PREDIS

2.2.4 Storage

Domain Insight with EURAD Roadmap

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This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945098.

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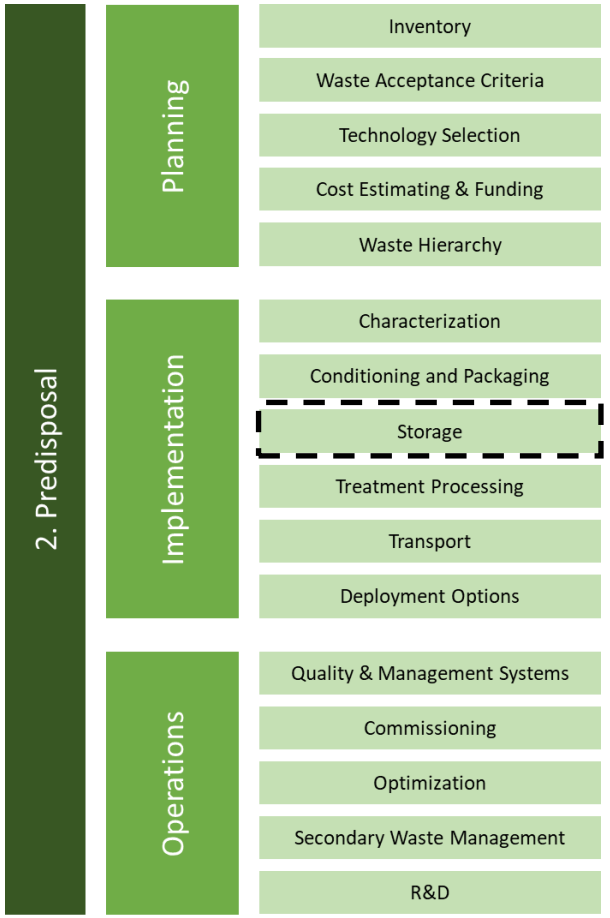
Introduction to Storage (1)

- **Storage** → essential component of the radioactive waste management lifecycle.
- Provides a **safe** and **secure** environment for waste, spent fuel and nuclear materials awaiting treatment, conditioning or packaging, and for packaged waste awaiting disposition (e.g. final disposal)



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Introduction to Storage (2)

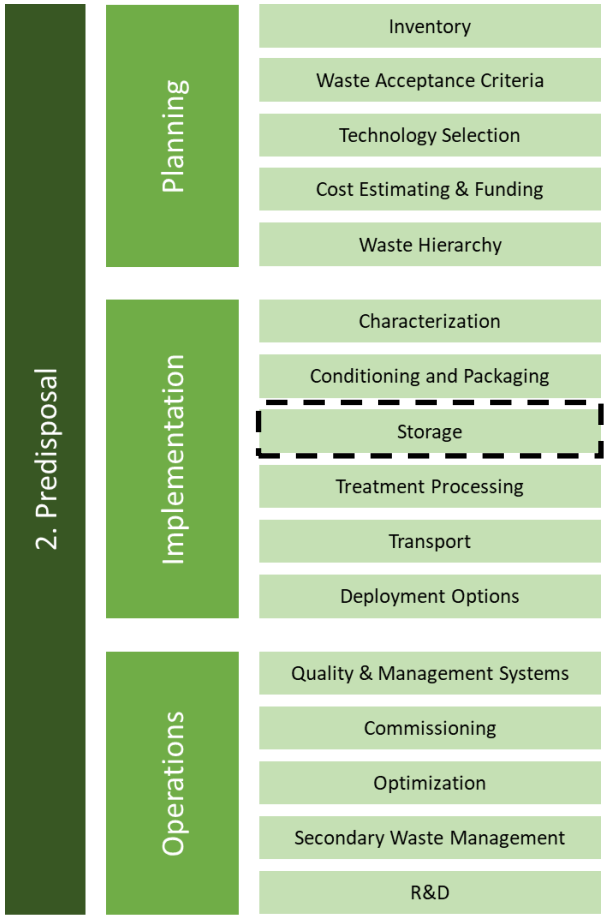
- **Wide range of different store types**
  - Depending on activity, dose rate, cooling and criticality control requirements


COVRA LOG Store (Welbergen, 2009)


Trawsfynydd ILW store (Magnox North, 2009)


CLAB Store for spent fuel, Sweden (Nirex, 2004)

ZWILAG SCISF ILW Store (Heep, 2011)



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Typical overall goals and activities in the domain of storage (Based on EURAD Roadmap GBS)

- Domain Goal

  Package waste accounting for future transport and deposition, and maintain safe interim storage of packages

- Domain Activities
  - Planning and Programme Initiation: Inventory, location and configuration of wastes/packages/processing facilities and interim storage facilities. Location and timescales for subsequent waste management steps, including final disposal, if possible. Attention to safety and stakeholder requirements.
  - Programme Implementation: Construction of on-site, regionalised or centralised storage facilities for raw waste (if needed) and packaged waste. Store lifetimes in the context of national plans for final disposal.
  - Programme Operation/Optimisation and Closure: Manage reviews and updates of store safety cases, responding to latest R&D and technology developments for monitoring, security, potential need for rework or overpacking of damaged waste packages during retrieval. Store decommissioning.

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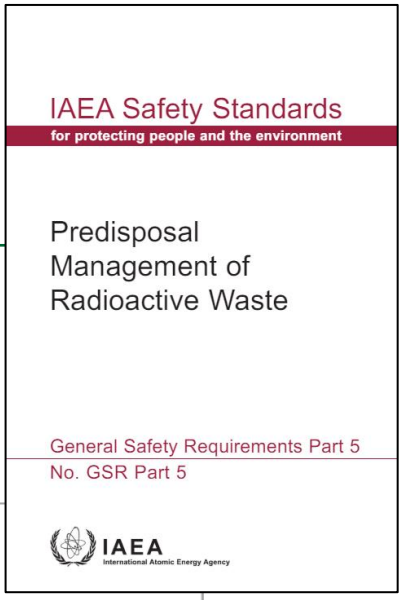
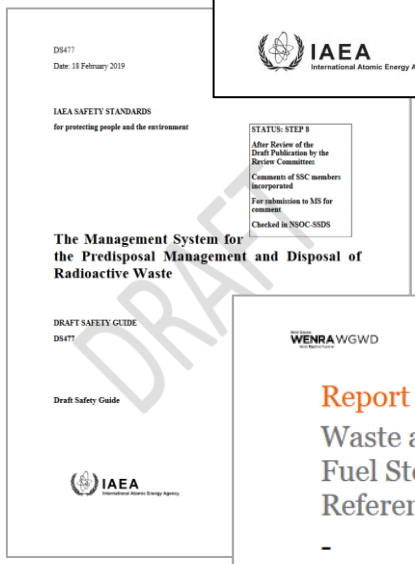
International Legislation, Requirements and Guidance (1)

- Directive 2011/70/EURATOM established a Community framework for the responsible and safe management of spent fuel and radioactive waste in 2011 → Need for all EU countries to have a national policy for spent fuel and radioactive waste management.
- IAEA Safety Standard, Predisposal Management of Radioactive Waste: General Safety Requirements (GSR Part 5) applied to all facilities and activities involved [IAEA, 2009].
- Safety guide (currently in draft) to support meeting the GSR's requirements [IAEA, 2019].
- Requirements for storage of RW and spent fuel by the Western European Nuclear Regulators' Association [WENRA, 2014].





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International Legislation, Requirements and Guidance (2)

- **Regulatory principle:** Health, environmental, security, quality and economic requirements should not be considered separately from safety requirements; an **integrated system** is needed to ensure an appropriate level of security without compromising safety and vice versa”
- **Security** is intended to prevent the unauthorised access of individuals and the unauthorised removal of radioactive material

COVRA HABOG Store (Welbergen, 2009)


Cask storage hall (ZWILAG, 2012)

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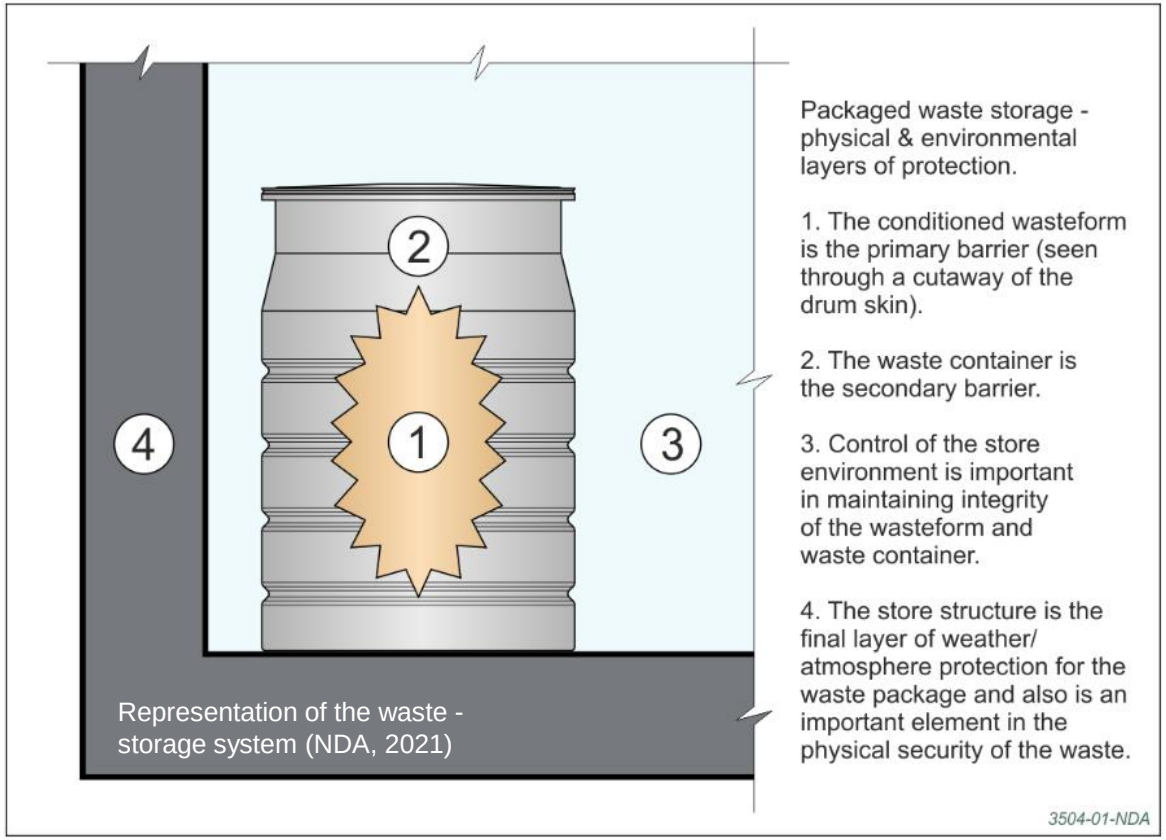
Planning and Programme Initiation (1)

- Assess the waste inventory, including the nature and quantities of the waste, to determine:
  - Shielding requirements
  - Cooling requirements
  - Criticality prevention requirements
  - Security and safeguards requirements
- Identify the location, other facilities present or planned (e.g. treatment plant):
  - Includes assessment of external hazards and risks e.g. earthquake, fire, snow/ice, flood, tsunami, malicious actions



Representation of the waste - storage system (NDA, 2021)

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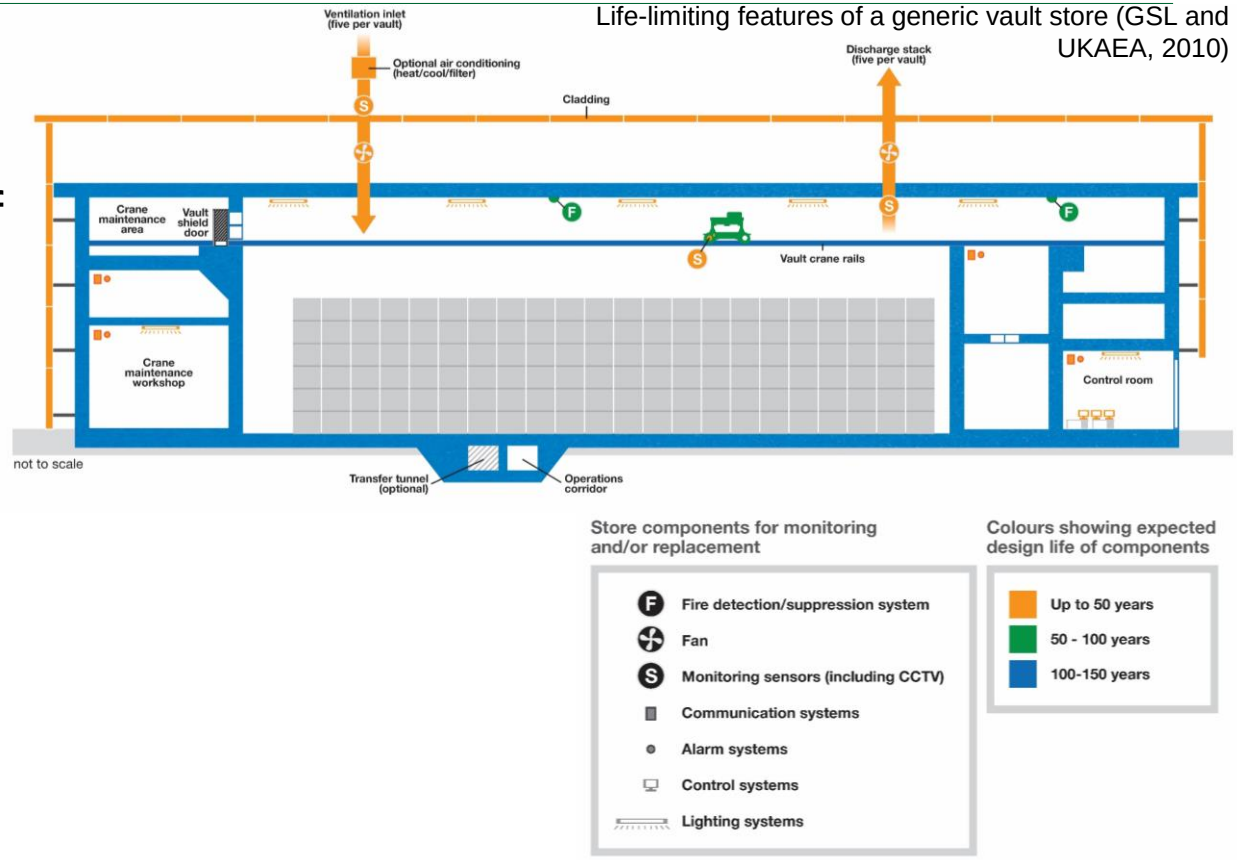
Planning and Programme Initiation (2)

- Detailed design will also need to consider:
  - Anticipated duration – design life of at least 100 years is good practice
  - Package import arrangements (throughput and transport containers)
  - Retrieval of packages following storage
  - Engineering feasibility
  - Safety case development
  - Stakeholder acceptance

Life-limiting features of a generic vault store (GSL and UKAEA, 2010)



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Programme Implementation

- Demonstration of store performance during commissioning
- Safety case – meeting the design requirements and addressing external factors
- Suitably qualified and experienced persons → to manage and operate the store over long periods
- Waste Acceptance Criteria need to be established (including conditioning and packaging requirements for import to the store, handling and emplacement, and subsequent retrieval and disposal requirements)
- Store environmental conditions (control of temperature and/or relative humidity to prevent corrosion of the container materials)
- Monitoring requirements
- Records management systems for the store design, material specifications and waste package-specific information

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Programme Operation and Closure

- Radioactive waste and spent fuel managed by their producers with a nominal storage life of 50 years and up to 100 years.
- During operation → periodic monitoring of the store structure, environmental conditions and waste packages.
- Asset management, including identification of life-limiting features and planned maintenance, refurbishment and replacement activities.
- Operate according to regulatory requirements → management of secondary waste, gaseous and liquid effluents
- Prior to store closure, update plans for store emptying. Retrieval of waste packages is linked to the availability of a near-surface disposal facility or DGR, or the construction of a replacement store.
- Once emptied, the store structure and equipment need to be decommissioned and all waste generated managed according to the waste hierarchy

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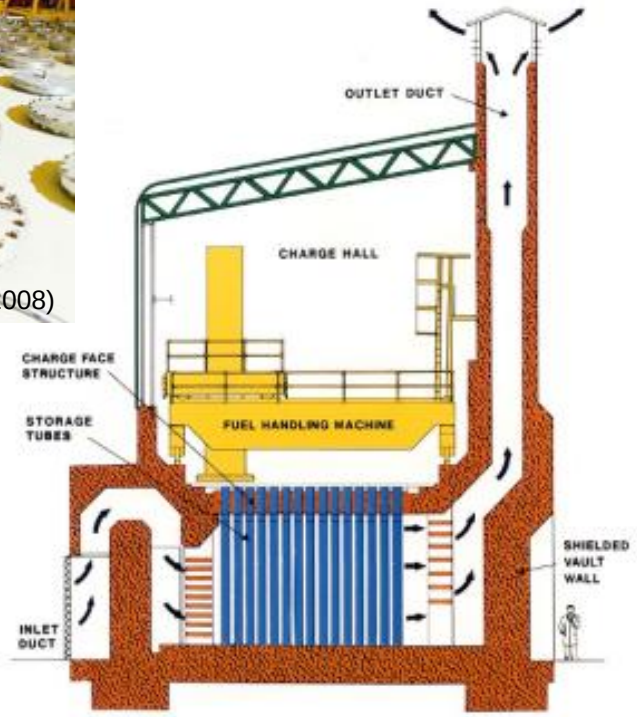
Critical issues, information, data or knowledge in the domain of Storage

- Safety management and verification, including development and updating of a safety case for the storage facility and its contents (containment, shielding, criticality safety and heat management if applicable)
- Design
- Operations, including asset management.
- Security and safeguards
- Knowledge management systems are critical enablers for the continued operation and maintenance of the store over long time periods, including retrieval of waste at the end of the storage period

CASCAD (CEA, 2008)



Charge plug store for spent fuel (Carter, 2008)

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Maturity of knowledge and technology

- More than **five decades of experience** show that surface storage facilities provide safe and secure containment as long as the storage facilities are appropriately designed, constructed and maintained to ensure containment integrity
- Further RD&D is not required for storage of contact-handled RW and spent fuel in dry cask storage in existing facilities with established safety cases and monitoring procedures based on visual inspection
- Remote monitoring and inspection methodologies and digital twins may be needed for HLW, nuclear materials and spent fuel where access is more challenging
- For legacy facilities, confidence may need to be developed that the waste packages and/or store will remain in good condition and can continue to operate beyond their original design life

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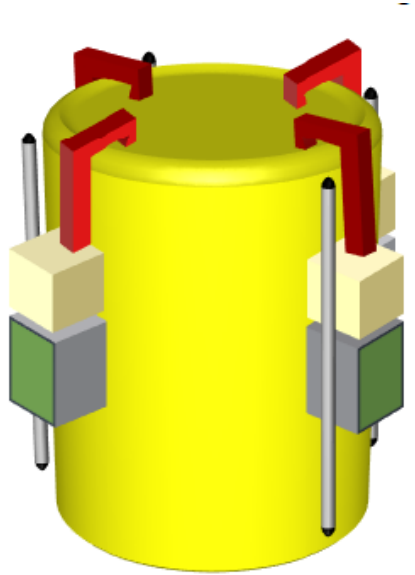
Future advances in the storage domain

- New technologies related to storage include:
  - the use of remote sensing technologies, including robotics, for package monitoring to reduce human exposure and improve confidence in the store system performance,
  - Non-destructive evaluation techniques to assess package integrity
  - Use of sensing technologies that employ wireless power supply for functioning and data transmission
  - Data handling protocols and decision framework models
  - Storage of interim products with potential to form part of a future disposal solution following the interim storage period
  - Use of decay storage management for SL-ILW
  - Use of long-term storage as a management option for disused sealed radioactive sources
  - Dual-use casks that can be used for both transport and storage



SciFi and SiLiF sensors, PREDIS D7.3

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Optimisation challenge and innovations

- WP7 of EC PREDIS project (2020-2024):
  - Focused on improving our understanding of cemented waste storage and handling prior to disposal, including use of monitoring technologies and digital twins to demonstrate store and package quality assurance
  - *In-situ* monitoring using remote-operated cameras and inclusion of dummy or mock-up packages in stores equipped with internal RFID (radio frequency identification) sensors
- EURAD (2019-2024):
  - ROUTES → experience and knowledge on RWM routes between WMOs, TSOs and REs from different MS.
  - Spent fuel characterisation and evolution until disposal project → development of characterisation techniques to better understand the physiochemical evolution of irradiated spent fuels under normal and credible accident scenarios following reactor discharge
  - Interaction with the civil society work package → to improve understanding on RD&D performed to support the development of safe solutions of processing and disposal of RW.

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Past RD&D projects on Storage

- IAEA Technical Report on Interim Storage → Safety requirements and outlined types of storage facilities and operational good practice, TRS-390 [IAEA, 1998].
- IAEA Coordinated Research Project → Behaviours of cementitious materials in long term storage and disposal of radioactive waste, TECDOC 1701 [IAEA, 2013].
- NEA support the development of safe and economically efficient management of all types of RW including spent fuel [NEA, 2020].
- Individual MS → RD&D and guidance on best practice for storage of RW and spent fuel

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Uncertainties

- Storage is an advanced topic with **minimal uncertainties**
- Existing implementation guidance provides good practice and advice
- Evolution of stakeholder requirements, including WAC for disposal facilities, during the storage period is a significant uncertainty. Risk can in part be mitigated by maintaining good records
- Other uncertainties that could be addressed by RD&D:
  - Understanding of expected waste package evolution during storage
  - Understanding the potential for long-term storage as a management option
  - Understanding of the impacts of extended storage (beyond 100 years)
  - Understanding of expected store infrastructure evolution and methods to extend the operating period of the store beyond its design life and nuclear-specific asset management experience
  - Development of multi-purpose waste packages that can be used for transport, storage and disposal
  - Development of new digital and remote monitoring of packages and store building infrastructure
  - Development of remote package and infrastructure monitoring techniques to support extended operational periods
  - Development of approaches for package remediation following interim storage, including damaged waste packages
  - Development of techniques for package repair or reinstatement

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Guidance, training and communities of practice (1)

Guidance

- IAEA (1998), Interim Storage of Radioactive Waste Packages, Technical Reports Series No.390
- NEA Nuclear Energy Agency (2020), Storage of radioactive waste and spent fuel, NEA Report no. 7406
- UK Nuclear Decommissioning Authority (2021), Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach, Issue 4

Training

- IAEA Spent Nuclear Fuel Storage training course available in IAEA Learning Management System
- Storage topics covered in EURAD training course on RWM

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Guidance, training and communities of practice (2)

Active communities of practice and networks

- The WENRA working group on waste and decommissioning (WGWD) addresses the regulatory aspects relating to RW, spent fuel and decommissioning matters, including storage.
- The NEA Expert Group on the Economics of Extended Storage of Spent Nuclear Fuel (EGEES) is gathering and appraising available knowledge from member countries to identify and assess the impact of technical, safety and regulatory, economic and social factors related to different storage options, fuel types and technical conditions.
- IAEA International Predisposal Network (IPN) is a forum for the sharing of practical experience and international developments on RWM activities before disposal.
- In the UK, the Store Operations Forum (SOF) brings together Nuclear Decommissioning Authority (NDA) strategic leads, Nuclear Waste Services (NWS), waste producers and store operators to engage, coordinate and drive strategy development through shared learning.

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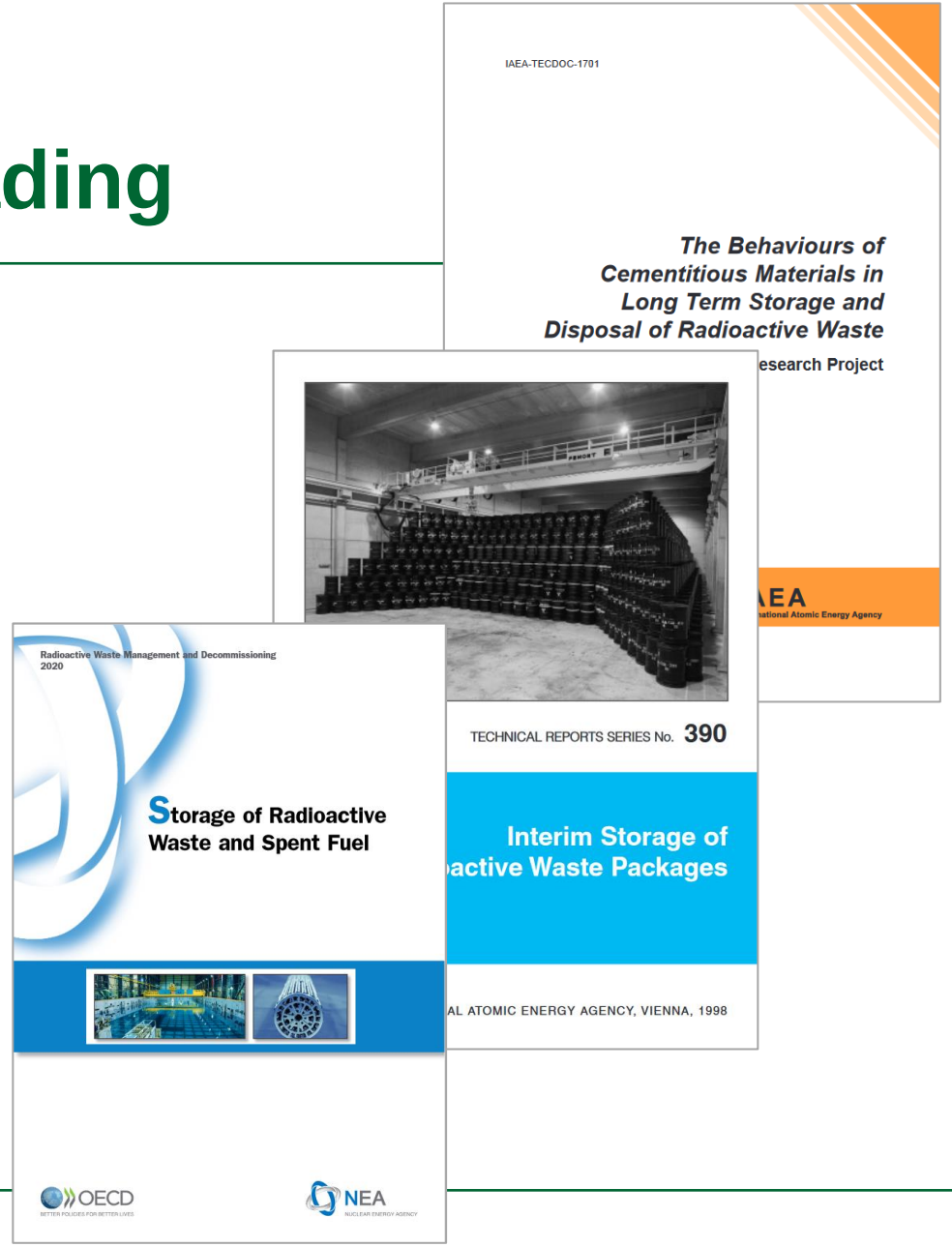
Selected references for further reading

- IAEA (1998), Interim Storage of Radioactive Waste Packages, Technical Report Series No.390
- IAEA (2013), The Behaviours of Cementitious Materials in Long Term Storage and Disposal of Radioactive Waste, TECDOC 1701
- NEA (2020), Storage of Radioactive Waste and Spent Fuel, NEA Report no. 7406
- PREDIS (2024) D7.3 Innovative Integrity Testing and Monitoring Techniques, V1.2
- Western European Nuclear Regulators Association (2014), Report: Waste and Spent Fuel Storage Safety Reference Levels, Version 2.2
- Examples of storage strategies and implementation in national programmes including The Netherlands, Nagra (Switzerland), Ondraf-Niras (Belgium), Sogin (Italy) and Nuclear Decommissioning Authority (UK).

Full reference list (including links) included in Domain Insight report



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Thank you for your attention!

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