The Abdus Salam
International Centre
for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA
International Atomic Energy Agency

2473-9

Joint ICTP-IAEA School on Nuclear Energy Management

15 July - 3 August, 2013

Lecture Notes

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The IAEA Nuclear Energy Management School
ICTP, Trieste, 15- 2 August 2013

Deciding on Decommissioning Strategy

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Content

- About decommissioning (definition and goals)
- Decommissioning strategies
- Section of optimal strategy
- Planning and implementing decommissioning
- Current status
- IAEA role and activities

Decommissioning

- Decommissioning definition:
  - The administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a nuclear facility
- Decommissioning objectives:
  - to place nuclear facilities that have reached the end of their useful lives in such a condition that they pose no unacceptable risks to the public, to workers or to the environment,
  - to reuse facilities and sites for new purposes

Why Decommissioning is Needed?

- Decommissioning needed for:
  - NPP, fuel production facilities, WM and SF management facilities
  - Research reactors and other research facilities dealing with nuclear and radioactive material
  - Medical and industrial radiological facilities
  - Military facilities for nuclear applications
- Successful decommissioning requires:
  - Legislative and regulatory framework
  - Necessary infrastructure (technical and human resources, financial provisions)
  - Policy and strategy for decommissioning

Decommissioning Strategies

- **Three main decommissioning strategies:**
  - Immediate dismantling (as soon as facility cease to operate)
  - Deferred dismantling: Safe enclosure (for several decades) → dismantling
  - Entombment (long term) → facility converted into a form of waste disposal

Immediate dismantling

- Full decommissioning to the final state in a continuous manner soon after the end of operation
- Starting with removal of spent fuel and other highly toxic materials (post-operational clean-out)
- Advantages:
  - Early release of site for future uses
  - Availability of operating staff knowledge and labour
  - Avoiding surveillance and maintenance costs over an extended period
- Constraints:
  - Availability of waste disposal capabilities or interim storage arrangements
  - Suitable technologies (high radiation fields!)

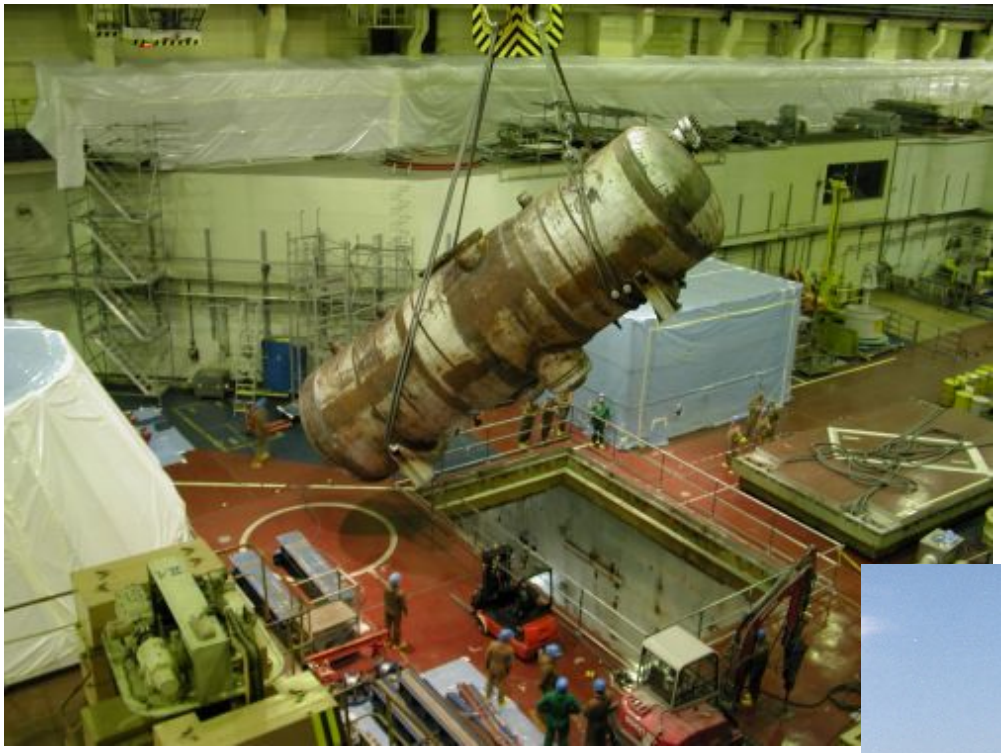
Deferred dismantling

- It includes at least one extended period of surveillance and maintenance of the facility (up to 100 years)
  - Starting with post-operational clean-out and/or removal of spent fuel
  - Followed by activities to put the facility in optimal state for surveillance and maintenance
- Advantages:
  - Use of radioactive decay to reduce radiation dose to workers
  - Less waste of higher activity or waiting for disposal solution
  - Waiting for sufficient funds
- Disadvantages:
  - Long-term facility maintenance and security costs
  - Risk of loss of knowledge
  - Restriction on use of the site

Entombment

- Leave the heart of the facility *in situ,* usually covered over by earth and/or concrete – treating the site as disposal facility
  - Fuel removal and other materials for recycle and reuse still takes place
  - Limited dismantling and modification to provide optimal entombment
- Advantages:
  - Reduced volumes of waste
  - Lower workload and costs
- Disadvantages:
  - Extended environmental monitoring programme necessary
  - Stakeholder concerns over long-term implications

Examples of Immediate Dismantling



Immediate dismantling of NPPs in Greifswald, Germany

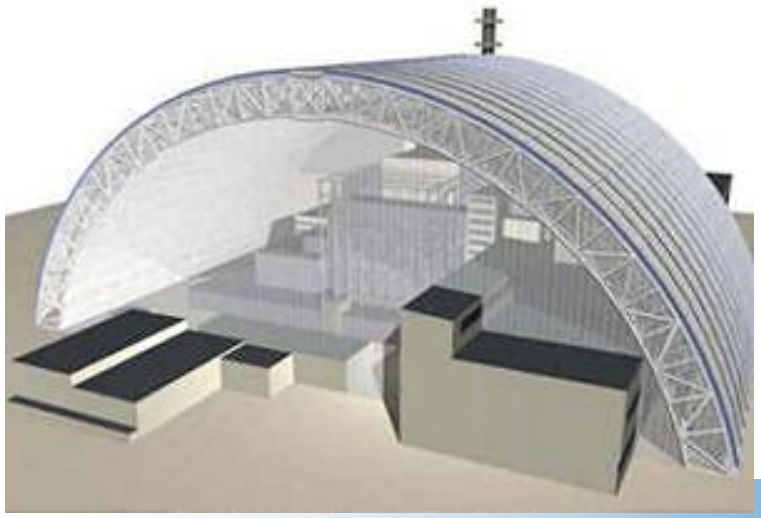
Immediate dismantling of V-1 NPP in Bohunice, Slovak Republic

Example of Deferred Dismantling

Safe enclosure of Vandellos I NPP in Spain (20 years or more)

Example of Entombment

New Sarcophagus for 4th unit of Chernobyl NPP



Selection of strategy

- Factors that influence selection of strategy:
  - National policy and regulatory requirements on decommissioning
  - Availability of financial resources
  - Cost estimates
  - Decommissioning technologies and equipment
  - Spent fuel and waste issue
  - Safety and security
  - Regulatory aspects
  - Social and economic impacts
  - Stakeholder consideration
  - Facility specific issues

Selection of strategy

- In selecting preferred strategy all relevant factors need to be identified and considered in a systematic and auditable way
  - In more complex situations a multi-variant decision process using weighting and scoring system may be useful
  - Results should be tested for sensitivity to changes in any of initial assumption
  - Risk of regulatory changes or unexpected plant conditions should be considered (strategies that do not foreclose later changes of approach!)

Planning for Decommissioning

- Successful decommissioning depends on careful and organized planning
- Preliminary plans:
  - IAEA recommends to prepare initial decommissioning plan for each facility and before it is put in operation
  - regular review and update during the operation necessary
  - important also to enable adequate financial arrangements
- Final decommissioning plans
  - First detailed plan should be prepared before the end of facility operations
  - The extent, content and degree of detail in the decommissioning plan depends on the complexity and hazard potential of the installation

Financial provisions

- Adequate financial resources are prerequisite for successful decommissioning
- Early decommissioning plans and cost estimates are necessary
  - selection of methodology for cost estimation
  - Periodic cost updates
- Funding schemes vary from country to country
  - Funds accumulated over the entire lifetime of the facility
  - Funds collected over shorter period
  - Operator required to make a down payment to get the first operating licence
- Conservative investment strategy

Start of Decommissioning

- Decommissioning-related activities should start well before final shutdown (planning, preparation of licensing documentation, pre-decommissioning characterization etc.);
- Transition from operation to decommissioning has to be used for careful preparation of decommissioning activities (see IAEA TRS No. 420)
- Decommissioning license shall be issued by national nuclear regulator
- Start of decommissioning not necessarily linked to spent fuel removal, but it is recommended

Active Phase of Decommissioning

- Active phase includes the following technical activities:
  - Decontamination of equipment and building surfaces;
  - Dismantling of nuclear facility technology;
  - Demolition of buildings and structures;
  - Waste characterization, segregation, treatment, storage, transportation and disposal;
  - Environmental remediation related to decommissioning of nuclear facility;
  - Site clearance before the license termination

Decommissioning Technologies

- Many decommissioning technologies available (also commercially)
- Remotely operated and robotics technologies are used for work in environment with high radiation and/or physically not accessible for staff
- Innovative or substantially modified techniques are needed in case of prototype nuclear facilities or facilities shut-down after an accident
- R&D on decommissioning technologies is / will be needed in the most difficult cases (Chernobyl, Fukushima)

Robotic arm Maestro, France

Manipulator DENAR-41, Slovakia

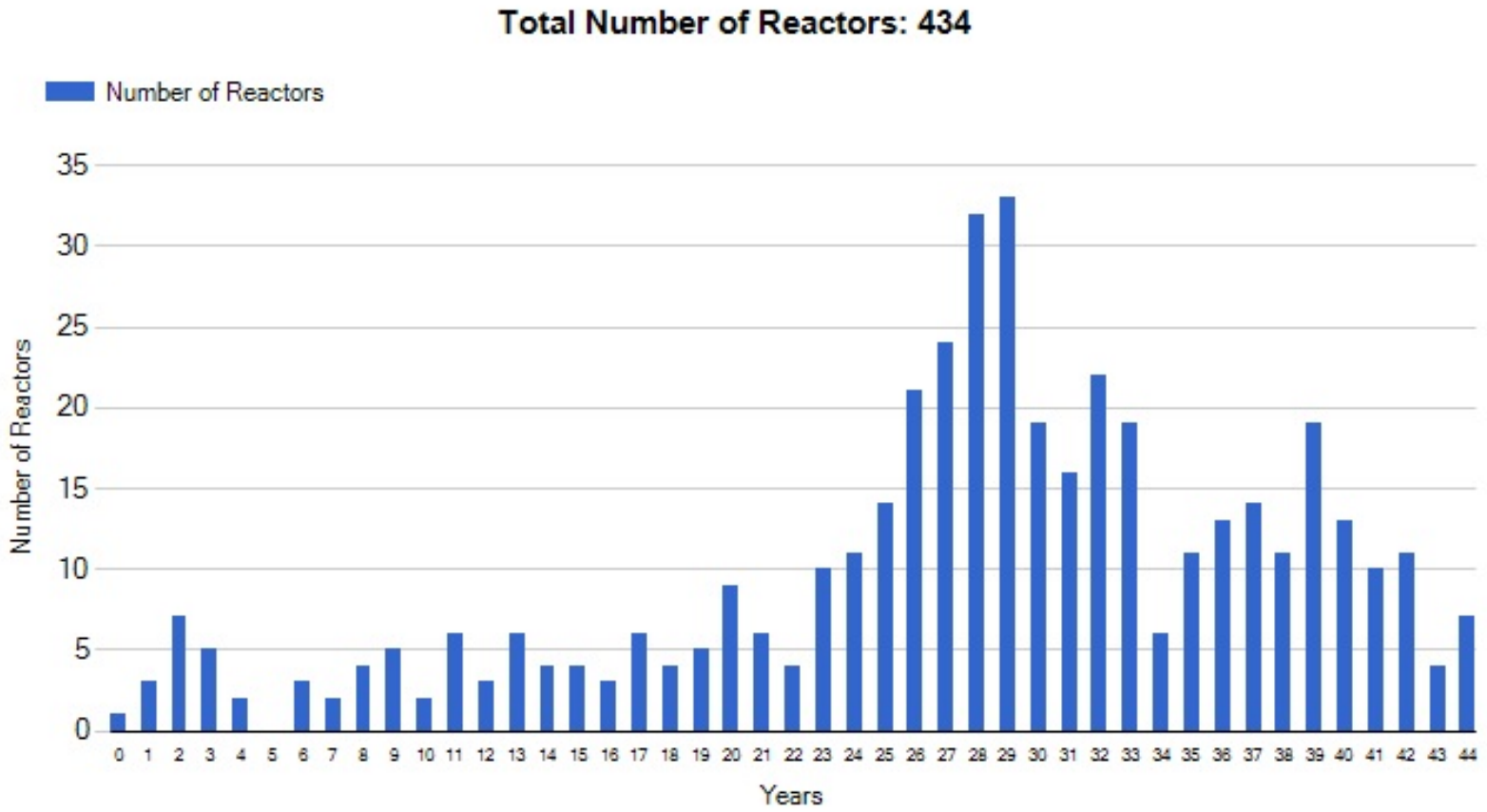
Final Decommissioning Phase

- Decontamination and dismantling activities completed
- All radioactive material removed
- Final survey performed
- Final decommissioning report prepared
- Application for license termination issued (it is necessary to demonstrate to the authorities that no radioactivity above prescribed levels is left)
- Post-decommissioning activities:
  - Non-nuclear dismantling (e.g. remaining buildings),
  - Landscaping,
  - Site reuse / redevelopment

Current Status

- Current status of decommissioning worldwide:
  - 16 power reactors were shut-down and fully dismantled;
  - 50 power reactors are in process of being dismantled;
  - 60 power reactors are being kept in safe enclosure mode;
  - 3 power reactors were entombed;
  - 18 power reactors do not yet have specified decommissioning strategies
- More than 450 research reactors already decommissioned or in a process of dismantling or shut-down and awaiting decommissioning
- Future prospects:
  - Ageing of current fleet of NPPs
  - Impact of Fukushima

Operational Reactors by Age



Reactor Age (Yr)

Impact of Fukushima

- After Fukushima accident increased demand for decommissioning:
  - In Japan activities related to decommissioning and clean-up in Fukushima
  - Some countries decided for early shut-down of NPPs
  - At international level revisiting different aspects and plans for decommissioning of reactors shut-down in abnormal conditions

IAEA Priorities in Decommissioning

- Establish and encourage use of internationally agreed safety standards for decommissioning
- Encourage and support establishment of national policy for decommissioning and strategy for its implementation in each country using nuclear technology
- Stimulate countries for early planning and preparing for decommissioning of nuclear/radiological facilities (including newcomer countries)
- Support countries in developing or strengthening their capacities/capabilities for decommissioning
- Encourage and support cooperation, sharing of knowledge and experience including lessons learned from accidents

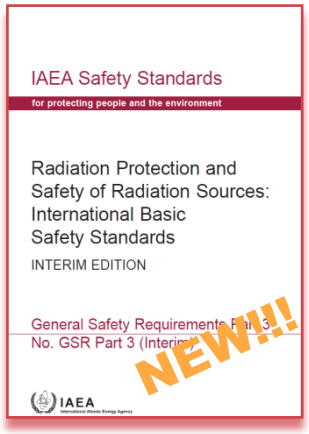
What tools and means are available?

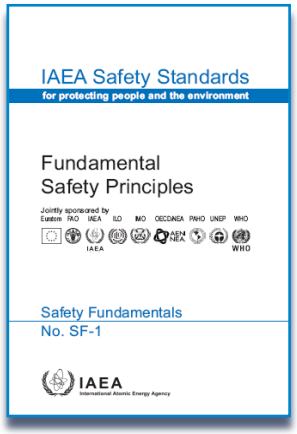
- Joint Convention, Safety Standards and guides for harmonization of safety approaches
- Technical publications on specific topics with guides and recommendations
- Technical cooperation programme
- Networks and eLearning
- International harmonization projects
- Action Plan for Nuclear Safety
- Peer reviews

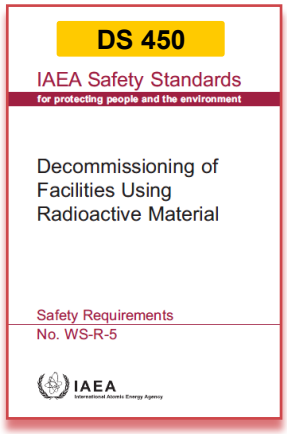
Safety Standards

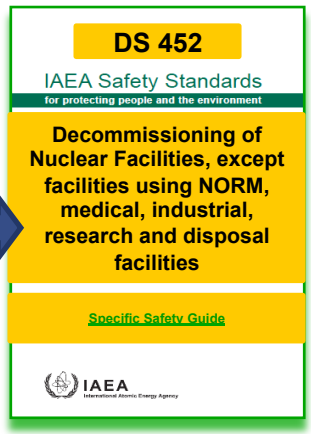
- IAEA develops safety standards related to decommissioning of all types of facilities, release of sites and materials from regulatory control, safety assessment and management of contaminated scrap metal;
- Safety Standards reflect international consensus on the safety level needed to protect people and the environment from the ionizing radiation;
- Three basic categories – Safety Fundamentals, Safety Requirements, Safety Guides;
- IAEA Safety Standards are revised on regular basis to incorporate new knowledge, experiences and good practices

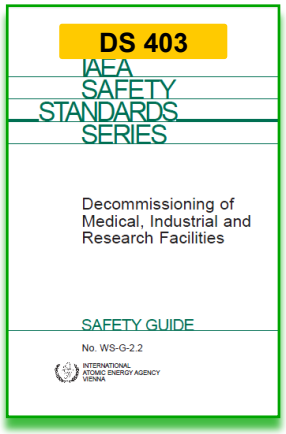
Safety Standards on Decommissioning

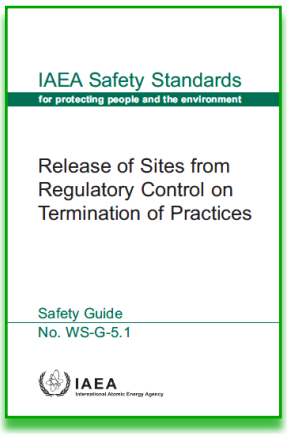


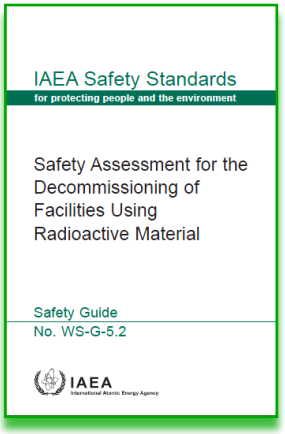












Technical Publications

- More than sixty publications in decommissioning area were published by the IAEA from 80-ies
- Several types of technical publications:
  - Nuclear Energy Series reports (NES) with
    - Principles and Objectives
    - Guides
    - Technical reports
  - Technical Report Series (TRS)
  - TECDOCs
  - Safety reports

NES Publications

IDN - Decommissioning Network

- IDN – International Decommissioning Network
  - a tool to address the needs of Member States through thematic and strategically focused approaches
  - A tool to encourage and facilitate sharing of information between practitioners, i.e. between and among those with extensive decommissioning experience and those seeking to learn from this experience
  - A tool to promote application of “good practices" in decommissioning technology, planning, project management, and the management of nuclear wastes
  - To provide opportunities for practical hands-on training and sharing of user-oriented experience
- Documents, meetings, training events, workshops, video demonstrations

CONNECT project

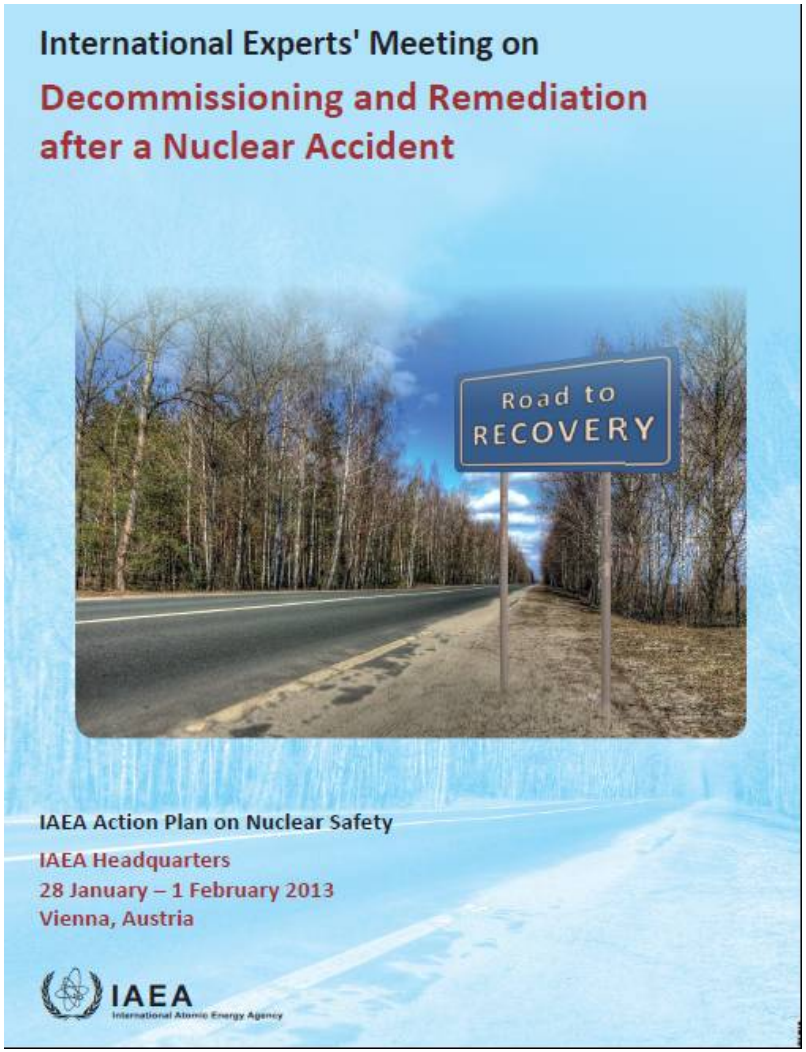
- a collaboration platform hosted by the IAEA
- a gateway for interconnecting IAEA Networks
- CONNECT provides professionals in the IAEA's communities of practice (Networks) with access to high-quality training materials and a means to share and collaborate on-line.

Action Plan on Nuclear Safety

- Action Plan on Nuclear Safety (NSAP) prepared after Fukushima accident and endorsed by the Member States at GC 2011
- The ultimate goal of the Action Plan is to strengthen the global nuclear safety framework
- NSAP includes 12 Actions, 39 Sub-actions, 172 Activities and 647 Tasks in different areas
- NSAP action: protection of people and the environment from ionizing radiation following a nuclear emergency

IEM – International Expert Meeting

- Held from 28 January to 1 February 2013 in Vienna
- Addressing decommissioning and remediation after an accident
- Focusing on the complex technical, societal, environmental and economic issues after an accident



IAEA Comprehensive Report on Fukushima

- Preparation announced at 56th General Conference in 2012, the Report to be completed in 2014
- Scope: description, causes and consequences of the accident, safety assessment, emergency preparedness, radiological consequences and post-accident recovery
- The chapter on post-accident recovery addresses remediation and decommissioning and dismantling
- Comprehensive work on-going with almost 100 external experts involved divided in five Working Groups

Specific topics under Action Plan

- Number of on-going and planned activities related to decommissioning and clean-up:
  - report on the experience and lessons learned worldwide in clean-up and decommissioning of nuclear facilities in the aftermath of accidents
  - collecting experience on approaches, techniques, tools and equipment to deal with clean-up, decontamination and decommissioning after an accident
  - Management of large volumes of radioactive waste as a result nuclear accident

Peer Review services

- International Peer Review of UK Magnox Decommissioning Programme: first review in 2008, follow-up in 2011
- International Peer Review of Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Units 1-4:
  - First mission to Japan in April 2013 to provide an independent review of planning and implementation of decommissioning activities; team of 13 experts (external and IAEA)
  - Second mission planned later this year to provide more detailed and holistic review of the Roadmap and mid-term challenges including the review of agreed specific topics

In Conclusion…

- Decommissioning activities expected to increase also in future
- Many experiences in decommissioning collected so far – decommissioning considered as mature industry
- New challenges related to decommissioning after an emergency
- Still many countries lacking skills and experience in this area and need assistance
- The need for cooperation and sharing of knowledge and experience important in the future