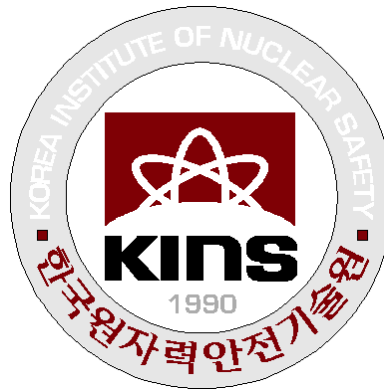


# Decommissioning



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**Korea Institute of Nuclear Safety**

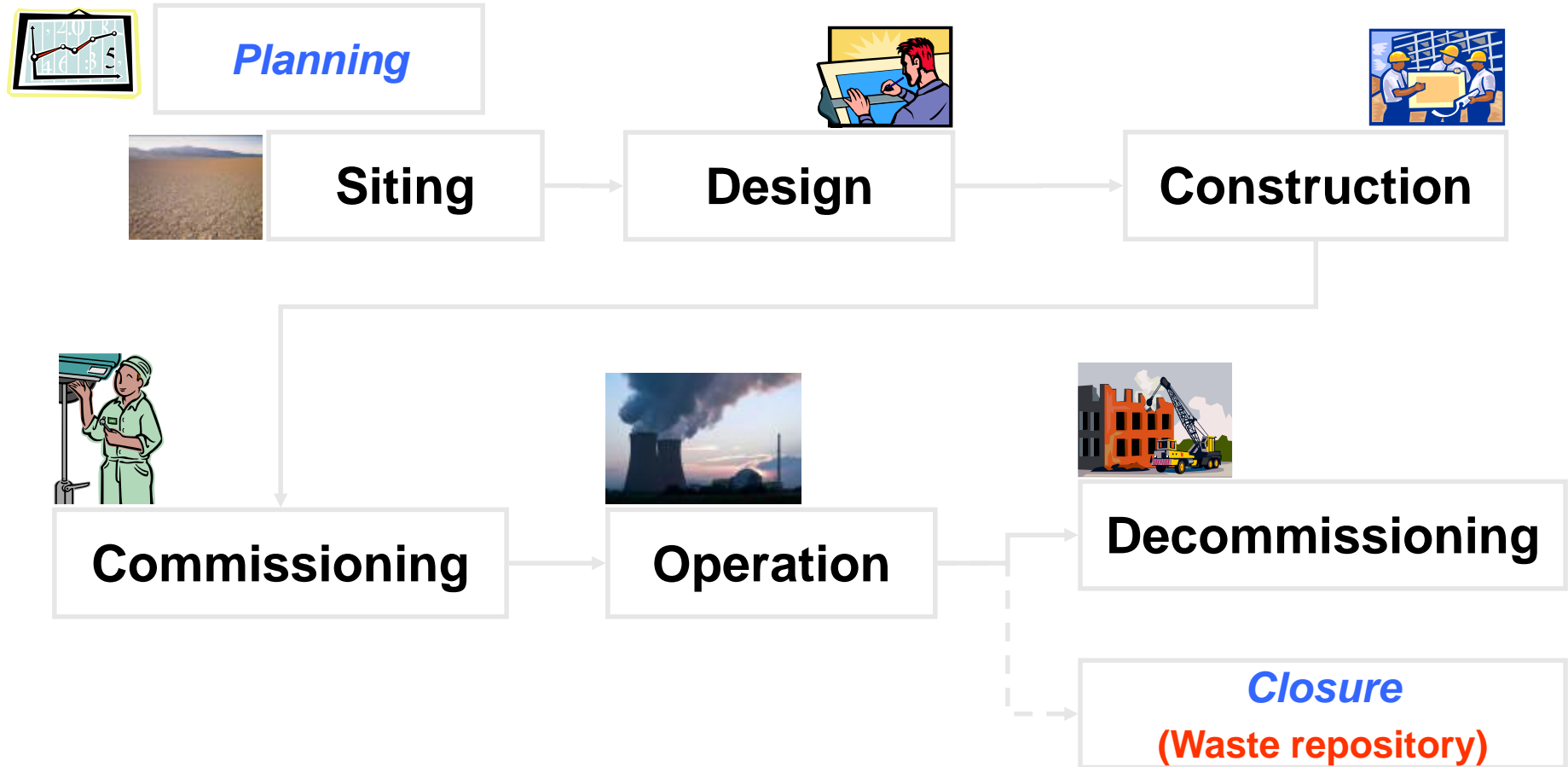
# Contents

- I. Introduction**
- II. IAEA's Safety Standards**
- III. Decommissioning Process**
- IV. Korean Experience**

# Introduction

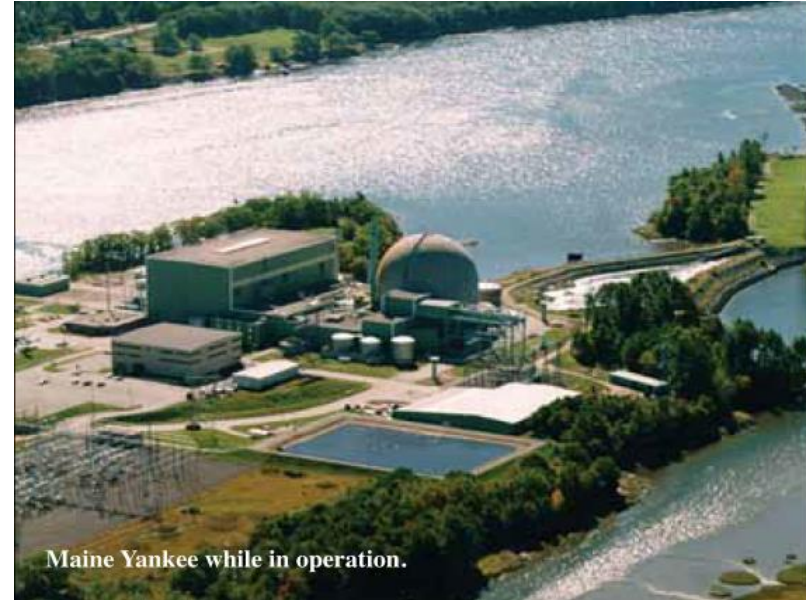


# Six major stages of the lifetime of an nuclear facilities (IAEA GSR Part 6)



# Why Decommissioning? (Reason)

- End of facility operation mission
  - Production mission or research program
- End of facility design life/technically obsolete
  - Uneconomical, unsafe or operations prohibited
- Changes in governmental policy
  - Existing nuclear programs
- Others – accident, etc.



# What is Decommissioning ? (Definition)

- The administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility.( IAEA 2014, IAEA GSR Part 6)
- Remove a facility or site safely from service and reduce residual radioactivity to a level that permits: 1)release of property for unrestricted use and termination of the license or 2) release of the property under restricted conditions and termination of the license.( US NRC, 10CFR50.2 Definitions)

# Decontamination (Definition)

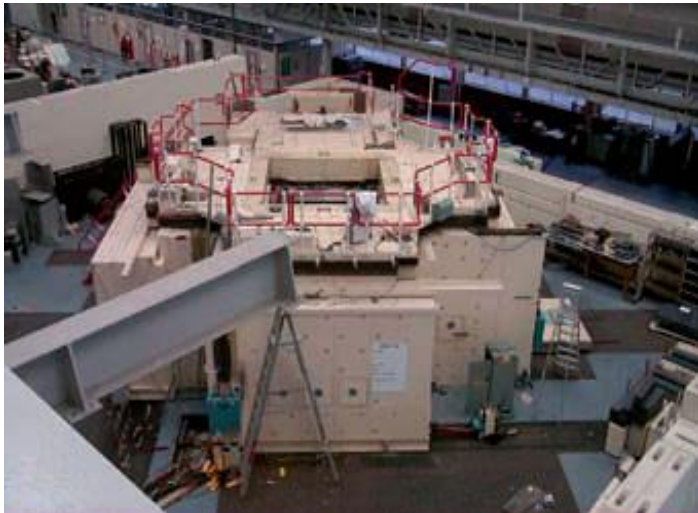
- Defined as the removal of contamination from areas or surfaces of facilities or equipment by washing, heating, chemical or electrochemical action, mechanical cleaning or by other means.





# Dismantlement (Definition)

- Defined as the removal of equipment or structures (clean or radioactive) typically to allow for the completion of the decommissioning process by use of any of or some combination of thermal, mechanical, or electrical removal methods.





# Objective of Decommissioning

- **Placing a facility into such a condition that the decommissioned facility poses no unacceptable risk to the public, the workers or the environment**
  - ▶ The gradual removal of radiological and non-radiological hazards (and regulatory controls) linked to hazards
  - ▶ The return of facilities and sites to new, productive uses

# Decommissioning strategies

IAEA classification

## ■ Immediate dismantling;

- ▶ Facility are removed or decontaminated to a level that permits the facility to be released for unrestricted use, or with restrictions

## ■ Deferred dismantling;

- ▶ Facility are either processed or placed in such a condition that they can be safely stored and maintained until they can subsequently be decontaminated and/or dismantled to levels that permit the facility to be released for unrestricted use or with restrictions

## ■ Entombment;

- ▶ Contaminants are encased in a structurally long lived material until radioactivity decays to a level permitting the unrestricted release of the facility, or release with restrictions

# Immediate Dismantling

## Features

- ❑ All radioactivity above specified levels is removed
- ❑ Allows clearance or unrestricted use
- ❑ Normally begins very soon after shutdown (2 - 5 years)
- ❑ Allows use of current work force
- ❑ Work force remains relatively stable during period
- ❑ Does not allow for significant decay of radionuclides
- ❑ Waste and spent fuel management facilities must be available
- ❑ Funding must be available to complete the activities
- ❑ Preferred option if resources are available

# Deferred Dismantling

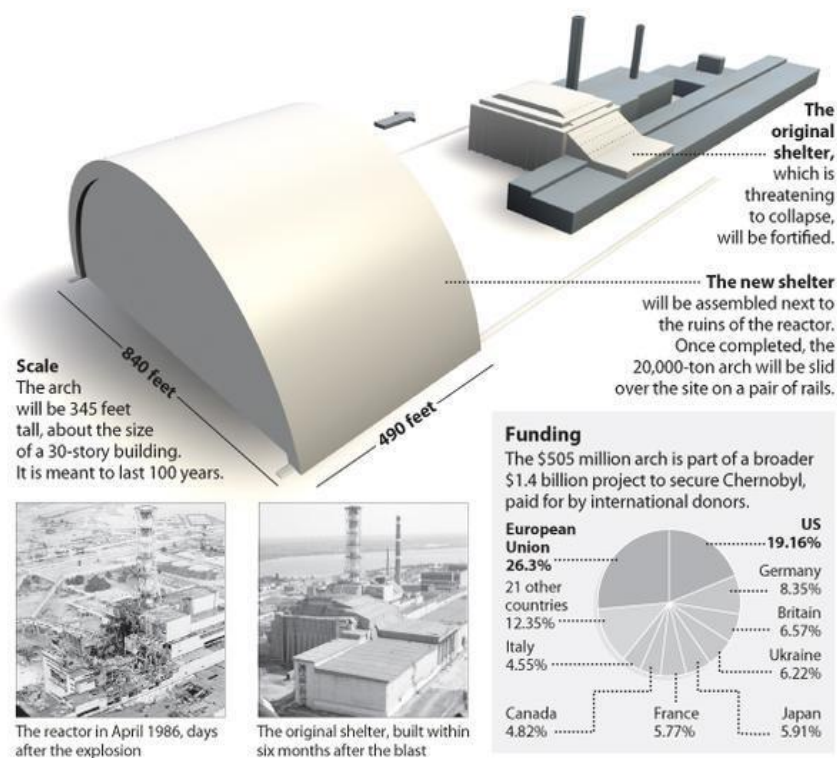
## Features

- ❑ Facility is placed into long-term storage to allow decay of RN
- ❑ Dismantling is deferred from 10 to 60 years
- ❑ Systems are drained, waste removed & areas secured
- ❑ Lose current work force knowledge
- ❑ Portions of the site may be used for other purposes
- ❑ Option if waste disposal or spent fuel management facilities are not available
- ❑ Allows for the collection of funds
- ❑ Work force reduced until dismantling begins
- ❑ Spent fuel may be an issue
- ❑ May be the preferred option if multiple facilities are on-site
- ❑ Sometimes called Safe Storage or Safe Enclosure

# Entombment

## Features

- ❑ Radioactivity encased on-site
- ❑ Controlled area is reduced in size
- ❑ Remaining structure must be monitored and maintained
- ❑ Becomes a waste repository
- ❑ May be the preferred option for countries with only a research reactor and no waste disposal facilities

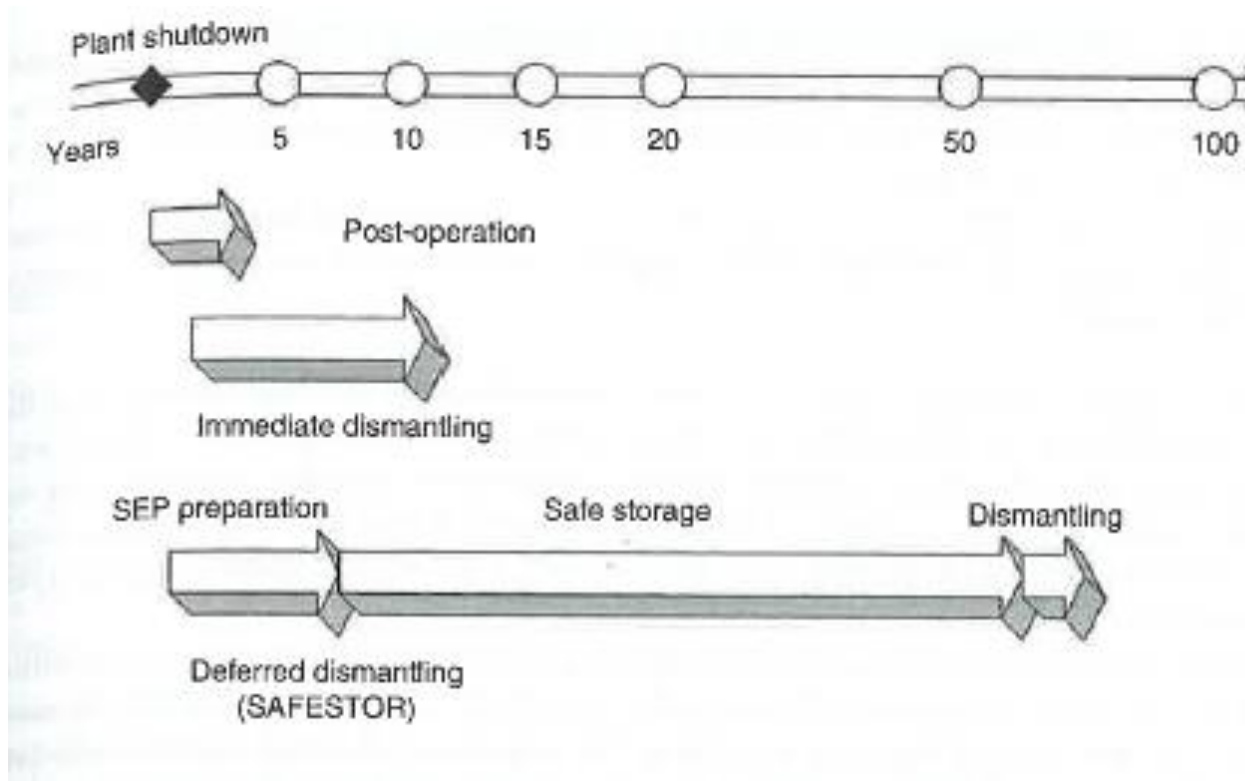


# Factors Affecting for Strategy Selection

- ☐ Governmental policy, laws and regulations
- ☐ Availability of waste management system
- ☐ Safety assessment of the hazards
- ☐ Availability of funding
- ☐ Physical status of the facility
- ☐ Availability of experienced staff
- ☐ Future use of facility or site
- ☐ Type of facility and residual activity
- ☐ Social and economic impact



# Decommissioning strategies and timescale



from "Handbook of Nuclear Engineering, Volume 5" Chapter 27 Figure 1, Springer (2010)

# IAEA's Safety Standards for Decommissioning

## Maine Yankee



# Overview of IAEA Global Standards

- ▶ **Global Reference Point for a High Level of Nuclear Safety**

- ▶ **Safety Fundamentals**

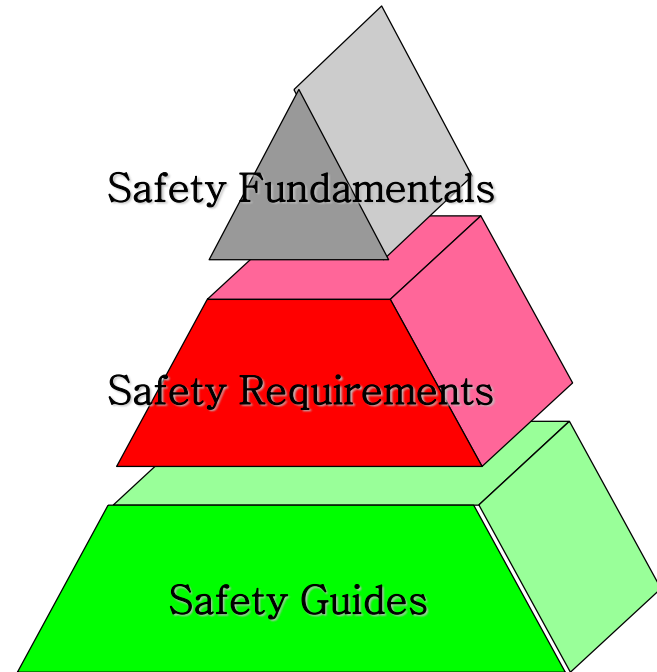
- ▶ Basic objectives, concepts and principles to ensure safety

- ▶ **Safety Requirements**

- ▶ Requirements which must be satisfied to ensure safety for particular activities or application areas (“**shall**” statements)

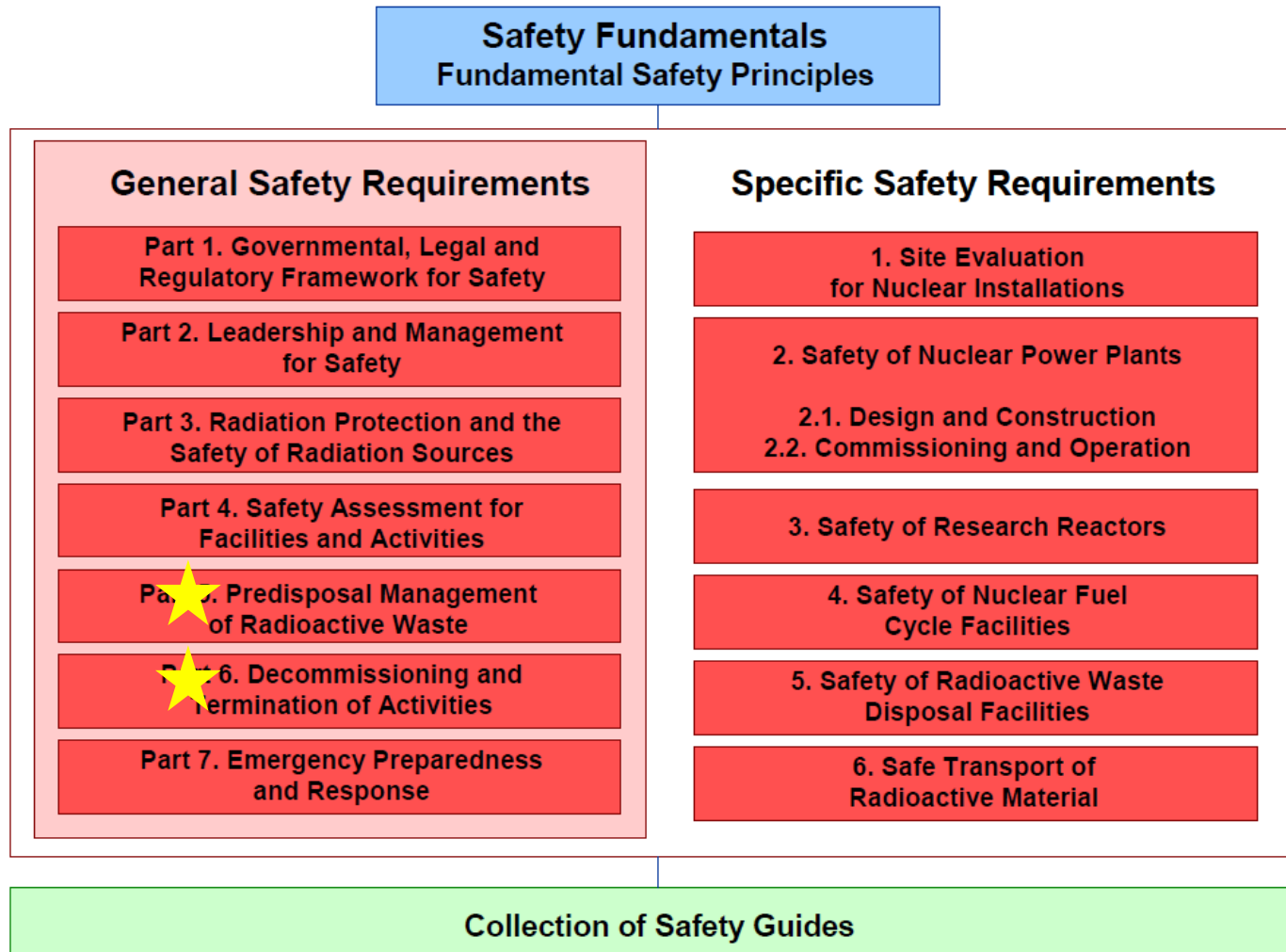
- ▶ **Safety Guides**

- ▶ Recommendations, on the basis of international experience, of measures to ensure the observance of safety Requirements (“**should**” statements)



# IAEA Safety Standards

## Structure



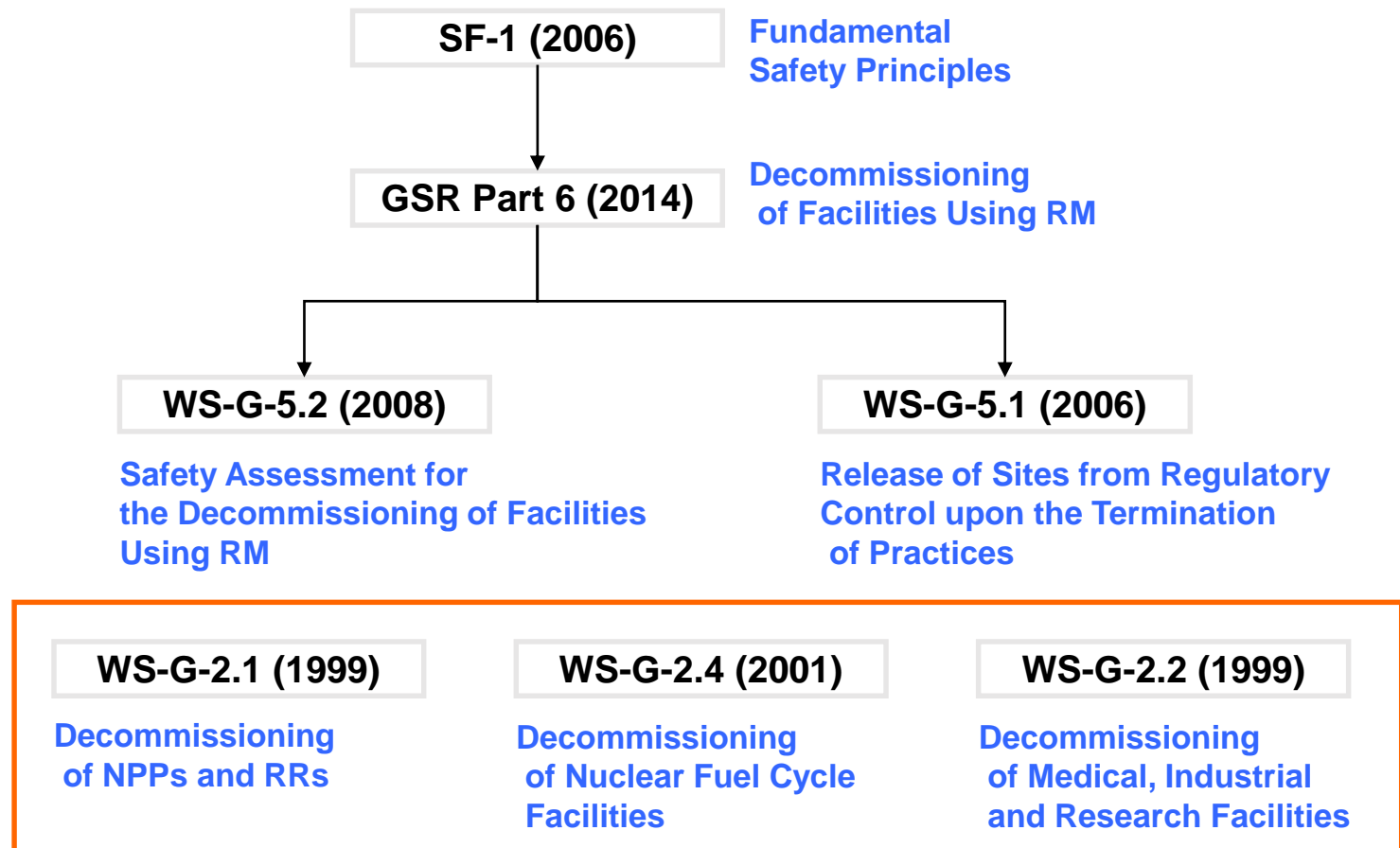
# IAEA Safety Standards for Decommissioning

**Safety  
Fundamentals**

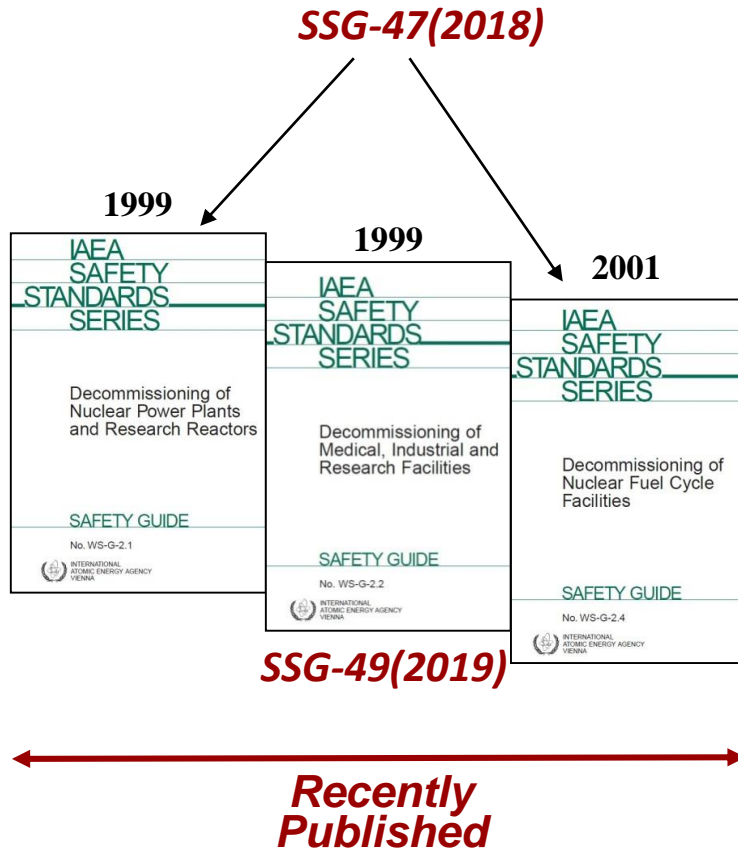
**General Safety  
Requirements**

**General Safety  
Guides**

**Specific Safety  
Guides**



# IAEA Safety Standards for Decommissioning



2014

IAEA Safety Standards  
for protecting people and the environment

Decommissioning of  
Facilities

General Safety Requirements Part 6  
No. GSR Part 6



2004

2006

2008

IAEA SAFETY STANDARDS SERIES	IAEA Safety Standards for protecting people and the environment	IAEA Safety Standards for protecting people and the environment
Application of the Concepts of Exclusion, Exemption and Clearance	Release of Sites from Regulatory Control on Termination of Practices	Safety Assessment for the Decommissioning of Facilities Using Radioactive Material
SAFETY GUIDE No. RS-G-1.7	Safety Guide No. WS-G-5.1	Safety Guide No. WS-G-5.2

**SSG-47(2018): Decommissioning of Nuclear Power Plants, Research Reactors and other Nuclear Fuel Cycle Facilities**

**SSG-49(2019): Decommissioning of Medical, Industrial and Research Facilities**



# Safety Requirements (IAEA GSR Part 6, 2014)

## 1. Introduction

## 2. Protection of People and Environment

- ▶ R1: Radiation protection and safety
- ▶ R2: Graded approach
- ▶ R3: Assessment of safety

## 3. Responsibilities associated with DECOM.

- ▶ R4: Responsibilities of the government
- ▶ R5: Responsibilities of the regulatory body
- ▶ R6: Responsibilities of the operator

## 4. Management

- ▶ R7: Integrated management system

IAEA Safety Standards

for protecting people and the environment

Decommissioning of  
Facilities

General Safety Requirements Part 6

No. GSR Part 6



# Safety Requirements (IAEA GSR Part 6, 2014)

## 5. DECOM. Strategy

- ▶ R8: Selecting a decommissioning strategy

## 6. Financing

- ▶ R9: Financing of decommissioning

## 7. Planning

- ▶ R10: Planning of decommissioning/R11: Final decommissioning plan

## 8. Conduct of Actions

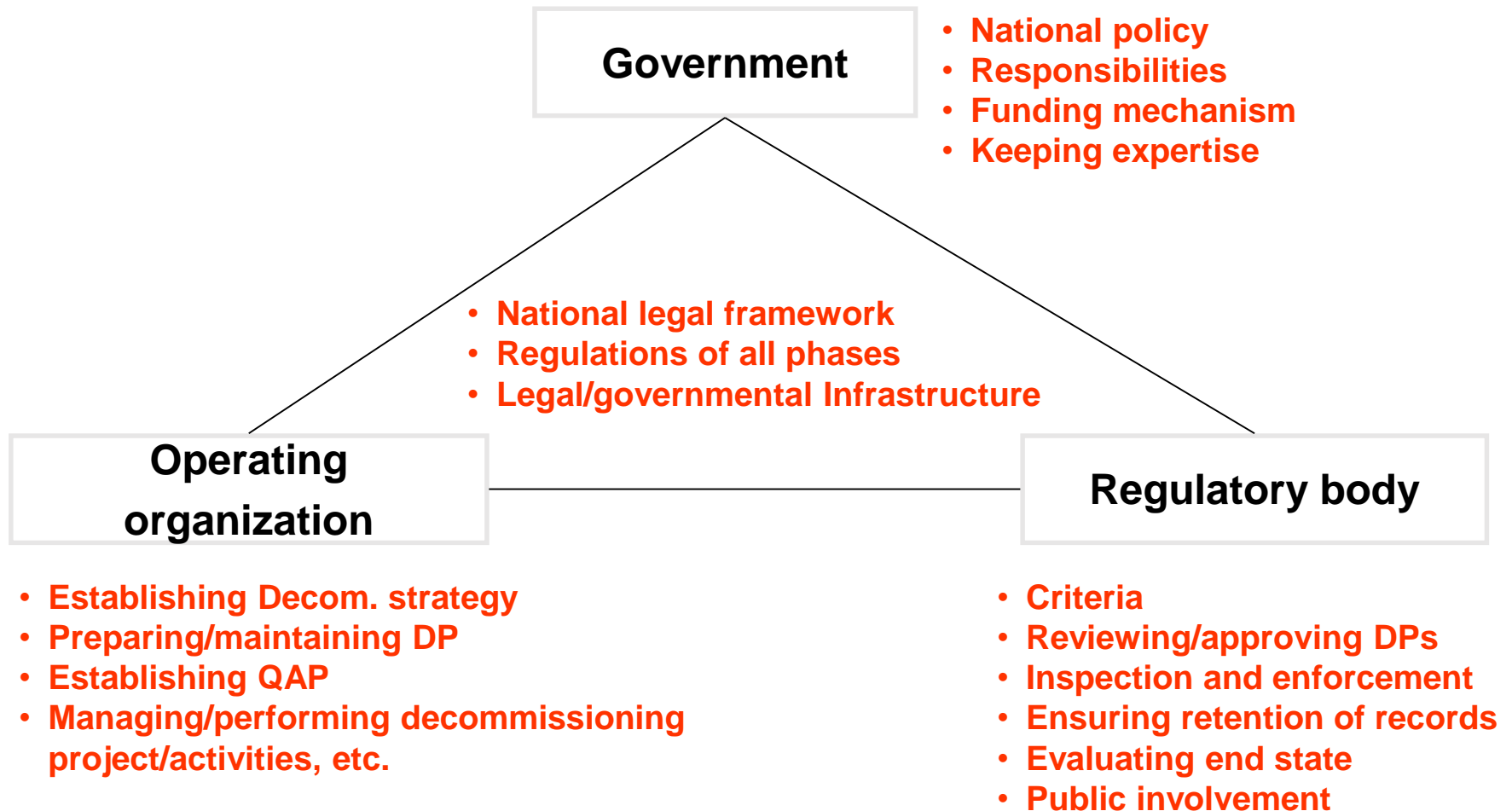
- ▶ R12: Conduct of decommissioning actions/R13: Emergency planning/R14: RWM

## 9. Completion and Termination of Authorization

- ▶ R15: Completion of decommissioning actions and termination of authorization

# Responsibilities associated with Decom.

General



# Responsibilities associated with Decom. Government

- **Defining the national policy**
  - ▶ for decommissioning and
  - ▶ for management of the resulting radioactive waste
- **Defining the legal/technical/financial responsibilities of organizations to be involved**
- **Ensuring that the necessary scientific and technical expertise remains available both**
  - ▶ for the operating organization and
  - ▶ for the independent regulatory and other national review functions
- **Establishing a mechanism to provide and ensure adequate financial resources for safe and timely Decom.**

# Responsibilities associated with Decom.

Regulatory body

- Establishing **requirements for DP** and **criteria** for permanent shut down and decommissioning (e.g. clearance of material, end state, removal of controls, etc.)
- Reviewing initial DP; reviewing/approving final DP
- **Inspection** of Decom. activities and **enforcement** actions
- Policies/requirements for **retention of records/reports**
- Evaluating **the end state** of a decommissioned facility
- Ensuring **stakeholder involvement**
  - ▶ Giving interested parties an opportunity to provide comments on the plan before it is approved

# Responsibilities associated with Decom.

Licensee

- Establishing a **Decom. strategy** and a **QAP**
- Preparing/maintaining a **DP**
- Notifying the regulatory body prior to shutting down
- Managing/performing **Decom. project/activities**
  - ▶ Identifying an acceptable destination for **Decom. waste**
  - ▶ Performing safety/environmental **impact assessments**
  - ▶ Preparing/implementing appropriate **safety procedures**
- Ensuring properly trained, qualified and competent **staff**
- Keeping records and submitting reports as required
- Performing radiological surveys in support of Decom.
  - ▶ Ensuring the end state criteria by final survey



# Decommissioning management

## ■ **IMS shall be applied to all aspects of Decom.**

- ▶ An **integrated system for management and implementation of Decom.** shall be established as part of operator's organization
  - Prime responsibility shall remain with the operator
  - Transfer of responsibility is ensured by procedures
- ▶ Individuals shall have the necessary skills, expertise and training to perform decommissioning safely
- ▶ Decommissioning shall be controlled through the **written procedures**
- ▶ Documents and records shall be prepared and retained

## ■ **Management shall be commensurate with the project's complexity, size of the facility and hazards associated with the decommissioning of facility**

# Decommissioning strategies

- **Licensee** shall define a Decom. strategy
- **Immediate dismantling** shall be the preferred strategy
  - ▶ Deferred dismantling or entombment shall be justified by considering RWM capacity, fund, workforce, etc.
- **Strategy shall be reviewed if the shutdown of facility is sudden.**
- **Measures for RWM** shall be available in a timely manner
  - ▶ Clearance shall be applicable
- **Site strategy for Decom. for sites with more than 1 facility**
  - ▶ Interdependences of facility shall be considered in DP for **each facility**

# Financing

- **National legislation shall set out financial provisions**
  - ▶ responsibilities and mechanism
- **Financial resources shall cover all costs**
  - ▶ associated with safe decommissioning, waste management, etc.
- **Financial assurances shall be available when needed**
  - ▶ even in the event of premature shutdown
  - ▶ prior to OL or license renewal
- **Cost estimate shall be updated**
  - ▶ On the basis of the periodic update of the DP
- **In the case of conditional release of the site, financial assurance for all necessary controls shall be available**

# Decommissioning plan

(1of2)

- **DP shall be maintained throughout the lifetime of facility**
- **DP shall be supported by a safety assessment**
- **DP shall be based upon a graded approach**
- **Lifetime consideration of Decom.**
  - ▶ For new facilities, Decom. shall be considered in the siting, design, construction, commissioning, operation, and through to the license termination
  - ▶ For existing facilities, DP shall be prepared ASAP
- **Initial DP shall be submitted with OL application**
  - ▶ To be reviewed/updated appropriately
- **Baseline survey shall be performed prior to construction**
  - ▶ To be updated prior to commissioning

# Decommissioning plan

(2of2)

- **Institutional knowledge, and records/reports shall be retained/maintained**
- **Final DP shall be submitted prior to implementation phase**
  - ▶ Details of the timeframe and funding for decommissioning
  - ▶ Detailed characterization survey shall be done
  - ▶ Methodology and criteria for demonstrating end state shall be stated
- **Ensuring stakeholder involvement**
  - ▶ Interested parties shall have an opportunity to review the final DP and provide comments
- **For deferred dismantling, the DP shall demonstrate the safety of the option**

# Conduct of decommissioning

- National safety **standards and requirements** shall be met
- Operator shall implement the final DP once the RegulatoryBody has approved it.
- **Optimized D&D techniques** shall be chosen
  - ▶ New methods shall be justified and optimized
- **Emergency** planning arrangements shall be established
- All **Decom. waste** streams shall be properly managed
- Regulatory body shall conduct safety review/inspection



# Completion of decommissioning

- Fulfillment of the **end state criteria** shall be demonstrated
  - ▶ The end state shall be evaluated by the regulatory body
- **Final Decom. report** shall be documented and submitted
- Record-keeping and retention system shall be established
- For **on-site waste storage**, authorization shall be issued for the facility
  - ▶ A revised, new or separate authorization can be considered
- In the case of the **conditional site release**, appropriate controls shall be maintained and a revised authorization shall be issued, as appropriate.

# Decommissioning Process

## Big Rock Point



# Strategy Development

- Ensuring the **continued safety** of the public and the workforce and the protection of the environment
- **Reducing hazards** through proper planning of associated tasks
- Achieving an **appropriate balance** in the use of environmental, social and economic **resources**, both **now and in the future**
- **Releasing** facilities, material, equipment and sites **from regulatory control** wherever possible

# Main phases of decommissioning

## ■ Preparatory phase

- ▶ Development of decommissioning strategy
- ▶ Initial decommissioning planning (DP)
- ▶ Initial radiological characterization
- ▶ Transition

## ■ Implementation phase

- ▶ Preparation, submission, and then implementation of final DP
- ▶ Project management
- ▶ Management of waste
- ▶ **(Completion phase)**
  - *Demonstration of compliance with end state criteria*
  - *License termination*

# Facility transition

## ■ Transition?

- ▶ Time period **between facility shutdown and implementation** of the decommissioning strategy
- ▶ A part of operational phase

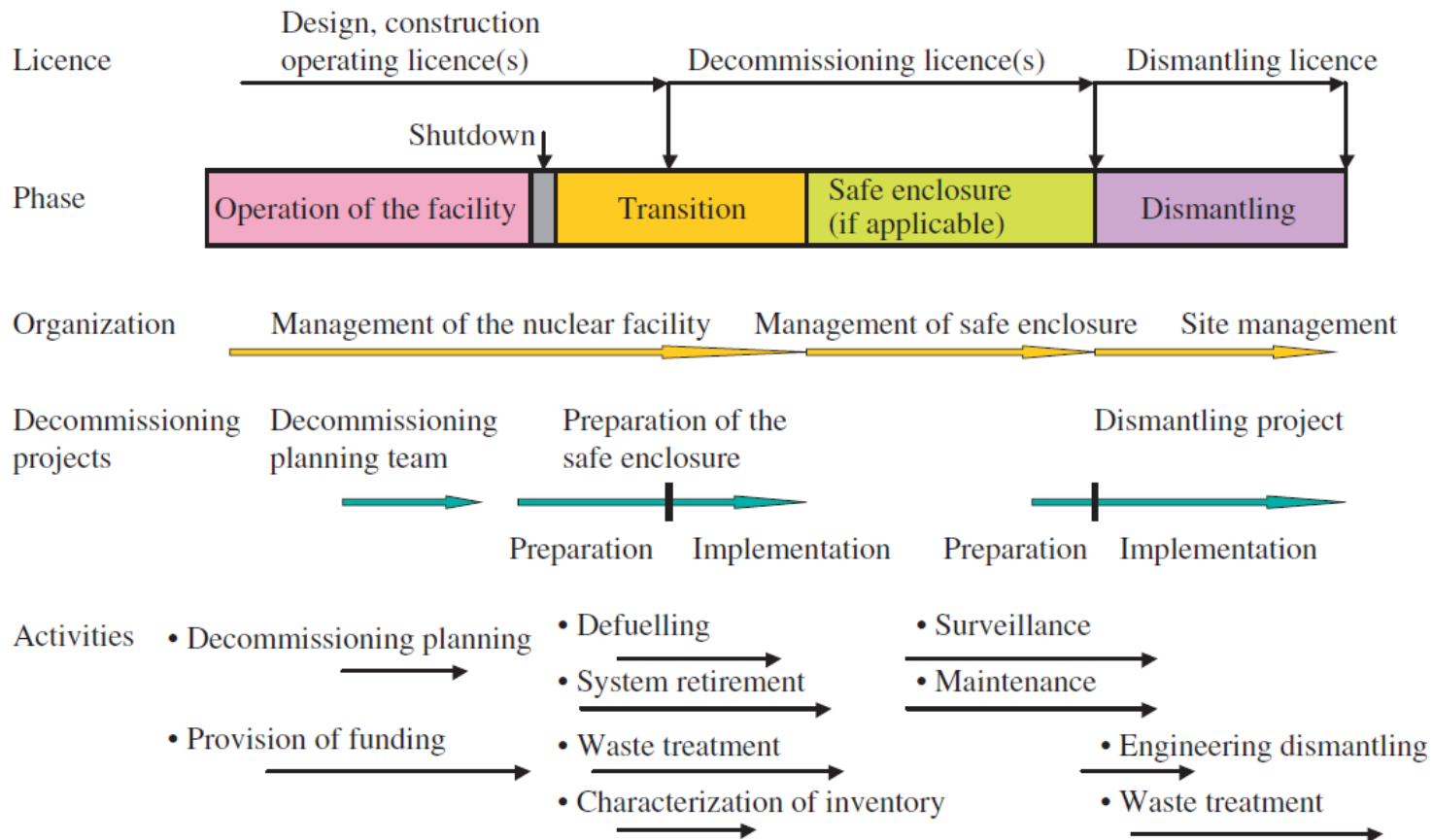
## ■ Main activities

- ▶ Removing major radioactive materials from operation
  - spent fuel, sources and operational radioactive waste, etc.
- ▶ Draining systems and process liquids
- ▶ Completing the characterization survey
- ▶ Submitting the final DP to regulatory body for approval

# Stepwise decommissioning process

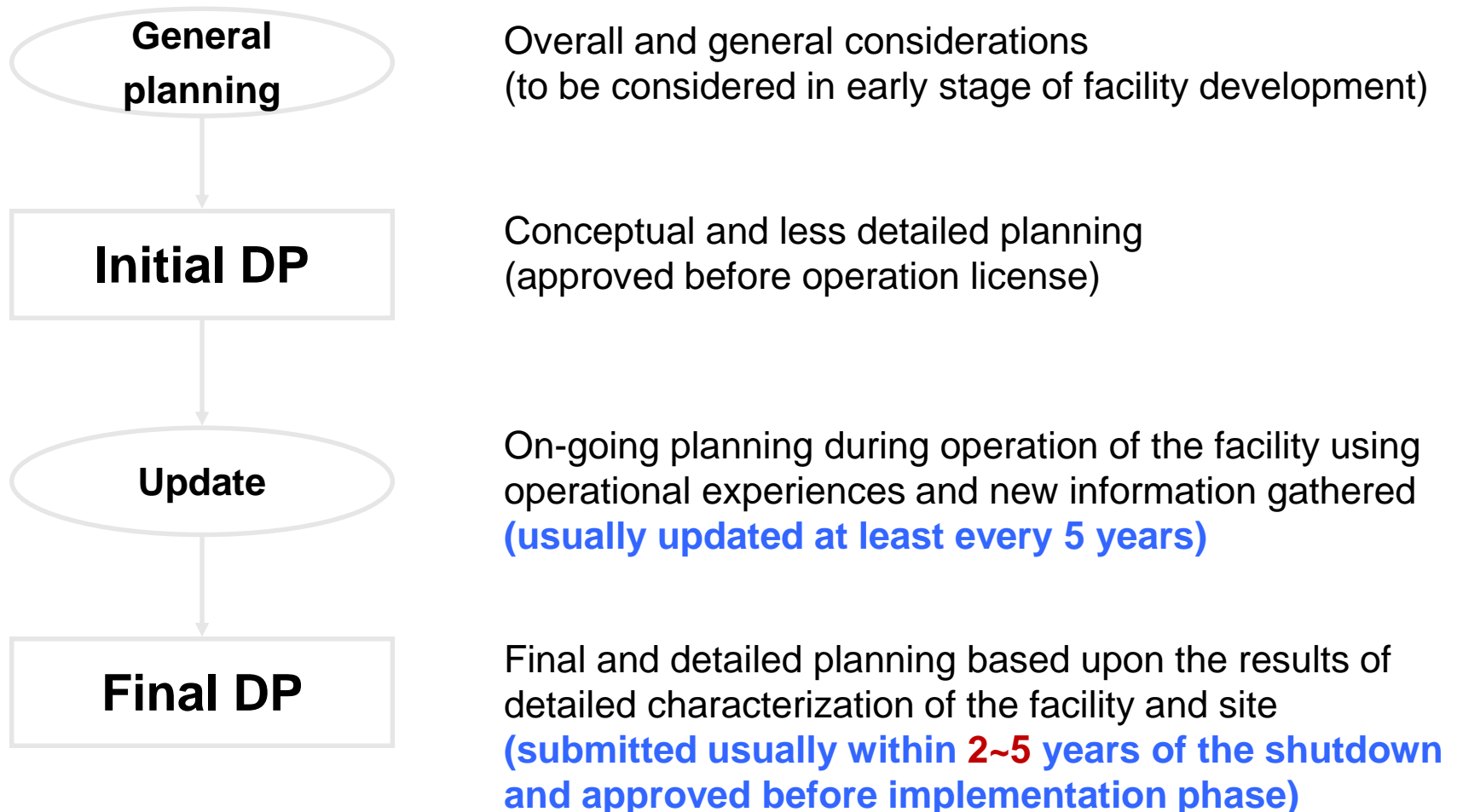
Facility stage	Decommissioning activity
Design, construction, and commissioning	<ul style="list-style-type: none"> <li>• Developing initial DP</li> </ul>
Operation	<ul style="list-style-type: none"> <li>• Updating DP</li> <li>• Finalize safe enclosure plan, if applicable</li> <li>• Prepare shutdown plan</li> </ul>
Transition	<ul style="list-style-type: none"> <li>• Source term reduction, defuel &amp; waste conditioning</li> <li>• Developing site preparation plan</li> <li>• Developing surveillance and maintenance plan</li> </ul>
Preparation	<ul style="list-style-type: none"> <li>• Site preparation</li> <li>• Initial dismantling</li> </ul>
Deferred dismantling	<ul style="list-style-type: none"> <li>• Updating final DP</li> <li>• Surveillance and maintenance</li> </ul>
Decontamination and dismantling	<ul style="list-style-type: none"> <li>• Decontamination and dismantling</li> </ul>
Completion	<ul style="list-style-type: none"> <li>• Final status survey</li> <li>• License termination</li> </ul>

# Decommissioning related activities during the lifecycle of an NPP



From IAEA TRS No. 420 FIG.1 (2004)

# Decommissioning planning





# Standard format and contents of DP

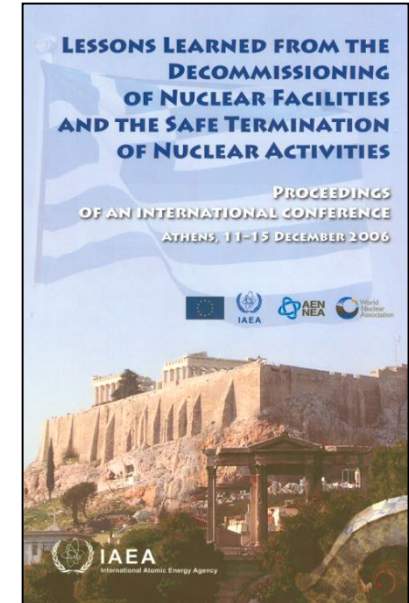
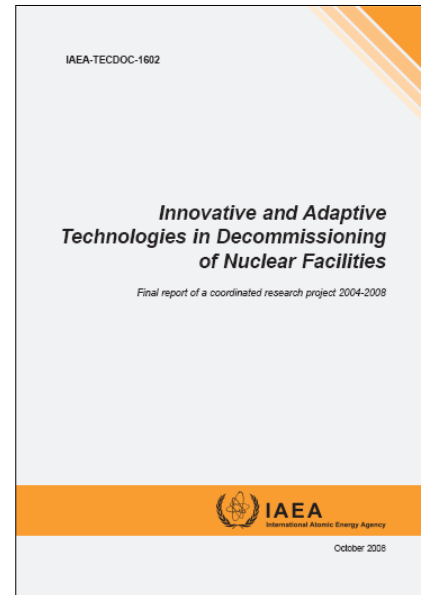
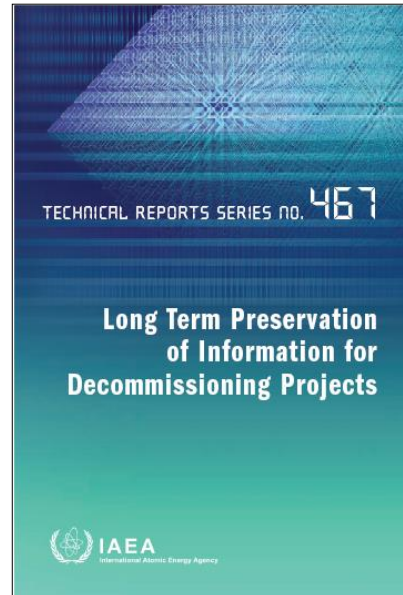
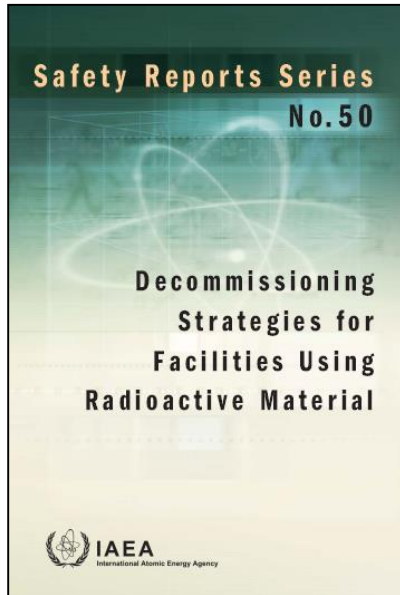
1. Introduction
2. Facility Description
3. Decommissioning Strategy
4. Project Management
5. Decommissioning Activities
6. Surveillance and Maintenance
7. Waste Management
8. Cost Estimate and Funding Mechanisms
9. Safety Assessment
10. Environmental Assessment
11. Health and Safety
12. Quality Assurance
13. Emergency Planning
14. Physical Security and Safeguards
15. Final Radiation Survey

From IAEA SRS No. 45 (2005)

# IAEA Publications

- ▶ More than 60 publications on decommissioning (since 1980-s)
  - ▶ Safety Standards
  - ▶ Safety Report Series
  - ▶ Nuclear Energy Series
  - ▶ Technical Report Series
  - ▶ TECDOC
- ▶ Some publications cover both decommissioning and environmental remediation aspects
- ▶ Some publications prepared in cooperation with other organizations, e.g. NEA OECD

# Supporting publications



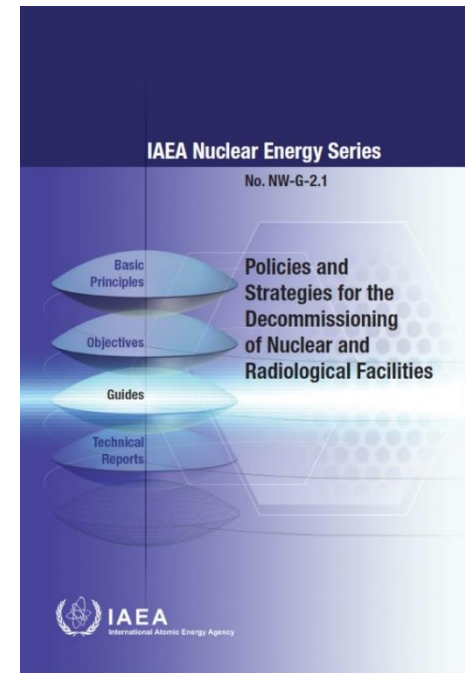
- ▶ Entombment - experiences in planning and implementation
- ▶ Methodologies for Source Term Assessment for Decommissioning (focus on activation)
- ▶ Generic (Reference) Regulations for Decommissioning

# IAEA Safety Reports

- ▶ Safe Enclosure of Nuclear Facilities During Deferred Dismantling, Safety Reports Series No. 26 (2002)
- ▶ Safety Considerations in the Transition from Operation to Decommissioning of Nuclear Facilities, Safety Reports Series No. 36 (2004)
- ▶ Standard Format and Content for Safety Related Decommissioning Documents, Safety Reports Series No. 45 (2005)
- ▶ Decommissioning Strategies for Facilities Using Radioactive Material, Safety Reports Series No. 50 (2007)
- ▶ Monitoring for Compliance with Exemption and Clearance Levels, Safety Reports Series No. 67 (2012)
- ▶ Safety Assessment for Decommissioning, Safety Reports Series No. 77 (2013)

# IAEA NE Series and other technical reports(NEA)

- ▶ Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities (NW-G-2.1)
- ▶ Selection and Use of Performance Indicators in Decommissioning (NW-T-2.1)
- ▶ Redevelopment and Reuse of Nuclear Facilities and Sites: Case Histories and Lessons Learned (NW-T-2.2)
- ▶ Decommissioning of Small Medical, Industrial and Research Facilities: A Simplified Stepwise Approach (NW-T-2.3)
- ▶ International Structure for Decommissioning Costing (ISDC) of Nuclear Installations, developed jointly with the OECD Nuclear Energy Agency and the European Commission (NEA Report no. 7088)



# Technical publications – recent and under preparation

- Design Lessons Drawn from the Decommissioning of Nuclear Facilities, IAEA-TECDOC-1657
- Planning, Management and Organizational Aspects of the Decommissioning of Nuclear Facilities, IAEA-TECDOC-1702
- Cost Estimation for Decommissioning of Research Reactors\*
- Decommissioning of Pool-like Facilities\*
- Management of Human Resources during Decommissioning with a Focus on Motivation Aspects\*
- Decommissioning – Managing the Unexpected\*
- Decommissioning of Particle Accelerators\*

\*IAEA Nuclear Energy Series reports

# Korean Experience on Decommissioning



# Status of Decommissioning in Korea

- ✚ Decontamination and Dismantling of KRR-2 was completed in March 2009
- ✚ KRR-1 is under decommissioning
- ✚ Completion of Decommissioning of Uranium Conversion Facility of KAERI
  - released from regulatory control in April 2012
  - Safety review of release of site from regulatory control was finished and its review result of KINS was reported to NSSC in March 2012.
  - NSSC officially notified the release from regulatory control to KAERI in April 2012.
- ✚ Korea has no experience for NPP decommissioning
  - Kori NPP unit 1 : under final stage of Final Decommissioning Plan
  - Wolsong NPP unit1 : has now shut down for decommissioning
- ✚ IRRS mission (July 2011) recommended to enhance the framework of decommissioning
- ✚ Development of regulatory framework and technology for decommissioning has been carrying out since 2012



# Permanent Shutdown /Decommissioning of NPPs

## ❑ Permanent Shutdown



### ◆ Kori Unit 1 (PWR, 587MWe, operated from 1978)

- Korea's 1<sup>st</sup> NPP & Shut down in June 2017
- Application for decommissioning within 5 years from Permanent Shutdown
  - Final Decommissioning Plan (FDP)
  - Decommissioning Quality Assurance Program
  - Collecting opinions from local residents

### ◆ Wolsong Unit 1 (PHWR, 678MWe, operated from 1983)

- Korea's 1<sup>st</sup> PHWR (CANDU) & Shut down in Dec. 2019
- Preparing Decommissioning Application same as Kori Unit 1

## ❑ Preparation of decommissioning

- ◆ NSSC developed guidelines for safety review of FDP in June 2020
- ◆ Application of decommissioning for Kori Unit 1 submitted May 2021
- ◆ Regulatory Activity for Permanent Shutdown NPPs
  - Periodic Inspections by Guidelines for each reactor type

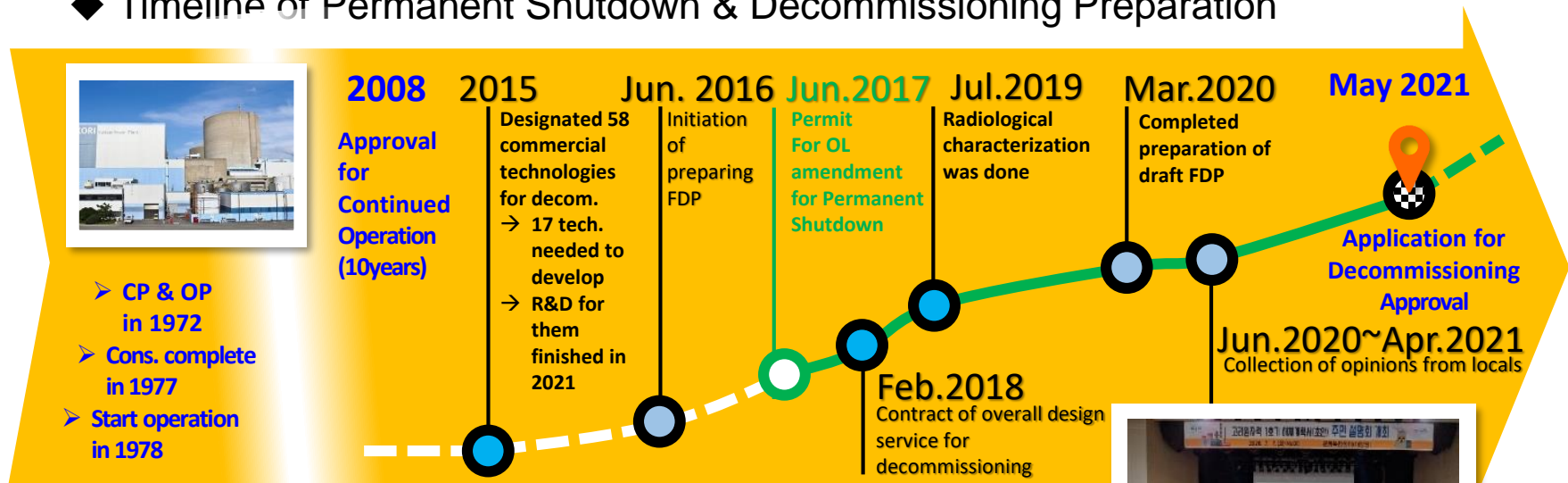
# Permanent Shutdown and Decommissioning of NPPs

## ❑ Permanent Shutdown of Kori Unit 1

- ◆ Ongoing Safety Management & Regulatory Control

## ❑ Application for Decommissioning Approval of Kori Unit 1

- ◆ NSA requirements (within 5 years after Permanent Shutdown, FDP, DQAP & Public opinion)
- ◆ Timeline of Permanent Shutdown & Decommissioning Preparation



## ◆ Overview of Decommissioning Plan of Kori Unit 1

- Strategy : DECON
- End State of Site : Limited Reuse
- Period : 13 years after approval of Decommissioning

# Decommissioning of KRR-1, 2

## + Basic Information

	Type	Operation
KRR-1	TRIGA Mark-II	1962 to Jan. 1995
KRR-2	TRIGA Mark-III	1972 to Dec. 1995

## + D&D History

- 1998: All SF rods, returned to the US
- Nov. 2000: DP, approved by the MEST
- June 2001: D&D works, started
- Mar. 2009: KRR-2, finished decontamination / dismantling
- Dec. 2009: KRR-1, decided to be completely decommissioned and now under decommissioning

## + Budget : 20 million USD

- will add 0.3m USD for KRR-1 decommissioning

*KRR-1*



*KRR-2*



## + Waste Management

- Total amount of RW: 1,460 drums
- Portion of RW to total Dismantled Material: 15%

# Decommissioning of KRR-1 & 2



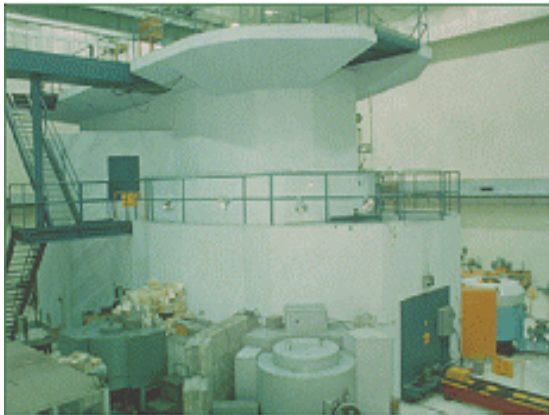
KRR-1



decommissioning



The Inside of KRR-1



KRR-2



decommissioning



Large amount of RW



# RWM in decommissioning of KRR-1 & 2



Keep dust from spreading



Reclassification of RW



Solidification



Cutting metals



Reclassification of Metals



Repackaging

Safety First KINS,  
trusted by the public



Thank You



한국원자력안전기술원  
KOREA INSTITUTE OF NUCLEAR SAFETY