> Partitioning and Transmutation

Partitioning and transmutation of nuclear waste

acatech POSITION PAPER – Executive Summary and Recommendations

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NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

In June 2011, the German government's announcement of the transition to renewable energy (known as the 'Energiewende') marked the beginning of the end for electricity production using nuclear power. The goal is for all electricity production at Germany's nuclear power stations to cease by 2022. However, no definitive answer has yet been provided to the question of where and how the radioactive waste from these power plants will be permanently disposed of. In particular, there is currently no permanent storage facility for highly radioactive heat-generating waste. Whilst this type of waste only represents a small fraction of the overall volume, it accounts for 99 percent of the total radioactivity of the waste from nuclear plants. The Repository Site Selection Act came into force on 26 July 2013. The Act sanctions an open-ended search resulting in the selection of a permanent repository site for heat-generating radioactive waste. One of the key factors governing the choice of site is the type and quantity of waste to be permanently stored there. Partitioning and transmutation (P&T) technology transforms part of the long-lived, highly radioactive material in spent fuel rods into shorter-lived fission products. This technology is the subject of ongoing research and development and could provide one means of reducing the long-term hazard potential of heat-generating waste.

The idea of partitioning is to separate spent nuclear power plant fuel into the left-over uranium that was not fissioned in the reactor, as well as plutonium and the minor actinides (neptunium, americium and curium). The remaining fission and activation products are vitrified and must then be permanently disposed of in a repository for heat-generating waste. The partitioning process also produces secondary waste products in the form of decontamination and rinse water. The separated uranium can be reused by reactors in countries that still use nuclear power; failing that, it would need to be permanently disposed of in Germany as waste with negligible heat generation. According to current licensing rules, repositories for waste with negligible heat generation would also have to be provided for the secondary waste (decontamination and rinse water).

At a glance

- No clear strategy currently exists for the permanent disposal of heat-generating radioactive waste from Germany's nuclear power plants
- Partitioning and transmutation (P&T) could provide one means of reducing the long-term hazard potential of heat-generating waste
- The idea of partitioning is to separate spent fuel into uranium, plutonium and the minor actinides neptunium, americium and curium
- Transmutation involves bombarding the plutonium and minor actinides with fast neutrons at a transmutation facility, transforming at least 90 percent of them into shorter-lived or stable nuclides. In addition to researching and developing P&T, the societal implications of the different courses of action should also be assessed

The transmutation process is only performed on the plutonium and minor actinides. By bombarding this material with fast neutrons at a transmutation facility, at least 90 percent of it is transformed into shorter-lived or stable nuclides. The resulting isotopes must then be permanently disposed of as heat-generating waste with a low long-term radioactivity level. The as yet undeveloped transmutation facilities would comprise nuclear facilities that would be required to meet Gen IV reactor safety standards. This would mean that they would be safer than the nuclear reactors that are currently used to produce electricity.

P&T opportunities

If rolled out successfully on an industrial scale, P&T could significantly reduce the volume of heat-generating waste destined for permanent disposal by as much as a third (from 28,000 to 9,500 cubic metres). The extraction of the uranium during the first stage of partitioning makes a particularly important contribution to this outcome. At the same time, however, the volume of waste with negligible heat generation would increase by around a third (from approx. 300,000 to approx. 400,000 cubic metres).

By deploying P&T, it is possible to reduce the total radioactivity level in the repository for heat-generating waste just a few centuries after the waste is stored, thus also reducing its hazard potential. If the already vitrified heat-generating waste is disregarded, the level of radioactivity (or weighted radiotoxicity value) in the repository for highly radioactive heat-generating waste is roughly the same after 1,000 years as it would be after 1,000,000 years if P&T had not been deployed. Although this means that P&T can reduce the hazard potential of the stored waste, according to currently available safety analyses it has a negligible impact on the risk of radiation leaking from the repository.

The risk of plutonium being stolen from the repository and used for illicit purposes is reduced. Since the separated plutonium is transformed into other isotopes at transmutation facilities, only negligible quantities of it make their way into the permanent repository. This becomes particularly important once the automatic protection provided by the high local radiation dose rate has diminished. After partitioning, the mobile fission and activation products that were separated from the spent fuel and now require permanent disposal can be more effectively conditioned (e.g. by immobilising the waste in a matrix). This lowers the risk of them leaking from the spent fuel, thereby reducing the long-term risk of them contaminating the biosphere.

By extracting the americium, P&T can also reduce the heat build-up in the repository for heat-generating waste after a period of some 70 to 100 years. If the waste is permanently disposed of after this period has elapsed, it is possible to reduce the minimum distances between the storage boreholes and waste containers that must be observed owing to the maximum design temperature. However, a similar reduction in heat emissions could also be achieved through natural decay without P&T after a suitable interim storage period.

P&T risks

The P&T facilities that would have to be built could pose a threat to both human beings and the environment. The risk is similar to that of operating plants for reprocessing or conditioning spent fuel rods or Gen IV nuclear reactors.

During the 150 or so years during which P&T would be deployed, there would be an increased risk of radioactive materials being misused by third parties. Depending on the process employed, partitioning produces both plutonium and minor actinides either in pure or compound form. There is a danger that these could be stolen while being transported to transmutation or interim storage facilities. This danger is compounded by the fact that the permanent repository needs to be kept open for longer.

The fact that only relatively small quantities of waste would need to be partitioned and transmuted in Germany would result in a high unit cost per tonne of waste. At least in Germany, the construction and operation of P&T facilities would not be cost-effective compared to permanent disposal methods not involving P&T.

The vast majority of people in Germany are opposed to any facilities connected with nuclear technology. It is likely that the construction and operation of new P&T facilities would meet with public opposition.

In the past, nuclear power has often been a hot topic in the media. It is therefore possible that media coverage of the planning, construction and operation of P&T facilities would be predominantly negative.

acatech recommendations in brief:

- P&T research should be carried out in a European context.
- Future German involvement in European P&T initiatives should be subject to assessment.
- Involvement in research programmes should not result in path dependence causing Germany to favour the use of P&T.
- A comprehensive interdisciplinary study should be produced to provide a basis for deciding whether Germany should participate in European P&T initiatives. A decision will probably have to be taken within the next 10 to 15 years. It will be necessary to ensure timely planning of the processes governing when and how the public and the relevant professional organisations are involved in this decision.
- Germany should adopt a European perspective whilst ensuring that national research initiatives take account of the statutory goals associated with Germany's nuclear phase-out.
- German industry should treat the potential deployment of P&T in Europe as an opportunity that should be taken as long as circumstances allow it.
- Research should focus on the following key areas:
  - efficient partitioning
  - efficient transmutation of the partitioned transuranic elements
  - safety assessment of facilities
  - assessing the societal implications of the different courses of action.
- Research should be structured in an interdisciplinary manner in order to ensure that scientific and technological discoveries are properly evaluated and communicated.
- A research alliance should be established.

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