since this gives a good feel for the level of potential health detriment to an individual person employed on that activity over a period of time. It is less helpful to quote maximum worker doses, as these can vary considerably over the life of a facility according to the tasks being performed and the approach chosen. Maximum doses are nevertheless always kept within the legal dose limit and generally by a large margin. Information on the range of individual doses experienced in the UK nuclear industry is available in the Health Protection Agency's (now Public Health England) report entitled "Ionising Radiation Exposure for the UK Populations: 2005 Review"[74].

5.18 In contrast, the figures quoted for doses to members of the public are generally those to a "representative person"– that is those members of the public who could be the most exposed (see Box 2 below).

Box 2
How do we work out what the radiological health detriments might be?

The science of how radiation and radioactive materials may affect human health has been studied over a long period and has for some years been reviewed regularly by international and national scientific bodies. These bodies maintain their scientific independence from Governments and from commercial interests. Recommendations on the approach to be taken to protect people are made by the International Commission on Radiological Protection ("ICRP") and these are considered by a range of national bodies. This Application is based on the authoritative advice from these bodies.

Over the many years that the subject has been studied, it has become established that exposure of people to radiation can be usefully expressed in terms of the radiation dose they receive. The dose can be derived from things that can be measured using a prescribed methodology that has been refined over the years. Radiation dose may then be used to calculate the potential health effects of any exposure to radiation using risk factors which, again, are recommended by bodies such as the ICRP and endorsed by national authorities.

The potential routes by which people could be exposed to radiation and hence receive a radiation dose are:

- External radiation dose (shine) from certain types of radioactive materials, which (if not completely shielded) could affect people in close proximity;
- Internal radiation dose from radioactive materials that, once released, are in a form that means they could be inhaled or could enter the food chain and therefore be eaten or drunk.

In order to calculate potential doses to members of the public the concept of critical groups is applied. Based on surveys of the habits of people living in the vicinity of a nuclear site and who could be affected by it, assumptions can be made, for example, about where they live, what they eat, how much time they spend in various locations. These can then be used to define a set of characteristics for a hypothetical group of people whose habits would result →

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[73] As explained in Box 2, the ICRP's 2007 Recommendations note that the person most at risk of radiation exposure from a particular practice for calculating potential doses is known as the "representative person". Previous iterations of the ICRP Recommendations called this person a member of the "critical group". We have used the newer term in this application for the sake of consistency.

[74] "Ionising Radiation Exposure of the UK Population: 2005 Review", Health Protection Agency (now Public Health England), HPA-RPD-001, May 2005.

in them being the most exposed to any radioactive discharges from the site. The hypothetical group of people following these habits is termed the "critical group". This approach originates from the ICRP and is one that has been adopted over several decades as part of the approach to radiation protection. In its most recent (2007) guidance, ICRP has continued to support this approach but has advised that the term "representative person" should be used in place of "critical group" to avoid any potential misunderstanding arising from the terminology. Although some dose assessments referenced in this application pre-date the 2007 ICRP Recommendations, and so originally used the term "critical group", we have adopted the newer term throughout the application for consistency.

Designers of nuclear facilities take significant steps to prevent radioactive materials being released into the environment except under tightly controlled arrangements and then only for very small quantities. There have been many years' experience in making these measures more and more effective. This has resulted in a position where the potential releases of particular radioactive materials from particular types of facility are now well understood.

In addition, nuclear facilities both in the UK and worldwide have been subject to very extensive programmes of monitoring resulting in a large body of information on how much radioactivity has been released into the environment and how it has subsequently behaved. These programmes have provided an important input to examining evidence of possible health effects linked to radiation around nuclear sites (see Annex 4).

There are two basic approaches to deriving figures for the additional radiation exposure caused by a nuclear site:

- The first is to use the measurements taken around the site to calculate doses to people; and
- The second is to measure the amount of radioactive material discharged (either in gaseous or liquid form) and to use computer models to calculate what radiation dose this could cause.

Both approaches have their advantages and disadvantages. In the first, it is not possible to separate the dose from radioactivity due to the site from other sources of radioactivity. It can also be extremely difficult to measure accurately the level of radioactivity in the environment when the discharges are very small. The second approach is dependent on the calculational models which tend to err on the side of over-estimating possible doses given the uncertainties involved. However this method is able to show the link between the estimate of dose and a particular discharge from a particular source. Putting all this knowledge together, leads to a very robust and widely accepted process for deriving the scale of potential radiological health detriment for the type of nuclear facility covered in this application.

Assessment of Detriments from Potential Accidents

5.19 For potential accidents, the approach is to examine the possible additional risks from the Proposed Practice taking into account the likelihood of accidents and their potential radiological consequences. Again, for members of the public, the figures stated are for those who could potentially be most at risk (the "representative person").

Use of Collective Dose

5.20 This application does not attempt to quantify the *collective* radiation dose for all potential sources of exposure associated with the Proposed Practice. The concept of collective dose is described in Box 3.

Box 3

Collective Dose

The "collective dose" for a particular group of people from a particular source of radiation means the sum of all the individual doses that each person receives as a result of exposure to that source. It is a useful way of examining the safety implications of something where a number of different people may be exposed to radiation at a range of different levels.
The unit of collective dose is the "man-sievert". As an example: if a team of 3 people are each exposed to a dose of 1 millisievert (mSv) in carrying out a task, the total collective dose for

that task is 3 man-millisieverts or (3 man-mSv).

Although it can be a useful tool in optimising the level of radiological protection – e.g. assessment of the collective dose can help determine the best way to carry out a planned task – the mis-application of this concept can lead to some confusion.

Take for example the question "What is the collective dose from cosmic radiation?" The problem in answering this question is in deciding just how many people to include, and over what time period to calculate their individual doses from this source with the answers reached varying widely according to what is decided.

In this example the number of people chosen could be (say)

- The UK population (63 million); or
- The world population (7 billion); or
- The world population over future generations.

Similarly the timespan over which their doses are calculated could be chosen as (say)

- 1 year; or
- A typical human lifetime; or
- The lifetime of the human race on the Earth.

In this example it might be of interest to know what the annual collective dose from cosmic radiation is to the UK population in one year. The answer is:

Number of people in UK x the average annual individual dose
= 63,000,000 x 0.3 millisievert
= 18,900 man-sievert

When this is compared with the collective dose to the people working on a single unit nuclear station (between around 0.5 and 1.5 man-sievert per year) the cosmic radiation figure above looks very large. However, this is because it is shared between a much larger number of people and the average individual doses are actually quite comparable. So in this case it makes more sense to compare the average individual doses than the collective doses. More generally, it is important to use collective dose figures very carefully; to understand what assumptions they have been based on; and to ask what they equate to in terms of an average individual radiation dose.

Because this application indicates very low levels of representative person dose from all relevant sources and also provides figures for average individual doses, numerical estimates of collective doses to the public are not generally provided.

5.21 Collective dose can be a useful parameter where optimisation of radiological protection is being undertaken, especially in situations where there are judgments to be made about alternative approaches which could result in different numbers of people receiving relatively significant doses. However since this application concerns justification, it focuses on individual doses to those that could be most affected, and in all cases shows that these would be small. Some indication of the very low level of additional individual dose to an "average" member of the UK public is provided to confirm that these doses are so low as to be of no concern in terms of potential health detriment. These figures are derived from a calculation[75] of collective dose to a defined population using a methodology recommended by the Health Protection Agency (now Public Health England).

5.22 This approach is in line with the latest Recommendations of ICRP[76] which provide the following guidance on the use of collective dose (or more precisely collective effective dose) in relation to the derivation of potential health detriment:

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[75] EA, SEPA, Northern Ireland Environment Agency, FSA. Principles for the Assessment of Prospective Public Doses arising from Authorised Discharges of Radioactive Waste to the Environment, Radioactive Substances Regulation under the Radioactive Substances Act (RSA-93) or under the Environmental Permitting Regulations (EPR-10). August 2012.

[76] Recommendations of the ICRP. ICRP Publication 103. December 2007. Executive Summary, paragraph (k).

> *"The collective effective dose quantity is an instrument for optimisation, for comparing radiological technologies and protection procedures, predominantly in the context of occupational exposure. Collective effective dose is not intended as a tool for epidemiological risk assessment, and it is inappropriate to use it in risk projections. The aggregation of very low individual doses over extended time periods is inappropriate, and in particular, the calculation of the number of cancer deaths based on collective effective doses from trivial individual doses should be avoided."*

5.23 It should be noted that because very few people are located in the vicinity of the releases, and share the habits that are used in the assessment of doses to a "representative person", the adoption of this approach is conservative.

5.24 Those factors that are relatively more significant to the health detriment are treated at greater length than those whose contribution is so small as not to affect the overall balance between health detriments and net benefits.

5.25 The next section considers the following sources of potential radiological health detriment to the public and workers under the following headings:

- Uranium mining and extraction;
- Uranium conversion, enrichment and nuclear fuel element manufacture;
- Normal nuclear power station operation – radiological impact for the public;
- Normal nuclear power station operation – radiological impact for workers;
- Transport of radioactive materials – radiological impact on public and workers;
- Potential transport accidents – impact on public and workers;
- Potential reactor accidents – radiological impact for public and workers;
- Decommissioning – routine doses to workers; and
- Decommissioning impact of discharges and accidents on workers and the public.

Review of Level of Radiological Health Detriment

5.26 Radiation dose has been used for many years to quantify the health significance of exposure to sources of radiation – whether natural or man-made. Internationally accepted methods have been used to estimate doses to humans from the different types of radiation exposure associated with the activities listed above. The same approaches can be used to assess the doses that result from a range of everyday activities involving exposure to radioactivity (see Boxes 4 and 5 below).

Box 4

What is the level of radiation exposure (dose) to people in the UK?

The UK's safety and environmental regulatory controls are focused on ensuring that any routine exposures of the public to radioactive materials are at such a low level that the potential additional radiation dose arising from them will also be small.

The UK regulatory regime also requires that the probability of accidental releases of radioactivity from all causes is reduced to a very low level and that, notwithstanding this requirement, there are systems and procedures to mitigate any possible releases that could occur. The effectiveness of this approach in limiting the scale of any potential radiological health detriment is shown in the examples of regulated practices referred to in this Application.

The Table below shows how much radiation we receive from sources affecting the UK population. These show that the dose received from all man-made sources is less than the variability in naturally occurring background radiation across the UK.

Average annual doses to UK population from all sources of radiation*

Source	Dose (mSv)
All natural sources (average)	2.2
Made up on average from:	
Natural gamma radiation	0.35
Natural cosmic radiation	0.33
Naturally radioactive materials internal to our bodies	0.25
Naturally occurring radioactive radon gas (with a range, depending on location)	1.3 (1 to 6)
Medical exposure to radiation (X-rays etc.)	0.41
Occupational exposure	0.006
Fallout from earlier nuclear weapons testing	0.006
Products containing radioactivity	0.0001
Discharges from nuclear industry	0.0009

Examples of additional levels of radiation exposure from specific activities

Source Dose	Dose (mSv)
Scheduled return airline flight from UK to New York	0.1 per trip
1 week holiday in Cornwall	0.15 per week
1 CT scan of the abdomen	10 per scan
Working for a year as a flight attendant in an airline	2 per year

* The figures on these tables come from HPA-RPD-001 or from “Living with Radiation” (1998) published by the NRPB (subsumed into the Health Protection Agency and now Public Health England)

Box 5
Risks

It is possible to convert assessed doses into risks using risk factors. The internationally recommended (ICRP) risk factor for total health detriment for all ages is 5.7% per Sv of which around 95% (i.e. 5.5% per Sv) is due to the risk of contracting cancer. The remaining risk arises from hereditary effects. The corresponding risk of inducing a cancer that would prove fatal is about 5%, although this value will be dependent on underlying health and medical care. The total health detriment ICRP risk factor has been adopted in the Table below to derive the theoretical risks of health detriment associated with the individual doses presented in the Application. Applying this factor, the risks for members of the public are those set out below:

Source of Additional Exposure	**Additional Dose**	**Theoretical risk of health detriment per year**	
Public		Scientific	Colloquial
Public dose	Dose limit = 1mSv per year	5.7 x 10^{-5}	Around 1 in 17,500
Bounding value for purposes of justification for individual dose to any member of the public from introduction of the Proposed Practice	Less than 0.3mSv per year	Around 1.7 x 10^{-5}	Less than 1 in 58,500
Evidence on the maximum level of dose to any member of the UK public that currently arises from any of the activities that could be required as part of the Proposed Practice(indicates the impact of “optimisation”)	Less than 0.085mSv per year (uranium enrichment)	Less than 4.8 x 10^{-6}	Less than 1 in 206,000
Sizewell B representative person dose	0.021mSv per year	Around 1.2 x 10^{-7}	Around 1 in 830,000
Population dose			
Per caput dose to UK public from Sizewell B discharges (at full discharge authorisation limits)	Less than 3 x 10^{-6}mSv	Less than 1.7 x 10^{-10}	Less than 1 in 6,000,000,000
Per caput dose to UK public from all existing UK nuclear industry discharges	Around 0.0009mSv per year	Around 5.1 x 10^{-8}	Around 1 in 19,500,000
Some other sources of radiation dose			
Dose from one return flight a year to New York	Around 0.1mSv per year	Around 5.7 x 10^{-6}	Around 1 in 175,000
Dose to someone who spends 1 week a year in Cornwall (and comes from part of the UK with typical natural background level)	Around 0.15mSv per year	Around 8.6 x 10^{-6}	Around 1 in 117,000
Dose from one CT scan of abdomen per year	Around 10mSv per year	Around 5.7 x 10^{-4}	Around 1 in 1,750

Lower risk factors have been proposed for workers reflecting the different age profile and health compared with the general population; however, the same factor is used conservatively to calculate the risk for workers and the results are shown below:

Source of Additional Exposure	**Additional Dose**	**Theoretical risk of health detriment per year**	
Workers		Scientific	Colloquial
Workers dose	Dose constraint = 20mSv per year	Around 1.1 x 10^{-3}	Around 1 in 880
Bounding value for the average level of dose to any worker in the UK assessed to arise from the Proposed Practice	Less than 10mSv per year	Less than 5.7 x 10^{-4}	Less than 1 in 1,750
Maximum potential average individual worker dose identified in application	Less than 1mSv per year	5.7 x 10^{-5}	Less than 1 in 17,500
Other sources of radiation dose to workers			
Average annual dose to member of typical air crew	Around 2mSv per year	Around 1.1 x 10^{-4}	Around 1 in 8,800

It should be noted that:

- The risk factors used above are derived on the cautious assumption that there is a linear, no-threshold relationship between radiation dose and risk. As explained in Annex 4, this approach is adopted out of prudence for the purpose of managing exposure to radiation and is likely to err in the direction of caution and so overestimate risks from low level exposure to radiation.

- In their latest Recommendations, the ICRP specifically advise against using collective dose assessments (or the “trivial”, average per caput population dose figures that can be derived from them) as a tool for either risk projections, or for the calculation of health effects. These risks can be set in context with reference to the information provided by Public Health England (formerly the UK Health Protection Agency) (“PHE”) on its website[77]:

    - According to PHE, in the UK the chance of a person contracting some type of cancer during their life is between 20 and 25% (between a 1 in 5 and 1 in 4 chance).

    - PHE estimates that over a lifetime the exposure of an average person in the UK to radiation from all sources contributes about 1% to the overall lifetime cancer risk they have from all causes (i.e. the 20–25% figure above).

    - Natural background radiation accounts for the vast majority of the radiation exposure contributing to this 1% cancer risk. All non-medical, man-made sources of radiation only contribute about one hundredth part of this already small 1% risk contribution above.

    - PHE therefore concludes that, compared with other known cancer risk factors in the population such as cigarette smoking, excessive exposure to sunlight and poor diet, the risk to the population from all non-medical man-made radiation is very small indeed.

Assessment of Potential Radiological Health Detriment
Uranium Mining and Extraction

5.27 Although uranium was once mined in Cornwall (for its application in ceramics rather than for nuclear fuel), all mining and milling of uranium, or its extraction by in-situ leaching, for use in the nuclear industry now takes place outside the UK as part of existing, established practices. New UK nuclear power stations, including those deploying the Proposed Practice, would represent only a small additional source of demand for uranium above that arising from the

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[77] http://www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1195733811256?p=1158934607741.

international market. Potential additional radiological detriments from this part of the fuel cycle are therefore only considered briefly in this Application for completeness.

5.28 The United Nations Scientific Committee on the Effects of Atomic Radiation ("UNSCEAR") has derived estimates[78] of 0.025mSv/y - using a model mine and mill having the features of existing sites - for the average additional individual radiation dose to members of the public within a 100km radius of a mining site. UNSCEAR say considerable deviation is possible for specific sites largely influenced by the mining technique and quality of the management of tailings. UNSCEAR also reports[79] doses to those working in the uranium mining industry and shows that doses in recent times have been below the levels set by international bodies and have been falling.

5.29 Uranium mining was one of the topics referred to in the 2007 consultation on nuclear power. The subsequent White Paper concluded:

> *"We remain satisfied that stringent regulation here and overseas (where uranium is mined) provides adequate environmental safeguards to assess and mitigate the impacts."*

5.30 Any additional radiological health detriment arising from uranium mining and extraction in support of the UK's implementation of the Proposed Practice will thus be very small.

Uranium Conversion, Enrichment and Nuclear Fuel Element Manufacture

5.31 Extracted uranium is supplied as uranium oxide (U_3O_8) or "yellowcake", and has to be converted into other chemical forms for enrichment and incorporation into nuclear fuel. The uranium conversion, enrichment and nuclear fuel assembly manufacturing services needed by any new nuclear power stations could be sourced either from UK or from overseas suppliers. This Application considers the potential radiological health detriment of these activities on the assumption conversion, enrichment and manufacture take place in the UK.

5.32 The regulatory framework for nuclear fuel conversion, enrichment and manufacture is essentially the same as for the operation of a nuclear power station. A nuclear site licence is required by the Operator of any site carrying out this work, and this licence would contain conditions relevant to minimising potential radiological detriments from the site's activities. Any such site would also require a permit under EPR 2010[80] and an approval under the permit granted under section 2 of the Nuclear Installations Act 1965 for any disposal of radioactive substances from the site. The EPR 2010 permit would place a regulatory requirement for the minimisation of any discharges into the environment through the application of Best Available Techniques ("BAT")[81]. In addition, the Ionising Radiations Regulations (1999)[82] would require controls to be in place to limit the exposure of the public and workforce. In addition, enrichment activities require a permit under section 2 of the Nuclear Installations Act 1965 (as well as a nuclear site licence), and the disposal of any waste from enrichment activities undertaken pursuant to such a permit requires the Secretary of State's further approval under s.2(1).

5.33 Experience from recent nuclear fuel conversion, enrichment and fabrication in the UK has shown that this approach results in a very low level of radiological health impact from these processes, both for workers and members of the public. The latest publically available figures show the

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[78] UNSCEAR 2008 Report, Volume 1, Annex B, Paragraph 160 – 161.

[79] UNSCEAR 2008 Report, Volume 1, Annex B, Table 58.

[80] 'authorisation' remains the relevant term in Scotland and Northern Ireland although in this Application the terms authorisation and permitting should be read interchangeably.

[81] Environment Agency. Regulatory Guidance Series, No RSR 2, The regulation of radioactive substances activities on nuclear licensed sites. paragraph 63. This states: "Within the wider field of radiological protection, different regimes use different terminology and have their own guidance on this topic, eg reducing risks as low as reasonably practicable (ALARP) (ONR), use of best practicable means (BPM) and best practicable environment option (BPEO) (previously in the UK but now only in Scotland and Northern Ireland) and now best available techniques (BAT) in England and Wales. However, all of the above involve the same process, ie making a judgement between options by comparing benefits in terms of safety, environmental protection etc, and costs in terms of time, effort or money."

[82] The Ionising Radiations Regulations 1999 Statutory Instrument No. 3232.

average worker doses at the two sites involved in these processes in the UK was 0.7mSv[83] for conversion and manufacturing (in 2010 at the Springfields site near Preston) and 0.48mSv[84] for enrichment (in 2011 at the Capenhurst site near Chester). This is the result of the relatively low level of radioactivity present within unirradiated (new) nuclear fuel and the very small amounts of radioactivity that are released during uranium conversion, enrichment and fuel element manufacture.

5.34 The environments around UK nuclear sites are monitored closely for radioactivity. Results obtained over many years for the Springfields uranium conversion and fuel element manufacturing site confirm that doses to even the most exposed members of the public (the representative person) are very low. The most recent results quoted in the annual joint report by the Environment Agency ("EA"), Food Standards Agency ("FSA"), Northern Ireland Environment Agency ("NIEA"), and Scottish Environment Protection Agency ("SEPA")[85] estimated the highest representative person dose during 2012 to be 0.068mSv/y.

5.35 These numbers are derived from measurements of extremely small amounts of radioactivity; they overestimate the radiological detriment due purely to conversion and fuel manufacture because not all of the radioactivity measured in the environment around Springfields will have originated from the work done on that site. For example, radioactivity originating from historic atmospheric nuclear weapons testing, from the Chernobyl accident, and from past liquid discharges from the Sellafield site will have been included. Because these are representative person doses, it is also clear that doses to the majority of people living in the vicinity will be less than these figures.

5.36 The same report assesses the maximum representative person dose to members of the public in the vicinity of the Capenhurst site (which amongst other activities carries out uranium enrichment) as 0.085mSv/y in 2012. Again, this number overestimates the radiological detriment due purely to enrichment because it is based on measurements of all sources of radioactivity in the vicinity of the site, not just those arising from the enrichment process. As above, doses to the vast majority of people who do not share the habits and location of the representative person will be less.

5.37 Fuel enrichment and manufacturing processes required to support the Proposed Practice would be very similar to those already carried out at the sites referred to above. It is clear that doses to public and workers from these activities easily meet relevant limits and are within the relevant dose constraints for the public. The assessment above therefore provides a reasonable basis for assessing the broad scale of radiological health detriment that could arise from these processes were they to take place in the UK as part of the introduction of the Proposed Practice.

5.38 Thus the maximum potential radiological health detriment from these activities, if carried out in the UK in support of the implementation of the Proposed Practice would be small. The maximum individual annual dose to any member of the public would be within the 0.3mSv constraint. Worker doses would be well within the dose limit, and average annual doses less than the 10mSv figure adopted for the purposes of this application.

5.39 The additional average individual dose to the UK population from uranium conversion, enrichment and fuel manufacture has not been directly assessed.

5.40 However, given that these activities are ones that already take place in the UK and noting that the average individual dose to a member of the public in the UK from all nuclear industry activities is estimated as being only around 0.0009mSv/y (see Table in Box 5 that assesses risks) which is insignificant in comparison with the dose from natural background radiation, it is clear that the additional contribution would also be insignificant.

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[83] Springfield Fuels Limited – annual Environment Health & Safety Report 2010/11 http://www.nuclearsites.co.uk/resources/upload/Springfields%20Annual%20EHS%20Report%202010-11.pdf.

[84] Urenco Sustainability report 2012: http://www.urenco.com/page/335/Sustainability-Report-2012.aspx.

[85] Radioactivity in Food and the Environment, 2012. RIFE-18.

Normal Nuclear Power Station Operation – Radiological Impact for the Public

5.41 Nuclear power stations in England and Wales are permitted to dispose of radioactive substances under Schedule 23 of Environmental Permitting (England and Wales) Regulations 2010 ("EPR 2010"), which is enforced by the EA in England and Natural Resources Wales in Wales. In Scotland and Northern Ireland disposals of radioactive substances are still authorised under the Radioactive Substances Act 1993 ("RSA 1993") and are enforced by SEPA and NIEA respectively. These EPR 2010 Permits and RSA Authorisations permit/authorise limited discharges of low level fluid waste (liquids and gases) to the environment, volume reduction of combustible waste by incineration on site, and limited transfer of solid low level wastes ("LLW")[86] to other sites. It is the potential radiological detriment from these activities that is assessed in this section. As was explained earlier, the Direction issued in May 2000 to the Environment Agency and Schedule 23 of the EPR 2010 prescribe values for the dose constraint to be applied to a single site or to a new facility.

5.42 Other waste products containing higher levels of radioactivity (intermediate level waste) would be stored on the station (or at an alternative licensed facility) until final disposal in a stable solid form to an engineered waste repository (see Chapter 6).

5.43 Spent fuel would be stored on site until transported to another nuclear site for further interim storage, disposal or, possibly, reprocessing. The potential radiological health detriments of onsite or offsite storage are included here as part of normal station operation. The radiological detriments of spent fuel transport and disposal are covered later in this chapter. The reprocessing of spent fuel is not part of the Proposed Practice and is accordingly not addressed here. This approach aligns with the Government's position that their view[87]:

> *"Remains that in the absence of any proposals from industry, new nuclear power stations built in the UK should proceed on the basis that spent fuel will not be reprocessed."*

5.44 In addition to the requirement to remain below discharge limits specified in an EPR 2010 Permit (or equivalent authorisation in Scotland or Northern Ireland), the operator is currently required to use BAT (BPM / BPEO) to minimise the activity of radioactive waste produced on the site that will require disposal under the Environmental Permit (or Authorisation in Scotland and Northern Ireland). In doing this the operator needs to:

[A] Prevent the unnecessary creation of waste or discharges;
[B] Minimise waste generation; and
[C] Minimise the impact of discharges on people and the environment

on the basis that the operators use the techniques which represent BAT to achieve these objectives, as a whole.

5.45 For new nuclear power stations the regulatory pressure to use BAT (BPM/BPEO) should ensure that actual discharges are not only within the authorised limits but are reduced still further.

5.46 As explained, the UK environment agencies have been directed to assess any future proposal for a permit or an authorisation to discharge radioactivity against dose constraints set at levels below the national dose limits for members of the public. This approach is in line with that set down in the Euratom Basic Safety Standards Directive relating to implementation of the optimisation principle as part of overall radiological protection. The single site constraint protects members of the public from the cumulative effect of exposure to radioactivity from different facilities located on the same site.

5.47 Ahead of completing the optimisation stage, which will take place after justification as part of site specific UK licensing and permitting, it is not possible to present definitive figures for the UK ABWR against these constraints. However, the confidence in the capability of the UK ABWR to meet these constraints can be derived from the following.

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[86] The terms "low", "intermediate" and "high" level waste (LLW, ILW and HLW) are explained in Chapter 6 of this Application.

[87] A White Paper on Nuclear Power, Cm 7296, January 2008.

5.48 The performance of other modern reactor designs already assessed in the UK is relevant. The Environment Agency has recently issued an environmental permit[88] for the EPR™ to be built at Hinkley Point C for which the calculated doses at the permit levels were considerably less than the dose constraints. As part of the Generic Design Assessment ("GDA") process, the Environment Agency issued Decision Documents[89] for the EPR™ and AP1000® stating that the predicted doses for each reactor would be within the constraints. Before that, it had published its conclusions following the completion of stage 2 of the Generic Design Assessment process for each of the four reactor designs (EPR™, AP1000®, ESBWR, and ACR) then under consideration. These reports[90] included the statement that each of the designs is expected to be capable of meeting the 0.3mSv per year constraint. The Justification Decision documents[91] stated that the radiation dose which members of the public would receive from the normal operation of an EPR™ or AP1000® on an annual basis would be below detectable risk levels in the context of overall radiation exposure.

5.49 Annex 1 states that in Japan the doses to the public from reactor operation activities were below 0.02mSv/y. Dose modelling as part of the GDA process has been undertaken for the UK ABWR and this indicates the capability to meet the 0.3mSv/y dose constraint.

5.50 Like the EPR™ and AP1000® designs, the UK ABWR has been designed to ensure that the requirement to keep radiation doses to the public below dose constraints and the statutory annual limit of 1mSv/y can be achieved by a large margin. These designs build on the experience with other operating designs and incorporate features to ensure levels of safety and environmental protection that are at least as good as those provided today so that, following the optimisation stage of the radiological protection process, their impact can be expected to be similar to or even smaller than that of existing UK nuclear power stations.

5.51 The latest assessment of doses to the public at Sizewell has shown a maximum representative person dose of 0.021mSv most of which was due to direct radiation from Sizewell B. Another representative person (adult occupants over sediment) received a dose of 0.01mSv from liquid discharges. EdF Energy has also reported[92] doses (estimated using discharge modelling) to the most exposed member of the public from discharges from any of their stations which include Advanced Gas Cooled Reactors ("AGRs") of 0.006mSv.

5.52 Further indication of the low level of radiological impact of a modern light water reactor power station can be obtained from the estimates[93] published by the European Commission based on reported discharges of radioactivity from EU power stations for the period 2004 to 2008. Twenty-

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[88] Generic Design Assessment. UK EPRTM nuclear power plant design by AREVA NP SAS and Electricité de France SA. Decision Document. Environment Agency 2011.Generic Design Assessment . AP1000® nuclear power plant design by Westinghouse Electric Company LLC. Environment Agency 2011.

[89] Generic Design Assessment of new nuclear power plant designs. Statement of findings following preliminary assessment of the submission by: AREVA NP SAS and Electricité de France SA for their UK EPR design. Environment Agency March 2008.

Generic Design Assessment of new nuclear power plant designs. Statement of findings following preliminary assessment of the submission by: Westinghouse Electric Company LLC for their AP1000® design. Environment Agency March 2008.

Generic Design Assessment of new nuclear power plant designs. Statement of findings following preliminary assessment of the submission by: GE-Hitachi Nuclear Energy International LLC for their ESBWR design. Environment Agency March 2008.

Generic Design Assessment of new nuclear power plant designs. Statement of findings following preliminary assessment of the submission by: Atomic Energy of Canada Limited for their ACR-1000 design. Environment Agency March 2008.

[90] The Justification of Practices Involving Ionising Radiation Regulations 2004. The reasons for the Secretary of State's Decision as Justifying Authority on the Regulatory Justification of the Class or Type of Practice being: "The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in a light water cooled, light water moderated thermal reactor currently known as the EPR designed by AREVA NP.", DECC October 2010.

The Justification of Practices Involving Ionising Radiation Regulations 2004. The reasons for the Secretary of State's Decision as Justifying Authority on the Regulatory Justification of the Class or Type of Practice being: "The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in a light water cooled, light water moderated thermal reactor currently known as the AP1000® designed by Westinghouse Electric Company LLC." DECC October 2010.

[91] http://www.edfenergy.com/about-us/energy-generation/nuclear-generation/nuclear-safety-security/radiation-exposure.shtml#.

[92] Implied doses to the population of the EU arising from reported discharges from EU nuclear power stations and reprocessing sites inthe years 2004 to 2008, Radiation Protection 176, European Commission: http://ec.europa.eu/energy/nuclear/radiation_protection/doc/publication/176.pdf.

[93] http://www.edfenergy.com/about-us/energy-generation/nuclear-generation/nuclear-safety-security/radiation-exposure.shtml#.

five countries, which were EU Member States in 2004, were included in the study. Estimates of both individual and collective doses were made for each site and selected years 2004 and 2008.

5.53 For the discharges that were made in 2008, the dose to an individual 500m from the aerial discharge release point of Sizewell B was calculated to be 0.0025 mSv/y. The corresponding dose to an individual 5000m from the aerial discharge point was calculated to be substantially lower at 0.00012 mSv/y. The dose to the most exposed member of the public from liquid discharges from the Sizewell site (again in 2008) from the Sizewell site (including the then operating Sizewell A Magnox station) is calculated to be 0.0036 mSv/y.

5.54 The calculations of collective dose were truncated at 500 years. For the discharges from Sizewell B in 2008 the collective dose to the European population was calculated to be 0.47 manSv. In comparison, the annual collective dose to the EU population was estimated to be several hundred thousand manSv.

5.55 For perspective, the individual dose rate derived for an average UK citizen is nearly a million times smaller than the dose rate received from other naturally occurring sources of radiation. While Permit applications for any nuclear power station(s) built as part of the Proposed Practice have not yet been made, it is clear that, even if the discharges significantly exceeded those referred to above, the potential health detriment would remain very small.

5.56 The annual joint report[94] by the EA, FSA, NIEA and SEPA also provides estimates of the representative person doses to members of the public living near each of the UK's current nuclear power stations. These estimates are based on measurements of radioactivity in the environment and can overestimate the contribution from the power station itself where other sources are significant. The latest report quotes total representative person doses in the range 0.005mSv/y and 0.032mSv/y.

5.57 UNSCEAR reports[95] that annual reported public doses from reactor sites around the world are in the range 0.001 to 0.5mSv/y, with modern designs at the low end of this dose range.

5.58 The very low level of these radiological detriments is a direct result of the fact that only very small quantities of radioactive material are discharged during normal operation by designs of the type that would be accepted in the UK. The EA[96] has stated that:

> *"We expect any new power station designs to meet the highest environmental standards, and in our view there should be a requirement for new plant that Best Available Techniques (BAT) should be used to achieve this."*

5.59 This expectation is echoed in the Government's White Paper which states that regulation by the environment agencies:

> *"Will help ensure that radioactive wastes created and discharges from any new UK nuclear stations are minimised and do not exceed those of comparable power stations across the world".*

5.60 It is therefore reasonable to conclude that any new nuclear stations permitted or authorised in the UK as part of the Proposed Practice would result in additional radiation doses, to those most exposed, that would be less than the 0.3mSv/y constraint. It is also reasonable to conclude that average individual doses to the UK population as a whole would be at levels so small they would be insignificant in terms of any radiological health detriment.

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[94] Radioactivity in Food and the Environment, 2012. RIF E-18.

[95] UNSCEAR 2000, Annex C, http://www.unscear.org/unscear/en/publications.html.

[96] The Environment Agency's Submission to DTI - Pre-licensing assessments of new nuclear power stations and streamlining the regulatory process.

Normal Nuclear Power Station Operation – Radiological Impact for Workers

5.61 The UK's Ionising Radiations Regulations 1999 require employers to put arrangements in place to manage radiological protection of their workers so as to keep them as low as is reasonably practicable ("ALARP"). These regulations also impose a dose constraint of 20 mSv per year for routine exposures received by individuals as a result of their exposure to radiation at work (the limit being no more than 50mSv in any one year with the average over a 5 year period not exceeding 20mSv per year). These regulations would be applied to protect workers from all sources on-site including interim storage of fuel and waste at any new nuclear power station(s) involving the Proposed Practice.

5.62 The 2005 Health Protection Agency report[97] covering UK radiation exposure up to 2003 (the most recent available) gives the average annual radiation dose to power station workers across all operators as 0.18 mSv. To give some feel for the maximum doses, this report records 34 workers (out of more than 13,000) with individual doses in the band from 5 to 10 mSv/y, and no worker receiving a dose above this level. Thus the highest individual dose among nuclear power station workers during 2003 was less than one quarter of the maximum dose permitted in any one year (50mSv). It should be recognised that it is possible that, in some years, higher individual worker doses could be incurred than are illustrated by the 2003 UK figures. Nevertheless, the data for maximum individual doses to nuclear power station workers in the UK over a number of recent years[98] shows that the application of a legal requirement to reduce any exposures to a level as low as reasonably practicable combined with strict dose limits is effective in reducing the maximum individual doses and the number of workers involved.

5.63 UNSCEAR reports[99] that the average annual individual dose to workers in power stations worldwide had fallen to around 1.0 mSv/y by 2002 and since then there is evidence from the World Association of Nuclear Operators ("WANO") that doses have fallen further. The most recent report from WANO[100] shows the trend in collective radiation exposure per reactor unit for the period from 1990 to 2012 and this data is reproduced in Figures 5.1 and 5.2. Over this period the collective dose for each unit of Pressurised Water Reactor ("PWR") and for each unit of Boiling Water Reactor ("BWR") has been more than halved. Since the number of staff has not changed significantly across these stations, this translates to a significant reduction in average individual worker doses at PWR and BWR stations over this period.

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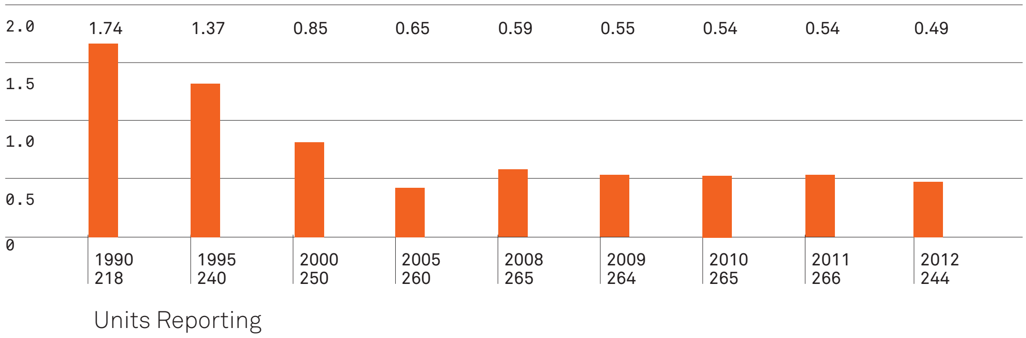
[97] "Ionising Radiation Exposure of the UK Population: 2005 Review" HPA-RPD-001 published by the Health Protection Agency.

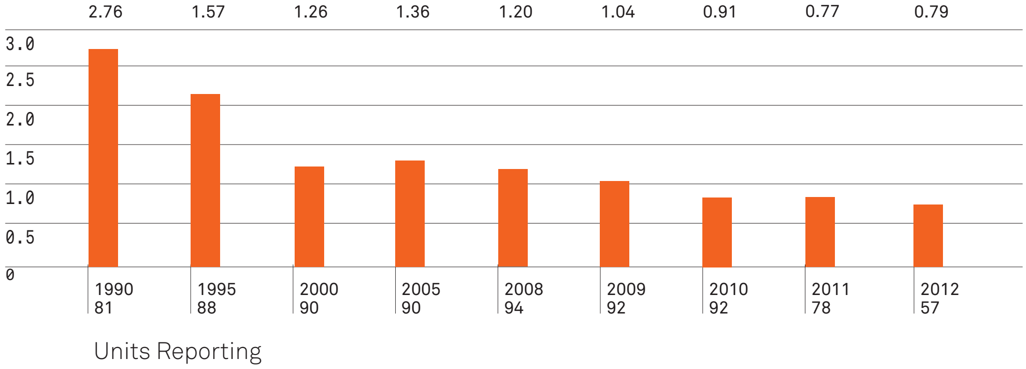
[98] See for example: Nuclear Safety Advisory Committee: Nuclear Industry Accident and Dose Data 2006–7 — October 2007.

[99] UNSCEAR 2008, Annex B [Table 66, p363].

[100] WANO Performance Indicators 2012. See http://www.wano.info/publications/performance-indicators/.



← Figure 5.1 Collective Radiation Exposure (PWRs). Man-Sieverts per unit

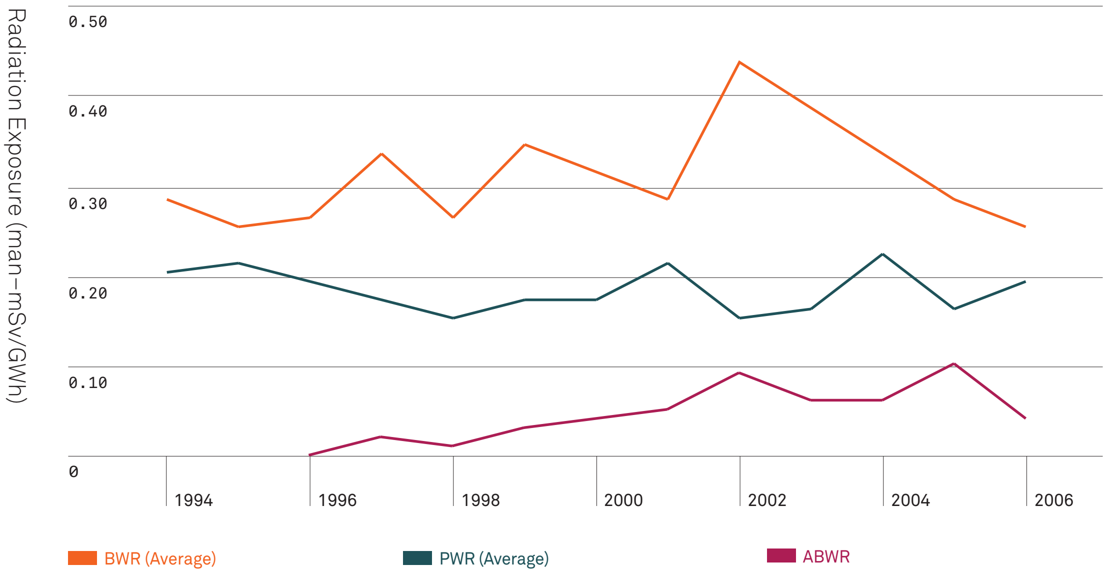


← Figure 5.2 Collective Radiation Exposure (BWRs). Man-Sieverts per unit

5.64 Generally doses from BWRs are higher than those from PWRs because of their direct steam cycle. However the ABWR incorporates design enhancements (see Annex 1 for further information on these enhancements) that result in dose uptakes comparable with modern PWRs. The OECD-NEA's Information System on Occupational Exposure ("ISOE") reports[101] the results of optimisation of worker radiological protection in nuclear power plants. The 21st annual report quotes collective doses for 2011 as follows:

All Pressurised Water Reactors (PWR)	0.65 man-Sv/unit
All Boiling Water Reactors (BWR)	1.18 man-Sv/unit
Sizewell B (the UK PWR)	0.536 man-Sv
Average for Japanese PWRs	0.96 man-Sv/unit
Average for Japanese BWRs	1.05 man-Sv/unit

5.65 This is further supported by Figure 5.3 which shows the radiation exposure trends for average PWRs and BWRs and for the ABWR in Japan.



← Figure 5.3 Radiation Exposure Trends for Nuclear Power Plants in Japan.

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[101] Occupational Exposures at Nuclear Power Plants, Twenty-first Annual Report of the ISOE Programme, 2011: http://www.isoe-network.net/index.php/publications-mainmenu-88/annual-reports.html.

5.66 In summary, the designs of nuclear power station that fall within the Proposed Practice would certainly be capable of meeting national radiation dose limits. There is additional evidence that average annual doses to staff would fall well below these levels as a result of the modern designs and application of the UK requirement for doses to be ALARP. The data presented above from WANO for currently operating BWRs is consistent with average annual doses to power station workers at least 10 times lower than the 20mSv/y dose constraint and therefore clearly well within the 10mSv/y figure adopted in this application.

Transport of Radioactive Materials – Radiological Impact on Public and Workers

5.67 Radioactive materials transport required as part of the deployment of new nuclear power station(s) would comprise:

- The transport of new fuel assemblies to the station(s);
- The transport of spent fuel from the station(s); and
- The transport of radioactive waste materials – either during normal operation or as part of the station's decommissioning.

5.68 All of these types of transport are already undertaken within the UK and have been justified on a generic basis. Transport of radioactive material linked to new nuclear power station(s) as part of the Proposed Practice would be subject to existing UK regulations that are framed so as to ensure that any possible radiological health detriment resulting from transport is low. While the packages used in transport associated with the Proposed Practice may differ in detail from those used currently, they will be required to meet the same standards and so provide the same level of protection.

5.69 The UK regulatory regime for transport is managed by the Radioactive Material Transport Programme of the Office for Nuclear Regulation ("ONR") and is based on the IAEA Regulations for the Safe Transport of Radioactive Materials[102]. The regime in Europe for the transport of dangerous goods is founded in the European Agreement concerning the International Carriage of Dangerous Goods by Road[103] and the Convention concerning International Carriage by Rail[104], and has been implemented in UK law by means of a statutory instrument[105]. These regimes follow principles for the minimisation of dose to the public and the workforce. In addition, Public Health England regularly reviews the radiological impacts from the transport of radioactive materials within the UK for the ONR.

5.70 A 2005 study[106] carried out by the HPA (now Public Health England) of the radiological impact of the normal transport of radioactive material in the UK showed that the largest potential dose to any member of the public was around 0.020mSv per year with this dose dominated by the contribution from the transport of radioactive materials used within the medical and health sector. Spent fuel from the UK's gas-cooled reactors has been routinely transported during the period covered by this HPA study, which estimated that around one thousand package movements of this type take place each year. Despite this, the contribution from transport of spent fuel to exposure of the public was assessed as extremely small at around 18 times lower than the contribution from medical transport.

5.71 More recently the World Nuclear Transport Institute ("WNTI") has re-published a study[107] of radiation doses from the transport of nuclear fuel cycle materials. A well as collating published

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[102] Regulations for the Safe Transport of Radioactive Materials. IAEA.

[103] European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) (2012 edition applicable from January 2013).

[104] Convention concerning International Carriage by Rail (COTIF). See Appendix C of the Convention, which contains the Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) (with effect from 1 January 2013).

[105] The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009, S.I. No. 1348.

[106] Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail NRPB W66.

[107] Radiation Dose Assessment for the Transport of Nuclear Fuel Cycle Materials: http://www.wnti.co.uk/media/31656/IP8_EN_MAR13_V2.pdf.

sources, the study also draws upon information from WNTI member companies. This reports maximum public doses from transport of spent fuel of less than:

- 0.004mSv via road transport;
- 0.006 mSv via rail; and
- 0.001 mSv via sea.

5.72 The level of radioactivity in new fuel and in solid radioactive waste is very much lower than in spent fuel so that the radiological impact from these types of transport would be even lower.

5.73 In proportion to the electricity generated, new nuclear power stations would use smaller quantities of fuel and produce smaller quantities of operational solid wastes than the current UK nuclear fleet comprising mainly gas-cooled reactors. This is a consequence of the smaller amount of fuel required per unit of electricity generated and the generally more compact dimensions of the newer and water cooled technologies. Over 60 years a single ABWR (with a power output of 1350MWe) would produce of the order of 1200m^3 LLW and 600m^3 of ILW in total (20m^3/y of LLW and 10m^3/y of ILW and irradiated items) based on arisings quoted in Annex 1. As an illustrative comparison, Bradwell (with a reference power output of 246MWe), had produced a total of 1500m^3 LLW and 1024m^3 ILW over its 41 year lifetime prior to final dismantling and site clearance[108]. The contribution to public radiological detriment from the Proposed Practice would therefore be at most comparable with the very low level reported in the HPA and WNTI studies.

5.74 The HPA study[109] also looked into the impact on the workforce associated with the movement of radioactive materials. It stated that:

> *"Estimated doses received during the transport of irradiated fuel flasks are low. Health Physics workers are likely to receive the highest doses from these operations, with an estimated 0.050mSv annually."*

5.75 The HPA study also established that the estimated worker dose from movement of irradiated fuel flasks was around 1/100th of the estimated worker dose from the movement of medical and industrial isotopes.

5.76 The WNTI study also reports maximum worker doses of from transport of spent fuel of:

- Less than 1mSv via road transport;
- 0.2 mSv via rail; and
- Less than 1mSv via sea.

5.77 The same stringent regulatory principles would be applied to the transport of radioactive materials associated with the Proposed Practice and therefore should be expected to meet these same high standards of protection for workers and the public. This view is the same as that reached by the Government following its consultation on new nuclear power stations[110]:

> *"Having reviewed the arguments and evidence put forward, and given the safety record for the transport of nuclear materials and the strict safety and security regulatory framework in place, the Government believes that the risks of transporting nuclear materials are very small and there is an effective regulatory framework in place that ensures that these risks are minimised and sensibly managed by industry."*

5.78 The Secretary of State, in his 2010 Justification Decision[111] relating to the EPR™, has also stated the following:

> *"The Secretary of State also considers that radioactive waste and spent fuel arising from any EPR™ built in the UK could be effectively managed to ensure that the potential risks or*

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[108] Radioactive Waste Inventory: Annual Report, Bradwell Site, 1st April 2012, M/WF/BRW/REP/0001/12, Issue 1, Aug 2012.

[109] Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail NRPB W66, page iv.

[110] A White Paper on Nuclear Power, Department of Business, Enterprise and Regulatory Reform, January 2008.

[111] The Justification of Practices Involving Ionising Radiation Regulations 2004 The reasons for the Secretary of State's Decision as Justifying Authority on the Regulatory Justification of the Class or Type of Practice being: "The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in a light water cooled, light water moderated thermal reactor currently known as the EPR designed by AREVA NP." October 2010.

> *detriments from its handling, storage, transport or disposal are within acceptable limits."*

5.79 Thus, the maximum potential radiological health detriment from the transport of radioactive materials carried out in support of the implementation of the Proposed Practice would be small, with the maximum individual annual dose to any member of the public being small (less than 0.020 mSv/y) and maximum worker doses (less than 1mSv/y) well below annual dose limits.

Potential Transport Accidents – Impact on Public and Workers

5.80 As explained above, the UK Regulatory Regime for transport is based on the IAEA Regulations for the Safe Transport of Radioactive Material[112] and European and UK legislation. Protection for the public and workers against the effects of accidents during transport is achieved by requiring:

> *"Containment of the radioactive contents; control of external radiation levels; prevention of criticality; and prevention of damage caused by heat."*

5.81 In addition, Public Health England, as part of its regular review of the transport of radioactive materials within the UK, publishes the radiological consequences resulting from any transport accidents in the UK.

5.82 A report[113] has been prepared covering the entirety of the data available in the national data base RAMTED from 1958 up to and including 2004 and annual updates[114] have been produced subsequently. These reports show that the most serious radiological consequences arising from accidents during transport have occurred as the result of improperly packaged radiography sources and that, as a result of better training, only two of these have occurred since the mid-1980s. Among the events whose radiological implications were considered worthy of study, there was only one that related to transport associated with nuclear power. This event involved a worker mistakenly placing a component from the lid of a road transport flask in his cab for several hours which resulted in a small additional dose to him. No power station-related transport events were identified that could have resulted in doses to a member of the public[115]. Incidents after 2005 comprise a small number (3) of accidents involving packages containing uranium ore concentrate, all of which were assessed as giving rise to a dose consequence of less than 1 mSv.

5.83 The transport packages with the greatest hazard potential under accident conditions would be those used to transport spent fuel from any new nuclear power station. However these packages would have to meet very stringent regulations that would make it extremely unlikely that any significant release of radioactivity could take place even under extreme accident conditions. For example, the IAEA specifies[116] that packages must be able to withstand a fully engulfing fire at 800°C for at least 30 minutes; be capable of withstanding a 9m drop (equivalent to a 250km per hour impact with a concrete block); survive at 200m depth in water for 1 hour; and at 15m depth for 8 hours without any rupture of the containment. There is a large body of evidence[117] to show that the current IAEA Type B[118] test requirements are sufficiently severe to cover all reasonably conceivable situations and cover all the situations which can be realistically envisaged in the

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[112] IAEA Specific Safety Requirements SSR-6: Regulations for the Safe Transport of Radioactive Material.

[113] Review of Events Involving the Transport of Radioactive Materials in the UK, from 1958 to 2004, and their Radiological Consequences. HPA-RPD-014.

[114] Radiological Consequences Resulting from Accidents and Incidents Involving the Transport of Radioactive Materials in the UK, HPA-RPD-021 (2005 Review), HPA-RPD-034 (2006 Review), HPA-RPD-048 (2007 Review), HPA-RPD-056 (2008 Review), HPA-CRCE-003 (2009 Review), HPA-CRCE-024 (2010 Review), HPA-CRCE—037 (2011 Review).

[115] Review of Events Involving the Transport of Radioactive Materials in the UK, from 1958 to 2004, and their Radiological Consequences – Table 8.

[116] Regulations for the Safe Transport of Radioactive Material – 2005 Edition, IAEA TS-R-1, 2005.

[117] Examples of references where these types of tests are described can be found at: http://www.patram.org/PATRAM_FP_07.pdf. See also: http://www.patram.org/PATRAM_FP_07.pdf.
http://www.tes.bam.de/de/umschliessungen/behaelter_radioaktive_stoffe/dokumente_veranstaltungen/patram_2010/Patram2010_Final%20Program.pdf.

[118] Type B tests are outlined in IAEA-TECDOC-295 (1983) and require that packages can be demonstrated to perform adequately in normal operation of transport, and withstand a range of challenges to represent accidents. The various tests are designed to confirm performance against water sprays, free drops, compression and penetration (normal operation), together with the demonstration of sufficient resilience against mechanical and thermal challenges, and water immersion (accidents).

transport of spent fuel, higher activity waste and other fuel cycle materials. This includes experimental evidence from the successful crash testing of IAEA packages in a range of situations. For example, the CEGB programme of testing culminating in the 1984 demonstration of a train impacting an irradiated fuel transport flask and the tests in the US conducted at Sandia National Laboratory with various "missiles" impacting on fuel flasks; etc.

5.84 With regard to the transport of un-irradiated fuel and solid waste materials, the hazard potential is much lower because these materials are much less radioactive. For a significant radiological health detriment to arise, members of the public would need to be exposed to any released materials over a prolonged period following any accident or for radioactive materials to be inhaled or ingested. Emergency arrangements that are required to be in place to respond to transport accidents would ensure these risks are reduced to very low levels.

5.85 In summary, radioactive materials transport operations associated with this Proposed Practice would be no different in nature to those from the existing UK nuclear programme, and the arrangements to ensure high levels of safety would be similar. The risks from transport accidents linked to new nuclear power stations, therefore remain low, and would have very little potential to impact on public health.

Potential Reactor Accidents – Radiological Impact for Public and Workers

5.86 It is a fundamental principle of UK nuclear safety regulation[119] that *"all reasonably practicable steps must be taken to prevent and mitigate nuclear or radiation accidents".* All licensed nuclear sites maintain and rehearse regularly their emergency arrangements which are provided to mitigate the consequences of an accident if it were ever to occur. These arrangements are a requirement of the Nuclear Site Licence and are subject to the Radiation (Emergency Preparedness and Public Information) Regulations 2001. Appropriate arrangements would have to be provided for any new facilities licensed as a result of the introduction of the Proposed Practice.

5.87 The UK approach to accident safety is enforced through the ONR as the independent nuclear safety regulator. The ONR has published its "Safety Assessment Principles" ("SAPs")[120] which provide guidance to its inspectors on the assessment of the safety of nuclear installations against this (and other) requirements that affect the potential radiological detriment from accidents to nuclear installations licensed in the UK. This application focuses on just one element of the ONR approach – the Basic Safety Levels ("BSL") and Basic Safety Objectives ("BSO") for accidents.

5.88 These two concepts are explained in the paragraphs below. The criteria relating to these levels and objectives provide a basis for assessing the potential scale of radiological detriment from accidents ahead of the completion of the licensing process for a particular design.

5.89 Through their Basic Safety Levels and Basic Safety Objectives, the ONR has set down two standards for determining whether the risk posed by accidents to the public is likely to be sufficiently low to be acceptable for a particular design of nuclear plant. This is just one of the tools used by ONR during the licensing process.

5.90 The ONR's Safety Assessment Principles state:

> *"It is [ONR's] policy that a new facility or activity should at least meet the BSLs."*

5.91 They go on to explain:

> *"The BSOs form benchmarks that reflect modern nuclear safety standards and expectations."*

5.92 Thus a Basic Safety Level sets the minimum standard likely to be acceptable, with the Basic

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[119] Safety Assessment Principles for Nuclear Facilities. Fundamental Principle 6 (FP.6), para. 42. HSE 2006.

[120] Safety Assessment Principles for Nuclear Facilities. HSE 2006.

Safety Objective representing the more challenging safety expectation that nuclear plant would achieve an acceptably low level of risk.

5.93 The SAPs set out target BSLs to limit the total predicted frequencies of accidents on an individual facility, grouped in "bands" according to the scale of radiation dose that could arise if the accident were to occur (see table 5.1 below). The requirement is to demonstrate that a design has achieved a predicted frequency of accidents in each of these "bands" which falls below these BSLs. Put simply, the designer must convince the ONR that the likelihood of accidents occurring across all levels of severity is acceptably low.

5.94 Recognising that severe accidents could affect large numbers of people if they were ever to occur, the ONR's Safety Assessment Principles set down additional Basic Safety Level and Basic Safety Objective criteria to limit their likelihood. These are framed in terms of the assessed probability per year of an accident that could give rise to 100 or more additional deaths in society as a whole. Such events must be shown to occur with no more likelihood than 1 chance in 100 thousand per year (at the Basic Safety Level) and the benchmark for modern designs (i.e. the Basic Safety Objective) is a likelihood of no more than 1 chance in 10 million per year of such a scale of accident. There are corresponding likelihoods for accidents leading to other numbers of deaths which are shown in the Table 5.1 below.

← Table 5.1 Summary of ONR BSLs and BSOs for Off-site Accidents.

Predicted off site dose, mSv (i.e. a measure of severity of accident)	**Predicted likelihood of accident occurring that could lead to this level of dose in any 1 year: (i.e. the maximum acceptable likelihood of accidents at this level of severity occurring)***	
	Basic Safety Level	Basic Safety Objective
0.1 – 1	1	1 chance in 100
1 – 10	1 chance in 10	1 chance in 1,000
10 – 100	1 chance in 100	1 chance in 10 thousand
100 – 1000	1 chance in 1,000	1 chance in 100 thousand
> 1000	1 chance in 10 thousand	1 chance in 1 million

*Adapted from ONR Safety Assessment Principles

5.95 In the most recent assessment of a modern reactor design against these Basic Safety Objectives, the ONR concluded in their assessment of the EPR™ reactor design under the GDA process[121] that the PSA (Probabilistic Safety Assessment) results presented by EDF and AREVA meet the BSOs presented in Table 5.1. This is an example of how ONR applies their expectations. We would expect other modern evolutionary type (Gen III/III+) reactors such as the UK ABWR to have a broadly similar risk profile.

5.96 The ONR has published an explanatory note on the numerical targets within its Safety Assessment Principles.[122] This explains that the additional risk of death from accidents to a person just outside the boundary of a plant which just met the BSL above would be "slightly above 1 x 10^{-5}/y" (which means one chance in one hundred thousand per year). Similarly the additional risk from a plant which just met the BSO would be "slightly above 1 x 10^{-7}/y" or one chance in ten million per year.

5.97 The Sizewell B power station was licensed against a previous version (1992) of the ONR Safety Assessment Principles and thus also provides another illustration of the effect of this approach on the level of radiological health detriment from potential accidents. In his report following the Sizewell B Public Inquiry (which heard a large amount of detailed evidence on this subject), the Inspector concluded that the maximum risk of death to any member of the public from accidents at the station would be around 4.2 x 10^{-8} per year. In more everyday language, this means a risk of about 1 chance in 25 million per year that someone living close to the station could be killed as the result of an accident. Statistically, this means that the additional annual risk of death to

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[121] Generic Design Assessment – New Civil Reactor Build, Step 4 Probabilistic Safety Analysis Assessment of the EDF and AREVA UK EPR™ Reactor, ONR, ONR-GDA-AR-11-019, Revision 0, 10 November 2011.

[122] Numerical Targets and Legal Limits in Safety Assessment Principles for Nuclear Facilities – an Explanatory Note. HSE December 2006.

those living closest to the power station is about the same as the average annual risk we all face of being killed by an aircraft falling on us. For people living further away, the risk is even lower. Whilst no one would claim that calculations like this provide a precise number for the frequency of such very unlikely events, the figure does give a reasonable indication of the very low level of risk posed. The same report concluded that the likelihood of accidents leading to 100 or more additional deaths in society was around 1 in 100 million per year – i.e. well within the BSO set down in the ONR's Safety Assessment Principles.

5.98 Modern evolutionary nuclear reactor designs such as ABWR have been developed to provide levels of safety comparable with or even higher than those described above. Thus the risk of additional radiological health detriments from accidents at plants falling within the Proposed Practice should be very small, with a maximum risk of death to any member of the public of around 1×10^{-5}/y and most probably very much less than this. This conclusion is in line with that reached by the Government following its 2008 consultation.[123]

Radiological Impacts of Severe Accidents and Consequences Worldwide

5.99 As in our 2008 Application, our view is that the risk of an accident involving the Proposed Practice in the UK resulting in significant detriments is low. This section identifies the principle reasons for this conclusion. Annex 5 sets out in more detail the reasons that this remains our view even in the light of the Fukushima accident.

5.100 A modern reactor design has many measures to ensure both workers and the public are protected. An Operator of the Proposed Practice will be supported by a series of highly robust design features that are described in more detail in Annex 1. Annex 5 explains that these features give a great deal of confidence that the essential safety functions of long term cooling and containment can be maintained even in the event of an extreme event or other accident. It should also be recognised that in the UK, all licensed nuclear sites maintain and rehearse their emergency arrangements which are provided to mitigate the consequences of an accident if it were ever to occur. Annex 5 also explains the robust regulatory regime and the safety culture that will be required of any UK Operator of the Proposed Practice to ensure that the risks of accidents are as low as reasonably practicable. Taking these factors into account, Annex 5 concludes that the risk of significant detriment following a severe accident from the deployment of the Proposed Practice is very low.

5.101 However, to ensure that this analysis is comprehensive, an overview of the radiological detriments that have resulted consequent to severe reactor accidents is provided in Annex 5 (which describes the Windscale, Three Mile Island, Chernobyl and Fukushima accidents).

5.102 This is a brief summary of the more detailed overview. Not all the accidents described in Annex 5 resulted in a large release of radioactivity to the environment, for example, the accident at Three Mile Island. High doses of radiation may be received by workers and emergency personnel in their efforts to return the nuclear power plant to a stable condition after the onset of an accident, as was seen at Chernobyl and most recently at Fukushima. Radioactive contamination may be distributed over a wide area including neighbouring countries however counter measures – such as sheltering, prohibition of certain food items or drinking water, and evacuation – should adequately manage the risk such that members of the the public do not receive doses that exceed those from the natural background.

5.103 In the UK there are substantial provisions that ensure a high level of nuclear safety is maintained including effective and independent regulation of any UK operator of the Proposed Practice. If an accident were to occur, its consequences would be mitigated. As a result the risk of detriment

is considered to be low. These provisions continue to evolve, and are subject to on-going review and improvements.

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[123] A White Paper on Nuclear Power, Cm 7296, January 2008.

Decommissioning – Routine Doses to Workers and the Public

5.104 The strategy for decommissioning any new nuclear power station(s) licensed in the UK would be examined by regulators at the site licensing stage – i.e. before the station was built. Regulators would need to be satisfied that the work is capable of being carried out in a way that would meet regulatory requirements. A detailed decommissioning plan has to be maintained throughout the life of the plant and at the end of a station's operational life, a final decommissioning plan, safety case, and environmental impact assessment would also have to be approved by regulators before decommissioning work on the site could begin.

5.105 Workers involved in the decommissioning of nuclear power stations, like those at operating stations, are protected by the requirement for operators to comply with nuclear site licence conditions and the Ionising Radiation Regulations 1999, which require employers to put suitable arrangements in place for the radiological protection of their workers. As with normal power station generation, these Regulations also limit individual worker exposure to no more than 100mSv over a 5 year period with a maximum of 50mSv in any single year. ONR's Basic Safety Level for the average annual individual dose for workers at 10mSv also applies. Evidence from stations currently undergoing decommissioning is that the doses achieved would be much below these levels.

5.106 The average annual collective dose per reactor to workers at reactors which are shut down or in some stage of decommissioning are reported[124] to have decreased from around 0.3manSv per year in 1992 to around 0.05manSv in 2009. Individual worker dose rates are not readily derived, but these figures show a 6-fold reduction in collective dose to workers worldwide at cold shutdown or decommissioning reactors between 1992 (with around 20 units reporting) and 2011 (with nearly 60 units reporting). For comparison, the same reference reports that the average annual collective dose for operating reactors has dropped from around 2manSv to 1manSv over the same period.

5.107 In several respects, the decommissioning of modern reactor plant is more straightforward than it is for the range of plant within the responsibility of the Nuclear Decommissioning Authority (NDA). Sellafield Ltd[125] report the average individual dose as 1 mSv/y. Workers involved in decommissioning UK ABWR plant would receive protection similar to that described above, for decommissioning activities at existing UK nuclear sites. As a result, their doses would be at a similarly low level. In the light of the evidence above, the average annual individual doses to workers should be well below the 10mSv/y figure adopted in this application.

5.108 As during the operating phase, there would be the potential for members of the public living near the station to receive very small additional exposure as a result of the discharge of very small quantities of radioactivity to the environment under permits granted by the relevant environmental agencies under the Environmental Permitting (England and Wales) Regulations 2010 ("EPR 2010") in England and Wales. As during normal operation the permits should ensure discharges are such that dose levels pose no threat to the public.

5.109 The additional average individual dose to the UK population from the decommissioning of new nuclear facilities (the EPR™, the AP1000® or the UK ABWR) has not been directly assessed. However, given that decommissioning activities are already taking place in the UK, and noting that the average individual dose to a member of the public in the UK from all nuclear industry activities is estimated to be only around 0.0009mSv/y (see Table in Box 4 earlier in this Chapter), it is clear that the contribution that decommissioning activities could make to radiation doses would not be significant.

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[124] Occupational Exposures at Nuclear Power Plants Twenty-first Annual Report of the ISOE Programme, 2011. http://www.isoe-network.net/index.php/publications-mainmenu-88/annual-reports.html.

[125] Sellafield Ltd Safety Performance Report: http://www.sellafieldsites.com/wp-content/uploads/2013/02/SEL_SafetyReport_med.pdf.

Decommissioning Impact of Discharges and Accidents on Workers and the Public

5.110 The purpose of decommissioning is to progressively reduce the radiological hazard on site and the Decommissioning Plan approved by the regulator should ensure this. Following final shutdown of the reactor, short-lived nuclides decay quickly reducing the inventory of radioactivity in the fuel and therefore the risks, and the decay heat in the fuel falls initially quickly and then more slowly. Eventually the decay heat will have fallen to a level when the fuel can be removed from the reactor and be placed in a spent fuel facility on site and then eventually removed from site. During decommissioning the inventory of radioactivity would also reduce as material was removed from site and sent for disposal.

5.111 In considering potential accident scenarios throughout the decommissioning process, the ONR would apply the same Safety Assessment Principles (SAPs) as those used for operating plant to ensure workers and the public are protected. In conclusion, the decommissioning of any new nuclear plants developed as part of the Proposed Practice would therefore pose a minimal risk of radiological health detriment, either through permitted discharges or through accidents which could result in radiological health impacts to workers or the public.

Spent Fuel Management and Radioactive Waste Disposal

5.112 The UK's classification of radioactive wastes is explained in Chapter 6. Most low level waste from reactor operation is currently disposed of routinely in the LLW Repository (the national facility near Drigg in Cumbria), whereas higher activity waste (see Chapter 6, paragraph 6.35) and spent fuel is currently in interim storage either at the stations or in licensed storage facilities pending a final deep geological disposal facility. Radioactive waste from the Proposed Practice would be expected to follow the same approaches.

5.113 Most low level waste would go to a national facility.

5.114 Following interim storage on the reactor site or another nuclear licensed site, higher activity wastes and spent fuel from any new nuclear power station(s) would use the same disposal routes as adopted for similar materials from existing nuclear installations. The Government endorsed this view in its White Paper on Nuclear Power[126].

5.115 Having reviewed the arguments and evidence put forward, the Government believes that it is technically possible to dispose of new higher-activity radioactive waste in a geological disposal facility and that this would be a viable solution and the right approach for managing waste from any new nuclear power stations. The Government considers that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities and that this should be explored through the Managing Radioactive Waste Safely programme[127]. Whilst this report did not assess the UK ABWR design, the waste and spent fuel from the Proposed Practice is expected to be very similar to the designs in our 2008 Application. More detailed information on UK ABWR waste will be available to DECC in the form of a UK ABWR disposability assessment which is expected to be complete during consideration of this application.

5.116 The Nirex report[128] that was published just ahead of the Managing Radioactive Waste Safely policy paper points out that, in order to fully assess the waste implications, further work is required which would be based on additional data on proposed reactor designs. The report also comments that, by considering details such as the presence and form of materials in the

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[126] A White Paper on Nuclear Power, Cm 7296, January 2008, Page 99.

[127] Policy paper: Managing radioactive waste safely: a framework for implementing geological disposal, DEFRA/DECC/WO/NIO, June 2008. p21. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/68927/7386.pdf.

[128] The Gate Process: Preliminary analysis of radioactive waste implications associated with new build reactors, Feb 2007, Number: 528386, Executive Summary.

waste and any special materials used in new designs, any implications of new build for the final repository design could be minimised. The repository would be designed[129] to incorporate features that ensure that the off-site dose would fall within the design targets. These are set for the public at 1% of the individual annual dose limits stated in the Ionising Radiations Regulations 1999 – i.e. doses to the public of less than 0.01mSv per annum. The design target for workers is less than 1mSv per annum (for those whose work involves some exposure) and less than 0.1mSv per annum for non-radiation workers.

5.117 Therefore, assuming the same facilities were used, any radiological health impact from interim storage and disposal of new build waste (together with spent fuel for which the decision has been made to manage by final disposal) from the Proposed Practice (whether or not as part of an overall nuclear new build programme involving other technologies such as the AP1000® and EPR™) would be a small increment to that which would arise from existing wastes, whether or not any new types of station are built.

5.118 Alternatively, if separate disposal facilities were constructed for the interim storage and disposal of higher level waste and spent fuel from any new nuclear station(s) and engineered to meet the same levels of radiological protection, the additional doses to workers and to members of the public would be at a very low level.

5.119 It is therefore concluded that the potential additional health detriment associated with radioactive waste interim storage and disposal arising from the implementation of the Proposed Practice will be small. The additional radiation dose to the members of the public potentially most exposed would certainly be less than 0.3mSv – indeed, as explained above, the design target for a UK waste repository is more than a factor of 10 lower than this. Under the design targets proposed by Nirex, average individual doses to those workers who could be exposed to radiation would be at least 10 times lower than the 10mSv/y figure adopted in this application.

Summary of Results

Overall Level of Potential Health Detriment to Workers and the Public

5.120 Table 5.2 summarises the assessments reported above. This shows that all relevant processes required as an integral part of the Proposed Practice could be undertaken within relevant UK dose limits and constraints, or within the accident Basic Safety Levels set out in assessment guidelines by the ONR. Maximum representative person doses to the public would all be below the 0.3mSv/y constraint for new nuclear facilities, with negligible additional radiation doses to other individuals within the UK and wider population. Maximum radiation doses to workers would certainly be below the annual dose limits with average worker doses at least a factor of 10 lower than this, and certainly below the 10mSv/y figure adopted in this application. These figures define an outer envelope for the level of radiological health detriment for the Proposed Practice.

5.121 The actual levels of radiological health detriment that would follow from the new practice would be determined by optimisation and would be below the bounding levels identified above as a consequence of the application of the requirements of the UK regulatory regime, which require doses to be reduced below limits and constraints to a level as low as is reasonably achievable, although the precise levels cannot be predicted at this early stage.

5.122 However, the evidence presented in this application of how these regulations have affected other, similar processes at existing nuclear sites is helpful in giving a broad indication of what optimisation will deliver.

5.123 The largest individual radiological health detriment quantified here for these existing activities is that for the average dose to workers involved in decommissioning facilities (which at 1 mSv/y is still below the basic safety level of 10 mSv/y).

5.124 For the public, the highest representative person dose identified (if relevant) arises from any UK located fuel manufacturing, conversion or enrichment facility (see below) on the conservative

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[129] NDA, Radioactive Waste Management Directorate, 'Radiological Protection Policy Manual' RWM02, Revision 1, September 2010.

assumption that it is the same as currently assessed for the UK sites at Springfields and Capenhurst. Even for these, the largest potential contributors, representative person doses to the public are shown to be considerably below the 0.3mSv/y level.

5.125 Table 5.2 summarises both the bounding value for a particular potential source of radiological exposure and the additional information provided in this Chapter on the impact that optimisation could have. For the purpose of Justification, it is not necessary or appropriate to prejudge what precise impact optimisation will have, but it would be misleading not to recognise the fact that it will certainly reduce doses and potential detriments further from the enveloping values quoted here. Finally, it should be noted that no member of the public is likely to be a member of more than one of the critical groups (or type of representative person) identified in Table 5.2, so it would not be correct to treat these maximum potential radiation doses from the various sources of exposure as additive. The UK's approach of using dose constraints would protect the public from excessive exposure as the result of several different facilities being located at the same site.

5.126 The risk of significant radiological health detriment from potential accidents has also been shown to be small. Conservatively assuming that any new facilities licensed in the UK as part of the Proposed Practice only just meet the ONR's Basic Safety Level, the additional risk of death to a person just outside the plant boundary could be at most "slightly more than 1 x 10^{-5} per year" – i.e. one chance in one hundred thousand. Although it is not possible at this early justification stage to quote more precise numbers, modern designs including the UK ABWR will be designed to achieve levels of accident safety well within the BSL so that the maximum risk will be lower than this "bounding" value. Evidence presented in this Chapter indicates a more realistic level of risk of death to an individual member of the public close to the site boundary from accidents at a single reactor would be around one chance in 25 million per year.

← Table 5.2 Comparison of Effects of Optimisation Against Dose Constraints

Potential Source of additional Radiological Health Detriment as a result of the Proposed Practice	Relevant dose constraint for activity (mSv/y)	Further relevant information provided in Application on possible effect of optimisation
Maximum Additional Doses to the UK Public		
Dose from uranium conversion and fuel manufacture	Less than 0.3	RIFE monitoring report shows representative person dose at Springfields is 0.068mSv/y
Dose from uranium enrichment	Less than 0.3	RIFE monitoring report shows representative person at Capenhurst is around 0.085mSv/y
Dose from normal operation of a modern evolutionary design water cooled reactor falling within the Proposed Practice	Less than 0.3	RIFE monitoring report shows representative person dose of 0.021mSv/y at Sizewell
Estimated max. dose to any member of public from transport of radioactive materials	No specified limit but protection provided by regulations limiting dose rates from transport packages	A figure of around 0.02mSv/y is estimated for irradiated fuel transport in an HPA report
Dose to public from radioactive waste disposal	Less than 0.3	The Nirex design target for a future repository is less than 0.01mSv/y

Average individual doses to workers (NB maximum doses always less than dose limit)

Fuel enrichment	Less than 10	Urenco report an average individual dose of 0.48mSv/y at Capenhurst
Uranium conversion and fuel manufacture	Less than 10	Springfields Fuels Limited report an average individual dose of 0.7mSv/y at Springfields
Nuclear power station workers in normal operation	Less than 10	The HPA estimate an average individual dose of 0.18mSv/y for UK stations
Workers in radioactive materials transport	Less than 10	The WNTI cite a maximum individual dose worldwide from irradiatedfuel transport of 1 m Sv/y
Decommissioning	Less than 10	Sellafield Ltd report the average individual dose at Sellafield site as 1mSv/y
Waste disposal repository	Less than 10	Nirex have proposed a design target of less than 1mSv/y for those exposed or less than 0.1mSv/y for others

5.127 As is also illustrated in Table 5.2, even with quite cautious assumptions, the radiological health impacts for workers as a result of the Proposed Practice would also be small and well below regulatory limits. In every case, the average annual worker doses identified are lower than the 10 mSv/y figure adopted in this application as a bounding level (and derived from the ONR's Safety Assessment Principles as the Basic Safety Level for assessing new installations). Actual average levels of exposure would be much below this figure, as a result of the modern designs within the Proposed Practice and the application of the optimisation principle. Worker doses would be lower than those already accepted by employees such as aircrews or health workers in non-nuclear industries.

5.128 Table 5.3 in the conclusion section below compares the assessed radiological health detriments with figures from some other activities currently undertaken within the UK.

Conclusion on the Level of Potential Radiological Health Detriment

5.129 The objective of this Chapter has been to provide a high level indicative assessment of the potential radiological health detriment that might be associated with the development of new nuclear power stations involving the Proposed Practice. The Chapter has also identified a maximum or bounding level of radiological health detriment for the Proposed Practice so as to enable the comparison with its benefits to be made with confidence.

5.130 For the Proposed Practice we are seeking to justify, we believe it is sufficient to state that maximum doses to individual members of the public from the practice will always be less than 0.3mSv/y, and those to workers will always be well within limits and, on average, less than 10mSv/y.

5.131 This high level assessment shows that the scale of potential health detriment from all potential activities associated with new nuclear stations is small, and there is no doubt that applicable regulatory dose limits and constraints could be met. This is the result of the mature status of the industry: modern nuclear power station design, and the efforts of both the national and international approaches to regulating this industry that have been refined over many years.

5.132 For those individual members of the general public who could be most affected, the maximum likely radiological dose from the deployment of the Proposed Practice is assessed to be of the same order as one additional return air flight from the UK to New York per year. Alternatively, the impact could be expressed as being about the same as the additional radiation dose that someone could receive by spending a week's holiday in Cornwall rather than remaining somewhere where natural background radiation is at the UK's average level. However, it would be wrong to suggest that for the purposes of demonstrating justification (as opposed to optimisation) it is necessary to rely on these very low figures. Doses to workers as a result of the Proposed Practice would be low. They would be comparable with, or lower than, those to which workers in the nuclear power industry (and other industries which entail radiation exposure, such as the airline industry) are currently exposed.

5.133 The design of every facility (new or existing) required to implement this Proposed Practice will have to meet stringent safety and security requirements. These requirements will ensure that UK ABWR reactors would have a low likelihood of accidents with risk levels demonstrated to be as low as reasonably practicable. The risk of significant radiological health detriment arising from accidents will thus be very small.

5.134 This Chapter provides an indication of the scale of potential radiological health detriment against which the potential benefits of electricity generation from new UK nuclear station(s) should be weighed and this is summarised in Figures 5.3 and 5.5.

Table 5.3 Summary of Bounding Health Detriments from Proposed Practice and Comparison with Other Common Radiation Exposures

Source of Additional Exposure	**Additional Dose**
Public	Dose limit = 1 mSv per year
Bounding value for the purposes of justification of individual dose to any member of the public from introduction of the Proposed Practice	Less than 0.3mSv per year
Evidence on the maximum level of dose to any member of the UK public that currently arises from any of the activities that could be required as part of the Proposed Practice (indicates the impact of “optimisation”)	Less than 0.085mSv per year (uranium enrichment)
Dose from one return flight a year to New York	Around 0.1mSv[130] per year
Dose to someone who spends 1 week a year in Cornwall (and comes from part of UK with typical natural radiation level)	Around 0.15mSv[131] per year
Dose from one CT scan of abdomen per year	Around 10mSv per year
Workers	Dose constraint = 20mSv per year
Bounding value for the average level of dose to any worker in the UK assessed to arise from the Proposed Practice	Less than 10mSv per year
Maximum potential average individual worker dose identified in application	Less than 1mSv per year
Average annual dose to classified workers within UK nuclear industry	Around 0.7mSv per year
Average annual dose to member of typical UK air crew	Around 2mSv per year

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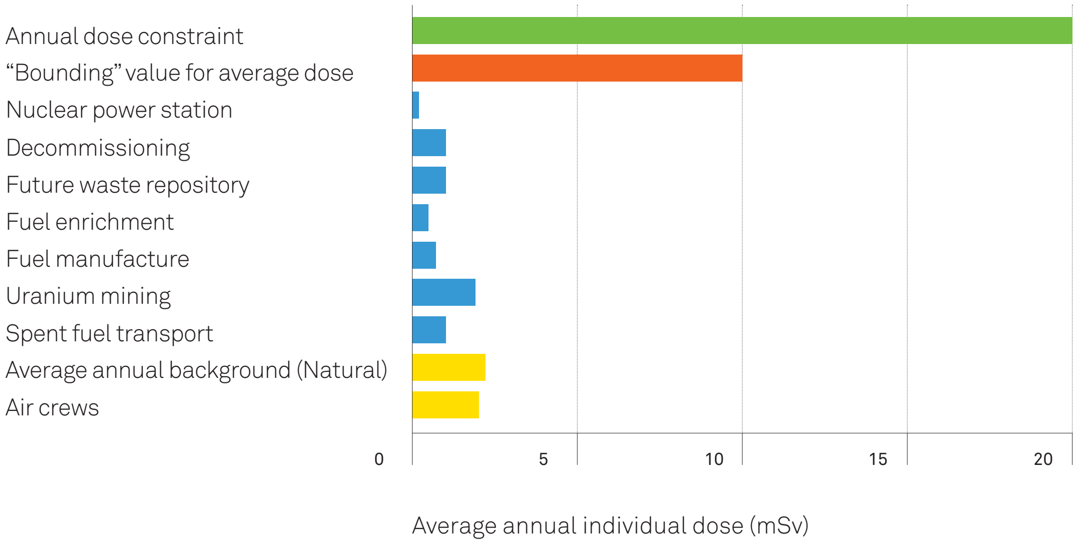
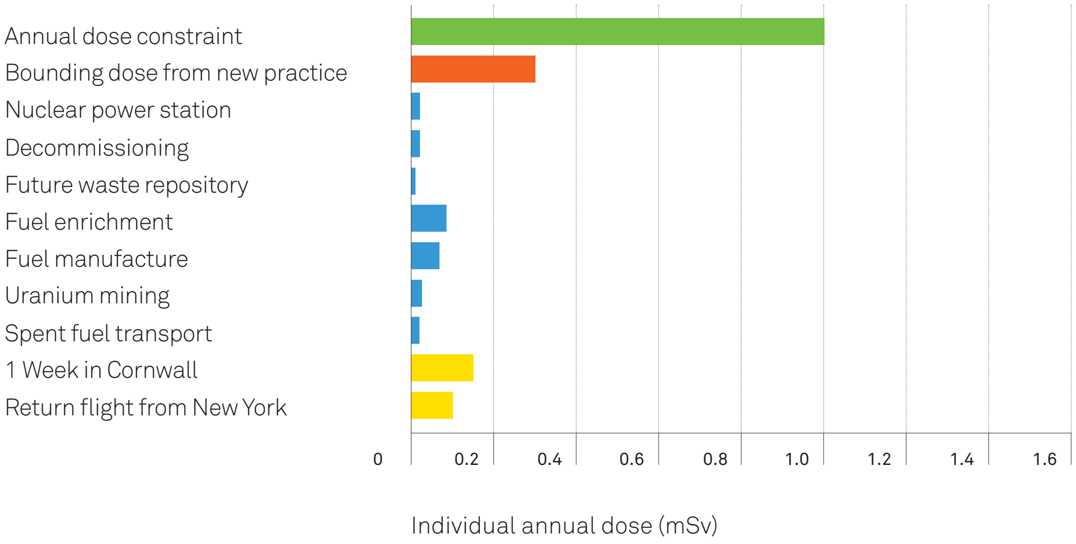
[130] Health Protection Agency (formerly NRPB) Booklet “Living with Radiation”.

[131] “Ionising Radiation Exposure of the UK Population: 2005 Review” HPA-RPD-001 published by the Health Protection Agency.



← Figure 5.4 Scale of Radiological Health Detriments (Workers)



← Figure 5.5 Scale of Radiological Health Detriments. Maximum Doses to the Public (for Representative Persons

SIX

OTHER POTENTIAL DETRIMENTS

RADIOACTIVE WASTE AND DECOMMISSIONING

Other Potential Detriments
Radioactive Waste and Decommissioning

The operation and eventual decommissioning of a programme of new nuclear power stations of the UK ABWR type would add a relatively small volume of radioactive waste to that which already requires management and disposal in the UK.

The types of waste created by the Proposed Practice would be similar to those which already exist, and for which management and interim storage arrangements over a prolonged period of decades, if required, are currently in place. While not every aspect of radioactive waste disposal has yet been demonstrated, the Government remains firmly committed to geological disposal of nuclear waste and is confident that the Managing Radioactive Waste Safely ("MRWS") programme will be put into effect.

From outside the UK, there is also considerable and growing international experience to build on. Radioactive waste and spent fuel from new nuclear power stations could be stored safely for long periods until a disposal facility became available.

The impact that a programme of UK ABWRs would have on the size of repository built would be determined principally by the quantity of additional spent fuel requiring disposal. The detriment arising from this scale of increase in below ground repository excavation (over that already required to dispose of existing legacy waste and spent fuel) would be manageable.

Decommissioning of nuclear facilities is well understood and there is extensive and growing international experience available.

Liabilities associated with nuclear power plants, including waste management and decommissioning, are the ultimate responsibility of the site licence holder and cannot be delegated or assigned to other parties. Government has legislated to require that operators have in place an approved Funded Decommissioning Programme ("FDP") before plant construction can begin. The FDP will help Government to ensure that the costs relating to the management of radioactive waste and spent fuel, and the decommissioning of new nuclear power stations are considered; and secure financing arrangements are in place to meet the full costs of decommissioning and the operator's full share of waste management and disposal costs.

On this basis, it is concluded that the detriment associated with the need to manage radioactive waste and to decommission any new nuclear power station would be small in relation to the major benefits that the power station could provide to the UK.

Introduction

6.1 This Chapter addresses the impacts of radioactive waste management and decommissioning in relation to justification of the Proposed Practice. It does not examine the potential radiological health detriments as these are addressed in Chapter 5. The issues covered within this Chapter are therefore:

- The extent to which there can be confidence that the radioactive waste created during the operation of any new nuclear power station and resulting from its eventual decommissioning will be managed responsibly and without significant detriment; and
- The extent to which the nuclear liabilities and costs associated with the above will be met without placing a significant and detrimental burden on the UK taxpayer.

6.2 This Chapter outlines the main types and quantities of radioactive waste that would require management, and ultimately disposal, during the plant's operational life and the period of site management following this. The relevant UK policy and regulations are set out. It describes how these various waste types are currently managed in the UK and, where appropriate, what plans there are for the future. It also gives examples of where experience exists in the UK, or elsewhere of similar waste management solutions.

6.3 For decommissioning and its associated waste, a similar approach is taken. Regulatory requirements are summarised together with the relevant Government policy, and examples are provided to give confidence that these requirements can be achieved in practice.

6.4 On this basis, it is demonstrated that there can be confidence that neither radioactive waste management and disposal, nor decommissioning, should result in a detriment to the UK that is significant when compared to the scale of the benefits identified in earlier Chapters.

Commentary on our 2008 Application

6.5 Although there are design differences between the UK ABWR and the already justified AP1000® and EPR™ reactors, which may lead to differences in safety cases and differences in operational regimes, they will all generate very similar types of radioactive wastes both during operation and decommissioning[132]. The principles and technologies used in their decommissioning will be very similar, if not identical in some respects. For these reasons, many of the conclusions and comments in the Justification decisions for the AP1000® and the EPR™ (the "2010 Justification Decisions" [133]) will relate directly to the UK ABWR. Where this is judged to be the case, such conclusions and comments have been reproduced in quotations and italics in the relevant sections that follow. This is in no way intended to pre-empt the Justifying Authority's views on this Application or the views of the regulators and other statutory consultees. However, we feel that it is a valid way of supporting the arguments that we make in this Application.

Radioactive Waste and its Management (During Operational Life)

6.6 An important difference between power stations "burning" nuclear fuel as opposed to fossil fuels is the extent to which the waste products created are contained and kept separate from the environment. Another important difference is that the quantities involved are quite different in scale.

6.7 In conventional fossil fired stations (coal, oil and gas), all of the fuel is consumed in the process and the gaseous combustion products are released via the chimney into the environment. In the case of coal, the solid waste residues (mainly ash) that cannot be utilised elsewhere, such as for construction materials, are disposed into landfill. The quantities of the waste materials produced by a large fossil station every year can be measured in millions of tonnes, comprising carbon dioxide, nitrogen oxides (gases) and, for coal, ash and other solid wastes. In a nuclear power plant, the fuel is not consumed in this way. When it is unloaded from the reactor after use, it is effectively identical in weight, size and appearance to when it was loaded. Virtually all of the waste products generated by the nuclear reaction remain inside the sealed fuel pins and are never released into the reactor, still less into the environment. The quantity of spent nuclear fuel to produce the equivalent amount of electricity as a fossil fired station is measured in tens, not millions, of tonnes. For a 1000MW power station operating for a year (and producing about 8TWh of electricity) a nuclear power station would use about 25 tonnes of enriched nuclear fuel whereas a coal-fired station would burn about 2.5 million tonnes of coal.

6.8 The radioactive materials that need to be managed during the operating lifetime of nuclear power stations comprise:

[1] Spent nuclear fuel, which is where the overwhelming majority of all of the radioactivity created by operating the power station will be contained;
[2] Much smaller quantities of the radioactive material generated within the fuel that has passed into the reactor either due to its ability to diffuse through the can surrounding the fuel, or, infrequently, as a result of leaks in the can;
[3] Materials that become radioactive (are activated) due to their being exposed to radiation from the nuclear chain reaction inside the reactor and that are then removed from the reactor, for example as components or via clean-up filters or chemical treatment plant; and

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[132] Support for this judgment comes from the IDM paper – Advice on the influence of Reactor Technology on the Definition of Classes or Types of Practice for New Build Justification – available at: http://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file49232.pdf.

[133] The 2010 Justification Decisions are available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47935/667-decision-ap1000-nuclear-reactor.pdf.

[4] Materials (for example, tools, gloves, or filters) that become contaminated with radioactive material originating from 1, 2 or 3 above.

The dismantling and decommissioning of the station would generate additional wastes. These are covered later in this Chapter.

6.9 Modern nuclear power stations of the UK ABWR type covered by the Proposed Practice aim to reduce the quantities of radioactivity released from the fuel and created through activation. They also provide clean-up systems to ensure that such materials, when present in a mobile form (i.e. gaseous, liquid or particulate), are removed from within the reactor or its associated systems and are safely contained. Apart from contaminated clothing and other miscellaneous items (see item 4 above), it is these clean-up systems that are the main source of the solid radioactive waste that must be managed by the plant operator until its ultimate disposal. These systems are also the source of the very small quantities of radioactive material that are permitted for controlled discharge into the environment following careful measurement and characterisation.

6.10 In the UK, solid radioactive waste is classified by the amount of radioactivity it contains, and also by whether special arrangements are needed as a consequence of the level of heating created by the radioactivity within it. The Box below explains the four categories:

- Very Low Level Waste ("VLLW");
- Low Level Waste ("LLW");
- Intermediate Level Waste ("ILW"); and
- High Level Waste ("HLW").

6.11 Spent nuclear fuel is not normally classified as a waste material in the UK because some of the materials within it have the potential to be extracted and re-used as a fuel. However, its radioactive content and its level of heat generation mean that, for the purposes of storage and disposal, it can be thought of as being similar to HLW. Government's view is that any new nuclear power station that might be built in the UK should proceed on the basis that spent fuel will not be reprocessed and this is the position for the UK ABWR which will thus produce VLLW, LLW, ILW and spent fuel (HLW) as the main categories of waste.

6.12 The quantities and types of VLLW, LLW, ILW and spent fuel produced during operation of power stations that fall within the Proposed Practice would depend on individual station design, operational practices and the application of regulation. Annex 1 contains data for the ABWR design and provides an indication of the quantities of LLW, ILW and spent fuel.

6.13 There is a balance to be struck between the degree of clean-up carried out on a power station and the quantity of discharges. Liquid and gases can be subjected to increased levels of clean-up so as to further reduce the amount of radioactivity that is discharged. However, this will be at the expense of generating a greater volume of solid radioactive materials, which will then require storage at the nuclear site. Striking this balance at the optimum point will ultimately be an outcome of applying the UK licensing and environmental permitting regulatory processes, which are briefly described in paragraphs 6.15 to 6.17.

Classification of Radioactive Wastes

Radioactive wastes in the UK are categorised according to their heat generating capacity and activity content:

- **High level waste (HLW)**
  This is waste with radioactivity requiring special storage or disposal facilities to accommodate its heat generating qualities (thermal power exceeding about 2kW per cubic metre). In practice, this waste consists of reprocessing waste. The 1000 cubic metres of conditioned HLW that will be produced in the UK will account for 95% of the total radioactivity in UK radioactive wastes.

- **Intermediate level waste (ILW)**
  This is waste with radioactivity levels exceeding those of low level waste, but not requiring storage or disposal facilities to accommodate heat generation (thermal

power below about 2kW per cubic metre). This waste would mainly consist of filters and ion-exchange resins (a type of chemical separator) that had been used to remove radioactive contaminants from gaseous or liquid streams prior to reuse.

- **Low level waste (LLW)**
  This waste contains radioactive materials that makes it unacceptable for disposal with ordinary refuse, but it does not exceed 4GBq/te+ of alpha or 12GBq/te+ beta/gamma activity. This waste can include a variety of materials, including, for example, redundant equipment, paper towels, clothing, air filters and even smoke alarms.

- **Very low level waste (VLLW)**
  High volume VLLW (bulk disposals) is waste with a maximum concentration of 4MBq/te of total activity that can be disposed of in specified landfill sites.
  There is an additional limit for tritium for wastes containing this radionuclide.

Wastes that can be disposed of with ordinary refuse - with each 0.1m^3 of material containing less than 400kBq of beta/gamma activity. If a material is below a very low threshold value of non-natural radioactivity (currently 0.4 becquerel per gram for most materials)* its disposal is not subject to authorisation.

+ This unit is Giga-becquerels per tonne where “Giga” means “1000 million”.
* The unit of radioactivity called the “Becquerel” is explained in the Glossary.

6.14 A large body of nuclear safety, environmental protection and transport regulation is relevant to the management of radioactive waste and spent fuel. Of particular significance in relation to the scale of detriments considered here are the requirements stemming from the Environmental Permitting (England and Wales) Regulations 2010, the Environment Act 1995 and the Nuclear Installations Act 1965. These are summarised below.

Environmental Permitting Regulations (EPR 2010) and Radioactive Substances Act (RSA93)

6.15 The Environmental Permitting (England and Wales) Regulations 2010 (“EPR 2010”) came into force on the 6th April 2010 and have partially replaced the provisions of the Radioactive Substances Act (“RSA93”) in England and Wales in relation to disposals and discharges into the environment. The EPR 2010 creates a requirement for permits to cover all disposals, including any discharges of radioactivity, into the environment. Permits are granted by the Environment Agency (“EA”) (in England) and by Natural Resources Wales (“NRW”) (in Wales). In Scotland, the Scottish Environment Protection Agency (“SEPA”) applies the Radioactive Substances Act (which also applies in Northern Ireland) and which has similar requirements to the EPR 2010. Key features within these permits are limits on quantities of radioactivity (with separate limits for various types) and a requirement to use best available techniques (“BAT”) to limit the amount of radioactivity released into the environment (amongst other things).

6.16 Different regulatory regimes in the field of radiological protection have their own guidance and use different terminology, including: reducing risks as low as reasonably practicable (“ALARP”); use of best practicable means (“BPM”); best practicable environment option (“BPEO”); and now, in England and Wales, best available techniques (“BAT”). However, all of the above terminology relates to the idea of making a judgement between options by comparing benefits in terms of safety, environmental protection etc. against costs in terms of time, effort or money. BAT is the means (for example, plant and processes) that an operator uses to control disposals of radioactive waste into the environment. BAT is within the control of the operator and is how the operator seeks to demonstrate that doses to the public are kept to as low as reasonably achievable (“ALARA”). The EA, NRW and SEPA consider BAT and BPM (which remains in force in Scotland) to be equivalent terms with essentially the same assessment and determination processes, and which deliver equivalent levels of environmental protection.

Nuclear Installations Act 1965

6.17 The Nuclear Installations Act 1965’s particular significance in relation to radioactive waste is the requirement under Licence Condition 32 to minimise so far as is reasonably practicable the rate of production and total quantity of radioactive waste accumulated on a site and to record the waste so accumulated.

Optimisation

6.18 It should be clear from the discussion above that the requirement to strike a balance between accumulating solid waste onsite through higher and higher levels of clean-up, and permitting any radioactivity to be discharged, arises directly from UK regulation. Establishing this balance is an important part of the radiological process referred to by the International Commission on Radiological Protection ("ICRP") as "optimisation" – a process which takes place after justification and which has yet to be carried out for the UK ABWR. The basis for optimisation and the ALARA principle is the Basic Safety Standards Directive ("BSS"). Optimisation of the UK ABWR will be delivered progressively in the UK through the GDA process and subsequent site specific regulatory processes.

Authorised Discharges of Radioactive Material

6.19 As explained above, only very small quantities of radioactive materials are released into the environment by the operation of modern evolutionary reactor designs. Ahead of the optimisation stage, which is carried out in the UK through regulatory processes overseen by the environment agencies and the ONR, it is not possible to provide specific figures for the level of discharge that will be permitted. However, it is possible to give an indication of the level from knowledge of what has previously been authorised under the same regulatory arrangements. The authorised limits for Sizewell B (which were the subject of review and public consultation in 2006) are:

For liquid radioactive materials:

Radionuclide	Discharge Limit
Tritium	80 TBq/y
Caesium-137	20 GBq/y
Other activity	130 GBq/y

For gaseous radioactive materials:

Radionuclide	Discharge Limit
Tritium	3 TBq/y
Carbon-14	0.5 TBq/y
Noble gases	30 TBq/y
Iodine-131	0.5 GBq/y
Beta particulate	100 MBq/y

6.20 The units in these Tables are mega-, giga-, and terabecquerel per year (MBq/y, GBq/y and TBq/y).

6.21 The very small potential for any radiological health detriments linked to these levels of discharge are described in Chapter 5. This is a consequence of the tiny quantities of radioactivity involved and the amount of dilution that takes place following their discharge. As explained in paragraph 6.1 above, this Chapter addresses the impacts of radioactive waste management and decommissioning in relation to justification of the Proposed Practice. It does not examine the potential radiological health detriments as these are examined in Chapter 5.

6.22 To illustrate the point above, it may be useful to express the Sizewell B authorisation in units that are more familiar. The authorisation permits a maximum of around only one quarter of a gram of tritium to be discharged in liquid form per year; this is then diluted by millions of tonnes of cooling water. The permitted amount of specifically identified gaseous radionuclides that may be discharged each year is only a few grams from all sources. While it is the amount of radioactivity (measured in becquerels) that is important, these figures do illustrate the degree to which a nuclear power station ensures that virtually all of the radioactive waste products generated from the utilisation of uranium within it are contained safely and are not released.

6.23 In the past, studies have generally focused on the potential impact that radioactivity in the environment could have on human health (as covered in Chapter 5). The widely accepted view has been taken that if people are protected then other species in the environment will also be protected.

6.24 This approach, however, would not take account of the requirements of Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora ("the Habitats Directive"), which are transposed in national law by the Conservation of Habitats and Species Regulations 2010 (the "Habitats Regulations"). The Habitats Regulations require the decision-making authority to make an appropriate assessment of the likely significant effects of a specific new nuclear power station project on European sites of nature conservation importance[134] in view of the site's conservation objectives. The developer is required to provide sufficient information (including in relation to avoidance and mitigation measures) in order for the appropriate assessment to be made.

6.25 Possible adverse effects on nature conservation sites of European importance were identified by the Nuclear Habitats Regulations Assessment ("HRA") undertaken in relation to the National Policy Statement for Nuclear Power Generation ("EN-6") produced by DECC in July 2011. Further studies will need to be carried out, as part of the appropriate assessment and environmental impact assessment ("EIA") processes for individual development consent applications, to determine the significance of any effects and any effectiveness of any mitigation measures.

6.26 The Environment Agency published a report in May 2009[135], which presented assessments of the impact of discharges of radioactive substances on European Sites of Nature Conservation Importance (Natura 2000 sites) in the UK. These assessments involved the calculation of dose rates to organisms in coastal, freshwater and terrestrial environments, taking account of the combined impact of discharges from multiple authorised releases and cautiously assuming that discharges occur at the authorisation limits. All discharges authorised under the Radioactive Substances Act 1993[136] that could have an impact on a Natura 2000 site were included in the assessment. The total dose rates calculated in the Stage 3 review, were compared to a threshold of 40 microgray/h, below which the Environment Agency, Natural England and the Countryside Council for Wales (now part of Natural Resources Wales) agreed there would be no adverse impact on the integrity of a Natura 2000 site.

6.27 The total dose rates for the worst affected organism were calculated to be less than 40 microgray/h for all but two Natura 2000 sites (the Ribble and Alt Estuaries SPA and the Drigg Coast SAC). The source of the discharges leading to these dose rates is the Springfields site. The calculated total dose rate for the worst affected organism for the Ribble and Alt Estuaries SAC was 520 microgray/h. This was significantly in excess of the agreed threshold and so this Natura 2000 site was included in Stage 4 (the revision of permits to ensure no adverse effects – for example, by changing the type, amount and location of discharges) of the Habitats Regulations implementation process. A separate report is available for the Ribble and Alt Estuaries[136a]. This concluded that previously agreed new authorisation limits for the Springfields Fuels Limited site (in effect from January 2008) would ensure that the dose rates to reference organisms and feature species would be less than 40 microgray/h. The total dose rate calculated for the Drigg Coast SAC was just greater than the 40 microgray/h threshold. The source of the discharges leading to these dose rates is the Sellafield site. However, it is recognised that the assessment approach used was cautious. Using the more recent EC-funded ERICA tool, the dose rate for the worst affected organism (phytoplankton) was calculated to be 20 microgray/h. The Drigg Coast SAC was also considered in an ERICA case study which concluded that there would be no significant adverse impact from ionising radiation on the sand dune biota.

6.28 In 2007, the World Nuclear Association undertook an independent examination of the ecological risk assessments for a number of sites around the world with enhanced levels of radiation and radioactivity[137]. The study examined sites with high levels of radioactivity of natural origin (for

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[134] Such as Special Areas of Conservation ("SAC") and Special Protection Areas ("SPA").

[135] 'Habitats Assessment for Radioactive Substances, Science Report SC060083/SR1 http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho0309bpml-e-e.pdf.

[136] Such discharges would not be permitted under the EPR 2010.

[136a] Impact of radioactive substances on Ribble and Alt estuarine habitats, Better regulation science programme, Science report: SC060083/SR2, http://test.environment-agency.gov.uk/static/documents/Business/SCHO0309BPMN-e-e.pdf.

[137] 'Overview of representative ecological risk assessments conducted for sites with enhanced radioactivity', prepared for the World Nuclear Association by SENES Consultants Limited, November 2007: http://db.world-nuclear.org/reference/pdf/wna-senes-1107.pdf.

example, from mining, fertilizer production and the oil and gas industry), including radioactive waste management sites and even the Chernobyl site. The results showed that for normal operations of nuclear fuel cycle sites, sites involving natural radioactivity and for radioactive waste management and disposal sites, the potential for effects in non-human species is small. The report concludes:

> *"The current system of radiological protection has been based on the protection of people, assuming that if humans were adequately protected, then "other living things are also likely to be sufficiently protected" (ICRP 1977) or "other species are not put at risk" (ICRP 1991). The representative ERAs [environmental risk assessments] considered in this review show that the application of the current system of radiological protection, which includes a variety of standard protective practices for containing radioactive sources, controlling and limiting radioactive releases to the environment, and protecting people, have in fact also provided an adequate level of protection to populations of non-human biota."*

6.29 On this basis, it is concluded that there will be no other significant detriments arising from permitted (or authorised in Scotland) discharges of radioactivity associated with the Proposed Practice. In the 2010 Justification Decisions[138] the Justifying Authority concluded:

> *"In relation to these discharges the Secretary of State is satisfied that the regulatory regime is sufficiently robust to ensure that doses arising from such discharges will remain within limits and will be as low as reasonably achievable (ALARA)."*

Solid Radioactive Waste Management

Very Low Level Radioactive Waste

6.30 The Government announced a policy on LLW and High Volume-VLLW ("HV-VLLW") management in March 2007. The policy included revised regulation around the disposal of such wastes to landfill. Changes in environmental permitting have allowed the disposal of LLW and HV-VLLW to specified landfill sites in the UK, of which three are now in operation and are accepting such wastes from the operation and decommissioning of existing UK nuclear facilities.

Low Level Radioactive Waste

6.31 Most of the waste of this type that arises from the operation of existing UK nuclear power stations is routinely managed and disposed of in the national low level repository near Drigg in Cumbria. The quantity of waste arising during a year's operation is small – typically a few normal lorry loads for currently operating designs. LLW arising from the Proposed Practice would be managed in accordance with UK regulatory requirements and in a manner consistant with current waste material. While the quantities would be dependent on detailed design and operational practice, they would be similar in scale to those currently experienced for existing reactors. There are currently some types of LLW that may not be suitable for disposal at the LLW repository near Drigg (although such wastes are not expected from the Proposed Practice). The volumes involved are relatively small and CoRWM concluded that these types of waste could be disposed of in a deep geological repository with higher activity wastes[139]. Any such similar waste streams from new nuclear stations could follow the same arrangements.

6.32 Under Government policy, the NDA is responsible for developing and maintaining a national strategy for handling LLW from nuclear sites and for ensuring continued provision of the waste management and disposal facilities required both for normal operation and decommissioning. To fulfil their responsibility in this area the NDA have used the hierarchy of options for managing wastes, as required by the revised EU Waste Framework Directive. This gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then other recovery such as energy recovery, and last of all disposal (for example in landfill). Using this waste hierarchy priority approach, the NDA has made significant advances in recycling material, rather than disposing of it, and such an approach would be used when considering the routing of waste from a UK ABWR.

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[138] The 2010 Justification Decisions paragraph 1.40.

[139] Managing our radioactive waste safely. CoRWM 700, July 2006.

6.33 As a result, there should be no significant detriment from this LLW material. Its transport offsite would also have an insignificant impact in the context of other road traffic; and its ultimate disposal should be practicable in facilities such as the national low level waste repository near Drigg, or its successors. The conclusion of the Justifying Authority on LLW in the 2010 Justification Decisions[140] was:

> *"The Secretary of State is satisfied that the LLW originating from any new nuclear power stations would not vary greatly from that of existing nuclear power stations, and expects that LLW from new nuclear power stations would be handled in a manner similar to current practice and in line with Government policy on LLW."*

Intermediate Level Waste

6.34 ILW from the UK's existing nuclear power stations is stored safely and securely on site pending its ultimate disposal when a national repository becomes available. The UK ABWR design would incorporate engineered facilities, as described for the ABWR in Annex 1, capable of safely managing the ILW produced during its operation.

6.35 The quantity of ILW generated during normal operation of a UK ABWR power station would be small and it would be entirely feasible, and is the plan for the UK ABWR, to store the ILW produced during the lifetime of a station safely on the site of the station. Indeed, as explained above, this is the current UK practice for all operating nuclear power stations. Alternatively, this waste could be transported offsite to a suitable facility for interim storage ahead of ultimate disposal. ILW would also be "packaged" so as to limit the radiation exposure to workers during handling and to ensure no waste is released during transport, interim storage or in the disposal facility. To facilitate this, the NDA has published guidance on the interim storage of higher activity waste packages[141] (where "higher activity" refers to HLW, spent fuel, ILW and LLW unsuitable for prompt disposal at LLWR) and on the acceptability of waste packaging, together with a process to ensure that waste producers are compliant with these requirements[142].

6.36 As explained above, decisions between various treatment options would involve identifying the best available technique ("BAT") and applying the principle of optimisation (implemented through the UK licensing and permitting processes or authorisation in Scotland) as is required under UK regulation. Key factors which influence the volume of operational ILW arisings include:

- The amount of "raw" waste arising which is itself influenced by detailed plant design and the level of clean-up applied to waste streams (see paragraph 6.13 above);
- The options selected to "condition" this waste; and
- The packaging applied to enable its handling, transport and disposal, which is itself linked to the conditioning option above, and the length of time during which the radioactivity levels within the waste have been reducing before its disposal (which affects the amount of shielding required).

6.37 The range of possible options available for waste conditioning and packaging is increasing steadily, with some offering potential further benefits through volume reduction. Given that decisions on how best to manage ILW from any future UK stations will be taken in the light of all the options available at that time, any estimates made now of the packaged volume of waste requiring disposal need to be seen as indicative. In a report prepared by Nirex (the pre-cursor to the Radioactive Waste Management Directorate "RWMD" within the NDA) as part of Government's 2007 consultation on the future of nuclear power, it was estimated that a 10 GW(e) programme of new nuclear stations could increase the UK inventory of ILW by between 2.5 and 4.5%[143]. These figures include both the waste arising during operation and the waste associated with eventual decommissioning. The figures are based on reasonable during operations assumptions, but

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[140] The 2010 Justification Decisions, paragraph 7.193.

[141] Interim Storage of Higher Activity Waste Packages, Industry Guidance, NDA, August 2011: https://www.nda.gov.uk/documents/upload/Interim-Storage-of-Higher-Activity-Waste-Packages-Integrated-Approach-August-2011.pdf.

[142] NDA Waste and Nuclear Materials Unit Position Paper: Letters of Compliance (LoC) Assessment Process, January 2008: www.nda.gov.uk/documents/upload/WNM-PP-011-Letters-of-Compliance-LoC-Assessment-Process-1-January-2008.pdf.

[143] The Gate Process: Preliminary analysis of radioactive waste implications associated with new build reactors. Nirex (now part of NDA) February 2007. http://www.nda.gov.uk/documents/biblio/upload/The-Gate-Process-Preliminary-Analysis-of-Radioactive-Waste-Implications-Associated-with-New-Build-Reactors.pdf.

could vary according to the size of any new reactor programme and the assumptions in the areas listed in the paragraph above. If, for example, much greater levels of clean-up were assumed and less credit were taken for radioactive decay before waste disposal the figure could rise. It is clear, however, that the scale of additional ILW created by new nuclear stations is likely to be relatively modest in comparison with the quantity that is already committed and requires management, interim storage and disposal. It should also be noted that this work shows that, on the assumption that ILW and spent fuel (or HLW) are disposed of in a co-located repository[144], it is the additional quantity of spent fuel from a new build programme that would be likely to determine the increase in below ground footprint of a future repository. Spent fuel is addressed later in this Chapter.

6.38 The UK currently has no facility for the disposal of ILW. However, since 2001, Government has been running a very thorough consultation process on the disposal of higher activity wastes, as defined in paragraph 6.35 above, under the title "Managing Radioactive Waste Safely (MRWS)".

6.39 As part of this process the independent Committee on Radioactive Waste Management ("CoRWM") was established in 2003 to make recommendations to Government on the long-term management and disposal of these wastes. CoRWM made its recommendations[145] to Government in October 2006 and Government subsequently accepted the Committee's main recommendation which was that geological disposal, preceded by safe and secure interim storage was the way forward for the long term management of the UK's higher activity wastes. CoRWM renewed this commitment to geological disposal in its 2013 Annual Report[146].

6.40 This approach has already been implemented in some other countries (see Annex 3). In the 2010 Justification Decisions, the Justifying Authority states:

> *"Geological disposal is the way higher activity waste (spent fuel and ILW) will be managed in the long term. This will be preceded by safe and secure interim storage until a geological disposal facility (GDF) can receive waste"; and*
>
> *"The Secretary of State considers, based on scientific consensus and international experience, that despite some differences in characteristics, waste and spent fuel from AP1000®s/EPR™s would not raise such different technical issues compared with nuclear waste from legacy programmes as to require a different technical solution."*

In paragraph 6.5 it was noted that the UK ABWR will generate very similar types of radioactive wastes and so it is expected that the same statements can be made in relation to higher activity wastes from a UK ABWR.

6.41 In the National Policy Statement for Nuclear Power Generation[147] published in July 2011, the Government provided further comment on its position on waste management and disposal:

> *"In reaching its view on the management and disposal of waste from new nuclear power stations the Government has in particular satisfied itself that:*
>
> - *Geological disposal of higher activity radioactive waste, including waste from new nuclear power stations, is technically achievable;*
> - *A suitable site can be identified for the geological disposal of higher activity radioactive waste; and*

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[144] Co-disposal implies that ILW/LLW and HLW/SF will be disposed of in separate disposal modules that implement different Engineering Barrier System designs appropriate to the different wastes and share a common access and surface facilities See; Summary section of Post-closure performance assessment: considerations of a co-located GDF in the safety case, Galson Sciences and Quintessa, QRS-1378P-R1, May 2009 (report for NDA/RWMD) http://www.nda.gov.uk/documents/biblio/upload/Post-closure-Performance-Assessment-Consideration-of-a-Co-located-Geological-Disposal-Facility-in-the-Safety-Case.pdf.

[145] CoRWM Final Report. CoRWM 700 July 2006.
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&ved=0CCgQFjAA&url=http%3A%2F%2Fwww.sepa.org.uk%2Fradioactive_substances%2Fradioactive_waste%2Fhigher_activity_waste_guidance%2Fidoc.ashx%3Fdocid%3D38be0f57-7207-4253-a7ff-9763d400a90d%26version%3D-1&ei=qCJyUu3jEYSL7AbUsIDoCQ&usg=AFQjCNEsN4bcEir_V_sDSp1IFmY0dOu1Mg&bvm=bv.55819444,d.ZGU.

[146] CoRWM 9th Annual Report 2012 to 2013.
https://www.gov.uk/government/publications/corwm-ninth-annual-report-2012-to-2013.

[147] National Policy Statement for Nuclear Power Generation (EN-6), URN 11D/716, DECC, July 2011
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47859/2009-nps-for-nuclear-volumeI.pdf.

> - *Safe, secure and environmentally acceptable interim storage arrangements will be available until a geological disposal facility can accept the waste.*
>
> *The UK has robust legislative and regulatory systems in place for the management (including interim storage, disposal and transport) of all forms of radioactive waste that will be produced by new nuclear power stations".*

6.42 Government recently held a consultation (from 12th September 2013 - 5th December 2013) to gather views on how aspects of the siting process for a geological disposal facility ("GDF") for higher activity radioactive waste could be revised and improved. In his written statement[148] to Parliament when launching the consultation, the Secretary of State said:

> *"As I confirmed in my statement in January this year, the Government remains wholly committed to geological disposal as the right policy for the long-term, safe and secure management of higher-activity radioactive waste, and continues to favour a site selection process based on working in partnership with interested local communities. This approach is consistent with similar geological disposal programmes that are ongoing in other countries."*

Spent Fuel Quantities

6.43 The NDA has estimated the amount of spent fuel that would be produced over a 60 year lifetimes of the AP1000® and EPR™ reactors[149]. The UK ABWR fuel assembly will be smaller in cross section than either the AP1000® or EPR™ reactor fuel assemblies. However, from a reactor physics perspective, a UK ABWR would produce similar quantities of spent fuel (measured in terms of weight) as an AP1000® or an EPR™, if they were all to generate the same quantity of electricity.

6.44 As acknowledged in the 2010 Justification Decisions (paragraph 7.66) relating to the AP1000® and EPR™ reactors, there is uncertainty around the quantity of spent fuel that might be produced by any new reactor technology. The quantity will depend on a number of factors, including the reactor power output, its operational lifetime and various other operational considerations including the reactor refuelling regime, which affects fuel burn-up.

6.45 The reference design currently being used by the NDA for its studies in relation to the establishment of a GDF assumes that spent fuel assemblies will be packaged in copper canisters prior to disposal, as is planned in Sweden and Finland. Such canisters can hold 4 spent fuel assemblies from an AP1000® or EPR™ reactor or 12 spent fuel assemblies from a typical BWR.

6.46 In connection with the Generic Design Assessment of the AP1000® and EPR™ reactors, the NDA performed disposability assessments for both AP1000® and EPR™ spent fuel. The key finding of these assessments was confirmation that AP1000® and EPR™ spent fuel could be disposed of in the GDF being planned for the UK's legacy nuclear waste.

6.47 The NDA's disposability assessments also included an estimate of the percentage increase in the spent fuel and ILW disposal area of the GDF that a nuclear programme using each type of reactor would have. The NDA's estimate was presented using a hypothetical programme size of 10GW(e) for each reactor, concluding that a 10GW(e) AP1000® programme would increase the GDF spent fuel and ILW underground disposal area by 55%, and the EPR™ by 50%. These hypothetical base figures will be able to be used to estimate the actual effect of an overall UK nuclear programme of a particular size or technology mix. Since the quantity of UK ABWR spent fuel will be very similar to the AP1000® and EPR™, it can be concluded that the disposal footprint will be of a similar size, having a similar impact on the GDF as the EPR™ and AP1000® practices. The precise value will be available in the "NDA Disposability Assessment of UK ABWR waste and spent fuel", which we understand is intended to be published during the time in which the Justifying Authority is considering this application.

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[148] https://www.gov.uk/government/speeches/consultation-on-the-site-selection-process-for-a-geological-disposal-facility.

[149] The 2010 Justification Decisions paragraphs 7.67 & 7.68.

6.48 In the 2010 Justification Decisions, it is stated (at paragraphs 1.37 and 7.191) that:

> *"The Secretary of State is satisfied that a GDF would be able to, and would be required to, meet the strict dose limits and risk guidance level required by the UK regulatory regime"*
>
> *"......the Secretary of State is satisfied that it is technologically feasible to build a GDF which could contain both higher activity wastes arising from existing nuclear power stations and from any AP1000®/EPR™ which might be built in the future, with only very low levels of health detriment."*

Based on the considerations above, there is no reason why a similar conclusion would not be reached for the UK ABWR.

Spent Fuel Management

6.49 Spent fuel management options are identified in Annex 1 to this Application. The radiological safety of the transport of spent fuel is addressed in Chapter 5. Just as for ILW, there would be no significant detriments not already covered that would arise from storage of spent fuel on site (or at some other offsite facility) during the plant's operational life and the period of site management following this. The number of container movements required to transport spent fuel to an interim store or disposal facility would be modest – typically around 150 movements would be sufficient for a station's 60 year period of operation. This number also gives an indication of the relatively small volume of spent fuel that would require interim storage and disposal.

6.50 Again, as described above for ILW, the UK currently has no facility for the ultimate disposal of spent fuel. However, CoRWM recently suggested[150] that new build wastes, including spent fuel, should be regarded as part of the inventory of wastes that will need to be managed in due course. The Government has accepted this suggestion and is proposing to add new build spent fuel and waste to the "Baseline Inventory" which will then be considered in the MRWS process as this is taken forward.

6.51 The volume of spent fuel created by any new UK ABWR would depend on the number of stations, the exact design following optimisation, and the length assumed for their operational lives – with key parameters being the reactor power and the amount of energy extracted from each tonne of fuel before it is discharged (termed the fuel "burn-up"). The burn-up also influences the level of radioactivity within each tonne of spent fuel and this in turn affects the level of heat generated within the fuel as the radioactivity inside it decays away. The space required for the disposal of spent fuel (or HLW from its reprocessing) within a repository is governed as much by the level of heat generation within the material as it is by the physical volume of the individual packages.

6.52 As explained earlier, there is no technical reason why spent fuel could not be disposed of within the same deep geological repository provided for existing similar waste or in an extension to it. The spent fuel from a new programme of UK ABWR reactors would not need to be disposed of immediately, but could be stored safely on site (or elsewhere) until the site was decommissioned and a suitable repository was available.

6.53 On the above basis the detriment associated with managing and ultimately disposing of additional spent fuel from the Proposed Practice should not lead to a significant detriment.

Decommissioning and its Associated Waste Management

6.54 All major industrial facilities have to be decommissioned eventually. This applies to energy facilities such as offshore oil platforms or wind turbines just as much as it does to nuclear facilities. This section sets out why dealing with this aspect of the Proposed Practice would not give rise to significant detriments.

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[150] CoRWM 8th Annual Report, 2012
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225380/CoRWM_Eighth_Annual_Report_2011_to_2012.pdf.

The Regulatory Framework for Decommissioning

6.55 Before a new nuclear station can be constructed in the UK, its decommissioning must be considered under one of the standard conditions laid down within the Site Licence[151]:

> *"The licensee shall make and implement adequate arrangements for the decommissioning of any plant or process which may affect safety."*

In addition, decommissioning is subject to the same key regulatory controls that apply during normal operation – including other site licence requirements, radiation protection provisions and environmental permitting (or authorisation in Scotland). In addition, under the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999, licensees are required to produce an environmental assessment to identify and consider the impacts and mitigate them as far as practicable.

6.56 These regulations and the accompanying guidance[152] require that the ONR consult with the public, consider the assessment, and grant consent for decommissioning to start only when it is satisfied that there is *"adequate information, conclusion that environmental benefits far outweigh detriments, no significant impact on the environment of other countries and recognition that some issues are adequately covered by other regulatory regimes."* [153]

6.57 The European Commission will also need to be satisfied that other countries will not be adversely affected by the decommissioning of a new nuclear power plant, as prescribed by Article 37 of the Euratom Treaty [154]. Further, a regulatory regime requiring independent assessment, funding and management of liabilities and costs associated with the decommissioning of new nuclear facilities and the management of nuclear waste is now firmly established in the UK. This is addressed in more detail in paragraphs 6.69 to 6.77 below.

The Decommissioning Process

6.58 The basic objectives of this process are:

- To ensure the continued safety of the public, the workforce, and the environment;
- To minimise the environmental impact of the station as far as reasonably practicable;
- To decommission the station as soon as it is reasonably practicable to do so; and
- To release land for other use as appropriate.

6.59 In order to manage this process the following principles are used:

- The safety of the public, staff, the protection of the environment, and plant are of paramount importance throughout all decommissioning activities;
- Decommissioning wastes will be managed in accordance with the same principles as operational wastes, and will be minimised wherever possible; and
- All relevant environmental and decommissioning legislation and regulations in the management of decommissioning will be adhered to.

6.60 The decommissioning process can be broken down into the following stages:

- Defuelling;
- Post-operations clean out;
- Dismantling;
- Site clearance; and
- De-licensing.

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[151] Standard Nuclear Site Licence Condition 35. Available at http://www.hse.gov.uk/nuclear/silicon.pdf.

[152] Guidance on the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations, HSE, 2007: http://www.hse.gov.uk/nuclear/eiadrguidance.pdf.

[153] See Summary of A decision on the application to carry out a decommissioning project at Oldbury Nuclear Power Station (under EIADR as amended), Nuclear Report NUC27, HSE, 2008. http://www.hse.gov.uk/nuclear/nuc27.pdf.

[154] Treaty Establishing the European Atomic Energy Community 1957 (as amended). See also http://ec.europa.eu/energy/nuclear/radiation_protection/article37/article_37_en.htm.

These stages are described further in Annex 3 where progress on decommissioning since 2008 is referred to.

6.61 There are two main technical options for progressing through the stages of decommissioning:

- Prompt decommissioning (or early site clearance), which involves the progressive and complete removal of the reactor and all its ancillary buildings over a relatively short period of time, typically up to 25 years; or
- "Safestore", in which the dismantling is deferred for a period of time to allow the radioactivity in the reactor to reduce. Deferral periods may vary; for gas cooled reactors in the UK they are typically between 70 and 100 years.

6.62 The selection of which option is appropriate involves striking a balance between the benefits of deferral on the one hand, and the value attached to removing the ongoing liability and restoring the site to an alternative use. This depends on the design of the plant, the technology available at the time for dismantling, the availability of suitable facilities for waste disposal and the value attached by society to completing site clearance. At the current time, it would appear more likely that a new UK ABWR power station would follow the prompt decommissioning option although the deferred approach could also be adopted.

Waste and Discharges from Decommissioning

6.63 Waste associated with decommissioning can be divided into three categories:

- Intermediate level waste: comprising for example active parts from the reactor pressure vessel and its internals. Primary circuit pipe work and equipment (pumps, valves, etc.) may also need to be classified as ILW if it is impracticable to decontaminate them;
- Low level waste: this waste consists of the least radioactive components and equipment as well as the residues from the treatment and decontamination of concrete and steel surfaces; and
- The remainder of the waste consists mainly of non-radioactive concrete that can be re-used on site to fill in excavated sections and upgrade the site.

6.64 Although the quantities of these types of waste would be larger than those arising during normal operation, the same principles would be applied to the way in which they are managed and ultimately disposed of.

6.65 Experience has also shown that the scale of discharges of radioactivity from a decommissioning reactor site need not increase as a result of decommissioning work and for some specific radioactive elements discharges will be reduced.

Potential Detriments from Decommissioning

6.66 Just as would be the case when decommissioning any industrial facility of an equivalent scale, the volumes of waste produced from decommissioning a nuclear power station would be significant. However, experience has shown that the great majority of this waste would be conventional concrete rubble, which could be reused as fill for the restoration of the site, and steels which could be recycled as scrap. The potential detriment associated with the impact of additional decommissioning waste on a UK repository is covered earlier in this Chapter.

6.67 The principal non-health related impact from decommissioning will be the number of transport movements taking waste and recyclable materials off-site. Although much of the conventional waste could be re-used onsite for site restoration, substantial volumes of scrap steel for recycling and radioactive wastes for disposal will need to be removed from the site. The non-radiological environmental impacts of decommissioning, including traffic impacts, are discussed in Chapter 7.

6.68 The other non-health related impacts of decommissioning have also been assessed to be minor. Extensive work has now been carried out in the UK on the preparation of environmental impact assessments for decommissioning and these have identified a number of impacts such as socio-economic, air quality and noise. Overall, the studies, such as the one in support of the application to decommission the Magnox power station at Wylfa[155], found that these were both negative and positive impacts, and there were no significant detriments. In addition to this analysis the decommissioning of a number of nuclear facilities has been successfully carried out with a growing number of sites demonstrating the feasibility of all the techniques required (see Annex 3).

Funding the Waste and Decommissioning Liabilities

6.69 Government legislated in the Energy Act 2008 to ensure that operators of new nuclear power stations will have secure financing in place to meet the full cost of decommissioning and their full share of waste management and disposal costs, by requiring the approval of a Funded Decommissioning Programme ("FDP") as a pre-condition to the development of a new nuclear power station[156]. To provide assistance to operators in understanding their obligations under the Energy Act 2008, following public consultation, Government published its Funded Decommissioning Programme Guidance for New Nuclear Power Stations ("FDP Guidance") in December 2011[157].

6.70 The FDP regime requires that the prospective operator of a new nuclear power station submits detailed estimates for waste and decommissioning liabilities and arrangements for funding the associated liabilities that will accrue. The guidance suggests that the operator's proposal be in two parts:

- A decommissioning and waste management plan ("DWMP") that describes how the prospective operator will manage and store waste and how it proposes to decommission the plant, and establishes the expected future costs of any post-operation activities (such as waste storage and final decommissioning) and therefore the target amount that will need to be accumulated in the decommissioning fund; and
- A funding arrangements plan ("FAP") that sets out how the prospective operator will set aside and manage funds during the operation of the plant, including any security to be provided, to ensure the estimated costs from the DWMP can be met.

6.71 Government has indicated that it will be for the prospective operator to propose suitable arrangements, but has made it clear that Government's overarching objective of the FDP regime is to ensure that operators make prudent provisions for:

- The full costs of decommissioning their installations and remediating the relevant sites;
- Their full share of the costs of safely and securely managing and disposing of their waste; and
- That in doing so, the risk of recourse to public funds is remote.

6.72 Where funds are put aside to pay for decommissioning and waste management in accordance with the FDP regime, there are three key risks that could lead to the fund ultimately being inadequate to meet the liabilities. The first is that the target amount, covering all the costs of decommissioning, proves to have been wrongly calculated and underestimated. The second risk is that the investments made by the fund do not grow sufficiently to meet the target amount. Lastly, there is the risk that the operator that is responsible for providing funding becomes insolvent.

6.73 To mitigate these risks, Government set up the Nuclear Liabilities and Financing Assurance Board ("NLFAB") to provide the Secretary of State with impartial scrutiny and advice on the suitability of FDPs submitted by potential operators. NLFAB advises the Secretary of State on the financial arrangements that operators submit for approval[158].

6.74 The Energy Act 2008 and subsequent legislation requires that post-operation (and some during-

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[155] Non-Technical Summary of the Environmental Statement in support of the Application to decommission Wylfa nuclear power station, 2013 update, Magnox, March 2103. http://www.hse.gov.uk/consult/condocs/cdwylfa/2013-non-technical-summary.pdf.

[156] Energy Act 2008, section 45.

[157] DECC. The Energy Act 2008: Funded Decommissioning Programme Guidance for New Nuclear Power Stations, December 2011.

[158] See NLFAB internet pages at https://www.gov.uk/government/organisations/nuclear-liabilities-financing-assurance-board.

operation) costs are assessed in detail[159] and the FDP guidance states that the target value for fund assets will be expected to include *"a prudent risk-based contingency"*[160], and that an investment strategy is proposed for approval. The FDP guidance also states that *"the Operator must make provision to manage and mitigate the risk of the Fund being insufficient"* and provides additional guidance as to how that might be provided[161]. The guidance states that *"the Fund entity and the Fund Assets must also be protected from the Operator's creditors in the event of the Operator's insolvency"*[162].

6.75 Operators are required to compile Annual Reports and Quinquennial Reports, the latter of which is to ensure *"that the plans for decommissioning of the site and for the management and disposal of waste arisings continue to be realistic, clearly defined and achievable and that the corresponding cost estimates are robust"*[163]. These reports must be accompanied by an independent assessment of whether the operator's costs (or changes to those costs) are reasonable[164] and an independent valuation of assets and security[165]. In parallel, regular assessments of the fund's investment performance are required and a view is taken on likely future returns. A significant increase in the target amount or a shortfall in fund performance will invariably trigger a requirement for the operator to reassess both the value of the fund and planned future contributions.

6.76 Decommissioning and waste management are essentially engineering exercises and the detailed costs and risks can be estimated and managed by the operator. For intermediate level waste and spent fuel disposal Government has established a regime[166] whereby it will enter an agreement with potential operators to provide a fixed waste disposal cost and schedule. This will give the potential operator certainty as to the price and timing of transfer of responsibility for waste and spent fuel to Government prior to disposal, against which funds can be accumulated. This price will contain a risk premium to provide protection to the taxpayer.

6.77 In summary, the arrangements for ensuring that decommissioning and waste liabilities are fully funded by the operator will ensure that any risk of detriment to the public purse is minimised as far as practicable to low levels.

Conclusion

6.78 This Chapter has reviewed the possible non-health related detriments associated with the Proposed Practice arising from radioactive waste and decommissioning. It is concluded that demonstrable or feasible solutions exist for safely managing the additional quantities of radioactive waste and spent fuel arising and for decommissioning the stations. The risk that waste, spent fuel and decommissioning liabilities associated with new nuclear stations, including the UK ABWR, could fall to the public purse will also be reduced to low levels so far as practicable by arrangements developed by Government.

6.79 This conclusion is in line with Government's own statement[167] on these issues following widespread consultation with the public:

> *"Having reviewed the arguments and evidence put forward, the Government believes that it*

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[159] Energy Act 2008, Section 45 and The Nuclear Decommissioning and Waste Handling (Designated Technical Matters) Order 2010, Section 3.

[160] FDP Guidance, section 2c.37.

[161] FDP Guidance, section 2c.74.

[162] FDP Guidance, section 2c.14.

[163] FDP Guidance, section 2a.14.

[164] A DTM (Designated Technical Matters) verification report, see Nuclear Decommissioning and Waste Handling (Finance and Fees) Regulations, 2013, section 4.

[165] A financial verification report, see Nuclear Decommissioning and Waste Handling (Finance and Fees) Regulations, 2013, section 4.

[166] DECC. Waste Transfer Pricing Methodology for the disposal of higher activity waste from new nuclear power stations. December 2011. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42629/3798-waste-transfer-pricing-methodology.pdf.

[167] A White Paper on Nuclear Power, Cm 7296, January 2008. http://webarchive.nationalarchives.gov.uk/20100512172052/http://www.decc.gov.uk/media/viewfile.ashx?filepath=what we do/uk energy supply/energy mix/nuclear/whitepaper08/file43006.pdf&filetype=4.

is technically possible to dispose of new higher-activity radioactive waste in a geological disposal facility and that this would be a viable solution and the right approach for managing waste from any new nuclear power stations. The Government considers that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities and that this should be explored through the Managing Radioactive Waste Safely programme. The Government considers that waste can and should be stored in safe and secure interim storage facilities until a geological facility becomes available. Our policy is that before development consents for new nuclear power stations are granted, the Government will need to be satisfied that effective arrangements exist or will exist to manage and dispose of the waste they will produce. The Government also believes that the balance of ethical considerations does not rule out the option of new nuclear power stations."

SEVEN

OTHER POTENTIAL DETRIMENTS

ENVIRONMENTAL IMPACTS

Environmental Impacts

All major infrastructure projects have impacts on the environment. These are addressed at a generic level through the Strategic Environmental Assessment process*, and then again in detail on a project by project basis through the Environmental Impact Assessment ("EIA")** and the environmental permitting*** processes, which must take place before a project can be approved. European law imposes strict requirements for each process.

This Chapter previews those issues which are likely to be most relevant to the Proposed Practice. This Chapter will show that:

- The overall environmental impacts from the Proposed Practice would be small;
- All environmental impacts would be properly mitigated and kept to a minimum;
- The Proposed Practice would meet all applicable standards and regulations; and
- The environmental impacts would not be unique to the Proposed Practice and would be comparable to, or less than, those of other large scale electricity generation.

In terms of the environmental impacts of the Proposed Practice, there are no significant differences identified from those addressed in our 2008 Application. There have been some significant changes in environmental and planning legislation since our 2008 Application, and these are reflected in this Chapter.

* As explained in the National Policy Statements for Overarching Energy (EN-1) and Nuclear Power Generation (EN-6)

** The Infrastructure Planning (Environmental Impact Assessment) Regulations 2009

*** The Environmental Permitting (England and Wales) Regulations 2010 and The Pollution Prevention and Control (Scotland) Regulations 2012 (PPC 2012). PPC 2012 came into force on 7 January 2013.

Introduction

7.1 Major infrastructure projects (including nuclear power stations) inevitably have an impact on the environment. It is for this reason that a detailed environmental assessment is required as part of the application for a Development Consent Order ("DCO") under the Planning Act 2008, which must be decided in accordance with the Overarching National Policy Statement for Energy ("EN-1") and the National Policy Statement for Nuclear Power Generation ("EN-6"). This Chapter provides a preview of the environmental impacts that would be addressed during any such consenting process within the UK to ensure that there are no unacceptable environmental impacts from the deployment of the Proposed Practice.

7.2 It is important to note that these impacts are not a consequence of the use of ionising radiation, and broadly similar impacts would result from the construction of large scale coal or gas-fired generation projects. Renewable generation also involves many of the environmental impacts covered in this Chapter.

7.3 Government concluded in its White Paper[168] that: *"The environmental impacts of new nuclear power stations would not be significantly different to those of other forms of electricity generation, and that they are manageable given the requirements in place in the UK and Europe to assess and mitigate the impacts."*

7.4 These impacts are therefore covered in this Application to provide a full picture of the benefits and detriments involved in the Proposed Practice, and to demonstrate that the detriments do not significantly erode the overall benefit.

7.5 The following sections consider the potential scale of environmental impacts during operation, the means by which they would be addressed and mitigated, and the regulatory regime in place to control them[169]:

- Conventional waste management;
- Traffic and transport;
- Air quality;
- Aquatic environment;

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[168] A White Paper on Nuclear Power, Cm 7296, January 2008, page 103.

[169] Environmental impact assessment processes also examine the socio-economic impacts of a project. The potential socio-economic impacts of the Proposed Practice are addressed in Chapter 4 (Economic Assessment) of this application.

- Cooling towers;
- Chemicals;
- Noise and vibration;
- Light; and
- Landscape and visual effects.

7.6 The key potential environmental impacts of construction are assessed below for completeness. The construction of a nuclear plant does not raise any unique environmental issues different to those of any major infrastructure construction project. The construction of any new nuclear power station, like any other major construction project, would be undertaken in compliance with all of the relevant legislative requirements. The following sections are addressed in this application:

- Habitat and species protection;
- Traffic, transport and laydown;
- Noise;
- Air quality; and
- Conventional waste.

7.7 Plant decommissioning is also briefly considered for completeness.

Environmental Impacts During Operation

Conventional Waste Management

7.8 The requirements for managing conventional waste from the operational phase of the Proposed Practice are the same as for any other conventional waste producer. For nuclear power stations, the waste generated would typically include office paper, lubricating oil, cardboard and plastics. This would be broadly similar to that expected from any fossil fuel powered station or major technical enterprise.

7.9 Conventional waste would be segregated from radioactive materials so as to maximise the potential for reuse, recovery or recycling. Any hazardous conventional waste streams would be controlled rigorously.

7.10 It should be noted that the amount of waste produced is governed less by the design of the plant than by the waste management system adopted by the operator. Appropriate mitigation measures will be applied in accordance with the waste hierarchy (reduce, re-use, recycle) as identified in relevant waste strategies including that for England[170]. In this respect, the Proposed Practice is no different to other major industrial facilities, and no different from nuclear plants which are currently in operation, or the subject of the 2010 Justification Decisions.

7.11 Conventional waste would be managed in accordance with best practice and in compliance with relevant regulations[171]. As a result, any environmental impacts would be small and would be mitigated.

Traffic and Transport

7.12 The principal transport impacts resulting from the operational phase of the Proposed Practice would be increased road and rail movements.

7.13 The volumes of radioactive waste and spent fuel that would be generated by the Proposed Practice are described in Chapter 6. Given their relatively small scale, the number of any associated transport movements required would be very low.

7.14 With regard to operational transport requirements, there would be regular road deliveries to the site. However, there would be no need for the frequent delivery of large quantities of supplies

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[170] The Waste Strategy for England 2007, p.18. Available at: http://www.official-documents.gov.uk/document/cm70/7086/7086.pdf.

[171] For example, the Landfill (England and Wales) Regulations 2002; the Hazardous Waste (England and Wales) Regulations 2005; and the List of Wastes (England) Regulations 2005.

(such as fuel – see paragraph 2.17) or the shipment off site of large waste volumes. As a result, there would be no major addition to existing commercial traffic. The resulting increase to local noise levels would consequently be small, and similar to (or smaller than) those of any other large electricity-generating station.

7.15 Most of the permanent workforce would probably commute to the site using private vehicles. However, shift-working arrangements would result in the staggering of these movements, diminishing the impact. As necessary, travel plans could be established in order to minimise the impact on the environment of the journeys of employees and third parties. It should also be noted that any project would invariably undergo a design and access analysis which is likely to include a "travel plan" [172], as part of the development consent process.[173]

7.16 An additional itinerant workforce would be needed periodically (about every 12 to 24 months) for reactor outages (for approximately 1 – 2 months). This workforce would comprise around 800 extra staff, although the numbers would vary at different outages. Again, the effects of transport could be mitigated where possible, using experience from similar projects to ensure no significant impacts. These mitigation measures might include the site travel plan and the use of designated advisory routes.

Air Quality

7.17 Operation of the Proposed Practice would result in no significant effects on air quality. Unlike fossil fired plants, there would be no significant emissions of air pollutants such as CO_2, SO_x, NO_x or airborne particulate matter.

7.18 Whilst ancillary equipment such as auxiliary boilers and emergency diesel generators might lead to some minor emissions, they would generally be operated intermittently, and only then within the conditions of an Environmental Permit required under the Environmental Permitting (England and Wales) Regulations 2010. A requirement for the adoption of Best Available Techniques ("BAT") would be applied to mitigate any potential impacts in accordance with this regime.

7.19 The main source of emissions is expected to be the diesel generators, which are only required to operate in certain very infrequent events. However, it is important that they operate reliably when needed. In order to confirm this reliability, they are regularly tested by starting and running them for a short period - typically monthly for around an hour. In addition, auxiliary boilers are operated during the plant outage.

7.20 As an example of light fuel oil consumption at a nuclear power station, for the planned third unit at Loviisa (a nuclear site in Finland), it was estimated that the annual light fuel oil consumption would total around 1200 tonnes per year[174]. Assuming a sulphur content of, at most, 0.1% results in emissions of around 4000 tonnes of carbon dioxide, 0.7 tonnes of sulphur dioxide, 4 tonnes of nitrogen oxide and 0.5 tonnes of particulate matter.

7.21 Low level radioactive waste, such as contaminated oil, might be incinerated on site to reduce radioactive waste volumes (see Chapter 6). However, this is only assumed to be an option that could be utilised if determined to be the Best Available Technique for that plant and site, and volumes incinerated would be small. The non-radioactive emissions from incineration of, for example, light contaminated oils are considered to be covered by the above mentioned estimates, since these would be small in comparison to the 1200 tonnes of light fuel oil used per year. The radioactive discharges are addressed in Chapter 5.

7.22 Against this background, and on the basis of past experience with existing nuclear plants, there can be confidence that all the necessary air quality standards would be met, and any environmental impacts would be small.

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[172] EN-1 requires that a travel plan is submitted with a DCO application where appropriate.

[173] Nuclear power plant projects require a "Development Consent Order", the application for which must comply with the Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009. Regulation 5(2)(q) requires this to include all documents "necessary to support the application" and the Planning Inspectorate's "Advice note six: Preparation and submission of application documents" provides a "design and access statement" as an example of such a document.

[174] Environmental Impact Assessment Report, Supplementing the Loviisa Nuclear Power Plant with a third unit, Fortum Power and Heat Oy, 2007.

Aquatic Environment

7.23 This section addresses the possible impacts that will arise from the use of cooling water during the operation of the Proposed Practice.

7.24 Large volumes of water are already abstracted from UK rivers and transitional and coastal waters for electricity generating purposes, whether by fossil-fired or nuclear power stations. The water abstracted is passed through the condenser where the water temperature is increased. The abstracted water is then returned to its source at a temperature above ambient water temperature, leading to localised increases of water temperature.

7.25 The amount of cooling water needed for the Proposed Practice would depend on whether direct water cooling or cooling towers were used. The former is the most efficient form of cooling and would require approximately 40 m^3/s of cooling water for every 1000 megawatts of electricity generated. This volume is broadly similar to that required for other forms of steam cycle electricity generation.

7.26 In addition, the installation of cooling water (and in fact any other) infrastructure in the marine environment in connection with the Proposed Practice will require assessment and licensing under Part 4 of the Marine and Coastal Access Act 2009. The potential environmental impacts of the infrastructure will be assessed before such a licence is granted, and this will invariably impose conditions which will be monitored so as to adequately mitigate those potential environmental impacts[175].

7.27 The potential effects of water abstraction and discharges on marine life are well known and can be considered under the following categories, detailed below:

- Thermal effects;
- Chemical effects, due to biocide treatment of the cooling water; and
- Impingement and entrainment of marine organisms.

7.28 The use of cooling towers would lead to different effects. These are described separately below.

7.29 In addition to the use of water for cooling purposes, water might be abstracted for other purposes. Water will be used, for example, for process water, tap water and to supply fire fighting systems.

Thermal Effects

7.30 Thermal discharges cause the temperature of the receiving water to rise slightly, resulting in a range of direct and indirect effects on the environment. In certain circumstances, these can cause death or damage to some organisms, stimulation of productivity, and a reduction of dissolved oxygen concentrations. In certain circumstances, a long-term temperature rise could also lead to changes to the species mix (for example, encouraging more species native to warmer areas).

7.31 Discharges which arise during both the construction and operation of the power station will be regulated under the Environmental Permitting (England and Wales) Regulations 2010 by the Environment Agency ("EA") in England and by Natural Resources Wales ("NRW") in Wales. Any permits issued will allow EA/NRW to impose conditions or limits, for example, in relation to temperature and flow.

7.32 Following guidance issued by the Department for the Environment, Food and Rural Affairs ("Defra"), temperature rises caused by power stations will be assessed against draft Water Framework Directive standards published by UK Technical Advisory Group 29 (2008)[176] on the requirements for coastal and transitional waters to have good ecological status. In addition to draft standards on absolute temperature, there are additional requirements in draft standards specifying that, outside the mixing zone, a maximum temperature uplift relative to background

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[175] For example, see the detailed list of environmental conditions imposed on the Marine Licence by the MMO for the Hinkley Point C nuclear project: http://www.marinemanagement.org.uk/licensing/public_register/cases/documents/hinkleypointc/marinelicence.pdf.

[176] UK Technical Advisory Group on the Water Framework Directive, UK Environmental Standards and Conditions, Final Report. April 2008.

(ΔT) of +3°C is allowable, except for waters of high ecological status, where a 2°C uplift limit is proposed.

7.33 The direct water cooling arrangements deployed by the Proposed Practice would be similar to those of existing nuclear stations and those which are the subject of the 2010 Justification Decisions. As with existing nuclear stations, cooling water intake and discharge would be routinely monitored by plant staff to ensure that the discharge of cooling water was managed within the limits set by the EA/NRW in the Environmental Permit, or Scottish Environment Protection Agency (SEPA), in the case of authorisation.

Chemical Effects

7.34 The Proposed Practice could also result in chemical effects as a result of the need to dose the cooling water with a biocide to prevent the growth of marine organisms, such as mussels and algae, which might otherwise impede the operation of the cooling water system. Low level chlorination (by sodium hypochlorite injection) would likely be the method used.

7.35 Since any dosing regime for new plant would benefit from existing operational experience, and would be subject to the application of BAT, there should be no significant release of residual biocide within the cooling water discharges that would have significant impact on the receiving waters.

Effects on Marine Organisms

7.36 There are two types of impact associated with abstraction on coastal plant. The first, impingement, is where organisms are drawn into the plant and then become impinged upon screens. The second, entrainment, is where organisms are drawn into the plant and, due to their small size, pass through the subsequent systems before being expelled to sea.

7.37 In direct cooled power stations, water is pumped into the stations via large diameter intakes which remove water from a sufficient depth to avoid reentraining the more superficial, buoyant, tidally oscillating thermal plume, and to protect fish. In this context the intake structures and water intake velocity are key factors, and these are determined by site-specific characteristics.

7.38 Estimated annual total quantities of fish impinged at current UK estuarine and coastal power stations are given in the table[177] below. Another source[178] provides the following estimates on numbers of fish impinged:

Station	Net electrical capacity [MW]	Annual total catch [Tonnes]	Specific catch [kg/10^6 m^3]
Wylfa	480	2.4	5
Hinkley B	1300	24	31
Fawley	2000	6.4	19
Dungeness A	410	93	190
Dungeness B	1200	20.6	40
Sizewell	480	43	73
Kingsnorth	2000	6.6	4.4
Dunkirk	600	13	19
Gravelines	5400	240	48

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[177] Using water well? Studies of power stations and the aquatic environment, Turnpenny and Coughlan, Innogy plc, 2003.

[178] Technical Evaluation of US Environmental Protection Agency Proposed Cooling Water Intake Regulations for New Facilities, Pisces Conservation Ltd, Prepared by Drs P. A. Henderson and R. M. H. Seaby, November 2000.

Power Station	Pumping rate (m^3s^{-1})	Pumping rate Gallons per day	Impingement Numbers per annum
Hinkley	30	6.85E+08	9.27E+05
West Thurrock	50	1.14E+09	1.76E+07
Sizewell A	34.2	7.81E+08	3.73E+06
Wylfa	68	1.55E+09	3.98E+04
Fawley	50	1.14E+09	6.00E+05
Oldbury	26.5	6.05E+08	1.76E+06
Heysham	30	6.85E+08	7.70E+05
Dungeness B	42.4	9.68E+08	1.10E+06
Hartlepool	40	9.13E+08	4.82E+06
Kingsnorth	64	1.46E+09	9.93E+05
Torness	50	1.14E+09	2.18E+04
Coolkeeragh	11.5	2.62E+08	1.73E+04
Ballylumford	29.4	6.71E+08	1.04E+05
Kilroot	16.6	3.79E+08	1.11E+05
Belfast West	9.1	2.08E+08	1.51E+04
Gravelines	240	5.48E+09	2.16E+08
Dunkerque	21.2	4.84E+08	6.20E+05
Paluel	86	1.96E+09	1.35E+08

7.39 A wide range of technologies is in common use for fish deterrents and fish screening. The choice of technology and design for new nuclear power stations would be chosen on the basis of operating experience at existing power stations both in the UK and abroad, appropriate expertise in fish protection and the latest available regulatory guidance[179]. As a result, the impacts on fish and other marine fauna would be mitigated.

Cooling Towers

7.40 If cooling towers were used, there would be a potential environmental issue relating to the emission of bacteria within the plume from the tower. However, the mechanisms of bacteria growth in cooling tower systems are well understood, and methods for prevention of bacteria growth and dispersion are available.

7.41 The design and operation of any cooling towers required for the Proposed Practice would be based on the lessons learned from past operating experience, and would follow similar guidelines[180]. As a result, the majority of environmental impacts would be mitigated or unlikely to occur. This could be achieved through the appropriate use of technology, such as hybrid cooling towers with plume abatement. It is likely that there would be significant visual impacts, but not to the extent that they would be unacceptable against the character of the surrounding landscape. Such impacts would be assessed and regulated as part of the development consent process. In particular, the Nuclear National Policy Statement (EN-6) confirms that proponents of new nuclear projects would be required to justify the use of large natural draught cooling towers before they were permitted[181]:

> *"Cooling towers may increase a nuclear power station's visual impact on the landscape. Paragraph 5.9.4. of EN-1 sets out that the IPC should expect the applicant to justify the use of a natural draft cooling system given that the towers are very large and can emit significant steam plumes".*

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[179] For example, the Environment Agency June 2010 paper entitled 'Cooling Water Options for the New Generation of Nuclear Power Stations in the UK', SC070015/SR3.

[180] Integrated Pollution Prevention and Control (IPPC) Reference Document on the application of Best Available Techniques to Industrial Cooling Systems, December 2001, European Commission.

[181] EN-6, Volume 1, paragraph 3.10.4.

Chemicals

7.42 In order to prevent bio-fouling occurring within the cooling water system, it is envisaged that there would be a requirement to chlorinate the cooling water discharge. This could lead to the discharge of chlorinated breakdown products, referred to as Total Residual Oxidant ("TRO"), in the marine environment. The chlorination regime and the discharge standards for TRO would be controlled in accordance with the conditions and limits set out in the operational Environmental Permit. Therefore, it is not expected that there would be any significant environmental impact. Whilst there would be a requirement to store and use various chemicals on-site for operational purposes, such as water treatment processes, these would not be released into any permitted discharges. In addition, any chemical handling would be undertaken in accordance with the Control of Substances Hazardous to Health ("CoSHH") Regulations 2002, thereby controlling exposure to chemicals and protecting workers' health.

7.43 Discharges which arise during both the construction and operation of the power station will be regulated under the Environmental Permitting (England and Wales) Regulations 2010 by EA/NRW.

Noise and Vibration

7.44 The design of the buildings and plant would ensure that the continuous operating noise from the Proposed Practice would be minimal and would represent only a small addition to the existing background level. Whilst some additional noise might result from the intermittent operation of ancillary equipment, such as steam vents and auxiliary diesel generators, these systems would only be operated infrequently under abnormal conditions. Noise control during the operation of the power station would be subject to conditions and limitations specified within the Environmental Permit.

Light

7.45 In addition to any street lighting, the outside perimeter of the plant site would require some security lighting. Environmental effects would be mitigated by ensuring that lighting was correctly positioned, directed downwards rather than upwards, and that no unnecessary lighting was used. As a result, environmental effects would be small.

Landscape and Visual Effects

7.46 Land usage for the operational site would be in the range of 50 -70 hectares, broadly comparable to large scale coal and gas-fired electricity generating plants. There would be no demand for large storage areas.

7.47 Visual impacts could be expected from large structures such as the reactor building, chimney and transmission lines. The largest effect would be from cooling towers (discussed above), if they were used, which could cause visible plume formation. This could result in effects on the landscape, as a result of visible plume, similar to any conventional thermal power station.

7.48 Since transmission lines would be required by all centralised generating plant, and would have similar impact, they are not considered in this application. If located at an existing power station site, a new nuclear power station using the proposed technology may not necessarily require new transmission lines. Installation of any new lines, where required, would be subject to approval under the requirements of the Planning Act 2008 for Nationally Significant Infrastructure Projects. There may also be a requirement for development, subject to planning control by the local planning authority under the Town and Country Planning Act 1990, for example, for new sub-stations.

7.49 The landscape and visual effects of the Proposed Practice would be mitigated in the light of experience from past projects. Visual impacts would be minimised, for example, by ensuring that the design followed the relevant guidelines[182].

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[182] Guidelines for Landscape and Visual Impact Assessment, Landscape Institute and Institute for Environmental Assessment 2002.

Environmental Impacts During Plant construction

7.50 The construction of a nuclear power plant takes several years and involves a large workforce during this period. Some examples of the possible scale for the construction period are given below. Environmental impacts caused by both the construction and the operation of a nuclear power plant would be addressed together under the UK's environmental protection development consent regimes.

Habitat and Species Protection

7.51 Like many other large infrastructure projects, the development of a nuclear power plant could potentially impact on sensitive species and habitats.

7.52 The impacts on species and habitats from the Proposed Practice will depend primarily on the sites where new nuclear power plants are deployed. This potential impact was assessed in the Strategic Environmental Assessment undertaken during the preparation of the Nuclear National Policy Statement (EN-6), which identified potentially suitable nuclear new build sites. In particular, the Nuclear NPS noted that development of the NPS designated sites had the potential to cause significant effects on protected European sites (i.e. Special Area of Conservation ("SAC") or a Special Protection Area ("SPA")) and that further consideration would need to be given to the potential effects when applications are made for specific developments. This consideration takes place under the Conservation of Habitats and Species Regulations 2010 (the "Habitats Regulations")[183], which transpose the requirements of the Habitats Directive 92/43/EEC[184]. The Habitats Regulations require the decision-making authority to make an appropriate assessment of the likely significant effects on the protected European sites, in view of the site's conservation objectives, before deciding whether to authorise the development of a new nuclear power station. The developer is required to provide sufficient information (including in relation to avoidance and mitigation measures) in order for the appropriate assessment to be made.

Traffic, Transport and Laydown

7.53 All large construction projects require people and material to be brought to the site, resulting in greater traffic and workforce movements than during operation. Additional space ('lay down areas') is required, although this can be restored after construction to a standard agreed as part of any planning consent.

7.54 As with any major infrastructure construction project, there will be a significant number of lorry and staff movements to the site. The table below identifies the estimated bulk construction material and the number of vehicle movements required for the Hinkley Point C project (the construction of two EPR™ units) as stated in the the Freight Management Strategy recently approved by the Secretary of State[185]:

Unit 1 & 2	Weight (T)	No. vehicles
Site works	1,335,136	88,250
Civil construction	3,157,080	120,383
Installation	300,000	47,100
SF store & ILW store	373,036	8,290
Site wastes	242,000	21,084

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[183] The Habitats Regulations 2010 available at http://www.legislation.gov.uk/uksi/2010/490/contents/made.

[184] The Habitats Directive 92/43/EEC available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:NOT.

[185] See Table 7.1 of Appendix 3.7 of EdF. Transport Assessment – Annex 7 to Environmental Statement. Available at: http://infrastructure.planningportal.gov.uk/wp-content/ipc/uploads/projects/EN010001/2.%20Post-Submission/Application%20Documents/Environmental%20Statement/4.19%20-%20Annex%207%20-%20Transport%20Assessment/4.19%20-%20Annex%207%20-%20Transport%20Assessment.pdf.

7.55 The design and access statement presented by the developers of the Hinkley Point C nuclear project in England estimated the peak construction workforce to be around 5,600 workers[186]. The Transport Assessment for the project included a solution to mitigate the transport impacts of this workforce through a combination of shift management, on-site accommodation, park and ride bus services, walking, cycling and travel plans[187].

7.56 For Hinkley Point C, the draft Freight Management Strategy estimated *"the number of HGVs at peak construction in 2016/17 is approximately 230 vehicles per day in a single direction[188]"*. If a temporary jetty is used then the total number of HGV movements for the construction phase will be 290,000, a reduction of 140 vehicles per day.

7.57 In common with the Hinkley Point project, these types of impacts will be addressed during the consenting process for any site-specific deployment of the Proposed Practice. Relevant conditions (for example, use of travel plans and advisory routes, as were agreed for Hinkley Point C) may be incorporated as conditions of the Development Consent Order, and management systems will be employed to ensure compliance with these conditions.

Noise

7.58 Noise levels are presented using the decibel unit (dB). Examples of noise levels of different sounds are listed below.[189]

Noise Source	Sound Pressure level in dB
30m from a military jet aircraft take off	140
Passing heavy goods vehicle at 7m	90
Business office	60
Normal conversation at 1m	55
Remote country location without any identifiable sound	20

7.59 During the construction stages, there are different sources of noise, for example, power tools and heavy mobile equipment, including trucks, bulldozers and front-end loaders.

7.60 At this stage, it is not possible to state definitively what the noise impact from the construction of the proposed plant would be at residential locations, and it is anticipated that it would be managed under the 'prior consent process' under section 61 of the Control of Pollution Act 1974.

7.61 For example predictions of noise levels during construction for the proposed Hinkley Point C station are below 70 dB during daytime at the closest residential location to the site[190].

7.62 Construction noise would be the subject of restrictions imposed through Development Consent Order conditions to the extent that this was identified as necessary by planning authorities.

Air Quality

7.63 The influence of construction on air quality is dependent upon the number of movements, construction activities, the composition of traffic flows and how existing traffic flows are affected. The air quality effects would need to be assessed as part of the detailed planning consent for the sites and included in the air quality chapters of the EIAs.

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[186] Draft Overview of Hinkley Point C Construction, February 2011.

[187] EdF. Transport Assessment – Annex 7 to Environmental Statement.

[188] Draft Freight Management Strategy, February 2011.

[189] "Horizontal Guidance for Noise, Part 2 – Noise Assessment and Control", IPPC H3, Environment Agency, June 2004, section 1.2.1.

[190] Volume 2, Hinkley Point C – Chapter 11 Noise and Vibration, October 2011.

7.64 Appropriate mitigation measures could be used to reduce the impact of construction, such as those proposed within the Air Quality Management Plan for Hinkley Point C. Examples include control measures for emissions from plant and equipment, dust, and particulate and odours[191].

Conventional Waste

7.65 During the construction of the third unit at Olkiluoto in Finland, the most conventional waste created in one year (2009) was 12,567 tonnes. Of this waste over 85% was recyclable.[192] Whilst this reactor is an EPR™ design rather than the UK ABWR, this gives a good example of the amount of waste generated by a large nuclear project.

Plant decommissioning

7.66 Essentially, the decommissioning of a nuclear plant is the reverse of its construction - the materials brought to the site will be disassembled, ensuring that all the waste products, both radioactive and non-radioactive, are safely managed. Please note that this section only deals with environmental impacts and further information on decommissioning can be found in Chapter 6.

Regulation

7.67 Decommissioning a nuclear station is covered by analogous UK regulatory processes to those applied for its construction, with the result that environmental impacts are controlled. In particular, the Nuclear Installations Act 1965 provides that a licensed nuclear operator retains the responsibility to ensure the safety of a nuclear site until such time as it presents no risks relating to ionising radiation (unless another person assumes this responsibility as a successor licensee), even after the revocation or surrender of a licence. This enduring responsibility, combined with mandatory nuclear site licence condition obligations to maintain preparedness for, and implement, decommissioning, will ensure that the safe decommissioning of all plant will be achieved.

Environmental Impact Assessment

7.68 Before decommissioning or dismantling of a nuclear reactor or power station can take place, a licensee must apply to the Office for Nuclear Regulation ("ONR") for approval of a decommissioning plan, which must first undergo EIA pursuant to the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 as amended ("EIADR"). The environmental statement that is required to be prepared under the EIADR process is required to assess similar environmental impacts to those assessed during the EIA process for the construction of a nuclear plant (for example, those relating to air quality and dust, noise and vibration, socio-economic factors, surface water, traffic and transport and radioactive discharges). This EIADR process will ensure that all potential environmental impacts are identified and adequately mitigated before a decommissioning plan is implemented.

Transport

7.69 A similar number of transport movements are required for the decommissioning of a plant as during construction. However, their phasing would depend on the timeframe over which decommissioning is completed, which is usually longer than that for construction. Vehicle movements, for example, might be higher at the beginning (for removal of spent fuel) and again at the end when buildings will be demolished. Staff requirements in general will be lower during decommissioning than during operation, and there will be no regular requirement for additional staff during outages. As a result, it can be assumed that potential environmental impacts will lie somewhere between the operation and construction impacts. For the majority of the time, environmental impacts will be lower or comparable to normal operations, and only at the last stage of decommissioning will they be comparable to the construction period.

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[191] Environmental Statement - Annex 3, Hinkley Point C Development Site. Environmental Management and Monitoring Plans (page 7-10).

[192] TVO – Environmental Report 2012 – available at http://www.tvo.fi/uploads/File/2013/Ymparistoraportti_ENG_sivuina.pdf.

Decommissioning Conclusion

7.70 Experience on the Magnox units, for which consent to start decommissioning has been granted by the ONR, leads to the conclusion that the environmental benefits would far outweigh the detriments. This is further assured through the requirement to develop an environmental management plan, including mitigation measures, report on their implementation and effectiveness, and providing for changes to such measures in the light of experience. It is therefore concluded that there is substantial experience to demonstrate that the decommissioning of a nuclear power station presents a very low environmental detriment.

Conclusion

7.71 The above analysis, which has been undertaken on the basis of past experience, use of available standards and application of legal requirements, shows that the various types of potential environmental impact of the Proposed Practice, both individually and in aggregate, would be acceptable. Most impacts would be comparable with those of any major infrastructure construction project, and would be adequately prevented or mitigated through the UK's existing comprehensive development and environmental regulatory regimes.

EIGHT

OTHER POTENTIAL DETRIMENTS

OTHER CONSIDERATIONS

EIGHT

Other Potential Detriments
Other Considerations

The wider impacts resulting from the adoption of the Proposed Practice would result in no significant detriments.

There would be no material change to existing very small proliferation risks.

Station structural resilience, shielding and comprehensive security measures also ensure that they are at low risk from malicious and terrorist acts.

Stringent health and safety standards would continue to provide a safe workplace, and the risk of industrial accident would be very low.

Stations would be protected against the effects of climate change.

The risks of detriment from a severe accident, even following an extreme event, would be very low.

Introduction

8.1 This Chapter considers other potential detriments that might result from adoption of the Proposed Practice involving the UK ABWR. The following detriments are examined in the sections below:

- Non-Proliferation;
- Security;
- Industrial Safety;
- Climate Change Impacts; and
- Extreme Events and Severe Accidents.

8.2 The principal changes since our 2008 Application are:

- The addition of consideration of the factors that lead us to conclude that the risk of significant detriment from extreme events remains low, even in the light of Fukushima; and
- A general update of the information provided in relation to the other detriments that we consider in this Chapter.

Non-Proliferation

8.3 The potential for the proliferation of nuclear weapons from the deployment of civil nuclear power stations arises from the fact that certain materials used in, or arising from, nuclear power could, if diverted from peaceful use, be processed for use in the manufacture of nuclear weapons. However, an effective regulatory framework is already in place to prevent any such diversion from the UK's existing nuclear fleet, and a new programme of nuclear power stations including the Proposed Practice would not materially change the existing, very low, proliferation risk. There would be major technical difficulties involved in obtaining weapons-grade material from UK ABWR irradiated fuel. As noted by the Sustainable Development Commission ("SDC")[193] before it was closed in 2011, the safeguards measures that are in place have been effective throughout the decades-long operation of the UK civil nuclear industry in ensuring that materials diversion has not taken place. More recently in 2012, OECD-NEA stated in their overview of nuclear energy [194] that:

> *"To date, national and international controls on nuclear materials and key technologies have largely succeeded in preventing the proliferation of nuclear weapons".*

8.4 The cornerstone of international efforts to prevent the spread of nuclear weapons is the Nuclear Non-Proliferation Treaty ("NPT")[195] and the associated safeguards provided by the verification regime of the International Atomic Energy Agency ("IAEA").

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[193] Sustainable Development Commission. The role of nuclear power in a low carbon economy - Paper 6: Safety and security. This is an evidence-based report by the SDC with contributions from Large & Associates and AMEC NNC, March 2006. Available at: http://www.sd-commission.org.uk/publications/downloads/Nuclear-paper6- SafetyandSecurity.pdf.

[194] Nuclear Energy Today, 2nd Edition 2012, http://www.oecd-nea.org/pub/nuclearenergytoday/6885-nuclear-energy-today.pdf.

[195] Treaty on the Non-Proliferation of Nuclear Weapons. IAEA INFCIRC/140, 1970.

8.5 The NPT's main objective is that states have a right of access to the peaceful use of nuclear power in return for accepting that they will not use such programmes to work towards developing nuclear weapons. In addition, the nuclear weapons states (including the UK) have agreed to pursue negotiations in good faith towards nuclear disarmament.

8.6 The UK is a Depository Power for the NPT, has IAEA safeguards on its civil facilities and has implemented additional IAEA safeguards measures via the Nuclear Safeguards Act 2000. Furthermore, the UK is also subject to European safeguards as laid out in the Euratom Treaty[196]. This treaty also includes independent verification measures to ensure that nuclear material is not diverted from peaceful use.

8.7 Any new nuclear power stations built in the UK, including any using UK ABWR technology, would be subject to these IAEA and European Commission safeguards measures, which have been effective internationally in verifying a wide range of reactors and associated fuel cycle plants over many years. Nuclear new build based on the introduction of modern designed, light water cooled reactors (including the UK ABWR) would present no new issues of principle.

8.8 Any new nuclear power station would provide interim facilities for spent fuel to be stored. These reactors and their associated on-site fuel storage would not present any technological challenge to safeguards verification.

8.9 Plutonium or highly enriched uranium is required to construct nuclear weapons. Extracting plutonium from irradiated fuel from nuclear power plants is difficult, and the fuel elements used in modern commercial light water reactors would not be a good source material for a weapons-related enrichment facility. The reactors use low enriched fuel, and are operated to maximise the value of the nuclear fuel. It is physically impossible to create a nuclear explosion from fissile material of such low enrichment; neither new nor irradiated fuel is weapons-grade material.

8.10 The Government's continued commitment to this effective regulatory framework was confirmed in its March 2013 Long-term Nuclear Energy Strategy[197]:

> *"The UK is a signatory and an active participant to a number of international treaties and agreements on the non-proliferation of nuclear technologies and resources. The UK takes its responsibilities under such agreements very seriously and it is highly unlikely that this will diminish in the future. Indeed as new technologies and fuel cycles are developed, the focus on non-proliferation is likely to increase further."*

8.11 The paragraphs above show that any additional risks of proliferation resulting from the Proposed Practice are very small. Any associated detriment is therefore also very small. The Government stated in its White Paper on Nuclear Power[198] that:

> *"The Government continues to believe that new nuclear power stations would pose very small risks to safety, security, health and proliferation. We also believe that the UK has an effective regulatory framework that ensures that these risks are minimised and sensibly managed by industry."*

Security

8.12 New nuclear power stations, like the UK's existing nuclear fleet and other major infrastructure installations, could be potential targets for terrorist attacks or other malicious acts because of the perceived impacts on health and the economy and the publicity they would attract. The following sections consider the security measures in place to minimise this risk, and describe the inherent design features of nuclear power plant that would mitigate the consequences were an attack to take place. They demonstrate that potential security-related detriment from the Proposed Practice is very small.

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[196] Treaty establishing the European Atomic Energy Community.

[197] HM Government. Long-term Nuclear Energy Strategy. March 2013, page 6.

[198] A White Paper on Nuclear Power, Cm 7296, January 2008. http://webarchive.nationalarchives.gov.uk/20100512172052/http://www.decc.gov.uk/media/viewfile.ashx?filepath=what we do/uk energy supply/energy mix/nuclear/whitepaper08/file43006.pdf&filetype=4.

Security Measures and Regulatory Framework

8.13 Security measures for nuclear power plants in the UK are regulated under the Nuclear Industries Security Regulations (2003) (SI 2003. No 403). These regulations are applicable to the whole of the nuclear industry and make provision for the protection of nuclear material and other radiological material ("ORM"), both on sites and in transit, against the risks of theft and sabotage, and for the protection of sensitive nuclear information, such as site security arrangements and sensitive areas of plant. Consequently, each site licensee is required to develop and implement a Nuclear Site Security Plan ("NSSP") to ensure the security of its site.

These plans are subject to the scrutiny and approval of an independent security regulator, the Office for Nuclear Regulation - Civil Nuclear Security ("ONR – CNS"), which is part of the ONR.

8.14 The comprehensive measures required include not just the physical aspects of the security regime (access control, alarms, CCTV, etc.) but armed response requirements and processes to ensure the reliability of staff and contractors to protect against the possibility of 'insider threat' and the security of computer systems. All are subject to prior approval, independent review and audit by ONR-CNS.

8.15 In addition to deploying a well trained guard force, the UK is unique in having a dedicated armed Constabulary (the "Civil Nuclear Constabulary or "CNC") that is accountable for providing the necessary armed response at nuclear facilities, including the generating stations, and for certain nuclear materials in transit. It is managed by the Civil Nuclear Police Authority ("CNPA") and is independently audited and reviewed by Her Majesty's Inspectorate of Constabulary ("HMIC"). The roles and responsibilities of the CNC are defined in the Energy Act 2004.

8.16 Staff, contractors and CNC officers with access to nuclear sites are required to undergo security checks to a level which is dependent on the nature of their work. The assessment of individuals' reliability is an ongoing process. This assists in the provision of a level of protection against infiltration threats and insider threats.

8.17 Nuclear site licensees are under a legal requirement to undertake emergency exercises that demonstrate their ability to implement satisfactory contingency plans. Licensees must also exercise their security and counter-terrorist arrangements to the satisfaction of ONR-CNS.

8.18 More generally, operators and the regulator review security measures in line with current threat assessments, and the ONR-CNS regularly inspects sites to ensure that the security arrangements detailed in security plans are being followed.

8.19 Against this background, as noted in the ONR's report to the Secretary of State for Energy and Climate Change[199], the ONR believes that the security risks associated with nuclear power stations can be appropriately managed. The Deputy Chief Inspector (Civil Nuclear Security) states:

> *"I can report that in the 12 months from 1 April 2011 to 31 March 2012, I have been satisfied with the standards, procedures and commitment with regards to security in the civil nuclear industry."*

8.20 Furthermore the Government invited nuclear security experts from the IAEA International Physical Protection Advisory Service (IPPAS) Mission to assess civil nuclear security arrangements in the UK. The mission visit took place in October 2011 and its objectives included assessment of the UK's legal and regulatory framework on the physical protection of nuclear material and nuclear facilities and its compliance with IAEA guidelines. The IAEA concluded the state of civil nuclear security is sufficiently robust, including the legal and regulatory framework[200].

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[199] The state of security in the civil nuclear industry and the effectiveness of security regulation, report to the Secretary of State for Energy and Climate Change, April 2011 – March 2012: http://www.hse.gov.uk/nuclear/documents/cn-security-annual-review.pdf.

[200] This mission is reported in the annual report on the state of security in the civil nuclear industry to the Secretary of State for Energy and Climate Change, April 2011 – March 2012. The mission is also reported in a press release from the Department of Energy and Climate Change that can be found at: https://www.gov.uk/government/news/nuclear-security-mission-to-sellafield-and-barrow-completed. This notes that the Mission Team's work resulted in a 'CONFIDENTIAL' report that contains site-specific information and, for reasons of national security, cannot be made publicly available.

8.21 Additionally, the Government has enacted legislation to provide additional protection beyond the substantial provisions described above. The Terrorism Act 2006 contains provisions which enable the UK to ratify the UN Convention for the Suppression of Acts of Nuclear Terrorism, which the UK signed in September 2005. The Terrorism Act 2006 makes it an offence to utilise radioactive materials or facilities for terrorist purposes. The Anti-Terrorism, Crime and Security Act 2001 provides for sanctions against the unauthorised disclosure of sensitive information on the security of nuclear sites, nuclear material and proliferation-sensitive nuclear technology.

8.22 The security regulatory framework is continuing development towards a goal setting, outcomes based and performance measurement approach. The first step has been the production of a National Objectives, Requirements and Model Standards (NORMS) document. This places greater onus on operators to propose and justify security arrangements that meet ONR defined security objectives.

Physical Protection and Design Features

8.23 The potential vulnerability of nuclear power stations to terrorists or other malicious threats is further reduced by the same design features that provide high levels of protection against the effects of postulated incidents and accidents. The same features that safeguard people and the environment from a radiation release also help defend the station from malicious threats.

8.24 Modern reactors are protected by massive structures and are designed to safely withstand extreme events, both natural and man-made. Their structural resilience to earthquakes and the thickness of their shielding make them extremely robust.

8.25 After the attacks of 11 September 2001, a detailed study[201] was undertaken of the possible impact of a commercial aircraft on US nuclear facilities, including reactor buildings and spent fuel ponds. The study concluded that the structures that house the nuclear fuel are robust and would protect the fuel from the impact of such aircraft. For new nuclear plants, even more structural resilience than that of operating plants is expected: this is identified in Annex 1 for UK ABWR.

8.26 Reactor fuel is made of ceramic pellets that are difficult to fragment and require strong nitric acid to dissolve. The pellets are highly durable, neither explosive nor volatile and are not easily broken up into breathable particles. They are enclosed in metal casings that are necessarily extremely strong and corrosion resistant to survive intact in the high temperatures and pressures of a reactor core. The reactor core, with its extensive steel and concrete shields, further protects the fuel.

8.27 Once removed from the reactor, the highly radioactive nature of the spent fuel means that specialised handling equipment is required. Outside the reactor buildings, this necessitates the transport of the fuel in very robust containers weighing over 100 tonnes. Accordingly, the risks of theft of spent fuel are very low.

8.28 In addition to their physical robustness, nuclear reactors are protected by extensive safety systems. The “defence in depth” concept applied to the design of safety systems means that it is unrealistic to be able to defeat or damage sufficient systems to bring about a significant release of radioactivity. Nonetheless, emergency arrangements are in place, and exercised, to make dynamic decisions if it is appropriate and safe to do so in relation to the immediate shut down of reactors in the event of a heightened terrorist threat against them.

Dirty Bombs

8.29 A “dirty bomb” is a mix of conventional explosives with radioactive powder or pellets. When the explosives are detonated, the blast carries radioactive material into the surrounding area. In order to construct and detonate a dirty bomb, radioactive material must first be acquired. Such radioactive material could come from the radioactive sources used worldwide for medical purposes and in research applications, and material held within secure nuclear power stations within spent fuel or intermediate level waste does not add significantly to this risk. The same

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[201] http://www.nei.org/corporatesite/media/filefolder/EPRI_Nuclear_Plant_Structural_Study_2002.pdf.

design features and security measures that protect a nuclear power plant also ensure the security of radioactive materials from theft.

Conclusion

8.30 Accordingly it is concluded that there are effective security provisions in place to protect against terrorism and other malicious acts and that therefore any potential detriment associated with security risks is low.

Industrial Safety

8.31 The nuclear industry applies high standards to all aspects of worker health and safety, both in relation to radiation exposures and general industrial safety. WANO annually report worldwide trends in the nuclear power station industrial safety record. Figure 8.1[202] below shows steadily improving industrial safety performance that compares well to other industries. Against this background the potential industrial safety detriments relating to the Proposed Practice would be very low, and similar to or lower than those resulting from other major industrial infrastructure projects.

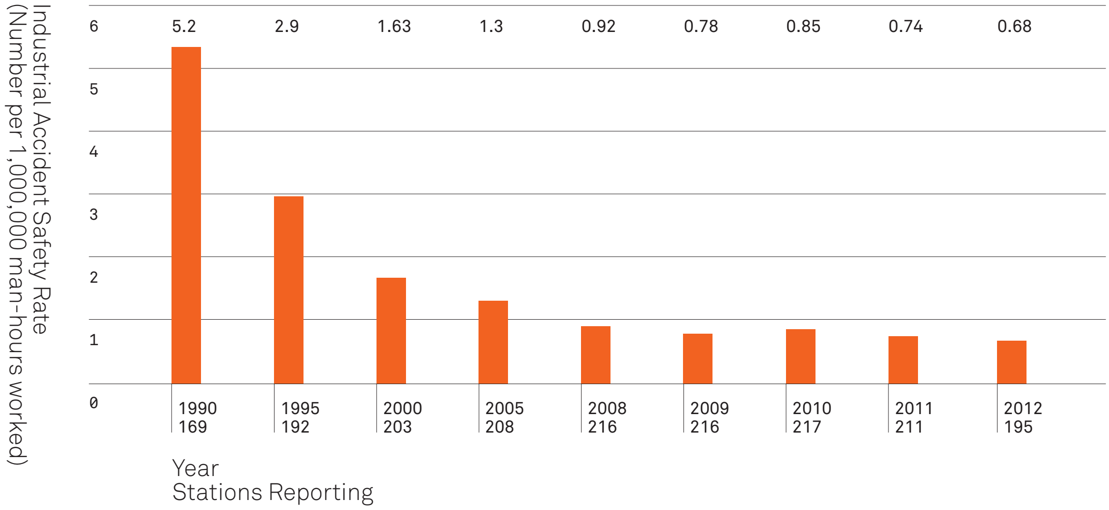

Figure 8.1 Industrial Safety Rate at Nuclear Power Stations as reported by WANO

Impacts of Climate Change

8.32 The siting of new nuclear power stations takes into account the implications of climate change, including the possibility of more severe weather patterns and rising sea levels in costal locations.

8.33 The Nuclear National Policy Statement (EN-6, Volume I) confirms that a flood risk assessment was undertaken as part of the Strategic Siting Assessment which identified the nuclear sites listed in that EN-6 as potentially suitable for new nuclear development[203]. The climate change risk assessment concluded that they “have the potential to be protected from the risks of flooding over their operational lifetime”. Any proposed development incorporating the Proposed Practice will need to incorporate climate change adaptation measures to take account of the effects of climate change, including: coastal erosion and increased likelihood of storm surge and rising sea levels; effects of higher temperatures; and increased risk of drought, which could lead to a lack of available process water. This section provides further discussion of ABWR capability.

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[202] From WANO Performance Indicators 2012 available at: http://www.wano.info/wp-content/uploads/2013/04/2012WANO-PI-eng_web-SP.pdf.

[203] Nuclear National Policy Statement (EN-6, Volume I), paragraph 3.6.3, and the SSA criteria in EN-6, Volume II.

Increases in severe weather

8.34 The ABWR design is highly robust, with substantial capability to withstand extreme events such as high temperature, and so scope for any detriment to arise from a more intense weather patterns is very small. This will be further confirmed for the UK ABWR initially through the GDA process[204] and then for site specific projects as part of permissioning under the nuclear site licence.

8.35 Regarding the impact of more severe weather predicted to occur in the UK, the range of effects of such weather is already within the range sustained by nuclear power stations elsewhere in the world.

Flooding

8.36 Developers of new nuclear power station projects in the UK are required to demonstrate that projects are consistent with both general flood risk policies applicable to energy projects in Section 5.7 of the Overarching National Policy Statement for Energy (EN-1), as well as the more conservative requirements for nuclear projects as set out in Section 3.6 of the Nuclear National Policy Statement (EN-6, Volume I) in order to be granted development consent. These require, in particular, that adaptation to potential increases in flooding in the future is possible.

8.37 The approach that would likely be taken by a nuclear operator when preparing an application for a DCO can be broadly summarised as follows[205]. The first step is to quantify the flood risk over the expected construction, operation and decommissioning period of the power station. Quantification is based on a conservative assessment. The second step is to ensure that the nuclear power station is properly protected. There are two approaches to providing flood risk protection. Either the power station is sited above the highest predicted water level or it is provided with purpose-built sea defences and other flood defences that are designed to resist predicted extreme water levels. Flood defences are not necessarily confined to engineered structures but may also include “soft” measures such as vegetated embankments as part of the local shoreline management plan.

8.38 Any UK ABWR station will need to include robust flood defence provisions as outlined above. These would ensure that any new power stations involving the Proposed Practice would be protected from any increase in flooding risks due to climate change. A UK ABWR power station would therefore be no more prone to flooding risk than operating or other new build reactors.

Regulatory Requirements

8.39 The UK has robust regulatory requirements to ensure that climate change impacts are considered and adequate provisions are made to assure the safety of nuclear power plant, including those in the relevant National Policy Statements, as set out above.

8.40 Nuclear operators are responsible for funding their own flood risk management and coastal protection defences and for ensuring they are compatible with other defences in the area. This obligation remains in force until operation has ceased, and waste in interim storage has been removed from the site. As part of this, nuclear operators have to cooperate with the relevant environmental regulators who have responsibility for flood risk management.

Predictions

8.41 A consistent understanding of potential climate change impacts for the UK is provided by UK Climate Projections[206]. Their projections are based on a methodology designed by the Met Office and reflect scientists’ best understanding of how the climate system operates, how

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[204] EN-6 confirms in Section 3.6 that “The GDA process looks at the capability of the power station’s generic design features to take into account the effects of climate change”.

[205] An example of the considerations taken by the nuclear regulators (both environmental and nuclear safety) in assessment of the approach for Hinkley Point C, can be seen in “External Hazards Assessment to Inform Nuclear Site Licensing of Hinkley Point C”, Office for Nuclear Regulation, Assessment Report: ONR-CNRP-AR-12-107, Revision 1, 14 December 2012. http://www.hse.gov.uk/nuclear/hinkley-point-c/assessment-reports.htm.

[206] http://ukclimateprojections.defra.gov.uk/.

it might change in the future, and allow a measure of the uncertainty in future climate projections to be included. UK Climate Projections is funded by Government (including the devolved administrations).

8.42 Operators also commission site specific studies where further detail is required to ensure that plant provisions are adequately defined to cope with potential impacts.

Development Consent

8.43 The Nuclear National Policy Statement (EN-6) and the Overarching National Policy Statement for Energy (EN-1) provide the primary basis for development consent decisions taken by the Secretary of State (advised by the Planning Inspectorate ("PINS")) on applications it receives for nuclear power stations.

8.44 As detailed above, these National Policy Statements explicitly require that an application for a Development Consent Order must include information as to how the development incorporates adaptation measures to take account of the effects of climate change. In assessing any proposed development, PINS would be advised as to the adequacy of the applicant's proposed measures by the relevant environmental regulator (the Environment Agency in England or Natural Resources Wales in Wales) and the Office for Nuclear Regulation ("ONR").

8.45 Accordingly, there are robust processes in place to ensure that any proposal to deploy the Proposed Practice would only proceed if the ability to safely withstand the impacts of climate change were demonstrated.

Nuclear Safety

8.46 The ONR expects operators to provide a high standard of protection against flood risk and other external hazards, to ensure that facilities can withstand predicted sea level rises and increased storm surges. Operators are required to review the level of protection required against all external hazards every ten years as part of the facility's Periodic Safety Review required pursuant to standard nuclear site licence conditions. Each review will take into account the most recent climate change projections, and provide the basis for any necessary enhancements to plant provisions and operating arrangements to be identified and implemented to maintain the safety of the plant to the end of its life. This regular scrutiny and review ensures that any changes in external hazards are identified, and any necessary further measures implemented.

Conclusion

8.47 As demonstrated above, the Proposed Practice presents no material climate change risks, and so will not affect the overall level of very low risk associated with the UK ABWR. Accordingly, any potential detriment associated with the effects of climate change is very low.

Considerations of Extreme Events and Severe Accidents

8.48 Since our 2008 Application, the 2011 Fukushima accident in Japan, resulting from a massive earthquake and tsunami, highlighted the potential for multi-unit nuclear power stations to be affected by extreme natural disasters and for a severe accident to adversely impact cooling and long term electrical power supplies.

8.49 Annex 5 provides more detailed information underlying our unchanged conclusion that the risk of significant detriments from extreme events and severe accidents is low. The Annex provides a discussion of the factors underlying this conclusion, which are:

- The capability and resilience of UK plants that is being further enhanced in the light of lessons from Fukushima;
- The commitment of UK operators to nuclear safety;
- Stress tests conducted on EU nuclear installations in response to Fukushima to ensure that

any further improvements to the resilience of plants were identified for implementation; and
- The robustness of the regulatory regime and the independence and effectiveness of the UK nuclear regulator in promoting and overseeing high levels of governance in the nuclear industry.

8.50 Annex 5 also reviews previous reactor accidents and concludes that the measures described in this Application in Annexes 1 and 5 ensure that the risk of a severe accident involving the Proposed Practice and the resulting detriments are very low.

8.51 Overall it is concluded that there are substantial provisions that ensure a high level of nuclear safety is maintained by nuclear operators of a nuclear power plant such as our Proposed Practice. As a result of these extensive and highly regulated provisions the risk of detriment resulting from extreme events causing widespread station impacts such as sustained loss of cooling or electrical power supplies is considered to be low. These provisions continue to evolve and are subject to on-going review and improvement.

Overall Conclusion

8.52 The considerations in this Chapter lead the applicant to conclude that:

- There would be little change to the existing very small proliferation risks;
- Security measures would provide protection against terrorism and other malicious acts;
- Stringent health and safety standards would provide a safe workplace;
- Stations would be protected against the effects of climate change; and
- The risks of detriment from a severe accident, even following an extreme event, would be very low.

8.53 For these reasons, the wider impacts resulting from adoption of the Proposed Practice would result in no significant detriments.

NINE

SUMMARY

SUMMARY OF NET BENEFITS AGAINST RADIOLOGICAL HEALTH DETRIMENTS

Summary of Net Benefits against Radiological Health Detriments

9.1 This Application has described the benefits and detriments to the UK associated with implementing the Proposed Practice, together with its potential radiological health detriments. This final chapter draws these benefits and detriments together, and concludes that the net benefits outweigh the potential radiological health detriments.

9.2 Our approach here is to assess the broad scale of the “net benefit” provided by the Proposed Practice, and to compare this with the scale of the potential radiological health detriment. As we judge the benefits relating to security of supply and carbon reduction to be so significant, we have not attempted in this Application to detail or rely on any other potential benefits that might also arise. We have, however, sought to consider the full range of potential detriments that could in theory counter the significant benefits of the Proposed Practice.

Security of Supply Benefits

9.3 By providing large scale electricity generation, UK ABWR plants would help to achieve the diverse generation mix sought by the Government which will increase the resilience of the UK’s electricity system.

9.4 Sufficient uranium is available to fuel existing and potential new power stations. The relatively small volume of nuclear fuel required for electricity generation means that nuclear fuel can be stockpiled if future supply becomes uncertain. A typical reactor will operate with fuel cycle lengths in the range of 12 to 24 months.

9.5 For these reasons, the Proposed Practice would contribute significantly to the UK’s energy security, representing a major benefit of the Proposed Practice.

Carbon Reduction Benefits

9.6 There is a scientific consensus that human activities are causing global climate change by adding greenhouse gases to the atmosphere. The UK has established legally binding climate change targets requiring an 80% reduction in greenhouse gas emissions from 1990 levels by 2050. This will require the UK to significantly reduce its dependence on fossil fuels.

9.7 Nuclear power is a low carbon-generating technology, with emissions across the entire life cycle of a nuclear plant comparable to those from renewable resources. Since 1970, nuclear generation has avoided the emission of over 1.6 billion tonnes of carbon dioxide.

9.8 For these reasons, the Proposed Practice would contribute significantly towards meeting the UK’s carbon reduction obligations, representing a further major benefit from the Proposed Practice.

Economic Assessment

9.9 When data relating to the costs of nuclear energy is compared with data relating to the costs of other generation technology, it can be seen that nuclear is expected to remain a competitive form of generation, particularly when compared against other low carbon technologies.

9.10 Furthermore, the current Electricity Market Reform policy and proposals provides a mechanism for the Government to determine, through its negotiations with individual nuclear developers, whether it considers that an individual project will represent value for money and be a cost effective addition to the UK generation mix.

9.11 As the risk of a nuclear accident in the UK is very low, the risk of detriment to the UK economy arising from the economic costs associated with a nuclear accident is correspondingly low.

9.12 For these reasons, the risk of a significant detriment to the UK economy from the Proposed Practice is very low. When security of supply and carbon reduction benefits are taken into account, adoption of the Proposed Practice is likely to be beneficial for the UK economy.

Consideration of Potential Detriments

9.13 We now consider whether there are any detriments that are significant enough to counter the major benefits that have been identified above. Our Application makes clear the extensive regulatory provisions and high levels of governance that are in place to ensure that the detriments we describe will be managed to the levels that we describe.

Radioactive Waste, Spent Fuel and Decommissioning

9.14 New nuclear power stations in the UK would create a manageable amount of additional radioactive waste. The types of waste and spent fuel created would be similar to the types of waste that are produced by existing nuclear power stations, and for which management and interim storage solutions currently exist. The Government is firmly committed to geological disposal and is confident that the 'Managing Radioactive Waste Safely' programme will be put into effect. Outside the UK, there is also considerable and growing international experience in managing nuclear waste.

9.15 The waste materials and spent fuel arising from the Proposed Practice could be disposed of within a deep geological repository, and they could be safely stored until this repository becomes available. Any additional excavation within the repository that would be required to accommodate the additional waste material would not represent a significant detriment to the UK.

9.16 The process of decommissioning nuclear facilities is now well understood and there is extensive and growing international experience in this regard.

9.17 Nuclear liabilities associated with radioactive waste management and decommissioning are the ultimate responsibility of the site licence holder. The Government has legislation in place which requires the Operator to have an approved Funded Decommissioning Programme ("FDP") before plant construction can begin. The FDP helps the government ensure that secure financing arrangements are in place to meet the full cost of waste management and decommissioning.

9.18 For these reasons, there can be confidence that the overall detriment from radioactive waste, spent fuel and decommissioning associated with the Proposed Practice would be small.

Wider Environmental Impacts

9.19 Other environmental impacts would be comparable with those associated with other large-scale electricity generation. They would be properly addressed and mitigated. UK ABWR reactors would meet all applicable standards and regulations.

9.20 For these reasons, the overall environmental impacts, and the associated detriment from the Proposed Practice in this area, would be small.

Other Considerations

9.21 There would be little change to the existing small risks associated with proliferation.

9.22 There are effective security provisions and regulations in place to protect against terrorism and other malicious acts and therefore any potential detriment associated with security risks would be low. Nuclear Power Stations would also be protected against the effects of climate change.

9.23 Existing stringent health and safety standards would provide for a safe workplace in nuclear power stations, and the risk of accidents would be very low.

9.24 For these reasons, there are no other considerations which suggest that the adoption of the Proposed Practice would result in a significant detriment to the UK.

Summary of the "Net Benefit"

9.25 Having considered all the above potential detriments, none have been identified which could, either alone or when combined with other detriments, be of sufficient scale to detract significantly from the major benefits to the UK that the Proposed Practice would bring.

Scale of Potential Radiological Health Effects

9.26 UK ABWR stations and their associated processes would be capable of meeting all applicable radiation dose limits and constraints. The regulatory system governing the Proposed Practice would ensure, following optimisation, that doses fall further below these limits. We estimate that the additional annual dose to a member of the public most affected would be very low and of the same order as for a person taking one additional annual return air flight from the UK to New York.

9.27 Doses to workers as a result of the Proposed Practice would be low. They would be comparable with, or lower than, those to which workers in the nuclear power industry (and other industries which entail radiation exposure, such as the airline industry) are currently exposed.

9.28 Stringent safety and security requirements would ensure that the likelihood of an accident leading to a significant release of radioactive material would be very remote. UK ABWR reactors would have a very low risk of accidents with risk levels demonstrated to be as low as reasonably practicable. For these reasons, the overall radiological health detriment of the Proposed Practice would be very small.

Overall Conclusion

9.29 The security of supply and low carbon benefits for the UK from the Proposed Practice are very significant. Consideration of a wide range of potential detriments has confirmed that, when potential detriments are taken into account, the Proposed Practice would result in a major net benefit. By comparison, the potential radiological health detriments, even without relying on the full effects of optimisation, would be small and are outweighed by the net benefit of the Proposed Practice.

9.30 The applicant therefore concludes that the Proposed Practice should be Justified.

ONE

ANNEX I

DESCRIPTION OF ABWR

Annex 1 – Description of ABWR

List of Tables

List of Illustrations

Abbreviations and Acronyms List

ABWR	Advanced Boiling Water Reactor
AC	Alternating Current
AC	Atmospheric Control System
ADS	Automatic Depressurisation System
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AOO	Anticipated Operational Occurrence
ARI	Alternative Rod Insertion
ATWS	Anticipated Transient Without Scram
BAT	Best Available Technique
B/B	Backup Building
BOP	Balance of Plant
BWR	Boiling Water Reactor
C/B	Control Building
CDF	Core Damage Frequency
CFR	Code of Federal Regulations (in US)
CNS	Civil Nuclear Security
CRD	Control Rod Drive System
CST	Condensate Storage Tank
CUW	Reactor Water Clean-up System
DBA	Design Basis Accident
DC	Direct Current
DCR	Design Certification Rule
D/G	Emergency Diesel Generator System
DiD	Defence-in-Depth
D/S Pit	Steam Dryer and Steam Separator Pit
DWC	Drywell Cooling System
EA	Environment Agency
ECCS	Emergency Core Cooling Systems
FCS	Flammability Control System
FDW	Feed Water System
FMCRD	Fine Motion Control Rod Drive
FPC	Fuel Pool Cooling Clean-up System
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GE	General Electric
GEH	GE Hitachi Nuclear Energy
GNF	Global Nuclear Fuel
GTG	Gas Turbine Generator
GW	Gigawatt
HECW	HVAC Emergency Cooling Water System
HEPA	High Efficiency Particulate Absorption (filter type)
Hitachi-GE	Hitachi-GE Nuclear Energy, Ltd.
HPCF	High Pressure Core Flooder System
HSE	Health and Safety Executive
HVAC	Heating Ventilating and Air Conditioning Systems
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
ICMS	Integrated Construction Management System
ILW	Intermediate Level Waste
kg	kilogramme

LLW	Low Level Waste
LLWR	Low Level Waste Repository
LOCA	Loss of Coolant Accident
LPFL	Low Pressure Core Flooder System
LUHS	Loss of Ultimate Heat Sink
LWMS	Liquid Radwaste Management System
MCPR	Minimum Critical Power Ratio
MCR	Main Control Room
mm	millimetre
MOX	Mixed OXide
MS	Main Steam System
MSIV	Main Steam Isolation Valve
MSLBA	Main Steam Line Break Accident
NB	Nuclear Boiler System
NDA	Nuclear Decommissioning Authority
NPP	Nuclear Power Plant
NSC	Nuclear Safety Commission (in Japan)
NSSS	Nuclear Steam Supply Systems
OG	Off-gas System
ONR	Office for Nuclear Regulation
PCV	Primary Containment Vessel
PSA	Probabilistic Safety Assessment
PWR	Pressurised Water Reactor
R/B	Reactor Building
RCCV	Reinforced Concrete Containment Vessel
RCIC	Reactor Core Isolation Cooling System
RCW	Reactor Building Cooling Water System
RHR	Residual Heat Removal System
RIP	Reactor Internal Pump
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RRS	Reactor Recirculation System
RSS	Remote Shutdown System
RSW	Reactor Building Service Water System
Rw/B	Radwaste Building
S/B	Service Building
SBO	Station Black-Out
SFP	Spent Fuel Pool
SGTS	Standby Gas Treatment System
SLC	Standby Liquid Control System
S/P	Suppression Pool
SPCU	Suppression Pool Clean-Up System
SRV	Safety Relief Valve
SWMS	Solid Radwaste Management System
TAF	Top of Active Fuel
T/B	Turbine Building
TEDE	Total Effective Dose Equivalent
UHS	Ultimate Heat Sink
UPS	Uninterruptible Power Supply
VLLW	Very Low Level Waste

1. Introduction

1.1 ABWR Overview

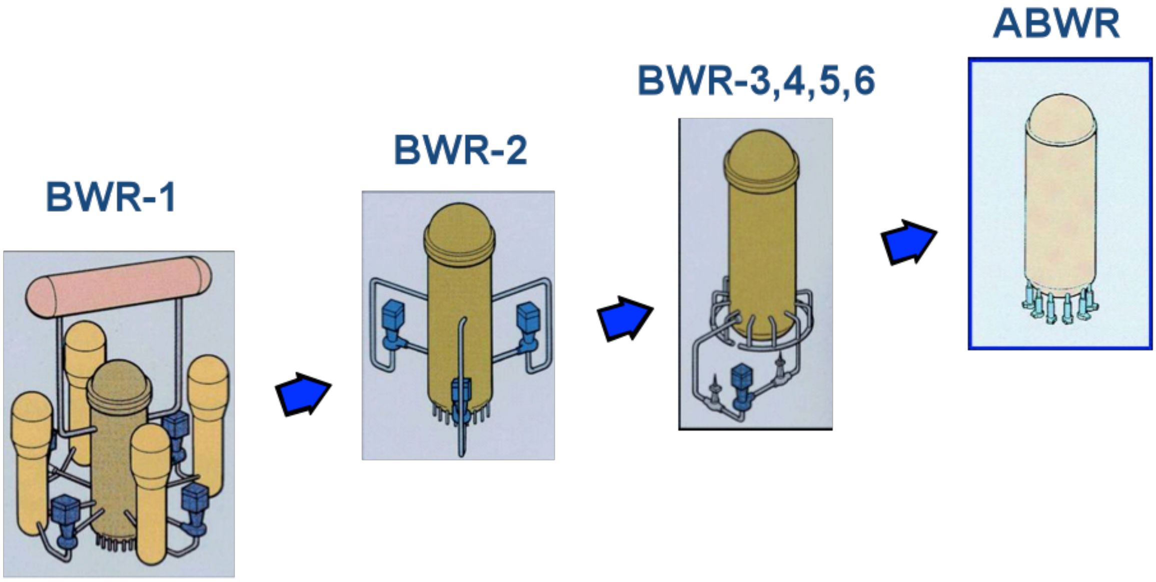
A1.1 The Advanced Boiling Water Reactor (ABWR) fulfils Generation III+ objectives for evolutionary light water reactor design that offer enhanced safety, higher operability, reduced equivalent dose, enhanced performance and cost efficiency compared to earlier generation plants. The ABWR is the first Generation III+ reactor design to come into operation in the world with the first ABWRs Unit 6 and Unit 7 of Kashiwazaki-Kariwa Nuclear Power Station, operating in Japan since November 1996 and July 1997, respectively.

A1.2 One of the world's most common types of nuclear power generating plants, Boiling Water Reactors (BWRs), are characterized by a system wherein steam generated inside the reactor by boiling light water through the thermal nuclear fission reaction is directly passed to the turbine to generate electricity.

A1.3 In a boiling water reactor, ordinary (light) water is used to remove the heat produced inside the reactor core by the thermal nuclear fission process. The water coolant boils in the reactor pressure vessel. The resulting steam passes through steam separators and dryers above the core and then directly to the turbine generator which generates electricity. The steam passes through condensers where it is cooled using water from the sea or cooling towers, and returns as feedwater to the reactor. The water coolant also acts as a moderator to enable thermal fission.

A1.4 Figure A1-1 illustrates the evolution that the BWR design has undergone from the first reactor type to the current ABWR to improve the design by simplifying and enhancing safety.

Figure A1.1
Evolution of
BWR Design



NSSS

A1.5 The original BWRs incorporated an external steam drum as well as steam generators, and utilised recirculation pumps external to the RPV. In the BWR-2 product line the steam drum was replaced with steam separators and dryers within the RPV, and the steam generators were completely eliminated Although various improvements were incorporated with each evolution of the product line from BWR-3 to BWR-5, one key change for these products was the incorporation of jet pumps inside the RPV and external recirculation pumps for forced recirculation of reactor core flow. The ABWR replaced the external recirculation pumps and the jet pumps with Reactor Internal Pumps (RIPs), as well as incorporation of many other improvements as explained in the following sections.

Containment

A1.6 The torus design of the Mark I provided a large surface area for venting steam, but presented challenges in its construction and that of the reactor building surrounding it. The ABWR adopts the simpler geometry of a right circular cylinder constructed using reinforced concrete, but otherwise retains characteristics closer to those of the Mark II containment design. The ABWR RCCV results in a compact structure integrated with the reactor building with improved seismic stability and resistance as well as higher construction and cost effectiveness.

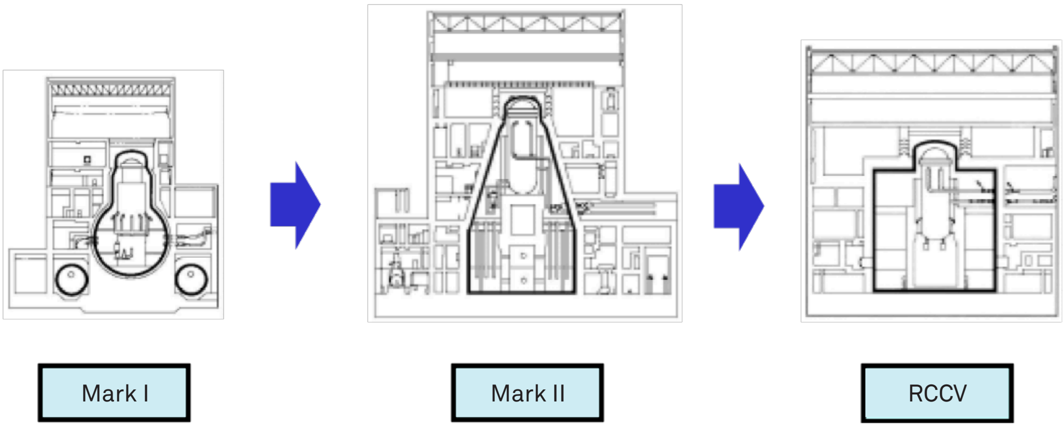


Figure A1.2 Evolution of BWR Containment Design

A1.7 The ABWR was developed primarily in Japan and the USA. The development began in 1978 by Japanese electric utilities and plant manufacturers, including Hitachi Ltd. in Japan and General Electric Company in the US, in collaboration with various international partners.

A1.8 The main technological improvements employed in the ABWR design compared to earlier BWR designs are the following:

- [1] Large scale, highly efficient plant (see Table A1-1)
- [2] Highly economical reactor core (see Core and Fuel Design section)
- [3] Reactor coolant recirculation system driven by internal pumps (see section Nuclear Steam Supply section)
- [4] Advanced control rod drive mechanism (see section Nuclear Steam Supply section)
- [5] Overall digital control and instrumentation (see Instrumentation and control section)
- [6] Reinforced concrete containment vessel (see Figure A1-2)

Table A1.1: Key Specifications of ABWR

	Item	Specification
Output	Plant Output	1350MWe
	Reactor Thermal Output	3926MWt
Reactor Core	Fuel Assemblies	872
	Control Rods	205 rods
Reactor Equipment	Recirculation System	Internal pump method
	Control Rod Drive	Hydraulic / Electric motor drive method
Reactor Containment Vessel		Reinforced concrete with built-in liner
ECCS / PCV cooling System		3 divisions
Residual Heat Removal System		3 divisions
Turbine System	Turbine (final blade length)	52 inches
	Moisture Separation Method	Reheat type

A1.9 The UK ABWR derives from the generic design of the ABWR. The standard design of the first ABWR (Kashiwazaki-Kariwa units 6 & 7) together with further improvements and optimisation from subsequent ABWR plants will be the design reference for the UK ABWR.

A1.10 Addtionally, the UK ABWR will incorporate new features to deliver a higher level of protection against severe external hazards beyond the design basis as described in this document. This includes post-Fukushima countermeasures from the lessons learned and aircraft crash countermeasures.

A1.11 Furthermore, it is expected that the UK ABWR design will incorporate any additional changes to deal specifically with UK requirements.

A1.12 The UK ABWR is now being assessed under the GDA process. It is expected that the regulators' (ONR and EA) GDA Step 2 assessment reports will be available to inform the Secretary of State's decision on the ABWR Regulatory Justification application.

1.2 About Hitachi-GE Nuclear Energy, Ltd.

A1.13 Since the introduction to Japan of the boiling water reactor technology, by General Electric in the 1960s, Hitachi has participated in the design, development and construction of over 20 nuclear power plants within Japan.

A1.14 Hitachi-GE Nuclear Energy, Ltd. (Hitachi-GE) was founded on 1 July 2007 as a strategic global alliance by Hitachi, Ltd and General Electric (GE). Its US based counterpart is GE-Hitachi Nuclear Energy (GEH). Hitachi-GE offers nuclear power services including R&D, design and manufacture.

A1.15 Today, Hitachi-GE has participated in the construction of all 4 operating ABWRs in Japan with responsibilities ranging from the complete plant (Shika 2), the nuclear island (Kashiwazaki-Kariwa 7) or the turbine island (Kashiwazaki-Kariwa 6, Hamaoka 5). Hitachi-GE are involved in the on-going construction of the Shimane 3 and Ohma ABWRs in Japan.

2 Plant Design

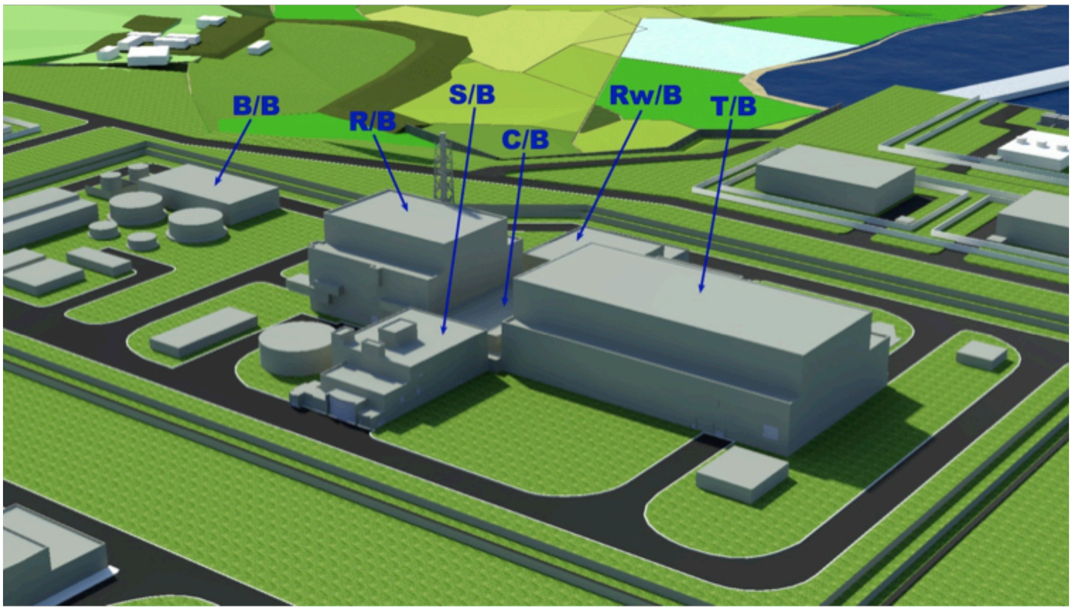
2.1 Plant Layout

A1.16 Figure A1-3 is a close-up view of the general site layout of a conceptual ABWR, which shows the major facilities comprising the Reactor Building, the Turbine Building, the Control Building, the Radwaste Building, and the Service Building. All facilities containing radioactive substances have been designed with physical robustness and provided with shielding to minimise radiation exposure.

A1.17 The latest ABWRs including the UK ABWR have been provided with further safety enhancements and additional resilience against extreme events such as loss of cooling and all electrical power supplies as a result of flooding or seismic events.

A1.18 These measures include reinforcement of conventional buildings and additional facilities such as the Backup Building as well as plant layout designs to mitigate site specific external hazards.

→ Figure A1.3 ABWR General Layout Plan



Building Legend

B/B	Backup Building	Rw/B	Radwaste Building
C/B	Control Building	S/B	Service Building
R/B	Reactor Building	T/B	Turbine Building

The principal facilities are described as follows.

Reactor Building (R/B)

A1.19 The Reactor Building is a reinforced concrete structure that forms the Secondary Containment housing the Primary Containment Vessel (PCV), a Reinforced Concrete Containment Vessel (RCCV) integrated with the Reactor Building within which the Reactor Pressure Vessel (RPV), the drywell, the wetwell and the Suppression Pool (S/P) are located. Additionally, the major portions of the Nuclear Steam Supply System (NSSS), the steam tunnel, the Spent Fuel Pool (SFP), the refuelling area, the emergency diesel generators, the essential power, the non-essential power, the Emergency Core Cooling Systems (ECCS), the Heating Ventilating and Air Conditioning Systems (HVAC) and other support systems are located within the Reactor Building.

Turbine Building (T/B)

A1.20 The Turbine Building houses all the components associated with the power conversion and auxiliary systems. This includes the portion of the main steam system belonging to the turbine side, the turbine-generator, the main condenser, the turbine bypass system, condensate demineralizers, the air ejector, the steam packing exhauster, the offgas system, and the condensate and feedwater pumping and heating equipment.

Control Building (C/B)

A1.21 The Control Building includes the Main Control Room (MCR), the computer facility, the cable tunnels, some of the plant essential switchgear, some of the essential power and the essential HVAC system.

Radwaste Building (Rw/B)

A1.22 The Radwaste Building houses all equipment associated with the collection and treatment of the liquid and solid radioactive waste generated in the plant.

Service Building (S/B)

A1.23 The Service Building houses other facilities such as drain treatment facility, laboratories, changing rooms, toilets, etc.

Backup Building (B/B)

A1.24 The Backup Building is a new facility introduced post Fukushima as a countermeasure to enhance safety by providing a frontline base during emergencies and a storage facility for accident management. The building is separated from the R/B and specially protected against external hazards. The building includes alternative core cooling systems, alternative power supply systems, portable systems for accident management, alternative control panels.

2.2 Nuclear Steam Supply Systems

A1.25 The Nuclear Steam Supply Systems (NSSS) generates steam through the thermal nuclear fission process and directly transfers it to the turbine system. The systems comprising the NSSS are the following:

- Reactor Pressure Vessel housing the nuclear fuel and its internal components
- Reactor Recirculation System (RRS);
- Control Rod Drive System (CRD); and
- Nuclear Boiler System (NB):
  - Main Steam System (MS)
  - Feed Water System (FDW)

Reactor Pressure Vessel and Internal Components

A1.26 The Reactor Pressure Vessel (RPV) houses the reactor core (nuclear fuel) which is the heat source for steam generation. The vessel contains this heat, produces steam within its boundaries, and serves as one of the fission product barriers during normal operation.

A1.27 The RPV design is based on proven BWR technology. One of the most important enhancements introduced for the ABWR is the lack of any large nozzles below the top of the core. This configuration precludes any large pipe ruptures below this elevation. This is a key factor in ABWR safety since it helps to maintain the core completely and continuously flooded for the entire spectrum of design basis Loss of Coolant Accidents (LOCA).

A1.28 The vessel contains the core support structure that extends to the top of the core, steam outlet nozzles, feedwater inlet nozzles, steam separator, steam dryer, structures to support the Reactor Internal Pumps (RIP) and control rod drives, instrumentation and other internals.

Reactor Recirculation System (RRS)

A1.29 The RRS has two main functions.

[1] The RRS provides forced circulation of reactor coolant for energy transfer from the fuel to the coolant and, as a result, generates a larger amount of steam compared to passive circulation. For this purpose, the RRS uses an arrangement of ten Reactor Internal Pumps (RIPs) mounted at the bottom of the RPV to force reactor coolant flow through the lower plenum of the reactor and upward through openings in the fuel support castings, through the fuel bundles, steam separators, and down to the annulus to be mixed with feedwater and recirculated again.

[2] The RRS can also be used to vary reactor power by changing the recirculation flow by adjusting the RIPs speed.

A1.30 The introduction of RIPs mounted at the bottom of the RPV (instead of conventional primary loop recirculation pumps that are externally mounted), results in a simpler design and a more compact containment compared to previous BWRs. The elimination of external piping and the design of the internal pumps with a wet motor, reduces the likelihood of coolant leakage and significantly contributes to minimisation of personnel's radiation exposure during maintenance and inspection tasks. Additionally, the elimination of external piping and large nozzles below the core assures no core uncovery for postulated pipe breaks and reduces the likelihood of LOCA.

A1.31 From an operating perspective, the RIPs core flow control features allow simpler and more efficient operation compared to previous BWRs. Additionally, these features reduce the likelihood of ECCS actuation since they can be used to mitigate the effects of certain abnormal operating states by controlling power and fuel thermal margin.

Control Rod Drive System (CRD)

A1.32 The CRD controls changes in core reactivity during power operation by movement and positioning of the neutron absorbing control rods within the core in fine increments according to the control signals from the Rod Control and Information System. The drive mechanism for this mode of operation is the Fine Motion Control Rod Drive (FMCRD) which positions the control rod by electric motor for insertion and withdrawal during normal operation.

A1.33 Additionally, the CRD provides rapid control rod insertion in response to the signals from the Reactor Protection System to rapidly shut down the reactor (scram). In this case the motive power for rapid rod insertion (as required in response to abnormal conditions) is provided by stored hydraulic power from compressed nitrogen gas.

Nuclear Boiler System (NB)

A1.34 The NB is divided into two subsystems

- The Main Steam System (MS) which consists of 4 steam lines to direct the steam flow from the RPV steam outlet nozzle to the main turbine; and
- The Feed Water System (FDW) which consists of 2 lines that transport feedwater from the feedwater pipes in the steam tunnel through the RCCV penetrations to the nozzles on the RPV.

A1.35 The MS is provided with steam flow restrictors in each steam outlet nozzle to limit the flow rate in the event of postulated main steam line break. The system also incorporates provisions for relief of over-pressure conditions in the RPV through the Safety Relief Valves (SRV) and Main Steam Isolation Valves (MSIV) on each line to isolate the primary containment when necessary.

2.3 Auxiliary Systems

Reactor Water Clean-up System (CUW)

A1.36 The CUW consists of piping, valves, pumps, heat exchangers and filter demineralizers to remove impurities from the reactor primary coolant water to maintain water quality within acceptable limits during the different plant operating modes.

Fuel Pool Cooling Clean-up System (FPC)

A1.37 The purpose of the FPC is to cool the pools located in the Reactor Building (Spent Fuel Pool (SFP), Steam Dryer and Steam Separator Pit (D/S Pit), Reactor Well and spaces between) and maintain the quality of the pool water. The FPC cools the SFP by removing the decay heat from the spent fuel and maintains the temperature below the specified values. It also maintains the quality of the water in the pools in conformance with the quality regulations by removing the impurities and controls the pools water level by supplying water and performing drainage. Moreover, the FPC filter demineralizers clean the water in the S/P to satisfy the requirements of water quality standards using the Suppression Pool Clean-up System (SPCU).

Suppression Pool Clean-up System (SPCU)

A1.38 The purpose of the SPCU is to clean the water in the S/P by transferring the pool water through the FPC filter demineralizers and returning it back to the S/P. The treated water can also be utilized for water-filling of the upper pools (Reactor Well and D/S Pit). Moreover, the SPCU is capable of drawing water from the Condensate Storage Tank (CST) or the S/P to supply water to the SFP as required.

Reactor Building Cooling Water System (RCW)

A1.39 The RCW consists of 3 independent divisions to supply cooling water to the plant auxiliaries in order to preserve the determined functions. Plant auxiliaries include both non-safety and safety equipment. The RCW recirculates water through the closed loop comprising the RCW heat exchangers and the loads for normal operation, shutdown or hot standby in the case of non-safety equipment; after automatic initiation for abnormal conditions in the case of safety equipment; and continuously for the FPC, the RSW and the HVAC Emergency Cooling Water System (HECW) auxiliaries.

Reactor Building Service Water System (RSW)

A1.40 The RSW consists of 3 independent divisions to cool and remove the heat from the RCW by supplying service water from the sea. The RSW provides service water to the RCW Heat Exchangers from the water intake pit in order to remove the heat and discharges it into the water discharge pit back to the sea.

Drywell Cooling System (DWC)

A1.41 The DWC provides conditioned air/nitrogen to the drywell head area, upper and lower drywell, and shield wall annulus during plant normal operation, refuelling outages and normal operation transients to cool equipment and maintain the drywell temperature within the limits to ensure the integrity of the concrete structure.

Atmospheric Control System (AC)

A1.42 The main function of the AC is to inject nitrogen into the PCV to inert the atmosphere against hydrogen combustion. The AC inerts the PCV after refuelling outages, maintains a slightly positive pressure within the PCV, vents the PCV atmosphere to maintain the pressure within the determined range and de-inerts the PCV for plant shutdown by replacing it with air.

Other Auxiliary Systems

A1.43 Other auxiliary systems include radwaste management systems, instrument air and service air supply systems, house steam supply systems, makeup water supply systems, heating ventilating and air conditioning systems, draining systems.

2.4 Core and Fuel Design

Design

A1.44 The reactor core of the ABWR is configured as an upright cylinder containing 872 fuel assemblies located inside the RPV, where the coolant flows upward through the core and boils to generate steam. The main core components are the fuel assemblies, the control rods, the core shroud, the core plate, the upper grid and nuclear instrumentation.

A1.45 Each fuel assembly consists of a fuel bundle, which contains the fuel rods. The fuel rods are tubes with a cladding made of zircaloy into which UO_2 fuel pellets are loaded and plugged at both ends. Each fuel assembly is surrounded by a zircaloy channel box. The channel box directs the flow of coolant through the fuel bundle and guides the control rods. The latest fuel assembly design contains a 10x10 array of fuel rods and the hardware necessary to support and maintain the space between fuel rods.

→ Table A1.2 ABWR Fuel Parameters

Fuel bundle length	4468 mm
Overall weight	300 kg
Heavy metal weight	180 kg
Weight of UO_2	200 kg
Fuel burn-up	50 GWd/t
Total number of fuel assemblies discharged over 60 years	9600

A1.46 The core and fuel design methods employed for design analyses and calculations have been verified by comparison with data from operating plants, test data and detailed computer calculations. Throughout the history of the BWR, Hitachi and General Electric have continually implemented advanced core and fuel design technology, such as control cell core, spectral shift operation, axially varying gadolinia and enrichment zoning, fuel cladding with improved corrosion resistance, part length fuel rods, and wider water gaps in the ABWR core. As these technological improvements are added, the core and fuel design parameters are optimised to achieve better fuel cycle economics, while improving fuel integrity and reliability and while maintaining overall reactor safety.

A1.47 Thus, there is confidence that a low proportion of fuel failures will continue to be observed (as on current operating plants). Recent world BWR experience indicates a failure rate (between 2006 and 2010) in the range 0.7 to 6.4 leaking fuel assemblies per thousand. Even in the event of failure, the fuel remains in the fuel rod and thus radioactivity largely remains trapped in the fuel rod. This confinement of radioactive material means that there is little or no carryover of radioactivity from the fuel to the turbine with the principal constituent being noble gases.

A1.48 The main source of radioactivity in the steam is therefore the nitrogen (the ^{16}N isotope) produced from a nuclear reaction between ^{16}O (in water) and neutrons in the reactor core. ^{16}N has a short half-life of about 7.1 seconds. ABWR incorporates enhanced shielding compared to earlier BWRs around the turbine to protect operators.

A1.49 The average bundle enrichments and batch sizes are a function of the desired cycle length. The ABWR core uses fuel with a range of enrichments less than 5%.

A1.50 The low enriched uranium and fuel manufacture can be sourced through GNF or other fuel suppliers. The ABWR, like all commercial BWRs, is capable of utilizing mixed oxide (MOX) fuel.

Fuel Management

A1.51 The flexibility of the ABWR core design permits significant variation of the intervals between refuelling. The first shutdown for refuelling can occur anywhere up to 13 months after commencement of initial power operation. Thereafter, the cycle length can be extended up to 18 months. Based on current operational BWR practices, a 24 month fuel cycle length should be achievable for ABWR if required by a utility although further work would be needed to establish specific ABWR management and design provisions.

A1.52 Spent nuclear fuel is exchanged with new fuel during reactor shutdown to form the new reactor core. The refuelling machine that performs this fuel exchange operation travels or moves laterally over the reactor well and Spent Fuel Pool to load and unload the fuel. The automatic refuelling machine, developed by Hitachi, performs this operation with high precision by using a process computer that automatically controls the speed and position of the refuelling machine in four-dimensions; bridge travel, trolley travel, grapple vertical and rotational.

2.5 Safety Systems

A1.53 The ABWR safety design concept is based on inherent safety features and enhanced engineered safety systems compared to previous BWRs.

A1.54 The safety systems constitute the enhanced engineered safety measures to ensure control of reactivity, core cooling and decay heat removal, and containment of radioactive material. The major safety systems are the following:

- Reactor Protection System (RPS);
- Emergency Core Cooling Systems (ECCS);
- Containment Systems; and
- Residual Heat Removal system (RHR)

A1.55 The Reactor Protection System (RPS) is the overall complex of instrument channels, trip logic, trip actuators and scram logic that initiate rapid insertion of control rods (scram) to rapidly shut down the reactor when required to avoid fuel damage, limit system pressure and restrict the release of radioactive material.

A1.56 The purpose of the Emergency Core Cooling Systems (ECCS) is to inject water into the RPV and depressurise it as necessary to ensure core cooling function. The ECCS configuration comprises 3 redundant divisions provided with high pressure and low pressure water injection systems, which are supplied AC power from the respective division of the redundant Emergency Diesel Generator System (D/G) in the event of loss of off-site power. As shown on Figure A1.4, the ECCS injection network is comprised of one RCIC train and two HPCF trains for high pressure injection, and three LPFL trains for low pressure injection in conjunction with the Automatic Depressurisation System (ADS) which assists the injection network under certain conditions.

A1.57 The containment systems are designed to prevent the release of radioactive material by confinement. As shown on Figure A1.4, the containment systems comprise the Primary Containment and supporting systems (Flammability Control System (FCS)), and the Secondary Containment with the Standby Gas Treatment System (SGTS).

A1.58 The purpose of the Residual Heat Removal System (RHR) is to remove heat from the containment following an abnormal event to limit the increase in containment pressure and temperature. This is accomplished by cooling and recirculating the suppression pool water and, if necessary, by the use of containment sprays.

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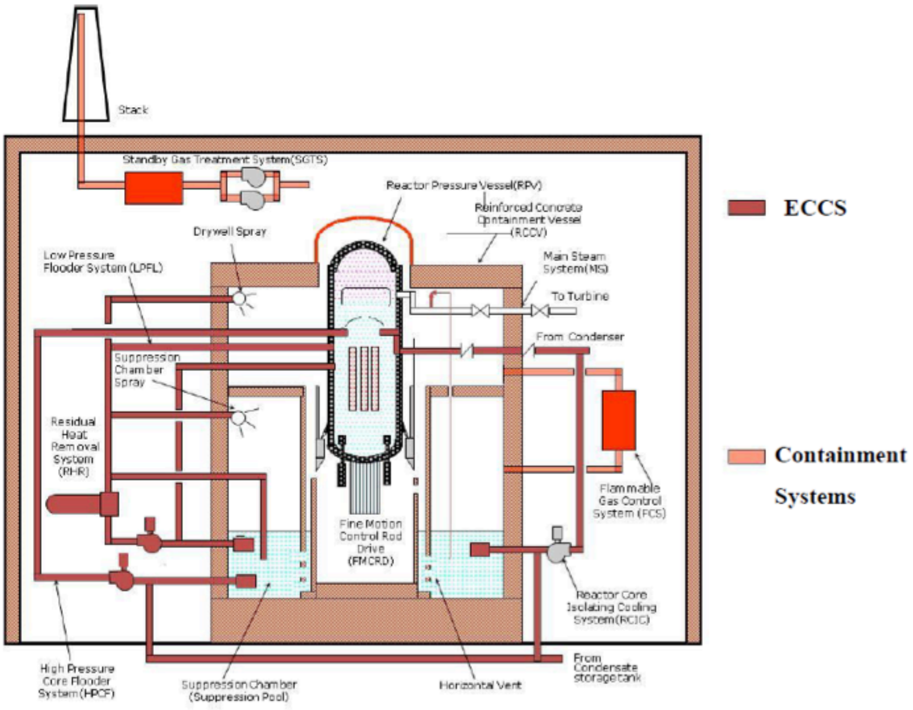
Figure A1.4
Graphical Overview of Safety Systems



Each group is described in details as follows.

Reactor Protection System (RPS)

A1.59 The RPS consists of 4 protection channels with 2 out of 4 logic configuration. The main function is to implement rapid reactor shut down (scram) by hydraulically inserting the control rods. The scram signals are derived from multiple parameters such as high neutron flux, high reactor pressure, low RPV water level, high drywell pressure, main steam line isolation, high seismic acceleration, etc. to ensure reactor shut down is initiated under all abnormal circumstances.

Emergency Core Cooling Systems (ECCS)

A1.60 The ECCS comprises the following systems:

High Pressure Core Flooder System (HPCF)

A1.61 The primary purpose of the HPCF is to maintain the reactor vessel water inventory after small breaks which do not depressurise the reactor vessel and thus limit the fuel cladding temperature. The HPCF consists of two independent and physically separated divisions automatically initiated either by high pressure in the drywell signal or low water level in the RPV signal.

Reactor Core Isolation Cooling System (RCIC)

A1.62 The purpose of the RCIC is to supply makeup water into the RPV to assure that sufficient reactor inventory is maintained in order to perform adequate core cooling and prevent reactor fuel overheating for transients, accidents conditions such as LOCA and to complete plant shutdown. The RCIC is automatically initiated upon a determined water level in the vessel and injects high pressure water into the RPV by using a steam-driven pump, which makes it operable even upon total loss of AC power, (also known as Station Black-Out (SBO)). The RCIC steam supply line branches from one of the main steam lines leaving the RPV and goes to RCIC turbine.

Low Pressure Core Flooder System (LPFL)

A1.63 The primary purpose of the LPFL is to provide reactor vessel water inventory makeup and core cooling during large breaks and to provide containment cooling. Following ADS initiation, the LPFL also provides inventory makeup following small breaks. The LPFL consists of three independent and physically separated divisions automatically initiated either by high pressure in the drywell signal or low water level in the RPV signal.

Automatic Depressurisation System (ADS)

A1.64 The ADS utilises part of the Safety Relief Valves (SRVs) to reduce reactor pressure during small and medium piping breaks. This feature is very useful in the event of HPCF failure because by automatic or manual actuation of the SRVs the reactor pressure can be quickly reduced and thus, water inventory can be supplied to the reactor pressure vessel using the LPFL.

Containment Systems

A1.65 The containment systems comprise the following systems:

Primary Containment Vessel (PCV)

A1.66 Primary Containment Vessel is a pressure suppression type Reinforced Concrete Containment Vessel (RCCV) which is comprised of a drywell and wetwell (air space plus suppression pool). The PCV is designed to withstand the loads (pressure, temperature, dynamic load) which would occur following any postulated LOCA and not to exceed the prescribed leakage rate with operating the isolation function properly

Flammability Control System (FCS)

A1.67 The purpose of the FCS is to limit the concentration of hydrogen and oxygen below the flammability limits, and thus prevent an excessive increase in pressure and temperature due to the heat released by the reaction of these gases in the PCV following a LOCA.

Secondary Containment

A1.68 Secondary Containment is a reinforced concrete building that forms an envelope surrounding the PCV above the basemat (with the exception of the barrier inside the main steam tunnel). As well as providing containment, it also protects the PCV from the impact of external loads.

Standby Gas Treatment System (SGTS)

A1.69 The SGTS controls the emission of fission products by maintaining a negative pressure in the secondary containment and by filtering gaseous effluents prior to discharge to the atmosphere following a postulated LOCA or a fuel handling accident. The SGTS also processes gaseous effluents from the PCV and the secondary containment when it is required to limit the discharge of radioactivity to the environment during normal and abnormal plant operation.

Residual Heat Removal system (RHR)

A1.70 The Residual Heat Removal system (RHR) has the following functions:

Containment Cooling

A1.71 The RHR system is designed to remove heat from the containment to limit the temperature of the water in the suppression pool and the atmospheres in the drywell and suppression chamber following a LOCA, to control the suppression pool temperature during normal operation of the SRVs and the RCIC System, and to reduce the suppression pool temperature following an isolation event, which requires isolation of the reactor in case of a fault, such as inadvertent MSIV closure.

Primary Containment Spray Cooling

A1.72 In conjunction with the LPFL, the primary containment spray cooling prevents the containment pressure and temperature rising due to the outflow of reactor coolant in case of a feedwater piping break from exceeding the maximum operating pressure and maximum operating temperature. It can also remove iodine released in the gas phase in the containment.

2.6 Balance of Plant

A1.73 The power conversion system is designed to produce electricity by passing the steam generated in the reactor through the turbines, collect and condense this steam into water, and return the water to the reactor as heated feedwater. The heat rejected to the condenser is removed by circulating water and discharged to the heat sink (either the sea or cooling towers).

A1.74 The main power conversion components are located in the Turbine Building and consist of the main steam portion belonging to the turbine side, the turbine system (high pressure turbine and low pressure turbine), the main condenser, condenser evacuation system, turbine gland steam system, turbine bypass, steam extraction system, condensate cleanup system, and condensate and feedwater pumping and heating system to the reactor.

A1.75 Normally, the turbine power heat cycle utilises all the steam generated by the reactor. However, an automatic pressure-controlled turbine bypass system designed for 33% of the rated steam flow is provided to discharge the excess of steam directly to the main condenser. Although the ABWR standard design is for 33% bypass, this capability could be increased if required by the utility.

2.7 Instrumentation and Control

A1.76 The ABWR instrumentation and control (I&C) design features redundancy, diversity, fault tolerant operation, and self-diagnostics while the system is in operation. It also incorporates extensive automation of the operator actions which are required during a normal plant start-up, shutdown and power range manoeuvres. This is made possible by the extensive use of advanced digital technologies and appropriate hardwired provisions.

A1.77 The instrumentation and control systems of the ABWR provide reactor shutdown functions, ECCS functions, control of the reactor, control of the BOP, an extensive and hierarchically-arranged alarm displays, prevention of the operation of the plant under unsafe or potentially unsafe conditions, monitoring of process fluids and gases, and monitoring of the performance of the plant.

A1.78 Total plant control is achieved from the Main Control Room (MCR) for all modes of operation. The MCR design incorporates advanced human-machine interface technologies to provide enhanced operability and improved reliability. In the event that the MCR becomes uninhabitable, the Remote Shutdown System (RSS) is provided to bring the reactor to a safe shutdown state. The UK ABWR safety provisions are further enhanced, as the B/B is equipped with alternative control panels as well as equipment providing additional diversity for the safety systems.

2.8 Electrical Power

Main Power Circuit (Off-site Power Supply)

A1.79 In Japan, the ABWR plant is connected to the off-site power supply system by two connections, main connection and backup connection. Auxiliary loads are supplied power from main connection side to which main generator is connected for plant normal operation. If the main connection side is not available, auxiliary loads are supplied from the backup connection. The UK ABWR power supply provisions will be configured to meet UK nuclear safety requirements.

On-site AC Power Supply (Diesel Generators)

A1.80 The on-site Emergency Diesel Generator System (D/G) supplies power to the safety functions necessary for reactor shutdown and cooling systems in the event of loss of off-site power supply. The diesel generators are designed with redundancy, and to be electrically and physically separated and independent from each other as well.

A1.81 To further enhance the on-site AC power supply, Alternative AC Generators (D/G or GTG) will be installed in the Back-up Building.

Instrumentation Power Supply (Uninterruptible Power Supply and DC).

A1.82 Uninterruptible Power Supply (UPS) and DC instrumentation power supply systems supply power to the safety instrumentation loads. These systems are divided into 4 divisions, which are electrically and physically separated and independent from each other as well.

2.9 Diverse Reactor Shutdown Systems

A1.83 The purpose of the Standby Liquidation Control System (SLC) is to shut down the reactor in a safe manner from full power operation to cold shutdown conditions and maintain this state by injecting neutron absorbing solution into the core in the unlikely event that control rod insertion is not available.

A1.84 The SLC injects borated water from the SLC Storage Tank through the High Pressure Core Flooder System (HPCF) flooder sparger.

A1.85 An Alternate Rod Insertion function (ARI) is provided in case an ATWS event occurs due to a failure of the reactor protection system. The alternate rod insertion function (ARI) inserts the control rods by opening exhaust valves installed on the instrumentation air system piping. The ARI facility (from detector to the exhaust valves) is independent of the reactor protection system.

2.10 Control Room

A1.86 ABWR design features are provided to ensure that the control room operators can remain in the control room and take actions to safely operate the plant under normal conditions and to maintain it in a safe state under accident conditions. These features include radiation shielding, air filtration and ventilation systems, lighting and fire protection.

3 Nuclear Safety and Licensing

3.1 Safety Design

A1.87 In order to ensure nuclear safety, the nuclear power plant must be capable of delivering the following three main safety functions at all times:

- Control of Reactivity;
- Cooling and Decay Heat Removal; and
- Containment of Radioactive Material

A1.88 As described in the Safety Systems section, the ABWR safety design uses inherent safety measures and enhanced engineered safety measures to deliver these three main safety functions and thus ensure nuclear safety.

Inherent Safety

A1.89 Inherent safety derives from the self-regulating features of BWRs, which are the Doppler effect and the void effect.

A1.90 Doppler reactivity feedback occurs simultaneously with a change in fuel temperature and opposes the power change that caused it. ABWR has an inherently large moderator-to-Doppler coefficient ratio which permits use of coolant flow rate for adjustment of reactor power and hence load following.

A1.91 The negative void reactivity coefficient provides an inherent negative feedback during power transients. Because ABWR has a large negative moderator coefficient of reactivity, prompt inherent dynamic behaviour compensates for any rapid increase in reactivity.

Enhanced engineered safety

A1.92 The BWR uses direct-cycle operation and has sufficiently large water inventory and steam buffer in the RPV to facilitate direct water injection into the reactor following a postulated pipe rupture.

Therefore, the basic approach to achieve safety in the BWR is to provide redundant and diverse methods for water injection based on Defence-in-Depth philosophy.

A1.93 The following is a summary of the ABWR major enhancements in engineered safety compared to earlier BWRs:

- Protection of containment against external loads by the R/B reinforced concrete structure;
- Elimination of nozzles of large diameter below the core region of the RPV by the provision of RIPs. Therefore, RPV water level would decrease more slowly in the event of a LOCA;
- Multiple and diverse layers of defence for each reactor water level before core uncovery.
- Highly reliable Reactor Protection System with 2 out of 4 logic configuration;
- Rapid reactor shutdown by hydraulic control rod insertion and diverse reactor shutdown systems through the Reactor Protection System, the Alternative Rod Insertion (ARI), and the Standby Liquid Control System (SLC); and
- Redundant and diverse ECCS with a high pressure injection system in addition to the low pressure injection system. This ensures that in the event of a LOCA, the core flooding will be maintained and safety will be preserved. With this type of system, according to the results of a probabilistic safety assessment, core damage frequency will be less than in conventional BWR, and thus safety is enhanced.

Post-Fukushima enhancements

A1.94 Countermeasures from the lessons learned against Station Blackout (SBO) and Loss of Ultimate Heat Sink (LUHS) caused by severe external hazards beyond the design basis are under evaluation. Nevertheless, the UK ABWR will include enhancements such as the following:

- Enhancement of core cooling systems with alternative water injection measures and portable pumps;
- Alternative portable heat removal systems to ensure Ultimate Heat Sink (UHS);
- Enhancement of PCV cooling and venting systems to prevent damage;
- Enhancement of AC and DC power supply sources with alternative and diverse systems;
- Enhancement of building structures and layout to secure components and power panels in

the event of severe external hazards such us flooding;
- Enhancement of the spent fuel pool cooling with alternative injection methods and additional pool water temperature and level monitoring systems;
- Enhancement of accident management and operability procedures; and
- Provision of enhanced countermeasures against core meltdown.

A1.95 The robustness and availability of the ABWR design against faults and hazards has been demonstrated by deterministic safety analysis as well as by Probabilistic Safety Assessments (PSA). The capability of the UK ABWR to maintain safety for all hazards identified in the UK general envelope will be evaluated as part of the GDA process.

A1.96 For aircraft impact, the UK ABWR layout will provide sufficient separation of safety systems to ensure availability of cooling to prevent core damage.

3.2 Defence-in-Depth

A1.97 The ABWR safety features are based on the Defence-in-Depth (DiD) concept wherein conservative design is provided for postulated design basis accidents. Multiple, segregated and diverse layers of protection are provided with each layer of protection being designed to provide the three main safety functions with no reliance on the other layers upon all 5 levels established by IAEA. In addition, accident management and interface of with off-site emergency response are considered in ABWR design.

- Level 1 – Prevention of abnormal operation and failures;
- Level 2 – Control of abnormal operation and detection of failures;
- Level 3 – Control of accidents within the design basis;
- Level 4 – Control of severe plant conditions including prevention of accident progression and mitigation of severe accident consequences; and
- Level 5 – Mitigation of radiological consequences of significant releases of radioactive materials.

A1.98 Levels 2 and 3 of the criteria are achieved by providing well-designed safety systems, as explained in the Safety Design section. Level 2 and Level 3 ensure the high safety of the ABWR and this is reflected in the low calculated Core Damage Frequency (CDF) for ABWR compared with IAEA target. In addition, ABWR has countermeasures to control severe plant condition in case of beyond design basis accidents like ATWS, SBO and LUHS. The key provisions can be summarised as:

- Diverse reactor shutdown systems:
  - Alternative Rod Insertion (ARI)
  - Standby Liquid Control System (SLC)

- Alternative core cooling systems and Ultimate Heat Sink (UHS):
  - Diversity of alternative water injection capabilities
  - Enhancement of mobility by applying portable pumps.
  - Diversity of heat sink through the use of portable heat removal system.

- Prevention of PCV damage:
  - Enhancement of PCV cooling systems and venting systems

- Alternative power sources:
  - Alternative DC power sources
  - Diversity of AC power sources (water-cooled diesel generators, air-cooled diesel generators)

- Ensuring building structures to secure components and power panels in the event of external hazards such as flooding.

- Alternative Spent Fuel Pool (SFP) cooling:
  - Diversity of pool water injection methods.
  - Enhancement of accident management and operability by external water injection measures.

  - Incorporation of additional SFP temperature and water level monitoring systems in case of severe accident.
- Countermeasures in the event of core meltdown (countermeasures for wet and dry scenarios).

3.3 Safety Analysis

A1.99 The robustness and suitability of the ABWR design against faults and hazards has been demonstrated by deterministic safety analysis as well as by Probabilistic Safety Assessments (PSA).

Deterministic Safety Analysis

A1.100 Deterministic safety analysis has been carried out to demonstrate the adequacy of the design for safety systems and safety related systems on ABWR in Japan and the US.

A1.101 For example, the following events of Anticipated Operational Occurrences (AOOs) and Design Basis Accidents (DBAs) are analyzed. Consequently, all of the acceptance criteria for AOOs and DBAs in Japan are met by the safety systems of ABWR.

Events Evaluated for DBA in Japan

- AOOs
  - [1] Abnormal change in reactivity or power distribution in the core
    - [A] Control rod withdrawal error at reactor start-up
    - [B] Control rod withdrawal error at power
  - [2] Abnormal change in heat generation or removal in the core
    - [A] Partial loss of reactor coolant flow (Trip of three reactor internal pumps)
    - [B] Loss of off-site power
    - [C] Loss of feedwater heating
    - [D] Recirculation flow control failure (Runout of all reactor internal pumps)
  - [3] Abnormal change in reactor coolant pressure or reactor coolant inventory
    - [A] Generator load rejection with bypass / with failure of all bypass valves
    - [B] Inadvertent MSIV (Main Steam Isolation Valve) closure
    - [C] Feedwater controller failure – Maximum demand
    - [D] Reactor pressure regulator in the open direction
    - [E] Loss of all feedwater flow

- DBAs
  - [1] Loss of reactor coolant or considerable change in core cooling
    - [A] Loss of coolant (LOCA)
    - [B] Loss of reactor coolant flow (Trip of all reactor internal pumps)
  - [2] Abnormal reactivity insertion or rapid change in reactor power
    - [A] Control rod drop
  - [3] Abnormal release of radioactive materials to the environment
    - [A] Offgas treatment system failure
    - [B] Main steam line break (MSLBA)
    - [C] Fuel assembly drop (Fuel Handling Accident)
    - [D] Loss of coolant (LOCA)
    - [E] Control rod drop
  - [4] Abnormal change in pressure and atmosphere etc. in the primary containment
    - [A] Loss of coolant (LOCA)
    - [B] Generation of flammable gas
    - [C] Generation of dynamic load

Acceptance Criteria in Japan

- AOOs
  - [1] Minimum critical power ratio: > Safety Limit MCPR

[2] Fuel cladding shall not be damaged mechanically, i.e., cladding circumferential strain: < 1%.

[3] The fuel enthalpy: < design limit (no damage) of fuel in the “Reactivity insertion event evaluation guidelines” published by NSC (Nuclear Safety Commission of Japan) (for Reactivity Insertion Accident)

[4] The pressure on the reactor coolant pressure boundary: < 9.48 MPa [gauge] (1.1 times the maximum allowable working pressure)

- DBAs
  [1] Peak cladding temperature: < 1200°C
  [2] Maximum cladding oxidation: < 15% of cladding thickness
  [3] The fuel enthalpy : < the limit value to prevent the generation of mechanical energy in the “Reactivity insertion event evaluation guidelines” published by NSC (Nuclear Safety Commission of Japan) (for Reactivity Insertion Accident)
  [4] The pressure on the reactor coolant pressure boundary: < 10.34 MPa [gauge] (1.2 times the maximum allowable working pressure)
  [5] The pressure on the primary containment pressure boundary: < 310 kPa [gauge] (the maximum allowable working pressure)
  [6] Effective dose for the public: < 5mSv

Probabilistic Safety Assessment (PSA)

A1.102 PSA, which has been performed in Japan and US, demonstrate that the enhanced safety features of the ABWR result in improved safety levels compared to earlier BWRs. ABWR achieves Core Damage Frequency (CDF) and large early release frequency (LERF), which are much less than the IAEA safety targets, by its inherent and enhanced engineered safety features.

A1.103 Furthermore, future assessments for the UK ABWR during the GDA process will be performed to demonstrate that accident risks are as low as reasonably practicable (ALARP).

3.4 Dose Targets and Limits

A1.104 For each new generation of BWRs, the goal has been to simplify the design and improve operations compared to predecessors, including improvements in workers and public’s safety.

A1.105 The UK ABWR inherited a technologically rich legacy of design, development and operating experience from which it became a plant that minimises radiological exposure to the workers and the public, and minimises radwaste and discharges from all sources of radiation. This means that it is expected that the UK ABWR will be demonstrated to meet UK radioactive dose targets as well as the As Low As Reasonably Practicable (ALARP) principle during the on-going GDA assessment process.

On-site Dose

Normal Operation

A1.106 The ABWR combines advanced facility design features and administrative procedures conceived to keep the occupational radiation exposure to personnel As Low As Reasonably Practicable (ALARP). During the design phase, the designs of layout, shielding, ventilation and monitoring instrument are integrated with traffic, security and access control and plant operation results are continuous feedback during the design phase. Moreover, clean and controlled access areas are separated. Reduction of plant personnel’s radiation exposure is principally achieved by:

[1] Minimizing the necessity for and the time spent by personnel in radiation areas by improvements such as reduction of inspection times by introduction of RIPs, reduction of the time for maintenance by the introduction of FMRCDs, installation of permanent monorails and cranes, semi-automated removal tools, etc.

[2] Minimizing the radiation levels in routinely occupied plant areas in the vicinity of plant equipment expected to require personnel attention by improvements such as materials selection to minimize radiation, equipment and piping design to reduce accumulation of radioactive material (seamless pipes), cleaning-up systems, leakage drain systems, shielding, ventilation systems, etc.

A1.107 The maximum individual annual worker dose is controlled by the Plant Operator's administrative procedures. In Japan, it is a common practice to limit maximum doses to 20mSv, which is 2/5 of the regulatory annual limit of 50mSv and 1/5 of the regulatory 5-year total limit of 100mSv.

A1.108 As the radiation dose rates from equipment and piping strongly affects worker occupational radiation doses, dose rate reduction is an important issue in both the ABWR design and for plant operation. Examples of ABWR provisions include:

- Adequate shielding and separation distance from the radiation source, provided for BWRs, result in low radiation dose rates on the turbine operating floor.

A1.109 When the turbine steam condenser is opened for its annual maintenance, gaseous radioactive iodine is present and control measures are required to minimise releases to the Turbine operating floor and hence worker and public radiation exposures. These measures include:

- Conduct of Turbine Condenser Purge using a Local Filtered Ventilation System from nuclear reactor shutdown before Condenser opening; and
- Application of various water chemistry control methods that reduce radioactivity levels in reactor coolant water and the rate of radioactive deposition rate.

A1.110 As a result, ABWR has significantly lower operator doses than previous BWRs as illustrated by the graph below.

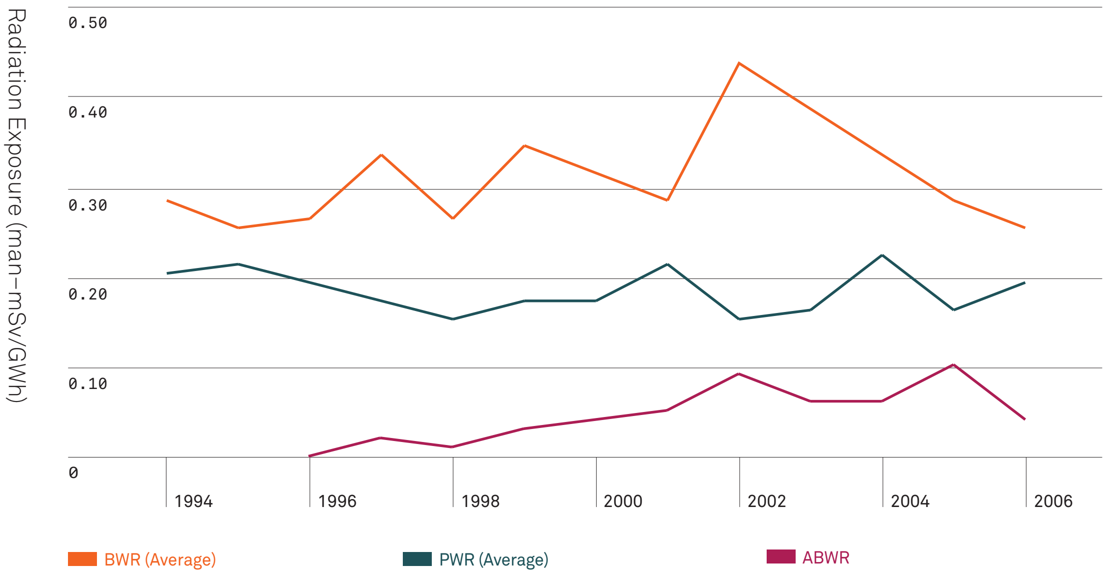


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Figure A1.5 Radiation exposure trends for Nuclear Power Plants in Japan.

***Source:"Operational Status of Nuclear Facilities in Japan", JNES**

Accident Conditions

A1.111 The layout and shielding considerations for normal operation also benefit the plant workers during accidents. The ABWR limiting evaluations have been done in the event of Design Basis Accident (DBA) and are based on US regulations requiring radiological evaluations considering the release of a significant fraction of the core inventory of fission products to the containment. The only on-site location permanently occupied after accidents is the Main Control Room. Calculated exposure to workers located in the control room after the postulated DBA is under 100mSv (10rem) TEDE (Total Effective Dose Equivalent).

Off-Site Dose

Normal Operation

A1.112 The design incorporates features to minimise off-site liquid and airborne releases during normal operation. The governing radiological regulation used in the US for radioactive species release concentrations is 10 CFR 20, Appendix B. Dose criteria is contained in 10 CFR 50, Appendix I, which specifies acceptable dose limits, which, if met, satisfy the US ALARA considerations.

A1.113 The main provisions for off-site dose reduction are the following:

- The Off-gas System (OG) processes gaseous fission products that might be released to the reactor steam from the fuel rods. Activated charcoal tanks provide hold-up to allow decay of radioactivity to acceptably low levels before release to the environment.
- The Liquid Radwaste Management System (LWMS) processes all contaminated liquids on-site. The design philosophy is to recycle the 100% of the water supplied to the plant, but there may be times when there is high water inventory in the plant, and consequently some diluted water needs to be discharged.

A1.114 The evaluated annual dose resulting from normal operation includes multiple radiation paths such as external exposure from gaseous effluents, internal exposure by inhalation, internal exposure from agricultural products, and internal exposure from sea products. In Japan the results of public exposure dose from the reactor operation activities is below 20μSv/y, which is low compared to the annual exposure dose from natural radiation and medical exposure. This level also gives confidence that the UK 0.3mSv dose constraint for a site can be met. For further dose reduction from normal operation, Hitachi-GE are continuously improving management and operation design provisions.

A1.115 Dose modelling of potential public doses from operation of UK ABWR have been undertaken by Hitachi-GE to support its submissions into the GDA process. Dose modelling of potential public doses from operation of UK ABWR have been undertaken by Hitachi-GE to support its submissions into the GDA process. Additionally, during the GDA process, it will be necessary to show that public doses are As Low As Reasonably Achievable (ALARA) and that this has been achieved by use of Best Available Techniques.

A1.116 Radiation dose rate (nGy/h) at the Monitoring point (actual data) around Kashiwazaki-Kariwa site is under 200nGy/y. A change in weather conditions can cause the dose value to fluctuate with the highest values at Kashiwazaki-Kariwa being reported during rainfall. The deviation in the dose level is low and does not influence radiological health effects.

A1.117 The conclusions of this work are for GDA consistent with Japanese experience.

Accident Conditions

A1.118 Many regulatory requirements and plant features are aimed at providing protection of the public against radiation releases from accidents. The results of the radiological consequences in the event of DBAs are around 0.01mSv, which demonstrates that the ABWR has large margin below the target dose value of 5mSv in Japan.

A1.119 An assessment in a UK context will be undertaken during the GDA process: the assessment will address the ability of the ABWR to demonstrate accident risks are as low as reasonably practicable.

3.5 Security Considerations

A1.120 The security performance of the UK ABWR will be assessed as part of the GDA process. There are no unique factors that affect the ability of the ABWR to deliver high levels of security compared to other nuclear power plant. For the UK, conceptual security arrangements will be assessed during Generic Design Assessment (GDA) process. Site specific security measures will be developed by the utility in a site security plan based on the conceptual security arrangements.

A1.121 Furthermore, the ABWR will be able to resist the deliberate impact of a large aircraft such that the integrity of the reactor building is maintained and the fuel in the reactor core and spent fuel pool is cooled and protected from severe damage.

A1.122 The ABWR, similar to existing BWRs, will meet safeguards verification requirements and represents no unique technology challenges with safeguards provisions on BWRs well established in Europe and elsewhere in the world.

3.6 Licensing Status

A1.123 The ABWR design has already been reviewed and approved by US and Japanese regulatory bodies, which accounts for a high degree of confidence in the robust basis of the design and safe operation of the ABWR.

A1.124 The US NRC issued the U.S. ABWR final Design Certification Rule (DCR) in the Federal Register on May 12, 1997. Prior to its expiry, US NRC provided its acceptance to review the GE-Hitachi Nuclear Energy Design Certification Renewal Application for the US ABWR in February 2011.

A1.125 Hitachi-GE has already completed the design and construction scope of 4 ABWR units now operating in Japan. The units are Units 6 and 7 of Kashiwazaki-Kariwa Nuclear Power Plant of TEPCO (in commercial operation in 1996 and 1997 respectively), Unit 5 of Hamaoka Nuclear Power Plant of Chubu Electric Power Co. (commercial operation in 2005) and Unit 2 of Shika Nuclear Power Plant of Hokuriku Electric Power Company (commercial operation in 2006). A further 2 units are under construction in Japan, Unit 3 of Shimane Nuclear Power Station and Unit 1 of Ohma Nuclear Power Station, which is the world’s first ABWR constructed to use MOX fuel (Mixed Oxide, an oxide fuel based on a mixture of uranium and plutonium) in the entire core.

A1.126 With regard to the United Kingdom, the Office for Nuclear Regulation (ONR) and the Environment Agency (EA) signed GDA agreements with Hitachi-GE in April 2013. The ABWR commenced Step 2 of the GDA assessment process in January 2014.

4 Operation and Maintenance

A1.127 The BWR design has gone through a series of evolutionary changes and has achieved significant technological evolution with the current generation of ABWRs. The major key features of the ABWR evolutionary design which have contributed to the improvement and facilitation of operation and maintenance tasks are the following:

- Improved safety and reliability;
- A simpler and more robust design;
- Advanced design and construction technologies; and
- Enhanced fuel.

4.1 A Summary of the Major Contributions to Operation and Maintenance

A1.128 By the introduction of RIPs at the bottom of the RPV instead of conventional primary loop recirculation pumps (external), the design has been greatly simplified. The results are less and easier maintenance and inspection, and more efficient and simpler operation by RIP power control features.

A1.129 The FMCRD has been developed to support high ABWR plant operation performance. The control rods are electrically controlled by motors during normal operation, which enables the operator to control the reactor power precisely by only operating a reduced range of control rods. This in combination with the RIPs result in easier power control. Furthermore, FMCRD features have contributed to shorten the start-up time required before reaching rated power and to reduce and simplify maintenance and inspection tasks.

A1.130 The ABWR digital monitoring and control system featured by multiple and fault-tolerant improved technologies as well as the use of optical multiple transmission technology in the creation of hierarchical information networks offers benefits such as the following. Large-scale display board facilities displaying the plant overall status where warnings are displayed using hierarchies, for improved identification and diagnostic; expanded automation controlling operation which mainly reduce the load on the operator to monitoring; and integrated digital control systems improving reliability and easing maintenance.

A1.131 Installation of permanent monorails and cranes, semi-automated removal tools and provision of local maintenance areas has contributed considerably to facilitate maintenance and inspection tasks.

A1.132 The ABWR can reduce the consumption of fuel by using spectrum shift operation, one of the characteristics of the BWRs and high burn-up fuel, which increases the energy produced per unit of uranium and represents up to a 15% of uranium saving in comparison to the PWRs.

A1.133 Thermal efficiency is enhanced by a high efficient turbine system based on the direct-cycle properties. The system is featured by a 52-inch long blade for the last stage of the turbine, a two-state moisture separator re-heater, and a heater drain pump-up system connected to the condensate system.

A1.134 Although the ABWR standard design is for 33% turbine bypass, this capability could be increased if necessary enhancing plant operating flexibility and adaption to grid necessities.

A1.135 Hence, the key features mentioned above contribute to improve plant overall performance compared to earlier BWRs, reduce costs and capital by:

- Less and shorter (simpler) maintenance, inspections and unscheduled outages;
- Simpler operation;
- Less personnel required for operation and maintenance;
- Longer and more efficient fuel cycle;
- Higher thermal efficiency; and
- Higher operation rate (capacity factor).

5 Spent Fuel and Radioactive Waste Management

5.1 Overview

A1.136 The ABWR has been developed to significantly reduce waste generation by adopting improved technologies and efficient operation. The radioactive waste treatment systems have been developed to reduce the radioactive material discharge to the environment. An example of the improvements with regard to the discharges of radioactive material to the environment is the adoption of a Hold-up system using charcoal adsorbers for gaseous waste. The radwaste treatment systems comprise the Liquid Radwaste Management System (LWMS), the Off-gas System (OG), and the Solid Radwaste Management System (SWMS).

5.2 Liquid Radwaste Management System (LWMS)

A1.137 The LWMS is designed to control, collect, process, handle, store, and dispose of liquid radioactive waste generated as the result of normal operation, including anticipated operational occurrences. All potentially radioactive liquid wastes are collected in sumps or drain tanks at various locations in the plant and transferred to collection tanks in the radwaste facility.

A1.138 System components are designed and arranged in shielded enclosures to minimise exposure to plant personnel during operation, inspection, and maintenance. Tanks, processing equipment, pumps, valves, and instruments that may contain radioactivity are located in access–controlled areas.

A1.139 The LWMS normally operates on a batch basis. Provisions for sampling at important process points are included. Protection against accidental discharge is provided by detection and alarm of abnormal conditions and by administrative controls.

A1.140 The LWMS is divided into several subsystems, so that the liquid wastes from various sources can be segregated and processed separately, based on the economical and efficient process for each specific type of impurity and chemical content.

A1.141 LWMS has been designed and operated to recycle treated liquid waste as much as possible except for detergent liquid waste such as laundry drain. However, there may be times when liquid discharges may be necessary due to capacity limits for on-site storage. Assessments to be provided during the GDA process will show that these discharges will achieve very low levels. All liquid discharges would be checked to confirm that they are indeed very small and that they meet the conditions and limitations specified in the Environmental Permit.

5.3 Off-gas System (OG)

A1.142 The Off-gas System processes off-gas contains radioactive noble gases and radiolytic hydrogen and oxygen from the main condenser and controls the release of radioactive gaseous to the site environs so as to maintain the exposure of persons outside the controlled area at ALARA level.

A1.143 The Off-gas System process equipments are located in the Turbine Building to minimise piping and housed in a reinforced-concrete structure to provide adequate shielding. Off-gas charcoal absorbers are installed in a temperature-monitored and controlled room to maintain the capability of the charcoal.

A1.144 The Off-gas System also reduces the possibility of an explosion from the radiolytic hydrogen and oxygen contained in the off-gas. This is accomplished by the catalystic recombination of the radiolytic hydrogen and oxygen within an Off-gas recombiner. The moisture in the off-gas is condensed to reduce the volume of off-gas within an OG condenser.

A1.145 The remaining non-condensables (principally air with a slight amount of radioactive krypton and xenon) are passed through Off-gas charcoal adsorbers, which provide adequate holdup volume of activated charcoal beds to allow time for the radioactive krypton and xenon to decay. After processing, the radioactive gas is monitored and discharged to the environment through the stack.

A1.146 Assessments to be provided during the GDA process will show that discharges will achieve very low levels. Gaseous discharges would be checked during operation to confirm that they are indeed very small and meet the conditions and limitations specified in the Environmental Permit.

5.4 Solid Radwaste Management System (SWMS)

A1.147 The SWMS is designed to control, collect, handle, process, package, and temporarily store wet and dry solid radioactive waste prior to shipment. This waste is generated as a result of normal operation and anticipated operational occurrences. These wastes are categorised as wet solid wastes (such as spent ion exchange resin beads and filter backwash arising from the operation of the LWMS etc.) or dry solid wastes (such as HEPA filters, protective clothing, tissue paper etc.). Both Low Level Waste (LLW) and Intermediate Level Waste (ILW) are processed by the SWMS.

A1.148 The SWMS functionally consists of the following four sub-systems:

- The wet solid waste collection sub-system;
- The wet solid waste processing sub-system;
- The dry solid waste accumulation and conditioning sub-system; and
- The container storage sub-system, until the packaged waste is sent off-site for disposal.

A1.149 A single ABWR operating for 60 years is estimated to generate approximately 20m^3/yr + miscellaneous waste of Low Level Waste (LLW) and approximately 10m^3/yr + irradiated metal waste of Intermediate Level Waste (ILW). The actual volumes of waste generated by an operating ABWR would depend on a number of site-specific factors, for example the waste strategy (including optimisation of treatment) adopted by the utility and the operating cycle selected (i.e. the period between outages).

A1.150 Disposability Assessments will be undertaken by NDA and LLWR for ABWR radioactive wastes during the GDA process. The results are expected to be available to inform the Secretary of State's consideration of this application. These assessments are expected to show that ABWR wastes can be accommodated within UK final disposal facilities (GDF and LLWR).

5.5 Spent Fuel Management

A1.151 The ABWR has a design life of 60 years at full power operation. The design incorporates a spent fuel storage pool with sufficient floor space for approximately 15 years of normal operation plus a full core off load with the installation of additional spent fuel racks.

A1.152 The capacity of the Spent Fuel Pool in the Reactor Building is 400% of the core so eventually (after a minimum of 10 years of operation) fuel will need to be moved out of the Spent Fuel Pool (SFP) to make room for newly discharged bundles. There are several options available to the operating utilities to deal with the spent fuel removed from the pool:

- Transfer to an additional interim spent fuel storage pool to house the spent fuel expected when the normal spent fuel pool is full; and
- Transfer to an interim dry storage facility.

A1.153 These options will be studied during the UK GDA process to consider whether this continues to represent the Best Available Technique (BAT) taking into account UK national policy for new build nuclear reactors.

A1.154 A Disposability Assessment will be undertaken by NDA for ABWR spent fuel during the GDA process. The results are expected to be available to inform the Secretary of State's consideration of this application. The assessment is expected to will show that ABWR spent fuel can be accommodated within the UK GDF as ABWR fuel is similar in nature to other spent fuels already assessed by NDA (with respect to materials, burn-up and dimensions).

6 Construction

A1.155 To improve the construction period, safety and quality, Hitachi-GE have continuously improved their construction technologies since their first involvement in Nuclear Power Plant (NPP) construction in the 1970's. Nowadays, Hitachi-GE have 4 main construction strategies as shown below.

- Reduction of on-site work volume: This is achieved through broader application of large module/block construction methods;
- Levelling of on-site manpower: This is achieved through open-top and parallel construction and floor packaging methods;
- Improvement of on-site productivity: This is achieved through front-loaded construction engineering and detailed schedule management with Hitachi-GE's CAE system.
- Improvement of on-site support work efficiency; and
  This is achieved through development and introduction of an Integrated Construction Management System (ICMS).

A1.156 These strategies contribute to Hitachi-GE's excellent execution of NPP projects (safety, quality, on-Schedule and on-Budget).

A1.157 ABWR has a reference construction schedule of about 40 months from first concrete to fuel loading. This schedule is being studied to develop proposals to fit conditions in UK.

7 Decommissioning

A1.158 New nuclear power stations must be considered to facilitate future decommissioning in a safe and environmentally acceptable way at the early stage. This includes design principles and fulfilment of IAEA requirements related to decommissioning. The incorporation of decommissioning considerations into the ABWR design has been applied by lessons learnt from Hitachi-GE's work all over the world. Furthermore, the ABWR has been designed with features to facilitate decommissioning of the plant to keep doses to workers ALARP and to minimize radioactive waste arising from decommissioning.

A1.159 Estimates of raw unconditioned decommissioning waste volumes indicate that approximately 28,000 tons of LLW and 1,000 tons of ILW will be generated. It should be noted that the LLW also includes waste rubble for Very Low Level Waste (VLLW) disposal. The waste arising from decommissioning is compatible with UK waste management strategies. The actual volume of decommissioning waste will depend on a number of site-specific factors, such as the decommissioning strategy adopted by the utility (prompt or delayed) and the end stage of the site post decommissioning.

8. Other Environmental and Health Effects

A1.160 The non-radiological environmental and health impacts associated with the operation of the ABWR are described as follows.

8.1 Cooling Water Systems

A1.161 During operation, the cooling water abstraction requirements (assuming sea water cooling) will be around 56m^3/s, which leads to a sea water temperature rise of 12°C. A detailed site specific assessment will be required to assess the effects of abstraction and the thermal discharges and demonstrate that the impact on the local marine environment has been minimized.

8.2 Chemicals

A1.162 The chemicals used in ABWR will be similar to those in all other BWR nuclear power plants. Major chemicals will include the following:

- Oxygen, nitrogen and hydrogen gases, stored cryogenically;
- Hydrochloric acid , sodium hydroxide, sodium hypochlorite; and
- Propane, gasoline, diesel fuel.

A1.163 Based on the low quantities used, the impact from discharges to air or to water should be very low.

A1.164 During the GDA process, an assessment of the quantities and form of these chemicals will be undertaken to assess whether an ABWR site is likely to fall under the Control of Major Accident Hazard (COMAH) Regulations.

8.3 Conventional Waste

A1.165 The conventional waste generated by the ABWR is expected to be broadly similar to that from any other nuclear power plant. The exact amount of conventional waste produced will depend on the exact methods of operation of the ABWR and also the practices of the utility owner.

A1.166 The waste hierarchy will be followed to ensure that waste generation is minimised and waste streams are appropriately controlled and segregated as is the practice at any large industrial facility in the UK.

8.4 Noise

A1.167 The major sources of continuous noise from the ABWR plant are the following:

- Stand-by diesel generators (when operating);
- Transformers, turbine generator units; and
- Large motor-driven pumps (circulating water, feedwater, etc).

A1.168 For a UK ABWR these will be operated in accordance with the conditions and limitations specified in the Environmental Permit.

8.5 Air Quality

A1.169 The stand-by diesel generators would be used for only a few hours per year for periodic tests or if the grid connection is lost. The emissions from the stand-by diesel generators are small and would be operated in accordance with the conditions and limitations specified in the Environmental Permit.

TWO

ANNEX 2

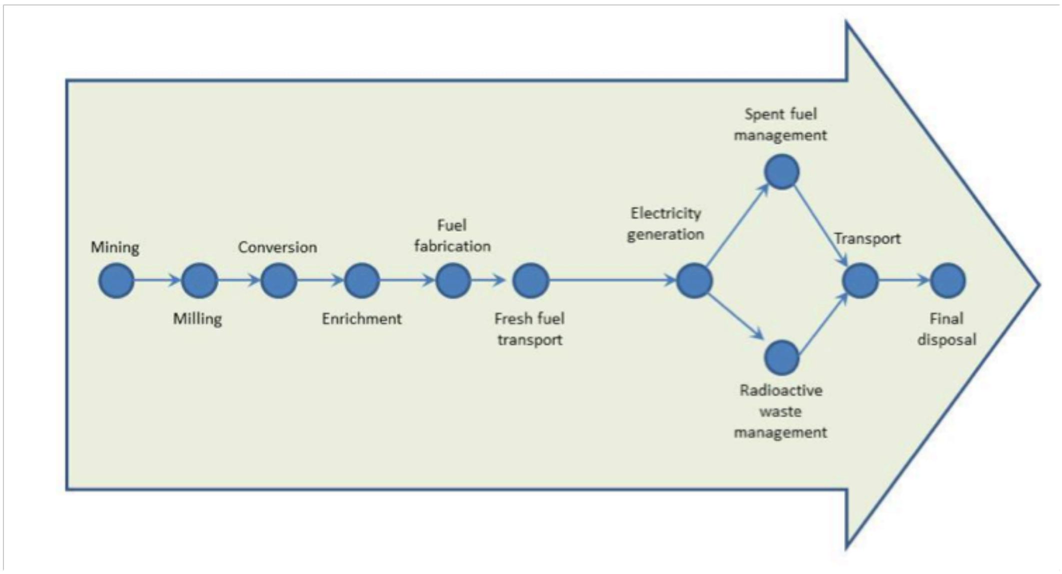
NUCLEAR FUEL CYCLE

Annex 2 – Nuclear Fuel Cycle

Introduction

2.1 The nuclear fuel cycle is the progression of nuclear fuel through a series of differing stages. The front end consists of the steps to manufacture the fuel and its use in electricity generation. The back end consists of those steps to safely manage and then dispose of spent nuclear fuel. Figure A2.1 below is a schematic of an open fuel cycle as fuel is disposed of after use.

→
Figure A2.1
Nuclear Fuel
Cycle Overview



Uranium Mining and Milling

A2.2 Uranium deposits are found in rocks around the world. The largest producers of uranium are Kazakhstan, Canada and Australia. Other uranium producing countries include Russia, Namibia, and Niger. Uranium is recovered either by mining hard rock or by in situ leaching, in which either a strong acid or a strong alkaline solution is used to dissolve the uranium and bring it to the surface.

A2.3 Milling of mined ore extracts the uranium to produce a uranium oxide concentrate that is shipped from the mill. This concentrate is sometimes referred to as “yellowcake”. The remainder of the ore, containing most of the radioactivity and nearly all the rock material, becomes tailings, which are contained and treated in engineered facilities near the mine (often in a mined out pit). Leaching does not involve the disposal of tailings.

A2.4 There are no uranium mines in the UK, and thus no mining or milling activities in the UK.

Conversion, Enrichment and Fuel Fabrication

A2.5 Natural uranium is a mixture of two radioactive isotopes (atomic forms) of uranium (^{235}U and ^{238}U). ^{235}U makes up on average just 0.7% of natural uranium and is the only uranium isotope capable of undergoing fission by slow moving (“thermal”) neutrons. Inside a nuclear reactor the nuclei of ^{235}U atoms split (fission) and, in the process, release energy.

A2.6 The solid uranium oxide from the mine is purified and converted into gaseous form as uranium hexafluoride (UF_6) for the enrichment process. Enrichment increases the fraction of the ^{235}U isotope through the use of diffusion or centrifuge technology. Both methods use the physical properties of molecules, specifically the 1% mass difference between ^{235}U and ^{238}U, to separate the isotopes.

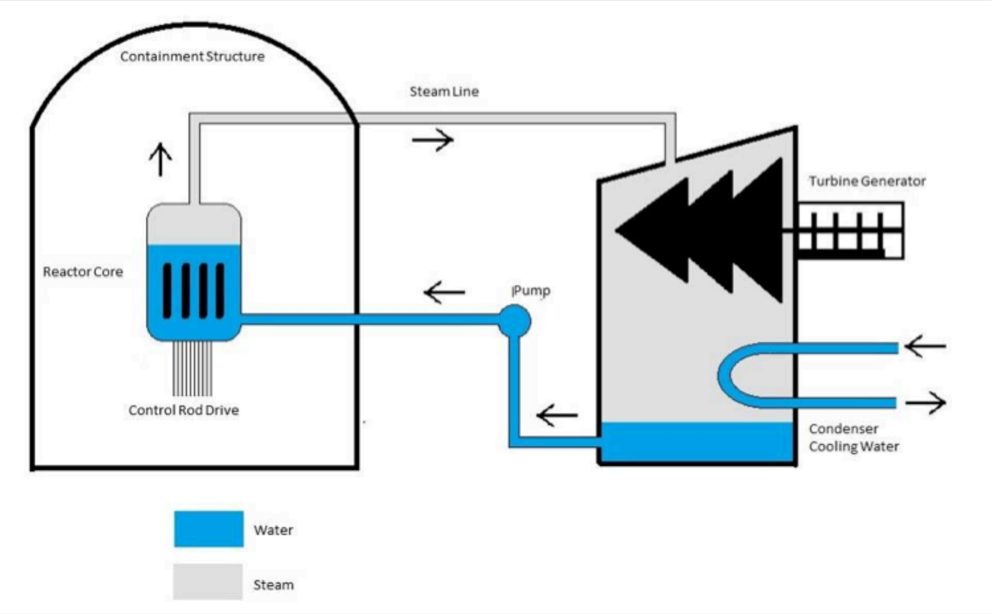
A2.7 The enriched uranium hexafluoride is subsequently converted to uranium oxide powder (which has a very high melting point), and these are pressed into ceramic pellets. These are then loaded into hollow metal tubes to form fuel rods. Clusters of these rods held in a regular geometry by grids form fuel assemblies (or elements) for use in the core of the nuclear reactor. The fabricated fuel is robust; the fuel pellets have a high melting point and are chemically stable and are themselves enclosed in gas tight metal tubes which are resistant to chemical corrosion.

A2.8 The UK ABWR reactor technology, in common with most reactor designs for electricity generation, utilises nuclear fuel of low enrichment i.e. the proportion of ^{235}U has generally been increased to around 5% or less. It is physically impossible for uranium at this level of enrichment to sustain a nuclear chain reaction without the presence of a moderator (a material like water or graphite that slows down neutrons). It is also impossible for a nuclear explosion to be achieved with material at this low level of enrichment.

A2.9 Conversion, enrichment and fuel manufacture for the new technology could be sourced from either overseas or from the UK.

Electricity Generation

A2.10 Nuclear reactors produce electricity by heating water to make steam. This steam is then used to drive turbines that generate electricity as shown below in Figure A2.2 (note: this depicts a generic BWR design. Specific information about the ABWR design can be found in Annex 1). In this respect nuclear reactors are similar to other thermal power stations, where the heat is provided by burning coal or gas.



→
Figure A2.2 Schematic of electricity generation from a boiling water nuclear reactor

A2.11 The ^{235}U atoms in the fuel in the reactor vessel release energy by splitting (fission). This is illustrated below in Figure A2.3. Each fission releases neutrons that can then cause other uranium atoms to undergo fission resulting in a chain reaction. A moderator is used to slow down the neutrons to help achieve this process, and control rods absorb excess neutrons to ensure the chain reaction continues at a controlled rate.

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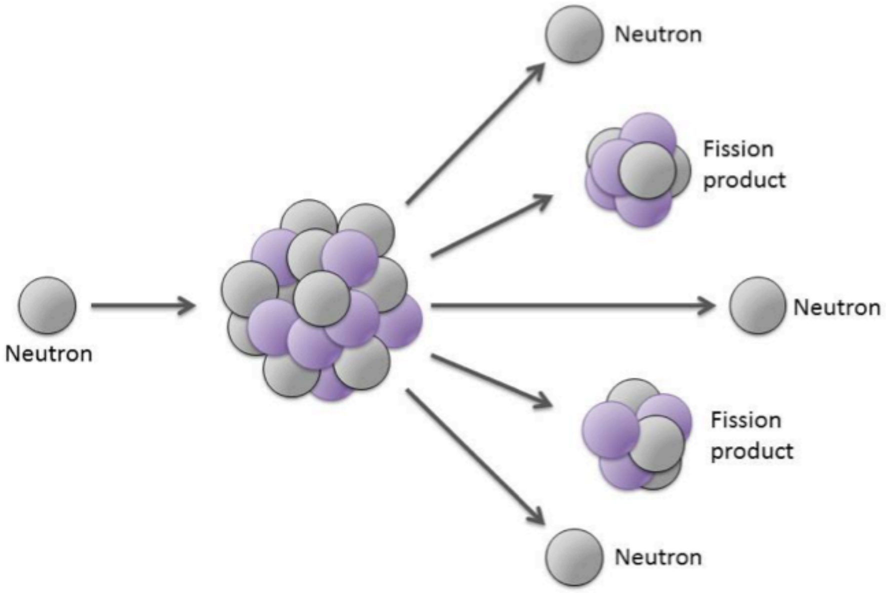
Figure A2.3
Schematic of
Fission Process



A2.12 The main source of additional radioactivity generated as a result of this process are the fission products – the fragments remaining after the ^{235}U nucleus has split in two. These fission products remain trapped inside the fuel pellets' ceramic structure and within its metal cladding.

A2.13 Further information specific to the UK ABWR is provided in Annex 1.

Spent Fuel Management

A2.14 A nuclear fuel assembly can produce a very large amount of energy before it needs to be replaced. Typically assemblies remain inside the reactor for 3-4 years. Most modern reactors are shutdown for refuelling – typically refuelling is at 1-2 year intervals when a quarter to a third of the fuel inside the reactor is replaced with fresh fuel.

A2.15 When removed from a reactor, a fuel assembly emits both radiation and heat, principally from the fission products inside each fuel rod. Spent fuel is unloaded into an engineered storage "pond" (which looks like a very deep swimming pool) adjacent to the reactor where its radiation and heat level gradually decreases. In these ponds the water provides both radiation shielding and absorbs the heat. Spent fuel may be held in such ponds for periods from several months to many years.

A2.16 After storage in the ponds there are two main options available to the plant owner. The first is transfer of fuel to engineered wet or dry storage awaiting a final repository for disposal. With this option, fuel could be stored on site throughout the life of the station or transported to a central location. The second option, which Government has made clear would be subject to further consultation and policy approval[207], would be for transfer to a reprocessing facility where useful fissile material (plutonium and/or reprocessed uranium) within the spent fuel could be recovered for future reactor re-use and the smaller quantity of remaining waste fission products separated for subsequent encapsulation and storage in a repository.

Radioactive Waste Management

A2.17 Nuclear power stations generate radioactive waste in solid, liquid and gaseous forms. The vast majority of radioactivity generated remains confined within the fuel and is safely stored and managed as described above. Liquid and gaseous wastes are filtered and treated and only very small quantities are permitted to be discharged into the environment in accordance with the Environmental Permitting (England and Wales) Regulations 2010 (EPR10). These regulations require permits to cover all disposals including any discharges of radioactivity into

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[207] A White Paper on Nuclear Power, Cm 7296, January 2008.

the environment. Key features within these permits are limits on quantities of radioactivity (with separate limits for various types) which may be discharged and a requirement to use "best available techniques" (BAT) to limit the amounts of radioactivity released into the environment. The treatment of liquid and gaseous wastes means that most of the radioactivity is captured and contained on solid media (for example in filters, resins etc.). Solid low level waste (LLW) from power stations is packaged and disposed of in the national Low Level Waste Repository in Cumbria. Solid intermediate level waste (ILW) generated during reactor operations is packaged and will be stored on a nuclear licensed site until final disposal in the deep Geological Disposal Facility can be made.

Decommissioning

A2.18 Decommissioning is the final stage in the life cycle of any power plant, prior to returning the site back to a "green field" or "brown field" condition for re-use. The key stages in the decommissioning process are set out at Annex 3.

A2.19 To date about 100 commercial reactors and over 250 research reactors have been retired from operation and some of these have been fully decommissioned and dismantled.[208] Progress is being made in decommissioning commercial UK reactors under the aegis of the Nuclear Decommissioning Authority (NDA). Further information on world-wide experience in decommissioning is included in Annex 3.

Transport

A2.20 The operation of nuclear power stations requires the transport of radioactive materials to and from the site. Radioactive materials transport linked to UK ABWR power station(s) would comprise:

- The transport of new fuel assemblies to the station;
- The transport of spent fuel from the station; and
- The transport of radioactive waste materials – either during normal operation or as part of the station's decommissioning.

A2.21 These movements may take place by sea, road or rail. All three types of transport would be subject to UK regulations, which are framed so as to ensure that any possible additional radiological health detriment resulting from transport is extremely low. Radioactive material containers for highly radioactive material (e.g. spent nuclear fuel) are of high integrity to provide a very high level of protection for the public and workers from their radioactive contents. The containers are designed to withstand severe impacts without releasing their contents: this is demonstrated through a series of stringent tests as set out in IAEA regulations.[209]

A2.22 Transport of radioactive materials is a well-established practice: about twenty million packages of all sizes containing radioactive materials are routinely transported worldwide annually on public roads, railways and ships. Only around 5% of these movements are related to the nuclear power industry. Since 1971 there have been some 7,000 shipments of used fuel (over 80,000 tonnes) over many million kilometres. In summary, the industry has over 40 years of experience of nuclear transport with no transport accidents that have resulted in the release of radiation.

Low Level Waste Disposal

A2.23 Low level wastes arising from UK ABWR operations would be transported to the low level repository for final disposal.

A2.24 The UK has a low level radioactive waste disposal facility located close to the West Cumbrian coastline in the North West of England at Drigg. Established in 1959, the site has safely disposed of low level waste for over 50 years. Low level waste is placed in engineered containers and is grouted prior to disposal in engineered concrete vaults.

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[208] Decommissioning Nuclear Facilities, Oct 2013 http://www.world-nuclear.org/info/inf19.html.

[209] Regulations for the Safe Transport of Radioactive Material, 2012 Edition, No. TS-R-1, http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1570_web.pdf.

Intermediate and Spent Fuel Disposal

A2.25 ILW and spent fuel from UK ABWR stations would ultimately be transported to the UK Geological Disposal Facility (GDF) for final disposal.

A2.26 The Nuclear Decommissioning Authority (NDA) has responsibility for implementing geological disposal of higher activity radioactive waste. They are carrying out preparatory work to plan for geological disposal pending identification of a site under the Government's Managing Radioactive Waste Safely (MRWS) process.

A2.27 More information on waste management and disposal can be found in Chapter 6.

THREE

ANNEX 3

WASTE DISPOSAL AND DECOMMISSIONING

Annex 3 – Waste Disposal and Decommissioning

Introduction

A3.1 At the end of the life of any power plant, it is necessary to decommission and demolish the facility so that the site can be made available for other uses. For nuclear plants, the term decommissioning includes all clean-up of radioactivity and progressive dismantling of the plant. In 2013 the International Atomic Energy Agency (IAEA) reported that throughout the world 144 nuclear power plants had been permanently shut down. Of these, 16 have been fully dismantled. Approximately 50 are in the process of being dismantled with about 60 other reactors being kept in a safe enclosure mode.

A3.2 This Annex provides further background information relevant to Chapter 6 on:

- Worldwide approaches to disposal of radioactive waste;
- The different phases that comprise the decommissioning of a nuclear power station; and
- Worldwide experience of carrying out decommissioning.

Worldwide Experience on Radioactive Waste Disposal

A3.3 Geological disposal at a depth of some hundreds of metres in a carefully engineered repository was first formally advanced as an appropriate, safe solution to radioactive management over fifty years ago, in the United States.[210] Following decades of research and development it has become the preferred option for the eventual disposal of solid, high level and long-lived intermediate level wastes (ILW) in almost every country with a nuclear power programme. Whilst the timescales and routes to eventual disposal vary from country to country – with different approaches to interim storage, for example – emplacement in a geological repository is the anticipated endpoint. This preference is generally expressed in national policy documents or laws.

A3.4 The international situation is highly transparent. For example, the IAEA Joint Convention on Spent Fuel and Radioactive Wastes[211] now obliges all signatory states (which include the UK) to submit regular, detailed overviews of their national waste management programmes.

A3.5 About 20 repositories are projected to be commissioned around the world by the end of 2030.[212]

Worldwide Approaches to Disposal of ILW

A3.6 In a number of countries disposal facilities for short-lived wastes have been developed at depths in excess of 80-100m. For example underground repositories for LLW and short-lived ILW have been operational in Finland for many years. Both the Olkiluoto and Loviisa nuclear power stations have on-site LLW and short-lived ILW repositories where conditioned wastes are disposed of in reinforced concrete silos approximately 70-100 metres underground. The final repository for short lived radioactive waste (SFR) at Forsmark in Sweden uses a concrete silo constructed in a granite vault about 60m below the surface. The same repository utilises large rock vaults (160m long and 10-16m high) for lower activity wastes and has been operating since 1988.

A3.7 Long-lived wastes such as transuranic waste (TRU) and long-lived intermediate-level waste (LL-ILW) need to be buried at a depth in excess of several hundred metres. The half-lives of some of the components of these wastes are many orders of magnitude greater than for short-lived wastes. It is therefore important to isolate these wastes from man's environment for a long time. Burying at depth will ensure that events such as glaciation do not expose the waste, that there is a lower risk of accidental intrusion by a future society, and that the return time and dilution of any groundwater contaminated by solutes is increased. In the USA, transuranic defence-related waste has been disposed of at the Waste Isolation Pilot Plant (WIPP) in New Mexico since 1999. WIPP is currently the only operating Geological Disposal Facility for long lived waste. The repository is at a depth of 655m in bedded salt and has a disposal capacity of about 175,000m^3.

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[210] National Academy of Sciences, 1957. The Disposal of Radioactive Waste on Land. National Academy of Sciences. Publication 519, NAS Washington DC, September 1957.

[211] IAEA, 1997, The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. GOV/INF/821-GC(41)/INF/12. International Atomic Energy Agency.

[212] IAEA, Vienna http://www-ns.iaea.org/conventions/waste-jointconvention.htm http://www.iaea.org/Publications/Factsheets/English/manradwa.html.

As of September 2013, a total of 11,586 waste shipments have been made and 88,623m^3 has been disposed of.

A3.8 All countries with repository plans for disposing of high level waste (HLW) or spent fuel also have plans for geological disposal of long-lived ILW (for example, arising from reactor decommissioning) and sometimes for all of their ILW. In some concepts (e.g. Switzerland) this would require a small extension to a spent fuel/HLW repository in the form of one or more caverns for the ILW packages. In other countries, a separate repository is planned (e.g. Sweden) and in Japan a low-level radioactive waste disposal centre at the Japan Nuclear Fuel Ltd. (JNFL) site at Rokkasho-Mura has been in operation since 1992.

Worldwide Approaches to Disposal of HLW and Spent Fuel

A3.9 Progress on providing deep geological repositories for HLW and/or spent fuel is most advanced in Finland (operations expecting to commence around 2020) and Sweden (operations expecting to commence around 2027).

A3.10 Sweden is planning to encapsulate all of its spent fuel in copper canisters which will then be deposited in bedrock, (embedded in clay), and at a depth of 500m. Fabrication techniques for the canisters have been tested at the Canister Laboratory in Oskarshamn and an application was submitted in November 2006 to build the plant. Site investigations for the repository were begun at two sites - Oskarshamn and Forsmark in 2002, with the aim of selecting the most suitable site. In 2009 Forsmark was chosen by the Swedish Nuclear Fuel and Waste Management Company (SKB) as the repository site and in 2011 a licence application for the repository was submitted to the Government and the Environmental Court. Construction of the encapsulation facility and the repository is expected to begin in 2019 with first disposal commencing in 2027.

A3.11 In Finland, detailed site characterisation was undertaken at four sites in the period 1993-2000 and in 1999 an application was made to Government to proceed with the repository project and an underground rock characterisation facility called ONKALO at Olkiluoto. Parliament ratified the Government decision in May 2001 (by 159 votes to 3). Construction of the rock characterisation facility, which will eventually become an integral part of the repository, began in 2004 and in 2013 the inclined tunnel stands at 4,987m long and extends to a depth of 455m. A construction application for a Geological Disposal Facility (GDF) for Spent Nuclear Fuel was submitted to the Government in December 2012 with operations planned to commence around 2020.

A3.12 In the USA, more than two decades of extensive scientific effort was conducted to determine whether Yucca Mountain, Nevada, was a suitable site for a repository. This culminated in the US Senate approving the development of a repository in July 2002. A licence application for construction of a GDF for High Level Waste and Spent Nuclear Fuel at Yucca Mountain in Nevada was submitted in 2008, but the project was suspended in 2009, and the review of the licence frozen. The courts have now ruled that a new siting process, as recommended in 2012 by the Blue Ribbon Commission, on America's Nuclear future may be introduced, although this will require a change in the law. A draft Bill was placed before Congress in April 2013 seeking to amend the original law.

A3.13 In France a siting process to determine a suitable location for a Geological Disposal Facility was launched in 1992 with a National Call for volunteering. In 1998 an Underground Research Laboratory (URL) in the Meuse/ Haute-Marne region of France was licensed. A series of legally mandated public debates were initiated in May 2013 which will be followed by the final selection of sites for surface and underground installations. It is expected that a licence application for construction of the geological repository will be submitted to the CNE (Comité national d'evaluation des establissements publics à caractère scientifique, culturel et professional) and the ASN (Nuclear Safety Authority) in 2015. It is planned that construction of the repository will commence in 2019 with reception of the first waste packages in 2025.

The Stages of Decommissioning

A3.14 The decommissioning process can be broken down into the following stages:

- Defuelling;
- Post-Operations clean out;

- Dismantling;
- Site clearance; and
- De-licensing.

Defuelling

A3.15 Defuelling of the reactor(s) would be the first step of decommissioning, and would take place as early as possible once the reactor had been shut down for the last time. This activity accounts for the removal of 99.9% of the radioactive materials from within the reactor. Fuel is extracted from the reactor in the same manner, and using the same equipment, as routine refuelling operations during the electricity generation phase. The fuel from the reactor would initially be stored in the fuel ponds for a period of approximately five years, before it was moved to a "stand-alone" interim storage facility which could be on the power station site, but may be elsewhere. Interim storage would last until transport to a final disposal repository. Arrangements for storage of the lifetime arisings of fuel from the station will have been developed as part of planning for the operational life of the station (see section on spent fuel management in Chapter 6).

A3.16 Completion of defuelling would allow those plant and systems previously required for the safe handling of the fuel to be decommissioned and the rate of progress of the station decommissioning can then be independent of the disposal timetable for the spent fuel itself.

A3.17 The long-term care and maintenance and ultimate decommissioning of any on-site interim storage facilities would be incorporated into the station's decommissioning strategy.

Post-Operations Clean Out (POCO)

A3.18 Once the reactor has ceased operating, post-operations clean out can begin. This phase is run as far as possible concurrently with defuelling, although clean out of some areas would need to wait until the fuel ponds are empty.

A3.19 During this phase the plant is decontaminated. The term decontamination covers the broad range of activities intended to remove or reduce the radioactive contamination in or on materials, structures and equipment at a power station. Decontamination will be carried out on various internal and external surfaces of components and systems, building surfaces and the tools used during operations and decommissioning. The process of decontamination associated with decommissioning can be conducted before, during or after dismantling.

A3.20 Decontamination helps to reduce the radiation doses to workers during decommissioning (see Chapter 5 for more details on dose during decommissioning). It also minimises the volume of radioactive waste by cleaning materials with only surface contamination, so allowing materials to be re-used or recycled.

A3.21 A number of decontamination techniques such as chemical washing, shot blasting (with different types of media), high pressure water, surface scabbling and peelable coatings have been developed and are currently in use during decommissioning, both in the UK and internationally.

Dismantling

A3.22 Dismantling involves cutting up large components into smaller pieces that are then removed. There are many available dismantling techniques such as diamond wire sawing, shearing, manual disassembly, thermal cutting and high pressure abrasive cutting applicable to reactor decommissioning that have been used internationally and in the UK.

Site Clearance

A3.23 During this stage the final buildings and materials are removed from the site for reuse, recycling or disposal. The interim storage facilities for ILW and spent fuel would also be removed at this stage if a final disposal facility was operating and all these materials had been removed and transported off-site. If a disposal facility were not available, they would remain on the site in interim surface storage facilities.

A3.24 Once this work has been completed, a survey of the power station site would be performed to demonstrate that the residual activity levels on the land are at or below the levels stated in the decommissioning plan and at or below the levels the regulator requires for the land to be released in order to be re-used for other pre-defined purposes.

De-licensing

A3.25 The final stage is when the operator of the site makes an application to the regulator for the site to be de-licensed. This is the process where there has been demonstrated to be no further need for regulatory control and the land can be released to be reused for other purposes.

Worldwide Experience in Decommissioning

United Kingdom

A3.26 Of the ten Magnox power stations in the UK only one (Wylfa) is still in operation with the remaining nine stations at various stages of decommissioning. All sites will be decommissioned in accordance with the "Care and Maintenance" (C&M) strategy which comprises four main steps:

[1] Defuelling;
[2] Prepare the site for Care and Maintenance by:
  - Removing all conventional ancillary plant, equipment and buildings; and
  - Rendering the site passively safe for the medium to long term with minimal need for human intervention.

[3] Care and Maintenance phase:
  - Maintain the bulk reactor structure (the reactor "Safestore") for a period of decades to allow radioactivity to decay; and
  - Transfer ILW to the GDF.

[4] Final site clearance:
  - Dismantle and remove the reactor Safestore and the ILW store; and
  - Clear the site and release it for re-use.

A3.27 Two stations, Oldbury and Sizewell A, are still being defueled. Chapelcross recently completed defueling some 6 weeks ahead of schedule. During the defueling period, as associated systems and plant are no longer required for operation, they are shut down, de-energised, drained of working fluids and gases, isolated and placed in a quiescent and passively safe state pending decommissioning. Some preparation work for the C&M phase is also carried out during defueling.

A3.28 Seven of the Magnox stations have had all of their fuel removed and preparations are now underway to place them into Care and Maintenance. Two of these stations (Bradwell and Trawsfynydd) are undertaking accelerated decommissioning with a view to moving into the C&M phase within the next few years, some 10 years earlier than originally planned. All of the remaining stations, including Wylfa, are expected to enter C&M before 2030.

A3.29 Although decommissioning work is challenging, safety is always the prime objective. It is reassuring to note therefore that Magnox was awarded the engineering and construction sector award at the 2013 RoSPA awards for the second year running.

A3.30 The following paragraphs provide some additional details of progress on power reactor decommissioning in the UK.

A3.31 Berkeley power station closed in 1989, and defueling of the site was completed ahead of target in June 1992 with around 85,000 fuel elements discharged from the reactors. This was followed by the removal of asbestos insulation at the plant and its subsequent clean-up and dismantling. The decommissioning included the removal of reactor cooling circuit gas ducts and boilers, the complete dismantling and decontamination of the fuel handling equipment and cooling ponds, and the deplanting and demolition of the turbine hall, cooling water plant and ancillary buildings. It was possible for substantial quantities of plant, equipment and materials to be re-used or recycled. Contaminated plant was decontaminated where possible to minimise the quantities of radioactive waste resulting from decommissioning. Finally, the height of the reactor buildings was reduced and they were enveloped in a robust cladding to prepare the reactors for their extended period of "safestore". Work is now in progress to retrieve and process the operational wastes accumulated on the site during its operational life.

A3.32 Trawsfynydd power station was closed in 1993, and defuelling was completed in 1995. The fuel route plant and equipment has been completely decommissioned and removed, and work is currently in progress to remove the contaminated surface layer of the fuel cooling ponds. Work is now complete to remove the reactor gas circuits, and the upper halves of the steam generators. This will facilitate the site's entry to care and maintenance and the eventual height reduction of the reactor building. All the plant has been removed from the turbine hall which has been demolished. Construction of a new interim waste storage facility has been completed, and management of the accumulated operational radioactive wastes is progressing well.

A3.33 The Windscale Advanced Gas Cooled Reactor (WAGR) operated from 1962-1981 was the prototype for the seven commercial scale Advanced Gas-cooled Reactor (AGR) stations now operated by EDF Energy. The decommissioning of WAGR was initially undertaken as a demonstration exercise and substantial progress has been displayed. Fuel removal was completed in 1983, with the fuel handling equipment, heat exchangers, reactor top biological shield and pressure vessel head all removed by 1995. In the period to 2006, the reactor core and remainder of the reactor vessel were also removed.

A3.34 The low power research reactor GLEEP at Harwell is an example in the UK where, following over 40 years of operation, decommissioning has progressed to the stage where the entire reactor has been removed and the land made available for economic regeneration.

United States

A3.35 There is a range of experience available from the USA. Ten plants classified as "power reactors" have either had their licenses terminated completely by the Nuclear Regulatory Commission (NRC), the US nuclear safety regulator, as a result of completed decommissioning or retain a license only for the purpose of fuel storage in an Independent Spent Fuel Storage Installation (ISFSI). An additional ten plants are recorded by NRC (April 2013) as being in SAFESTOR awaiting decommissioning. These include the San Onofre Unit 1 plant which is substantially decommissioned but had the removed reactor vessel in storage on the site. Humboldt Bay 3 and Zion 1 & 2 are recorded as having a "DECON" status indicating that active decommissioning is in progress. Two plants, San Onofre Units 2 and 3 have recently (July 2013) been declared as permanently shutdown by their owner and are expected to adopt DECON, which will include completion of the San Onofre Unit 1 decommissioning.

A3.36 At multi-unit nuclear power stations, the approach has generally been to place the first closed unit into storage until the others end their operating lives, so that all can be decommissioned in sequence. This optimises the use of staff and the specialised equipment required for cutting and remote operations, and achieves cost benefits. Thus, after 14 years of comprehensive clean-up activities, including the removal of fuel, debris, and water from the 1979 accident, the Three Mile Island Unit 2 was placed in Post-Defuelling Monitored Storage (SAFESTOR) until the operating licence of Unit 1 expires in 2014 at which time both units will be decommissioned together. Similarly, Indian Point Unit 1 was shutdown in 1974 and subsequently defueled. It is now in SAFESTOR condition awaiting closure of Unit 2.

A3.37 An example of a US DECON project is the 60MWe PWR reactor at Shippingport, Pennsylvania that operated commercially from 1957 to 1982. It was used to demonstrate the safe and cost-effective dismantling of a nuclear power plant and the potential for early release of the site. Defuelling was completed in two years, and five years later the site was released for use without any restrictions. Because of its modest size, the pressure vessel could be removed and disposed of intact. This has also been the approach of a number of subsequent larger US projects.

A3.38 Immediate DECON was also the option chosen for the facility at Fort St Vrain, Colorado, a 330MWe high-temperature, gas-cooled reactor which closed in 1989. This took place on a fixed-price contract for US$ 195 million (hence costing less than 1 cent/kWh despite only a 16-year operating life) and the project proceeded on schedule to clear the site and relinquish its licence early in 1997 - the first large US power reactor to achieve this.

A3.39 For Trojan (1,180MWe, PWR) in Oregon the dismantling was undertaken by the utility itself. The plant closed in 1993, steam generators were removed, transported and disposed of at the Hanford Site in Washington State in 1995, and the reactor vessel was removed and transported to Hanford in 1999. Except for the used fuel storage area, the site was released for unrestricted use in 2005.

A3.40 Another US DECON project was carried out at Maine Yankee, an 860MWe PWR plant that closed down in 1996 after 24 years of operation. The containment structure was finally demolished in 2004 and, except for 5 hectares of land used for the dry storage of spent fuel, the site was released for unrestricted public use in 2005 on schedule and within budget.

A3.41 Big Rock Point was a small (75MWe) BWR plant in Northern Michigan which operated from 1963 to 1997. Dismantling in line with a DECON strategy began shortly afterward, including intact removal of the reactor vessel and transport to a disposal site by rail. Decommissioning was completed in August 2006. The NRC announced the release of most of the site for unrestricted use in January 2007.

A3.42 San Onofre Unit 1 was shutdown in 1992. Dismantling commenced in 2000 and is essentially complete with the reactor internals removed, the reactor vessel removed and stored on site, and most structures removed or approved for leaving in place.

A3.43 The Rancho Seco nuclear plant (913MWe, PWR), located in Sacramento, California, was closed in 1989. A SAFESTOR decommissioning plan was formally approved in 1995, however the owner later decided on an incremental dismantling approach. Decommissioning was formally completed in October 2009 when the NRC announced that most of the site, with the exception of a small area for the spent fuel dry store, was delicensed and released for unrestricted public use.

Spain

A3.44 Spain's Vandellos-1, a 480MWe gas-graphite reactor, was closed down in 1990 after 18 years of operation, due to a turbine fire that made the plant uneconomic to repair. In 2003, ENRESA concluded phase 2 of the reactor decommissioning and dismantling project, which allows much of the site to be released. After 30 years in Safestore, when activity levels will have diminished by 95%, the remainder of the plant will be removed. The cost of the 63-month project was €93 million.

A3.45 Jose Cabrera power station is a 160MWe PWR which operated from 1968 until 2006. In 2010 after defueling and Post Operational Clean Out, the site license was transferred to ENRESA, the state decommissioning and waste management organisation. Decommissioning is proceeding with the reactor internals removed, the turbine hall deplanted and converted to a waste processing facility, and other components and structures removed. Reactor Vessel segmentation will commence late 2013/early 2014. Decommissioning is scheduled for completion by the end of 2016. Total cost of dismantling is expected to be €135million (2003 money values) plus €35million for spent fuel management and an undisclosed sum for waste disposal.

Japan

A3.46 Japan's Tokai-1 reactor, a UK Magnox design, is being decommissioned after 30 years of service, ending in 1998. After 5-10 years storage, the unit will be dismantled and the site released for other uses, reported to be scheduled for 2018, though this is expected to be deferred further. Total cost is expected to be about 93 billion Yen; 35 billion for dismantling and 58 billion for waste treatment.

Germany

A3.47 Germany chose immediate dismantling over safe enclosure for the closed Greifswald nuclear power station in the former East Germany, where five reactors had been operating.

A3.48 Similarly, the site of the 100MWe Niederaichbach nuclear power plant in Bavaria was declared fit for unrestricted agricultural use in mid-1995. Following removal of all nuclear systems, the radiation shield, and some activated materials, the remainder of the plant was below accepted limits for radioactivity and the state government approved final demolition and clearance of the site.

A3.49 The 250MWe Gundremmingen-A unit was Germany's first commercial nuclear reactor, operating from 1966-77. Decommissioning work started in 1983, and moved to the more contaminated parts in 1990, using underwater cutting techniques. This project demonstrated that decommissioning could be undertaken safely and economically without long delays, and with most of the metal being recycled.

A3.50 Stade was a 662MWe PWR that operated from 1972 until 2003. Decommissioning is in progress with the steam generators, reactor internals and reactor vessel removed by specialist contractors selected for each task. The release from supervision under the Atomic Energy Act is expected for 2014.

A3.51 Würgassen was a 640MWe BWR plant which operated from 1975 until 1994. Decommissioning has been in progress since 1997, mainly carried out by the site workforce and is now substantially complete. The reactor internals and vessel were segmented and packaged by a specialist contractor. The release from supervision under the Atomic Energy Act is expected end 2014.

France

A3.52 To decommission its retired gas-cooled reactors at the Chinon, Bugey, and St Laurent nuclear power stations, Électricité de France chose partial dismantling and postponed final dismantling and demolition for 50 years. As other reactors will continue to operate at those sites, monitoring and surveillance do not add to the cost.

A3.53 The PWR at Chooz A is a 310MWe PWR which operated from 1967 to 1991. It is an unusual design in that the reactor and its auxiliary systems were built into two rock caverns rather than being housed in a conventional containment building and annexes. Dismantling of all plant and systems outside the caverns began in 1999 and was completed in 2004. Since 2010, work has been carried out on removal of the systems within the cavern. Removal of the steam generators is complete and primary circuit removal is progressing. Removal of the reactor internals is planned for 2014.

A3.54 At Marcoule, a recycling plant is being built for steel from dismantled nuclear facilities. This metal will contain some activation products, but it can be recycled for other nuclear plants.

Summary

A3.55 International experience has demonstrated that, where appropriate waste disposal routes exist, nuclear facilities have been successfully and completely decommissioned. Modern reactor designs are more straightforward to decommission than older designs, using for example improved materials which are less susceptible to activation and employing routine decontamination during operations. In particular, the activated primary circuits are smaller and more straightforward to dismantle.

FOUR

ANNEX 4

SUPPLEMENTARY NOTES ON RADIATION

Annex 4 – Supplementary Notes on Radiation

How good is our understanding of the health risks from radiation exposure?

Radioactive materials and nuclear reactors are among sources of what is termed *ionising radiation.* Other sources include X-ray generators and cosmic rays that strike the Earth from outer space. Its effects on human health have been studied throughout the twentieth century and into the twenty-first century and over this time scientific understanding has advanced enormously, especially over the last 60 years. The health effects of exposure to ionising radiation are better understood than are the effects of chemical and biological exposures resulting from the use of many common everyday materials – with the possible exception of tobacco smoke, ionising radiation has been the most extensively studied of all environmental exposures.

This understanding is based on scientific research. Among the most important is the epidemiological study of people who have been exposed to this type of radiation, drawing on data gathered over many years. This includes studies of those who have been exposed through their jobs (such as hospital radiographers or nuclear industry workers) or through such major events as the atomic weapons explosions at Hiroshima and Nagasaki in Japan. International groups of scientists collaborate on this work and several bodies have developed a worldwide reputation as authoritative sources of advice. These include the International Commission on Radiological Protection (ICRP), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the Committee on the Biological Effects of Ionizing Radiations (BEIR) of the US National Research Council and, in the UK, Public Health England (PHE, previously the Health Protection Agency incorporating what was formerly the National Radiological Protection Board, NRPB).

In its most recently published 2007 Recommendations the ICRP saw no reason to change its existing advice on radiation dose limits – dose limits that have now been in place for over 20 years. This is evidence of a stable position.

Despite this stability, based on a high level of consensus and a mature scientific understanding, there remain areas of debate, continuing research and residual uncertainty. This is part of normal scientific progress as areas of uncertainty are addressed and reduced. However, it is important to recognise that the scale of this remaining uncertainty is too small to cast any significant doubt over the conclusions on radiological health detriment presented in this application.

More detail on this is provided below.

A4.1 Exposure to ionising radiation gives rise to two types of health effects: deterministic effects (now also known as tissue reactions) and stochastic effects. Deterministic effects occur only above certain threshold doses while stochastic effects are thought to be effects for which there is no dose threshold and for which the likelihood of occurrence is related to the level of exposure to radiation.

A4.2 The approach to radiological protection is designed to eliminate all deterministic effects and to reduce the probability of stochastic effects to a level that is acceptable to exposed individuals and society. What level is acceptable is derived from comparisons with the range of voluntary and involuntary risks that people accept in everyday life, including the risk posed by essentially unavoidable exposure to natural background radiation (see Box 5 in Chapter 5 of this application).

A4.3 The relationship between the probability of the occurrence of a stochastic health effect (the response) and the level of exposure to radiation (the dose) at the low levels of radiation exposure routinely experienced at work or in the environment is assumed, for the purposes of radiological protection, to be linear no-threshold (LNT) – put simply, the response is assumed to be directly proportional to the dose with no threshold dose below which the effect does not occur. This approach is taken because it is believed to be prudent and so is likely to err in the direction of caution. It is also an approach that has the considerable merit of practicality for those managing radiation protection. The commonly used shorthand statement "There is no such thing as a safe dose of radiation" derives from this assumption of no threshold dose for stochastic effects, but is a distortion of the LNT approach because it equates “safe” with “no effect at all, no matter how small”, which is not correct – it is the *level* of risk upon which a judgement is made as to whether or not an exposure is safe.

A4.4 Two types of stochastic health effect are of concern to radiological protection: cancer in the exposed individual and hereditary disease in the individual’s descendents. Studies have steadily shown that, of these two, the risk of the exposed individual developing cancer is relatively much larger than the risk to their descendants. The ICRP has assessed the nominal risk coefficients (the average additional risk, weighted by the health detriment of the effect, per unit radiation dose received) following low dose and/or low dose-rate exposure to be:

Exposed Population*	Cancer (Sv-1)	Heritable Effects (Sv 1)	Total Detriment (Sv-1)**
All ages	5.5%	0.2%	5.7%
Adult	4.1%	0.1%	4.2%

* The differences between the risk factors for the whole population and those for the adult population alone are due to the higher sensitivity of children to radiation-induced cancer and the longer length of time over which the risk is expressed, and the fact that younger people have a greater potential period for reproduction and passing on heritable effects.

**The somatic health effects are weighted to take account of the severity of the effect (e.g. lethality, years of life lost).

A4.5 These factors are based on an average of sex, age and population and are not meant to be exact. They are nominal risk coefficients derived for the purposes of making decisions on radiological protection not for predicting precise numbers of health effects in a specific population. Significant effort has been expended in recent years to quantify the uncertainty associated with these risk estimates. These uncertainty analyses take account of a range of possible contributions including, for example, variations to the assumption of the LNT relationship at low doses/dose-rates (see above). Overall, these indicate that the uncertainty in the coefficients tabulated is unlikely to be more than a factor of two in either direction (i.e. the “true” risk coefficients are likely to lie within a range from half to twice the risk coefficients adopted by the ICRP).

A4.6 This does not mean to say that the uncertainty cannot be smaller or larger for a particular set of exposure circumstances but that the overall risk coefficients upon which the framework of radiological protection is based will be accurate within a factor of around two.

A4.7 There are other issues under discussion within the scientific community that could, to varying degrees, affect radiation risk coefficients and radiological protection. Probably the most important of these is whether exposure to low levels of radiation can increase the risk of diseases other than cancer in the exposed individual, in particular, cardiovascular disease. There is little doubt that high radiation doses, such as those experienced from radiotherapy, increase the risk of heart disease due to tissue damage, but the central question is whether the much lower dose levels that are the usual concern of everyday radiological protection can materially raise the risk of such diseases.

A4.8 However, the ICRP has judged that the present scientific evidence is not persuasive that low dose/dose-rate exposure does increase the risk of non-cancer diseases in the exposed individual and has concluded that these diseases should not be included in the risk estimates that underly the Commission’s Recommendations for radiological protection. Nonetheless, ICRP is monitoring the evidence for radiation-induced non-cancer diseases to ascertain whether there is a need to include these diseases into the scheme of radiological protection. In particular, it will be important to properly account for the influence of major risk factors such as smoking and obesity before any effect of low-level radiation exposure can be fully assessed. This is illustrated by a study of the workforce of British Nuclear Fuels plc (BNFL), which found that the rate of mortality from diseases of the blood circulatory system increased in male radiation workers with the cumulative dose from external sources of radiation that they had received, mainly due to mortality among men who had received doses in excess of 300 mSv. The interpretation of this statistical association is not, however, straightforward, since a consistent pattern of mortality between sub-groups of workers (such as those who had also received doses from radioactive material within the body) was not seen. The authors concluded that further work was required to examine the possible influence upon the association of major risk factors in circulatory diseases (smoking, diet, etc.) before the finding could be properly understood.

What is the evidence of health effects around UK nuclear sites?

Despite the UK nuclear power industry's excellent safety record, there have been concerns raised over suggestions that there may be heightened levels of certain cancers in areas close to some nuclear sites. These concerns have been the subject of extensive independent research over a period of 30 years.

In the UK, the Committee on Medical Aspects of Radiation in the Environment (COMARE) is the independent expert body that has overseen this subject since its establishment in 1985. Its Tenth report was published in 2005. So far as nuclear power station sites are concerned the conclusion of this report was unambiguous:

> *"We can, therefore, say quite categorically that there is no evidence from this very large study that living within 25 km of a nuclear generating site within Britain is associated with an increased risk of childhood cancer."*

In 2011, COMARE published its Fourteenth Report, considering further the incidence of childhood leukaemia around nuclear power stations in Great Britain. The report concluded:

> *"Based on the evidence presented in this review, COMARE sees no reason to change its previous advice to Government (as given in our tenth report – COMARE, 2005) that there is no evidence to support the view that there is an increased risk of childhood leukaemia and other cancers in the vicinity of NPPS [nuclear power plants] in Great Britain."*

The study of these issues is complex and a summary of the history is provided below.

A4.9 In November 1983 the broadcast of the TV documentary "Windscale – the Nuclear Laundry" led to understandable concern; the programme makers pointed to a notable excess in cases of childhood leukaemia that had occurred in the West Cumbrian coastal village of Seascale, adjacent to the Sellafield nuclear complex (previously known as "Windscale and Calder Works"). The implication was clear: radioactive discharges from Sellafield had been responsible.

A4.10 The Government immediately established an independent expert inquiry, chaired by Sir Douglas Black, to examine the claim, and the report of the inquiry was published in July 1984. In essence, that report confirmed that a notable "cluster" of childhood leukaemia had occurred in Seascale, but that the amounts of radioactive material discharged from Sellafield were more than one hundred times too small to be responsible.

A4.11 Reports of further "clusters" of childhood leukaemia near certain nuclear installations followed, in particular an excess of cases near the Dounreay establishment in Caithness, northern Scotland (home to the only large-scale fuel reprocessing plant in Britain other than at Sellafield). These reports, together with revisions that had to be made to the Sellafield discharge record, led to further concern, with suggestions that radiation exposures had been much greater than previously assessed and/or that the risk of childhood leukaemia from radiation had been seriously underestimated.

A4.12 Substantial research followed during the 1980s, overseen by the independent expert Committee on Medical Aspects of Radiation in the Environment (COMARE) that had been set up on the recommendation of Sir Douglas Black's group. By 1990, an effective scientific consensus had been reached that direct exposure to radioactive material discharged from nuclear installations could not be responsible for the reported "clusters". For example, it was shown that, if risk estimates for childhood leukaemia had been severely underestimated, then a pronounced excess of cases of childhood leukaemia should have occurred in Great Britain as a result of the fallout from atmospheric nuclear weapons testing during the late-1950s and early-1960s whereas no such marked increase had been observed. The study of the influence of fallout from nuclear weapons test explosions, which led to the intake of radioactive materials similar to those released from nuclear power stations, has continued, and although the global presence of these radionuclides is readily detectable and in quantities generally much greater than that from the discharges of nuclear installations, the absence of any discernable resulting increase in the incidence of childhood leukaemia weighs heavily against the intake of these radionuclides causing these "clusters".

A4.13 Research into these "clusters" nevertheless continued, and in 1990 Professor Martin Gardner and his colleagues appeared to have found a possible explanation for the Seascale "cluster" from an epidemiological study they had conducted in West Cumbria. Among many potential factors they had studied, radiation exposure of fathers working at Sellafield before the conception of their children seemed to be capable of accounting statistically for the Seascale cluster. The statistical association they found appeared significant, although a causal explanation was at odds with other scientific evidence relating to childhood leukaemia. A cause-and-effect interpretation of Gardner's statistical association became more unlikely when the same finding was not confirmed by other similar studies using independent data – for example, an excess of childhood leukaemia was not observed in the offspring of survivors of the atomic bombings of Hiroshima and Nagasaki, and it was found not to account for the excess of cases near Dounreay. Moreover, no increased rate of childhood leukaemia was found among children of the much greater number of Sellafield fathers who lived outside the village of Seascale. By the end of the 1990s the idea that childhood leukaemia "clusters" might be the result of radiation exposure of fathers was effectively abandoned.

A4.14 In 2008, the findings of a study (the "KiKK Study") of cancer in young children less than 5 years of age living in the vicinity of nuclear power stations in Germany were published. It was reported that, at the time of diagnosis, young children affected by cancer tended to live closer to the stations than young children free of cancer – a result that was essentially due to leukaemia among young children resident within 5 km of a nuclear power plant. These findings prompted the German Commission on Radiological Protection ("SSK", broadly equivalent to COMARE) to examine whether radiation exposure due to the operation of German nuclear power stations could be responsible. SSK concluded that

> *"The natural radiation exposure within the study area, and its fluctuations, are both greater, by several orders of magnitude, than the additional radiation exposure caused by the relevant nuclear power plants. If one assumes that the low radiation exposures caused by the nuclear power plants are responsible for the increased leukaemia risk for children, then, in light of current knowledge, one must calculate that leukaemias due to natural radiation exposure would be more common, by several orders of magnitude, than they are actually observed to be in Germany and elsewhere."*

A4.15 COMARE examined the KiKK Study as part of its Fourteenth Report. The Committee pointed to a number of difficulties faced by those conducting the KiKK Study, such as problems in selecting representative control children with which children affected by cancer were compared, and in the interpretation of the results. For example, distance from a nuclear power station was in terms of residence at diagnosis only, and full residential histories were not obtained, nor was any attempt made to assess radiation doses by taking into account factors such as wind direction or source of foodstuffs. Further, the influence of a previously known "cluster" of childhood leukaemia cases near the Krummel nuclear power station may not have been fully taken into account in interpreting the results of the KiKK Study. The Krummel cluster has been investigated intensively, but no evidence has been found to indicate that radioactive discharges could be involved.

A4.16 Studies attempting to reproduce the KiKK Study have now been conducted in a number of countries, the largest of these being carried out in France and Great Britain. In France, an association between residential distance and leukaemia in young children was found, but when doses from atmospheric discharges were estimated on the basis of wind direction rather than distance alone, the association disappeared. In Great Britain, in a study designed to be as similar as possible to the KiKK Study with the data available, no association with distance of maternal residence at birth from a nuclear power station was found. These two British and French studies do not support the notion of a material increase in the risk of leukaemia in young children living close to nuclear power stations, and give further reason to reject an interpretation of the findings of the KiKK Study in terms of radiation exposure.

A4.17 So, what is the explanation for the excesses of childhood leukaemia that have been found near certain nuclear installations? It should be appreciated that “clusters” of childhood leukaemia have been reported over many years (including reports from before the era of nuclear power), and that they are by no means associated only with nuclear installations. A striking example, and the most extreme cluster that has been reported, is that from the town of Fallon in rural Nevada, which is not close to a nuclear facility.

A4.18 An idea that has been discussed for many years, but which has been developed significantly since the late-1980s, is that infections play a major role in the development of childhood leukaemia. In the unusual conditions where previously isolated, largely rural, communities (such as West Cumbria or Caithness) undergo substantial population mixing (as occurred, for example, when large nuclear facilities were constructed in the 1950s and subsequently underwent major expansion), unusual infective processes may have resulted in raised risks and the observed “clusters”.

A4.19 For example, Professor Leo Kinlen has suggested that childhood leukaemia is a rare response to a common (but as yet unidentified) infection, and that unusual patterns of urban-rural population mixing lead to “mini-epidemics” of the relevant infection (that are often sub-clinical) and an enhancement of the rare response, childhood leukaemia. Professor Mel Greaves has suggested that it is the delayed exposure of the immune system of a young child to a broad range of infective agents that increases the risk of childhood leukaemia, and that circumstances encouraging the prevention of exposure to infections in the early years of life (such as the social isolation of the community and/or the child) increase the risk of the disease. Many studies have now pointed to the importance of infective patterns in determining the risk of childhood leukaemia, in many different circumstances, indicating that infection is indeed a major factor in the risk of childhood leukaemia. The village of Seascale and the area around Dounreay have undoubtedly been exceptionally unusual communities over many years – a high socio-economic class, mobile population within a geographically isolated area – conditions that will have been inevitably conducive to those infective patterns that are now believed to increase the risk of childhood leukaemia.

A4.20 Recent studies such as that covered by the COMARE Eleventh Report (2006), have demonstrated that the background risk of childhood leukaemia throughout Great Britain is far from uniform, and that “clusters” are a natural result of this geographically variable risk. What seems to have happened in the 1980s is that “clusters” near some nuclear installations were preferentially identified because of media and scientific interest in the phenomenon, and because social conditions around certain nuclear sites led to these areas being particularly prone to a raised risk of childhood leukaemia. However, with the broader perspective that is now available, it would appear that only a small fraction of the total pieces in the whole jigsaw was being examined – now that a greater proportion of the puzzle can be observed, the “clusters” near nuclear installations can be seen to fit into the general background pattern.

A4.21 Taking the evidence as a whole, it is most unlikely that those “clusters” that have been found near some nuclear facilities are indicative of a serious underestimation of the risk of exposure to radiation. Three decades of intensive research into whether the risk of childhood leukaemia has been seriously underestimated have not revealed any major shortcomings in the risk assessments that demonstrate that radiation doses received from radioactive discharges are far too small to cause the observed excesses of cases. For example, radionuclides released during the period of intense atmospheric nuclear weapons testing did not produce a discernible increase in childhood leukaemia incidence, which they should have done if risk estimates had been wildly wrong. In contrast, a better understanding of the pattern of childhood leukaemia incidence away from nuclear installations has indicated that “clustering” may well be a natural result of the way in which the major causes of childhood leukaemia behave. Infective processes appear to be related to the risk of childhood leukaemia, and unusual patterns of infection lead to unusual patterns of childhood leukaemia. The atypical population mixing experienced around large industrial installations (such as nuclear power stations) in predominantly rural areas, and the patterns of infections that they induce, could well be behind the excesses of cases of childhood leukaemia reported from areas around certain nuclear facilities, as well as areas away from such facilities.

Foundation References for the Risks to Health of Low Level Exposure to Ionising Radiation

Bithell JF, Murphy M F G, Stiller C A, Toumpakari E, Vincent T and Wakeford R. Leukaemia in young children in the vicinity of British nuclear power plants: a case–control study. British Journal of Cancer , 12 September 2013

Bithell JF, Keegan TJ, Kroll ME, Murphy MF, Vincent TJ. Childhood leukaemia near British nuclear installations: methodological issues and recent results. Radiat Prot Dosimetry 2008; 132:191-7.

Commission on Radiological Protection (SSK). Assessment of the "Epidemiological Study on Childhood Cancer in the Vicinity of Nuclear Power Plants" (KiKK Study). Position of the Commission on Radiological Protection. SSK, Bonn, 2008.

Committee on Medical Aspects of Radiation in the Environment (COMARE)

Committee on Medical Aspects of Radiation in the Environment (COMARE) (2011). Fourteenth Report. Further consideration of the incidence of childhood leukaemia around nuclear power plants in Great Britain. Health Protection Agency, May 2011

Committee on Medical Aspects of Radiation in the Environment (COMARE) (2006). Eleventh Report. The distribution of childhood leukaemia and other childhood cancer in Great Britain 1969-1993. Health Protection Agency, July 2006.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (2005). Tenth Report. The incidence of childhood cancer around nuclear installations in Great Britain. Health Protection Agency, June 2005.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (2004). Eighth Report. A review of pregnancy outcomes following preconceptional exposure to radiation. National Radiological Protection Board, February 2004.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (2002). Seventh Report. Parents occupationally exposed to radiation prior to the conception of their children: A review of the evidence concerning the incidence of cancer in their children. National Radiological Protection Board, August 2002.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (1996). Fourth Report. The incidence of cancer and leukaemia in young people in the vicinity of the Sellafield site, West Cumbria: Further studies and an update of the situation since the publication of the report of the Black Advisory Group in 1984. Department of Health, London March 1996.

Committee on the Biological Effects of Ionizing Radiations (BEIR Committee):

Health Risks from Exposure to Low Levels of Ionizing Radiation. The BEIR VII Report. The National Academies Press, Washington DC, 2006.

Greaves, MF (2006) Infection, immune responses and the aetiology of childhood leukaemia. Nature Reviews Cancer, 6: 193-203

Ford AM, Palmi C, Bueno C, Hong D, Cardus P, Knight D, Cazzaniga G, Enver T, Greaves M (2009) The TEL-AML1 leukemia fusion gene dysregulates the TGFß pathway in early B lineage progenitor cells. J Clin Invest, 119: 826-836

Papaemmanuil E, Hosking FJ, Vijayakrishnan J, Price A, Olver B, Sheridan E, Kinsey SE, Lightfoot T, Roman E, Irving JAE, Allan JM, Tomlinson I, Taylor M, Greaves M, Houlston RS (2009) Loci on 7p12.2, 10q21.2 and 14q11.2 are associated with risk of childhood acute lymphoblastic leukemia. Nature Genet, 41: 1006-1010

Anderson K, Lutz C, van Delft FW, Bateman CM, Guo Y, Colman SM, Kempski H, Moorman AV, Titley I, Swansbury J, Kearney L, Enver T, Greaves M (2011) Genetic variegation of clonal architecture and propagating cells in leukaemia. Nature, 469: 356-361

Health Protection Agency – Radiation Protection Division (formerly the National Radiological Protection Board, NRPB):
HPA advice on the application of ICRP's 2007 recommendations to the UK, 2008.

International Commission on Radiological Protection (ICRP):
ICRP Publication 103: Recommendations of the ICRP. Annals of the ICRP Volume 37/2-4, 2008.

ICRP Supporting Guidance 4: Development of the Draft 2005 Recommendations of the ICRP. A Collection of Papers. 2006

ICRP Publication 99: Low - Dose Extrapolation of Radiation Related Cancer Risk, 2006.

Kaatsch P, Spix C, Schulze-Rath R, Schmiedel S, Blettner M. Leukaemia in young children living in the vicinity of German nuclear power plants. Int J Cancer 2008; 122: 721-6.

Kinlen L. Childhood leukaemia, nuclear sites, and population mixing. Br J Cancer 2011. Br J Cancer. 2011 Jan 4;104(1):12-8

Kinlen L. An examination, with a meta-analysis, of studies of childhood leukaemia in relation to population mixing. Br J Cancer. 2012 Sep 25;107(7):1163-8.

Laurier D, Hémon D, Clavel J. Childhood leukaemia incidence below the age of 5 years near French nuclear power plants. J Radiol Prot 2008; 28: 401-3.

Little MP, Tawn EJ, Tzoulaki I, Wakeford R, Hildebrandt G, Tapio S, Elliott P. Comments: The non-cancer mortality experience of male workers at British Nuclear Fuels plc, 1946-2005. Int J Epidemiol 2008 Jul 9.

McGeoghegan D, Binks K, Gillies M, Jones S, Whaley S. The non-cancer mortality experience of male workers at British Nuclear Fuels plc, 1946-2005. Int J Epidemiol 2008; 37: 506-18.

McGeoghegan D, Binks K, Gillies M, Jones S, Whalley S. Comments on the study of McGeoghegan et al. Int J Epidemiol 2008 Jul 9.

National Council on Radiation Protection and Measurements (NCRP)
NCRP Report No. 136 - Evaluation of the Linear-Nonthreshold Dose-Response Model for Ionizing Radiation, 2001

Spix C, Schmiedel S, Kaatsch P, Schulze-Rath R, Blettner M. Case-control study on childhood cancer in the vicinity of nuclear power plants in Germany 1980-2003. Eur J Cancer 2008; 44: 275-84.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR):
UNSCEAR 2006 Report, United Nations, New York, 2008

UNSCEAR 2000 Report, United Nations, New York, 2000

FIVE

ANNEX 5

CONSIDERATIONS OF EXTREME EVENTS AND SEVERE ACCIDENTS

Annex 5 – Considerations of Extreme Events and Severe Accidents

Introduction

A5.1 This Annex provides detailed information underlying our conclusion in this Application that the risk of significant detriment from extreme events and severe accidents is low.

What Has Changed Since Our 2008 Application?

A5.2 Since our 2008 Application, the 2011 Fukushima accident in Japan - resulting from an earthquake and tsunami - highlighted the potential for multi-unit nuclear power stations to be affected by extreme natural disasters, and for a severe accident to adversely impact cooling and long term electrical power supplies.

A5.3 In the United Kingdom, extensive and highly regulated provisions ensure a high level of nuclear safety is maintained by operators of nuclear power plants such as our Proposed Practice. As a result, the risk of detriment resulting from accidents (including those caused by extreme events) is considered to be low. These safety provisions are subject to on-going review and improvements, continue to evolve and are therefore considered in more detail in this Application as compared to our 2008 Application.

Overview

A5.4 This Annex has two parts:

Part 1 provides a review of the safety provisions referred to above to protect against accidents, including those caused by extreme events. As a result of these provisions the risk of detriment resulting from extreme events causing widespread station impacts such as sustained loss of cooling or electrical power supplies is considered to be low.
Part 2 provides a review of severe reactor accidents at, or above, Level 5 on the International Atomic Energy Agency's ("IAEA") International Nuclear Event Scale. This concludes that the measures described elsewhere in this Application ensure that the risk of a similar severe accident involving the Proposed Practice and the resulting detriments are very low.

Part 1 – Safety Provisions

A5.5 There have been over 14,500 cumulative reactor-years of commercial operation over about 50 years of civil nuclear power generation,[213] with around 10,000 reactor-years of safe operation since the Chernobyl accident in 1986. In March 2011, Japan suffered one of the worst natural disasters in its history when a powerful earthquake and resultant tsunami hit the country. This led to a nuclear accident at the Fukushima Dai-ichi site. The accident highlighted the potential for multi-unit nuclear power stations to be affected by severe natural disasters, and for a severe accident to adversely impact the ability to maintain cooling and backup electrical power supplies.

A5.6 The implications of this accident to the UK were comprehensively examined by Dr. Mike Weightman, the then Chief Inspector of Nuclear Installations and head of the Office for Nuclear Regulation (the "ONR"). In relation to our Proposed Practice, particularly pertinent conclusions included:

- The UK is not subject to particularly extreme levels of natural hazards such as earthquake and tsunami by comparison with many areas of Europe and the rest of the world;
- There are no fundamental weaknesses in UK nuclear facilities;
- The UK regulatory regime is effective; and
- There are still lessons to be learnt around severe accident management.

A5.7 The following subsections provide an overview of the factors that together provide a high level of assurance that the risks from extreme events and severe accidents are effectively managed to be very low. These provisions remain subject to continuous improvement and development in the light of experience and lessons learnt, and will continue to evolve. These factors broadly encompass:

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[213] http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Safety-of-Nuclear-Power-Reactors/.

- The capability and resilience of UK plants that is being further enhanced in the light of lessons from Fukushima;
- The commitment of UK operators to nuclear safety;
- Stress tests conducted on EU nuclear installations in response to Fukushima to ensure that any further improvements to the resilience of plants were identified for implementation; and
- The robustness of the regulatory regime and the independence and effectiveness of the UK nuclear regulator in promoting and overseeing high levels of governance in the nuclear industry.

A5.8 Further information on the Fukushima accident is provided in Part 2 below.

Capability of UK Nuclear Power Plant

A5.9 Following a request from the Secretary of State for Energy and Climate Change, Dr. Weightman prepared a report on the implications of the Fukushima accident for the UK nuclear industry (the "Weightman Report"), released in September 2011.[214] On his report, Dr. Weightman stated:

> *"I remain confident that our UK nuclear facilities have no fundamental safety weaknesses. The Office for Nuclear Regulation already requires protection of nuclear sites against the worst-case scenarios that are predictable for the UK."* [215]

A5.10 Nevertheless, the Weightman Report identified a number of areas where further improvements could and should be made to further enhance the resilience of the UK nuclear power sector. In particular, the report identified actions that new nuclear plants should take to explicitly ensure weaknesses that were present in the Fukushima plant are not present in UK plants.

A5.11 The UK Government has accepted the Weightman Report and has affirmed its commitment to implementing its recommendations.[216]

A5.12 Annex 1 demonstrates that the UK ABWR addresses these requirements, the provisions of which are summarised here also. Compared to the generic ABWR, the UK ABWR will incorporate new features to deliver a higher level of protection against severe external hazards that are beyond the design basis. These will include post-Fukushima countermeasures from the lessons learned and aircraft crash countermeasures. In particular, the UK ABWR will include a Backup Building that can act as a frontline base during emergencies and as a storage facility for accident management. The building will be separated from the reactor building and will be specially protected against external hazards. The building will include alternative cooling systems, alternative power supply systems, portable systems for accident management and alternative control panels.

Commitment of UK Nuclear Operators to Nuclear Safety

A5.13 Prime responsibility for the safety of a nuclear power plant rests with the operator of the plant. This is in accordance with IAEA Fundamental Principles for Safety. Each nuclear site licensee is therefore responsible for the safety of its nuclear plant and also for the health and safety of workers and members of the public who might be affected by the plant's operations.

A5.14 Under the terms of the nuclear site licence, operators are required to make suitable arrangements to assure nuclear safety. A core requirement that permeates all the operator's activities, and is a duty that is set out in the Health and Safety at Work Act 1974, is the obligation to ensure that the risk of harm is kept as low as reasonably practicable ("ALARP"). The ALARP principle requires operators to demonstrate they have done everything practicable to reduce risks. This covers not only physical plant provisions and management control measures but also extends to broader organisational considerations (e.g. operators are required to demonstrate

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[214] Japanese earthquake and tsunami: Implications for the UK nuclear industry, Final Report, HM Chief Inspector of Nuclear Installations, September 2011, http://www.hse.gov.uk/nuclear/fukushima/final-report.pdf.

[215] Dr. Weightman's full statement can be found at: http://www.hse.gov.uk/nuclear/fukushima/final-report.htm.

[216] Charles Hendry MP, Weightman report on events at the Fukushima nuclear site, 1 December 2011: https://www.gov.uk/government/news/charles-hendry-written-ministerial-statement-on-nuclear-energy-matters.

their organisational capability and provision of adequate human and financial resources to ensure the safe operation of the plant at all times). This means that the licensee will have the knowledge and resources to ensure that they maintain at all times effective control of operations that take place at the licensed sites for which it is responsible. ONR has published its expectations in detail, and these expectations align with IAEA standards and guidance. A summary of these can be found in their recently published guide to nuclear regulation in the UK.[217]

A5.15 The UK's fifth national report on compliance with the IAEA Convention on Nuclear Safety obligations (published in 2010) highlights the high priority given to safety by UK nuclear utilities. Further, Dr. Weightman notes in his May 2011 interim report that the UK nuclear industry has a strong commitment to safety, concluding that:

> *"In response to the Fukushima accident, the UK nuclear power industry has reacted responsibly and appropriately displaying leadership for safety and a strong safety culture in its response to date."* [218]

A5.16 A similar statement was again made in the ONR's Chief Nuclear Inspector's first annual report issued in 2013, where it was observed that there is evidence of a high level of operational safety across the UK nuclear industry.[219]

A5.17 It is therefore concluded that UK nuclear operators have a strong commitment to nuclear safety, and the capability to maintain such safety. Any operator deploying the Proposed Practice will need to demonstrate such commitment to nuclear safety and organisational capability before ONR would grant a nuclear site licence.

European Stress Tests

A5.18 International oversight is an additional component of the already robust UK regulatory regime to ensure that severe accident risks are effectively managed to be very low.

A5.19 Following the Fukushima accident, every nuclear power generating country in Europe agreed to carry out safety 'stress tests' to reassess relevant safety margins. The tests were completed by licensed operators, and their respective national regulators compiled reports.

A5.20 17 such national reports were submitted for peer review by the European Nuclear Safety Regulators Group ("ENSREG") and the European Commission in December 2011.[220] ENSREG is an independent, authoritative expert body created in 2007 by the European Commission *"to help to establish the conditions for continuous improvement and to reach a common understanding in the areas of nuclear safety and radioactive waste management."* [221]

A5.21 The stress test reports emphasised the importance of continuous review and improvement in safety across European nuclear power plants, which is also a key feature of the UK regulatory regime. The European Commission concluded that: [222]

> *"Based on the stress tests, national regulators concluded that there are no technical reasons requiring the shutdown of any NPP in Europe, and identified a series of good practices."*

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[217] A guide to nuclear regulation in the UK, Office for Nuclear Regulation, http://www.hse.gov.uk/nuclear/documents/a-guide-to-nuclear-regulation-in-the-uk.pdf.

[218] Para 348 of Japanese earthquake and tsunami: Implications for the UK Nuclear Industry, Interim Report, HM Chief Inspector of Nuclear Installations, 18 May 2011.

[219] Page 17, last para of Nuclear safety events chief nuclear inspector's Annual report 2013, http://www.hse.gov.uk/nuclear/documents/cni-annual-report-2013.pdf.

[220] ENSREG. National Action Plans Workshop – Summary Report, June 2013. This report discusses the findings of the peer review of the national reports. http://www.ensreg.eu/sites/default/files/NAcP%20Workshop%20Summary%20Report.pdf.

[221] See ENSREG's website: http://www.ensreg.eu/.

[222] Communication from the European Commission to the Council and the European Parliament on the comprehensive risk and safety assessments ("stress tests") of nuclear power plants in the European Union and related activities, 4 October 2012: http://ec.europa.eu/energy/nuclear/safety/doc/com_2012_0571_en.pdf.

A5.22 However, the need for further improvements was identified to implement the lessons learnt from Fukushima. ENSREG is overseeing the implementation of such improvements at national level through ONR's "Regulators National Action Plan"[223], which extends to all UK nuclear installations. On the Plan, ONR's then Chief Nuclear Inspector Colin Patchett commented:

> *"I am satisfied that this is a comprehensive response that not only meets the requirements specified by ENSREG but also presents a statement of how the UK Office for Nuclear Regulation will be vigorous in ensuring the outcomes of this work, internally, with government and with the licensees will be followed up to completion and reported on."*

Robustness of Regulatory Regime

A5.23 The existence of an effective regulatory regime which governs the UK nuclear industry to secure high levels of plant safety and operator competence provides important assurances that the risk of potential detriments arising from accidents will be low, and will be mitigated in the way that is described in the above section on the commitment of UK nuclear operators to nuclear safety. An essential element of this governance is the effectiveness and independence of ONR as the nuclear safety regulator.

Adequacy of Safety Standards

A5.24 The safety levels demanded by the UK regulatory regime meet international requirements that arise through treaty and other legal obligations, as well as defined benchmarks.

A5.25 The UK is a signatory[224] to the International Convention on Nuclear Safety[225] which entered into force on 24 October 1996. This Convention legally commits participating states to maintain a high level of safety for nuclear power plants by setting international benchmarks to which states subscribe. Under the terms of the Convention, the UK regularly submits reports for peer review that describe how the UK satisfies its obligations under the Convention.[226]

A5.26 The IAEA has developed a system of fundamental safety principles, standards and guides for ensuring nuclear safety[227]. The IAEA safety standards have a status derived from the IAEA's Statute, which authorizes the IAEA *"To establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialised agencies concerned, standards of safety for protection of health and minimisation of danger to life and property ... and to provide for the application of these standards".*

A5.27 The UK is also part of the Western European Nuclear Regulators Association ("WENRA")[228] A key objective of WENRA is to develop a common approach to nuclear safety, and part of this objective is the establishment of a forum for the sharing of experience and the discussion of significant safety issues. WENRA has developed common reference safety levels for reactor safety, decommissioning safety, radioactive waste and spent fuel management to act as a benchmark for the various national practices.[229] Furthermore, WENRA has established safety objectives for new nuclear power plants that set out a common position to promote enhanced safety as compared to existing ones, especially through design improvements.[230]

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[223] UK ONR ENSREG Related 'National Action Plan', UK Office for Nuclear Regulation response to ENSREG Action Plan, A Statement on ONR's Actions Extracted from the UK Post Japanese Earthquake and Tsunami Implementation Plan, HM Chief Inspector of Nuclear Installations, 31st December 2012, http://www.hse.gov.uk/nuclear/fukushima/ensreg-report.pdf.

[224] Please see: http://www.iaea.org/Publications/Documents/Conventions/nuclearsafety_status.pdf.

[225] Convention on Nuclear Safety, IAEA INFCIRC/449, 5 July 1994. Available at: http://www.iaea.org/Publications/Documents/Infcircs/Others/inf449.shtml.

[226] The UK reports to the Convention meetings, presentations and responses to questions raised at the meetings can be downloaded from the ONR website at: http://www.hse.gov.uk/nuclear/legal.htm.

[227] http://www-ns.iaea.org/standards/default.asp?s=11&l=90&w=1.

[228] List of WENRA Observers and Members: http://www.wenra.org/members-and-observers/.

[229] Harmonization of Reactor Safety in WENRA Countries, Report by WENRA Reactor Harmonization Working Group, January 2006, http://www.wenra.org/media/filer_public/2012/11/05/rhwg_harmonization__report_final.pdf.

[230] WENRA Statement on Safety Objectives for New Nuclear Power Plants, November 2010, http://www.wenra.org/media/filer_public/2012/11/05/wenra_statementonsafetyobjectivesfornewnuclearpowerplants_nov2010.pdf.

A5.28 In the UK, ONR has established a set of Safety Assessment Principles[231] ("SAPs") to guide its regulatory decision making as to whether site licensees have met their legal obligations to reduce risks so far as is reasonably practicable. ONR regularly reviews the SAPs to ensure consistency with IAEA safety standards and WENRA reference levels. ONR also base their decision making on the adequacy of the provisions made by operators to comply with the conditions attached to each nuclear site licence [232].

A5.29 Within the EU, international conventions are supplemented by the Euratom Nuclear Safety Directive (2009/71/EURATOM, adopted 25 June 2009), which establishes a Community framework for the nuclear safety of nuclear installations and provides binding legal force to the main international nuclear safety principles described above. The UK implements the requirements of the Euratom Nuclear Safety Directive[233] into national law mainly through the Nuclear Installations Act 1965 and the standard conditions attached to a nuclear site licence, and is required to report on the implementation of the Directive to the European Commission in 2014.

Effectiveness of the Regulator

A5.30 In the case of nuclear safety, ONR is currently an agency of the HSE with sufficient resources and capability to provide assurance of a strong, transparent and independent regulatory regime for nuclear safety and security. To further strengthen these objectives, later this year ONR will be established as an independent public corporation through provisions of the Energy Act 2013.

A5.31 The effectiveness of the UK nuclear regulator has been independently assessed by the IAEA. In 2005, the UK government invited the IAEA to send a modular Integrated Regulatory Review Service ("IRRS") mission to the UK to review the readiness of ONR to regulate new nuclear power stations. The first mission in 2006 concluded that the UK has a mature and transparent regulatory system with highly trained, expert and experienced nuclear inspectors[234]. A second IRRS mission in 2009 concluded that ONR was making good progress in addressing the areas for improvement identified in its first mission. The third and most recent mission was concluded on 9 October 2013, and a report will be published around early 2014. The preliminary findings[235] of the mission have confirmed that the UK has made considerable progress since the previous IRRS reviews, and noted that the response of the UK regulatory regime to the implications of the Fukushima accident had been timely and effective. Bill Borchardt, the IRRS team leader, stated that:

> *"The staff of ONR is clearly dedicated to their mission to secure the protection of people and society from the hazards of the nuclear industry. I am confident that ONR will use the results of this mission to further enhance their regulatory programs."*

A5.32 Further, the UK's environmental regulators are each independent statutory bodies held to account by Government (the UK Parliament in the case of the Environment Agency; the Welsh Government in the case of Natural Resources Wales; and the Scottish Ministers in relation to SEPA).

Conclusion

A5.33 The UK has an effective and independent regulator in place with the capability and resources to ensure that high levels of nuclear safety are maintained by operators of new nuclear power plants where the Proposed Practice is deployed.

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[231] Safety Assessment Principles for Nuclear Facilities, 2006 Edition, Revision 1: http://hse.gov.uk/nuclear/saps/saps2006.pdf.

[232] Licence condition handbook, Issue Date: October 2011: http://www.hse.gov.uk/nuclear/silicon.pdf.

[233] Nuclear Safety Directive (NSD) 2009/71/Euratom – July 2011.

[234] Integrated Regulatory Review Service Report to the Government of the United Kingdom, 26 March – 4 April 2006: http://www.hse.gov.uk/nuclear/regulatoryreview/irrsreducedscope.pdf.

[235] http://www.pressreleasepoint.com/iaea-mission-concludes-peer-review-uks-nuclear-regulatory-framework.

Part 2 – Overview of Severe Accidents

IAEA International Nuclear Event Scale

A5.34 The International Nuclear and Radiological Event Scale ("INES")[236] is a worldwide tool for communicating to the public the safety significance of nuclear and radiological events. Events are classified by the following scale: levels 1–3 are called "incidents" and levels 4–7 "accidents".

A5.35 This Annex provides an overview of commercial reactor accidents rated 5 and above on INES, and also considers the 1957 Windscale accident which occurred in the UK.

Description	Level	Example
Major Accident	Level 7	Fukushima (2011) Chernobyl (1986) (Widespread health and environmental effects. External release of a significant fraction of reactor core inventory).
Serious Accident	Level 6	
Accident with Wider Consequences	Level 5	Three Mile Island (1979 (severe damage to the reactor core). Windscale (1957) (Release of radioactive material to the environment following a fire in a reactor core).
Accident with Local Consequences	Level 4	
Serious Incident	Level 3	
Incident	Level 2	
Anomaly	Level 1	
No Safety Significance (Below Scale)	Level 0	

Windscale, UK, 1957

A5.36 **Overview of the Accident**

The Windscale fire of 10 October 1957 is the only nuclear event in the UK's history that has been rated as an "accident" according to INES: it was retrospectively ranked at level 5 in severity on the 7-point scale.

A5.37 The accident occurred when the core of the Unit 1 nuclear reactor at Windscale caught fire and burned for 3 days, releasing radioactive contamination into the surrounding area. Of particular concern at the time was the radioactive isotope iodine-131.

A5.38 **Radiological Consequences**

Iodine-131 was quickly identified as the major radiological hazard arising from the accident, which may lead to cancer of the thyroid. No one was evacuated from the surrounding area, but there was concern that milk might be dangerously contaminated. Milk from about 500 km² of nearby countryside was diluted and destroyed for about a month. A 2010 study of workers directly involved in the clean-up found no significant long-term health effects from their involvement.

Applicability to the Proposed Practice

A5.39 The Windscale accident demonstrated the importance of regulation of the nuclear industry and understanding the science of radiological protection. A committee chaired by Sir Alexander Fleck investigated the wider implications of the accident, which led to, among other things:

- The establishment of the National Radiological Protection Board (NRPB) in 1971 (since 2004, subsumed within the Health Protection Agency as the Radiation Protection Division) and now Public Health England; and

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[236] http://www.iaea.org/Publications/Factsheets/English/ines.pdf.

- The creation of the Nuclear Installations Inspectorate[237] (now part of ONR) to provide independent regulation of the civil nuclear power programme .

Three Mile Island (TMI-2), USA, 1979

Overview of the Accident

A5.40 TMI-2 was a 900 MWe pressurised water reactor located near Harrisburg, Pennsylvania, in the United States of America. The accident, which occurred on 28 March 1979, was caused by a cooling malfunction resulting in part of the core melting. The accident at TMI-2 was caused by a combination of equipment failure and the inability of plant operators to understand the reactor's condition because of poor training, and confusing control, indication and alarm systems.

A5.41 The accident was rated 5 on INES as it caused severe damage to the reactor core and the release of radioactivity inside the installation was high. There was, however, no significant release of radiation outside the containment.

A5.42 Today, the TMI-2 reactor is permanently shut down and all its fuel has been removed. The reactor coolant system is fully drained and the radioactive water has been decontaminated and evaporated.

Radiological Consequences and Other Impacts

A5.43 The partial meltdown resulted in the release of a small quantity of radioactive gas, however this was not enough to cause any significant dose to local residents. The average radiation dose to people living within 10 miles of the plant has been estimated to be 0.08 mSv, with no more than 1 mSv to any single individual. In response, and to allay any fears that these exposures might result in any radiation-induced health effects, principally cancer, the Pennsylvania Department of Health set up a registry of more than 30,000 people who lived within five miles of Three Mile Island at the time of the accident. The registry was discontinued in 1997 without any evidence of unusual health trends in the area.[238]

A5.44 Confused communications between government agencies and misunderstandings about the seriousness of the accident led to a debate about whether to evacuate or not. As a result of media reporting of the accident, many members of the public in the locality decided not to await official advice and left the area, effectively evacuating themselves. The manner in which these events unfolded over the first two days of the accident caused considerable fear and stress among some members of the public. These were the main consequences of the accident in terms of public health.

A5.45 The TMI-2 accident caused no injuries. Experts concluded that the amount of radioactive material released into the atmosphere was too small to result in discernible direct health effects to the population in the vicinity of the plant. This has been confirmed by a number of comprehensive studies by US Government departments, agencies and independent groups.

Applicability to the Proposed Practice

A5.46 The TMI-2 accident showed that design and operational measures to assure the adequacy and availability of safety systems are essential and that the phenomena associated with severe accidents were mostly unknown at the time. Consequently, reactor designs were improved to enhance the reliability of safety systems and take into account the possibility of severe accidents. The importance of human factors (including man-machine interface) became clear and improved training of operators also resulted. Emergency response planning also further developed in the light of TMI-2. The accident also demonstrated the value of conservative design provisions in nuclear power plants, such as the effective containment structure that limited the radiological releases to very low levels.

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[237] A guide to nuclear regulation in the UK, office for Nuclear Regulation: http://www.hse.gov.uk/nuclear/documents/a-guide-to-nuclear-regulation-in-the-uk.pdf.

[238] http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Three-Mile-Island-accident/.

Chernobyl, former Soviet Union, 1986

A5.47 **Overview of the Accident**
The Chernobyl nuclear power plant is located in Ukraine, which in 1986 was part of the Soviet Union. It consisted of four RBMK reactors, a Soviet designed reactor that was not built outside the Soviet Union, which had inherent power instabilities and other serious design flaws. During an experiment on reactor Unit 4 on 26 April 1986, a sudden power surge caused a steam explosion that ruptured the reactor vessel. The experiment had been carried out by operators in violation of safety regulations and with important safety systems switched off. Further violent fuel-steam interactions destroyed the reactor core and severely damaged the reactor building. The large graphite moderator in Unit 4 burned for a further 10 days and large releases of radioactivity occurred. The accident was a result of a combination of several factors including design flaws in the reactor and important safety systems being over-ridden by the operators, which allowed the reactor to reach an unstable condition.

A5.48 The reactor unit is now enclosed by a large concrete sarcophagus to stop the release of radioactivity into the atmosphere.

Radiological Consequences and Other Impacts

A5.49 In 2006 the Chernobyl Forum (an initiative of the IAEA, in co-operation with the World Health Organisation, UNSCEAR, the World Bank, the Governments of Belarus, the Russian Federation and Ukraine, and various other international bodies) produced a report assessing the health, environmental, and socio-economic Impacts.[239] Their findings and those of UNSCEAR[240] are summarised below.

A5.50 The highest radiation doses were received by emergency workers and on-site personnel during the first days of the accident; 134 of these workers received radiation doses that were sufficiently high to produce acute radiation sickness (“ARS”) from which 28 workers died. The local Soviet authorities delayed evacuation of communities near Chernobyl for about 36 hours, and did not immediately impose food restrictions. This led to tens of thousands of children receiving high doses (>1 Sv) to the thyroid gland from radioactive iodine (which concentrates in the thyroid), mainly through drinking heavily contaminated milk. As a consequence, excess cases of thyroid cancer started to appear in 1989-1990 among those exposed as children (whose thyroids are especially sensitive to radiation-induced cancer). To date, several thousand thyroid cancers in the heavily contaminated areas of the former Soviet Union can be attributed to exposure to radioactive iodine from the accident, which aligns with predictions from standard radiation risk models for thyroid cancer. Thyroid cancer is usually treatable, so in the great majority of these cancers did not prove fatal.

A5.51 Apart from this increase in thyroid cancer incidence among those exposed at a young age, there has been no clearly demonstrated increase in the incidence of other solid cancers or leukaemia due to radiation in the most affected populations. This is because the doses received by other tissues were much less than the thyroid doses received from the intake of radioactive iodine. Even a large study of childhood leukaemia in the heavily contaminated areas could not unambiguously find an increase in risk associated with exposure.

A5.52 The study of the health effects of Chernobyl is very difficult in light of the dissolution of the Soviet Union in the early-1990s, due to the impact on record keeping, and more importantly, due to the difficulties in distinguishing these specific effects from the general health effects of the associated socio-economic turmoil. For example, whilst mortality rates in western Europe have steadily decreased since the 1990s, mortality rates across Russia markedly increased, including in the far east which was hardly affected by Chernobyl contamination. Nonetheless, studies continue to investigate whether health effects may be discerned.

A5.53 An international expert group for the Chernobyl Forum has made projections to provide an estimate of the possible health impacts of the accident. The projections indicate that, among the most exposed populations (recovery operation workers, evacuees and residents of the so-called ‘strict control zones’), total cancer mortality might increase by up to a few per cent owing to Chernobyl related radiation exposure. Against a background of an estimate of one hundred thousand cancer deaths from all non-Chernobyl related causes in these populations,

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[239] Chernobyl’s Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine. The Chernobyl Forum: 2003–2005. Second revised version.

[240] UNSCEAR 2008 Report, Annex D: http://www.unscear.org/unscear/en/chernobyl.html.

this Chernobyl-related percentage increase could eventually result in up to several thousand additional fatal cancers. An increase of this magnitude would be very difficult to detect, even with very careful long term epidemiological studies.

A5.54 The cloud of radioactive material from Chernobyl affected much of Europe outside the Soviet Union, although to a much lesser extent than the heavily contaminated areas of present-day Ukraine, Belarus and the Russian Federation. Consequently, and unsurprisingly given the low doses involved, no unequivocal health effects in populations resident outside the former Soviet Union that may be attributable to Chernobyl contamination have been found, even for thyroid cancer and childhood leukaemia.

A5.55 One group of people where health effects may be detected is the recovery workers, who worked in difficult conditions, especially in the early years after the accident. Over half a million workers have been involved in recovery operations, including nearly a quarter of a million during 1986-1987 when exposure would have been highest. There are indications of an excess risk of leukaemia in these recovery workers, which is not unexpected, although these studies are not easy to conduct.

A5.56 There were other impacts, however, which include: the evacuation of about 115,000 people from the areas surrounding the reactor and the relocation of about 220,000 people from Belarus, Russia and Ukraine; and an increase in psychological problems among the affected population, compounded by the economic depression that followed the break-up of the Soviet Union.

A5.57 An overview of the economic consequences, particularly for Belarus and Ukraine, is provided in the 2003-2005 report of the Chernobyl Forum[241]. The report advises that the resulting costs of Chernobyl accident continue to have a significant economic effect on the budgets of these countries. A variety of government estimates put the cost of the accident over decades at hundreds of billions of dollars comprising: the direct costs of the accident; indirect costs from the loss from use of agricultural land and the closure of industrial facilities; and opportunity costs including the additional energy costs resulting from the loss of power from the Chernobyl plant.

Applicability to the Proposed Practice

A5.58 In conclusion, the Chernobyl accident in 1986 was the most severe nuclear accident in the history of the global nuclear industry. It occurred in a reactor design limited to countries within the direct influence of the former Soviet Union, that was not licensable in Western Europe and occurred as a result of the actions of the operators that were in direct contravention of the operational procedures for the reactor design.

A5.59 However, Chernobyl clearly illustrated the trans-boundary impacts of a nuclear accident and so following the tragic accident at the Chernobyl nuclear generating station, nuclear operators worldwide were determined to work together to ensure such an accident could never happen again. From this, the World Association of Nuclear Operators ("WANO") was formally created on 15 May 1989 with the objective of maximising the safety and reliability of nuclear power plants worldwide. WANO is being renewed after the Fukushima accident in 2011 to further increase the standard of nuclear safety across the world[242].

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[241] Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf.

[242] See WANO website: http://www.wano.info/about-us/history/.

Fukushima, Japan, 2011

A5.60 **Overview of the Accident**
On 11 March 2011, Japan suffered a magnitude 9 earthquake and major tsunami. The three operating reactors at the Fukushima Dai-ichi nuclear power site shut down safely after the earthquake as intended, however a tsunami (estimated to be over 14 metres high) later inundated the site. The earthquake resulted in loss of power supplies to the site, so the site was electrically isolated, but the diesel generators started up to provide emergency power. However, the diesel generators were inundated by the tsunami and failed; the tsunami also caused damage to the emergency heat exchangers. Without power, the reactors could not be adequately cooled, the reactors overheated, the fuel was severely damaged, and over the next few days hydrogen explosions occured and radioactive material was released into the environment.

A5.61 As a precaution, tens of thousands of people were quickly evacuated from the area of up to 20 km from the site. A major release of radioactive material on 15 – 16 March to the northwest of the site badly contaminated an area extending some 40 km from Fukushima Dai-ichi, so that other communities had to be evacuated, and some of the communities to the northwest of the site remain evacuated. However, it would appear that prompt evacuation and food restrictions limited the doses received as a consequence of the accident, particularly to the thyroids of children from intakes of radioactive iodine. All the other reactors in Japan that were operating at the time – some closer to the epicentre than Fukushima – shut down safely without any release of radioactive material or serious damage.

Radiological Consequences and Other Impacts

A5.62 The World Health Organization (“WHO”) has assessed the health risk to the Fukushima nuclear power plant emergency workers, people in the local region, the rest of Japan, and outside Japan[243]; their conclusions based on preliminary dose assessments are as follows:

- Outside the geographical areas most affected by radiation, even in locations within the Fukushima prefecture, the predicted risks remain low and no observable increases in cancer above natural variation in baseline rates are anticipated.
- In the two most affected locations of the Fukushima prefecture, the preliminary estimated effective doses for the first year ranged from 12 to 25 mSv. In these areas the risk for some cancers may be somewhat elevated above baseline rates in certain age and sex groups – at most, the additional cancer risk over a lifetime is about 1%. For exposed infants in these communities, the thyroid dose, mainly from the intake of radioactive iodine, could be in the range 100-200 mSv, which is much less than children received in the areas heavily contaminated by Chernobyl. The additional risk of thyroid cancer over a lifetime from this dose is about ½%.

- WHO reports the operator TEPCO’s dose data for nearly 20,000 workers employed in 2011, which shows:

    - About 2/3 of workers received low doses, so that any additional risk of cancer will be within the range of normal fluctuations in background risks.
    - About 1/3 of workers received thyroid doses that, for the youngest workers, could generate a proportional increase of thyroid cancer over a lifetime of around 20%.
    - This is also the proportional increase in the risk of leukaemia that may be experienced by the youngest of <1% of workers who received moderate external doses
    - Six workers received high thyroid doses due to the inhalation of radioactive iodine at the height of the accident. The additional risk of thyroid cancer over a lifetime for the youngest of these workers is a few percent, and there may also be a risk of other thyroid disorders.

A5.63 At the time of submission of this application, UNSCEAR is in the process of finalizing a major study to assess the radiation doses and associated effects on health and environment[244]. When

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[243] WHO, Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami based on a preliminary dose estimation.

[244] http://www.unscear.org/unscear/en/fukushima.html.

finalized in early 2014[245], it will be the most comprehensive scientific analysis of the information available to date.

A5.64 Although the accident was rated as 'major' on the INES (along with Chernobyl) the magnitude of the radioactive release that resulted was much lower (by a factor of about six). The UK, in common with many other countries, studied the events surrounding the incident in order learn lessons that could be used to further increase the resilience of its operating reactors, even though these are not subject to external events of such severity (e.g. tsunami).

Investigation of the Event

A5.65 Although the sequence of events that resulted in the Fukushima accident was initiated by a powerful earthquake and tsunami, a number of post-accident studies have concluded that the release of radioactive material that resulted from multiple steam explosions at several of the reactors can be attributed directly to a combination of factors that were specific to this location and situation, and a failure of the operators to fully implement the lessons learnt from TMI-2 and Chernobyl.

A5.66 Principally, inadequate provisions were in place to protect the coastal facility from a foreseeable severe tidal event in what is a seismically active location.[246]

A5.67 Further, a combination of organisational deficiencies and poor communication between the operator, the regulator and the Government hindered the timely and adequate response to the crisis. The report produced by the Fukushima Nuclear Accident Independent Investigation Commission of the National Diet of Japan in 2012 concluded that:

> *"Although triggered by these cataclysmic events, the subsequent accident at the Fukushima Dai-ichi Nuclear Power Plant cannot be regarded as a natural disaster. It was a profoundly manmade disaster – that could and should have been foreseen and prevented. And its effects could have been mitigated by a more effective human response."*

A5.68 Similarly, the Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company in their July 2012 final report commented extensively on major problems after the accident[247].

A5.69 Dr Weightman the HM Chief Inspector of Nuclear Installations led a thorough analysis of the Fukushima event and its implications for the UK. In this, he drew on national and international expert opinion, and led a fact-finding mission to Japan in June 2011 - including a visit to the Fukushima Dai-ichi plant. His findings were published in September 2011 in a final report[248]. Commenting[249] on this report, Mike Weightman said:

> *"I remain confident that our UK nuclear facilities have no fundamental safety weaknesses. The Office for Nuclear Regulation already requires protection of nuclear sites against the worst-case scenarios that are predictable for the UK. But we are not complacent. Our philosophy is one of continuous improvement. No matter how high our standards, the quest for improvement must never stop. We will ensure lessons are learned from Fukushima. Action has already been taken in many cases, with work under way to further enhance safety at UK sites."*

Applicability to the Proposed Practice

A5.70 The Fukushima accident highlighted the potential for multi-unit nuclear power stations to be affected by severe natural disasters, and also for a severe accident to adversely impact the ability to maintain cooling and long term electrical power supplies.

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[245] http://www.unscear.org/unscear/publications.html - this notes the expected date of publication of Annex A to UNSCEAR's 2013 Report: "Sources, effects and risks of ionizing radiation" as being January 2014.

[246] For example, the seawall at the Onagawa Nuclear Power Plant was adequately tall and robust to prevent serious damage to the power plant.

[247] Executive Summary of the Final Report, Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company: http://www.cas.go.jp/jp/seisaku/icanps/eng/finalgaiyou.pdf.

[248] Japanese earthquake and tsunami: Implications for the UK nuclear industry. Final Report. HM Chief Inspector of Nuclear Installations. September 2011: http://www.hse.gov.uk/nuclear/fukushima/final-report.pdf.

[249] http://www.hse.gov.uk/nuclear/fukushima/final-report.htm.

A5.71 An operator of the Proposed Practice will be supported by a series of highly robust design features that are described in more detail in Annex 1. These give a great deal of confidence that the essential safety functions of long term cooling and containment can be maintained even following a postulated extreme event or other accident. Taking into account the robust regulatory regime and the safety culture that will be expected of the operator, the risk of significant detriment from deployment of the Proposed Practice is low.

Overall Conclusion

A5.72 There are substantial provisions that ensure a high level of nuclear safety is maintained by nuclear operators of a nuclear power plant such as our Proposed Practice. As a result of these extensive and highly regulated provisions the risk of detriment resulting from extreme events causing widespread station impacts such as sustained loss of cooling or electrical power supplies is considered to be low. These provisions continue to evolve, and are subject to on-going review and improvements.

SIX

ANNEX 6

GLOSSARY

Annex 6 – Glossary

2008 Application	The NIA application submitted to the Justifying Authority in 2008 seeking Justification of new nuclear power stations in the UK.
2010 Justification Decisions	The reasons for the Secretary of State's Decision as Justifying Authority on the 2008 Application – for the EPR™ and AP1000® – October 2010.
Appropriate Assessment	A competent authority must make an appropriate assessment of the likely significant effects on the protected European sites (SACs and SPAs) in view of the site's conservation objectives, before deciding whether to authorise a particular development.
Activation	This term refers to the process of creating a radioisotope. This is achieved when a stable element is bombarded with either neutrons or protons.
Activity content	Attribute of an amount of a radionuclide. Describes the rate at which transformations occur in it. Unit becquerel, symbol Bq. 1 Bq = 1 transformation per second.
ALARP	As low as reasonably practicable. It is a key part of the general duties of the Health and Safety at Work etc. Act 1974. This involves weighing a risk against the trouble, time and money needed to control it.
Baseload plant	Power station that provides a continuous, steady electricity supply and does not greatly vary its output over a 24-hour period.
Basic Safety Level (BSL)	Basic Safety Level (BSL) BSLs and BSOs (see below) are used by UK nuclear inspectors to translate the TOR (Tolerability of Risk) framework into targets. ONR's policy is that the BSLs indicate dose limits, dose levels, or risk levels which a new facility or activity should at least meet.
Basic Safety Objectives (BSO)	BSLs and BSOs (Basic Safety Objectives) are used by UK nuclear inspectors to translate the TOR (Tolerability of Risk) framework into targets. The BSO dose/risk levels have been set at a level where ONR considers it not to be a good use of its resources or taxpayers' money, nor consistent with a proportionate regulatory approach, to pursue further improvements in safety. In contrast, licensees have an overriding duty to consider whether they have reduced risks to as low as reasonably practicable (ALARP) on a case by case basis irrespective of whether the BSOs are met. As such it will in general be inappropriate for licensees to use the BSOs as design targets, or as surrogates to denote when ALARP levels of dose or risk have been achieved. The ONR SAPs explain further that the BSOs form benchmarks that reflect modern nuclear safety standards and expectations.
Becquerel	The international (SI) unit used to measure quantities of radioactivity. The unit is extremely small, 1 Becquerel (Bq) is 1 disintegration per second. An average adult body contains around 7 thousand becquerels (7KBq) of radioactive material.
Biocide	A chemical agent that is capable of destroying living organisms.
Chain reaction	A reaction that stimulates its own repetition, in particular where the neutrons originating from nuclear fission cause an on-going series of fission reactions.
Chlorination	To disinfect (water) by addition of chlorine.
Collective dose	The total radiation dose incurred by a population. This is the sum of all of the individual doses to members of a particular group of people. The unit of collective dose is man-sievert – see chapter 5 for more information.
Collective effective dose	The total effective dose incurred by a population. This is the sum of all of the individual effective doses to members of a particular group of people. The unit of collective effective dose is man-sievert.
Condenser	Any device for reducing gases or vapours to liquid or solid form. A condenser is used to convert the exhaust steam from a steam turbine back to water.
Control rod	A rod, plate, or tube containing a neutron absorbing material such as boron used to control the power of a nuclear reactor. By absorbing neutrons, a control rod prevents the neutrons from causing further fissions.
Conversion	Chemical process turning Uranium Oxide U_3O_8 into uranium hexafluoride UF_6 preparatory to enrichment.
Core	The central part of a nuclear reactor containing the fuel elements and any moderator.
Cosmic radiation	Ionising radiation that originates from outer space and the sun. It contributes about 13% of public radiation levels on Earth.

Critical	The condition within a nuclear reactor where an average of 1 neutron emitted by each nuclear fission goes on to induce a further nuclear fission. That is, a stable power condition where the rate of nuclear fission remains constant over time.
Decommissioning	The process of closing down a nuclear reactor, removing the spent fuel, dismantling some of the other components, and preparing them for disposal. The term is also applied to other nuclear facilities.
Defence in depth	The provision of a series of levels of defence aimed at preventing accidents and for dealing with the consequences of any accidents so as to minimise them. This entails a provision of multiple barriers against the release of radioactive materials to the environment. Key aspects of the defence in depth approach are: • Prevention of abnormal operation and plant failures e.g. through high quality design and construction; • Provision of equipment and operating practices that prevent or control operational disturbances so as to avoid them becoming problems; • Provision of redundant and diverse systems to detect problems and place the plant into a safe state; • In the event of a severe accident, provision of design features and procedures to prevent or limit radioactive releases and for management of the damaged plant; and • Provision of emergency control and an on and off-site emergency response in the highly unlikely event of significant releases of radioactive substances.
Detriment	The Basic Safety Standards Directive defines health detriment as an estimate of the risk of reduction in length and quality of life occurring in a population following exposure to ionising radiations. This includes loss arising from somatic effects, cancer and severe genetic disorder. This Application also describes other potential (non-radiological health) detriments.
Diffusion technology and centrifuge technology	There are two enrichment processes in large-scale commercial use, each of which uses uranium hexafluoride as feed: gaseous diffusion and gas centrifuge. Both use the physical properties of molecules, specifically the 1% mass difference, to separate the isotopes. The product of this stage of the nuclear fuel cycle is enriched uranium hexafluoride, which is reconverted to produce enriched uranium oxide.
Dirty bomb	A device designed to spread radioactive material by conventional explosives.
Dose	Quantity of energy imparted by ionising radiation to a unit mass of matter such as tissue.
Dose limit	The value of the effective dose or the equivalent dose to individuals from planned exposure situations that shall not be exceeded. [From ICRP 103]
Dose constraint	A prospective and source-related restriction on the individual dose from a source, which provides a basic level of protection for the most highly exposed individuals from a source, and serves as an upper bound on the dose in optimisation of protection for that source. For occupational exposures, the dose constraint is a value of individual dose used to limit the range of options considered in the process of optimisation. For public exposure, the dose constraint is an upper bound on the annual doses that members of the public should receive from the planned operation of any controlled source. [From ICRP 103]
Effective dose	The weighted sum of doses to take into account the different radiation sensitivities of different tissues and organs. The unit of effective dose is sievert (Sv).
Emission	The action of discharging something, especially heat, light, gas or radiation.
EN-1	The Overarching National Policy Statement for Energy.
EN-6	The National Policy Statement for Nuclear Power Generation.
Enrichment	The physical process of increasing the proportion of ^{235}U to ^{238}U. Natural uranium is 99.3% ^{238}U with ^{235}U only constituting about 0.7%.
Fissile material	Material which can undergo nuclear fission following the absorption of a neutron, e.g. ^{235}U, ^{233}U, ^{239}Pu.
Fission	A process in which a nucleus splits into two or more nuclides and energy is released. Frequently refers to the splitting of a nucleus of ^{235}U into two approximately equal parts by a thermal neutron also resulting in the emission of other neutrons.

Fission fragments	The nuclides formed by the fission of heavy elements, plus any nuclides formed by subsequent radioactive decay of fission fragments.
Fossil fired plant	Coal, gas and oil-fired electricity generating power plants.
Fuel flasks (cask)	A heavily shielded container used to store and/or ship radioactive materials. Lead and steel are common materials used in the manufacture of flasks.
Fuel rods	A long, slender tube that holds the fuel pellets; fuel rods are assembled into bundles called fuel elements or fuel assemblies that are loaded individually into the reactor core.
Gamma radiation	Gamma radiation is one of the three types of naturally occurring ionising radiation. Gamma rays are electromagnetic radiation, like X-rays. They are the most energetic form of electromagnetic radiation, with a very short wavelength of less than one-tenth of a nanometre.
Generic Design Assessment	The process being used in the UK by the nuclear regulators (ONR and EA) to generically assess new nuclear power station designs. The regulators make rigorous and structured examination of the generic safety, security and environmental aspects of new reactor designs. Site specific applications to build the designs still need to be made. See http://www.hse.gov.uk/newreactors/ for further information.
Geological Disposal Facility (GDF) or Geological repository	A purpose built facility for deep burial of higher activity radioactive wastes with no intention of later retrieval.
Greenhouse gas emissions	Radiative gases in the Earth's atmosphere which absorb long-wave heat radiation from the earth's surface and re-radiate it, thereby warming the Earth. Carbon dioxide and water vapour are examples.
Heat exchangers	Any device that transfers heat from one fluid (liquid or gas) to another fluid or to the environment.
Higher activity waste	Refers to high level waste, spent fuel, intermediate level waste and low level waste unsuitable for prompt disposal at a low level waste repository.
In situ leaching	The recovery of minerals from the ground by dissolving them and pumping the resultant solution to the surface where the minerals can be recovered. There is no physical excavation or waste rock generated. Also known as solution mining.
Ionising radiation	Radiation that contains enough energy to remove tightly bound electrons from the orbit of an atom causing the atom to become charged or ionised. Examples are alpha particles, gamma rays, x-rays and fast neutrons.
Irradiated	Exposed to radiation or reactor fuel and components that have been subject to neutron irradiation and hence become radioactive themselves.
Isotope	Nuclides with the same number of protons but different numbers of neutrons. Not a synonym for nuclide.
Justification	High level assessment pursuant to the Justification of Practices Involving Ionising Radiation Regulations 2004 (SI 2004 No 1769) to demonstrate the economic, social or other benefits resulting from a new class or type of practice involving the use of ionising radiation outweigh the radiological health detriments. In this Application, potential (non-radiological health) detriments are also discussed.
Justification Regulations	The Justification of Practices Involving Ionising Radiation Regulations 2004.
Light water reactor	A reactor that uses natural water as a moderator and coolant, and low-enriched uranium as fuel. The most common type of nuclear power reactor currently in use around the world.
Load factor	The ratio of the actual output of a power plant over a period of time and its potential output if it had operated at full capacity over that time period.
Milling	Process by which minerals are extracted from ore, usually at the mine site.
Moderator	A material used in nuclear reactors to reduce the energy and speed of the neutrons produced as a result of fission.
Net benefit	Advantageous result that does more good than harm.
Optimisation	The process of determining what level of protection and safety makes exposures and the possibility and magnitude of potential exposures, 'as low as reasonably achievable, economic and social factors being taken into account', (ALARA).
Outage	A period of interruption of a reactor's operation to enable scheduled maintenance and refuelling to be performed.

Pellets	The uranium fuel for nuclear reactors in the form of ceramic uranium oxide cylinders. These “pellets” are stacked in long tubes to form fuel rods.
Periodic safety review	A comprehensive assessment against modern standards of the state of a facility to determine whether it is adequately safe and can continue to be adequately safe to the next periodic safety review. It is ONR policy that site licensees conduct a periodic safety review once every 10 years.
Plutonium	A heavy, radioactive, metallic element with atomic number 94. It exists in only trace amounts in nature.
Practice	The Basic Safety Standards Directive defines a “practice” as “a human activity that can increase the exposure of individuals to radiation from an artificial source or from natural radiation sources where use is being made of its radioactive, fissile or fertile properties …”. The latest ICRP Recommendations and the proposed recast of the BSS distinguish between existing, planned and emergency exposure situations.
Proposed Practice	The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in a light water cooled, light water moderated thermal reactor currently known as the UK ABWR designed by Hitachi-GE Nuclear Energy, Ltd.
Radiation	The emission and propagation of energy by means of electromagnetic waves or particles.
Radioactivity	The spontaneous decay of an unstable atomic nucleus, giving rise to the emission of radiation.
Radon	A heavy radioactive gas given off by rocks containing radium (or thorium). ^{222}Rn is the most common isotope.
Reactor	A piece of equipment designed to contain materials undergoing a reaction.
Representative person	Those individuals in the population of interest who receive, or are expected to receive, the highest doses. This term is the equivalent of, and replaces “average member of the critical group”.
Reprocessing	Chemical treatment of spent reactor fuel to separate uranium and plutonium from the small quantity of fission waste products and transuranic elements, leaving a much-reduced volume of high-level waste.
Risk factors	The probability of cancer and leukaemia or hereditary damage per unit equivalent dose. Usually refers to fatal malignant diseases and serious hereditary damage. The unit of measurement is Sv^{-1}.
Shielding	Any material or obstruction that absorbs radiation and so can be used to reduce radiation levels to protect personnel or materials from the effects of ionising radiation.
Shutdown	Cessation of fission in a reactor (usually by the insertion of control rods into the core).
Spent fuel	Fuel assemblies removed from a reactor after use.
Tailings	Ground rock remaining after particular ore minerals (e.g. uranium oxides) are extracted.
Thermal neutron	Any free neutron (one that is not bound within an atomic nucleus) that has an average energy of motion (kinetic energy) corresponding to the average energy of the particles of the ambient materials. Relatively slow and of low energy, thermal neutrons exhibit properties that make them desirable in nuclear reactor chain-reactions.
Thermal plume	A thermal plume is a column of hotter fluid moving through another: for a power station this would be the discharged cooling water.
Uranium	A mildly radioactive element with two isotopes which are fissile (^{235}U and ^{233}U) and two which are fertile (^{238}U and ^{234}U). Uranium is the basic fuel of nuclear energy.
Waste management	The control of radioactive waste from creation to disposal.
Yellowcake	A uranium oxide concentrate that is sometimes referred to as “yellowcake”. This is the form in which uranium is marketed and exported.

SEVEN

ANNEX 7

ABBREVIATIONS

Annex 7 – Abbreviations

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
ARS	Acute Radiation Sickness
BAT	Best Available Techniques
BEIR	Biological Effects of Ionising Radiations
BPEO	Best Practicable Environment Option
BPM	Best Practical Means
BSL	Basic Safety Levels
BSO	Basic Safety Objectives
BSS	Basic Safety Standards
BWR	Boiling Water Reactor
CCC	Committee on Climate Change
CCGT	Combined Cycle Gas turbine
CCS	Carbon Capture and Storage
CCTV	Closed Circuit Television
CEGB	Central Electricity Generating Board. Pre-privatisation in 1990 the CEGB were responsible for generation and supply of electricity to local Electricity Boards
CFD	Contract For Difference
CHP	Combined Heat and Power
CNC	Civil Nuclear Constabulary
CNPA	Civil Nuclear Police Authority
CNS	Civil Nuclear Security
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COTIF	Convention concerning International Carriage by Rail
CT	Computerised Tomography
CUSC	Connection and Use of System Code
dB	Decibel
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DWMP	Decommissioning and Waste Management Plan
EA	Environment Agency
EC	European Comission
EIA	Environmental Impact Assessment
EIADR	The Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999
EMR	Electricity Market Reform
EPR 2010	Environmental Permitting (England and Wales) Regulations 2010
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EU	European Union
FAP	Funding Arrangement Plan
FDP	Funded Decommissioning Programme
FiT CFDs	Feed-in Tariffs with Contracts for Difference
FOAK	First of a Kind
FSA	Food Standards Agency
GB	Great Britain
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GDP	Gross Domestic Product
GHG	Green House Gas
Hitachi-GE	Hitachi-GE Nuclear Energy, Ltd.

HGV	Heavy Goods Vehicle
HLW	High Level Waste
HMIC	Her Majesty's Inspectorate of Constabulary
HMSO	Her Majesty's Stationery Office
HPA	Health Protection Agency (see also Public Health England)
HRA	Habitats Regulations Assessment
HSE	Health and Safety Executive (see also ONR)
HV-VLLW	High Volume - Very Low Level Waste
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	Intermediate Level Waste
IPCC	Intergovernmental Panel on Climate Change
IPPAS	International Physical Protection Advisory Service
IPPR	Institute for Public Policy Research
ISOE	Information System on Occupational Exposure
LCAs	Life Cycle Assessments
LCOE	Levelised Cost of Electricity generation
LCTP	Low Carbon Transition Plan
LLW	Low Level Waste
LUEC	Levelised Unit Electricity Cost
MRWS	Managing Radioactive Waste Safely
NDA	Nuclear Decommissioning Authority
NEA	Nuclear Energy Agency (part of the OECD)
NIA	Nuclear Industry Association
NIEA	Northern Ireland Environment Agency
NLFAB	Nuclear Liabilities and Financing Assurance Board
NOAK	Nth of a Kind
NORMS	National Objectives Requirements and Model Standards
NPS	National Policy Statement
NPT	Non Proliferation Treaty
NRPB	National Radiological Protection Board (UK) which became part of the Health Protection Agency (HPA) which in turn was subsumed into Public Health England (PHE)
NRW	Natural Resources Wales (Cyfoeth Naturiol Cymru in Welsh)
NSSP	Nuclear Site Security Plan
OECD	Organisation for Economic Co-Operation and Development
ONR	Office for Nuclear Regulation, which at the date of this Application is an agency of the HSE, but which is due to be established as a body corporate by the Energy Act 2013.
ONR – CNS	Office for Nuclear Regulation - Civil Nuclear Security – part of ONR
ORM	Other Radiological Material
PHE	Public Health England
PINS	Planning Inspectorate
PSA	Probabilistic Safety Assessment
PWR	Pressurised Water Reactor
RID	Regulation Concerning the International Carriage of Dangerous Goods by Rail
RIFE	Radioactivity In Food And The Environment
RSA	Radioactive Substances Act
RWMD	Radioactive Waste Management Directorate – part of NDA
SAC	Special Areas of Conservation
SAPs	Safety Assessment Principles
SDC	Sustainable Development Commission
SDR	Special Drawing Rights

SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
TMI	Three Mile Island
TRO	Total Residual Oxidant
UK	United Kingdom
UN	United Nations
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
US	United States
VLLW	Very low level waste

EIGHT

ANNEX 8

LIST OF AMENDMENTS MADE TO DECEMBER 2013 APPLICATION

Annex 8 – List of Amendments made to December 2013 Application

AMENDMENT	RATIONALE
Cover Sheet Application date amended to say "December 2013 (updated February 2014)"	*Explanatory*
Add to Contents Pages: Annex 8 – List of Amendments made to December Submission	*Explanatory*
Paragraph 0.8 bullet point 3 amended as follows: "… Since ~~the~~ our 2008 Application the Government has been taking steps to ensure that the nuclear regulator is appropriately resourced and responsive for the challenges of the nuclear sector, as well as increasing ~~the~~ its transparency and accountability (although the regulatory requirements have not changed). To achieve this, the Office for Nuclear Regulation ("ONR") has been established as an agency of the Health and Safety Executive ("HSE"), and through the Energy Act 2013 ~~it is anticipated it~~ will be established as an independent statutory corporation later this year ~~through the Energy Bill (which is expected to receive Royal Assent early in 2014)~~."	*Typographical correction and update on legislation.*
Paragraph 0.15 amended as follows: "It is worth emphasising that although this Application relates to new nuclear power station technology, the UK nuclear industry has almost 60 years' experience of operating nuclear power stations within a ~~strict~~ robust goal setting regulatory regime that places the onus on operators to demonstrate to the regulators high levels of safety and environmental protection. It has an excellent record of safety and looking after the welfare and health of both its workers and the public and environmental protection. The existing ~~robust~~ regulatory system will continue to evolve in line with technological and societal developments to remain effective."	*Clarification to reflect breadth and nature of regulatory system.*
Additional paragraphs and footnotes inserted: see paragraphs 2.22 to 2.26 of the Application. *New paragraph 2.29 redrafted as follows:* "Although there are examples of the need to respond to specific issues (which are outlined above in relation to ABWR), this is strongly mitigated by worldwide operational capability that has now matured and achieved the increased reliability trends seen over the past 20 years[32]. ….".	*Further information provided for clarification.*
Table 4.2 amended as follows: "Table 4.2 Levelised Cost Estimates for Nuclear Projects (£/MWh)*" *Footnote added to bottom of table:* "*10% discount rate, (highs and lows reflect high and low capital cost estimates). Source: 'Electricity Generation Costs', DECC, July 2013."	*Correction of errata in document to insert unit.*
Paragraph 4.16 amended as follows: "…These long-term contracts, also known as Feed-in Tariffs with Contracts for Difference ("FiT CFDs", or simply "CFDs"), are intended to increase the rate of investment and lower the cost of capital in relation to new relevant energy infrastructure development, thereby reducing costs to electricity consumers (compared with a "do nothing" scenario). ~~An Energy Bill proposing to provide a statutory basis for CFDs is currently before Parliament.~~ The Energy Act 2013 provides a statutory basis for CFDs.[52]" *Footnote 52 amended as follows:* ~~"Energy Bill 2012-13, available at: http://services.parliament.uk/bills/2013-14/energy.html.~~ ENERGY ACT 2013 AVAILABLE AT HTTP://WWW.LEGISLATION.GOV.UK/UKPGA/2013/32/CONTENTS/ENACTED."	*Update to reflect the grant of Royal Assent for the Energy Act 2013 on 20 December 2013.*

AMENDMENT	RATIONALE
Paragraph 5.5 amended as follows: "…It is these ~~stages~~ licensing and permitting processes that have the greatest impact in determining what level of radiological health detriment is ultimately permitted. These essential regulatory ~~stages~~ processes will follow Justification if new nuclear power stations using UK ABWR technology are deployed in the UK and apply to all stages of the life cycle of a station from design, construction and commissioning through to operation, decommissioning and final waste disposal. The application of optimisation means that, in practice, radiological doses from the nuclear industry are very significantly below legal limits."	*Clarification.*
Footnote numbering corrected as follows: Ref 66 corrected to 67 Ref 67 corrected to 68 Ref 68 corrected to 69 Ref 69 corrected to 70 Ref 71 corrected to 72 Ref 72 corrected to 72a	*Correction of errata in document.*
Paragraph 5.44, amended as follows: "In addition to the requirement to remain below discharge limits specified in an EPR 2010 Permit (or equivalent authorisation in Scotland or Northern Ireland), the operator is currently required to use BAT (BPM / BPEO) to minimise the activity of radioactive waste produced on the site that will require disposal under the Environmental Permit (or Authorisation in Scotland and Northern Ireland). In doing this the operator needs ~~should seek~~ to:"	*Clarification to reflect legal requirement*
Following paragraph numbering inserted: Paragraph 5.93 Paragraph 5.94 Paragraph 5.95	*Correction of errata in document.*
Table 5.1 heading amended as follows: Predicted likelihood of accident occurring that could lead to this level of dose in any 1 year: (i.e. the maximum acceptable likelihood of accident at this level of severity occurring)*	*Correction of errata in document to insert *.*
Paragraph 5.107 first sentence amended as follows: In several respects, the decommissioning of modern reactor plant is more straightforward than it is for the range of plant within the responsibility of the Nuclear Decommissioning Authority (NDA). Sellafield Ltd report the average individual dose as 1 mSv/y.	*Clarification of acronym meaning.*
Paragraph 6.8 point [4] amended as follows: "[4] Materials (for example, tools, gloves, or filters) that become contaminated with radioactive material originating from ~~either of~~ 1, 2 or 3 above."	*Correction of errata.*
Paragraph 6.27 amended as follows: "The total dose rates for the worst affected organism were calculated to be less than 40 microgray/h for all but two Natura 2000 sites (the Ribble and Alt Estuaries SPA and the Drigg Coast SAC). The source of the discharges leading to these dose rates is the Springfields site. The calculated total dose rate for the worst affected organism for the Ribble and Alt Estuaries SAC was 520 microgray/h. This was significantly in excess of the agreed threshold and so this Natura 2000 site was included in Stage 4 (the revision of permits to ensure no adverse effects – for example, by changing the type, amount and location of discharges) of the Habitats Regulations implementation process. A separate report	*Insertion of reference for information cited.*

AMENDMENT	RATIONALE
is available for the Ribble and Alt Estuaries[136a]. This concluded that previously agreed new authorisation limits for the Springfields Fuels Limited site (in effect from January 2008) would ensure that the dose rates to reference organisms and feature species would be less than 40 microgray/h. The total dose rate calculated for the Drigg Coast SAC was just greater than the 40 microgray/h threshold. The source of the discharges leading to these dose rates is the Sellafield site....” *Footnote inserted as follows:* “[136a] Impact of radioactive substances on Ribble and Alt estuarine habitats, Better regulation science programme, Science report: SC060083/SR2, http://test.environment-agency.gov.uk/static/documents/Business/SCHO0309BPMN-e-e.pdf.”	
Paragraph 6.62 amended as follows: “The selection of which option is appropriate involves striking a balance between the benefits of deferral on the one hand, and the value attached to removing the ongoing liability and restoring the site to an alternative use....”	*Correction of typographical error.*
Page 87, 1st paragraph of orange box amended as follows: “All major infrastructure projects have impacts on the environment. These are addressed at a generic level through the Strategic Environmental Assessment process*, and then again in detail on a project by project basis through the Environmental Impact Assessment (“EIA”)** and the environmental permitting*** processes ~~process**~~, which must take place before a project can be approved. European law imposes strict requirements for each process.” *Add footnote to bottom of orange box as follows:* “*** The Environmental Permitting (England and Wales) Regulations 2010 and The Pollution Prevention and Control (Scotland) Regulations 2012 (PPC 2012). PPC 2012 came into force on 7 January 2013.”	*Clarification of regulatory processes.*
Paragraph 7.10 amended to: “... Appropriate mitigation measures will be applied in accordance with the waste hierarchy (reduce, re-use, recycle) as identified in relevant waste strategies, including that ~~The Waste Strategy~~ for England[170] ...”	*Clarification to acknowledge different countries’ waste strategies.*
Paragraph 7.24 amend to: “... The water abstracted is passed through the condenser where the water temperature is increased. ~~It~~ The abstracted water is then returned to its source at a temperature above ambient water temperature, leading to localised increases of water temperature.”	*Clarification.*
Paragraph 8.22 second, comma inserted in sentence: “The first step has been the production of a National Objectives, Requirements and Model Standards (NORMS) document.”	*Typographical correction.*
Paragraph 8.33 amended as follows: “ ... Any proposed development ~~developed~~ incorporating the Proposed Practice will need to incorporate climate change adaptation measures to take account of the effects of climate change... ”.	*Correction of typographical errata in document.*
Paragraph A1.115 amended as follows: “Dose modelling of potential public doses from operation of UK ABWR have been undertaken by Hitachi-GE to support its submissions into the GDA process. Dose modelling of potential public doses from operation of UK ABWR have been undertaken by Hitachi-GE to support its submissions into the GDA process. Additionally, during the GDA process, it will be necessary to show that public doses are As Low As Reasonably Achievable (ALARA) and that this has been achieved by use of Best Available Techniques.”	*Clarification.*

AMENDMENT	RATIONALE
Paragraph A1.116 amended as follows: “Radiation dose rate (nGy/h) at the Monitoring point (actual data) around Kashiwazaki-Kariwa site is under 200nGy/y. ~~All of maximum dose values were reported during rain. The increase of dose values originate in change of a meteorological condition, and this deviation is lower than dose level for biological health influence.~~ A change in weather conditions can cause the dose value to fluctuate with the highest values at Kashiwazaki-Kariwa being reported during rainfall. The deviation in the dose level is low and does not influence radiological health effects.”	*Clarification of meaning.*
Paragraph A1.126 amended as follows: “With regard to the United Kingdom, the Office for Nuclear Regulation (ONR) and the Environment Agency (EA) signed GDA agreements with Hitachi-GE in April 2013. The ABWR commenced Step 2 of the GDA assessment process in January 2014.” ~~At the time of submission of this application, the ABWR is expected to commence Step 2 of the GDA assessment process in January 2014.~~”	*Update.*
Paragraph A1.145 amended as follows: “After processing, the radioactive gas~~eous~~ is monitored and discharged ~~released~~ to the environ~~s~~ment through the stack.”	*Clarification.*
Paragraph A5.30 amended as follows “In the case of nuclear safety, ONR is currently an agency of the HSE with sufficient resources and capability to provide assurance of a strong, transparent and independent regulatory regime for nuclear safety and security. To further strengthen these objectives, later this year ONR will be ~~is in the process of being~~ established as an independent public corporation through provisions of the Energy Act 2013 ~~Bill 2012-13~~.”	*Update to reflect the grant of Royal Assent for the Energy Act 2013 on 20 December 2013.*
Page 168, Table amended as follows: Move text as a 2nd entry for Level 5: “Windscale (1957) (Release of radioactive material to the environment following a fire in the a reactor core)” Level 4 then has no entry against it.	*Correction of errata in document.*
Glossary: ONR definition amended as follows: – “ONR - Office for Nuclear Regulation, which at the date of this Application is an agency of the HSE, but which is due to be established as a body corporate by the Energy ~~Bill~~ Act 2013.”	*Update.*

The Nuclear Industry Association (NIA) is the trade association and representative voice of the UK's civil nuclear industry. We represent 62,000 UK nuclear workers across more than 260 member companies.

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