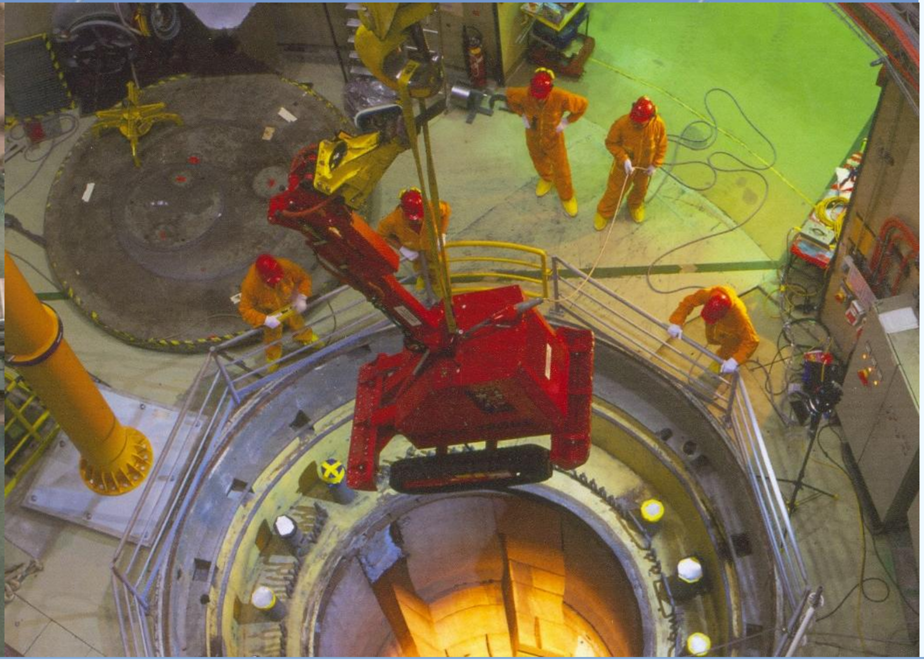
Post Operations
Decommissioning of Nuclear Power Plants Abroad
Lessons Learned in Western Countries

Moscov, 19 June 2017



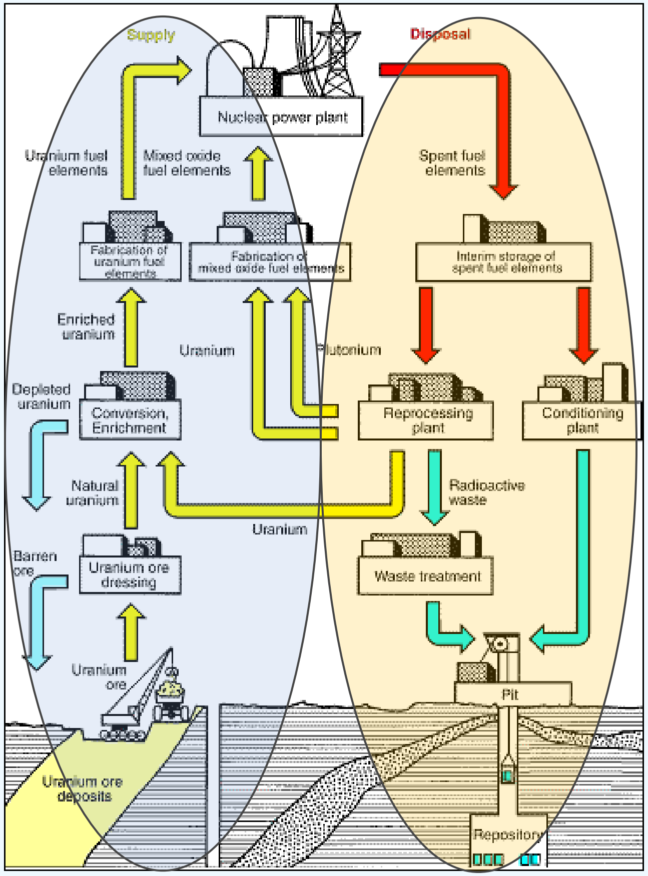
Topics

1. Overall View on Decommissioning
2. Decommissioning of Nuclear Facilities – Basics
3. Licensing and Supervisory Procedures
4. Safety and Radiation Protection
5. Processes and Technologies
6. Residual Materials and Waste Management
7. Risks from Decommissioning

Overall View on Decommissioning (1)

FRONT END

- Mining
- Conversion
- Enrichment
- Fuel Fabrication



Source : www.euronuclear.org

BACK END

- Spent Fuel Storage
- Reprocessing
- Decommissioning
- Waste Conditioning
- Waste Disposal

Overall View on Decommissioning (2)

BACK END

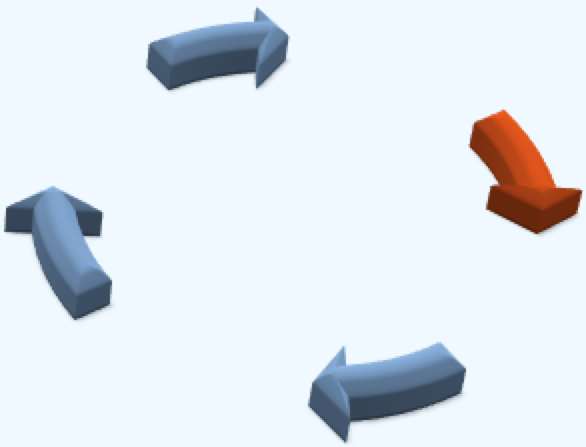
- Spent Fuel Storage
- Reprocessing
- Decommissioning
- Waste Conditioning
- Waste Disposal

MOTIVATION

- Environmental Protection
- Protection of Population
- Saving Ressources by Material Recycling
- Re-use of Infrastructure Elements

COMMERCIALLY REASONABLE
ENVIRONMENT-FRIENDLY
LEADING TO PUBLIC ACCEPTANCE OF NUCLEAR

Overall View on Decommissioning (3)



- Provider of nuclear technology offer back end solutions mastering **ALL** steps of the nuclear cycle
- ROSATOM shall develop its own back end expertise and capabilities
  - to service its own nuclear fleet and
  - to offer this service on foreign markets

Overall View on Decommissioning (4)

What NUKEM as a ROSATOM asset can provide (examples):

Dismantling of NPP components

- Reactor at Kahl NPP (Germany)
- Multi-Purpose-Reactor at Karlsruhe RC (Germany)
- Reactor at Brennilis NPP (Design, France)
- Reactor pressure vessel at KKP1 NPP (Germany)

Spent Fuel Storages

- Dukovany NPP (Czech Republic)
- Kozlodui NPP (Bulgaria)
- Ignalina NPP (Lithuania)

Waste Disposal Facilities

- Chernobyl NPP (Ukraine)
- Kozlodui NPP (Bulgaria)

Overall View on Decommissioning (5)

What NUKEM as a ROSATOM asset can provide (examples, continued):

Waste treatment infrastructure for decommissioning of NPP

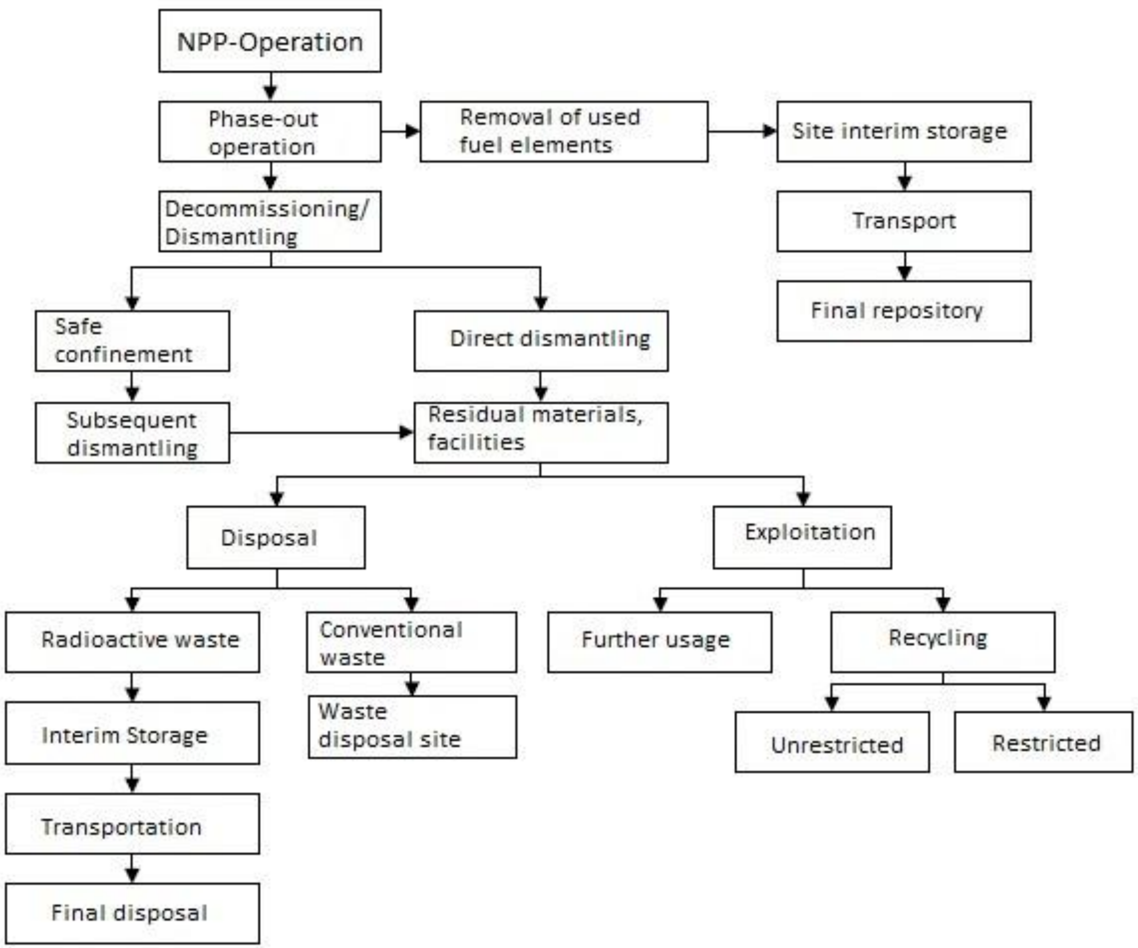
- Waste treatment facility at Chernobyl NPP (Ukraine)
- Waste treatment facility at Ignalina NPP (Lithuania)

Design and Consultancy for Decommissioning of NPP

- Planning of Kozlodui NPP decommissioning (Bulgaria)
- Planning of Mezamor NPP decommissioning (Armenia)

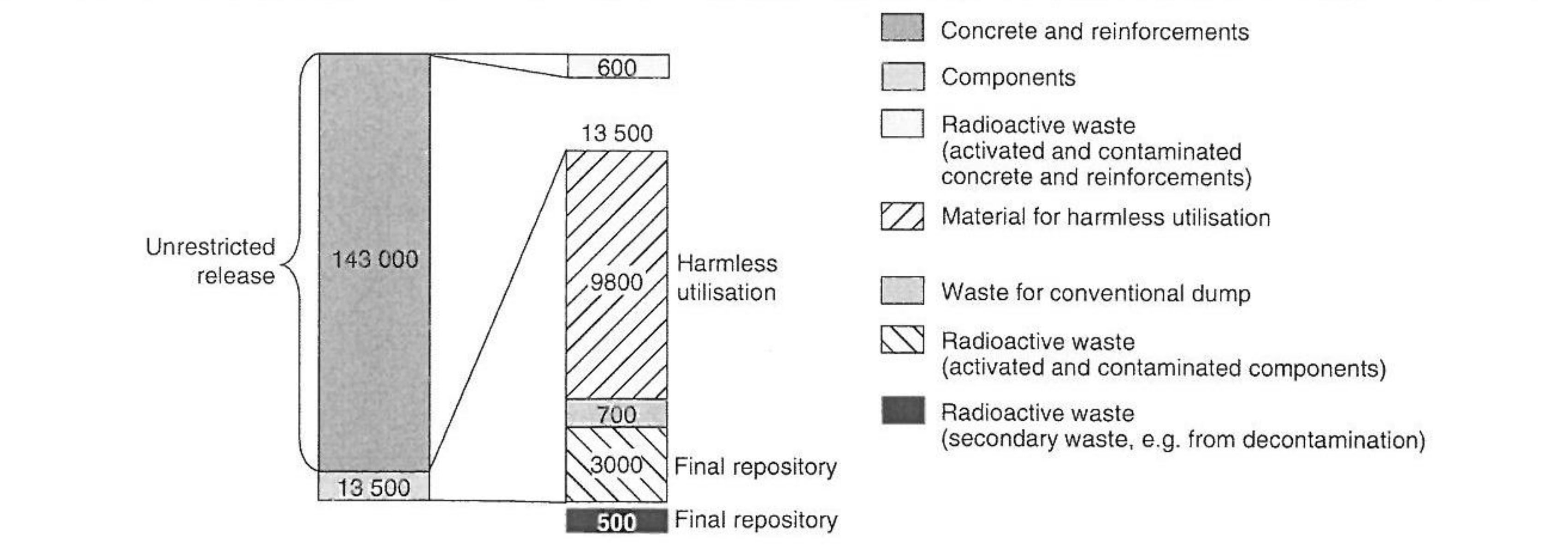
Decommissioning of Nuclear Facilities
- Decommissioning procedure – Options

Each decommissioning step contains potential for decisions and optimization!



Decommissioning of Nuclear Facilities
- Decommissioning procedure – Material flow

Minimisation of radioactive waste



Dismantling and waste disposal quantities of the radioactive controlled area of a reference PWR (figures in Mg) (source: VGB)

Source: VL-Skript

Licensing and Supervisory Procedures
- Direct dismantling vs safe confinement -

	Direct dismantling	Safe confinement
Advantages	• Availabilitiy of personal with plant specific knowledge of the operating history • Minimization of economical impact on the local region • Funding safety	• Reduction of radioactive inventory • Simplfication of dismantling operations due to reduces radiation load • Delay of final storage
Disadvantages	• Higher existing level of radioactive radiation • Technically more complex due to higher exposure • Enhanced individual and collective dose	• Complex installation works for safe confinement • Loss of plant specific knowledge • Reduced acceptance by the people „dangerous residues"…

- in Germany direct dismantling is preferred due to its advantages
- other countries – other decisions

Licensing and Supervisory Procedures
- Licensing -

- Legal framework defined by country specific nuclear legislation → approval by responsible authority required.

- To obtain the approval the required documents need to be submitted to the respective responsible authority.

- It has to be shown (description of the optimization potentials):
  - Approach
  - Planned dismantling methods
  - Applicable procedures
  - Environmental impacts
  - Provisions for radiation protection

Safety and Radiation Protection
- Safety aspects -

Ultimate safety objective: Protection of staff and environment against inadmissible exposure to radiation

- Safety during decommissioning is provided by application of a set of technical and administrative measures

- Composition of the hazard potential:
  - Radioactive inventory
  - Probability of release of radioactive substances

- Optimisation potential:
  Reduction of radioactive inventory due to the process of dismantling and decontamination operations

Safety and Radiation Protection
- Radioactive Inventory-

Activity in Bq

10^{20} to 10^{21}	• Facility shut-down
10^{16}	• Fuel elements removed
10^{12}	• Systems decontaminated
10^{10} to 10^{11}	• Open surfaces, components, buildings decontaminated

example PWR

Processes and Technologies
- Basics -

- Necessity of technologies for different processes:
  - Decontamination, Dismantling, demolition
  - Measurement of radioactivity
  - Waste conditioning
- Selection of technologies by owner/operator of the facility:
  - Depends on amount and type of radioactive inventory
  - Contamination chart as tool for decisions
- Criteria for technology selection (potential for optimization) :
  - Aspects of radiation protection
  - Suitability and effectivity of the process
  - Highest amount on free release of residues and plant parts
  - Volume reduction
  - Local boundaries

Processes and Technologies
- Decontamination processes -

Mechanical	Thermal	Chemical/ Electro-chemical
Cutting/ Chipping • Drilling, Grinding • Polishing, Abrasion (dry/wet) • *Applied at:* – NPP Würgassen – NPP Stade – NPP Kahl Impact • Water jet • Dry ice • Hammering, pricking • *Applied at:* – NPP Würgassen – NPP Stade	• Laser-decontamination • *Applied at:* – Laboratory tests – Prototypes	• Mineral acids: – Nitroc acid – Sulfuric acid – Phosphoric acid • Acidic salts – Sodium phosphates • Organic acids – Formic acid – Oxalic acid – Citric acid • Bases – Potassium hydroxide – Sodium hydroxide

Processes and Technologies

- Dismantling processes -

Thermal	Mechanical
• Melting of material using: – Flames – Light arcs – Laser-beams • Suction of particle emissions • Applied at: – NPP Greifswald (manual / remote controled) – NPP Gundremmingen (remote controled) – NPP Windscale (UK)	• Used for metal and concrete • Producing kerf by mechanical removal of material • Applied at: – Nuclear reactor BR3 of Nuclear Research Center Mol (Belgium) – Experimental NPP Kahl – NPP Brennilis

Residual Materials and Waste Management
- Decay storage -

- Alternative option for large, highly activated parts (Reactor pressure vessel (RPV), steam generator, etc.)
- Advantages:
  - Use of less complex dismantling processes due to decreased radioactivity
  - Possible recycling or disposal of some parts as conventional waste
- Applied at:
  - NPP Greifswald (steam generator and RPV)
  - NPP Rheinsberg (steam generator and RPV)

Source: GRS

Risks from Decommissioning

-Decommissioning specifics-

New build	Decommisioning
Design and status known	Status partly unknown (Activation / Contamination)
Working under designed shielded conditions	Working with open radioactive sources
Licensing process proved and known	Licensing process not yet proved and partly unknown
Storage and disposal infrastructure for small amounts of waste	Storage and disposal infrastructure for huge amounts of waste

Risks from Decommissioning
-Risks 1-

Technical Risks

- Technologies for decontamination and cutting available
- Supply chain and service provider available
- Technologies redundant, experiences for nearly all decommissioning tasks

HARDLY ANY TECHNICAL RISKS

Risks from Decommissioning
-Risks 2-

Project Management Risks

- Hidden scope of contamination
- Leads to additional decontamination effort
  - Leads to project delay
    - Leads to additional costs for staff
    - Leads to additional radioactive material to be treated
    - Leads to additional casks for storage and disposal

RISK OF ADDITIONAL COSTS AND DELAY

Summary and Recommendations

- Decommissioning is an essential part of the nuclear cycle
- ROSATOM as a full service provider shall cover that area by
  - pooling ressources and experiences already available
  - further develop its own capabilities
- Standardization of individual steps is possible for decommissioning projects
- For dismantling technical process remains an individual project for each facility
- Most options and modules in dismantling steps are industrial standard
- Experience exchange from practical application maintains implementation of a „best practise approach"
- Keeping schedule and budget under not fully known circumstances can be considered the biggest challenge