Nuclear Decommissioning Authority

Eden Nuclear and Environment

NDA Strategy (2021)

Integrated Impact Assessment Report

Volume 1: Main Report

Final Draft

March 2021

Contents

Executive summary 1

1.0 Introduction 4

1.1 Introduction 4
1.2 Objectives of the IIA 4
1.3 Purpose of the report 4
1.4 IIA report structure 5

2.0 Project background 6

2.1 The NDA mission 6
2.2 The NDA estate 6
2.3 NDA Strategy (2021) 6

3.0 Baseline conditions 8

3.1 Introduction 8
3.2 Environment 8
3.3 Socio-economics 9
3.4 Health 9

4.0 Strategy themes and topics 10

4.1 NDA Strategy (2021) themes and topics 10
4.2 Site Decommissioning and Remediation 10
4.3 Spent Fuels 11
4.4 Nuclear Materials 12
4.5 Integrated Waste Management 12

5.0 Baseline scenarios and preferred and credible options 15

5.1 Baseline scenarios and preferred and credible options 15
5.2 Site Decommissioning and Remediation 15
5.3 Spent Fuels 17
5.4 Nuclear Materials 18
5.5 Integrated Waste Management 18

6.0 Approach to assessment and methodology 20

6.1 Introduction 20
6.2 Requirements of SEA, SeIA and HIA 20
6.3 Other regulatory regimes 21
6.4 Geographic scope 22
6.5 Temporal scope 23
6.6 Key assessment steps 23
6.7 Determining significance and accounting for uncertainty 24
6.8 Baseline activities 26
6.9 Proposed assessment framework and guide questions 26
6.10 Assumptions and uncertainty 26
6.11 Response to informal scoping consultation 26

7.0 A, SeIA and HIA topics 28

7.1 Strategic Environmental Assessment topics 28
7.2 Socio-economic Impact Assessment topics 31
7.3 Health Impact Assessment topics 32

8.0 Integrated Impact Assessment of the NDA Strategy (2021).......... 36

8.1 Introduction 36
8.2 Site Decommissioning and Remediation 36
8.3 Spent Fuels 44
8.4 Nuclear Materials 51
8.5 Integrated Waste Management 56
8.6 Cumulative effects 58

9.0 Measures to mitigate risks and enhance opportunities 61

9.1 Introduction 61
9.2 Potential mitigation / enhancement measures 61
9.3 Potentially vulnerable groups 66
9.4 Proposed monitoring 66

10.0 Conclusions and next steps 67

10.1 General conclusions 67
10.2 Next steps 67

11.0 References 68

Appendix A Register of assumptions and uncertainties 72

Appendix B IIA assessment guide questions 76

Executive summary

Overview

The NDA is undertaking its third five-year review of its Strategy, in accordance with the Energy Act 2004. The Strategy reviews the NDA's strategic position, establishing and maintaining strategic direction on activities across the sites in its estate. The strategies that have been selected are carried out by Site Licence Companies (SLCs), which manage the sites on the NDA's behalf and under its strategic guidance.

The Integrated Impact Assessment (IIA) of the NDA Strategy (2016) has been reviewed and updated to align with Strategy (2021) and the latest NDA Business Plan (2020-2023). Underpinning data and the legislative context review in Volume 3 of the IIA have been updated and options have been revised and reassessed in line with updates to the NDA Strategy in Volumes 1 and 2. The main changes are as follows:

- Reprocessing at the Thermal Oxide Reprocessing Plant (THORP) has ceased. As a result, the option to extend processing capability for spent oxide fuels has been removed.
- Credible options for the management of exotic spent fuel were under development at the time of the 2016 IIA. They have now been defined and have been assessed in the 2021 IIA.
- In the 2016 IIA, the options for the decommissioning topic were continuous decommissioning and deferred decommissioning. In the 2021 IIA, the continuous decommissioning option has been split into two options: 'decommissioning at a pace' and 'decommissioning slowly but without interruption'.
- The option to hold uranium as a nil value asset has been removed as no credible end-point was identified (sale for reuse is a separate option that has been retained).
- New Government commitments have been introduced including the commitment to reduce carbon emissions to net zero by 2050 and new clean air commitments to increase air quality.
- Environment agencies' *Management of radioactive waste from the decommissioning of nuclear sites: guidance on the requirements for release from radioactive substances regulation* (GRR) was published, which directly affects NDA sites.
- Environmental baseline data such as air pollution, biodiversity and carbon dioxide emissions have been updated.
- Health baseline data including cancer incidence, life expectancy at birth and deaths from coronary heart disease have been updated.
- Socioeconomic baseline data such as site employment figures, business births and deaths and indices of multiple deprivation figures have been updated.

The IIA of the NDA Strategy (2021) comprises the combined assessment results of a Strategic Environmental Assessment (SEA)[1], Health Impact Assessment (HIA) and Socio-economic Impact Assessment (SeIA).This report details the findings of the IIA of the NDA Strategy (2021) to be used in statutory consultation alongside the NDA Strategy (2021) document. This report will also serve as a guide for future assessment work undertaken by the NDA, SLCs and other relevant parties. The assessment methodology will inform future selection of preferred options.

For the purposes of this assessment, the potential impacts of the NDA Strategy (2021) are divided into generic phases and activities involved in implementing the preferred strategic options.

Construction of new facilities / modification of existing facilities

Construction of facilities such as treatment plants and stores could have a range of potential environmental impacts. This may include changes in air quality from the emission of pollutants, increases in noise and vibration from the movement and use of plant and machinery, and changes in the local landscape. The movement of construction traffic and activities such as excavation also have the potential to result in land

[1] This statement is simplified; SEA and IIA both include health and socio-economic assessments, whereas "SEA" in this report refers to all other aspects related to environment which are covered under SEA.

and water contamination. Construction would involve the use of energy and materials which, given the extent of facilities that may be required under some options in the Strategy, may be substantial and would lead to carbon emissions (with implications for climate change).

Environmental impacts such as these could lead to effects on health. For example, changes in air quality have been linked to increased risk of cardiovascular and respiratory conditions, whilst increases in noise and vibration can cause disturbance and annoyance. The movement of construction traffic can affect the local road network, increasing the risk of road accidents and driver stress. Health effects may also occur if construction leads to a loss of, or decline in recreational facilities and amenity spaces, as this can affect the level of physical activity undertaken by the local population.

Construction would provide opportunities for employment, both in terms of construction jobs and specialist nuclear and engineering roles, and may create opportunities for education and training.

Operation of new facilities

During the operational phase of facilities, there would be ongoing energy use and carbon emissions, which might have implications for climate change. A number of options in the Strategy would generate considerable amounts of waste material, which may subsequently increase in volume, depending on the technologies used to treat them.

New facilities may be operational for many years, which would have a lasting impact on the local landscape and may adversely affect the quality of views from locations surrounding the NDA sites. There may also be increased risks of flooding and, if the site is located in a coastal region, risks from changes in the coastal environment such as erosion, sea level rise and changes in wave patterns.

From a radiological perspective, all options set out in the Strategy are in some way designed to reduce the risk or hazard associated with radioactive materials, wastes and contamination in line with the NDA mission. For some options, this will involve converting or conditioning the radioactive material into a safer and more secure form. Changes in the risk profile of radiological discharges over time may have implications from a health perspective.

Operation of new facilities would support jobs of various types, including specialist nuclear engineering and managerial positions in addition to general plant operation and maintenance roles. For some options, knowledge and skills which could be of national benefit may be developed, while education and training may be required to implement others.

Closure of facilities (existing and new)

The closure of facilities, which is required for a number of options in the Strategy, could result in a range of environmental impacts. These would largely be associated with decommissioning activities such as excavation and demolition which can produce air and noise pollution, and may lead to or worsen land and water contamination. On the other hand, removal of structures and facilities can lead to landscape and visual improvements, as well as improving soil and water quality in the long-term, thereby facilitating the reuse of land for other purposes.

During this phase there are likely to be substantial transport movements of plant, equipment and wastes. This may have implications from an air quality perspective, and may put nature and cultural heritage features near to site access roads at risk of impacts.

In terms of health, changes in traffic on the local road network may increase the risk of accidents and lead to driver stress, which can trigger physiological responses such as elevated heart rate. Health effects such as annoyance and anxiety may also be caused by noise and vibration from traffic increases and demolition.

The closure of facilities may lead to a number of socio-economic effects, including potential loss of employment, knowledge, skills and in some cases national assets. However, the closure of facilities and other activities which facilitate decommissioning of a site may also free up land for alternative uses. If this land can be divested, it may become a local asset, potentially providing some form of environmental, economic or community benefit.

Maintenance of existing facilities

From an environmental perspective, the ongoing maintenance of facilities will require the use of materials and energy. This may be to renovate existing structures or to replace structures which have reached the end of their life. Such activities can lead to emissions of carbon dioxide and other greenhouse gases. Maintaining facilities may also extend visual impacts upon the local landscape.

Maintenance activities support employment and can create other socio-economic opportunities, such as improved knowledge and skills. An example of this is the knowledge and skills gained from developing techniques for extending the life of radioactive waste stores.

In terms of radiological risks, ongoing maintenance of facilities is undertaken to minimise radiological risks to the environment and the public. In some situations, the radioactive material being stored in such facilities may itself become more hazardous over time; in such cases, maintaining existing facilities indefinitely, as an alternative to developing a better long-term management route, could be seen as having a slightly adverse impact. This approach would only be adopted if it helped to ensure an overall reduction in risk for the site, work programme or facility in question.

Mitigation and Conclusions

Many of the adverse environmental impacts identified above could be reduced or avoided if combined treatment or storage facilities can be developed, or if existing facilities can be reused. Some of the adverse socio-economic impacts of closing facilities may be mitigated by transferring staff to other facilities or sites.

As there is considerable uncertainty regarding how preferred options will be implemented at a future time and at the site level, the results of this assessment should be viewed as being indicative of potential impacts of the Strategy but not absolute or certain. The nature and significance of identified impacts should be validated in the course of future assessment work when more detailed information is available. Such work would enable appropriate mitigation measures to be determined and applied. The results of this IIA should be used to inform this work, as well as future decision-making made by the NDA and the SLCs that operate its sites.

1.0 Introduction

1.1 Introduction

The NDA is undertaking its third five-year review of its Strategy, in accordance with the Energy Act 2004. The Strategy reviews the NDA's strategic position, establishing and maintaining its strategic direction on activities across the sites which comprise its estate. The strategies that have been selected are carried out by Site Licence Companies (SLCs), which manage the sites on the NDA's behalf and under its strategic guidance.

The version currently under development is the NDA Strategy (2021) (otherwise referred to as the 'Strategy'). The NDA is committed to ensuring that the development of its Strategy is in accordance with the requirements of the European Union's Strategic Environmental Assessment (SEA) Directive and transposing UK SEA Regulations.

The NDA also wishes to adhere to good practice by conducting an SEA, Health Impact Assessment (HIA) and Socio-economic Impact Assessment (SeIA), and reporting on these three strands in an Integrated Impact Assessment (IIA) that fulfils the requirements of the SEA Regulations.[2]

IIAs are used by plan- and policy-makers to inform various options, policies and strategies. They draw together different types of assessment to provide a broad and holistic perspective which can be easily communicated to stakeholders.

1.2 Objectives of the IIA

In order to guide the approach taken for conducting the IIA, two key objectives were identified:

- To robustly and transparently assess the potential environmental, health and socio-economic effects of strategic options set out in the Strategy; and
- Where appropriate, inform development of strategy and provide a suitable methodology for future assessment work.

In order to achieve these objectives, it is essential that the assessment methodology is well defined, reproducible and can be audited robustly. The methodology is also intended to be adaptable to meet future IIA guidance and requirements.

1.3 Purpose of the report

This report details the findings of the IIA of the NDA Strategy (2021) to be used in statutory consultation alongside the Strategy document. The report will also serve as a guide for future assessment work undertaken by the NDA, SLCs and other relevant parties. The assessment methodology will inform future selection of preferred options.

The IIA (including the methodology and assessment guide questions) has been incorporated into the NDA's Value Framework (a toolkit used to support NDA decision-making). Relevant environmental, socio-economic and health topics considered in the IIA are therefore taken into account in the assessment and selection of strategic options, as they are guided by the Value Framework. This helps the NDA to identify potential impacts associated with activities across its estate.

The findings of the IIA provide an indicative overview of environmental, socio-economic and health effects of the Strategy. This will help to define the overall context for future decisions, which will also be based on site-specific factors and other important aspects such as cost, affordability and feasibility.

[2] Note that SEA and IIA both include health and socio-economic assessments. Here, we cover health and socio-economic assessments in the HIA and SeIA respectively. We use the term SEA to refer to the assessment of environmental aspects only.

In line with good practice for IIA, the purpose of the assessment is to objectively *inform* decisions, not to make or prescribe such decisions, or bias future decisions by portraying options as more or less favourable overall. The assessment should not foreclose implementation of certain options in the future, and should instead compare options objectively against consistent criteria and an established baseline.

In many cases, detailed site-based factors and other currently unknown factors such as future government policy and international agreements may influence which option is ultimately implemented. Where possible, these factors have been taken into account; recognising that such factors will primarily be considered in the course of future assessment work.

1.4 IIA report structure

The IIA Report is split into three volumes:

- **Volume 1:** consists of an introduction, the project background, descriptions of preferred and credible options, the approach to assessment and methodology, results of the assessment, the measures identified to mitigate risks and enhance opportunities, and conclusions and next steps;
- **Volume 2:** provides the detailed assessment of preferred options and reasonable alternatives; and
- **Volume 3:** consists of a baseline report and review of relevant policy and legislation.

2.0 Project background

2.1 The NDA mission

The Nuclear Decommissioning Authority (NDA) is a non-departmental public body established under the Energy Act 2004. The NDA mission is to deliver safe, sustainable and publicly acceptable solutions to the challenge of nuclear clean-up and waste management.

The UK's Nuclear Legacy

The NDA has responsibility to oversee the clean-up and decommissioning of 17 of the UK's civil public sector nuclear sites (see Figure 2-A). These range from Sellafield, a complex operational site, to previously operational nuclear power stations and nuclear research facilities.

Radioactive waste is material that has no further use and is above a certain (very low) level of radioactivity. Over the years the UK has accumulated a substantial legacy of radioactive waste from various civil nuclear and defence programmes. Waste also arises in non-nuclear industries, for example where radioactive materials are used for medical and industrial purposes.

The NDA develops nuclear decommissioning plans and implements them through an estate-wide Strategy. This Strategy sets the pace and priority of decommissioning activities across the estate, and ensures the safe management of spent fuels, nuclear materials and radioactive wastes. The Strategy is based on a process of identifying and selecting preferred strategies which balance safety, cost and security with achieving benefits for the environment and society.

2.2 The NDA estate

The NDA estate includes reactors, chemical plants, research and development facilities, fuel fabrication and reprocessing facilities, waste treatment facilities and waste stores. Some plants date from the 1940s and 1950s, including a number of the Legacy Ponds and Silos at Sellafield. These facilities are ageing and contain significant quantities of spent fuels, presenting some of the highest risk and one of the NDA's greatest decommissioning challenges.

Some facilities across the estate continue to form an essential part of the nation's nuclear infrastructure, which means they must continue to be operated safely and effectively until they have fulfilled their purpose.

2.3 NDA Strategy (2021)

Under the Energy Act 2004, the NDA is required to publish a Strategy setting out its strategic direction for activities across its estate. This Strategy is subject to periodic review, formal public consultation and approval by ministers. The first Strategy was published in 2006 with an update published in 2011 and a further update published in 2016. This Integrated Impact Assessment (IIA) accompanies the NDA Strategy (2021) document, and provides an overview of its potential environmental, socio-economic and health effects.

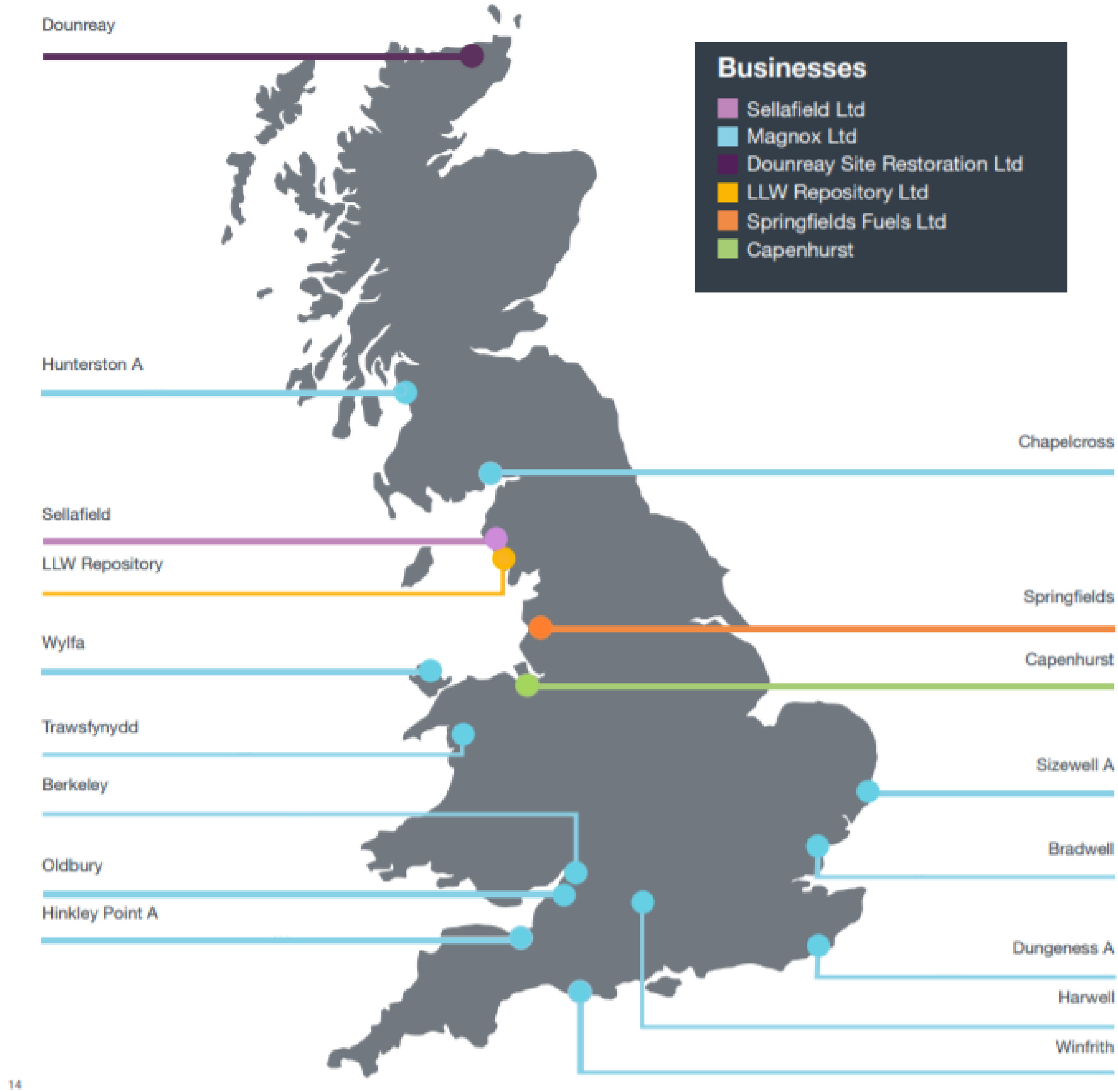

Figure 2-A: The NDA Estate [1]

3.0 Baseline conditions

3.1 Introduction

To inform the assessment, information was collected on the baseline environmental, health and socio-economic conditions at each of the NDA sites. This information includes both existing conditions and future conditions that would be likely to evolve assuming there are no further changes to the NDA Strategy. The results of this exercise are presented in Volume 3 of this IIA Report, which includes a description of the 17 sites comprising the NDA estate.

Understanding the baseline at each of the NDA sites is important, both for determining the nature and extent of potential impacts of the Strategy, and ultimately in identifying options which may positively influence environmental, social and health conditions.

The key issues highlighted by the baseline data gathering exercise are outlined below.

3.2 Environment

From an environmental perspective, some of the main issues at the sites are associated with the use of materials and the generation, storage and treatment of wastes. Substantial volumes of waste (radioactive and especially non-radioactive) are produced as sites undergo decommissioning. Following retrieval, much of the radioactive waste is stored in purpose-built facilities pending treatment or disposal, whilst non-radioactive and some low-level radioactive waste (LLW) is treated for reuse, where possible, or otherwise transported to authorised disposal sites. This creates a range of additional environmental issues around air quality, noise, landscape, radiological discharges, energy use and carbon emissions.[3]

Due to their industrial nature, many of the NDA sites are prominent features within their respective landscapes and are widely visible across surrounding areas. Most of the sites are in coastal locations, which could put them at risk from changes in the coastal environment. This may include increased rates of erosion, changes in tidal surges or sea level rise. Such changes may be precipitated or accelerated by climate change.

Many of the sites have areas of chemical and radiological land contamination which may require remediation as part of decommissioning activities. The nature, extent and severity of such contamination varies from site to site, and across different parts of a site. Management of such contamination is an important element in moving sites towards their site end state.

Across the sites there is ongoing management of radiological discharges and wastes. At a number of sites, radiological discharges continue within authorised limits, while others have seen discharges reduce or cease since the end of the operational phase. Decommissioning can cause short-term increased discharges of radioactivity before reducing radiological risks in line with the NDA mission.

During the course of nuclear operations, many of the NDA sites have, and some continue to, draw water from and make discharges to water bodies. Such abstractions and discharges have been made within regulatory limits, and in most cases, have decreased since the operational phase ended. The Sellafield site continues to abstract water to support ongoing operations. Decommissioning activities undertaken at other sites may also continue to affect the water environment through abstraction and discharges.

Energy use and carbon emissions are important issues at the NDA sites. Decommissioning activities such as demolition and operational activities such as reprocessing at Sellafield require energy and generate direct and indirect carbon emissions.

3 'Carbon emissions' is a conventional term used in place of greenhouse gas emissions, which are typically measured using units of 'carbon equivalents' (CO_2e). As such, the term 'carbon emissions' refers to all greenhouse gas emissions for the purposes of this assessment.

3.3 Socio-economics

Due to their remote locations, many of the sites are major employers in the surrounding area or region, and because of the varying nature of nuclear operations ongoing at each of the sites, these jobs range from construction and demolition work to specialist nuclear and civil engineering and managerial positions.

Similarly, some of the sites have been and continue to be a major source of investment into the local and regional economies. This comes not just from employment but also from multiplier effects and activities in the sites' supply chains.

At one time or another, each of the sites in the NDA's estate may have been considered a national asset, supplying electricity derived from nuclear power or advancing the nation's nuclear capabilities through experimental research. Some sites such as Sellafield contain facilities which continue to serve as national assets and must be maintained as such until they have fulfilled their purpose. Others continue to undergo decommissioning and may eventually be divested for redevelopment to potentially become a local asset. An example of this is the transfer of some of the research facilities at Berkeley Centre (owned by NDA and adjacent to the Berkeley reactor decommissioning site) to South Gloucestershire and Stroud College, with a view to providing training in the renewable energy and nuclear sectors.

The demand for nuclear skills comprises existing generation, decommissioning, civil new build, defence and research and development [2]. Uncertainty in the number and nature of new build facilities creates ambiguity in predicting future workforce demand profiles. There is potential for the pool of available qualified nuclear staff to be in increased demand between now and 2030 [2], which could potentially impact the NDA mission at any time. As a result of an aging workforce and potential increase in demand from new build, a net inflow of staff is required into the industry, along with redeployment of skilled workers [2]. However, the number of staff anticipated to be required at NDA sites is expected to reduce, with some decommissioning sites anticipated to have no staff within the next 10 years [3].

3.4 Health

The main health risks arising from activity at NDA sites come from conventional sources such as construction, demolition and transport. Environmental impacts of construction works can have implications from a health perspective. Changes in air quality can lead to increased risk of cardiovascular and respiratory illness. Increases in noise levels and alterations to the landscape can lead to disturbance and annoyance, while changes in water quality may result in adverse health effects if the water is used for drinking supplies or recreational activities. Increases in traffic due to the movement of materials, plant and workers has the potential to increase the risk of road accidents on routes leading to and from the sites. Such environmental effects can also affect the attractiveness of local recreational and amenity features, which might lead to declines in levels of physical activity undertaken by the local population.

Across the sites, radiological health risks are an important consideration. Whether it is demolishing an office block or management of High Level Waste (HLW) arising from spent fuel reprocessing, radiological safety remains a key priority. This will continue to be the case until the sites have reached their end states. The use of safety cases, minimisation of waste, adherence to 'as low as reasonably achievable' (ALARA) principles and requirements to demonstrate the use of 'best available techniques' (BAT) help to ensure risks to workers, the public and the environment are minimised and kept well within statutory limits.

Mental health and well-being is another important health issue relating to activities across the NDA estate. Increased stress and anxiety can be experienced by those living close to industrial sites which generate noise, dust and other environmental effects. On the other hand, by providing and maintaining employment opportunities and encouraging investment into the local community, sites can also positively influence the mental health and well-being of the local population.

4.0 Strategy themes and topics

4.1 NDA Strategy (2021) themes and topics

As set out in the Strategy, there are four driving strategic themes under which the NDA groups its core activities. These are set out in Box 1 below.

Box 1: NDA's four driving strategic themes

Site Decommissioning and Remediation

Site Decommissioning and Remediation is the main strategic theme delivering the NDA's mission. It outlines the NDA's approach to decommissioning redundant facilities, securing the land required by decommissioning activity and the means by which contamination of ground and groundwater will be managed.

Spent Fuels

The Spent Fuels theme defines the NDA's approach to managing the diverse range of spent nuclear fuels for which it is responsible, including Magnox, Oxide and Exotic spent fuels.

Nuclear Materials

The Nuclear Materials theme sets out the NDA's approach to dealing with the inventory of plutonium and uranics currently stored on some of its sites.

Integrated Waste Management

Integrated Waste Management considers how the NDA manages all forms of waste arising from operation and decommissioning of its sites. This theme is supported by the work of Radioactive Waste Management Ltd. (RWM), a subsidiary focusing on implementation of geological disposal, and Low Level Waste Repository Ltd., a SLC working to develop management solutions for low level radioactive waste.

These four driving themes are supported by a fifth theme; 'Critical Enablers'. This theme covers other aspects of the NDA's activities such as transport and logistics, public and stakeholder engagement and land and property management, which support the overall delivery of the NDA mission. For the purpose of this assessment, Critical Enablers have been considered, where relevant, under each of the four driving themes.

Within each driving strategic theme, activities may be further broken down into topic strategies. For example, the Spent Fuels strategy is split into three individual topics: Spent Magnox Fuel, Spent Oxide Fuel and Spent Exotic Fuel. These topic strategies form part of the overarching Strategy.

A short description of the four strategic themes discussed above and their associated topic strategies is provided below.

4.2 Site Decommissioning and Remediation

All nuclear facilities are to be decommissioned when they reach the end of their operational life. Decommissioning means *taking out of active use and dismantling*. It may involve retrieval of waste, decontamination and full or partial dismantling of the facility and demolition of buildings. Where necessary, the land may be remediated afterwards to reduce contamination.

All decommissioning work needs to be undertaken carefully, minimising risks to people and the environment. Complex decommissioning projects are usually completed in stages, which aim to progressively reduce the hazard posed by the redundant facility.

In some cases, the dismantling of certain parts of nuclear facilities or the remediation of contaminated land may be deferred for several decades to allow time for short-lived radionuclides to decay, or in the case of contaminated land, organic contaminants to degrade.

4.3 Spent Fuels

In the UK, all of the commercial nuclear power reactors use uranium as fuel. Over time, the amount of uranium-235 available to sustain nuclear fission decreases as it is gradually used up. In order to maintain power output, some of the used fuel is periodically removed from the reactor and replaced with fresh fuel. The spent fuel still contains some uranium-235 (typically between 20 and 60 percent of that present in the pre-irradiated fuel) and also plutonium that was created as a result of the nuclear reactions.

There are generally two options for the management of spent fuel, namely long-term storage (followed by disposal) and reprocessing. There are a variety of spent fuel storage options used internationally, for example storage in dry casks or storage under water in a fuel pond. Reprocessing can be used to recover the remaining uranium and the plutonium from the fuel, which can then be used to manufacture new nuclear fuel if it is economically viable.

Reprocessing is a complex process that is undertaken on an industrial scale at Sellafield, and is now, after several decades of operation, is at the end of the programme. It involves dissolving the spent fuel in acid and separating out the uranium and plutonium products from other elements which are not useful. These non-useful elements are managed as Intermediate Level Radioactive Waste (ILW) or LLW depending on their level of radioactivity. See Section 4.5.1.

The uranium recovered by reprocessing can be reused to manufacture new fuel. The plutonium can also be used to manufacture new fuel, such as when mixed together with uranium to produce mixed oxide fuel (MOX). It should be noted that specialist (and potentially expensive) new fuel fabrication facilities for recycling of reprocessed uranium and plutonium would need to be constructed if reuse was considered in UK facilities.

Currently fuel is stored at Sellafield predominantly in ponds, although some arrangements are being delivered for storage of some fuels in self-shielded boxes.

Most of the waste arising from reprocessing is highly radioactive and contains both fission and activation products that were produced while the fuel was in the reactor. These wastes are typically incorporated into stable wasteforms through processes such as vitrification and encapsulation, and then stored safely until they can be disposed of.

Spent fuel from Magnox reactors in the UK (and previously from some overseas reactors) has been reprocessed at Sellafield for over 50 years. A facility (THORP) for reprocessing Advanced Gas Cooled Reactor (AGR) fuel and from some overseas reactors closed in 2018 and is now being prepared for decommissioning. The Magnox reprocessing plant is expected to cease operations at the end of 2020. The processes used for managing both types of spent fuel are broadly similar, though there are some technical differences.

4.3.1 Spent Oxide Fuel

The majority of the NDA's oxide fuel inventory is AGR which is uranium dioxide is uranium dioxide (UO_2) based. Since the mid 1990s, AGR spent fuel has been reprocessed in THORP at Sellafield until the closure of this facility in 2018. However, the Sellafield site is still receiving spent AGR fuel from the operating EDF power stations. This spent fuel will be interim-stored in ponds until a suitable disposal facility is available.

4.3.2 Spent Magnox Fuel

Magnox is a uranium metal-based fuel. The use of reprocessing to manage Magnox spent fuel has been ongoing for over 50 years. Over 50,000 tonnes of Magnox fuel have been manufactured, used to generate electricity and reprocessed in this time. All Magnox reactors have ceased operating. No additional Magnox spent fuel will be produced other than the quantity currently in the Magnox fuel cycle.

4.3.3 Spent Exotic Fuel

In the early days of the nuclear industry from the 1940s until the 1980s, there was a large government-funded research programme into a range of nuclear reactor technologies. Many different reactor designs and fuel types were investigated. This research led to the successful development of the early Magnox reactors and the later AGR reactors that have been built and operated commercially in the UK. At the Dounreay site in the north of Scotland, research was undertaken on fast breeder reactor technology.

Due to their novel design and operations, a diverse range of solid and liquid wastes came from these experimental reactors. The spent fuel from these reactors is termed 'exotics'. In addition, any fuels that cannot be reprocessed at Sellafield would be managed as part of the exotics fuel inventory.

4.4 Nuclear Materials

Plutonium and uranium are nuclear materials. The NDA holds large stocks of nuclear materials arising from reprocessing and enrichment activities. These materials are not considered to be wastes owing to their potential economic value, and continue to be stored safely and securely whilst cost-effective lifecycle solutions are developed for their management.

4.4.1 Plutonium

As a result of historic reprocessing operations, the UK has generated a stockpile of separated civil plutonium (Pu) in the form of plutonium oxide, scrap mixed oxide fuel and miscellaneous residues.

At the end of the planned reprocessing programme, around 140 tonnes of separated plutonium will be in safe and secure storage in the UK.

The NDA continues to work with the government to develop a policy which places UK civil plutonium beyond reach and provides a secure solution for long-term management.

4.4.2 Uranium

The NDA owns uranium arising from historic or current nuclear fuel cycle operations such as enrichment, fuel fabrication and reprocessing. There is a wide variety of types (populations) of uranium, all stored safely and securely on a number of sites.

Civil nuclear materials are not deemed to be waste. At this time, the NDA holds its uranium as a nil-value asset pending development and implementation of long-term management options. In the future, assessment may ascribe a value or a liability to each type of uranium. The dividing line between value and liability is likely to be sensitive to external commercial factors such as the future price of freshly mined natural uranium and may change markedly with time.

This may mean that the NDA chooses to continue to securely store some types of uranium for extended periods, pending a decision on whether to dispose or realise a commercial value through sale.

4.5 Integrated Waste Management

The nature of waste materials arising from operational and decommissioning activities across the NDA estate varies considerably. Some of these wastes are highly radioactive and must be managed in specially designed and custom-built treatment and storage facilities, whilst some may have sufficiently low levels of radioactivity to be suitable for reuse. LLW that cannot be reused may be disposed of at existing facilities such as the LLW Repositories, at the LLWR (Low Level Waste Repository) in Cumbria, and at Dounreay in Scotland, or at a number of licensed landfill sites. Other wastes are non-radioactive and can be managed using conventional routes.

Wherever practicable, management of radioactive and non-radioactive wastes will involve reuse, recycling or recovery rather than disposal.

The strategy for integrated waste management is broken down into: Radioactive Waste, Liquid and Gaseous Discharges and Non-radioactive Waste.

4.5.1 Radioactive Waste

In the UK, radioactive wastes are classified according to the type and quantity of radioactivity they contain and how much heat this radioactivity produces [4].

High Level Waste (HLW) – waste that is sufficiently radioactive for its decay heat to significantly increase its temperature and the temperature of its surroundings, such that heat generation has to be taken into account in the design of storage and disposal facilities.

Intermediate Level Waste (ILW) – waste whose radioactivity exceeds the limits for Low Level Waste (see below), but whose decay heat is insufficient for heat removal to be a factor in the design of storage or disposal facilities.

Low Level Waste (LLW) – has a much lower potential hazard than other categories, and radioactivity below the threshold for Intermediate Level Waste.

Very Low Level Waste (VLLW) – is a sub-category of LLW, and comprises waste that can be safely disposed to appropriately permitted landfill facilities. The major components of VLLW from nuclear sites are building rubble, soil and steel items from the dismantling and demolition of nuclear facilities.

Radioactive waste management is covered by two strategic topic areas: Higher Activity Waste (HAW) and Solid LLW management (liquid and gaseous discharges are covered under a separate topic, see Subsection 4.5.2). HAW includes HLW, ILW and a relatively small volume of LLW that is unsuitable for management under the *UK Strategy for Management of Solid LLW from the Nuclear Industry* [5], in most cases because of the nature of the radionuclides contained in the waste. LLW from the nuclear industry is divided into operational and decommissioning waste. Operational LLW arises from routine monitoring and maintenance activities and includes wastes such as plastic, paper, clothing, wood and metallic items. LLW from decommissioning comprises mostly building rubble, soil and various metal items including plant and equipment. LLW makes up more than 90% of the UK's radioactive waste legacy by volume but contains less than 0.1% of the total radioactivity [6].

Historically, NDA produced separate LLW and HAW strategies. However, as the programme moves towards supporting large-scale decommissioning and site remediation this distinction is no longer fit for purpose. In 2019, NDA published a new Radioactive Waste Strategy that applies to all radioactive waste generated within the NDA estate (including materials that may become waste at some point in the future) [7]. It replaces the previous NDA strategy for HAW and is consistent with the UK strategy for solid LLW (discussed below), providing a consolidated position.

For HAW, the long-term management policy of the UK government is to package and hold wastes in secure interim storage facilities until they can be transferred to a geological disposal facility (GDF). The 2014 *White Paper on Implementing Geological Disposal* [8] and supporting policy paper [9] set out the UK government's framework for managing HAW in the long-term through geological disposal, recognising that a GDF will be 'implemented alongside ongoing interim storage and supporting research'. The Welsh government has adopted a policy for the management and disposal of HAW that is consistent with the UK government policy [10] and has its own policy for the engagement process for communities in Wales [11]. The Scottish government published its policy on HAW in January 2011 [12] and its associated implementation strategy in 2016 [13]. The Scottish government policy is that management of HAW should be in near-surface facilities.

The UK policy on the long-term management of HAW (e.g. graphite) recognises that it is appropriate to investigate alternative options to a GDF for some of the inventory where there could be the potential to improve the overall management of HAW. NDA's strategic preference is to develop Near-Surface Disposal and NDA will support government policy development in this area.

The NDA's overarching strategy is to treat and package the HAW inventory into a form that can be safely and securely stored for many decades. The current planning assumptions are that, at the appropriate time, HAW stored in England and Wales will be transported to and disposed of at an appropriate disposal facility whereas HAW in Scotland will be managed in near-surface facilities.

The UK LLW Strategy was developed by NDA in response to the 2007 UK LLW Policy [14] and was updated by BEIS in 2016 [5]. Key themes and strategic objectives are captured within the 2019 Radioactive Waste Strategy [7], however, the UK LLW strategy [5] is the overarching strategic document for the management of

LLW. The strategy focuses on application of the waste hierarchy, best use of existing LLW management assets and the need for new fit-for-purpose waste management routes.

4.5.2 Liquid and Gaseous Discharges

Liquid and gaseous discharges are generated by SLCs during operations and decommissioning. Such discharges are generated at all stages of the nuclear fuel cycle. Discharges are primarily associated with fuel fabrication, spent fuel storage, decommissioning and most significantly spent fuel reprocessing.

In June 2009, the UK government published its revised UK Strategy for Radioactive Discharges to inform decision-making by industry and regulators [15].[4] This sets out how the UK will implement its obligations in respect of the OSPAR Radioactive Substances Strategy 2020 intermediate objective [16]. As the NDA has a significant role in its development and implementation, a separate strategy for the NDA estate is not required.

4.5.3 Non-radioactive Waste

NDA sites generate non-radioactive waste including demolition rubble, packaging, paper and food waste. Some non-radioactive waste is hazardous, such as asbestos, process chemicals and oil. Overall, the nuclear industry's contribution to total UK waste volumes is very small compared to that of UK households and non-nuclear industry (approximately 0.2 per cent of hazardous waste and 0.04 per cent of other Directive waste).[5]

The non-radioactive waste strategy also covers waste that has radioactivity levels which are below the thresholds that require regulatory controls for radiological protection purposes.

The UK has a well-established, comprehensive and prescriptive regulatory regime for the management of non-radioactive waste. Waste management strategies have been developed at national, regional and local levels by the UK government and devolved administrations and local and regional authorities. The NDA has collated the established practices and principles that underpin these strategies and implements them across its estate.

4 The strategy was reviewed by the Department for Business, Energy and Industrial Strategy (BEIS) in 2018 [17] and it was concluded that good progress against the targets has been made; the strategy was not updated.

5 Directive Waste is defined in the Waste Management Licensing Regulations (1994) as being any substance or object in the categories set out in Part II of Schedule 4 of the Regulations that the producer or holder discards, intends to discard or is required to discard.

5.0 Baseline scenarios and preferred and credible options

5.1 Baseline scenarios and preferred and credible options

This IIA covers a number of credible strategic options set out in the NDA Strategy (2021.

The NDA defines credible options as [18]:

> *those options which could potentially be accomplished, safely, while complying with the law, and using technology which is either available or capable of being developed within the foreseeable future, and which allow decisions to be made on a timescale that is commensurate with any strategic imperatives.*

Using this definition, non-credible options are those deemed not to comply with the law, or to be at a stage where the technology is immature or incapable of being implemented on appropriate timescales to achieve the strategic objectives.

Note that the intention of this IIA Report is to provide an indicative assessment of current credible options but not to preclude the adoption of other management options in the future. Such an approach recognises the fact that some options not currently considered to be credible or preferred on the basis of their level of technical development, may become more credible in the future as the technology matures. Changes in government policy and site-specific considerations can also influence the credibility of strategic options over time.

For each strategic theme and topic, a number of credible options have been identified and defined in consultation with the NDA. These are identified and described in the following sections.

Where applicable, the baseline scenario (to be used as the basis for comparison in the assessment) is indicated.

For the purpose of the assessment, the baseline scenario for each topic has been agreed with the NDA Strategic Leads during this impact assessment, and represents the proposed evolution of NDA activity in the absence of a further change in any given strategy (i.e. NDA Strategy (2021)). Where no preferred option or multiple preferred options were identified in the previous Strategy, options have been assessed qualitatively through discussion of the potential environmental, socio-economic and health risks.

5.2 Site Decommissioning and Remediation

This strategic theme is divided into the four topics discussed below.

5.2.1 Decommissioning

There are three broad credible options for Decommissioning:

1. **Decommissioning at a pace.**

2. **Decommissioning slowly but without interruption.**

3. **Deferred decommissioning** that involves one or more periods when the facility is purposely made safe for a period of quiescence, during which only routine maintenance activities would be carried out.

Decommissioning is undertaken on a case-by-case basis. As such, there is no baseline scenario and these options have been assessed and compared through discussion of the potential environmental, socio-economic and health effects associated with them.

5.2.2 Land Quality Management

Land Quality Management involves managing risks to people and the environment from radioactive and non-radioactive contamination in ground and groundwater. This is done through prevention and remediation (including control and monitoring).

Four credible options have been identified for Land Quality Management. These are:

1. ***In situ* management without intervention** (e.g. monitored natural attenuation or monitored natural decay).
2. ***In situ* management with intervention** (e.g. enhanced bioremediation or physical treatment)
3. ***Ex situ* management for reuse** (this may involve a process such as soil washing to make material suitable for reuse).
4. ***Ex situ* excavation for disposal** (this option involves removing the material from the ground and transferring it to an authorised waste disposal site).

Due to decisions being taken on a case-by-case basis, no single preferred option for implementing this strategy was identified in the previous Strategy, meaning there is no baseline scenario and these options have been assessed and compared through discussion of the potential environmental, socio-economic and health effects associated with them. Any of the credible options might be preferred under specific conditions.

5.2.3 Site End States

Every NDA site will have an agreed site end state. The site end state sets out the long-term restoration objectives for the site, considering the land's next planned use or probable future uses. For many NDA sites, the end state is not scheduled to be achieved for many decades, so it is important to ensure there is flexibility in the long-term site remediation plans. Over time, the description of the end state becomes more detailed as decommissioning progresses and a clearer picture of the site's characteristics emerges.

A wide range of issues could affect the proposed end state, such as changes in policy and regulations, advances in technology and changes in the desires of a community over generations. It may not be realistic or necessary to remediate a site completely (i.e. removing all hazards so that the site may be suitable for any use). For some sites, remediation will focus on preparing the site for a specified beneficial use.

There are three credible options for the Site End States strategy:

1. **Leave the hazard where it is and prevent use.**
2. **Make land suitable for next planned use.**
3. **Remove the hazard completely so that the risk does not need to be controlled.**

As site end states are by their nature a very site-specific consideration, there was no single preferred option identified in the previous Strategy, and as such there is no baseline scenario. Options have therefore been assessed and compared through discussion of the potential environmental, socio-economic and health effects associated with them.

5.2.4 Land Use

Whilst the Site End States strategy describes the condition to which designated land and associated structures and infrastructure need to be restored, Land Use is about understanding how sites can be used following the end of decommissioning or during interim periods of decommissioning and remediation activities.

There are three options for Land Use:

1. **Retain land as an NDA asset / liability.**
2. **Retain land on behalf of government as a national asset.**
3. **Divest the land (leasehold or freehold) for social, environmental or economic benefit.**

There is no baseline scenario for this topic, as land use following final site clearance is a very site-specific consideration. Options have been assessed and compared through discussion of the potential environmental, socio-economic and health effects associated with them.

5.3 Spent Fuels

Within the Spent Fuels theme, there are three individual topic strategies, reflecting the three groups of spent fuels for which the NDA is responsible.

5.3.1 Spent Oxide Fuel

The three credible options available for managing spent oxide fuel are:

1. **Continued interim storage of fuel in existing facilities pending treatment and packaging prior to disposal to a GDF** (baseline scenario).
2. **Build new storage facilities and interim store pending treatment and packaging prior to disposal to a GDF** (credible alternative option to be assessed in detail).

5.3.2 Spent Magnox Fuel

Two credible options were assessed for managing the remaining inventory of spent Magnox fuel:

1. **Continue as planned, maximise the reprocessing of suitable spent Magnox fuel prior to ending operations around the end of the 2020/21 financial year. Interim store remaining material pending treatment and packaging prior to disposal to a GDF** (baseline scenario).
2. **Stop reprocessing of suitable spent Magnox fuel early and interim store the remaining material pending treatment and packaging prior to disposal to a GDF** (credible alternative option assessed in detail).
3. **Extend reprocessing operations to ensure all suitable spent Magnox fuel is reprocessed and interim store Magnox spent fuel not suitable for reprocessing pending treatment and packaging prior to disposal to a GDF** (credible alternative option assessed in detail).

5.3.3 Spent Exotic Fuel

Exotic spent fuel management options differs from the options for Magnox and Oxides, primarily due to the unique nature of the inventory, which has mostly been produced from experimental research into nuclear reactor technologies. Within the inventory, there are several different forms of exotic spent fuel. However the high-level strategy for exotic fuels is similar to that for all NDA fuels, which is to consolidate, interim store and eventually dispose (pending a decision on the appropriate disposal facility). The consolidation of exotic fuels is currently continuing across the NDA estate

As work to identify and develop credible options for the disposition of spent exotic fuels that cannot be managed using existing facilities was ongoing at the time of writing, the 2016 IIA did not identify credible options. However, since 2016, credible options for the ongoing management of exotic spent fuels have been identified and developed. No decisions have yet been made on the long-term management options for exotic spent fuels, although only a small quantity will need bespoke solutions, with the rest to be managed alongside Magnox and AGR fuels.[6] The following credible options for each of the different exotic spent fuels have been identified:

1. **Consolidate exotic spent fuels at Sellafield, and interim store in existing or modified facilities pending treatment and packaging prior to disposal in a GDF.**

[6] Spent Dragon Fuel has now been declared as a waste and been encapsulated for storage and disposal. Spent Dragon Fuel is no longer considered as part of the Spent Fuels strategy.

2. **Consolidate exotic spent fuels at Sellafield, build new storage facilities and interim store pending treatment and packaging prior to disposal in a GDF.**

There are a number of different types of exotic fuels and the preferred option may vary with the fuel type, therefore the options will be assessed via discussion.

5.4 Nuclear Materials

This strategic theme comprises the two topics of Plutonium and Uranium, discussed below.

5.4.1 Plutonium

Three credible options exist for managing the NDA inventory of civil plutonium:

1. **Continued safe and secure storage, renovating and replacing stores as required** (baseline scenario).
2. **Build facilities to make fuel to enable use in a third-party reactor prior to storage and disposal to a GDF** (credible alternative option assessed in detail).
3. **Build facilities to condition and treat plutonium prior to storage and disposal to a GDF** (credible alternative option assessed in detail).

5.4.2 Uranium

The credible options for managing the uranium inventory are:

1. **Continued safe and secure storage pending sale for reuse.**
2. **Continued safe and secure storage pending conditioning to an appropriate form for disposal.**

In similarity to the 2016 IIA, these options will be assessed through discussion. Consequently, no baseline scenario has been identified.

5.5 Integrated Waste Management

Unlike Spent Fuels and Nuclear Materials where there are clear credible options for how the inventory is managed, for Integrated Waste Management (including management of both radioactive and non-radioactive waste), there are few areas for strategic optioneering from an NDA perspective.

5.5.1 Radioactive Waste

As outlined in Section 4.5, in the UK, radioactive wastes are classified according to the type and quantity of radioactivity they contain and how much heat this radioactivity produces [4].

The NDA Strategy for radioactive waste management covers two categories of radioactive waste: HAW and solid LLW.

Higher Activity Waste (HAW)

In England and Wales, the government policy is for HAW to be disposed of in a GDF and using alternative disposal systems. The Scottish government policy is that the management of higher activity radioactive waste should be in near-surface facilities. As the NDA's strategy is selected to meet the requirements of these policies, in effect there is no strategic decision for the NDA to make (although the NDA works closely with government to identify and develop solutions). In other words, the NDA's strategic position is to comply with and deliver government policy regarding the management of HAW.

As the initial stage of the HAW management route is fixed (i.e. retrieve the waste from the sites) and the end stage is also fixed (i.e. geological disposal or alternative disposal systems in England and Wales and near-surface management in Scotland), the intermediary stage must involve some form of treatment, conditioning and / or packaging to make the waste suitable for disposal. From an NDA perspective, it is during this stage that there is the greatest scope for strategic decision-making.

Credible management options available during this stage revolve around two issues:

- where the waste is stored; and
- where the waste is treated.

The assessment has considered the treatment and storage of HAW, for which there are three credible options:

1. **Storage / treatment at local (on or near site) facilities.**
2. **Storage / treatment at regional facilities.**
3. **Treatment at national facilities*.**

* Storage of wastes in a single national facility is not considered to be credible owing to the existence of numerous suitable storage facilities across the country.

Decisions regarding the management of HAW are undertaken on a case-by-case basis. As such, no single preferred option was identified in the previous Strategy, meaning there is no baseline scenario. Options have therefore been assessed and compared through discussion of the potential environmental, socio-economic and health effects associated with them.

Solid LLW

The NDA strategy for managing solid LLW, which includes VLLW, is consistent with the UK Nuclear Industry LLW Strategy [5]. Therefore, from an NDA perspective, there are no strategic decisions to make and no credible options require assessment.

5.5.2 Liquid and Gaseous Discharges

The NDA strategy for managing liquid and gaseous discharges is to implement the UK Strategy for Radioactive Discharges, which it helped to develop [15]. Therefore, from an NDA perspective, there are no strategic decisions to make and no credible options to assess.

5.5.3 Non-radioactive Waste

The UK has a well-established, comprehensive and prescriptive regulatory regime for the management of non-radioactive waste. The NDA adheres to this regime and implements it across its estate. As a result, there are no strategic decisions for the NDA to make and no credible options require assessment.

6.0 Approach to assessment and methodology

6.1 Introduction

The IIA of the NDA Strategy (2021) comprises the combined assessment results of a SEA[2], HIA and SeIA. Each assessment has been completed by relevant specialists, with ongoing dialogue to ensure consistency and effective information sharing across them. The results of both the environmental and socio-economic assessments have been used to inform the HIA.

6.2 Requirements of SEA, SeIA and HIA

Strategic Environmental Assessment

The NDA is committed to ensuring that the development of strategy is in accordance with the requirements of the European Union's SEA Directive and transposing UK Regulations.

SEA became a statutory requirement following the adoption of European Directive 2001/42/EC (the SEA Directive) "on the assessment of the effects of certain plans and programmes on the environment". The SEA Directive was transposed into UK legislation on the 20 July 2004 as Statutory Instrument No. 1633 – The Environmental Assessment of Plans and Programmes Regulations 2004 ("the SEA Regulations").

The objective of SEA as set out in the Directive is:

> *to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development.*

According to the SEA Regulations, where an environmental assessment is required, an environmental report must be prepared which:

> *Identifies, describes and evaluates the likely significant effects on the environment of-*
>
> *a) Implementing the plan or programme; and*
>
> *b) Reasonable alternatives taking into account the objectives and the geographical scope of the plan or programme; and …*
>
> *Is made available for the purpose of consultation.*

Health Impact Assessment

The NDA Strategy (2021), which covers activities at each of the 17 sites that make up the NDA estate, could have potential effects upon public health. In order to understand the potential risks for health effects associated with the Strategy, a HIA has been undertaken.

HIA is a means of assessing the likely health effects of plans, programmes and projects. In itself, it is not a statutory requirement[7], but in 2005 the Office of the Deputy Prime Minister (ODPM) published *A Practical Guide to the Strategic Environmental Assessment Directive* [46], which noted that:

> *Responsible Authorities may find it helpful to draw on the methods of Health Impact Assessment when considering how a plan or programme might affect people's health.*

[7] HIA has a strong statutory link via European Directive 2001/42/EC (the SEA Directive). In undertaking SEA, the likely significant effects on population and human health must be considered. A HIA provides a formal methodology to assess these aspects.

The purpose of HIA is to assist decision-makers, not to make the decision for them [19]. HIA seeks to inform and enhance the decision-making process, making decisions more holistic and robust. It aims to:

- highlight practical ways to enhance the positive health, equality and well-being effects of a proposal; and
- remove or minimise the negative health, equality and well-being effects of a proposal.

By incorporating HIA into this assessment, the NDA is aiming to demonstrate good practice and integrate HIA into its strategic decision-making.

Socio-economic Impact Assessment

Employees at individual NDA sites generally number in the hundreds. Given their largely remote locations, this makes many of the sites important providers of employment and contributors to the local, and in some cases regional economy. Changes at the sites as they move through their respective decommissioning programmes therefore have the potential to affect the socio-economic characteristics of local communities, particularly by affecting those directly employed at the sites and organisations in the sites' supply chains.

The potential for the NDA Strategy to have socio-economic implications is a key consideration in its development, as underlined by a requirement in the Energy Act (2004). By incorporating SeIA into this assessment, the NDA is aiming both to demonstrate good practice in giving due regard to socio-economic considerations, and to integrate SeIA into its strategic decision-making.

6.3 Other regulatory regimes

There are a number of other types of assessment, which do not directly apply to this Strategy, but have potential relevance. These have been considered below.

6.3.1 Habitats Regulations Assessment

A Habitats Regulations Assessment (HRA) refers to the several distinct stages of Assessment which must be undertaken in accordance with the Conservation of Habitats and Species Regulations 2017 (as amended) [20] and the Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended) [21] to determine if a plan or project may affect the protected features of a habitats site before deciding whether to undertake, permit or authorise it. The plan can only be adopted if, having undertaken a HRA, it is concluded that the integrity of the protected site is not adversely affected, or that there is shown to be an absence of alternative solutions and imperative reasons of overriding public interest for why the plan should be implemented [22].

Whilst the Strategy sets out the NDA's preferred strategy under each 'strategic theme' (see Chapter 4.0), it does not set out site-specific strategies, plans or requirements. In addition, where there are potential site-specific aspects of a preferred strategy, it is not possible or appropriate at this stage to determine potential adverse effects on a European site for the following reasons:

- The options are at a preliminary and high-level, and do not include specific development proposals or indicative designs or locations (only carrying the broad assumption for the assessment that any new facilities required would be within existing nuclear-licensed boundaries).
- There is inherent flexibility in the Strategy and thus options for individual sites (i.e. alternative solutions can still be identified at the site level). The Strategy is limited to providing the current position and maturity at the time of publication, and is subject to periodic review and continual development. Options for delivering the Strategy are continually evolving, and SLCs which manage the NDA's estate ultimately have to deliver the Strategy in accordance with Site Strategic Specifications which ensure that the NDA's strategic requirements are incorporated into the sites' Lifetime Plans.
- Site-wide planning must take account of the wider operations and functions of the sites, which are not within the Strategy's remit, and the timing of options implementation is not specific enough at the Strategy level to account for conditions at the time.

- Project-level optioneering, assessment and design is more appropriate and capable of ensuring the protection of the integrity of Natura 2000 sites; minimising the need to revert to reasons of overriding public interest in dealing with the problem of the UK's radioactive waste legacy.

Due to the nature of the Strategy, in which there remain unknown factors such as operational decisions to be made by the SLCs, as well as the local siting and design of facilities, it is not possible to ascertain whether there will be an effect on specific Natura 2000 sites (or any other sites designated for nature conservation). Where specific proposals relating to the implementation of the Strategy are identified as having potential effects, a HRA will be undertaken as necessary in liaison with relevant stakeholders such as Natural England, Natural Resources Wales or Scottish Natural Heritage. The HRA would be managed by the appropriate SLC and completed prior to implementation of the proposals. The above approach is consistent with legal advice obtained by the NDA in January 2009 and which was reviewed in April 2010.

6.3.2 Water Framework Directive Assessment

Under the EU Water Framework Directive (2000/60/EC) (WFD), transposed to UK legislation through the Water framework regulations [23], the Environmental Permitting Regulations (England and Wales) [24] and the Environmental Authorisations (Scotland) Regulations [25], there is a legal requirement to carry out an assessment of the impact of any construction or modification to water bodies in the UK that are classified under the WFD. The primary aim of the WFD is to improve and maintain the ecological status and potential of all water bodies. The ecological status comprises a series of biological, physical, chemical and hydromorphological 'quality elements'.

The NDA's Strategy does not make decisions regarding the local siting and design of any facilities, which may determine potential impacts on WFD water bodies. It is therefore not possible to undertake a WFD assessment at this stage. WFD assessment would have to be screened and completed as necessary at the project level.

6.3.3 Environmental Impact Assessment

Environmental Impact Assessment (EIA) is an assessment process required of certain projects under various legislation, including the devolved Town and Country Planning (Environmental Impact Assessment) regulations [26,27,28] and the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 2018, (EIADR) [29]. An EIA is the process of information gathering, consultation and impact assessment leading to preparation of an Environmental Statement (ES) for consultation or consideration alongside a planning application (including development consent orders to the Planning Inspectorate).

As EIA applies to specific projects, it is not directly applicable to the Strategy. However, it is likely that any large development required to implement the Strategy would require EIA, or at the very least, a form of non-statutory environmental assessment. It is intended that this IIA will inform any future EIA in terms of the risks of adverse effects, opportunities for benefits and uncertainties identified.

6.4 Geographic scope

The geographic scope of the assessment covers the UK, as the 17 sites which comprise the NDA estate are spread across these countries with the exception of Northern Ireland.

Where the policy of the UK government or the Scottish or Welsh devolved administrations may influence the geographic scope of a particular option, the assessment follows the Strategy in adhering to government policy. Anything beyond the geographic scope set out in policy has been considered beyond the scope of this assessment, for example, the storage and disposal of Higher Activity Waste (HAW) using international facilities.

Whilst the assessment has been informed, where possible, by the baseline conditions at each site, due to the high-level nature of the Strategy, specific assessment boundaries have not been set for individual IIA topics. It has, however, been necessary to constrain the baseline data gathering exercise according to the following set of assumptions:

- transport movements associated with the Strategy are considered to be very small at a national scale, and so consideration of the effects of options on transport is restricted to local transport networks only;[8]
- climate change, whilst an inherently global issue, has been considered only from the national perspective, as the scale of the Strategy is such that it is most appropriate to view effects in the context of national and industrial sector emission contributions;
- socio-economic effects may have local, regional or national implications and therefore require consideration at these spatial scales;
- certain health issues (e.g. those with links to socio-economics) also require consideration at local, regional and national scales.

The Baseline Report (contained in Volume 3 of the IIA Report), has been developed using a geographic boundary of between 100 m and 5,000 m around each site for topics deemed appropriate for consideration at a local scale.

6.5 Temporal scope

The temporal scope of the assessment reflects the period of time for which the Strategy applies. It is therefore assumed that the Strategy will be in operation until the final site in the NDA estate achieves its stated End State. This is anticipated to be Sellafield in the year 2120. However, it is also assumed that the Strategy will be reviewed and updated on a 5-year cycle within this period.

It is important to note that in reality such dates are not fixed, as new technologies may be developed which speed up decommissioning programmes. Similarly, unforeseen circumstances may extend decommissioning timescales. The assessment considers this uncertainty and the factors that may influence it, and seeks to account for it through development of a clear set of assumptions. These are reported in a register of assumptions and uncertainties (see Appendix A).

As the Strategy applies over such a long timescale, it has been important to consider the potential intergenerational impacts of the Strategy. In some instances, particularly for topics such as climate change and radiological emissions and discharges, strategic decisions made by the NDA may have impacts that extend beyond 2120.

Short, Medium and Long-term

Assessment timescales have been considered in relation to the decommissioning programmes of sites across the NDA estate. Impacts have therefore been categorised into those which are expected to occur or be experienced in the *short-term* (within 10 years of an option being implemented), *medium-term* (10-25 years) and those which may occur, be experienced or extend into the *long-term* (25 years and beyond).

The exact timescales over which impacts will occur is uncertain. Results outlined in the assessment should therefore be viewed as indicative.

6.6 Key assessment steps

A set of key steps was developed and applied during the assessment. These were:

1. identify the risks of (or opportunities for) effects of the strategic options identified in the Strategy, and how they might occur;
2. identify any existing legislative requirements and forms of mitigation which may already address the risks;
3. where the risk of (or opportunity for) an effect remains, assess the potential significance (based on the magnitude of the effect and the sensitivity of receptors), where possible taking into account uncertainties and factors which may cause the significance to vary;
4. recommend further mitigation and enhancement measures; and

[8] Transport movements associated with disposal of radioactive wastes will be covered in assessments elsewhere.

5. recommend monitoring and response mechanisms.

For some options, insufficient information was available to conduct step 3 as above. Instead, the assessment of these options focuses on identifying and discussing environmental, socio-economic and health effects and their management and mitigation, as well as opportunities for potential benefits.

6.7 Determining significance and accounting for uncertainty

6.7.1 Significance

One of the key challenges involved in assessing the NDA Strategy relates to its high-level nature and the wide range of nuclear decommissioning and operational activities it covers. These activities will take place over long timescales (some up to 100 years or more) and across 17 different sites. For these reasons, the IIA has moved away from attempting to state significance without consideration of detailed site-level factors and information. Instead, the assessment focuses on determining *'risks'* or *'opportunities'* for significant effects, with due consideration of the factors which may alter either the risk or the significance.

The first step in the assessment was to identify whether or not a risk or opportunity exists. If a risk (or opportunity) was found to exist (i.e. the option could have a significant effect upon a receptor), the next stage was to consider the significance of such an effect. This involved determining the potential magnitude of the impact (adopting a 'worst case' scenario) and the sensitivity of potential receptors (see Figure 6-A).

		Sensitivity of Receptor / Indicator					
Magnitude of Impact		**Low**		**Medium**		**High**	
	High	Moderate		Major		Major	
		+ +	– –	+ + +	– – –	+ + +	– – –
	Medium	Minor		Moderate		Major	
		+	–	+ +	– –	+ + +	– – –
	Low	Minor		Minor		Moderate	
		+	–	+	–	+ +	– –

Figure 6-A: Impact Significance Matrix

Magnitude is based on the following elements:

- **Nature of the impact** - i.e. can it destroy a feature or remove it, or will it reduce its health, performance or status?
- **Degree, intensity and extent of losses or gains** - i.e. even if on a relatively small scale or over a short period of time, could total destruction of a feature or extinction of a local population of a species occur?
- **Spatial scale** - i.e. what is the geographical area over which the effect would be perceived or experienced?

Sensitivity is based on consideration of a receptor's relationship to change. A receptor that is deemed sensitive is either more likely to experience change of any type or would experience a greater degree of change – i.e. the impacts of the change on the receptor would be greater.

For certain topics, it was not possible to determine the sensitivity of particular receptors to potential impacts. Instead, baseline indicators were used to represent the potential for receptors to experience impacts. This applied to the topics shown in Table 6-A below.

Table 6-A: Topics for which indicators have been used

Topic	Receptors	Indicator	Data Source
Air quality	Local population, flora and fauna, non-motorised users (e.g. pedestrians, equestrians and cyclists)	Local air quality (concentrations of relevant pollutants: NO_x, PM_{10} and SO_2)	Defra 2019 [30], Environment Agency [31], SEPA [32].
Coastal change and flood risk	Local population and infrastructure in coastal areas and areas at risk of flooding	Environmental Agency Flood Risk Map	Environment Agency [33], SEPA [34], Natural Resources Wales [35]
Water resources and quality	Flora and fauna, people, water bodies, water abstraction points	Local water quality (EU Water Directive Rating), water abstraction volumes	River Basin Management Plans (various)
Climate change and energy	The atmosphere, the oceans, flora and fauna, soils, people	Energy sector greenhouse gas emissions and nuclear contribution to total emissions	Her Majesty's Government (HMG) [36] and the Department for Business, Environment and Industrial Strategy (BEIS) [37].
Landscape and visual Impacts	Local population, non-motorised users, flora and fauna, tourists and visitors to the area	Landscape effects, visual effects	Defra MAGIC GIS application [38], Scottish Natural Heritage Landscape Character Types GIS application [39]
Radiological emissions and discharges	The environment, people, flora and fauna	Emissions /discharge rates at the site, RIFE total reported doses to the public	RIFE Report 2018 [40]

For such topics, the sensitivity of the indicator has been considered in the determination of impact significance.

Where there is unlikely to be a risk or opportunity for a significant effect, this is presented as neutral / negligible impact, represented as "0" in the assessment tables.

It should be noted that the significance classifications presented in the assessment are indicative and not absolute. Consideration of site-level factors and detailed information needs to be incorporated into future assessments so that the results of the IIA can be validated when there are fewer uncertainties.

6.7.2 Uncertainty

Uncertainty is accounted for in the assessment through identification of the factors which may influence either the magnitude of a specific impact, or the sensitivity of the receptors (or indicators in the case of some topics). It has been reported according to the following key:

?? – result is considered highly uncertain and will almost certainly require further detailed assessment at a later stage, for example as part of a detailed EIA at a project level

? – result is considered uncertain and may require further detailed assessment at a later stage

✓ – result is considered fairly certain and is unlikely to vary enough to require further assessment

Such ratings have been used to account for the uncertainty that exists in how the Strategy may be implemented at a site level, or at a future time. The intention is that the results of the assessment, including these ratings, will be used to inform future assessment work: for example, project-level EIA.

6.8 Baseline activities

For a number of the strategic themes and topics, there are certain inherent activities which will be undertaken regardless of which option is selected and ultimately implemented. These activities have been termed 'baseline activities', because they bear no influence on future decision-making and are deemed to be beyond the scope of strategic consideration.

6.9 Proposed assessment framework and guide questions

In order to support the IIA, a number of guiding assessment questions were developed to cover the range of environmental, health and socio-economic issues relevant to the assessment of the Strategy. These questions are the same as were used in the IIA of the last Strategy (2016). The assessment guide questions used in the IIA can be found in Appendix B.

6.10 Assumptions and uncertainty

In order to support the assessment and ensure transparency and robustness, a set of assumptions and uncertainties have been documented in a register. These assumptions and uncertainties cover all aspects of the assessment, including the methodology, IIA topics and the strategic options set out in the Strategy.

The register is presented in Appendix A.

6.11 Response to informal scoping consultation

The IIA of Strategy (2016) has been reviewed and updated to reflect Strategy 2021. As the IIA was updated rather than produced as a new document, a scoping workshop was not held. Instead, a scoping report was produced summarising the planned changes to the IIA and circulated to representatives of Statutory Consultees in an informal review process. Review comments were collated and addressed in the updates made to the IIA. Some of the main points raised by reviewers, and the actions taken to address them, are listed below.

- It was suggested that flora should be added as a receptor under the landscape assessment topic. **Action taken –** flora was added as a receptor.
- A number of additional sources were recommended for use in updating the IIA including for example Dynamic Coast work [41], Scotland's national coverage of landscape character assessment [39], The State of Nature Scotland Report [42], the UK State of Nature Report [43], the Nature Networks Evidence Handbook [44] and the 25 Year Environment Plan [45]. **Action taken –** the suggested sources were utilised in the relevant reports.
- Reference to the requirement for biodiversity net gain was not consistent throughout the scoping report. **Action taken –** the requirement for biodiversity net gain was incorporated in Volume 1 and Volume 3 of the IIA.
- It was suggested that extreme heat, drought and subsidence could be considered with respect to climate change considerations. **Action taken** - Although it is too early to assess impacts of these issues on the NDA Strategy, it has been recommended (Volume 3, section 4.3.2) that these issues might be considered in future IIAs for future NDA Strategies
- It was noted that some NDA sites are valued in as a result of their iconic design or appearance. **Action taken -** this has been added to consideration of Cultural Heritage.

- Changes to text regarding land use were suggested to included agricultural land quality. **Action taken –** the suggested text was added to Volume 1 of the IIA.
- It was noted that some temporary landscape or visual impacts could occur during decommissioning. **Action taken -** text on landscape and visual impact was added to cover temporary impacts during decommissioning.

7.0 A, SeIA and HIA topics

7.1 Strategic Environmental Assessment topics

The selection of environmental topics to be included in this IIA has been informed by guidance on undertaking strategic environmental assessment (SEA) [46], and consideration of the baseline conditions and activities that are taking place at the NDA sites. These topics are outlined below.

7.1.1 Air quality

Air quality is defined as the condition of the air with respect to the presence (or absence) of pollutants. Emissions from plant and machinery used in nuclear decommissioning and operational activities can contain a number of pollutants, including oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons, carbon dioxide (CO_2) and particulate matter (PM). The quantity of each pollutant emitted depends upon the technology used and the period of time over which activity is taking place.

The presence of such pollutants in the air can have wide ranging consequences from an environmental and health perspective. Air with a high concentration of pollutants can exacerbate respiratory conditions such as asthma and bronchitis. From an environmental point of view, pollutants such as NO_x, CO and CO_2 can have significant global warming potential, thereby contributing towards climate change if present in high concentrations. In sufficient concentrations, NO_x can also lead to deposition of nitrogen in sensitive habitats, contributing to eutrophication or otherwise degrading the habitat.

7.1.2 Biodiversity, flora and fauna

Biological diversity, or ‘biodiversity’, is the term given to the variety of life on Earth. It is the variety within and between all species of plants, animals and micro-organisms and the ecosystems within which they live and interact. It performs a number of important roles, from maintaining the function of the biosphere as a whole, to providing food and medicine ingredients and enhancing health and well-being.

Nature conservation is concerned with maintaining a viable population of the country’s characteristic fauna, flora and wildlife communities. Impacts on nature conservation are broadly split into two categories; habitats and species. The ‘species’ category can include both fauna and flora species.

Activities across the NDA estate could have the potential to affect biodiversity directly through land-take, which results in loss of, severance from or damage to habitats and declines in populations of species, or indirectly through changes in air quality, noise and other forms of pollution. The Environment Bill 2020 [47] sets out how UK government plans to protect and improve the natural environment in the UK. It introduces a mandatory requirement for biodiversity net gain in the planning system which will have to be taken into account in future plans across the NDA estate.

7.1.3 Climate change

Climate change is one of the key challenges facing the UK and the world today. The Welsh Government and the Scottish Government have both declared a climate emergency [48,49]. The Stern Report [50] and the Intergovernmental Panel on Climate Change [51] have highlighted the range of risks it poses and how urgently an appropriate response is needed. The Climate Change Act 2008 (Climate Change Act) made the UK the first country in the world to have a legally binding long-term framework to cut carbon emissions. It also introduced legally-binding carbon budgets, and created a framework for enhancing the UK’s ability to adapt to climate change. The Climate Change Act requires national greenhouse gas (GHG) emissions to be reduced by at least 80 per cent by 2050, compared to 1990 levels.

The government signed up to the Paris agreement in 2015 and this came into force in November 2016 [52]. It includes commitments to emissions reductions to reduce the impact of climate change, to adaptation and resilience to climate change, and to providing finance to support these, all in the context of sustainable development and eradication of poverty. The emissions reductions are designed, specifically, to hold the increase in the global average temperature to well below 2°C above pre-industrial levels with the aspiration of pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. It applies to all greenhouse gases not controlled by the Montreal Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). At least 40% domestic reduction in greenhouse gas emissions is required by 2030, compared to 1990 levels. In 2019 the government made an additional commitment to reduce emissions further than the Paris agreement required [53]. The commitment is that the UK will cut emissions to 'net zero' by 2050 i.e. 'net zero above the 1990 baseline for the 6 Kyoto protocol gases. Scotland has committed to 'net zero' by 2045 [54]

Decommissioning falls under the 'Industrial process' sector in UK GHG emissions reporting (the energy sector covers emissions from fuel combustion for electricity and other energy production sources). In 2018, the industrial process sector was the seventh biggest contributor to UK GHG emissions behind transport, energy supply, business, residential, agriculture and waste management [55].

Such emissions may be generated by the NDA sites directly through the use of energy, plant and machinery, or indirectly through the transport of materials, wastes and workers. NDA is working to understand its current baseline carbon emissions and how the NDA estate can support Government commitments on achieving carbon neutrality. This work will enable a more detailed assessment of the impacts of climate change on NDA strategy to be undertaken in a future IIA if required, particularly with regard to adaptation and mitigation.

7.1.4 Coastal change and flood risk

Coastal change refers to changes which may affect the coastal environment, including coastal waters and shores. Potential changes to the coastal environment might include changes in rates of erosion, sea level and wave frequency and strength. As these effects can be affected by climate change, this topic has strong links to the climate change and energy topic (see Section 7.1.3).

Flood risk is a combination of the probability and the potential consequences of flooding from all sources. This includes flooding from rivers and the sea, directly from rainfall on the ground surface and rising groundwater, overwhelmed sewers and drainage systems, and from reservoirs, canals and lakes and other artificial sources [56].

Coastal change and flood risk is a relevant topic to the Strategy for two reasons. Firstly, 15 out of 17 sites in the NDA estate are directly on the coast, one is on low-lying land near the coast and only one is inland. They may therefore be susceptible to potential impacts from coastal change and flooding. Secondly, the timescales over which the sites are likely to be operational or undergoing decommissioning may mean that they become increasingly sensitive to changes brought about by climate change.

7.1.5 Cultural heritage

Assessment of cultural heritage generally considers potential impacts under three sub-topics:

- archaeological remains – the material remains of human activity from the earliest periods of human evolution to the present, which may be buried traces of human activities, sites visible above ground, or moveable artefacts;
- historic buildings – architectural or designed or other structures with a significant 'historical value', which may include structures that have no aesthetic appeal or structures not usually thought of as buildings', such as milestones or bridges; and
- historic landscape – the current landscape, whose character is the result of the action and interaction of natural and human factors, and includes evidence of past human activities, which is a significant part of the historic landscape, and may derive both from archaeological remains and historic buildings within it.

Historic features or archaeological remains may be affected by activities across the NDA's estate. This could be effects to the integrity of cultural heritage receptors in the form of damage or degradation caused by land-take or noise and vibration, or, as is more likely the case, effects on their setting from changes in the landscape. Some buildings on NDA sites are valued as a result of their iconic design or appearance.

7.1.6 Geology and soils

This topic considers potential effects of the Strategy on soil resources and quality (including contamination and the potential for activities to disturb historic contamination). The potential for effects on protected or important geological features such as designated geological sites has also been considered.

Soils may be used, damaged or removed during construction and decommissioning activities. The quality of land (including agricultural) at, and in proximity to, the NDA sites may also be influenced by the implementation of specific techniques to reduce or remove contamination.

7.1.7 Landscape and visual impacts

The landscape takes its character from a combination of elements, including topography, watercourses, land use and pattern, vegetation, public open space and cultural heritage features. Landscapes vary considerably in character and quality, and are often considered a key component of the distinctiveness of any local area or region. Impacts on landscape involve two receptor groups: people seeking to enjoy the landscape and the physical fabric of the landscape itself.

Many sites within the NDA estate are in a rural setting and as such tranquillity and remoteness are valued in these areas. The majority of the sites comprising the NDA estate are large and industrial, containing multiple facilities and structures which may affect the local landscape. As decommissioning of sites progresses, the visual impact of the sites may reduce. There may be temporary landscape and visual impacts during decommissioning or care and maintenance phases, for example cladding, construction or lighting impacts.

7.1.8 Noise and vibration

Noise in its widest sense can be defined as ‘unwanted sound’. It can come from industrial, agricultural, domestic, transportation or natural sources, and if experienced at high levels, may cause disturbance to people and wildlife.

Vibration is a low frequency disturbance which, at high levels, can produce physical movement in buildings and their occupants. Vibration can be affected by the use of plant and machinery, and changes in traffic flows and the types of vehicles on the road network. Piling during construction is the most likely source of vibration problems, especially driven piles. Increased levels of vibration have the potential to cause nuisance and physical damage.

Many of the activities undertaken at NDA sites have the potential to generate noise and vibration.

7.1.9 Materials and waste

Wastes are substances or objects which are disposed of, are intended to be disposed of, or are required to be disposed of by the provisions of national law. A ‘radioactive waste’ is any waste that contains radioactive material above certain low levels of radioactivity defined in legislation. Any small amounts of radioactivity in the materials below these levels are similar to background levels of radiation found in the natural environment.

Not everything that is radioactive is a ‘radioactive waste’. Some materials are potentially useful or continue to have value. These are usually described as ‘radioactive materials’. Radioactive materials include uranium and plutonium, which can be used to manufacture nuclear fuel, and spent fuels, which can be reprocessed to produce plutonium and uranium.

Most radioactive waste produced in the UK is solid and made from a variety of materials and items, including discarded protective clothing used by workers, redundant tools and equipment, or concrete and steel from dismantled buildings. Some radioactive wastes are liquids or sludges but these are usually turned into solids by drying them or incorporating them into a solid matrix (usually cement or glass) to make them more stable and easier to manage.

Across the NDA estate, large quantities of radioactive and non-radioactive materials and wastes are generated, stored, treated and where appropriate disposed of. Some materials are used in the construction of new facilities or maintenance of existing facilities. Certain wastes are produced during the course of operational activities such as reprocessing, whilst other forms of waste are produced as a result of decommissioning.

7.1.10 Radiological emissions and discharges

During the course of a nuclear site's operation and decommissioning, emissions and discharges of radioactivity may be made to the environment. This radioactivity is associated with the materials used and the processes involved, for example nuclear power generation using reactors. Discharges of radioactivity to the environment are controlled through strict authorisations granted to operators. Such limits are set well below the levels at which perceptible adverse effects might be experienced by humans, flora and fauna.

As the NDA Strategy covers the management of radioactive materials and wastes, the potential for changes in radioactive emissions and discharges is considered in strategic assessment and decision-making.

7.1.11 Water resources and quality

The water environment provides a number of vital functions to support communities. From providing drinking supplies to serving as recreational facilities, water bodies of all types are fundamental for maintaining a healthy and active population.

Maintaining water resources and quality, including minimising pollution and abstraction, is a key consideration for the Strategy. Abstractions from and discharges to water bodies are generally an ongoing occurrence at nuclear sites.

7.2 Socio-economic Impact Assessment topics

7.2.1 Employment

Employment is an important socio-economic consideration. The creation and maintenance of employment opportunities can help to reduce poverty and facilitate sustainable economic and social development in communities. The contribution of economic growth to poverty reduction depends on the ability of workers to respond to the increasing demand for labour.

Job-creation is considered a core element in national strategies relating to growth, poverty and social equality.

Employment is important in the context of the NDA Strategy as the strategic options contained within it may differ in terms of the opportunities they provide. Some options may result in losses or changes in employment that need to be factored into decision-making and may require appropriate mitigation.

7.2.2 Knowledge and skills

The 'knowledge and skills' topic encompasses an assessment of the existing UK skills base, and the way in which the existing baseline draws upon that skills base.

Over recent years there has been increasing pressure on the current knowledge and skills base of the nuclear industry – employers in the nuclear sector have often reported difficulties recruiting appropriately skilled staff for specific roles, which can lead to wage inflation. As many of the options contained in the Strategy are likely to draw on the nuclear skills base, as well as requiring construction and other roles, there is potential for this to impact the wider nuclear industry and other infrastructure developments.

The Strategy may also facilitate development of new knowledge and skills, which may be of national benefit. Similarly, a number of options may result in closure of facilities as part of ongoing decommissioning activities. This can lead to decay or loss of skills and knowledge.

7.2.3 Education and training

The 'education and training' topic is an assessment of the future UK skills base and the way in which the existing baseline will input into and draw from that skills base.

It is widely recognised in the nuclear industry that there is a need to ensure skills development at all levels, including in some areas where the time required to reach an adequate level of skill may take years, noting that the current civil nuclear workforce is ageing, which increases the risk of losing expertise and knowledge.

The options identified in the Strategy may require a substantial construction, operational or decommissioning workforce over a period of time ranging from a few months to many years. This can have two potential impacts on the future UK skills base:

- the Strategy or option can support the creation of a skills "pipeline", and release skilled workers into the wider labour force; or
- the Strategy or option can continuously draw upon the wider skills base.

Depending on the extent of these impacts, there may be additional effects upon other nuclear industry activities and future developments.

7.2.4 Economy

For the purpose of this assessment, the 'Economy' topic is more specifically defined as a consideration of the potential for the Strategy to deliver gross value added (GVA). GVA is considered to be an important measurement of the contribution of strategic options to the national economy, and an indicator of the wider benefits of improving and stimulating local economies in areas where the options are implemented.

The options contained in the Strategy may vary in their different potential for creating employment and economic opportunities. It is important that this is factored into strategic decision-making.

7.2.5 Local and national assets

Local assets are defined within this assessment as infrastructure designed to meet the needs of the local community at a local or regional level. This includes health and community facilities, emergency services and transport infrastructure which enables accessibility and connectivity.

National assets are defined as facilities or infrastructure that provide services of national importance, for example spent nuclear fuel reprocessing or radioactive waste treatment. Their importance is linked to the availability of alternative facilities or infrastructure which serves the same purpose.

The NDA Strategy and the strategic options identified in it may have the potential to result in changes to local and national assets. This could involve development of new or maintenance or loss of existing assets.

7.3 Health Impact Assessment topics

This HIA focuses on a range of health issues relevant to the NDA Strategy.

The process of undertaking HIA involves identifying and considering a range of 'determinants' of physical and mental health. According to the World Health Organization [57], 'determinants' of health include the social and economic environment, the physical environment and a person's individual characteristics and behaviours.

Taking into account a wide variety of available guidance, a range of health and well-being determinants have been identified and, where appropriate, combined to form seven key themes, against which the potential beneficial and adverse health effects of the Strategy have been assessed:

- respiratory and cardiovascular conditions associated with changes in air quality;
- annoyance, sleep disturbance, cardiovascular effects and other health effects associated with changes in noise levels;
- effects on physical activity and obesity;
- health and safety effects from road traffic changes;
- health effects relating to changes in the water environment;

- radiological safety related health effects;
- mental health and well-being.

These themes are described below.

7.3.1 Respiratory and cardiovascular conditions associated with changes in air quality

This topic has strong links to the air quality topic (see Section 7.1.1). Of the pollutants considered under air quality, concentrations of particulate matter (PM) and oxides of nitrogen (NO_x) are a primary concern from a health perspective. Studies have shown that there is a direct association between proximity to busy roads (including those used by a large number of heavy vehicles) and respiratory illness [58]. Cardiovascular health effects, respiratory ailments and levels of chronic disease may also be influenced by changes in air quality [59,60].

As the NDA Strategy may result in activities which can affect air quality, including construction, operation, decommissioning works and transport, there is potential for this to lead to a change in the risk of respiratory and cardiovascular conditions amongst the local population.

7.3.2 Annoyance, sleep disturbance, cardiovascular effects and other health effects associated with changes in noise levels

Changes in the noise environment can lead to a range of health effects. This might include declines in communication skills, school performance, sleep and heightened aggression and annoyance. Such effects may generate anxiety and stress, which could lead to increased risk of cardiovascular conditions. In extreme cases, elevated noise levels can result in hearing damage [61].

Construction, operational and decommissioning activities associated with the Strategy could result in changes in noise and vibration. Such changes may lead to negative health effects such as annoyance, anxiety and stress amongst local residents and non-motorised users travelling close to sites.

7.3.3 Effects on physical activity and obesity

In order to achieve recommended daily activity levels, it is important that adults and children have access to suitable recreational resources and amenity spaces. In addition, healthy habitats and populations of wildlife can be important aspects of recreation, both through direct enjoyment of nature and through activities such as bird-watching, cross country walking, camping, water-based recreation activities such as boating, angling and canoeing and many others.

Recreation, amenity and levels of physical activity could be affected by the Strategy through:

- changes in transport infrastructure, including alterations to walking, cycling and public transport facilities;
- alteration of the environment surrounding the recreational facility, including effects on wildlife and natural habitats, as well as effects on visual amenity;
- changes in the local road network that affect access to recreational and amenity features;
- effects on light, noise, air and water quality in the vicinity of the development; and
- disturbance and disruption of people due to noise, visual disturbance and temporary traffic disruption.

7.3.4 Health and safety effects from road traffic changes

Changes in traffic volumes and patterns (including vehicle types) can alter the risk of road traffic accidents and affect journey times. Increases in journey times can result in heightened stress and anxiety for travellers, which may lead to increased risk of cardiovascular conditions.

Studies have shown that as traffic increases, people modify their behaviours [62]. This means that social networks may also be at risk because of reduced connectivity and 'road dominance' (i.e. the dominance of roads over other transport options) in or near to residential areas. This can affect people's sense of community and inhibit healthy social interaction, which may lead to negative effects on mental health and well-being.

In addition, impacts on transport infrastructure can affect stress levels experienced whilst travelling, which can lead to further health effects such as cardiovascular problems and anxiety.

The Strategy, and the options identified within it, may result in changes to local transport networks and traffic levels around sites. Traffic changes could occur during construction, operation and decommissioning activities, from the transport of staff and increased local population (in-migration for employment and additional housing requirement), or due to possible changes in infrastructure to accompany works, for example alterations to improve road safety and traffic flow. This might be accompanied by new or widened roads, which can increase road dominance in a community and may reduce social interaction.

7.3.5 Health effects relating to changes in the water environment

Changes in the water environment, which may include changes in quality or the availability of water resources, can affect drinking water quality and food supplies. Such changes can also affect agriculture, direct recreation facilities (e.g. angling, kayaking, canoeing and other recreational activities that involve water) or wider recreational resources, for example views of water along countryside walks or public bridleways.

In the course of construction, operation and decommissioning of nuclear facilities, abstractions from, and discharges to, water bodies are an ongoing occurrence. The extent to which the water environment is affected depends on a number of factors and may vary between different strategic options. Such changes in the water environment have the potential to result in health effects relating to drinking water quality and food supplies, or loss of or changes to recreational facilities and resources.

7.3.6 Radiological safety related health effects

Everyone is exposed to a low level of radiation in everyday life, as there is some radioactivity in the natural materials around us, particularly rocks and soils, and some radioactive particles reach us from outer space. In the UK, any radioactive exposure that is imposed on the public that is over and above this natural background is subject to regulation, based upon European standards and international recommendations on radiological protection. The treatment, storage, transport and disposal of radioactive materials is heavily regulated and has very strict requirements with regard to management and design.

Health and well-being effects related to radiological safety could include fear of exposure, and the effects this has on physical and mental health and well-being. For example, the stress and anxiety that may be associated with living nearby, or routinely undertaking activities close to, a nuclear facility.

The public dose limit for radiological discharges to air and water is set at 1 millisievert[9] per year, a level at which discharges would not pose a significant health risk to human health or populations of fauna. Current aerial discharges from the nuclear industry and waste management facilities are well below the public dose limit.

Within these limits, strategic options contained in the Strategy might vary in terms of the risk associated with hazards and the nature of intervention, if any, required to maintain safety.

7.3.7 Mental health and well-being

Mental health is defined by the World Health Organisation (WHO) as [64]:

> *a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community.*

9 1 millisievert (mSv) = 1 thousandth of a Sievert, the unit used to measure doses of radiation to living tissue. The average annual dose to a member of the public in the UK from entirely natural sources of radiation is 2.7mSv [63]

The mental health and well-being of a population may be influenced by a number of factors. This includes changes to the physical environment – for example, through changes in air and water quality, noise and vibration, the landscape and the availability and accessibility of recreational, amenity and community facilities, as well as changes in socio-economic aspects such as employment, income and opportunities for education and personal development.

Changes in employment and income can have a number of effects on people's mental health, including happiness and self-confidence, sense of control, and stress levels. In studies of long-term trends, being employed has been shown to lower the probability of suffering impaired mental health [65], and is also linked with greater physical health such as lower rates of heart disease and other chronic diseases [66,67]. Further studies have also identified that low income can lead to poor health, and vice versa [65].

The NDA Strategy has the potential to affect the mental health and well-being of the local population in a number of ways.

- Increased pollution from construction, operational and decommissioning activities. This might include changes in air, water and land quality or increased disturbance and annoyance from noise and vibration. Although these would generally be captured as physical health effects, there are strong links between physical and mental health.
- Loss of or changes to recreational facilities and areas of amenity. This could come from changes to the local landscape or from loss of nature sites or biodiversity.
- Rapid demographic change as sites are closed and some employees choose to leave the local area to seek new employment. These changes can affect the social health and support networks of the local population, as well as general happiness and satisfaction with the area.
- Employment opportunities created to implement strategic options could provide income for workers and enable them to develop knowledge and skills.
- Economic development locally, community investment and potential future development at sites may provide a range of benefits which positively influence mental health and well-being.
- Gradual loss of jobs that would otherwise be maintained in the long-term, for example those associated with storage of nuclear materials. The loss of these jobs can affect people's self-confidence levels, happiness, stress levels, and increase the likelihood of risk behaviours such as smoking and drinking.

8.0 Integrated Impact Assessment of the NDA Strategy (2021)

8.1 Introduction

This chapter presents the findings of the IIA in the form of risks and opportunities for environmental, socio-economic and health effects associated with the NDA Strategy (2021). It is split by theme and topic.

For each topic strategy, the NDA objective as identified in the Strategy is provided, alongside a description of the preferred option and its potential effects. Alternative credible options are listed where applicable.

8.2 Site Decommissioning and Remediation

8.2.1 Decommissioning

Decommissioning involves decontamination and full or partial dismantling of facilities following the end of operations and the removal of operational material and waste (sometimes known as Post Operational Clean Out, POCO). The approach to decommissioning is developed on a case-by-case basis, reflecting the specific nature of the facility in question. The NDA estate includes reactors, chemical plants, research facilities, waste management facilities, fuel fabrication and reprocessing plants, all of which present different decommissioning challenges.

NDA Objective

To deliver site end states as soon as reasonably practicable with a progressive reduction of risk and hazard.

Baseline Scenario

Decommissioning is undertaken on a case-by-case basis. As such, there is no baseline scenario.

Strategy (Preferred Option)

The NDA strategy is to decommission its sites as soon as reasonably practicable, taking account of lifecycle risks to people and the environment and other relevant factors. There are three broad credible options for implementing this strategy, with each option being preferred under specific conditions. Generally, the NDA preference is to not defer decommissioning, except where there are clear benefits to be had from deferring work. Where deferred decommissioning is preferred, there needs to be a clear and well-documented case for this.

Option Description

Decommissioning at a pace

Under the decommissioning at a pace option, buildings are dismantled, decontaminated and in some cases demolished, with the majority of activity occurring over the short-term.

Decommissioning slowly but without interruption

Under this option, buildings are dismantled, decontaminated and in some cases demolished over the short- to medium-term with no periods of care and maintenance.

Deferred decommissioning

In the deferred decommissioning option, there may be one or more periods of care and maintenance with no active decommissioning. During such periods, programmes are implemented to ensure that the required level of safety and asset management is maintained. Decommissioning would still be completed, but activity may peak during the short and long-term. Deferred decommissioning may apply only to particular buildings or structures in a facility or at a site, whilst everything else around it is cleared without interruption.

Potential Effects

Environmental risks and opportunities

Decommissioning at a pace offers an environmental opportunity in terms of reducing the hazard and risks associated with land and facilities most quickly; allowing access to subsurface contamination, which can then be managed more efficiently. This could lead to short-term improvements to the landscape and air and water quality. Additionally, decommissioning at a pace can make use of existing infrastructure which might otherwise need to be maintained or upgraded if decommissioning is deferred. Decommissioning more slowly would still offer these benefits, but hazard reduction and improvements to landscape and air and water quality would be realised over a longer timeframe than if a site was decommissioned at a pace.

In some cases, deferring decommissioning can provide an opportunity to allow natural decay, which reduces the radiological risk to the public and the environment during decommissioning and may reduce the level of physical activity needed to clean up a site or facility. This reduction in activity may reduce environmental impacts such as noise and vibration, air and water pollution. If there are short-lived radionuclides, then deferred decommissioning may reduce the waste management burden, with potential knock-on implications in terms of reduced transport. Decommissioning slowly could also enable these benefits to be realised, depending on the order in which facilities were decommissioned.

The use of deferred decommissioning is highly dependent on site-specific considerations, such as the nature of the contamination and the facilities being decommissioned. It may not always be suitable, in which case such opportunities may not be realised.

Decommissioning at a pace could put a strain on waste management and storage facilities, as greater volumes of waste would arise in the short-term that would need to be disposed or stored until an appropriate disposal facility was available. There may also be some strain on waste management and storage facilities from slower decommissioning (without a period of care and maintenance) depending on the order in which facilities were decommissioned and the type of waste generated. Slower and deferred decommissioning may allow more time to plan appropriate management routes for waste generated, as well as allowing transport movements to be spread out over time. However, there may be a trade-off in terms of extended duration of impacts on land use and the landscape, particularly in the case of deferred decommissioning due to the period of care and maintenance.

Socio-economic risks and opportunities

Decommissioning slowly without interruptions offers opportunities in terms of maintaining a skilled workforce and jobs in the supply chain. It can also mean that land becomes available for alternative uses more quickly than if decommissioning is deferred. Decommission at a pace would make land available for alternative uses the soonest. Such uses may include supporting new facilities or providing some other form of socio-economic or environmental benefit (see Section 8.2.4).

A key socio-economic risk associated with decommissioning at a pace is the potential for skills and the workforce to be 'locked up' on a particular site or area of a site. This may prevent other sites or areas receiving attention, which could have further implications from an environmental and health perspective. This may also occur if a number of sites are being decommissioned slowly over the same time period.

A risk associated with deferred decommissioning is the potential for jobs and skills to be lost during periods of deferral due to a decline in demand. However, deferred decommissioning would offer the opportunity to maintain some jobs and the possibility of reusing facilities during the deferral period.

Health risks and opportunities

Under the decommissioning at a pace option, it is likely that more intensive activity would be required to clean up the site or facility. This could lead to higher magnitude environmental impacts in the short -term, which may have implications for health. Intensive demolition or excavation works, for example, could result in changes in air quality which might lead to slightly increased risks of cardiovascular and respiratory illness amongst the local population.

Decommissioning more slowly without interruption and deferred decommissioning may provide opportunities to spread out environmental impacts (and associated health impacts) over time, but at the risk of incurring negative effects on mental health and well-being due to extended impacts on the landscape and land use. As deferring decommissioning allows time for radioactive decay, doses received by workers may be lower (noting that in either case doses to workers will be managed and minimised as far as reasonably practicable). It may also be possible to reduce worker doses during slower decommissioning by planning to decommission some facilities later in the schedule to allow time for radioactive decay.

Maintenance of jobs over a longer period of time under the slower and deferred decommissioning options could offer mental health and well-being benefits (although there would be a decline in jobs during periods of deferral under that option) and may enable attention (in terms of resources, skills and workforce) to be diverted to sites and facilities where health risks are higher. This could be considered an additional health opportunity of slower or deferred decommissioning.

Decommissioning at a pace could have a negative impact on workers' and their families' mental health and well-being, as once a site is decommissioning the workforce is no longer required there so workers would have to relocate to other sites or seek employment in a different industry. Decommissioning slowly and deferred decommissioning may also require workers to relocate, depending on decommissioning programme, with associated mental health and well-being impacts on workers and their families.

Alternatives

As all three decommissioning approaches are considered to be preferred options under certain conditions, there are no alternative credible options requiring assessment.

8.2.2 Land Quality Management

Land quality management involves managing risks to people and the environment from radioactive and non-radioactive contamination in ground and groundwater. This is done through prevention and remediation (including control and monitoring).

Decisions over how remediation is carried out, including whether contaminated land is treated *in situ* or *ex situ*, are made on a case-by-case basis taking into account a range of relevant factors. Such factors include the nature of the contamination, the risks to people and the environment and the Site End State (see Section 8.2.3).

NDA Objective

To ensure that land quality is managed to protect people and the environment.

Baseline Scenario

As decisions regarding land quality management are made on a case-by-case basis, there is no baseline scenario.

Strategy (Preferred Option)

Risk to people and the environment is the NDA's primary and enduring consideration in deciding how to manage land contamination. This risk is determined in part by the nature, extent and likely behaviour of any contamination.

The NDA strategy is to employ early risk-based decision-making to ensure remediation is proportionate to the level of risk. At higher levels of risk, there is less flexibility in the way land quality is managed. Often the decision is driven by the need to reduce risk. Action will be taken as soon as reasonably practicable to minimise the time at risk. As levels of risk decrease, the strategy is to take account of sustainable development to promote socio-economic opportunities and maximise environmental protection.

Due to decisions being taken on a case-by-case basis, there is no single preferred option for this strategy. Instead, there are four credible options which may each be preferred under certain conditions.

Option Description

In situ management without intervention

This option may only be suitable for certain types of contamination. Under this option, the contamination would be managed where it is, with controls in place to ensure the contamination does not spread or worsen in order to allow the contamination to attenuate. Such controls would likely include active and ongoing monitoring, which is why this option is sometimes referred to as monitored natural attenuation, a recognised approach in Environment Agency guidance [68]. Beyond the monitoring activities needed to ensure the contamination does not worsen, activity under this option would be minimal.

In situ management with intervention

There are many potential intervention measures available to remediate contaminated land, depending on the contaminants. Some use physical processes, which may include construction of barriers, whilst others may involve chemical or biological treatment. The common element of such sub-options is the treatment of the contamination where it is, without the need to excavate the material or remove it from the site.

Ex situ management for reuse

Contaminated material that has been excavated can be treated through various processes in order to make it suitable for reuse. Such processes may include washing or separation of lightly contaminated soils from more highly contaminated soils. Reusing treated material can offer a number of advantages, particularly in terms of reducing requirements for transport. The NDA has had considerable success in recent years reusing excavated material at its sites in line with the Waste Hierarchy [69].

Ex situ excavation for disposal

In many cases, the historic strategy for dealing with contaminated land was to excavate it and transport it off-site for disposal. In recent years, in line with government policy and sustainable development principles, there has been a significant shift away from this option towards treating material *in situ* or treating it for potential reuse so that it is no longer considered waste. This helps reduce environmental impacts associated with excavation and transport, and pressure on authorised disposal sites. In some cases however, particularly where risks are highest, there may be little choice but to excavate contaminated material and transport it off-site for disposal. Under these conditions, this option may be preferred.

Potential Effects

Environmental risks and opportunities

In situ management without intervention, due to the minimal activities required, has very few environmental risks; providing it has first been established that the contamination is not spreading or getting worse. As the contamination would be left where it is to allow natural attenuation to take place, there would be very small energy use requirements, waste generation, vehicle movements and impacts in terms of pollution. However, use of the option is highly dependent on the nature of the contamination being correctly understood and whether potential pathways exist which might lead to effects on receptors (people, water, flora and fauna). As such, it may not always be suitable. In the event that the contaminant does not attenuate naturally and remains in a relatively unchanged form for an extended period of time, there would be very few long-term environmental opportunities offered by this option in terms of improving land quality.

In situ management with intervention offers opportunities in terms of improving land quality, and avoids many of the adverse environmental effects such as air and noise emissions associated with options that include excavation. Such opportunities may come with a trade-off in terms of environmental risks in the short and medium-term. For example, intervention could involve processes which use energy and generate pollutant emissions. Intervention also involves disturbing contaminants and may increase the risk of contaminants spreading or additional releases of contaminants.

Ex situ excavation for reuse would have short-term impacts associated with excavation activities. This may include transport of plant and equipment, energy use and emissions of air pollutants. Energy may also be used in treating excavated material. The main environmental opportunity offered by the *ex situ* for reuse option is the avoidance of waste, which under the disposal option would require transport to an authorised site. Reusing existing material may also help to reduce material requirements for other developments at a site. This could have environmental implications in terms of avoiding transport movements and carbon emissions.

Excavating contaminated land for disposal is the option with the greatest environmental risks, as there would be short-term impacts from changes in air quality, noise and vibration, and landscape from the excavation activities, followed by longer-term impacts of transporting wastes to suitable disposal facilities.

Socio-economic risks and opportunities

From a socio-economic perspective, *in situ* management without intervention offers the least socio-economic opportunities, as employment would largely be restricted to monitoring activities. There would also be few opportunities to enhance knowledge and skills or provide education and training.

In contrast, *in situ* management with intervention would provide a range of opportunities to enhance knowledge and develop skills, although the extent of these opportunities would largely depend on the intervention technology used. There may also be opportunities for education, training and employment.

In situ management with intervention gives greater control over timescales than management without intervention, which can help free up land for alternative uses more quickly.

Ex situ excavation for reuse and *ex situ* excavation for disposal would each create employment and may lead to economic investment, but would be unlikely to create many opportunities in terms of enhancing knowledge and skills or education and training.

Finally, removing contaminated material from the ground can provide greater control over timescales, allowing the land to be freed up for alternative uses more quickly (see Section 8.2.4).

Health risks and opportunities

All options would offer health opportunities as the hazard would be removed or reduced. Intervention and excavation potentially offer the most opportunities from a health perspective, as the time 'at risk' is reduced. However, there is a trade-off in terms of short-term environmental impacts which may influence health. For example, works to excavate contaminated material and transport it off-site could lead to changes in air quality which might influence the risk of cardiovascular and respiratory illnesses, while increased traffic might influence the risk of road accidents on the local transport network.

Alternatives

The four credible options outlined above may each be considered preferred under specific conditions and could all be used to implement the NDA strategy. Therefore, there are no other options requiring assessment.

8.2.3 Site End States

The NDA owns significant quantities of land, of which around one quarter is designated land that has been assigned by the government for decommissioning and remediation. As part of its responsibilities to government, the NDA is required to propose the end state for the designated land at each of its sites. The site end state describes the condition to which the site (land, structures and infrastructure) will be taken and, where necessary, should be accompanied by a description of the controls required to protect people and the environment from any residual hazards.

Site end states together define objectives for the ongoing management of structures, infrastructure and land quality. They also have implications for the management of spent fuels, nuclear materials and waste arising from operational and decommissioning activities.

Since Strategy (2016), NDA has worked with the regulators and government to ensure that the regulatory regimes in the UK are flexible enough to accommodate a range of end states and that residual controls do not restrict future use of land unnecessarily. Significant progress has been made, including the publication of Guidance on Requirements for Release from Radioactive Substances Regulation [70] by the environment agencies and discussion of amendments to the Nuclear Installations Act 65.

NDA Objective

To define credible objectives for the decommissioning and remediation of each site (or part of a site).

Baseline Scenario

The expected state to which land and structures will be returned following decommissioning activities varies from site to site across the NDA estate. For some sites, potential high-level site end state options have been identified. For others, this will be an ongoing process over the period of years it takes to implement the site's decommissioning programme. As site end states are by their nature a very site-specific consideration which is based on a wide range of relevant factors and constraints, there is no baseline scenario.

Strategy (Preferred Option)

The NDA strategy is to employ pragmatic, risk-based remediation objectives that enable beneficial reuse of sites wherever possible. This recognises that there may be both risks and opportunities associated with decommissioning and remediation activities. In some cases, there may be a tipping point beyond which remediation does more harm than good.

As a site gets closer to the end of its decommissioning journey, the end state will need to be defined in increasing levels of detail. As far as possible, this should be informed by a clear view of the future land use to ensure the safety of future users, and maximise beneficial reuse of structures, infrastructure and land (see Section 8.2.4).

The NDA's preferred option to achieve this strategy is to take its sites, on a site-by-site basis, to a condition suitable for their next planned use (in line with relevant planning requirements) or their probable future use(s) where remediation occurs before the next use is planned.

Option Description

Under the preferred option, sites would be remediated only as far as is required to be suitable for their next planned use. Where the next planned use does not need a nuclear site licence, the licence will be surrendered, with any residual radioactive or non-radioactive contamination subject to appropriate permit, planning and institutional controls.

Potential Effects

The next planned use option ensures that the level of intervention (taking into account the cost, energy use and risk to workers) and the volume of waste generated are appropriate (no more or less than required) to meet the requirements of the site's next planned use. Whilst this can help to ensure that environmental, health and socio-economic risks are minimised, the exact nature and extent of risks (and therefore impacts) will be dependent on the next planned use and the activities needed to make the land suitable for it.

Environmental risks and opportunities

Activities required to make land suitable for a next planned use are likely to generate a range of short to long-term environmental impacts, including changes in air, water and soil quality, the generation of carbon emissions and wastes, and changes to habitats or landscape. The exact extent of such impacts and whether they were a risk or opportunity would depend on the next planned use and the current state of the land. For example, in order to make the land suitable for use as a car park, the extent of physical activity (and thus the magnitude of associated environmental impacts) may be reduced when compared to making the land suitable for use as a residential development. There would be various environmental opportunities, including opportunities to remove contamination, improve long-term air, water and soil quality at the site, enhance biodiversity and remove structures or facilities which have adverse landscape and visual impacts.

Socio-economic risks and opportunities

Under the preferred option there would be opportunities to enhance knowledge and develop skills. Regardless of the next planned use for a site, a degree of remediation may need to take place to make the site safe. Generally speaking, the greater the extent of intervention required, the greater the opportunities may be for developing knowledge and skills and promoting education and training, though this is not always the case. Such intervention would generate employment.

A further socio-economic opportunity associated with this option is the potential for reuse or divestment of the land which, following remediation, may become a local or national asset.

Health risks and opportunities

The main health opportunity associated with taking sites to a condition suitable for their next planned use is the removal of hazards which may affect land, water and air quality. Removal of such hazards may also free the land up for alternative uses, which could include amenity or recreational features. Creation of such features could positively impact levels of physical activity undertaken by the local population, thereby providing health benefits.

Remediation of a site to a condition suitable for its next planned use has the potential to generate adverse environmental impacts in the short to medium-term, though these would be reduced compared to making a site suitable for any foreseeable use. Such impacts could have adverse implications for health. For example, an increase in air pollutant emission can influence the risk of cardiovascular and respiratory illnesses amongst the local population.

Making land suitable for its next planned use may offer further opportunities to facilitate dialogue with stakeholders, which can have a positive effect on community cohesion and may lead to mental health and well-being benefits.

Alternatives

Leave the hazard where it is and prevent use

This option would not involve physical activity to improve the condition of the site, but may involve minimal activity to maintain, stabilise it or prevent further contamination. For the most part, it would rely on controls (legal or administrative tools or actions such as restrictions on land use, environmental monitoring requirements, and site access and security measures) to manage risks to people and the environment.

This option is only suitable in extreme cases where remediation is very difficult and turning the site into a disposal site (that needs to be managed by preventing use) is preferable to attempting extensive and costly remediation in order to create a new facility or alternative land use.

Managing the risk using controls could offer some opportunities from an environmental perspective in terms of reducing the physical activity needed in the short and medium-term (and therefore the magnitude of impacts). This might include avoiding pollution-generating activities such as excavation, vehicle movements and energy use.

Under this option no environmental opportunities would be realised in terms of improving water and soil quality at the site in the long-term. The hazard would also still exist in a relatively unaltered form (although monitoring would be used to ensure risks did not increase). This could have potential health implications.

Preventing the site from being reused would limit socio-economic opportunities, but may lead to some employment to undertake monitoring activities.

Remove the hazard completely so that the risk does not need to be controlled

Under this option, the site would be restored to a condition where it can be used for any foreseeable use without the need for additional remediation or management controls. The level of intervention required to achieve this would likely exceed that required under the other two credible options.

This may mean that environmental impacts (both adverse and beneficial) associated with intervention activities are greater. For example, removing the hazard completely would likely lead to high-magnitude adverse impacts in terms of air quality, noise and vibration, carbon emissions, energy use and waste in the short to medium-term, but may result in long-term improvements in air, water and soil quality, as well as positive habitat, landscape and visual impacts. It is also likely that greater volumes of waste would be generated which may then need to be removed from the site.

Due to the increased level of intervention required to make the land suitable for any foreseeable use, there may be a range of socio-economic opportunities provided, including employment, development of skills and opportunities for education and training. This could have positive health effects in terms of mental health and well-being. On the other hand, removing the hazard completely would likely take longer, and thus the land would not be made available for reuse as early as it would be under the next planned use option. This could limit the attainment of socio-economic opportunities such as investment into the local economy and jobs.

From a health perspective, removing the hazard completely may offer greater long-term health opportunities than the two other credible options, depending on the disposal route. However, in the short to medium-term, the greater level of intervention required could increase health risks as environmental impacts would likely be of higher magnitude.

8.2.4 Land Use

The NDA's Site End States strategy describes the condition to which designated land and associated structures and infrastructure need to be restored. In support of this, its Land Use strategy explores how land can be used either following completion of decommissioning and remediation activities or on an interim basis prior to achieving the site end state.

NDA Objective

To optimise the reuse of NDA sites.

Baseline Scenario

The identification of potential options and agreement upon a preferred future land use is, by its nature, a site-specific consideration. There are many factors that affect how a site could be used. These can include the physical characteristics of the site, particularly location, and external factors such as commercial interest and local planning policy. Evaluating these factors can support defining the end state, especially for sites where the next owner, and consequently the next use, is unknown.

Due to the site-specific nature of this strategy, there is no baseline scenario.

Strategy (Preferred Option)

The NDA strategy is to identify credible uses for its land either when decommissioning and remediation is complete or on an interim basis prior to achieving the site end state. Part of this commitment is an aspiration to encourage the reuse of brownfield land over greenfield land, in line with government policy.

The NDA is committed to investigating reuse opportunities, recognising that there is a need to balance the cost of achieving an end state against the socio-economic and/ or environmental value the next use will bring.

Whilst the NDA's preferred option is to divest the land for some benefit, it is recognised that there may be situations in which the land may need to be retained as a government asset or as an NDA liability.

Option Description

The next use of a site will be defined by the next owner in accordance with the planning regime and incorporating consultation with stakeholders as appropriate.

Suitable potential land uses may vary from site to site, and could range from anything as simple as a recreation area to a new nuclear build site or a business and technology park. Due to these varying potential uses, it is difficult to predict the environmental, socio-economic and health impacts associated with the Land Use strategy.

A range of potential land uses and associated environmental, socio-economic and health opportunities are given below. It should be noted that this is for illustrative purposes only. Actual future land uses for sites will be developed through ongoing consultation between the NDA, local authorities, local communities and other relevant stakeholders.

Potential Effects

Environmental opportunities

Decommissioning and clean-up of sites may facilitate development of new nuclear build. This could offer a number of environmental opportunities, including the avoidance of environmental impacts associated with development of new sites. Such development at existing sites would also offer opportunities by providing a low carbon form of power generation, which could have a positive impact from a climate change perspective.

Environmental opportunities may be provided if sites are converted into nature conservation sites or habitats. This could help to promote biodiversity and improve local landscapes.

Socio-economic opportunities

Clean-up and closure of the NDA sites may provide socio-economic opportunities if a community service or facility can be established. This might include a business park or some other facility which provides benefits to the local economy. Such development would likely support employment and could lead to opportunities to enhance knowledge and skills.

Development of a college or research establishment could promote opportunities for education and training. An example of this is the transfer of some of the research facilities at Berkeley Centre (owned by NDA and adjacent to the Berkeley reactor decommissioning site) to South Gloucestershire and Stroud College with a view to providing training in the renewable energy and nuclear sectors.

If land is used to support the new generation of nuclear build this could provide an opportunity to create a national asset, providing jobs and economic investment into the community or region.

Health opportunities

Creation of recreational or amenity space or some other form of community facility could lead to health opportunities from improvements in mental health and well-being, as well as having positive physical health implications if it leads to increased levels of physical activity.

In addition, the actual process of determining a future land use in itself may offer health opportunities if it promotes community cohesion through an effective stakeholder consultation process.

Alternatives

The alternative credible options to divesting the land for some socio-economic or environmental benefit are to either retain the land as a government asset or to retain the land as an NDA liability. Such options would offer little in the way of opportunities, and would only be preferred in the event that a more suitable use could not be identified.

8.3 Spent Fuels

8.3.1 Spent Oxide Fuel

Oxide fuel is used in Advanced Gas-Cooled Reactors (AGR) operated by EDF Energy (EDFE) in the UK, and in Light Water Reactors (LWR) operated by numerous utilities throughout the world. Spent oxide fuel has historically been reprocessed in the Thermal Oxide Reprocessing Plant (THORP) at Sellafield which started operation in 1994, and ceased in 2018.

The NDA is contractually committed to receive and manage all of the spent fuel arising from the seven currently operating EDFE AGR power stations in England and Scotland. EDFE has publicly declared its intention to operate these stations for as long as it is safe and economic to do so and to seek significant life extensions to its AGR reactors. Given the cessation of AGR spent fuel reprocessing in THORP, the remainder of this spent fuel is to be placed into interim storage pending a future decision over its long-term management.

NDA Objective

To ensure the safe and secure storage, management and disposition of UK owned oxide and overseas origin fuels held in the UK.

Baseline Scenario

THORP closed in 2018, so the NDA no longer has oxide fuel reprocessing capability. As such, the baseline scenario is now for the continued interim storage of spent oxide fuels in existing facilities pending treatment and packaging prior to disposal to a GDF.

Strategy (Preferred Option)

In the previous Strategy the NDA committed to reprocess the contracted amount of spent fuel in THORP, completing THORP reprocessing as soon as practicable, while interim storing, immobilising and then eventually disposing of any unreprocessed spent fuel to a GDF.

Reprocessing at THORP has now ceased, and re-opening THORP is no longer deemed a credible option. As such, in delivering the current strategy, the NDA seeks to continue with the preferred option from the previous Strategy: to store, immobilise and dispose of unreprocessed spent oxide fuel to a GDF. As the disposal end point is viewed as fixed, the only strategic decision to be made by the NDA is whether to store spent oxide fuel in existing or new storage facilities. The preferred option is to store spent oxide fuel in current facilities at the Sellafield site, namely in THORP Receipt and Storage.

Option Description

Under this option, the remaining inventory of spent oxide fuel will be stored in THORP Receipt and Storage, prior to treatment, packaging and disposal to a GDF.

Potential Effects

Environmental risks and opportunities

Managing the spent oxide fuels inventory through existing storage facilities, avoids most of the short, medium and long-term environmental impacts associated with construction, operation and decommissioning of a new facility to store the inventory. These impacts may include emissions of air pollutants, noise and vibration, landscape and visual impacts, energy use and consumption of raw materials. Some construction may still be required to maintain existing stores and would be required to build a packaging plant to enable disposal of the unreprocessed spent fuel. However, such a packaging plant may be required in any case if constructing new storage facilities.

Operation of the packaging plant (which is required under both options) could generate a number of environmental impacts, particularly from a materials and waste perspective, as several thousand tonnes of spent oxide fuel would be packaged to produce a waste product.

Managing the spent oxide fuel in existing facilities may lead to slightly greater volumes of water abstraction, given the current wet storage of spent oxide fuels, however any such benefit is likely to be small compared to water abstraction volumes for the site as whole. Managing the spent oxide fuel in existing facilities may also lead to slightly greater radiological discharges and operational waste volumes compared to newer facilities, because newer facilities would be optimised to reduce these disbenefits. However, given the current stringent controls on radiological discharges, which are very low, any such benefit would be small. In addition, construction of new facilities would lead to increased decommissioning waste volumes, which would likely dwarf any benefits in terms of operational waste generation.

There may be additional increased risk of corrosion of spent fuel stored in current storage facilities, which could lead to releases to the ground or water environment. Such risks, although low, would need to be carefully managed.

Socio-economic risks and opportunities

Under this option, current jobs at THORP Receipt and Storage would be maintained, however new jobs from construction of new facilities would not be created.

Considerable employment would be generated through construction of a packaging plant for the spent oxide fuels prior to packaging and disposal to a GDF. This would range from lower-skilled construction jobs to highly specialist engineering and managerial skills.

Management of the spent oxide fuels using existing facilities offers limited opportunities for developing new knowledge and skills, with the exception of the knowledge and skills that might be gained from implementing techniques to prolong the life of existing interim stores. This might lead to some minor opportunities for education and training.

Development of a packaging plant offers some minor opportunities to enhance knowledge and skills in the conditioning of radioactive wastes. Construction of the facility may also offer socio-economic opportunities by creating a national asset that could be used to manage other waste streams.

Finally, continued operation of THORP Receipt and Storage and supporting infrastructure will maintain investment into the local economy in the short-term to long-term. Opportunities for investment may be provided by construction and operation of the packaging plant, but such opportunities will not be as large as if new storage facilities were constructed.

Health risks and opportunities

In terms of health risks, construction activities required to develop a packaging plant could lead to short-term adverse changes in air quality, which might influence the risk of respiratory and cardiovascular conditions amongst the local population. Noise and vibration could possibly lead to annoyance and anxiety, while construction traffic could increase the risk of accidents on the local road network. There is also a risk of releases of non-radioactive contaminants to the ground and water environment, which could have further health implications, though these could be controlled through implementation of a construction environmental management plan. However, such risks would all be greater if new storage facilities were constructed.

This option may offer some health opportunities by avoiding the additional movement of the spent oxide fuel to a new facility prior to packaging and disposal to a GDF. These risks would include conventional risks associated with transport movement and air quality, but also the small radiological risk associated with movement of radioactive waste. Such radiological risks would likely be partially or fully offset by new facilities being built to more modern standards, and therefore offering a higher level of radiological protection. However, extensive controls are in place to manage radiological risks in existing facilities, so any benefit would be very small.

Avoiding the construction of new facilities would likely have mental health benefits through the avoidance of environmental effects including reduced air quality, noise and vibration generation, and visual and landscape effects. However, construction of new facilities would lead to mental health benefits associated with employment opportunities. Overall, the effects on mental health of storing spent oxide fuel in existing facilities is likely to be small.

Alternatives

There is one credible alternative option to storing the oxides inventory using existing facilities, which is to store the oxides inventory in a new pond, cask store or dry store. The potential environmental, socio-economic and health impacts of this option compared to the baseline is considered in the detailed assessment presented in IIA Report: Volume 2 – Section 3.1.

8.3.2 Spent Magnox Fuel

The Magnox reactors were the first generation of commercial nuclear power stations to operate in the UK. All of these twenty six reactors have now been shut down. The last remaining operating reactor at Wylfa ceased generating in December 2015.

The NDA has the responsibility to defuel and decommission all of these Magnox reactors. Prior to decommissioning, spent fuel is removed from reactor cores and sent to Sellafield for reprocessing.

Reprocessing was identified as the preferred option for managing Magnox spent fuel as the fuel and alloy in which it is encased are both susceptible to corrosion in water over time. Reprocessing allows the spent fuel to be broken down into its components of uranium, plutonium and waste.

NDA Objective

To ensure the safe management and disposition of spent Magnox fuel, completing Magnox reprocessing as soon as practicable.

Baseline Scenario

The use of reprocessing technology to manage spent Magnox fuel has been ongoing for over 50 years. Over this time the facilities that support reprocessing have aged and deteriorated, leading to a number of recent performance issues.

Reprocessing spent Magnox fuel at Sellafield has and continues to facilitate decommissioning at other sites across the NDA estate. The baseline scenario is to maximise the reprocessing of suitable Magnox spent fuel prior to ending operations around the end of the 2020/21 financial year. Any remaining material will be interim stored pending treatment and packaging prior to disposal to a GDF.

As of July 2019, there remains about 850 tU of Magnox fuel to reprocess. Following the cessation of reprocessing operations, the reprocessing plant, along with its supporting infrastructure will undergo Post Operational Clean Out (POCO) ahead of decommissioning.

Strategy (Preferred Option)

The NDA strategy is to reprocess all Magnox fuel in line with the Magnox Operating Programme (MOP 9) [71].

The MOP outlines the timeframes and targets for activities at Magnox sites. Detailed co-ordination of all activities ensures a smooth sequence of transport movements and efficient operation of the reprocessing facilities at Sellafield.

Reprocessing of spent Magnox fuel has been the UK’s historic strategic position for over 50 years and remains the current preferred option.

Option Description

In this option, the reprocessing of suitable spent Magnox fuel is maximised until operations cease at the end of the 2020/21 financial year.

Reprocessing involves firstly removing the metal fuel casing in a procedure called decanning. The casing is then managed separately as ILW.

After decanning, the uranium fuel bar is dissolved in acid to produce a radioactive solution containing the uranium, plutonium and other fission by-products that were contained in the spent fuel. The uranium and plutonium in solution needs to be extracted and separated from the remaining and unwanted products. This is done as a sequence of chemical extractions.

Following the extraction of uranium and plutonium, almost all of the unwanted products remain in the aqueous solution, which is drawn off as a separate liquid waste stream. This liquid waste is highly radioactive, and is referred to as Highly Active Liquor (HAL).

Finally, the separated liquid plutonium and uranium product streams are solidified for safe storage. At this stage they fall under the plutonium and uranium strategies respectively (see Sections 8.4.1 and 8.4.2).

Removal of spent fuel from Magnox sites facilitates other decommissioning activities and is an important milestone in the sites’ decommissioning programmes.

Potential Effects

Environmental risks and opportunities

One of the main environmental risks associated with Magnox reprocessing is the potential for liquid and aerial discharges. These are managed in line with government targets as set out in the UK Strategy for Radioactive Discharges [15].

There are a number of other environmental impacts associated with continuing to reprocess the Magnox inventory. These include the ongoing use of energy and generation of carbon emissions associated with equipment and the movement of workers, and the landscape and visual impacts of the plant and stores. These impacts are short-term as the plant is scheduled to be shut down at the end of the 2020/21 financial year.

Reprocessing spent Magnox fuel produces plutonium, uranium and HAL, all of which are radioactive and require careful management. Although there are appropriate management routes in place to deal with these products (see Sections 8.4.1 and 8.4.2), this could be considered an environmental risk from a radiological perspective. Indeed, extending Magnox reprocessing beyond the end of the 2020/21 financial year would exacerbate such risks, which are avoided under the baseline option.

There are also risks associated with the use of aqueous processes and solvents during the extraction of plutonium and uranium. The use of such processes can lead to risks of hazardous releases to water bodies. Given the extensive controls that are put in place to avoid, minimise and monitor releases of contamination to the water environment, any residual risks are generally small.

Such risks may also be offset somewhat by the opportunities that come from converting the spent fuel into a form less susceptible to corrosion. Long-term interim wet storage of spent Magnox fuel can lead to contamination and degradation of interim storage facilities, therefore the baseline option is to store any unprocessed spent Magnox fuel in self-shielded boxes. A greater number of such facilities would be required if Magnox reprocessing operations ceased early, whereas extended reprocessing increases the likelihood of significance maintenance associated with supporting plant failure (see 'Alternatives' section). As such, ceasing reprocessing at the end of the 2020/21 financial year likely balances the environmental risks and opportunities of avoiding construction and maintenance activities.

One of the main opportunities associated with ceasing reprocessing at the end of the 2020/21 financial year is the avoidance of continued operation of the Magnox reprocessing plant at decreased throughput rates, which would result from the attempt to reprocess the entire spent Magnox fuel inventory. Such extended reprocessing would be associated with significant energy usage and would delay the decommissioning of the Magnox reprocessing plant, with associated landscape and visual effects.

Ceasing reprocessing at the end of the 2020/21 financial year would also likely avoid the need for the construction of additional self-shielded box store that is assumed to be needed if reprocessing operations ceased early. Such construction would have a range of short, medium and long-term environmental impacts, including changes in air quality, noise and vibration, landscape and visual impacts, material and energy use and contamination to soil and the water environment. These impacts are avoided under the baseline option. However, it is acknowledged, that the difference in impacts between the baseline option and ceasing reprocessing operations early narrow as the end of the 2020/21 financial year are approach.

Socio-economic risks and opportunities

Reprocessing spent Magnox fuel at Sellafield has and continues to bring economic investment into the local and regional economy. This investment may be direct, through supporting employment, and in turn has multiplier effects on the local economy. Such economic opportunities would continue under this option until the end of the 2020/21 financial year, and perhaps for some time after this as the facilities are decommissioned, but would eventually decline.

From an employment perspective, continuing to reprocess the Magnox inventory will maintain jobs over the next few months. These jobs are associated with operation of the plant and stores, in addition to managerial and administrative positions that may be required to support reprocessing activities. Once Magnox reprocessing has ceased, and the facilities are shut down in preparation for decommissioning, these jobs will be lost. Some opportunities for job creation may exist to undertake decommissioning, which could help to offset some of these losses, as could the potential transfer of jobs to other facilities. Such employment changes may affect the nature of local communities and the local economy.

Ceasing reprocessing at the end of the 2020/21 financial year offers limited opportunities to develop new skills or knowledge. However, such knowledge and skills would likely be enhanced if reprocessing operations were extended to cope with more heavily-corroded spent Magnox fuels.

Health risks and opportunities

The main opportunity provided by this option from a health perspective is the conversion of spent fuel into form less susceptible to corrosion in storage. Such corrosion can lead to land and water contamination which could have adverse health implications if not managed appropriately. However, as reprocessing generates HAL, a highly radioactive waste which requires careful management, overall there may be an adverse effect on radiological safety from continued reprocessing, though risks remain well within acceptable limits. Ceasing operations at the end of the 2020/21 financial year somewhat balances these competing effects.

If an alternative option were implemented to deal with the spent Magnox inventory, construction or maintenance activities would lead to environment-related health risks such as changes in air quality, noise and traffic.

Finally, the maintenance of jobs to operate the plant and stores until the end of the 2020/21 financial year may have a positive impact in terms of mental health and well-being, although this benefit is small compared to ceasing reprocessing operations early, and would be greater, but ultimately only delayed, if reprocessing operations were extended.

Alternatives

There are two credible alternative options to ceasing reprocessing of suitable spent Magnox fuel at the end of the 2020/21 financial year. These alternative options are to cease reprocessing operations early, by a few months, or to extend reprocessing operations to ensure all suitable spent Magnox fuel is reprocessed. In both alternatives, any unreprocessed spent Magnox fuel or fuel that is not suitable for reprocessing would be placed in interim stores pending treatment, packaging and disposal to a GDF. The potential environmental, socio-economic and health risks associated with these alternative options are assessed in IIA Report: Volume 2 – Section 3.2.

8.3.3 Spent Exotic Fuel

In addition to bulk Magnox and oxide fuels, the NDA also manages a smaller inventory of non-standard fuels, commonly referred to as “exotics”. These fuels include metallic, oxide and carbide materials that have come from earlier nuclear industry activities such as the development of research, experimental and prototype fuels and reactors.

Some, but not all, of these fuels share common characteristics with bulk Magnox and oxide fuels, and can be managed in the same way, for example through reprocessing. Some, however, present their own particular management challenges due to their diverse and sometimes unique properties. In some cases, tailored solutions for long-term management and disposition may be required.

NDA Objective

To ensure the management and ultimate disposition of all exotic fuels, developing options for those fuels which cannot be effectively managed through routes for Magnox or oxide fuels.

Baseline Scenario

In recent years, the NDA has taken a series of decisions to transfer the entire exotic fuel inventory to Sellafield for management. This strategy of consolidation enables clean-up and decommissioning of other sites in the NDA estate.

With this approach, the NDA aims to optimise the use of suitable facilities, skills and capability at Sellafield to treat and manage exotic spent fuels.

Since 2012, transfer of exotic fuels to Sellafield has been underway, with the fuel being appropriately managed upon arrival at the site.

The baseline scenario is to continue to manage the exotics inventory through existing facilities at Sellafield. There are two options for how the inventory can be stored: in existing (potentially modified) facilities or in new facilities. In either case storage would be an interim measure before disposal to a GDF.

Given the varying nature of the exotic fuels, different storage options may be implemented for different parts of the inventory.

Strategy (Preferred Option)

Where the properties of the exotic fuels share common characteristics with bulk fuels such as Magnox and oxides, it may be practicable and economic to manage them using the same facilities. The NDA has therefore identified that its preferred option is to continue managing the exotic inventory using existing facilities, reprocessing the spent fuels, where possible, alongside bulk fuels.

Any part of the inventory which cannot be reprocessed alongside bulk fuels will be stored pending availability of a GDF. Two options have been identified for these fuels, and the preferred option may vary with fuel type.

Option Description

Interim store in existing or modified facilities

Under this option, exotic spent fuels are consolidated at Sellafield and interim stored in existing or modified facilities pending treatment and packaging prior to disposal in a GDF. Exotics not currently stored at Sellafield will be moved in the short-term, and interim stored for the medium- to long-term. Modifications to existing stores, if required, would occur in the medium-term.

Interim store in new facilities

Under this option, exotic spent fuels are consolidated at Sellafield and interim stored in newly built facilities pending treatment and packaging prior to disposal in a GDF. The new stores would be built in the short- to medium-term and exotic spent fuels would be moved to the new facilities when they are available. Interim storage would be required for the medium- to long-term.

Potential Effects

Environmental risks and opportunities

For exotic spent fuels that cannot be reprocessed or remain following closure of the reprocessing plants, the main difference between the options is the impact of constructing a new store compared to using or modifying an existing store.

Impacts of constructing new storage facilities include short-term changes in air and water quality and landscape and visual impacts. Noise may also be generated from vehicle movements and the use of plant which would require energy and could generate carbon emissions. Modifications to an existing store could cause similar impacts on a smaller scale.

Constructing a new facility rather than utilising an existing facility requires more resources. It would also generate more waste, as it creates an extra store to decommission once fuels have been transferred to the GDF. However, as the facility would be designed with decommissioning and the waste hierarchy in mind, the impact of this would be minimised as far as reasonably possible.

Socio-economic risks and opportunities

Construction of a new store would generate more construction jobs in the short-term than modifying an existing store. There would be a small contribution (in comparison to the impact of the whole Sellafield site) to the local economy during this period.

Under both options, personnel would be required to operate the stores and transport waste to a GDF when it becomes available. Appropriate education and training, and maintenance of knowledge and skills would be required.

Health risks and opportunities

Modifying an existing store may lead to higher worker doses than constructing a new store, as some radioactive material will already be in place in an existing store. A new store may have improved shielding compared to an older store, although it may be possible to improve existing shielding if required, and existing worker exposures are already managed and minimised within safe and legal guideline values.

Air quality and associated health impacts, such as increased risks of cardiovascular and respiratory illness amongst the local population, are likely to be worse under the new storage facilities option in the short-term whilst it is being constructed. Annoyance and road traffic impacts will also be greater at this time compared to if a store is being modified, although both options have an impact.

Both options require maintenance of jobs over a longer period of time, which could offer mental health and well-being benefits.

Alternatives

Where part of the exotics inventory is suitable for management alongside bulk fuels such as Magnox and spent oxide fuels, potential effects are covered under the assessments of those strategies (see Sections 8.3.1 and 8.3.2). There are a number of different types of exotic fuels, and which of the preferred options is selected for exotic fuel management may vary with each fuel type. There are no additional alternative options for managing the remaining exotic spent fuels, as the decision has been made to consolidate the fuels at Sellafield, and they will require disposal in a GDF due to their activity and heat generation.

8.4 Nuclear Materials

8.4.1 Plutonium

On completion of reprocessing operations at Sellafield, there will be around 140 tonnes of separated plutonium from civil sources in the UK. This inventory will need to be managed in a way that puts the vast majority of UK plutonium beyond reach, in line with UK government priorities.

NDA Objective

To ensure the safe and secure management of separated plutonium stocks held by the NDA and to work with the government to develop a long-term solution.

Baseline Scenario

The historic strategic position has been to safely and securely store the UK's stockpiles of plutonium from civil sources, renovating and replacing stores as required. For the purpose of the assessment, this is the baseline scenario.

Strategy (Preferred Option)

In 2011, informed by NDA strategic options work, the UK government proposed a preliminary policy view to pursue reuse of plutonium, by converting the vast majority of the UK civil separated plutonium into fuel for use in nuclear reactors. Any remaining plutonium whose condition is such that it could not be converted into fuel would be immobilised and treated as waste for disposal.

As outlined in reference [72], whilst reuse of plutonium is the preferred policy position, there is currently an insufficient understanding of the options to confidently move into implementation. In the meantime, the NDA's strategy for plutonium stocks is to continue to safely and securely store them on its sites in suitable facilities in line with regulatory requirements.

The NDA continues to work with the UK government in developing strategic options for the implementation of its policy to put plutonium beyond reach by undertaking further strategic work on its behalf. This work covers both reuse and conditioning and treatment options. In either case, disposal to a GDF is the ultimate end point of the plutonium stocks, either after irradiation in a reactor or after suitable conditioning and treatment.

Option Description

Continued safe and secure storage

The NDA's stocks of plutonium are contained in custom-built stores that ensure safe and secure storage. Over the past five years the NDA has continued to retrieve materials from older stores and consolidate them in state of the art facilities such as the Sellafield Product and Residue Store (SPRS).

This option would involve continuing to store the plutonium inventory, repackaging the materials and replacing the stores as required. Generally speaking, the packages for the two different types of plutonium, Magnox and THORP, have 50 and 40 year life respectively. There is a new facility at Sellafield which is designed to repack the Magnox plutonium packages to achieve 100 year storage life. Therefore, repackaging will be required aligned to the respective package life requirements, or utilisation of the plutonium (whichever comes first). Although some of the older storage facilities have limited life availability, the most modern plutonium store has been built to a "50 + 50" year life expectation (with the additional 50 years subject to Regulatory approval). Additionally there are plans to build extensions to the modern store in future years to accommodate the plutonium that would need to be removed from the older stores over the next two decades, if required. This means that as long as the materials continue to be stored pending development of a long-term disposition solution, there will continue to be ongoing maintenance activities, in addition to monitoring to ensure that levels of radioactivity stay well within legally acceptable limits. It should be noted that, as a development from the NDA Strategy (2016), all UK civil plutonium is now located at Sellafield following the Dounreay consolidation programme.

Potential Effects

Environmental risks and opportunities

There are a number of environmental risks associated with maintaining the baseline scenario of continued safe and secure storage. These include the major landscape and visual impacts that come from the presence of the stores at the site and the air, noise and water quality impacts resulting from activities to repackage the material and replace the stores on a periodic basis. It should be noted that such impacts are spread out over time, as the plutonium requires repackaging due to the package life and the modern stores are built to a “50 + 50” year design life.

There would be some ongoing energy use and carbon emissions associated with this option, when stores are constructed, for maintenance and monitoring activities and for ongoing vehicle movements to transport plutonium to the stores. Impacts from flooding are a further environmental risk with continued storage, as the potential for flooding is regarded as an ongoing issue for Sellafield. This risk may become more prevalent over time due to the anticipated effects of climate change, including both sea-level rise and storm surges.

From a radiological risk perspective, plutonium decay in storage gives rise to alpha, neutron and gamma radiation, which can be hazardous to the workforce and requires careful management. If the stored plutonium was accidentally released, there would be a significant local (and potentially wider) environmental risk. Storage of the plutonium on a continuous basis would increase the time at risk, although environmental risk is mitigated by regular maintenance, monitoring and treatment activities.

Socio-economic risks and opportunities

Whilst continued safe and secure storage of the plutonium inventory prevents the land the stores are built on from being used for alternative purposes, construction, maintenance and repackaging activities do support ongoing employment. The current strategy of plutonium storage consolidation into modern stores reduces the overall footprint of stores on the site over time. This includes construction jobs, monitoring and management positions.

In terms of knowledge and skills, continued storage offers little in the way of opportunities. There are also limited opportunities to provide education and training.

A case could be made that the existing plutonium storage facilities constitute a national asset, providing a means to store the UK’s civil plutonium stocks safely and securely. Storing the materials on a continuous basis would therefore preserve a national asset which could be used to store future arisings of plutonium.

Health risks and opportunities

Due to the build-up of alpha, neutron and gamma radiation over time, storing the plutonium on a continuous basis could be seen to have a negative impact in terms of radiological safety-related health risks. However, there are strict controls in place to monitor any changes in radiation levels, and any impacts would be appropriately mitigated to minimise radiological risks to people and the environment.

A number of health risks associated with this option are linked to environmental effects that would result from activities to maintain and replace the facilities. This might include changes in air quality which can influence the risk of respiratory and cardiovascular illnesses amongst the local population, as well as noise and vibration which can cause disturbance. As these effects would be spread out over time and would be relatively minor, any potential residual health risks would likely be minor or negligible.

Continued safe and secure storage offers very little in the way of health opportunities. Arguably the maintenance of jobs could be considered a minor benefit in terms of mental health and wellbeing, though this may be offset by negative impacts from the ongoing presence of facilities and hazardous material on the site.

Alternatives

Reuse

Although there is currently insufficient understanding of options to enable the preferred policy position of reuse to be implemented, the NDA continues to work closely with technology suppliers, developers and the UK government in order to establish how the reuse option could be secured and implemented.

For the purpose of this assessment, an assumption has been made that a fabrication facility would be required to convert the plutonium stocks into new nuclear fuel. The new nuclear fuel would then be transported to the reactors in which it is to be used.

The potential environmental, socio-economic and health effects of implementing the reuse option are considered in the IIA Report: Volume 2 – Section 4.1.

Condition and treat

An alternative credible option to continuing to store, or reusing the plutonium as fuel, is to construct a suitable treatment facility or multiple facilities to convert the material into a safe form for disposal in a geological facility. This would also require construction of one or more suitable interim storage facilities.

The potential environmental, socio-economic and health effects of implementing the condition and treat option are considered in IIA Report: Volume 2 – Section 4.1.

8.4.2 Uranium

NDA's uranium has been produced from fuel cycle operations such as enrichment, fuel fabrication and reprocessing since the 1950s. Uranium is a nuclear material, and is not usually classed as a waste as all uranium has the potential to be reused in nuclear fuel to generate electricity.

The two main types of uranium, by inventory mass, considered in this assessment, which are owned and strategically managed by the NDA, are Depleted Uranium Hexafluoride (UF_6), also known as "Hex" or "Tails", and Magnox Depleted Uranium (MDU), a product of spent fuel reprocessing. Both Tails and MDU are defined as forms of depleted uranium.

Other types of uranium include High Enriched Uranium (HEU), Low Enriched Uranium (LEU) and THORP-Product Uranium (TPU).

NDA Objective

To ensure the management and disposition of its uranium inventory.

Baseline Scenario

The NDA manages significant stocks of uranium which are held safely and securely at several locations. The NDA owns the majority of the uranium on its sites, while the remainder is owned by others including the Ministry of Defence, EDF Energy and overseas utilities.

The NDA's uranium stocks are currently held as a nil value asset pending development and implementation of disposition options which might include reuse or disposal.

At the Capenhurst and Springfields sites, approximately 26,000 tU of Hex is stored in about 11,000 cylinders. The majority of this material is owned by the NDA. As there is currently no market interest in the purchase of this material, and it is the greatest hazard on these two sites, the NDA has decided to deconvert the Hex stored in these cylinders into a form of uranium oxide which is more suitable for long-term management.

Urenco are constructing a deconversion facility (the Tails Management Facility, TMF) at their Capenhurst site in Cheshire. In 2011, the NDA entered into an agreement with Capenhurst Nuclear Services (CNS) (a subsidiary of Urenco) for NDA's Hex to be deconverted into a more stable oxide form (U_3O_8) in the TMF.

The Magnox Depleted Uranium (MDU) continues to be stored at Capenhurst in uranium trioxide (UO_3) form, a stable orange-yellow powder stored in steel drums.

Strategy (Preferred Option)

Owing to the diverse nature of the uranium owned by NDA, there is no single preferred management option for the whole inventory. The preferred option therefore needs to be determined on a group-by-group basis.

There are two broad credible management options that might be chosen to manage a particular group of uranium materials. These are:

- continued safe and secure storage pending sale to a third party for recycling and reuse;
- continued safe and secure storage pending conditioning to an appropriate form for disposal.

The NDA continues to manage its uranium in line with UK government policy.

Option Description

Continued safe and secure storage pending sale to a third party for reuse

Under this option, the assets used to store uranium, including the storage buildings and containers, require ongoing maintenance. The maintenance regime includes regular inspections to ensure the packaging meets the required containment standards and to identify potential degradation in advance.

Repacking into more durable containers such as stainless steel drums has been successful in maintaining safe and secure storage to-date, and is a straightforward operation which can, if necessary, be used again in the future.

As uranium is not heat-producing and the radiological risks associated with the inventory are much lower, packages and storage cans do not need to be replaced as often as for more hazardous materials such as plutonium. The approximate time before the uranium oxides would require re-packaging is around 100 years.

Subject to NDA estate-wide funding and hazard reduction priorities, the NDA will continue to reduce the hazard and improve security associated with continued uranium storage. A key example of this is the deconversion of Hex to U_3O_8 at Capenhurst to produce a more chemically stable material.

Uranium can be returned to the nuclear fuel cycle under commercial terms, but this is dependent on the availability of suitable processing facilities and market prices. As the NDA does not have its own fuel fabrication facilities, under this option the NDA would seek to sell its uranium into the nuclear fuel market where ‘value for money’ can be demonstrated.

In the short-term, recycling uranium into the nuclear fuel cycle is driven by the prevailing conditions in the uranium market. At times when natural uranium, conversion, enrichment and fabrication prices are low, utilities can cost-effectively supply fuel to their reactors from freshly-mined uranium. When these prices are high, utilities seek value from their own, or from others’, stocks of uranium, notably reprocessed uranium, and in doing so they avoid future costs of ownership such as storage.

Utilities usually buy fuel manufactured from material which has been enriched from freshly mined uranium. Consequently, the realisable value of the NDA’s uranium inventory is strongly influenced by its enrichment and any impurities present. As the vast majority of the NDA’s uranium are depleted, the opportunities to return these materials to the fuel cycle are limited.

Continued safe and secure storage pending conditioning to an appropriate form for disposal

Although uranium is not currently classified as a waste, all or part of the uranium inventory may be declared as waste if it were decided at some point that they had no further use.

The NDA is factoring in the possible inclusion of uranium into the design and development of a GDF. The ultimate disposal route and any prior conditioning for these materials have yet to be developed. Moreover, the case for whether large volumes of uranium should be committed to a GDF has not yet been evaluated. Disposal in an alternative manner could be preferable.

Whilst the possibility of using a future GDF is being considered, with detailed assessment work being undertaken on behalf of the NDA, the prospect of using near-surface facilities has not been foreclosed and is still considered to be a credible option pending a final decision or government policy.

Similar to safe and secure storage pending sale to a third-party, this option would require regular maintenance and inspection of existing storage facilities, repackaging on a periodic basis, and hazard reduction activities.

Potential Effects

Environmental risks and opportunities

There are a number of environmental risks associated with the baseline scenario of continued safe and secure storage, which include landscape and visual impacts of the existing stores and any pollution generated from maintenance activities required to repackage the material or replace the stores.

Material and waste impacts would be considerable for the disposal option, as this option would involve construction of new facilities, in addition to classifying approximately 50,000 tonnes of depleted uranium as waste, although it should be noted that sale of uranium to third-parties would ultimately lead to generation of depleted uranium also.

Construction impacts may include short-term changes in air and water quality and landscape and visual impacts. Noise may also be generated from vehicle movements and the use of plant which would require energy and could generate carbon emissions.

Environmental impacts associated with construction would be avoided under the sell option. This option would also offer opportunities in terms of landscape and visual impacts by facilitating closure of existing facilities.

It is important to note that the sell option is highly dependent on market conditions and external factors such as the availability of technologies to use the uranium. Therefore, any landscape and visual and land use opportunities may not be realised for many years, during which time there would be ongoing environmental impacts associated with continued storage, including repackaging and replacing the stores.

Socio-economic risks and opportunities

Whilst storage of the uranium inventory on a continuous basis would prevent the land the stores are built on from being reused, maintenance and repackaging activities support ongoing employment. This includes construction jobs, monitoring and management positions.

Such jobs would be lost under the disposal option but could to some extent be offset by operational jobs created to manage a conditioning facility and interim stores. In addition, there would be short-term employment opportunities created during construction of the new facilities.

Under the sell option, jobs involved in managing and maintaining existing stores would be lost when the stores closed, with no new employment created. Depending on the timescales over which the uranium is sold, there may be an opportunity to transfer some of these jobs to other areas of the NDA’s operations.

In terms of knowledge and skills, the disposal option may offer opportunities to enhance knowledge and skills in the area of uranium conditioning, which could then be applied to the management of other radioactive materials. The sell option would not directly lead to development of knowledge and skills but may facilitate indirect advances in the area of uranium reuse in fuel.

Health risks and opportunities

From a health perspective, under both credible options the Hex inventory would be deconverted in Urenco’s purpose-built facility at Capenhurst. This would help to convert the uranium into a more stable and less hazardous form, thereby reducing radiological health risks. In particular, risks associated with cardiovascular and respiratory illness may be reduced, as canisters used to store Hex can leak if they are not actively maintained.

Short-term construction impacts associated with the disposal option, such as changes in air quality and noise and vibration, could have health impacts by slightly increasing the risk of cardiovascular and respiratory illness amongst the local population. Construction traffic may also put pressure on the local transport network which could increase the risk of road accidents and lead to increased driver stress.

Long-term, the disposal option could have some health risks because the long half-life of uranium-238 and the radiological hazard associated with its daughter products have the potential to lead to risks in the very far future. This will be evaluated using a suitable methodology once a disposal site has been determined.

In contrast, selling the uranium inventory may offer health opportunities, as risks associated with the build-up of hazardous daughter products of uranium can be more appropriately managed in the course of treatment prior to fabrication into fuel. It should be noted that these risks are generally very small and dependent on the type of uranium involved. Closure of existing stores may also offer landscape, visual and land use opportunities, which could lead to positive effects on mental health and well-being.

The creation of employment associated with disposal could lead to positive effects on mental health and well-being. The opposite would be true for the sell option, where employment associated with maintaining stores and repackaging the uranium would be lost.

Alternatives

As both of the credible options identified above might be preferred for dealing with a particular group of uranium, there are no other alternative credible options requiring assessment.

8.5 Integrated Waste Management

8.5.1 Radioactive Waste – Higher Activity Waste

Waste management is not a straightforward process of retrieval and disposal. It includes a series of steps: pursuing opportunities for waste minimisation, reuse and recycling, waste processing, packaging, storage, records management, transport and then, where applicable, final disposal.

Following retrieval, radioactive wastes often undergo some form of treatment to make them suitable for disposal. The technologies used to treat the wastes will vary depending on their specific characteristics, the availability of appropriate facilities, time constraints and other relevant factors. Such decisions are made on a case-by-case basis.

The Radioactive Waste strategy is divided into two topics: HAW and LLW. As outlined in Section 4.5, the assessment has focused on the management of HAW. Solid LLW management is covered by the UK Strategy for the Management of Solid Low Level Waste from the Nuclear Industry [5], Liquid and Gaseous Discharges are covered by the UK Strategy for Radioactive Discharges [15] and non-radioactive waste is managed according to an established, comprehensive and prescriptive regulatory regime.

HAW comprises HLW, ILW and a relatively small volume of LLW that is unsuitable for disposal at the LLWR in Cumbria or the LLW disposal facility at Dounreay.

From a strategic perspective, the key decisions that need to be made regarding HAW relate to:

1. Where the waste is treated
2. Where the waste is stored (either prior to treatment, following treatment or both)

NDA Objective

To manage radioactive waste and dispose of it where possible, or place it in safe, secure and suitable storage, ensuring the delivery of UK and devolved administration's policies.

Baseline Scenario

Owing to the varying nature of wastes requiring management and their location at sites across the UK, decisions regarding the management of HAW are generally undertaken on a case-by-case basis. As such there is no baseline scenario.

Strategy (Preferred Option)

The NDA's overarching strategy is to treat and package HAW into a form that can be safely and securely stored for many decades. The current planning assumptions are that, at the appropriate time, the stored waste in England and Wales will be transported to and disposed of in a suitable facility. For HAW arising in Scotland waste will be managed long-term in near-surface facilities. The NDA HAW strategy supports policy development and implementation.

There are three broad credible options for implementing this strategy of relevance to this assessment; treatment and storage of HAW locally (at or close to the sites where it arises), treatment and storage at regional hubs and treatment at a national facility. Each option may be preferred under certain conditions. Storage of HAW at a national facility is not considered to be credible owing to the number of suitable facilities that already exist across the UK.

Option Description

Treatment and storage locally

Under this option there would be treatment and storage facilities at or in close proximity to existing NDA sites. These facilities would likely be smaller in scale than regional or national facilities and may not be specialised owing to the different types of HAW for which they would need to be suitable.

Treatment and storage regionally

In this option there would be a number of regional hubs for HAW storage and treatment. These facilities would likely be located at or in close proximity to the site with the highest volume of waste in a particular area. Sufficient transport infrastructure would need to be in place to ensure that the facility is equipped to receive and manage waste transported from neighbouring sites.

Treatment nationally

This option would involve establishing a single national facility that would serve all NDA sites for a specific purpose. Its implementation would be dependent on the availability of sufficient transport infrastructure.

It should be noted that this option does not imply a single treatment facility would be developed to manage all HAW arisings. Instead it is likely that a number of specialised national facilities could be established to manage specific types of waste.

Potential Effects

Environmental risks and opportunities

From an environmental perspective, the main risks are associated with transport of the wastes to facilities and the footprint of the facilities themselves (including the extent of construction activities involved).

Treatment and storage of wastes locally would involve fewer transport movements than using regional or national facilities. This could provide environmental opportunities in terms of reduced air quality and noise and vibration impacts. Use of regional treatment and storage hubs would likely involve more movements than local facilities but less than the national option.

In terms of the facility footprint, the use of numerous local facilities may involve the greatest material requirements. The regional and national options therefore offer opportunities for achieving economies of scale, which has environmental implications in terms of materials, energy use and carbon emissions.

On the other hand, creation of a single national facility would have the largest physical environment footprint. This includes landscape and visual impacts, and may include releases of pollutants to air, water and the ground. Risks of impacts to biodiversity, wildlife and cultural heritage features may also be greater than under the local and regional options, although this is highly dependent on the final location of such a facility.

A degree of packaging and treatment may have to take place prior to transfer of wastes to regional or national facilities, in which case this may result in duplication of efforts and associated environmental risks relating to materials and energy. Avoiding these activities would be an environmental opportunity of using local facilities.

Risks from radiological discharges would be managed through the use of extensive controls such as the ALARA principle and BAT, and are, therefore, considered unlikely to vary significantly between the options.

Socio-economic risks and opportunities

In terms of socio-economic opportunities, the use of local treatment and storage facilities may allow socio-economic benefits such as jobs and investment to be spread amongst a number of communities. In contrast, consolidation of waste at a single national facility could lead to job losses and may require some specialist workers to relocate. It would also mean socio-economic benefits are confined to one particular area.

The main opportunity offered by a single national facility or a number of regional facilities is the freeing up of land at other sites, thereby allowing them to undergo decommissioning and closure. This is less likely to be possible under the local option, meaning that opportunities to reuse the land or divest it for some socio-economic or environmental benefit may not be realised (see Section 8.2.4).

Local facilities may be more complex to design, owing to the need for them to manage a range of different waste types, rather than having a single national or regional facility to manage all wastes of a particular type. This could be seen as an opportunity in terms of advancing knowledge, skills, education and training, or as a risk if it locked-up skills and resources which could be better directed elsewhere. In such a situation, creation of a single specialised facility to manage a particular waste stream may offer socio-economic opportunities, however these would be confined to one spatial area.

Health risks and opportunities

One of the main health opportunities offered by the local treatment and storage option is the avoidance of risk associated with transport movements. This includes the risk of traffic accidents and changes in air quality that can influence the risk of cardiovascular and respiratory illness amongst the local population. Treatment at or close to sites may also reduce health risks by ensuring that wastes are converted to a safe and secure form more quickly.

Whilst it is likely that wastes would need to be treated and packaged under the regional and national options to facilitate transport, this could create a logistical challenge which extends the timescale over which wastes are managed. Alternatively, there is a chance that the need to construct multiple local facilities may result in some construction being deferred for funding reasons.

Development of regional or national facilities and subsequent transport of wastes to such facilities may enable decommissioning and remediation to take place at other sites across the estate. This could have positive mental health and well-being effects. On the other hand, loss of or relocation of jobs under a regional or national option could adversely affect the mental health and wellbeing of a local community. This could be seen as a health opportunity under the local option.

Alternatives

As treatment and storage of HAW locally and regionally, and treatment of HAW nationally could all be considered preferred options under certain conditions, there are no alternative credible options requiring assessment.

8.6 Cumulative effects

8.6.1 Types of cumulative effect

‘Cumulative effects’ are those which arise from two or more impacts occurring simultaneously, whereby an impact that may not have a significant effect on its own may combine with another to produce a cumulative effect that is significant. There are two main types of cumulative effect relevant to the Strategy. These are:

- **intra-strategy effects**: effects which could result from preferred strategic options being taken forward, whereby the timing of option implementation either overlaps to change the severity of an effect (whether to increase or reduce it), or follows sequentially to prolong an effect; and
- **inter-plan effects**: effects of other strategies, plans or programmes acting in combination with the NDA Strategy.

8.6.2 Intra-strategy effects

The four driving strategic themes of the Strategy do not operate in isolation at each of the NDA's sites. Instead, all four themes interact with one another and with a fifth theme covering 'Critical Enablers'. The potential environmental, health and socio-economic effects of implementing the Strategy may therefore be altered (increased or decreased) if preferred options under different themes result in development or changes in transport and other infrastructure over similar timescales (including in sequence, which may extend the duration of an effect), or in overlapping geographies.

For most of the sites in the NDA estate, the two strategic themes with the highest level of interaction, and thus most probability for cumulative effects are Site Decommissioning and Remediation and Integrated Waste Management. The Spent Fuels and Nuclear Materials themes may also interact at certain sites.

Interaction between Site Decommissioning and Remediation and Integrated Waste Management

Successful site clean-up depends on the availability of suitable waste management routes and facilities, and as such, these two themes are inextricably linked. The three credible options for the Decommissioning strategy are 'at pace', 'slowly but without interruption' and 'deferred' (see Section 8.2.1 for descriptions). As stated in Section 8.2.1, decommissioning at a pace may put a strain on existing waste management or storage facilities, as greater volumes of waste may be generated in the short-term. As such, decommissioning at a pace may not only accelerate the effects identified for the Integrated Waste Management options (see Section 8.5), but potentially increase them, unless new facilities are built or additional capacity is identified within the current system. Decommissioning slowly may have a similar effect but allows more time for impacts on waste management facilities to be negated. The extent to which such effects are increased would depend on the number of sites or facilities undergoing uninterrupted decommissioning compared to deferred.

Slow uninterrupted or deferred decommissioning may allow more time to plan appropriate management routes for waste generated, as well as allowing transport movements to be spread out over time. However, there may be a trade-off in terms of extended duration of impacts on land use and the landscape, as the sites will not be remediated as quickly.

The interactions identified above and the choice decommissioning approaches can impact on the timing of achieving site end states, and therefore the timescales over which environmental, health and socio-economic effects occur (see Section 8.2.3).

As with the Decommissioning strategy, there is a potential interaction between the Land Quality Management strategy and Integrated Waste Management. Depending on the specific conditions of the site and nature of contaminants involved, there is potential for *ex situ* remediation options (which involve excavation) to generate waste materials requiring management under the Integrated Waste Management theme. This may require the provision or expansion of waste management facilities.

Spent Fuels and Nuclear Materials: Additional Cumulative Effects

Management of spent fuels and nuclear materials is an important consideration in the decommissioning and clean-up of a site and has further links to the Integrated Waste Management theme. The timing for defueling of sites, for example, may affect decisions on the preferred decommissioning approach, and can also influence Integrated Waste Management and Land Quality Management decisions (e.g. continued operation of facilities can restrict access to areas of contamination or limit space for *in situ* remediation activities to be used).

Magnox fuels are all held at Sellafield, Spent oxide fuels are also mainly present at Sellafield, with additional inventory being transferred to the NDA via contract with EDF Energy from its seven AGR power stations in England and Scotland. Exotic fuels are present mainly at Dounreay and Sellafield.

In terms of nuclear materials, the UK stocks of civil plutonium are primarily located at Sellafield, with a very small amount stored safely at Dounreay. The NDA owns uranium held at multiple sites, with the aim to consolidate the inventory at Capenhurst and possibly in part at Sellafield, or send to Springfields for processing.

As such, only four of the 17 NDA sites are affected by this potential cumulative effects issue, but seven non-NDA sites could be affected in terms of their future decommissioning programmes. It is not currently envisaged that implementation of any credible option set out in the Strategy would pose a risk to delivery of these contractual commitments.

8.6.3 Inter-plan effects

The NDA's remit is focused on historic issues, as per its mission to ensure that civil public sector nuclear legacy sites are decommissioned safely, securely, cost effectively and in ways that protect the environment. However, there remains some influence from other government policies and plans on how the NDA's Strategy is ultimately implemented. These include:

- **The UK Strategy for the Management of Solid Low Level Radioactive Waste in the nuclear industry [5]:** the timing and capacity of LLW management may theoretically influence selection and implementation of Site Decommissioning and Remediation and Integrated Waste Management strategies.
- **The Ministry of Defence's Submarine Dismantling Project (SDP):** the reactor cores of disused submarines form ILW, which will be interim-stored at Capenhurst [73].
- **The Department of Energy and Climate Change (DECC) National Policy Statement (NPS EN-6) for Nuclear Power Generation ('New Nuclear Programme') [74]:** the government has identified the following sites as potentially suitable for the development of new nuclear power stations in England and Wales before the end of 2025: Bradwell; Hartlepool; Heysham; Hinkley Point; Oldbury; Sizewell; Sellafield; and Wylfa.[10]
- **Advanced Nuclear Technologies:** the UK government recognises that the advanced nuclear sector, which encompasses a wide range of nuclear reactor technologies under development, has the potential to play an important role in the UK's industrial strategy and is funding development work in this area [75]. If advanced nuclear technologies reactors are built in the UK, they may be sited on or close to NDA sites.

For the MoD's SDP, the New Nuclear Programme and advanced nuclear technologies, issues around potential cumulative effects involve the potential for simultaneous construction or intensive decommissioning and remediation activities, which could generate higher than expected transport requirements, demand for nuclear skills and qualified personnel, or lead to timing issues and constraints on options requiring facilities within existing nuclear-licensed site boundaries. The timing of implementation (design, construction and operation) of such developments relative to implementation of the NDA Strategy is uncertain, making it difficult to accurately predict potential cumulative effects. It is crucial that SLCs and the NDA liaise with, and are informed by, relevant parties during future options development and decision-making at the site level.

[10] In 2017, the government held a consultation on the siting criteria and process for a new national policy statement for nuclear power with single reactor capacity over 1 Gigawatt [76]. The new nuclear National Policy Statement for the period 2026 to 2035 may identify alternative sites within the NDA estate.

9.0 Measures to mitigate risks and enhance opportunities

9.1 Introduction

In line with requirements of Strategic Environmental Assessment, potential measures have been identified to mitigate adverse and enhance positive effects that may result from implementing the NDA Strategy (2021). These measures are generic to better reflect the high-level nature of the Strategy, and may not always be applicable in practice. The decision over which specific measures are needed will usually be made at the discretion of the Site Licence Companies which operate the NDA sites, in accordance with the NDA's Value Framework.

9.2 Potential mitigation / enhancement measures

Table 9-A contains a range of potential mitigation and enhancement measures which could be used to manage impacts of the NDA Strategy, but is by no means an exhaustive list. Opportunities should be explored to identify additional measures in the course of future assessment work. Measures in bold may be particularly effective at mitigating or minimising adverse environmental, socio-economic and health effects.

Table 9-A Potential mitigation and enhancement measures

Mitigation / Enhancement Measure	Phase / Activity relevant to			Topics relevant to
	Design & construction of new / modification of existing facilities	Operation of new facilities	Closure of existing / future facilities	
Locate facilities away from nature and heritage features and receptors	✓			Cultural heritage
	✓			Biodiversity, flora and fauna
Use low embodied carbon (recycled) materials	✓			Climate change and energy
Create travel plans to manage movement of workers and minimise impacts to public transport	✓			Health and safety effects from road traffic changes
				Climate change and energy
				Air quality
				Respiratory and cardiovascular conditions
Use sustainable urban drainage systems (SUDS) to reduce flood risk and effects on the water environment	✓			Water resources and quality
				Health effects from changes in water environment
				Biodiversity, flora and fauna

Mitigation / Enhancement Measure	Phase / Activity relevant to			Topics relevant to
	Design & construction of new / modification of existing facilities	Operation of new facilities	Closure of existing / future facilities	
Design measures such as bunds for noise and tree planting and screening for landscape and visual impacts	✓			Noise and vibration Health effects from changes in noise levels Landscape and visual impacts
Develop combined or shared facilities – e.g. packaging plant for all types of spent fuel	✓			All topics
Source materials locally where possible – this could offer local economic benefits	✓			Materials and waste Economy Health and safety effects from road traffic changes Air quality Respiratory and cardiovascular conditions
Develop on brownfield land	✓			Geology and soils Local and national assets Physical activity and obesity
Consult with institutions to identify and promote education and training opportunities	✓	✓	✓	Education and training Mental health and Well-being
Liaise with local institutions to support ongoing skills development		✓	✓	Knowledge and skills Education and training
Reinvest in the local economy	✓	✓		Economy Mental health and well-being
Explore opportunities to maintain or transfer jobs to other facilities or sites		✓	✓	Employment Knowledge and skills Mental health and well-being
Explore opportunities to divest land			✓	Local and national assets
Explore opportunities to create or enhance habitats and nature features	✓		✓	Biodiversity, flora and fauna Physical activity and obesity

Mitigation / Enhancement Measure	Phase / Activity relevant to			Topics relevant to
	Design & construction of new / modification of existing facilities	Operation of new facilities	Closure of existing / future facilities	
				Mental health and well-being
Use construction and demolition management good practice and procedures – e.g. timing of noise-generating activities.	✓		✓	Air quality Respiratory and cardiovascular conditions Noise and vibration Health effects from changes in noise levels Geology and soils Materials and waste Mental health and well-being
Consider use of carbon capture technologies	✓	✓	✓	Climate change and energy
Consider effects of climate change at local level and adapt accordingly (e.g., through weather resilience plans, ensuring buildings are designed to consider expected conditions)	✓	✓	✓	Climate change and energy Health effects from changes in the water environment Local economy
Minimise air pollutant emissions	✓	✓	✓	Air quality Respiratory and cardiovascular conditions
Minimise number of traffic movements	✓	✓	✓	Air quality Noise and vibration Health effects from changes in noise levels Health and safety effects from road traffic changes Biodiversity, flora and fauna Cultural heritage
Create a traffic management plan to manage traffic on roads between sites and major transport routes	✓	✓	✓	Health and safety effects from road traffic changes Mental health and well-being
Minimise water abstraction and usage	✓	✓	✓	Water resources and quality

Mitigation / Enhancement Measure	**Phase / Activity relevant to**			**Topics relevant to**
	Design & construction of new / modification of existing facilities	Operation of new facilities	Closure of existing / future facilities	
				Health effects from changes in the water environment
Monitor and minimise discharges to water bodies	✓	✓	✓	Water resources and quality Health effects from changes in water environment Radiological emissions and discharges Radiological safety related health effects
Reuse existing facilities where possible (avoids construction and demolition impacts)	✓	✓	✓	All topics
Reuse wastes (apply the Waste Hierarchy)	✓	✓	✓	Materials and waste Climate change and energy Geology and soils Air quality
Attempt to utilise and maintain existing skills base	✓	✓	✓	Employment Knowledge and skills
Use waste segregation and characterisation to manage wastes	✓	✓	✓	Materials and waste
Identify and develop appropriate waste management routes prior to waste generation	✓	✓	✓	Materials and waste
Ensure adequate transport infrastructure is in place. Make safety improvements and avoid 'road dominance' where possible	✓	✓	✓	Local and national assets Health and safety effects from road traffic changes
Minimise light pollution and visual disturbance	✓	✓	✓	Landscape and visual impacts
Minimise disturbance to or loss of amenity and recreational features	✓	✓	✓	Physical activity and obesity Mental health and well-being
Undertake further assessments, e.g. Habitat regulations assessment (HRA) and EIA	✓	✓	✓	All topics

Mitigation / Enhancement Measure	**Phase / Activity relevant to**			**Topics relevant to**
	Design & construction of new / modification of existing facilities	Operation of new facilities	Closure of existing / future facilities	
Assess the capacity of local health services and facilities to manage changes in demand	✓	✓	✓	All health topics
Undertake open and clear communication with communities and other relevant stakeholders	✓	✓	✓	Mental health and well-being

9.3 Potentially vulnerable groups

Certain groups of people in the communities surrounding the NDA sites may be more vulnerable than average to potential environmental, socio-economic and health impacts of the Strategy. The NDA document '*A proposed approach to Equality Impact Assessment'* notes that under the Equality Act 2010 (applying to England and Wales[11]), public bodies are required to assess the effects of their activities and decisions relative to equalities issues and be transparent and accountable to communities about the decisions they are making.

The effects of the Strategy may be experienced differently by different population groups, with some groups potentially more vulnerable than others. Effects may also vary between communities in terms of their geographical nature as urban or rural, coastal or inland communities.

Sensitivity to health effects from environmental change is generally greatest amongst children, the elderly and those suffering with long-term illness. Poor health or reduced mobility can make such people more vulnerable to most health effects, as they are less likely to find effective means to adapt to changes, and may have reduced access to appropriate treatment.

Vulnerable groups such as the elderly and children can also be highly susceptible to changes in the road network. Impacts which affect safety can result in more significant injuries in the event of road accidents, as well as deterring them from undertaking outdoor activities that are beneficial for health, such as walking and cycling. These vulnerable groups are also likely to be more significantly affected by improvements to the road network.

From a socio-economic perspective, those most vulnerable to potential impacts tend to have lower disposable incomes and less access to services and facilities. Those with low income may be more at risk of impacts from changes in employment. In addition, those from less wealthy backgrounds may face greater barriers to education and training, and so any provision of opportunities might benefit them the most. Finally, a change in economic investment into a community might be felt most keenly by self-employed local businesses in the site's supply chain.

Potentially vulnerable groups should be identified and taken into account in the course of future assessment work, with adverse impacts mitigated wherever possible. Ongoing communication and engagement can help to identify the needs and concerns of these groups, and may lead to opportunities for positive impacts.

9.4 Proposed monitoring

As the Strategy is high-level, topic-by-topic environmental, health and socio-economic monitoring which is spatially specific and targeted at certain effects is not appropriate to define at this stage. It is proposed that the following would, however, address the need to track the status of the environment in strategic decision-making:

1. Possible periodic updates to the Baseline Report and Policy and Legislative Context Review (see IIA Report: Volume 3);
2. Achievement of further integration of the IIA methodology and findings into the NDA's Value Framework and strategic decision-making;
3. Evaluation of the application of the IIA results and assessment guide questions by the NDA / SLCs in future decision-making, including considered amendment / refinement to its findings based on more detailed knowledge, changes in assumptions or updated information; and
4. Targets and level of achievement for each of the measures proposed in Section 9.2.

[11] Does not apply in Northern Ireland. However, Northern Ireland has its own range of equalities legislation. For more information, see the Equality Commission for Northern Ireland website: http://www.equalityni.org/.

10.0 Conclusions and next steps

This Integrated Impact Assessment (IIA) aims to inform, but not drive, future NDA strategic decision-making. As such, there are a number of general conclusions that can be drawn from the IIA of the NDA Strategy (2021). These are listed below, along with potential next steps.

10.1 General conclusions

- For most of the Site Decommissioning and Remediation and Integrated Waste Management strategies the preferred option varies, and is selected on a case-by-case basis.
- Development of new and modification of existing facilities will be needed for some of the preferred strategic options. This generally involves a range of major environmental and health risks and socio-economic opportunities.
- Implementation of a number of the preferred options may put pressure on the existing nuclear skills base. This pressure will be increased aligned to any future demand from the UK's new nuclear build programme.
- Health risks associated with options are linked to environmental and socio-economic changes.
- Many adverse impacts of construction can be mitigated by reusing existing facilities.
- Some of the adverse socio-economic impacts associated with closing facilities may be mitigated by transferring staff to alternative facilities or sites.
- Adverse environmental impacts from construction could be reduced if joint treatment or storage facilities are constructed to manage different types of materials and wastes. For example, one packaging plant could be constructed to manage spent Magnox, oxide and exotic fuels that are not reprocessed.
- There is considerable uncertainty regarding how options will be implemented at a future time and at the site level. The results of this assessment should therefore be viewed as being indicative of potential impacts but not absolute or certain.
- The results of this IIA should be used to inform future, more detailed assessments, to help select strategic options, as well as inform future decision-making made by the NDA and the SLCs which operate its sites.
- Specific impacts upon particular receptors may be more appropriately assessed as part of project-level EIAs.

10.2 Next steps

- The IIA assessment results will be used as part of the context for future strategic decision-making alongside other important aspects such as cost, feasibility, security and site-specific factors.
- The assessment methodology will be used in future assessment work.
- Statutory consultees, key stakeholders and the general public will be consulted to obtain feedback on the IIA and identify potential improvements.

Following public consultation, this IIA Report will be published alongside the NDA Strategy (2021). The outcomes of the consultation and its influence on development of the Strategy and the IIA will be documented in an IIA Post-Adoption Statement.

11.0 References

1 Nuclear Decommissioning Authority, Business Plan 1 April 2019 to 31 March 2022, March 2019.

2 Nuclear Skills Strategy Group, *Nuclear Workforce Assessment 2019*, November 2019.

3 Nuclear Skills Strategy Group, Nuclear Workforce Assessment 2019, underpinning data provided by S Bennett (personal communication March 2020).

4 ONR, *ONR Guide LC33: Disposal of Radioactive Waste*, NS-INSP-GD-033 Revision 5, June 2019.

5 DECC; The Scottish Government; Welsh Government; DOE, *UK Strategy for the Management of Solid Low Level Waste from the Nuclear Industry*, February 2016.

6 BEIS; NDA, *2019 UK Radioactive Waste Inventory*, December 2019.

7 BEIS; NDA, *Radioactive Waste Strategy September 2019*, September 2019.

8 Department for Energy and Climate Change, *Implementing Geological Disposal: A framework for the long-term management of higher activity radioactive waste,* 2014.

9 BEIS, *Implementing geological disposal – working with communities: updated framework for the long term management of higher activity radioactive waste*, December 2018.

10 Welsh Government, *Welsh Government Policy on the Management and Disposal of Higher Activity Radioactive Waste*, 2015.

11 Welsh Government, *Geological Disposal of Higher Activity Radioactive Waste: Working with Communities*, January 2019.

12 Scottish Government, *Scotland's Higher Activity Radioactive Waste Policy 2011*, 2011.

13 Scottish Government, *Higher-activity Radioactive Waste: Implementation Strategy*, December 2016.

14 Welsh Assembly Government, Scottish Executive, Defra, *Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom*, March 2007.

15 Welsh Assembly Government, DOE The Scottish Government, DECC, *UK Strategy for Radioactive Discharges*, July 2009.

16 OSPAR Commission, *The North-East Atlantic Environment Strategy*, OSPAR Agreement 2010-3, 2010. https://www.ospar.org/site/assets/files/1200/ospar_strategy.pdf Accessed 25/06/20.

17 BEIS, *UK Strategy for Radioactive Discharges 2018 Review of the 2009 Strategy*, June 2018.

18 NDA, *Progress on approaches to the management of separated plutonium: Position Paper*, January 2014.

19 WHO, The Role of HIA in Decision Making, 2020. https://www.who.int/hia/policy/decision/en/ Accessed 30/04/20.

20 *The Conservation of Habitats and Species Regulations 2017*, Statutory Instruments 2017 No. 1012, October 2017. http://www.legislation.gov.uk/uksi/2017/1012/contents Accessed 30/04/20.

21 Conservation of Offshore Marine Habitats and Species Regulations 2017, Statutory Instruments 2017 No. 1013, October 2017. http://www.legislation.gov.uk/uksi/2017/1013/contents/made Accessed 30/04/20.

22 Ministry of Housing, Communities and Local Government, *Guidance on the use of Habitats Regulations Assessment*, July 2019.

23 HM Government (2017). *The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017*. UK Statutory Instruments 2017 No. 407

24 The Environmental Permitting (England and Wales) Regulations 2016 as amended in 2018 and 2019. UK SI 2018 No 428 and UKSI 2019 No 39.

25 *The Environmental Authorisations (Scotland) Regulations 2018*. SSI 2018 No 219.

26 *The Town and Country Planning (Environmental Impact Assessment) Regulations 2017*. Statutory Instruments 2017 No.571

27 *The Town and Country Planning (Environmental Impact Assessment) (Wales) Regulations 2017*. Wales Statutory Instruments 2017 No. 567 (W. 136)

28 *The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017*. Scottish Statutory Instruments 2017 No. 102

29 *Nuclear Reactors (Environmental Impact Assessment for Decommissioning) (Amendment) Regulations 2018*, Statutory Instruments 2018 No. 834

30 Department for Environment, Food and Rural Affairs (Defra), Clean Air Strategy 2019, 2019.

31 Environment Agency, *Pollution Inventory*, December 2019. https://data.gov.uk/dataset/cfd94301-a2f2-48a2-9915-e477ca6d8b7e/pollution-inventory. Accessed 04/03/20.

32 SEPA, *Scottish Pollutant Release Inventory*, 2017. https://www.sepa.org.uk/environment/environmental-data/spri/ Accessed 04/03/20.

33 England and Wales: Environment Agency Flood Map for Planning (Rivers and Sea) - https://flood-map-for-planning.service.gov.uk/

34 SEPA Flood Maps - http://map.sepa.org.uk/floodmap/map.htm

35 Natural Resources Wales Flood Map - https://maps.cyfoethnaturiolcymru.gov.uk/Html5Viewer/Index.html?configBase=https://maps.cyfoethnaturiolcymru.gov.uk/Geocortex/Essentials/REST/sites/Flood_Risk/viewers/Flood_Risk/virtualdirectory/Resources/Config/Default&layerTheme=1

36 HMG, *UK local authority and regional carbon dioxide emissions national statistics: 2005-2017*, June 2019. https://www.gov.uk/government/collections/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics. Accessed 04/03/20.

37 BEIS, UK local authority carbon dioxide emissions estimates 2017, June 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/812139/Local_authority_2017_greenhouse_gas_emissions_statistical_release.pdf. Accessed 04/03/20.

38 Defra, MAGiC map, https://magic.defra.gov.uk/MagicMap.aspx

39 Scottish Natural Hertigae, Landscape Character Types (LCTs) SNH 2019, 2019. https://www.arcgis.com/apps/webappviewer/index.html?id=e3b4fbb9fc504cc4abd04e1ebc891d4e&extent=-2030551.0017%2C6851563.2052%2C1100309.6769%2C8923312.4198%2C102100 Accessed 02/06/20.

40 Cefas, Radioactivity in Food and the Environment (RIFE 24), 2018.

41 Rennie, A.F., Hansom, J.D., and Fitton, J.M., Dynamic Coast - National Coastal Change Assessment: Cell 6 - Mull of Kintyre to the Mull of Galloway, CRW2014/2, 2017. http://www.dynamiccoast.com/outputs.html Accessed 22/04/20.

42 State of Nature Partnership, *State of Nature Report Scotland*, 2019.

43 State of Nature Partnership, *State of Nature Report*, 2019.

44 Natural England, Nature Network Evidence Handbook, NERR081, March 2020.

45 Department for Environment, Food and Rural Affairs, A green future: our 25 year plan to improve the environment, 2018.

46 Office of the Deputy Prime Minister; Scottish Executive; Welsh Assembly Government; Department of the Environment in Northern Ireland, *A Practical Guide to the Strategic Environmental Assessment Directive, 2005*.

47 Department for Environment, Food and Rural Affairs, *Policy Paper Environment Bill 2020,* March 2020. https://www.gov.uk/government/publications/environment-bill-2020. Accessed 28/04/20.

48 Welsh Government, *Welsh Government makes climate emergency declaration*, https://gov.wales/welsh-government-makes-climate-emergency-declaration. Accessed 31/01/20.

49 Scottish Government, *The Global Climate Emergency - Scotland's Response: Climate Change Secretary Roseanna Cunningham's statement*, May 2019. https://www.gov.scot/publications/global-climate-emergency-scotlands-response-climate-change-secretary-roseanna-cunninghams-statement/ Accessed 22/04/20.

50 N Stern, *Stern Review: The Economics of Climate Change*, 2006. https://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/media/4/3/Executive_Summary.pdf Accessed 29/04/20.

51 IPCC, *Climate Change 2014 Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 2014. https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf Accessed 29/04/20

52 United Nations, Paris Agreement, 2015. http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf Accessed 04/02/20.

53 Climate Change Act 2008 (2050 Target Amendment) Order 2019 UK Statutory Instruments 2019 No. 1056

54 The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019

55 BEIS, *2018 UK Greenhouse Gas Emissions, Final Figures*, February 2020. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/862887/2018_Final_greenhouse_gas_emissions_statistical_release.pdf Accessed 29/04/20.

56 Ministry of Housing, Communities & Local Government, Flood Risk and Coastal Change, March 2014. https://www.gov.uk/guidance/flood-risk-and-coastal-change Accessed 29/04/20

57 WHO, *The Determinants of Health*. 2020 https://www.who.int/hia/evidence/doh/en/ Accessed 29/04/20

58 Committee on the Medical Effects of Air Pollutants (COMEAP), *The Mortality Effects of Long-term Exposure to Particulate Air Pollution in the United Kingdom*, 2010.

59 COMEAP, *The Effects of Long-term Exposure to Ambient Air Pollution on Cardiovascular Morbidity: Mechanistic Evidence*, October 2018.

60 COMEAP, *Long-term Exposure to Air Pollution and Chronic Bronchitis*, July 2016.

61 Ad Hoc Expert Group on Noise and Health, *Environmental Noise and Health in the UK*, 2010.

62 Cave B, Coutts A, *Health Evidence base for the Mayor's draft Cultural Strategy*. London: South East London Strategic Health Authority and East London & the City Health Action Zone, 2002.

63 Public Health England, *Ionising Radiation: Dose Comparisons*, March 2011. https://www.gov.uk/government/publications/ionising-radiation-dose-comparisons/ionising-radiation-dose-comparisons Accessed 29/04/20

64 WHO, *Mental Health: Strengthening Our Response*, March 2018. https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response Accessed 29/04/20.

65 Institute of Health Equity, *Health Equity in England: The Marmot Review 10 years on Executive Summary*, 2020. http://www.instituteofhealthequity.org/resources-reports/marmot-review-10-years-on Accessed 29/04/20.

66 Alavinia, S.M. and Burdorf, A., *Unemployment and retirement and ill-health: a cross-sectional analysis across European countries*. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2467501/ Accessed 29/04/20.

67 Jin, R.L., Shah, C.P., and Svoboda, T.J., *The Impact of Unemployment on Health: A Review of the Evidence.* Canadian Medical Association Journal, Vol 153, No 5, pp529-540, 1995.

68 Environment Agency, *Guidance on the Assessment and Monitoring of Natural Attenuation of Contaminants in Groundwater*, R&D Publication 95, June 2000.

69 Defra, *Guidance on Applying the Waste Hierarchy*, June 2011.

70 SEPA; Environment Agency; Natural Resources Wales, *Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release from Radioactive Substances Regulation*, Version 1.0. July 2018.

71 NDA, *The Magnox Operating Programme (MOP9),* 2012

72 NDA, *Progress on Plutonium Consolidation, Storage and Disposition,* March 2019.

73 Ministry of Defence, MOD Selects Nuclear Storage Site as Submarine Dismantling Project progresses, July 2016. https://www.gov.uk/government/news/mod-selects-nuclear-storage-site-as-submarine-dismantling-project-progresses. Accessed 30/04/20.

74 DECC, National Policy Statement for Nuclear Power Generation (EN-6), July 2011.

75 BEIS, *Policy Paper Advanced Nuclear Technologies*, November 2019. https://www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies#advanced-nuclear-technology-framework Accessed 30/04/20

76 BEIS, *Consultation on the Siting Criteria and Process for a New National Policy Statement for Nuclear Power with Single Reactor Capacity Over 1 Gigawatt Beyond 2025*, December 2017.

Appendix A Register of assumptions and uncertainties

Uncertainties relating to content in the NDA Strategy (2016) are presented in the register below, alongside assumptions that have been made in the course of the assessment.

Whilst the aim of any environmental, socio-economic or health assessment should be to minimise uncertainty, given the high-level nature of the Strategy and the nature of nuclear operations, for example the very long timescales involved, this has not always been possible. The results of the assessment should therefore be viewed as indicative and not absolute.

Uncertainties, including some of those listed below, are likely to be reduced in the course of further assessment work.

Ref.	Aspect of Assessment	Theme / Topic / Option	Uncertainty / Assumption	Details
01	General / Methodology	Future evolution of the baseline	Uncertainty / Assumption	Assumptions and uncertainties specific to establishment of the baseline are outlined in the Baseline Report – see the IIA Report: Volume 3.
02	General / Methodology	Changes in option credibility	Uncertainty	Options currently considered non-credible may become credible in the future. This can be linked to changes in technology, government policy and legislation.
03	General / Methodology	HAW Disposal, Integrated Waste Management,	Assumption	NDA will implement UK policies and strategies regarding radioactive waste management and disposal.
04	General / Methodology	Geographic Scope	Assumption	Geographic scope of the assessment is based on an assumption that government policy will remain the same. i.e. no use of overseas waste management facilities.
05	General / Methodology	Temporal Scope	Assumption	Temporal Scope is based on the assumption that the NDA Strategy will apply until the final site achieves its stated end state. However, it is recognised that this date is not fixed and the Strategy will be reviewed and updated on a 5-year cycle over this period.
06	General / Methodology	Decommissioning Timescales	Uncertainty	Changes in technology can speed up decommissioning timescales. Similarly, unforeseen circumstances can result in delays.
07	General / Methodology	Impact Timescales	Uncertainty	Timescales over which impacts will occur and be experienced is largely uncertain. Estimates have been based upon guidance, experience of similar schemes and professional judgement, but should be viewed as indicative and not absolute.
08	General / Methodology	Information Availability	Uncertainty	For some options insufficient information was available to complete a detailed assessment. Instead the assessment focused on identifying risks of and opportunities for environmental, health and

Ref.	Aspect of Assessment	Theme / Topic / Option	Uncertainty / Assumption	Details
				socio-economic impacts. Where appropriate, further assessment will be undertaken in due course to reduce uncertainty around the potential impacts of these options.
09	General / Methodology	Receptor Sensitivity / Impacts upon specific Receptors	Uncertainty	For some IIA topics it was not possible to determine the sensitivity of particular receptors to impacts, nor appropriate to assess the direct impacts upon these receptors given the high-level nature of the Strategy. In such circumstances indicators were used to represent the potential for receptors to experience effects. Specific impacts upon particular receptors are more appropriately assessed as part of a project-level Environmental Impact Assessment.
10	General / Methodology	Implementation of the Strategy	Uncertainty	Regarding how the Strategy is applied at a site level or at a future time. For example, options may be implemented in phases, or with modifications to assumed design specifications and components.
11	General / Methodology	Option Definition	Uncertainty	Options have been identified and defined in consultation with the NDA, but are not necessarily fixed and may be subject to change based on further assessment (and in some cases government policy). The means by which options will be implemented and their specific components may also vary from current assumptions.
12	General / Methodology	The geological disposal facility (GDF)	Uncertainty / Assumption	For a number of options involving disposal of radioactive waste to a GDF, the GDF is anticipated to be available to receive waste legacy ILW from around 2040 and legacy HLW and spent fuels from around 2075. If there are any delays to this programme, this may have implications in terms of environmental, socio-economic and health effects.
13	IIA Topics	Air quality	Assumption	National Air Quality Objectives will remain constant for the foreseeable future.
14	IIA Topics	Biodiversity, flora and fauna	Assumption	Currently designated habitats and protected species will remain so for the foreseeable future. No additional nature sites in proximity to the NDA sites will become designated, statutorily or as local wildlife sites.
15	IIA Topics	Climate change and energy	Assumption	National and industrial sector carbon emission targets will remain constant.
16	IIA Topics	Coastal change and flood risk	Uncertainty	The coastal environment may change over time. Such changes may be precipitated or accelerated by climate change. Where possible this uncertainty has been factored into the assessment.

Ref.	Aspect of Assessment	Theme / Topic / Option	Uncertainty / Assumption	Details
17	IIA Topics	Cultural heritage	Assumption	Cultural heritage features such as listed buildings and scheduled monuments in proximity to NDA sites will continue to be statutorily designated. It is also assumed that no buildings or features nearby will become designated.
18	IIA Topics	Materials and waste	Assumption	Estimated current inventory and future waste arisings have been taken from the Radioactive Waste Inventory [6] (NDA, 2019). For the purpose of this assessment, it has been assumed that these estimates are within an acceptable degree of accuracy.
19	IIA Topics	Materials and waste	Assumption	There will be no changes to the radioactive waste classification thresholds, for example, the classification boundary between ILW and LLW.
20	IIA Topics	Radiological emissions and discharges	Assumption	It is assumed that under normal circumstances all radioactive emissions and discharges are, and will continue to be, made within statutory and permitted limits.
21	IIA Topics	Radiological safety related health effects	Assumption	The statutory public dose limit for radiological discharges to air and water will not change.
22	IIA Topics	Radiological safety related health effects	Assumption	Any option considered credible could be safely implemented without an unacceptable or unmanageable increase in radiological risk.
23	Strategic Options	Magnox (Baseline Scenario)	Assumption	The Magnox reprocessing plant will not continue to be operated significantly beyond the current estimated completion date around the year 2020.
24	Strategic Options	Oxides (Baseline Scenario)	Assumption	Any spent oxide fuel not contracted for reprocessing would be interim stored, pending a future decision on whether to declare them as waste for disposal in a GDF.
25	Strategic Options	Uranium (All options)	Assumption	The inventory of uranium hexafluoride (Hex) owned by the NDA will be deconverted in the URENCO facility at Capenhurst into a form of uranium oxide which is more suitable for long-term management.
26	Strategic Options	Uranium (Indefinite Storage)	Assumption	For illustrative purposes and to enable assessment of options individually, it has been assumed that continued safe and secure storage of uranium would be a credible option in its own right. However, in reality, continued storage does not mean storage indefinitely, as at some point in time another option would need to be implemented to manage the uranium

Ref.	Aspect of Assessment	Theme / Topic / Option	Uncertainty / Assumption	Details
				inventory (i.e. sale or disposal).
27	Strategic Options	Uranium (Sell)	Uncertainty / Assumption	The ability of the NDA to sell its inventory of uranium is highly dependent on market conditions and the availability of suitable technologies to use the material. Consequently, for the purpose of the assessment, it has been assumed that the uranium inventory would be sold immediately following implementation of the option. In reality, the material may continue to be stored for an extended period of time until it can be sold.
28	Strategic Options	Uranium (Dispose)	Uncertainty	The means by which the uranium inventory would be treated for disposal is yet to be determined. One option is the possible inclusion of uranium into the design and development of a future GDF.

Appendix B IIA assessment guide questions

IIA Topic	Assessment Guide Questions		
	Generic Guide Question ***"Could the option…"*** Check for relevance.	**Detailed Guide Question** Check need for further assessment / investigation.	
		Risks of adverse effects ***"Is there a risk that the option could…"***	**Opportunities for benefits** ***"Is there an opportunity that the option could…"***
ENVIRONMENT			
Air quality	• … cause a change in non-radioactive discharges (e.g. NO_x, SO_x and particulate matter)?	• … result in emissions which cause a breach of air quality objectives?	• … achieve a reduction in emissions which helps to prevent the risk of a breach of air quality objectives?
Climate change and energy	• … cause a change in direct emissions of carbon dioxide (CO_2) and other greenhouse gases (GHG)?	• … inhibit achievement of industry CO_2 and GHG targets?	• … achieve a reduction in emissions which helps to achieve industry CO_2 and GHG targets?
	• … cause a change in indirect emissions of CO_2 or other GHG due to use of materials (embodied carbon) or change in energy use?	• … inhibit achievement of national CO_2 and GHG targets?	• … achieve a reduction in emissions which helps to achieve national CO_2 and GHG targets?
Biodiversity, flora and fauna	• … have any effects on protected and/ or notable (national or local) species of fauna or flora?	• … have lasting (over a period of more than several years) effects on populations of protected and/ or notable species?	• … generate increase, or help to prevent reduction in, populations of protected and/or notable species (including vulnerability to future impacts)?
	• … have any effects on designated and/ or important non-designated habitats?	• … cause lasting loss of habitat and/ or severance to habitat?	• … create or enhance habitat, prevent its loss, or reduce severance to habitat?

IIA Topic	Assessment Guide Questions		
	Generic Guide Question ***"Could the option…"*** Check for relevance.	**Detailed Guide Question** Check need for further assessment / investigation.	
		Risks of adverse effects ***"Is there a risk that the option could…"***	**Opportunities for benefits** ***"Is there an opportunity that the option could…"***
Landscape and visual impacts	• … have any effects on landscapes / seascapes or the visual environment?	• … result in lasting degradation of landscape / seascape character, loss of landscape / seascape features or changes to valued (e.g. locally, regionally) views?	• … result in improvement of landscape / seascape character, protection / enhancement of landscape / seascape features, or of valued views?
Cultural heritage	• … have an effect on valued (designated or otherwise) historic buildings, features or sites, or any other known aspects of cultural heritage?	• … result in damage / degradation to an historic building, feature or site, or any other known aspect of cultural heritage?	• … lead to enhancement of, or prevent the loss (preservation) of, an historic building, feature or site?
	• … have an effect on surface or sub-surface archaeology?	• …result in damage to or loss of archaeological features or assets?	• … result in prevention of loss (preservation) of archaeological features or assets?
Geology and soils	• …result in a change in non-radioactive discharges to the ground?	• … lead to or worsen ground contamination that would then require corrective measures?	• … help to reduce or remove existing ground contamination?
	• … result in a change in soil resources or quality?	• … lead to a loss of soils (e.g. through construction / excavation) or decline in soil quality?	• … prevent the loss of soils, enable long-term restoration of soils or lead to improvements in soil quality?
Water resources and quality	• … result in a change in non-radioactive discharges to groundwater or surface water?	• … lead to or worsen groundwater or surface water pollution that would slow or prevent the achievement Water Framework Directive (WFD) objectives?	• …help to improve / remove existing groundwater or surface water pollution, and/ or achieve WFD objective?

IIA Topic	**Assessment Guide Questions**		
	Generic Guide Question ***"Could the option…"*** Check for relevance.	**Detailed Guide Question** Check need for further assessment / investigation.	
		Risks of adverse effects ***"Is there a risk that the option could…"***	**Opportunities for benefits** ***"Is there an opportunity that the option could…"***
Noise and vibration	• …result in changes in the noise environment beyond the site boundary?	• … lead to noise levels which breach guideline values (e.g. World Health Organisation)?	• … lead to an improvement in the noise environment at sensitive receptors, e.g. residents, schools, health-related facilities, etc.?
Materials and waste	• … lead to a change in material requirements?	• …lead to a substantial increase in material volumes from primary resources (e.g. not recycled materials), or of a finite or scarce resource?	• … lead to a substantial reduction in the requirement for primary and/ or finite or scarce resources?
	• … lead to a change in waste arisings?	• … lead to a substantial increase in waste arisings requiring disposal (e.g. not reusable, recyclable or recoverable)?	• … lead to a substantial reduction in waste arisings requiring disposal (e.g. through prevention, reuse, recycling or recovery)?
Coastal change and flood Risk	• …result in changes to the frequency or severity of (including vulnerability to) flooding from any source, e.g. groundwater or surface water?	• …lead to increased flood risk or increased impacts of floods (e.g. through expansion of/ changes to infrastructure in flood prone areas)?	• …lead to reduced flood risk or vulnerability to floods?
	• …result in changes to the rate of, or vulnerability to, landscape change, including coastal / fluvial erosion and sea level rise?	• …lead to increased coastal / fluvial erosion in any location (e.g. secondary impacts of construction / engineering) or increased vulnerability to landscape change?	• …lead to reduced impacts of coastal / fluvial erosion or vulnerability to landscape change?

IIA Topic	**Assessment Guide Questions**		
	Generic Guide Question ***"Could the option…"*** Check for relevance.	**Detailed Guide Question** Check need for further assessment / investigation.	
		Risks of adverse effects ***"Is there a risk that the option could…"***	**Opportunities for benefits** ***"Is there an opportunity that the option could…"***
Radiological emissions and discharges	• … cause a change in radioactive discharges (to air, water or ground)?	• … inhibit achievement of nuclear sector targets ('expected outcomes') as part of the UK Discharge Strategy, in line with OSPAR commitments?	• … lead to a reduction in discharges which helps to achieve of nuclear sector targets as part of the UK Discharge Strategy?
	• … cause a change in exposure of people or the environment to radiological emissions?	• … result in a breach of statutory dosage limits caused by radiological emissions?	• … achieve a reduction in exposure of people or the environment to emissions?
SOCIO-ECONOMICS			
Employment	• … result in changes to employment at one or more skills levels (e.g. by NVQ level)?	• … result in a net loss of total jobs, or an imbalance in skills levels?	• … result in net job gains, or help improve or sustain the balance in skills levels?
Education and training	• …result in changes to education and training requirements / provision?	• …lead to losses of education and/ or training provision?	• …lead to preservation / provision of education and/ or training?
Knowledge and skills	• … result in changes to specialist knowledge and/ or skills?	• … lead to losses of specialist knowledge and/ or skills?	• …help to retain or improve specialist knowledge and/ or skills?
Economy	• …result in changes to the NDA's contribution to economies (local, regional or national)?	• …lead to increased pressure on economies and/ or direct economic losses?	• …lead to reduced pressure on economies and/ or direct economic gains?
	• …result in changes to other sectors, such as tourism?	• …lead to declines in other economic sectors?	• …lead to improvements in other economic sectors?
	• …result in other indirect changes to levels of investment into an area?	• …lead to declines in levels of investment into an area?	• …lead to improvements in level of investment into an area?

<table>
<tr><th rowspan="3">IIA Topic</th><th colspan="3">Assessment Guide Questions</th></tr>
<tr><th rowspan="2">Generic Guide Question
"Could the option…"
Check for relevance.</th><th colspan="2">Detailed Guide Question
Check need for further assessment / investigation.</th></tr>
<tr><th>Risks of adverse effects
"Is there a <u>risk</u> that the option could…"</th><th>Opportunities for benefits
"Is there an <u>opportunity</u> that the option could…"</th></tr>
<tr><td>Local and national assets</td><td>• …result in changes to local and/ or national assets, such as the infrastructure which supports services or facilities valuable to communities?</td><td>• …lead to loss / restriction of locally, and/ or nationally important assets?</td><td>• …lead to improvements / provision of locally and/ or nationally important assets?</td></tr>
<tr><td colspan="4">**HEALTH**</td></tr>
<tr><td>Respiratory and cardiovascular conditions associated with changes in air quality</td><td>• …result in any effects on air quality which may have health implications for the public?</td><td>• …result in air quality changes which may negatively influence the health of the public and/ or breach air quality standards?</td><td>• …result in air quality changes which may positively influence the health of the public and/ or prevent a breach of air quality standards?</td></tr>
<tr><td>Annoyance, sleep disturbance and other health effects associated with changes in noise levels</td><td>• …result in any effects on noise and vibration which may have health implications for the public?</td><td>• …result in noise or vibration changes which may negatively influence the health of the public and/ or result in a breach of noise standards?</td><td>• …result in noise or vibration changes which may positively influence the health of the public and/ or prevent a breach of noise standards?</td></tr>
<tr><td>Effects on physical activity and obesity</td><td>• …lead to changes in levels of physical activity, or how people access and utilise recreation and amenity areas?</td><td>• …lead to declines in the levels of physical activity of the public?</td><td>• …lead to an increase in the levels of physical activity of the public?</td></tr>
<tr><td>Health and safety effects from road traffic changes</td><td>• …lead to changes in levels of traffic, public transport services, journey times, etc. for the public?</td><td>• …lead to traffic changes which may negatively influence the health of the public?</td><td>• …lead to traffic changes which may positively influence the health of public?</td></tr>
</table>

<table>
<tr><th rowspan="3">IIA Topic</th><th colspan="3">Assessment Guide Questions</th></tr>
<tr><th rowspan="2">Generic Guide Question
“Could the option…”
Check for relevance.</th><th colspan="2">Detailed Guide Question
Check need for further assessment / investigation.</th></tr>
<tr><th>Risks of adverse effects
“Is there a risk that the option could…”</th><th>Opportunities for benefits
“Is there an opportunity that the option could…”</th></tr>
<tr><td>Health effects relating to changes in the water environment</td><td>• …result in any effects on water quality or availability which may have health implications for the public?</td><td>• …result in water quality changes which may negatively influence the health of the public?</td><td>• …result in water quality changes which may positively influence the health of the public?</td></tr>
<tr><td>Radiological safety related health effects</td><td>• …lead to changes in radiological safety which may have health implications for the public?</td><td>• …lead to radiological safety changes which may negatively influence the health of the public and/ or breach statutory public dosage limits?</td><td>• …lead to radiological safety changes which may positively influence the health of the public and/ or prevent a breach of statutory public dosage limits?</td></tr>
<tr><td>Mental health and well-being</td><td>• …result in any effects which may have implications for the mental health and well-being of the public or lead to changes in access to health-related facilities or services, or how people obtain the support and services they need to be healthy?</td><td>• …result in any effects which may have negative implications for the mental health and well-being of the public or result in cultural or institutional effects which may negatively influence the health of the public?</td><td>• …result in any effects which may have positive implications for the mental health and well-being of the public or result in cultural or institutional effects which may positively influence the health of the public?</td></tr>
</table>

Glossary

Advanced Gas Cooled Reactor (AGR): A second generation power reactor that uses a uranium oxide fuel and is cooled by gas.

Care and Maintenance: The period during decommissioning after defueling and Post Operational Clean Out (POCO) when a reactor is kept in a safe and passive condition to allow time for the shorter-lived radionuclides to decay. This period is sometimes called quiescence.

Centrifuge: A very fast spinning cylinder that is used to separate the isotope needed in nuclear fuel, uranium-235, from the slightly heavier isotope uranium-238.

Characterisation: The process of assessing the composition of radioactive materials and wastes, and classifying them based on their levels of radioactivity, and physical and chemical properties.

Conditioning / Immobilisation: The process of converting a hazardous material into a safer and potentially less mobile form.

Contamination: Radioactive particles that have accumulated on an exposed surface by contact with a radioactive material or waste.

Decontamination: Removing or reducing the radioactive or chemical contamination on materials or items. This may be done using chemical methods to wash off or dissolve contamination, or physical methods such as grinding to remove contaminated material on solid surfaces.

Decommissioning: The activities undertaken at the end of the life of a nuclear facility to decontaminate, dismantle and demolish it.

Dismantling: Taking apart a facility in a carefully controlled manner. This allows each part of the facility to be handled separately and different materials to be segregated.

Enrichment: The process of increasing the concentration of the uranium-235 isotope using a centrifuge during the manufacture of nuclear fuel.

Embodied Carbon: Embodied carbon refers to carbon dioxide emitted during the manufacture, transport and construction of building materials, together with end of life emissions.

Fission: The splitting apart of heavy atoms in a nuclear reactor to produce smaller atoms and release energy.

Fuel Element Debris (FED): Waste material made up of metal components from the cladding of nuclear fuel roads, after their use.

Full-Time Equivalent (FTE): This is the ratio of the total number of paid hours (full-time, part-time, contracted) by the number of working hours in that period. It provides a measure of employees working full time.

Geological Disposal: A long-term management option which involves disposing of radioactive waste deep underground in a highly-engineered geological disposal facility (GDF).

Hazard: Anything that has the potential to cause harm to people or the environment.

Hex: Uranium hexafluoride, a compound into which uranium ore and oxides are converted before enrichment in gaseous form by centrifuge.

High Level Radioactive Waste (HLW): Radioactive wastes that have such a high radioactivity content that they generate heat. This waste is produced at Sellafield as a by-product from the reprocessing of spent nuclear fuel.

Intermediate Level Wastes (ILW): Radioactive wastes with a radioactivity content above the limit for LLW but are not heat generating. ILW is produced during normal operations, maintenance and decommissioning activities at nuclear facilities, and also by reprocessing of spent nuclear fuel.

Isotope: Atoms of the same element which have the same number of protons but different number of neutrons. Two common isotopes of uranium include uranium-235 and uranium-238, both have 92 protons in their nucleus but different numbers of neutrons.

Low Level Radioactive Waste (LLW): Radioactive wastes which are not suitable for disposal as ordinary wastes, but have only low levels of radioactivity.

Low Level Waste Repository (LLWR): The facility in Cumbria used for the disposal of LLW.

Magnox: A type of reactor that uses uranium metal fuel. Named after the magnesium non-oxidising alloy sleeve used to contain the fuel.

Mixed Oxide Fuel (MOX): A nuclear fuel that combines a mixture of uranium and plutonium oxides.

Nuclear Fuel Cycle: The sequence of activities involved in the production and use of nuclear fuel. It begins with mining uranium ore and involves enrichment, fuel manufacturing, using fuel in a power reactor, and the management of the spent nuclear fuel afterwards.

Nuclear Power Reactor: A purpose built power station that uses nuclear fuel to produce heat and to generate electricity.

Post Operational Clean Out: The first stage in preparing plant for Care and Maintenance after operations have ceased.

Plutonium (Pu): A heavy, radioactive element that is produced in nuclear fuel as a result of the nuclear fission process.

Radiation: The process of emitting (radiating) energy in the form of particles or electromagnetic waves.

Radioactive decay: The spontaneous disintegration (splitting apart) of an unstable nucleus, releasing energy in the form of particles (alpha and beta), neutrons or electromagnetic energy (gamma rays).

Radioactive waste: A waste material or item containing levels of radioactivity above limits that are defined in law or regulation, and so must be stored and disposed with appropriate prior approval.

Recycling: Processing a waste material to convert it into a useful product.

Reprocessing: A treatment process for spent nuclear fuel that recovers uranium and plutonium, which could be used in the manufacture new nuclear fuel.

Remediation (or restoration): Cleaning-up the land around a facility to remove or treat any areas of land contamination. This is often done after the buildings have been demolished.

Scabbling: Mechanical removal of the contaminated surface layer of a structure or building (a physical method of decontamination).

Site End State: The ‘End State’ of a site is the physical condition of the site at the point at which the NDA has finished its business.

Spent (nuclear) fuel: Fuel that has been used in a nuclear reactor.

Swarf: Fragments of Magnox fuel cladding that are produced when the cladding is stripped and removed from the fuel during reprocessing.

Thermal oxide reprocessing plant (THORP): The facility on the Sellafield site used to reprocess spent oxide fuel from UK Advanced Gas Cooled Reactors and some overseas customers.

Uranium (U): The heaviest known naturally-occurring element. Uranium is used as fuel in nuclear power plants.

Value Framework: A combination of factors which the NDA considers when selecting a preferred strategic option, helping balance its top priority of risk and hazard reduction alongside socio-political and affordability considerations.

Vitrification: The process of immobilising radioactive waste liquids in glass.

Acronyms

ALARA	As low as reasonably achievable	**AGR**	Advanced gas-cooled reactor
BAT	Best available techniques	**CO**	Carbon monoxide
CO_2	Carbon dioxide	**GHG**	Greenhouse gases
GDF	Geological Disposal Facility		
HAL	Highly active liquor	**HAW**	Higher Activity Waste
HIA	Health Impact Assessment	**HLW**	High Level Waste
IIA	Integrated impact assessment	**ILW**	Intermediate Level Waste
LWR	Light water reactor	**LLW**	Low Level Waste
MDU	Magnox depleted uranium	**MOX**	Mixed oxide fuel
NDA	Nuclear Decommissioning Authority	**NO_x**	Oxides of nitrogen
PM	Particulate matter	**POCO**	Post Operational Clean Out
PWR	Pressurised water reactor	**RWM**	Radioactive Waste Management Limited
SeIA	Socio-economic Impact Assessment	**SEA**	Strategic Environmental Assessment
SLC	Site Licence Company	**SPRS**	Sellafield Product Residue Store
SO_2	Sulphur dioxide	**THORP**	Thermal Oxide Reprocessing Plant
TMF	Tails Management Facility	**UF_6**	Uranium hexafluoride (“hex”)
UO_3	Uranium trioxide	**VLLW**	Very Low Level Waste