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Faster disposal (transmutation) of highly radioactive waste and accompanying research on Small Modular Reactors (SMR)

The potential of

(1) Transmutation (= disposal of nuclear waste while reducing the decay time to less than 1 per thousand compared to conventional disposal) and
(2) Small Modular Reactors (SMR)

should be researched as a

priority.

The need for reliable, low-carbon power generation is growing worldwide as part of the energy transition, particularly in the context of the increasing use of artificial intelligence and energy-intensive data centers. At the same time, the safe disposal of highly radioactive waste remains one of the greatest challenges, which must also be considered from the perspective of intergenerational justice. Transmutation, a process for converting long-lived radioactive isotopes into shorter-lived or stable elements, offers the potential to significantly mitigate the final disposal problem by reducing the decay time to less than 1 per mil compared to conventional disposal. In addition, Small Modular Reactors (SMR) offer a flexible, scalable option for sustainable power generation. With certain SMR models, nuclear waste can also be used as fuel and thus disposed of. Targeted research and development in both areas can open up new avenues for a resilient and sustainable energy supply and exploit synergies between transmutation and SMR technologies. Germany should strategically integrate this potential into its research and innovation policy.

Scientific and technological starting position
Transmutation is based on advanced technologies to convert long-lived radioactive isotopes into shorter-lived or stable elements. They have the advantage over conventional concepts that they can use the fissile material more efficiently and significantly reduce radioactive waste. Specifically, accelerator-driven systems (ADS) consist of

a particle accelerator that shoots high-energy protons at a target material (e.g. lead bismuth). This interaction produces neutrons, which are used in a subcritical reactor to split long-lived radionuclides. As ADS systems do not require a self-sustaining chain reaction, they are considered to be particularly safe and flexible in their application for converting radioactive substances. While countries such as France, Belgium and Japan have already made significant progress in this area, Germany has so far lacked a targeted, long-term research strategy.

At the same time, small modular reactors (SMRs) are becoming increasingly important internationally. These compact reactors offer a flexible option for decentralized power and heat supply, particularly for industrial processes and energy-intensive applications such as cloud computing and data centers for artificial intelligence applications. The latter in particular require uninterruptible power, which SMRs can supply. SMR concepts are being actively developed and tested in many countries, while Germany has not yet conducted any structured accompanying research into this technology. Of particular interest here are possible synergies between SMRs and transmutation, as certain SMR designs use fast neutrons, which are required for transmutation processes. Targeted research could drive the development of efficient hybrid solutions for electricity production and waste minimization.

The path to a German strategy for transmutation and SMR research
Targeted measures are to leverage the potential of both technologies. These include

- Establishment of a national research program for transmutation and accompanying research of SMR with the involvement of existing research institutions, universities and industrial partners.
- Strengthening international cooperation with leading research projects such as MYRRHA (Belgium), SMR developments in the USA, Canada and the UK as well as projects for the combined use of fast reactors for transmutation.
- Promotion of pilot projects to demonstrate technological feasibility and scalability.
- Development of a regulatory framework for the integration of transmutation strategies and SMR concepts into German energy and waste management policy.

Policy measures required
Analogous to the BMBF's position paper on fusion research published in 2023, it is also necessary to formulate a strategic orientation for transmutation and SMR and to intensify research for both technologies. Such a position paper should:

- Clarify the scientific and technological relevance of both research areas.
- Outline a roadmap for the development and implementation of corresponding research projects.
- Identify the necessary political and financial course for long-term funding.