# NUCLEAR ENERGY INFRASTRUCTURE AND PUBLIC SAFETY

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## ABSTRACT

*This paper examines the possible reduction in nuclear capacity by 2040 as well as the critical role that nuclear power plays in promoting the production of low-carbon electricity, especially in developed nations. The future of nuclear power is threatened by ageing nuclear reactors, a lack of fresh investments, and difficult market conditions, despite the fact that nuclear power significantly reduces CO2 emissions. Using scenarios from the World Energy Outlook, the ramifications of a "nuclear fade case," in which nuclear capacity could decrease by two-thirds, are examined, emphasizing the hazards to energy security and elevated CO2 emissions. The report makes policy proposals to support new nuclear projects, prolong plant lifespans, and advance cutting-edge technologies. To secure nuclear power's position in accomplishing global climate goals and balancing the shift to renewable energy, it highlights the need for international cooperation and legislative support.*

**Keywords:** Nuclear Power, Low-Carbon Energy, Advanced Economies, CO2 Emissions, Energy Transition, Nuclear Fade Case, Policy Recommendations, Renewable Energy, Energy Security, Sustainable Development.



## INTRODUCTION

Hydropower and nuclear power are the mainstays of low-carbon electricity production. Three-quarters of the world's low-carbon generation comes from them combined. Nuclear power has cut CO2 emissions by more than 60 gigatons over the last 50 years, which is equivalent to almost two years' worth of global energy-related emissions. However, at a time when the world needs more low-carbon electricity, nuclear power has started to decline in developed economies, with reactors closing and little new investment undertaken. The significance of nuclear power in developed economies and the causes that could contribute to its eventual decline are the main topics of this report. Research indicates that if nothing is done, nuclear power in developed nations may decrease by two-thirds by 2040. The implications of such a "nuclear fade case" for costs, emissions and electricity security using two World Energy

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Outlook scenarios are examined in the New Policies Scenario and the Sustainable Development Scenario. Achieving the pace of $CO_2$ emissions reductions in line with the Paris Agreement is already a huge challenge, as shown in the Sustainable Development Situation. It calls for a significant expansion in nuclear power as well as investments in renewable energy and efficiency. The difficulties of trying to pursue this course with significantly less nuclear power are highlighted in this paper. It suggests a number of potential government initiatives aimed at ensuring the safety of currently operating nuclear power plants, promoting the development of new nuclear technologies, and supporting the construction of future nuclear facilities. The globe runs the risk of a sharp drop in the use of nuclear power in developed economies, which may lead to billions of tons of additional carbon emissions, as many nations face an uncertain future. Because of safety concerns and other considerations, some nations have chosen not to use nuclear power. Many others, however, still see a role for nuclear in their energy transitions but are not doing enough to meet their goals.

Nuclear power has avoided about 55 Gt of $CO_2$ emissions over the past 50 years, nearly equal to 2 years of global energy-related $CO_2$ emissions. However, despite the contribution from nuclear and the rapid growth in renewables, energy-related $CO_2$ emissions hit a record high in 2018 as electricity demand growth outpaced increases in low-carbon power.

**AN AGING NUCLEAR FLEET**



The significance of the nuclear fleet to global low-carbon energy transitions is highlighted by the possibility that absent significant lifetime extensions and new projects, $CO_2$ emissions might reach 4 billion tons. For many years to come, the nuclear fleet will supply low-carbon electricity to emerging and developing nations, especially China. However, many nuclear facilities are approaching the end of their intended lifespans, and the average age of the nuclear fleet in industrialized nations is 35 years. Due to their advanced age, nuclear reactors are starting to shut down; by 2025, it is anticipated that 25% of the nuclear capacity in advanced economies will have been shut down.

Reactor life extensions are significantly less expensive than building a new plant, and their prices are comparable to those of other clean energy sources, such as new wind and solar PV projects. They still constitute a significant capital investment, though. Depending on the site's condition, extending the operational life of 1 GW of nuclear power for at least 10 years might cost anywhere from \$500 million to slightly more than \$1 billion. Investments in lifetime extensions are hampered by challenging market conditions. Nuclear is at risk of closing early if more expenditures are required because margins for many technologies have been drastically cut or erased by an extended period of low wholesale energy prices in most advanced economies. As such, the feasibility of extensions depends largely on domestic market conditions.

**United States**

In the United States, some 90 reactors have operational licenses through 60 years, yet several have already retired early, and many more are at risk due to relatively low wholesale electricity prices.

**European Union**

In the European Union, the case for nuclear lifetime extensions is stronger. The economic case remains compelling even if the decrease in wind and solar PV costs accelerates.

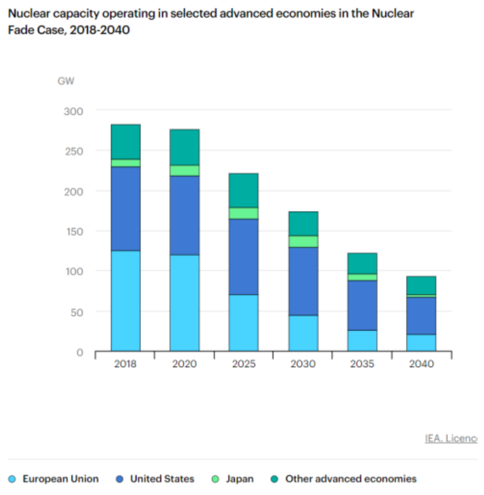
**Japan**

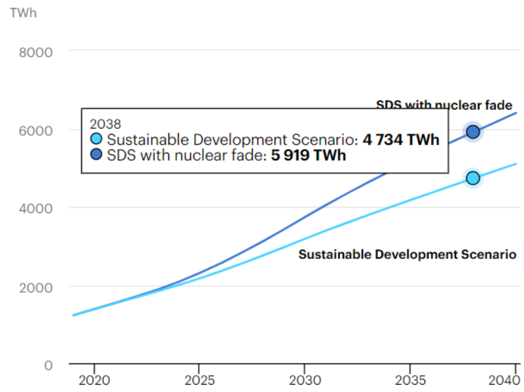
Nuclear extensions are even more competitive in Japan, where renewables remain expensive and coal and gas must be imported.

**THE NUCLEAR FADE CASE**



The nuclear fleet in developed economies may experience a sharp reduction because of these difficulties. Without further funding for lifetime extensions or new initiatives, the IEA's Nuclear Fade Case examines what might occur over the ensuing decades. In this scenario, the amount of nuclear power in industrialized economies would decrease by two-thirds by 2040, from over 280 GW in 2018 to a little over 90 GW. With nuclear's portion of the power mix dropping to just 4%, the European Union would experience the biggest loss. The percentage would plummet from 8% in the US to 2% in Japan, which is significantly less than their 2030 goal of 20–22%. The Nuclear Fade Case has many ramifications, such as the requirement for large extra investment and potential concerns about electricity security given the growing importance of gas-fired capacity in supplying peak demand. The clean energy transition will be more costly and challenging without more nuclear, needing an additional $1.6 trillion in investment in advanced economies over the next 20 years. Importantly, by 2040, a significant clean energy deficit would appear, necessitating even faster deployment of wind and solar PV to close the gap.




## POLICY RECOMMENDATIONS

In this context, countries that intend to retain the option of nuclear power should consider the following actions:

• **Keep The Option Open:** Authorize lifetime extensions of existing nuclear plants for as long as safely possible.

• **Value Dispatchability:** Create an electrical market that appropriately values the system services such as capacity availability and frequency control services—necessary to preserve the security of electricity. Ensure that nuclear power plants and other providers of these services receive competitive, nondiscriminatory compensation.

• **Value Non-Market Benefits:** Establish a level playing field for nuclear power with other low-carbon energy sources in recognition of its environmental and energy security benefits and remunerate it accordingly.

• **Update Safety Regulations:** Update safety rules as needed to guarantee nuclear reactors continue to operate safely. This should, if feasible, involve permitting nuclear power facilities to operate in a flexible manner in order to provide ancillary services.

• **Create A Favorable Financing Framework:** Create risk management and financing frameworks that facilitate the mobilization of capital for new and existing plants at an acceptable cost taking the risk profile and long-time-horizons of nuclear projects into consideration.

• **Support New Construction:** Ensure that licensing processes do not lead to project delays and cost increases that are not justified by safety requirements.

• **Support Innovative New Reactor Designs:** Accelerate innovation in new reactor designs with lower capital costs and shorter lead times and technologies that improve the operating flexibility of nuclear power plants to facilitate the integration of growing wind and solar capacity into the electricity system.

• **Maintain Human Capital:** Protect and develop the human capital and project management capabilities in nuclear engineering.

## INTERNATIONAL COLLABORATION

Boost international collaboration in the nuclear energy sector to exchange technological innovations, standardise regulations, and promote best practices. This involves working together to build next-generation reactors, research and development of safety procedures, and cooperative waste management initiatives. Fostering global collaborations can also aid in streamlining nuclear fuel and component supply chains, increasing project efficiency and cutting expenses. It also enables nations to exchange expertise on handling nuclear security issues and enhancing public understanding of nuclear energy's contribution to climate goals. Furthermore, crucial concerns like nuclear non-proliferation and the avoidance of nuclear material misuse can be addressed by international cooperation in the nuclear energy sector. By sharing best practices and information through platforms like the International Atomic Energy Agency (IAEA), nations can bolster global nuclear security, and emergency preparedness and achieve climate goals.

## NUCLEAR POWER CAN PLAY AN IMPORTANT ROLE IN CLEAN ENERGY TRANSITIONS

Today, nuclear power contributes significantly to the production of electricity; in 2018, it accounted for 10% of the world's electrical supply. Nuclear power is the largest low-carbon form of electricity generation in mature economies, making up 18% of total generation. But in recent years, the proportion of the world's electrical supply has been decreasing. Advanced economies have been the main drivers of this, as nuclear fleets age, new capacity additions have slowed to a trickle, and some facilities constructed in the 1970s and 1980s have been abandoned. The shift to a clean electrical system has been hindered as a result. Due to the drop in nuclear power, the overall percentage of clean energy sources in the total electricity supply in 2018 remained at 36%, despite the remarkable rise of solar and wind power. To accelerate the decarbonization of the energy supply, that decline must be stopped. Global sustainable energy transitions will require a variety of technologies, including nuclear power. Electricity is becoming the primary source of energy worldwide. Therefore, transforming the power sector—which now produces the most CO2 emissions—into a low-carbon source that lowers emissions from fossil fuels in sectors like industry, transportation, and heating is essential to creating clean energy systems. Nuclear power can contribute significantly alongside fossil fuels through carbon collection, utilization, and storage, even though renewable energy sources are predicted to remain at the forefront. Most of the world's energy consumption and CO2 emissions come from nations that envision nuclear power playing a part in the future. However, the growth of clean power would need to be three times faster than it is now in order to reach a trajectory that is consistent with sustainability aspirations, including international climate goals. By 2040, 85% of the world's electricity would need to originate from clean sources, up from 36% at the moment. The trend would need an 80% increase in worldwide nuclear power generation by 2040, in addition to significant expenditures in efficiency and renewable energy. There are several ways that nuclear power plants support the security of electricity. Power grid stability is aided by nuclear power reactors. They can modify their operations to adapt to changes in supply and demand to a certain degree. The demand for these services will grow as the proportion of variable renewables, like as wind and solar photovoltaics (PV), rises. By lowering reliance on imported fuels, nuclear reactors can improve energy security and mitigate the effects of seasonal variations in renewable energy generation.



**LIFETIME EXTENSIONS OF NUCLEAR POWER PLANTS ARE CRUCIAL TO GETTING THE ENERGY TRANSITION BACK ON TRACK**

In developed economies, policy and regulatory choices continue to be crucial for the future of ageing reactors. Their nuclear fleets are 35 years old on average. In addition to having the biggest active nuclear fleets (more than 100 gigawatts apiece), the US and the EU also have some of the oldest reactors—the average reactor in the US is 39 years old, while in the EU it is 35 years old. In most cases, the initial design lifetime for operations was 40 years. Around one-quarter of the current nuclear capacity in advanced economies is set to be shut down by 2025 – mainly because of policies to reduce the nuclear role. The fate of the remaining capacity depends on decisions about lifetime extensions in the coming years. In the United States, for example, some 90 reactors have 60-year operating licenses, yet several have already been retired early and many more are at risk. In Europe, Japan and other advanced economies, extensions of plants' lifetimes also face uncertain prospects.

There are economic considerations as well. In general, lifetime extensions are cost-competitive with other energy generation technologies, such as new wind and solar projects, and are far less expensive than new construction. However, in order to replace and renovate essential parts that allow plants to continue operating safely, a substantial investment is still required. Certain plants in the United States are becoming financially unviable due to low wholesale power and carbon pricing, as well as new rules governing the use of water for reactor cooling. Furthermore, nuclear power is frequently penalized by markets and regulatory frameworks that fail to recognize its worth as a clean energy source and its role in ensuring the security of electricity. Most of the nuclear power reactors in developed nations run the risk of losing too soon as a result.

**THE HURDLES TO INVESTMENT IN NEW NUCLEAR PROJECTS IN ADVANCED ECONOMIES ARE DAUNTING**

The prospects of accomplishing clean energy transitions will be greatly impacted by the outcome of plans to construct new nuclear power facilities. The need to ramp up renewables would be lessened if longer extensions were made possible and premature decommissioning was avoided. However, nuclear power can only offer short-term assistance for the transition to greener energy systems in the absence of new buildings Getting investment is the largest obstacle to new nuclear projects. The magnitude of nuclear projects, which demand billions of dollars in upfront investment, and their competitiveness with alternative power production technologies are issues that new nuclear plant plans must deal with. These scepticisms are particularly prevalent in nations that have implemented competitive wholesale markets. There are several obstacles unique to nuclear power technologies that could stop investment. The primary challenges include the size of the investment and the lengthy lead times; the potential for future policy or electrical system changes; and the danger of construction issues, delays, and cost overruns. The advanced reactors still under construction in the United States, Finland, and France have been delayed for a long time. They have turned out to cost far more than originally expected and dampened investor interest in new projects. For example, Korea has a much better record of completing the construction of new projects on time and on budget, although the country plans to reduce its reliance on nuclear power.

**WITHOUT NUCLEAR INVESTMENT, ACHIEVING A SUSTAINABLE ENERGY SYSTEM WILL BE MUCH HARDER**

Emissions, costs, and energy security would all be impacted if industrialized economies saw a decline in investment in both new and current nuclear facilities. By 2040, nuclear power capacity in industrialized nations would have decreased by almost two-thirds if no additional investments were made to build new projects or prolong the operating lives of current nuclear power plants. Under the government's current policy goals, nuclear would be largely replaced by gas and, to a lesser extent, coal, while renewable investment would continue to increase. This would make gas even more crucial to a nation's electrical security. Cumulative CO2 emissions would rise by 4 billion tons by 2040, adding to the already considerable difficulties of reaching emissions targets. As additional power generation capacity and related grid infrastructure are constructed to replace retiring nuclear units, investment requirements would rise by over USD 340 billion. Although it would take a tremendous amount of work, it is conceivable to make the clean energy transition with less nuclear power. Regulators and policymakers would need to figure out how to set up the right environment to encourage the required investment in other clean energy technologies. There would be a significant lack of low-carbon electricity in advanced economies. The primary sources tasked with replacing nuclear would be wind and solar photovoltaics, and their development rates would need to reach previously unheard-of levels. In developed economies, wind and solar PV capacity has grown by roughly 580 GW over the last 20 years. To counteract nuclear decline, however, over five times as much would have to be constructed during the next 20 years. Numerous non-market obstacles, such as the general public's and society's acceptance of the projects and the corresponding construction of network infrastructure, would need to be removed for wind and solar PV to reach that growth. On the other hand, nuclear power can help reduce the cost of changing the electrical system and ease the technical challenges of integrating renewables. Electricity grids lose flexibility as nuclear power fades. New gas-fired power plants, more storage (such as batteries, pumped storage, or chemical technologies like hydrogen), and demand-side measures (where customers are urged to adjust or reduce their use in real-time in response to price signals) are some ways to counteract this. Although increasing connectivity with other systems would also offer more flexibility, its usefulness is reduced when all of the systems in an area have extremely high proportions of solar and wind PV.

## OFFSETTING LESS NUCLEAR POWER WITH MORE RENEWABLES WOULD COST MORE

Customers pay more for electricity when nuclear is removed from the mix. In developed economies, a dramatic reduction in nuclear would result in a significant rise in the amount of money required for the electrical grid and alternative power sources. From 2018 to 2040, advanced economies will need to invest an additional USD 1.6 trillion in the electrical sector. The cost of installing new renewable capacity is far higher than that of prolonging the lives of existing nuclear reactors, even with recent drops in wind and solar costs. Costs are also raised by the requirement to update old lines and expand the transmission infrastructure in order to connect new plants and handle the increased power output. Since nuclear power has low fuel costs and operation and maintenance account for a small percentage of overall energy supply costs, the additional investment needed in advanced economies would not be covered by savings in operating expenses. The average annual cost of energy delivery in industrialized economies would be over USD 80 billion higher in the absence of extensive lifetime extensions or new projects.



## STRONG POLICY SUPPORT IS NEEDED TO SECURE INVESTMENT IN EXISTING AND NEW NUCLEAR PLANTS

To guarantee fair competition, nations that have retained the option of employing nuclear power must change their regulations. Barriers to funding lifetime extensions and additional capacity must also be addressed. Nuclear power and other low-carbon technologies' clean energy and energy security qualities should be prioritized when building electricity markets. Given the extremely high cost of projects and the unfavourable recent experiences in some nations, securing investment in future nuclear facilities would require more extensive regulatory action. Investment policies need to overcome financing barriers through a combination of long-term contracts, price guarantees and direct state investment. Advanced nuclear technologies that are suitable for private investment, such as small modular reactors (SMRs), are gaining popularity. The development of this technology is still ongoing. There is a case to be made for governments to support it by providing subsidies for early deployment, startup capital, and research and development money. For SMR manufacturers to take advantage of economies of scale, reactor designs must be standardized. Maintaining skills and experience in nuclear technology requires ongoing development and operation. The relatively slow pace of nuclear deployment in advanced economies in recent years means there is a risk of losing human capital and technical know-how. Maintaining human skills and industrial expertise should be a priority for countries that aim to continue relying on nuclear power.

## CONCLUSION

In conclusion, nuclear energy continues to play a significant role in the shift to low-carbon power systems, particularly in developed nations. Nuclear energy's future is uncertain due to ageing infrastructure, financial difficulties, and coverage obstacles, notwithstanding its significant contribution to lowering CO2 emissions over the past few decades. Nuclear capabilities should drastically decrease by 2040 without significant investment in lifetime extensions and new projects, primarily due to increased dependency on fossil fuels and improved emissions. Strong coverage assistance is needed to provide a favourable financial environment, understand the cost of nuclear's low-carbon benefits, and market new technologies like small modular reactors (SMRs) to maintain the nuclear position during easy strength shifts. By balancing nuclear energy with renewables, superior economies can ensure a greater secure, sustainable, and cost-powerful strength destiny.

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