NUCLEAR ENERGY: THE PROS AND CONS

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FES Just Climate acts as a think tank about current and coming trends, and a policy advisor in ongoing debates. We support FES offices and their partners in shaping the industrial revolution of our times.

This article is part of our Nuclear Energy Series: Energizing the Debate. It includes a mapping of nuclear energy in the OSCE region, the pros and cons of nuclear energy, as well as arguments for the debate.

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DISCLAIMER

This publication provides an overview of the key pros and cons arguments that are dominating the debate on the use of nuclear energy. This is a non-exhaustive list that intends to provide the readers with a review of the most frequently used argumentation regarding nuclear energy. This analysis is part of our Nuclear Series project, where we provide an overview of nuclear energy in Europe and detail the pros and cons arguments.

INTRODUCTION

In the struggle for a coherent energy transition in Europe and with the ongoing Russian war on Ukraine, nuclear energy seem to experience a comeback.

While the previous act was dominated by a spiraling energy price crisis, funneled by gas and coal shortages, the most recent scene is shaped by a continental scramble for energy sovereignty from Russian carbon exports. Among the countries that have called upon nuclear energy as an interim or long-term solution are the United Kingdom, Belgium and the Netherlands. Belgium has decided to delay its phase out nuclear energy by extending the life of two of its seven reactors, while the Netherlands stated that it will increase its nuclear capacities.

When it comes to evaluating the role of nuclear energy should play in the energy transition, the technical nature of many arguments – as well as the politically motivated difference in the way the opportunities and risks are portrayed – present challenges in the public debate.

In this analysis, we aim to shine a light on the most important points in the evaluation of nuclear energy. We provide an overview of the main arguments in favor and against nuclear energy, followed by facts checks on the biggest issues and concerns.

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GLOSSARY

European Pressurized Reactor (EPR): The European Pressurized Reactor, or called internationally Evolutionary Power Reactor (EPR), is a third generation pressurized reactor that can generate up to 1 660 MW. Currently, three EPR are operational - Taishan 1 and 2 in China since 2018 and 2019, and Olkiluoto in Finland since 2022. Three EPR are under construction - one in Flamanville, France, and two in Hinkley Point, United Kingdom. These three projects suffer from costs and construction time overrun. Moreover, the construction of fourteen other EPR are in the pipeline in France, United Kingdom, and India.

Framatom: A nuclear energy company owned at 75% by Electricité de France, a largely state-owned French electricity company.

Generation reactor: Nuclear reactors are categorized by "generation" - I, II, III, III+, and IV. Their classification takes into account economic competitiveness, safety, security and non-proliferation, grid appropriateness, commercialization, and the fuel cycle for nuclear waste.

Generation I reactors were designed in the 1950s and 1960s, and launched civilian nuclear power. They were primarily developed in the United States, United Kingdom, France and the Soviet Union. They stopped operating in the 1990s.

Generation II reactors are commercial reactors, which aims to be economical and reliable. They began operating in 1960s especially in China, the Soviet Union, France, the United States, and the Republic of Korea. They were designed to be operational for 40 years, and their construction stopped in the 1990s. However, some countries like the United States decided to extend their lifespan. It is worth noting that both the Chernobyl and the Fukushima power plants were using Generation II reactors.

Generation III reactors are improved Generation II reactors in terms of safety systems and fuel technology. These improvements enable the reactors to be operational for a longer time - estimated at 60 years. They began operating in the 1990s and are still running to this day.

Generation III+ reactors offer safety improvements compared to Generation III reactors. Generation III and III+ reactors are considered to have set the safety and construction standards worldwide.

Finally, Generation IV reactors are currently being researched since the 2000s. They could present advantages in terms of costs, safety, reliability, and non-proliferation resistance. They could develop a close fuel cycle for the reactor, partially solving the problem of nuclear waste. The 2010 European Sustainable Nuclear Industrial Initiative supports three Generation IV projects in the EU.

Kilowatt and megawatt per hour: The power generated by nuclear energy is calculated by kilowatt or megawatt per hour.

Levelized Costs of Electricity (LCOE): Is the basic economics metric for any generating plant. It is calculated by the total cost to build and operate a power plant over its lifetime, divided by the total electricity output dispatched from the plant over that period cost per megawatt/hour). According to the Fraunhofer Institute, the method of Levelized Costs of Electricity makes it possible to compare different types of power generation.

Proliferation: Designates the spread nuclear weapons, nuclear technology, fissionable material and nuclear weapons-making information to the countries that do not possess these. This principle is established by the Non-Proliferation Treaty in 1968.

Partitioning & transmutation: Designates the separation of atoms of spent nuclear fuel in order to reduce its toxicity. Then follows the transmutation process: the changing of nature of nuclei of atoms into more stable elements, reducing even more its toxicity.

Rosatom: Established in 2007, Rosatom is a Russian state-owned nuclear company.

Small Modular Reactor (SMR): The International Atomic Energy Agency defines Small Modular Reactors as advanced reactors that can produce a capacity of 300 MW per unit. They are smaller than regular nuclear reactors, can be assembled by a factory and transported as a unit to a location of installation, and use nuclear fission to generate energy.

CAN NUCLEAR ENERGY SERVE AS A BRIDGE FOR THE ENERGY TRANSITION?

PROS

Nuclear power has a low carbon footprint, and new smaller reactors can be commissioned faster than conventional reactors because of the use of off-the-shelf designs and components.

Also, nuclear energy has a **smaller land-occupation footprint** than renewable energy sources.

CONS

In a nuclear power plant's life cycle, emissions of around 117 g of CO2 per kilowatt-hour have to be taken into account. As a comparison, natural gas comes out at around 442 g of CO2 and onshore wind at around 9 g of CO2 per kilowatt-hour. **The CO2 footprint of an armada of SMRs produces a higher overall figure per kilowatt-hour**.

Considering SMR reactors currently planned, under construction or in operation, **the assumption of a fast availability cannot be relied upon**. On the contrary, planning, development and construction times usually exceed the original time schedules. Another specific problem is that with every new design must to be new, and therefore lengthy, licensing processes.

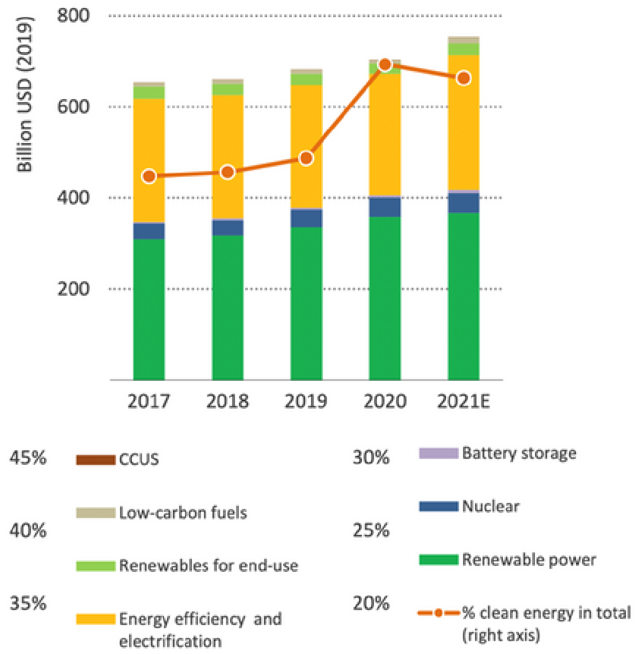
Continued innovation is key to enable green technologies to continue to outperform their carbon-heavy competitors. The numbers, however, reveal a remarkable disbalance between the investments in nuclear and renewable research and the investments in the expansion of the respective energy source: in 2019, 15% of research and development funds of IEA member states were allocated to renewables, against 21% for nuclear. In the same year, only 5.1 GW of nuclear, but 184 GW of renewables were added to the grid. This stands in harsh contrast to the 256 billion euros invested in renewable energy expansion in 2021, 17 times the global investment in nuclear power in that year.

CONCLUSION

In short, to further accelerate the expansion of renewables, research investments have to match market realities. A continued focus on nuclear research as an "interim technology" is neither economically nor ecologically sensible.

Finally, nuclear energy is a financially exclusive technology. It is important to make an energy-market entry for energy communities or municipal utilities attractive, push a decentralized energy transition and in turn increase competition to level the playing field. At the same time, it is also crucial to account for the needs of heavy industries (i.e., steel, chemical, cement etc.) in terms of finding the most suitable energy sources to support the energy intensity of their industrial processes.

Global investment in clean energy and energy efficiency, 2017 - 2021



Source: International Energy Agency

CAN NUCLEAR ENERGY GUARANTEE ENERGY INDEPENDENCE FROM RUSSIA?

PROS

Currently, the EU buys **45% of its gas**, around a third of its oil and a third of its coal from Russia. Increasing the share of nuclear energy supply would relax Russia's grip on the European energy supply. Accordingly, countries such as Netherlands and Belgium have turned to nuclear energy, by delaying their phase out of nuclear or enhancing their capacities.

CONS

As it stands now, nuclear power sovereignty in Europe is wishful thinking, as **Moscow still has a firm grip** on the European nuclear power system. Around **20% of uranium** is imported from Russia and a quarter of services, i.e. conversion and enrichment of uranium, are provided by Russia. It could be argued that supply and services can be compensated through contracts with other suppliers. However, one — in the words of Euratom — "significant vulnerability" remains. There are 18 Russian-designed reactors in the EU, running exclusively on Russian nuclear fuel.

The **supply-chain grip extends to the financial structure of the nuclear industry**, as Russia's Rosatom and France's Framatom are bound by numerous financial and organizational agreements. It should be pointed out that the French uranium recycling programme and with it the country's nuclear waste management would be void as soon as Rosatom is sanctioned.

While the process of looking for answers on how and why Europe has willingly put itself in a Russian headlock has just started, the continent should be careful not to fall for all the energy-related temptations offered by the silent actor on stage – China. While the public debate about gas and oil sanctions is raging, there should be a substantial awareness about the financial support Russia is receiving through its nuclear industry's ties to the EU.

CONCLUSION

Given the current situation, **we should be cautious** in looking to nuclear power capacities as a patron for securing the energy supply, while other energy sources can be adjusted away from Russian dependence.

> Domestically produced energy with wind turbines or photovoltaic are independent from geopolitical issues and contribute to the fight against climate change.

CAN NEW TECHNOLOGIES HELP TO DELIVER THE ENERGY TRANSITION?

PROS

Technological advances promise to solve some of the industry's biggest flaws. Third-generation reactors are significantly safer than the models in operation today. Fourth-generation reactors aim to rule out accidents altogether.

Some fourth-generation designs have the potential for significant technological breakthroughs. Among the most exciting are plans for reactors that are able to run on nuclear fuel for several decades; others have the ability to process old nuclear fuel, thus closing the nuclear fuel cycle and solving the problem of nuclear waste.

The argument for the Small Modular Reactor (SMR) goes: the energy source is safe, has low carbon emissions and can be commissioned more quickly than conventional reactors. These features could make SMRs a go-to option, also for the Global South.

CONS

In practice, there are already safety concerns in regard to third-generation reactors. The first third-generation reactor to be completed, built by Framatom and China's CGN, had to be shut down after gas leaks and small levels of radiation posed a direct threat to the plant and the public.

Fourth-generation reactors may include promising designs; however, **these reactors will not be able to deliver a fast-paced energy transition.** France seemed to acknowledge this issue, as it suspended its fourth-generation research project ASTRID after spending 738 million euros of public investment on it. The official explanation was: "in the current energy market situation, the perspective of industrial development of fourth-generation reactors is not planned before the second half of this century."

While designs of SMRs differ, some certainties remain: though the risks per reactor are lower, the higher number of reactors effectively **multiplies the threats of malfunction and proliferation risks** of nuclear material.

The most important concern is that **SMRs are not ready yet to deliver the transition**: they should be ready by 2030s, and only if their prototypes prove to be successful in 2020s.

Small Modular Reactors (SMR) are expected to have lower investment costs and a higher power generation per unit.

However SMRs are not market ready yet, as their prototypes are still being developed. If successful, SMRs can only be market ready in the 2030s.

IS NUCLEAR ENERGY A RELIABLE SOURCE OF ENERGY?

PROS

As renewable energy sources rely on external factors such as sun and wind, nuclear power is needed to ensure a stable energy supply. The argument often goes: base-load energy capacity is needed to safeguard a stable and reliable energy supply.

Nuclear energy is needed until the energy grid infrastructure has been adapted to the reality of “energy-rich” and “energy-poor” regions.

CONS

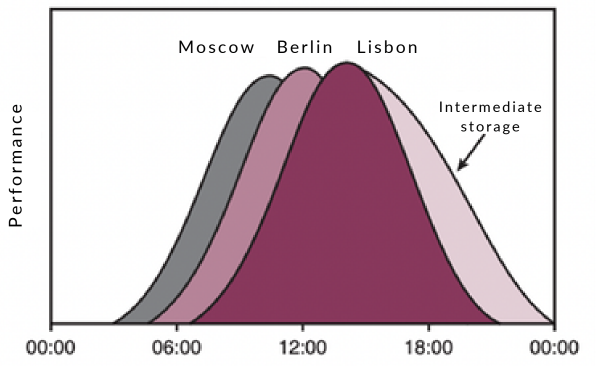
Put simply, **nuclear and renewable energies are a difficult match**.

Renewables provide a weather-dependent, fluctuating energy supply. **The development of a European energy grid is key** to cope with these fluctuations. As EU member states showcase different paths and different paces in each other’s energy transitions, they will need take turns in stabilizing their neighbors’ energy supply. However, to fully shift the European energy supply to renewables, storage capabilities and flexible interim technologies will be needed. Therefore the key question is **whether nuclear reactors can be such a flexible bridge technology**, especially since gas-fired power plants have drastically lost their economic appeal with Russia’s war on Ukraine and the European push to get rid of Russian gas supply. Designed for and in an environment of fossil-energy sources, **nuclear reactors are not built to be taken on and off the grid in short intervals**. On-and-off operation is deemed to put stress on materials, which have in many cases already surpassed the date to which they were calculated to last. The consequence of this can be observed in France, where nuclear plants have to be taken off the grid more and more regularly because of material exhaustion.

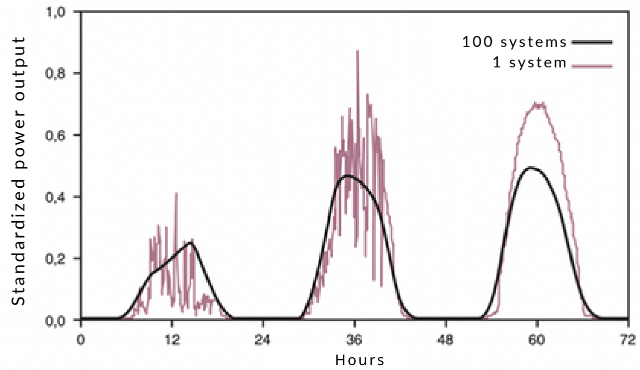
In April 2022 in France, sometimes only 28 of 56 nuclear reactors were connected to the grid. With an aging nuclear fleet and reactors not specifically designed for on and off use, nuclear and renewable are only compatible if a country is willing to significantly increase risks. Indeed, it is **highly questionable if France will be able to sustain a stable electricity supply** in the years to come. Not betting on renewable power early enough might prove to be a costly decision for France.

Additionally, with lower operational hours, the continued use of nuclear power plants designed and financially calculated for continuous use **becomes less and less economically sensible**.

Finally, **climate change threatens the nuclear industry**, as water-intensive inland nuclear power plants may contribute to localized water stress and competition for water uses, according to the IPCC.



PV supply in Europe in relation to time and place, source



PV supply in Europe in relation to time and place, source

CAN WE SOLVE THE PROBLEM OF NUCLEAR WASTE STORAGE?

PROS

Evidence from Finland, Sweden and France shows that broad political support, coherent waste policies and a well-managed decision-making process for final storage can boost public support of nuclear energy.

Some fourth-generation reactors have the ability to process old nuclear fuel, thus closing the nuclear fuel cycle and solving the problem of nuclear waste. New partitioning and transmutation technologies can reduce the time needed for nuclear waste to be kept in final storage.

France has managed to recycle the majority of its spent nuclear fuel, showing that it is possible to significantly reduce the problems with spent nuclear fuels.

CONS

The **different stages of the nuclear cycle all have unique environmental and proliferation risks**. Scenarios in which new partitioning and transmutation technologies are being used to treat nuclear waste and shorten the time needed for final storage add to the uncertainty of a clear-cut time frame. The lead time alone is suggested to take several decades, while the implementation period would take between 55 and 300 years. Such a process would increase proliferation risks, as separated plutonium would have to be stored at different facilities over extended periods. Spent fuel rods that have already been reprocessed are not suitable for partitioning and transmutation technologies. In any case, **the question of a safe storage site for these wastes remains**.

France — through Framatom, a nuclear energy company owned at 75% by Electricité de France, a largely state-owned French electricity company — **does not have the means to convert its used uranium**. This is supposed to be done by Rosatom in Siberia. Effectively, as Russia has more than enough uranium itself, Rosatom just stores France nuclear waste in one of Russia's closed cities, where access is only possible with special permits. Given an overdue public debate on the subject, **France will have to unravel its entanglements with it its financial support of the Russian nuclear industry**, effectively disrupting the country's nuclear waste processes.

The question of the storage of nuclear waste remains unresolved.

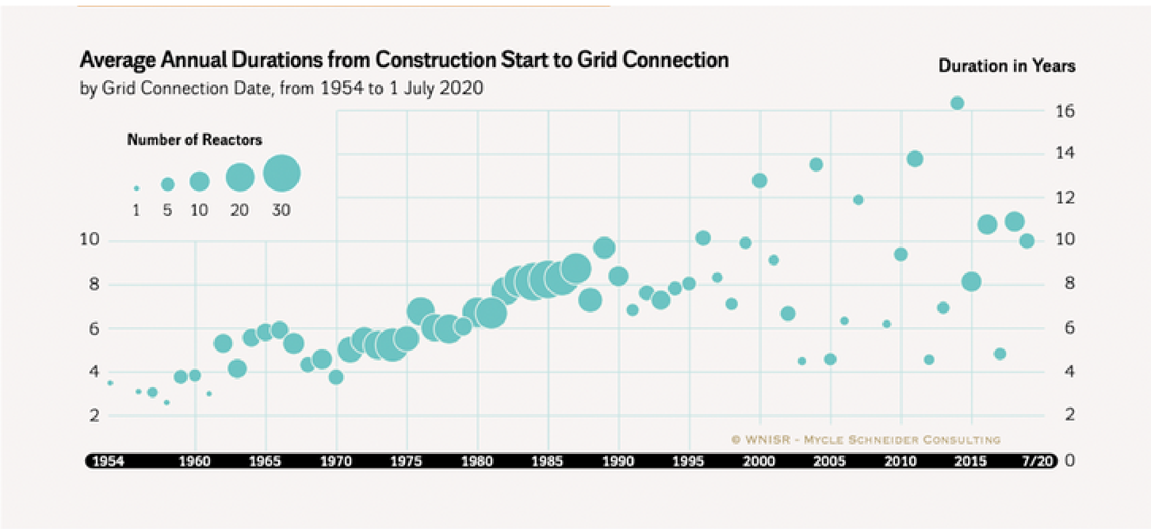
CAN NUCLEAR ENERGY BE READY ON TIME TO ANSWER THE ENERGY AND CLIMATE CRISIS?

The latest IPCC report has reiterated that, in order to limit global warming to 1.5 ° or even 2°,the next two decades are decisive. It is therefore crucial to evaluate whether nuclear energy resources can support the energy transition fast enough to achieve this goal.

The time it takes to construct modern European pressurized reactors — the only modern reactor type currently under construction in Europe — can be estimated to take between 8 (if Hinkley Point C will be on schedule) and 16 years, with delays making up for most of the construction time and planning processes not taken into account. Older studies show that, globally, the average construction time overrun of nuclear reactors is 64% – bearing in mind that this number is likely to be higher as the construction time of newer-generation reactors is not taken into account.

IPCC numbers suggest that, in order to make up for the loss in capacity of old, phased-out nuclear power plants and still have a “positive” impact on a path to 1.5°, as many as 160 new nuclear power plants would have to be added globally by 2030 — an all but realistic scenario given the average duration for planning, financing and construction. Indeed, it is no overstatement that there is no conceivable way countries can meet their 2030 Paris goals by embarking on nuclear power programmes now.

It should also be noted that, due to financial and structural shortcomings, no Western nuclear power company is in a position to push a nuclear power expansion. Russia, whose state-run company Rosatom had more contracts than the next four competitors combined in 2019, ruled itself out from leading such a charge.



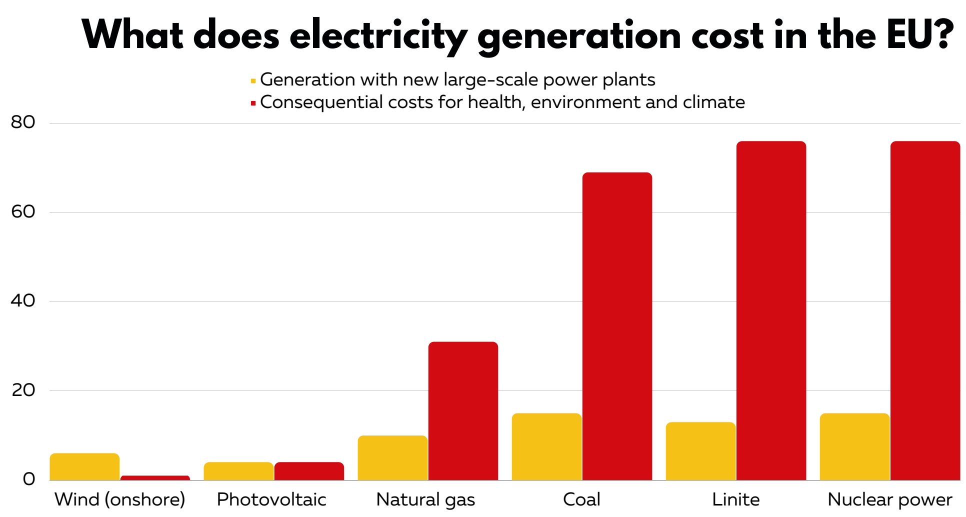
Source: World Nuclear Industry Status Report 2020, p. 49

IS NUCLEAR ENERGY CHEAP?

Nuclear energy has gradually lost its competitive position compared to renewable energy sources. The levelized cost of electricity (LCOE) produced by nuclear power is higher than that of onshore wind energy and photovoltaics, as well as offshore wind energy (depending on the study). Simultaneously, the trend is running against nuclear energy. With construction time overruns being the norm, construction costs and therefore the LCOE rise as well. Innovations have made renewable energy sources cheaper, whereas old and extended nuclear power plants make nuclear energy more expensive. Indeed, nuclear power seems to be the only technology that manages to actually become more costly with new innovation, rather than the other way around. Moreover, more than 9,5 billion euros of investments are required to finance a nuclear power plant, according to the IPCC.

SMRs seem to share this habit of **costs and construction time overruns**, as well as the need for high up-front investments. Amid substantial uncertainties, estimations for first generations SMRs come out at LCOEs of USD 131-190 per MWh. It also looks like the economic promise of SMRs has one clear shortcoming: scalability. Studies suggest that as many as 3000 SMRs would have to be constructed globally for it to be economically sustainable.

To pave the way for more renewable energy sources in the grid, countries have adopted specific policies, such as feed-in tariffs, feed-in premiums or priority feed-ins. These policies, together with a changed electricity price market, impact the financial calculations of existing and proposed nuclear power plants — part of the reason for electricity companies' resistance against an energy transition to renewable energies.



Source: Deutsche Welle, Fraunhofer ISE, UBA, DIW, 2021

IS NUCLEAR ENERGY SAFE?

Nuclear safety, critics' original worry with nuclear power, is still rational and should remain a principal concern. The most catastrophic incidences – i.e. Kyshtym 1957, Three Mile Island in 1979, Ukraine's Chernobyl in 1986 and Japan's Fukushima in 2011 – are well known. There have been **31 other serious incidents** at nuclear power stations worldwide since 1952, according to data from the International Atomic Energy Agency. Currently, around a fifth of France's aging nuclear reactors have been shut down because of safety issues; the older reactors get, the higher the risk of accidents.

New Gen. III reactor designs with passive and enhanced safety systems as well as SMRs reduce the risk of accidents. These generator types are, however, not likely to have any impact on the energy transition, as can be seen in Point of discussion 3.

Climate change directly treathens nuclear facilities and the energy supply equation. One visible pattern is the repeated shutdown of French nuclear power plants during summer months due to increasingly low water levels. Water-intensive inland nuclear power plants can add to local water stress and competition for shared water resources.

Finally, **nuclear facilities can become targets during conflicts**. Russian forces occupied the Chernobyl nuclear power plant and fired missiles near the Zaporizhzhia power plant in April 2022 during the invasion of Ukraine.

31 incidents since 1952

Three Mile Island in 1979, Chernobyl in 1986, Fukushima in 2011.

1/5 of france's nuclear fleet is shut down

Due to safety concerns. The average age of French reactors is 35 years old. The older the reactor, the higher the accident risks.

Risks of terror attacks

During conflicts. Russian forces occupied the Chernobyl nuclear power plant and fired missiles near the Zaporizhzhia power plant in April 2022 during the invasion of Ukraine.

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