The Abdus Salam
International Centre
for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2374-28

Joint ICTP-IAEA School of Nuclear Energy Management

5 - 23 November 2012

Radioactive Waste Management

MELE Irena

International Atomic Energy Agency, IAEA
Division of Nucelar Fuel and Waste Technology
Department of Energy, NE
Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna
AUSTRIA

The IAEA Nuclear Energy Management School
ICTP, Trieste, 5- 23 November 2012

Radioactive Waste Management

Irena Mele
Waste Technology Section, IAEA

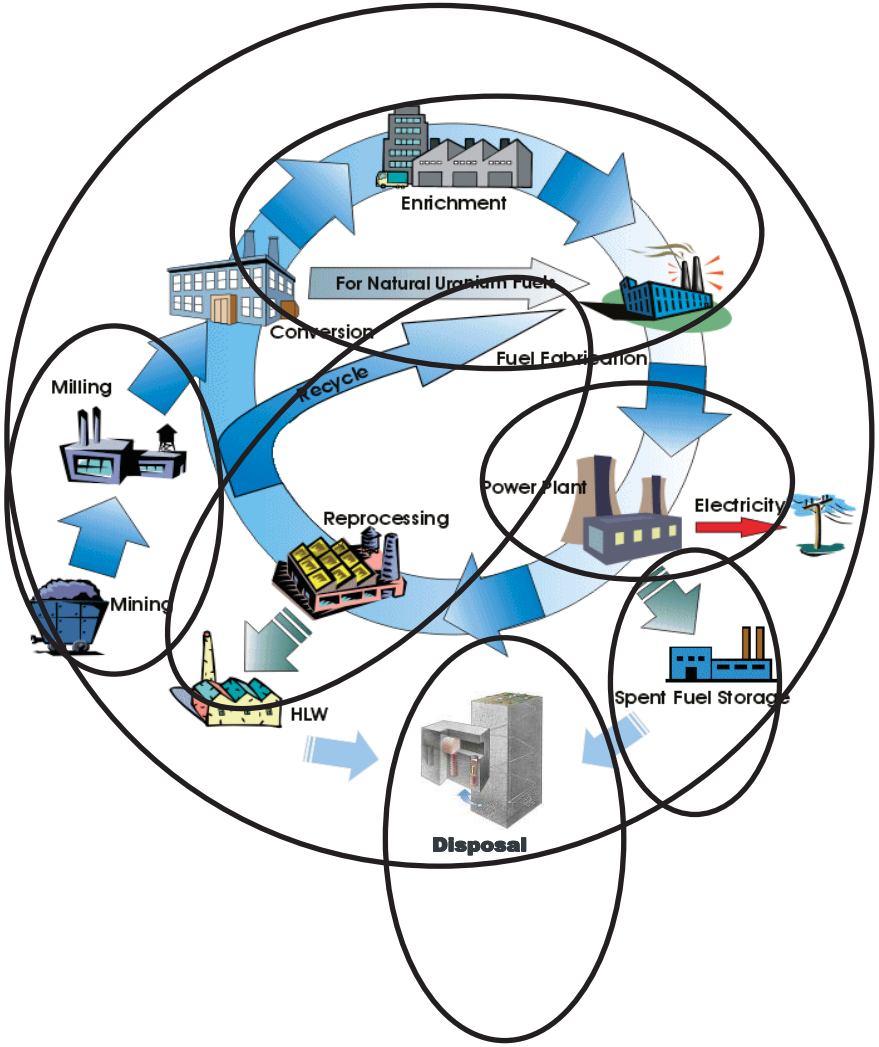
Content

- About RWM (principles and goals)
- Policies and strategies for RWM
- Options and technologies for RWM
  - Predisposal phase (L/ILW)
  - Disposal (L/ILW)
  - Spent Fuel (SF) disposal
- IAEA role and activities
- Conclusions

What is radioactive waste?

- Waste is material for which no further use is foreseen
- The waste can be in gaseous, liquid or solid form.
- Radioactive waste is a waste that contains or is contaminated with, radionuclides at concentrations equal to or higher than clearance levels established by the regulatory body (definition for legal and regulatory purposes)

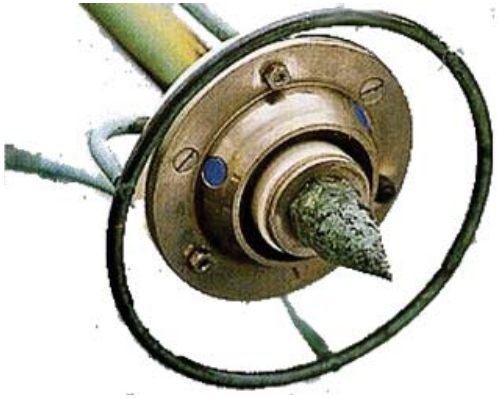
Nuclear Fuel Cycle and Waste



- Uranium production
- Fuel fabrication
- Power production
- Spent fuel storage
- Spent fuel recycle
- Decommissioning of facilities
- Environmental remediation activities

Non-Nuclear Fuel Cycle Waste

- Application of radioactive material in medicine, industry, agriculture and research
- Research reactors
- Non-nuclear industry (mining of ores, oil industry, phosphate industry, etc.)



Lightning conductor

Radioisotope thermoelectric generator - RTG

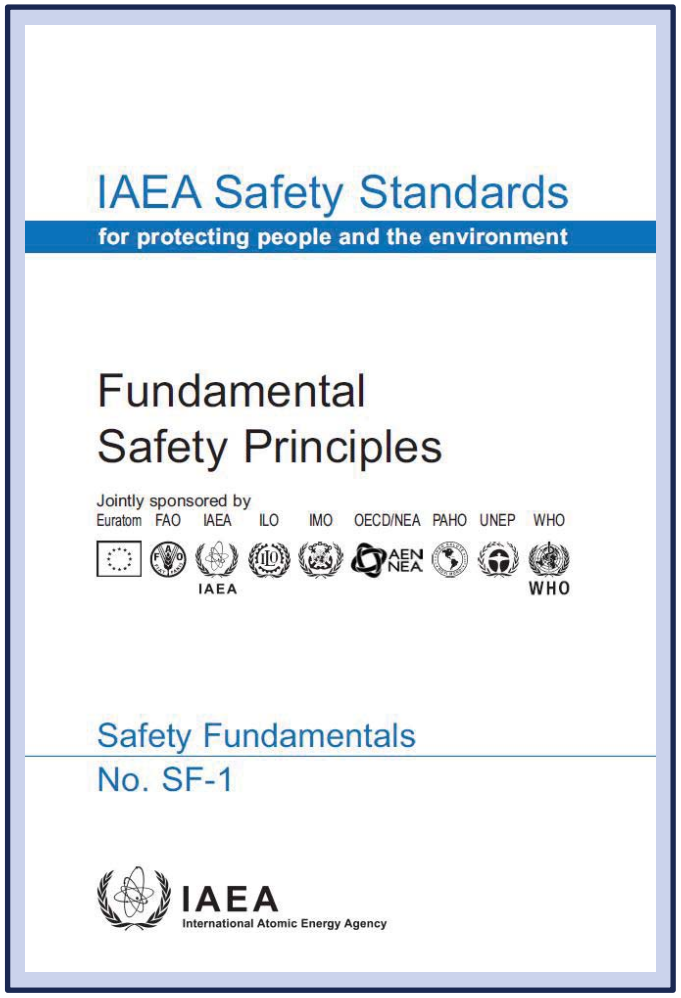
Teletherapy machine

RWM Needed in Many Countries

- 30 countries with NPP
- Between ~ 7 – 15 newcomers by 2030
- Majority of MSs using radioactive sources
- All these countries have or will have radioactive waste and need solutions for this waste
- Development of RWM infrastructure is particularly challenging for:
  - small nuclear programmes,
  - countries with nuclear applications only and
  - newcomer countries

Radioactive Waste management (RWM)

- All activities, administrative and operational, that are involved in the handling, pretreatment, treatment, conditioning, transport, storage and disposal of radioactive waste
- The primary Goal of RWM is to protect people and the environment from the harmful effects of ionizing radiation, now and in the future and without an undue burden on following generations



Policies and Strategies for RWM

What is needed for consistent RWM?

- Adequate legislative and regulatory framework for RWM and SFM
- Adequate RWM system
  - Clear allocation of responsibilities for RWM
  - Necessary capabilities (facilities, human resources)
  - System for financing RWM

National RWM policy

RWM Strategy

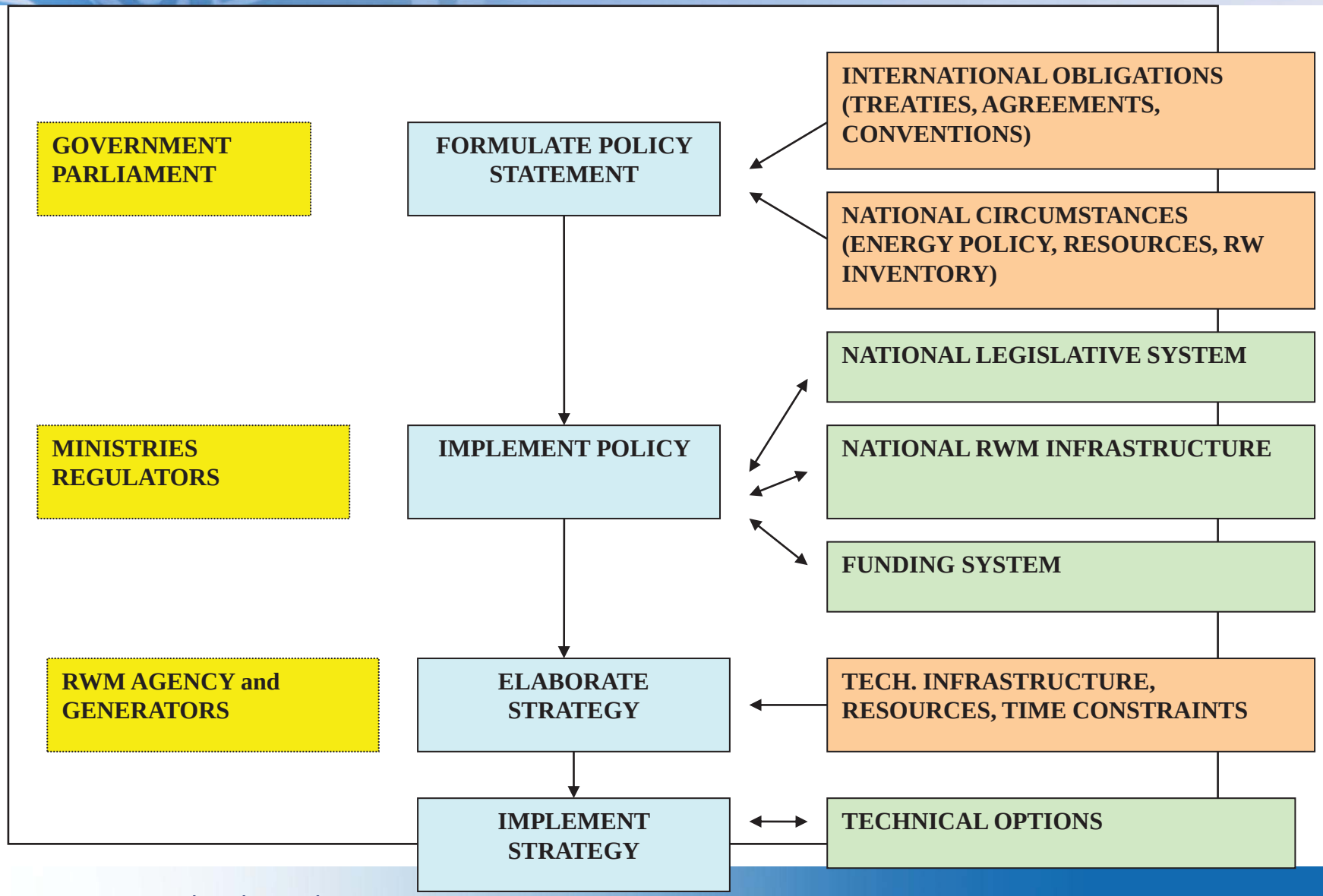
What is RWM policy?

- Policy is a set of established goals or requirements which normally define national rules and responsibilities
- Policy is established by the national government
- Policy:
  - Is often codified in the national legislative system
  - provides principles, infrastructure and formal requirement for its implementation and
  - provides principles, infrastructure and formal requirement for the development of appropriate strategies

What is RWM strategy?

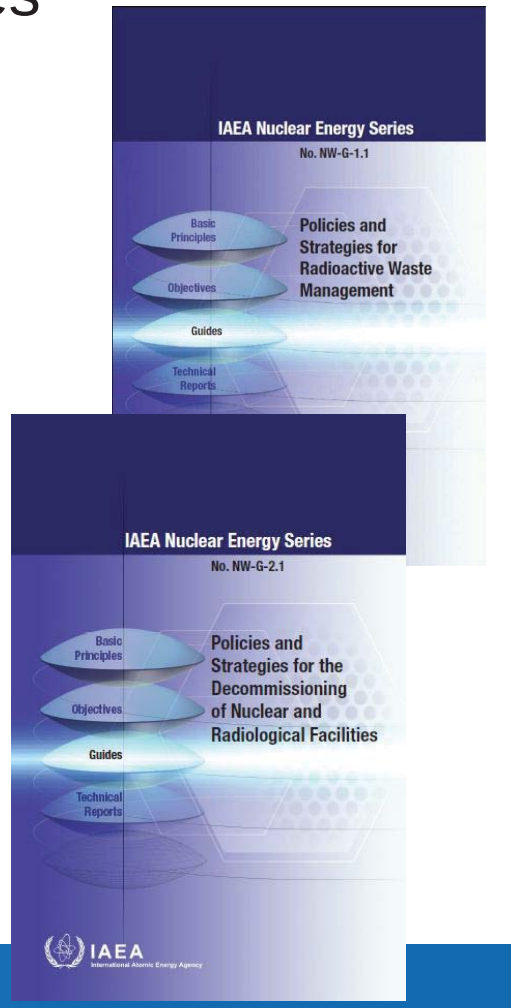
- Strategy is the means (organizational, technical) for achieving the goals and requirements set out in the national policy
- Strategy:
  - Is formulated from a national perspective, usually by waste management organization
  - More than one strategy may be developed to cover the goals and requirements of the national policy
  - The individual strategies may address different types of waste (e.g. reactor waste, decommissioning waste, institutional waste, etc.) or waste belonging to different owners
- The line separating policy from strategy is not sharp and sometimes mixtures exist

Policy & strategy scheme



RWM Policies and Strategies

- Policies & strategies needed for:
  - countries with existing nuclear programmes
  - countries with only nuclear applications
  - in countries embarking on nuclear
- IAEA guidance document:
  - Policies and Strategies for RWM, (NE Series, 2009)
  - Policies and Strategies for decommissioning of nuclear and radiological facilities, (NE Series, 2011)
  - Policies and Strategies in ER (in preparation)



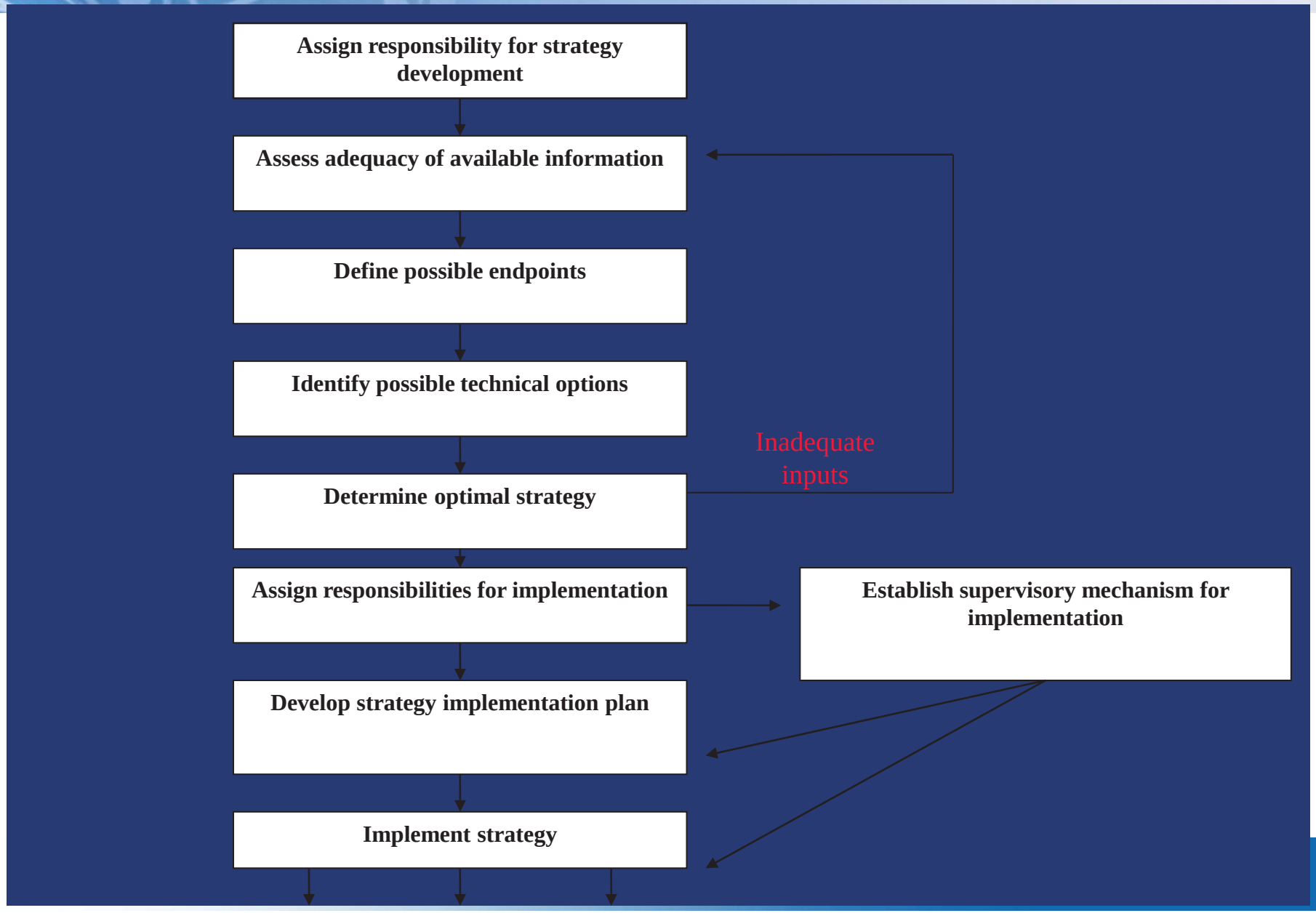
Main Policy elements

- Allocation of responsibilities (legislation, regulatory body, WMO)
- Provision of resources (human and financial)
- Safety and security objectives
- Waste minimization (recycling, clearance concept)
- Export/import of radioactive waste
- Management of spent fuel
- Management of radioactive waste (incl. disuses sealed sources, NORM?)
- Public information and participation

Strategy development

- The following considerations are important when developing the strategy:
  - Strategic approaches (recycling, immediate or deferred disposal, multinational facilities)
  - Compliance with policy (waste recycling, clearance, environmental protection, export/import, SF as a resource or waste, return of disused sources, NORM waste,…)
  - Graded approach
  - Resources (financial, human, technical)
  - Generic technical options (shared, centralised, mobile facilities)
  - Country specifics (population, climate, neighbours)
  - Constraints on strategy selection (non- and nuclear)
  - Public sensitivity
  - Uncertainties

Strategy formulation and implementation

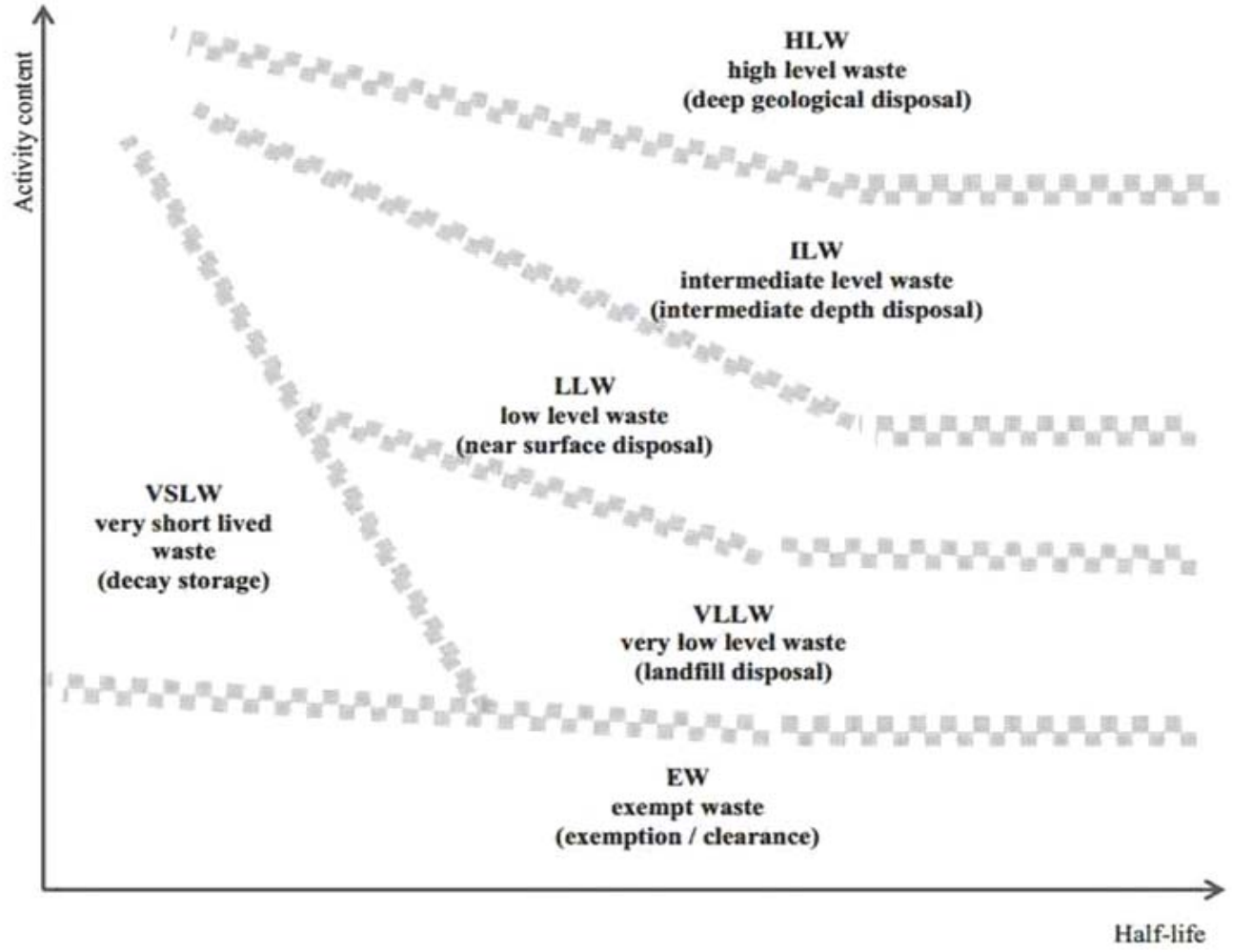


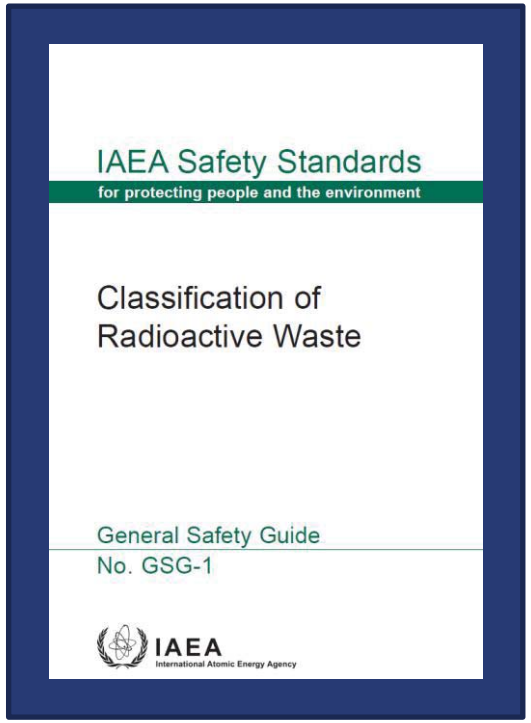
Options and Technologies for RWM

Approaches for managing radioactive waste

- Delay and decay
  - Waste stored until desired reduction of activity
- Collect and contain
  - Waste collected, processed, packed, stored and finally disposed of (isolation of waste)
- Dilute and disperse
  - Discharging of effluents with strict concentration and quantity limitations

IAEA Classification of RW





Examples of LLW, ILW & HLW

LLW includes loosely contaminated materials (e.g. paper, rags, tools, clothing, filters). Generally the waste does not require significant shielding during handling and interim storage

ILW includes e.g. resins, chemical sludges and metal fuel cladding, as well as contaminated materials from reactor decommissioning. The waste has levels of penetrating radiation sufficient enough to require shielding during handling and interim storage.

SNF/HLW includes the fission products and transuranic elements in the fuel itself or arising from reprocessing (e.g. spent fuel bundles, liquors). It generates significant heat and requires substantial shielding

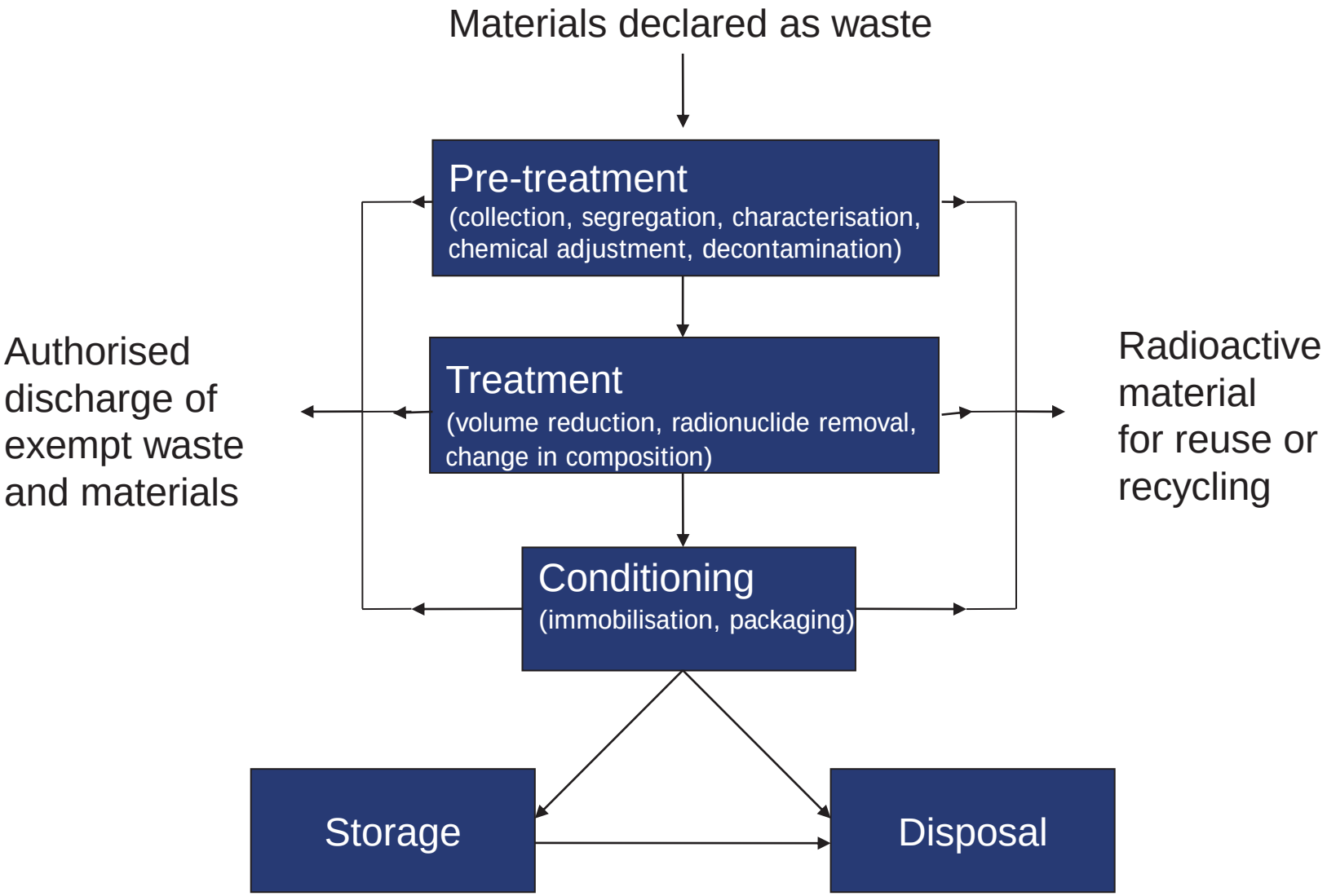
Selection of RWM Options

- Key Technical and technological criteria
  - Waste characteristics
  - Scale of technology application (now and in the future)
  - Availability of technology, flexibility
  - Robustness of technology
  - Treated and conditioned product properties
  - Volume reduction
  - Complexity; maintenance
  - Compatibility with existing processes
  - Site availability, geological conditions

Selection of RWM Options

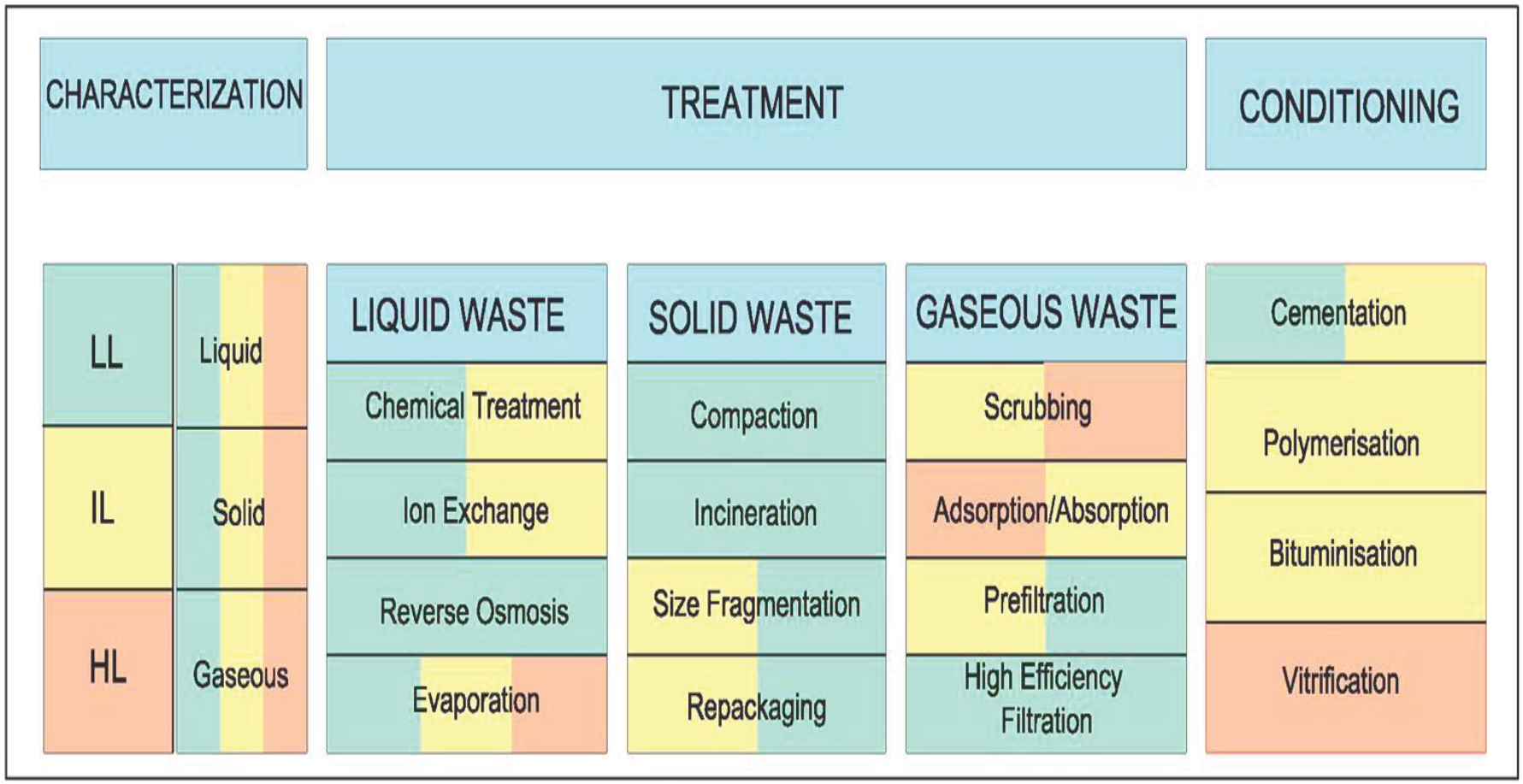
- Key Non-technical factors
  - Adequacy of the national waste management system
  - National policy and strategy
  - Compliance with regulations
  - Available infrastructure, interrelations of WM steps
  - Manpower and competency
  - Resources
  - Socio-political situation
  - Potential international co-operation
  - Financial and practical feasibility
  - Cost efficiency

The Basic Steps in RWM



RWM prior the disposal

Predisposal steps and options



In most cases packaging will be required for shielding, confinement and/or for handling purposes

Pretreatment

Waste collection

Checking for contamination

Segregation of waste

Sorting of waste

Treatment by Compaction

Low pressure in-drum compactor

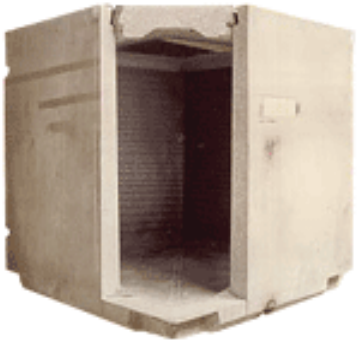
High pressure drum compactor (super-compactor)

Conditioning of Waste

In-drum cementation facility

Waste Packaging

CYLINDRICAL CONTAINERS



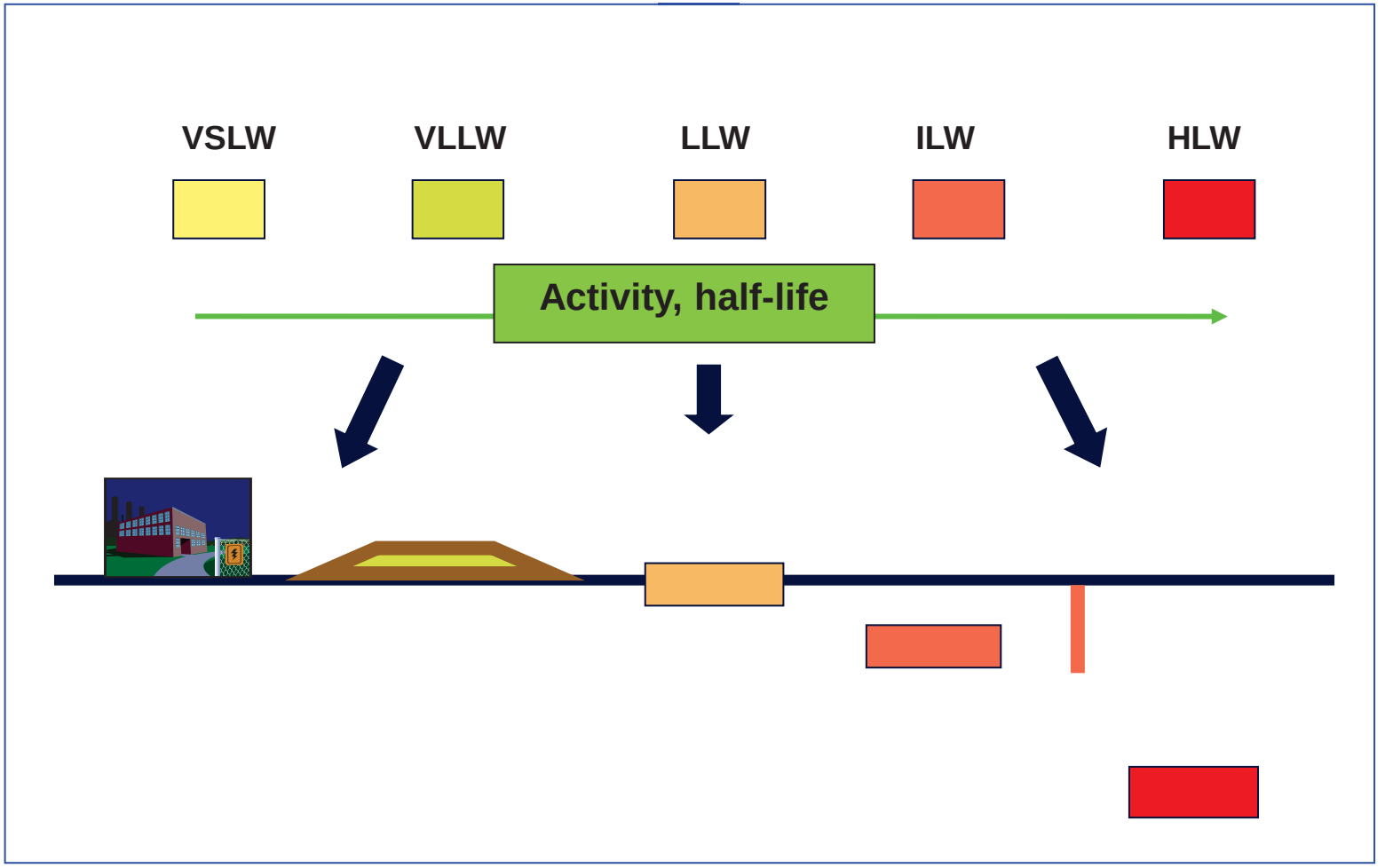
CUBICAL CONTAINERS

Transport of concrete container

Storage of Waste

Disposal

Disposal options



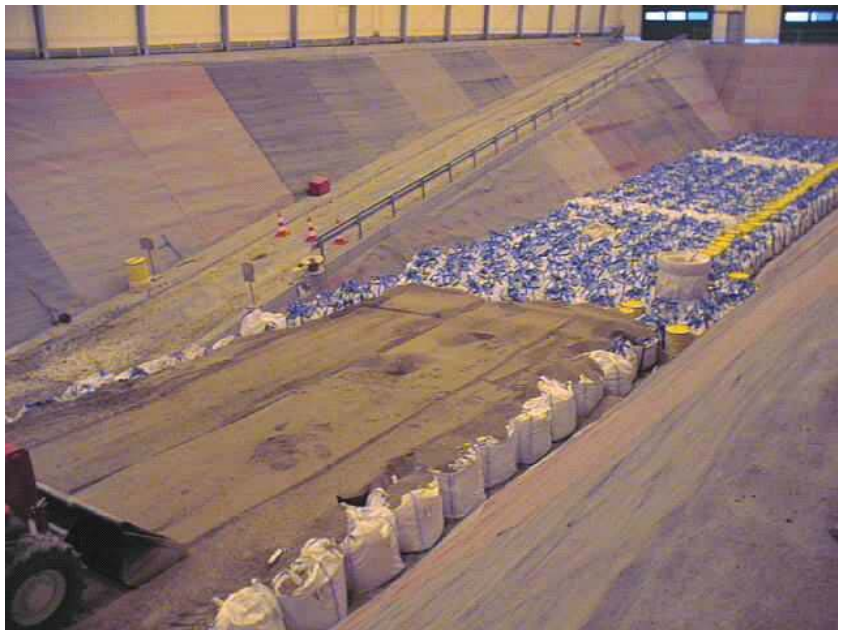
Disposal of LLW

- Disposal facilities for LLW successfully operating in many countries
- Different types of repositories: surface, near surface and underground (geological)
- But many nuclear and non-nuclear countries still need to develop repositories

EUROPE: (Belgium); Bulgaria; Czech R.; Finland; France; (Germany); Hungary; Latvia: Lithuania; Norway; Poland; Romania; Russian F.; Slovakia; (Slovenia); Spain; Sweden; (Switzerland); Ukraine; United Kingdom
AFRICA: (Egypt); (Ghana); South Africa
AMERICAS: (Argentina); (Brazil); (Canada); (Chile); Mexico; (Peru); United States of America
ASIA and the PACIFIC:(Australia); China; India; (Iran); (Iraq); Japan; (Jordan); (Rep. of Korea); (Malaysia); (Pakistan); (Philippines)

Disposal of VLLW

- For very low level waste disposal in trenches
- VLLW repositories in operation in France and Spain



Surface disposal of LLW

Disposal in Trenches

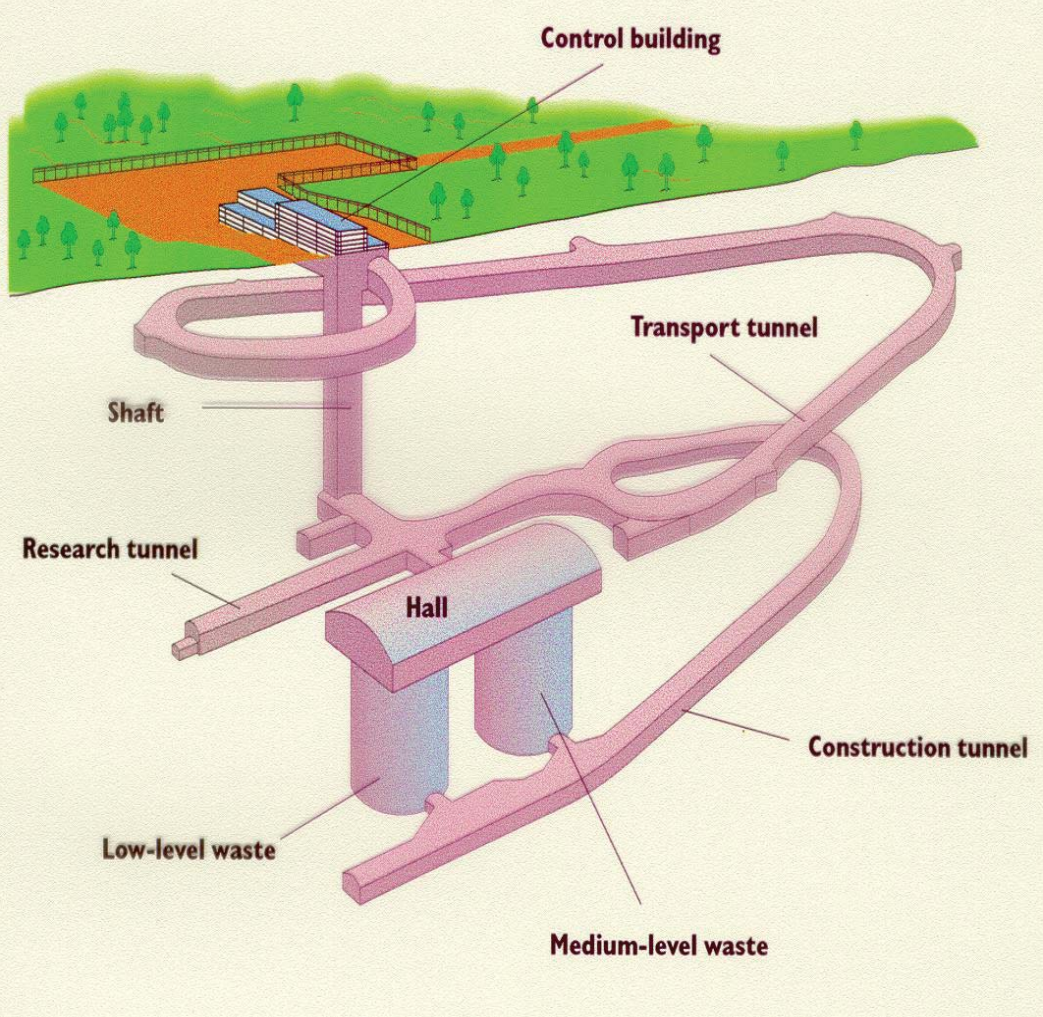
LLW Disposal in Richland, Washington

LLW in Vaalputs, South Africa

Surface disposal in Japan

Rokkasho

L/ILW disposal in Olkiluoto

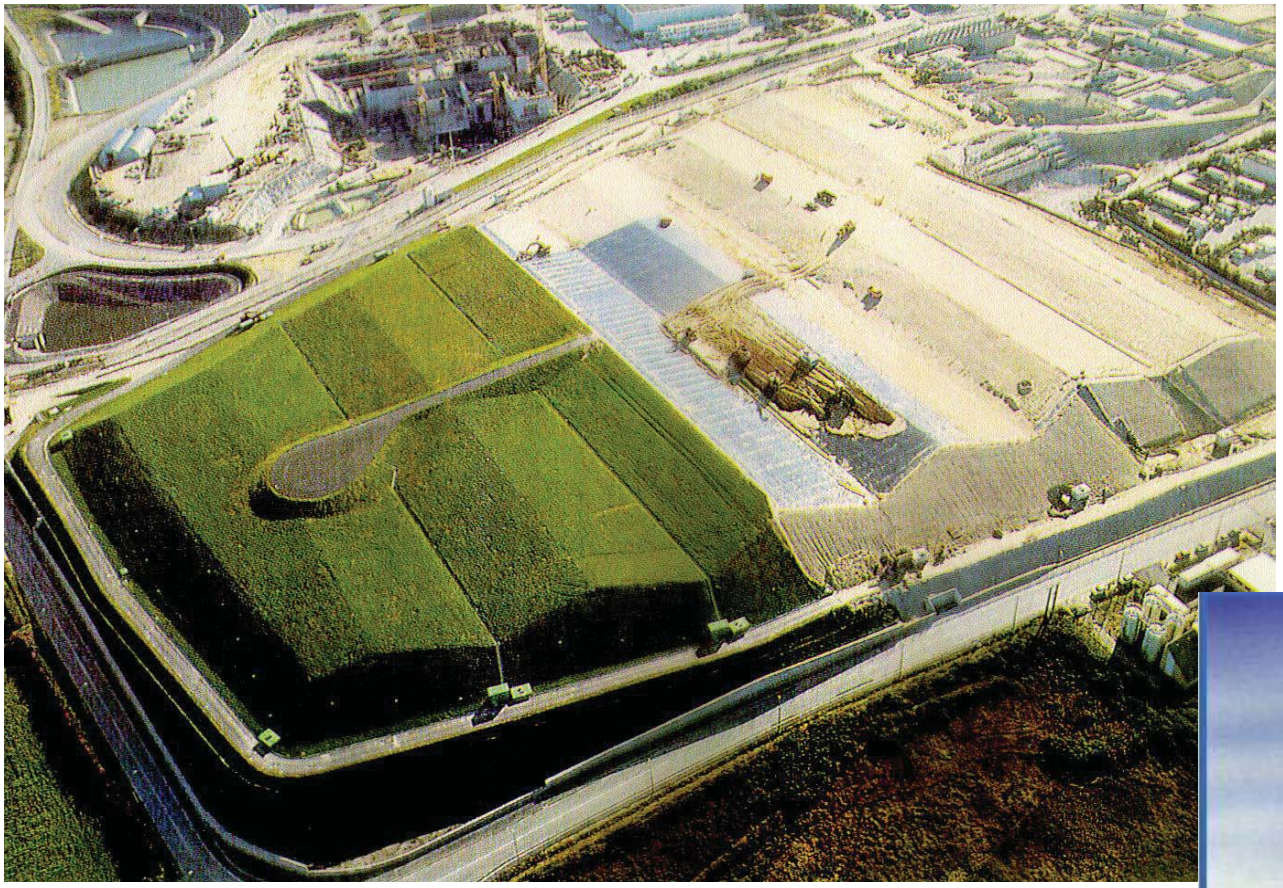


L/ILW in SFR Forsmark

Surface disposal in France

Centre de l'Aube

Centre de la Manche, France



Closure of the repository

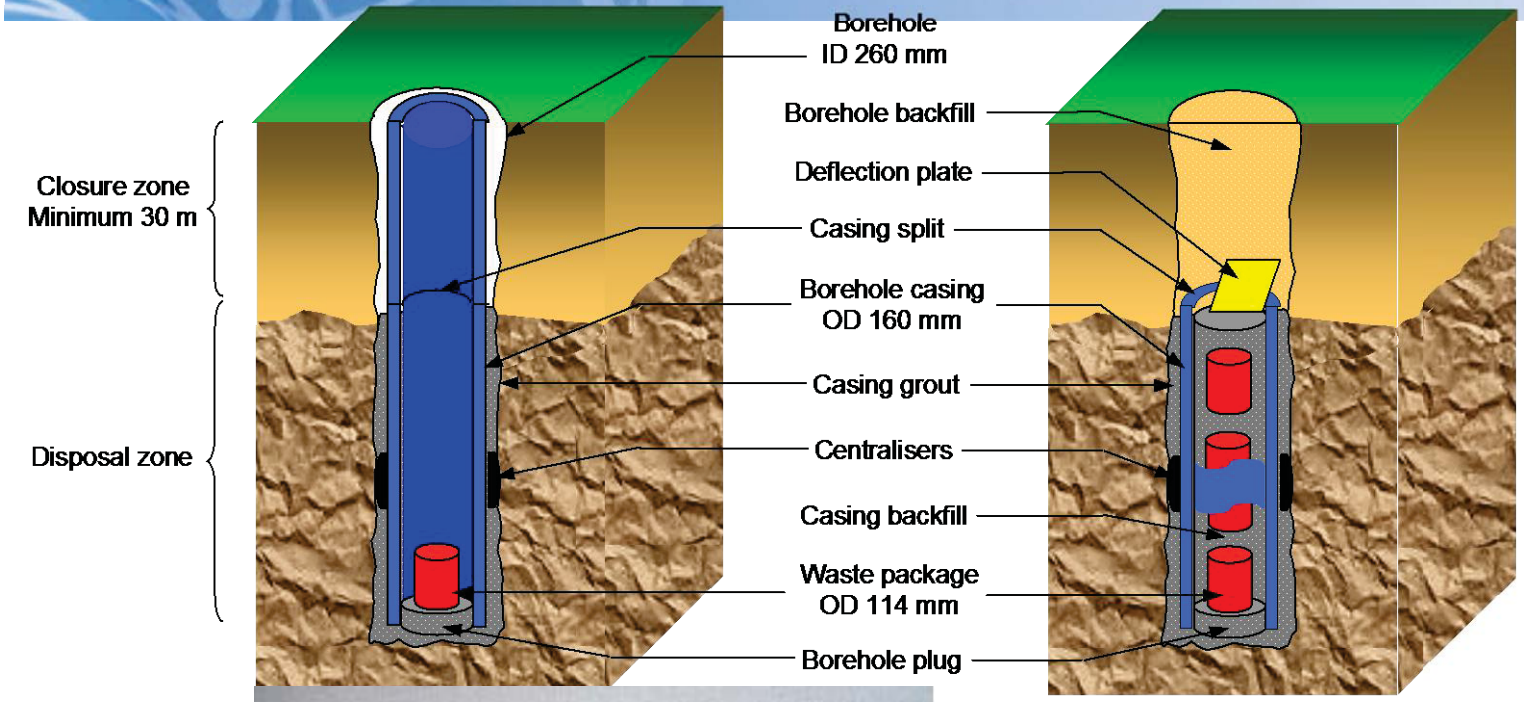
Non-heat generating waste in Morsleben

Morsleben

Non-heat generating waste in Konrad

Disposal of TRU waste in WIPP, USA

Concept of Borehole Disposal



For small volumes of waste (DSRS)

Simple technology

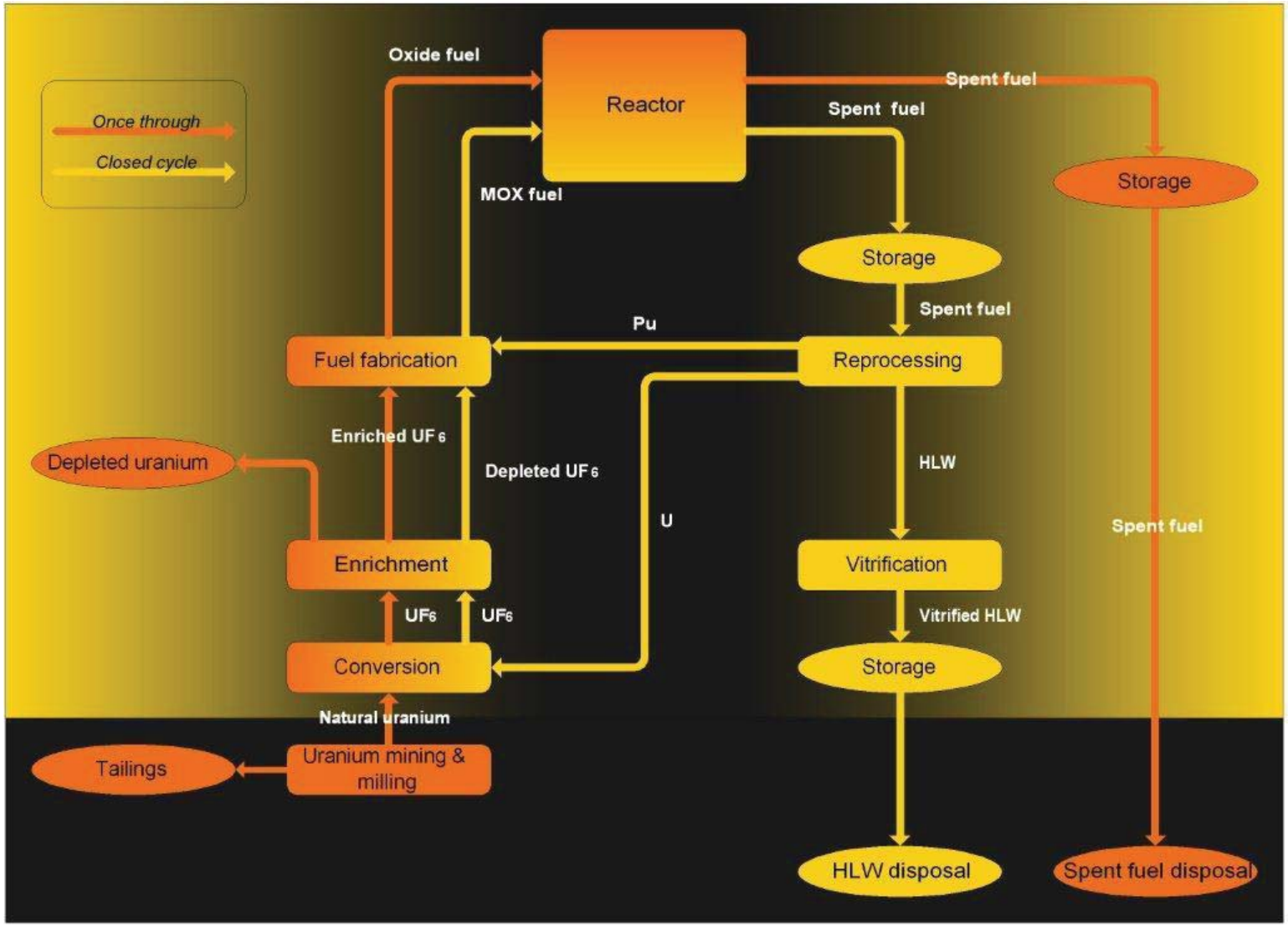
Cost effective

Spent Fuel and HLW Disposal

Basic options for SF management

- Once-through cycle – spent fuel stored and then disposed of → Direct disposal of SF
- Closed fuel cycle – reprocess SNF, Pu + U recycled and waste disposed of → Disposal of HLW and L/ILW from reprocessing

The Nuclear Fuel Cycle



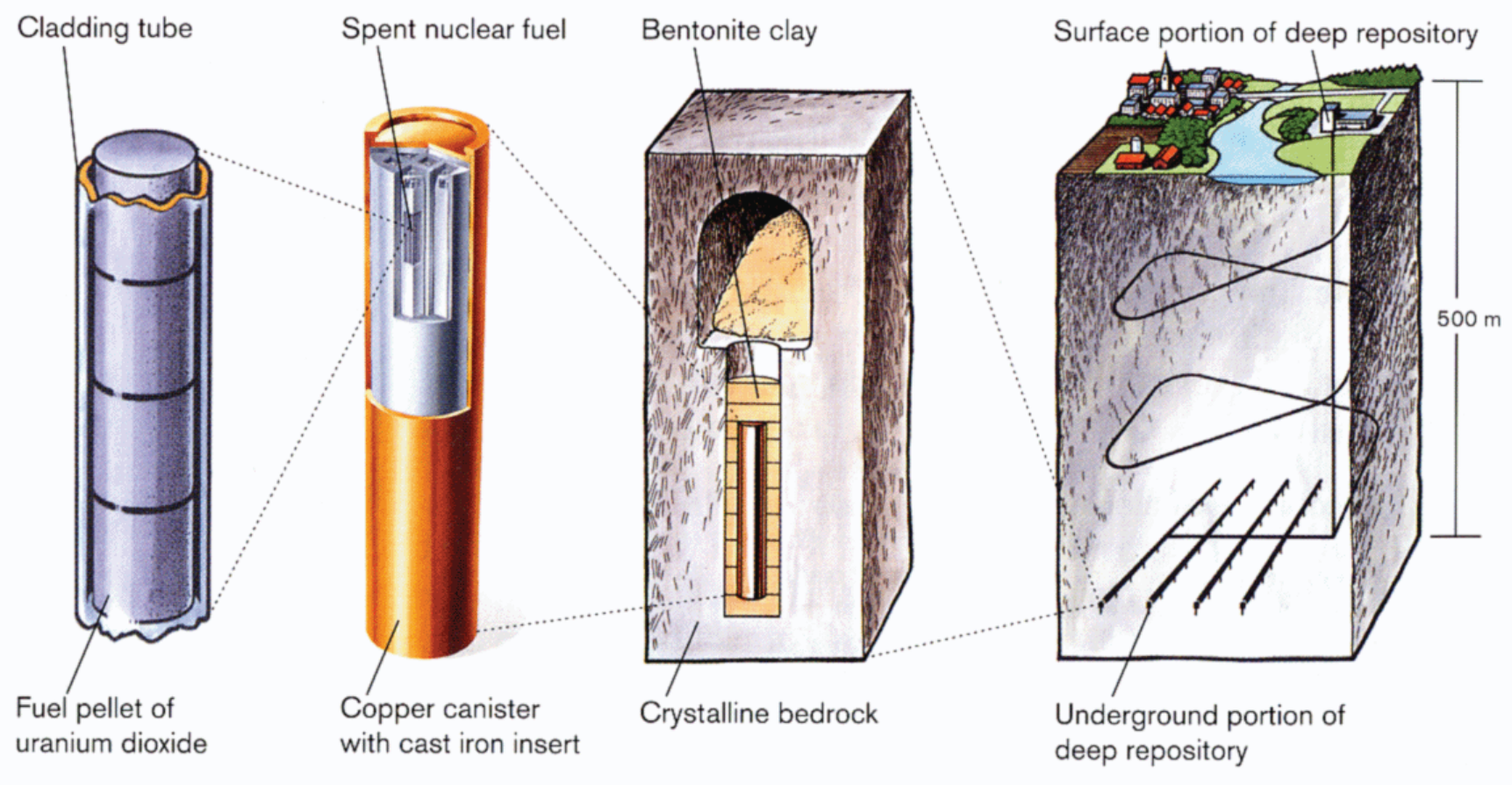
Comparison: once-through – closed fuel cycle

	Once-through cycle (for 1 GW year)	**Closed fuel cycle (for 1 GW year)**
U-ore extraction	205 t	130 t
Tailings	58 000 m^3	38 000 m^3
Conversion and enrichment	30 m^3 L/ILW	20 m^3 L/ILW
Fuel production	40 m^3 L/ILW (long-lived)	25 m^3 L/ILW (long-lived)
Production of MOX fuel	-	30 m^3 L/ILW (long-lived)
Reactor operation	80 m^3 L/ILW	80 m^3 L/ILW
Fuel reprocessing	-	4 m^3 HLW, 20 m^3 L/ILW (long-lived), 84 m^3 L/ILW
Spent fuel	10 – 12 m^3 SF	-

Geological disposal

- Technical solutions for geological disposal available
- Geological repositories designed as passive facilities
- Safety based on multi-barrier approach
  - Natural barriers
  - Engineered barriers
- Possible host rock: granite, clay,salt...

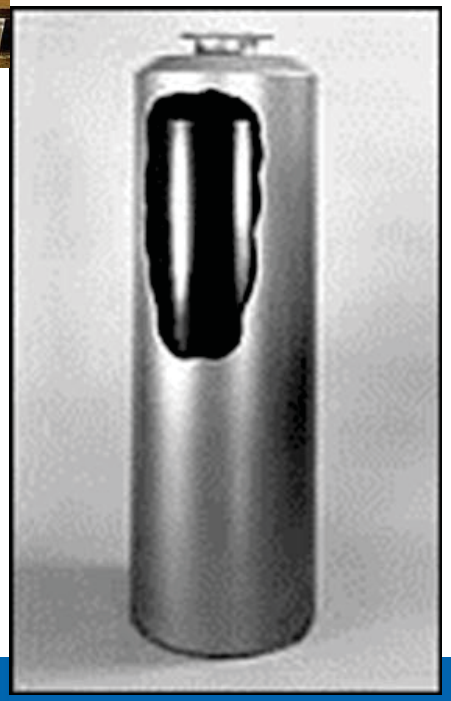
Multi-barrier system



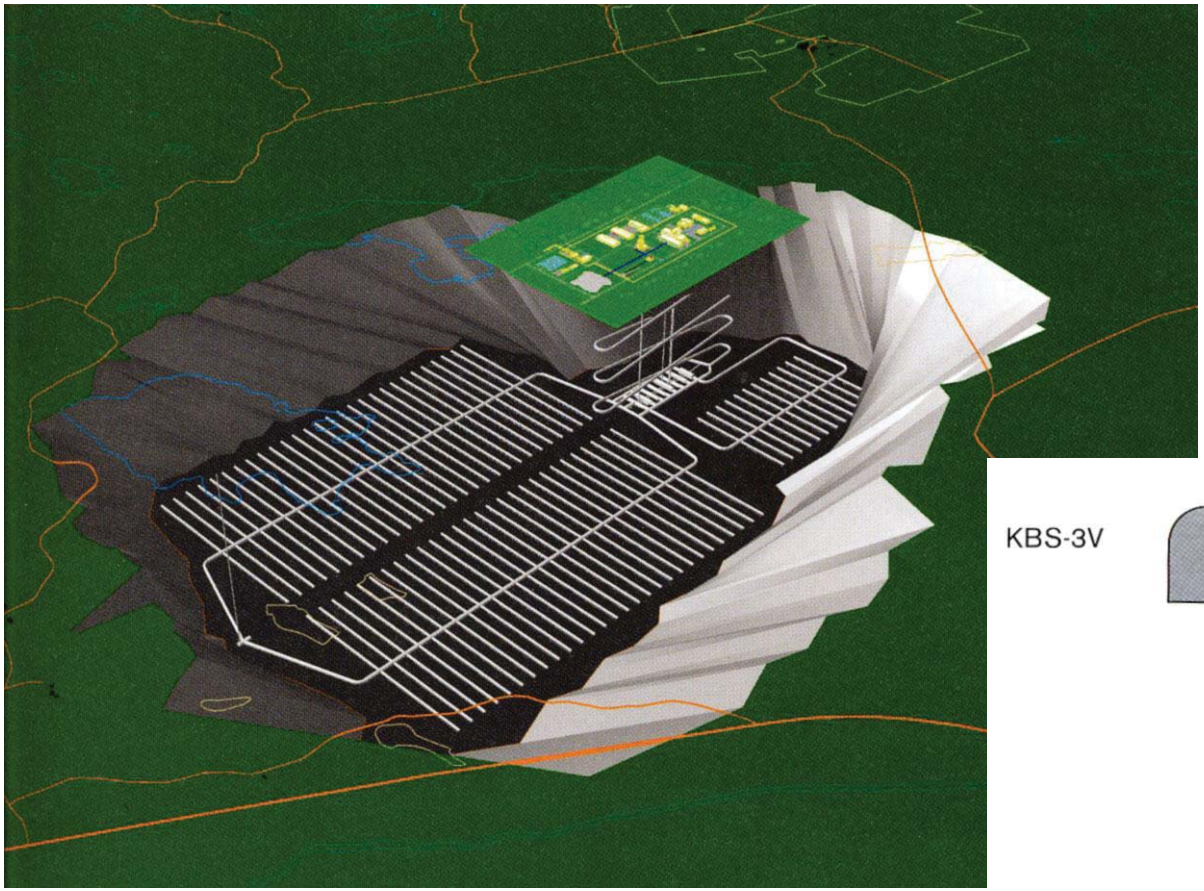
Encapsulation of SF and HLW

Copper canisters for SF

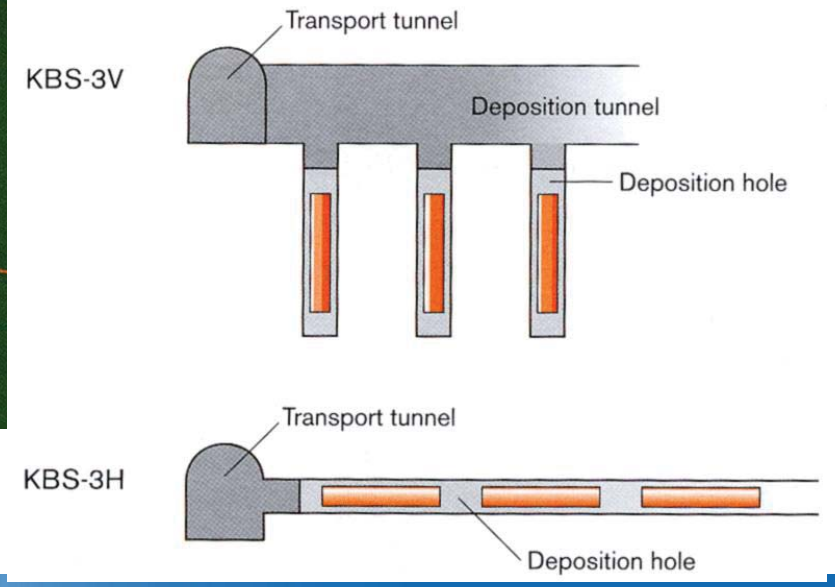
Pouring of glass and HLW to container



Getting close to first operating repositories

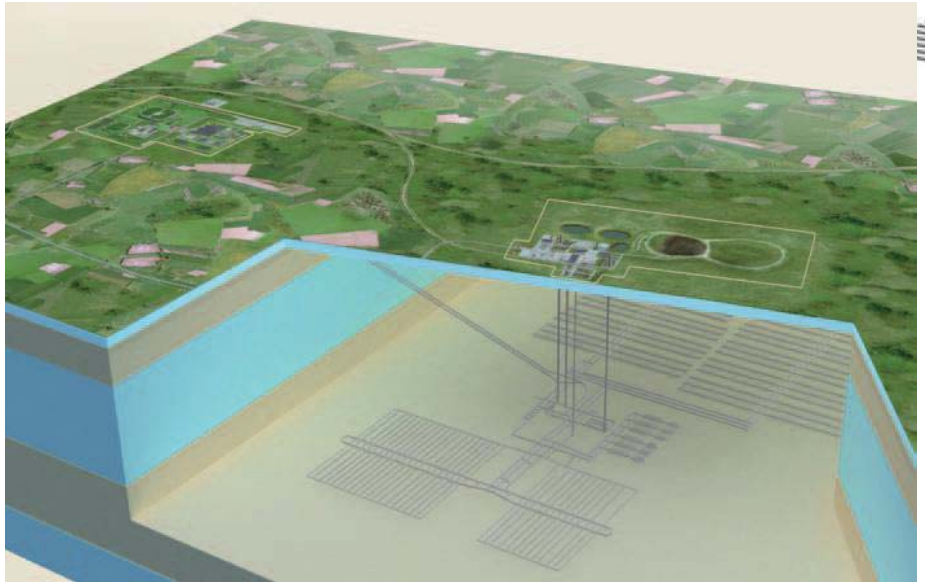


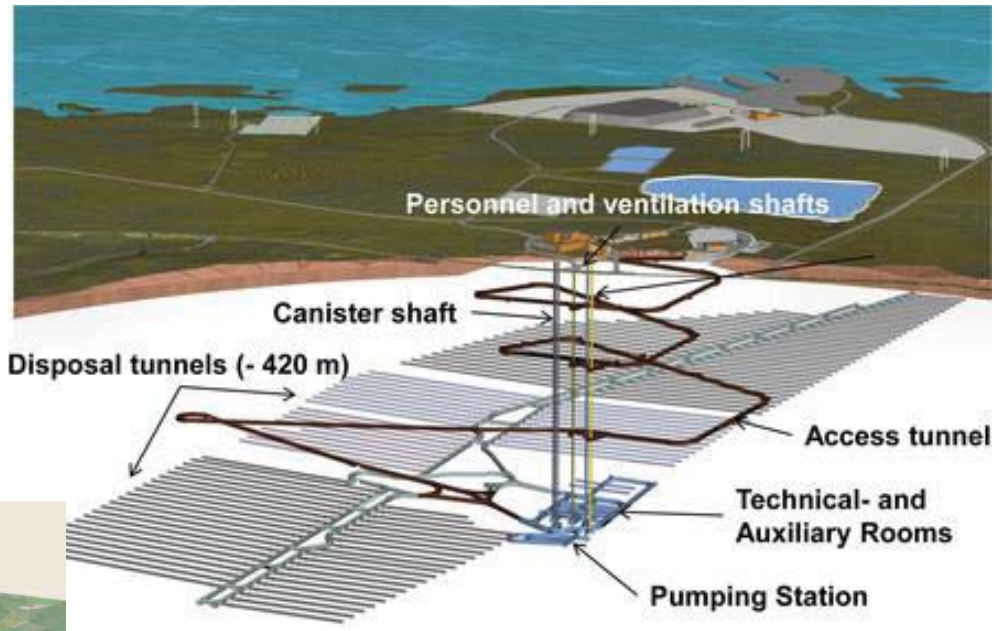
Geological disposal in Sweden



Getting close to first operating repositories

Disposal concept in France





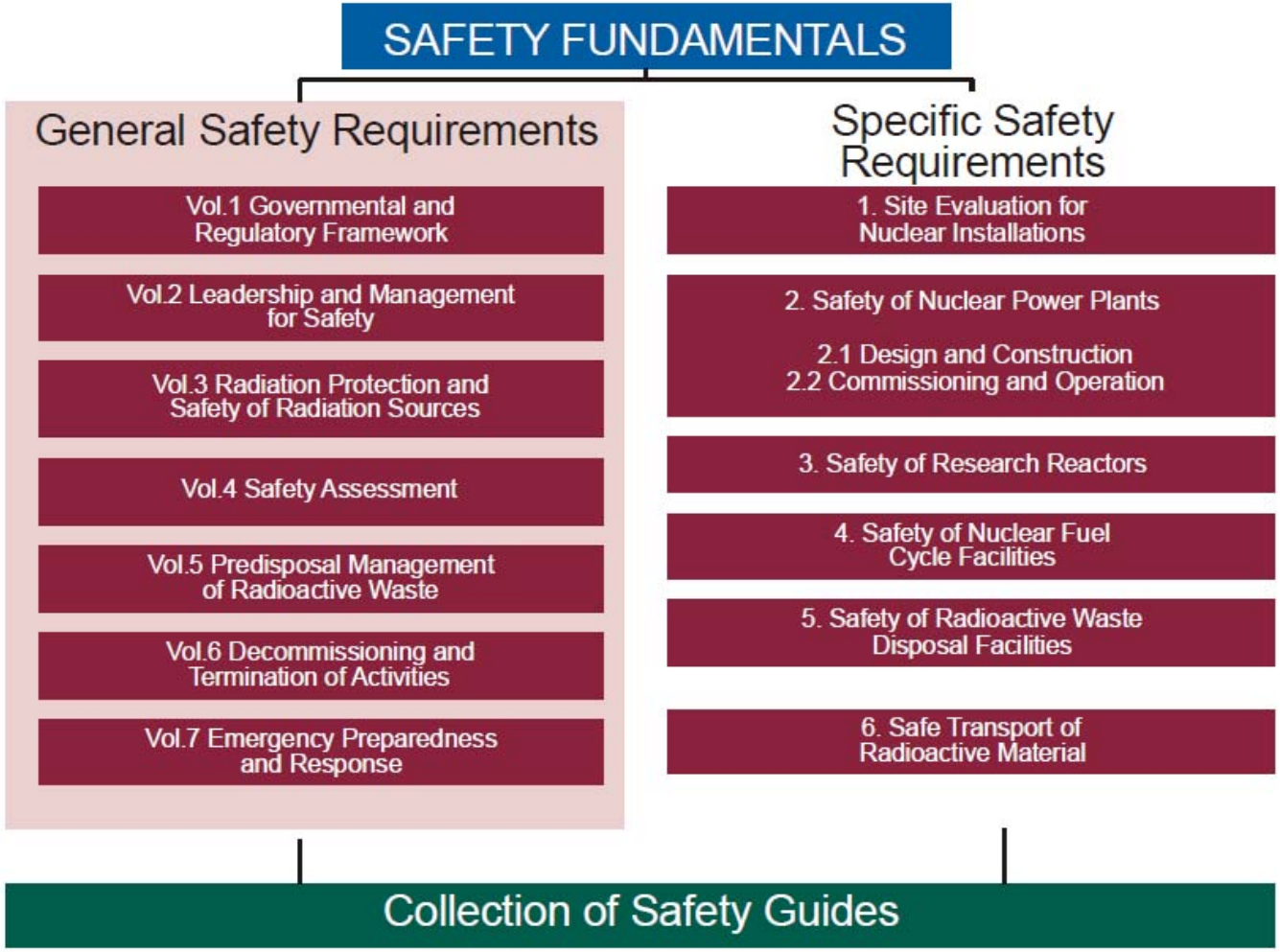
Geological repository in Finland.

IAEA Activities to Assist Member States

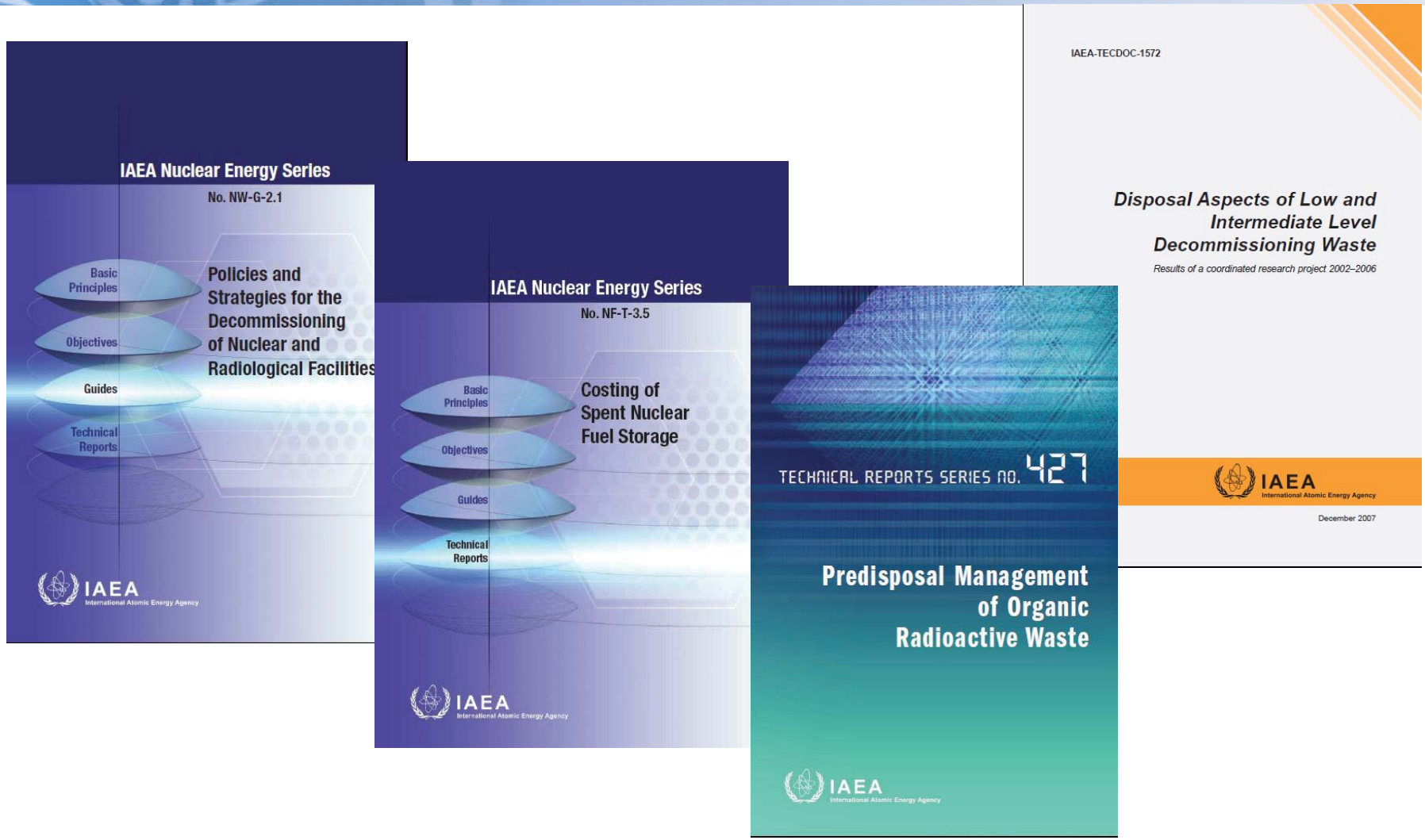
IAEA activities

- Joint Convention, Safety Standards and guides for harmonization of safety approaches
- Facilitating international cooperation, information exchange and capacity building:
  - Technical reports and publications
  - Coordinated research projects
  - Networks
  - Databases
  - Training courses and eLearning
  - Conferences and Symposia
- Technical assistance to Member States
- Review services

Safety Standards and Guides



Technical reports



http://www.iaea.org/OurWork/ST/NE/NESeries/ClickableMap/

RWM Networks

- Networks are new tool to address the needs of Member States through thematic and strategically focused approaches
- Five Networks focused on the following areas:
  - Geological Disposal **(URF Network**, established in 2001)
  - Decommissioning of nuclear facilities (**IDN**, established in 2006)
  - Near-Surface Disposal of LLW (**DISPONET**, established in 2009)
  - Environmental Remediation of radioactively contaminated sites and environmental management of active sites (**ENVIRONET**, established in 2009)
  - Characterization of LILW (**LABONET**, established in 2011)

CONNECT – Network of Networks

- Further development of Networks on-going to facilitate interactions between members and participants
- Connecting the Network of Networks for Enhanced Communications and Training in Radioactive Waste Management, Decommissioning and Environmental Remediation
- **CONNECT** allows users to communicate directly with others in near real-time, either on a one-on-one basis or with multiple users.
- Training and eLearning materials are also being developed to be available via CONNECT

Conclusions

- Safe and efficient RWM is an important component of prosperous and peaceful use of nuclear energy and radioactive materials
- Technologies are available and being further developed
- IAEA plays an active role in developing and maintaining high standards of RWM in Member States
- IAEA is also strongly promoting international cooperation and exchange of information
- Cooperation beneficial for developing and developed programmes as well as for countries embarking on nuclear

IAEA Assistance

- Many countries seek IAEA assistance in addressing waste issue:
  - Currently more than 80 TC projects related to RWM in 37 countries and in all regions
  - Required assistance mainly related to waste processing, storage and disposal of LLW
  - Assistance related to geologic disposal of SF and HLW mostly focused on:
    - Development of adequate policy and long-term strategy/programme for SF/HLW
    - Development of necessary infrastructure and financing schemes for SF and HLW management

IAEA Priorities in RW and SF Management

- Encourage and support establishment of a policy for SFM and RWM and strategy for its implementation in each country using nuclear technology
- Stimulate countries introducing nuclear power to develop adequate policies and strategies at an early stage in their nuclear programmes
- Support countries with small nuclear programmes in their efforts for disposal solutions, encouraging cooperation and pooling of resources