

Planning of decommissioning: methods, approaches and advanced techniques

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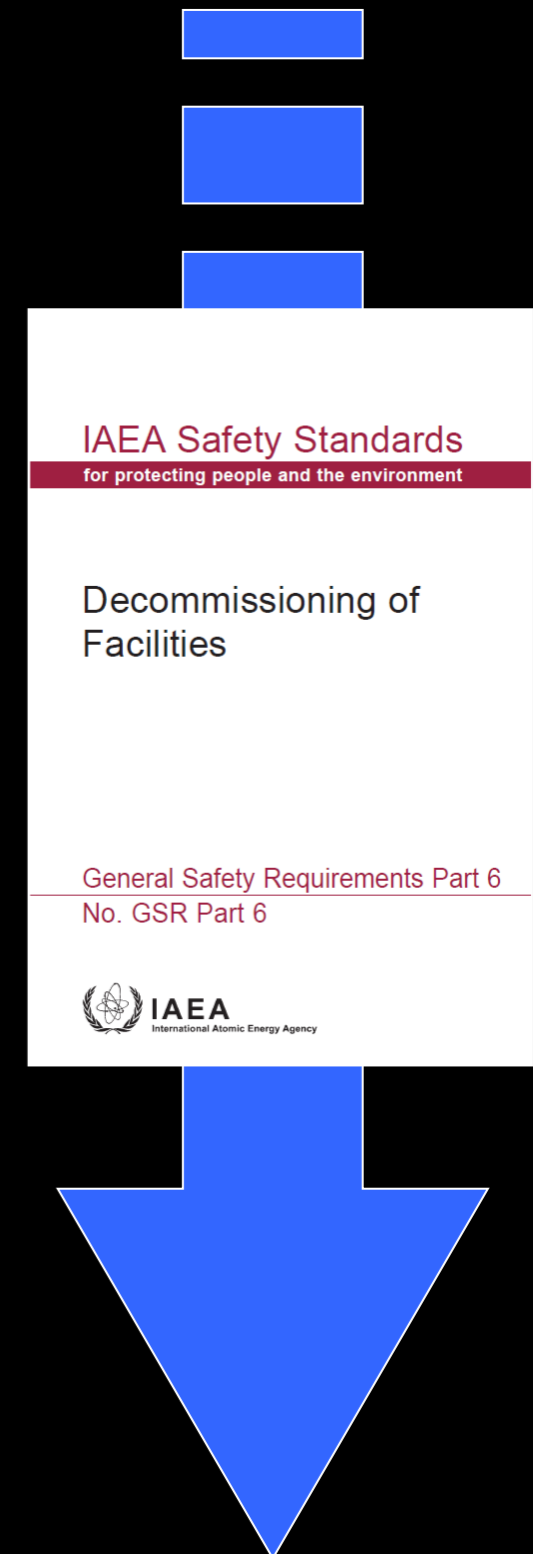
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Decommissioning Safety Requirements

- Decommissioning should be considered in design phase of a facility (Initial Decommissioning Plan)
- Data collection during Operations to assist Decommissioning
- Decommissioning Strategy
- Radiological and Physical Characterisation post-Operations
- Final Decommissioning Plan including Waste Management Plan
- Termination (End State) & Delicensing

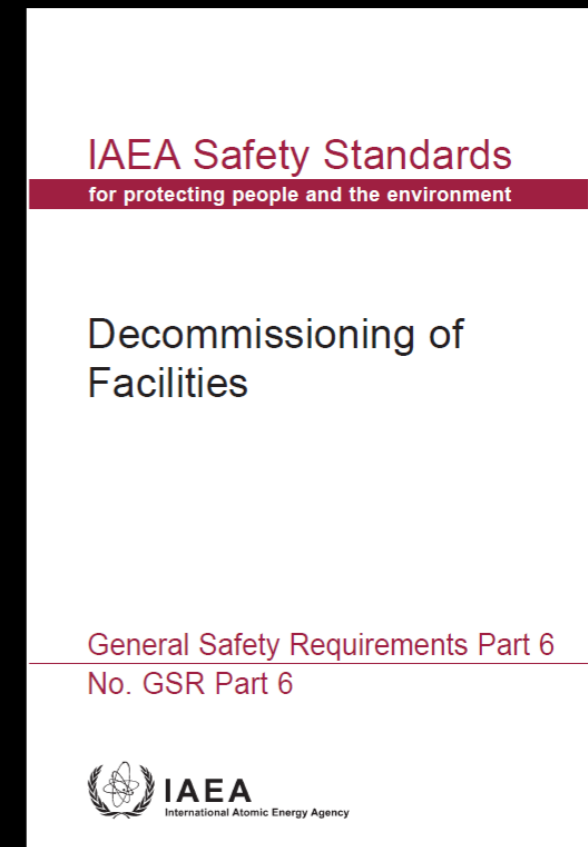


Decommissioning Standards

- GSR Part 6, Decommissioning of Facilities (2014)
- WS-G-2.1, Decommissioning of Nuclear Power Plants and Research Reactors (1999)
- WS-G-2.2, Decommissioning of Medical, Industrial and Research Facilities (1999)
- WS-G-2.4, Decommissioning of Nuclear Fuel Cycle Facilities (2001)
- WS-G-3.1, Remediation Process for Areas Affected by Past Activities and Accidents (2007)
- WS-G-5.1, Release of Sites from Regulatory Control upon Termination of Practices (2006)
- IAEA RS-G-1.7 Application of Concepts of Exclusion, Exemption and Clearance

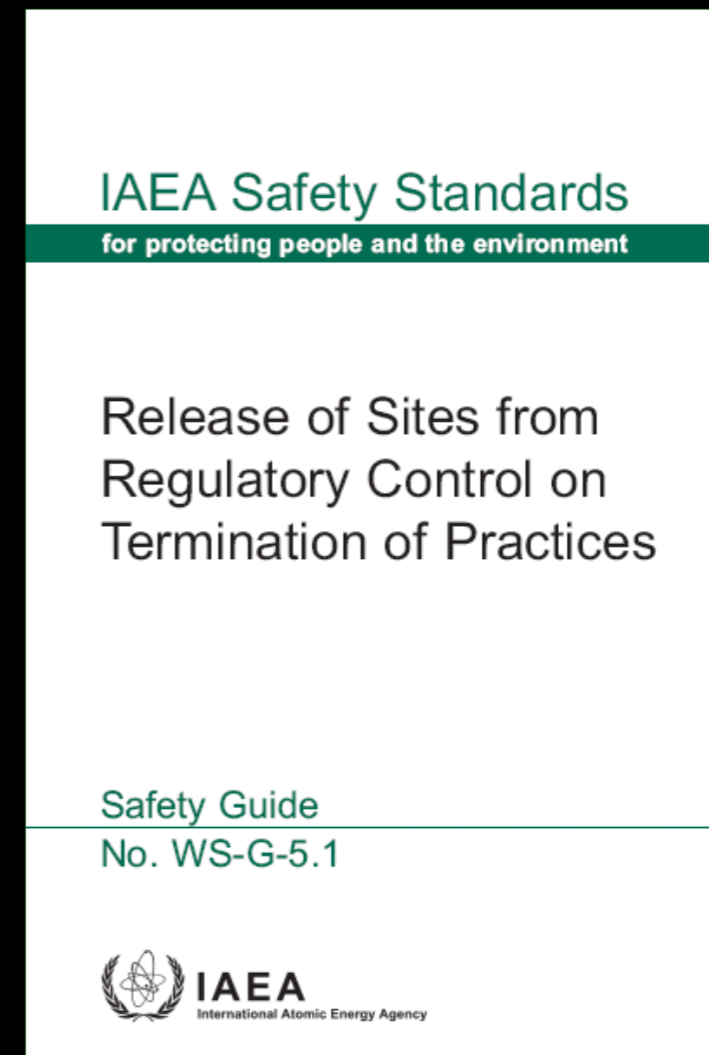
Decommissioning Safety Requirements

- GSR Part 6 establishes **15 Requirements** focusing on:
 - Protection of People & Environment
 - Responsibilities
 - Governmental
 - Regulatory
 - Licensee
 - Decommissioning Management System
 - Decommissioning Strategy
 - Finance
 - Decommissioning Planning
 - Conduct of Decommissioning (including Waste Management)
 - Termination



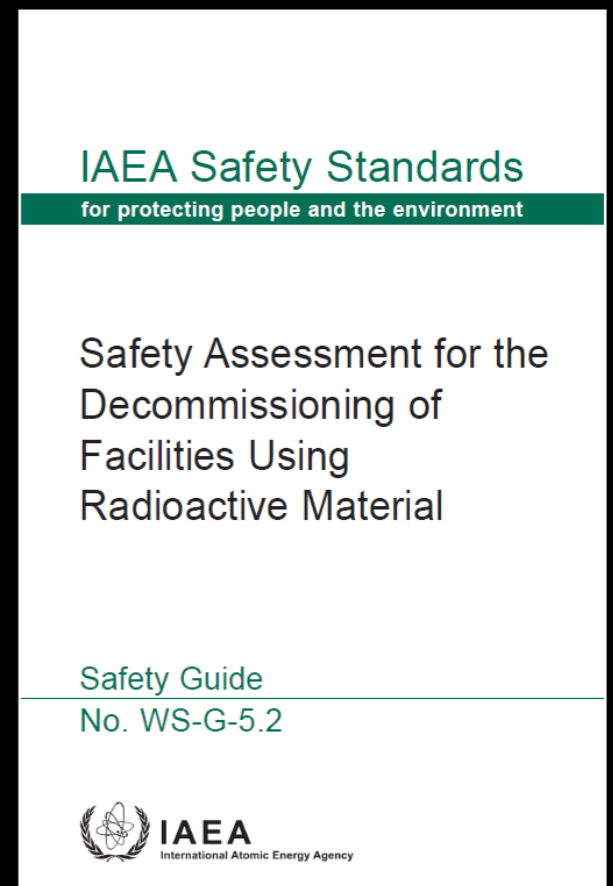
Decommissioning Safety Guides

- Site release is part of decommissioning
- Defines dose constraints
- Approach for derivation of site specific release criteria
- Cleanup of sites
- Unrestricted and restricted release
- New practice on a released site

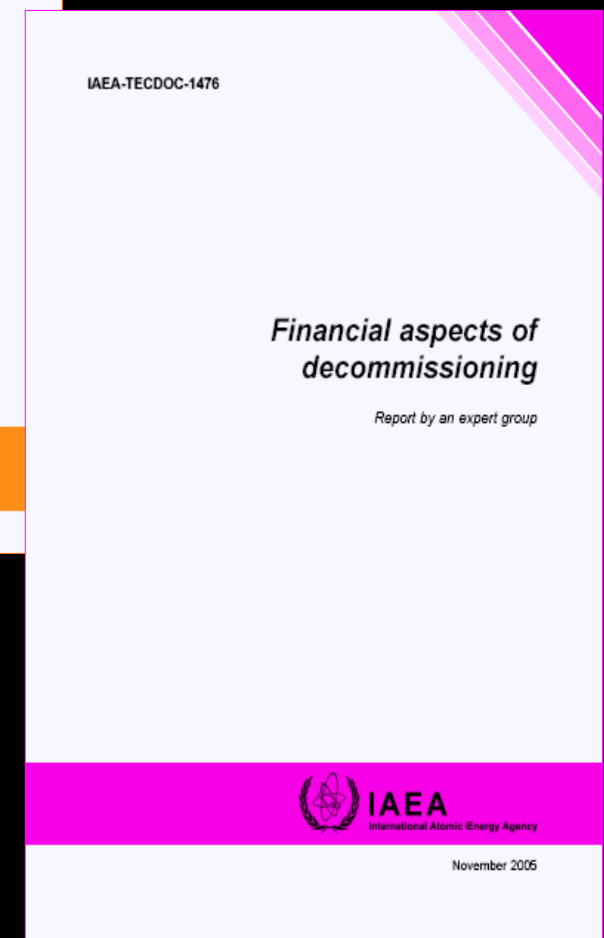
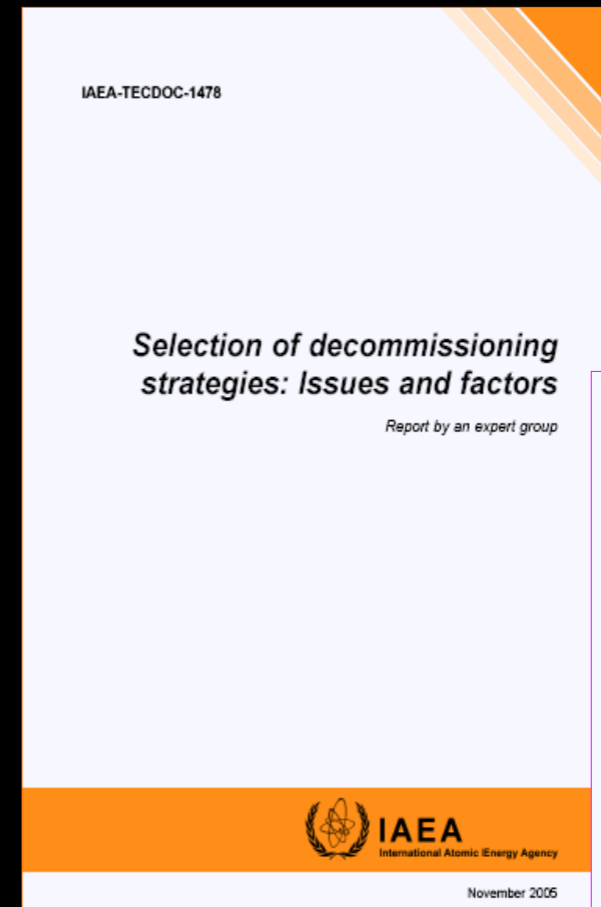
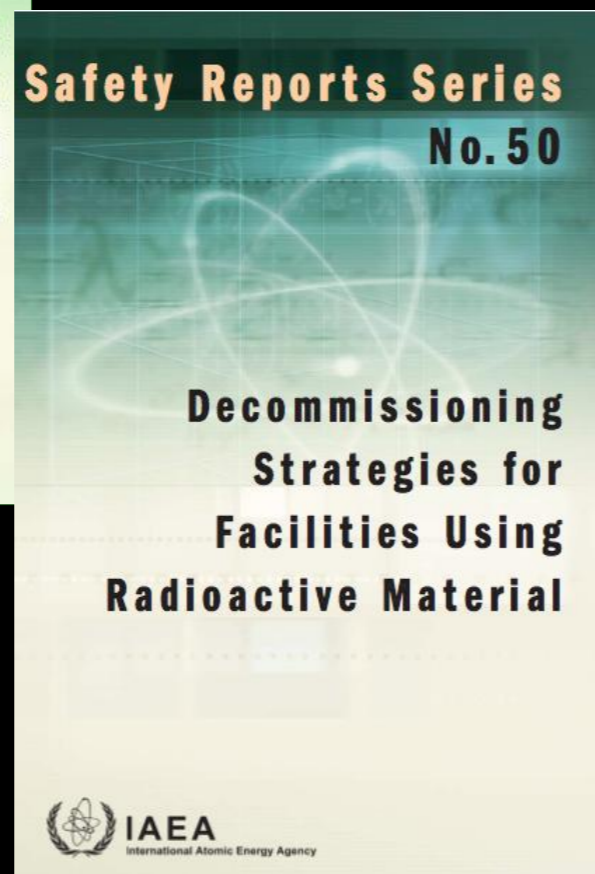
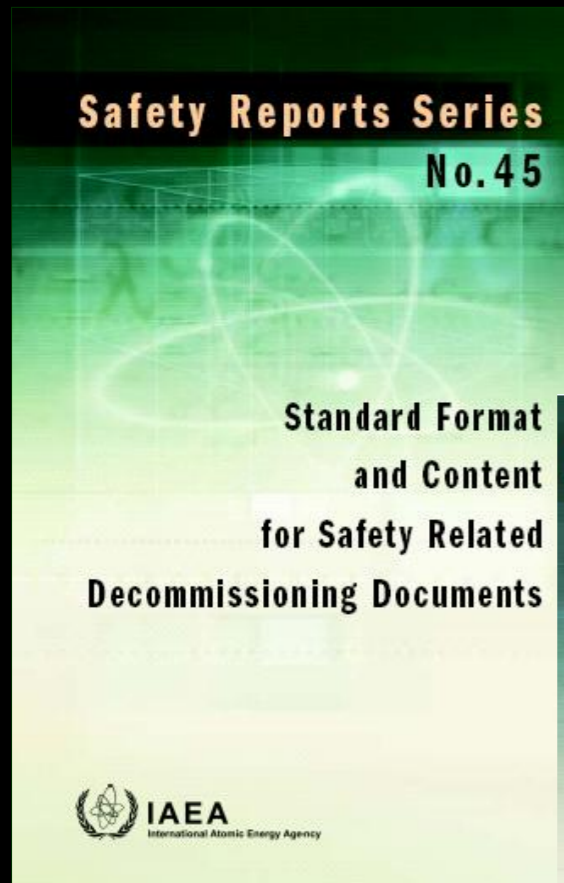


Decommissioning Safety Guides

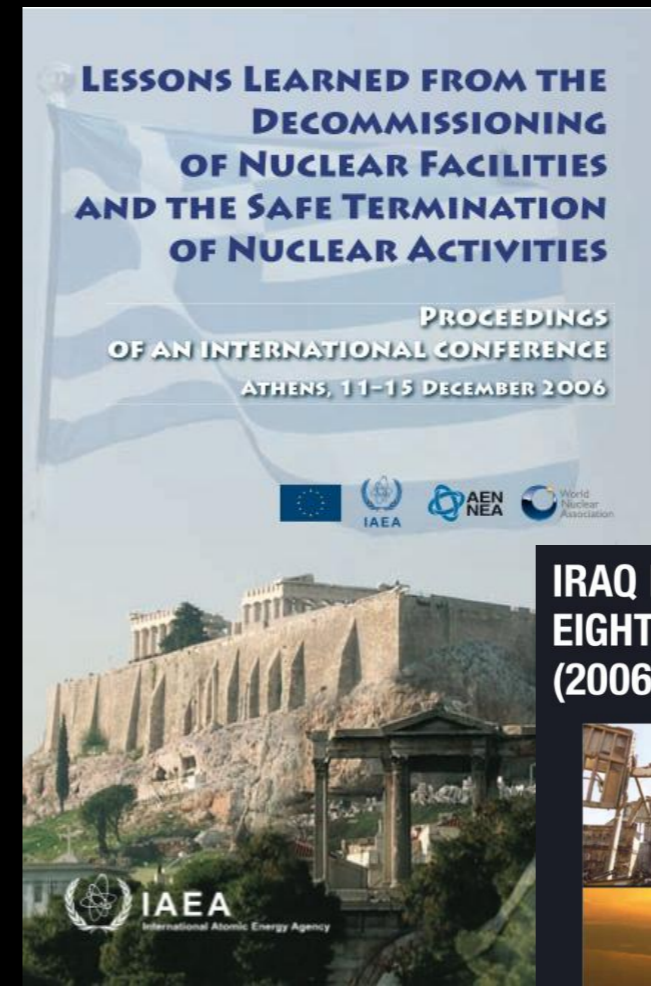
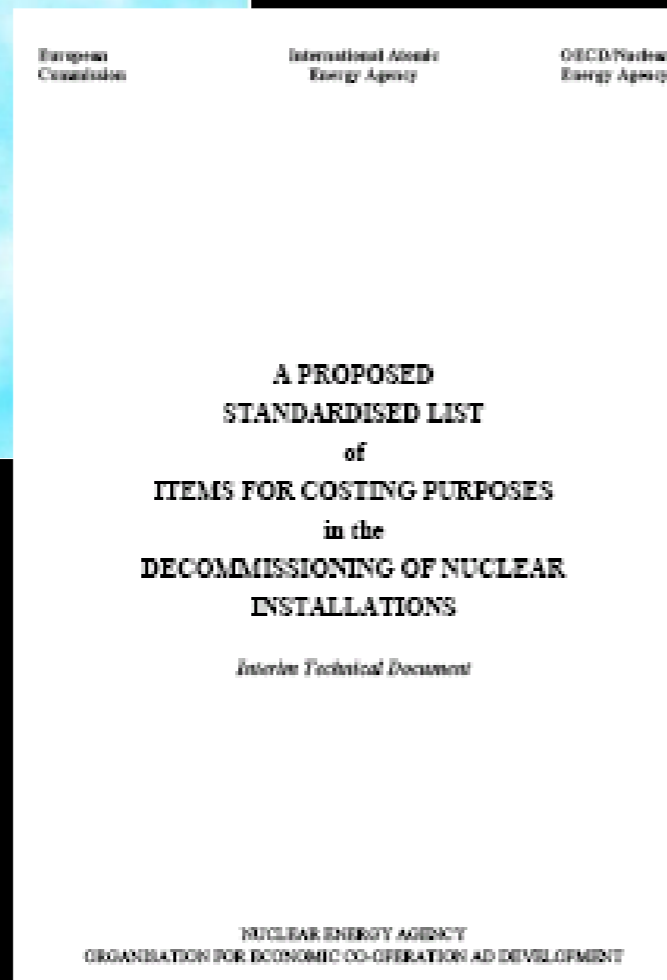
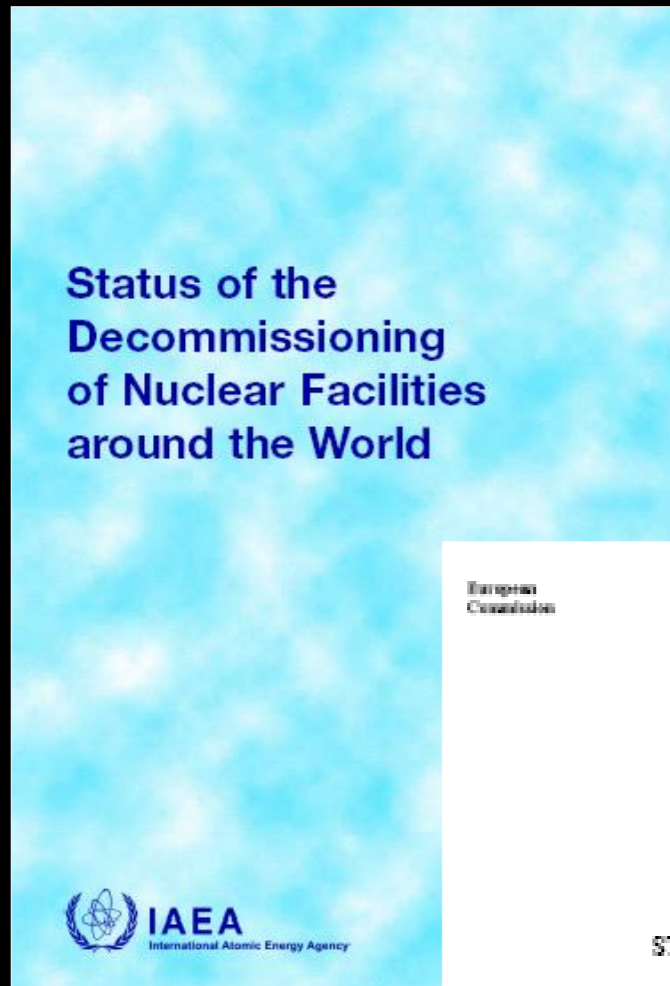
- WS-G-5.2 assists Operators, Regulatory Body and specialists in the application of a graded approach
- Content includes:
 - Safety Assessment Framework; (4.5)
 - Description; (4.6 to 4.10)
 - Hazard Identification & Screening; (4.11 to 4.27 & A1)
 - Hazard Analysis; (4.28 to 4.38)
 - Engineering Analysis; (4.39 to 4.42)
 - Safety Measures; (4.43 to 4.47)
- Independent Review (4.48 to 4.51)
- Regulatory Review (Section 5)

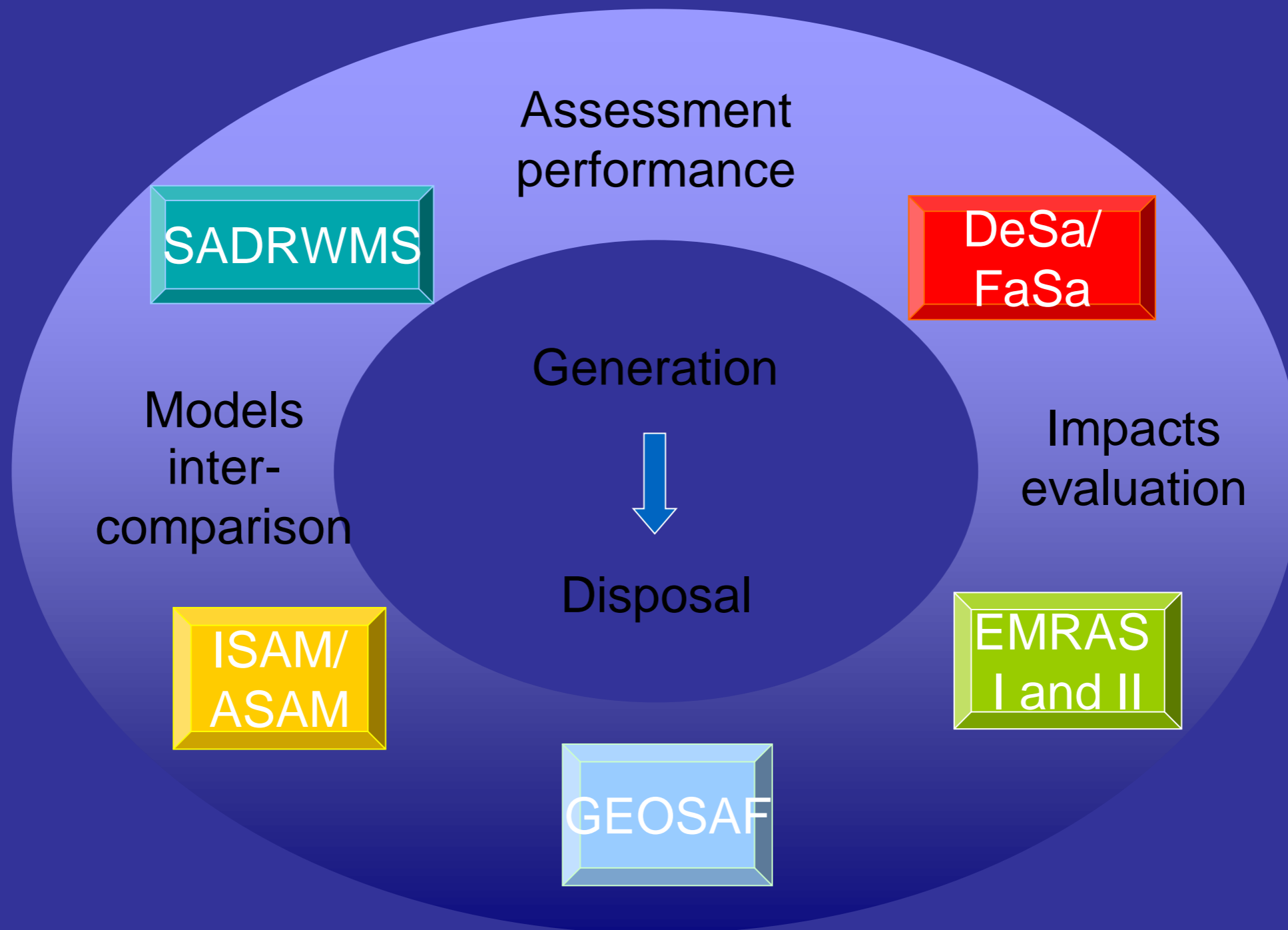


Decommissioning Supporting Materials



Decommissioning Supporting Materials





Safety Demonstration Framework for Management of Radioactive Waste and Decommissioning

SADRW

DeSa/
FaSa

Models
inter-
comparison

Impacts
evaluation

ISAM
ASAM

EMRAS
I and II



Peter Ormai
(PURAM, Hungary)

Safety Demonstration of Radioactive
Waste and Decommissioning

Decommissioning Methodologies and Approaches

DeSa Project (2004-2007)

- **Scope – all facilities using radioactive material**
- **Objectives**
 - **Safety assessment methodology**
 - **Application to three test cases**
 - **NPP (Barseback NPP, Sweden)**
 - **Research reactor (DR-1, Denmark)**
 - **Nuclear laboratory (Dounreay, UK)**
 - **Regulatory Review**
 - **Graded approach**
- **Over 50 experts from over 30 MSs**
- **Safety report published**
- **Significant contributor to WS-G-5.2**
- **Follow-up FaSa project commenced in 2008**

Decommissioning Methodologies and Approaches

FaSa



Decommissioning Planning WG

Decommissioning Conduct WG

Completion of Decommissioning WG

Mining and Mineral Processing Test Case

NPP Test Case

Research Reactor Test Case

Fuel Fabrication Test Case

Implementation of Safety Assessment Results WG

Review of Use of Safety Assessment Results WG

Decommissioning Methodologies and Approaches

2004-2007

2008-2011

2011 -



DeSa
project

FaSa
project

FaSa follow-up
project

Safety
Assessment
Methodology

Use of Safety
Assessment
Results in
Planning, Conduct
and Termination

Safety Assessment
and
Decommissioning
Plan/Safety Case



WS-G-5.2

WS-R-5 (now
GSR Part 6)



Revision of WS-G-
2.1, 2.2. and 2.4.



Revision of WS-R-5
(now GSR Part 6)

Application of Methodologies

- **Demonstration project on decommissioning of research reactor (R2D2P)**
 - **TRIGA Research Reactor in Philippines**
 - **Started 2006**
 - **Working Groups**
 - **Planning**
 - **Regulation**
 - **Decommissioning**
 - **Meetings, workshops, expert missions**

Application of Methodologies

- **Peer reviews**
 - **Development of a systematic appraisal mechanisms in the field of decommissioning - based on Safety Standards**
 - **IRRS – assistance to Regulatory Bodies**
 - **Decommissioning Peer Review Service**
 - **Assistance to operators**
 - **Bradwell NPP, UK (2008)**

Application of Methodologies

- **Reviews of decommissioning plans:**
 - **Decommissioning plans (e.g. Lithuania, Kazakhstan)**
 - **ChNPP (Ukraine) (May 2007)**
 - **Heavy water reactor in China (June 2007)**
 - **VVR-S research reactor in Romania (Sept 2007)**



Application of Methodologies

- **Further technical assistance to Iraq**
 - **Three WGs**
 - **Characterisation of sites**
 - **Prioritization**
 - **Legal and regulatory framework**
 - **Meetings, trainings, technical visits**



IRT-5000 Research Reactor

Tammuz-2 Research Reactor



Decommissioning Objective

Removal of the radiological and non-radiological **hazards** associated with the operation of a nuclear facility or system that will allow the facility to be **released from regulatory control**; and **protect the worker, general public and the environment** during the process



Terminology

Decommissioning	The administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a nuclear facility
Decontamination	The complete or partial removal of radioactive substances or material from surfaces or from within a system or item
Dismantlement	The disassembly or demolition and removal of any structure, system or component during decommissioning

Why Decommission?

Safety Issues

Governmental policy change

Programme completed

Uneconomical operation

Obsolete technology

Accident or unplanned event



Overall Decommissioning Process

Facility Stage	Design, Construction & Start-up Phase	Operating Phase	Transition Phase	Preparation Phase	Deferred Dismantling Period	Decontamination & Dismantling Phase	Final Phase
Decommissioning Activity	Initial Decommissioning Plan	Update Decommissioning Plan Finalize Safe Enclosure Plan & Prepare Shutdown Plan	Source Term Reduction & Waste Conditioning Prepare Site Preparation Plan	Site Preparation & Initial Dismantling	Update Final Decommissioning Plan Surveillance & Maintenance	Decontamination & Dismantling Activities	Final Survey & License Termination

Facility Transition



- The time period between facility shutdown and implementation of the decommissioning strategy
- **Part of operational phase**
- **Remove spent fuel, sources and operational radioactive waste**
- Drain systems and process liquids
- Characterization survey completed
- Final decommissioning plan submitted to regulatory body for approval

Preparation Phase

- Activities that must be performed to place the facility into a position to implement the next phase
- **Will depend on the selected strategy**
- Normally begins when final decommissioning plan has been approved
- If Immediate Dismantling is the selected strategy
 - Physical Actions - Update systems, expand change rooms, new systems
 - Administrative Actions - Contract subcontractors, organize staff, prepare work procedures, buy equipment and supplies
- If Deferred Dismantling is the selected strategy
 - Physical Actions – Dismantle some minor systems, isolate areas, modify security systems
 - Administrative Actions – Reorganize staff, prepare detailed surveillance & maintenance plan

Surveillance & Maintenance Phase (only if decommissioning is deferred)

- Ensures a safe conditions are maintained at the facility awaiting dismantlement
- May last for a period of only a few months to many years
- Maintain only necessary systems to ensure safety and security
- Provide surveillance to spot deterioration
- Perform maintenance of essential systems
- Very reduced staff (normally <10)

Decontamination & Dismantling Phase

- Main phase for removing the radiological and non-radiological hazards
- Perform decontamination and dismantling activities
- Waste management is a key issue
- Rigorous project management required
- Monitor activities for radiological and non-radiological hazards for personnel safety and environmental protection

Final Phase

- Perform **final radiological survey**
- Prepare **final project report**
- Request license termination from regulatory body
- Receive notification of **termination of license**
- **Removal from Regulatory Control**
- Project Completed

Planning Process

Decommissioning of a facility is a PROJECT and should be operated using sound project planning principles and project management techniques.

- General Planning
 - General thoughts for the licensee to consider
- **Initial Planning**
 - Planning that is conceptual in nature
- Ongoing Planning
 - Incorporation of details from new information
- **Final Planning**
 - Detailed planning prior to conduct of field activities

The degree of detail will vary from facility to facility and will increase from initial to final decommissioning planning.

General Planning

- Successful decommissioning depends on careful and organized planning
- The planning requirements have to be consistent with regulatory requirements
- A detailed project scope is mandatory for initiating even the most general planning
- The extent, content and degree of detail of planning depends on the complexity and hazard potential of the installation
- One goal of the planning process is the development of a decommissioning plan
- Pertinent facility records are critical in the development of the decommissioning plan

Initial Planning

- An **Initial Decommissioning Plan** shall be prepared and submitted with each construction application for a new facility
- This plan would contain a **lower level of detail** than that which would be contained in the Final Decommissioning Plan
- Operating facilities without an Initial Decommissioning Plan should prepare one without undue delay

Initial Decommissioning Plan

- Basic information on the complexity of the facility decommissioning
- Establishes a funding mechanism
- Lists assumptions for decommissioning
- Describes the procedures and requirements for collection of data during
 - Construction
 - Operation
 - Maintenance
- Provides input to engineering design of the facility
- Updated regularly as changes occur

Ongoing Planning

- During on-going facility operations, the Decommissioning Plan shall be **routinely reviewed**, updated and made more comprehensive with respect to:
 - Technological advances
 - Incidents/abnormal operating events
 - Regulations and government policy
 - Cost estimates and financial provisions
- Additionally - to be incorporated into the Decommissioning Plan are:
 - Safety considerations, and
 - Any significant systems and structural changes

Final Planning

- Upon notice of final shutdown of the facility, the operating organization should initiate detailed studies and finalize planning for decommissioning
- The operating organization should then submit an **application for decommissioning including a Final Decommissioning Plan for review and approval by the regulator**
- With appropriate approval from the Regulatory Body, the Decommissioning Plan may be amended or refined as the decommissioning proceeds

Final Decommissioning Plan

- Operator shall develop and maintain the Decommissioning Plan
- A **comprehensive plan** that provides the basis for showing the regulatory body that decommissioning activities can be performed safely
- **Regulatory body shall approve the plan and any modifications**
- Certain aspects of the Decommissioning Plan – for example waste management or health and safety aspects - may be detailed further in a separate plan or report on that particular aspect of the project

Decommissioning Plan Contents

- Introduction
- Facility Description
- Decommissioning Strategy
- Project Management
- Decommissioning Activities
- Surveillance and Maintenance
- Waste Management
- Cost Estimate and Funding Mechanisms
- **Safety Assessment**
- **Environmental Assessment**
- **Health and Safety**
- **Quality Assurance**
- **Emergency Planning**
- **Physical Security and Safeguards**
- **Final Radiological Survey**
- **Appendices (if necessary)**

Decommissioning Plan – Facility Description

- Introduction
- Facility Description
 - **Physical description of the site and facility**
 - Include maps, drawings, and pictures
 - Description of major systems and equipment
 - Radioactive and hazardous material inventory
 - **Operational history**
 - Abnormal **events** that occurred during operation
 - Previous decommissioning activities
 - Any large-scale modification or refurbishment carried out during operating life.

Decommissioning Plan - Decommissioning Strategy

- Objectives of Project
- Decommissioning alternatives considered
- Safety principles and criteria for each
- Selection and **justification of preferred strategy**
- Any research and development effort required for each decommissioning strategy (e.g. development of dismantling tools).

Decommissioning Plan – Decommissioning Strategy

- Specific information for each strategy considered
 - Regulatory
 - Safety- radiological and non-radiological
 - Schedule
 - Cost
 - Waste types and volumes
 - Dose estimates - worker and public
 - Technology
 - Social factors

Decommissioning Plan – Project Management

- Legal and regulatory requirements
- Organization and responsibilities
- Safety culture
- Training and qualifications
- Resources and staffing levels, contractor support
- Schedules

Decommissioning Plan – Decommissioning Activities

- Description of each **phase**
- Describe major tasks associated with each phase
- Description of contaminated structures, systems and equipment
- Description of associated contamination
- Use a Work Breakdown Structure or equivalent Project Management process

Decommissioning Plan – Surveillance and Maintenance

- Identify equipment and systems required to support decommissioning
- Schedule each system for dismantlement
- Identify replacement systems to support
 - Maintenance and surveillance
 - Subsequent decommissioning activities

Decommissioning Plan – Surveillance and Maintenance

- Schedule periodic maintenance of each system
- Identify equipment recalls and changes in manufacturer requirements for maintenance
- **NOTE:** Much greater effort if deferred dismantling option is the preferred decommissioning strategy

Decommissioning Plan – Waste Management

- **Identification** of individual waste streams
- **Characterization** of waste streams
- Procedures
 - Waste handling
 - Packaging
- Calculations
 - Correlation factors
 - **Waste volume estimates by type**
 - **Transportation**
- Waste disposition

Decommissioning Plan - Cost Estimate and Funding Mechanism

- **Cost Estimate**

- Base on Decommissioning Project Work Breakdown Structure activities and schedule
- Includes labour, expense and capital
- Develop appropriate contingency
- Identify all assumptions

- **Funding Mechanism**

- Detail funding collection process throughout life
- Identify contingency funding
- Develop cost estimates for contingency restart

Decommissioning Plan - Safety Assessment

- Identify assessment framework (radiological and non-radiological)
 - Relevant safety criteria
 - Assessment approach
 - End-points of assessment (dose, risk)
 - Timeframes, etc.
- Perform **hazards analysis** (radiological and non-radiological)
 - Normal and abnormal **events**/scenarios
 - Assess potential consequences
 - Identify preventive and mitigating measures

Decommissioning Plan - Safety Assessment

- Compare analysis results with safety criteria
 - Demonstrate safety to operator, regulatory body, stakeholders
 - Serve as a basis for formal approvals
 - Justify selection of decommissioning strategy
 - Establish or validate limits, controls, conditions
- **Develop operating limits and conditions**
- Describe the safety-related activities
 - **May subdivide the decommissioning activity into phases - separate safety assessment by phase**
- Consider impact of other activities in adjacent areas on the safety of the decommissioning project

Decommissioning Plan - Environmental Assessment

- Evaluates the radiological and non-radiological impact of decommissioning activities on the environment
- Consider all pathways and activities
 - Surface water, ground water, gaseous, airborne particulate, direct radiation
 - Decontamination, dismantlement, remediation, transportation
- Assess **environmental hazards** from each proposed decommissioning activity
- Identify methods to minimize or mitigate environmental impact

Decommissioning Plan - Health and Safety

- Radiation Protection
 - Optimization analyses
 - Each major activity
 - Dose Projection prior to the activity
 - Dose Assessments following the activity
 - Contamination and radiation control
 - Monitor for changes in the radiological conditions
 - Radiological instrumentation program
 - Radiological worker and visitor training

Decommissioning Plan – Quality Assurance

- Description of the QA program
- Personnel training and qualification
- Document Control activities and requirements
- Control of measuring and test equipment
- QC activities and requirements
- Audits and surveillance
 - Corrective action program
- Records management
- Lessons Learned

Decommissioning Plan - Emergency Planning

- Emergency Services
 - Fire protection
 - Emergency medical
 - Utility companies
- Emergency Monitoring
 - Special teams
 - Emergency equipment and instruments
- Emergency Communications
 - Emergency Operations Centre location and capabilities
 - Communications with workers, contractors, sub-contractors and public officials
- Drills and Exercises

Decommissioning Plan – Physical Security and Safeguards

- Organization
- Site access control
 - Identification program
 - Access control reduction plan
- Coordination with local security agencies
- Communications coordination
- Security for special nuclear material
- Consideration for changes due to decommissioning project activities
- Note: This section may be classified (i.e. access controlled)

Summary

- Decommissioning is an orderly, phased final step in the life of a nuclear facility
- Focus on the shutdown/transition is a key step in the decommissioning process
- Planning for decommissioning is an ongoing process
- The Decommissioning Plan is the single document that captures information for the project
- Project schedule, controls and execution were discussed with respect to project planning
- Numerous IAEA reference documents are available

Failing to plan is planning to fail!

Thank you for your time.
Any questions?

Project Initiation

- Project initiation begins when the **decision** is made to permanently shut down a facility and proceed to implementation of the decommissioning strategy.

Project Initiation

- Key tasks for project initiation include:
 - Planning the **transition of the existing staff** from operations to decommissioning
 - Setting up a management organization
 - Evaluating whether to use outside Contractor or to self-perform the project
 - Identifying resources and how to obtain them
 - Performing preliminary **site characterizations** to bound the scope of the work
 - Preparing baseline cost and schedule estimates to monitor and control expenditures
 - Evaluating **fuel disposition options**

Transition Phase Activities

- Following permanent shutdown of the facility, the activities necessary to **prepare the facility for decommissioning** are begun. These activities include:
 - Site characterization
 - Regulatory notifications and any required initial public interactions
 - Implementation of revised safety and authorization bases
 - Staff reorganization
 - Bid specification preparation – as appropriate

Transition Phase

- During this phase of the project, the decommissioning organization begins to work more closely to prepare the facility for decommissioning.

Other key actions include:

- Awarding major contracts and subcontracts
- Identify special contractor requirements
- Preparation of detailed procedures
- Facility changes to ready the site for decommissioning activities

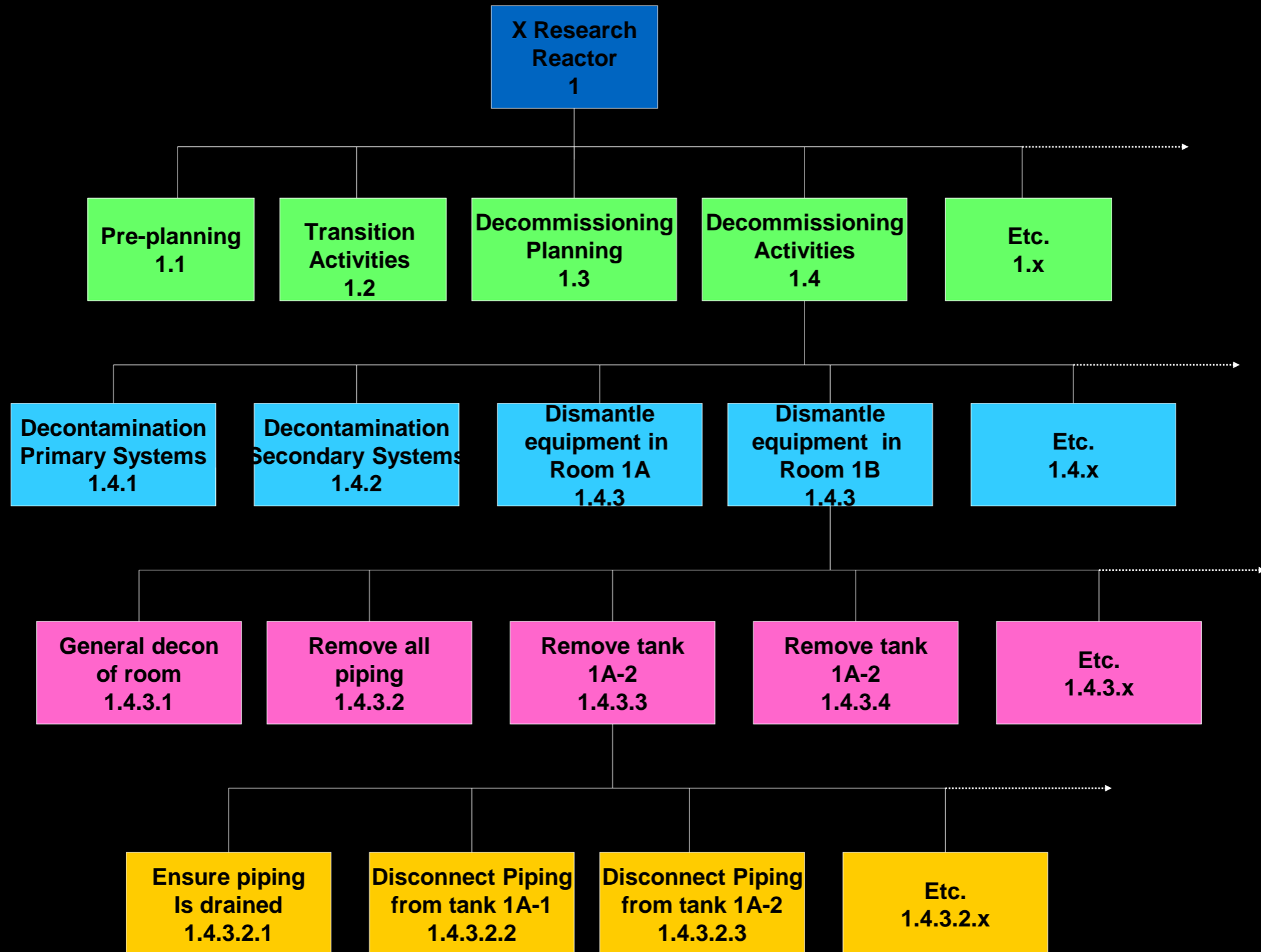
Transition Phase - Final Preparation for Decommissioning

- Prepare Final Decommissioning Plan
- Identify work activities
 - Identify work sequence
 - Assign resources
 - Balance budget and resources against activity requirements
 - Establish a Work Breakdown Structure
 - Develop an integrated work schedule
- Obtain specialized equipment
- Schedule special contractors
- Obtain Decommissioning License or approval from Regulatory Body

Development of the Work Breakdown Structure (WBS)

- Categorize cost elements and work activities into **logical groupings**
- Identify direct or indirect **relationships**
- Work groupings
 - Typically related to the accounting system used for budgeting
 - Track major elements against decommissioning costs
- WBS elements
 - Generally arranged in a hierarchical format
 - Top level of the WBS is the overall project
 - Subsequent levels used to track increasing levels of detail in the project

Example WBS Level 5



Project Scheduling

- Project schedule
 - Developed during project planning
 - **Based on a WBS approach**
 - Integrates resources, cost and activity **duration**
 - Requires graphical output
- Critical activities
 - Plan and coordinate lead time for resources
 - Schedule budget to ensure activity success
- **Identify key elements** (i.e. waste shipments)
 - Make a detailed list of tasks for each key element
 - Tie each line item in the schedule to resources and duration to complete the task

Project Scheduling

- Specific elements in a project schedule may include:
 - Preliminary site characterization
 - Safety assessment and licensing documentation
 - Preparation of the Decommissioning Plan
 - Obtaining required permits and approvals
 - Facility design/ engineering/ modifications to support decommissioning
 - Decontamination
 - Dismantlement and demolition
 - Waste management
 - Final radiological survey
 - License termination actions

Example WBS Based Schedule

WBS #	Task Name	Labor Hours (x 1000)	Budget (includes labor) (x 1000€)	T = - 3	T = 0	T = 3	T = 6	T = 9	T = 12	T = 15	T = 18	T = 24
				Months	Months	Months	Months	Months	Months	Months	Months	
1	Decommission Research Reactor		2000	[Gantt bar from T=-3 to T=24]								
1.1	Pre-shutdown planning		30	[Gantt bar from T=-3 to T=0]								
1.2	Final Shutdown		===	Milestone at T=0								
1.3	Preliminary Studies		30	[Gantt bar from T=0 to T=3]								
1.4	Project Execution		1905	[Gantt bar from T=3 to T=18]								
1.4.1	Decommissioning Activities		1740	[Gantt bar from T=3 to T=15]								
1.4.1.1	Decon/Remove Auxilary Systems		870	[Gantt bar from T=6 to T=12]								
1.4.1.2	Decon/Remove Reactor Systems		870	[Gantt bar from T=9 to T=15]								
1.4.2	Final Status Surveys		150	[Gantt bar from T=15 to T=18]								
1.4.3	Confirmatory Surveys		15	[Gantt bar from T=18 to T=24]								
1.4.4	License Termination		===	Milestone at T=24								
1.5	Closeout Actions		35	[Gantt bar from T=24 to T=24]								
1.5.1	Non-radiological remediation		25	[Gantt bar from T=24 to T=24]								
1.5.2	Demobilization		5	[Gantt bar from T=24 to T=24]								
1.5.3	Closeout Documentation		5	[Gantt bar from T=24 to T=24]								

Project Execution

- Decommissioning activities
 - Spent fuel transfer and storage
 - Draining and deactivation
 - Decontamination
 - Dismantlement
 - Waste management, packaging, transport, and disposal
 - Surveillance and maintenance (S&M)
- Final surveys and license termination
- Confirmatory/verification surveys

Project Controls

- Quality Assurance
- Project Baselines
 - Baseline Cost Estimate
 - Baseline Schedule
 - Program Evaluation and Review Technique (PERT)
 - Baseline Exposure Estimate
 - Other Control Parameters

Project Closeout

- License termination
 - Radiological and hazardous material have been satisfactorily removed
 - Regulatory Body approval
- Site management may need to perform additional tasks to reach the agreed upon final end state
- Long term monitoring or institutional controls are developed and implemented if necessary
- Following completion of physical work to reach the end point
 - Generate Project Decommissioning Report
 - Transfer records and documentation

References

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- IAEA Safety Report No. 45 Standard Format and Content of Safety Related Decommissioning Documents (2005)
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- IAEA TRS No. 399 Organization and Management for Decommissioning of Large Nuclear Facilities (2000)
- IAEA TRS No. 414 Decommissioning of Small Medical, Industrial and Research Facilities (2003)
- IAEA TRS No. 446 Decommissioning of Research Reactors: Evolution, State of the Art, Open Issues (2006)

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- IAEA Waste Safety Guide No. WS-R-2 Predisposal Management of Radioactive Waste, Including Decommissioning (2000)
- IAEA Technical Report Series No. 386 Decommissioning of Nuclear Facilities Other than Reactors (1998)

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- IAEA Technical Reports Series No. 351, Planning and Management for the Decommissioning of Research Reactors and Other Small Nuclear Facilities (1993)
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