Decommissioning – three main strategies:
Immediate dismantling,
Safe enclosure (Deferred dismantling),
Entombment

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Overview

- Decommissioning – when and why?
- Law, regulations and guidelines
- Three main strategies
- Is there an optimal strategy?
- Experience
- There is an optimal strategy
Decommissioning – when and why?

- At the end of their operating time nuclear power plants reach the end of their service life
- The end of the service life typically depends on technical or economical marginal conditions
- Legal obligations may play a role (i.e. some states who will join the EU like Lithuania, Germany with the new regulations in the Atomic Act)
- The end of the life cycle leads to the decommissioning of the nuclear power plant
- The need of a free site for erecting a new facility (e.g.: the Russian concept for an “energy site“ with the whole infrastructure including satellite towns)
Decommissioning of nuclear power plants

- Like other industrial facilities conventional safety aspects have to be considered
- In the case of the decommissioning of a nuclear power plant, special precautions have to be taken
- The main difference to conventional industry facilities is their special inventory: radioactive material
- The radiological aspects demand the inclusion of radiological safety aspects
Decommissioning – three main strategies

- **Immediate dismantling**
  The dismantling commences after the end of the operation

- **Safe enclosure (Deferred dismantling)**
  The nuclear power plant will be locked for about 30 years
  After this period a dismantling will take place

- **Entombment**
  The nuclear power plant will be entombed „forever“
Basic aspects - International regulations

- IAEA Safety guides
  - Decommissioning of facilities using radioactive Material No. WS-R-5
  - Safety reports Series No. 50
    Decommissioning Strategies for facilities using radioactive Material
  - Safety guides for nuclear waste, i.e. for nuclear facilities as long they are used and for disposal facilities
Basic aspects - International regulations

- **WENRA** (Western European Nuclear Regulator’s Association)
  - WGWD - Decommissioning Safety Reference Levels Report (version 2.0, November 2011)
  - WGWD Waste and spent fuel storage safety reference levels report (version 1.0, December 2006, newer one: version 1.2, September 2011)

- **WANO** (World Association of Nuclear Operators)
National regulations

- National regulations are based upon international guidelines
- The countries have the free choice of creating their laws, international law should be respected
- If a law is ratified, it has to be fulfilled
- Changes in the law are difficult to deal with
- This may be evident if the decommission process is already running

E.g.: Germany: the last change in the Atomic Act forbids a nuclear power generation under commercial aspect, first for the old 8 reactors and successive for the other ones.
Which strategy? General considerations

- One main strategy has to be chosen
- There are several aspects for the choice of the strategy, i.e. legal, technical, radiological and economical aspects
- If a main strategy is allowed by law, it can be chosen
- The target is important:
  - Deconstruction, remediation and release of the site – „green fields“
  - Release of existing buildings and plants – industrial utilisation
  - Further nuclear use – utilisation under nuclear energy law
Which strategy? Technical and radiological aspects

- The type of the nuclear facility
  - BWR
  - PWR (esp. VVER)
  - Gas-cooled
  - RBMK
  - RR

- Vendor of the nuclear installations

- Space for the flow of the waste
  - Dismounting, conditioning facilities
  - Decontamination facilities (reducing amount of radioactive waste)
  - Intermediate storage capacity

- Radiological aspects
  - Space available at power plant
  - Usage of remote-operated systems possible?

- Availability of a disposal site (Repository)
Immediate Decommissioning

- Advantages
  - Personnel from operation is available (and their knowledge)
  - Operating history is well known
  - Time scale is well defined, also the costs
  - Existing infrastructure can be used (i.e. ventilation, cranes)
  - No further consideration of duration of life are needed
  - Current laws and guidelines

- Disadvantages
  - Higher collective dose
  - Greater complexity if shieldings or remote controlled systems are used
  - Final repository is needed
  - Intermediate storage of radioactive waste is needed if no final repository exists
Safe enclosure, followed by decommissioning

- Advantages
  - Activity is reduced (for Co-60 by a factor of 64 after 30 years), “decay storage”
  - Lower collective dose
  - A greater part of the material can be reused (clearance)

- Disadvantages
  - Loss of Co-60 as a key nuclide
  - Loss of knowledge and experience
  - Preliminary work must be done under same dose rates like immediate decommissioning – no benefit
  - Control must be established for 30 years
  - Safety relevant parts must be checked for 30 years additional lifetime
  - Infrastructure like cranes and ventilation has to be assessed for 30 years
Entombment

- **Advantages**
  - Fast
  - Less expensive than other methods
  - Only little material goes to final repository (no big storage capacity needed)

- **Disadvantages**
  - Preliminary work must be done under same dose rates like immediate decommissioning, but less work needed
  - Material can not be reused (cleared) and is wasted
  - Site can not be reused
  - Unwanted legacy for future generations
  - Local final repositories are created
  - Public opinion
e.g.: Entombment is not recommended in Germany and even not by the IAEA:

Entombment, in which all or part of the facility in encased in a structurally long lived material, is not considered a decommissioning strategy and is not an option in case of planned permanent shutdown. It may be a solution only under exceptional circumstances (e.g. following a severe accident) for an existing facility.

IAEA, Decommissioning of Facilities, Draft Safety Requirements DS450
Masses expected during decommissioning

- Supervised zone: 2/3
  - Clearance / Exemption (several paths are possible)
    - Unrestricted release
    - Recycling
    - Landfilling
  - Radioactive waste
  - Reuse (under defined circumstances)
- Controlled zone: 1/3
  - 97.2%
  - 2.4%
  - 0.4%

The fractions are valid for BWR and PWR.
Experience

- Experience has shown that good planning and preparation is important
- Resources of the plant itself can be effectively used
- If several plants have to be decommissioned in sequence, economic advantages and radiological benefits may arise
- A good communication between operator, supervisory and licensing authorities and experts helps to ensure the process
- The optimum is reached if the decommissioning process runs smooth, saves time and money and takes care of the workers
Experience

- But experience also has shown, that the mass distribution as displayed above needs:
  - Fine decontamination techniques
  - Long term security for the possibility of free and restricted release
  - A good path for concrete
  - An interim storage
  - A repository

The advantages, disadvantages and experiences lead to a situation where not a single strategy fits all requirements, but a mixed strategy does well.
PWR, Phase concept

Decommissioning – three main strategies

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Interim storage
Decontamination
Decontamination of buildings

Maine Yankee
DWR 900 MW
In operation 1972 - 1997
Long-term interim storage – the Dutch case

- Some 200 producers of radioactive waste, varying from NPP, research facilities, industries and hospitals
- Annual amount approx. 200 tonnes
- Treatment: supercompaction and cementation, packaging in 220l drums
- Storing at COVRA
- Starting the C2C approach (cradle to cradle) to declassify most the waste after decaying time of 20 to 100 years
- A special procedure for declassifying was installed
  - Selection of decayed waste drums
  - Dismantling of metal drum
  - Crushing the concrete mantle
  - Shredding the pellets
  - Incineration of burnable waste/reuse of concrete
From cradle to cradle: Incineration or recycling of the exempted waste
Reducing the activity

- very short lived (T1/2<5y)
- short lived (T1/2<30,5y)
- long lived nuclides

Years
- Exemption
- Specific Clearance
- RS-G-1.7
Reducing the number of drums

Long lived wastes should be separated

- Exempted
- Long lived nuclides
- Short lived (T1/2 < 30.5y)
- Drums with very short lived (T1/2 < 5y)
Waste Volume and Costs (with decay storage)

**Volume**
Increase of waste for NPP in Germany (with decay storage):
approx. 115,000 Mg or 100,000 m³

**Costs**
⇒ For conditioning approx. 6,000 €/Mg => approx. 0,7 Bill. €
⇒ repository approx. 12,000 €/m³ => approx. 1,2 Bill. €
⇒ new interim storage capacities on site (10 Mio € per site)
  => approx. 0,15 Bill. €
⇒ additional costs for transport and casks (approx. 10,000 container,
  approx. 25,000 €/Cont.) => approx. 0,25 Bill. €
⇒ Sum approx. 2,3 Bill. €

⇒ Costs for research reactors and industrial plants?
Waste Volume and Costs (without decay storage)

- **Volume**
  Increase of waste for NPP in Germany (without decay storage):
  approx. 210,000 Mg or 180,000 m³

- **Costs**
  - For conditioning approx. 6,000 €/Mg => approx. 1,26 Bill. €
  - Repository approx. 12,000 €/m³ => approx. 2,16 Bill. €
  - New interim storage capacities on site (10 Mio € per site)
    => approx. 0,15 Bill. €
  - Additional costs for transport and casks (approx. 18,000 container, approx. 25,000 €/Cont.)
    => approx. 0,45 Bill. €
  - **Sum** => approx. 4 Bill. €
  - Costs for research reactors and industrial plants?
Is there a preferred strategy?

- There are several aspects for the choice of the strategy
  - Legal aspects
  - Technical aspects
  - Radiological aspects
  - Economical aspects
  - Political aspects
Life cycle – Life circle?

- Development
- Construction
- Operation
- Decommissioning

?
There is a preferred strategy

- According to our experience direct dismantling is the preferred strategy
- Entombment
  - Produces industrial ruins – “forever” and local final repositories
  - Prevents further use of the site
- Safe enclosure
  - Leads to loss of experience and knowledge and needs an intense documentation status for the following generation
  - The radiological situation gets more difficult – despite the reduction of the exposition
- Direct dismantling
  - Allows the usage of the experience and the knowledge of the personnel from operating time
  - Job security for personnel, new jobs could be induced
  - Leads to a clean site, ready-to-use
Summary

- There are several strategies possible
- Many of these strategies have been used worldwide or are currently used
- Our preferred strategy is direct decommissioning with an interim storage to reduce the amount of radioactive waste and new solutions for the concrete, that could be responsible strategy for all parties involved
- According to exceptional conditions, maybe another strategy or mixed strategies may be preferred
Thank you for your attention

and to my colleague Dr. M. Bauerfeind for help and collecting pictures