Costs and Financing of Decommissioning Nuclear Power Plants

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Agenda

Basic Liability for Decommissioning and Waste Management

- **In general:**
  - In order "*to avoid imposing undue burdens on future generations*" (Article 3 of the IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management Convention), one unifying concept, observed in nearly every country, is the polluter-pays-principle, which makes the operator liable for the costs of these activities.
  - These obligations and liabilities arise with the start of operation.

- **But:**
- sooner or later states often become directly involved at some point, including financially.
- This is especially true for waste management, as the polluter-pays-principle applies in most cases only for the decommissioning and dismantling of the reactors.
- For the long-term storage of radioactive waste, a variety of organizational models has evolved in which the national authorities – not the operator of the nuclear facility – more or less assume technical and financial liability for the very long-term issues of waste management.

Overview and nature of the funds

- **External segregated fund:**
  - The operators pay their financial obligation into an external fund.
  - Here, private or state-owned independent bodies manage the funds.
  - An external fund can exist with or without transfer of the liabilities and with or without a short-fall guarantee by the operator.
- **Internal non-segregated fund:**
  - The operator pays into a self-administrated fund and manages the financial resources, which are held within its own assets.
- **Internal segregated fund:**
  - The operator is obliged to form and manage funds autonomously.
  - The assets must be segregated from other businesses or earmarked for decommissioning and waste management purposes.
- **Public budget:**
  - State authorities take over the financial responsibility including the accumulation of financial resources (for instance via taxes and levies).
  - This option is typically used for legacy nuclear power plant fleets and orphan sites (sites where the former operator has declared bankruptcy or simply does not exist anymore, such as the former East German reactors).

Accumulation of the funds

- **The accumulation of the funds can either be achieved by a fee:**
  - a levy set on the sale of electricity,
  - “internally” by the operators who set aside funds from the revenue obtained from the sale of electricity,
  - or by the investment of the funds.
- **A crucial aspect is whether funds or future provisions are based on discounted or undiscounted costs:**
  - If the costs are **not discounted**, the operators have to set aside the full amount of the estimated costs. Only a few nuclear funding systems use undiscounted costs.
  - If costs are **discounted**, the funds are expected to grow over time. Here the provisions are determined using the inflation rate until the due date and then discounted with an interest rate, which is supposed to represent the expected rate of return. The employed discount rates range widely (e.g. 5.5% in Germany, 1.5% in Spain).
- **A cost escalation rate is not always assumed.**
- **Accumulation also depends on the scope of the fund:**
  - One option is the integrated coverage of liabilities for decommissioning and waste management in only one fund (e.g. Sweden: utilities pay a fee on the price of electricity, which accumulates in an integrated fund for decom & waste).
  - In some countries, different accumulation methods are simultaneously in place for the two processes (e.g. USA: operators are obliged to set aside funds for decommissioning but also pay a fee on the sale of electricity for high-level waste management (although the accumulation is currently stopped).

Cost estimations

- **In order to accumulate funds, costs need to be estimated.**
- **Different cost estimation methods are conceivable (e.g. order-of-magnitude estimate, budgetary estimate, definitive estimate).**
- **In reality, most cost estimates are budgetary estimates based on studies and estimates from the 1970s and 1980s, which are then extrapolated.**
- **In Switzerland and Sweden, detailed cost studies are the basis for provisions to the fund.**
- **In most cases, the waste management organization is responsible for developing cost estimates for the long-term management of radioactive waste.**
  - This organization can be state-owned (such as in the UK, Germany and Spain) or in some cases utility-owned, as in Sweden and Switzerland.
- **In general, the owners or licensees are responsible for developing cost estimates for decommissioning, which they submit periodically to the competent authority for review or approval (for example, every three years in Finland, and every five years in Switzerland).**
- **For decommissioning, cost estimations also heavily depend on the reactor technology and the decommissioning strategy.**
  - For example, at some plants in the US, large components such as the reactor pressure vessel and the steam generators were removed and disposed of in one piece, a strategy that heavily reduces costs. However, in Germany, large components must by law be taken apart on site.

Agenda

Nuclear power reactor Decommissioning

- **What does it mean?**

Decommissioning refers to the ***administrative*** *and* ***technical actions*** *taken to remove all or some of the regulatory controls from an authorized facility so the facility and its site can be reused.* - IAEA

- **How can the process be monitored?**

3-Stage-Classification

Warm-up-Stage: Measures prior to the treatment of the hot zone.

Hot-zone-Stage: Removal of the reactor pressure vessel, the reactor internals and the biological shield.

Ease-off-Stage: Measures to release site form regularly control.

Standard procedures of decommissioning

Warm-up-Stage

- Defueling the reactor
- Overview of all radioactive inventory
- Removal of **peripheral parts and machinery**, that are not needed during the decommissioning phase
- Set up of a technical and logistical **infrastructure for the decommissioning project**

On-site transport of SNF

Image: GSR (2017)

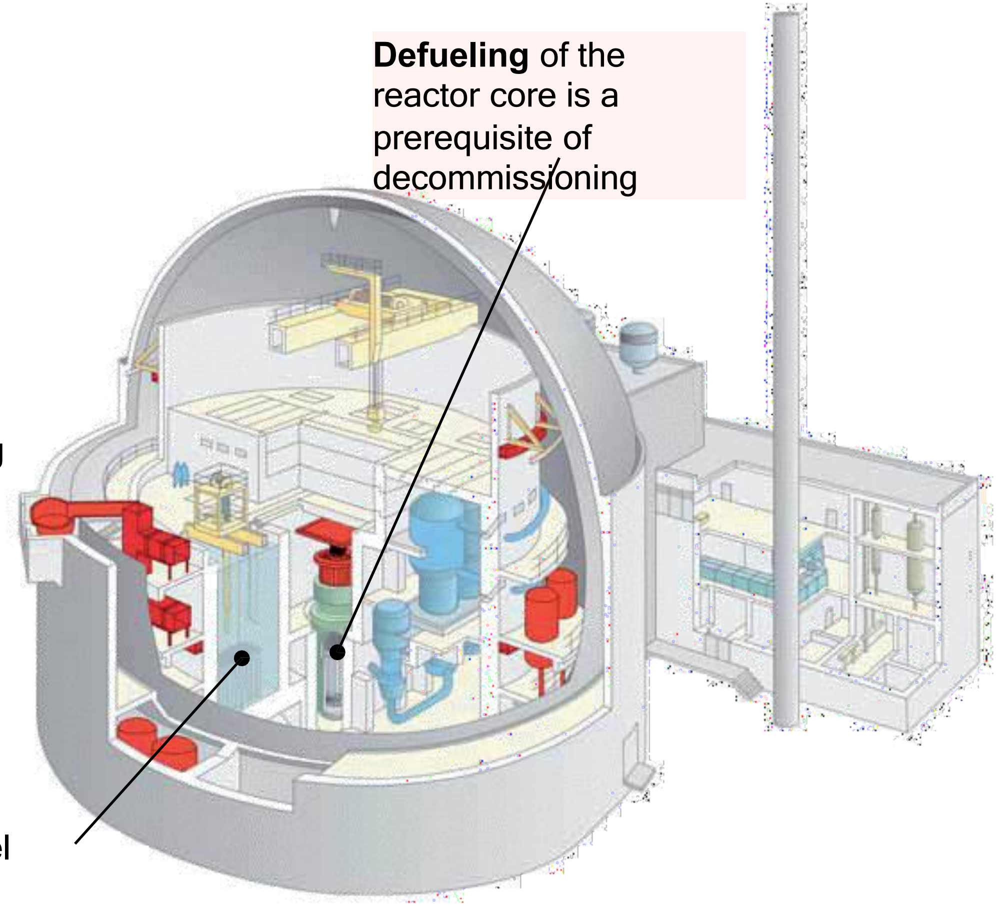
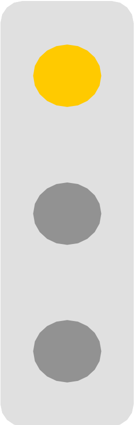


Image: GSR (2017)

Standard procedures of decommissioning



Warm-up-Stage

- Deconstruction and dismantling of higher contaminated parts, e.g. the steam generator

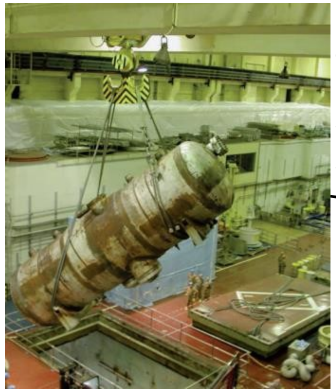


Image: GSR (2017)

- Preparations for the dismantling of highly contaminated (or activated), large scale parts

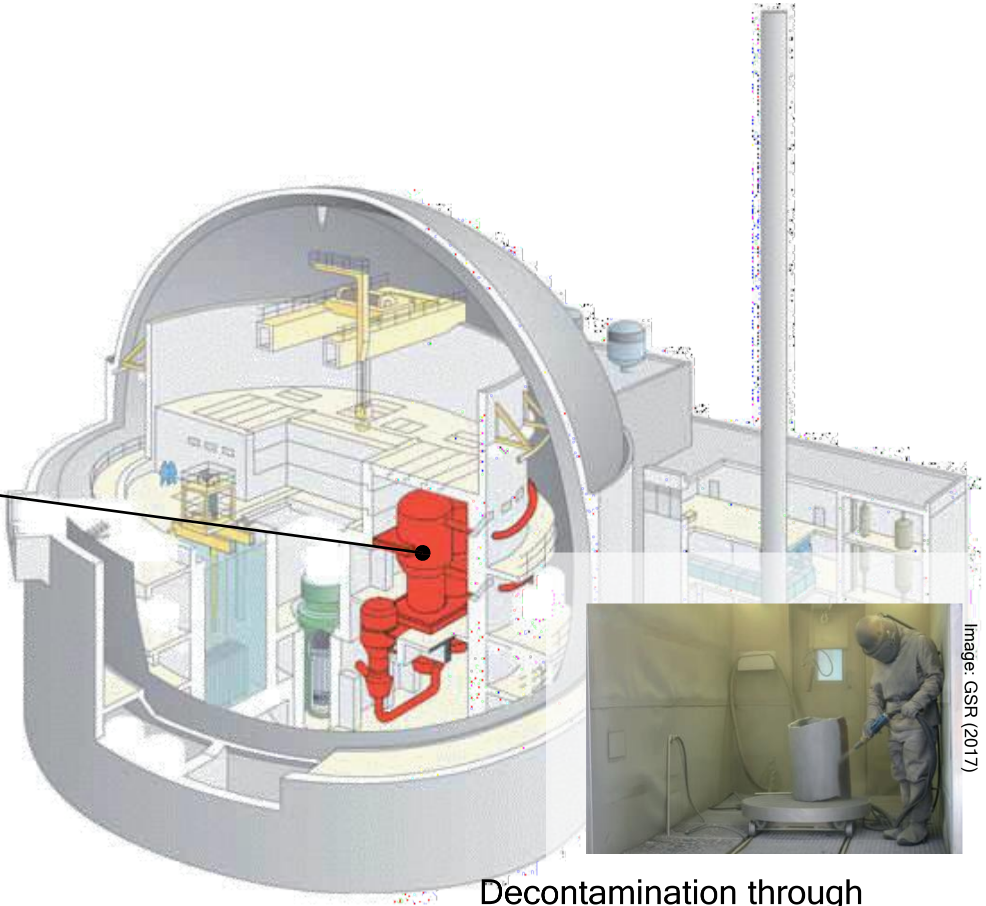


Image: GSR (2017)

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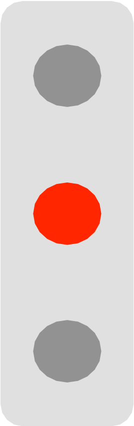
Decontamination through sandblasting

Standard procedures of decommissioning



Hot-Zone-Stage

- Deconstruction and dismantling of **highly contaminated parts e.g. RVP, biological shield**

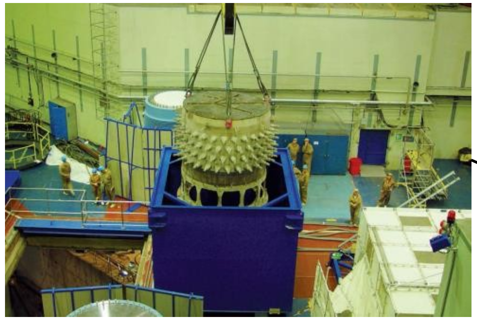
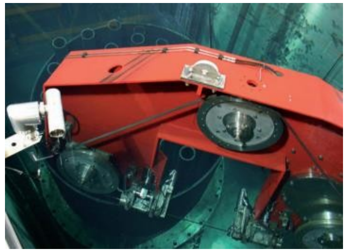


Image: GRS (2017)

Remote controlled underwater cutting



Images: GRS (2017)

One-piece removal

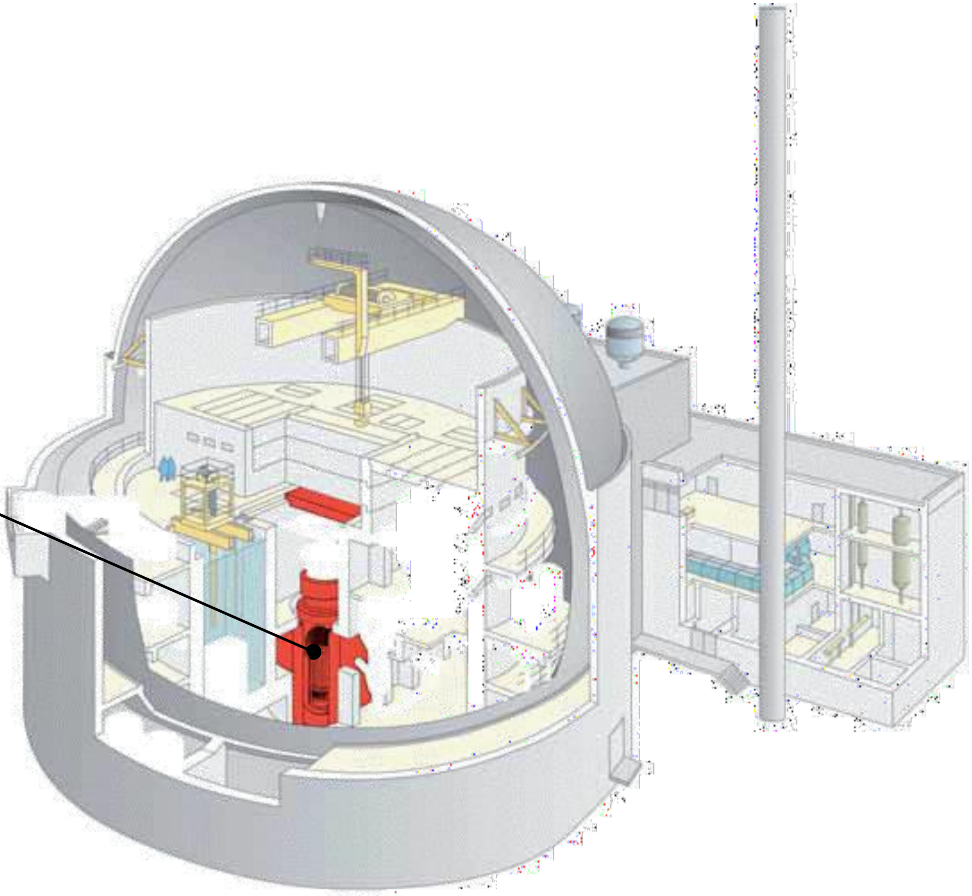


Image: GRS (2017)

Standard procedures of decommissioning

Ease-off-Stage

- Deconstruction and dismantling **remaining parts and machinery**
- **Decontamination** of the buildings

Image: GSR (2017)

Markings for surface decontamination

- Release from regulatory control

Image: GSR (2017)

Measurements for release

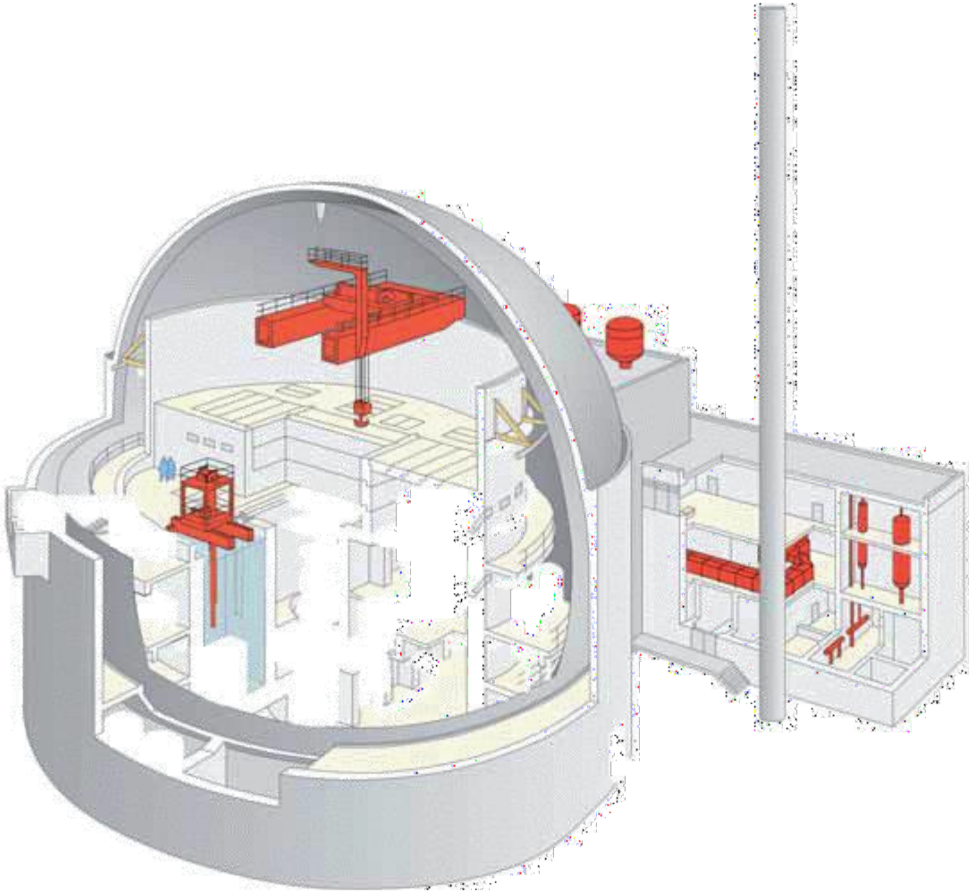
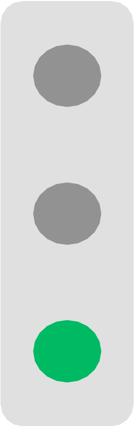


Image: GSR (2017)

Standard procedures of decommissioning

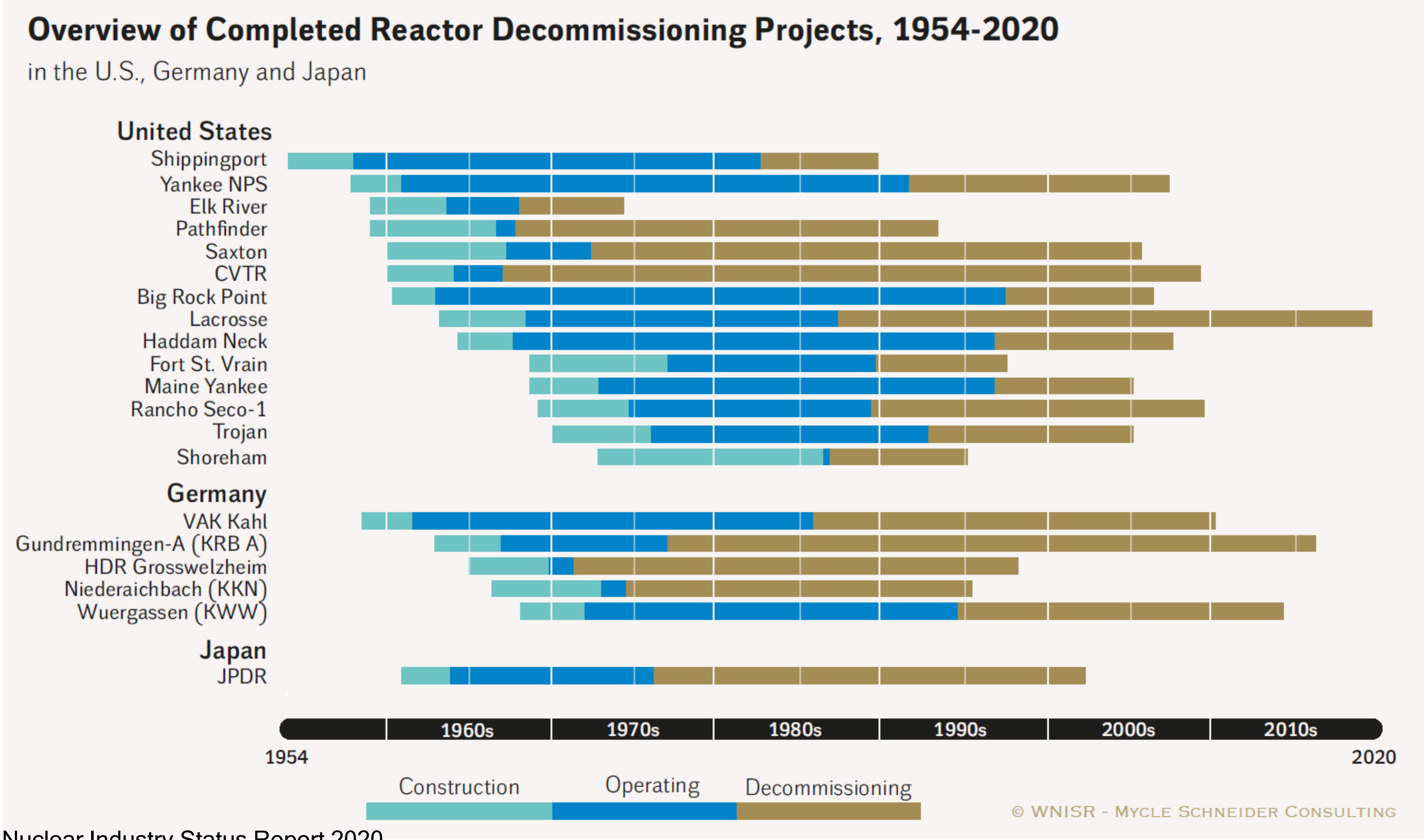


Ease-off-Stage

- Demolishing of the buildings
  - **Greenfield**: No further nuclear related purpose of the site
  - **Brownfield**: Further “generation use” (e.g. gas turbine) or further nuclear related uses of the site, e.g. (interim) storage facility for nuclear waste

Images: GSR (2017)

Decommissioning takes much longer than expected, in some cases even longer than construction and operation combined



Source: World Nuclear Industry Status Report 2020

Decommissioning costs

- **Data on actual decommissioning costs are scarce, with only three countries having completed decommissioning projects to full dismantling.**
- **In the US, where the most reactors were completely decommissioned decommissioning costs show a high variance, from US$280/kW to US$1,500/kW.**
- **In Germany, only two commercial reactors have finished decommissioning:**
  - Gundremmingen-A was completed after 23 years of dismantling work with a latest estimate of around €2.2 billion in 2013 (US$2.5 billion) or €9,300/kW (US$10,500/kW).
  - At Würgassen, decommissioning costs were around €1.1 billion (US$1.2 billion) or €1,700/kW (US$1,900/kW).
  - Where decommissioning costs are available, they exceed construction costs.
  - Final costs are only available for the two prototype reactors.
  - All German decommissioning projects experienced cost increases up to six percent per year, which were much higher than the general inflation rate and the assumed nuclear-specific inflation rate.
- **Not one nuclear reactor of 1 GW of capacity and 40 years of operation has been dismantled.**
- **The decommissioning of the oldest reactors has in most cases not even started and faces particular technical, organizational, and financial challenges (e.g. GCRs).**
- **A lack of “real” decommissioning costs may lead to underestimation of costs and hence increases funding risks.**

Agenda

1) Financing fundamentals
2) Decommissioning and cost experiences
3) **Organizational models for financing**
4) Summary

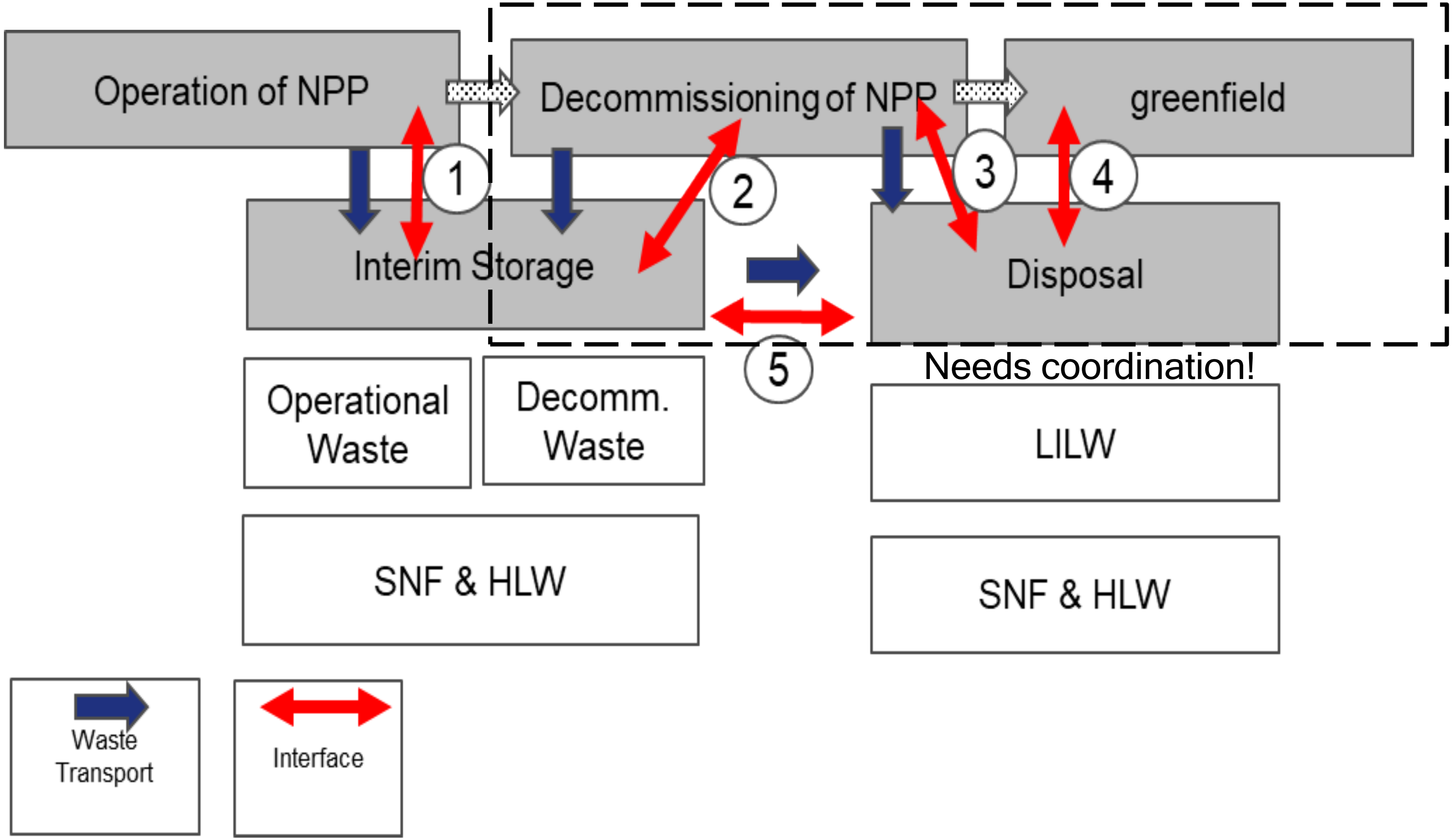
Organizational models for decommissioning

- **In theory, the polluter-pays-principle is applied to decommissioning in most nuclear countries.**
  - However, there are some cases where the state takes over the liability for decommissioning (for example, for the former East German reactors).
- **The organization that is principally liable is not always the organization that fully pays for decommissioning activities, however.**
  - For instance: Bulgaria, Lithuania, and the Slovak Republic get EU support for decommissioning in exchange for having closed their older Soviet nuclear power plants.
  - In Spain, the liability for decommissioning and the facility are both transferred to the state-governed radioactive waste management agency ENRESA. The former operators do not have to further contribute to the decommissioning fund.
- **Not all nuclear countries require that decommissioning funds be managed externally and segregated from the operator or licensee.**
  - Decommissioning is in some cases still financed through internal segregated and restricted funds, such as in France and the Czech Republic.
  - Internal non-segregated funds were abandoned in nearly all countries, except for Germany (and South-Korea, although here the operator is publicly owned).
- **In more and more countries, external bodies take over the funds for decommissioning.**
  - In Switzerland and Sweden for instance, the decommissioning expenses will be paid by the external, restricted decommissioning funds.

Organizational models for decommissioning

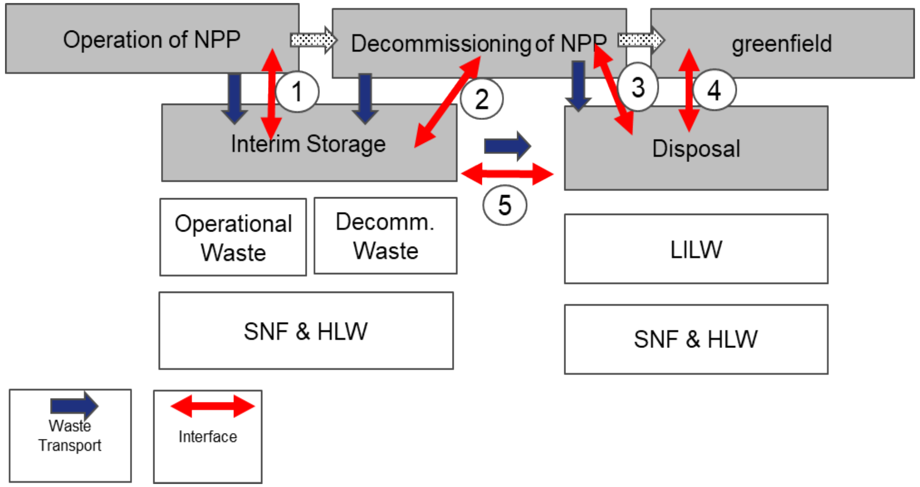
- **The decommissioning funds can be fed by a charge or fee, included in the electricity price or a compulsory government charge.**
  - Some countries have both mechanisms, for example for different generations of nuclear reactor (e.g. Germany, UK).
- **In addition to a lack of preparedness and technical expertise, countries decommissioning nuclear facilities are also struggling with and predicting potential further financial shortfalls in decommissioning funding.**
  - It is unclear whether enough money has been accumulated to pay for complete decommissioning, or if the taxpayers will have to step in.
  - This risk of underfunding seems to be an issue in nearly all countries facing decommissioning.
- **In most countries, the funds already set aside do not cover the cost estimates:**
  - EDF has only set aside around €18.5 billion (US$20.9 billion) or 58 percent of the estimated costs for decommissioning.
  - In the Czech Republic, only 15 percent of the funds for Temelín and 28 percent of the funds for Dukovany have been accumulated.
  - In 2016, in the US, the balance in the Nuclear Decommissioning Trust Fund (NDT) was around US$64 billion with specific decommission cost per reactor of around US$700/kW for public power utilities and US$850/kW for investor-owned utilities.
- **Early shutdowns, shortfalls in decommissioning funds, and rising decommissioning costs are forcing some plants to delay decommissioning in order to build up additional funds.**

Interfaces between value-added stages need coordination



Interfaces between value-added stages need coordination

- **Interface 2** between decommissioning and interim storage in **Germany**:
  - DE: public company BGZ took over the on-site interim storage facilities of SNF and gradually of LILW.
  - Coordination between conditioning of wastes (private) and storage (public).



- **Interface 3** between decommissioning and low-and intermediate level waste disposal:
  - **U.S**: available waste disposal infrastructure facilitates disposal.
  - **Germany**: Würgassen cannot be released from regulatory control as buildings are used for LILW interim storage.
- **Interface 4** between greenfield and spent nuclear fuel disposal in the **U.S**:
  - Lack of coordination between utilities and Department of Energy (responsible for the management of spent nuclear fuel).
  - No full regulatory release possible but the site license might be reduced to the independent spent fuel storage installation.

Integrated organizational models

- Due to the great interdependences between decommissioning, storage, and disposal, an integrated, external, segregated, and restricted ("ringfenced") fund seems to be the most suitable approach to finance the future costs for decommissioning and waste management processes.

- Integrated funding means the scope of the fund covers decommissioning and waste management. Countries with an integrated funding system include Sweden, Switzerland, and the UK (but only for the operational EDF Energy reactors).

- In the Swiss funding system cost estimates for specific nuclear reactors determine contributions to the fund.

- Switzerland has created two funds: one to finance decommissioning and one to finance the disposal of waste.

- Operators of nuclear power plants have to pay fees to both funds, which are under the supervision of the Swiss Federal Council.

Integrated funding systems for decommissioning and waste management in Sweden, Switzerland, and the UK as of December 2018

	SWEDEN	SWITZERLAND	UK*
FINANCING SCHEME	one external segregated and restricted fund	two external segregated funds (for waste management and for decommissioning)	one external segregated and restricted fund
ACCUMULATION	fee on electricity price (set individually for each plant)	payment by operator	payment by operator
TOTAL COST ESTIMATES	US$ 10.7-11.8 billion	US$ 24.6 billion***	US$ 26.5 billion**
SET ASIDE FUNDS, (IN % OF COST ESTIMATE)	US$ 7.2 billion**** (61-67%)	US$ 7.39 billion (30%)	US$ 12.1 billion (46%)

Source: Own depiction.
Notes: *EDF Energy reactors **as of 2018 ***Estimated total costs for a 50-year operating period as of 2019 ****as of 2017

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Decommissioning: Technically complex and major challenges in terms of the long-term planning of execution and financing

- **Duration and costs have been largely underestimated. The few projects that have started encounter, in nearly all the cases, delays as well as cost increases.**
- **The U.S. have decommissioned the highest number of reactors (14), but these case studies cannot be used as a reference for other cases.**
- **In all the cases, interim storage facilities were needed, hindering decommissioning or even rendering the regulatory release of the site impossible.**
- **High variance for future cost estimations.**
- **In most cases cost estimates are drawn up the operators, industry, or state agencies and not publically available for independent energy experts.**
- **As an increasing number of reactors are shutting down ahead of schedule due to unfavorable economic conditions, the risk of insufficient funds is increasing.**
- **Difference in decommissioning policy (e.g. removal of large components, definition of decommissioning and cost estimates) makes international comparisons difficult.**
- **Global outlook: Decommissioning is only at its very beginnings and is outpacing new constructions**

Vielen Dank!

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