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The Fall and Rise of European Nuclear Energy

Tamás Orbán

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[ABSTRACT] *Despite being among the most effective energy sources, the share and production of nuclear power have been in decline across the European Union, primarily due to safety and environmental concerns. However, as the need for nuclear energy significantly increased for various reasons over the last decade, a landmark study – which testified to its safety, efficacy and cleanliness – made it possible for the EU to classify nuclear power as a 'green' and sustainable source of energy, and therefore eligible for investment funds. This, in turn, prompted new investments across the bloc with two primary aims: complementing renewables in order to reach climate neutrality by 2050 and help diversify the energy mix of Europe in order to reduce dependence on Russian hydrocarbons. Yet, because of the large number of nuclear power plants already decommissioned in Europe in the past, the current rate of investment in nuclear energy may not be enough to reach the desired goals and results.*

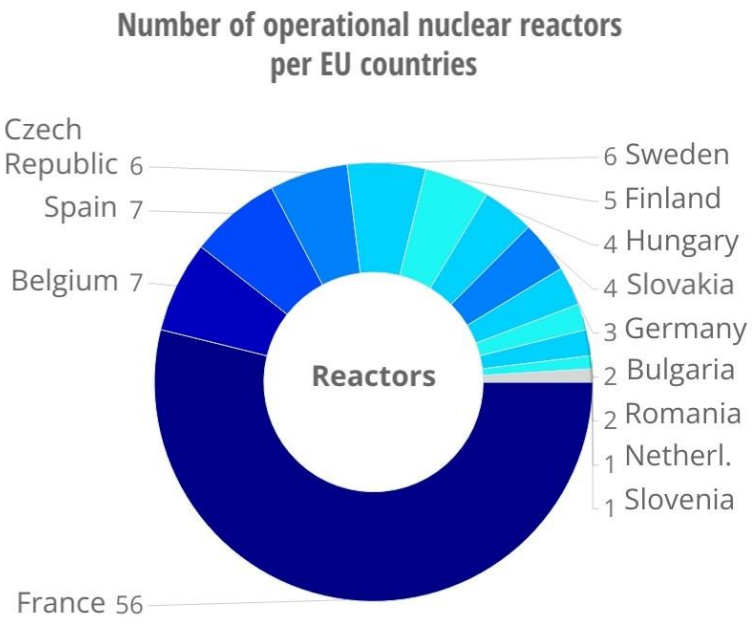
The European energy markets have plunged into chaos since the start of the Russian invasion of Ukraine, and the EU member states now look for alternatives to replace the strategically disadvantageous Russian energy sources. Restructuring the EU's energy mix has long been considered across the continent even before the war in Ukraine, since the bloc aims to achieve climate neutrality by 2050. Nuclear energy is seen as both the ultimate answer as well as the ultimate taboo in relation to these problems, and the debate around it might have cost us valuable time from embarking on the path of green transformation. Because, quite simply, Europe will have no option but to invest in nuclear power if it hopes to achieve its goals.

The current state of European nuclear energy

Before moving on to the future of the European Union's nuclear power in terms of the possibilities presented in regard to energy diversification and as an alternative to Russian hydrocarbons, we need to see first the current share of nuclear energy within the European consumer market, as well as the number, capacity and distribution of the operational reactors. Then, we are ought to look at the political and social atmosphere surrounding the issue of nuclear energy at the moment, which will – undoubtedly – contribute to the extent of how effectively Europe will be able to use nuclear as a means to fill the gap that fossil fuels will inevitably leave behind.

Reactors, capacities and importance of nuclear energy across the EU

As of August 2022, there is a total of 171 operational nuclear power plant units (nuclear reactors) in Europe, with a net electric capacity of 145.1 thousand MWe*. If we take away the non-EU countries within this tally (Russia, Belarus, Ukraine, Switzerland and the UK), we then get 106 working reactors and a capacity of 115.6 thousand MWe across thirteen countries (see the chart).[1]

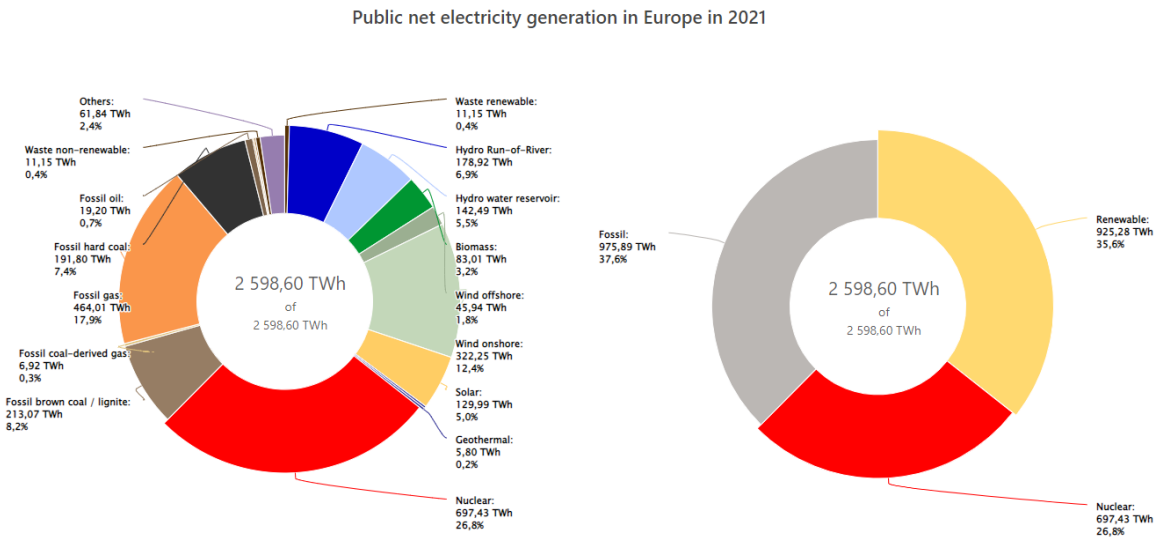


Operational nuclear reactors per EU members.
Source: Tamás Orbán, Data: *ENS*, 2022

In 2021, these reactors' combined gross energy production amounted to 697.4 TWh, or 26.8% of the EU's total energy output. This makes nuclear energy the largest individual component

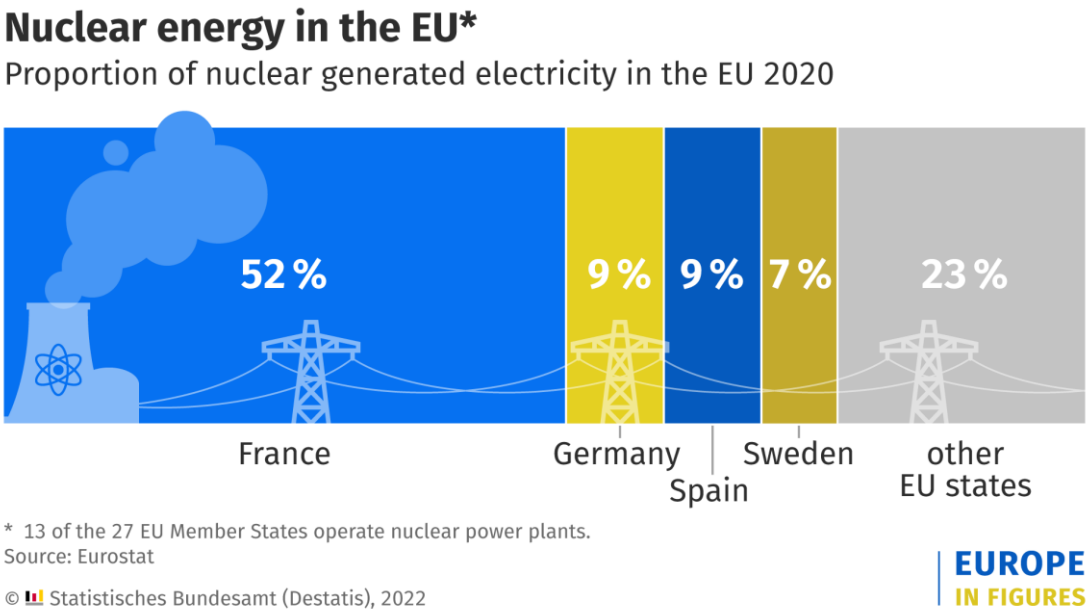
* MWe – Megawatts electric, the net electricity output capability of an electric plant, as opposed to MWt (Megawatts thermal), the input energy required for generating electricity.

of the EU's total energy production, followed by gas (17.9%) and onshore wind turbines (12.4%).[2]



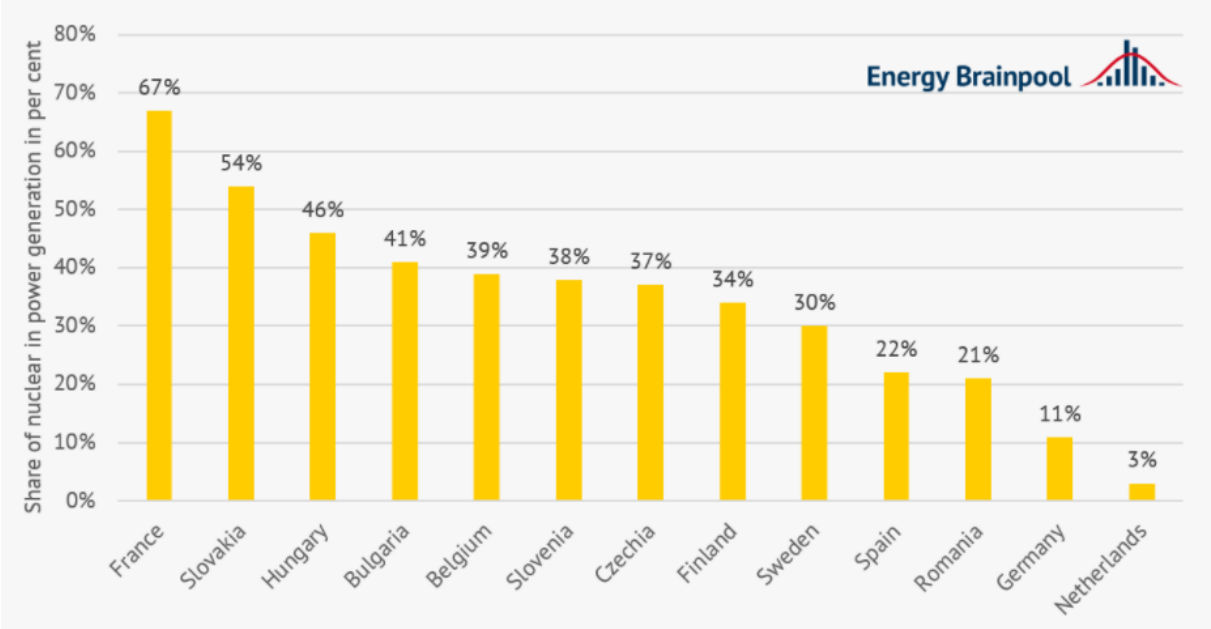
Electricity generation in the EU in 2021, in individual (left) and cumulative (right) break-up.
Source: *Energy-Charts*, 2022[3]

By far, the biggest producer of nuclear energy is France (with its 56 working reactors), generating 51.8% of all the EU's nuclear energy production in 2020 (based on the latest available *Eurostat* database), followed by Germany (9.4%), Spain (8.5%) and Sweden (7.2%) and nine other member states (23.1%).[4]



Share of nuclear energy generated by each EU member. Source: *Destatis*, 2022[5]

However, because the more developed a country, the bigger its energy consumption is, the most relevant data is the EU members' share of nuclear energy production relative to their total energy output. In this regard, France is still at the top (67%), but is followed by Slovakia (54%), Hungary (46%) and Bulgaria (41%) with similarly high numbers.[6]



Share of electricity generation from nuclear power per EU countries. Source: *Göss*, 2022[7]

Green or not: political debates and their consequences

While these charts show that nuclear power bears significant importance within the European energy infrastructures, a tendency for negative growth can also be observed in some EU member states due to political debates around nuclear energy and its impact on the environment.

The political debate around nuclear energy is almost as old as the technology itself. Ever since commercial nuclear plants became widespread in Europe during the late 1960s and early 1970s, the question of nuclear waste management took an increasingly central role in shaping nuclear energy policy. Then, public opposition to nuclear power gained even greater momentum after the accident at the US' Three Mile Island plant in 1979, which caused a number of states to halt or reconsider their ambitious construction programmes aimed at significantly upgrading their existing nuclear infrastructure. Later, due to the loud social response to the 1986 Chernobyl disaster, some of the biggest nuclear power producers

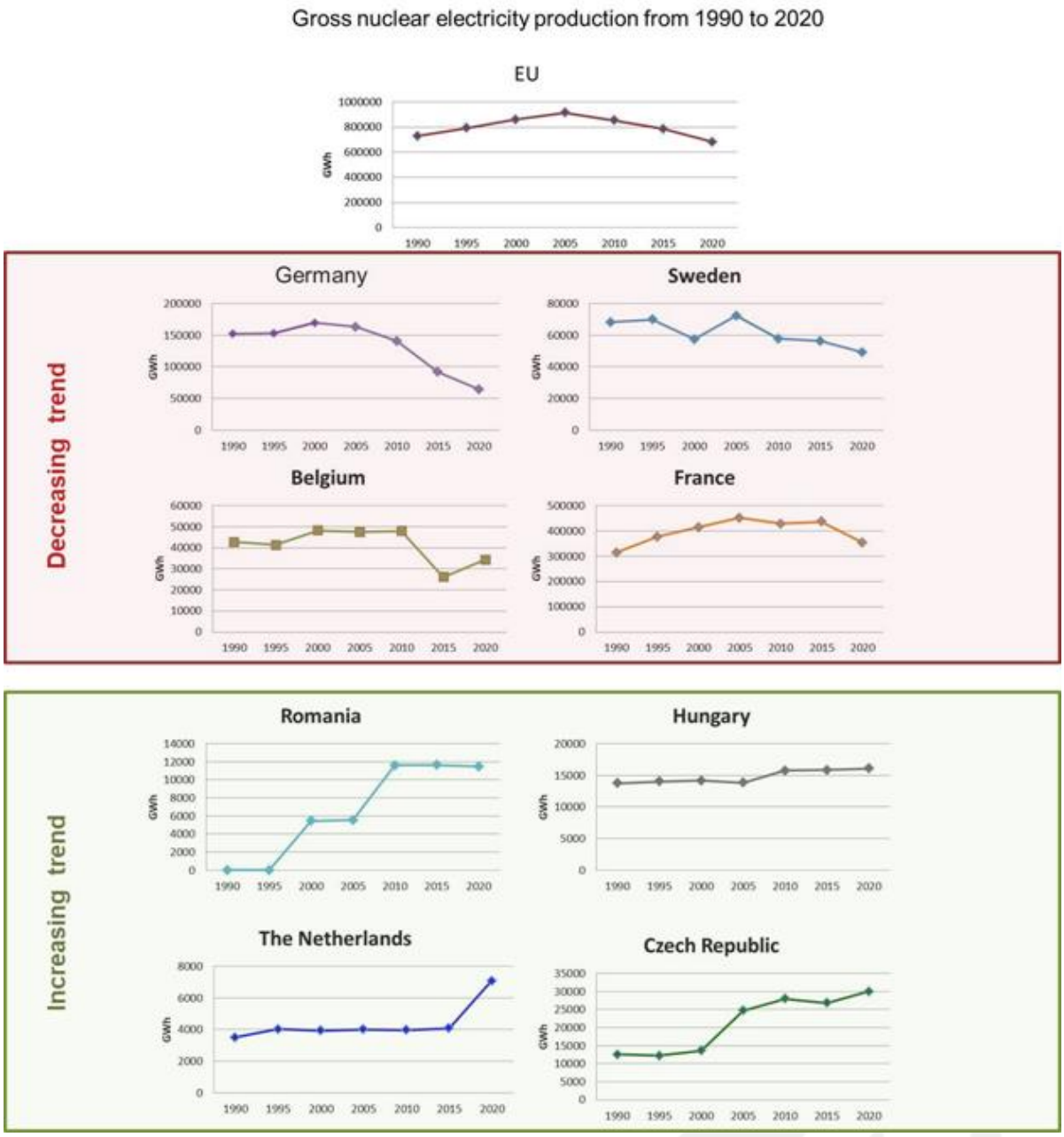
(including Germany and Italy) decided to gradually phase out nuclear from their power mix, and recommitting to this decision after the 2011 disaster at Japan's Fukushima power plant.[8]

These trends, however, do not reflect on a general consensus of the EU member states, as the different countries have largely different views on nuclear power. France, for instance, had built an entire image around being Europe's nuclear powerhouse and put atomic energy at the front and centre of its energy mix. Others, such as most Central European countries have viewed nuclear in a generally positive light, but still have serious public policy debates about it periodically. Some countries, such as Germany, Spain and Switzerland, have changed their outlook on nuclear energy because of these public policy debates, and are currently in the midst of phasing out nuclear entirely. Ten EU countries, including Austria, Denmark, Italy and Norway, have not only completed their phase-out programmes but remain committed to not producing nuclear energy in the future, while some – due to climate concerns and energy independence – are now planning to reverse this process and reopen or replace their decommissioned power plants, such as in Belgium, Greece or Lithuania.

In fact, between during 2020-21, as the European Union prepared its new energy taxonomy regulation (more on that later), two distinct groups emerged, defining the two sides of the debate. On one hand, there are the countries which have been dubbed the 'anti-nuclear alliance' (Austria, Denmark, Germany, Luxembourg and Portugal), while on the other hand there is the 'pro-nuclear alliance', initially comprised of ten countries (Bulgaria, Croatia, Finland, France, Hungary, Poland, Romania, Slovakia, Slovenia and the Czech Republic) and then also joined by the Netherlands and Sweden.[9] Note that among those advocating for the use of nuclear power there is also Poland, a country without a single reactor, demonstrating that nuclear power – as a political issue – is no longer a matter of individual interests at the level of member states, but has serious implications on the future of the entire bloc.

Nonetheless, if all countries are examined together, the overall European trend in nuclear power production has turned negative for almost two decades now. Nuclear electricity production within the EU27 reached its peak in 2004, and it has decreased by 25.2% by 2020. The greatest drops in production was registered by Germany (-61.5%), Sweden (-26.5%) and Belgium (-26.2%), while the greatest increase in nuclear energy production had been observed

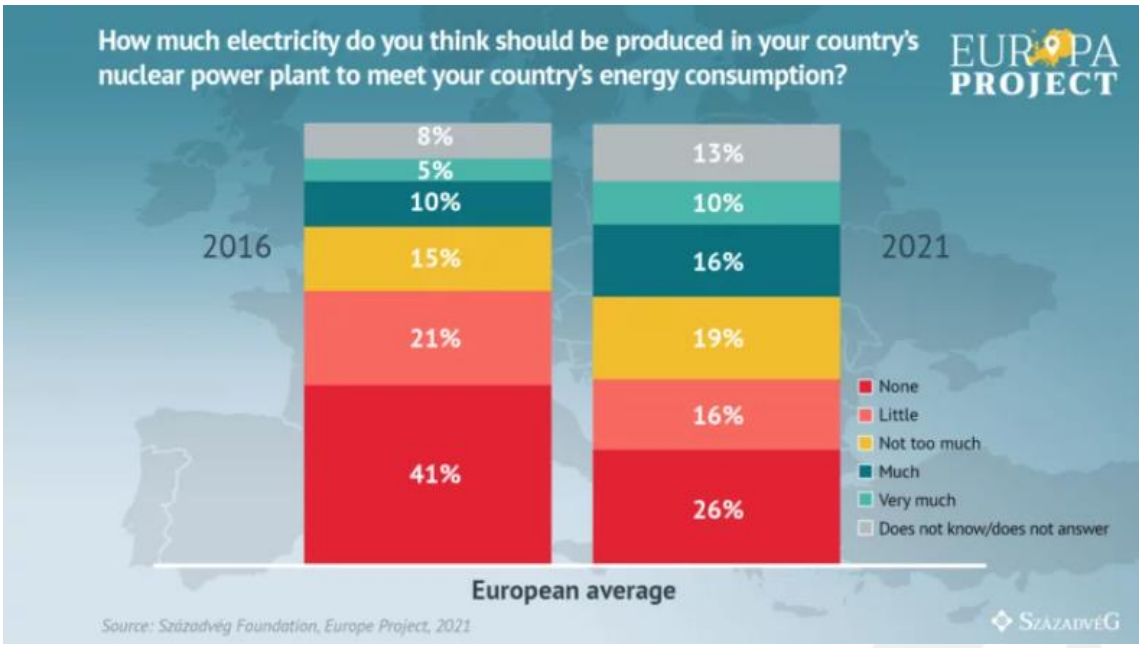
in Romania (more than doubling its output), Hungary (19.3%), the Netherlands (17.8%) and the Czech Republic (15.3%).[10]

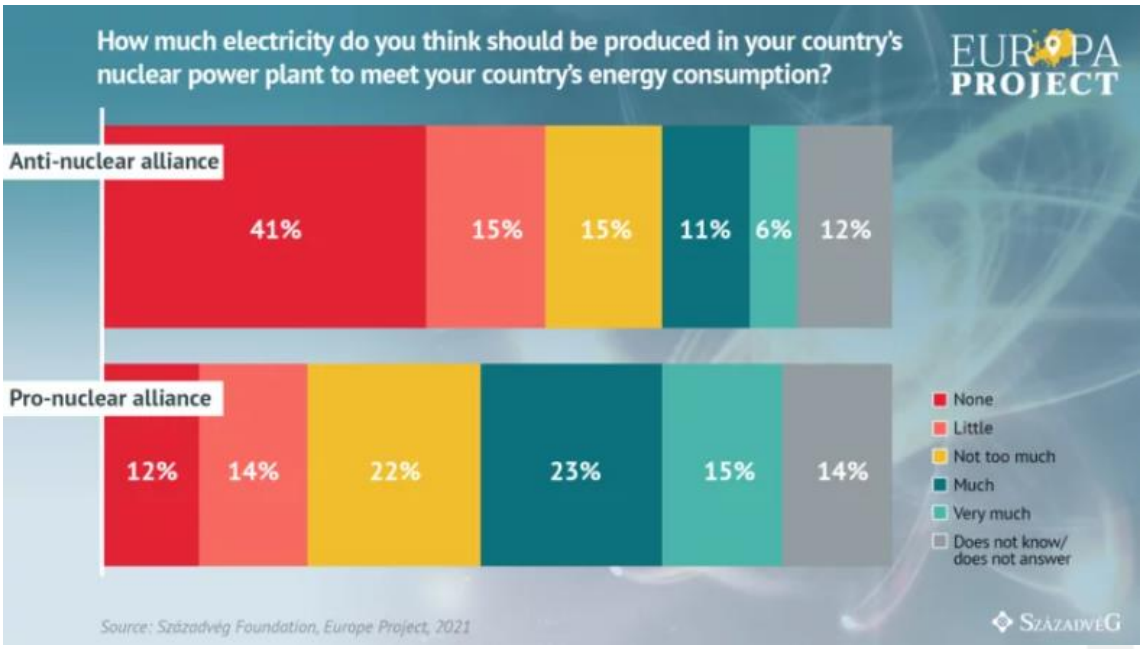


Changes in nuclear energy production across Europe, 1990-2020. Source: Pilloni, 2022[11]

As of May, 2022, there is a total of 200 nuclear reactors in permanent shutdown globally, 72 of which (more than 35%) are in the European Union. The EU member state with the most decommissioned nuclear reactors is by far Germany (30), followed by France (14) and Sweden (7).[12]

Yet, despite this trend of decreasing electricity production from nuclear sources across Europe, the public opinion on nuclear energy may change significantly in view of the energy crisis caused by the Russian invasion of Ukraine, as well as concerns over not reaching the climate targets in time. Even before the war, public support for nuclear energy has grown significantly over the last five years across the EU, going from 15% in 2016 to 26% by 2021, while rejection of the energy source in the same period decreased from 62% to just 42%. If the countries of the 'anti-nuclear' and 'pro-nuclear' alliances (mentioned above) are measured separately, their division even at the level of public opinion becomes apparent. 56% of the citizens of the anti-nuclear countries somewhat or strongly reject the use of nuclear power, while only 26% of those who live in the pro-nuclear countries do.[13]





European public opinion on the use of nuclear energy. Source: *Századvég*, 2021[14]

Future prospects of European nuclear energy

Nuclear as the means of building a climate-friendly future

Based on the findings of the 2014 'Synthesis Report' of the *Intergovernmental Panel on Climate Change* (IPCC), at least 80% of the world's electricity production must be low-carbon by 2050 for the planet to stand a realistic chance of keeping global warming within the desired 2 °C change compared to pre-industrial levels.[15] In 2019, 63% of the world's total electricity production was still generated from the burning of fossil fuels, which prompted many countries, including the whole European Union, to look for sustainable alternatives to replace high-carbon emitters in their energy mix as soon as possible.

In July 2021, the European Commission's *Joint Research Centre* (JRC) concluded its scientific report on sustainable, low-carbon alternatives to fossil fuels which can help the bloc reach net-zero emission levels by 2050.[16] The report found that nuclear power was, in fact, eligible for the 'green' investment label, and for several reasons. Nuclear power is not only green in terms of its carbon footprint but also safe, economically feasible and environmentally friendly. Nuclear power's CO^2 emission levels are among the lowest of all forms of electricity generation, most similar to onshore wind power. Regardless of the Chernobyl and Fukushima accidents, nuclear power is deemed an 'exceptionally safe' way to produce electricity, and

'has by far the lowest number of direct fatalities of any major energy source.' Since most of the costs associated with nuclear power are construction (and not management) fees, and nuclear plants usually operate for decades (up to 80 years), nuclear is also one of the most cost-competitive forms of low-carbon energy production. The most commonly debated question of nuclear waste can be solved easily: nuclear power plants produce one of the least amounts of waste and most of it is not highly radioactive. No harmful spill radioactive waste was recorded in history and – as technology advances – modern repositories are likely to prevent any from happening in the future. Finally, nuclear has lower environmental footprint than most renewables – such as solar parks or onshore wind – since they take up far less space and do not disturb the wildlife, while similarly to them, not releasing any air pollutants.[17]

Recognising these apparent advantages of nuclear power, the EU initiated a lengthy debate on whether it should include nuclear power in its sustainable energy investment framework, starting in January 2023. Even though the most vocal opponents of this move, Austria and Luxembourg even threatened to take the European Commission to court over it, the 'pro-nuclear alliance' (with the Visegrad Group in its centre) eventually won, and the European Commission finalised the inclusion of nuclear, as an environmentally friendly alternative, into the new taxonomy by June 2022.[18] Although – due to the environmental concerns – the EC's decision was ready by December 2021, the outbreak of the war in Ukraine two months later (as well as the widening energy crisis associated with it) significantly helped sway the MEPs into adopting a more pro-nuclear position. The new taxonomy plan was challenged immediately and made subject of a parliamentary vote on in July 2022, but the MEPs continued to back the inclusion of nuclear by a majority of 328 against the 278 who voted against it.[19] The new sustainable taxonomy plan will therefore enter into effect on January 1, 2023.

Those who are against the notion of increasing the share of nuclear power in the European energy mix are not only concerned about the nuclear waste or potential safety issues leading to Chernobyl-like catastrophes in the future, but they also fear that it will weaken the development of renewable energy infrastructures, such as wind and solar energy. Therefore, the question arises: which type of energy provides the most optimal route for reaching our climate goals by 2050? The answer is neither, or both. Empirical research has shown that neither nuclear nor renewables can be developed quickly enough to complete the transition

in time, and while both have their advantages, both have considerable disadvantages too. The construction of nuclear power plants takes significantly longer than wind or solar parks, for instance, but on the other hand, renewables have higher maintenance costs per kWh and contribute much more to environmentally harmful practices – affecting the wildlife by taking up too much land area, or requiring many scarce elements, such as lithium, to be mined extensively. [20] For instance, one nuclear reactor generates as much electricity as close to a thousand regular wind turbines or ten million solar panels while needing only a fraction of the construction materials renewables do.[21] Nonetheless, we can anticipate that technological advancement will make both categories even more sustainable in the future, but for now, Europe needs both of them in order to stand a chance of reaching its net-zero carbon emission goals in time.

If we take the 2050 deadline out of the equation (and assume that renewable technology will advance in parity with nuclear technology), then replacing all fossil fuels with nuclear in the long-term would, in fact, be the most optimal course, since nuclear power produces the cheapest, safest and most environmentally friendly carbon-alternative energy in the world.[22]

Nuclear as an alternative in the post-Russian energy era

The Russian invasion of Ukraine left Europe searching for quick alternatives to Russian hydrocarbons as a means of reducing its energy dependence on Moscow. In 2020, more than 29% of the European Union's imported crude oil came from Russia, while the share of Russian gas surpassed 40%.[23] The dependence on Russian energy varies among the member states; for some, it's merely marginal, but for others, Russian hydrocarbons take up the majority of their energy mix. For instance, Latvia, Austria, Bulgaria and Finland are heavily dependent on Russian gas (with 75-92% of their supplies coming from Russia),[24] while the most dependent on Russian oil are Slovakia, Lithuania, Poland and Finland, by 67-78%.[25] The current geopolitical situation proved that Russia is willing to take advantage of these high numbers when it comes to applying pressure on the EU, therefore one of the primary objectives of the European energy policies going forward is to replace all Russian hydrocarbons as soon as possible. But can nuclear energy play a role here?

Both natural gas and oil are highly difficult to replace with electricity since we would need comprehensive infrastructure updates in both cases. Fortunately, natural gas has also been

added to the new EU taxonomy as a 'transitional' energy source, which means members can freely invest in and develop their infrastructure without needing to replace it entirely. By increasing domestic production, finding new suppliers and issuing some practical adjustments, the economist think tank Bruegel estimated that up to 190 billion cubic meters (bcm) of alternative gas might be available for the EU, which could – theoretically – replace all the Russian gas, which last year stood at only 155 bcm.[26]

With oil, the question is more complicated. According to the *International Energy Agency* (IEA), the European Union's crude oil imports from Russia stood at 2.2 million barrels per day (bpd) in 2021, as well as 1.2 million bpd of refined oil products.[27] The costs of replacing all oil and petroleum-based technology with electricity overnight would be simply too high to be considered feasible. Instead, the European Union plans to gradually phase out oil consumption by the 2050s by incentivising electric car manufacturing and buying alike, as well as investing in charging infrastructures.[28] This is where nuclear power can play a crucial part, along with renewables such as wind, solar and geothermal energy. Now, the most optimal course – and the one likely to happen – will be diversifying the EU's oil supplies by switching to other producers until the bloc no longer has to import from Russia, and starting the gradual phase-out afterwards.

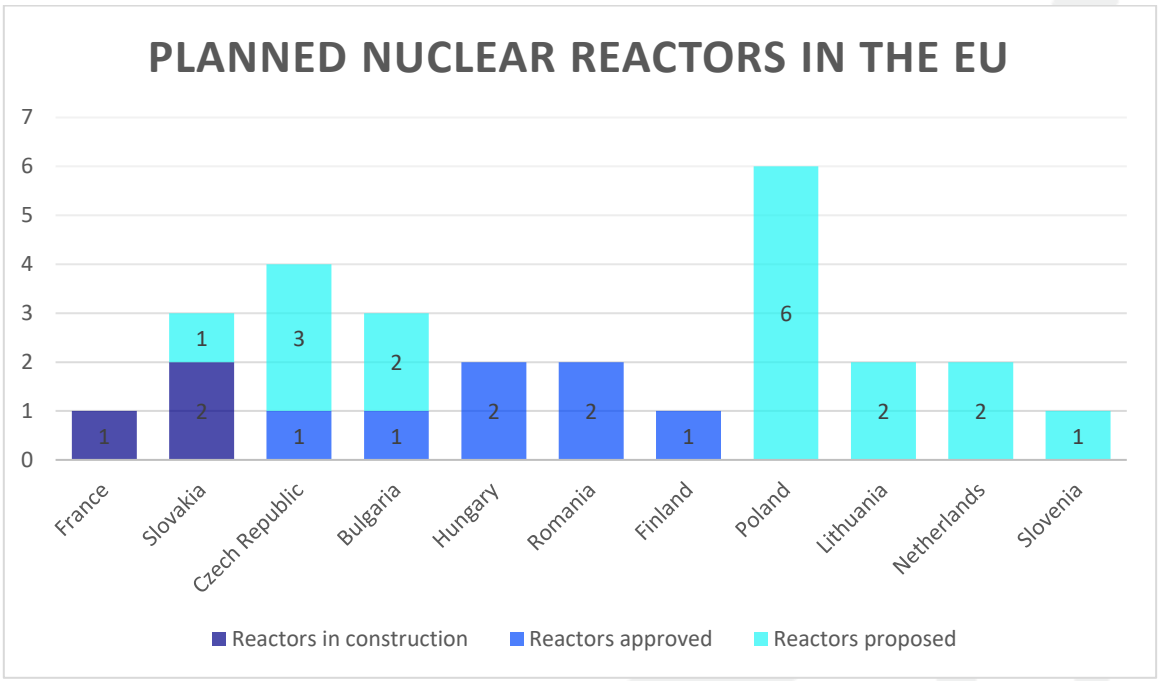
Switching to nuclear or renewables will not solve Europe's dependency problem in the short run, since the Russian hydrocarbons cannot be instantly replaced by electricity. The question here, therefore, is basically the same as in regards to the climate policy goals: which energy source has the most balanced offer of a quick enough yet affordable replacement of all fossil fuels in the long run?

Plans for the future: how quickly can Europe rebuild its nuclear fleet?

The European Commission's long-term strategy for achieving climate-neutrality by 2050, published under the title 'A Clean Planet for All', estimated that by the end of the period, *"the share of the electricity in final energy demand will at least double […] and electricity production will increase substantially to achieve net-zero greenhouse gas emissions, up to 2.5 times of today's levels […]"*.[29] This means that in order to keep up with the growing demand as well as the decarbonisation goals, Europe will require an estimated 250% increase in electricity

production. The paper also envisioned that in the most optimal scenario, 80% of this electricity production will be achieved by renewable sources, and nuclear will account for around 15%.[30]

The EU's latest move to classify nuclear as green energy – and as such, make it qualified for sustainable investment funds – was much needed even only for keeping the generational capacity of nuclear plants at the current level. The average age of the EU's nuclear fleet currently exceeds 30 years, which means that without an estimated €45-50 billion investment – which can be used to extend the existing reactors' lifetime – most will have to be shut down in the early 2030s. Furthermore, in order to keep nuclear power as the most important complementary source of power to renewables even beyond 2050 at the desired minimum of 15%, the European Union will need to invest at least €500 billion in constructing new generation power plants across the bloc. Eleven member states are already in the midst of or at least seriously considering the construction of new plants for over €400 billion, but another one hundred billion would be needed to be approved by 2045 for the decarbonisation to remain on track.[31]



Planned nuclear reactors in the EU, per country (as of September 2022).

Source: Tamás Orbán, data source: *WNA*, 2022[32]

In the European Union, there are currently three reactors under construction, seven have been approved and awaiting construction, while another 17 have been proposed. Among the

countries investing in nuclear energy now, two member states – Poland and Lithuania – did not have any nuclear reactors before. The Polish nuclear project is set to be the largest in the coming years, with the construction of six large-scale nuclear reactors by 2040, which would help the country reset its heavily coal-dependent energy sector. Warsaw received offers for the construction from French, South Korean and US-based firms, and the latter will likely come out as the winner of the bidding race.[33] If all of these 27 reactors across the EU will be completed over the course of the next decades (and no further reactors will be decommissioned), the number of operational nuclear reactors will increase to 133. In order to achieve carbon neutrality by 2050, therefore, the bloc will need a minimum of 6-10 additional nuclear reactors, and possibly even more, depending on how quickly renewable power sources (such as solar parks and wind turbines) are being installed.

Furthermore, while renewable power is cheaper to generate (thus seems more appealing in the long term), it's also less efficient than nuclear, which means that way more renewable plants would have to be built to achieve the same effect. When adding the cost of installation and maintenance to the lifetime cost of electricity generation of each type (with the goal of reducing CO_2 emissions), the cost of mitigating CO_2 by 1% is $3.04 in the case of nuclear power, while the average cost for mitigating the same 1% in the case of renewables becomes $7.09.[34] From this, we can stipulate, that as the energy crisis becomes more severe, countries of Europe will increasingly turn towards nuclear energy, some not only as a complementary source to renewables as the European Commission suggested, but by following the French example and treating it as the primary source of energy. Even Germany, the country that has been the keenest on following through with its decommissioning plans, has announced that it will keep its last two reactors as 'back-up' power sources.[35]

There are many variables that could influence the final energy mix of 2050, however, we can predict that nuclear power will play a bigger role in it than planned some years ago. While Europe is undoubtedly experiencing a new 'nuclear rush' in face of the energy crisis – while wanting to reach a climate-neutral energy mix and end Russian dependency in the same time – the question is whether we still have time to build enough reactors to achieve these goals. The 27 reactors planned to be built in the following years seem promising, but compared to the 72 that have been decommissioned in Europe (a majority due to political, ideological, and baseless environmental reasons), it feels like Europe will have to pay severely for the mistakes

of the past. Nonetheless, investing in nuclear power will predictably get greater importance in the coming decades.

Conclusions

Nuclear energy plays a vital role in the current energy mix of the European Union and provides roughly one-third of all electricity generated within the bloc. However, the EU's nuclear energy sector has been declining since the mid-2000s, mostly due to ideological and political reasons. The political debate surrounding nuclear energy (based on environmental and safety concerns), as well as the widespread lobby for (the questionably) greener renewable energy sources have set back the development of the entire field by decades, leaving a gap that is going to prove hard to fill.

The political perception as well as the public image of nuclear power has been slowly changing over the last decade, simultaneously with the solidifying concerns for climate change. The European Union has set the goal of becoming carbon neutral by 2050, but it became apparent that by relying solely on renewables it won't be able to reach it. Therefore, the European Commission's decision to include nuclear power as a source of sustainable and green energy – backed by a study that concluded its safety, environmental friendliness and outstanding efficacy – represents an important turning point for the whole bloc in adopting a more feasible approach to reaching the desired climate targets.

The energy crisis that ensued after the Russian invasion prompted lawmakers in Europe to even strongly consider recommitting to nuclear energy and announcing new investments to construct additional nuclear reactors in the coming decades – not only in order to reach climate goals but also as a means of diversifying their energy mix and therefore reduce their dependency on Russian hydrocarbons. However, due to the large number of power plants decommissioned in the past, the current plans for new reactors are not even enough to ensure that nuclear power will produce the minimal requirement (of 15% of the energy mix) in 2050, therefore even more power plants will be needed to construct as soon as possible.

The role of nuclear energy in Europe will inevitably increase substantially in the coming years and decades, but – as a consequence of the decades-long anti-nuclear policy-making across Europe – the speed of the development may not be great enough to produce the desired results. Only with enough funds and political will can Europe's nuclear capacity be properly rebuilt.

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