Nuclear Power in a Clean Energy System

By Keisuke SADAMORI
International Energy Agency (IEA)

Nuclear power, along with hydropower, forms the backbone of low carbon electricity generation today; together they provide three-quarters of global low-carbon generation today. Over the past 50 years, nuclear power has reduced CO2 emissions by over 60 gigatonnes – nearly two years' worth of global energy-related emissions. Yet in the advanced economies, nuclear power has begun to fade, with plants closing and little new investment, just when the world requires more low-carbon electricity. This paper focuses on the role of nuclear power in the advanced economies today and the factors that put nuclear power there at risk of decline tomorrow. The paper shows that without action nuclear power in the advanced economies could fall by two-thirds to 2040. It examines the implications of such a decline for emissions and for electricity security.

Achieving the pace of CO_2 emission reductions in line with the Paris Agreement is already a huge challenge, requiring large increases in efficiency and renewables investments, as well as an increase in nuclear power. This paper identifies the even-greater challenges of attempting to follow this path with much less nuclear power, including an additional USD 1.6 trillion in investment needs and 5% higher cost to consumers in advanced economies. This paper recommends several actions to governments open to nuclear power that aim to ensure existing plants can operate as long as they are safe, support new nuclear construction, and encourage new nuclear technologies to be developed.

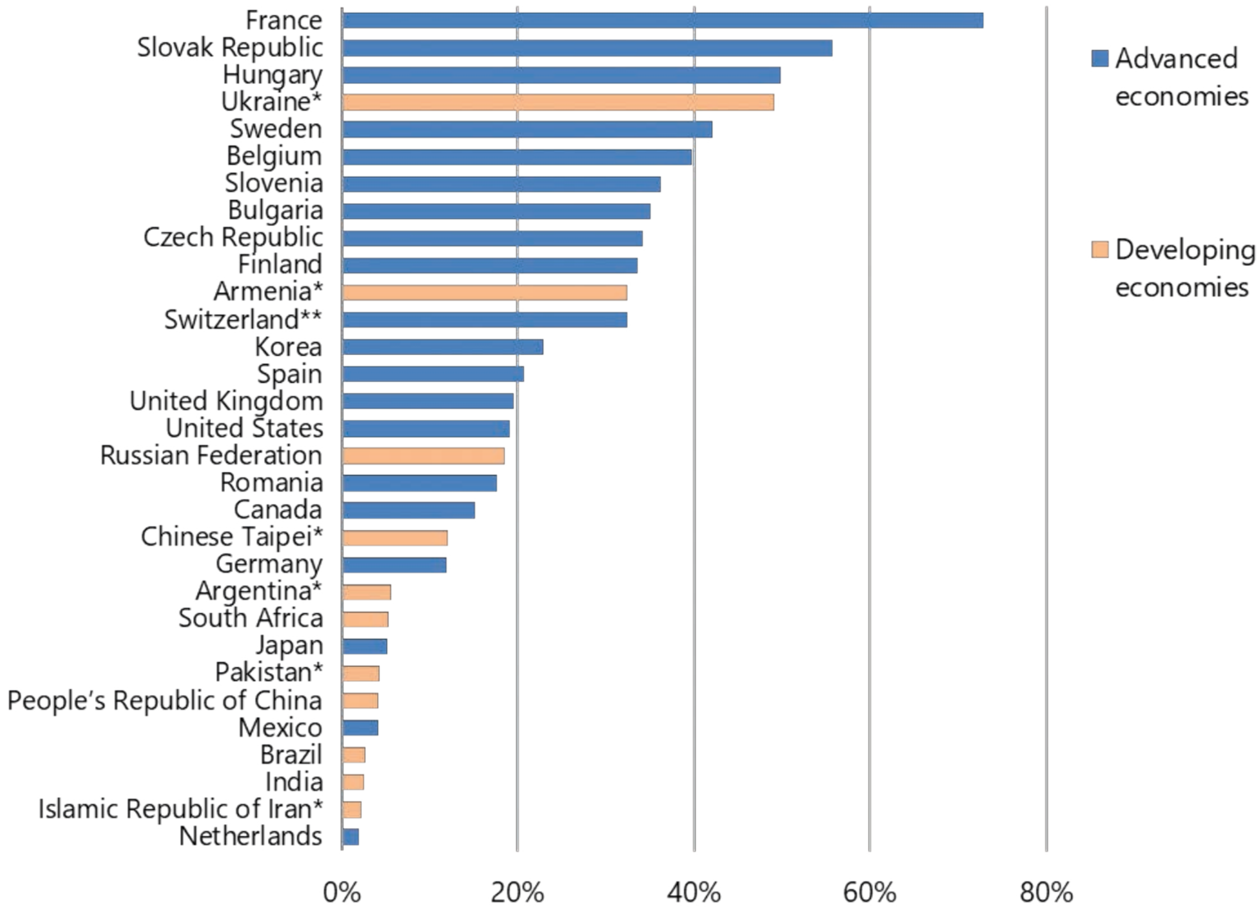
Nuclear power can play an important role in clean energy transitions

Nuclear power today makes a significant contribution to electricity generation, providing 10% of global electricity supply in 2018. In advanced economies, nuclear power accounts for 18% of total energy and is the largest low-carbon source of electricity.

However, its share of global electricity supply has been declining in recent years. That has been driven by advanced economies, where nuclear fleets are ageing, additions of new capacity have dwindled to a trickle, and some plants built in the 1970s and 1980s have been retired. This has slowed the transition towards a clean electricity system. Despite the impressive growth of solar and wind power, the overall share of clean energy sources in total electricity supply in 2018, at 36%, was the same as it was 20 years earlier because of the decline in nuclear. Halting that slide will be vital to stepping up the pace of the decarbonisation of electricity supply.

A range of technologies, including nuclear power, will be needed for clean energy transitions around the world. Global energy is increasingly based around electricity. That means the key to making energy systems clean is to turn the electricity sector from the largest producer of CO_2 emissions into a low-carbon source that reduces fossil fuel emissions in areas like transport, heating and industry. While renewables are expected to continue to lead, nuclear power can also play an important part along with fossil fuels using carbon capture, utilisation and storage. Countries envisaging a future role for nuclear account for the bulk of global energy demand and CO_2 emissions. But to achieve a trajectory consistent with sustainability targets – including international climate goals – the expansion of clean electricity would need to be three times faster than at present. It would require 85% of global electricity to come from clean sources by 2040, compared with just 36% today. Along with massive investments in efficiency and renewables, the trajectory would need an 80% increase in global nuclear power production by 2040.

Nuclear power plants contribute to electricity security in multiple ways. Nuclear plants help to keep power grids stable. To a certain extent, they can adjust their operations to follow demand and supply shifts. As the share of variable renewables like wind and solar photovoltaics (PV) rises, the need for such services will increase. Nuclear plants can help to limit the impacts from seasonal fluctuations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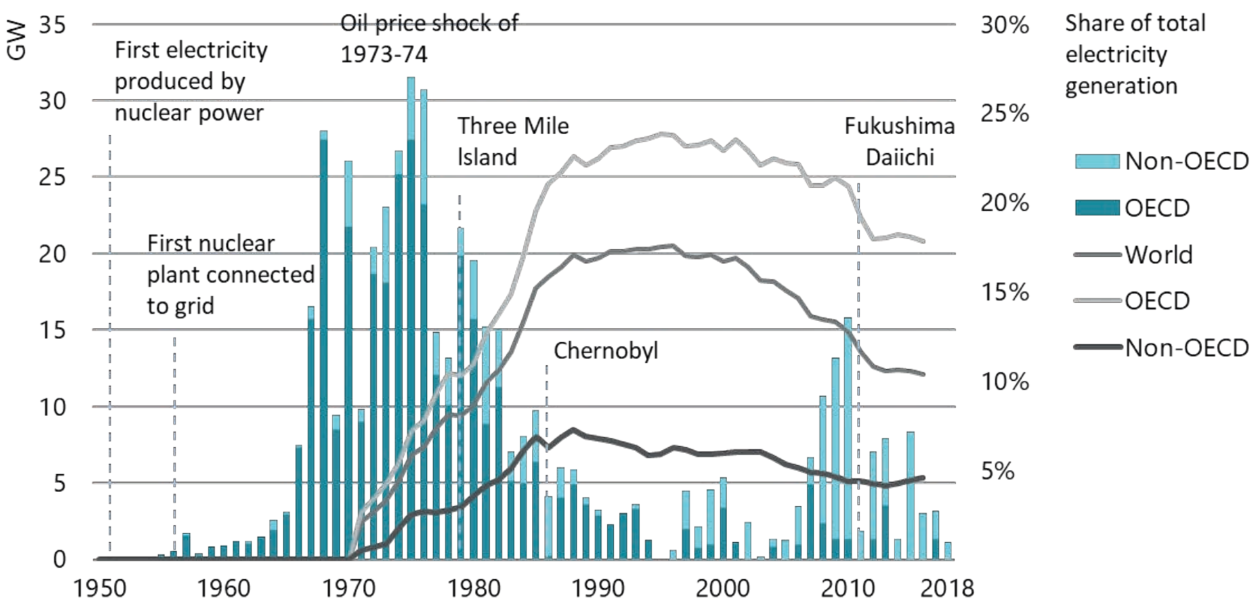
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First electricity produced by nuclear power
First nuclear plant connected to grid
Oil price shock of 1973-74
Three Mile Island
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Fukushima Daiichi
1950
1960
1970
1980
1990
2000
2010
2018
30%
25%
20%
15%
10%
5%
Share of total electricity generation
Non-OECD
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in output from renewables and bolster energy security by reducing dependence on imported fuels.

Lifetime extensions of nuclear power plants are crucial to getting the energy transition back on track

Policy and regulatory decisions remain critical to the fate of ageing reactors in advanced economies. The average age of their nuclear fleets is 35 years. The European Union and the United States have the largest active nuclear fleets (over 100 gigawatts each), and they are also among the oldest: the average reactor is 35 years old in the European Union and 39 years old in the United States. The original design lifetime for operations was 40 years in most cases. 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 nuclear's 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.

Economic factors are also at play. Lifetime extensions are considerably cheaper than new construction and are generally cost-competitive with other electricity generation technologies, including new wind and solar projects. However, they still need significant investment to replace and refurbish key components that enable plants to continue operating safely. Low wholesale electricity and carbon prices, together with new regulations on the use of water for cooling reactors, are making some plants in the United States financially unviable. In addition, markets and regulatory systems often penalise nuclear power by not pricing in its value as a clean energy source and its contribution to electricity security. As a result, most nuclear power plants in advanced economies are at risk of closing prematurely.

The hurdles to investment in new nuclear projects in advanced economies are daunting

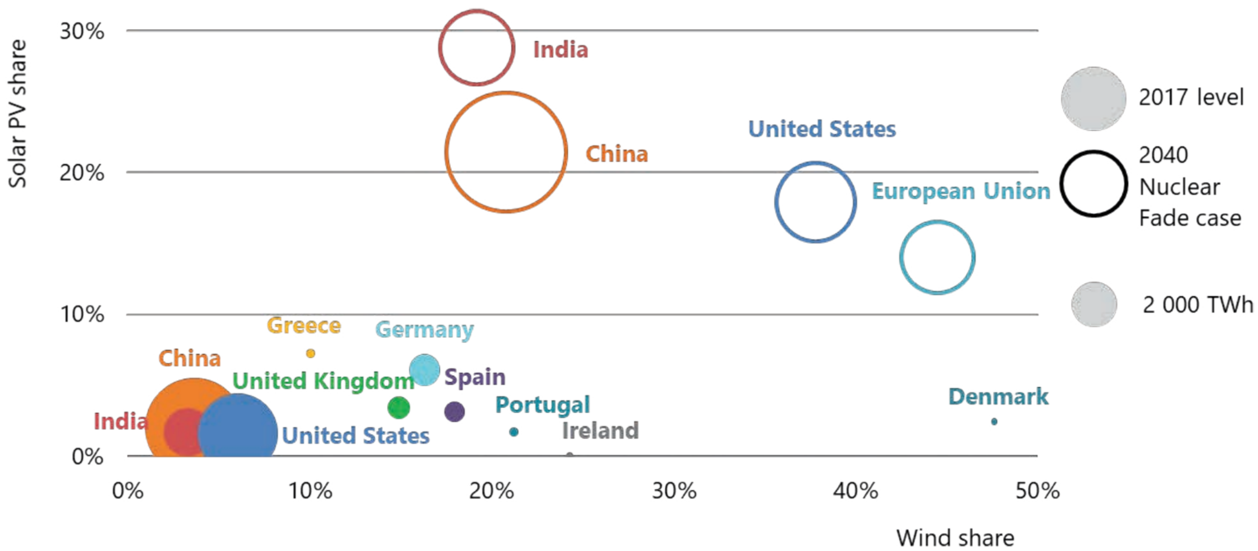
What happens with plans to build new nuclear plants will significantly affect the chances of achieving clean energy transitions. Preventing premature decommissioning and enabling longer extensions would reduce the need to ramp up renewables. But without new construction, nuclear power can only provide temporary support for the shift to cleaner energy systems.

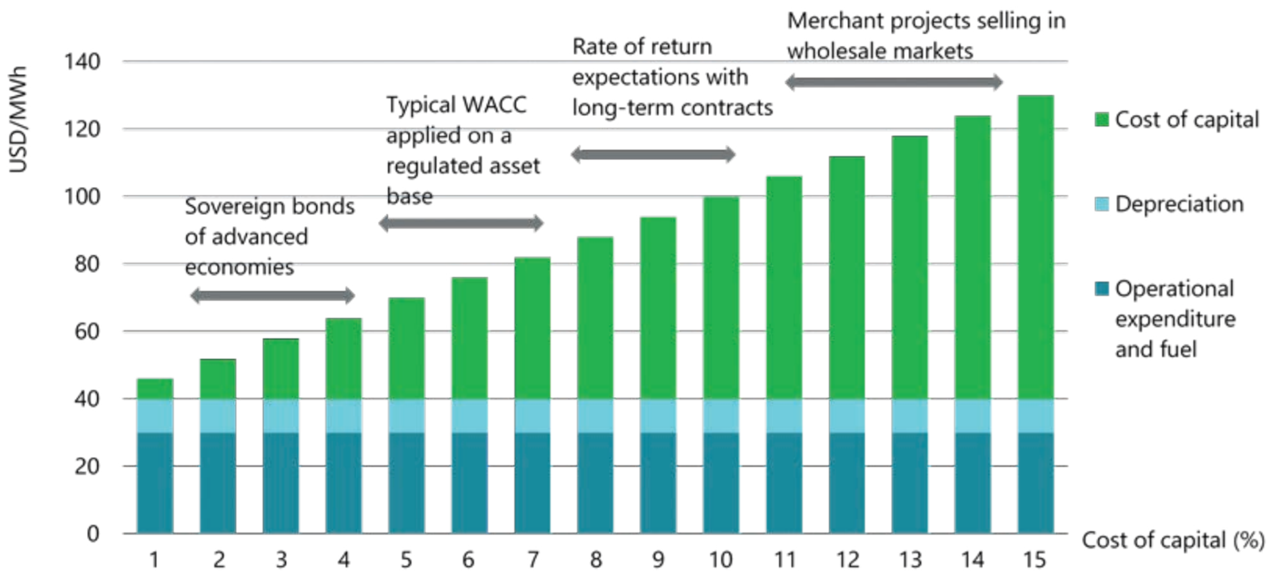
The biggest barrier to new nuclear construction is mobilising investment. Plans to build new nuclear plants face concerns about competitiveness with other power generation technologies and the very large size of nuclear projects that require billions of dollars in upfront investment. Those doubts are especially strong in countries that have introduced competitive wholesale markets.

A number of challenges specific to the nature of nuclear power technology may prevent investment from going ahead. The main obstacles relate to the sheer scale of investment and long lead times; the risk of construction problems, delays and cost overruns; and the possibility of future changes in policy or the electricity system itself. There have been long delays in completing advanced reactors that are still being built in Finland, France and the United States. 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 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

A collapse in investment in existing and new nuclear plants in advanced economies would have implications for emissions, costs and energy security. In the case where





no further investments are made in advanced economies to extend the operating lifetime of existing nuclear power plants or to develop new projects, nuclear power capacity in those countries would decline by around two-thirds by 2040. Under the current policy ambitions of governments, while renewable investment would continue to grow, gas and, to a lesser extent, coal would play significant roles in replacing nuclear. This would further increase the importance of gas for countries' electricity security. Cumulative CO_2 emissions would rise by 4 billion tonnes by 2040, adding to the already considerable difficulties of reaching emissions targets. Investment needs would increase by almost USD 340 billion as new power generation capacity and supporting grid infrastructure is built to offset retiring nuclear plants.

Achieving the clean energy transition with less nuclear power is possible but would require an extraordinary effort. Policy makers and regulators would have to find ways to create the conditions to spur the necessary investment in other clean energy technologies. Advanced economies would face a sizeable shortfall of low-carbon electricity. Wind and solar PV would be the main sources called upon to replace nuclear, and their pace of growth would need to accelerate at an unprecedented rate. Over the past 20 years, wind and solar PV capacity has increased by about 580 GW in advanced economies. But in the next 20 years, nearly five times that much would need to be built to offset nuclear's decline.

For wind and solar PV to achieve that growth, various non-market barriers would need to be overcome such as public and social acceptance of the projects themselves and the associated expansion in network infrastructure. Nuclear power, meanwhile, can contribute to easing the technical difficulties of integrating renewables and lowering the cost of transforming the electricity system.

With nuclear power fading away, electricity systems become less flexible. Options to offset this include new gas-fired power plants, increased storage (such as pumped storage, batteries or chemical technologies like hydrogen) and demand-side actions (in which consumers are encouraged to shift or lower their consumption in real time in response to price signals). Increasing interconnection with neighbouring systems would also provide additional flexibility, but its effectiveness diminishes when all systems in a region have very high shares of wind and solar PV.

Offsetting less nuclear power with more renewables would cost more

Taking nuclear out of the equation results in higher electricity prices for consumers. A sharp decline in nuclear in advanced economies would mean a substantial increase in investment needs for other forms of power generation and the electricity network. Around USD 1.6 trillion in additional investment would be required in the electricity sector in advanced economies from 2018 to 2040. Despite recent declines in wind and solar costs, adding new renewable capacity requires considerably more capital investment than extending the lifetimes of existing nuclear reactors. The need to extend the transmission grid to connect new plants and upgrade existing lines to handle the extra power output also increases costs. The additional investment required in advanced economies would not be offset by savings in operational costs, as fuel costs for nuclear power are low, and operation and maintenance make up a minor portion of total electricity supply costs. Without widespread lifetime extensions or new projects, electricity supply costs would be close to USD 80 billion higher per year on average for advanced economies as a whole.

Strong policy support is needed to secure investment in existing and new nuclear plants

Countries that have kept the option of using nuclear power need to reform their policies to ensure competition on a level playing field. They also need to address barriers to investment in lifetime extensions and new capacity. The focus should be on designing electricity markets in a way that values the clean energy and energy security attributes of low-carbon technologies, including nuclear power.

Securing investment in new nuclear plants would require more intrusive policy intervention given the very high cost of projects and unfavourable recent experiences in some countries. Investment policies need to overcome financing barriers through a combination of long-term contracts, price guarantees and direct state investment.

Interest is rising in advanced nuclear technologies that suit private investment such as small modular reactors (SMRs). This technology is still at the development stage. There is a case for governments to promote it through funding for research and development, public-private partnerships for venture capital and early deployment grants. Standardisation of reactor designs would be crucial to benefit from economies of scale in the manufacturing of SMRs.

Continued activity in the operation and development of nuclear technology is required to maintain skills and expertise. 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.

Policy recommendations

The following recommendations are directed at countries that intend to retain the option of nuclear power. The IEA makes no recommendations to countries that have chosen not to use nuclear power in their clean energy transition and respects their choice to do so.

- Keep the option open: Authorise lifetime extensions of existing nuclear plants for as long as safely possible.
- Value dispatchability: Design the electricity market in a way that properly values the system services needed to maintain electricity security, including capacity availability and frequency control services. Make sure that the providers of these services, including nuclear power plants, are compensated in a competitive and non-discriminatory manner.
- 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: Where necessary, update safety regulations in order to ensure the continued safe operation of nuclear plants. Where technically possible, this should include allowing flexible operation of nuclear power plants to supply ancillary services.
- Create an attractive financing framework: Set up risk management and financing frameworks that can help mobilise 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 standardisation and enable learning-by-doing across the industry.
- Support innovative new reactor designs: Accelerate innovation in new reactor designs, such as small modular reactors (SMRs), 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.

Bibliography

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