Clara Dassonville and Thies Siemen

Nuclear Energy: The Arguments for the Debate

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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

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Nuclear Energy: The Arguments for the Debate

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 and political nature of many arguments present challenges for 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 intended to fuel the debate.

This publication is part of our Nuclear Series. 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.

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

The most recent IPCC report has once again emphasized that in order to limit global warming to 1.5° or even 2°, the next two decades are decisive. With the backdrop of accelerating climate change and uncertainties over energy security amidst the Russian war on Ukraine, the path to a coordinated energy transformation has become blurred. Among the countries that have chosen nuclear as an interim or long-term solution are the United Kingdom, Belgium and the Netherlands. Belgium has decided to backtrack on its decision to phase out nuclear energy by declaring it would extend the life of two of its seven reactors; its northern neighbor also announced that it would increase its nuclear capacities. After briefly reconsidering its nuclear phaseout, Germany has decided to remain on course, shutting off the last nuclear reactor at the end of this year. All of the IPCC's energy scenarios rely on growth in nuclear potential. When widening the scope, this outlook becomes all but certain. In light of this situation, it is crucial to answer the most important question first: **are there nuclear technologies available that can help the effort to achieve climate and energy transformation goals quickly enough**?

In Europe, the only large nuclear reactors that are currently being built are **two European Pressurised Reactors** (EPR), with one finished in Finland at the beginning of this year, as well as two Russian-designed VVER-440/213s in Slovakia.

Based on the developments at Olkiluto in Finland, Flamanville in France and Hinkley Point C in the UK, **the construction time of the EPR can be estimated to be between 8 and 16 years**. On average, delays make up for most of the construction time, planning processes not taken into account. On a broader and lengthier global scale, studies show that the average time overrun for nuclear reactors is around 64 percent – a number that is likely to be higher if the most recent project were included. As for the fate of the EPR and the future of large modern European reactors, it will be crucial to see whether the newest reactor, Hinkley Point C, can benefit from learning effects and reduce cost and construction time compared to the first-of-their-kind EPRs. Taking planning and commissioning processes into account, globally, the time lag between the decision to build a nuclear reactor and its commissioning is observed to lie between 10 and 19 years. Accordingly, the average construction time varies greatly. This stands in contrast to the planning security needed to reconfigure the energy supply.

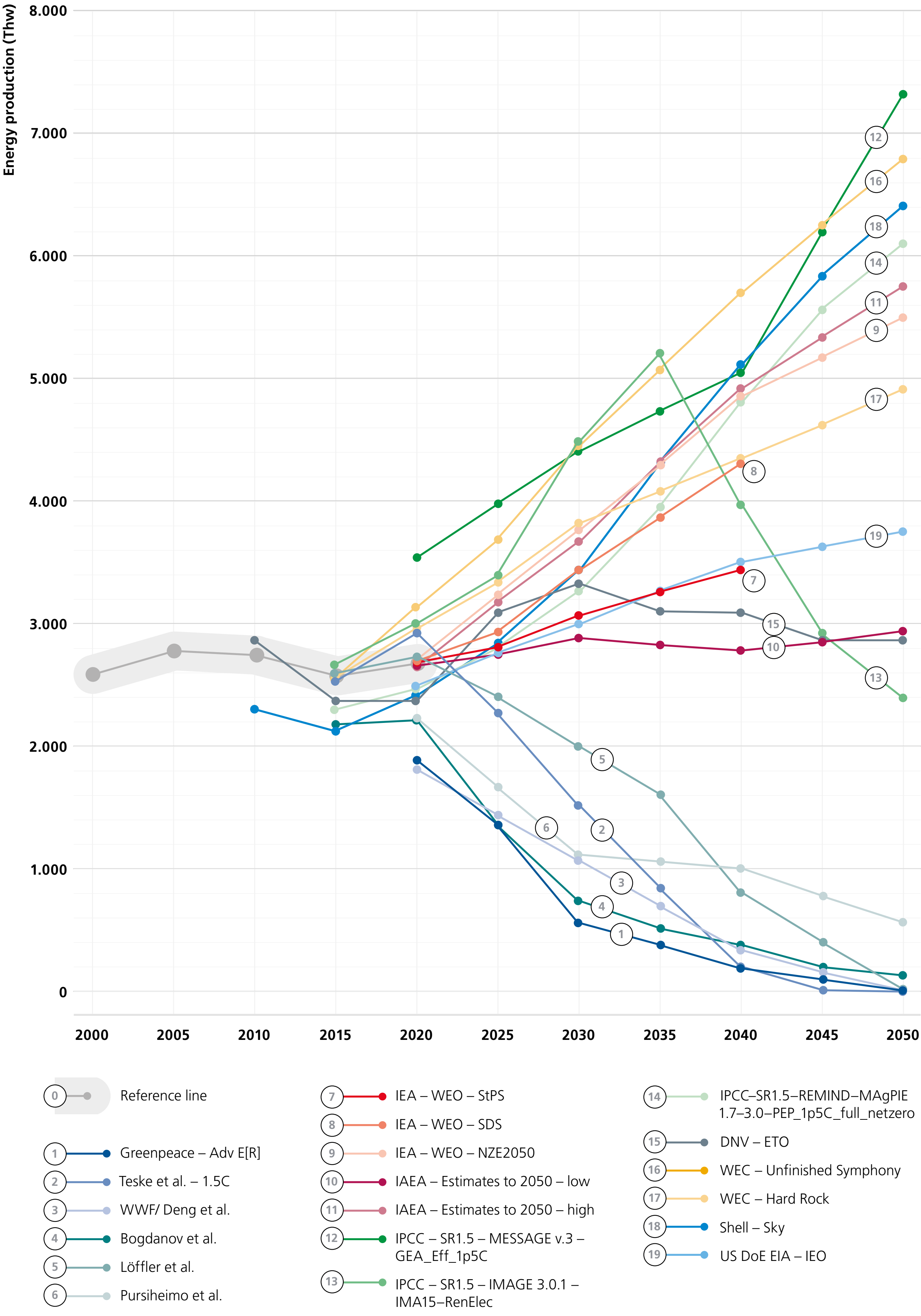
Amidst this unpredictability, policymakers have to deal with another nuclear uncertainty – the aging nuclear fleet. Even with broad lifetime extensions, the signs are clear: in the coming two decades, numerous nuclear reactors will have to be taken off the grid. IPCC numbers suggest that, in order to make up for the loss of capacity of old, phased-out nuclear power-plants and still have a »positive« impact on the 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 of 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**. For Framatom, as the biggest Western nuclear company (which through Electricité de France, is majority-held by France with a 83.88 percent share), to lead such a charge, it would have to be restructured and geared for nuclear expansion. Amidst 41 billion euros debt for the energy giant, a possible nationalisation under EU regulation scrutiny and the pro-nuclear EU Taxonomy all but cast in iron, EDF will have to clear many hurdles before it can embark on international 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.

With the slowing pace of nuclear power plant construction and given the time frame of around two decades for planning and construction, **pursuing nuclear power is no viable path to mitigate global warming within a time frame that is compatible with EU's net-zero goals**.

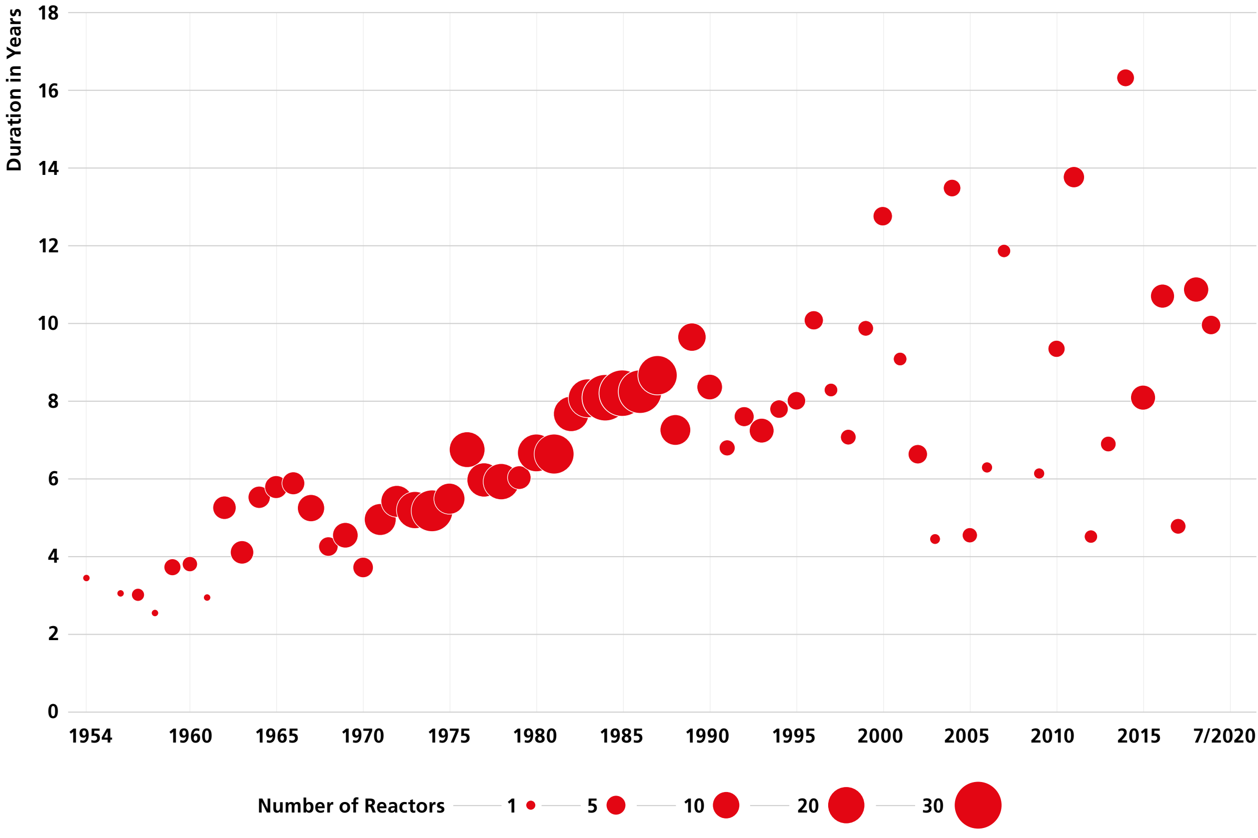
As Macron himself has assessed, »We need to massively develop renewable energies, because it is the only way to meet our immediate electricity needs, since it takes 15 years to build a nuclear reactor.« Yet, with tens of billion euros in debt, 200,000 jobs directly or indirectly tied to the nuclear sector and an aging nuclear fleet that shows an increasing number of power shortages, **France is »in too deep« to fully surrender its nuclear path**.

Figure 1
Projections of the development of nuclear energy capacities in global energy scenarios by study



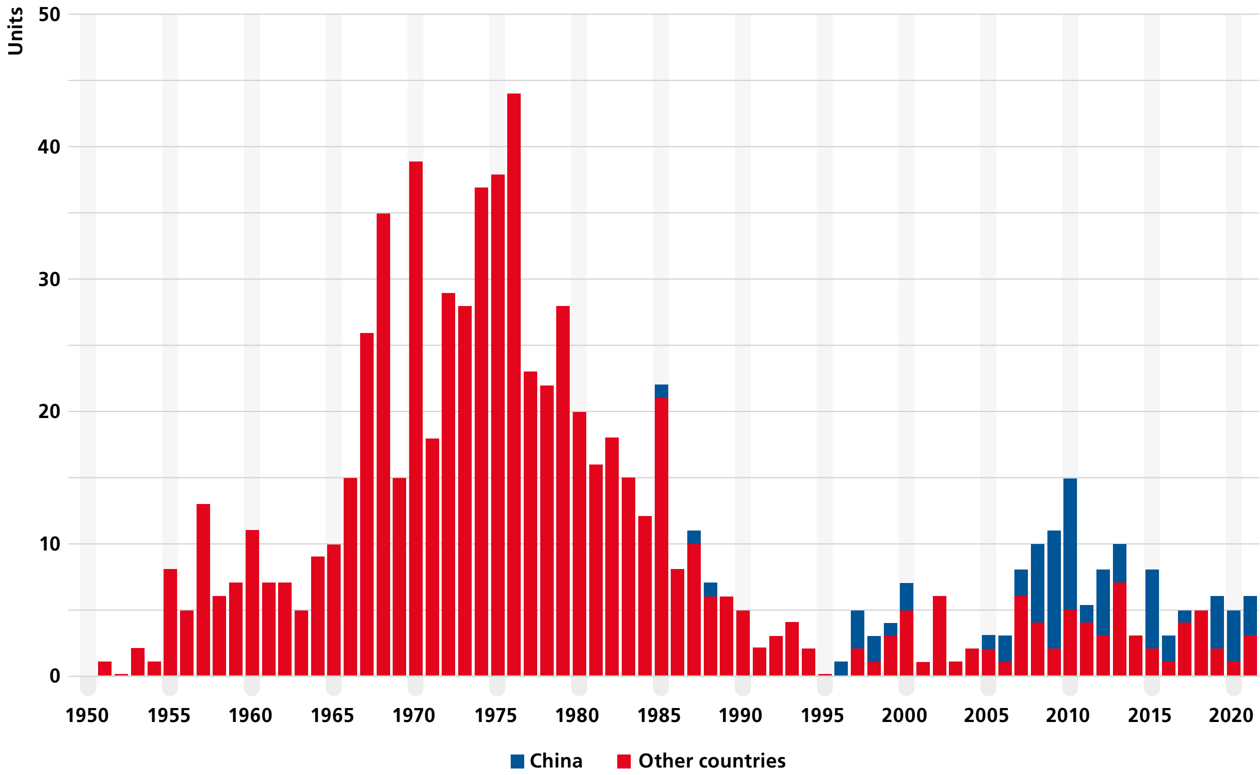
Source: Wealer et al. (2021), p. 57; https://climate-science.press/wp-content/uploads/2021/12/00Diskussionsbeitrage-S4F-9-2021-Kernkraft-V1.0.pdf

Figure 2
Average Annual Durations from Construction Start to Grid Connection (by Grid Connection Date, from 1954 to 1 July 2020)



Source: World Nuclear Industry Status Report 2020, p. 49; http://www.worldnuclearreport.org/IMG/pdf/wnisr2020_lr.pdf

Figure 3
Construction Starts of Nuclear Reactors in the World (in Units, from 1951 to 1 July 2021)



Notes: Construction of Bushehr-2, started in 1976, was considered abandoned in previous versions of this figure. As construction was restarted in 2019, it now appears as »Under Construction«. The Chinese reactor Shidao Bay-1 is now considered as two reactors, and construction starts in 2012 reflect this change.
Sources: World Nuclear Industry Status Report 2021, p. 57; https://www.worldnuclearreport.org/IMG/pdf/wnisr2021-lr.pdf

IS NUCLEAR ENERGY CHEAP?

Initially, it can be argued that the world-leading nuclear powers did not ascend into this position for economic reasons. Some scholars claim that the USA under Eisenhower decided to develop nuclear power plants for political reasons, seeking to demonstrate positive aspects of nuclear technology and to instigate a technology race with the Soviet Union. Similarly, in France, nuclear technology was seen as a way to develop French infrastructure and re-establish a leading role on the global stage. **Leaving aside political and military motives, can an economic case be made for nuclear power now?**

The increase in construction time is matched and often surpassed by the **cost overruns** of nuclear power plants. In France, the Flamanville 3 project will cost around 9.4 billion more. At the end of March, EDF announced that the cost for Hinkley Point C in the UK was likely to rise, with an update due in the summer of 2022. The last update saw the project at 26–27 billion euros, up from an original budget of around 21 billion euros. The reoccurring pattern of construction cost overruns is one of several cost drivers for nuclear. Overall, more than 9,5 billion euros of investments are required to finance a nuclear power plant, according to the IPCC.

As can be observed below, the levelised cost of electricity produced by nuclear power is higher than that of onshore wind energy and photovoltaic, as well as offshore wind energy (depending on the study). Simultaneously, the trend is running against nuclear energy. With new innovations, renewable energy sources become cheaper whereas old and extended nuclear power plants make nuclear energy more expensive. Indeed, nuclear power seems to be the only technology which manages to actually become more costly with new innovation rather than the other way around. The verdict being that **nuclear energy is gradually losing a competitive position** compared to renewable sources.

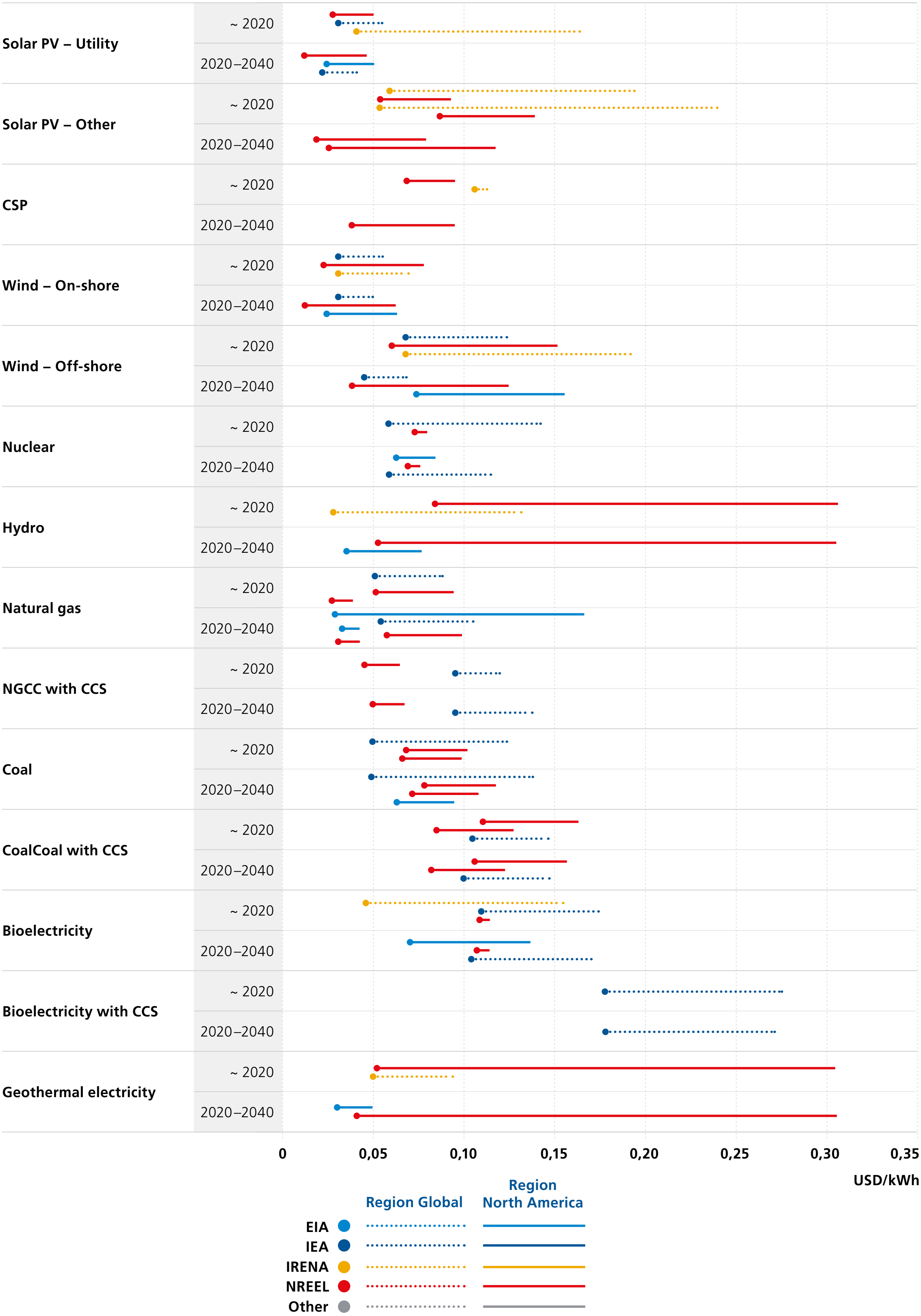
A study by Lazard, looking at the historical development of LCOEs for the US, shows even greater differences; some scholars argue that public sector reports tend to see nuclear energy as positive, since they are influenced by political motives.

The historical development of LCOE in the USA indicates the cost declines of renewable-energy generation technologies; these are driven by factors including decreasing capital costs, technological innovation and increased competition.

According to an MIT (Massachusetts Institute of Technology) study, 35 nuclear power plants with a combined power output of 58 GW were uneconomic as early as 2017. Twelve power plants were therefore closed even though they still had the viability to run for ten to twenty years more.

SMRs seem to share the habit of cost and construction time overruns, as well as the need for high up-front investments. In example, the cost of the Chinese experimental reactor CEFR rose from 1,210 US $/kWe to 19,357 US $/kWe. Amid substantial uncertainties, estimations for first-generation SMRs come out at LCOEs of USD 131–190 per MWh. The IPCC expects the effects of learning from first generation SMRs to reduce cost by about 19–32 percent. 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 to make it economically sensible to invest in the concept.

Figure 4
Range of LCOEs (in USD/kWh), from recent studies for different electricity generating technologies
(circa 2020 and in the future between 2020–2040)



Source: IPCC: Climate Change 2022, Chapter 6, p. 66; https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf

IS NUCLEAR ENERGY SAFE?

Critics' original worry with nuclear power, namely its safety, 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.

With climate change progressing, the variables of the energy supply equation are changing. One visible pattern is the repeated shutdown of French nuclear power plants during summer months due to decreasing 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.

CAN NUCLEAR ENERGY GUARANTEE ENERGY INDEPENDENCE FROM RUSSIA?

PROS

Currently, the EU buys 45 percent of its gas, around a third of its oil and a third of its coal from Russia. Increasing the share of nuclear energy supply again would relax Russia's grip on the European energy supply. Accordingly, some countries have turned to nuclear energy, reactivating 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 percent 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. Amidst these entanglements, it is no wonder there are no EU sanctions on the Russian nuclear industry at the time of writing.

With modernisation and digitalisation, the energy grid in general and nuclear power plants in particular are under a growing threat of **cyber-attacks**.

While the process of looking for answers to how and why Europe has willingly put itself in a Russian headlock has just started, the continent should be careful not to fall for 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 public debate about the **financial support Russia is receiving through its nuclear industry's ties to the EU**.

CONCLUSION

Given the entanglements of the European nuclear sector with Russia, ramping up nuclear energy capacities **will not lead to European energy sovereignty** in the short or medium-term, while **other energy sources can be adjusted away** from Russian dependence.

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.

Most prominently advocated for by Emmanuel Macron, who vowed to get French versions ready for export by 2030, SMRs are at the centre of the attention. The basic argument for the many different designs is the more or less the same: the energy source is safe, has low carbon emissions and can be commissioned more quickly than conventional reactors. features that make it a safe go-to option, especially for less developed countries.

CONS

While third-generation nuclear reactors in theory have safer designs, there are already safety concerns in practice: 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 – as stated by the company itself in a letter to US authorities, asking for approval to help CGN despite trade restrictions.

Fourth-generation reactors may include promising designs; however, these reactors will can not be ready on time. France has even suspended its fourth-generation research project ASTRID after spending 738 million euros on it. The official explanation: »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.«

Because of the different definitions for SMRs, it is difficult to find an exact answer to the question of the actual number of SMRs in operation globally. Based on the most recent IAEA definition indicated in our glossary, there currently is a single-digit number of SMRs in operation globally: two 50 MW KLT-40S reactors which are part of a Russian floating nuclear power plant based on nuclear powered icebreakers, two experimental reactors in China, the CEFR with 65 MW of thermal and 20 MW of electrical capacity, and the 210 MW HTR-PM. Depending on the scope of »modularity«, there is also a number of small reactors in operation in India, the PHWR-220.

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. With an overall higher number of reactors, the reactors will likely have to be placed closer to population hubs, in turn increasing the risk to local populations.

Furthermore, as observed above, the economic bet that countries are willing to import SMRs to meet their climate goals is bold, as SMRs do not scale as well as bigger power plants and are therefore likely to have higher overall cost for the energy produced.

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

PROS

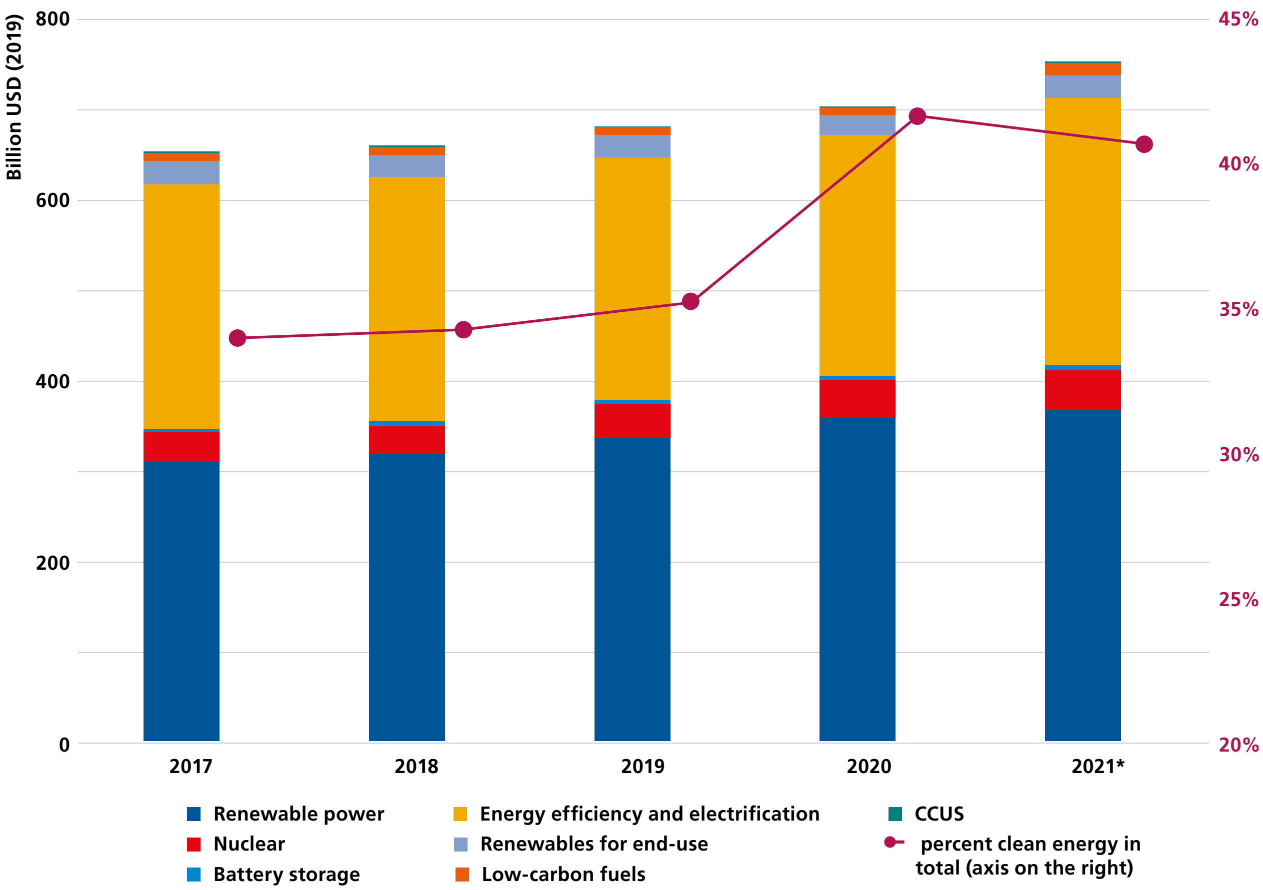
Nuclear power has a **low carbon footprint**. Moreover, new smaller reactors can be commissioned faster than conventional reactors because of the use of off-the-shelf designs and components.Finally, nuclear energy has a smaller land-occupation footprint than renewable energy sources.

CONS

In a nuclear power plant's life cycle, emissions of around 117 grams of CO_2 per kilowatt-hour have to be taken into account. As a comparison, natural gas comes out at around 442 grams of CO_2, onshore wind at around 9 grams of CO_2 per kilowatt-hour, and solar energy at 33 grams of CO_2 per kilowatt-hour. The CO_2 footprint of an armada of SMRs produces a higher overall figure per kilowatt-hour.

Considering the 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 many times over. Another specific problem is that with every new design, there have to be new and, therefore, lengthy licensing processes.

Figure 5
Global investment in clean energy and energy efficiency (2017–2021)



* Estimation
Source: International Energy Agency, p. 21; https://www.iea.org/reports/world-energy-investment-2021

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 percent of research and development funds of IEA members states were allocated to renewables, against 21 percent 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 stark contrast to the 256 billion euros invested in renewable energy expansion in 2021, 17 times the global investment in nuclear power in that year.

In short, to further accelerate the expansion of renewables, **research investments have to match market realities**.

Finally, nuclear energy is a technologically and financially exclusive technology. It is important to make an energy-market entry for energy communities or municipal utilities attractive, push a decentralised energy transition and, in turn, increase competition to level the playing field.

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.

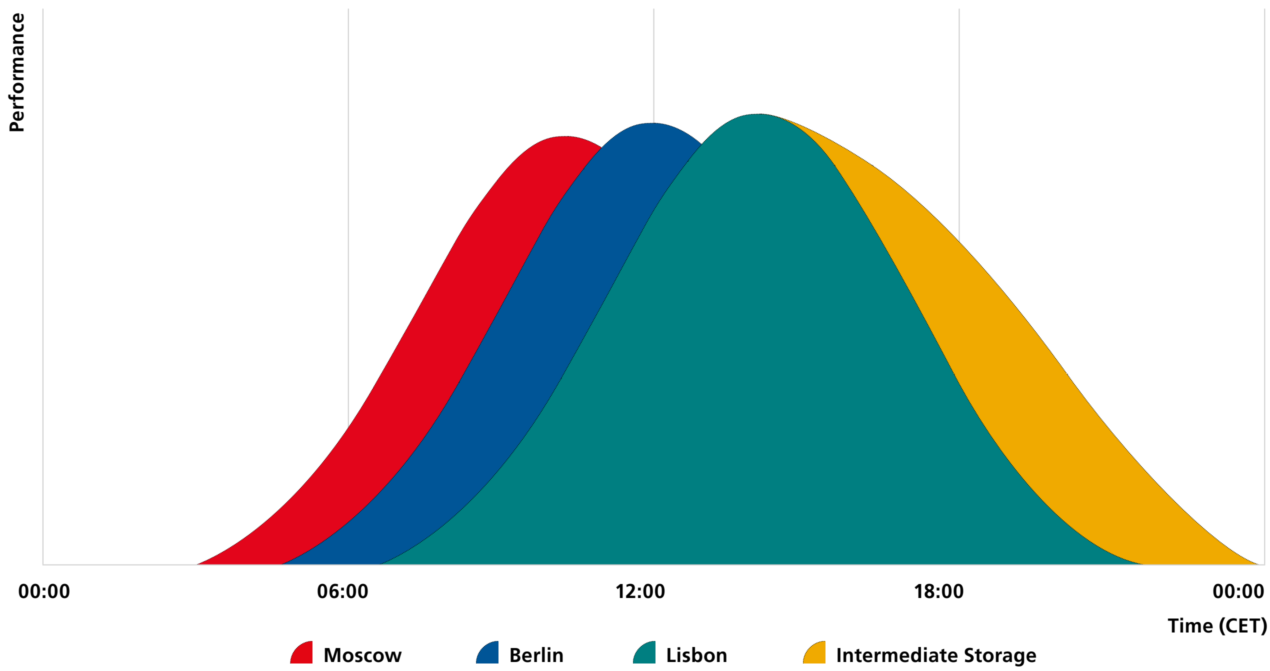
CONS

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

Renewables provide a weather-dependent, fluctuating energy supply. **To cope with natural fluctuations, the development of a European energy grid is key**. 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. PV should be seen in the context of a connected grid. However, to fully shift the European energy supply to renewables, storage capabilities and flexible interim technologies will be needed. The key question is, therefore, 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.

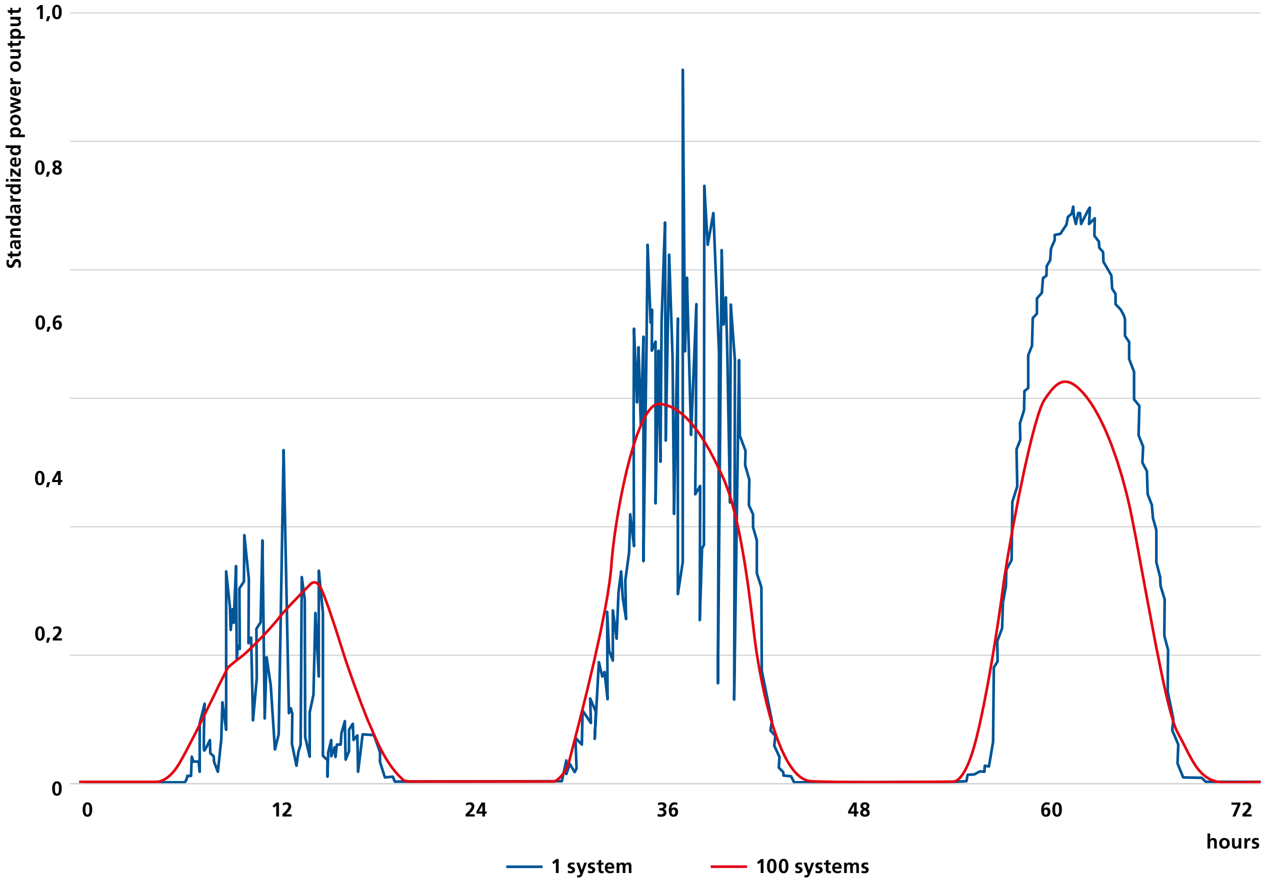
Designed for and in an environment of fossil-energy sources, **nuclear reactors are not built to be taken on and off the grid in short intervals**. On-and-off operation is deemed to put stress on materials, which have in many cases already surpassed the date to which they were calculated to last; the 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.

Figure 6
Photovoltaic supply in Europe in relation to time and place



Source: WBGU (2003), p. 84

Figure 7
Balancing the fluctuation in photovoltaic power generation through the networking of several plants
(Comparison between a strongly fluctuating individual plant and the mean value of one hundred spatially separated plants with the same output)



Source: WBGU (2003), p. 84

In April 2022, **only 28 of 56 of France's nuclear reactors were connected to the grid at times**. This shows that, 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 the risk. Indeed, it is highly questionable whether France will be able to sustain a stable electricity supply in the years to come.

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**.

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 scenario, the question of a safe storage site for these wastes remains.

France – through Framatom, a nuclear energy company owned at 75 percent 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**, as stated on the company's website. 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.

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 percent 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.

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