



# The black swans of nuclear repositories – an overview of external events with a potentially serious impact on the long-term operation and safety

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**Abstract.** For Germany, the time until completion and final closure of a repository is estimated to be up to 150 years. So far, it has been implicitly assumed that external political, economic, and infrastructural functions that are necessary for the construction, operation, and closure of such facilities will be fully in place throughout the entire operating period. These include, for example, power supply, presence of well-trained staff, and effective oversight. Event sequences initiated by natural disasters or human-made crises may lead to unintentional long-lasting disruptions of these external safety functions. They are currently only partly considered in safety assessments. To make repository concepts robust against such scenarios, a forward-looking risk analysis is required that creates the basis for a holistic comparative risk assessment of different repository concepts. It provides a starting point for the development of additional resilient structures, management processes, and safety functions.

A risk analysis includes an assessment of event-specific vulnerabilities as well as potential consequences of unintended external hazards for various disposal concepts. The first step of this process would be a hazard analysis – a summary and evaluation of external event sequences that have the potential to compromise essential safety elements of a repository within the predicted operation period. These can be divided into political–economic crises and event sequences following transnational natural disasters.

A look at the political development of the past 150 years shows that even if only the present territory of Germany is considered, there have been profound disruptions, such as three wars, several major economic depressions, revolutionary government changes, and attempted military coups. This summary shows that political and economic stability as well as a continuous orderly operation cannot be taken for granted. Historic as well as present experiences from the country where the repository is planned as well as the neighbouring regions should be considered when assessing the potential consequences of such events.

Local natural disasters are already taken into account in site selection, e.g. risk of flooding, volcanism, or earthquakes. Less attention is typically given to the indirect effects of transnational disastrous events. These include climatic extremes (e.g. droughts), cosmic and geological disasters (e.g. geomagnetic storms) and their climatic consequences (e.g. volcanic winter), and pandemics. Such natural disasters may cause economic depressions and subsequently contribute to political turmoil (e.g. the drought of 1788 as one of the causes of the French Revolution in 1789).

At the stage of concept design, additional safety elements, measures, and processes should be included that help to manage situations of external stress and to avoid irreversible processes that challenge the safety architecture of the repository.