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Nuclear power generation and the urgency of fighting climate change

With the fight against climate change becoming more urgent than ever, nuclear energy is making a comeback in the discussions around the energy transition. The recent energy price crisis driven by fossil fuels and natural gas (sometimes also considered a necessary transition fuel) is also providing additional arguments in favour of nuclear.Although nuclear provides a substantial share of power generation capacity in some countries, it only delivers around 10% of the power generation worldwide, or about 4% of total world energy supply.

Nuclear – a carbon free source of energy?

Nuclear power plants provide near-zero carbon electricity. However, the complete nuclear fuel lifecycle requires energy in its mining, fuel preparation, enrichment and fuel post-treatment phases, representing around 10% of the output of the corresponding plants. Hence, if these nuclear power plants are part of a generation mix with CO_2 emissions, their indirect emissions per unit of power produced are about 10% of those of the mix. As an example, in the German mix, which has CO_2 emissions of the order of 200g/kWh, the nuclear plants are responsible for emissions of the order of 20g/kWh for each kWh that they generate. If these plants were in a fully decarbonised mix – consisting of only nuclear and/or renewable energy sources (RES) – their total lifecycle emissions would be close to zero.

An essential baseload for some

Some countries have made the decision to rely on nuclear power generation for baseload, as it can provide a stable supply of energy which can be seen as a benefit to the economy. The best example is probably Japan, which even after the Fukushima disaster, has not changed its position on nuclear energy. It still considers nuclear as a baseload power and aims to keep 20-22% of nuclear generation in the energy mix in 2030. Japan needs at least 30 operational plants to achieve this target. Only seven of the 33 commercial nuclear power plants are currently operating. The restart of more nuclear power generation remains uncertain because other energy sources like LNG are required to maintain a stable supply and achieve the 2050 carbon neutrality target. However, high gas prices could prompt the restart of more reactors, to allow proper economic growth.

Complementarity to the intermittent Renewable Energy Sources (RES)

With more and more intermittent RES (wind and solar), power generation mixes require a clever arrangement of more interconnections, some sort of energy storage and dispatchable power sources. Like gas plants, nuclear is a dispatchable source, which can be brought on and off at will. However, by design and because of their size, nuclear power plants are much better suited to baseload duties and are not an obvious solution to back up the intermittency of RES. Gas power plants are intrinsically much better suited for this.

In the current EU electricity market design, nuclear exhibits very low operating expenses (OPEX), lower than gas options. With substantial capital expenditures (CAPEX) and very low OPEX, nuclear appears as a direct competitor to wind and solar rather than as a complementary source, at least from the economic point of view in the current market settings, so that more nuclear can certainly be seen as detrimental to the deployment of more RES.

Extending the life of existing nuclear plants

Nuclear power plants are originally designed for a certain lifetime. They usually require major maintenance every 10 years. On the occasion of these major revisions, it is possible to extend their life, from around 30 years, to 40, 50 or even 60 years. The original capital expenditure is of course already fully amortised, even if the major revisions represent a substantial additional cost. Life-extended nuclear power plants, with most of the CAPEX already amortised and low OPEX are able to provide low-cost electricity (below 40€/MWh, when current EU prices are between 100-300€/MWh)[1,2], and therefore have large operating margins, especially with the price set by gas in the current fuel price crisis.

Life extensions of course pose a safety question, as not everything can be changed, maintained or replaced in the existing plant. The vessel containing the reactor core, for instance, cannot be changed, and nuclear radiations make it more brittle year after year.

Cost and construction time of new nuclear

New European Pressurised Reactors (EPRs) are very expensive to build and have very long construction schedules. Only three are currently being installed in the Europe. Flamanville, in France, was initially budgeted at 3.3B€, and is now nearing completion at well above 10B€[3], after 10 years of construction work. Olkiluoto 3 in Finland and Hinkley Point C in the UK have similar trajectories. Such costs are of the order of 5M€ per MW of capacity, when wind and gas are around 1M€/MW and when PV is around 800K€/MW[4,5].

Only Russia and China are currently building significant numbers of new nuclear reactors, apparently at costs which are only a fraction of those experienced in the EU.

There are of course technologies other than the standard EPR. SMRs (Small Modular Reactors) of several types have been around conceptually for a while. They would be more flexible than the large EPRs, but specific costs are likely to be even higher. Even more exotic technologies like fast breeders and thorium reactors could be envisaged but are unlikely to provide the swift answer that the climate emergency requires.

1 https://www.iea.org/reports/projected-costs-of-generating-electricity-2020
2 https://www.statista.com/statistics/1267500/eu-monthly-wholesale-electricity-price-country
3 https://www.montelnews.com/news/1194318/edfs-levy-confirms-flamanville-epr-start-up-in-2023
4 https://www.iea.org/reports/projected-costs-of-generating-electricity-2020
5 https://www.statista.com/statistics/1267500/eu-monthly-wholesale-electricity-price-country

The trouble with nuclear

It is worth remembering why nuclear is sometimes so unpopular, and why several countries like Germany have decided to phase it out.

Safety is a major issue. The accidents of Chernobyl and Fukushima are in everyone's memory. Chernobyl was of course not the EPR technology, and Fukushima was the result of a tsunami, but the fact remains that even if a nuclear accident has a very low probability (of the order of 1 major accident per million years per reactor, so 1 major accident per 1000 years with 1000 reactors), such major accidents have devastating consequences.

Waste is another problem. Every nuclear reactor generates nuclear waste, a fraction of which has a very long life (several thousands and even million years). This waste was originally dumped at sea, but this was prohibited in 1994. In the absence of a long-term solution (deep underground storage prevails), nuclear waste is currently stored in temporary storage places all around the world. New types of nuclear reactors could of course produce less waste than present technologies. Research is also looking at ways to improve the recycling of nuclear material (such as in mixed oxide fuels), and at ways to treat waste, including the possibility of transmutation.

Accidents also produce waste material in a wider sense, like the Fukushima disaster which has generated more than one million tons of water used to cool the reactors after the accident. This water, after suitable treatment, will very likely be dispersed in the ocean in the coming years.

Nuclear proliferation is another issue. A multiplication of nuclear facilities and transports (between fuel preparation, power plants, fuel post-treatment, waste storage sites) can only lead to greater risks that nuclear material ends up in the wrong hands.

Conclusions

Nuclear is a power generation technology like no other. It certainly has interesting characteristics in the context of the energy transition required for the fight against climate change, with its very low greenhouse gas emissions. Nuclear is also unrivalled in unpopularity with certain people or communities, and the memory of nuclear accidents remains present in the minds of the masses. The urgency of the fight against climate change is however changing this difficult equilibrium, and nuclear is becoming more ubiquitous in discussions around the energy transition than it has been in the recent past. A lot is at stake and the issue of nuclear deserves a constructive debate about whether or not it can help address the climate crisis.

FTI Consulting facilitates stakeholder dialogues on controversial issues and can help you better understand and navigate this complex landscape.

PIERRE DECHAMPS
Senior Advisor
pierre.dechamps@fticonsulting.com