Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
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Effects of climate change on nuclear power plants

Nuclear power plants can be affected by various weather events such as heat, drought, forest fires, floods, hurricanes, storm surges and extreme cold events.

New scientific findings give raise to fears that climate change is progressing even faster than expected, which means that even within the lifetime of existing nuclear power plants the effects will be much more dramatic than previously assumed. Those effects can lead on the one hand to a drop in the efficiency and an increase in the frequency and duration of outages, and on the other hand safety relevant effects are possible. This must be taken into account when designing new plants and retrofitting existing nuclear power plants. Moreover, both climate change itself and the measures taken to mitigate it may trigger social, societal and political developments, in the worst case armed conflicts, which means an enormous additional risk potential for nuclear facilities.. All of this therefore needs to be included in nuclear power plants vulnerability analysis. Given the urgency of decarbonising the energy system, preference should be given to other, more readily available, less risky technologies in order to avoid the delays that have been shown to result from diversions of capacity and investment in nuclear power.

Starting point

Nuclear power plants are in principle designed to withstand the extreme weather conditions of the respective sites. All regulatory requirements in this regard are based on long-term weather statistics from the past, which no longer reflect today's weather situations, let alone those that can be expected during the remaining lifetime of the plants in operation or new plants to be built, as most nuclear power plants were built in the late 1960s to the early 1980s[1] - i.e. before climate change became significant[2]. These nuclear power plants are therefore confronted with unexpected weather conditions in terms of intensity, extent or frequency.

Effects on nuclear power plants

From an economic perspective, climate change is primarily relevant due to a drop in efficiency and an increase in the frequency and duration of outages. Measures include the relocation of intake openings for cooling water or the temporary raising of temperature restrictions by the authorities.

The safety of nuclear power plants can be impaired by a wide range of weather events: Heat, drought, forest fires, floods, hurricanes, storm surges, extreme cold events and more[3]. Extremes typically change more than average values with climate change, and their effects often worsen exponentially with higher values. In order to capture the highest risks, less probable situations must therefore also be taken into account. In any case, average climate projections are not sufficient for vulnerability assessments.

Sea level rise will become a problem for at least one hundred seashore nuclear power plants in the medium and long term, as it is expected to rise by up to 1 metre[4], perhaps

[1] Mycle Schneider et al, "The World Nuclear Industry Status Report 2023," ed. Mycle Schneider and Anthony Froggatt, The World Nuclear Industry Status Report (Paris: Mycle Schneider Consulting, 2023). worldnuclearreport.org/IMG/pdf/wnisr2023-v5.pdf

[2] James Hansen, Makiko Sato, and Reto Ruedy, "Global Warming Acceleration: Causes and Consequences," Annual review, (2024). columbia.edu/~jeh1/mailings/2024/AnnualT2023.2024.01.12.pdf

[3] GAO, Nuclear Power Plants. NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change, GAO-24-106326 (Highlights of GAO-24-106326, a report to congressional requesters, 2024).

[4] IPCC, *Synthesis Report of the IPCC Sixth Assessment Report (AR6). Longer Report.* (22 MARCH 2023, 2023). ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf.

even up to 2.5 metres[5] this century, even if the Paris climate targets are met[6]. Nuclear power plants close to the coast are already increasingly affected by storm surges[7], and when spring tides, air pressure and wind conditions whip masses of water towards the coast, extreme flooding and systematic erosion of coastal cliffs occur. Even flood risk maps which do not take into account extreme values, changes in the trajectories, intensities and frequencies of low pressure systems, suggest that both the Dungeness Nuclear Power Plant and the planned Sizewell C Nuclear Power Plant site in the UK, for example, will be substantially under water at least once a year.

Weather events can also trigger simultaneous failures of various systems and components (common cause failures) or jeopardise nuclear power plants through cascading events (such as a mudslide upstream that causes a dam to burst and sudden severe flooding in a power plant). Encompassing systematic analyses, broken down to the individual nuclear power plants, as for supplied the USA[8], are not available for European nuclear power plants.

New scientific findings make significantly accelerated climate change appear possible

The unexpected, dramatic warming of the last nine years could be an outlier in the chaotic climate system and a consequence of natural climate variability, or it could be an indication that climate models have so far underestimated the climate sensitivity of greenhouse gases and aerosols. In this case, global warming will continue to accelerate and the 1.5°C target will no longer be achievable.

Recent studies have also fuelled fears that the North Atlantic branch of thermohaline ocean circulation (AMOC) could possibly reach a tipping point within a few decades and

[5] James Hansen et al, "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modelling, and modern observations that 2 °C global warming could be dangerous " *Atmos. Chem. Phys.* 16 no. 6 (2016), doi.org/10.5194/acp-16-3761-2016, atmos-chem-phys.net/16/3761/2016/.

[6] Paul Dorfman, *Climate Change. UK Nuclear*, Nuclear Consulting Group (2021), nuclearconsult.org/wp/wp-content/uploads/2021/06/Climate-Change-UK-Nuclear-June-2021.pdf

[7] British Oceanographic Data Centre" BODC, "GESLA (Global Extreme Sea Level Analysis) high frequency sea level dataset - Version 2." (2018). data-search.nerc.ac.uk:443/geonetwork/srv/api/records/19e0ccbf8e575a139b7b70a6e875ef8b.

[8] GAO, Short Nuclear Power Plants. NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change.

thus destabilise the entire global climate in a chain reaction[9]. Action cannot be delayed to await the result of the scientific debate, because at that point it may be too late to take action. Climate protection measures are therefore more urgent than ever.

For nuclear power plants, this means on the one hand that the potentially accelerated developments must be taken into account not only in planning, but also in current safety reviews of nuclear power plants in terms of serious risk assessments. On the other hand, these developments emphasise once again that enhancing nuclear power capacities, as a climate protection measure is too slow[10]. Greenhouse gas emissions must be halved by 2030 - even on the basis of the IPCC scenarios - and the expansion of nuclear energy cannot make a significant contribution within this period. However, it can delay the expansion of renewables[11]. Unless there is a joint effort to drive forward the rapid expansion of renewable energies, any efforts to decarbonise after 2050 could become obsolete.

[9] René M. van Westen, Michael Kliphuis, and Henk A. Dijkstra, "Physics-based early warning signal shows that AMOC is on tipping course," *Science Advances* 10, no. 6 (2024), doi.org/doi:10.1126/sciadv.adk1189, science.org/doi/abs/10.1126/sciadv.adk1189.
Peter Ditlevsen and Susanne Ditlevsen, "Warning of a forthcoming collapse of the Atlantic meridional overturning circulation," *Nature Communications* 14, no. 1 (2023/07/25 2023), doi.org/10.1038/s41467-023-39810-w, doi.org/10.1038/s41467-023-39810-w.
Helge F. Goessling, Thomas Rackow, and Thomas Jung, "Recent global temperature surge intensified by record-low planetary albedo," *Science* 0, no. 0, doi.org/doi:10.1126/science.adq7280, science.org/doi/abs/10.1126/science.adq7280

[10] Nikolaus Muellner et al, "Nuclear energy - The solution to climate change?," *Energy Policy* 155 (2021/08/01/ 2021), doi.org/10.1016/j.enpol.2021.112363, sciencedirect.com/science/article/pii/S0301421521002330?via%3Dihub.

[11] Peter Hennicke et al, "Das Atomstromsystem bremst die sozial-ökologische Transformation zur Dekarbonisierung," *in Vorbreitung* (2024).

Climate change will affect the economic, social and political environment in which NPPs operate

Climate change reaches beyond the aspect of the changing climate. It exacerbates many social problems through increasing the scarcity of vital resources such as food, water and housing, increased disease, economic inequality, declining productivity and financial losses. The destabilisation of political structures can lead to war and terror[12]. How can the nuclear safety even of small modular reactors (SMRs) be guaranteed in this environment if capacity is tripled by 2050, as agreed at the COP in Dubai in 2022?

Nuclear power plants, once regarded as a guarantee for the exclusion of warlike actions in their vicinity, threaten to become weapons in wars. The Zaporizhzhya nuclear power plant in Ukraine, the largest nuclear power plant in Europe, was directly involved in the war in Ukraine. Although it was never directly bombed, the destruction of safety-relevant infrastructure (power lines, cooling systems or data lines)[13] or other circumstances[14] could inadvertently trigger a serious accident at any time. The radioactive cloud could contaminate areas far beyond Ukraine.

These aspects should not be forgotten when discussing the expansion of nuclear power and the connection between nuclear power and the climate.

[12] Maximilian Kotz, Anders Levermann, and Leonie Wenz, "The economic commitment of climate change," *Nature* 628, no. 8008 (2024/04/01 2024), doi.org/10.1038/s41586-024-07219-0, doi.org/10.1038/s41586-024-07219-0.
Luke Kemp et al, "Climate Endgame: Exploring catastrophic climate change scenarios," *Proceedings of the National Academy of Sciences* 119, no. 34 (2022/08/23 2022), doi.org/10.1073/pnas.2108146119, doi.org/10.1073/pnas.2108146119.
Peter Schwartz and Doug Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security,* U.S. Dept. of Defense (Washington: U.S. Dept. of Defense, 2/2004 2003), stephenschneider.stanford.edu/Publications/PDF_Papers/SchwartzRandall2004.pdf, purl.access.gpo.gov/GPO/LPS69716.
[13] Wolfgang Kromp, "Aspekte Nuklearer Sicherheit unter Kriegsbedingungen," in *Sicherheit neu Denken. The Status of Europe after the Ukraine Crisis*, ed. Paul Ertl (Vienna: National Defence Academy, 2023).
[14] Mycle Schneider et al, "The World Nuclear Industry Status Report 2022," ed. Mycle Schneider and Anthony Froggatt, The World Nuclear Industry Status Report (Paris: Mycle Schneider Consulting, 2022). worldnuclearreport.org/IMG/pdf/wnisr2022-v3-lr.pdf.

Conclusions

The following conclusions can be drawn from the above considerations:

- As part of safety reviews, existing nuclear power plants must be subjected to stress tests that are based on future climate scenarios with a very high spatial and temporal resolution and that take into account unlikely but high-risk climate changes.
- The regulatory authorities must demand concrete plans for adapting to climate change by the end of the nuclear power plants' service life, including the expected costs.
- Risk analyses of societal changes and their impact on the safety of nuclear power plants are necessary, despite the considerable uncertainties inherent in such analyses.
- Efforts to combat climate change must take a major leap forward in order to avoid abrupt climate change and minimise the need for adaptation. Nuclear energy cannot make a significant contribution to this. Its expansion should therefore be postponed.
- Every effort must be made to achieve and secure peace, as nuclear power plants or other nuclear facilities in war zones pose high risks. Moreover, to quote the preamble to the UN Horizon 2030 Agenda: "There can be no sustainable development without peace and no peace without sustainable development".

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