## Introduction

Net zero refers to achieving an overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere. To achieve net zero, we need to cut down the use of fossil fuels like coal, oil and gas and make transition to renewable energy and other source of energy that emit low carbon emission. This is where nuclear power, a low carbon source energy contributes to the climate change agenda and form a part of the solution.

Globally, nuclear power plants produce more than one quarter of all low carbon electricity. Over the past five decades, nuclear power has cumulatively avoided the emission of about 70 gigatonnes (Gt) of carbon dioxide (CO2) and continues to avoid more than 1 Gt CO2 annually. Nuclear generation will need to double by 2050 if we are to reach our net zero climate goals according to experts at the IAEA.

A major environmental concern related to nuclear power is the creation of radioactive wastes. Radioactive waste occurs in various form, gaseous liquid or solid and may range from slightly radioactive to the highly radioactive such as the spent fuel. Radioactive wastes are subject to special regulations that govern their handling, transportation, storage, and disposal to protect human health and the environment. Solid progress in radioactive waste management continued to be made in decades, particularly in the advancement of deep geological repository (DGR) programmes and the continued safe deployment of predisposal technologies. However, we need continuous development and innovative ideas for Radioactive Waste Management (RWM) for Sustainable Development and Zero emissions.

## Waste from Nuclear Power Plants

Nuclear power plants (NPPs) have been in commercial operation for over 50 years. During this time, radioactive waste operators have focused on avoiding generation of radioactive waste as well as minimizing the volume of waste that is generated. They have done this by adopting good practices such as source reduction (e.g. not taking packaging material into the radiological controlled area), volume reduction (e.g. decontamination of metallic items), and minimization (e.g. using washable PPE).

A typical 1000 MW(e) Pressure Water Reactor (PWR) generates between 100 and 200 $m^3$ of waste per year – this is equivalent to 500 to 1000 200 litre drums of waste. Most of that waste (~90%) is considered Low Level Waste (LLW) and includes routine operational waste such as contaminated clothing, floor sweepings, paper and plastic. Waste is also generated from the NPP support for example the processing of cooling water and storage pond water, from equipment decontamination and from routine facility maintenance. Waste from processing of primary coolant water and the off-gas system includes spent resins and filters, as well as some contaminated equipment.

A smaller volume (~7%) of Intermediate level Waste (ILW) is generated during reactor maintenance, upgrade and fuel outages; for example the replacement of activated core components such as control rods or neutron sources.

Spent fuel, if declared as waste, is classified as High Level Waste (HLW) and contains 96% of the radioactivity.

Much of the solid LLW is sorted and segregated on-site at the time of generation and packaged for storage or directly to the disposal facility. The liquid LLW is usually characterized and stored on-site in tanks awaiting further processing for storage and disposal. Gaseous effluents are usually filtered in real-time and are either discharged according to the local regulatory standards or collected in a filtration and scrubbing system and processed as radioactive waste.

Decommissioning of NPPs usually generates a large volume of Very Low Level Waste (VLLW) and LLW as well as waste that can be cleared from regulatory control should the national legislation permit this.

Decommissioning of a typical PWR generates between 6,000 $m^3$ and 12,000 $m^3$ of waste. This varies considerably according to the reactor operating history, decommissioning strategy deployed and the national legislation and regulatory framework and for these reasons, the volume of waste generated tends not to be proportional to the plant capacity.

**Radioactive Waste Management (RWM)**

All countries are responsible to provide solutions for the safe, secure & safeguarded management of their national radioactive waste inventories. Embracing the concept of "Cradle-to-Grave", radioactive waste should be responsibly managed from the point it is generated to disposal.

In managing radioactive waste, the principles for safe, secure, and sustainable RWM are to be observed.

A sound RWM take into accounts Waste Hierarchy. In an ascending order, the most desirable hierarchy is waste avoidance, followed by minimization, reuse, recycle and lastly disposal.

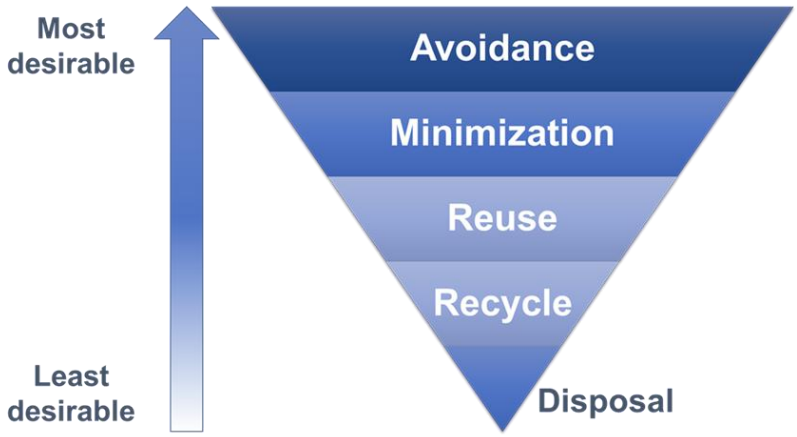


Fig.1: Waste Hierarchy

Waste avoidance could be achieved by improving design and operations and avoidance of accidents. Minimizing waste produced is achieved through clearance, decay storage, decontamination, dismantling, segregation. Reuse and recycle often relates to sealed radioactive sources that are used in industry that utilizes nuclear technology.

**Principal Approaches** pertaining to Endpoints include:

- Dilute & Disperse – this refers to authorized discharges of gaseous fluid and effluent to the environment, in planned and controlled releases
- Delay & Decay – involves storing of radioactive waste to reduce the radioactivity through decay.
- Concentrate & Contain – this applies to all radioactive waste requiring disposal as endpoint (VLLW, LLW, ILW and HLW)

The objective of RWM 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. The steps in managing radioactive waste can be broadly grouped into predisposal and disposal.

The aim of predisposal steps is to minimize the amount of waste going into disposal as disposal is costly. It includes pre-treatment (collection, segregation, size reduction, chemical adjustment and decontamination) followed by treatment, then conditioning (immobilization, packaging and overpacking) and finally storage.

The endpoint for radioactive waste managed with the principal approach of Concentrate & Contain is disposal. The purpose of a disposal facility is to provide for long term safe management of the disposed inventory. Near-surface repositories as adequate solutions for disposal of VLLW and LLW, however ILW and HLW require disposal in geological repositories.

**Additional reading materials**

Additional reading materials and references are available below. Click on the link to bring you directly to the source.

1. How Can We Get Carbon Emissions to Net Zero? | IAEA
2. Policies and Strategies for Radioactive Waste Management Policies and Strategies for Radioactive Waste Management | IAEA
3. Disposal of Radioactive Waste Disposal of Radioactive Waste | IAEA