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ENVIRONMENTAL IMPACTS ASSOCIATED WITH RADIOACTIVE WASTE MANAGEMENT: A REVIEW OF STANDARDS AND PRACTICES ACCORDING TO THE DO NOT SIGNIFICANT HARM APPROACH OF THE EUROPEAN TAXONOMY

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CONTENT

1. FOREWORD

Nuclear energy leads to the production of different categories of radioactive wastes which are classified according to their level of radioactivity (very low, low, intermediate and high-level waste) and their decay over time (very short, short and long live waste). The majority of radioactive waste which have been produced over several decades of electricity production at nuclear power plants over Europe are disposed of in surface or sub surface facility according to national safety standards. These standards are consistent with IEAE and European safety standards which includes the protection of the environment.

High level waste and spent fuel, which account for 1% or less of the total amount of radioactive waste produced by electricity generation in nuclear power plant, have been stored in dedicated facilities, also for decades and also according to national regulations and, indeed, international safety standards. Monitoring of such facilities show that environment around these facilities is protected. Regarding final disposal of these waste, national, European and international R&D programs have been implemented since the 1960ies. These programs lead most countries to consider that while high level waste and spent fuel are currently safely stored, final disposal in geological repository appear as the best option for the long-term management (e.g. up to 1 million years) of these wastes. Indeed, Finland, Sweden and France will operate such a disposal facility in the coming decades.

This report provides a review of standards and practices with regards to the safety of radioactive waste disposal which are currently in operation as well as geological disposal. It was prepared in conjunction with the publication of the Taxonomy Technical Report by the EU Technical Expert Group (TEG) on Sustainable Finance. The preparation of this report was funded by EDF S.A.

Abstract

Nuclear energy leads to the production of different categories of radioactive wastes. The majority of radioactive waste which have been produced over several decades of electricity production at nuclear power plants are disposed of in surface or sub surface facility according to national regulations. These regulations are consistent with IEAE and European safety standards which includes the protection and conservation of non-human species, both animal and plant, and their biodiversity; environmental goods and services such as the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; etc.

This report provides an overview of standards applying to and actual experiences related to waste management facilities with regards to the European Taxonomy Do No Significant Harm to environment criteria approach. This report focuses on high level waste and spent fuel, geological disposal and criteria 3 to 6 of the European Taxonomy Report: sustainable use and protection of water and marine resources; transition to a circular economy, waste prevention and recycling; pollution prevention and control and protection of healthy ecosystem.

This report provides robust evidence that safety standards (in line with UN goals for sustainable development) that applies to current and future waste management storage and disposal facilities allow for a high level of protection of the environment. Current and future management of radioactive waste complies with the European Taxonomy DNSH approach.

Résumé

L'énergie nucléaire conduit à la production de différentes catégories de déchets radioactifs. Ces déchets, très majoritairement à vie courte et de faible activité, qui ont été produits au cours de plusieurs décennies de production d'électricité dans les centrales nucléaires, sont entreposés ou stockées dans des installations de surface ou de sub-surface dans le respect des réglementations nationales. Ces réglementations sont conformes aux standards de sûreté établis aux échelles internationale (AIEA) et européenne (Directive Euratom) qui inclut de fait la protection et la conservation des biotas non humains, animaux et végétaux et de leur biodiversité ; des produits et services agricoles telle que la production de denrées alimentaires ; des ressources agricoles, forêts, eaux piscicoles et du tourisme , etc…

Ce rapport met en perspective les standards de sûreté qui réglementent la gestion des déchets radioactifs ainsi que l'impact sur l'environnement d'installations d'entreposage ou de stockage de déchets radioactifs au regard des critères de l'approche *Do No Significant Harm to the Environnement* de la Taxonomie européenne pour une Finance Durable (absence de préjudice significatif à l'environnement). Ce rapport porte en particulier sur les déchets de haute activité et le combustible nucléaire usé, le stockage géologique et les critères 3 à 6 de la Taxonomie européenne (utilisation durable et protection des ressources en eau et du milieu marin ; transition vers une économie circulaire, prévention des déchets et recyclage ; prévention de la pollution, contrôle et protection des écosystèmes).

Ce rapport établit la robustesse des standards de sûreté (en lien avec les objectifs de l'ONU pour le développement durable) qui impliquent un niveau élevé de protection de l'environnement et qui s'applique aux installations présentes et futures d'entreposage et de stockage des déchets radioactifs. La gestion actuelle et future des déchets radioactifs est conforme à l'approche DNSH de la Taxonomie Européenne.

2. EXECUTIVE SUMMARY AND KEY POINTS

Context

The Taxonomy Technical Report from the EU Technical Expert Group on Sustainable Finance (TEG) published in June 2019 provides a list of economic activities which can make a substantial contribution to climate change mitigation or adaptation while avoiding significant harm to four further EU environmental objectives: sustainable use and protection of water and marine resources, transition to a circular economy, waste prevention and recycling, pollution prevention control and protection of healthy ecosystems[1].

Electricity, gas, steam and air conditioning supply is discussed in the Taxonomy Technical Report. Electricity generation is indeed responsible for approximately 25% of EU greenhouse gas emissions. For natural gas-fired power, which is included in the Taxonomy, the TEG Report indicates the following: '*Natural gas-fired power: unabated natural gas-fired power generation is not expected to meet the required threshold. Gas-fired power with carbon capture and sequestration* [CCS] *may qualify. However, this will be subject to the requirement that fugitive emissions across the gas supply chain need to be measured rather than estimated*'.

When it comes to nuclear energy, the TEG recognizes the near to zero greenhouse gas emissions in the energy generation phase and the actual potential of nuclear energy as a contributor to EU climate mitigation objectives. But '*it was not possible for TEG, nor its members, to conclude that the nuclear energy value chain does not cause significant harm to other environmental objectives on the time scales in question*'. The TEG considers that there is no robust evidence regarding the DNSH to environmental criteria for the long-term management of high-level radioactive waste (HLW). The TEG does indeed not consider the considerable existing information related to the safe management of radioactive waste in geological repository and related international, European and national standards and regulations, strategies and experiences.

Low and Intermediate Level Waste (LLW and ILW) make up to 97–98% of the total waste volume produced by a nuclear power plant. Disposal facilities for LLW and ILW are already in operation or under construction around the world. These include near surface engineered facilities for LLW in China, the Czech Republic, France, India, the Islamic Republic of Iran, Japan, Poland, Slovakia, Spain, the UK and the USA, among others. Construction of a new LLW near surface repository in Bulgaria began in August 2017. Engineered facilities for LLW and ILW sited in geological formations (at varying depths) are in operation in Finland, Germany, Hungary, the Republic of Korea, Sweden and the USA. The Konrad Repository for LLW and ILW in Germany is under construction and scheduled to start operation in 2027.

There is indeed a lot of experience in the disposal of radioactive waste, including geological disposals. These facilities are operated and monitored according to National Authorities requirements which are consistent with International Safety Standards.

International Safety Standards

The International Atomic Energy Agency (IAEA) is the world's central intergovernmental forum (under the umbrella of the United Nations) for scientific and technical co-operation in the nuclear field. It

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[1] Taxonomy : Final Report of the technical Expert Group on Sustainable Finance, March 2020.

works for the safe, secure and peaceful uses of nuclear science and technology, contributing to international peace and security and the United Nations' Sustainable Development Goals[2]. All EU countries are Member States of IAEA.

Within IAEA, the Department of Nuclear Safety and Security aims at providing a sustainable nuclear safety and security framework to protect people, society and the environment. It develops safety standards for radioactive waste management. Safety means the protection of people and the environment against radiation risk, and the safety of facilities and activities that give rise to radiation risks. The protection of the environment means the protection and conservation of: non-human species, both animal and plant, and their biodiversity; environmental goods and services such as the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; amenities used in spiritual, cultural and recreational activities; media such as soil, water and air; and natural processes.

The IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was adopted in Vienna on September 5th 1997 and entered into force on June 18th 2001. It is a legally binding instrument which addresses the issue of spent fuel and radioactive waste management safety on a global scale. Contracting parties, which include the European Atomic Energy Community and all EU countries, report every three years progress achieved with regards to the implementation of the obligations under the Joint Convention. The Joint Convention is connected to Chapter 22 of Agenda 21 by the United Nations Conference on Environment and Development in Rio de Janeiro adopted in 1992, which reaffirms the paramount importance of the safe and environmentally sound management of radioactive waste. Therefore, the Joint Convention (which includes protection of the environment as defined below), asking for '*a systematic safety assessment and an environmental assessment appropriate to the hazard presented by the facility and covering its operating lifetime shall be carried out*', provides substantial guarantees that the current, short, mid- and long-term standards management of spent fuel and high-level waste will meet the DNSH to environment criteria objective of the TEG.

European Union Legislation

All 27 European Union Member States are members of the Euratom and Contracting Parties to the Joint Convention. The 2011/70/Euratom Directive was established to ensure appropriate national arrangements for a high level of safety in spent fuel and radioactive waste management. It is a regulatory binding document. National framework provides the concepts or plans and technical solutions for spent fuel and radioactive waste management from generation to disposal.

With regards to the long-term management of high-level waste and spent fuel, the Directive calls for planning and implementing disposal facilities and outlines that '*It is broadly accepted at the technical level that, at this time, deep geological disposal represents the safest and most sustainable option as the end point of the management of high-level waste and spent fuel considered as waste. Member States, while retaining responsibility for their respective policies in respect of the management of their spent fuel and low, intermediate or high-level radioactive waste, should include planning and implementation of disposal options in their national policies. Since the implementation and development of a disposal facility will take place over many decades, many programmes recognise the necessity of remaining flexible and adaptable*'.

[2] https://www.iaea.org/about/overview

The 2011 Directive is consistent with the IAEA Joint Convention and international safety standards. National Regulations based on the Directive are therefore consistent with the DNSH to environmental criteria (3 to 6) as defined in the TEG Report.

National experiences

Environmental impacts associated with storage of spent fuel on the short, long and infinite time were analyzed in details by the US Nuclear Regulatory Commission (NRC). It concludes that for short and long terms environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. The list of impacts considered by the NRC encompasses criteria 3 to 6 defined for the DNSH approach in the TEG Report.

In Sweden, as part of the Environment Impact Assessment, long-term impacts on non-human biota from a repository for the disposal of spent nuclear fuel at Forsmark were assessed. Results were published and provided by SKB (Swedish Nuclear Fuel and Waste Management Company) in a dedicated technical report. Results show that '*neither negative effects of the repository on biodiversity nor sustainable use of natural resources in the Forsmark area are of concern. Nevertheless, technical refinements of the methods used to assess the safety of non-human biota are ongoing, and international developments should be kept under review during the repository construction phase and methods of analysis refined if and as required*'.

In Germany, an IAEA ARTEMIS[3] report from 2018 indicates that '*The safe management of radioactive waste and spent fuel in Germany in current facilities, including the Konrad facility that is currently being prepared for operation, is supported by appropriate and, where necessary, updated safety documentation according to requirements defined by nuclear licensing procedure […] the IRRS[4] team raised no specific concerns relating to compliance of authorising procedures with IAEA safety requirements regarding to the role of safety assessment in the context of licensing for spent fuel storage or other radioactive waste management facilities'.*

Currently, **there are hundreds of radioactive waste disposals and spent fuel storage which are safely operated around the world according to national safety regulation which is consistent with international safety standards and, indeed, consistent with the DNSH to environmental criteria defined in the TEG report**. **Among them, geological disposals.**

Prior to 2050, there will be several geological disposals for HLW and spent fuel in operation (Finland, Sweden, France, etc.), which conception and building carefully followed International Standards and were assessed though a number of national and international technical review. **High and medium level wastes, as well as spent fuel, are safely stored or disposed of according to current international and national safety standards.**

Carbon Capture and Sequestration (CCS)

Currently, there is no CCS plant operating in conjunction with a gas-fired power plant in Europe.

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3 ARTEMIS is an integrated expert peer review IAEA service for radioactive waste and spent fuel management, decommissioning and remediation programmes.

4 The Integrated Regulatory Review Service helps host States strengthen and enhance the effectiveness of their regulatory infrastructure for nuclear, radiation, radioactive waste and transport safety. https://www.iaea.org/services/review-missions/integrated-regulatory-review-service-irrs

The Report published in 2017 by the EC on the implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide stated that '*Compared to the previous reporting period, Member States have generally not determined any new areas from which storage sites may or may not be selected. Only Poland has determined one storage area. Five German federal states are preparing decisions or have passed laws limiting or banning underground storage of CO_2, including for research purposes*'.

With regards to feasibility of retrofitting for new large-scale combustion plants, the Report indicates *'Assessments were carried out in Belgium (one), the Czech Republic (one), Germany (five), Romania (six), Poland (ten), Slovenia (one) and Spain (five). Assessments found that CCS is not economically feasible. Some further difficulties were found for some of the plants - no suitable storage sites in Belgium and Estonia or technical incompatibility with the flexible operation of a plant'.*

Presenting the Principles for Taxonomy development, the TEG indicates that the regulation established the following requirements '*cover all relevant economic activities within a specific sector and ensure that those activities are treated equally if they contribute equally towards one or more environmental objectives, to avoid distorting competition in the market*'. While CCS is included in the Taxonomy because it '*is a key technology for the decarbonation of Europe'*, a fair and honest analysis of available scientific, technical, operation knowledge and experience would lead to the conclusion that nuclear energy should be part of the Taxonomy.

3. CONTEXT

The Taxonomy Technical Report from the EU Technical Expert Group on Sustainable Finance (TEG) published in March 2020 provides a list of economic activities which can make a substantial contribution to climate change mitigation or adaptation while avoiding significant harm to four further EU environmental objectives: sustainable use and protection of water and marine resources, transition to a circular economy, waste prevention and recycling, pollution prevention control and protection of healthy ecosystems (e.g. criteria do no significant harm, DNSH, to other environmental objectives)[5]. In other words, economic activities, even when making a substantial contribution to climate change mitigation and/or adaptation, will not be eligible for the Taxonomy if they cannot be performed in a way which avoids significant harm to other environmental objectives. The list provided in the Taxonomy Technical Report is not exhausted and additional activities should be added in the future. Based on the EU Taxonomy, capital markets are expected to identify and respond to investment opportunities that contribute to EU environment policy objectives (sustainable finance).

Among the various economic sectors that were investigated, 'Electricity, gas, steam and air conditioning supply' is discussed in the Taxonomy Technical Report. Electricity generation is indeed responsible for approximately 25% of EU greenhouses gas emissions. For electricity generation, the TEG proposes an emission threshold of 100g CO_2 eq.kWh^{-1} to be reduced every five years to a final 0g CO_2 eq.kWh^{-1} in 2050. Eligibility to the Taxonomy is based on ISO-14044 compliant Life Cycle Emissions analysis, except for some technologies such as '*solar, wind and existing hydropower (in the EU),* (which) *are exempt from the requirement for LCEs on the basis of the existing research base on the issue*'. For natural gas-fired power, the TEG Report indicates the following:

'Natural gas-fired power: unabated natural gas-fired power generation is not expected to meet the required threshold. Gas-fired power with carbon capture and sequestration may qualify. However, this will be subject to the requirement that fugitive emissions across the gas supply chain need to be measured rather than estimated'.

However, production of electricity from gas combustion is included in the Taxonomy.

When it comes to nuclear energy, the TEG recognizes the near to zero greenhouse gas emissions in the energy generation phase and the actual potential of nuclear energy as a contributor to EU climate mitigation objectives. Moving towards DNSH criteria, the TEG indicated the following:

'*On potential significant harm to other environmental objectives, including circular economy and waste management, biodiversity, water systems and pollution, the evidence about nuclear energy is complex and more difficult to evaluate in a taxonomy context. Evidence often addresses different aspects of the risks and management practices associated with nuclear energy. Scientific, peer-reviewed evidence of the risk of significant harm to pollution and biodiversity objectives arising from the nuclear value chain was received and considered by the TEG. Evidence regarding advanced risk management procedures and regulations to limit harm to environmental objectives was also received. This included evidence of multiple engineered safeguards, designed to reduce the risks. Despite this evidence, there are still empirical data gaps on key DNSH issues. For example, regarding the long-term management of High-Level Waste (HLW), there is an international consensus that a safe, long-term technical solution is needed to solve the present unsustainable situation. A combination of temporary storage plus permanent disposal in geological formation is the most promising, with some countries are leading the*

[5] Taxonomy : Final Report of the technical Expert Group on Sustainable Finance, March 2020.

way in implementing those solutions. Yet nowhere in the world has a viable, safe and long-term underground repository been established. It was therefore infeasible for the TEG to undertake a robust DNSH assessment as no permanent, operational disposal site for HLW exists yet from which long-term empirical, in-situ data and evidence to inform such an evaluation for nuclear energy.

Given these limitations, it was not possible for TEG, nor its members, to conclude that the nuclear energy value chain does not cause significant harm to other environmental objectives on the time scales in question. The TEG has not therefore recommended the inclusion of nuclear energy in the Taxonomy at this stage. Further, the TEG recommends that more extensive technical work is undertaken on the DNSH aspects of nuclear energy in future and by a group with in-depth technical expertise on nuclear life cycle technologies and the existing and potential environmental impacts across all objectives'.

Therefore, production of electricity from nuclear energy has not been included in the Taxonomy.

The position of the TEG relies on the consideration that there is no robust evidence regarding the DNSH criteria regarding the long-term management of high-level waste (HLW). There may be other elements underlying the decision of the TEG, but they are not provided in the TEG Report. It should be outlined that when considering that '*Gas-fired power with carbon capture and sequestration may qualify*', the TEG considers potential for CCS technology, while, in the same time, the TEG does not consider the considerable existing information related to the safe management of radioactive waste in geological repository and related international, European and national standards and regulations, strategies and experiences.

This report intends to provide arguments related to HLW management with regards to DNSH to environmental objectives 3 to 6 as described in the TEG Report (*§8.2, Table 7 P.46*, see Figure 1), e.g. sustainable use and protection of water and marine resources (3), transition to circular economy, waste prevention and recycling (4), pollution prevention control (5) and protection of healthy ecosystem (6). It thus aims at contributing to an equal treatment for nuclear energy and other energy in order to avoid distorting competition in the market. This report also highlight how high and medium level wastes, as well as spent fuel, are currently safely stored or disposed of according to current international and national safety standards.

Table 7 – Do no significant harm criteria for environmental objectives 3-6

Objective	Conditions for causing 'significant harm'
(3) Sustainable use and protection of water and marine resources	*The activity is detrimental to a significant extent to good status of Union waters, including freshwater, transitional waters and coastal waters, or to good environmental status of marine waters of the Union.*
(4) Transition to a circular economy, waste prevention and recycling	*The activity leads to significant inefficiencies in the use of materials in one or more stages of the life-cycle of products, including in terms of durability, reparability, upgradability, reusability or recyclability of products; or where that activity leads to a significant increase in the generation, incineration or disposal of waste.*
(5) Pollution prevention and control	*The activity has relative high emissions to air, water and land compared to a level of environmental performance that is based on BAT principles.*
(6) Protection of healthy ecosystems	*The activity is detrimental to a significant extent to the good condition of ecosystems.*

Figure 1. DNSH to environmental objectives 3 to 6

4. APPROACH

The management of radioactive waste produced by the use of nuclear energy for non-military purpose (electricity generation, medical application, research, industrial application, agriculture, etc.) is discussed in quite a large number of documents. These documents are related to a broad scope of topics: safety standards, regulations, experiences, environmental impact assessment, long-term, etc. There has never been an accident dealing with storage facility of medium and high-level waste leading to significant harmful effects on the environment. A number of documents providing robust arguments on the safe management of high-level waste and spent fuel were selected and analyzed. Relevant information was structured based on a three-level approach: international standards (mainly based on IAEA documents), European standards (mainly based on EC Directive 2011/70/Euratom) and national regulations and experiences. Information is, for each level and as far as feasible, structured with regards to DNSH approach as proposed in the TEG Report.

5. INTERNATIONAL STANDARDS FOR THE MANAGEMENT OF HIGH-LEVEL WASTE AND SPENT FUEL

5.1. Definitions[6]

Safety means the protection of people and the environment against radiation risk, and the safety of facilities and activities that give rise to radiation risks. The protection of people against exposure to ionizing radiation or exposure due to radioactive material and the safety of sources, including the means for achieving this, and the means for preventing accidents and for mitigating the consequences of accidents if they do occur. The protection of the environment means the protection and conservation of: non-human species, both animal and plant, and their biodiversity; environmental goods and services such as the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; amenities used in spiritual, cultural and recreational activities; media such as soil, water and air; and natural processes such as carbon, nitrogen and water cycles[7].

Radioactive waste are categorized according to their level of activity and the decay period. National Authorities may consider different approach for the classification schemes for radioactive waste, but these schemes are generally consistent and consider the following categories:

- VLLW - Very Low-Level Waste,
- LLW/ILW SL - Low-Level Waste and Intermediate Level waste, Short-Lived,
- LLW-LL - Low-Level Waste, Long Lived,
- ILW-LL - Intermediate-Level Waste, Long Lived,
- HLW - High Level Waste.

5.2. The International Atomic Energy Agency

The International Atomic Energy Agency (IAEA) is the world's central intergovernmental forum (under the umbrella of the United Nations) for scientific and technical co-operation in the nuclear field. It works for the safe, secure and peaceful uses of nuclear science and technology, contributing to

[6] https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1830_web.pdf

[7] While operating according to safety standards, a nuclear facility respect environment DNSH criteria 6.

international peace and security and the United Nations' Sustainable Development Goals[8]. The European Commission and the IAEA have been cooperating since 2003 on areas such as radiation protection, safe management of radioactive waste, environmental remediation, etc[9]. All EU countries are Member States of IAEA. Within IAEA, the Department of Nuclear Safety and Security aims at providing a sustainable nuclear safety and security framework to protect people, society and the environment from the harmful effects of ionizing radiation. The Department develops safety standards for radioactive waste management.

The IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, in order to ensure the protection of people and the environment from harmful effects of ionizing radiation. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the storage and disposal of radioactive waste. These standards reflect an international consensus and commitment on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation and are, indeed, adequate to assess the management of radioactive waste generated by nuclear electricity generation with regards to the DNSH criteria as defined in the TEG Report.

5.3. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

5.3.1. Context

The Joint Convention was adopted in Vienna on September 5th 1997 and entered into force on June 18th 2001. It is a legally binding instrument addressing the issue of spent fuel and radioactive waste management safety on a global scale. It applies to spent fuel resulting from the operation of civilian nuclear reactors and to radioactive waste resulting from civilian applications. In addition, it covers planned and controlled releases into the environment of liquid or gaseous radioactive materials from regulated nuclear facilities. Contracting parties, which include the European Atomic Energy Community and all EU countries, report every three years progress achieved with regards to the implementation of the obligations under the Joint Convention (last reports were provided in 2018 for the 6th Review Meeting[10]).

The Joint Convention is connected to Chapter 22 of Agenda 21 by the United Nations Conference on Environment and Development in Rio de Janeiro adopted in 1992, which reaffirms the paramount importance of the safe and environmentally sound management of radioactive waste. As stated in the TEG Report, '*The EU has also played a leading role in the development of international climate and sustainable development policy, with a strong commitment to key international agreements such as the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention on Biological Diversity (UNCBD) and the United Nations Convention to Combat Desertification (UNCCD), Sustainable Development Goals (SDGs), the Paris Agreement on climate change*' (§1.2, P. 11).

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8 https://www.iaea.org/about/overview

9 https://www.iaea.org/about/partnerships/european-union

10 https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste/documents

In this context , the Joint Convention provides relevant guarantees with regards to the respect of DNSH criteria, ensuring the application of short, mid- and long-term standards for the management of spent fuel and high-level waste. The definition of safety is here again outlined: safety means the protection of people and the environment against radiation risk, and the safety of facilities and activities that give rise to radiation risks. The protection of the environment means the protection and conservation of: non-human species, both animal and plant, and their biodiversity; environmental goods and services such as the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; amenities used in spiritual, cultural and recreational activities; media such as soil, water and air; and natural processes such as carbon, nitrogen and water cycles.

5.3.2. Content

The Joint Convention aims '*to ensure that during all stages of spent fuel and radioactive waste management there are effective defenses against potential hazards so that individuals, society and the environment are protected from harmful effects of ionizing radiation, now and in the future, in such a way that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations*' (Art. 1)[11].

A number of elements of spent fuel and radioactive waste management are relevant to DNSH criteria as defined in the TEG Report, from the design of a spent fuel storage or disposal facility, to its operation and decommissioning:

- '*Before construction of a spent fuel management facility,* ***a systematic safety assessment and an environmental assessment appropriate to the hazard presented by the facility and covering its operating lifetime shall be carried out***' (Art. 8).
- '***Each Contracting Party shall take the appropriate steps to ensure that at all stages of radioactive waste management individuals, society and the environment are adequately protected against radiological and other hazards*** […] ***ensure that the generation of radioactive waste is kept to the minimum practicable*** […] *aim to avoid imposing undue burdens on future generations*' (Art. 11)
- *[…] review (i) the safety of any radioactive waste management facility existing at the time [and] to ensure that, if necessary, all reasonably practicable improvements are made to upgrade the safety of such a facility.* (Art. 12.)
- *Siting of proposed facilities (i) to evaluate all relevant site-related factors likely to affect the safety of such a facility during its operating lifetime [and] after closure [and] (ii)* ***to evaluate the likely safety impact of such a facility on individuals, society and the environment****.* (Art. 13)
- *The design and construction of a radioactive waste management facility provide for suitable measures* ***to limit possible radiological impacts on individuals, society and the environment, including those from discharges or uncontrolled releases****. (iv) The technologies incorporated in the design and construction of a radioactive waste management facility are supported by experience, testing or analysis.* (Art. 14)
- *(iii) measures are taken to prevent unplanned and uncontrolled releases of radioactive materials into the environment [and] (v) each contracting party shall take appropriate steps to ensure that discharges shall be limited.* (Art. 24).

11 https://www.iaea.org/sites/default/files/infcirc546.pdf

The Joint Convention includes clearly the protection of the environment and the respect of the DNSH criteria as defined in the TEG Report.

5.4. Safety Requirements for Predisposal Management of Radioactive Waste

The IAEA established Safety Standards for the predisposal management of radioactive waste[12] which covers all the steps in the management of radioactive waste from its generation up to its disposal, including processing, storage and transport. This publication deals with the application of the fundamental safety principles to the management of radioactive waste prior their disposal, e.g. objectives, criteria and requirements for the protection of human and the environment that apply to the siting, design, construction, commissioning, operation and shutdown of facilities for the predisposal management of radioactive waste.

The document indicated that '***Requirements for environmental protection that are associated with predisposal management of radioactive waste have to be established by the relevant national regulatory bodies, with all potential environmental impacts that could reasonably be expected taken into consideration***'. Requirement 8 outlines that '*radioactive waste arisings shall be kept to the minimum practicable, applying the following measures: reduce waste generation, reuse items as originally intended, recycle materials and, finally, consider disposal of waste*'.

The required approach is fully consistent with the waste management hierarchy recommended by the United Nations[13] (and then with DNSH criteria 4 among others, as defined in the TEG Report). Long-term safety of storage facilities that may operate for decades is considered as outlined in Requirement 11 '*Waste shall be stored in such a manner that it can be inspected, monitored, retrieved and preserved* […] *For long term storage in particular, measures shall be taken to prevent degradation of the waste containment*'. Among other requirements, periodic safety review is also to be mentioned: 'The operator shall carry out periodic safety reviews and shall implement any safety upgrades required by the regulatory body following this review'.

A Nuclear Energy Agency (NEA) review of national practices[14] showed attention paid by Regulators to this IAEA requirement (among others): '*It has been found that, whatever the regulatory approach used, the regulations in all the countries surveyed require PSR* (Periodic Safety Review) *for storage facilities, usually every ten years.* ***This requirement is in agreement with the contents of the applicable IAEA Safety Standards***'. National regulators comply with International Standards requirements and, therefore, with requirements related to the protection of the environment.

5.5. Safety Standards for Geological Disposal of Radioactive Waste

Over the last decades, a number of options have been investigated worldwide for the safe management of spent fuel and high-level waste over the long-term (up to 1 million years), such as long-term interim storage, transmutation, deep boreholes. Results of in-depth research have shown that geological repository is currently the best option for a long term and safe management of high-level waste and spent fuel:

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[12] Predisposal Management of Radioactive Waste, General Safety Requirements Part 5, No. GSR Part 5, IAEA.

[13] Guidelines for National Waste Management Strategies, Moving from Challenges to Opportunities, United Nation Environment Programme, 2013.

[14] The Safety of Long-term Interim Storage Facilities in NEA Member Countries, NEA/CSNI/R(2017)4, June 2017

- In the United Kingdom: '*no credible alternatives have emerged that would accommodate all of the categories of waste in the inventory for disposal. In any realistic future scenario, some form of GDF will remain necessary*'[15].
- In the USA : '*Deep geologic disposal capacity is an essential component of a comprehensive nuclear waste management system for the simple reason that very long-term isolation from the environment is the only responsible way to manage nuclear materials* […]. *The conclusion that disposal is needed and that deep geologic disposal is the scientifically preferred approach has been reached by every expert panel that has looked at the issue and by every other country that is pursuing a nuclear waste management program*'[16].
- In Germany: '*Following an in-depth review of a number of options for the final disposal of high-level radioactive waste in particular, the commission recommends disposal in a purpose-built mine in a deep geological formation*'[17].
- In France, '*Disposal in deep geological rocks is considered by most countries as the reference solution for the final disposal of medium and high-level long life radioactive waste*'[18].
- In Belgium, the board of the National Agency in charge of radioactive waste management (ONDRAF) decided on February 9th 2018 to propose deep geological repository as national policy for the long-term management of high level and/or long life radioactive waste[19].

IAEA Safety Standards Series No. WS-R-4 set out standards and requirements for the siting, design and construction of geological disposal of radioactive waste[20]. Within these Safety Standards, the IAEA outlines gain that '*The primary goal of geological disposal is the protection of human health and the environment in the long term, after the geological disposal facility has been closed*'. Development of Geological repository of radioactive waste as recommended by the Agency is well articulated with the TEG Report DNSH criteria:

- §2.1 The objective of radioactive waste management is to deal with radioactive waste in a manner that **protects human health and the environment now and in the future without imposing undue burdens on future generations**.
- §2.3 By applying the strategy of concentrate and contain [*radioactive*] waste, the entry of radionuclides into the biosphere is limited and the corresponding hazards associated with the waste are considerably reduced.

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15 Department of Energy and Climate Change, Implementing Geological Disposal: A Framework for the long-term management of higher activity radioactive waste, URN 14D/235, July 2014.

16 Blue Ribbon Commission on America's Nuclear Future, Report to the Secretary of Energy, January 2012.

17 Summary Report of the German Commission on the Storage of High-Level Radioactive Waste, July 2016. http://www.nuclear-transparency-watch.eu/wp-content/uploads/2017/02/Summary_Report-of-the-German-Commission-on-the-Storage-of-High-Level-Radioactive-Waste_EN.pdf

18 https://www.irsn.fr/dechets/dechets-radioactifs/Pages/stockage-international.aspx

19 https://afcn.fgov.be/fr/dossiers/dechets-radioactifs/gestion-des-dechets-radioactifs/depot/stockage-geologique-de-dechets#Définition

20 IAEA Safety Standards Series No. WS-R-4, Geological Disposal of Radioactive Waste, Safety Requirements, IAEA Publication 1231, Vienna, 2011.

- §2.9 No releases, or only very minor releases, of radionuclides (such as small amounts of gaseous radionuclides) and no significant doses to members of the public may be expected during the normal operation of a geological disposal facility.
- §2.13 **The primary goal of geological disposal is the protection of human health and the environment in the long term, after the geological disposal facility has been closed**.
- §2.18 Estimates of doses due to the future migration of radionuclides from a geological disposal facility are indicators for the protection of people. **[…]. Other factors to be considered may include the protection of groundwater resources and the ecological sensitivity of the environment.**
- §2.19 The impact of non-radioactive materials present in a geological disposal facility should be assessed […]. Factors that should be considered include […] **the protection of groundwater resources, and the ecological sensitivity of the environment** [and the impacts] considered in the safety assessment.
- §3.12 & 3.13 The operator is responsible for developing a practical and safe geological disposal facility and for demonstrating its safety, consistent with the requirements of the regulatory body.[…] The operator is also responsible for preparing a thorough safety case, on the basis of which decisions on the development, operation and closure of the geological disposal facility will be made [via] research and development [and] establishes technical specifications that are justified by the safety assessment, to ensure that the geological disposal facility is developed in accordance with the safety case.
- §3.15 **Throughout the development of a geological disposal facility, an appropriate understanding of the relevance and implications for safety of the available options shall be developed by the operator with the ultimate goal of providing an optimized level of operational and post-closure safety**.
- §3.18 The operator shall site, design, construct, operate and close the geological disposal facility in such a way that post-closure safety is ensured by passive means and does not depend on actions being taken after the closure of the facility.
- §3.26 & 3.28 The natural and engineered barriers shall be selected and designed so as to ensure that post-closure safety is provided by means of multiple safety functions […] The presence of multiple barriers and safety functions provides assurance that […] a sufficient margin of safety will remain.
- § 3.29 Containment of waste implies designing for the minimal release of radionuclides […] The containment of the radionuclides in the [highly concentrated radioactive] waste form and packaging over an initial period of several hundreds to thousands of years ensures that the majority of shorter lived radionuclides decay in situ. […]. Such containment may not be practicable or necessary for lower activity long lived waste.
- § 3.32 **The geological disposal facility shall be sited in a geological formation and at a depth that provide isolation of the waste from the biosphere and from humans over the long term, for at least several thousand years** […] Isolation is an inherent feature of geological disposal.
- § 3.45 The safety case and its supporting assessments shall illustrate the level of protection provided and shall provide assurance that safety requirements will be met. The safety case […] addresses both operational safety and post-closure safety. […] § 3.46 All aspects of operation relevant to radiation safety are considered, including […] normal operations, accident, expected range of possible developments. […] § 3.48 **Sensitivity analyses and uncertainty analyses will be undertaken [to] […] test the robustness [and] resilience of the geological system** […] In particular with […] quantitative analyses.
- § 3.76 Plans shall be prepared for the post-closure period to address the issue of institutional control and the arrangements for maintaining the availability of information on the geological disposal facility […] institutional controls may contribute to safety. Arrangements will be made

to be able to pass on information about the geological disposal facility to future generations to enable them to make any future decisions on the geological disposal facility and its safety.

The excerpts provided are in line with DNSH criteria as described in the TEG Report. A geological disposal which conception, operation and decommissioning adequately respect IAEA standards comply with the DNSH approach. This is particularly the case for criteria 3 (protection of water resources), 5 (pollution prevention and control) and 6 (protection of healthy ecosystem).

5.6. Report on Climate Change and Nuclear Power

Since 2009, IAEA publishes almost yearly a Climate Change and Nuclear Power publication[21]. The 2018 edition provides an overview of the most important linkages between climate change and nuclear energy, based on the latest knowledge on climate change, its impacts and efforts to mitigate it. It discusses the role of the energy sector in climate change and the possible contribution of nuclear energy to reducing GHG emissions. The challenges on radioactive waste are recognized and presented in Chapter 5 of the Report.

Interim storage of spent fuel under wet or dry conditions is a more than 50 years old practice. There are 151 such facilities which are operated safely worldwide (2018). Most of these facilities have been deployed over the last 25 years. They are safety operated and monitored and allow a flexible approach for the development of safe final disposal solution for spent fuel as well as HLW. While complying to safety standards that apply to any nuclear facility, these facilities comply with DNSH criteria. Current pre-disposal management of HLW and spent fuel show no adverse effect on human health and non-human biota and are in line with DNSH criteria defined by the TEG Report.

In addition to spent fuel and HLW, which constitute approximately 1% of radioactive waste inventory, it should be reminded that '*there are two other categories of radioactive waste that are worthy of note: low level waste (LLW) and intermediate level waste (ILW). LLW and ILW make up 97–98% of the total waste volume produced by an NPP, but they constitute only 8% of the total waste radioactivity. Disposal facilities for LLW and ILW are already in operation or under construction around the world. These include near surface engineered facilities for LLW in China, the Czech Republic, France, India, the Islamic Republic of Iran, Japan, Poland, Slovakia, Spain, the UK and the USA, among others. Construction of a new LLW near surface repository in Bulgaria began in August 2017. In addition, engineered facilities for LLW and ILW sited in geological formations (at varying depths) are in operation in Finland, Germany, Hungary, the Republic of Korea, Sweden and the USA. Further disposal facilities for LLW and ILW are at different licensing stages in Belgium, Canada, Lithuania, Romania and Slovenia. The Konrad Repository for LLW and ILW in Germany is under construction and scheduled to begin accepting waste in 2027*'.

Regarding disposal of radioactive waste in geological repository, the IAEA outlines the following: '*For the final disposal of spent fuel and HLW, the most common strategy is to plan to use deep geological formations. Progress towards opening spent fuel and HLW disposal facilities is supported by extensive engineering studies and rigorous review by independent regulators. Finland and Sweden have made the greatest advances in this field. In November 2015, the authorities in Finland granted Posiva, an organization with expertise in nuclear waste management, a construction license for Finland's spent fuel and HLW disposal facility in Olkiluoto.*'.

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[21] https://www.iaea.org/publications/search/topics/nuclear-power-and-climate-change

5.7. Comparison of Geological Disposal of Carbon Dioxide and Radioactive Waste

CCS technology is included in the Taxonomy while there is no actual information related to its environmental impacts. Regarding similarities between CCS technology and geological repository for radioactive waste, the existing corpus of data, research, knowledge and standards which exist for the latest, it seems inadequate (unfair) not to include nuclear energy in the taxonomy.

Emission of CO_2 can be reduced by various types of measure including CO_2 capture and geological disposal. Hence, the emplacement of radioactive waste and CO_2 in deep geological formations is considered to be a safe method for isolating these substances from people and from the accessible biosphere. The IAEA established in 2014 a report entitled Techno-economic Comparison of Geological Disposal of Carbon Dioxide and Radioactive Waste which stated that Safety assessment methodologies are significantly better established for radioactive waste than for CO_2 disposal: '*Policy, regulatory and institutional settings are relatively well defined for radioactive waste disposal and policies are developing rapidly for CCS in some countries, for example in Europe*.' Discussing this question in its 2018 report on Climate Change and Nuclear Power[22], the IAEA mentions '*It relies on technologies to capture CO_2 before, during or after burning coal or gas and to store it in underground geological formations. This would significantly reduce GHG emissions from burning fossil fuels. The most common criticism of CCS is obviously the issue of possible leakages from disposal sites that could result in releasing CO_2 into the atmosphere. Additionally, despite the initial enthusiasm regarding the possible contribution of CCS to climate change mitigation efforts, the technology has been showing rather mixed results at industrial scales up to now. CCS projects currently under way are facing significant delays and cost overruns. Specifically, the Kemper power plant in the USA was expected to become the flagship gas fired power plant using CCS technology. The start of its operations was originally scheduled for 2014. However, after significant construction delays and cost overruns made it the most expensive power plant in history (per unit of generating capacity), the idea of using CCS was completely abandoned in June 2017. Currently, the Kemper power plant is expected to operate as a regular gas fired power plant. It is, therefore, not surprising that projections increasingly postpone the expansion of the CCS technology into the more distant future*'.

Currently, there is no CCS plant operating in conjunction with a gas-fired power plant in Europe. The Report published in 2017 by the EC on the implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide stated that '*Compared to the previous reporting period, Member States have generally not determined any new areas from which storage sites may or may not be selected. Only Poland has determined one storage area. Five German federal states are preparing decisions or have passed laws limiting or banning underground storage of CO_2, including for research purposes*'. With regards to feasibility of retrofitting for new large-scale combustion plants, the Report indicates '*Assessments were carried out in Belgium (one), the Czech Republic (one), Germany (five), Romania (six), Poland (ten), Slovenia (one) and Spain (five). Assessments found that CCS is not economically feasible. Some further difficulties were found for some of the plants - no suitable storage sites in Belgium and Estonia or technical incompatibility with the flexible operation of a plant. However, even if the assessments were not positive, many of the permitted power plants are setting aside land for the equipment to remove and compress CO_2 and are designed in such a way that CCS can be connected later on without major layout modifications, e.g. in the Czech Republic, Estonia, Germany and Poland*.

[22] Techno-economic Comparison of Geological Disposal of Carbon Dioxide and Radioactive Waste . IAEA-TECDOC-1758, IAEA, 2014.

CCS technology is a key technology for the EU to reach CO_2 abatement objectives. It was thus included in the Taxonomy while there is no practical experience and information related to its environmental impact on short, medium and long term. CCS technology raises significant questions regarding its long-term ability to store CO_2 as well as public concerns and opposition, having in mind here that *long-term* means 100 or 1 000 years.

The IPPC 2014 Report indicated that '*Carbon dioxide capture and storage (CCS) technologies could reduce the lifecycle GHG emissions of fossil fuel power plants. While all components of integrated CCS systems exist and are in use today by the fossil fuel extraction and refining industry, CCS has not yet been applied at scale to a large, operational commercial fossil fuel power plant. CCS power plants could be seen in the market if this is incentivized by regulation and/or if they become competitive with their unabated counterparts, for instance, if the additional investment and operational costs, caused in part by efficiency reductions, are compensated by sufficiently high carbon prices (or direct financial support). For the large-scale future deployment of CCS, well-defined regulations concerning short- and long-term responsibilities for storage are needed as well as economic incentives. Barriers to large-scale deployment of CCS technologies include concerns about the operational safety and long-term integrity of CO_2 storage as well as transport risks. There is, however, a growing body of literature on how to ensure the integrity of CO_2 wells, on the potential consequences of a pressure build-up within a geologic formation caused by CO_2 storage (such as induced seismicity), and on the potential human health and environmental impacts from CO_2 that migrates out of the primary injection zone*'.

6. EUROPEAN STANDARDS AND REGULATIONS FOR THE MANAGEMENT OF SPENT FUEL AND RADIOACTIVE WASTE

6.1. COUNCIL DIRECTIVE 2011/70/EURATOM of 19 July 2011 Establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste

All 27 European Union Member States are also members of the Euratom and Contracting Parties to the Joint Convention. The 2011/70/Euratom Directive was established to ensure appropriate national arrangements for a high level of safety in spent fuel and radioactive waste management. It is a regulatory binding document. National framework provides the concepts or plans and technical solutions for spent fuel and radioactive waste management from generation to disposal. Among others, an important item of the Directive deals with peer reviews which allow for developing and exchanging experience and ensuring high standards.

The Directive recognizes that '*The Joint Convention, concluded under the auspices of the IAEA, represents an incentive instrument which aims at achieving and maintaining a high level of safety worldwide in spent fuel and radioactive waste management*'. Additionally, with regards to the long-term management of high-level waste and spent fuel, the Directive outlines that '*It is broadly accepted at the technical level that, at this time, deep geological disposal represents the safest and most sustainable option as the end point of the management of high-level waste and spent fuel considered as waste. Member States, while retaining responsibility for their respective policies in respect of the management of their spent fuel and low, intermediate or high-level radioactive waste, should include planning and implementation of disposal options in their national policies. Since the implementation and development of a disposal facility will take place over many decades, many programmes recognise the necessity of remaining flexible and adaptable*'. The Directive establishes a Community framework for '*ensuring responsible and safe management of spent fuel and radioactive waste to avoid imposing undue burdens on future generation.*' (Article 1).

Implementation of the Directive into national regulations ensure a safe management of high-level waste and spent fuel on short, medium and long-terms. The Commission recognized that research and development of a robust disposal site and concept for such waste and materials require a long process. Peer reviews play a key role to ensure best available techniques are implemented (‘*Peer review could serve as an excellent means of building confidence and trust in the management of radioactive waste and spent fuel in the European Union, with the aim of developing and exchanging experience and ensuring high standards*’).

National [policies shall be based on the following principles: ‘[…] ***the generation of radioactive waste shall be kept to the minimum which is reasonably practicable****, both in terms of activity and volume, by means of appropriate design measures and of operating and decommissioning practices,* ***including the recycling and reuse of materials*** *(b) the interdependencies between all steps in spent fuel and radioactive waste generation and management shall be taken into account (c) spent fuel and radioactive waste shall be safely managed, including in the long term with passive safety features*’.

The 2011 Directive is consistent with the IAEA Joint Convention. National Regulations based on the Directive are therefore consistent with the protection of the environment and the DNSH criteria (3 to 6) as defined in the TEG Report.

6.2. Report from the Commission to the Council and the European parliament on progress of implementation of Council Directive 2011/70/EURATOM in the Community's territory and the future prospects, Second Report, December 2019

The Radioactive Waste Directive requires (under article 14(1)) the Member States to submit every three years to the European Parliament and Council a progress report on the implementation of the Directive and an inventory of radioactive waste and spent fuel. This report is the second publication to date. As far as peer reviews are concerned, Figure 2 extracted from Commission Staff Working Document Progress of Implementation of Council Directive 2011/70/Euratom provides the current status of the process.

MS	National programme and/or National framework	Competent regulatory authority
AT	2020 (ARTEMIS)	2018 (IRRS)
BE	2022 (ARTEMIS)	2013 (IRRS), 2017 (IRRS follow-up)
BG	2018 (ARTEMIS)	2013 (IRRS), 2016 (IRRS follow-up)
HR	2021 (ARTEMIS)	2015 (IRRS), 2019 (IRRS follow-up)
CY	2020 (ARTEMIS)	2017 (IRRS), 2021 (IRRS follow-up)
CZ	2023 (ARTEMIS)	2013 (IRRS), 2017 (IRRS follow-up)
DK	2020 (ARTEMIS)	2020 (IRRS)
EE	2019 (ARTEMIS)	2016 (IRRS), 2019 (IRRS follow-up)
FI	2022 (ARTEMIS)	2012 (IRRS), 2015 (IRRS follow-up), 2022 (IRRS full scope)
FR	1996 and 2005, IAEA Review of specific waste management projects 2018 (ARTEMIS)	2014 (IRRS), 2017 (IRRS follow-up)
DE	2019 (ARTEMIS)	2019 (IRRS)
EL	*No data*	2012 (IRRS), 2017 (IRRS follow-up)
HU	2021 (ARTEMIS)	2012 (IRRS follow-up), 2015 (IRRS), 2018 (IRRS follow-up)
IE	2021 (ARTEMIS)[34]	2015 (IRRS), (IRRS follow-up requested in 2018)
IT	2021 (ARTEMIS)	2016 (IRRS), 2021 (IRRS follow-up)
LV	2019 (ARTEMIS)	2019 (IRRS)
LT	2021 (ARTEMIS)	2016 (IRRS), 2020 (IRRS follow-up)
LU	2018 (ARTEMIS)	2018 (IRRS)
MT	2023 (ARTEMIS)	2015 (IRRS), 2020 (IRRS follow-up)
NL	2023 (ARTEMIS)	2014 (IRRS), 2018 (IRRS follow-up), 2023 (IRRS)
PL	2017 (ARTEMIS) after 2020 (ARTEMIS follow-up)	2013 (IRRS), 2017 (IRRS follow-up)
PT	*No data*	2020 (IRRS)
RO	2019 (ARTEMIS)	2011 (IRRS), 2017 (IRRS follow-up), 2021 (IRRS)
SK	2021 (ARTEMIS)	2012 (IRRS), 2015 (IRRS follow-up)
SI	2021 (ARTEMIS)	2011 (IRRS), 2014 (IRRS follow-up), 2021 (IRRS)
ES	2018 (ARTEMIS)	2008 (IRRS), 2011 (IRRS follow-up), 2018 (IRRS)
SE	2022 (ARTEMIS)	2012 (IRRS), 2016 (IRRS follow-up), 2022 (IRRS)
UK	*No data*	2006, 2009, 2013 (IRRS), 2014 (IRRS follow-up),

Figure 2. Recent and planned international peer reviews as per Article 14(3) of the Directive

According to the report, there are currently 30 dedicated facilities for VLLW and LLW in place in 13 Member States and 6 new facilities are planned.

In addition, '*All but one of the Member States with nuclear programmes, plus one Member State with research reactors and planning to build nuclear power plants have plans for deep geological disposal (see Table 9 for details). Finland, France and Sweden expect to have their disposal facilities operating by 2035, while the timeframes for the other twelve Member States range from 2065 to 2100, or even later. In view of these long timespans, Member States have put in place plans for long-term spent fuel storage, mainly planning using dry storage technology for long-term storage*' and '*About one third of Member States (mainly Member States with nuclear power plants) have addressed safety demonstration in their reports though concrete examples of safety assessments and safety cases mainly, for large nuclear facilities and producers of spent fuel and radioactive waste*'.

Excerpts from the main report are provided hereafter:

§ 2.3 [For Very Low and Low Level Activity Waste] The Commission encourages Member States to implement waste reduction and optimization measures, and to report on the concrete plans for disposal of all radioactive waste, including decommissioning waste, institutional waste, and other waste from remediation activities.
[For Intermediate Level Waste, High Level Waste and spent fuel] All Member States with nuclear power programmes except one have plans to develop geological disposal facilities […] France, Finland and

Sweden […] demonstrated concrete steps towards practical implementation. These 3 Member States are amongst the most advanced in the world. Globally, Finland is the first country where the construction of a deep geological facility has begun and is expected to be in operation by 2024. It will be followed by Sweden in 2032 and France in 2035.
§ 3.2 [National Framework for the management of radioactive waste:] …most Member States have made significant efforts to improve their national framework and implement the Directive.
§ 3.3 [Competent regulatory authority] **the Commission concluded that all Member States have one or more competent regulatory authorities**, in line with Article 6(1) of the Directive.
§ 3.4 [License holder] all Member States […] ensure that the primary responsibility for spent fuel and radioactive waste management rests with license holders. […] Overall, Member States have established legal requirements on license holders to provide for and maintain adequate financial and human resources.
§ 3.5 [Expertise and skills] The majority of Member States have legal requirements in place to ensure the training and education of staff of all parties involved development and maintenance of expertise and skills is better defined and reported …
§ 3.6 [Financial resources] the Decommissioning Funding Group and collaboration with international organizations, works to improve the understanding of financial issues [and cost estimation methods] related to […] management of spent fuel and radioactive waste.
§ 3.7 [Transparency] To date all national reports and notified national programs provide detailed information on the policy and legal framework regulating the transparency arrangements. Member States inform the public via web sites, reports, media, etc. and consult the public and stakeholders via different mechanisms for public information.
§ 3.8 Over **half of the Member States underwent strategic environmental assessments of their national programs and over two thirds consult the public in the framework of the environmental impact assessment as a precondition for issuing licenses for nuclear and radioactive waste management installations**.

Four Member States operate five underground research laboratories for spent fuel, intermediate level waste and high level waste disposal. Member States progressed significantly in planning and carrying out self-assessments and peer reviews of the national programs and/or national frameworks.

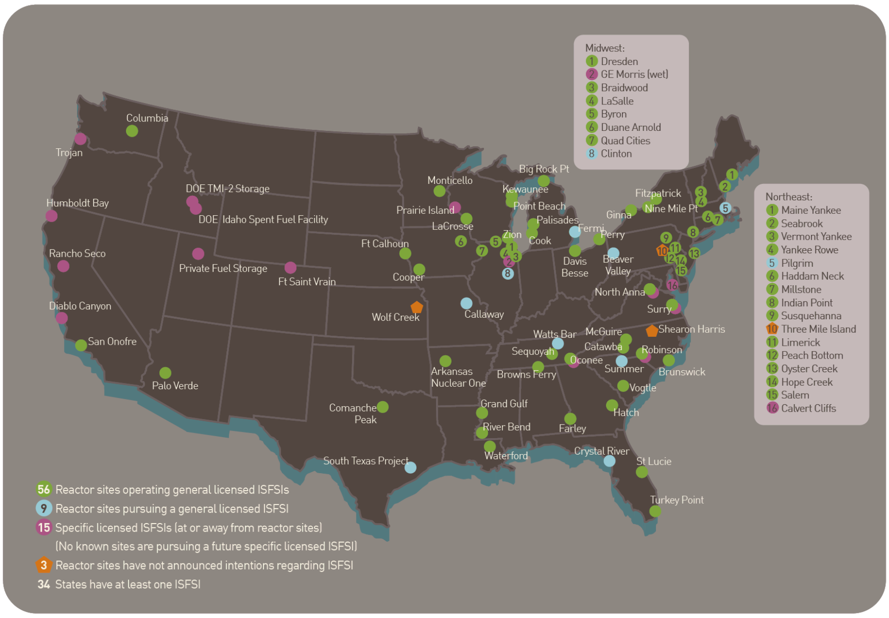
The Report shows progress of Member States in the transposition of the Directive and the application of safety standards for the management of radioactive waste, ensuring a move forward a long-term safe management of HLW and spent fuel that include protection of the environment and fits with DNSH criteria as defined by the TEG.

7. EXPERIENCES IN THE STORAGE AND DISPOSAL OF RADIOACTIVE WASTE AND SPENT FUEL

This Chapter is devoted to actual experience, data, assessment as provided by different stakeholders: UN Organization, Regulatory Authorities or Radioactive Waste Management Agencies. It intends to demonstrate that radioactive waste and spent fuel arising from the civil nuclear industry are safely managed, according to national regulations and international standards and in line with the TEG Report DNSH criteria.

7.1. Spent Fuel Storage in the USA

There are more than 150 interim storage of spent fuel under wet or dry conditions operated worldwide (2018). These facilities are classified as Nuclear installations, subject to national safety standards. The USA houses a number of these facilities as outlined in Figure 3.



https://www.nrc.gov/waste/spent-fuel-storage/map-fuel-storage-facilities.pdf

Figure 3. Map of U.S. Independent Spent Fuel Storage Installations

The U.S. Nuclear Regulatory Commission (U.S. NRC) is an independent agency of the United States government established in 1974. The NRC's regulatory activities are focused on reactor safety oversight and reactor license renewal of existing plants, materials safety oversight and materials licensing for a variety of purposes, and waste management of both high level waste and low level waste. NRC staff conducts an environmental review of each independent spent fuel storage installation (ISFSI) to comply with the National Environmental Policy Act (NEPA). The NRC's NEPA requirements are in 10 CFR Part 51. In 2014, NRC staff evaluated the environmental impacts of continued storage of spent fuel. This evaluation is documented in NUREG-2157[23] and shows that the long-term storage of spent fuel has a low environmental impact. These results confirm that the storage of spent fuel prior to their disposal does not significant harm with regards to the protection of the environment. The NRC addressed various scenarios and timeframes and a large scope of environmental impacts. Results are summarized in Figure 4. NRC defined the standard of significance for assessing environmental issues as:

- Small: environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
- Moderate: environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
- Large: environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

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23 https://www.nrc.gov/docs/ML1419/ML14196A105.pdf

Resource Area	Short-Term Storage	Long-Term Storage	Indefinite Storage
Land Use	SMALL	SMALL	SMALL
Socioeconomics	SMALL	SMALL	SMALL
Environmental Justice	Disproportionately high and adverse impacts are not expected.		
Air Quality	SMALL	SMALL	SMALL
Climate Change	SMALL	SMALL	SMALL
Geology and Soils	SMALL	SMALL	SMALL
Surface Water			
Quality	SMALL	SMALL	SMALL
Consumptive Use	SMALL	SMALL	SMALL
Groundwater			
Quality	SMALL	SMALL	SMALL
Consumptive Use	SMALL	SMALL	SMALL
Terrestrial Resources	SMALL	SMALL	SMALL
Aquatic Ecology	SMALL	SMALL	SMALL
Special Status Species and Habitat	Impacts for Federally listed threatened and endangered species and Essential Fish Habitat would be determined as part of the consultations for the ESA and the Magnuson–Stevens Fishery Conservation and Management Act.		
Historic and Cultural Resources	SMALL	SMALL to LARGE	SMALL to LARGE
Noise	SMALL	SMALL	SMALL
Aesthetics	SMALL	SMALL	SMALL
Waste Management			
Low-Level Waste	SMALL	SMALL	SMALL
Mixed Waste	SMALL	SMALL	SMALL
Nonradioactive Waste	SMALL	SMALL	SMALL to MODERATE
Transportation	SMALL	SMALL	SMALL
Public and Occupational Health	SMALL	SMALL	SMALL
Accidents	SMALL	SMALL	SMALL
Sabotage or Terrorism	SMALL	SMALL	SMALL

Figure 4. Summary of Environmental Impacts associated with storage of spent fuel

Figure 4 shows that environmental impacts associated with storage of spent fuel are small on the short and long term, e.g. environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

The list of impacts considered encompasses criteria 3 to 6 defined for the DNSH approach in the TEG Report and allows to conclude that the current approach for the management of spent fuel is safe and consistent with the DNSH to environment criteria approach.

7.2. United Kingdom

The Low Level Waste Repository (LLWR) has been the UK's principal facility for the disposal of solid low level radioactive waste (LLW) since it opened in 1959. It is regulated by the Environment Agency under the Environmental Permitting (England and Wales) Regulations 2010. The Guidance on Requirements for Authorisation for Near-Surface Disposal Facilities on Land for Solid Radioactive Waste sets a fundamental protection objective: 'to ensure that all disposals of solid radioactive waste to facilities on land are made in a way that safeguards the interests of people and the environment now and in the future, commands public confidence and is cost-effective.'

An Environmental Safety Case was published in 2011 to support an application for a new Permit to continue to dispose of LLW at the site[24]. In its concluding statement, the Report mentioned that '*We have assessed the environmental safety of the SDP, showing that impacts are appropriately low and consistent with regulatory guidance*'.

Results of environmental monitoring of nuclear facilities in United Kingdom are documented in the RIFE (Radioactivity In Food and the Environment) series of reports[25]. Results associated with the monitoring of the LLWR for 2018 are provided in Figure 5. Impacts to both human (6 $\mu Sv.y^{-1}$) and non-human biota associated with these values are low and well below regulatory limits.

Low Level Waste which are currently disposed of in LLWR according to international and UK safety standards are safely managed.

24 LLW Repository Ltd, The 2011 Environmental Safety Case, https://www.gov.uk/government/publications/llwr-the-2011-environmental-safety-case-main-report-llwrescr1110016. This document presents the arguments and evidence concerning the environmental safety of disposals of solid radioactive waste at the LLWR, at present and in the future, consistent with the Agency's Guidance on Requirements for Authorisation.

25 Radioactivity in Food and the Environment, 2018. RIFE -24, October 2019. https://wcssg.co.uk/wp-content/uploads/2018/12/Radioactivity_in_food_and_the_environment_2018_RIFE_24.pdf

Table 7.2 Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2018

Material	Location or selection[b]	No. of sampling observ-ations[b]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Milk		1	<5.0	17	<0.05	0.035	<0.22	<0.55	<0.0072	<0.40	<0.10
Deer muscle		1	<4.0	33	<0.05	0.030	<0.10	<0.07	<0.035	<0.44	<0.11
Eggs		1	<9.4	37	<0.03	<0.043	<0.06	<0.08		<0.25	<0.09
Potatoes		1	7.3	15	<0.06	<0.036	<0.21	<0.21	<0.035	<0.56	<0.14
Sheep muscle		1	<10	32	<0.04	<0.043	<0.10	<0.07	<0.034	<0.35	<0.10
Sheep offal		1	<5.6	34	<0.03	0.034	<0.07	<0.07	<0.039	<0.20	<0.06
Barley		1	22	77	<0.05	0.25	<0.09	<0.08	<0.12	<0.50	<0.11
Sediment	Drigg Stream	4[E]			<0.38	<1.3	<0.51	<0.25		<2.4	<1.3
Freshwater	Drigg Stream	4[E]	<3.1		<0.27	<0.036					
Freshwater	Railway drain	1[E]	<3.1		<0.25	0.17					

Material	Location or selection[b]	No. of sampling observ-ations[b]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{129}I	^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.0050	<0.04	0.16		<0.30				
Deer muscle		1	<0.014	<0.05	0.95	0.95	<0.28				
Eggs		1	<0.025	<0.03	<0.03	<0.031	<0.18				
Potatoes		1	<0.021	<0.07	0.29	0.29	<0.34				
Sheep muscle		1	<0.017	<0.04	0.51	0.51	<0.35				
Sheep offal		1	<0.018	<0.02	0.19	0.19	<0.11				
Barley		1	<0.018	<0.05	0.12	0.12	<0.25				
Sediment	Drigg Stream	4[E]		<0.33	52		<1.5	5.1	9.5	9.7	9.4
Freshwater	Drigg Stream	4[E]		<0.29	<0.24			<0.0022	<0.0066	<0.0016	<0.0011
Freshwater	Railway drain	1[E]		<0.26	<0.21			<0.0020	<0.015	<0.0037	<0.0039

Material	Location or selection[b]	No. of sampling observ-ations[b]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1				<0.000035	<0.000059	<0.22	<0.000024		
Deer muscle		1				<0.00021	0.00014	<0.56	0.00011		
Eggs		1				<0.000030	0.000018	<0.22	0.000078		
Potatoes		1				<0.00010	0.0013	<0.25	0.0017		
Sheep muscle		1				0.000014	0.00012	<0.25	0.00041		
Sheep offal		1				0.00074	0.0055	<0.35	0.0053		
Barley		1				0.00061	0.0032	<0.24	0.0076		
Sediment	Drigg Stream	4[E]	14	<0.97	13	<2.3	14	61	33	<110	460
Freshwater	Drigg Stream	4[E]	0.011	<0.0019	0.0098	<0.0042	<0.0032	<1.1	<0.0031	<0.043	0.39
Freshwater	Railway drain	1[E]	0.013	<0.0016	0.012	<0.00063	<0.0011	<0.97	<0.0068	<0.065	0.69

a *Except for milk and freshwater where units are Bq l^{-1}, and for sediment where dry concentrations apply*
b *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
E *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Figure 5. Concentration of radionuclides in terrestrial food and the environment near Drigg, 2018

7.3. Finland

Posiva Oy is currently constructing a geological disposal for spent fuel that should be in operation by 2025.

An Environmental Impact Assessment[26] of the project was published by Posiva Oy in 1999 in accordance with the Finish Regulation: '*Under Section 24 of the Nuclear Energy Decree, an environmental impact assessment report must be appended to the application for a decision for the final disposal facility for spent nuclear fuel. The application is to be addressed to the Council of State* […] *When considering an application for a decision in principle, the government requests a preliminary assessment of the safety of such a facility from the Radiation and Nuclear Safety Authority (STUK)*'.

26 http://www.posiva.fi/files/738/The_final_disposal_facility_for_spent_nuclear_fuel_small.pdf

The Report provides a detailed assessment of impact on nature and utilization of natural resources; impact on land use, cultural heritage, the landscape, buildings and the urban image; effects on human health and social impacts.

The Report concludes that '*There are no provincially or nationally valuable natural sites, Natura 2000 areas or nationally endangered species on the potential construction sites or where new roads would need to be built. Regional ecological links would not be broken. […] All in all, the impact on landscape is minimal. […] Activities causing vibration, dust and noise can be carried out so as not to cause environmental impacts. […] Based on safety analysis and other reports, the project's impact on human health would remain insignificantly small, both locally and when examined from a broader perspective. […] The risk of incurring health detriments from accidents and from the uncertainties and unprecedented future events involved in the project is also estimated to remain negligible. […] The long-term safety of final disposal has been the most important starting point in planning the final disposal concept. One of the core objectives in research carried out over the past 20 years or so has been to obtain sufficient grounds on which to assess long-term safety. Safety analyses carried out indicate that the concept can adequately guarantee to protect the environment and people's health in each site as far into the future as possible detriments from the waste could ever emerge*'.

This conclusion provides arguments on the long-term safety of the disposal facilities for spent fuel and is consistent with the DNSH to environment criteria 3 to 6 as defined in the TEG Report.

7.4. France

7.4.1. High Level Waste storage at Orano La Hague site

In France, HLW (3 650 m^3 for the whole country as of end 2016) have been produced as a by product of spent fuel reprocessing and are mostly stored in the Orano La Hague plant. Orano published annual environmental report providing information on the regulatory framework, annual gaseous and liquid discharges, environmental monitoring and impacts[27].

A conservative dose assessment to the most exposed individual shows an impact on human in the order of 0,01 $mSv.y^{-1}$ for the whole site (including dry storage of HLW). Additionally, the Report, based on analyses achieved by Eurofins (p. 63), concludes that discharges of the site has no significant impact on phytoplankton and mussels.

This analysis shows that the current management of HLW at Orano La Hague site, based on safety standards, respects the DNSH to environmental criteria 3, 4 and 6.

7.4.2. Wet storage of spent fuel at nuclear power plant site

In France, spent fuel is stored for heat decay at all EDF nuclear power plant sites for several years. Schematically, a nuclear power plant can be seen, in addition to a number of nuclear reactors, as also a short time storage facility for spent fuel (as well as other radioactive waste). Assessment of the impacts of a nuclear power plant provides indeed upper values for a spent fuel storage facility.

A recent Article (*On the use of reference areas for prospective dose assessments on populations of wildlife for planned atmospheric discharges around nuclear installations*) published in Environmental

[27] Rapport d'information du site Orano la Hague, Orano Cycle, 2018.

Research[28], provides a radiological impact assessment of radioactive discharges (based on IAEA methodology) for 2 operating nuclear power plants: Chinon in France and Atucha in Argentina.

This assessment is based on actual discharges and shows that '*the maximum absorbed doses in any case were 1.4.10^{-6} mGy/d for Chinon and 7.4.10^{-4} mGy/d for Atucha. In all the cases the absorbed doses for every RAP [Reference Animals and Plants] and for the two NPPs were well below the minimum DCRL [Derived Concentration Reference Level] where any effect is observed in any organism: 0.1 mGy/d*'.

This result indicates that discharges associated with the operation of nuclear power plant in accordance with safety standards/regulations, that includes discharges associated with interim storage of spent fuel, respect DNSH to environment criteria 3, 4 and 6 as defined in the TEG Report.

7.4.3. Low Level and Intermediate Level Short-Lived Waste (LLW/ILW-SL) at Andra Aube disposal facility

Low and Intermediate short-lived radioactive waste (LLW/ILW-SL) (close to 60% of the total France radioactive waste inventory) are permanently disposed of at Andra storage facility located in Aube (Figure 6).

A report on the radiological state of the environment in France is published on a 3-year basis by the French Nuclear Safety and Radiological Protection Institute (IRSN)[29]. It deals with the whole French territory with focuses on nuclear facilities, which includes Andra LLW/ILW-SL disposal.

Figure 6. LILW Andra disposal, France

Monitoring of the environment shows that between 2015 and 2017, iodine isotopes and tritium were not detected in the atmosphere and in rainwater, as well as in grass and soils. Monitoring of river water, sediments, fish and aquatic plants shows no measurable impact or marking of the environment. These results illustrate that storage of LLW/ILW-SL fits with the DNSH to environment criteria 3, 4 and 6 as defined in the TEG Report.

[28] https://www.sciencedirect.com/science/article/abs/pii/S0013935119308540?via%3Dihub

[29] https://www.irsn.fr/FR/expertise/rapports_expertise/Documents/environnement/IRSN-ENV_Bilan-Radiologique-France-2015-2017.pdf

7.4.4. Cigeo

The French National Agency for radioactive Waste Management (Andra) is currently developing a license application for the construction of a geological disposal facility, Cigéo. Within this process, a safety options dossier (DOS) was provided to the Nuclear Safety Authority (ASN) and reviewed by the French Institute for Nuclear Safety and Radiological Protection (IRSN). An IAEA peer review report on the dossier was also published[30]. This document sets out the chosen objectives, concepts and principles for ensuring the safety of Cigéo.

ASN published its views on the Cigeo DOS[31]. ASN considers that '*the project has on the whole reached satisfactory technological maturity at the safety options file stage*' and '*the safety options file is documented and substantiated and constitutes a significant step forward by comparison with the "Clay 2005" and "Milestone 2009" files*'.

The IAEA International Review Team (IRT) indicated that '*Based on the Safety Options Dossier and the discussions during the review mission, the IRT concludes that there is reasonable assurance about the robustness of the disposal concept*' and identified areas to strenghen Andra's existing knowledge base. With regards to uncertainty analysis, the IRT mentioned that '*Through discussion with the IRT, Andra showed that it applies a systematic and state-of-the-art approach to sensitivity and uncertainty analysis*'.

Regulatory oversight and international peer review ensure respect of national and international safety standards within the conception and development of Cigeo geological disposal for HLW. Compliance with safety standards ensure protection of the environment and DNSH to environmental criteria 3 to 6 as defined in the TEG Report. Assessment of Cigeo impacts on non-human biota is on-going.

7.4.5. IAEA Artemis mission in France, 2018

At the request of French authorities, the IAEA organized an ARTEMIS review of the French Policy on Spent Fuel and Radioactive Waste Management to provide independent expert opinion and advice on radioactive waste and spent nuclear fuel management, decommissioning and remediation, based upon the IAEA safety standards and technical guidance, as well as international good practice. France requested this review to fulfil its obligations under Article 14.3 of the Council Directive 2011/70/Euratom of 19 July 2011.

In the Artemis dedicated report[32], the independent experts recognized that '*Overall, the Review Team was impressed with the nature and implementation of the French national programme. The team consensus is the French national programme is comprehensive and coherent in fostering safety across the spectrum of laws, regulations, and decrees, and their effective implementation by the pertinent waste management organizations. Consequently, there are no recommendations made by the team, though a number of suggestions and best practices are note.* […] *The Review Team is of the collective opinion that France is in a good position to continue meeting high standards of safety for radioactive waste and spent fuel management in the country*'.

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30 International Peer Review on the 'Safety Options Dossier' of the project of disposal of radioavtive waste in deep geological formations: Cigeo. Peer Review Report, November 2016, Paris, France.

31 ASN Opinion 2018-AV-0300 of 11 January 2018 concerning the safety options file presented by Andra for the Cigeo project for deep geological disposal of radioactive waste.

32 https://www.iaea.org/sites/default/files/documents/review-missions/final_artemis_france_report_.pdf

Management of radioactive waste in France, which includes future geological disposals, complies with international safety standards and, thus, DNSH to environmental criteria 3 to 6 as defined in the TEG Report.

7.5. Sweden

In Sweden, the spent fuel is currently safety stored in deep-water-filled storage pool in the Central Interim storage Facility for Spent Nuclear Fuel, CLAB[33]. Spent fuel will be disposed of in a geological repository at Forsmark.

For the disposal of spent nuclear fuel at Forsmark, long-term impact on non-human biota from a repository was assessed through the Environment Impact Assessment using the ERICA tool. Results were published and provided by SKB in a dedicated technical report. Results show that '*neither negative effects of the repository on biodiversity nor sustainable use of natural resources in the Forsmark area are of concern. Nevertheless, technical refinements of the methods used to assess the safety of non-human biota are ongoing, and international developments should be kept under review during the repository construction phase and methods of analysis refined if and as required*'.

The ERICA tool[34] is a software system used to assess the radiological risk to terrestrial, freshwater and marine biota. The tool is maintained by the Norwegian Radiation Protection Agency (Norway), The Environment Agency (UK), the Centre for Ecology and Hydrology (UK), IRSN (France), the Swedish Radiation Safety Authority (Sweden) and CIEMAT (Spain).

These results are also outlined in a SKB Technical Report[35] dealing with the assessment of risk to non-human biota from a repository for the disposal of spent nuclear fuel at Forsmark: '*In all cases the estimated dose rates were several orders of magnitude lower than the used screening level (10 µGy h*$^{-1}$*) which indicates that no impacts on populations would occur. The maximum dose rates in the base case were one order of magnitude higher than those of the pulse-release. In the base case, the highest dose rate was estimated for reference limnic phytoplankton and highest dose rate in terrestrial ecosystems was calculated for peat moss (similar values). The maximum dose rate in marine ecosystems was estimated for representative zooplankton species and was two orders of magnitude lower than those for limnic and terrestrial ecosystems*'.

The Swedish project for geological disposal complies with DNSH to environment criteria 3, 5 and 6.

7.6. Germany

ARTEMIS reviews provide independent expert opinion and advice, drawn from an international team of specialists convened by the IAEA. Reviews are based on the IAEA safety standards, technical guidance and international good practices[36]. An Artemis Mission took place in Germany in 2019, which

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33 https://www.skb.com/our-operations/clab/

34 http://www.erica-tool.eu

35 Assessment of risk to non-human biota from a repository for the disposal of spent nuclear fuel at Forsmark. Technical Report-13-23. SKB, December 2013.

36 https://www.iaea.org/services/review-missions/integrated-review-service-for-radioactive-waste-and-spent-fuel-management-decommissioning-and-remediation-artemis

results are provided in Integrated Review Service for radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (Artemis) Mission to Germany, IAEA, 2019[37]. Germany requested this ARTEMIS review to fulfil its obligations under Article 14.3 of the Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community Framework for the Responsible and Safe Management of Spent Fuel and Radioactive Waste.

This report indicates that '*The safe management of radioactive waste and spent fuel in Germany in current facilities, including the Konrad facility that is currently being prepared for operation, is supported by appropriate and, where necessary, updated safety documentation according to requirements defined by nuclear licensing procedure […] the IRRS[38] team raised no specific concerns relating to compliance of authorising procedures with IAEA safety requirements regarding to the role of safety assessment in the context of licensing for spent fuel storage or other radioactive waste management facilities. The ARTEMIS Review Team draws no different conclusion*'.

Management of radioactive waste in Germany, which includes future geological disposals, complies with international safety standards and, thus, DNSH to environmental criteria 3 to 6 as defined in the TEG Report.

7.7. OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) entered into force on 25 March 1998. The Radioactive Substances thematic Strategy (Radioactive Substances Strategy, RSC) sets the objective of *preventing pollution of the OSPAR maritime area from ionising radiation through progressive and substantial reductions of discharges, emissions and losses of radioactive substances, with the ultimate aim of concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances*. In achieving this objective the following issues should, *inter alia*, be taken into account: (1) radiological impacts on man and biota, (2) legitimate uses of the sea, and (3) technical feasibility.

RSC undertakes periodic evaluations to analyse the progress that Contracting Parties to the OSPAR Convention have made in reducing discharges of radioactive substances to the North-East Atlantic, in order to meet the objective of the OSPAR Radioactive Substances Strategy (RSS).

In the Fourth Periodic Evaluation of Progress Towards the Objectives of the OSPAR Radioactive Substances Strategy, it is outlined that '*While environmental concentration data have not been considered in this evaluation, the radiological impacts on man and marine biota of these discharges are expected to be low, as previously concluded in the Third Periodic Evaluation*' and '*There is clear evidence of progress made by Contracting Parties towards the OSPAR RSS objectives for the nuclear sector*'.

These elements highlight commitment of the nuclear industry as a whole to effectively meet OSPAR RSC objectives which is connected with DNSH criteria 3 (Sustainable use and protection of water and

37 https://www.iaea.org/services/review-missions/calendar?type=3172&year%5Bvalue%5D%5Byear%5D=&location=All&status=All

38 The Integrated Regulatory Review Service helps host States strengthen and enhance the effectiveness of their regulatory infrastructure for nuclear, radiation, radioactive waste and transport safety. https://www.iaea.org/services/review-missions/integrated-regulatory-review-service-irrs

marine resources), 5 (pollution prevention and control) and 6 (protection of healthy ecosystem). Results includes interim storage of spent fuel at Nuclear Power Plant as well as HLW interim storage at Orano la Hague plant for instance.

7.8. UNSCEAR[39]

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established by the General Assembly of the United Nations in 1955. Its mandate in the United Nations system is to assess and report levels and effects of exposure to ionizing radiation. Governments and organizations throughout the world rely on the Committee's estimates as the scientific basis for evaluating radiation risk and for establishing protective measures. The Assembly invited 27 UN Member States to nominate scientists as representatives to the Committee. Representatives to the Committee, their alternates and their advisers, and the Committee as a collective, maintain high ethical standards in how they discharge their duties, and the Committee is administered in a way that promotes unbiased evaluations with high scientific integrity.

In UNSCEAR 2008 Report Sources and Effects of Ionizing Radiation, Volume 1, Annex B, the UNSCEAR indicated '*Doses due to solid waste disposal have been estimated on the basis of the projected eventual migration of radionuclides through the burial site into groundwater. These estimates depend critically on the assumptions about the containment of the solid waste and the site characteristics, and accordingly are generally highly uncertain. The approximate normalized collective effective dose due to low- and intermediate-level waste disposal is, however, relatively low, […]. The worldwide average annual per caput effective dose rate would be about 1 nSv per year of practice*'.

1 $nSv.y^{-1}$ is basically 6 orders of magnitude lower than the average natural background (see Annex 2). In the IAEA Basic Safety Standard for Radiological Protection, '*a practice or a source within a practice may be exempted without further consideration from some or all of the requirements of these Standards under the terms of para. I.1(a) provided that under all reasonably foreseeable circumstances the effective dose expected to be incurred by any individual (normally evaluated on the basis of a safety assessment) owing to the exempt practice or the exempt source within the practice is of the order of 10 µSv or less in a year*'. 10 $\mu Sv.y^{-1}$ remains 4 orders of magnitude higher than 1 $nSv.y^{-1}$. The global impact of LLW and ILW waste disposal is extremely low, which provide confidence in the respect of the DNSH to environmental criteria as defined in the TEG Report.

8. CONCLUSION

Medium and High-Level waste as well as spent fuel and all radioactive waste are safely managed, according to high level safety standards which are developed and controlled at the International, European and National levels.

Safety is commonly understood as prevention of severe accident. But it is a far broader concept: safety means the protection of people and the environment against radiation risk, and the safety of facilities and activities that give rise to radiation risks. The protection of the environment means the protection and conservation of: non-human species, both animal and plant, and their biodiversity; environmental goods and services such as the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; amenities used in spiritual, cultural and recreational activities; media such as soil, water and air; and natural processes such as carbon, nitrogen and water cycles. This involves that

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39 https://www.unscear.org

Medium and High-Level waste as well as spent fuel and all radioactive waste are managed in a way which DNSH to environment criteria 3 to 6 as defined in the TEG Report. Protection of the environment is also a requirement of the European Council Directive 2011/70/Euratom which covers all radioactive waste and spent fuel storage and disposal facilities.

There are hundreds of storage and disposal facilities, including geological disposal, currently operated according to safety regulations based on international safety standards. Monitoring and follow-up of these facilities indicate that they do not significant harm to environment criteria 3 to 6 as defined in the TEG Report. Finland will operate by 2025 a geological disposal for spent fuel. A number of such disposal are planned to be in operation by 2050 (France, Sweden, etc.).

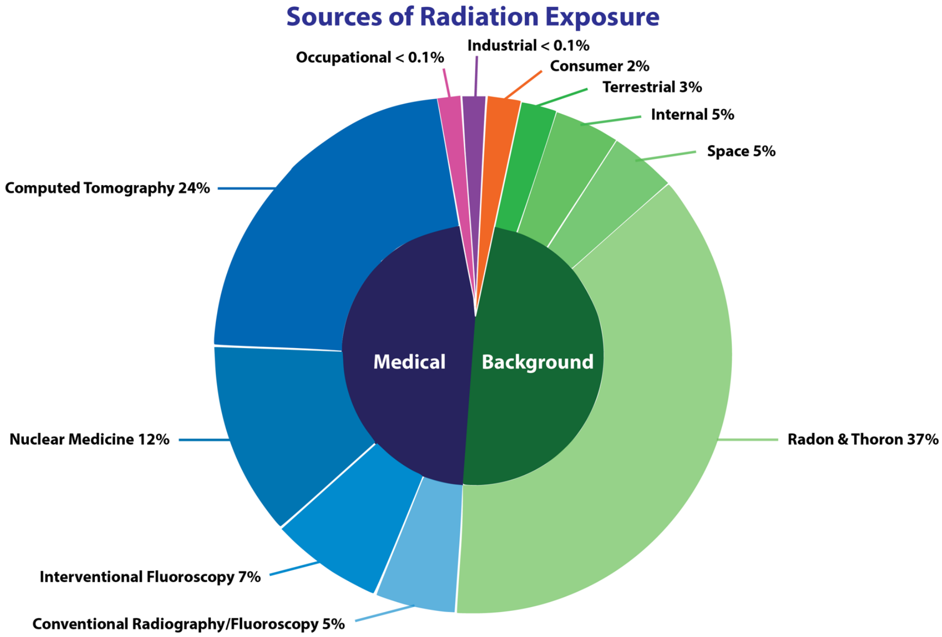
Operating experiences, technical and scientific knowledge, current R&D work, international peer reviews, National Safety Authority follow-up, etc. provide a robust set of scientific and technical evidence that geological disposals are safely developed and will be safely operated and monitored according to current safety standards which successfully apply to existing radioactive waste storage and disposal facilities.

Production of Electricity from Gas Combustion is included in the European Taxonomy '*Gas-fired power with carbon capture and sequestration* [CCS] *may qualify*'. There is no operating carbon capture and sequestration facility in conjunction with a gas-fired power plant. The recent report by the EC on the implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide shows no significant progress. Long-term behavior of CCS and potential impacts on human health and the environment is uncertain.

Therefore, production of Electricity from Nuclear should be, considering existing evidences as well as TEG advice on CCS, included in the European Taxonomy.

9. ANNEX 1. HUMAN EXPOSURE TO IONISING RADIATION SOURCES

Human beings are exposed to radiation every day, from natural sources such as minerals in the ground, and man-made sources such as medical X-rays. According to the National Council on Radiation Protection and Measurements (NCRP, USA), the average annual radiation dose per person in the USA is 6.2 mSv. Nuclear industry (from uranium mining to disposal of radioactive waste), which is included in the industrial source of radiation exposure (see Figure 7), represents less than 0.05% of the total.



Average Annual Radiation Dose

Sources	Radon & Thoron	Computed Tomography	Nuclear Medicine	Interventional Fluoroscopy	Space	Conventional Radiography/ Fluoroscopy	Internal	Terrestrial	Consumer	Occupational	Industrial
Units mrem (United States) mSv (International)	228 mrem 2.28 mSv	147 mrem 1.47 mSv	77 mrem 0.77 mSv	43 mrem 0.43 mSv	33 mrem 0.33 mSv	33 mrem 0.33mSv	29 mrem 0.29 mSv	21 mrem 0.21 mSv	13 mrem 0.13 mSv	0.5 mrem 0.005 mSv	0.3 mrem 0.003 mSv

(Source: National Council on Radiation Protection & Measurements, Report No. 160)

Figure 7. Exposure to ionizing radiation sources (US data, https://www.epa.gov/radiation/radiation-sources-and-doses)

10. ANNEX 2. ASSESSMENT OF LONG-TERM RADIOLOGICAL EFFECTS ON PLANTS AND ANIMALS FROM A DEEP GEOLOGICAL REPOSITORY: NO DISCERNIBLE IMPACT DETECTED

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3636368/
J. Torudd, P. Saetre, Ambio. 2013 May; 42(4):506-516

Abstract

This study investigates whether non-human biota are protected against harmful effects of ionizing radiation after a possible future release of radioactive matter from a planned repository for spent nuclear fuel. Radiation dose rates to a broad spectrum of organisms were calculated based on data from sampled organisms and modeled activity concentrations. Calculations were performed with the ERICA Tool, a software program which applies a screening dose-rate value of 10 microgray per hour (µGy h^{-1}) for all types of organisms. Dose rates below this value are thought to result in minimal risk to the individual or population. All calculated dose rates were below the screening value and below the lowest relevant band of “derived consideration levels” proposed by the International Commission on Radiological Protection. This provides a sound basis for arguing that no individuals or populations of examined species would be harmfully affected by a possible radioactive release from the repository.

Conclusion

Given that dose rates for all investigated organisms are far below the screening dose rate of 10 µGy h^{-1}, and the fact that identified uncertainties were found to have no significant effect on these results, it follows that a potential release from the repository is highly unlikely to cause detrimental effects on the survival and reproduction of individual organisms. This conclusion can be generalized to the two significant release scenarios, and encompasses endangered species, species that are of economic or biological importance, as well as species that are important for ecosystem function. As no effects are expected at the level of the individual organism, effects at the levels of populations, communities, and ecosystems are also highly unlikely.

Thus, from this assessment it is concluded that neither negative effects of the repository on biodiversity nor sustainable use of natural resources in the Forsmark area are of concern. Nevertheless, technical refinements of the methods used to assess the safety of non-human biota are ongoing, and international developments should be kept under review during the repository construction phase and methods of analysis refined if and as required.