Note:
This is a translation of the ESK presentation entitled
"Vergleich der Massenströme bei der Stilllegung von Kernkraftwerken in Deutschland und Frankreich".
In case of discrepancies between the English translation and the German original,
the original shall prevail.

Comparison of the mass flows from decommissioning of nuclear power plants in Germany and France

Entsorgungskommission (ESK) / Nuclear Waste Management Commission (ESK)
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PREFACE

This ESK presentation is an updated version of the ESK presentation of 4th December 2014 with the same title. It was adopted at the 99th ESK meeting on 15th June 2022.

The updated version takes into account the following:

- The terms were adapted to the nomenclature of the amended Radiation Protection Ordinance, in particular the use of the German terms that are translated literally as "specific clearance" and "unrestricted clearance". The German term that translates literally as "restricted clearance" is no longer used. Detailed explanations are given in the ESK information paper on the clearance of radioactive material and removal of non-radioactive material from the dismantling of nuclear power plants of 1st September 2022..

- The French regulations have meanwhile been updated, taking into account in particular amendments to the French environmental law "Code de l'environnement".

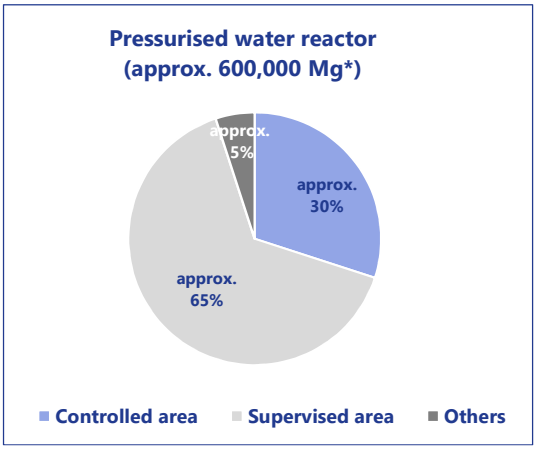
- Current data from German decommissioning projects and from individual French reference plants were taken into account and, in addition, compared with published data from Switzerland.

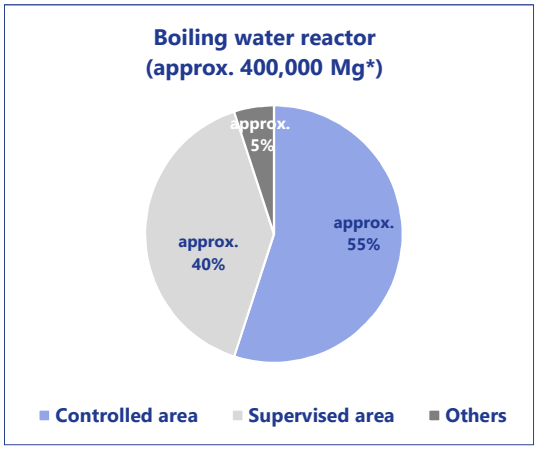
This presentation sketches the respective procedures in their basic points to highlight, in particular, the differences in the management of residues with very low levels of contamination between France and Germany.

The management of spent fuel and high-level radioactive waste will not be dealt with in this presentation.

Total mass from the dismantling of a German NPP

more than 90% of it building structures





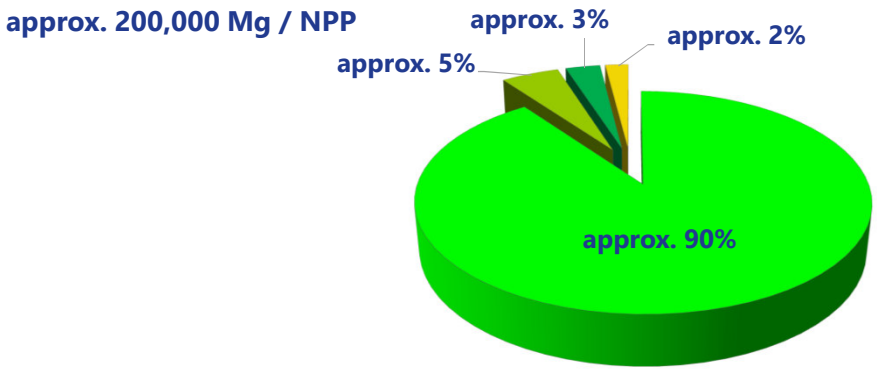
*** Total masses of all buildings from radiation protection areas and other areas averaged over several sites**

The total masses given here refer to the nuclear power plants to be dismantled in Germany. Some of the smaller plants already dismantled produced significantly lower masses. The dismantling of individual nuclear power plants commissioned in the 1980s, such as the Krümmel nuclear power plant (KKK), produced significantly larger total masses, without resulting in significant differences with regard to the percentages shown here.

Although the total mass of all buildings of an NPP site averaged over several sites - including the on-site storage facilities for spent fuel - is significantly higher for sites with pressurised water reactors than for those with boiling water reactors, the masses from the NPPs' controlled areas to be disposed of are approximately the same for boiling water and pressurised water reactor sites with about 200,000 Mg each.

For logistical reasons, external waste treatment centres are built at the sites of some plants. Even if the additional masses from the dismantling of these buildings are taken into account, the above data do not change significantly.

Total mass from a controlled area / Germany



- approx. 180,000 Mg specific clearance of buildings (approx. 90%)
- approx. 10,000 Mg unrestricted clearance (approx. 5%)
- approx. 6,000 Mg specific clearance for landfilling and incineration (approx. 3%)
- approx. 4,000 Mg radioactive waste (approx. 2%)

About 90% of the total mass of about 200,000 Mg resulting from the dismantling of a controlled area in Germany are decontaminated building masses that are subjected to specific clearance for reuse (conventional further use without restrictions is possible) or specific clearance for demolition (conventional utilisation of the resulting rubble without restrictions is possible). These building masses were assigned to unrestricted clearance in accordance with the Radiation Protection Ordinance 2001. The Radiation Protection Ordinance 2018 does not result in any changes to the procedure for the clearance of buildings in technical terms compared to the 2001 ordinance.

For about 5% of the material flow resulting from the dismantling of the controlled areas, unrestricted clearance as solid material is possible. For another around 3%, the radioactivity still present can be neglected under certain conditions (= specific clearance for landfilling and incineration). Here, specific boundary conditions must be met for disposing of or recycling the material, which are also defined by the authority in a clearance procedure. If the boundary conditions associated with this specific clearance are met, the resulting dose is also in the range of 10 µSv per year and can be neglected.

Small percentages of the masses are subjected to controlled recycling, which means that, for example, metallic components are melted down for the production of items that are further used under a nuclear or radiation protection licence, for example as containers for radioactive waste or as shielding. In addition, a small amount of scrap metal is cleared for recycling. In total, these waste management routes account for significantly less than 1% of the total mass from a controlled area and are not shown in this diagram for ease of presentation.

Due to various measures and optimised techniques in the dismantling and decontamination of plants, components and buildings, the amount of radioactive waste produced is minimised and averages in Germany about 4,000 Mg per nuclear power plant, which corresponds to about 2% of the controlled area masses.

Total mass France (zoning using the example of Fessenheim)

approx. 403,000 Mg from two reactor units

with

- **approx. 385,000 Mg waste for conventional waste management (= non-contaminated zone)**
- **approx. 18,000 Mg radioactive waste (= potentially contaminated zone):**

  radioactive waste for disposal
  - **TFA** **approx. 12,000 Mg** **→ Centre Morvilliers (CIRES)**
  - **FAMA** **approx. 6,000 Mg** **→ Centre de l'Aube (CSA)**
  - **MAVL** **approx. 200 Mg** **→ CIGEO**

While the figures relating to the masses produced in Germany represent values averaged over several sites, the figures from France presented here refer to the expected masses from one representative plant, which is the Fessenheim nuclear power plant with its two 900 MWe pressurised water reactors. In the coming decades, another 32 similar 900 MWe pressurised water reactors will be decommissioned at other sites. A comparison of the situation in the countries should therefore be made primarily on the basis of the percentage distribution of the material flows rather than on the basis of the absolute masses. Here, it should be noted that the percentage distribution of waste volumes in France refers to the total mass, but in Germany only to the controlled area. The French procedure therefore includes larger quantities of material for which contamination has not to be assumed from the operating history.

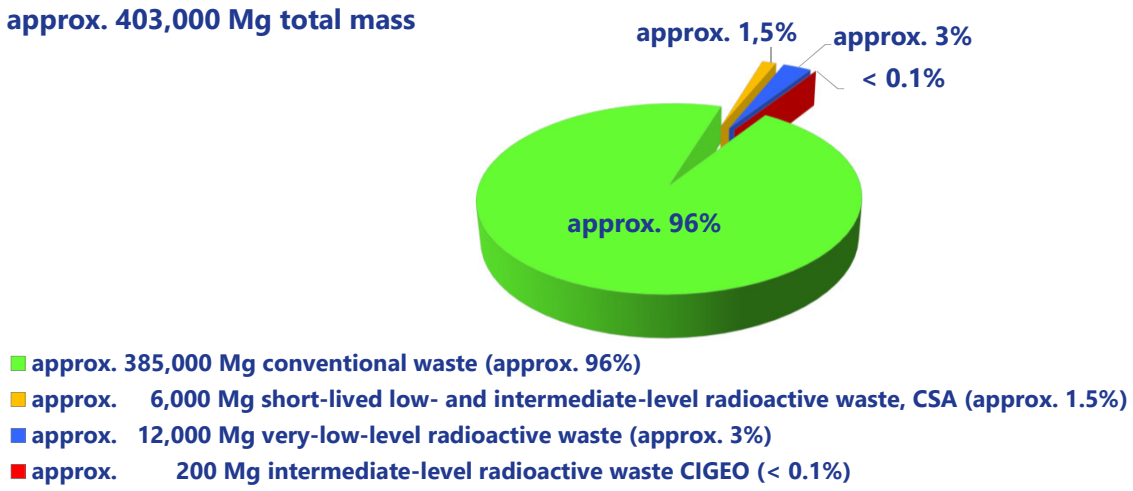
The radioactive waste from decommissioning of pressurised water reactors (boiling water reactors do not exist in France) is divided into three categories, each of which is assigned to the respective facility:
(1) very low-level radioactive waste (TFA),
(2) low- and intermediate-level radioactive waste with short-lived radionuclides (FAMA), and
(3) intermediate-level waste with long-lived radionuclides (MAVL).

The figures shown (total mass and waste masses) do not include 2,000 Mg of waste from stored steam generators that are intended for recycling and do not originate from decommissioning and dismantling.

Waste classification and French abbreviations:

French abbreviation	Meaning (French)
TFA	très faible activité
FAMA	faible et moyenne activité à vie courte
MAVL	moyenne activité à vie longue

Predicted distribution of material flows in decommissioning projects for Fessenheim (France)

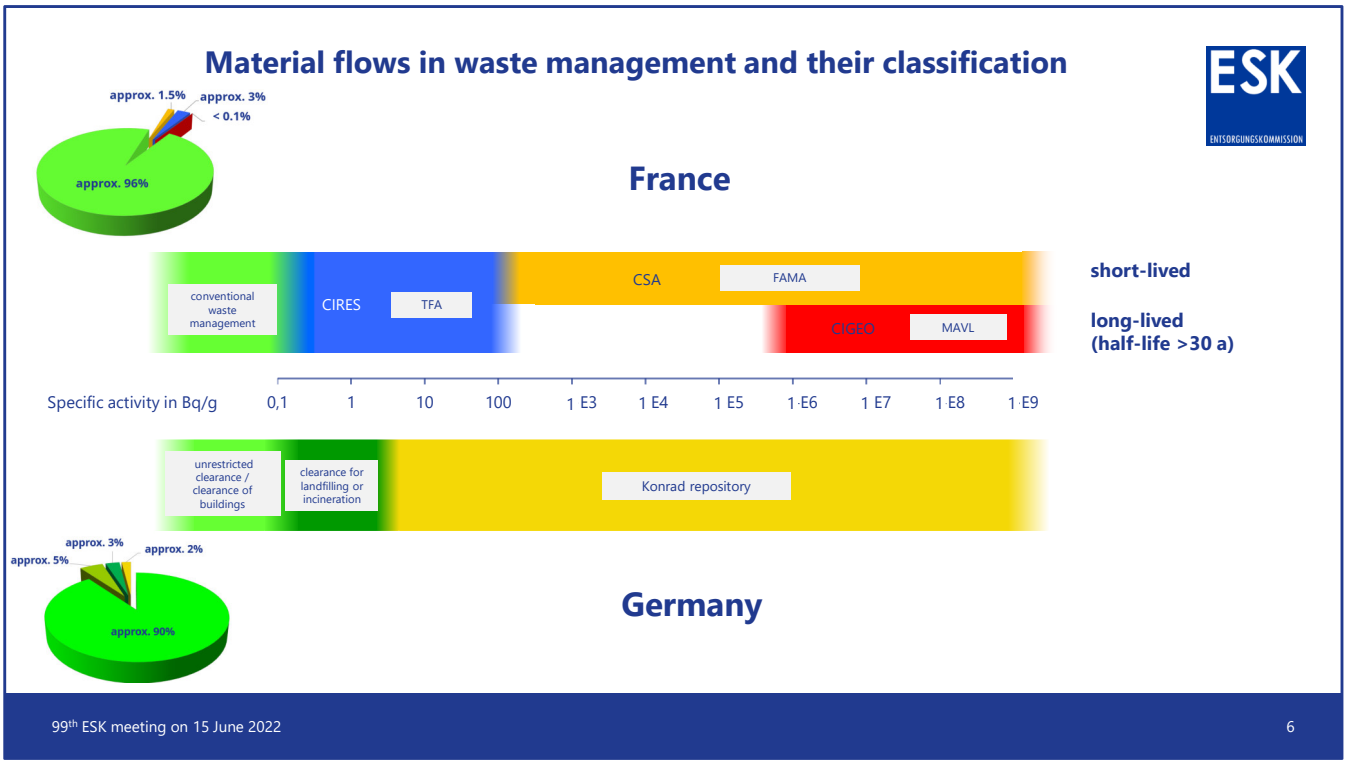


By far the largest part amounting to about 96% of the total mass of 403,000 Mg is assigned to the zone with conventional waste according to the French approach of "waste zoning" (ASN Guide 14, 2016) and recovered or disposed of conventionally. About 4.5% of the total mass is considered potentially contaminated and is categorised as radioactive waste. This differs from the German approach, where initially the entire controlled area is considered potentially contaminated, but most of it can be cleared. Accordingly, the German clearance (which does not exist in France) therefore corresponds to the assignment to the non-contaminated zone. The zoning can be adapted to the measurements during the dismantling of the plant.

In France, about 1.5% of the total mass is assigned to low- and intermediate-level radioactive waste (FAMA), which is disposed of at the Centre de l'Aube (CSA), a surface disposal facility.

A material flow (TFA) about twice as large, amounting to about 3% of the total mass, but with significantly lower specific activities, or of materials originating from potentially contaminated areas which might not be radioactive themselves, is disposed of in a surface landfill (CIRES - Centre Morvilliers) for very low-level radioactive waste.

Less than 0.1% of the total mass is intermediate-level radioactive waste with long-lived radionuclides (half-life >30 years). This waste (MAVL) is to be disposed of in the CIGEO geological disposal facility at a depth of 500 m when it will be in operation.



When comparing the transitions between the different categories of material flows in waste management, it should be noted that these are defined nuclide-specifically in both countries and take different concepts into account.

Apart from the fact that there are significant differences for individual nuclides, the following generalised statements can be made with regard to the specific activities of the material flows resulting from the dismantling of nuclear power plants:

- Conventional waste management (after control measurements) of the non-contaminated zone in France largely corresponds to the specific clearance of buildings in Germany. This includes, in particular, the building masses of the decontaminated controlled area buildings, which are the dominant contributors to the waste masses in both countries.
- Specific clearance for landfilling and incineration in Germany differs significantly from the disposal of very low-level radioactive waste (TFA) in France. The nuclide-specific limitations of the specific activity in the case of clearance for landfilling and incineration in Germany are partly several orders of magnitude lower than those of the waste acceptance requirements for the TFA disposal facility in France. Since, on the other hand, the total mass of the zone classified as potentially contaminated cannot be cleared in France, it may also happen that material has to be transferred to the TFA disposal facility that could be cleared in Germany.
- Another part of the TFA waste that is disposed of in a near-surface disposal facility in France, in Germany would have to be disposed of in a disposal facility for non-heat-generating waste in deep geological formations.
- In contrast to Germany, where it is intended to dispose of all radioactive waste in deep geological formations, in France, the very low-level radioactive waste (TFA), as well as the low- and intermediate-level radioactive waste (FAMA) with half-lives of less than 30 years, is disposed of in separate facilities on the earth's surface. The different disposal concepts in Germany and France also result in different requirements for the radioactive waste.
- Long-lived intermediate-level radioactive waste (MAVL) is also to be disposed of in deep geological formations in France. This, however, concerns less than 0.1% of the total mass from the dismantling of nuclear power plants.

Example: Contamination-free or fully decontaminated building structures from controlled areas

Germany:

- **specific clearance by clearance measurement at the "standing structure"**
- **rubble that can be recycled without restrictions after demolition**

France:

- **based on control measurements, the building structure is assigned to the "conventional zone"**
- **rubble that can be recycled without restrictions after demolition**

For the largest material flow generated during the dismantling of a nuclear power plant - the rubble from the massive building structures - the procedures in Germany and France differ rather in philosophy, and maybe in the density of controls, than in the result.

While in Germany, the buildings are for the most part measured at the "standing structure" in a clearance procedure defined by the authority and controlled by authorised experts consulted, in France, the decontaminated building structures are assigned to the "conventional zone" after control measurements have been carried out.

In both cases, the rubble produced during demolition can be recycled without restrictions.

Summary

- By far the largest material flow generated during the dismantling of nuclear power plants,
  - in France, is managed as conventional waste management according to the "zoning" approach and/or after control measurements, taking into account the operating history (case-by-case decision) after approval by the ASN, and
  - in Germany, it is cleared for non-detrimental utilisation in a clearance procedure defined and reviewed by the authority.
- In percentage terms, these material flows are about the same in France and in Germany per nuclear power plant.
- Due to the different activity limits and the fact that clearance is not possible in France, part of the material emplaced in a TFA disposal facility in France would be cleared in Germany, while another part would be emplaced in the Konrad repository in a deep geological formation.
- The difference in the material flows assigned to radioactive waste in France and Germany is due to the different efforts required to minimise radioactive waste and to decontaminate residues in the two countries.