Nuclear Decommissioning and Radioactive Waste Management

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Contents

Definitions (from IAEA SAFETY GLOSSARY, 2018 Edition)

'Decommissioning' is the **set of administrative and technical actions** taken to allow the **removal of some or all of the regulatory controls** from a facility to a predetermined **end-state**.

This does not apply for that part of a final disposal facility in which radioactive waste is emplaced (**repository**), or for certain facilities used for the **disposal** of naturally occurring radioactive material (**NORM**) or of residues from the **mining** and **processing** of radioactive **ores**.

For all of these the term **closure** is used instead of decommissioning.

'***End State'*** is a predetermined criterion defining the point at which a specific task or process is to be considered completed.

Used in relation to decommissioning activities as the final state of decommissioning of a facility; and used in relation to remediation as the final status of a site at the end of activities for decommissioning and/or remediation, including approval of the radiological and physical conditions of the site and remaining structures.

'Regulatory control' is any form of control or regulation applied to facilities or activities by a **regulatory body** for reasons relating to nuclear safety and radiation protection or to nuclear security.

Then, '*Nuclear decommissioning*' is a broad process covers all steps from ceasing the operation of a nuclear installation to its final **total** release from **regulatory control (or part of it).**

Objectives

Two generally are the main objectives of decommissioning:

Unrestricted use (*in technical slang, i.e.:* "***green field***"). The use of an area, building or material without any radiological restrictions (as if it has never had radioactivity).

There may be other restrictions on the use of the area or material, such as planning restrictions on the use of an area of land or restrictions related to the chemical properties of a material. In some situations, these restrictions could, in addition to their primary intended effect, have an incidental effect on radiation exposure, but the use is classified as unrestricted use unless the primary reason for the restrictions is radiological.

Restricted use (*in technical slang, i.e.:* "***brown field***"). The reuse of the site under restrict conditions (considering residual radioactivity effects). The use of an area, building or materials subject to restrictions imposed for reasons of radiation protection and safety.

Restrictions would typically be expressed in the form of prohibition of particular activities (e.g. house building, growing or harvesting particular foods) or prescription of particular procedures (e.g. materials may only be recycled or reused within a facility).

Political framework

What do we need to develop a safe, effective and efficient decommissioning process?

Policy is a set of ideas, or a plan of what to do in particular situations that have been officially accepted by a group of people, an entrepreneurial organization, a government or a political party. It represents a system of pre-arranged guarantees for all stakeholders.

The national policy shall be promulgated as a statement of the government's intent.

Legal and Regulatory Framework is a set of laws and regulations for achieving objectives and a high level of safety during the lifetime of nuclear facilities, from commissioning to end state of decommissioning

Regulatory Authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating the safety of nuclear installations, radiation safety, the safety of radioactive waste management and safety in the transport of radioactive material.

Strategy is an action plan designed to achieve a long-term or general goal, taking into account the legal and regulatory framework, the boundary conditions and uncertainties.

Decommissioning plan is a (or set of) document containing detailed information on the proposed decommissioning of a plant, including decontamination and/or removal of structures, systems and components, the development of procedures, processes and work activities to achieve of the approved end-state.

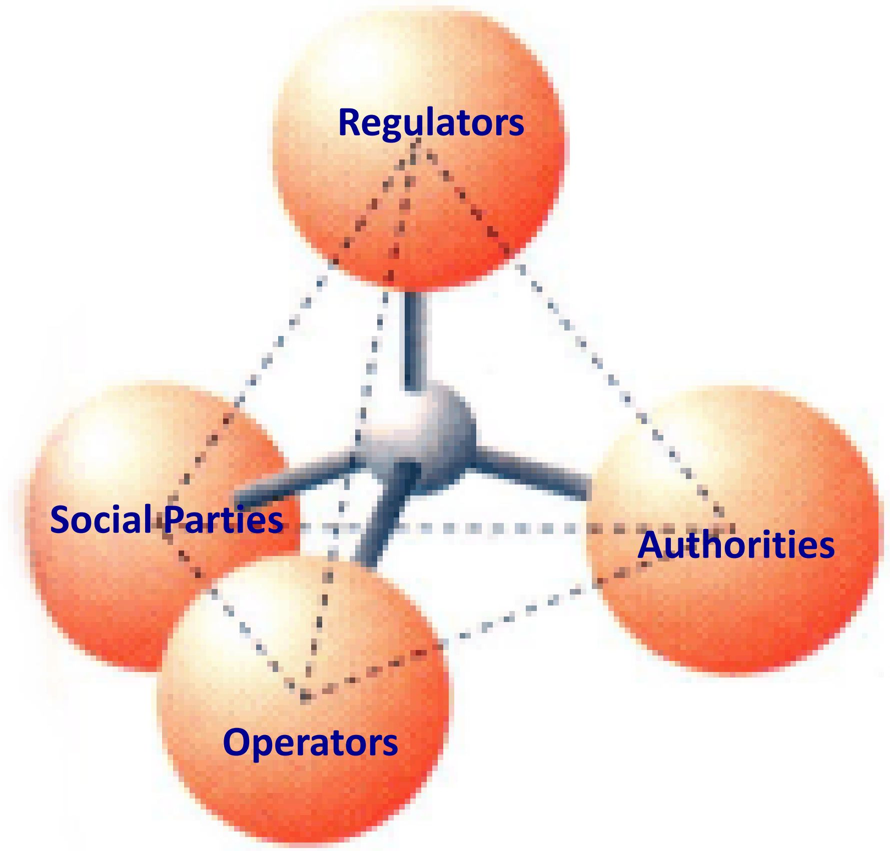
Boundary condition is the set of conditions and infrastructures necessary to develop the decommissioning plan.

Related Parties

Decommissioning, involving all activities undertaken to remove radioactive contamination from and to dismantle the facility with the aim that it may be released from regulatory control and the site reused for other purposes, requires timely and effective management.

A proper and effective management of nuclear decommissioning requires (at least and overall):

- a clear and robust regulatory system,
- an effective authority,
- a participating social parties, and
- efficient operators



Safety Management System

The set of national and international **regulators**, control **authorities** and **operators** are the basis of the **safety** management system.

Supranational Bodies

OECD-NEA

Study and documentation
Assistance to Member State
International S&T Cooperation
Economics
Best practices

EC-EURATOM

EC Directives
International treaties
Accounting and control of nuclear material
JRC technical support

IAEA

International treaties and conventions on safety and security

- Safety Fundamentals
- Safety Requirements
- Safety Guides, TEC-DOCs

National Bodies

Government and Ministries

International obligations
National policy and strategy for safety
Establishment of a framework for safety
Provision for licensing process, operation and decommissioning
Provision for technical services
…..

Regulatory and Control System

Authorization of facilities and activities
Technical surveillance and Inspection
Review and assessments of safety
Requirement of corrective action
Regulations and technical guides
Communication to population
….

Operators

Safe operation and physical protection
Demonstration of safety
Emergency preparedness and response, …

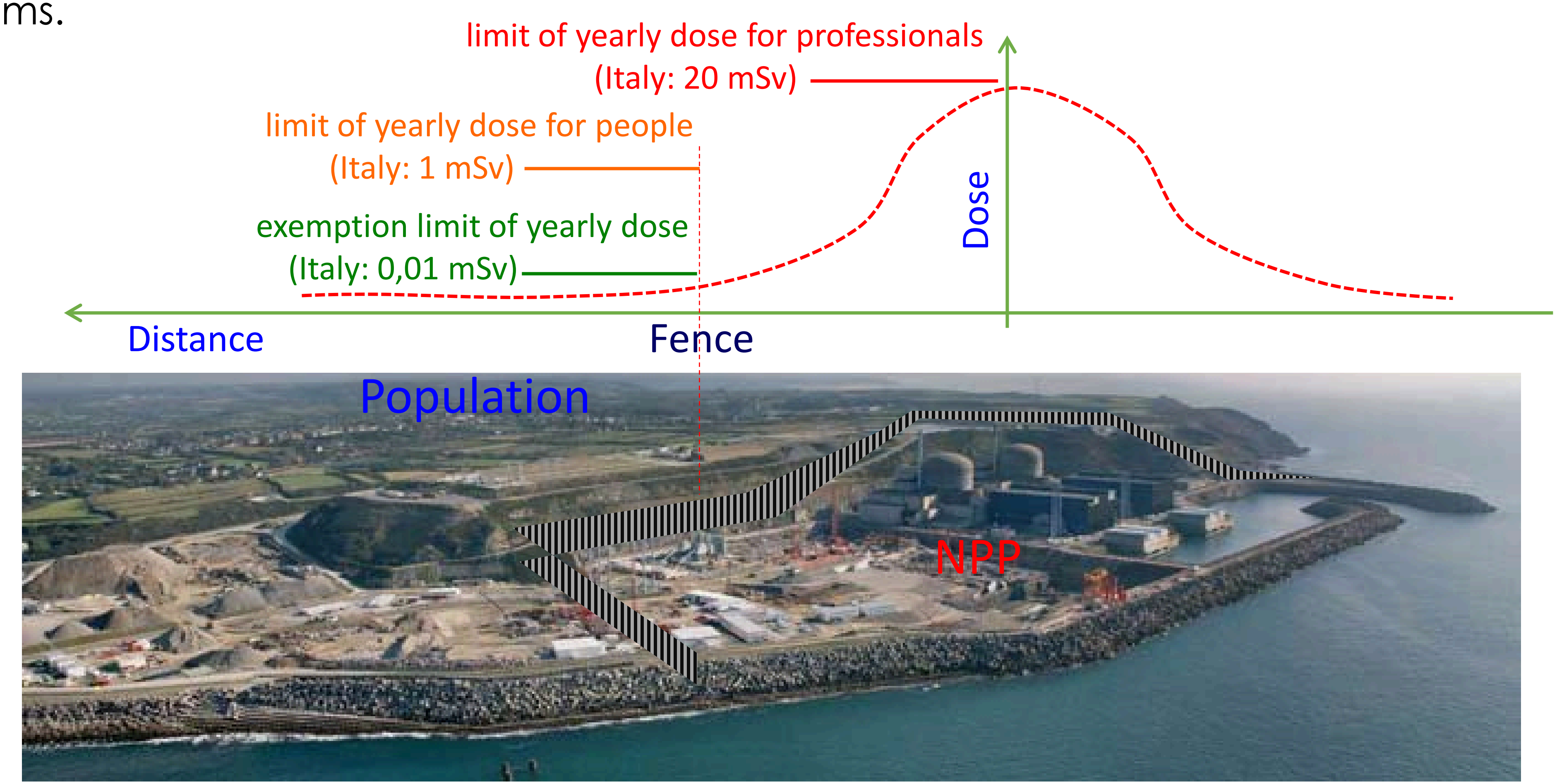
Funding for the operation, decommissioning of facilities and the management of radioactive waste and spent fuel, …

Knowledge and documentation

Internationally, **safety standards**, **information** and **best practices** are available.

Policy and regulations

Dose limit has to be kept in all circumstances (from the first criticality to the end state of decommissioning) by appropriate design, efficient means and adequate emergency systems.



Decommissioning strategy

Planning and implementation of a decommissioning project is a complex and **multi-disciplinary** process involving both **technical** and **non-technical** aspects.

Three decommissioning strategies have been defined by international community (*source* IAEA), namely:

- **immediate dismantling** commences shortly after shut down, if necessary following a short transition period to prepare for implementation of the decommissioning;
- **deferred dismantling**, as an alternative strategy, dismantling may be deferred for a period of up to several decades. Deferred dismantling is a strategy in which a facility or site is placed in a safe condition for a period of time, followed by decontamination and dismantling. It requires the continuous maintenance of containment systems;
- **entombment** is a strategy in which the remaining radioactive material is permanently encapsulated on site. Since it leaves the radioactivity in place with limited containment guarantees, entombment can not be considered a true practice of dismantling and **is not recommended**.

Benefit of decay on decommissioning

SOGIN

Deferred dismantling can bring significant benefits in terms of reducing the radioactivity to be handled, however it requires to keep the plants in safe conditions all the time necessary before starting the dismantling operations.

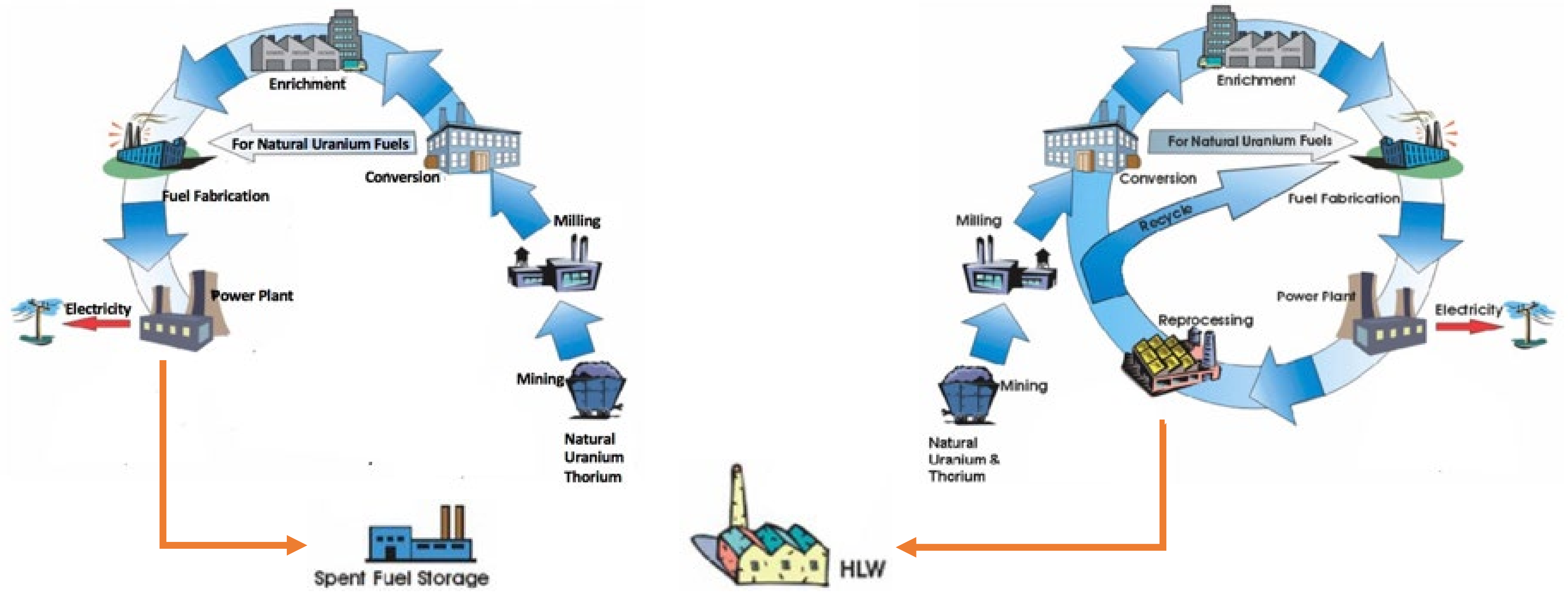
IAEA International Atomic Energy Agency EFFECT OF DECAY ON MASSES AND ACTIVITY OF STEELS FROM A 1000 MW(e) PWR

		Time after reactor shutdown					
		5 years of decay		25 years of decay		100 years of decay	
Surface activity (Bq/cm^2)	Average activity (Bq/g)	Mass (t)	Total activity (Bq)	Mass (t)	Total activity (Bq)	Mass (t)	Total activity (Bq)
37–370	10	800	8.0×10^9	440	4.4×10^9	240	2.4×10^9
3.7–37	1	1600	1.6×10^9	880	8.8×10^8	480	4.8×10^8
0.37–3.7	0.1	3200	3.2×10^8	1760	1.8×10^8	960	9.6×10^7
		99.9% beta–gamma, 0.1% alpha		99% beta–gamma, 1% alpha		95% beta–gamma, 5% alpha	

Nuclear facilities liable to decommissioning

For which infrastructures is decommissioning necessary?

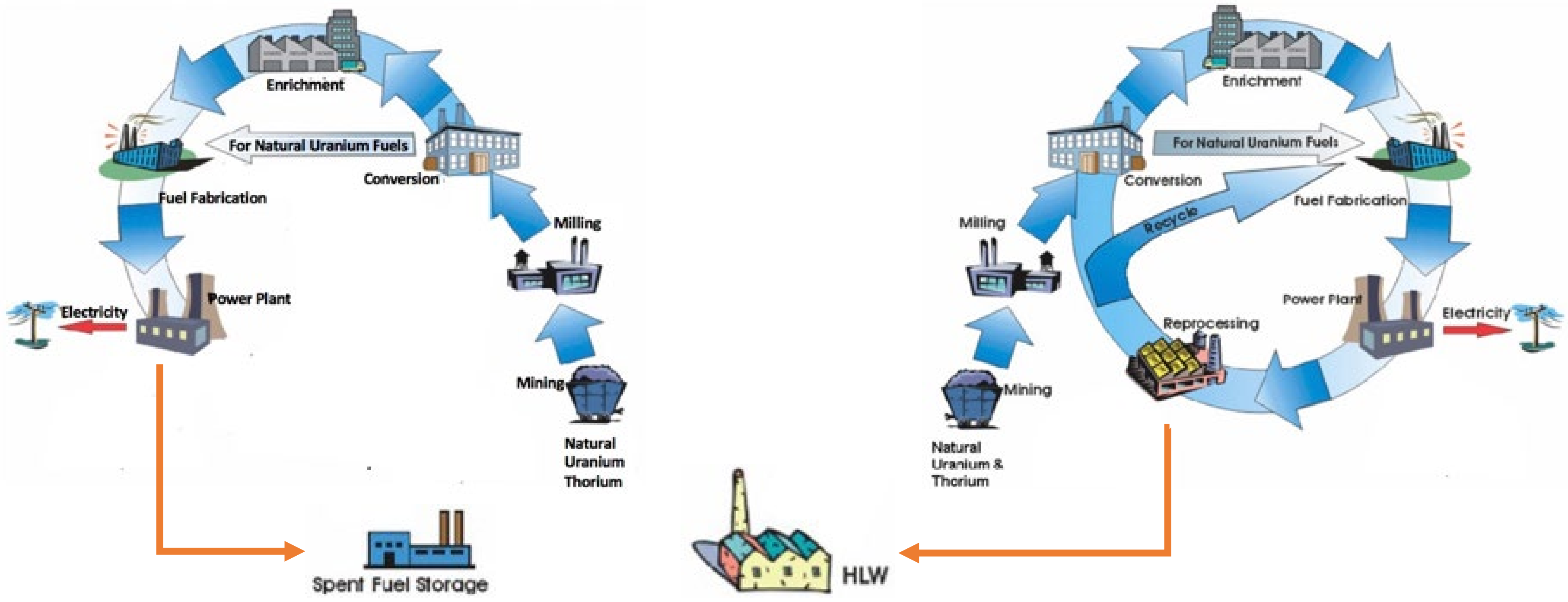
Fuel open cycle **Fuel closed cycle**



For all those involved in the nuclear fuel cycles
(although at different times and with different approaches)

Waste generation

Many types of waste are produced both during operation and decommissioning, to which it is necessary to give a **safe final destination**.



The **types and amounts of waste can be different**, but the treatment, conditioning and disposal systems are ultimately the same or very similar, since the parameter to be kept under control is still **radioactivity**.

Material generation in decommissioning

During dismantling a **large quantity of other materials** are produced with different levels of radioactivity (aqueous and organic liquids used for decontamination or deriving from draining plants and components, cementitious demolition materials, various metals from reinforced concrete structures or plant components, glasses, plastics, rubbers, paper, clothes, etc.).

For all these materials it is necessary to establish a system of **separate paths** that allows them to be classified as radioactive or non-radioactive material, reusable (at which conditions) or non-reusable, may be decontaminated or not, recyclable or not, clearable or not, with the aim of having homogeneous lots of materials or waste that can follow a predetermined route of removal or treatment.

Effective **Radiological Characterisation** tools within a robust **Quality Assurance** system are the keys for the success of the controlled material removal system.

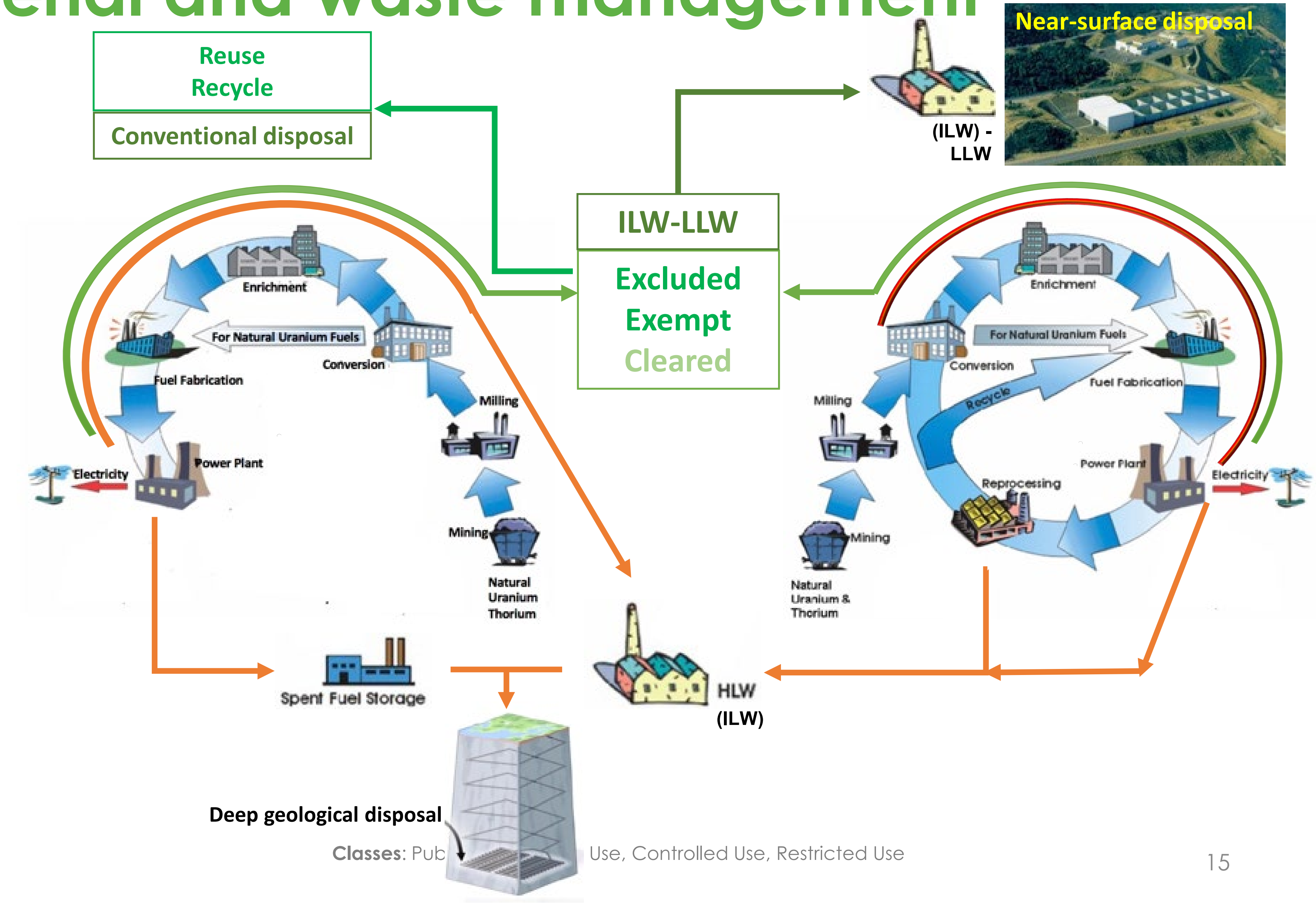

Drum monitor


Hexagon passive neutron counter


Open geometry


Segmented Gamma Scanner

Material and waste management



Benefit of decontamination on decommissioning

Effective decontamination process can bring significant benefits in terms of reducing the radioactivity to be handled and waste production.

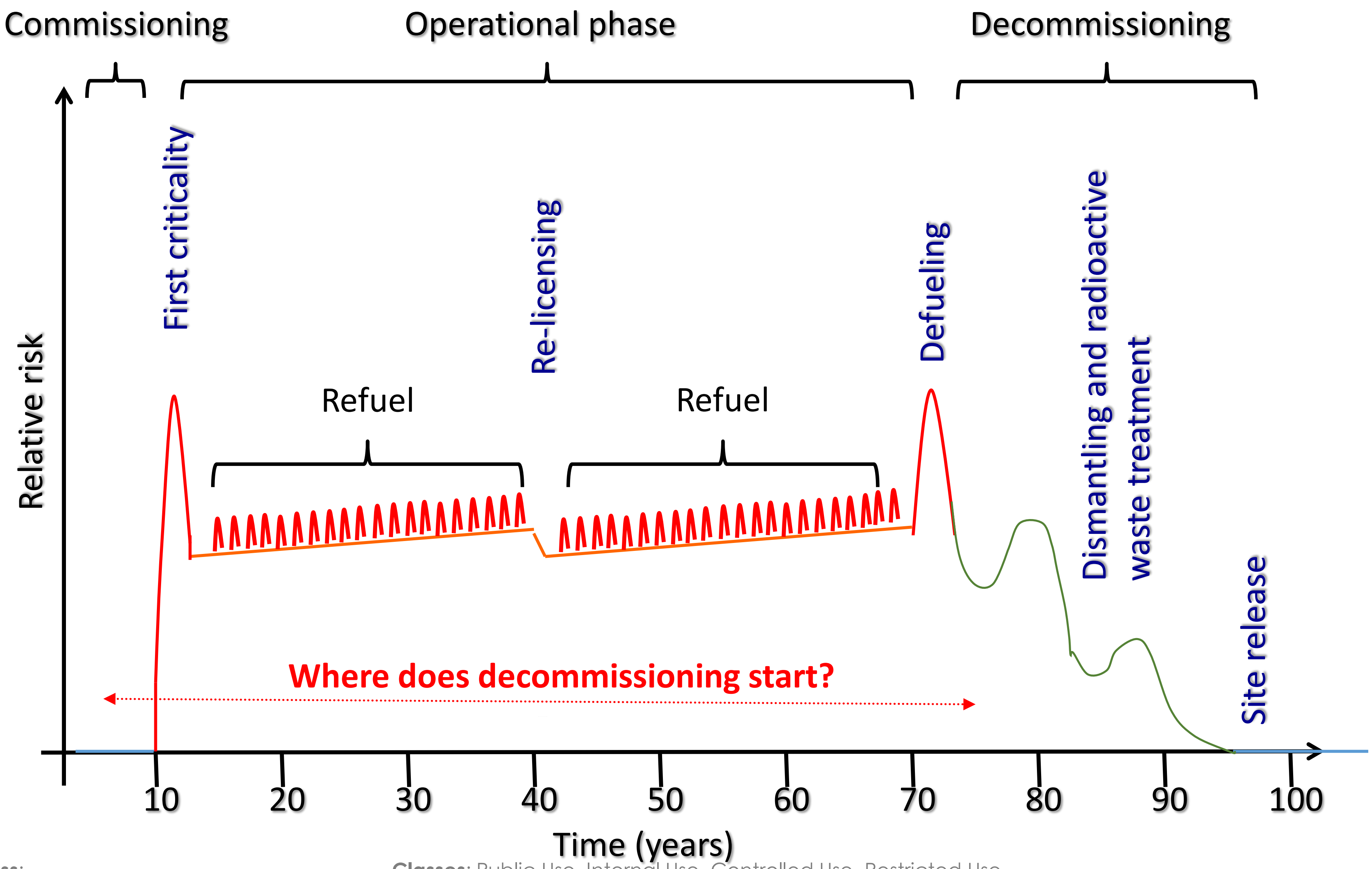
IAEA International Atomic Energy Agency

WASTE ARISINGS FROM THE DECOMMISSIONING OF THE WAK REPROCESSING PLANT

Material	Quantity (m^3)	Nature	Fate
High level liquid waste	52 (vitrified)	Radioactive waste 130 of 400 L casks	Storage
Contaminated plant, decontamination, wastes, etc.	1681	Conditioned radioactive waste (3360 m^3)	Disposal
	2840	Cleared	Recycling/reuse
Building rubble, structural materials, etc.	2279	Conditioned radioactive waste (4560 m^3)	Disposal
	110 000	Cleared	Recycling/reuse

Radioactive materials less than 3,5 %

Conceptual map of risks in plant life-time



Decommissioning Phases

1) Preparatory phase: Decommissioning planning needs to start before the final shutdown
2) Transition phase: includes Physical and Radiological Plant Characterisation and Site Preparatory Activities
3) Implementation phase: Dismantling and Demolition, Environmental Remediation and Radioactive Waste Management
4) End phase: Final Survey & Release from Regulatory Control

Security Class: Public Use

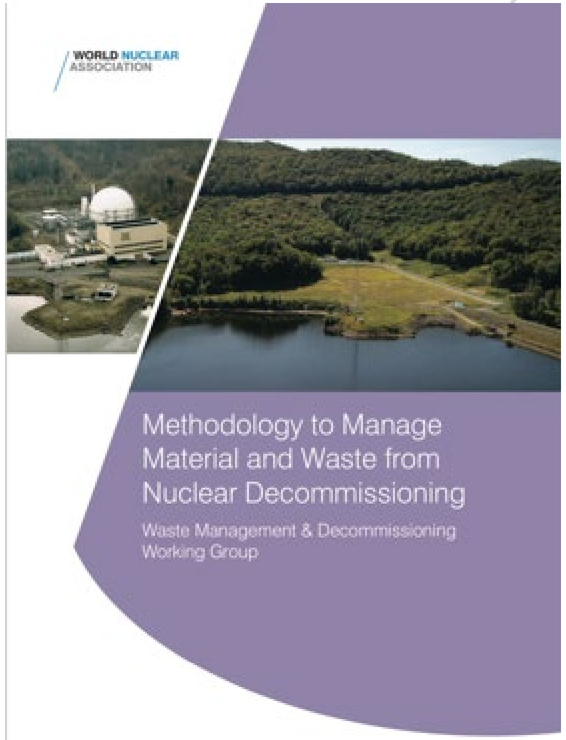
Classes: Public Use, Internal Use, Controlled Use, Restricted Use

Preparatory phase - decommissioning planning

Some elements of national policy are essential to develop an appropriate decommissioning program.

Before to draw up the decommissioning program it is necessary to evaluate the availability and the range of adequate:

- decommissioning funds;
- legislative and regulatory framework;
- fuel and waste management systems;
- suitable technologies and techniques;
- skilled human resources at the outset of the decommissioning activities;



and it is necessary to evaluate:

- Health, Safety and Environmental impact;
- Social impacts associated with decommissioning;
- Specific facility/site reuse demands.

Funding

The **availability of funding** for the duration of the project is essential to be able to safely manage the project.

In many countries where there are not enough funds set aside for decommissioning, governments intervene with alternative support measures.

In Italy an additional cost has been chosen for the electricity bill.

Delibera	a decorrere da	Lire/kWh	Euro cents/kWh
70/97 (*)	01-lug-97	1,5	-
161/98 (*)	01-mar-99	8	-
39/00 - 53/00	01-mar-00	0,6	-
146/01	01-lug-01	1	-
23/03	01-apr-03	-	0,06
252/04	01-gen-05	-	0,04
133/05	01-lug-05	-	0,03
321/06	01-gen-07	-	0,10
353/07	01-gen-08	-	0,18
ARG/elt 86/08	01-lug-08	-	0,180
ARG/elt 138/08	01-ott-08	-	0,164
ARG/com 44/10	01-apr-10	-	0,130
ARG/com 236/10	01-gen-11	-	0,086
ARG/com 201/11	01-gen-12	-	0,051

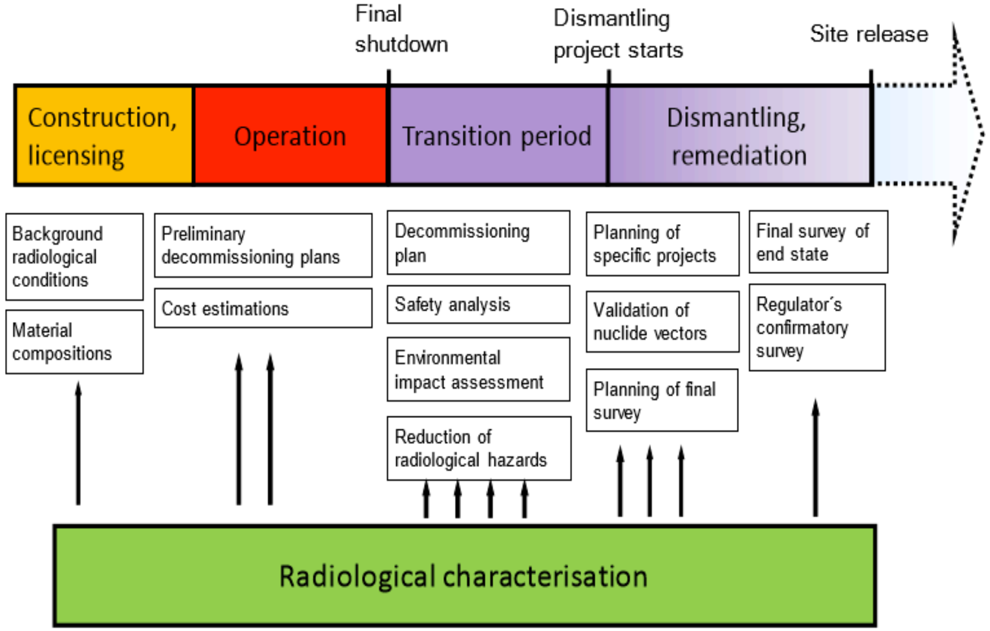
Characterisation process

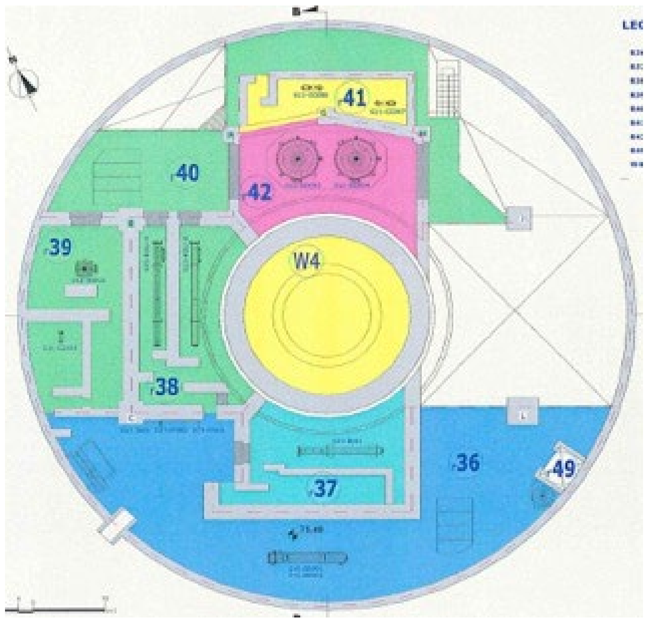
The knowledge of radioactivity distribution within the plant is one of the most important parameters to be known for the definition and execution of the decommissioning programme.

The principal objectives of the characterisation process are:

(1) to map radiation and contamination levels to plan for decommissioning activities in a safe and cost-effective manner and

(2) to develop a quantitative understanding of the nature of the wastes to be generated during the decommissioning process.

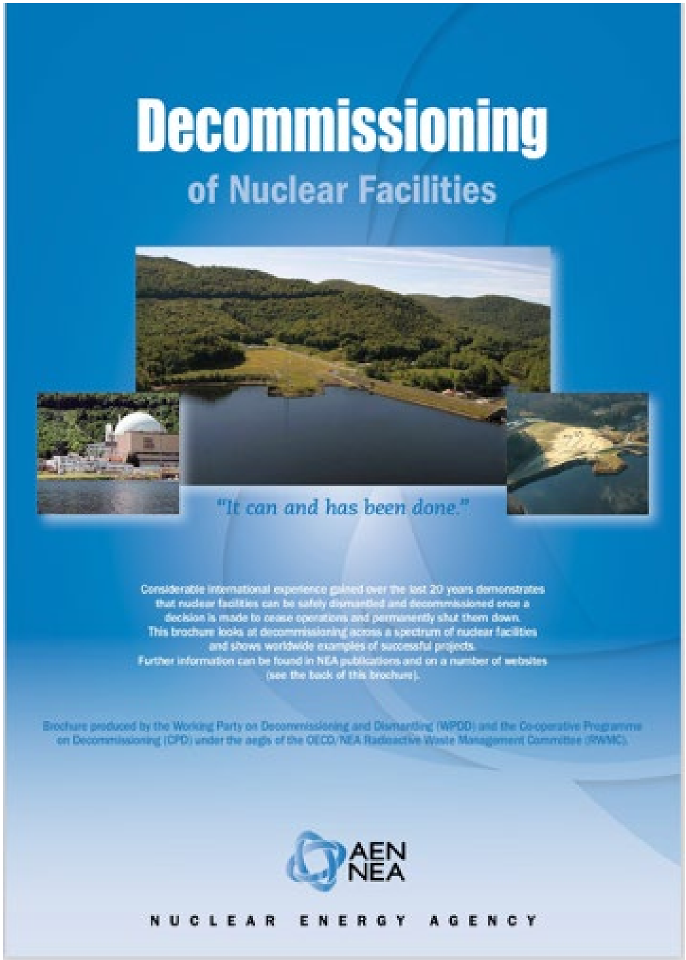




General documents and programs

The following documents as well as programs have to be addressed at a very early stage of the project, since most of them are necessary for the application of the **decommissioning authorization**:

- Environmental Impact Assessment
- Surveillance Program
- Training Program
- Quality Assurance Program
- Emergency Program
- Fire Protection Program
- Documentation Program
- Final Radiological Survey Program



Application for decommissioning authorization

A phase of study and preliminary activities are necessary to acquire the fundamental elements to draw up a concrete dismantling plan to be submitted to the approval of the regulatory authority. A robust plan generally contains (at least):

1. Overview
2. Description of the facility and operational history
3. Legal Framework
4. Decommissioning Strategy
5. Project Organization and Management
6. Organizational structure, a business plan, personnel and competencies
7. Quality assurance program
8. Physical and Radiological Inventory
9. Dismantling and Decontamination Techniques
10. Waste Management: Radioactive waste treatment and disposal
11. Temporary Installations and Equipment
12. Description of Decommissioning Activities and associated facilities
13. Methods for radioactive material removal, decontamination, dismantling
14. Safety and Environmental Impact Assessment
15. Counter measures against radioactive hazards
16. Description of programs during D&D. Work schedule
17. Final Radiological Survey
18. Decommissioning Costs

Final radiological survey

For its completeness, the decommissioning plan must provide the description of the final radiological control or postpone them to a subsequent phase that can be authorized separately.

The final radiological survey should include the following main facts:

- Description of the radiological conditions of the site;
- Demonstration of potential dose and risk from any residual contamination;
- Demonstration of compliance with all pre-set radiological parameters.

The final radiological survey includes a map of the plant with all reference areas and their justification.

It also gives details on the methods of justification, i.e. instruments used. The sampling process is described as well as the laboratory analysis and data validation and the quality control process.

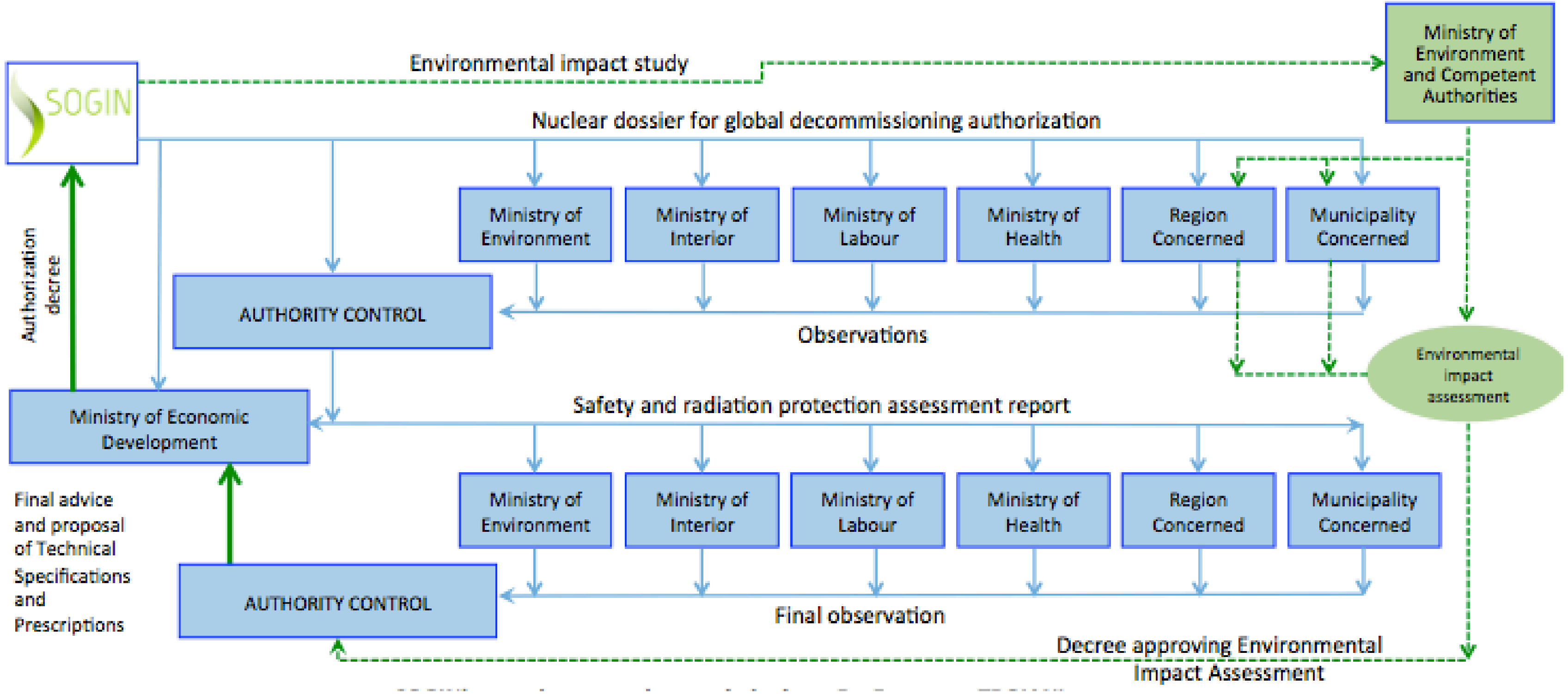
The final radiological survey is necessary for the application for the license for unrestricted use of site and the conventional demolition license.

Decommissioning licensing procedures

The decommissioning authorization process is very complex, proceeds step by step and involves many stakeholders.

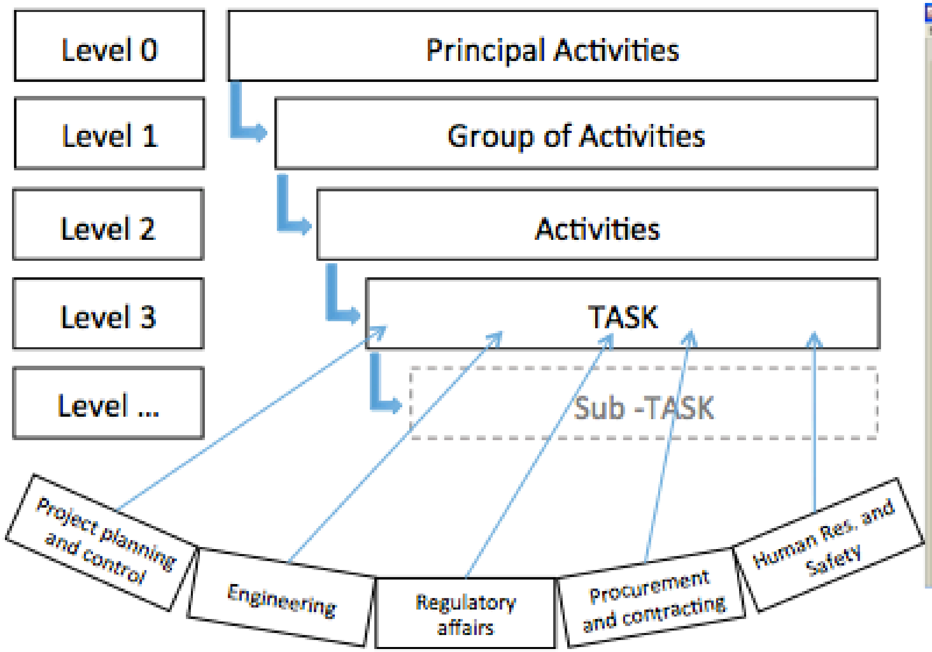
Local authorities can hold public debate sessions.

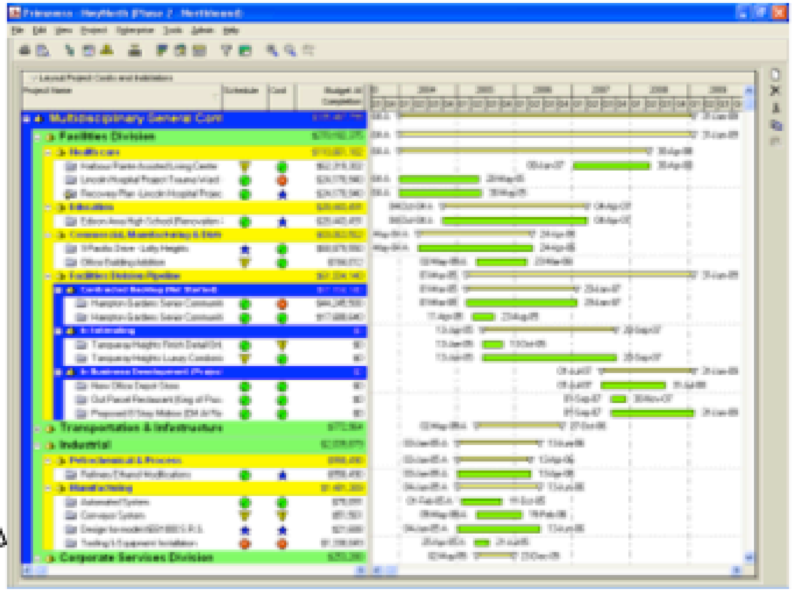
As an example the Italian case



Decommissioning programming

A **decommissioning time plan** has to be implemented, based on the achieved authorization (or submitted dossier), composed of several levels.
As an example, the Italian case is reported.





Decommissioning project: execution

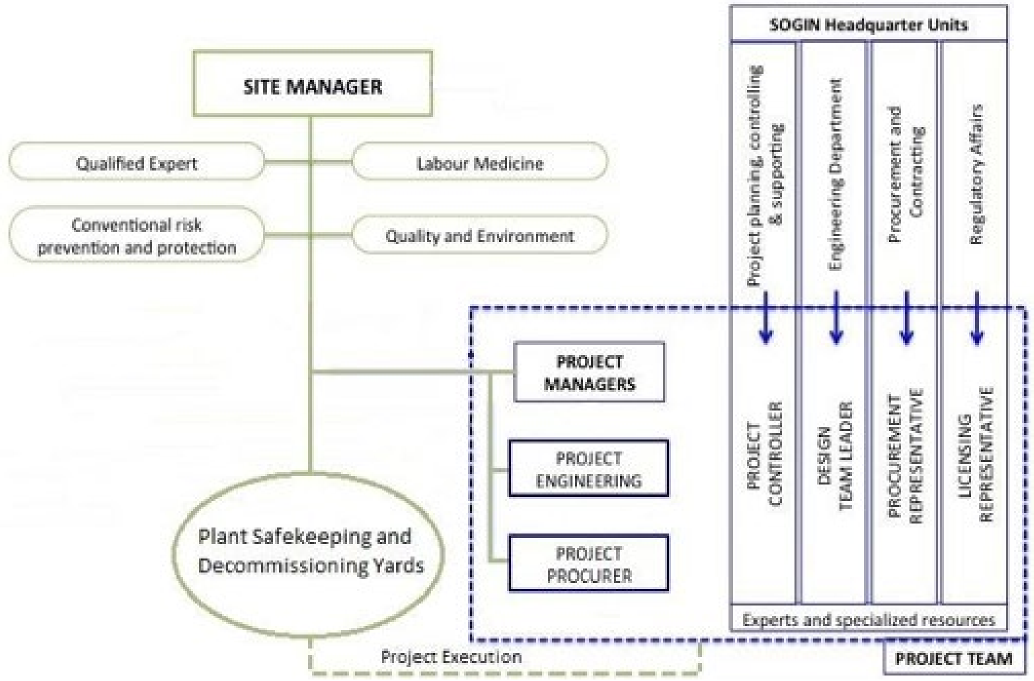
The responsibility for project management and implementation is normally the Site Manager, which can also appoint a reliable Project Manager.

As an example, in SOGIN which is multi-site organization, a Project Team system has been established.

The **Project Team** is a dynamic organizational structure that manages decommissioning projects.

Project Team is composed by specialized resources, both from the local Site and from headquarters' functions, who support Project Manager (PM) in managing and coordinating activities.

Project Team's members continue to depend on the Function or Site they are employed for, but at the same time they work for the Project Manager, within the Project.



Financial aspects of Decommissioning

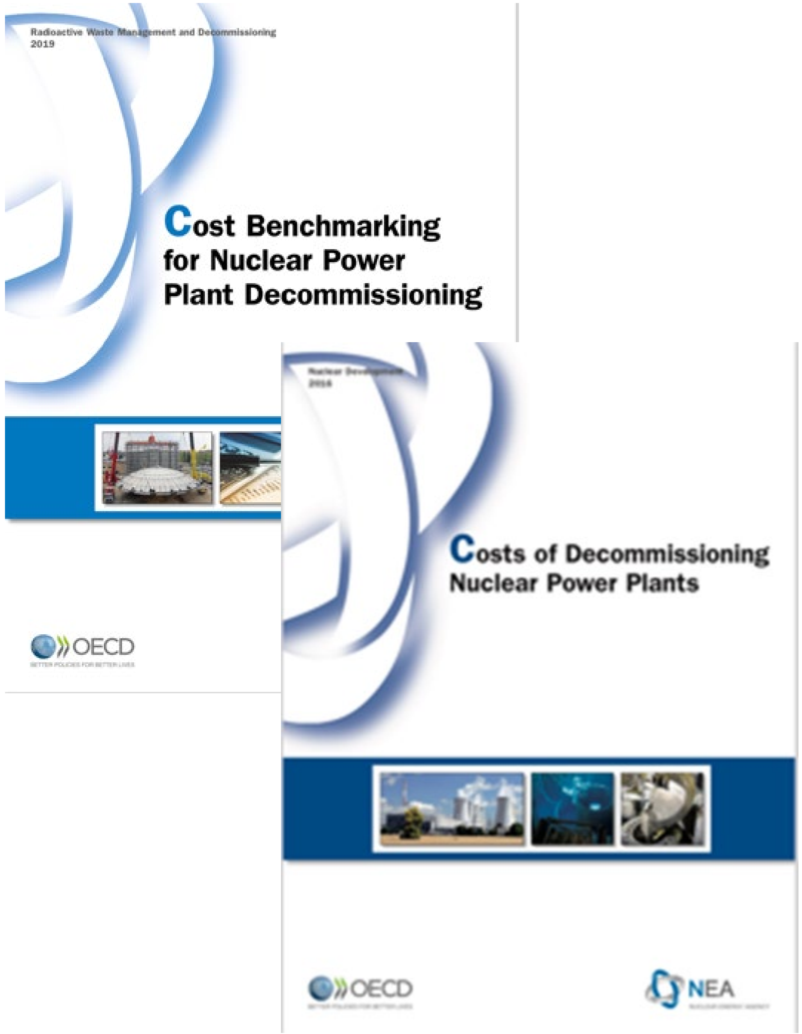
There exist three main types of decommissioning cost studies that organizations have to produce in order to get authorizations to perform decommissioning.

Namely, for the purpose of:

- securing funds;
- preparing a decommissioning plan within the context of licensing;
- detailed budgeting baseline for decommissioning implementation.

These cost studies are updated at different stages of the decommissioning process. Three observations can be made to this effect:

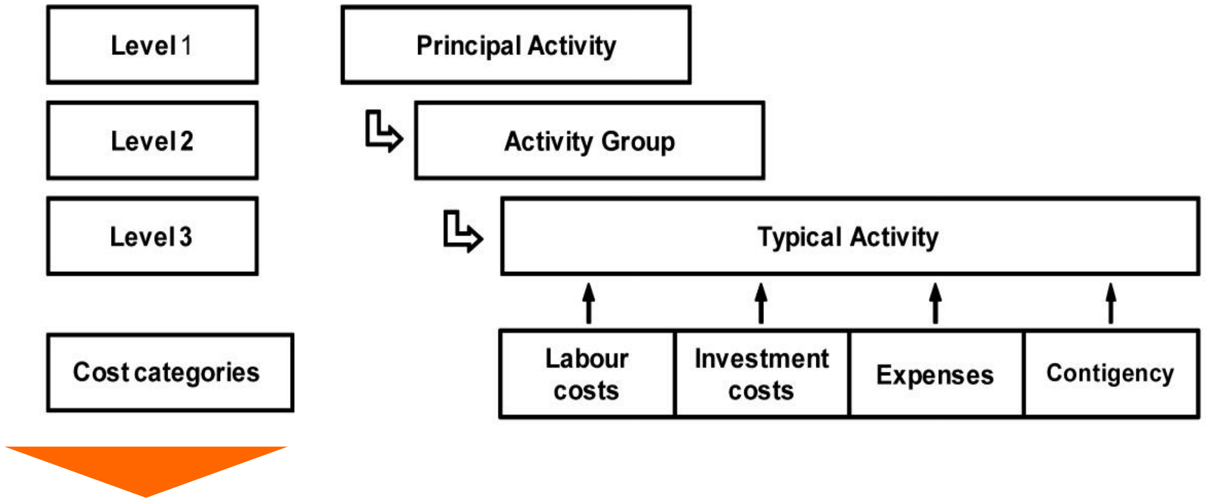
- each decommissioning cost study may be different in its details;
- it is desirable to make comparisons between cost estimates over time, and it is important to have a stable structure to each cost study;
- consideration should be given to coordinating the updates of decommissioning plans and funding schemes in relation to updates in the cost studies.



ISDC Standard methodology

The International Structure for Decommissioning Costing (ISDC) sets out a standardised structure of cost items for decommissioning projects and provides general guidance on developing a decommissioning cost estimate.

The ISDC focuses mainly on using the cost itemisation structure to ensure that all costs within the planned scope of a decommissioning project are reflected by identifying all typical activities of any decommissioning project.



- ISDC is a numbered hierarchical structure of typical decommissioning activities for any project
- Level 3 is the reference level; at this level are the cost data identified and presented
- Levels 2 and 1 are aggregating levels

Risk Analysis

Analysis of sensitivities and risks has to be performed at early stage of the project.

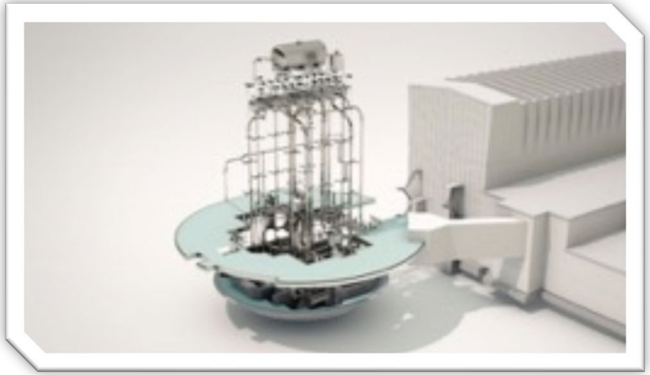
The following topics, as an example, have to be be analyzed:

- project duration (e.g. reduction of project time /delays);
- manpower requirements (e.g. tolerances in number off staff);
- dismantling efficiency (i.e. optimization of work);
- price escalation, wages, external services and provisions (i.e. changes in wages);
- decontamination and release of building structures (i.e. additional expenditures for building decontamination);
- spent fuel management (i.e. delay in the post-operational phase);
- waste treatment and packaging cost (i.e. different packaging strategy);
- ……

Probability and Impact Diagram

Probability	Severity 1	Severity 2	Severity 3	Severity 4	Severity 5
Molto Alta	6	12	18	36	72
Alta	4	7	14	28	56
Media	3	5	10	20	40
Bassa	2	3	6	12	24
Molto bassa	1	1	2	4	8

To this aim, 3D modelling helps in spooling definition, waste route definition (interferences during handling of large components, etc.), physical inventory (components masses), cost estimate (definition of spooling, cuts and man hours, etc.).



Periodic updates of plan

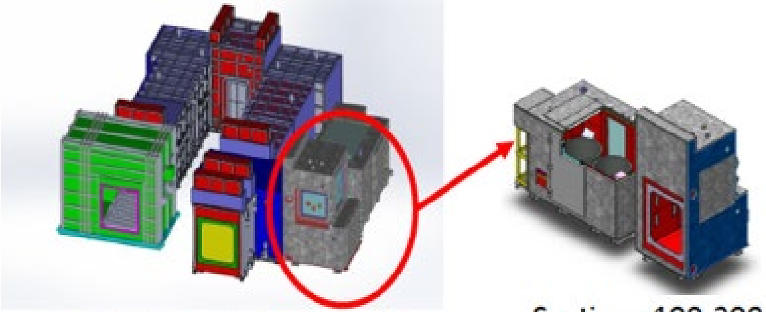
Basically, the decommissioning plan needs to be periodically updated, main in relation of external changing.

As decommissioning proceeds, the initial uncertainties can be reduced and the introduction of new technologies can streamline the subsequent stages.

Some topics can change fairly quickly and then create the need to review the project, as an example:

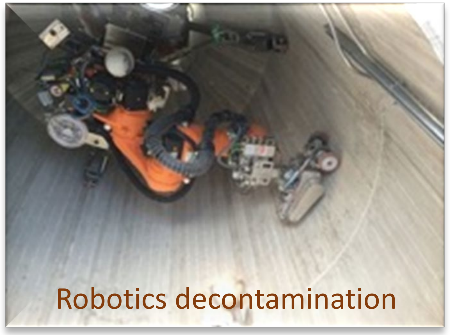
- Regulations
- Local situations
- Radiological inventory
- Waste management systems
- Repository waste acceptance criteria
- Technological Innovation


Home design system for cementation


SiCoMoR modules disposition

Sections 100-200

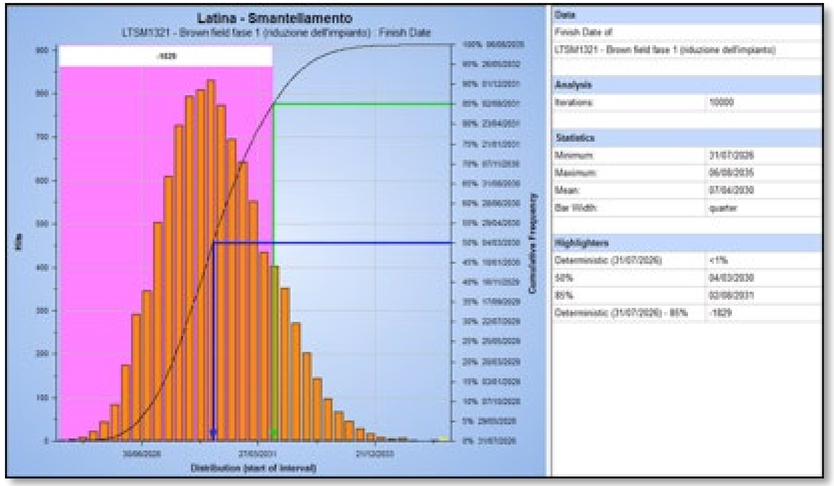

Confined alpha demolition system

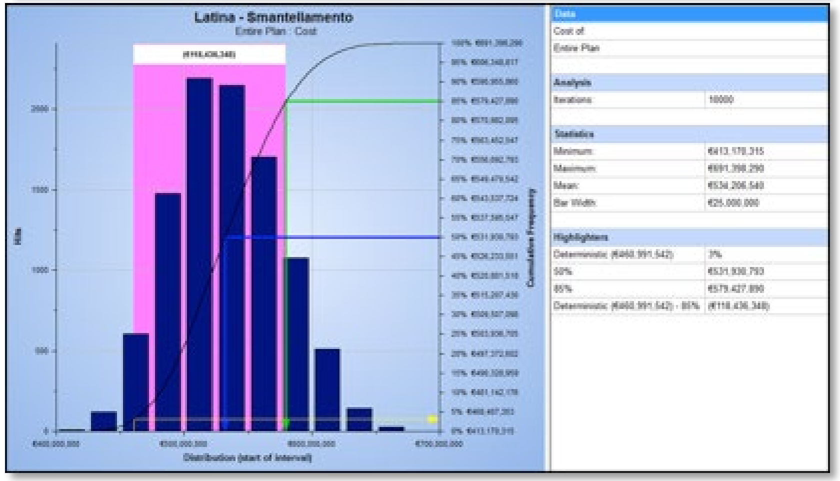

Robotics decontamination

Risk Analysis - outcomes

Sogin has developed a **customized IT solution for Project Risk Management** based on the integration between the "Primavera P6 System" and the "Risk Analysis Module".

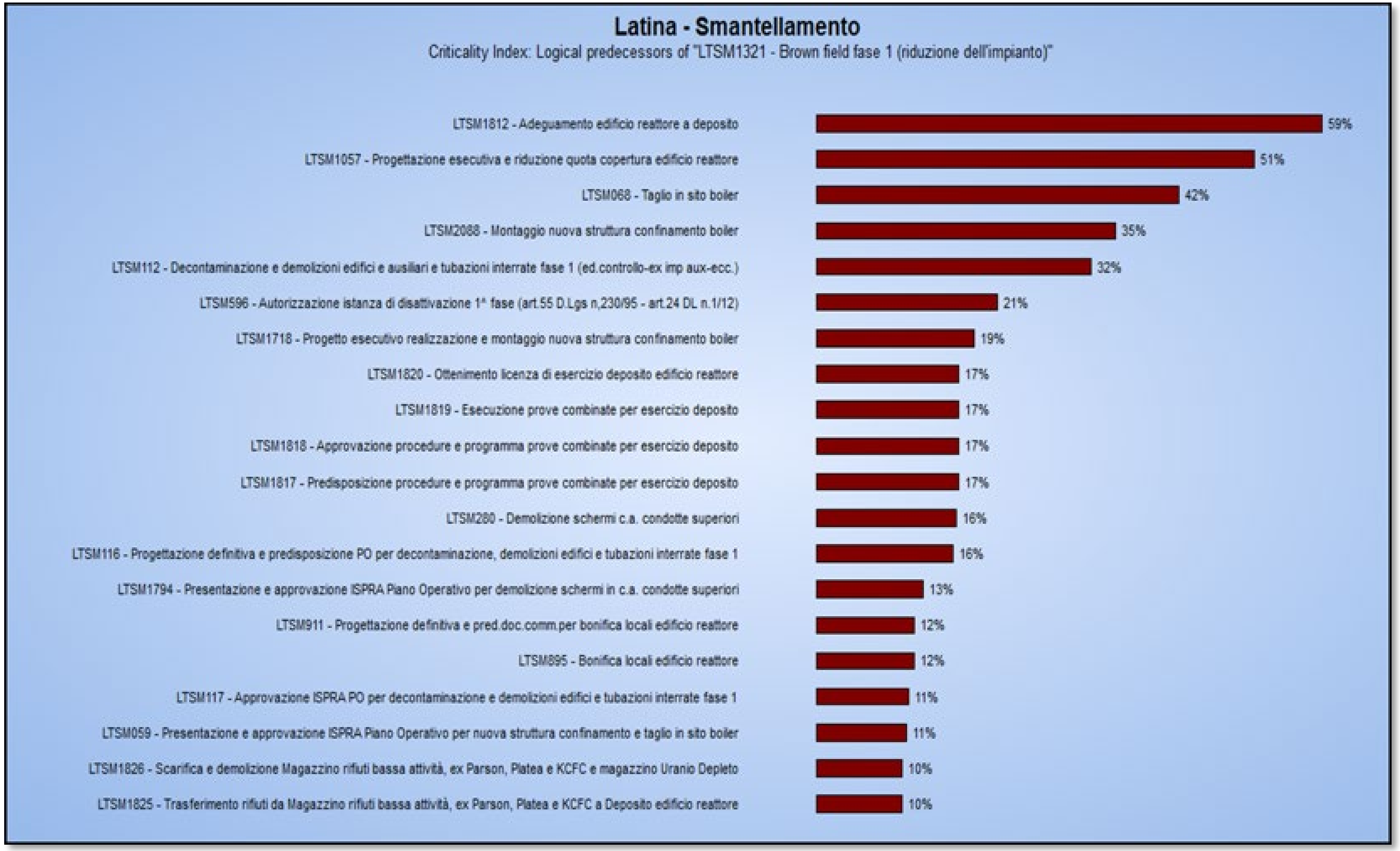
Results of **Montecarlo simulation** show the statistic distribution for both end of project dates and total project costs; on such distributions it is possible to identify time and costs variations associated to different confidence levels.





Risk Analysis - Criticality Index

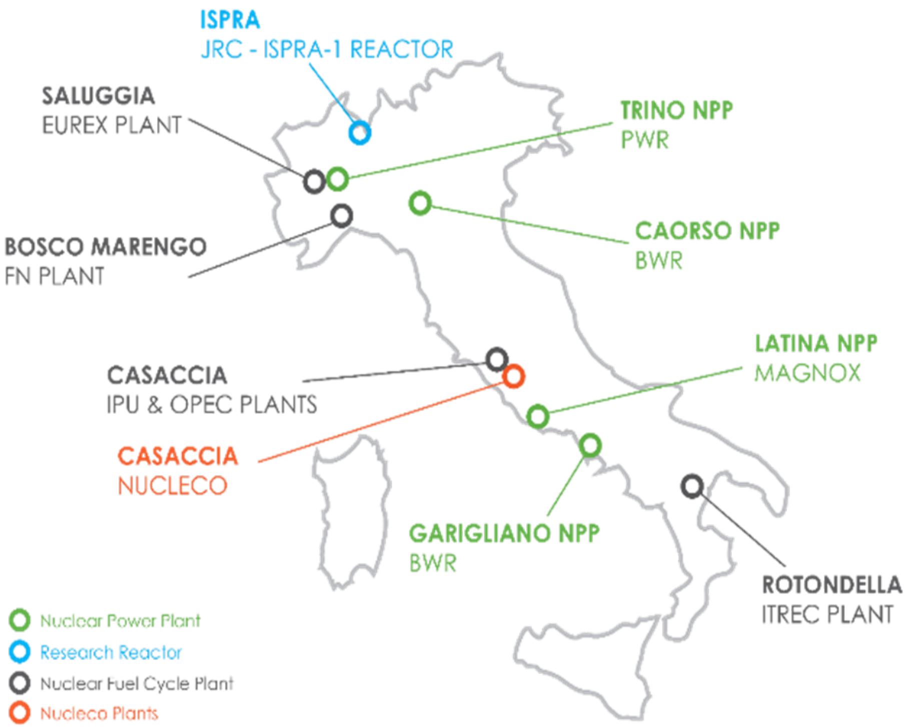
From risk analysis a list of critical path can be established



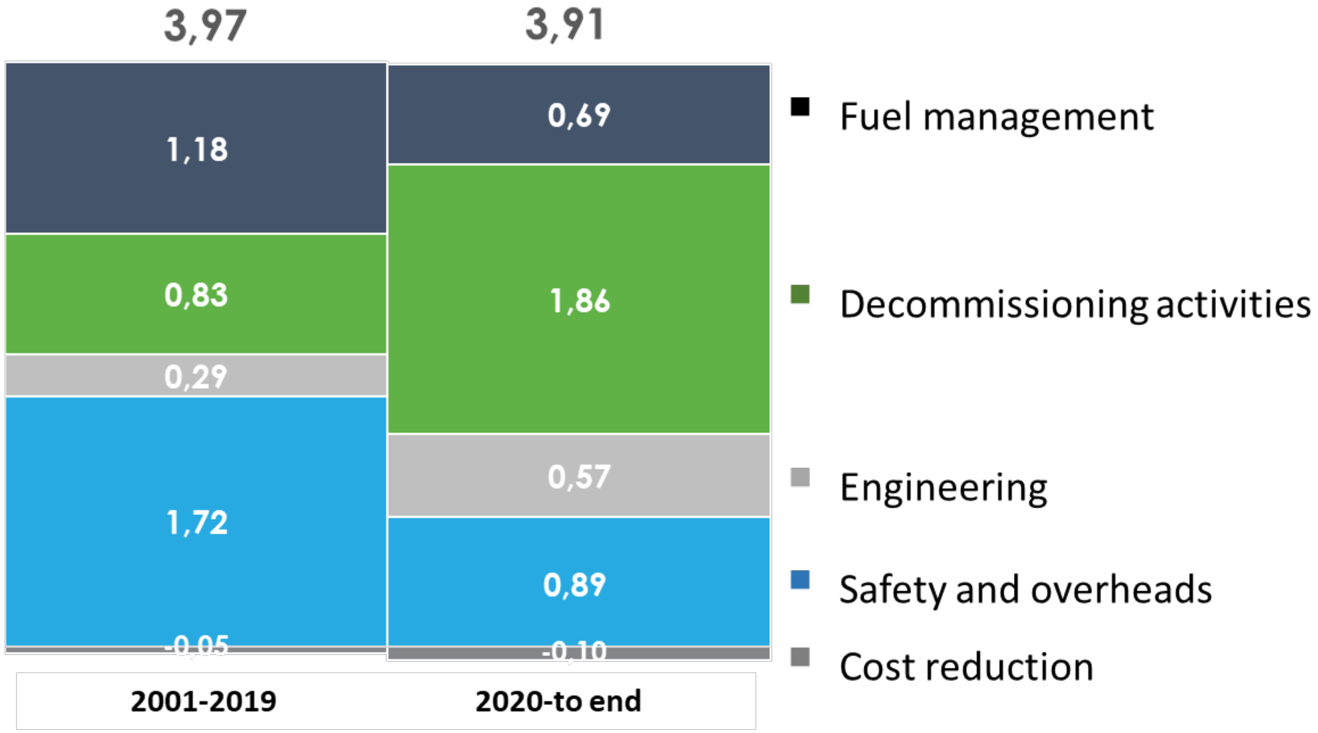
Decommissioning Value

Certified by IAEA Peer Review 2017

IAEA International Atomic Energy Agency

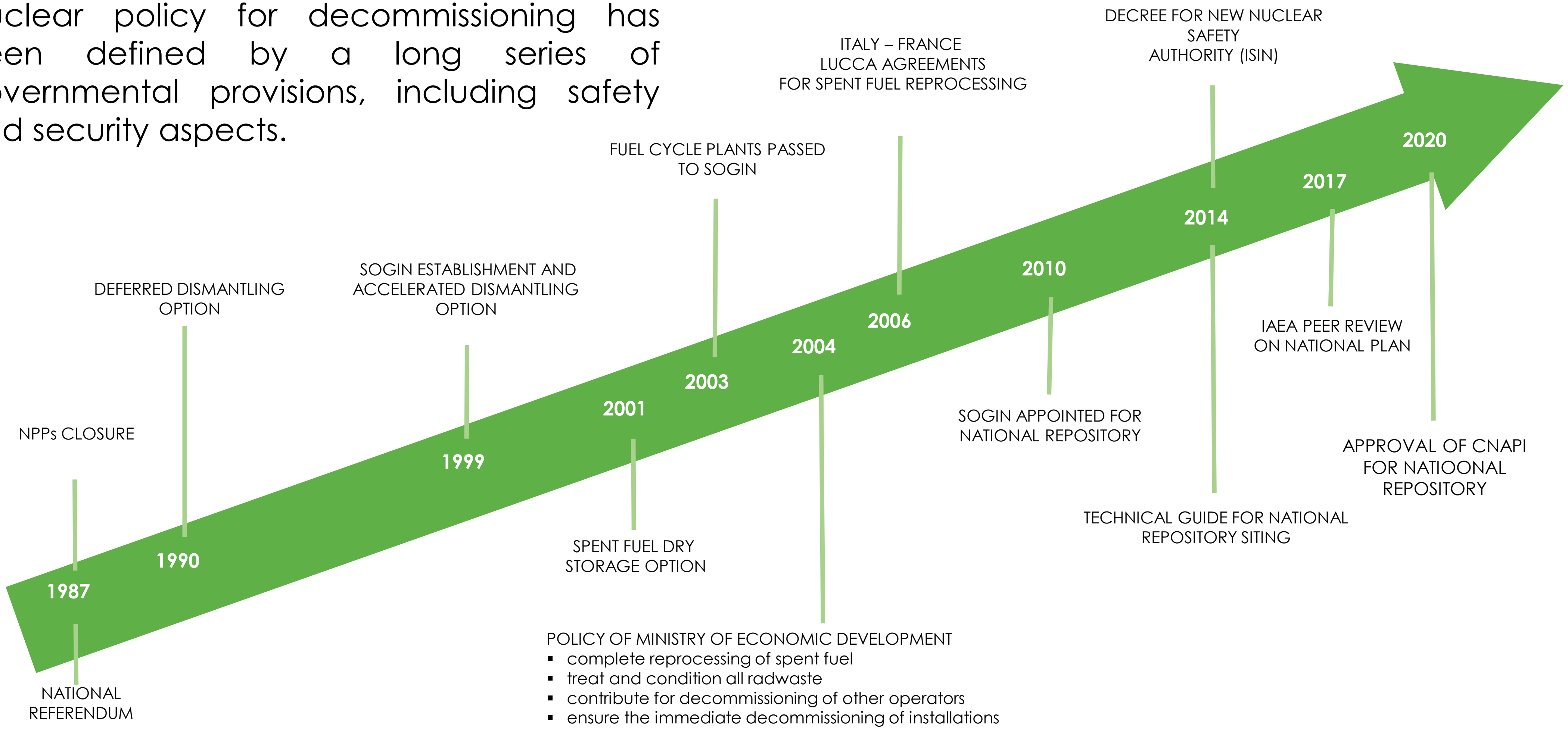


7,9 Billion €
VALUE OF THE LIFETIME PROJECT



Italian Policy and Strategy Overview

Nuclear policy for decommissioning has been defined by a long series of governmental provisions, including safety and security aspects.

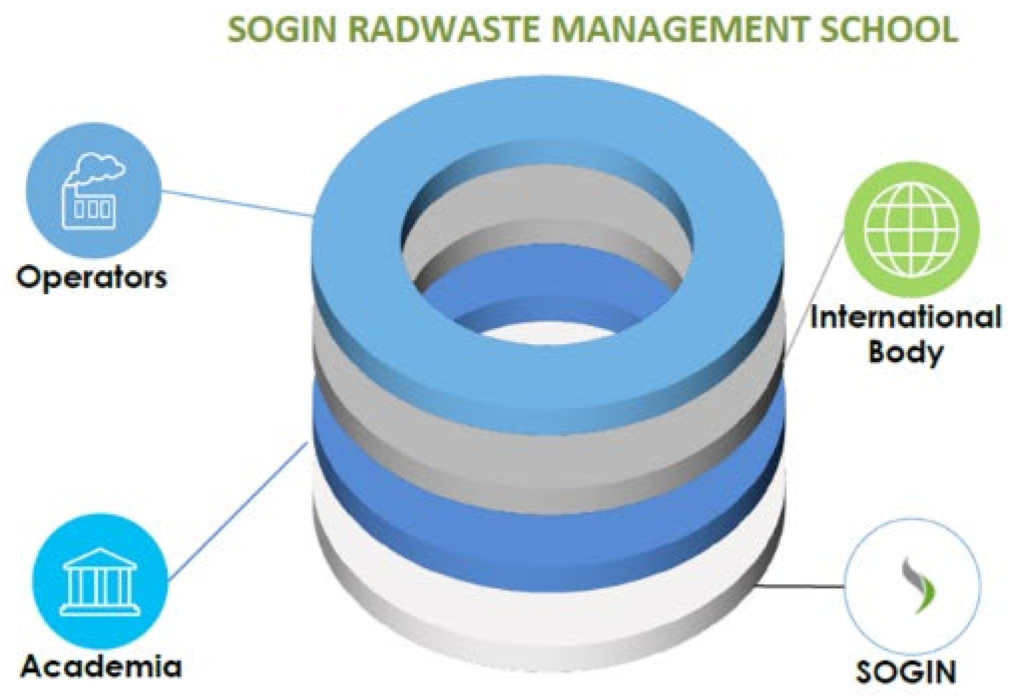


Sogin Approach to decommissioning

- The dismantling activities **start from the less contaminated areas** of the plant and progress towards the most contaminated ones. This means that activities start with the dismantling and demolition of auxiliary buildings and progress towards the nuclear islands;
- Dismantling activities of technological components/systems are **anticipated in those rooms/buildings that shall be reused** even if for other purpose, e.g. waste management facilities (WMF) or buffer storage facilities;
- Demolition activities can be anticipated for those buildings that are no longer necessary and conventional, whose demolition allows the **gaining of reusable volumes for other purposes** (e.g. the construction of new temporary storages on site);
- Demolition or structural adjustment activities can be anticipated for those buildings that **no longer meet current regulations**.
- **Treatment and conditioning** of the radioactive waste produced during the past operations and coming from decommissioning activities;
- **Temporary storage** of final waste packages on site till the availability of the National Repository for final disposal

Knowledge Management

Knowledge transfer to young generation is the key objective to ensuring continuity in decommissioning activities to be carried out according to the highest level of safety standards



OECD NESTet 2011

NUCLEAR EDUCATION AND TRAINING

UE ELINDER

European Learning Initiatives for Nuclear Decommissioning and Environmental Remediation

… in order to

NPPs Status of Decommissioning Activities

TRINO

- **ACHIEVEMENTS**
  - Removal of hazardous waste, particularly asbestos, and radioactive waste conditioning.
  - Removal of spent nuclear fuel from the site.
  - Chemical decontamination of the primary circuit (vessel and internals excluded).
  - Dismantling of secondary circuit.
  - Removal of non- contaminated materials.
- **WORK IN PROGRESS**
  - Temporary Storage Adaptation.
  - Plant assembly for treatment of high activity spent resins by wet oxidation.
  - Treatment and conditioning of previous waste
  - Removal of equipment from SFP
  - Preliminary design for RPV and RVI dismantling

CAORSO

- **ACHIEVEMENTS**
  - Removal of spent nuclear fuel from the site and radioactive waste conditioning.
  - Decontamination of thermal cycle (vessel and internals excluded).
  - Dismantling of RHR cooling tower and systems and components inside of Turbine Building and Off Gas building (5,800 ton of metallic scraps decontaminated and free released).
  - Construction of a waste route between RB and TB
- **WORK IN PROGRESS**
  - Adaptation of Turbine Building to radioactive waste buffer and WMF.
  - Treatment and conditioning abroad of exhausted resins
  - Adaptation of onsite temporary storage for LLW
  - Design of temporary storage for ILW
  - Preliminary design for RPV and RVI dismantling

LATINA

- **ACHIEVEMENTS**
  - Conditioning of radioactive waste.
  - Removal of spent nuclear fuel from the site.
  - Dismantling of primary circuit pipelines
  - Fuel pools remediation.
  - Construction of a new temporary storage facility.
  - Dismantling of component and demolition of turbine building
  - Demolition of boilers containment structures.
  - Construction of a new Effluent Treatment Plant.
- **WORK IN PROGRESS**
  - Construction of "Cutting Facility" for boilers treatment and metallic materials
  - Execution of activities for boilers dismantling

GARIGLIANO

- **ACHIEVEMENTS**
  - Removal of hazardous waste, particularly asbestos, and radioactive technological waste conditioning.
  - Removal of spent nuclear fuel from the site.
  - Remediation Trenches n. 2 and n. 3.
  - Stack dismantling and construction of a new one.
  - Construction of a new liquid waste treatment system.
  - Remediation of Trench n. 1.
  - Restoration of reactor building auxiliary systems.
- **WORK IN PROGRESS**
  - Dismantling of systems and components of the thermal cycle turbine building.
  - Design activities for Vessel Internals dismantling.
  - Restoration of the flooding circuit
  - Realisation of temporary storage facility for LLW and ILW

FCFs Status of Decommissioning Activities

SALUGGIA

- **ACHIEVEMENTS**
  - Conditioning of radioactive waste;
  - Transfer of liquid waste with higher radioactivity in the New Park Tanks;
  - Removal of spent fuel and nuclear materials from the site in the US (GTRI Program).
  - Construction of Temporary storages
  - Treatment and conditioning of old radioactive solid waste arising from fuel fabrication plant – IFEC.

WORK IN PROGRESS

- Realization of the plant for conditioning by cementation of radioactive liquids with high activity – CEMEX.

CASACCIA

- **ACHIEVEMENTS**
  - Removal, packaging and shipping of nuclear materials to the USA (GTRI Program).
  - Glove Boxes dismantling using alpha-tight tent technique
  - OPEC-2 building adaptation for storage of plutonium contaminated wastes.
  - Retrieval of old underground tank park, collecting radioactive liquid effluents.
  - Dismantling of plutonium contaminated glove boxes with greater complexity.
  - Operation of the OPEC-2 storage building with unconditioned LLW
- **WORK IN PROGRESS**
  - Conditioning of radioactive waste.
  - Commissioning of new glove box for in-drum cementation of alpha contaminated liquid waste

TRISAIA

- **ACHIEVEMENTS**
  - Conditioning of radioactive waste, both liquid and solids.
  - Removal of nuclear materials from the site to the USA (GTRI Program).
  - Remediation of underground storage.
- **WORK IN PROGRESS**
  - Realization of cementing plant for U-Th solutions.
  - Cask realization for the dry storage of Elk River spent fuel.
  - Realisation of a temporary storage facility for ILW and Cask

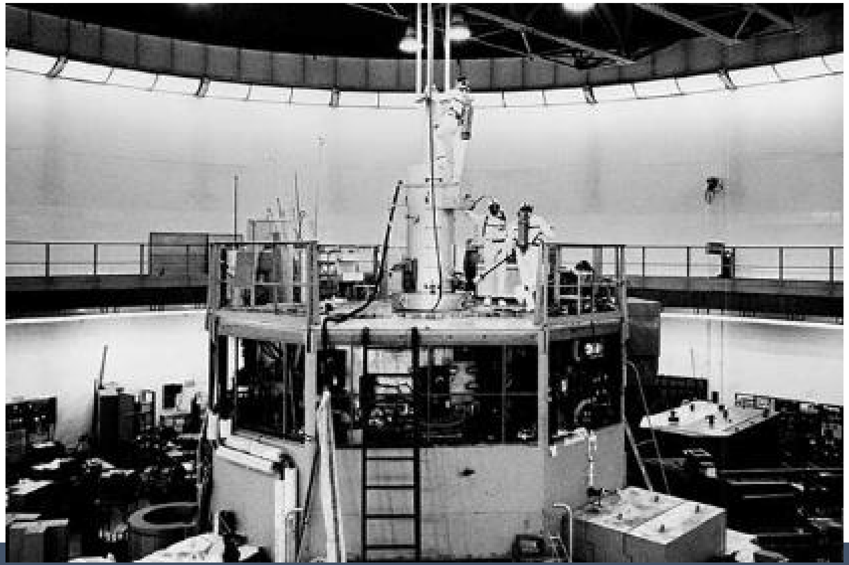
Fuel-Res Status of Decommissioning Activities

BOSCO MARENGO

- **ACHIEVEMENTS**
  - Conditioning of radioactive technological waste.
  - Removal of all nuclear materials from the site.
  - Fabrication cycle entirely dismantled.
  - Construction of Temporary storage.

WORK IN PROGRESS

Few remaining activities to reach end state



ISPRA 1

- **ACHIEVEMENTS**
  - Phase I dismantling application, presented by Sogin on April 2020
- **WORK IN PROGRESS**
  - Spent fuel pool emptying, drainage and purging
  - Design phase for temporary storage facility and other preliminary activities

Lessons learned

- ✓ **Lifecycle planning** is an important tool to ensure to have the necessary skills, resources, facilities, technical solutions and funding available on the projected time-frames
- ✓ **Innovation**, both in management approaches and technology development, is a key challenge aiming at improving performances, safety and waste minimization.
- ✓ Sharing the **good practices** and **lessons learned** gained from past activities, is essential to ensure the future development of robust and optimized decommissioning plans
- ✓ Early **stakeholder engagement** will facilitate development of mutually agreeable decommissioning solutions
- ✓ **Supply Chain engagement,** through specific workshops, help to provide a complete overview on decommissioning plans and future investments and to highlight the opportunities for the Suppliers
- ✓ **Knowledge transfer** to young generation is the key objective to ensuring continuity in decommissioning activities to be carried out according to the highest level of safety standards

Nuclear decommissioning and Circular Economy

Opportunities exist at different phases and levels

operation → safe store → dismantling and demolition → site restoration → post-decommissioning use

1. materials and components
2. buildings
3. local communities
4. whole regions

Circularity principles in current practices

- refurbishing and extending the life of existing plants
- recycling of metals and other materials that are conventional wastes
- reusing components from closed reactors
- repurposing buildings for processing and storage of waste, rather than constructing new ones
- reuse of demolition rubble as fill material

\+

Knowledge management

- Sharing experiences and Lessons learned
- Giving feedback for the design of new facilities

Strategic view

- Decommissioning as a sustainable process to support further development of the site

Decommissioning as an opportunity

Sogin Circular Economy Strategy

The **3 drivers** underlining the circular economy applied by Sogin to nuclear decommissioning are the following

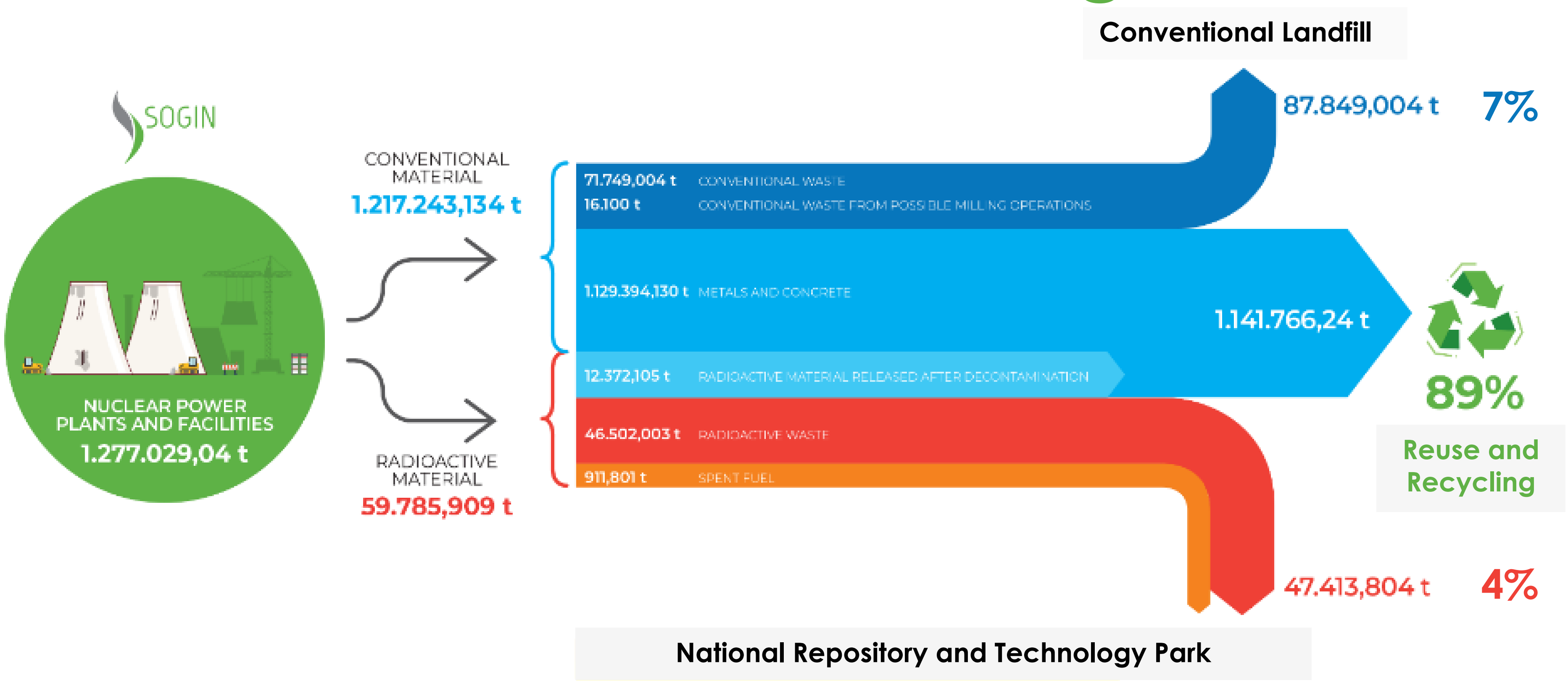
GREEN ENGINEERING

1	2	3
Re-use of structures, systems and components	Material Recycling	Environmental Impact Reduction

GREEN PUBLIC PROCUREMENT

The full implementation of the actions envisaged in the 3 objectives can be carried out by implementing green engineering and green public procurement policies.

Destination of decommissioning materials



Sustainability Objectives

- ✓ **minimizing** the amount of radioactive waste produced
- ✓ **recycling** metal and concrete materials
- ✓ **reusing** existing premises, areas and technological components
- ✓ **reducing** energy sources and using high-efficiency components
- ✓ **improving** environmental performance and green procurement

Innovation in D&D and RWM

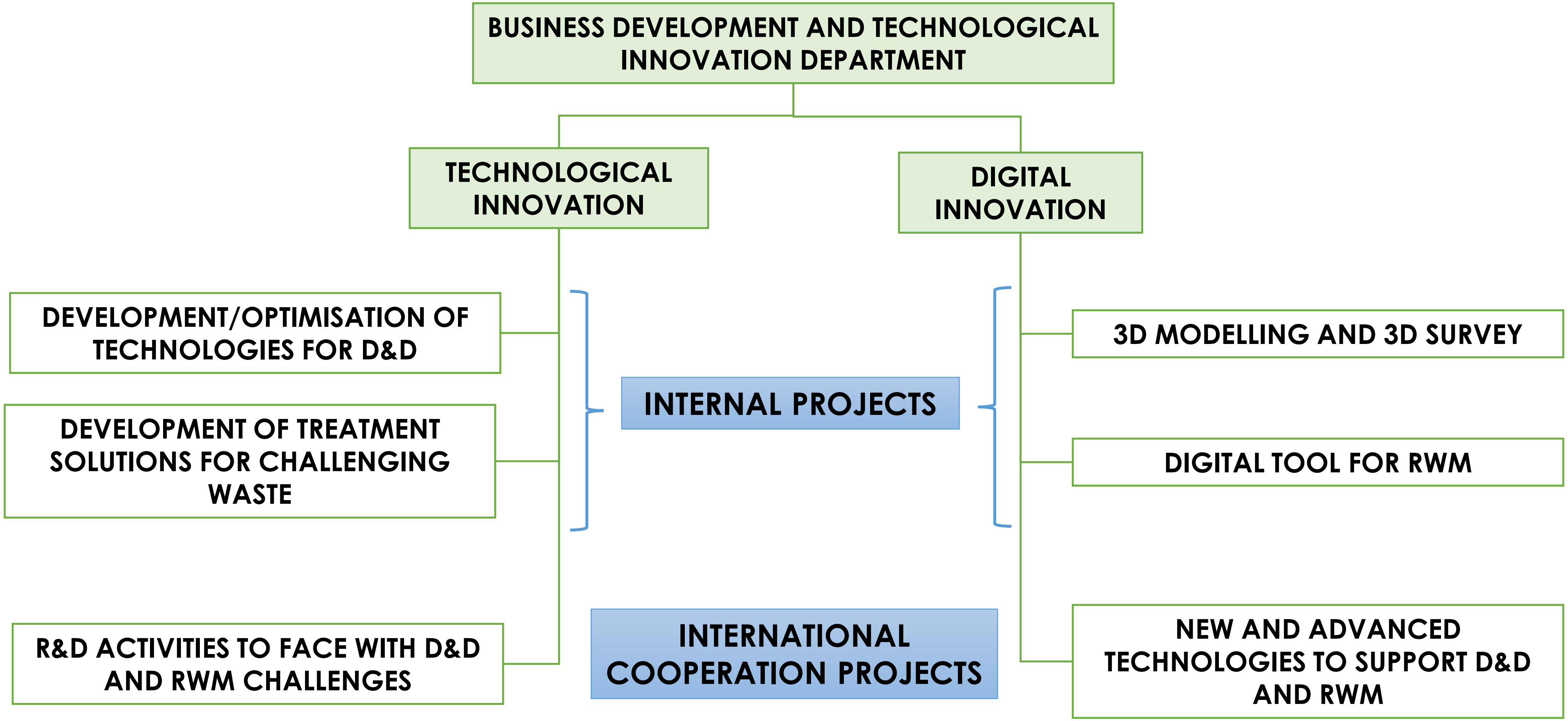
Innovation in D&D and RWM

Innovation, both in management approaches and technology development is a key point for making decommissioning and waste management more cost effective, faster and safer.

In SOGIN, the state-of-the-art technology for decommissioning of nuclear installations has been considered adequate to cope with most difficulties associated with the dismantling of such facilities.

Nevertheless, it has also been recognized the need to improve, adapt or optimise technologies for the specific needs.

Innovation in SOGIN



Internal Projects - SiCoMoR

Sogin Modular System for Waste Cementation

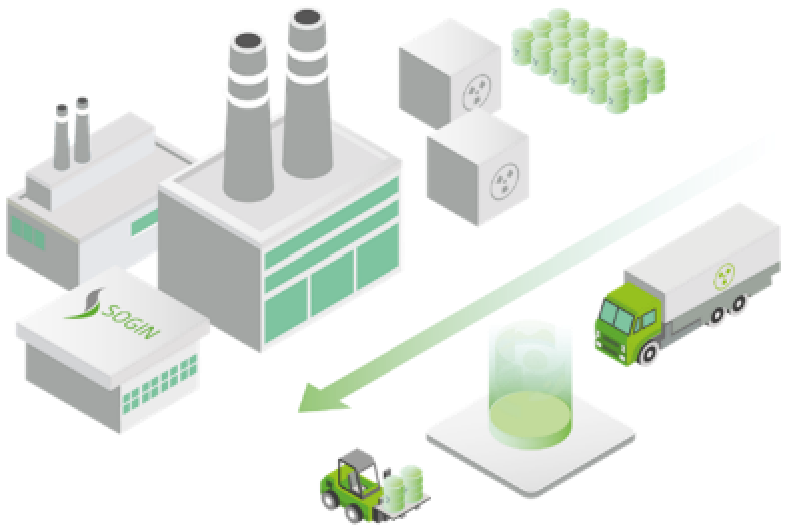
- Able to process different types of radioactive waste (liquid, sludge, resins, powder, etc.), containing beta/gamma and/or alfa emitters
- Modular system, transportable and easy dismountable, without any permanent building

- Due to modular concept, the plant can be assembled for different productivity
- It can be used for waste conditioning campaigns in different sites to optimize the re-use of resources
- Final waste package: cylindrical 440 l drum

Internal Projects - AIGOR

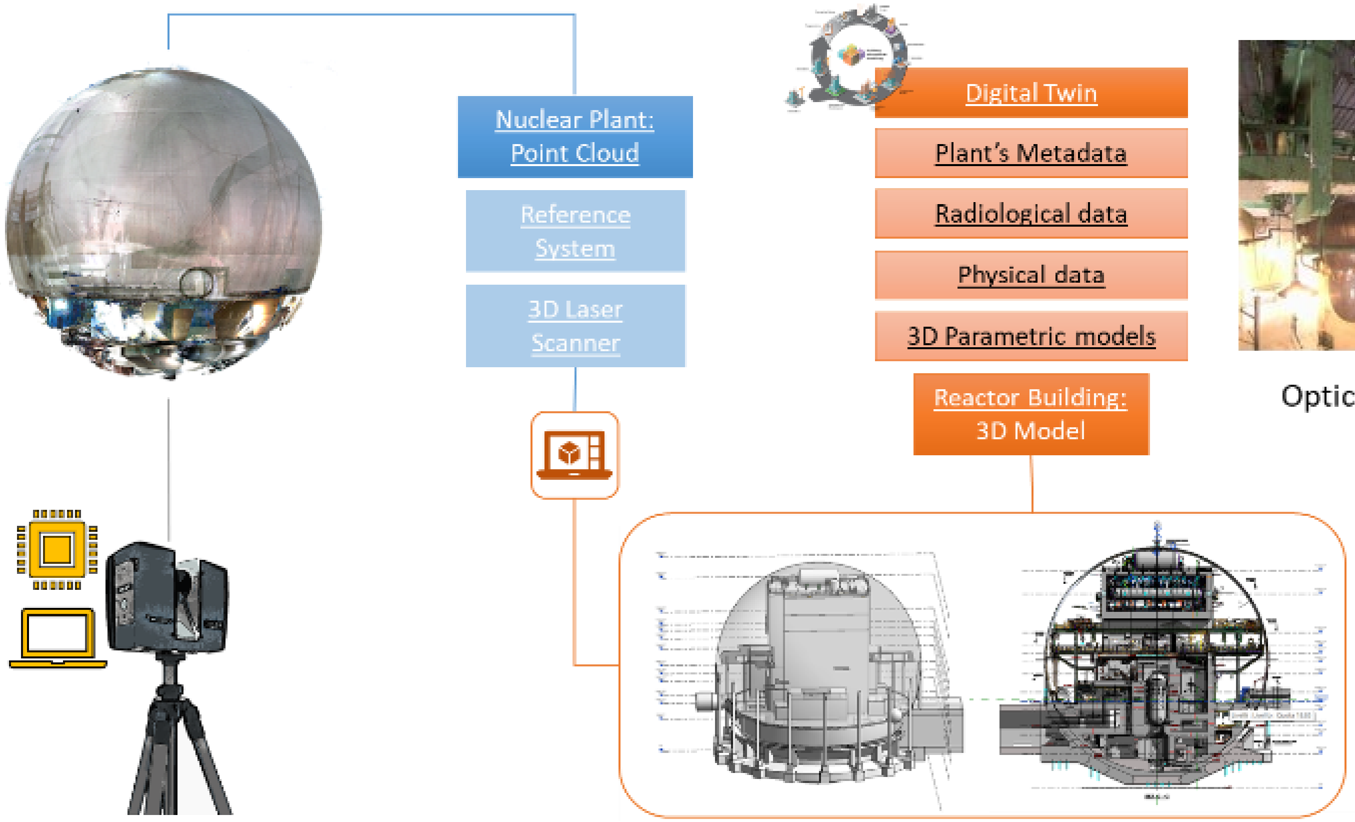
Sogin IT Tool for RWM

- AIGOR (IT Radioactive Objects Management System), to optimise RWM by a multi criteria analysis to select the most appropriate Waste Process Route for defined Waste Streams. Based on blockchain, it will ensure the integrity of data and processes, and the safety of information.

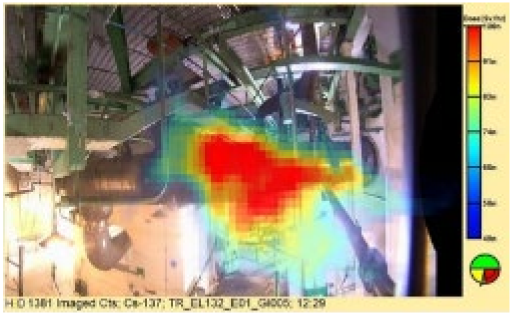


- Set up a center (at a national level) for collecting and archiving all the quantitative and qualitative data of the radioactive objects managed by Sogin
- Guarantee a homogeneous application of terminologies, classifications, treatment processes, etc. for similar types of radioactive objects in all decommissioning sites
- Ensure the connection with the historical data of a radioactive object for the purpose of reconstructing the processes to which it has been subjected over time

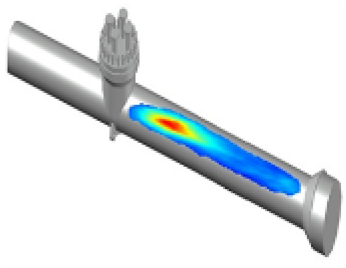
Internal Projects – NUCLECO 3D Survey



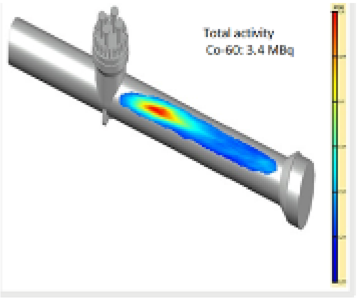
Optical image of the pipe



Gamma imaging on the pipe



Reconstruction of the assayed pipe



Final output

- **Data Input**: Historical Information (Plant Metadata) + Laser Scanning (Point Cloud) + Gamma Imaging (Radiological data)
- **Data Output**: 3D model of systems and components (all the technical, physical and radiological information are included) to proper feed the BIM Common Data Environment (CDE)

International Cooperation

- Sogin is actively taking part in the **EU Research and Innovation Framework Programme** to:
  - Benefit from the exchange of information and sharing of knowledge with other countries
  - Maintain expertise and development of specific solutions on complex issues related to D&D and RWM
  - Acquire a partial financing from the EC on some specific activities already included in the Sogin General Time-life Plans

- Sogin is actively taking part in the **working groups of the most important International Organizations** in the nuclear sector with two primary goals:
  - Play a pro-active role in drafting guidance / standard that will have an impact on Sogin activities
  - Be continuously updated to the best practices, know-how and international standards

> *Sogin has been designated IAEA Collaborating Center*

EU Research and Innovation Programme

What is it?

Research and Training (R&T) programmes implemented by the European Commission (EC), under the provisions of the European Atomic Energy Community (Euratom) Treaty, in which all European Union (EU) Members States participate.

What is its role?

To supplement and coordinate MS' programmes to perform joint and/or coordinated cutting edge research, to support knowledge creation and knowledge preservation. To avoid duplication and achieve critical mass if needed.

How is it implemented?

By Multi annual Framework Programmes (FP), 5 years +2 since FP7 and annual / biannual Work Programmes

Projects of up to five-years duration are funded after calls for proposals evaluated by independent experts

Latest programmes: HORIZON-2020 (2014-2020) – HORIZON EUROPE (2021-2027)

HORIZON-EURATOM Projects - Completed

SOGIN

SHARE
A roadmap for research in Decommissioning

June 2019
3 year project

11 Partners
9 Countries

StakeHolderS-based Analysis of Research for Decommissioning
https://share-h2020.eu/

The main objectives:

- to increase coordination between the various stakeholders involved in research activities related to decommissioning and who have an interest in ensuring that decommissioning can be implemented in a safe, effective and sustainable manner.
- SHARE consortium provided an inclusive roadmap for stakeholders in Europe and beyond. The aim of this roadmap is to jointly improve safety, reduce costs and minimize environmental impact in the decommissioning of nuclear facilities for the next 10 to 15 years.

micado

June 2019
3 year project

9 Partners
5 Countries

Migrant Integration Cockpits and Dashboards
https://www.micado-project.eu/

The goal of the project is to propose a cost-effective solution for non-destructing characterization of nuclear waste, implementing a digitization process that could become a referenced standard facilitating and harmonizing the methodology used for the in-field Waste Management and Dismantling & Decommissioning operations.

HORIZON-EURATOM Projects - Ongoing

SOGIN

INNO4GRAPH

September 2020
3 year project

13 Partners
5 Countries

INNOvative tools FOR dismantling of GRAPHite moderated nuclear reactors
https://www.inno4graph.eu/

The project will develop a set of tools and methods for graphite reactor dismantling operations, both before the actual dismantling operations (for decision-making and characterization of the graphite) and during the dismantling (for optimal extraction of the graphite).

Final workshop scheduled in Oct 2023 at the EDF demonstrator

CLEANDEM

March 2021
3 year project

11 Partners
4 Countries

Cyber physicaL Equipment for unmAnned Nuclear DEcommissioning Measurements
https://cleandem.wordpress.com/

Development of an Unmanned Ground Vehicle (UGV) Platform equipped with innovative radiological sensing probes which will support the D&D operations. The system will be able to provide also a 3D and fully detailed digital twin of the surveyed area augmented with radiological information provided by the sensors, thus enabling an efficient and effective planning of the dismantling actions.

The Final Demo will be carried out in the Sogin Eurex Plant (first quarter of 2024)

HORIZON-EURATOM Projects - *Ongoing*

SOGIN

PREDIS

September 2020
4 year project

47 Partners
17 Countries

Predisposal Management of Radioactive Waste
https://predis-h2020.eu/

The PREDIS project develops and improves safer treatment and conditioning methodologies and processes for wastes, for which no adequate or industrially mature solutions are currently available. It focuses on treatment of metallic materials, liquid organic waste and solid organic waste which can result from nuclear power plant operation, decommissioning and other industrial processes. The project also addresses digitalization solutions for improved safety and efficiency in handling and assessing cemented-waste packages in extended interim surface storage.

HARPERS
HARMONISED PRACTICES, REGULATIONS AND STANDARDS IN WASTE MANAGEMENT AND DECOMMISSIONING

June 2022
3 year project

24 Partners
13 Countries

HARmonised PracticEs, Regulations and Standards in waste management and decommissioning
https://www.harpers-h2020.eu/

Eestablish and clarify the benefits and added value of a more aligned practices, methodologies and approaches in decommissioning and radioactive waste management, including possibilities for shared processing, storage and disposal facilities between Member States (MS).

HORIZON-EURATOM Projects - *To Come*

SOGIN

Euratom Work Programme 2023-2025

Open for proposal: March 2023 – Selected projects start: Spring 2024

Co-funded European partnership on radioactive waste management **RWM**

EURAD-2 project - 5 years (2024-29)

Total Budget: EUR 20 million over the 3 years (2023-2025)[1] - 60% financed by EC

- Promotes knowledge transfer and the sharing of best practices between the advanced Member States and those at an early stage.
- Improve, innovate and develop science and technology for the management and disposal of radioactive waste
- Consolidate the knowledge for a safe start to operating the first geological disposal facilities
- Provide input to the next set of Member States with mature site selection programmes, in order to promote broadly accepted industrialisation of nuclear waste disposal in the EU.

[1] Additional budget is subject to the adoption of the Euratom Work Programme 2026-2027

Call HORIZON-EURATOM-2023-NRT-01-07: Innovative technologies for safety and excellence in decommissioning, including robotics and artificial intelligence **D&D**

Total Budget: EUR 4 million – (Innovation Action) - 70% financed by EC

- improve safety in the decommissioning of nuclear systems, minimising operational waste, dismantling waste and improving the environmental remediation of nuclear facilities;
- contribute to excellence in decommissioning, while developing cutting-edge technological innovation, competitive and resilient industry initiatives, future-proof jobs and skills for a fair transition.

SOGIN

We protect the present
We guarantee the future