RADIOACTIVE WASTE CHARACTERIZATION AND CONDITIONING

Pre-disposal Activities to address with various waste streams

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European Joint Programme on Radioactive Waste Management

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PRESENTATION OUTLINE

1. **Introduction**
2. **Generation**
   - Sources and Types of Radioactive Waste
   - Classification of Wastes
   - Characterization of Wastes
3. **Waste Processing**
   - Pre-treatment, Treatment
   - Conditioning
4. **Waste Storage and Transport**
5. **Waste Acceptance Criteria**
6. **Decision Making and Summary**
7. **References for Extra Information**

Image Source: IAEA, web page

PRESENTER OVERVIEW

Dr. Erika HOLT

Education: PhD Civil and Environmental Engineering, University of Washington, USA (2001)

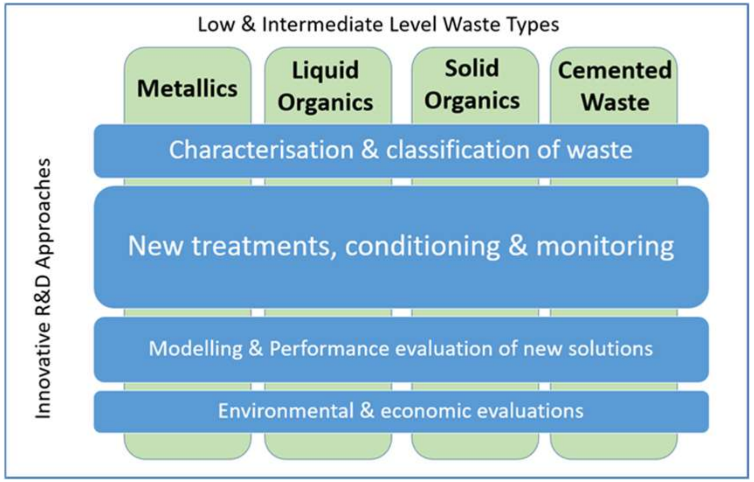
Current role: Customer Account Lead for nuclear energy clients, VTT Technical Research Centre of Finland

Earlier: Researcher, Team Leader, Portfolio Manager, EU Evaluator

Other tasks: Co-coordinator of the EU-PREDIS project, started September 2020, 4 years, budget 24 M€, 47 partners, 17 countries, sister project to EURAD

VTT (TSO) Finland representative to EURAD General Assembly

PREDIS Project Scope



1. INTRODUCTION: RADIOACTIVE WASTE PATHWAY, COVERING WHOLE LIFE CYCLE

- Need Holistic "cradle-to-grave" and iterative approach to knowledge gained
- At all stages should consider items like: infrastructure and materials management, safety and security, monitoring, funding and licensing, procedural ownership and liabilities and sustainability

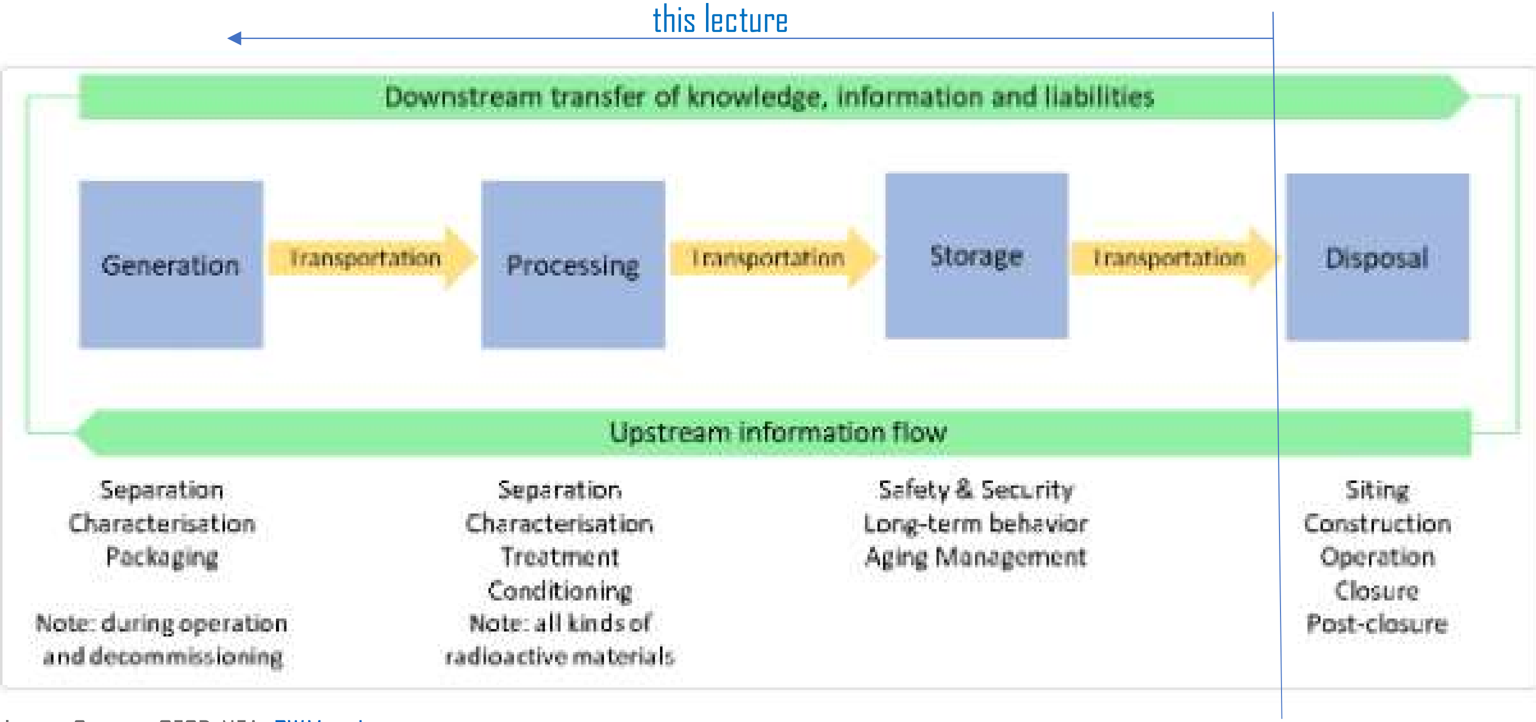


Image Source: OECD-NEA, RWM web page

A LOT OF GUIDANCE AND KNOW-HOW EXISTS ON THIS TOPIC

For instance, wide data-based of IAEA Guidelines

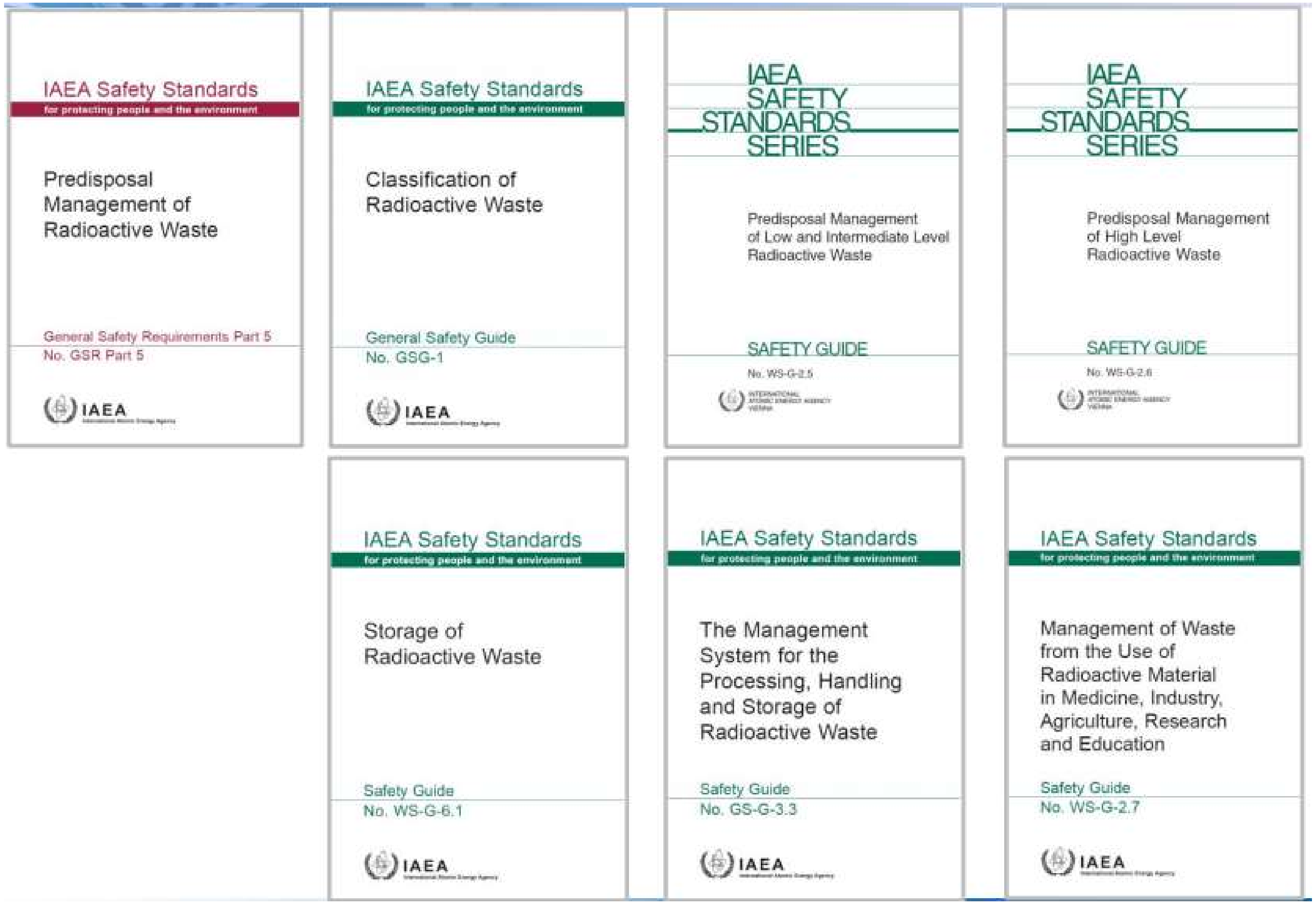


Image Source: IAEA Lecture by Magnus Vesterlind, online

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HOW PRE-DISPOSAL FITS WITHIN THE (FUTURE) EURAD ROADMAP

Theme

2. Predisposal

In conjunction with waste producers, identify and deliver solutions to optimise the management of radioactive waste throughout the predisposal phases of the radioactive waste management programme

Sub-theme

2.1 Predisposal Mgt.

Perform predisposal management of radioactive waste to support key risk and hazard reduction, and to help reduce costs and save space at interim storage and disposal facilities

2.2 Disposability Mgt.

Engage at an early stage with waste producers to develop and deliver cost-effective waste packaging solutions suitable for transportation, storage and eventual disposal

Domain

2.1.1 Waste generation

Characterise, classify and quantify radioactive waste in accordance with requirements established or approved by the regulatory body

2.1.2 Processing

Stabilise and minimise the quantity and volume of radioactive waste through processing

2.1.3 Storage

Conduct storage of radioactive waste

2.1.4 Transport

Transport radioactive wastes between facilities in accordance with regulatory standards

2.2.1 Disposability Assessment

Work closely with waste producers to ensure the disposability of packaging proposals, influence how wastes are being packaged economically (through specifications and guidance) and that appropriate records are maintained. This could include re-packaging to optimize safety and economics

2.2.2 Waste acceptance criteria

Ensure that waste packages are designed and produced so that the radioactive material is appropriately contained both during normal operation and in accident conditions that could occur in the handling, storage, transport and disposal of waste

2. GENERATION: SOURCES AND TYPES OF WASTE

SOURCES

- **Naturally occurring radioactive materials**
  - Soil, rock, rubble
- **Industrial Waste Streams**
  - Hospitals, nuclear medicine production, rare-earth mining, weapons reprocessing
- **Nuclear Power Plants**
  - Operation & maintenance
  - Spend Fuel
  - Decommissioning (dismantling)

TYPES

- **Solids**
  - Metals, concrete, plastics, wood, fabric, paper, asbestos ….
- **Liquids & Slurries**
  - Oils, filter sludge, ion-exchange resins, evaporator bottoms, re-processing and cleaning chemicals …
- **Gases**

At all times: Waste DOCUMENTATION (Record keeping) is critical – inventory, location, ownership, origin, treatments.

2. GENERATION: CLASSIFICATION OF WASTES

- **Varying levels, based on radionuclide activity, length of time for radioactive decay & heat produced.**
- **Classifications set by national (regulatory) definitions, globally inconsistent**
- **Inventory assessment responsibility of government (i.e. report to IAEA)**
- **Classification has high impact on safety requirements all stages (transport, treatment, storage, disposal)**

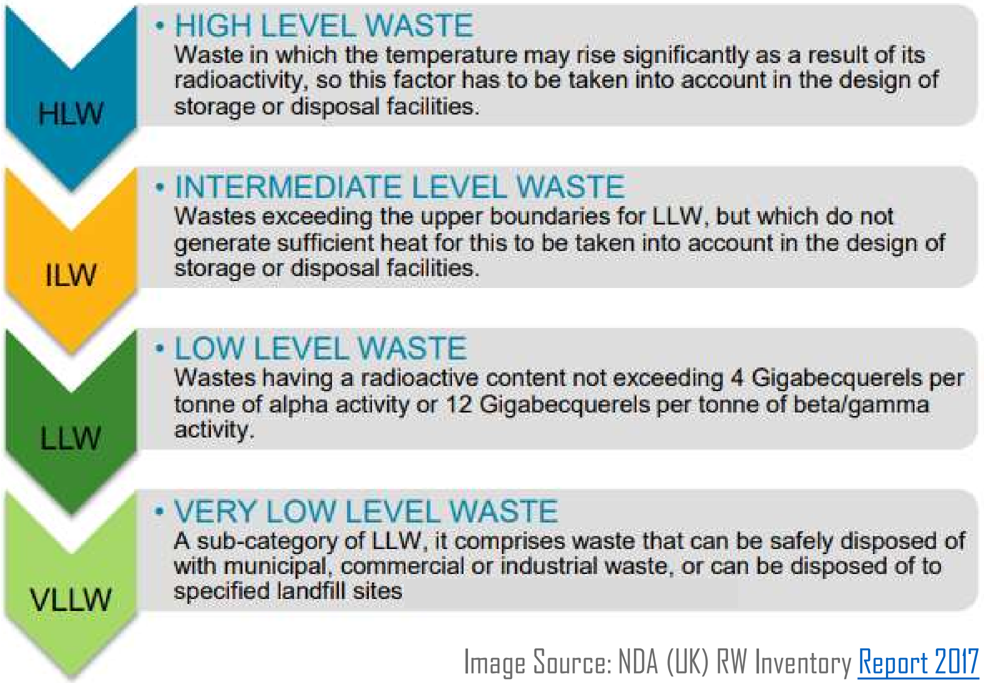


Image Source: NDA (UK) RW Inventory Report 2017

Classification based on lifetime, for instance LLW has regulatory d divide: short-lived and long-lived is half-life of 100 years (USA).

- Long-lived RNs: carbon-14, nickel-59, niobium-94, technetium-99, iodine-129, plutonium-241, and curium-242. The group "alpha emitting transuranic nuclides with half-lives greater than 5 years" is included in the long-lived table, as various isotopes of the group may have half-lives in the range of hundreds-of-thousand of years.
- Short-lived RNs: tritium (hydrogen-3), cobalt-60, nickel-63, strontium-90, and cesium-137. A group of unspecified "nuclides with half-lives less than 5 years" is included as short-lived.

2. GENERATION: CHARACTERIZATION OF WASTES

- **Properties to Characterize:**
  - The origin of the waste, the waste type and the physical state of the raw waste (solid, liquid or gaseous)
  - The criticality risk
  - The radiological properties of the waste (e.g. half-life, activity and concentration of radionuclides, dose rates from the waste, heat generation);
  - Other physical properties (e.g. size, mass, compactibility)
  - Chemical properties (e.g. the composition of raw waste, water content, solubility, corrosiveness, combustibility, gas generation properties, chemical toxicity);
  - Biological properties (e.g. biological hazards associated with the waste);
  - Intended methods of processing, storage and disposal.

Targeted waste in a drum packaging station for visual examination, Idaho, USA., Source: USA DOE, 2016 article on Idaho clean-up, web page

2. GENERATION: CHARACTERIZATION OF WASTES

- Methods for Characterization
  - visual characterization and continuous monitoring (sensors)
  - sampling and analysis of the chemical, physical and radiological properties
  - non-destructive or sometimes destructive methods, for waste packages
  - indirect methods based on process control and process knowledge, including modelling (minimize occupational exposure)

- **Characterization methods should be acceptable to the regulatory body, as part of the authorization process.**

Inert gas glove box, used when characterizing materials, Source: JGC web

2. GENERATION: CHARACTERIZATION OF WASTES, EXAMPLE CASES

- **Liquid radioactive waste should be characterized for processing purposes in accordance with its activity concentration and its content of chemical substances.**
  - For instance, radioactive waste containing organic matter may need special treatment.
  - Non-aqueous radioactive waste, such as oil, should be segregated for separate treatment.
  - If liquid radioactive waste is immobilized or solidified in a suitable matrix, chemical compatibility between the liquid waste and the matrix material should be ensured.
- **Solid radioactive waste should be classified in accordance with its radionuclide content (type and half-life of radionuclides) and its activity concentration, with account taken of the existing or likely disposal options, and should be segregated in accordance with the intended treatment and conditioning processes.**
  - For instance, sludge, cartridge filters, contaminated equipment and components, ventilation filters and miscellaneous items (such as paper, plastic or towels) may be segregated in accordance with the type of treatment and conditioning process, such as compaction, incineration or immobilization.

Source: IAEA SSG-41, Chapter 6.18-6.19, online

3. PRE-TREATMENT AND TREATMENT

- Target recycling and reuse of waste when possible, also "free release" (landfill)
- Minimize generation of additional (secondary, by-product) wastes
- Can take place in stationary or mobile facilities
- Should be done as close to the point of generation as possible (accounting for safety, security, financial, etc).

Image Source: NDA (UK) RW Inventory Report 2017

3. PRE-TREATMENT: WASTE PROCESSING

- **Reduction in the volume of the waste by processes**
  - Segregation
    - Often done at generation site
    - May include dismantling, cutting, robotics (i.e. in decommissioning)
  - Compaction – volume reduction
    - Often used for solid industrial LLW, maybe also ILW
    - Variable forces, 5 tonnes to 1000+tonnes
    - Volume reduction typically 3-10 times
  - Thermal processing (assistance of heat to break down organics, usually over 600C)
    - Variety of technics: incineration, gasification, HIP, GeoMelt ®
    - Caution from gases and fumes produced (filtered) and resulting ash needing conditioning with higher RN concentrations possible
    - Volume reductions up to about 100 times

- **Removal of radionuclides through techniques**
  - chemical processing

Thermal treatment facility, at National Nuclear Laboratory (UK).
Source: UK Government Case Study, web page

Metal melting at Cyclife (Sweden).
Source: Cycllife-EDF web-page

3. TREATMENT: CONDITIONING OF WASTES

- **Changing the form or composition of the waste through techniques**
  - chemical processing
- **Changing the form or properties of the waste by processes**
  - Solidification / Immobilization (cement-based, ceramic, polymer or bituminen)
  - Vitrification (stabilization with borosilicate glass)

- **Process can be "in-situ" (in-drum) or external**

Facility for storage, compacting and cementing radioactive waste, Source: Bilfinger,

4. INTERIM STORAGE & TRANSPORT OF WASTES

- **Storage is required at various stages:**
  - At time of generation (original source)
  - At facilities waiting for characterization, treatment/conditioning
  - Before and after packaging
  - Between transports
  - Waiting for final disposal
- **Requirements:**
  - Stored in a way so can be inspected and monitored
  - Packaged in a manner to allow for handling and transport
  - May need readiness for retrieval or re-processing
  - Account for intended time period (storage lifetime)
  - Prevent premature degradation or unexpected hazards
  - Passive safety features in-place

Storage hall for waste drums after characterization on automated lines at Saclay.
Source: CEA (France), 2006 Report

Source: IAEA SSG-41, Appendix 1, online

4. STORAGE: EXAMPLE SPECIFICATIONS NEEDED FOR WASTE PACKAGE

- **Radiological characteristics, of waste**
  - Radionuclide specific activities and half-lives
  - Total activity content (alpha, beta and gamma) and activity concentration levels
  - Dose rate
  - Heat output
- **Chemical and Physical properties, of waste form**
  - Chemical composition
  - Density, porosity, permeability to water and permeability to gases
  - Homogeneity and the compatibility of the waste with the matrix
  - Thermal stability
  - Percentage of water incorporated, exudation of water under compressive stress, shrinkage and curing
  - Leachability and corrosion rate
- **Chemical and Physical properties, of container**
  - Materials and composition (e.g. metal alloy, glass, ceramic)
  - Porosity, permeability to water and permeability to gases
  - Thermal conductivity
  - Solubility and corrosion in corrosive atmospheres or liquids such as water or brines.
- **Chemical and Physical properties, of waste package**
  - Number of voids in the container (which are to be minimized)
  - Characteristics of the lidding and sealing arrangements
  - Sensitivity to changes in temperature
- **Mechanical properties, of waste form**
  - tensile strength, compressive strength and dimensional stability.
- **Mechanical properties, of the waste package**
  - behaviour under mechanical loads (static loads and impact loads) or thermal loads
- **Containment Capability, of waste package**
  - The potential for diffusion and leaching of radionuclides in an aqueous medium
  - The potential for the release of gas under standard atmospheric conditions or conditions in a repository
  - The potential for the diffusion of tritium under standard atmospheric conditions or conditions in a repository
  - The capability of the waste package to retain radionuclides;
  - Water tightness and gas tightness of the package sealing device
- **Stability or Robustness, of waste package**
  - Behaviour under temperature cycling
  - Sensitivity to elevated temperatures and behaviour in a fire;
  - Behaviour under conditions of prolonged radiation exposure
  - Sensitivity of the matrix to water contact
  - Resistance to the action of microorganisms
  - Corrosion resistance in a wet medium (for metal containers)
  - Porosity and degree of gas tightness
  - The potential for swelling due to the internal buildup of gases

5. WASTE ACCEPTANCE CRITERIA (WAC)

Example: WAC for Supercompactable Waste Treatment (UK, LLW Repository Ltd, WSC-WAC-SUP, 2012):

- Waste shall not contain Thorium (Th-232) in excess of 1 MBq/t.
- The maximum radiation level at any point on the external surface of the Transport Container shall not exceed 2 mSv/h, and 100 µSv/h at 2 metres.

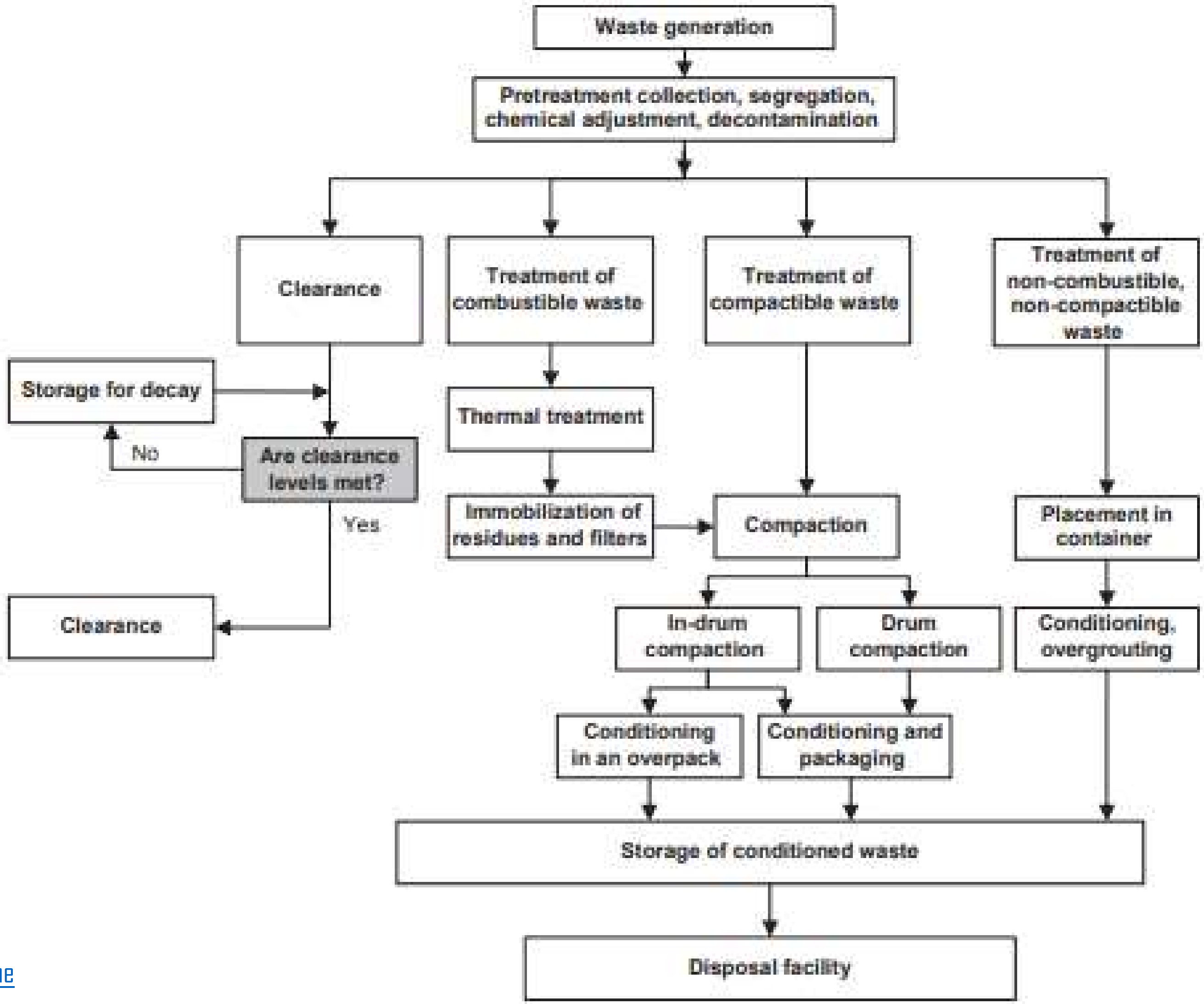
- **These are quantitative values that define the boundary conditions, i.e.**
  - Physical and chemical properties
  - Radiological properties
  - Packaging and transport requirement
  - Service specific requirements
- **Critical at various stages, for compliance of material and package to safety expectation**
  - " Generation - transport - storage – disposal "…. each might have own WAC!
  - Typically established at national (regulatory) level, but may use non-comparable measures or units
  - Global challenge to reach better consistency, transparency and guidance on WAC at various stages
- **Some countries / parties do not have WAC, and thus record-keeping and assumptions are critical for future decision making**
- **Good reference report of European country overviews produced in THERAMIN project (Deliverable 4.1 "WAC and requirements in terms of characterization") available online**

6. DECISION MAKING AND SUMMARY

- There are a wide-range of pre-disposal management and technology options, many of which are in-place already
- New technologies (safer, less waste, more effective) are coming on the market (and RD&D) constantly
- The market is growing, due to increased environmental stewardship demands, as well as decommissioning activities
- Pre-disposal activities must balance regulations, cost, time, technology, public acceptance (and maintain safety)
- Each case is individual and must be evaluated by local players (owner, regulator, implementer)

ULTIMATE GOAL: Perform predisposal management of radioactive waste to support key risk and hazard reduction, and to help reduce costs and save space at interim storage and disposal facilities

IAEA EXAMPLE: FLOW DIAGRAM FOR THE MANAGEMENT OF SOLID RADIOACTIVE WASTE



Source: IAEA SSG-41, Appendix 7, online

7. KEY RESOURCES FOR EXTRA INFORMATION

- **IAEA division of Radioactive waste and Spent fuel management** https://www.iaea.org/topics/radioactive-waste-and-spent-fuel-management
  - Pre-disposal Management of Radioactive Waste, General Safety Requirement Part 5 (No GSR Part 5), 2009, link
  - IAEA International Pre-Disposal Network (IPN) https://nucleus.iaea.org/sites/connect/IPNpublic/Pages/default.aspx
- **OECD-NEA Radioactive Waste Management (RWM)** https://www.oecd-nea.org/rwm/
- **SNE-TP: Sustainable Nuclear Energy Technology Platform (waste producers)** https://snetp.eu/
- **EU-THERAMIN project (2016-2020) Thermal treatment for radioactive waste minimization and hazard reduction** http://www.theramin-h2020.eu/
- **EU-PREDIS project Pre-disposal Management of Radioactive Waste (started 1.9.2020),** http://www.predis-h2020.eu/ **coming soon**

THANK YOU FOR YOUR ATTENTION!

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