Justification Application Volume 1 – Application

Including additional information requested on behalf of the Justifying Authority through a Notice under Regulation 16 of the Justification of Practices Involving Ionising Radiation Regulations 2004

New nuclear power stations

Submitted by the Nuclear Industry Association - November 2008
Chapter 4, section 4.43.
The heading to the second column in the table should read “Estimated collective dose (man-Sv)”.  

Chapter 6, section 6.35
There should be a footnote explaining that the table was reproduced from PV FAQs US Department of Energy Efficiency and Renewable Energy.

Annex 3, page 15
The Table containing the ICRP risk coefficients should be replaced by:

<table>
<thead>
<tr>
<th>Exposed Population*</th>
<th>Cancer ($\text{Sv}^{-1}$)</th>
<th>Heritable Effects ($\text{Sv}^{-1}$)</th>
<th>Total Detriment ($\text{Sv}^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All ages</td>
<td>5.5%</td>
<td>0.2%</td>
<td>5.7%</td>
</tr>
<tr>
<td>Adult</td>
<td>4.1%</td>
<td>0.1%</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

* 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 fact that younger people have a greater potential period for reproduction and passing on heritable effects.

Annex 6D, section 3.4
This should state “doses will be of the order of a “few $\mu$Sv per year”.
“Few mSv per year” is incorrect.
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Note: The additional information provided in response to the Notice under Regulation 16 has been incorporated at the end of the chapter to which the request relates.

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<td>Worldwide experience of decommissioning</td>
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<td>The health risks of radiation</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>6B AP1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6C EPR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6D ESBWR</td>
</tr>
</tbody>
</table>
Introduction

Chapter 0

Background and Context

0.1 Following the UK Government’s decision\(^1\) that it is in the public interest that new nuclear power stations should play a role in the country’s future energy mix alongside other low-carbon sources, the Department for Business Enterprise and Regulatory Reform (BERR) has issued a call for Justification applications for new nuclear power\(^2\). This application responds to that call.

0.2 The justification principle derives from the recommendations\(^3\) of the International Commission on Radiological Protection (ICRP). This 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 are therefore already adopted in the European Union Council Directive 96/29/Euratom (known as the Basic Safety Standards 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 Directive has been implemented in the UK through the Justification of Practices Involving Ionising Radiation Regulations 2004 (Justification Regulations) which came into force in August 2004. For nuclear energy the Justifying Authority is the Secretary of State for Business Enterprise and Regulatory Reform.

0.5 Following a consultation exercise that concluded in October last year, BERR has issued guidance on how the justification process would operate and on the expected application content in respect of new nuclear power stations.\(^4\) This application follows this guidance.

Purpose of the Justification Application

0.6 Justification is a high level assessment that is intended to take place early in the decision-making process. It is designed to establish, before a new class or type of practice is introduced, that it will provide an overall benefit.\(^5\) The BSS Directive defines the test as being that the benefits (whether economic, social or other) should justify the health detriments caused by the exposure to ionising radiation resulting from the practice. This is the test that has been adopted by the UK in the Justification Regulations which implement the BSS Directive.

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1 Meeting the Energy Challenge, A White Paper on Nuclear Power, Cm 7296, January 2008
3 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.
5 For convenience, the term “class or type of practice” is abbreviated in this document to “practice”.

0.7 Notwithstanding that the strict legal test set out in the Justification Regulations requires only that the benefits of a practice will outweigh the 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 takes this a stage further by suggesting that it should be the Net Benefit that is weighed against the radiological health detriment. Although this interpretation arguably goes beyond the Directive and the Regulations, our application has followed this approach.

0.8 The BERR interpretation of the justification “test” means it is necessary not only to assess the potential radiological health detriments associated with the practice, but also other potential detriments that could be significant when considered against the benefit derived from the practice. This application therefore provides a wide-ranging review of these other potential detriments.

0.9 In line with the above, this application focuses on the potentially very significant benefits to the UK in respect of the delivery of low carbon electricity and increased security of supply at affordable prices. While there are undoubtedly other potential benefits – including economic benefits to the companies involved in deploying the practice, as well as to their employees and to wider communities – this application does not rely on these benefits as part of its demonstration that the practice is justified. It is for this reason that all benefits are not, and do not need to be, assessed within this application. Nevertheless, the application does address the potential for detriment to the wider UK economy, by reference to the cost-benefit analysis already carried out by the Government, and shows that this is a very remote risk.

0.10 It is important to note that a conclusion that a proposed 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 had 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.

0.11 Finally it is worth emphasising that although this application relates to new nuclear power stations, the UK nuclear industry has over 50 years’ experience of operating nuclear power stations within a strict regulatory regime. It has an excellent record of safety and looking after the welfare and health both of its workers and the public. The existing robust regulatory system will continue to evolve in line with technological and societal developments to remain effective.

0.12 The global industry’s wealth of operating experience (12000 reactor years) and the sharing of best practice, especially since the Chernobyl accident in 1986, has improved safety and operational standards here and throughout the world. A key driver behind this is the World Association of Nuclear Operators (WANO) who have the objective of ensuring that an accident such as Chernobyl does not happen again.

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6 Key aspects of the existing and future regulatory and advisory structure for nuclear power are outlined at Annex C of the White Paper on Nuclear Power.
Structure of the Application

0.13 The following chapters provide an overview of the benefits and detriments of the proposed practice. Chapter 1 includes a description of the envelope for the proposed practice for which a justification decision is sought. The remainder of the application is divided into four 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).
- Identification of the potential radiological health detriments (Chapter 4).
- Identification of the potential detriments associated with the practice other than those to do with radiological health (Chapter 5 deals with those linked to radioactive waste and decommissioning, Chapter 6 covers environmental effects not associated with radioactivity, Chapter 7 deals with the potential detriment to the wider UK economy, and Chapter 8 covers other remaining areas).
- A final section (Chapter 9) that summarises the comparison between the net benefits and the radiological health detriments.

Applicant Details

0.14 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 six utilities (British Energy Group plc (Company Number SC2701804) of Systems House, Alba Campus, Livingston, EH54 7EG (“BE”); EDF Energy plc (Company Number 2366852) registered office 40 Grosvenor Place, Victoria, London, SW1X 7EN (“EDF Energy”); E.ON UK plc (Company number 3866970) of Westwood Way, Westwood Business Park, Coventry, CV4 8LG (“EON”); RWE Npower plc (Company number 3892782) of Windmill Hill Business Park, Whitehill Way, Swindon, SN5 6PB (“RWE”); Vattenfall AB (Publ) of SE-16287 Stockholm, Sweden (“Vattenfall”), and Iberdrola Generación S.A. Unipersonal, (Company Number: Reg. Mercantil de Vizcaya, t. 3863, I. 0, f. 199, sec. 8, h. BI-27059, insc. 1a, - NIF: A-95075586) of Cardenal Gardoqui Street number 8, 48008 Bilbao (“Iberdrola”) that are interested in new nuclear construction in the UK. The application includes information on four specific reactor designs provided by the nuclear construction vendors, Atomic Energy of Canada Limited/Énergie atomique du Canada limitée, whose head office is at 2251 Speakman Drive, Mississauga, Ontario, Canada L5K 1B2 (“AECL”); AREVA NP SAS whose registered office is at Tour AREVA, 1 Place de la Coupole, 92400, Courbevoie, France (“AREVA”); GE-Hitachi Nuclear Energy International LLC, 3901 Castle Hayne Road, Wilmington, NC 28401 USA (GEH) and Westinghouse Electric Company LLC, whose principal office is at 4350 Northern Pike, Monroeville, Pennsylvania 15146, USA (“WEC”).

0.15 The NIA is the trade association, information and representative body for the civil nuclear industry in the UK. It represents more than 140 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.

0.16 The NIA's address is:

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

0.17 All questions concerning this application should be addressed to Mr Keith Parker at the above address and marked “Justification Application”.
Proposed Practice, Technology Description, and Example Designs

Chapter 1

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. As part of the technology description, information is provided on the four designs that have successfully completed Step 2 of Generic Design Assessment (GDA) by the safety, security and environmental regulators (the ACR-1000 from AECL; the AP1000 from WEC; the EPR from AREVA; and the ESBWR from GEH). All fall within, and are therefore examples of the proposed practice. Detailed technical information on the 4 designs is provided at Annexes 6A, B, C, and D.

A description of the nuclear fuel cycle is provided at Annex 1.

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. The class or type of proposed practice for which justification is sought (“Proposed Practice”) is as described in paragraphs 1.3 to 1.8 of this application and can be summarised as:

“The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in light water cooled, water moderated thermal reactors using evolutionary designs.”

The proposed practice that is the subject of this application is confined to the category of “evolutionary designs” as described below, and within this category, to those designs that conform to the defining attributes set out in Table 1.1.

Meaning of “Evolutionary Designs”

1.4 The process defined by the IAEA\(^7\) to assess whether a design is evolutionary is set out in the flow chart on the opposite page.\(^8\)

1.5 The IAEA process differentiates between “existing plants”, where designs are already constructed or operated, and “advanced designs”, where this is not the case, but which are of current interest because they incorporate improvements over preceding and existing designs. “Advanced designs” include two distinct categories: evolutionary designs and designs requiring substantial development.

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7 IAEA-TECDOC-936, April 1997
8 Flowchart adapted from IAEA-TECDOC-936, April 1997. The italicised explanatory comments are added to identify examples of the designs that fall into each category.
1.6 The key distinction between these categories is that the latter involves substantial innovation and would therefore require a prototype or demonstration plant before commercial implementation. By contrast, an evolutionary design achieves improvement over current designs through small to moderate modifications, with a strong emphasis on maintaining consistency with established provenness so as to minimize technological risks. Thus, implementation of an evolutionary design requires at most engineering and confirmatory testing.

1.7 The proposed practice that is the subject of this application includes designs that are evolutionary in accordance with the flowchart adapted from IAEA-TECDOC-936, in April 1997. Such designs may cease to be considered evolutionary once they have been successfully developed, built, and operated. However, the benefits and detriments of such designs are not expected to change as a result of the passage of time, other than through the accumulation of operating experience. Thus, if a design is within the scope of an initial justification decision based on this application, it should remain part of a justified practice even when it can no longer be termed evolutionary, unless new and important information arises that leads to a review of the original justification decision.
Table 1.1 Defining Attributes of the Proposed Practice

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Defining Attribute of Proposed Practice</th>
<th>Further information provided in this Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Nuclear Characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fission process</td>
<td>Thermal energy fission</td>
<td>Annex 6</td>
</tr>
<tr>
<td>Fuel</td>
<td>Low enriched oxide fuel</td>
<td>Annex 6</td>
</tr>
<tr>
<td>Moderator</td>
<td>Water or Heavy Water</td>
<td>Annex 6</td>
</tr>
<tr>
<td>Coolant</td>
<td>Water</td>
<td>Annex 6</td>
</tr>
<tr>
<td>Status of Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design category</td>
<td>Evolutionary</td>
<td>IAEA flow chart above and Annex 6</td>
</tr>
<tr>
<td>Minimum regulatory status</td>
<td>Available for UK regulatory assessment</td>
<td>Annex 6</td>
</tr>
<tr>
<td>Radiological Health Detriment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Operation – workers</td>
<td>Effective individual dose in calendar year:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• below legal limit:  20mSv/a averaged over any 5 years,</td>
<td>Chapter 4 and Annex 3</td>
</tr>
<tr>
<td></td>
<td>• 50mSv in any one year*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• average for defined groups less than UK regulatory Basic Safety Level target (10mSv)**</td>
<td></td>
</tr>
<tr>
<td>Normal Operation – public</td>
<td>Below 1mSv legal dose limit</td>
<td>Chapter 4 and Annex 3</td>
</tr>
<tr>
<td></td>
<td>Maximum effective individual dose in calendar year complies with Basic Safety Standards Direction constraint: 0.3mSv/y from new plant***</td>
<td></td>
</tr>
<tr>
<td>Accident risk</td>
<td>Meets UK regulatory Basic Safety Level numerical targets for accidents</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>Security of Supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Origin of fuel</td>
<td>Available from diverse countries</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>Readiness for implementation</td>
<td>Design(s) within practice commercially available in UK</td>
<td>Annex 6</td>
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<tr>
<td>Carbon “Footprint”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifecycle CO₂ emissions</td>
<td>Considered low carbon</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>Radioactive Waste &amp; Decommissioning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radioactive wastes and spent fuel arisings</td>
<td>Compatible with UK disposal or interim storage plans</td>
<td>Chapter 5 and Annex 2</td>
</tr>
</tbody>
</table>


1.8 Four evolutionary advanced reactor designs are identified in this application, as set out in table 1.2 above. The Justifying Authority is requested to consider the Proposed Practice the subject of this application and to view the four identified designs, all of which have successfully completed Step 2 of the GDA process, as examples of technology falling within the Proposed Practice. These four designs demonstrate the net benefits that would result from the introduction of the practice. Further detail on these four designs and how they fall within the defining attributes of the proposed practice is provided in annexes 6A, 6B, 6C and 6D.

1.9 By following the process described in the flow chart above, and then testing against the defining attributes in Table 1.1, it can be shown that the four example designs ACR-1000, AP1000, EPR and ESBWR* are evolutionary designs falling within the envelope of the Proposed Practice.

1.10 The information provided in this application demonstrates that there are no differences between the four example designs that would make the detriments / benefits balance materially different. Accordingly, it is suggested that a single justification decision covering the entire envelope comprising the Proposed Practice could be made. We recognise, however, that it is for the Justifying Authority to decide whether the proposed class or type of practice, and the four example designs, constitute a single new class or type of practice or a number of different classes or types of practice. If the Justifying Authority decides that the application comprises more than one class or type of practice we ask that this application be treated as an application for justification of each of such new classes or types of practice. Were the Justifying Authority minded to consider each of the four example designs as separate classes or types of practice, each of those practices could be defined by reference to the details in paragraphs 1.4 to 1.8 above, and summarised as follows:

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Table 1.2  Examples of Evolutionary Advanced Reactor Designs

<table>
<thead>
<tr>
<th>Design</th>
<th>Design Organisation</th>
<th>Reactor Type</th>
<th>Design based on</th>
<th>Nominal Electrical Power Output</th>
<th>Further Information in this application</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACR-1000</td>
<td>Atomic Energy of Canada Ltd (AECL)</td>
<td>Heavy water moderated, light water cooled reactor</td>
<td>CANDU</td>
<td>1165 MW</td>
<td>Annex 6A</td>
</tr>
<tr>
<td>AP1000</td>
<td>Westinghouse Electric Company LLC, USA</td>
<td>Light water moderated, light water cooled reactor: pressurised water reactor type (PWR)</td>
<td>AP600</td>
<td>1100 MW</td>
<td>Annex 6B</td>
</tr>
<tr>
<td>EPR</td>
<td>Areva NP, France and Germany</td>
<td>Light water moderated, light water cooled reactor: pressurised water reactor type (PWR)</td>
<td>KonvoVN4</td>
<td>1600-1660 MW</td>
<td>Annex 6C</td>
</tr>
<tr>
<td>ESBWR</td>
<td>GE - Hitachi, USA</td>
<td>Light water moderated, light water cooled reactor: boiling water reactor type (BWR)</td>
<td>ABWR</td>
<td>1550 MW</td>
<td>Annex 6D</td>
</tr>
</tbody>
</table>

* All four designs are identified as evolutionary reactors in the OECD’s Annex I, Overview of Global Development of Advanced Nuclear Power Plants, 2003  
"The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in an evolutionary, light water cooled, water moderated thermal reactor known as ACR-1000 designed by Atomic Energy of Canada Ltd."

"The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in an evolutionary, light water cooled, water moderated thermal reactor known as AP1000 designed by Westinghouse Electric Company LLC, of the USA."

"The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in an evolutionary, light water cooled, water moderated thermal reactor known as EPR designed by AREVA NP, of France and Germany."

"The generation of electricity from nuclear energy using oxide fuel of low enrichment in fissile content in an evolutionary, light water cooled, water moderated thermal reactor known as ESBWR designed by GE-Hitachi of the USA."

1.11 A report prepared by Nexia Solutions and cited in the Government’s consultation document on justification suggests that one of our example designs, the ACR-1000, could fall within a separate class or type of practice. The argument appears to us to be:

(a) That it is useful to split thermal neutron reactor designs into light water reactors (LWRs) and heavy water reactors (HWRs)

(b) That, while ACR-1000 is a hybrid (it involves use of both light and heavy water), it could justifiably be allocated to the HWR group on the grounds that it can be refuelled on load and has a greater fuel throughput, albeit at lower enrichment, and these differences could be relevant to proliferation and spent fuel arisings.

1.12 In our view these technology differences would only matter if they were shown materially to affect the balance between the level of benefit and the radiological health detriment. We believe this application shows that these differences are not significant. Any additional detriments associated with the use of heavy water are shown in paragraphs 8.10 and 8.11 to be very small.

1.13 To the extent that, following a positive justification decision, future minor refinements are made to an evolutionary design which do not result in the design falling outside the defining attributes in Table 1.1, the design should continue to be treated as falling within the justified practice, whether that justified practice is defined with reference to the proposed practice, or any of the alternative characterisations of the proposed class or type of practice as discussed in paragraph 1.10 above.

**Scope of Practice**

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

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Annex 1 provides a brief description of the key aspects pertinent to the proposed practice. 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.

Table 1.3 Activities, and how they relate to the proposed practice

<table>
<thead>
<tr>
<th>Activity</th>
<th>Existing Practice (in its own right* or as part of an existing practice*)?</th>
<th>Material scale of change required (if an existing activity)?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium extraction (mining and milling or in-situ leaching)</td>
<td>Yes (although does take place outside the UK)</td>
<td>No</td>
<td>Information included in this application for completeness</td>
</tr>
<tr>
<td>Conversion</td>
<td>Yes</td>
<td>No</td>
<td>Information included in this application for completeness</td>
</tr>
<tr>
<td>Enrichment</td>
<td>Yes</td>
<td>No (unless all in UK)</td>
<td>Information included in this application for completeness</td>
</tr>
<tr>
<td>Fuel Fabrication</td>
<td>Yes</td>
<td>No (unless all in UK)</td>
<td>Information included in this application for completeness</td>
</tr>
<tr>
<td>Generation of electricity by new evolutionary design nuclear power stations</td>
<td>No</td>
<td>-</td>
<td>Assessed in this application</td>
</tr>
<tr>
<td>Spent Fuel Management**</td>
<td>Yes</td>
<td>Yes</td>
<td>Assessed in this application</td>
</tr>
<tr>
<td>Radioactive Waste Management**</td>
<td>Yes</td>
<td>Yes</td>
<td>Assessed in this application</td>
</tr>
<tr>
<td>Decommissioning**</td>
<td>Yes</td>
<td>Yes</td>
<td>Assessed in this application</td>
</tr>
<tr>
<td>Transport of fresh fuel, spent fuel and radioactive wastes</td>
<td>Yes</td>
<td>No (based on current rates of radioactive materials movements)</td>
<td>Information included in this application for completeness</td>
</tr>
<tr>
<td>Final disposal** (in UK)</td>
<td>Yes (LLW)</td>
<td>Yes</td>
<td>Assessed in this application</td>
</tr>
<tr>
<td></td>
<td>No (ILW &amp; spent fuel)</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

* Justified by virtue of being a class or type of practice existing in the UK prior to 13 May 200010
** ICRP emphasises that waste management and disposal operations should be treated as an integral part of the practice generating the waste11

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10 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 August 2007 http://www.defra.gov.uk/environment/radioactivity/government/legislation/pdf/justification-guidance.pdf
11 Radiation protection recommendations as applied to the disposal of long-lived solid radioactive waste, ICRP publication 81, 1998
1.16 Table 1.3 presents the scope of the practice described 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, decommissioning and radioactive waste disposal operations are treated as part of the practice generating the waste. In this application we also treat the transport of radioactive materials as being an integral and necessary part of the proposed new practice although we note that there are no implications from the practice beyond those arising from similar practices already carried out under existing justifications.
Chapter 1 - Addendum

Additional information provided in response to questions raised in relation to Chapter 1 in the Notice under Regulation 16 of the Justification of Practices Involving Ionising Radiation Regulations 2004

Q1. In para 1.7 the applicant states that the proposed practice includes designs that were classed as evolutionary in accordance with the IAEA-TECDOC-936, in April 1997. The applicant is asked to confirm whether it is their intention that only those designs requiring engineering and confirmatory testing at that time are included in the proposed practice and, if this is the case, provide evidence that the designs included in the application were deemed to be evolutionary in April 1997.

Date at which the Designs Are Deemed to be Evolutionary

The only relevance of April 1997 is that it is the date of publication of IAEA-TECDOC-936. The practice for which justification is sought encompasses reactor designs which are evolutionary (within the definition set out in the IAEA 1997 document) at the date of the justification application i.e. June 2008.

The 1997 IAEA technical document provides an authoritative definition of “evolutionary” designs. It is intended to distinguish those reactor designs available for commercial deployment that represent developments of earlier existing designs in terms of enhanced safety, economic and operational performance, among other improvements. It also distinguishes these “evolutionary” designs from advanced innovative designs that would require substantial research and engineering development before being ready for commercial deployment. The IAEA adopts a generic approach to describe designs and makes no reference to any specific designs. The IAEA definition of an “evolutionary” design can therefore be applied at any chosen point in time to determine whether a reactor design is “evolutionary” at that chosen point in time. It is important to note that whether a design is, or is not, “evolutionary” is determined by the technical features of that design and how those technical features relate to features within designs that have already been deployed and for which there is therefore prior experience.

The flowchart in paragraph 1.5 of the application is derived from the criteria identified by the IAEA as defining an evolutionary design and indicates that in the applicant’s view, and based on the material contained in the application, the 4 example designs can be defined as “evolutionary” at the time the justification application was made in June 2008.

Evidence that Designs are Deemed Evolutionary

For completeness, the reference in paragraph 1.9 to the fact that in 2003 OECD identified the four example designs as being evolutionary is included simply to indicate that the OECD considered each of the designs to be evolutionary using the 1997 definition developed by the IAEA. The 2003 date should not be regarded as having a wider significance as a reference point in time.

Q2. In Table 1.1 the applicant is asked to provide further clarification of what is meant by “designs within the practice commercially available in UK”. (i.e. At what point does the applicant consider that a design becomes commercially available in the UK?)

Our application identifies as a defining attribute “designs within the practice commercially available in the UK” because we believe it to be a key part of the practice that designs be capable of starting to deliver benefits on the required timescale; i.e. soon enough to fulfil the potential role identified by UK Government
for nuclear generation. In paragraph 2.15 reference is made to the possibility of an “energy gap” window, so that availability on this timescale would serve to increase the security of supply benefit.

In order to meet this attribute of UK commercial availability we suggest there are a number of factors to consider:

1. Potential owners/operators must have an interest in the technology (i.e. there needs to be a customer for the technology). All four example designs have one or more letters of support from potential operators as part of the process for qualification for entry into the GDA process that was managed by BERR in June 2007.

2. The vendor must offer the technology in the UK. Entry to the GDA process confirms the willingness of the vendor to participate in the UK market.

Q3. The applicant is asked to provide a further explanation of the contents of Table 1.3, including what is meant by “material scale of change” and why there would be a change of position if enrichment and fabrication were to take place solely in the UK.

Enrichment in the UK would be at Urenco’s Capenhurst site. According to Urenco’s 2007 annual report, last year the Capenhurst site had a capacity for 4200t separative work. This capacity is more than sufficient to fuel a UK fleet of, for example, 10 GWe. 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.

There is the capability to manufacture fuel for the designs in our proposed practice at Springfields at the existing LWR line\(^1\). However there is currently no LWR fuel manufacture (as Sizewell B fuel currently comes from an overseas supplier). Thus manufacturing fuel for a postulated 10 GWe UK fleet would represent a substantial increase over past LWR fuel throughput. In terms of overall fuel manufacture, the amounts required would be much less than the peak output in the 1980s.

So although there is nothing special or unusual about enrichment or fuel manufacture for a UK new build fleet, it is because there is a potential for significant upscale of current (in the case of fuel enrichment) or past (in the case of LWR fuel manufacture) operations that the application identifies a material scale of change if these activities were all in the UK. It is important to note that there would however be no material scale of change in the overall radiological detriment from these activities.

\(^1\) Springfields already has the capability to manufacture AP1000 fuel. EPR fuel could be manufactured with some tooling changes. Significant capital investment would be required to manufacture ESBWR or ACR fuel.
Q15. The applicant is asked to set out why it considers that for key parameters relevant to
Justification each of the four example designs would fall within the class or type of
practice defined in Volume 1.

The requirements for a design to fall within the proposed class or type of practice are
set out in Table 1.1 in Chapter 1. This response is therefore provided after Chapter 1
as it collates the detailed evidence that the 4 example designs do indeed fall within
the proposed type or class of practice.

The characteristics and associated defining attributes set out in Table 1.1 relate to:

- the key common factors that identify the broad technical features of designs
  within our proposed practice. Designs with technical features other than those we
  identify in the description of our proposed practice could have materially differing
  benefits and detriments and therefore are deemed to fall outside the class or type
  of practice that we define

- those characteristics needed in order to ensure that the designs are both capable
  of implementation in the UK to be able to deliver the identified benefit and
  available in the UK

- the potential radiological health detriment

- only those potential detriments that could significantly affect the balance between
  the scale of the net benefit from the practice and its potential to result in
  radiological health detriment. Not all the potential detriments considered in our
  application are sufficiently significant to have associated characteristics and
  defining attributes identified. Such detriments being small are therefore not
  sufficiently significant, either individually or in aggregate, to alter the balance of
  benefits and detriments.

Compliance with all the defining attributes is needed for a design to fall within our
proposed practice.

In the sections below we summarise for each characteristic and defining attribute:

- why they are relevant in terms of defining the practice

- what the evidence is within the application that each of the 4 designs meets the
  defining attributes.

Basic Nuclear Characteristics

The basic nuclear characteristics are a description of the broad technical similarities of
designs that are relevant to the potential benefits and detriments that are described
in our application. This is outlined in the description of these characteristics that
follows below.

Fission process

The reactors in our practice depend on thermal energy fission. This defining attribute
excludes fast reactors for reasons including:

- Fast reactors have different fuel cycle implications as they for example require fuel
to be enriched to around 20% (the designs in our practice are enriched to around
5%). Low enriched fuel requires less stringent safeguards measures for control
compared to high enriched fuel (over 20%).
The core of a fast reactor is much smaller than that of a thermal nuclear reactor, and it has a higher power density, requiring very efficient heat transfer. This means fast reactors generally use different coolants (e.g. liquid metal).

It is also relevant that there is relatively little experience of operating fast reactors: such past experience is a key factor in presenting evidence that other defining attributes such as those relating to “readiness for implementation” and “waste and decommissioning” can be met.

**Fuel**

The reactors in our practice utilise low enriched oxide fuel. Low enriched fuel requires less stringent safeguards measures for control compared to high enriched fuel (over 20%). Oxide fuel has a higher melting point than uranium metal fuel and is chemically stable. This chemical stability is essential for long term storage of fuel without degradation of the condition of the irradiated fuel and is therefore one of the key factors in meeting the defining attribute relating to radioactive waste and decommissioning.

**Moderator**

The reactors in our practice utilise light water or heavy water as moderator; we do not differentiate between these as the material properties of both are similar.

Other moderators are possible and are used but these have differing material properties that significantly affect benefits and detriments. For example graphite moderators have implications for waste management (e.g. graphite moderated reactors generate larger quantities of intermediate level solid radioactive waste than water moderated reactors).

**Coolant**

A range of coolants is possible: the reactors in our proposed practice utilise water as coolant. The significance of this is that for technologies using coolant of similar material and heat transfer properties a similar range of design solutions will be available (e.g. for heat transfer, radiological control and in the selection of materials for structures, systems and components). This is a major factor behind the comparable responses of the example designs to meeting the defining attributes relating to radiological health detriment and waste and decommissioning.

Annexes 6A-6D provide information from each of the 4 design vendors against these defining attributes. The Table below sets out the confirmation provided for each design that it complies with all of the above defining attributes.
Status of Design

The “status of design” characteristic has 2 defining attributes identified that must both be satisfied in order for a design to be capable of delivering the net benefits identified for our proposed practice, and to be capable of starting to do this in the timescales envisaged by UK energy policy.

Design category – evolutionary

Our response to Question 1 has clarified the meaning and significance of “evolutionary” in the definition of the proposed new practice making it clear that the term is a technical one that describes the pedigree and level of maturity of the engineered features within a particular design; the term is used in the way defined and promulgated by the IAEA.

The designs in our proposed practice are advanced evolutionary designs and therefore are considered to offer improvements over preceding and currently operating designs. This is necessary in order to meet Government, regulatory and industry expectations for performance that will be comparable to the best currently achieved in the world for operating reactors. This also gives a high degree of confidence that the net benefits identified can be delivered and that the detriments (both radiological and other) will indeed be small and as described in our application.

Other advanced designs, that are not evolutionary in nature, fall outside our proposed practice as they require substantial technology development, including prototype demonstration plants. Such designs are not commercialised and therefore there would be no reason for a utility to consider them for potential near term deployment.

Annexes 6A-6D provide information from each of the vendors for the 4 designs on their design status. The Table below sets out the confirmation provided for each design that it can be considered “evolutionary”.

<table>
<thead>
<tr>
<th>ACR-1000</th>
<th>AP1000</th>
<th>EPR</th>
<th>ESBWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex 6A Section 1 Introduction states that the ACR-1000 is a thermal, light water cooled, heavy water moderated pressure tube reactor. It produces energy by thermal fission of low enriched uranium (LEU), using UO₂ fuel.</td>
<td>Annex 6B Section 1 Introduction states that the AP1000 produces thermal energy by fission of low enriched uranium (LEU), using UO₂ fuel. The heat is transferred from the fuel by water.</td>
<td>Annex 6C Section 1 Introduction states that in reactors such as EPR, ordinary (light) water is utilised to remove the heat produced inside the reactor core by the thermal nuclear fission phenomenon. This water also slows down (or moderates) neutrons. Section 2.4 Fuel and Fuel Management states that the fuel rods consist of uranium dioxide pellets with uranium enrichments up to 5% U²³⁵ being considered.</td>
<td>Annex 6D Section 1 Introduction states that in a reactor such as the ESBWR ordinary light water is used to remove the heat produced inside the reactor core by the thermal nuclear fission process. Key ESBWR parameters identified include the fuel being low enriched UO₂ and the moderator being light water.</td>
</tr>
</tbody>
</table>
Minimum regulatory status

The “available for UK regulatory assessment” defining attribute is explained in our answer to Question 2. It recognises that for a design to fall within our proposed new practice it should be one capable of delivering the claimed UK strategic benefits on a timescale consistent with the national need that has been identified by Government. Regulatory review will take several years and this time period needs to be allowed for in assessing whether a design is potentially available on the required timescale.

We have identified as one test of this attribute the vendor’s willingness to submit their design for the demanding UK regulatory assessment process; this also indicates the degree of their commitment to the UK market and that the design’s stage of development is sufficiently mature for consideration.

Annexes 6A-6D provide information from each of the vendors for the 4 designs on their regulatory design status. The Table below sets out the confirmation provided for each design that it complies with the “available for UK regulatory assessment” defining attribute.

<table>
<thead>
<tr>
<th>Design</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACR-1000</td>
<td>Annex 6A Section 1 Introduction states that the ACR-1000 is an evolutionary development of AECL's CANDU 6 plant and retains the primary features of the CANDU “classic” design. It describes the principal design and implementation features included to enhance performance compared to the CANDU 6. It states that the ACR-1000 is designed to meet Generation III economic performance targets.</td>
</tr>
<tr>
<td>AP1000</td>
<td>Annex 6B Section 1 states that the AP1000 builds and improves upon the proven technology in current Westinghouse designed PWRs. It identifies that the advanced passive safety systems and extensive plant simplifications reduce cost and construction time whilst improving safety, operation and maintenance of the plant. The section concludes by stating that the incorporation of over 40 years of operating experience resulted in the evolution of the AP1000 design.</td>
</tr>
<tr>
<td>EPR</td>
<td>Annex 6C Section 1 states that the EPR evolutionary design is based on experience from several thousand reactor years of operation worldwide. The primary system design, loop configuration and main components are similar to those of currently operating PWRs forming a proven foundation for the design. Additionally the EPR takes into account the expectation of utilities as stated by the European Utility Requirements (EUR) and complies with specific safety requirements formulated by the French and German safety authorities.</td>
</tr>
<tr>
<td>ESBWR</td>
<td>Annex 6D Section 1 states that the ESBWR is an evolutionary boiling water reactor that combines improvements in safety with design simplification and component standardisation to produce a safer, more productive and more reliable nuclear power plant, with lower projected construction costs than plants in operation today. Figure 2 shows the evolution of the BWR system design through to the ESBWR.</td>
</tr>
</tbody>
</table>
Update on current position as at November 2008: All 4 example designs completed Stage 2 of the UK’s Generic Design Assessment. At the current time 2 of them (AP1000 and EPR) are actively engaged in Step 3 of this process. The vendors for ACR1000 and ESBWR have put their involvement on hold but intimated that they may wish to re-engage with the process at a later date.

Radiological Health Detriment

The justification test requires that the net benefits clearly outweigh the potential radiological health detriments of a practice. Thus defining attributes are identified for the radiological health detriment characteristic. As part of the defining attributes, Table 1.1 proposes levels below which the detriment is considered small. As the levels we propose correspond to regulatory requirements and constraints, this provides evidence of their acceptability for the purposes of justification. The levels we propose should not be interpreted as equivalent to the outcomes resulting from the optimisation processes that would occur during formal licensing.

Normal Operation – workers

The potential radiological health detriment to workers from the proposed new class of practice is clearly relevant to justification and therefore defining attributes are identified for this characteristic.

As Table 1.1 sets out, the scale of potential detriment is constrained through 2 defining attributes:

- a maximum level of individual dose (i.e. dose to any single worker). This is the current legal dose limit
- a level of average dose for those staff in defined groups. This is the Basic Safety Level (BSL) set by NII for radiation workers. This criterion is of greater significance in determining potential health detriment.

Annexes 6A-6D provide information from each of the vendors for the 4 designs against these defining attributes. The Table below demonstrates that each of the 4 designs is similar in respect of these defining attributes.
Normal Operation – Public

The potential radiological health detriment to the public is also clearly important in terms of justification. The most significant defining attribute within Table 1.1 of the application in this respect is the ability to comply with the Basic Safety Standards Direction constraint of 0.3mSv/y from a new plant.

Annexes 6A-6D provide information from each of the vendors for the 4 designs against this defining attribute. The Table below sets out why each of the 4 designs is similar in terms of this defining attribute.

<table>
<thead>
<tr>
<th>ACR-1000</th>
<th>AP1000</th>
<th>EPR</th>
<th>ESBWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex 6A Section 5.4 states design will meet the individual dose criterion. Section 5.5 states that average doses to radiation workers from this design will be well below the BSL for radiation workers.</td>
<td>Annex 6B Section 5 states that the BSL for average dose to defined groups of workers can be met by the design.</td>
<td>Annex 6C Section 3.4 states that the BSL (average dose) and dose limits will be comfortably met.</td>
<td>Annex 6D Section 3.4 states that the BSLs for individual workers and for defined groups (average dose) will be met by the design.</td>
</tr>
</tbody>
</table>

Accident Risk

The potential for accidents to add to the risk of radiological health detriment to the public is also a significant matter for justification. For this reason it has an associated defining attribute for the new class of practice; the level selected to assess acceptability is the BSL within the NII's Safety Assessment Principles setting numerical targets for accident likelihood and severity.

Annexes 6A-6D provide information from each of the vendors for the 4 designs showing how they meet this defining attribute.
Security of Supply

Chapter 2 of our application describes the generic features of our practice that contribute to security of supply. However, defining attributes are identified to ensure that designs falling within our proposed practice:

- do not have any specific features that might cause them to offer a lower security of supply than that described in our application (the “origin of fuel” defining attribute)

- are available in the UK (the “readiness for implementation” defining attribute) to provide the described benefits on the timescales needed to meet UK energy policy.

Origin of fuel

Paragraphs 2.17 to 2.24 of our application describe the generic reasons why our proposed practice is relatively invulnerable to fluctuations in the availability of fuel. A defining attribute relating to the availability of fuel from diverse sources is also identified to ensure that designs in our proposed practice do not have any features that will result in dependence on a single fuel source or supplier.

The table below sets out the confirmation provided in our application that each of the designs meet the requirements of this defining attribute.

<table>
<thead>
<tr>
<th>ACR-1000</th>
<th>AP1000</th>
<th>EPR</th>
<th>ESBWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex 6A Section 3.4 states that the design is expected to meet the NII’s Basic Safety Objectives for accidents (these are similar to but more stringent than the BSL targets).</td>
<td>Annex 6B Section 3.3 states that the low values for the core damage frequency and large release frequency give a good indication that the NII’s BSL targets will be met.</td>
<td>Annex 6C Section 3.4 states that analyses show the design complies with the NII’s Basic Safety Objectives for accidents (these are similar to but more stringent than the BSL targets).</td>
<td>Annex 6D Section 3.4 describes the design as being within the acceptance criteria of the UK licensing process in terms of accidents.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACR-1000</th>
<th>AP1000</th>
<th>EPR</th>
<th>ESBWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex 6A Section 2.7 Fuel states that in Canada there are two suppliers of CANDU fuel, GE-Hitachi Nuclear Energy Canada Inc. (GHNEC) and Cameco/Zircatec. Both fuel suppliers have reviewed the ACR-1000 reference fuel design and confirmed that they can manufacture this fuel. The ACR bundle is a simple fuel to manufacture and could be made under licence and supplied in the UK if desired.</td>
<td>Annex 6B Section 2.5 Fuel states that although the specific fuel design is unique to Westinghouse, refuelling can be achieved by using fuel from other vendors, thereby affording utility flexibility.</td>
<td>Annex 6C Section 2.4 Reactor Core states that the low enriched uranium and fuel manufacturing can be provided by different suppliers thus keeping the market open and allowing competition between suppliers.</td>
<td>Annex 6D Section 2.4 Core and Fuel Design states that the low enriched uranium fuel manufacture can be sourced through GEH or other fuel suppliers.</td>
</tr>
</tbody>
</table>
Readiness for implementation

In order to be fully capable of delivering all the security of supply benefits identified in our application, a reactor design has to be available for potential deployment in the UK on timescales to meet the requirements of UK energy policy. We have therefore identified the defining attribute “commercially available in the UK”.

As explained in our response to Question 2, we have used a number of factors in coming to the conclusion that the four example designs meet this defining attribute.

1. Potential owners/operators must have an interest in the technology (i.e. there needs to be a customer for the technology). All four example designs have one or more letters of support from potential operators as part of the process for qualification for entry into the GDA process that was managed by BERR in June 2007.

2. The vendor must offer the technology in the UK. Entry to the GDA process confirms the willingness of the vendor to participate in the UK market.

The discussion above under the “Minimum regulatory status” heading also sets out the information provided on our four example designs.

Carbon footprint

Lifecycle CO₂ emissions

Chapter 3 of our application sets out the reasons why nuclear technology is considered to be low carbon. The exact carbon footprint is not design specific, as it is dependent on non design specific factors such as uranium ore origin, enrichment processes used (some processes are more energy intensive than others) and the origin of energy used for activities such as enrichment and fuel manufacture. There have been a number of estimates of life cycle emissions (as described in paragraph 3.14 of our application), these all demonstrate broadly similar results. These conclusions therefore apply to all our example designs and hence there is no design specific discussion of this attribute in our application.

Radioactive Waste & Decommissioning

Radioactive wastes and spent fuel arisings

The applicant judges the detriment from radioactive waste and spent fuel to have the potential to be significant in terms of justification were there to be no defining attribute identified to constrain it. The issues here centre around confidence that the quantities and characteristics of these materials are such that they could be managed responsibly and without significant detriment, including potentially placing a significant financial burden on the UK taxpayer. This is captured by the defining attribute set out in Table 1.1 that these arisings should be “compatible with UK disposal or interim storage plans”.

The main application (para 5.27) explains that low level radioactive waste (LLW) from the new practice would be small in quantity (“a few normal lorry loads” per year) and capable of being managed in a consistent way as current LLW.
For intermediate level waste (ILW) and spent fuel the quantities are also stated to be small – such that they could be stored within the station boundary if necessary (paras 5.31 & 5.40). The application also quotes work performed by Nirex which showed that, on the basis of some reasonable assumptions, the impact of disposal of these materials and the material of this type generated during the ultimate decommissioning of the station, would be determined chiefly by the spent fuel quantity (paras 5.33 & 5.44). This work led to the application estimating that the scale of impact that a programme of size, for example, 10GW(e) could have on the below ground “footprint” of a future repository would be an increase of around 50%.

Annexes 6A-6D provide information from each of the vendors for the 4 designs against this defining attribute. The Table below sets out how each of the 4 designs are similar in relation to the waste and spent fuel arisings issues. The question of the potential financial detriment to UK taxpayers is answered in the application generically (paras 5.62-5.69); it is not something that depends on the design of the power plant and so it is not necessary to include this aspect in the Table.

<table>
<thead>
<tr>
<th>ACR-1000</th>
<th>AP1000</th>
<th>EPR</th>
<th>ESBWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex 6A Section 5.1 describes how LLW quantities are small (around 50m³) and could be managed in the same way as existing similar UK waste.</td>
<td>Annex 6B Section 5 states that the volume of LLW is anticipated to be comparable with or lower than that of operating PWRs worldwide.</td>
<td>Annex 6C Section 5 states that the quantity of solid waste (mainly LLW) would be around 80m³ and consistent with other comparable reactors worldwide and that this waste should be able to be disposed of without presenting any issues compared to existing UK wastes.</td>
<td>Annex 6D Section 5.4 estimates the quantity of LLW as around 160m³ per year. It is explained that this waste could be managed in the same way as existing similar wastes.</td>
</tr>
<tr>
<td>Annex 6A Section 5.2 explains that, although the mass of spent fuel would be greater than for an equivalent output PWR, the Nirex work showed the impact on a repository size would be very similar.</td>
<td>Annex 6B Section 5 refers to the Nirex assessment that the ILW (including that from decommissioning) and spent fuel from a 10GW(e) programme of AP1000 PWRs could be accommodated within a 50% increase in the below ground “footprint” of a future UK repository.</td>
<td>Annex 6C Section 5 refers to the Nirex assessment that the ILW (including that from decommissioning) and the spent fuel from a 10GW(e) programme of AP1000 PWRs could be accommodated within a 50% (or potentially lower) increase in the below ground “footprint” of a future UK repository</td>
<td>In Annex 6D Section 5.5 it is estimated that disposal of the spent fuel and ILW (including that from decommissioning) from a 10GW(e) programme of ESBWRs would increase the below ground footprint of a future UK repository by up to 50%</td>
</tr>
</tbody>
</table>
Security of Supply and Climate Change Benefits

Chapter 2 - Security of supply benefits

Two key conclusions\textsuperscript{12} of the Government’s White Paper on Nuclear Power are that nuclear power is:

“dependable – a proven technology with modern reactors capable of producing electricity reliably”, and...

“capable of increasing diversity and reducing our dependence on any one technology or country for our energy or fuel supplies.”

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

Nuclear power stations are relatively invulnerable to short-term fluctuations in the availability of fuel.

Provided a robust planning regime is introduced in accordance with Government proposals new nuclear stations could make a contribution by as early as 2017/18.

The economic benefit of secure electricity supplies from nuclear power is quantified in Chapter 7.

Introduction

2.1 This Chapter outlines the potential security of supply benefits that could result from the adoption of the proposed practice. The following sections consider the

- benefits of electricity to UK society;
- need for action to secure the UK’s electricity supplies;
- value of a diverse portfolio mix;
- contribution of new nuclear build;
- availability of nuclear fuel;
- role of baseload plant.

Benefits of electricity to UK society

2.2 Electricity is perhaps the most convenient and controllable form of energy available to us and underpins many of the productivity, transport, health and comfort benefits that societies largely take for granted in developed economies. The provision of affordable and reliable supplies is therefore fundamental to maintaining our quality of life, and to the sustainability and wellbeing of the UK’s economy.

2.3 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, a means of generating reliable, dependable, large-scale quantities of electricity as part of this mix. Irrespective of the other characteristics of nuclear as a source of generation, this is a substantial benefit when assessing justification.
Furthermore, 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 is a further substantial benefit of the practice, as is set out in the remainder of this chapter.

Need for action to secure the UK’s electricity supplies

2.5 As the 2007 Energy White Paper\textsuperscript{13} recognises, the UK faces a great deal of uncertainty about its energy supplies over the next couple of decades. The UK’s own natural resources are declining. Our oil and gas reserves are depleting significantly and the UK is already a net importer of oil. By 2020 around 80\% of our fuels are likely to come from overseas.\textsuperscript{14}

2.6 This coincides with rising worldwide demand for gas, which looks set to increase sharply over the medium term, largely driven by economic growth. Key sources of gas for the UK will in the short term include piped gas from Norway, and in the longer term Russia, and liquified natural gas (LNG) from Algeria and Qatar. Surface pipelines passing over great distances, and through many countries, to reach the UK, and increased global demand for gas, increase the likelihood of market or external events which could lead to interruptions to UK gas supplies. Alternative means of delivery of gas to the UK, particularly from the more distant sources, are provided by liquefied natural gas (LNG) technology, but reliance on deliveries of LNG by ship likewise raises questions of supply security, since ships can be delayed or diverted. It also incurs significant efficiency penalties in liquefying the gas, transporting it and re-converting it to the gaseous state on arrival in the UK.

2.7 Over the same period almost one third of the UK’s coal and oil-fired power stations are likely to close because of (among other things) environmental legislation. In addition on the basis of their published lives, and in the absence of further life extensions, all but one of our nuclear power stations will have shut by 2023. As a result the Government believes that energy companies will need to invest in around 30-35 GW of new generating capacity over the next two decades.

2.8 In the short to medium term the UK electricity generation sector is likely to construct further gas-fired stations to replace retiring plant and meet rising demand. This is confirmed by the 2007 Energy White Paper, which states “UK gas demand is set to continue growing over the next fifteen years, driven mainly by increased demand from the power sector”. As a result, the majority of our generation would either be dependent on foreign supplies of gas or be intermittent in nature, (i.e. generated by some renewable energy sources e.g. wind) with a reduced diversity in energy supplies.

Value of a diverse portfolio

2.9 Maintaining a more diverse generation mix, by avoiding overdependence on a single fuel source, would help mitigate these risks. As noted by the Energy White Paper\textsuperscript{15} a

\begin{footnotesize}
\begin{enumerate}
\item A White Paper on Energy, Cm 7124, May 2007, Page 186
\item A White Paper on Energy, Cm 7124, May 2007, Page 33
\item A White Paper on Energy, Cm 7124, May 2007, Page 127
\end{enumerate}
\end{footnotesize}
diverse supply of energy is an important factor in security of supply. Avoiding over-dependence on single sources lessens the impact of supply chain interruptions.

2.10 Although it might not necessarily lead to the lowest possible prices at any given time, a diverse mix of generating plant using a variety of fuels would contribute to stability in electricity prices over the longer term by enabling plant whose fuel costs had risen significantly to be displaced by plant which is cheaper to operate.

2.11 The White Paper on Nuclear Power recognises nuclear’s potential role in maintaining this stability: “(nuclear) fuel costs make up only a small proportion (around 10%) of the overall plant running costs, with uranium ore accounting for approximately 1.5% of total generation costs compared to gas plant where fuel costs represent around 70% of running costs. Fossil fuel prices have been volatile and subject to more sudden increases. Increases in fossil fuel costs are also more rapidly translated into increases in generation costs and electricity prices because fuel prices represent a higher proportion of the total cost of generating electricity. Nuclear power can therefore play a role as a hedge against such input price volatility.”

Contribution of new nuclear stations

2.12 The Government concludes in the White Paper on Nuclear Power that nuclear power is “capable of increasing diversity and reducing our dependence on any one technology or country for our energy or fuel supplies”.

2.13 The price of uranium is not directly correlated to global oil and gas prices, and because the fuel and operating costs are a low proportion of the overall costs nuclear generation is relatively unaffected by uranium price fluctuations and could act as a stabilising influence on UK wholesale electricity prices. It would also provide large-scale reliable and secure supplies of generation, which would help maintain electricity supplies in the event of disruptions to other fuel supplies.

2.14 New nuclear stations could be expected to deliver high levels of performance. The figures from the World Association of Nuclear Operators (WANO) on the following page show the performance of over 400 operating nuclear power units worldwide. Unit capability factor is a measure of the percentage of maximum energy generation that a plant is capable of supplying to the electrical grid; unplanned capability loss factor measures the amount of energy not supplied to the grid through unplanned losses. The most recent data from the World Association of Nuclear Operators show sustained levels of high capacity operation with very small unplanned losses. By using evolutions of international designs new nuclear stations within the proposed practice would be able to benefit from this worldwide operating experience, and could be expected to match or exceed the performance of the best current light water reactors.

2.15 The White Paper concludes that, given their long lead times, new nuclear stations could make an important contribution from 2018 onwards. This would be well within the “energy gap” window predicted by the Government between 2016-2022 caused by the closure of existing nuclear plant and coal plant opted out of the European Union’s Large Combustion Plant Directive (LCPD) requirements.

16 A White Paper on Nuclear Power, Cm 7296, January 2008, paragraph 2.35
17 A White Paper on Nuclear Power, Cm 7296, January 2008
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.

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.
2.16 New nuclear construction would not impact on the significant increase envisaged by Government in the UK’s renewable capacity. Renewables would continue to be supported by the Renewables Obligation (RO) arrangements, under which remuneration is based on the market value of the electricity plus the value of Renewable Obligation Certificates (ROC). Since the market value of the ROC increases if installed renewable capacity falls behind target, they should remain an attractive investment proposition. In addition the European Commission has recently proposed that the UK should source 15% of its total energy consumption from renewables by 2020.18

The availability of nuclear fuel

2.17 Nuclear power stations are relatively invulnerable to fluctuations in the availability of fuel. In this respect they are very different to, for example, a gas-fired power station, where a continuous supply of new fuel is required in order to generate electricity. A typical modern reactor (PWR/BWR) 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. This is part of the reason why the full cost of nuclear generation is relatively insensitive to the price of uranium.

2.18 There are sufficient uranium reserves to fuel both the existing and contemplated new nuclear stations, both in the UK and internationally. Volume requirements are small and there is the potential to acquire and stockpile fuel easily if required; (for instance, if the UK were to construct a fleet of ten new stations, the total annual fuel requirements could be housed in one modest-sized building). A modern reactor requires only a few tens of tonnes of fuel per annum.

2.19 Several of the most important supply countries for uranium are politically stable, with about half of known resources located in democratic market-based OECD countries such as Australia and Canada. Risks of fuel supply interruption are considered to be minimal to the extent that the Performance and Innovation Unit categorised nuclear energy as effectively an indigenous source of electricity.19

2.20 The most authoritative source on uranium resources is a joint report by OECD's Nuclear Energy Agency and the International Atomic Energy Agency (IAEA), called ‘Uranium – Resources, Production and Demand’, which is revised every two years. The latest edition was published in June 2006.

2.21 According to this report 4.7MtU of Identified Resources have been identified worldwide with a recovery cost below 130 US$/kgU. The OECD/IAEA estimate that there is a further 10MtU of Undiscovered Resources, making a total of 14.7MtU in all (of which 11.8MtU has a recovery cost below 130 US$/kgU).

18 The draft Renewables Directive provides the framework for achieving the EU’s target of securing 20 per cent of all its energy from renewable sources by 2020 and sets out proposed shares for the UK and other Member States to achieve this.

19 “The Energy Review”; Performance and Innovation Unit; February 2002
2.22 These resources could allow 220 years of electricity generation worldwide at current consumption rates, using existing reactor technology. The discovery of further uranium resources can be expected as historically worldwide expenditure on uranium exploration has been low, because selling prices have been depressed. Most of the sources of current supplies were identified in the last exploration cycle that ran from about 1970 to 1985.

2.23 Little effort has been made using modern surveying technology to identify resources that might be used to supply the market beyond the middle of the century. However following the announcement of new international nuclear programmes the spot market price of uranium has recently risen and this is stimulating greater investment in exploration. Australia, with some of the largest uranium resources in the world, has recently reported a 34% increase in its economically demonstrated and ‘inferred’ uranium resources.\[^{20,21}\]

2.24 Against this background the applicant is confident in the uranium market’s ability to meet the anticipated world demand for uranium, including the necessary new production facilities, even from a greatly expanded world nuclear programme. This conclusion was shared by Government in the White Paper:\[^{22}\]

> “Having reviewed the arguments and information put forward, and based on the significant evidence that there are sufficient high-grade uranium ores available to meet future global demand, and the relatively small impact that allowing energy companies to invest in new nuclear power stations in the UK would have on global demand for uranium, the Government believes that there should be sufficient reserves to fuel any new nuclear power stations constructed in the UK”.

### Role of Baseload Plant

2.25 The demand for 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.

2.26 The key attribute of baseload plants is their ability to generate continuously in a reliable and predictable way. In selecting the type of plant used to fulfil this role it makes sense to choose plant that has lower variable costs, and which is therefore cheaper to run at a high capacity than plant with high variable costs (e.g. due to fuel). Baseload plants are consequently generally operated continuously at high capacity and do not change production levels to meet variations in power demand. Fluctuations, including spikes, are handled by more responsive plants on the system which are faster to start but generally have higher marginal (fuel) costs. Many renewable energy sources (e.g. wind) have very low marginal costs but have output levels that are not continuous or predictable. For this reason these sources cannot fulfil the role of baseload generation.

\[^{20}\] Geoscience Australia: Australia’s Identified Mineral Resources 2007
\[^{22}\] A White Paper on Nuclear Power, Cm 7296, January 2008, Page 106
2.27 With the retirement of a large amount of existing coal-fired and nuclear capacity over the coming years there will be a requirement for new capacity to meet baseload demand. New nuclear power stations with their low variable costs, high availability/reliability and low carbon emissions (see chapter 3) are inherently better suited to meet future baseload demand than equivalent coal and gas fired plant with higher variable costs.

2.28 In addition, new nuclear designs will be more flexible than existing nuclear plant, since the capability to vary load is catered for in the plant design. Hence, new nuclear power plants would have the ability to respond to system demands and to operate outside of baseload where necessary.

Technical Failure

2.29 The Government concludes in its White Paper\textsuperscript{23} that nuclear power is “dependable – a proven technology with modern reactors capable of producing electricity reliably”.

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

2.31 The historical evidence available does not, however, support this. On the contrary, despite individual examples of the need to respond to specific issues in the various technologies used, international co-operation on common nuclear technologies is a major strength of the industry and one that has contributed to the increased reliability trends achieved over the past 20 years. The proposed practice would build on this by deploying evolutionary designs based on proven standardised international designs with a good reliability record. The probability of such faults would be low, not least because the UK would be able to benefit from many thousands of years of reactor operating experience worldwide.

Conclusion

2.32 This justification application covers evolutionary developments of proven nuclear power technology that will deliver the benefits derived from many years of reactor operating experience.

2.33 The adoption of the proposed practice would provide a significant net 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 it reduces dependence on imported energy and protects UK supplies in the event of fuel supply interruptions overseas. It also reduces electricity price volatility over the longer term. These benefits would be maintained by the construction of new nuclear stations. This benefit is one that was reaffirmed by the Government in the White Paper\textsuperscript{24}:

\textsuperscript{23} A White Paper on Nuclear Power, Cm 7296, January 2008 Page 37
\textsuperscript{24} A White Paper on Nuclear Power, Cm 7296, January 2008, Page 19
“Having reviewed the arguments and evidence put forward, the Government concludes that allowing energy companies the option of investing in new nuclear power stations would help the UK to maintain a diverse mix of electricity generating technologies with the flexibility to respond to future developments that we cannot yet envisage. Allowing energy companies the option of investing would therefore make an important contribution to the security of our energy supplies.”
Q4. Para 2.18 notes that the volume requirements for fuel are low in comparison to the global supply. The applicant is asked to provide further information to support this assertion including, where applicable, references to supporting sources and further quantification.

According to the joint report by OECD's Nuclear Energy Agency and the International Atomic Energy Agency, cited in Chapter 2, the world uranium demand from 440 reactors with an installed capacity of 369 GWe was 67,320 tonnes in 2004. This represents around 182 tonnes/year per GWe.

4,743,000 tonnes of uranium have been identified worldwide with a recovery cost below 130 US$/kgU. The OECD/IAEA estimates that there is a further 10 million tonnes of Undiscovered Resources. Current fuel fabrication capacity worldwide exceeds 10,000 tonnes uranium per year.

These data, in conjunction with that already presented in Chapter 2 of the application and the information on lifetime fuel requirements and the typical amounts of fuel that would be required during refuelling provided in Annex 6, are considered sufficient to demonstrate that the fuel volume requirement of all our example designs is low in comparison to global supply.
Security of Supply and Climate Change Benefits

Chapter 3 - Carbon Reduction

The Government’s White Paper on Nuclear Power concludes that nuclear power is: “low-carbon – helping to minimise damaging climate change.”

Its emissions across the entire life cycle are comparable to those from wind generation.

By generating electricity that would otherwise be produced by fossil-fuelled plant, new nuclear power stations can make a major contribution to meeting the UK’s carbon reduction targets.

The Sustainable Development Commission calculated that the electricity from the current UK nuclear fleet avoids the emission of 29 MtCO₂ per annum if assumed to be displacing gas fired generation. This is equivalent to just under half the annual UK emissions from cars. A series of new reactors providing the same amount of electricity would deliver the same scale of carbon saving benefit.

The economic benefit of carbon avoidance from nuclear power is quantified in chapter 7.

Introduction

3.1 The Prime Minister has described climate change as “quite simply the biggest challenge facing humanity”. Human activity, and particularly greenhouse gas emissions, is changing the world’s climate, with potentially devastating consequences, and we therefore “need to take determined long-term action to reduce carbon emissions in every aspect of the way we live, the way we use energy and the way we produce energy, including the way we generate electricity”.26

3.2 By providing low carbon generation the adoption of the new technology can make a major contribution to reducing carbon emissions from the electricity generating sector. This chapter outlines these carbon reduction benefits, and the following sections consider

- the contribution of the UK’s nuclear power stations to reducing emissions
- total carbon emissions across the nuclear fuel cycle.

Contribution of nuclear power plant to reducing UK carbon emissions

3.3 As the Government recognised in the White Paper nuclear power is a low carbon technology with emissions across the entire life cycle that are comparable to wind generation.27 This is considered in more detail in paragraphs 3.9 to 3.15 below.

3.4 Nuclear power stations contribute to reducing greenhouse gas emissions by generating baseload electricity that would otherwise largely originate from fossil fuels. Unlike nuclear stations fossil-fired plant emit significant volumes of greenhouse gases during operation. The amount of greenhouse gas emissions avoided through the use of

26 A White Paper on Nuclear Power, Cm 7296, January 2008, Page 4
27 A White Paper on Nuclear Power, Cm 7296, January 2008, Page 53
nuclear generation therefore depends on what mixture of fossil fuel generation is displaced and the assessment of the carbon benefits associated with nuclear power requires the making of assumptions in this respect.

3.5 The above chart shows the historic output from the UK’s nuclear power plants and the CO$_2$ emissions avoided. The emissions avoided through this generation are based on the prevailing mix of fossil fuel generation replaced by nuclear in each year.

3.6 On this basis, over the last 50 years, nuclear generation in the UK has avoided the emission of 1600 million tonnes of carbon dioxide (MtCO$_2$).

3.7 The Sustainable Development Commission (SDC) report on “The role of nuclear power in a low carbon economy” calculated that the current nuclear fleet avoids 7.95 Mtc (29MtCO$_2$ per annum) if it is assumed that gas fired generation is being displaced. This is equivalent to 5% of total UK carbon emissions. The figure for carbon avoided would increase to roughly double this figure if the displacement of coal generation were assumed.

3.8 DEFRA figures show that in 2005, 29Mt of carbon dioxide emissions was equivalent to:

- 42% of carbon emissions from UK passenger cars (total passenger car emissions in 2005 were 69MtCO$_2$).
- 100% of carbon emissions from UK heavy goods vehicles (HGVs) (total HGV emissions in 2005 were 29MtCO$_2$).
- 1160% of carbon emissions from UK domestic air travel (Total 2.5 MtCO$_2$)

28 Defra, Estimated emissions of carbon dioxide (CO$_2$) by IPCC source category, 1970-2005
### Total Carbon Emissions across the full Nuclear Life Cycle

**3.9** Nuclear power stations produce very little carbon dioxide emissions directly during electricity generation.

**3.10** 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 emissions associated with energy use during mining; and also with fuel extraction, enrichment, and the manufacture of its fuel. Like coal, energy is also used in management of the waste products from generation.

**3.11** The Parliamentary Office of Science and Technology (POST), which is charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology, has produced a briefing note on the carbon footprint of electricity generation. This compares the lifecycle emissions of different electricity systems currently used in the UK, including fossil-fuelled and low carbon, and uses the life cycle assessment (LCA) method to analyse the cumulative environmental impacts of a process or product through all the stages of its life. Conventional coal combustion systems have the largest footprint of the generating systems analysed, with emissions of greater than around 1 kilogram of carbon dioxide (or its equivalent in global warming terms) per kilowatt-hour of electricity generated (i.e. 1,000g CO$_2$ eq/kWh). Current gas powered electricity generation has a carbon footprint of about half this level.

#### Figure 2. Range of carbon footprints for UK & European ‘low carbon’ technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>UK</th>
<th>Southern Europe</th>
<th>Reservoir storage</th>
<th>Run-of-river</th>
<th>Offshore</th>
<th>Onshore</th>
<th>Range for UK wave energy converters</th>
<th>Sweden (Ringhals)</th>
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29 Postnote 268 October 2006
3.12 Nuclear power generation has a relatively small carbon footprint, which is around 200 times less than coal at about 5g CO\textsubscript{2} eq/kWh. This is a level broadly comparable to that of wind power. As the POST note points out operational emissions from nuclear generation account for less than 1% of the total with most emissions occurring during mining, enrichment and fuel fabrication. Decommissioning accounts for 35% of lifetime CO\textsubscript{2} emissions.

3.13 The graph on the previous page from the POST report shows the range of carbon footprints for UK and European ‘low carbon’ technologies.

3.14 Four studies by the IAEA, International Journal of Risk Assessment and Management, the Central Research Institute of Electric Power Industry, Japan, and Vattenfall are summarised below and demonstrate broadly similar results.

<table>
<thead>
<tr>
<th>Lifecycle Emissions gCO\textsubscript{2}/kWh</th>
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<tr>
<td>Nuclear</td>
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<tr>
<td>IAEA\textsuperscript{30}</td>
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<tr>
<td>International Journal of Risk \ Assessment &amp; Management\textsuperscript{31}</td>
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<tr>
<td>Central Research Institute of Electric Power Industry, Japan\textsuperscript{32}</td>
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<tr>
<td>Vattenfall\textsuperscript{33}</td>
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3.15 It has been suggested that the “carbon footprint” of nuclear would be increased if demand for uranium resulted in the widespread use of lower grade uranium ore. Studies show that there is sufficient high-grade uranium available to fuel a global expansion of new nuclear build. Nonetheless if, for some reason, these supplies were closed off and use of lower grade uranium ore became necessary, POST observed that the footprint of nuclear would only increase to a level comparable with other “low carbon” technologies.\textsuperscript{34}

Net contribution to UK’s overall emissions

3.16 Taken together these results bear out the Government’s position in the January 2008 White Paper\textsuperscript{35} which concluded that:

“After reviewing the arguments and evidence put forward, the Government is satisfied that, throughout their lifecycle, the CO\textsubscript{2} emissions from nuclear power stations are low. On reasonable assumptions, these emissions are about the same as

\textsuperscript{30} IAEA Bulletin 42 (2) 2000
\textsuperscript{31} Joop F. van de Vate, International Journal of Risk Assessment and Management 2002 - Vol. 3, No.1 pp. 59-74
\textsuperscript{32} Data presented by T Fujie, JAPC; Topnux 2006, London; March 2006
\textsuperscript{33} Life-Cycle Assessment Vattenfall’s Electricity In Sweden, Eng 30966_Lca_Divk, 2005
\textsuperscript{34} Postnote 268 October 2006
\textsuperscript{35} A White Paper on Nuclear Power, Cm 7296, January 2008, Page 53
those of wind generated electricity, and are significantly lower than emissions from fossil-fuelled generation. The Government therefore concludes that new nuclear power stations could make a material contribution to tackling climate change.”

3.17 The total additional annual carbon emissions resulting from a series of new nuclear stations providing the same energy as the existing nuclear stations would be less than 0.4MtCO₂, a very small proportion (less than 0.1%) of the UK’s total emissions of 556 MtCO₂. This would be far outweighed by the carbon reductions secured through the displacement of fossil-fuelled generation in the future energy mix.

3.18 Over their 60-year lifetime a series of new nuclear reactors providing the same amount of electricity as the existing ones could save 1.7 billion tonnes of carbon dioxide compared with generating the same energy from gas fired power stations. This is about three times the UK’s current total annual carbon emissions.³⁶

Conclusion

3.19 As the Government’s White Paper recognises, ruling out nuclear power as a low-carbon option would significantly increase the risk of the UK failing to meet its long-term carbon reduction goals.³⁷ By providing large-scale generation with a low carbon footprint, new nuclear plant would deliver a substantial net 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. Replacing existing nuclear stations with new nuclear plant would avoid between 29-58 MtCO₂ a year (8-16 MtC), compared to the emissions if they were replaced by gas and coal plant. This is up to 10% of the UK’s total emissions which were provisionally estimated to be 556 MtCO₂ (152 MtC) in 2006.

3.20 Since most of the UK’s existing nuclear fleet is currently scheduled to retire over the next 15 years, assuming no further life extensions, this contribution would be in jeopardy if no replacement nuclear plants were built. Much of the gap would probably be filled by large fossil-fuelled plant which could lock the UK into a higher carbon electricity-generating infrastructure for several decades. This would make the achievement of carbon reduction targets beyond 2020 more difficult and more expensive. A combination of nuclear and renewables would together make an important contribution to providing clean electricity supplies, with nuclear providing the reliable and continuous baseload capacity required to power an advanced industrial economy.

³⁶ The Sustainable Development Commission (SDC) quote nuclear as 4.4tC/GWh (16.1t CO₂/GWh), 12GW of new capacity at 90% load factor
³⁷ A White Paper on Nuclear Power, Cm 7296, January 2008, Page 53
Any overall radiological health detriment from deploying the new practice would be very small.

New UK nuclear power stations of the class proposed, and their associated processes, would be capable of meeting all applicable dose limits and constraints; indeed the mature regulatory processes governing this practice would lead to radiation doses 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. Doses to the UK population generally will be so low as to be of no possible health significance.

The 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).

Workers employed as a result of the new practice would receive doses comparable with or lower than those received currently by those employed in the nuclear power industry or in other activities involving exposure to radiation – such as airline crews. Ahead of optimisation it is clear that average worker doses will certainly be less than 10mSv per year.

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 practices would take place outside the UK, all have been considered here to ensure completeness.

In its recent 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.”

Introduction

4.1 This chapter outlines the potential radiological health detriment to members of the public and workers from the deployment of the proposed practice.

4.2 The high level approach in this application provides a comprehensive examination of potential radiological health detriment. There is clear evidence from analysis of the evolutionary designs falling within this application and the other processes required to support them that the UK’s regulatory radiological dose limits for workers and the public can be met, and that the required minimum standards for preventing and mitigating potential accidents will be delivered. It is also clear that all sources of public radiation exposure that would stem from this practice could meet the UK’s dose constraint for new facilities. There is also evidence available from existing nuclear power stations and from other related activities that would be required to

38 The Ionising Radiations Regulations 1999 Statutory Instrument No. 3232
support the new practice to illustrate the impact of UK and international safety and environmental regulation on reducing radiological health detriment below these dose limits and constraints.

4.3 Radiological protection follows principles laid down internationally. 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.

4.4 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. Optimisation involves striking a balance between the efforts (time, trouble, 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 authorised, and it is these stages that have the greatest impact in determining what level of radiological health detriment is ultimately permitted. These essential regulatory stages will follow justification if new nuclear power stations are to be licensed and built in the UK. The application of optimisation means that in practice radiological doses from the nuclear industry are very significantly below legal limits.

4.5 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), the first radiological protection principle, justification, can be met quite simply 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 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.

4.6 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 box following, and in addition, attention is drawn to the more detailed analysis contained in Annex 3 to this application.

4.7 Through a Direction, 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

39 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

40 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.
Environment Agency is tasked with specific requirements in relation to the implementation of the Euratom Basic Safety Standards Directive\(^{41}\) within England and Wales. (An equivalent Direction was issued by the Scottish Ministers to the Scottish Environment Protection Agency.) These Directions include the requirement on the agencies 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.”

4.8 The single source constraint specified above of 0.3mSv per year for new (post May 2000) facilities has therefore been adopted in this application as a useful parameter in describing the maximum individual public dose (and health detriment) from new facilities developed in the UK as part of the new practice. Similarly the NII’s Basic Safety Level for the average annual individual dose to people who work with radiation on a licensed site,\(^{42}\) which is set at 10mSv, has been adopted as the maximum average annual dose to workers from the proposed practice.

4.9 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 first Box 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.

4.10 The assessment here focuses on the potential individual radiation doses that could arise from the proposed practice for those aspects of the practice that would routinely take place (e.g. normal operation of the power station).

4.11 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 are available in the Health Protection Agency’s report HPA-RPD-001 cited later in this Chapter.

4.12 In contrast the figures quoted for doses to members of the public are generally those to the critical group – that is those members of the public who could be the most exposed (see second Box).

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\(^{41}\) The Radioactive Substances (Basic Safety Standards) (England & Wales) Direction 2000. Defra (and equivalent Direction from Scottish Ministers to SEPA).

\(^{42}\) Safety Assessment Principles for Nuclear Facilities. HSE 2006 (see para S85 Target 2).
For potential accidents, the approach is to examine the possible additional risks from
the practice taking into account the likelihood of accidents and their potential
radiological consequences. Again for members of the public the figures are for those
who could potentially be most at risk.

This application does not attempt to quantify the collective radiation dose for all
potential sources of exposure associated with the new practice. (The concept of
collective dose is described in the third Box) Collective dose can be a useful
parameter where optimisation of radiological protection is being undertaken,
especially in situations where there are judgements to be made about alternative

<table>
<thead>
<tr>
<th>Dose Limit for:</th>
<th>Workers</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Dose per person</td>
<td>20 mSv per year (mSv/y) averaged over defined periods of five years, and not greater than 50mSv in any one year</td>
<td>1 mSv per year</td>
</tr>
</tbody>
</table>

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) is about to publish its next report. Both 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
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 of collective dose to a defined population
using a methodology recommended by the Health Protection Agency\textsuperscript{43}.

4.15 This approach is in line with the latest Recommendations of ICRP\textsuperscript{44} which provide the
following guidance on the use of collective dose in relation to the derivation of
potential health detriment:

“(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.”

4.16 It should be noted that, in reality, only a very few people, if any, would receive the
level of doses presented here for those potentially most affected because very few
people would share the habits that are used in the assessment of doses to the critical
group.

4.17 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.

4.18 The following sources of potential radiological health detriment to the public and
workers are considered in the sections below:

- Uranium mining and extraction
- Uranium conversion, enrichment and nuclear fuel element manufacture
- Normal power station operation
- Transport of radioactive materials
- Potential transport accidents
- Potential reactor accidents
- Decommissioning
- Potential decommissioning accidents
- Radioactive waste and spent fuel management and disposal

4.19 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 at 4.18 above. The

\textsuperscript{43} Authorisation of Discharges of Radioactive Waste to the Environment – Principles for the Assessment

\textsuperscript{44} Recommendations of the ICRP. ICRP103 December 2007 Executive Summary para (k)
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. The latest position is summarized in a separate Box.

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 in their 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 their 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. Because the dose assessments referenced here pre-date this ICRP advice and so used the term “critical group”, we have retained this term throughout the application for consistency.

Designers of nuclear facilities take extraordinary 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 data base 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 3).

There are 2 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
- 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.

**Collective Effective 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 (60 million), or
- The world population (several billion), or
- The world population over the lifetime of the Earth (an almost infinite number).

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 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

= 60,000,000 x 0.3 millisievert
= 18,000 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 critical group 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.

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 compared to that from natural background radiation.

UK law 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

<table>
<thead>
<tr>
<th>Source</th>
<th>Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All natural sources (average)</strong></td>
<td>2.2</td>
</tr>
<tr>
<td>Made up on average from:</td>
<td></td>
</tr>
<tr>
<td>natural gamma radiation</td>
<td>0.35</td>
</tr>
<tr>
<td>natural cosmic radiation</td>
<td>0.33</td>
</tr>
<tr>
<td>naturally radioactive materials internal to our bodies</td>
<td>0.25</td>
</tr>
<tr>
<td>naturally occurring radioactive radon gas</td>
<td>1.3 (1 to 6)</td>
</tr>
<tr>
<td>Medical exposure to radiation (X-rays etc.)</td>
<td>0.41</td>
</tr>
<tr>
<td>Occupational exposure</td>
<td>0.006</td>
</tr>
<tr>
<td>Fallout from earlier nuclear weapons testing</td>
<td>0.006</td>
</tr>
<tr>
<td>Products containing radioactivity</td>
<td>0.0001</td>
</tr>
<tr>
<td>Discharges from nuclear industry</td>
<td>0.0009</td>
</tr>
</tbody>
</table>

The figures in these tables are taken from ”Ionising Radiation Exposure of the UK Population: 2005 Review” published by the Health Protection Agency HPA-RPD-001

### Examples of additional levels of radiation exposure from specific activities

<table>
<thead>
<tr>
<th>Source</th>
<th>Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduled return airline flight from UK to New York</td>
<td>0.06 per trip</td>
</tr>
<tr>
<td>1 week holiday in Cornwall</td>
<td>0.07 per week</td>
</tr>
<tr>
<td>1 CT scan of the abdomen</td>
<td>10 per scan</td>
</tr>
<tr>
<td>Working for a year as a flight attendant in an airline</td>
<td>2 per year</td>
</tr>
</tbody>
</table>

These figures come from HPA-RPD-001 or from “Living with Radiation” (1998) published by the NRPB (now subsumed into the Health Protection Agency)
same approaches can be used to assess the doses that result from a range of everyday activities involving exposure to radioactivity (see Boxes on pages 31 - 34).

Assessment of Potential Radiological Health Detriment

Uranium Mining and Extraction

4.20 Although uranium was once mined in Cornwall (for its application in ceramics rather than fuel), all mining and milling of uranium or its extraction by in-situ leaching for use in the nuclear industry now take place outside the UK under existing, established practices. New UK nuclear stations would represent only a small additional source of demand for uranium above that arising from the international market. Potential additional radiological detriments from this part of the fuel cycle are therefore only considered briefly in this justification application for completeness, and we do not attempt to describe the subject. Further information can be found at the World Nuclear Association’s website: http://www.world-nuclear.org/info/inf23.html

4.21 The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has derived estimates for the average additional individual radiation dose to members of the public within a 100km radius of a mining site\textsuperscript{45} of about 0.04mSv/yr and comments: “This [additional] dose rate would be imperceptible from variations of the normal background dose rate from natural sources.”

4.22 Doses to those working in the uranium mining industry in recent times have been below the levels set by international bodies. The World Nuclear Association reports:\textsuperscript{46}

"Radiation dose records compiled by mining companies under the scrutiny of regulatory authorities have shown consistently that mining company employees are not exposed to radiation doses in excess of the limits. The maximum dose received is about half of the 20mSv/yr limit and the average is about one tenth of it."

4.23 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.”

4.24 Any additional radiological health detriment arising from uranium mining and extraction in support of the UK’s implementation of the proposed new practice will thus be very small.

Uranium Conversion, Enrichment and Nuclear Fuel Element Manufacture

4.25 Extracted uranium is supplied as uranium oxide (U\textsubscript{3}O\textsubscript{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

\textsuperscript{45} UNSCEAR Annex C: Exposures to the public from man-made sources of radiation (www.unscear.org/docs/reports/annexc.pdf. (2006-01-18)

\textsuperscript{46} World Nuclear Association at www.world-nuclear.org/info/inf24.html
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. However, no material differences arise if the practice is carried out overseas.

4.26 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(s) is required by the site(s) carrying out this work and this Licence would contain conditions relevant to potential radiological detriments from the site’s activities. The site(s) would also require a Radioactive Substances Act (1993) authorisation for any disposal of radioactive substances from the site and these authorisations would place a regulatory requirement for the minimisation of any discharges into the environment through the application of the Best Practicable Means (BPM) or Best Available Techniques (BAT). In addition the UK’s Ionising Radiations Regulations (1999)\(^{47}\) would require controls to be in place to limit the exposure of the public and workforce.

4.27 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, either to workers or to members of the public. The average worker doses at the two sites involved in these processes in the UK was 0.69mSv for conversion and manufacturing (at the Springfields site near Preston) and 0.22mSv for enrichment (at the Capenhurst site near Chester) in 2003, the latest year for which collated data in the public domain is available.\(^{48}\) 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. International experience shows comparable doses with an average of 0.10mSv for enrichment and 1.03mSv manufacturing in the time period 1990-1994.\(^{49}\)

4.28 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 critical groups) are very low. The most recent results quoted in the annual joint report by the Environment Agency (EA), Food Standards Agency (FSA), Scottish Environment Protection Agency (SEPA) and Environment & Heritage Service\(^{50}\) estimated the highest critical group dose during 2006 to be 0.075mSv/\(\text{y}\). These numbers are derived from measurements of extremely small amounts of radioactivity; they overestimate the radiological detriment due purely to conversion and fuel manufacture as not all 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 and from the Chernobyl accident will have been included. Because these are critical group

\(^{47}\) The Ionising Radiations Regulations 1999 Statutory Instrument No. 3232

\(^{48}\) HPA-RPD-001

\(^{49}\) Source UNSCEAR 2000, Annex e

\(^{50}\) Radioactivity in Food and the Environment, 2006. RIFE-12
doses, it is also clear that doses to the majority of people living in the vicinity will be less than these figures.

4.29 The same report assesses the maximum critical group dose to members of the public in the vicinity of the Capenhurst site (which amongst other activities carries out uranium enrichment) as 0.008mSv/y in 2006. Again, this number overestimates the radiological detriment due purely to enrichment as 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 of the critical group will be less.

4.30 The above figures are for UK sites undertaking this type of work. In Germany\textsuperscript{51} the maximum dose to members of the public living near facilities involved with fuel fabrication and related activities is reported as 0.0001mSv/y.

4.31 Fuel enrichment and manufacturing processes required to support new nuclear station(s) would be very similar to those carried out at the sites referred to above, whether carried out in the UK or overseas. 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, with the assessment above providing 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 new nuclear power stations.

4.32 Thus the maximum potential additional radiological health detriment from these activities, if carried out in the UK in support of the implementation of the proposed new practice would be small with a maximum individual annual dose to any member of the public within the 0.3mSv constraint and worker doses well within the dose limit and with average annual doses less than the 10mSv figure adopted for the purposes of this application. The additional average individual dose to the UK population from uranium conversion, enrichment and fuel manufacture has not been directly assessed; 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 earlier in this Chapter), it is clear that the contribution would be insignificant.

**Normal Station Operation – Radiological Impact for the Public**

4.33 Nuclear power stations in the UK are authorised to dispose of radioactive substances under the Radioactive Substances Act 1993 (RSA 93), which is enforced by the EA in England and Wales, and by SEPA in Scotland. These RSA Authorisations permit 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)\textsuperscript{52} to other sites. It is the potential radiological detriment from these activities that is assessed in this Section. As was explained


\textsuperscript{52} What is meant by “low”, “intermediate” and “high” level waste (LLW, ILW and HLW) is explained in Chapter 5.
earlier, a Direction was issued in May 2000 to the environment agencies that sets down values for the dose constraint to be applied to a single site or to a new facility.

4.34 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 5).

4.35 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 its transport and disposal are covered in later sections. Reprocessing is not addressed further here as it is not a process required in support of this application and is a separate practice. This approach is in line with the statement by Government who have reaffirmed that: “Our view 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.”

4.36 In addition to the requirement to remain below discharge limits specified in the Authorisation, the operator is currently required to use the BPM to minimise the activity of radioactive waste produced on the site that will require disposal under Authorisation. This means the operator is required to:

(a) minimise the activity of gaseous and aqueous radioactive waste disposed of by discharge to the environment;
(b) minimise the volume of radioactive waste disposed of by transfer to other premises;
(c) dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public.

4.37 For new nuclear power stations this requirement may be expressed through the requirement to apply BAT to minimise the production and discharge or disposal of waste (see para 4.40). The result from either BPM or BAT is regulatory pressure to maintain actual discharges well within the authorised limits.

4.38 As explained, the UK environment agencies have been directed to assess any future proposal for 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 UK dose constraint applicable to a new single source (such as a new power station) is currently 0.3mSv per year; the constraint for a single site (on which there could be more than one facility with authorisations to discharge radioactivity) is currently 0.5mSv per year. 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.

4.39 Ahead of completing the optimisation stage, which will take place after justification as part of UK licensing and authorisation for a particular design on a particular site, it is not possible to present definitive figures against these constraints. However the

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53 A White Paper on Nuclear Power, Cm 7296, January 2008
Environment Agency has published its conclusions following the completion of stage 2 of the Generic Design Assessment process for each of the 4 reactor designs which are cited in this application as examples of the proposed practice. These reports\textsuperscript{54} include the statement that each of the designs is expected to be capable of meeting the 0.3mSv per year constraint.

4.40 This should not be surprising. Evolutionary reactor technologies covered by this application have been designed to ensure that the requirement to keep radiation doses to the public below these dose constraints and the statutory annual limit of 1mSv/y, can be achieved by a large margin. By definition they build on the experience with other existing designs and incorporate features to ensure levels of safety and environmental protection 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.

4.41 Evidence prepared by the National Radiological Protection Board (NRPB) at the request of the Hinkley Point C Public Inquiry Inspector provides a helpful illustration of the level of radiation dose resulting from a modern water moderated and cooled nuclear reactor station meeting UK standards. The Inspector examined evidence based on potential discharges from a PWR of the Sizewell B design and concluded that the dose to the most exposed member of the public from that station would be unlikely to exceed 0.015mSv per year\textsuperscript{55}. The Inspector also asked NRPB to assess the potential dose to a more typical member of the public living about 5km from the site and established this would be around 0.000076mSv per year. These 2 figures illustrate the significant difference (in this case a factor of 200) between the levels of dose to people inside and outside the defined critical group.

4.42 Further indication of the low level of radiological impact of a modern nuclear water reactor power station can be obtained from the estimates published by the Environment Agency for Sizewell B following a recent review of its authorisation to dispose of radioactivity\textsuperscript{56}. This report estimated that if discharges from the station were to take place at the full authorised limits the critical group dose would be around 0.015mSv per year. It can be seen this aligns well with the estimate derived for the maximum critical group dose at the public inquiry for the proposed Hinkley C station. The EA report referred to above also provides a range of estimates for the collective doses to the UK, European and World population that would result from discharges at the full authorised limits with the calculations truncated at 500 years using the methodology endorsed by the environment agencies and others for this purpose\textsuperscript{57}. It should be noted that, as the reference document itself explains, this methodology provides a conservative figure for the average individual annual dose as it embodies the assumption that the annual discharges continue at the same rate

\textsuperscript{54} Generic design assessment of new nuclear power plant designs: Statement of findings following preliminary assessment of the submission by [each of the 4 vendors]. Environment Agency 2008.

\textsuperscript{55} The Hinkley Point Public Inquiries: A Report by Michael Barnes QC. HMSO 1990.

\textsuperscript{56} Radiological Assessment – British Energy Sizewell B. Authorisation Review 2005/6 NMA/TR/2006/05 March 2006

\textsuperscript{57} Authorisation of Discharges of Radioactive Waste to the Environment – Principles for the Assessment of Prospective Public Doses (Interim Guidance) Dec 2002. EA/SEPA/DoENI/NRPB/FSA
throughout the 500 year period whereas the lifetime of the proposed nuclear power
station would, in fact, be much less than this.

4.43 The results from this report are set out in the Table below which confirms that the
collective doses are small and are delivered at individual dose rates that are minute.
For perspective the individual dose rate derived for an average UK citizen is nearly a
million times smaller than the dose rate they receive from other naturally occurring
sources of radiation. While the discharge authorisations for any nuclear power
station(s) built as part of the proposed new practice have yet to be determined, it is
clear that even if the discharges significantly exceeded those referred to above, the
potential health detriment would remain very small.

<table>
<thead>
<tr>
<th>Population group considered</th>
<th>Estimated collective dose (man-mSv)</th>
<th>Average individual dose (mSv per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>0.136</td>
<td>Less than 0.000003</td>
</tr>
<tr>
<td>Europe</td>
<td>1.17</td>
<td>Less than 0.000002</td>
</tr>
<tr>
<td>World</td>
<td>9.8</td>
<td>Less than 0.000001</td>
</tr>
</tbody>
</table>

4.44 The annual joint report by the EA, FSA, SEPA and Environment & Heritage Service\(^{58}\)
cited earlier also provides estimates of the critical group 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 critical group doses in the range between 0.009mSv/y and 0.55mSv/y. NB the latter figure originates from a nuclear station of the early
(steel pressure vessel) Magnox design where the dose from direct radiation shine
from the external gas coolant ducts was dominant; modern reactors covered by this
application do not share this characteristic.

4.45 The above figures are those reported for UK nuclear stations almost all of which are
located on coastal sites. For perspective the annual report on doses to the public\(^{59}\)
from German nuclear stations (all of which are sited inland) gives a maximum annual
dose figure of less than 0.01mSv/y. UNSCEAR reports 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.

4.46 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 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.”\(^{60}\)

\(^{58}\) Radioactivity in Food and the Environment, 2006. RIFE-12

\(^{59}\) Umweltaktivität und Strahlenbelastung Jahresbericht 2006. Bundesministerium für Umwelt,
Naturenschutz und Reaktorsicherheit (BMU). November 2007

\(^{60}\) The Environment Agency’s Submission to DTI - Pre-licensing assessments of new nuclear power stations
and streamlining the regulatory process.
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”.

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

**Normal Station Operation – Radiological Impact for Workers**

4.48 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 limit of 20 mSv per year for routine exposures received by individuals as a result of their exposure to radiation at work (or, exceptionally, 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 any new nuclear power station(s).

4.49 The 2005 Health Protection Agency report covering UK radiation exposure up to 2003\(^61\) (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, 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. 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\(^62\) show 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.

4.50 UNSCEAR reports that the average annual individual dose to workers in power stations worldwide had fallen to around 2 mSv/y by 1989 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\(^63\) shows the trend in collective radiation exposure per reactor unit for the period from 1990 to 2006. 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. The collective dose per unit of Pressurised Heavy Water Reactor (PHWR) has remained broadly

\(^{61}\) “Ionising Radiation Exposure of the UK Population: 2005 Review” HPA-RPD-001 published by the Health Protection Agency

\(^{62}\) See for example: Nuclear Safety Advisory Committee: Safety Performance Overview of the Major UK Nuclear Licensees Annual update - Jan 2004

constant over the same period but is at a comparable low level. 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. In 2006 the average annual collective radiation dose to workers per reactor unit operated by Electricité de France (EdF) was 0.69manSv which is very similar to the figure derived by WANO for PWRs worldwide.

4.51 In summary, the designs of nuclear power stations that fall within this practice would certainly be capable of meeting national radiation dose limits, and 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 water cooled reactors (i.e., the types of reactor from which the designs within this proposed practice have evolved) shows that the collective radiation dose to workers per reactor unit is broadly similar across the 3 basic types of water reactor technology and is consistent with average annual doses to power station workers at least 10 times lower than the 20mSv limit and therefore clearly well within the 10mSv/yr figure adopted in this application.

Transport of Radioactive Materials - Radiological Impact on Public and Workers

4.52 Radioactive materials transport required as an integral 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)
- The transport of radioactive waste materials – either during normal operation or as part of the station’s decommissioning.

4.53 All these types of transport are already undertaken within the UK and have been justified on a generic basis. Transport linked to new nuclear station(s) would be subject to existing UK regulations that are framed so as to ensure that any possible additional radiological health detriment resulting from transport is extremely low. While the packages used in transport associated with the new 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.

4.54 The UK regulatory regime for transport is managed by the Department for Transport (DfT) and is based on the IAEA Regulations for the Safe Transport of Radioactive Materials. This is made law in the EU by a European Agreement and Regulations, which are then implemented in UK law by means of a statutory instrument. These regulations all follow principles for the minimisation of dose to

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64 Regulations for the Safe Transport of Radioactive Materials. IAEA
65 European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) Class 7 (2007 Editions)
67 The Carriage of Dangerous Goods and Use of Pressure Equipment Regulations 2007, S.I. No. 1573
the public and the workforce. In addition the Health Protection Agency (HPA) regularly reviews the transport of radioactive materials within the UK for the DfT and the Health and Safety Executive (HSE).

4.55 A recent study carried out by the HPA 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.

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

4.57 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. The contribution to public radiological detriment from the new practice would therefore be at most comparable with the very low level reported in the HPA survey.

4.58 The HPA survey 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.’

4.59 The survey 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.

4.60 Drawing on past experience the transport of radioactive materials associated with the new technology would meet these same high standards of protection for workers. This view is the same as that reached by Government following their consultation on new nuclear power stations:

“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

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68 Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail NRPB W66
69 Survey into the Radiological Impact of the Normal Transport of Radioactive Material in the UK by Road and Rail NRPB W66, page iv
70 A White Paper on Nuclear Power, Cm 7296, January 2008
4.61 Thus the maximum potential additional radiological health detriment from the transport of radioactive materials carried out in support of the implementation of the proposed new practice would be small with a maximum individual annual dose to any member of the public less than the 0.02mSv and maximum worker doses far below the dose limit and the 10mSv/y dose adopted for this application.

Potential Transport Accidents – Impact on Public and Workers

4.62 As explained above, the UK Regulatory Regime for transport is based on the IAEA Regulations for the Safe Transport of Radioactive Material 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.”

In addition the HPA as part of its regular review of the transport of radioactive materials within the UK publishes the radiological consequences resulting from any accidents in the UK.

4.63 A report has been prepared covering the entirety of the data available in the national database RAMTED\(^\text{72}\) from 1958 up to and including 2004\(^\text{73}\). 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 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.\(^\text{74}\)

4.64 The transport packages with the greatest hazard potential under accident conditions would be those used to transport irradiated fuel from any new 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 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

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\(^{71}\) IAEA Safety Standard Series: Regulations for the Safe Transport of Radioactive Material

\(^{72}\) Radioactive Material Transport Event Database

\(^{73}\) Review of Events Involving the Transport of Radioactive Materials in the UK, from 1958 to 2004, and their Radiological Consequences. HPA-RPD-014

\(^{74}\) Review of Events Involving the Transport of Radioactive Materials in the UK, from 1958 to 2004, and their Radiological Consequences – Table 8
of evidence to show that the current IAEA Type B test requirements are severe and cover all the situations which can be realistically envisaged in the transport of spent fuel, VHLW and other fuel cycle materials.

4.65 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. It would be necessary for members of the public to be exposed to any released materials over a prolonged period following any accident or for radioactive materials to be inhaled or ingested for a significant radiological health detriment to arise. Emergency arrangements that are required to be in place to respond to transport accidents would ensure these detriments were avoided.

4.67 In summary, radioactive materials transport operations associated with this proposed new 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 quantities of material involved would represent only a small increment to the quantities of radioactive material already transported and for which the safety record is very high. Transport accidents linked to new nuclear power stations would therefore have very little potential to impact on public health.

Potential Reactor Accidents – Radiological Impact for Public and Workers

4.68 It is a fundamental principle of UK nuclear safety regulation that “all reasonably practicable steps must be taken to prevent and mitigate nuclear and radiation accidents”75. During the entire history of civil nuclear power stations licensed in the UK there has never been an accident that has led to a need to take action to protect the public from possible radiation detriments resulting from an accident. Despite this excellent record, 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.

4.69 The UK approach to accident safety is enforced through the Nuclear Installations Inspectorate (NII) as the independent nuclear safety regulator. The NII has published its “Safety Assessment Principles” (SAPs)76 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 here on just one element of the NII approach – the Basic Safety Levels (BSL) and Basic Safety Objectives (BSO) for accidents with these two concepts explained in the paragraphs below. The criteria relating to these levels and objectives provide a convenient basis for assessing the potential scale of radiological detriment from accidents ahead of the completion of the licensing process for a particular design.

4.70 Through one of their Basic Safety Levels and Basic Safety Objectives the NII have 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 NII during the licensing process.

4.71 The NII’s Safety Assessment Principles state:

“It is HSE’s policy that a new facility or activity should at least meet the BSLs”

They go on to explain:

“The BSOs form benchmarks that reflect modern nuclear safety standards and expectations.”

Thus a Basic Safety Level sets the minimum standard likely to be acceptable with the Basic Safety Objective establishing a more challenging safety target that the NII would expect a modern plant to aim for.

4.72 It is therefore reasonable to conclude that a new nuclear power station licensed within the UK would have safety characteristics that are better than the BSL and most probably lie somewhere near the BSO.

4.73 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. 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 NII that the likelihood of accidents occurring across all levels of severity is acceptably low.

4.74 Recognising that severe accidents could affect large numbers of people if they were ever to occur, the NII’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.

Extract from NII Safety Assessment Principles (for accidents) [words in italics added for clarity]
4.75 The justification stage is too early a point for the evolutionary reactor types, which are at the heart of the proposed new practice, to have been through a full licensing assessment against the NII criteria. However, all four designs identified as examples of the proposed practice have evolved from existing designs, with the aim of providing improvements in safety and reliability and Step 2 of the HSE’s Generic Design Assessment does provide an initial assessment indicating that each of the four examples is capable of meeting the regulatory expectations set out in paragraphs 4.73 and 4.74 above. In each of their statements recording the results of Step 2 for the 4 designs77, the NII comments that, while the arguments and evidence relating to the Basic Safety Objectives will be assessed in the next stage, the claims from the 4 vendors on the calculated core damage frequency, in conjunction with other arguments presented, gives them a strong indication that the BSOs will be met.

4.76 The HSE has published an explanatory note on the numerical targets within its Safety Assessment Principles78. 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.

4.77 The Sizewell B power station was licensed against a previous version of the NII Safety Assessment Principles and thus also provides an indication 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 (the figure is quoted in this form as this is how it appears in the Report). 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 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 NII’s Safety Assessment Principles.

4.78 Modern evolutionary designs of new nuclear power stations 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 new practice will be very small, with a maximum risk of death to any member of the public of around 1 x 10^{-5}/y and most probably very

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much less than this. This conclusion is in line with that reached by the Government following their recent consultation.  

Decommissioning – Routine Doses to Workers

4.79 Workers involved in the decommissioning of nuclear power stations, like those at operating stations, are covered by the nuclear site licence conditions and the Ionising Radiation Regulations (1999) requiring employers to put arrangements in place to manage the radiological protection of their workers. These Regulations also limit annual individual worker exposure to no more than 20mSv per year. Evidence from stations currently undergoing decommissioning is that the doses achieved would be much below this legal limit.

4.80 In the UK the Nuclear Decommissioning Authority (NDA) reports on health and safety performance at all civil nuclear power sites currently undergoing decommissioning. The 2006/7 annual report states:

“In radiological protection, the highest average individual dose for employees was less than 1mSv and for contractors was slightly above 1mSv, both well below the 20 mSv legal limit. The maximum individual dose for employees and for contractors was just over 9mSv, significantly less than in 2005/6.”

4.81 Looking more widely, the average annual collective dose per reactor to workers at reactors which are shut down or in some stage of decommissioning are reported to have decreased from around 0.3manSv per year in 1992 to around 0.1manSv in 2006. 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.

4.82 In several respects the decommissioning of modern reactor plant is more straightforward than for the range of plant owned by the NDA. Workers involved in decommissioning plant of the proposed new class or type of practice could expect to receive similar protection to that described above for decommissioning activities at existing UK nuclear sites. As a result their doses would be at a similarly low level with very little potential for any radiological health detriment. On the above evidence it is clear that average annual individual doses to workers will certainly be well below the 10mSv/y figure adopted in this application.

Decommissioning impact of discharges and accidents on Workers and the Public

4.83 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 was capable of being carried out in a way that would meet regulatory requirements. In addition the Energy Bill 2007-8 introduces a new requirement which will require anyone...
proposing to build a new nuclear station in the UK to submit a funded decommissioning programme to the Secretary of State for Business Enterprise and Regulatory Reform for his approval. Under provisions within the Bill, a potential operator of a new station is required to set out details of the steps to be taken in relation to what are described as the “technical matters”. The technical matters are details of the decommissioning of the installation, cleaning up of the site, and waste management and disposal activities undertaken during the generating life of the station.

4.84 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 authorisations granted by either EA or SEPA under the Radioactive Substances Act 1993 (RSA 93). These discharges would be comparable with or lower than those during normal operation resulting in similar or lower levels of dose to those assessed above for normal operation.

4.85 The accident hazard potential during decommissioning would be much lower than during operation as all fuel would by then have been removed from the reactor and with this the potential for nuclear fission heating eliminated. As a result there would not be a source of energy to disperse significant quantities of radioactivity even in the unlikely event that containment barriers were breached in an accident. During decommissioning the inventory of radioactivity would also reduce as material was sent for disposal.

4.86 In considering potential accident scenarios throughout the decommissioning process the NII would apply the same Safety Assessment Principles (SAPs) as used for operating plant – see section 4.71. This would mean that the decommissioning process would need to meet the same targets set out in section 4.76.

4.87 In conclusion therefore, the decommissioning of any new nuclear plants developed as part of the proposed new practice would pose minimal radiological health detriments either through authorised discharges or accidents that could result in radiological health impacts to workers or the public. The maximum additional critical group dose would be less than 0.3mSv/y. The additional average individual dose to the UK population from decommissioning facilities has not been directly assessed; however, given that these activities are ones that 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 as being only around 0.0009mSv/y (see Table earlier in this Chapter), it is clear that the contribution would be insignificant.

Spent Fuel Management and Radioactive Waste Disposal

4.88 The UK’s classification of radioactive wastes is explained in Chapter 5. Most low level waste from reactor operation is currently disposed of routinely in the national facility near Drigg in Cumbria, whereas higher level waste and spent fuel is currently in interim storage pending a final deep geological disposal facility. Radioactive waste from the proposed new practice would be expected to follow the same approaches.
Most low level waste would go to a national facility and, following interim storage on the reactor site or another nuclear licensed site, higher level waste materials and spent fuel from any new nuclear station(s) would use the same disposal routes as adopted for similar materials from existing nuclear installations. Government endorsed this view in its White Paper on Nuclear Power.  

4.89 The Committee on Radioactive Waste Management (CoRWM) determined that its recommendations to Government on managing the UK’s existing waste inventory remained robust under a number of alternative scenarios including the possible future development of a new programme of nuclear stations:

“The results of this investigation published at para. 18 of our Phase 2 report (document 1210) are that solutions for existing and unavoidable future wastes would also be robust in the light of all reasonably foreseeable developments in nuclear energy and waste management practices.”

CoRWM did identify some issues arising from new build that might make the implementation of their recommended solution more difficult but these were not technical in origin. The full statement on new nuclear build issued by CoRWM in March 2006 is provided at Annex 3.

4.90 From the full statement it can be seen that CoRWM considered that “Government decisions on new build should be subject to their own public assessment process, including consideration of waste, because such decisions raise different political and ethical issues….”. Radioactive waste from a new generation of nuclear stations was a subject addressed in the 2007 Government consultation. In the subsequent White Paper the Government stated:

“We have also concluded that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities…“

Government went on to conclude:

“Given the ability of interim stores to hold waste safely and securely, if necessary, for very long periods, we are satisfied that it is reasonable to proceed with allowing energy companies the option of investing in new nuclear power stations in advance of a geological disposal facility being available”.

4.91 Calculations by Nirex (now a part of the NDA) for the higher level waste and spent fuel arising from new nuclear stations indicate that:

“The preliminary assessments of the implications for transport, operational and post-closure safety have not identified any key issues at this stage that would prohibit the handling of additional wastes in the existing management concepts.”

The Nirex report goes on to point 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 waste and any special materials

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84 CoRWM statement on New Nuclear. March 2006
used in new designs, any implications of new build for the final repository design could be minimised. The repository would be designed to incorporate features that ensure that the off-site dose would fall within the design targets. These are set for the public at 2% of the individual annual dose limits stated in the Ionising Radiations Regulations – i.e. doses to the public of less than 0.02mSv per annum. The design target for workers is less than 2mSv per annum (for those whose work involves some exposure) and less than 0.5mSv per annum for others.

4.92 Therefore assuming the same facilities were used, any radiological health impact from interim storage and disposal of new build waste would be an insignificant increment to that which would arise from existing wastes, whether or not new stations are built. Alternatively, if separate disposal facilities were constructed for the interim storage and disposal of higher level waste 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.

4.93 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 new 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 5 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

4.94 The table below summarises the assessments reported above. This shows that all relevant processes required as an integral part of the proposed new practice could be undertaken within relevant UK dose limits and constraints, or within the accident Basic Safety Levels set in assessment guidelines by the NII. Maximum critical group 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 10 lower than this, and certainly below the 10mSv/y figure adopted in this application. These figures provide a boundary envelope for the level of radiological health detriment for the proposed practice.

4.95 The actual levels of radiological health detriment that would follow from the new practice would be determined by optimisation and would be below the boundary levels identified above as a consequence of the application of UK regulations, 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. 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. The largest individual radiological health detriment quantified here for these existing activities is that for the average dose to workers involved in decommissioning facilities. For the public the highest critical group dose identified is that for (if relevant) any UK located fuel manufacturing, conversion or enrichment facility (see below) on the conservative assumption that it is the same as currently assessed for the UK site at Springfields. Even for these, the largest potential contributors, critical group doses to the public are shown to be a factor of at least 4 below the 0.3mSv/y level.

4.96 The Table overleaf summarises both the boundary envelope value for a particular potential source of radiological exposure together with 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 identified in this Table, so it would not be correct to treat these maximum potential radiation doses from the various sources of exposure as additive. The UK's single site dose constraint of 0.5mSv/y would protect the public from excessive exposure as the result of several different facilities being located at the same site.

4.97 The 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 this new practice only just meet the NII'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, it is certain that modern evolutionary designs will 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 from accidents would be around one chance in 25 million per year at most.
As is also illustrated in the Table above, even with quite cautious assumptions, the radiological health impacts for workers as a result of the proposed new practice would also be very 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 NII’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 this practice and the application of the optimisation principle, with worker doses lower than those already accepted by employees such as aircrews or health workers in non-nuclear industries. The Table 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

4.99 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 that are the subject of this application. The chapter has also identified a maximum or bounding level of radiological health detriment for the practice so as to enable the comparison with its benefits to be made with confidence.

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

4.101 For those individual members of the general public who could be most affected, the maximum likely radiological dose from the deployment of the proposed new 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 as opposed to 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. For the 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 well within limits and on average less than 10mSv/y.

4.102 The design of every facility (new or existing) required to implement this proposed new practice will have to meet stringent safety and security requirements. These requirements will ensure that the likelihood of accidents which could lead to significant releases of radioactive materials will be very remote. New evolutionary designs of power station will certainly meet and will almost certainly exceed current standards for accidents. These standards and the approach in applying them to nuclear accident safety are well proven. Throughout the entire UK history of civil nuclear power station operation there has never been any accident requiring emergency action to protect the public. Any additional radiological health detriment arising from accidents will thus be very small.

4.103 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.
### Source of Additional Exposure

<table>
<thead>
<tr>
<th>Public</th>
<th>Additional Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bounding value for the purposes of justification of individual dose to any member of the public from introduction of the new practice</td>
<td>Less than 0.3 mSv per year</td>
</tr>
<tr>
<td>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 new practice (indicates the impact of “optimisation”)</td>
<td>Less than 0.075 mSv per year (uranium conversion and fuel manufacture)</td>
</tr>
<tr>
<td>Dose from one return flight a year to New York</td>
<td>Around 0.06 mSv(^{87}) per year</td>
</tr>
<tr>
<td>Dose to someone who spends 1 week a year in Cornwall (and comes from part of UK with typical natural radiation level)</td>
<td>Around 0.1 mSv(^{88}) per year</td>
</tr>
<tr>
<td>Dose from one CT scan of abdomen per year</td>
<td>Around 10 mSv(^{87}) per year</td>
</tr>
<tr>
<td>Workers</td>
<td>Dose limit = 20 mSv per year</td>
</tr>
<tr>
<td>Bounding value for the average level of dose to any worker in the UK assessed to arise from the proposed practice</td>
<td>Less than 10 mSv per year</td>
</tr>
<tr>
<td>Maximum potential average individual worker dose identified in application</td>
<td>Less than 2 mSv per year (target maximum for exposed workers at future repository)</td>
</tr>
<tr>
<td>Average annual dose to classified workers within UK nuclear industry</td>
<td>Around 0.7 mSv per year</td>
</tr>
<tr>
<td>Average annual dose to member of typical UK air crew</td>
<td>Around 2 mSv per year(^{87})</td>
</tr>
</tbody>
</table>

---

\(^{87}\) Health Protection Agency (formerly NRPB) Booklet “Living with Radiation”

\(^{88}\) “Ionising Radiation Exposure of the UK Population: 2005 Review” HPA-RPD-001 published by the Health Protection Agency
Sources of Exposure

Annual dose limit
"Bounding" value for average dose
Nuclear power station
Decommissioning
Future waste repository
Fuel enrichment
Fuel manufacture
Uranium mining
Spent fuel transport
Average annual background (natural)
Air crews

Scale of Radiological Health Detriments (workers)

Scale of Radiological Health Detriments. Maximum (Critical Group) Doses to the Public (note expanded scale)
Q5. The applicant is asked to provide further information in support of their assertion in Chapter 4 that the radiological health detriment associated with the class or type of practice is small, in particular information on the relevance of doses and on levels of risk.

The approach

The approach to assessing the potential radiological health impact of the proposed new class of practice is set out at the beginning of Chapter 4. As explained in para 4.9, in essence, this is to show that the relevant UK regulatory dose limits or constraints can be met and that this will constrain any radiological health impact to a low level – since that is a major purpose of these regulations. As stated in para 4.5, since the benefits of the proposed class of practice are shown to be very significant, the fact that it can meet these limits and constraints should be enough for it to be justified. Nevertheless, evidence is provided (from existing similar activities) to show that these limits and constraints can not only be met, but be met by a large margin and that this would apply equally to the proposed practice.

The UK has not defined a regulatory limit or constraint for the public in terms of collective dose or average individual dose. Instead, following the recommendations within the advice from ICRP and embodied in European and UK law, these limits and constraints are framed in relation to the people who could be most exposed, in the knowledge that this will provide a very high level of protection to all. This is confirmed in the application through the evidence presented on the level of average individual dose that results from existing practices that meet these UK limits or constraints.

Illustration of this approach for normal operation

This approach is illustrated below for the potential radiological health impact on the public from the operation of a new station falling within the proposed class of practice (see paras 4.33 to 4.47).

It is explained in the application that regulation would require the 0.3mSv/y constraint to be applied; that the use of BPM or BAT would also be required; and that the Government’s view is that this will help ensure that discharges do not exceed those of comparable nuclear stations worldwide. It is also stated that evolutionary reactors (which are those that fall within the proposed new class of practice) have been designed so that levels of safety and environmental protection are at least as good, if not better than, those of existing UK stations.

The UK regulators’ conclusion following Step 2 of their Generic Design Assessment for each of the 4 example designs is cited, which was that for each design they expect the dose to be “well within the source constraint of 0.3mSv/y”. (The reference documents from which this quote is taken are available via BERR’s website http://www.berr.gov.uk/whatwedo/energy/sources/nuclear/whitepaper/actions/gda/page47716.html). This conclusion together with the information provided by each of the vendors in Annex 6 of the application confirms that each of the 4 example designs is capable of meeting the relevant UK regulatory limits and constraints.
Evidence is provided 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 are 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 new class of practice.

In summary, the figures above substantiate the argument that nuclear stations falling within the proposed new class of practice would result in maximum (critical group) doses well within the 0.3mSv/y constraint adopted in the application. They also provide evidence that doses to people outside the critical group 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 class of practice will be very small.

### Level of Risk

The application does not provide a numerical estimate of the risk associated with the above doses; instead it relies on the fact that the levels are far below the dose constraints applied within UK regulation and so will by implication lead to risks of any radiological health detriment that will be sufficiently small in relation to the substantial benefits that are assessed for the purposes of this justification application.

It is however possible to convert these 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% is due to the risk of contracting cancer. The remaining risk arises from hereditary effects. This total health detriment ICRP risk factor has been adopted in the Table on the opposite page 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:

<table>
<thead>
<tr>
<th>Source of Additional Exposure</th>
<th>Additional Dose</th>
<th>Theoretical risk of health detriment per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Scientific</td>
</tr>
<tr>
<td>Public</td>
<td>Dose limit = 1mSv per year</td>
<td>$5.7 \times 10^{-5}$</td>
</tr>
<tr>
<td>Bounding value for the purposes of justification for individual dose to any member of the public from introduction of the new practice</td>
<td>Less than 0.3mSv per year</td>
<td>Around 1.7 $\times 10^{-5}$</td>
</tr>
<tr>
<td>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 new practice (indicates the impact of &quot;optimisation&quot;)</td>
<td>Less than 0.075mSv per year (uranium conversion and fuel manufacture)</td>
<td>Less than 4.3 $\times 10^{-6}$</td>
</tr>
<tr>
<td>Sizewell B critical group dose (at full discharge authorisation limits)</td>
<td>0.015mSv per year</td>
<td>Around 9 $\times 10^{-7}$</td>
</tr>
<tr>
<td>Population dose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per caput dose to UK public from Sizewell B discharges (at full discharge authorisation limits)</td>
<td>Less than 3 $\times 10^{-9}$mSv</td>
<td>Around 1.4$\times 10^{-10}$</td>
</tr>
<tr>
<td>Per caput dose to UK public from all existing UK nuclear industry discharges</td>
<td>Around 0.0009mSv per year</td>
<td>Around 5.1$\times 10^{-8}$</td>
</tr>
<tr>
<td>Some other sources of radiation dose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose from one return flight a year to New York</td>
<td>Around 0.06mSv per year</td>
<td>Around 3.7 $\times 10^{-6}$</td>
</tr>
<tr>
<td>Dose to someone who spends 1 week a year in Cornwall (and comes from part of the UK with typical natural background level)</td>
<td>Around 0.1mSv per year</td>
<td>Around 5.6 $\times 10^{-6}$</td>
</tr>
<tr>
<td>Dose from one CT scan of abdomen per year</td>
<td>Around 10mSv per year</td>
<td>Around 5.7 $\times 10^{-4}$</td>
</tr>
</tbody>
</table>
Similarly the calculation of risk for workers gives the results below:

<table>
<thead>
<tr>
<th>Source of Additional Exposure</th>
<th>Additional Dose</th>
<th>Theoretical risk of health detriment per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
<td>Dose limit = 20mSv per year</td>
<td>Around $1.1 \times 10^{-3}$</td>
</tr>
<tr>
<td>Bounding value for the average level of dose to any worker in the UK assessed to arise from the proposed practice</td>
<td>Less than 10mSv per year</td>
<td>Less than $5.7 \times 10^{-4}$</td>
</tr>
<tr>
<td>Maximum potential average individual worker dose identified in application</td>
<td>Less than 2mSv per year (target maximum for exposed workers at future repository)</td>
<td>Less than $1.1 \times 10^{-4}$</td>
</tr>
<tr>
<td>Average annual dose to classified workers within UK nuclear industry</td>
<td>Around 0.7mSv per year</td>
<td>Around $4.0 \times 10^{-5}$</td>
</tr>
<tr>
<td>Other sources of radiation dose to workers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average annual dose to member of typical air crew</td>
<td>Around 2mSv per year</td>
<td>Around $1.1 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

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 3, 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 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 (see para 4.15 of the application).

These risks can be set in context with reference to the information provided by the UK Health Protection Agency (HPA) on their website:

- According to the HPA, 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)

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

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Natural background radiation accounts for the vast majority of the radiation exposure contributing 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.

HPA 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.

Q6. **Para 4.64** refers to a “large body of evidence” supporting the assertion that IAEA’s Type B test requirements cover all situations that can be realistically envisaged in the transport of spent fuel. The applicant is asked to provide a representative sample of the supporting evidence, including references.

Here we refer to the experimental evidence from crash testing of IAEA packages in a range of situations: e.g. the CEGB programme of testing culminating in the 1984 demonstration of a train impacting an irradiated fuel transport flask; the tests in the US conducted at Sandia National Laboratory with various “missiles” impacting on fuel flasks; etc.

Examples of references where these types of tests are described can be found at:

http://www.patram.org/PATRAM_FP_07.pdf

This provides a link to the programme for the 2007 International Symposium on Packaging and Transportation of Radioactive Materials (PATRAM) which was the most recent held. It includes abstracts from a large number of technical papers on package safety and testing including (at page 49) a paper “Smash Hit! Magnox Lesson for Today” by Clive N. Young et al. describing the conclusions reached in the CEGB’s irradiated fuel transport flask testing programme.


This links to a presentation given in 2004 on behalf of the US Nuclear Regulatory Commission (NRC) on the results of their periodic assessment of the effectiveness of Type B standards in addressing “real world” transport accidents.

http://www.ingentaconnect.com/content/maney/ptssrm/2005/00000016/00000004/art00005

This provides a link to the paper “The relevance of IAEA tests to severe accidents in nuclear fuel cycle transport” Author: Wilkinson, W.L.


This provides a link to videos of a series of tests conducted by Sandia National Labs in the US to visually demonstrate the severity of the IAEA Type B Hypothetical Accident Condition impact test.


This is a link to a report entitled “Accident Conditions versus Regulatory Tests for NRC-Approved UF6 Packages” which assesses Type B package safety.
Q7. The applicant is asked to provide further information and quantification on dose levels experienced by workers involved specifically in the decommissioning of reactors.

Para 4.81 provides figures for the 3-fold reduction in collective dose to workers worldwide at cold shutdown or decommissioning reactors between 1992 till 2006. We do not have individual worker dose rates.
Chapter 5 - Radioactive Waste and Decommissioning

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

The impact such a programme would have on the size of repository would be determined principally by the quantity of additional spent fuel requiring disposal. Using reasonable assumptions, including that any spent fuel is co-located with intermediate level waste, a programme of 10 GW(e) of new generation could require an increase in the below ground “footprint” of a geological disposal facility of the order of 50%. The impact on the repository of the disposal of additional intermediate level radioactive waste from a new build programme is encompassed within this figure. The detriment arising from this scale of increase in below ground repository excavation (over that already required to dispose of existing waste) would be small.

The types of waste created by the proposed practice are similar to those already existing and for which management, interim storage, and disposal solutions exist. While not every aspect of radioactive waste disposal has yet been demonstrated, those that have not are in the course of being implemented under Government-led processes. From outside the UK, there is also considerable and growing international experience to build on. Radioactive waste and spent fuel from new nuclear station(s) could be stored safely for long periods until a disposal facility became available.

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

The Government has made it clear that the nuclear liabilities costs – both of radioactive waste and spent fuel management, and for the decommissioning of any new nuclear power stations – would have to be met by the owners of these facilities and not by the taxpayer. The industry is prepared to accept this and will conform to any reasonable arrangements established to ensure this objective is achieved.

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

Introduction

5.1 This Chapter addresses the impacts of radioactive waste management and decommissioning in relation to justification of the proposed new practice. It does not examine the potential radiological health detriments as these were included in the previous Chapter. The issues 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(s) and resulting from its eventual decommissioning will be managed responsibly and without significant detriment
The extent to which the nuclear liabilities costs associated with the above will be met without placing a significant and detrimental burden on the UK taxpayer.

5.2 The Chapter outlines the main types of radioactive waste that would require management and ultimately disposal during the plant’s operational life. 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 from the UK or elsewhere of similar waste management solutions.

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

5.4 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 in comparison to the scale of the benefits identified within earlier Chapters.

Radioactive Waste and its Management (during operational life)

5.5 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 is that the quantities involved are also quite different in scale.

5.6 In conventional fossil fired stations (coal, oil and gas) all the fuel is consumed in the process and the gaseous combustion products are released via the chimney into the environment, with (in the case of coal) the solid waste residues (mainly ash) that cannot be utilised elsewhere being disposed of to landfill. The quantities of these 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 identical in weight, size and appearance to when it was loaded. Virtually all the waste products generated by the nuclear reaction remain inside the sealed fuel pins and are never released into the environment; and 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.

5.7 The radioactive materials that require to be managed during the operating lifetime of nuclear power stations therefore comprise:

1. Spent nuclear fuel, which is where the overwhelming majority of all the radioactivity created by operating the power station will remain contained;

2. Much smaller quantities of the radioactive material generated within the fuel that have passed into the reactor either due to their ability to diffuse through the can surrounding the fuel, or due to occasional but very infrequent 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 separation plant;

4. Materials (e.g. tools, gloves, or filters) that become contaminated with radioactive material originating from either 2 or 3 above.

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

5.8 Modern nuclear power stations of the 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 solid radioactive waste that must be managed by the station until its ultimate disposal. These systems are also the source of the very small quantities of radioactive material that are authorised for controlled discharge into the environment following careful measurement and characterisation.

5.9 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)
- High Level Waste (HLW)

5.10 Spent nuclear fuel is not 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.

5.11 The quantities and types of LLW, ILW and spent fuel produced during operation of the power stations that fall within the proposed practice would depend on individual station design, operational practices and the application of regulation. The annexes containing data for the four example designs give an indication of these quantities.

5.12 There is a balance to be struck in the degree of clean-up carried out on the power station. Liquid and gaseous systems can be subjected to greater and greater levels of clean-up so as to reduce further and further the amount of radioactivity that is discharged. However, this will be at the expense of generating a greater and greater volume of solid radioactive materials that will then require storage on the station. Striking this balance at the optimum point will ultimately be an outcome of applying the UK licensing and authorisation regulatory processes, which are briefly described in paragraphs 5.14 to 5.17.
A large body of nuclear safety, environmental protection, and transport regulation is relevant to radioactive waste and spent fuel. However of particular significance in relation to the scale of detriments considered here are the requirements stemming from the Radioactive Substances Act, the Environment Act and the Nuclear Installations Act. These are summarised below.

**Radioactive Substances Act (RSA) and Environment Act**

5.14 The Radioactive Substances Act provides the basis for regulation of the disposal of radioactive substances. It leads to the requirement for authorisations to cover all disposals including any discharges of radioactivity into the environment.

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### Classification of radioactive wastes

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

- **High level waste (HLW)**
  These are wastes with radioactivity requiring special storage or disposal facilities to accommodate its heat generating qualities (thermal power exceeding about 2kW per cubic metre). In practice they would mainly consist of spent fuel or reprocessing wastes. The 2000 cubic metres of HLW in the UK account for 95% of the total radioactivity.

- **Intermediate level waste (ILW)**
  These are wastes with radioactivity levels exceeding those of low level wastes, but not requiring storage or disposal facilities to accommodate heat generation (thermal power below about 2kW per cubic metre). These 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 discharge or reuse.

- **Low level waste (LLW)**
  These wastes contain radioactive materials that make them unacceptable for disposal with ordinary refuse, but do not exceed 4GBq/te\(^+\) of alpha or 12GBq/te\(^+\) beta/gamma activity. They could cover a variety of materials, including for example redundant equipment, paper towels, clothing, air filters and even smoke alarms.

- **Very low level waste (VLLW)**
  Wastes that can be disposed of with ordinary refuse - with each 0.1m\(^3\) of material containing less than 400kBq of beta/gamma activity. This generally comprises articles similar to LLW but containing significantly less radioactivity.

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 under the Radioactive Substances Act.

\(^+\) This unit is Giga-becquerels per tonne where “Giga” means 1000 million

\(^*\) The unit of radioactivity called the “Becquerel” is explained later in this Chapter
Authorisations are granted by the Environment Agency (in England and Wales) and by the Scottish Environment Protection Agency (in Scotland). Key features within these authorisations are limits on quantities of radioactivity (with separate limits for various types) and a requirement to use “best practicable means” to limit the amounts of radioactivity released into the environment.

5.15 Another requirement (originating from statutory guidance issued in 2000 to the environment agencies under a provision of the Environment Act) is that the “best practicable environmental option” (BPEO) be adopted among those available for the management of waste products. The BPEO is the option that, for a given set of objectives, provides the most benefit or least damage to the environment as a whole at acceptable cost in both the long and the short term.

Nuclear Installations Act

5.16 The Nuclear Installations Act’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 the site at any time and for recording the waste so accumulated.

Optimisation

5.17 It should be clear from the 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 new nuclear stations.

Authorised Discharges of Radioactive Material

5.18 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 NII, it is not possible to provide specific figures for the level of discharge that will be authorised. However, it is possible to give an indication of the level from the 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:

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Discharge Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritium</td>
<td>80 TBq/y</td>
</tr>
<tr>
<td>Caesium-137</td>
<td>20 GBq/y</td>
</tr>
<tr>
<td>Other activity</td>
<td>130 GBq/y</td>
</tr>
</tbody>
</table>
5.19 The units in these Tables are mega-, giga-, and terabecquerel per year (MBq/y, GBq/y and TBq/y) and are explained in the Box below.

5.20 The very small potential for any radiological health detriments linked to these levels of discharge are described in the previous Chapter and can be found in the Environment Agency’s own reference89. This is a consequence of the tiny quantities of radioactivity involved and the amount of dilution that takes place following their discharge.

5.21 To illustrate this point it may be useful to express the authorisation set out above in units that are more familiar. The authorisation permits a maximum of only around 10 milligrams 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 gaseous radioactivity that may be discharged each year is less than 1 gram 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 station ensures that virtually all the radioactive waste products generated from the utilisation of uranium within it are contained safely and are not released.

5.22 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 4). The widely accepted view has been taken that if people are protected then so also will be other species in the environment.

5.23 More recent legislation, the Habitats Directive (Commission of the European Communities, 1992), requires a 3-stage approach to the assessment of the impact of radioactive discharges on sensitive habitats. The environment agencies have completed initial assessments and further research is being undertaken (Commission of the European Communities, 2004). The initial assessments have shown that, for important habitats in England and Wales such as Special Areas of Conservation (SAC) and Special Protection Areas (SPA) there are no adverse effects on the integrity of the sites from authorised discharges of radioactive substances.

5.24 In addition, an independent examination of a number of ecological risk assessments around many sites with enhanced levels of radiation and radioactivity published by the World Nuclear Association in 2007 has shown this approach to be correct. The study examined sites with high levels of radioactivity of natural origin (e.g. from mining, fertilizer production and the oil and gas industry), from radioactive waste

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<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Discharge Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritium</td>
<td>3 TBq/y</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>0.5 TBq/y</td>
</tr>
<tr>
<td>Noble gases</td>
<td>30 TBq/y</td>
</tr>
<tr>
<td>Iodine-131</td>
<td>0.5 GBq/y</td>
</tr>
<tr>
<td>Beta particulate</td>
<td>100 MBq/y</td>
</tr>
</tbody>
</table>

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."^90

5.25 On this basis it is concluded that there will be no other significant detriments arising from authorised discharges of radioactivity associated with the proposed practice.

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**Units of radioactivity – the Becquerel**

The international (SI) unit used to measure quantities of radioactivity is called the “Becquerel” (named after one of the scientists involved in some of the early research). This unit is extremely small:

1 Becquerel (Bq) is 1 atomic nucleus disintegrating per second

Since there are enormous numbers of atomic nuclei in even tiny quantities of matter this unit describes radioactivity in an extremely sensitive way.

For example, just 1 teaspoon of water (5 millilitres) contains around half a million, million, million, million (5 x 10^{23}) atomic nuclei and if just 1 of these nuclei were to disintegrate each second the amount of radioactivity in it would be 1 Bq.

Because the unit is so small it is necessary to use the prefix Kilo-, Mega-, Giga-, or Tera-becquerels to describe the quantity of radioactivity in materials where Kilo = 1 thousand; Mega = 1 million; Giga = 1 thousand million; and Tera = 1 million million.

Examples of some levels of naturally occurring radioactivity (potassium-40) as measured in becquerels:

An average adult body contains around 5 thousand becquerels (5 KBq) of potassium-40.

The first metre of soil below a football pitch contains around 2 million becquerels (2 MBq) of potassium-40.

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Solid Radioactive Waste Management

Very Low Level Radioactive Waste

5.26 Although non-licensed sites (such as hospitals and laboratories) use this category and dispose of this type of waste under authorisations to normal waste sites, waste falling within this classification from power station sites is currently treated in the same way as Low Level Waste (see below).

Low Level Radioactive Waste

5.27 Most of the waste of this type that arises from the operation of existing UK nuclear power stations is routinely managed and disposed of to the national low level repository near Drigg in Cumbria. The quantity arising during a year’s operation is small – typically a few normal lorry loads for currently operating designs. LLW arising from the proposed new practice would be managed within UK regulatory requirements and in a consistent manner to current material. While the quantities would be dependent on 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. The volumes involved are relatively small and CoRWM concluded these types of waste could either be disposed of in a deep geological repository with higher level (ILW) wastes or in other facilities (if such facilities were developed following the Government’s review of LLW). Any such similar waste streams from new nuclear stations could follow the same arrangements.

5.28 Under Government policy, the NDA is now 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.

5.29 As a result there should be no significant detriment from this LLW material. Its transport offsite would also have an insignificant impact against the background 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.

Intermediate Level Waste

5.30 Waste of this type from the UK’s existing nuclear power stations is stored on site pending its ultimate disposal when a national repository becomes available. Station designs covered by this application would incorporate specially engineered facilities capable of safely managing the ILW produced during their operations.

5.31 The quantity of these wastes generated during normal operation of nuclear stations falling within the proposed new practice would be quite small and it would be entirely feasible to store the lifetime arisings of ILW safely on the site of the station; indeed, as explained above, this is current UK practice for all operating nuclear power stations. Alternatively this waste could be transported offsite to a suitably licensed and authorised facility for interim storage ahead of ultimate disposal. ILW could be

91 Managing our radioactive waste safely. CoRWM 700 July 2006
stored “raw” or “conditioned” – that is put into a different form more suitable for longer-term storage or disposal. Once again it would be possible for this conditioning to be undertaken at the power station itself or at another offsite facility. ILW would also be “packaged” so as to limit the radiation exposure to workers during handling and to ensure no waste was released during transport, interim storage or in the disposal facility.

5.32 As explained earlier, decisions between various treatment options would involve identifying the best practicable environmental option (BPEO) and applying the principle of optimisation (implemented through the UK licensing and authorisation processes) 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 para 5.12 above)
- The options selected to “condition” this waste
- 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).

5.33 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 as part of the 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%\textsuperscript{92}. These figures include both the operational waste arising and the waste associated with eventual decommissioning. The figures are based on reasonable assumptions but could vary according to the size of any new reactor programme and 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 to the quantity that already is 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\textsuperscript{93}, 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 covered later in this Chapter.

\textsuperscript{92} The Gate Process: Preliminary analysis of radioactive waste implications associated with new build reactors. Nirex (now part of NDA) February 2007

\textsuperscript{93} Nirex define co-location as being a shared repository facility for both spent fuel/HLW and ILW in different excavations within the same rock mass but using a common access.
5.34 The UK currently has no facility for the disposal of ILW. However, since 2001 the UK Government has been running a very thorough consultation process on the disposal of higher activity wastes under the title “Managing Radioactive Waste Safely (MRWS”).

5.35 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\(^94\) 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. This approach has already been implemented in some other countries (see Annex 2).

5.36 Although CoRWM’s remit was to consider the management and disposal of legacy radioactive wastes, (i.e. those already existing or committed), it did issue statements on the applicability of its findings to wastes from any new nuclear reactor programme. A copy of one of these statements is provided at Annex 2 and this makes it clear that the Committee considered its recommendations remained robust against a new reactor programme. It must also be stated that the Committee advised that for political and ethical reasons Government should consult separately on new nuclear build and its implications for radioactive waste management and disposal.

5.37 The UK Government issued a further consultation\(^95\) as part of its MRWS programme in June 2007 seeking views on the implementation of the CoRWM recommendations, including the selection of a potential geological repository site. This stated:

“The UK Government believes that it would be technically possible to dispose of waste from new build through geological disposal.”

5.38 The White Paper on Nuclear Power\(^96\), published in January 2008 further stated that “the Government believes that it is technically possible to dispose of new higher activity 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”.

It went on to conclude

“Whilst the Government accepts that creating new waste raises ethical issues, we also agree with those who believe that nuclear power provides significant benefits for future generations as a low-carbon form of electricity generation and one that secures our energy supplies. On balance, we believe that not taking action now on climate change, by allowing energy companies to invest in new nuclear power stations, raises more significant inter-generational challenges in terms of climate change related CO\(_2\) and on-going security of energy supplies, than does the management of radioactive waste. Thus the Government concludes that the balance

\(^{94}\) CoRWM Final Report. CoRWM 700 July 2006


\(^{96}\) A White Paper on Nuclear Power, Cm 7296, January 2008
of ethical considerations does not warrant ruling out the option of new nuclear power stations.”

5.39 Given the above statements together with the evidence from CoRWM, which was itself informed by actual experience worldwide as to its feasibility, there is no reason why the limited quantities of ILW that would derive from new power stations of the type falling under the proposed practice could not be safely stored and ultimately disposed of in a way that avoided any significant detriment to the UK.

Spent Fuel Management

5.40 Spent fuel management options are explained in Annex 1 and the radiological safety of its transport is covered in Chapter 4. Just as for ILW there would be no significant detriments not already covered that would arise from its storage on site (or at some other offsite facility). The number of container movements required to transport spent fuel to an interim store or disposal facility would be modest – typically around 100 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.

5.41 Again, as described above for ILW, the UK currently has no facility for the ultimate disposal of spent fuel (or for the HLW that would be generated if the spent fuel from any new reactors were to be reprocessed). However, CoRWM’s recommendations covered these waste types and, as explained above, Government is now in the process of taking these recommendations forward.

5.42 The volume of spent fuel created by any new nuclear station(s) would depend on the number of stations, the design(s) chosen 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.

5.43 As explained earlier, there is no technical reason why spent fuel (or the HLW from its reprocessing) 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 reactors would not need to be disposed of immediately but could be stored safely on site (or elsewhere) until the station was decommissioned and a suitable repository was available. If this was the approach, the earliest that spent fuel disposal might begin would be around 2090 on current assumptions for the timing of new UK stations (assuming a 60 year station lifetime and a minimum 10 year delay before disposal). This timing is compatible with current assumptions on the timing for disposal of similar arisings from existing facilities. Spent fuel could be stored safely for longer periods if a repository were not available.
5.44 The potential impact of the additional spent fuel (as well as all the ILW from both operation and decommissioning) arising from a new nuclear reactor programme on the requirements for a repository was examined in a report prepared by Nirex to support the Government’s 2007 consultation on the future of nuclear power. This work estimated that a 10GW(e) programme could lead to an increase in the size of the final repository of between around 50% and around 90% depending on assumptions made. The higher value was derived on the assumption that spent fuel (and HLW) was disposed of in a separate repository to ILW, whereas the lower figure applied to the impact on the size of a co-located facility – i.e. the approach advocated by Government. The assessment was preliminary and should not be taken as definitive ahead of a more detailed assessment of a particular programme size and choice of reactor design, as well as the type of packaging used in spent fuel disposal. The work pointed to how the figure could be somewhat lower for some design assumptions involving higher fuel burn-up but it is also possible that with different assumptions a somewhat larger increase in below ground repository footprint could be derived. We therefore adopt the 50% figure as a reasonable central estimate of impact for the purposes of this justification application with an upper bound of less than 70% (for a 10GW(e) programme). While this potential scale of impact on the below ground footprint of a future UK repository is not insignificant, the level of detriment that would arise from this additional extent of excavation deep underground within a co-located repository should be manageable. It should also be noted that, as the Nirex report itself points out, more detailed work carried out for particular reactor designs could permit the impact of spent fuel disposal on a future repository to be minimised and so reduced below these preliminary estimates. As Annex 6 shows, all 4 example reactor designs are broadly comparable in terms of their potential impact on repository footprint.

5.45 On the above basis the detriment associated with managing and ultimately disposing of additional spent fuel from the proposed new practice should not lead to a significant detriment.

Decommissioning and its associated waste management

5.46 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 would not give rise to significant detriments.

The Regulatory Framework for Decommissioning

5.47 Before a new nuclear station may be constructed in the UK its decommissioning must have been considered under one of the standard conditions laid down within the Site Licence:


98 Nirex define co-location as being a shared repository facility for both spent fuel/HLW and ILW in different excavations within the same rock mass but using a common access.
“The licensee shall make and implement adequate arrangements for the
decommissioning of any plant or process which may affect safety.”
Excerpt from Licence Condition 35

5.48 In addition decommissioning is subject to the other regulatory controls as apply
during normal operation – including other site licence requirements, radiation
protection provisions and authorisations. In addition, under the Nuclear Reactors
(Environmental Impact Assessment for Decommissioning) Regulations 1999, licensees
are required to produce an environmental assessment to consider the impacts and
mitigate them where practicable.

5.49 The NII will 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.”

5.50 The European Commission will also need to be satisfied that other countries will not
be adversely affected by the decommissioning, as prescribed by Article 37 of the
Euratom Treaty. Further, the Government is in the process of reforming the
regulatory regime relating to the decommissioning of nuclear facilities and the
management of nuclear waste, to the extent that such regime would apply to new
nuclear power. This is addressed in paragraph 5.62 below.

The Decommissioning Process

5.51 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
- to release land for other use as appropriate.

5.52 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
- All relevant environmental and decommissioning legislation, and regulations in the
  management of decommissioning will be adhered to.

99 Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999
100 TRAITES 1957/EURATOM, volume 1.
The decommissioning process can be broken down into the following stages:

- Defuelling
- Post-Operations Clean Out
- Dismantling
- Site clearance
- De-licensing

These stages are described further in Annex 2.

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.

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 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 in the UK modern reactors of the type falling within the proposed new practice would follow the prompt decommissioning option. All four example designs are compatible with either the deferred or prompt approach to decommissioning.

Waste and Discharges from Decommissioning

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
- 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.

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.

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

5.59 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 uncontaminated 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.

5.60 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. However experience gained from decommissioning the UK’s first generation nuclear stations has shown that there are no significant adverse traffic impacts from decommissioning. There is no reason why this will not apply equally to new plants.

5.61 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 found that these were both negative and positive impacts, and there were no significant detriments.\(^\text{101}\) 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 2).

Funding the Waste and Decommissioning Liabilities

5.62 The UK Government is in the process of introducing legislative provisions setting out a funding mechanism that requires operators of new nuclear power stations to make sufficient and secure financial provision to cover their full costs of decommissioning and their full share of costs of waste management\(^\text{102}\). Because the sums of money involved are potentially very large, it is important to address the potential detriment that could arise should the amount of money set aside by the operator ultimately prove to be inadequate or unavailable so that the Government, as the funding body of last resort, is forced to assume the liabilities.

5.63 In February and March 2008 the Government introduced legislation into Parliament, and initiated a public consultation on the Guidance to be issued under that legislation on the detailed mechanism for liabilities funding\(^\text{103}\); a mechanism which is designed to minimise the risk that public sector funds will ultimately be required to support the decommissioning and waste management of new nuclear power stations.

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101 Bradwell, Environmental Statement in support of Application as required by Statutory Instrument 1999 No. 2892: Nuclear Reactors (Environmental Impact Assessment Decommissioning) Regulations 1999

102 A White Paper on Nuclear Power, Cm. 7296, January 2008

103 The Energy Bill 2008: Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations. BERR
stations. The framework for these arrangements was set out broadly in the 2007 Managing Radioactive Waste Safely consultation and in more detail in the 2008 Government White Paper on nuclear power.

5.64 Government envisages that the prospective operator of a new nuclear power station will submit to an independent body, the Nuclear Liabilities Financing Assurance Board, detailed arrangements for the funding of waste and decommissioning liabilities. These arrangements will be in two parts. A detailed decommissioning plan will establish the costs of final decommissioning and therefore the target amount that will need to be accumulated; and a legal agreement will set out the structure of the funding arrangements and the arrangements for its governance.

5.65 Government has indicated that it will be for the prospective operator to propose suitable arrangements, but has made it clear that these will have to meet a number of criteria. One fundamental requirement will be that the operator will have to set aside money to meet the liabilities and these contributions will accumulate in a fund that will be held by a body that is independent of both the operator and Government.

5.66 For the decommissioning funding there are three potential 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. 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.

5.67 To mitigate these risks, there are expected to be transparent review and reporting arrangements as well as provisions to protect from insolvency. The operator will be required to periodically recalculate the target amount through updating and revising the detailed decommissioning plans. In parallel, an assessment of the fund’s investment performance will be carried out and a view taken on likely future returns. An increase in the target amount or a shortfall in fund performance may trigger a recalculation of the annual contributions.

5.68 The situation for the funding of waste management and disposal (including spent fuel) is expected to be different. Decommissioning is essentially an engineering exercise and the detailed project costs and risks can be managed by the operator; however, waste and spent fuel disposal costs are outside the control of the operator and subject to a degree of uncertainty. To address this Government is proposing, for intermediate level waste and spent fuel, to provide a fixed waste disposal cost and schedule to the operator to provide certainty against which funds can be accumulated. This price will contain a risk premium to provide protection to the taxpayer. Potential future operators of new nuclear stations have stated that they are prepared to work within these arrangements and have pointed out that, provided the funding contributions are spread over the lifetime of any station, the costs arising from them should represent only a small proportion of the total cost of generation.

5.69 In summary therefore, the arrangements being developed for ensuring that decommissioning and waste liabilities are fully funded by the operator will ensure that any detriment to the public purse is minimised as far as practicable. For Government to be called on to make a contribution to these liabilities, it would be necessary for:
The funds established by the operator to be insufficient (despite all the measures proposed in the Bill to prevent this), and

- The security provided by the operator to have failed, and

- All the operator’s “related entities” to themselves have become insolvent.

Conclusion

5.70 This Chapter has reviewed the possible non-health related detriments associated with the proposed new practice arising from radioactive waste and decommissioning. It is concluded that demonstrable or feasible solutions exist for safely managing the relatively small 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 station(s) could fall to the public purse will also be reduced so far as practicable by arrangements currently under development within Government.

5.71 This conclusion is in line with the Government’s own statement on these issues following widespread consultation with the public:104

“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. 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.”

104 A White Paper on Nuclear Power, Cm 7296, January 2008
Para 5.42 notes that the amount of spent fuel created by a station would depend on design and burn-up rate. The applicant is asked to provide further information on the relationship between fuel usage, burn up rate and waste produced for the practice and the four example designs.

In the application we have sought to provide information on the scale of detriment arising from fuel usage, and from spent fuel and radioactive waste management and disposal. The application explains why the volume of these materials required by a particular design falling within the proposed new class of practice is not the only factor on which this detriment depends. Indeed it shows that despite detailed differences the 4 example designs actually have broadly similar levels of detriment per unit of electricity generated in terms of fuel usage and radioactive waste management and disposal. The arguments and evidence within the application are further explained below in the answer to the above question.

Fuel usage

It is important to be clear about the quantities of relevance to justification when measuring fuel usage for a power reactor.

Fuel usage can be measured in a variety of ways. For example:

- The mass or volume of uranium that has to be mined to produce a given amount of electricity; or
- The mass or volume of enriched and fabricated fuel that is required to be delivered to the power station.

In terms of justification we believe that it is the former that is more important in determining the aspects of benefit/detriment for the practice associated with fuel usage. The amount of uranium mined is relevant to the overall sustainability of fuel requirement, the quantity of material transported for conversion, enrichment etc. Spent fuel management and disposal is considered separately below.

The heat energy required to produce a given amount of electricity in a thermal power station is simply dependent on its thermal efficiency, and the reactor types which are the subject of this application can be considered to have broadly similar efficiencies (see below). Indeed in some cases siting could well have as much impact on thermal efficiency as specific reactor design.

<table>
<thead>
<tr>
<th>Example Reactor Type</th>
<th>Thermal Power (MWth)</th>
<th>Typical Electricity Output (MWe)</th>
<th>Typical Thermal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACR-1000</td>
<td>3180</td>
<td>1165</td>
<td>36</td>
</tr>
<tr>
<td>AP1000</td>
<td>3415</td>
<td>1100</td>
<td>32</td>
</tr>
<tr>
<td>EPR</td>
<td>4500</td>
<td>1600</td>
<td>36</td>
</tr>
<tr>
<td>ESBWR</td>
<td>4500</td>
<td>1560</td>
<td>35</td>
</tr>
</tbody>
</table>

The broadly comparable thermal efficiencies of these types of nuclear power stations means that, irrespective of their detailed design, approximately the same number of nuclear fissions has to take place per second to sustain a given electricity output level. These fissions take place within the U-235 nuclei in the fuel (or within fissile nuclei that are themselves created by neutrons released through U-235 fissions).
This in turn means that for a given electricity contribution the quantity of U-235 nuclei consumed will be about the same whichever reactor design is chosen. U-235 nuclei occur in nature as 0.7% of all uranium. Thus the amount of U-235 nuclei required to fuel a reactor translates directly to the amount of uranium that must be mined, converted, etc.

All the reactors falling within this application use uranium enriched to a low level in U-235, although the precise enrichment chosen may vary. A design with a higher enrichment (i.e. a higher concentration of U-235 per tonne of fuel) may appear to require less fuel to be loaded for a given electrical output and will be capable of sustaining a higher fuel “burn-up” (i.e. a greater quantity of energy can be released per tonne of loaded fuel before that fuel must be replaced). However this does not mean that less original uranium is required, simply that the enriched and fabricated uranium fuel loaded contains U-235 in a more “concentrated” (enriched) form. To provide this amount of U-235 nuclei approximately the same amount of uranium ore will have been required.

Thus the scale of detriment associated with the need to extract uranium-235 nuclei from the ground to fuel the different types of reactor falling within this application will be essentially the same and is not something that is dependent on the reactor design, or its burn-up or the level of fuel enrichment used.

Spent Fuel Management and Disposal

Spent fuel can also be measured in different ways. For example:

- The mass or volume of the irradiated fuel rods or assemblies produced as a consequence of the generation of a given amount of electricity; or

- The mass or volume of the packages required to contain this spent fuel (either for storage or disposal); or

- The size of the “footprint” within an underground repository required to dispose of this amount of packaged spent fuel.

In terms of justification we believe that the disposal “footprint” and the volume of packaged spent fuel are more important parameters in terms of detriment than the mass or volume of the fuel rods or assemblies themselves. Both the former quantities take into account the amount of radioactivity within the spent fuel, not just its weight or volume. And (continuing the explanation set out above) the amount of radioactivity within the spent fuel depends in turn on the number of U-235 fissions that have occurred within it.

As explained in the section above on fuel usage, all the reactor types relevant to this application require approximately the same number of U-235 fissions to produce a particular amount of electrical energy; as a result they also produce about the same amount of radioactivity within the spent fuel that is discharged. What differs between designs is the concentration of this radioactivity within a given amount of spent fuel, and the application considers the implications of this for justification as is reiterated below.

Para 5.42 of the application describes how the volume of packaged spent fuel and the size of repository footprint associated with its disposal is highly dependent on the
level of heat generation within the spent fuel. For fuel that has been stored for a comparable time after its removal from the reactor, the level of heat generation depends on the burn-up it has experienced. This means that a design of reactor that produces a greater mass of spent fuel assemblies for a given amount of electricity generation (because it uses less highly enriched fuel and has a lower fuel burn-up) will also produce fuel that requires a lower level of heat removal during its storage or disposal. For this reason the level of detriment associated with this type of reactor will not necessarily be different to that of the higher burn-up design.

The information presented in paras 5.40 to 5.45 of the application confirms that this is indeed the case for the 4 example designs described in the application. This leads to the conclusion that in terms of justification the detriment arising from spent fuel is not significantly different for any of the example designs despite differences in possible burn-ups, enrichment, fuel design etc.

Radioactive Waste Management and Disposal

Once again it is important to consider what is the appropriate measure when assessing the scale of detriment from radioactive waste material resulting from the proposed practice. For example:

- The mass or volume of the “raw” (unprocessed or packaged) wastes; or
- The amount of radioactivity within the various wastes; or
- The mass or volume of the processed wastes; or
- The mass or volume of the processed and packaged wastes; or
- The size of the footprint required for the disposal of these wastes.

The application considers this and explains that decisions taken by the eventual operator (that will themselves be subject to regulatory control and the radiological optimisation process) as to the way individual waste streams are processed and packaged will have a significant impact on these quantities. This means it is not possible to give precise quantification of all these quantities at the justification stage (see paras 5.11-12 and 5.32-33). However, it is explained that the amounts would certainly be small in comparison with the quantities of similar radioactive wastes already being managed within the UK (para 5.33). The application also explains that the possible impact on a future UK waste repository from any new nuclear stations would be relatively insensitive to the amounts of these types of wastes but would be dominated by the disposal footprint resulting from their spent fuel (para 5.33). The additional repository footprint required is described at para 5.44 of the application with information in Annex 6 (Section 5) for each of the 4 example designs showing that all would fall within this estimate and are broadly similar.

This leads to one of the conclusions in the application which is that, for the purposes of justification, the detriments arising from the need to manage radioactive wastes resulting from the proposed practice (whether from normal operation or decommissioning or from spent fuel) are not significantly different for any of the example designs.
Other Potential Detriments

Chapter 6 - Environmental Impacts

All major infrastructure projects have impacts on the environment; these are addressed at a generic level through the Strategic Assessment process required under European law, and again on a project by project basis in detail through the environmental impact assessment* which must take place before a project can go ahead.

This chapter previews those issues likely to be most relevant to the proposed practice. This shows 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
- the environmental impacts are not unique to the proposed practice and would to be comparable to, or less than, those of other large scale electricity generation

* Electricity Works (Environmental Impact Assessment) (England and Wales) Regulations 2007

Introduction

6.1 Major infrastructure projects inevitably have an impact on the environment. It is for this reason that a detailed environmental assessment is required as part of the planning process. 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.

6.2 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. Government concluded in the White Paper 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." 105

6.3 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 they do not significantly erode the overall benefit.

6.4 The following sections consider the potential scale of these impacts, the means by which they would be addressed and mitigated, and the regulatory regime in place to control them:

- Conventional Waste Management
- Transport and Traffic
- Air Quality
- Water Quality

105 A White Paper on Nuclear Power, Cm 7296, January 2008, page 103
6.5 This assessment focuses on the environmental impacts resulting from the operation of the nuclear plant since construction does not involve the use of ionising radiation. The plant's construction does not raise any unique environmental issues, is common to the deployment of any new generation technology and is not examined further. It is important to note however that the construction of any new nuclear power station, like any other major construction project, would be undertaken in compliance with all the relevant legislative requirements.

**Conventional Waste Management**

6.6 The requirements for managing conventional waste from 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 powered station or major technical enterprise.

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

6.8 Conventional waste would be managed in accordance with best practice and in compliance with the relevant regulations such as the Landfill and Waste regulations. As a result any environmental impacts would be both mitigated and small.

**Traffic and Transport**

6.9 The principal transport impacts resulting from the operation of the proposed technology would be increased road and rail movements.

6.10 The volumes of radioactive waste and spent fuel that would be generated by the proposed practice are described in chapter 5. Given their relatively small scale the number of any associated transport movements required would be very low.

6.11 With regard to other transport requirements there would be regular road deliveries to the site, but there would be no need for the frequent delivery of large quantities of supplies (including fuel), 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 (or smaller) than those of any other large electricity generating station.

6.12 Most of the permanent workforce would probably commute to the site by private vehicle. 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 employees and third party.

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journeys to site. It should also be noted that the project would be required to undergo a design and access analysis, likely to include a “green travel plan” as part of the planning assessment process, in line with the provisions of the General Development Procedure Order.

6.13 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 500-1000 extra staff, although the numbers would vary at different outages. Again the effects of transport could be mitigated where possible in the light of past 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

6.14 Operation of the proposed technology would result in no significant effects on air quality. Unlike fossil fired plant there would be no significant emissions of air pollutants such as CO₂, SOₓ, and NOₓ or airborne particulate matter.

6.15 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 required pollution prevention and control (PPC) permits. Best available techniques would be applied to mitigate any potential impacts in accordance with this regime.

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

Water quality

6.17 This section addresses the possible impacts that will arise from the use of cooling water.

6.18 Large volumes of water are already abstracted from UK rivers, 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. It is then returned at a temperature above ambient water temperature, leading to localised increases of water temperature.

6.19 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 30-40 m³/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.

6.20 The potential effects of water abstraction and discharges are well known and can be

considered under the following headings:

- Thermal effects
- Chemical effects, due to biocide treatment of the cooling water and,
- Marine Life.

6.21 The use of cooling towers would lead to different effects that are described separately.

**Thermal effects**

6.22 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. Again in certain circumstances, a long-term temperature rise could lead to changes to the species mix (e.g. with more species native to warmer areas).

6.23 Discharges to controlled waters are regulated by the Environment Agency under the Water Resources Act 1991. Clause 3 of Schedule 10 of that Act expressly allows the Environment Agency to impose conditions on discharge consents in relation to temperature, amongst other things. These limits have legal force, and allow the Environment Agency to ensure that the thermal effects of water discharges are properly managed to avoid environmental harm. Currently there are no statutory temperature standards for estuaries but the Environment Agency has produced guidance on assessing thermal discharges in relation to designated sites.\(^{108}\) Typically these have been assessed against the scale of temperature rise experienced by organisms transiting through the cooling system and deviation above a maximum temperature threshold in the receiving water.

6.24 The direct water cooling arrangements deployed by the proposed practice would be similar to those of existing nuclear stations. As with existing stations, cooling water intake and discharge would be routinely monitored by plant staff to ensure that the discharge of cooling water was managed within limits set by the Environment Agency under the Water Resources Act 1991.

**Chemical effects**

6.25 The proposed practice could also result in minor 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) is likely to be the method used.

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

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Marine Life

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

6.28 A wide range of technologies is in common use for fish screening. The fish screening design adopted for the new practice 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. As a result the impacts on fish and other marine fauna would be mitigated.109

Cooling towers

6.29 If cooling towers were used, there is the potential environmental issue of 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.

6.30 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 follow similar guidelines.110 As a result environmental impacts would be mitigated, and unlikely to occur.

Chemicals

6.31 The proposed practice would lead to no significant chemical effects. Whilst there would be a requirement for the use for example of hydrazine, boric acid and chloride, any chemicals handling would be undertaken in accordance with the Control of Substances Hazardous to Health (CoSHH) regulations by controlling exposure to chemicals and protecting workers’ health.

6.32 The discharge of any of these chemicals would be tightly controlled by UK legislation such as the Water Resources Act 1991 (as amended). This would ensure that environmental impacts would be minimal.

Noise

6.33 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.


Prevention and reduction of noise will be addressed under the regulatory regime of Integrated Pollution Prevention and Control. 111

**Light**

*6.34* In addition to any street lighting the outside perimeter of the plant site (fence) 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**

*6.35* Land usage for the proposed practice would be in the range of 50 -70 hectares, broadly comparable to large scale coal and gas generating plant. There would be no demand for large storage areas. As the overview below suggests land requirements would be considerably smaller than those for large-scale renewables.

### PV: The Land-Area Advantage

<table>
<thead>
<tr>
<th>Technology</th>
<th>Converter Efficiency (%)</th>
<th>Capacity Factor (%)</th>
<th>Maximum Packing</th>
<th>Land per year for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat-Plate PV</td>
<td>10%-20%</td>
<td>20%</td>
<td>25%-75%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10-50 km&lt;sup&gt;2&lt;/sup&gt;/GW</td>
</tr>
<tr>
<td>Wind</td>
<td>Low to 20%&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20%&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2%-5%&lt;sup&gt;e&lt;/sup&gt;</td>
<td>100km&lt;sup&gt;2&lt;/sup&gt;/GW&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.1% total&lt;sup&gt;g&lt;/sup&gt;</td>
<td>High- Plants compete for sunlight</td>
<td>1000km&lt;sup&gt;2&lt;/sup&gt;/GW&lt;sup&gt;h&lt;/sup&gt;</td>
<td>500,000 m&lt;sup&gt;2&lt;/sup&gt;/GWh&lt;sup&gt;i&lt;/sup&gt;</td>
</tr>
<tr>
<td>Solar Thermal or PVC Concentrators</td>
<td>15%-25%</td>
<td>25%</td>
<td>10-20%&lt;sup&gt;j&lt;/sup&gt;</td>
<td>20 km&lt;sup&gt;2&lt;/sup&gt;/GW&lt;sup&gt;k&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

* a www.windpower.org  
  b 0.5% or less light-to-biomass; then 33% to electricity, 0.1% total  
  c Site dependent  
  d Tilted arrays at high latitudes versus flat ones at the equator; room between for maintenance  
  e Pimentel 2002, Dohn Riley et al  
  f Tracking arrays need wider separation to avoid shadowing  
  g Hansen 2003  
  h Hughes 2002  
  i Pimentel 2002  
  j Cohen 2003  
  k at 15% module efficiency, 12% module-to-system operating efficiency losses

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6.36 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, if they were used, which could lead to plume formation. This could result in horizon marring effects with the impact of the plume influenced by the atmospheric conditions.

6.37 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 new lines would be in compliance with the proposed Planning Bill.

6.38 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.\(^{112}\)

Conclusion

6.39 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 environmental impacts in the identified areas, both individually and in aggregate, would be small. Most impacts would be comparable with or less than those of other large-scale electricity generation.

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\(^{112}\) Guidelines for Landscape and Visual Impact Assessment, Landscape Institute and Institute for Environmental Assessment 2002
Chapter 6 - Addendum

Additional information provided in response to questions raised in relation to Chapter 6 in the Notice under Regulation 16 of the Justification of Practices Involving Ionising Radiation Regulations 2004

Q9. Throughout Chapter 6 the application makes the assertion that environmental detriment of the designs within the practice would be no greater than “other forms of generation”, however there is a lack of information on the scale of those detriments relating to the proposed practice. The applicant is asked to provide further detail on the environmental detriments, including:

- 6.5 - Further information on the environmental impact of plant construction and decommissioning for the practice.
- 6.6 - Information on the scale of conventional waste produced by the practice.
- Information on the scale of the environmental impact on water quality, with particular regard to thermal increase (Para 6.22) and marine life (Para 6.28).

Introduction

Question 9 requests the Applicant to provide further detail on the ‘environmental detriments’ referred to in Chapter 6. A further level of information is provided below in response to this request.

It is important to note that environmental impacts for individual sites will be site-specific and will be subjected to rigorous review at the planning and environmental assessment stage of the consenting process. Nevertheless, the further indicative information provided below supports the position that the potential environmental impacts from the proposed new practice would not be so great as to undermine the very significant benefits of this practice.

Since our application was submitted, the view that the environmental detriments will be small has been supported by the conclusions of the environmental and sustainability study undertaken by BERR\(^1\) in support of its July 2008 consultation on the Strategic Siting Assessment (SSA) process. The study concludes that:

“While adverse impacts cannot be wholly ruled out, using the proposed SSA criteria to identify suitable sites for new nuclear power stations is likely to lead to outcomes which are, on balance, broadly in line with the principles of sustainability and environmental protection”.

Further information on the environmental impact of plant construction and decommissioning for the practice.

Plant construction

Areas for potential environmental impacts are described in Para 6.4 of the application. Those for construction would be similar in nature to those for operation, although the scale would be different. The construction period, estimated to be around 5 years, would be shorter than the operational phase. Examples of the possible scale for the construction period are given below. Both construction and operational environmental impacts would be addressed together under the UK’s environmental protection and planning regulations.

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All large projects require people and material to be brought to the construction site, resulting in greater traffic and workforce movements than during operation. Additional space (lay down areas) is temporarily required, although these can be restored afterwards to standards agreed as part of any planning consent.

**Traffic and transport**

For any equivalent scale of onshore electricity generation construction project there will be a significant number of lorry and staff movements to the site.

Table 1 provides an overview of estimated amounts of bulk construction material for Sizewell C\(^2\) (a twin-unit PWR station for which a planning application was lodged in the early 1990s).

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount [tonnes]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road surfacing</td>
<td>40,000</td>
</tr>
<tr>
<td>Concrete:</td>
<td></td>
</tr>
<tr>
<td>Aggregates</td>
<td>1,900,000</td>
</tr>
<tr>
<td>Cement</td>
<td>240,000</td>
</tr>
<tr>
<td>Pulverised fuel ash</td>
<td>80,000</td>
</tr>
<tr>
<td>Reinforcing steel bars</td>
<td>130,000</td>
</tr>
<tr>
<td>Structural steel sections</td>
<td>18,000</td>
</tr>
</tbody>
</table>

The total construction workforce was estimated to have a peak of around 7000 workers, averaging approximately 4350 workers during the main construction period. More recent environmental impact assessments for new nuclear stations in Finland at the Olkiluoto and Loviisa sites estimate the workforce to be around 3500 workers.

For construction of the third unit at Olkiluoto it is estimated that transportation (excluding commuter traffic) would increase the traffic volume by an average of 100 vehicles a day, or around 50 round trips per day. In addition it is estimated that around 40 deliveries will be made by sea\(^3,4\).

These impacts will be addressed during the consenting process. Relevant conditions (e.g. use of travel plans and advisory routes) may be incorporated into the planning consent, and management systems will be employed to ensure compliance with these.

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2 Proposed Sizewell ‘C’ PWR Power Station Environmental Statement
4 Environmental Impact Assessment Report, Supplementing the Loviisa Nuclear Power Plant with a third unit, Fortum Power and Heat Oy, 2007
Noise

Noise levels are presented using the decibel unit (dB). Examples of noise levels of different sounds are listed below

<table>
<thead>
<tr>
<th>Sound</th>
<th>Level dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>A quiet forest</td>
<td>20 – 30</td>
</tr>
<tr>
<td>A conversation (1m)</td>
<td>50 - 60</td>
</tr>
<tr>
<td>Office noise</td>
<td>65 – 70</td>
</tr>
<tr>
<td>A busy street (2m)</td>
<td>70 – 80</td>
</tr>
<tr>
<td>A rock concert</td>
<td>110 – 130</td>
</tr>
</tbody>
</table>

During the construction stages there are different sources of noise e.g. power tools, heavy mobile equipment including trucks, bulldozers, front-end loaders.

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 Control of Pollution Act Section 61 Prior Consent process.

Predictions of noise levels during construction for e.g. the proposed Pembroke Power Station are below 65 dB during daytime at the closest residential location to the site. Similar noise levels are estimated at the proposed Olkiluoto and Loviisa sites. A noise level of 45 dB is not expected to be exceeded during daytime beyond a distance of 1 km from these construction sites.

Air Quality

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.

Emissions during construction of the fourth unit at Olkiluoto for the maximum situation are estimated to be around:

<table>
<thead>
<tr>
<th>Type of emission</th>
<th>Tonnes per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>0.2</td>
</tr>
<tr>
<td>Nitrogen oxides (NO₃)</td>
<td>62</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>168</td>
</tr>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>7123</td>
</tr>
<tr>
<td>Particulate matter</td>
<td>1.4</td>
</tr>
</tbody>
</table>

It should be noted that the above mentioned figures include the emissions due to traffic movements related to the operation of three units at Olkiluoto, the disposal facility and that annual maintenance outages are in progress. The most intense phase of construction is assumed to last for around one year.

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5 Proposed Pembroke Power Station Consolidated Environmental Statement, Non Technical Summary, RWE Group, 2007
Conventional waste

It is estimated that around 11 000 tonnes of waste will be generated during the construction of the third unit at Olkiluoto. It is further estimated that about 500 – 1000 tonnes of this waste will be unsuitable for further utilisation and will be consigned to landfill.

Plant decommissioning

Potential areas for environmental impacts are similar to those for construction and operation, see para 6.4 of the application. Decommissioning a nuclear station is covered by analogous UK regulatory processes to those applied in its construction, with the result that environmental impacts are controlled. Essentially decommissioning the plant is the reverse of its construction i.e. the materials brought to the site will be disassembled and, where appropriate, removed. As a result a similar number of movements are required 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, 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 comparable to the construction time period.

Before decommissioning or dismantling of a nuclear reactor or power station can take place, a licensee must apply to the Health and Safety Executive (HSE, referred to as the Executive in EIADR) for consent, undertake an environmental impact assessment, and provide an environmental statement. The decommissioning environmental statement is required to assess similar detriments to those experienced during construction (e.g. air quality and dust, noise and vibration, socio-economic, surface waters, traffic and transport, radioactive discharges etc). Experience on the Magnox units, where consent to start decommissioning has been granted by HSE, 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, reports on their implementation and effectiveness, and providing for changes to such measures in light of experience. It is therefore concluded that there is substantial experience to demonstrate that the decommissioning of a nuclear power station presents very low detriments.

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Information on the scale of conventional waste produced by the practice.

Conventional waste

For the fourth unit at Olkiluoto the following amounts of conventional wastes are estimated to arise annually.\(^7\)

<table>
<thead>
<tr>
<th>Type of waste</th>
<th>Tonnes / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill waste</td>
<td>90</td>
</tr>
<tr>
<td>Paper and cardboard</td>
<td>25</td>
</tr>
<tr>
<td>Waste suitable for energy production</td>
<td>45</td>
</tr>
<tr>
<td>Biowaste</td>
<td>25</td>
</tr>
<tr>
<td>Metal</td>
<td>65</td>
</tr>
<tr>
<td>Wood</td>
<td>100</td>
</tr>
<tr>
<td>Glass</td>
<td>0.5</td>
</tr>
<tr>
<td>Hazardous waste*</td>
<td>20</td>
</tr>
</tbody>
</table>

* Hazardous waste is considered to consist of e.g. scrapped electrical and electronics components, solid oily wastes, solvents and fluorescent tubes and light bulbs. Such hazardous materials also occur at large fossil-fired plants.

It should be noted however that the amount of waste produced is governed less by the design than by the overall waste management system adopted by the operator. Appropriate mitigation measures will be applied irrespective of whether the amount of waste is \(x\) or \(5x\). Compliance with regulations will be required, which means that the amount of waste will relate to required activities and would only be produced on an “unavoidable” basis. In this respect the new practice is no different to other major industrial facilities, and no different from currently operating nuclear plants.

Impacts on air quality that is expected from the operation of ancillary equipment

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.

For the third unit at Loviisa it is estimated that the annual light fuel oil consumption will total around 1200 tonnes per year\(^8\). 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.

\(^7\) Environmental Impact Assessment Report, Extension of the Olkiluoto Nuclear Power Plant by a Fourth Unit, TVO, 2008

Low level radioactive waste such as contaminated oil might be incinerated on site to reduce radioactive waste volumes, see para 4.33. 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 emissions of incineration of e.g. 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.

Information on the scale of the environmental impact on water quality, with particular regard to thermal increase (Para 6.22) and marine life (Para 6.28)

Basis for deriving cooling water requirements

The residual heat needing to be discharged depends on the thermodynamics of the design and can be described by the efficiency. All designs use a water steam cycle with similar primary circuit pressures and temperatures and therefore have a similar efficiency. The efficiency for AP1000 is ~ 32% and EPR ~ 36 % and the other designs are within that range. Hence a similar amount of residual heat per MWe needs to be discharged. Residual heat to discharged is approximately:

\[
\text{Electric output} \times \left\{ \frac{1}{\text{thermal efficiency}} - 1 \right\}
\]

The estimate of the cooling water requirement of 30 – 40 m\(^3\)/s per 1000 MWe is based on the assumption of a 10 °C temperature increase between intake and outtake of cooling water. Heat discharged (MWth) is approx 4.2 Q (\(\Delta T\)) where Q is the coolant water flow and \(\Delta T\) the condenser rise for direct-cooling. For 1000 MWe plant with 40% thermal efficiency we get Q\(\Delta T\)=357 degC.m\(^3\)/s. For a \(\Delta T\) of 10°C this gives in the order of 36 m\(^3\)/s (in the range above).

The numbers provided in Annex 6 for the different designs are based on different assumptions for the temperature rise. For example for the AP1000 a temperature increase of 7°C was assumed, whereas 12°C was assumed for the EPR. Therefore the numbers are not only scaled according to power but in addition to temperature increase.

Some US plant use ‘cooling water’ which does not pass through the condensers to mix with condenser discharge cooling water pre introduction to the environment (in order to meet local environmental constraints) and this may distort somewhat the apparent m\(^3\)/s/1000 MWe for some plant.

Cooling water requirements when using cooling towers

If cooling towers are used the water requirements are only a fraction of that for direct cooling. Demand of cooling water for a natural draft tower is expected to be in the range of 1 - 2 m\(^3\)/s for a 1400 MWe plant. Again, actual demand depends on thermal efficiency of plant and design basis for the towers.
Potential thermal effects due to discharge of cooling water

Temperature increase of outlet cooling water is directly related to cooling water outflow. Within a range cooling water outflow temperature can be controlled by design of the cooling water system to mitigate possible environmental impacts (e.g. low temperature increase, high cooling water flow vs. high temperature increase, low cooling water flow).

Thermal impacts are typically assessed against two criteria:

- the deviation above ambient temperature of the receiving water, and
- exceedance of a maximum temperature threshold.

Temperatures for the two criteria will be determined in the light of site specific conditions. Examples of what the ranges of those temperatures are can be found, for example for a marine site in WQTAG 160, which recommends the following criteria:

‘For “special protection areas” (SPA) the maximum allowable deviation from ambient temperature to be 2°C at the edge of the mixing zone. The maximum temperature is recommended to be no higher than 28°C, as a 98 percentile at the edge of the mixing zone’

Potential impact on marine life due to water abstraction

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.

The impact on the marine environments strongly depends on the location and the design of the cooling water intake system. For example in the Environmental Statement for the proposed Pembroke Power CCGT station it is estimated that as a result of mitigation measures the impact on fish mortality by weight per unit volume of water abstracted is small. It is expected to be in the order of 10% of the annual diet of one grey seal, or the food required to annually support 2.5 1kg sized sea birds.

Estimated annual total quantities of fish impinged at current UK estuarine and coastal power stations are given in the table below.

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

9 Using water well? Studies of power stations and the aquatic environment, Turnpenny and Coughlan, Innogy plc 2003
Another source\textsuperscript{10} provides the following estimates on numbers of fish impinged:

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

This shows that the possible impact will very much depend on the specific location rather than the cooling water demand alone.

**Potential impacts if cooling towers were used**

For any nuclear station opting to use cooling towers a cooling tower design would be chosen according to guidelines\textsuperscript{11}.

**Q10. The applicant is asked to provide information on the environmental impact of water abstracted for use other than in cooling.**

In addition to the use of water for cooling purposes water might be abstracted for other purposes. Water will be used for example as process water, tap water and to supply fire fighting systems. For the third unit at Olkiluoto the daily amount is estimated to be approximately 210m\textsuperscript{3} (~80,000m\textsuperscript{3}/a). Depending on the plant design 100,000 – 200,000 m\textsuperscript{3}/a are estimated for the Lovisa site. At this stage it is not possible to determine whether water will be abstracted from the sea or rivers or e.g.

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\textsuperscript{11} Integrated Pollution Prevention and Control (IPPC) Reference document on the application of best available techniques to industrial cooling systems, December 2001, European Commission.
be taken from the municipal water system. However it should be noted that water abstracted for direct cooling purposes will be completely returned to the water body.

Q11. The applicant is asked to confirm whether the Control of Major Accident Hazards Regulations 1999 would apply to the chemicals mentioned in para 6.31.

It is possible that quantities of chemicals such as hydrazine and hydrogen needed for a plant would be sufficient to require regulation under the lower tier of the “Control of Major Accident Hazards Regulations 1999”.

Q12. The table after para 6.35 sets out figures on land area usage and efficiency for other types of generation. To make these comparisons meaningful, the applicant is asked, where possible, to provide information for nuclear generation in similar terms.

The table was reproduced from PV FAQs U.S. Department of Energy, Energy Efficiency and Renewable Energy. This reference did not include any other forms of generation besides the listed ones for comparison. A source providing information in a similar way for all sources of energy could not be found. Nonetheless using the information provided in Annex 6 one can derive a land usage factor in similar units; these are 0.09 – 0.2 km²/GW.
Chapter 7 - Economic Assessment

The Government’s White Paper on Nuclear Power concluded that:

- “Under the most likely scenarios for gas and carbon prices, nuclear power would yield economic benefits to the UK in terms of reduced emissions of CO\textsubscript{2} and improved security of supply”
- “On the basis of our cost-benefit analysis, we believe that nuclear power is likely to be an attractive economic proposition to [investors]”

Based on these conclusions, deployment of the practice is not expected to impose a detriment on the wider UK economy.

Introduction

7.1 This Chapter considers the potential economic impact of adoption of the proposed practice on the UK economy. In doing so it distinguishes the national economic perspective from that of a private sector developer. From the national viewpoint, it is important to establish that the resource costs of the practice are outweighed by its overall benefits, and hence that the practice should not be expected to impose a detriment on the wider UK economy. This conservative “no detriment” criterion is relevant here, since the present submission does not rely on demonstrating an economic benefit.

7.2 It is axiomatic that any private sector company that develops a nuclear project will expect it to yield benefits to that company and to its shareholders. Such a project will also benefit its employees and suppliers, as well as the exchequer through corporation taxes. To the extent that the economic cost of the development is lower than for alternative technologies and that it participates in a competitive energy market, consumers can also expect to benefit on average via downward pressure on electricity prices. As with any other form of generation, a successful project may therefore be expected to have a positive impact on the UK economy.

7.3 However nuclear developments also bring additional national benefits of avoided CO\textsubscript{2} emissions and increased security of supply. These benefits can be “monetised”, i.e. expressed as an additional economic amount to be taken into account in assessing the overall welfare balance. The proportion of the benefit that accrues to the developer depends to some extent on the existence of financial mechanisms to achieve this, such as carbon pricing. In making investment decisions, a private-sector company will take a view on the likely reward for these benefits, just as on the price for electricity. But from the viewpoint of the UK economy it is the overall welfare balance that matters.

7.4 Furthermore, if a nuclear developer’s expectations are not met and the company becomes insolvent part way through the project’s operating life, the impact on shareholders may differ from that on the wider UK economy. Such insolvency might arise, for example, during normal operation, during unusual, sustained low electricity prices, or following a severe accident that precluded return to service of the affected plant. Shareholders have limited liability and the value of their shares cannot fall below zero, whereas the cost of unfunded nuclear waste and decommissioning liabilities would ultimately fall to government. If it occurred, this could constitute a significant detriment to the UK economy.
7.5 Accordingly this chapter aims to assess the scope for economic detriment from a national perspective, and to demonstrate that, in practice, no detriment is to be expected. It is based on a review of the cost benefit analysis undertaken for the government, initially for the July 2006 Energy Review, and updated in April 2007 and then in January 2008 in the Nuclear White Paper. That analysis concluded that the practice was likely to be both economically attractive to investors and economically beneficial for the UK economy. Relevant extracts from the government’s analysis are quoted in italics to distinguish them from the commentary.

7.6 The Chapter also summarises the government’s “top-down” assessment of the economic consequences of allowing nuclear as part of the electricity mix in the medium to long term, out to 2050. That assessment was presented as Annex A of the Nuclear White Paper, and has been extended separately by Defra.

7.7 The Chapter does not aim to reproduce the investment appraisal undertaken by any company seeking to implement the practice in the UK. Nor does it aim to assess the financial strength of any such company or consortium. In practice, the participation of diversified multi-national companies with strong balance sheets would be expected to mitigate the risk of insolvency. The financial strength of such operators will be assessed as part of the decommissioning funding regime proposed by the Energy Bill, which will allow the government to impose financial obligations relating to nuclear clean up costs on a wide range of affiliates of nuclear operators to ensure that adequate finances are available if necessary, minimising the risk of a need for recourse to public funds. Furthermore, for nuclear power stations a large part of the unit cost of electricity is due to capital costs incurred in construction, rather than to ongoing operating costs. For example, under the central case in the government’s analysis these capital components amount to £25/MWh out of a total of £38/MWh. Once the station is operating, these costs do not recur. Thus even if the original developer / operator did become insolvent, it is likely to be economic to undertake financial restructuring in which part of the capital cost is written down, and a successor then continues to operate the station and deliver its benefits for the UK economy.

Overview of analysis

7.8 The Government’s analysis aimed to determine:

“Whether there is potential benefit to the UK in keeping the door open for [new nuclear] projects.”

Its approach was:

“To look at the range of costs and benefits associated with investment in new nuclear generation capacity. In theory, if the benefits exceed costs, it would be a good idea for the Government to enable (if not necessarily directly support) new nuclear build. If the costs exceed the benefits, then such a policy would, in theory, not be justified.”

114 A White Paper on Nuclear Power, Cm 7296, January 2008
The analysis was based on a range of independent studies. It accounted for the costs and benefits of nuclear power station projects as fully as possible, including the full costs of construction, operation, decommissioning and waste management and disposal. Thus it is considered to satisfy the Defra guidance\textsuperscript{116} that “This appraisal should include the economic… benefits and detriments” in respect of the potential for economic detriment.

7.9 The studies underpinning the government’s analysis vary in their treatment of costs sunk in developing the technology at a generic level. Such costs could include research and development by the international vendors involved, and also first-of-a-kind costs incurred for the first project employing that technology.

To the extent that sunk generic costs are excluded, this is in accord with the Defra guidance that:

“The justifying authorities would not necessarily ignore sunk costs… unless these sunk costs were generic to the class or type of practice. For example, research and development costs already incurred might be excluded if they were generic to a proposed new class or type of practice.”

To the extent that sunk generic costs are included, this tends to increase the estimated cost of nuclear generation. Hence any assessment involving such sunk costs is conservative when assessing the benefit of nuclear relative to other forms of generation.

7.10 In the present case, the families of evolutionary design within the practice generally build on decades of research and development and of commercial operating experience on earlier versions of the relevant design. This is true in particular for each of the four designs that exemplify the proposed practice. As far as implementation of the practice in the UK is concerned, these costs (and benefits) are clearly both generic and already sunk.

It is concluded that the government’s analysis is an appropriate basis from which to draw conclusions on the potential impacts of the practice on the wider UK economy.

Available capacity

7.11 The analysis takes it as axiomatic that it would be uneconomic to operate new nuclear power stations other than in baseload, or to displace existing plant so as to leave investors unable to recoup their investment. It assesses the likely retirement timescales for existing plant assuming that coal-fired plant that is opted-out under the Large Combustion Plant Directive will have closed and been replaced before the first new nuclear station can be commissioned. Even with these assumptions it concludes that:

“There would be scope for adding at least 6 GW of new nuclear capacity over the period 2021-2025, and there would be need for up to 14 GW of new capacity (nuclear or other) over the period 2018-2025.”

This takes account of the retirement of the existing stock of nuclear power stations and of likely demand growth, together with switching of existing gas-fired plants from baseload to mid merit / peaking operation.

The range of at least 6 up to 14 GW by 2025 would allow a substantial programme of new nuclear power stations, comprising between 3 and 8 units of the largest of the designs that exemplify the practice. It is concluded that deployment of the practice is not expected to impose an economic detriment on the wider UK economy through insufficient available capacity.

Resource cost

7.12 The analysis recognises that there are significant uncertainties in existing estimates of nuclear costs. Accordingly, it draws on a wide range of external assessments and reviews to derive a plausible range for forecast cost.

The sources considered comprise:

- Studies from the period 2002 to 2005, as reviewed by Thomas. This includes work by the Performance and Innovation Unit undertaken to inform the 2003 White Paper
- Studies from 2006 undertaken in connection with the Energy Review consultation. The most detailed of these was carried out by PB Power
- Information on current European nuclear construction projects in Finland and France. This includes a report prepared by NERA for the Sustainable Development Commission.

The analysis notes that the dominant sources of uncertainty are construction cost and duration, together with the cost of capital. The latter reflects the capital structure of the developer and the market risk that it has to bear. The analysis discounts estimates relating to regions unrepresentative of the UK economy, including Japan (high construction cost) and Eastern Europe (low cost). Finally, it takes account of the potential for bias towards underestimation of costs in information provided by the nuclear industry.

After a detailed review of published estimates for private sector development, including commercial financing costs, the review concludes that:

“The range of nuclear costs considered is £31/MWh to £44/MWh. The central assumption is a levelised cost of £38/MWh.”

Construction and financing costs are the largest component, taken as £25/MWh in the central case. The analysis regards this case as deliberately conservative when

118 “The economics of nuclear power”, PIU Energy Review working paper, February 2002
applied to a programme of nuclear projects. For example, each of the technologies described in this application is designed to operate for 60 years, rather than the 40 years assumed in the government's analysis. For the purpose of the application, however, the central case is considered appropriate to bound likely first-of-a-kind projects in the UK.

7.13 Set against this, the analysis assumes that the alternative baseload capacity would be provided by gas-fired stations, and that these would have a levelised cost of £37/MWh (with gas at 39.9p/therm) in the central case and a range of £25/MWh to £48/MWh.

The economic value of the difference between the two scenarios is evaluated by calculating the net present value (NPV), using as discount rate the Social Time Preference Rate considered appropriate to benefits and detriments to society as a whole. The analysis comments that:

"The methodology of levelising costs at a rate based on commercial financing costs and discounting back cost penalties / advantages at the STPR is consistent with the approach used in the UK Government’s Climate Change Programme Review (CCPR), which compares costs of alternative options for carbon reduction."

7.14 For the two central cases this difference is small though marginally unfavourable to nuclear, reflecting the small difference of £1/MWh in levelised cost. This is finely balanced compared with values in excess of £1bn/GW NPV at each extreme of the range.

7.15 The analysis specifically identifies a number of factors that could benefit new nuclear costs relative to historic UK experience, such as at Sizewell B. These include:

“Costly changes in safety standards during construction might be avoided through improvement of the regulatory framework and, in particular, through setting out detailed design standards prior to commencement of construction”

“It might be expected that costs for new reactor designs would fall after the first plant has been constructed; the cost premium in the case of Sizewell B would be diluted for a programme”

“There is likely to be a closer fit between risk and consequence: in other words, the prime contractors will have better incentives to control costs because they will suffer greater consequences in profit terms if they fail to do so”

“Big-project management techniques have improved over the last fifteen years; there is likely to be a more competitive, international process for letting a nuclear construction contract; a consortium taking on a nuclear project would probably offer terms that are closer to a turnkey (fixed price) contract than the cost-plus contracts that were characteristic of past nuclear construction”.

Each of these factors is expected to apply as a result of the policy and facilitative actions by government identified in the Nuclear White Paper.

7.16 In addition, the government is taking actions that are expected to reduce the planning period for new nuclear projects. The impact assessment for the Nuclear White Paper has estimated that, under this new framework, the pre-development and planning period could realistically be reduced from 8 to 5.5 years. It concludes
that, in the central case, this could reduce the levelised cost of nuclear by £1.3/MWh and increase its NPV by £155m/GW.\textsuperscript{121}

Welfare balance

7.17 The resource cost assessment outlined above does not yet take into account the benefits of nuclear for security of supply and environmental objectives, specifically carbon dioxide emissions. This is achieved by “monetising” these benefits, i.e. quantifying their economic value and then adding them to the resource cost to create a “welfare balance”.

7.18 The government’s analysis as updated in April 2007 monetised the avoided carbon emissions from nuclear generation relative to that from gas-fired CCGTs, using Defra’s estimates of the “social cost of carbon” – that is, the marginal benefit of carbon emissions reduction in terms of climate change and related adverse impacts. These estimates are £29/te CO\textsubscript{2} rising to £41/te CO\textsubscript{2} in 2060 in the central case, with a range of £18 rising to £30/te CO\textsubscript{2} in the low case and £51 rising to £63/te CO\textsubscript{2} in the high case. When the social cost of carbon is included, this leads to a central case benefit of £2bn/GW NPV for nuclear capacity, with a range of £1.3 to £3.3bn/GW NPV.

The social cost of carbon has subsequently been supplanted by the “shadow price of carbon” (SPC)\textsuperscript{122}. This captures the worldwide costs of the damage due to climate change caused by each additional tonne of greenhouse gas emitted. It rises in real terms by 2% per year reflecting rising incremental damage of each tonne of carbon as global temperatures rise.

Nevertheless, the Nuclear White Paper notes that the value of the SPC (£24/te CO\textsubscript{2} in 2006, £33 in 2020, £60 in 2050\textsuperscript{123}) is “within the range assumed for the carbon price. Therefore our view on the welfare balance of nuclear generation remains unchanged”.

7.19 The extent to which the economic benefits of lower carbon emissions will accrue to the project developer, and hence contribute to the profitability of investments in nuclear capacity, will depend on the effective price for carbon and whether this fully reflects the social / shadow cost. The analysis identifies that this is an endogenous uncertainty – that is, capable of being reduced by government action.

The Nuclear White Paper states that:

“The Government is committed to working to strengthen the EU’s Emissions Trading Scheme (EU ETS) and to building investor confidence in a long-term multilateral carbon price signal. We will keep open the option of introducing further measures to reinforce the operation of the EU ETS in the UK should this be necessary to provide greater certainty for investors.”


In this light, the application concludes that from the viewpoint of the wider UK economy, the practice provides a substantial economic benefit due to avoided CO\textsubscript{2} emissions. This benefit is also likely to accrue at least partly to the developer, thus mitigating the risk of insolvency in the event of sustained low electricity prices.

7.20 Meanwhile, the government’s analysis monetises the security of supply benefit by assuming that nuclear reduces the need for investment in oil distillate storage for gas-fired power stations.

“In a more unstable world subject to the possibility of repeated / prolonged fuel supply interruptions, new nuclear generation can be viewed as a hedge either against high gas prices, or high costs of ongoing electricity generation using oil”.

Distillate is an alternative fuel that can be used in the event of a serious interruption to gas supply, and it would otherwise be the least-cost option for avoiding interruption to electricity supply. The avoided cost of storage results in a further benefit of £100m/GW NPV.

7.21 The value derived in the analysis is substantially lower than the economic impact of actual interruption to electricity supply. The analysis implicitly assumes that sufficient distillate will be available in storage or from commercial markets to outlast any interruption to gas supply and prevent interruption to electricity supply.

However, as distillate is also a hydrocarbon fuel and is itself derived from oil, this discounts scenarios in which both gas and oil supplies are subject to sustained interruption, for example as a result of international political conflict. To this extent, the benefit derived in the analysis underestimates the economic benefit of nuclear generation.

7.22 When welfare balance is evaluated taking account of both the security of supply and the carbon benefits, the economic value of nuclear relative to gas becomes strongly positive in the central case. At a constant carbon price of £25/te CO\textsubscript{2}, the benefit is £1.5bn/GW NPV. The government’s analysis summarises the robustness of this conclusion as:

“Welfare balance is positive in central / high gas price, central / low nuclear cost worlds, and non zero carbon price worlds, and negative in low gas price / high nuclear cost worlds”.

In this light, the benefit of the practice to the wider UK economy increases yet further when the security of supply benefit is taken into account.

7.23 It is concluded that, after taking account of the contribution of avoided CO\textsubscript{2} emissions and increased security of supply as well as its resource cost, the practice is not expected to impose an economic detriment on the wider UK economy.
Severe accidents

7.24 A further potential detriment to the wider UK economy could be that posed by the consequences of a severe nuclear accident. The possibility in principle of such an accident has been demonstrated by experience at Windscale (1957)\textsuperscript{124}, Three Mile Island (1979)\textsuperscript{125} and Chernobyl (1986)\textsuperscript{126}.

Such an accident involving the practice covered by this application could result not only in radiological effects on workers and the public, but also in non-radiological health effects, for example through anxiety. There would also be major economic impacts including damage to the wider economy in the vicinity of the affected plant, and serious financial damage to the reactor operator. Furthermore, a proportion of these consequences could arise even if the accident involved a reactor outside the UK.

7.25 However, the past experience of nuclear accidents has prompted the development of strong regulatory and corporate governance arrangements focused on the over-riding priority of nuclear safety. These arrangements include:

- A legislative framework for licensing nuclear plant. In the UK this includes the Nuclear Installations Act 1965\textsuperscript{127} and the Radioactive Substances Act 1993\textsuperscript{128}.

- Independent regulators to monitor compliance with the legislation. In the UK these include HM Nuclear Installations Inspectorate, the Environment Agency and the Scottish Environment Protection Agency.

- Operator organisations, in particular the World Association of Nuclear Operators (WANO)\textsuperscript{129}. These recognise that any nuclear accident anywhere affects every nuclear power plant, and that cooperation between operators is needed to ensure that such an accident can never happen again. WANO was formed in May 1989 by “nuclear operators world-wide uniting to exchange operating experience in a culture of openness, so members can work together to achieve the highest possible standards of nuclear safety”… “Every organisation in the world that operates a nuclear electricity generating plant is a member of WANO”.

The governance arrangements in the UK are broadly paralleled in other countries that use nuclear plants for electricity generation.

The cumulative operating experience in electricity generation from nuclear plants can be expressed in reactor-years. On this basis, the operating experience accumulated since the Chernobyl accident has already exceeded the operating experience from the earliest civilian use of nuclear plant up to the time of that accident. This testifies to the effectiveness of the governance arrangements now in place.


\textsuperscript{125} US Nuclear Regulatory Commission Fact Sheet on Three Mile Island http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

\textsuperscript{126} Chernobyl: Assessment of Radiological and Health Impacts http://www.nea.fr/html/tr/chernobyl/allchernobyl.html


\textsuperscript{129} What is WANO http://www.wano.org.uk/WANO_Documents/What_is_Wano.asp
The government’s analysis does not seek to monetise the detriment due to potential severe accidents when calculating the welfare balance. Its reasons for not doing so are:

“Evidence suggests that the likelihood of such accidents is negligible, particularly in the UK context”

“The assumption is that this can be managed through design of regulatory and corporate governance arrangements for the nuclear industry”

“The literature suggests a range for the probability of major accidents (core meltdown plus containment failure) from $2 \times 10^{-6}$ in France, to $4 \times 10^{-9}$ in the UK. The associated expected cost is estimated to be of the order £0.03 / MWh to £0.30 / MWh depending on assumptions about discount rates and the value of life; using the figure at the top end of this range would not change the results of the cost benefit analysis”.

These values are drawn from a review undertaken in 2005 using the ExternE methodology, which was developed under the European Commission to monetise the external impacts of energy technologies.\(^\text{130}\)

In addition to these mitigating factors, which ensure a very low probability of severe accidents, all UK nuclear power station operators (as holders of nuclear site licences) are required by law to carry insurance or other financial arrangements. They also bear strict liability for certain incidents under the Nuclear Installations Act 1965. Under this act, there is currently an upper limit of £140 million on the operator liability. If claims exceed this limit they will in some circumstances be met by Government, and through a pooling arrangement by countries signatory to the Brussels Supplementary Convention\(^\text{131}\).

Recent updates to the conventions have increased this operator’s liability limit to 700 million euros (approximately £500 million) and introduced liability for losses beyond injury or property damage – for example the costs of measures to reinstate the environment. These new provisions would be implemented into UK law if the relevant legislation were passed. In the Nuclear White Paper, the government has confirmed that this is its intent:

“We intend to consult on amending [the Nuclear Installations Act] to include new heads of liability, such as the cost of measures of reinstatement of impaired environment, and the requirement for insurance or other financial security will also then be extended to cover these new liabilities. As mentioned in the consultation document, in accordance with our international commitments, there will continue to be certain potential liabilities that may fall to the Government as a result of a nuclear event”.

The Government’s April 2007 consultation document noted that “to the extent that commercial cover cannot be secured for all aspects of the new operator liabilities, the Government will explore the alternative options available”.


\(^{131}\) Convention of 31st January 1963 Supplementary to the Paris Convention of 29th July 1960, as amended by the additional Protocol of 28th January 1964 and by the Protocol of 16th November 1982 (*Brussels Supplementary Convention*)
It is concluded that deployment of the practice is not expected to impose an economic detriment on the wider UK economy associated with the risk of a severe accident.

**Cost-effectiveness in reducing carbon emissions**

**7.30** To complete its assessment, the government’s analysis compares the economic effectiveness of nuclear against other potential opportunities to invest in carbon reduction. To do this it ranks the potential options according to the detriment in NPV relative to gas per unit lifetime carbon emissions reduction, expressed in £/te CO$_2$.

**7.31** Under the central assumption of a levelised cost of £38/MWh, nuclear has a cost-effectiveness of £0.6/te CO$_2$, compared with £5.8-23/te CO$_2$ for the second-best option, which is retrofitting carbon capture and storage (CCS) to existing coal-fired plant. The wide range for this second option reflects cost uncertainty due to its early stage of development. The cost-effectiveness of the best of the established non-nuclear generating technologies, on-shore wind, is assessed as £28.6/te CO$_2$.

**7.32** Subsequently, the Nuclear White Paper has presented a marginal abatement cost curve which assesses the abatement potential of a wide range of measures, including electricity generation technologies. It concludes that:

> “On the basis of the assumptions we used, nuclear power is the most cost effective low-carbon generation technology. It has an estimated abatement cost of £1/t Carbon (equivalent to £0.3/tCO$_2$) compared with on-shore wind power, the next nearest currently available low-carbon electricity generation technology, which has an estimated abatement cost of £182/t Carbon (equivalent to £50/tCO$_2$).”

**7.33** Furthermore, the marginal abatement cost curve also shows technologies with an abatement cost exceeding that for nuclear, and also exceeding the shadow price of carbon, that are nevertheless already supported by government. These include both electricity generation and non-generation technologies. Among the generation technologies they include both on-shore and off-shore wind.

**7.34** Although the government’s earlier analysis and that in the White Paper differ in detail, for the purpose of this application their conclusion is clear. Because the levelised cost of nuclear generation is only marginally unfavourable relative to gas, but it avoids almost all the CO$_2$ that gas would emit, nuclear is the most cost-effective electricity generating technology for carbon abatement in which to invest. It is also more cost-effective than some other technologies that are already supported by government.

**Resource costs to government**

**7.35** In addition to the wider economic assessment set out above, the analysis identified the resource costs and risks falling specifically to government in enabling a new build nuclear programme. On resource costs it concluded that:

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“If it is decided to keep the door open, the related resource cost would be limited initially to work required for improving the planning process, and for elaborating details of waste and decommissioning funds.”

Work to improve the planning process is now in hand for England and Wales via the Planning Bill, with application across all categories of infrastructure. Work to establish waste and decommissioning funding arrangements is also now in hand.

In the Nuclear White Paper, the government has set out its intent:

“Through the Energy Bill, we are introducing legislative arrangements to ensure that operators of new nuclear power stations have secure financing arrangements in place to meet the full costs of decommissioning and their full share of waste management costs”.

7.36 On wider government liabilities, the analysis concluded that:

“Government financial liabilities would be limited for new nuclear projects brought forward on a commercial basis by project sponsors with strong balance sheets. The likelihood is that commercial projects would only be forthcoming in a world where the supporting policy framework is in place, in which case expected economic benefits would be positive.”

These are judged to result in limited resource costs and financial liabilities, so that:

“Keeping the door open for investment in new nuclear capacity would seem to be a low risk option from an economic point of view.”

The supporting policy framework now in hand, following the Nuclear White Paper, also includes Generic Design Assessment by safety, security and environmental regulators, Strategic Siting Assessment / Strategic Environmental Assessment by BERR, and the assessment of justification sought by this application.

In addition, provisions are in place to ensure that the cost of the safety and environmental regulators’ assessment is borne by the vendors of the designs and not by the government. They are then internalised as part of the cost of any project using that design. Further, the Energy Bill proposes that operators will bear the costs of the government’s assessment of proposals for funded decommissioning programmes put forward by operators.

The impact assessment for the Nuclear White Paper has made an indicative estimate of the expenditure required by Government to undertake the planning, funding, regulatory and other policy measures identified above. This estimate is up to £50m present value, with most of these costs being recovered from the industry.
7.37 It is concluded that deployment of the practice is not expected to impose an economic detriment on the wider UK economy as a result of the resource costs falling to government.

Conclusion of government’s analysis

7.38 The summary conclusions of the government’s analysis on nuclear economics and economic risk are that:

- “Investment in new nuclear capacity can be justified economically in some – but not all – the states of the world considered in this analysis:

- Adding new nuclear capacity could help to reduce forecast carbon emissions, and to reduce the level of forecast gas consumption / imports

- Within power generation, new nuclear appears to be a cost effective means for meeting carbon emissions reduction targets. Adding new nuclear capacity would not preclude investment in other forms of low carbon generation

- Investment in nuclear new build would result in carbon abatement cost savings sufficient to offset the nuclear cost penalty relative to gas fired plant in a central gas price scenario

- Adding new nuclear plant would also partially mitigate risks associated with dependence on imported gas. In particular, costs associated with insuring against the risk of fuel supply interruption (e.g. through adding gas storage capacity) could be reduced as nuclear plant is added. Investment in new nuclear capacity would also provide a hedge against the risk of high gas prices

- Nuclear investment is not justified at the higher end of the range of costs, or in a low gas price world.

- Keeping the door open for investment in new nuclear capacity would seem to be a low risk option from an economic point of view:

- The risk of high nuclear costs could be limited through design of the regulatory framework (e.g. through pre licensing of plant designs, and other rationalising of the planning process)

- If carbon reduction continues to be a Government objective, it is likely that the carbon price will be sufficiently high to justify nuclear investment, except in a low gas price world

- If the Government is averse to the strategic risks of dependence on imported gas, it could attach more weight to the benefits of adding nuclear capacity in a high gas price world rather than costs in a low gas price world

- The resource cost in keeping the door open to new projects is limited. Financial liability for the Government would be limited under the assumption that any projects will be delivered on a commercial basis (i.e. by investors with strong balance sheets, absent subsidy, etc)"
Long-term assessment

7.39 Annex A of the Nuclear White Paper complemented the “bottom-up” analysis of the cost-effectiveness of nuclear summarised above with a “top-down” assessment of the medium to long-term energy mix out to 2050. It considered how the UK could deliver its medium to long-term goals for energy policy without new nuclear power stations.

This assessment was based on a model of the UK energy system, the MARKAL-macro model. It analysed different long-term scenarios, and how these affected the combination of technologies that could allow the UK’s goal of reducing carbon emissions by 60% by 2050 to be met at least cost. In particular, it analysed scenarios in which new nuclear power stations were not allowed to be built, while still enforcing the requirement to meet the UK’s carbon reduction goal, and to do so at least cost to the UK economy.

7.40 The assessment found that to exclude new nuclear power stations would require more expensive options to be considered, both within and outside the electricity sector. These included even greater reductions in emissions from transport.

Furthermore, it noted that many forms of renewable generation are intermittent, and depend on external forces that are not always available (for example tides or wind). As a result electricity generation costs could be higher because of the greater costs of balancing the electricity system and of retaining or building thermal plant to maintain security of supply.

7.41 The assessment estimated the economic detriment attributable to these factors:

- “Delivering the 60% goal for CO\textsubscript{2} reduction in the scenario where we exclude new nuclear power stations, and all other technologies become available and are successfully deployed by 2050 at the cost assumed in the modelling, would by 2050 imply an additional annual cost to the UK economy of £1 billion compared to a scenario where nuclear power is available.”

- “If, in addition, the application of CCS [carbon capture and storage] on power generation were not to prove feasible, the model estimates that the cost in 2050 of achieving the 60% goal is likely to be at least an additional £5 billion per annum, compared to a scenario where all options were available.”

Irrespective of the precise target, because the modelling does not capture some of the uncertainties inherent in its assumptions, the assessment concluded that:

“We believe the cost estimates that the MARKAL model provides are likely to be at the lower end of estimates of the expected costs.”

Thus by 2050 the annual benefit to the UK economy from allowing new nuclear stations is likely to exceed £1bn. This supports the conclusion that deployment of the practice will not impose an economic detriment on the wider UK economy.

7.42 The government has also carried out further assessment using the MARKAL-macro model on the impacts of moving to a yet more tightly carbon constrained energy system, with reductions in CO\textsubscript{2} of 70% and 80% by 2050.\textsuperscript{138} To achieve these targets the electricity sector is key: it must almost fully decarbonise by the target date.

\textsuperscript{138} MARKAL Macro analysis of long run costs of climate change mitigation targets, Defra, 2007
The main change observed from moving to a 70% reduction is an overall higher level of generation delivered by nuclear generation. The 80% constraint has much higher levels of renewable use, driven by increasing electricity generation from wind. However to achieve this involves important practical challenges:

“It is worth noting that this is enabled by large amounts of wind generation (with little account for grid stability or constraint issues, planning etc) and a prominent role for CCS, a technological option still at the demonstration stage.”

<table>
<thead>
<tr>
<th>Scenario for CO2 price (£/te CO2) in 2050</th>
<th>60% reduction</th>
<th>70% reduction</th>
<th>80% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear allowed</td>
<td>65</td>
<td>145</td>
<td>215</td>
</tr>
<tr>
<td>Nuclear excluded</td>
<td>-</td>
<td>201</td>
<td>232</td>
</tr>
</tbody>
</table>

7.43 If nuclear is excluded from the mix, the modelling predicts that wind generation would fill the gap – but if this is constrained by the practical challenges, gas CCS becomes the significant generation technology. This is preferred over coal CCS because of its lower carbon intensity, and hence the higher penetration into the electricity mix that can be achieved within any finite CO2 storage capacity.

If both nuclear and CCS are excluded and the constraints on realistic wind penetration are taken into account, the focus falls onto reducing electricity demand:

“End-use sectors have to rely more heavily on conservation and endogenous demand response rather than low carbon electricity as before.”

7.44 The modelling predicts that, as the emission reduction targets become more stringent, the energy system requires a progressively higher CO2 price signal to respond appropriately, given the marginal abatement cost of the available alternatives. For the reference case of 60% reduction, the required price is approximately £65/teCO2. The impact of 70% and 80% reductions is set out in the table.

The increase in price required to achieve these reductions is substantial. It increases yet further if other alternatives such as CCS are also excluded.

The Macro model also makes a direct calculation of the consequences for gross domestic product (GDP), based on the interactions between the energy sector and the rest of the economy, and how this impacts on levels of consumption and investment. The reference GDP in 2050 is assumed to be £2.8 trillion.

As examples on a comparable basis, the loss in GDP to meet the emission reduction targets is estimated as 0.8% (£22.2bn) for 60% reduction, 1.1% (£29.8bn) for 70%, and 1.6% (£44.9bn) for 80%.

In the last case, if nuclear is excluded the loss increases to 1.71% – an incremental loss to GDP of £3bn. Again this supports the conclusion that deployment of the practice will not impose an economic detriment on the wider UK economy.

Overall conclusion on economics

7.45 Based on the government’s own analyses, adoption of the proposed practice is highly likely to be beneficial for the UK economy when environmental and security of supply benefits are taken into account.
7.46 It represents the most cost-effective means available within the generation sector of mitigating carbon dioxide emissions, and it is more cost-effective than some other technologies that are already supported by government.

7.47 Not all of the environmental and security of supply benefits may accrue to the developer of nuclear projects. Nevertheless, such projects are likely to be economic for developers given the government’s stated policy intent to pursue a range of facilitative actions, and to ensure a long-term price for carbon.

7.48 To the extent that the electricity market is competitive and that the economic cost of the practice is lower than for alternative electricity generating technologies such as gas, consumers can also expect to benefit via downward pressure on electricity prices.

7.49 Against the conservative criterion relevant to this submission, deployment of the practice is not expected to impose a detriment on the wider UK economy.
Other Potential Detriments

Chapter 8 - Other Considerations

The wider impacts resulting from the adoption of the proposed practice would result in no significant detriments.

There would be little change to existing very small proliferation risks.

Stringent health and safety standards would provide a safe workplace, and the risks of accidents would be very low.

Stations would be protected against the effects of climate change, and their structural resilience, shielding and security measures would provide protection against terrorism.

Operation would provide long term socio-economic benefits to local economies and wider short-term socio-economic benefits during construction.

Introduction

8.1 This Chapter considers other benefits and detriments that might result from adoption of the proposed technology. The following detriments are examined in the sections below:

- Non-Proliferation
- Industrial safety
- Climate Change Impacts
- Security

8.2 The final section outlines the potential socio-economic benefits arising from the construction and operation of a new nuclear power station.

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 would not materially change the existing very low proliferation risk. As noted by the Sustainable Development Commission (SDC)\(^{139}\), the safeguards measures that are in place have been effective to date in ensuring that materials diversion has not taken place. There would be major technical difficulties involved in obtaining weapons-grade material from irradiated fuel used in our example designs.

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\(^{139}\) The role of nuclear power in a low carbon economy Paper 6: Safety and security. An evidence-based report by the Sustainable Development Commission with contributions from Large & Associates and AMEC NNC March 2006,
8.4 The cornerstone of international efforts to prevent the spread of nuclear weapons is the Nuclear Non Proliferation Treaty (NPT)\textsuperscript{140} and the associated safeguards provided by the verification regime of the International Atomic Energy Agency (IAEA).

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 UK Safeguards Act 2000. Furthermore, the UK is also subject to European safeguards as laid out in the Euratom Treaty\textsuperscript{141}. 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 would be subject to these IAEA and EU safeguards measures, which have been effective internationally in verifying a wide range of reactors and associated fuel cycle plants over many years. New build based on the introduction of modern designed, light water cooled reactors would present no new issues of principle.

8.8 Any new 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 is difficult, and the fuel elements used in modern commercial light water reactors would not be a good source material for an 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 this low enrichment; neither new nor irradiated fuel is weapons-grade material.

8.10 The AECL ACR-1000 reactor uses heavy water (deuterium oxide), which is a material used in some nuclear weapons production processes. However this would be carefully controlled – see Annex 6A paragraph 8.1. This feature is not therefore considered to affect materially the assessment of the net benefits from this design in relation to the other example designs considered in this application.

8.11 Supplies of heavy water are readily available as described in Annex 6A. There is no requirement for a production facility in the UK.

8.12 The paragraphs above show that any additional risks of proliferation resulting from the proposed practice and the reactor technologies within the envelope of this application are very small. Any associated detriment is therefore also very small. The Government stated in its White Paper on Nuclear Power 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

\textsuperscript{140} Treaty on the Non-Proliferation of Nuclear Weapons. IAEA INFCIRC/140, 1970
\textsuperscript{141} 25 Treaty establishing the European Atomic Energy Community, 17
regulatory framework that ensures that these risks are minimised and sensibly managed by industry”. 142

**Industrial Safety**

8.13 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.143 Table 8.1 below shows steadily improving performance that compares well to other industries. Against this background the potential industrial safety detriments relating to new power stations such as the reactor technologies within the envelope of this application would be very low, and similar to or lower than those resulting from other major industrial infrastructure projects.

**Table 8.1 – Industrial Safety Accident Rate**
The industrial safety accident rate tracks the number of accidents that result in lost worktime, restricted work, or fatalities per 200,000 work-hours

<table>
<thead>
<tr>
<th>Stations Reporting</th>
<th>Number per 200,000 man-hours worked</th>
<th>Number per 1,000,000 man-hours worked</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990 169</td>
<td>5.20</td>
<td>7.50</td>
</tr>
<tr>
<td>1995 192</td>
<td>1.04</td>
<td>1.20</td>
</tr>
<tr>
<td>2000 203</td>
<td>0.58</td>
<td>0.30</td>
</tr>
<tr>
<td>2001 200</td>
<td>1.63</td>
<td>1.65</td>
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<tr>
<td>2002 203</td>
<td>1.65</td>
<td>1.54</td>
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<tr>
<td>2003 201</td>
<td>0.31</td>
<td>0.28</td>
</tr>
<tr>
<td>2004 210</td>
<td>1.54</td>
<td>1.06</td>
</tr>
<tr>
<td>2005 208</td>
<td>1.42</td>
<td>1.30</td>
</tr>
<tr>
<td>2006 209</td>
<td>1.50</td>
<td>1.21</td>
</tr>
</tbody>
</table>

**Impacts of Climate Change**

8.14 The siting of any new nuclear power stations would take into account the implications of climate change, including the possibility of more severe weather patterns and rising sea levels in some coastal locations. The technologies enveloped in this application are already highly robust with substantial capability to withstand

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142 A White Paper on Nuclear Power, Cm 7296, January 2008, Page 80
extreme events such as high temperature. The controls and measures to deal with any additional risks that may arise are being addressed as part of the generic design or site specific development process.

8.15 The Nuclear Installations Inspectorate expects operators to provide a high standard of flood risk protection to ensure 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. This regular scrutiny and review ensures that any changes in external hazards are identified and any necessary further measures implemented.

8.16 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 wastes in interim storage have been removed from the site.

8.17 It can be seen therefore that the risks from climate change will not materially change the very low risks from reactor technologies within the envelope of this application and so any potential detriment is very low.

Security

8.18 New nuclear power stations, like the UK's existing nuclear fleet and other major infrastructure installations, could be potential targets for terrorist attacks 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. The potential detriment from reactor technologies within the envelope of this application is therefore very small.

Security Measures and Regulatory Framework

8.19 Security measures for nuclear power plants in the UK are regulated under the Nuclear Industries Security Regulations (2003) (SI 2003. No 2003) as amended by the Nuclear Industries Security (Amendment) Regulations 2006 (SI 2006 No. 2815). The regulations are applicable to the whole of the nuclear industry and make provision for the protection of nuclear material, 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. Consequently the site licensee is required to develop and implement a security plan to ensure the security of the site. The plan is subject to the scrutiny and approval of an independent security regulator, the Office for Civil Nuclear Security (OCNS) which is now a division of the NII.

8.20 The comprehensive measures required include not just the physical aspects of the security regime (access controls, alarms, CCTV, etc) but armed response requirements, and processes to ensure the reliability of staff and contractors and the security of computer systems. All are subject to prior approval, independent review and audit by OCNS.
8.21 In addition to deploying a well trained guard force, the UK is unique in having a dedicated Constabulary (the Civil Nuclear Constabulary) 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).

8.22 Staff, contractors and Constabulary officers with access to nuclear sites are required to undergo security checks to a level of detail dependent on the nature of their work. The assessment of individuals’ reliability is an ongoing process. This provides a high level of protection against infiltration threats.

8.23 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 OCNS.

8.24 More generally operators and the regulator review security measures in line with current threat assessments, and the OCNS regularly inspects sites to ensure that the security arrangements detailed in security plans are being followed. Against this background, as noted in the Nuclear consultation paper, the OCNS believes that the security risks associated with building new nuclear power stations can be appropriately managed.

8.25 Additionally the Government has enacted legislation to provide additional protection beyond the substantial provisions described above. The Anti-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 Anti-Terrorism Act makes it an offence to utilise radioactive materials or facilities for terrorist purposes. The Anti-Terrorism, Crime and Security Act strengthens sanctions against the unauthorised disclosure of sensitive information on the security of nuclear sites, nuclear material and proliferation-sensitive nuclear technology.

Physical Protection and Design Features

8.26 The potential vulnerability of nuclear power stations to terrorist or other malicious threat is further reduced by the fact they are amongst the most robust civil structures in the world, and have a multi-layered defence.

8.27 Modern reactors are protected by massive structures and are designed to safely withstand extreme events, both natural and manmade. Their structural resilience to earthquakes and the thickness of the shielding make them extremely robust against aeroplane crashes, both random and intentional.

8.28 After the attacks of 11 September 2001, the Electric Power Research Institute undertook a detailed study 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 compared to operating plants is expected.
8.29 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.

8.30 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. Hence the risks of theft of spent fuel are very low.

8.31 In addition to their physical robustness, nuclear reactors are protected by extensive safety systems. The defence in depth concept applied 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 immediately shut down reactors in the event of a heightened terrorist threat against them.

Dirty Bombs

8.32 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 design features and security measures that protect a nuclear power plant also ensure the security of radioactive materials from theft.

Socio-economic benefits

8.33 In addition to the major security of supply and carbon reduction benefits described in chapters 2 and 3 there would also, as with other major infrastructure projects, be significant socio-economic benefits to the local economy resulting from a new nuclear power station. Depending on the design adopted and operational practices each nuclear power plant would employ around 500 workers: such long-term, high quality and stable jobs would be especially valuable in the remote communities that host nuclear power stations. During outages an additional workforce consisting of around 1000 people would contribute to the local economy. In addition, local businesses and services would benefit, both in terms of providing services to the station and from the wider economic effect.

8.34 The construction of the station would bring major benefits to the UK construction and manufacturing industry. Most of the engineering work on a new nuclear plant is not nuclear specific, but similar to work being carried out by many projects throughout the UK. A recent report by the NIA on the “UK capability to deliver a new nuclear build programme” concluded that, with relevant investment in
resources, the UK nuclear supply chain had the capability to deliver up to 80% of new nuclear power station projects. An assumed programme of 10 reactors such as those reactor technologies within the envelope of this application, located at 5 sites constructed over a period of 20 years could lead to the creation of over 2000 skilled jobs in the sector over the 20 year construction period and 450-500 hi-tech operational jobs at each station.

Conclusion

8.35 New nuclear power stations will be protected against the risks of proliferation, terrorism, and the possible impact of climate change. The potential detriments from the proposed practice, and therefore the reactor technologies within the envelope of this application, posed by these potential events are extremely small.

8.36 Conversely, implementation of the proposed practice could result in significant benefits to the local economy around sites and to the UK nuclear supply chain.
Chapter 8 - Addendum

Additional information provided in response to questions raised in relation to Chapter 8 in the Notice under Regulation 16 of the Justification of Practices Involving Ionising Radiation Regulations 2004

Q13. The applicant is asked to provide further information on security of supply and export control issues of heavy water, required for the ACR-1000 reactor.

Annex 6A provides further information as follows on the security of supply and export control issues for heavy water.

Heavy water is a controlled material and is therefore similar to other key reactor components such as reactor pressure vessel, steam generators and control rods. As stated in section 8.1 of Annex 6A, its import into the UK would require an export permit from International Trade Canada and a licence by the Canadian Nuclear Safety Commission (CNSC). The export of heavy water would be subject to a Nuclear Cooperation Agreement (NCA) signed by Canada and Euratom, to provide treaty based assurances that Canadian nuclear exports are used solely for peaceful purposes.

In relation to security of supply, subject to securing the appropriate export control assurances as described for Canada, heavy water can also currently be sourced from other countries including the USA, Argentina, Romania and India. The construction and operation of a heavy water plant in the UK to support an ACR-1000 project is therefore not required in the UK. AECL has offered to guarantee the supply of heavy water needs for any new ACR-1000 built in the UK.

Q14. The applicant is asked to provide further information on the “controls and measures” noted in para 8.14 to address additional risks from the implications of climate change.

Climate change has two principal effects that need to be considered in the safety of any nuclear power station. These are:

a. the possibility of more severe weather patterns (associated with increased temperatures, increased wind speed and increased precipitation intensity)

b. rising sea levels in some coastal locations in the UK.

The work\(^1\) done by British Energy for its sites in relation to new nuclear build illustrates the approach that would be taken by any operator.

Regarding the impact of more severe weather predicted to occur in the UK: the range of effects is already within the range sustained by nuclear power stations elsewhere. As stated in the application, the technologies enveloped by our application are already highly robust with substantial capability to withstand extreme events such as high temperature, and so any detriment from more intense weather patterns is very small.

Controls and measures would be required to deal with any additional risks from flooding.

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 of the outputs from the Intergovernmental Panel on Climate Change.

\(^1\) Climate change and replacement nuclear build, British Energy, November 2007
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.

The example reactors referenced in our application all include robust flood defence provisions and so together with any site specific flood defences would be protected from flooding risks due to climate change. The example designs are therefore no more prone to flooding risk than operating reactors. Confirmation of this is provided in our application as follows:

<table>
<thead>
<tr>
<th>ACR-1000</th>
<th>AP1000</th>
<th>EPR</th>
<th>ESBWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 3.1 of Annex 6A states “The implementation of these safety measures is provided by safety systems, safety support systems, safety-related systems and robust buildings and structures that meet high standards for diversity, reliability and protection against common mode events such as seismic, fires, flooding and unauthorised acts.”</td>
<td>Section 3.3 of Annex 6B states “The overall design of AP1000 includes features such as reinforced concrete structures, diverse and redundant systems which make the design well protected against all sorts of hazards (earthquake, flooding, fire, aircraft crash).”</td>
<td>Section 3.3 of Annex 6C states “The design of the safeguard systems and civil works structures minimises the risks from hazards (earthquake, flooding, fire, aircraft crash).”</td>
<td>Section 3.3 of Annex 6D states “....defence in depth has been demonstrated through a detailed PSA and associated sensitivity studies. These assessments demonstrate the physical robustness of the plant against internal and external hazards such as aircraft crash, earthquake, extreme temperatures, floods and fire.”</td>
</tr>
</tbody>
</table>
Chapter 9 - Summary of net benefits against radiological health detriments

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 strongly outweigh the potential radiological health detriments.

Our approach here is to assess the broad scale of the “net benefit” provided by the practice, and to compare this with the scale of the potential radiological health detriment. Because we judge the benefits from security of supply and carbon reduction to be so significant, we have not attempted to identify in this application any other potential benefits that might also arise. We have however sought to consider the full range of potential detriments that could in theory erode the significant benefits of the practice.

Detailed technical information on all four example designs (ACR-1000, AP1000, EPR and ESBWR) is provided in the annexes to the main application to demonstrate they fall within our proposed practice and share the defining attributes of the proposed practice. The example designs therefore each have a similar detriments/benefits balance to that we assess for the proposed practice. Whilst there are some specific differences between the technologies we do not believe that these affect the detriments/benefits balance. We therefore consider that the Justifying Authority decision on the proposed practice would also cover all four example designs and would be valid for other examples of evolutionary designs with the same defining attributes.

Security of Supply Benefits

By providing large scale, reliable and secure generation new nuclear plant would help achieve the diverse generation mix sought by government, and would help maintain electricity supplies in the event of disruption to fossil fuel imports. New nuclear stations could make a contribution by as early as 2017/18.

Sufficient uranium is available to fuel existing and potential new stations. Nuclear stations are relatively invulnerable to fluctuations in the availability of fuel. Low fuel and predictable operating costs would act as a stabilising influence on UK electricity prices.

For these reasons the new practice would contribute significantly to the UK’s energy security, and this represents a major benefit from the practice.

Carbon reduction benefits

Nuclear power is a low carbon generating technology with emissions across the entire life cycle comparable to those from wind generation. Over their 60-year lifetime a series of new nuclear reactors providing the same amount of electricity as the existing ones could save 1.7 billion tonnes of carbon dioxide compared with generating the same energy from gas-fired power stations. This is about three times the UK’s current total annual carbon emissions. The government has concluded that “ruling out nuclear power as a low-carbon option would significantly increase the risk of the UK failing to meet its long-term carbon reduction goals”.

For these reasons the new practice would contribute significantly towards meeting the UK’s carbon reduction targets and this represents a further major benefit from the practice.

Consideration of potential detriments

We now consider whether there are any detriments that are of a scale that they could significantly erode the major benefits identified above.

Radioactive Waste, Spent Fuel and Decommissioning

New UK nuclear power stations would create only a relatively small amount of radioactive waste, representing a manageable addition to those that already exists in the UK. The types of waste and spent fuel created would not be different to those already existing and for which management, interim storage, and disposal solutions exist. These solutions are either ones that have already been demonstrated in the UK or are being implemented under Government-led processes. From outside the UK, there is also considerable and growing international experience to build on.

These materials and the spent fuel arising from the practice could be disposed of within a co-located deep repository and could be safely stored until this became available. The additional excavation within the repository that could be required to accommodate the additional material does not represent a significant detriment to the UK.

Decommissioning of nuclear facilities is now well understood and, again, there is extensive and growing world-wide experience available.

The government has made it clear that the nuclear liabilities costs – both of radioactive waste and spent fuel management, and for the decommissioning of any new nuclear power stations – would have to be met by the owners of these facilities and not by the taxpayer. The applicant has confirmed the industry is prepared to accept this and will conform to any reasonable arrangements established to ensure this objective is achieved.

For these reasons there can be confidence that the overall detriment from radioactive waste, spent fuel and decommissioning associated with the new practice would be small.

Wider Environmental Impacts

Other environmental impacts would be comparable with or less than those of other large-scale electricity generation. They would be properly mitigated, and kept to a minimum. New nuclear power stations would meet all applicable standards and regulations.

For these reasons the overall environmental impacts and hence the associated detriment from the proposed practice in this area would be small.
Economic Assessment

9.17 The Government’s White Paper on Nuclear Power concluded that:

- “Under the most likely scenarios for gas and carbon prices, nuclear power would yield economic benefits to the UK in terms of reduced emissions of CO₂ and improved security of supply”
- “On the basis of our cost-benefit analysis, we believe that nuclear power is likely to be an attractive economic proposition to [investors]”

9.18 A new nuclear power programme is therefore expected to be economically beneficial to the UK and an attractive economic proposition to investors. The likelihood of an accident and associated economic penalties is so remote that it can be discounted.

9.19 For these reasons there is only a remote possibility that the practice might impose an economic detriment on the wider UK economy. Indeed it is much more likely that there would be a benefit, although our application does not rely on this.

Other Considerations

9.20 There would be little change to existing very small proliferation risks. Stringent health and safety standards would provide a safe workplace, and the risks of accidents would be very low. Stations would be protected against the effects of climate change, and structural resilience, shielding and security measures would provide protection against terrorism. Moreover, construction and operation would provide socio-economic benefits to local economies.

9.21 For these reasons the wider impacts resulting from the adoption of the proposed practice would result in no significant detriments.

Summary on the “Net Benefit”

9.22 Having considered all the above potential detriments, none have been identified that could be of sufficient scale either individually or in combination to detract significantly from the major benefits to the UK from the proposed practice.

Scale of Potential Radiological Health Effects

9.23 New UK nuclear power stations and their associated processes would be capable of meeting all applicable dose limits and constraints. The mature regulatory system governing this practice would lead, following optimisation, to doses that would be far below these levels. We estimate that the scale of the additional annual dose to those individual members of the public most affected would be of the same order as one additional return air flight from the UK to New York per year.

9.24 However we do not need to rely on such a low figure of radiological impact for the purposes of this justification application. In this application, which of necessity has to precede the results of radiological optimisation, we rely on the figure being less than 0.3mSv/y – the constraint for doses to the public from new facilities operated in the UK. This is a maximum figure for any member of the public; average individual doses
to the UK population as a whole have been shown to be so low as to be of no concern.

9.25 Stringent safety and security requirements would ensure that the likelihood of accidents leading to significant releases of radioactive materials would be very remote. New evolutionary designs of power station would meet and almost certainly exceed current standards for accidents. Throughout the entire UK history of civil nuclear power station operation there has never been any accident requiring emergency action to protect the public.

9.26 Doses to workers as a result of the new practice would also be low and comparable with or lower than those received currently by those already employed in the nuclear power industry or in other activities incurring exposure to radiation – for example airline crews.

9.27 The “Government stated in the White Paper on Nuclear Power that it “…continues to believe that new nuclear power stations would pose very small risks to safety, security, health and proliferation”.

9.28 For these reasons the overall radiological health detriment would be very small.

Overall Conclusion

9.29 The identified benefits for the UK from the proposed new practice are very significant. Consideration of a wide range of potential detriments has confirmed that, even taking these fully into account, there would be a major net benefit. By comparison the potential radiological health detriments, even without relying on the full effects of optimisation, would be small.

9.30 The applicant therefore concludes that the proposed practice should be justified.