No 378 | JANUARY 2023

SEE ENERGY BRIEF

Monthly Analysis

The Role of Nuclear Energy in Reaching Net Zero Targets – The Case of Europe and SE Europe

Introduction

Russia's invasion of Ukraine and the disruptions in global energy supplies that it has fuelled have made governments rethink their energy security strategies, putting a stronger focus on developing more diverse and domestically based supplies. For several governments, nuclear energy is among the options for achieving this. At the same time, many governments have in recent years stepped up their ambitions and commitments to reach net zero emissions. Exploring in depth nuclear power's potential role as a source of low or even zero emissions electricity that is available as base load, to enable increasingly greater inflows to the grid from renewables, such as wind and solar, is now under consideration in many countries around the world, including SE Europe.

In view of finding solutions for achieving the EU's decarbonisation goals, the European Commission launched an in-depth assessment in 2020 on the possible inclusion of nuclear energy, along the natural gas, in the EU taxonomy of environmentally sustainable activities. Following the assessment, the Commission prepared a draft text of a Complementary Climate Delegated Act, which includes specific nuclear and gas activities in the list of economic activities covered by the EU taxonomy. The draft text was formally adopted by the Commission in March 2022. As neither the European Parliament nor the Council objected to the text, the Commission Delegated Regulation (EU) 2022/1214 was published in the Official Journal in July 2022 and is in force from January 1, 2023. **(1)**

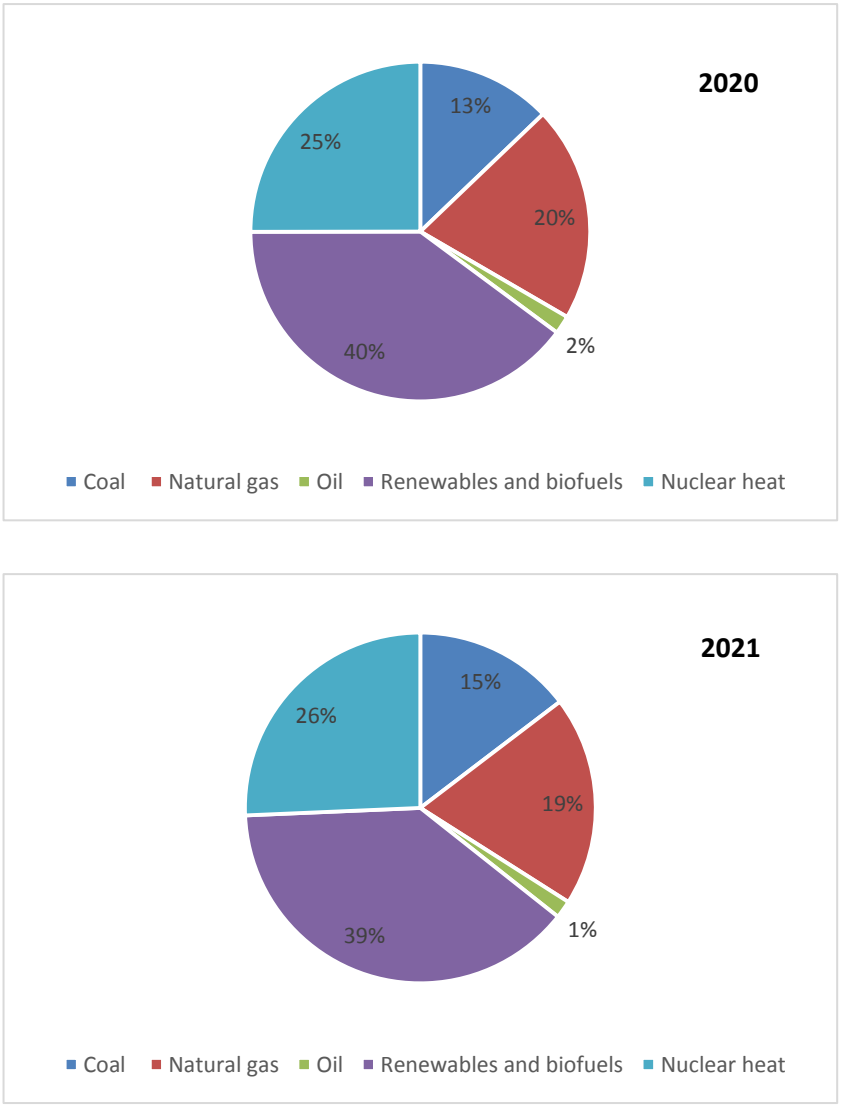
Of course, there are difficulties concerning nuclear investment, particularly in advanced economies, in the areas of cost, performance, safety and waste management. For countries where nuclear power is considered an acceptable part of the future energy mix, there should be policy, regulatory and market changes that could be implemented in order to create new investment opportunities. Also, new technologies, particularly small modular reactors, can play an important role in changing social perceptions and financial evaluations and their future deployment should be taken into serious consideration.

Nuclear Energy in Europe

The production of nuclear heat is obtained from the fission of nuclear fuels in nuclear reactors. This heat is subsequently transformed into steam and is used for the production of electricity. The remaining heat (about 2/3 of the total) is mainly lost, except for a very small part which is used for agriculture and urban heating. The total production of nuclear heat in the EU in 2021 was 186,663 thousand tonnes of oil equivalent (toe), a drop of 10.4% compared to 2012 and an increase of 6.6% compared to 2020. **(2)**

Nuclear heat is mostly used for the production of electricity. The gross electricity generation from nuclear plants within the EU in 2021 amounted to 731,701 GWh, which represents a 7.0% increase compared with 2020. Over the period 1990 to 2021, two different trends can be distinguished. From 1990 to 2004, the total amount of electricity produced in nuclear facilities in the EU rose by 26.9%, reaching a peak of 928,438 GWh in 2004, due to an increase in the number of reactors in operation. Between 2004 and 2006, the total production of nuclear power in the EU stabilised, before declining by 20.0% between 2006 and 2021, mainly due to a sharp drop of around 58.7% in nuclear production in Germany.

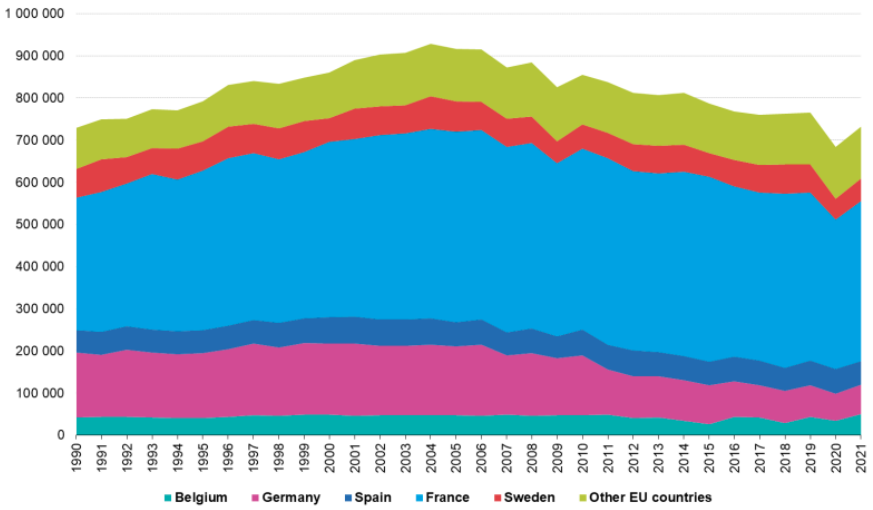
Figure 1: Gross Electricity Production by Energy Source in EU-27, 2020 and 2021



Source: Eurostat

The largest producer by far of nuclear power within the EU in 2021 was France, with a 51.8% share of the EU total, followed by Germany (9.4%), Spain (7.7%), Sweden (7.2%) and Belgium (6.9%). These five Member States produced 83.1% of the total amount of electricity generated in nuclear facilities in the EU in 2021, as shown in Figure 2.

Figure 2: Gross Nuclear Electricity Production (GWh) in EU-27, 1990-2021



Source: Eurostat

Contrary to the EU trend, seven countries increased their nuclear electricity production between 2006 and 2021. Romania, whose nuclear power production began only in 1996 (+100.4%), Hungary (+18.8%), Czech Republic (+18.0%), the Netherlands (+10.4%), Belgium (+7.9%), Finland (+3.0%) and Slovenia (+2.9%). During the same period, the remaining countries (including the main producers) decreased their nuclear electricity production. Lithuania definitively shut down its nuclear facilities in 2009. Germany recorded the highest decrease (-58.7%), followed by Sweden (-20.9%), France (-15.7%), Bulgaria (-15.4%), Slovakia (-12.7%) and Spain (-5.9%).

In 2021 at EU level, 25.4% of all electricity produced was generated by nuclear power plants. France had the highest share of nuclear in its electricity mix (68.9%), followed by Slovakia (52.4%) and Belgium (50.6%). The Netherlands and Germany were on the other end of the spectrum, with 3.1% and 11.8%, respectively.

Nuclear Energy in SE Europe

In SE Europe, there are five countries (Bulgaria, Hungary, Romania, Slovenia and Croatia) that currently operate nuclear power plants (NPPs), while Turkey, which is expected to build no fewer than 3 NPPs over the next decade, will commission its first NPP at Akkuyu within 2023. More specifically, Bulgaria has two operable nuclear reactors at Kozloduy, with a combined net capacity of 2.0 GWe. In 2021, nuclear energy covered 34.6% of Bulgaria's electricity needs. Hungary has four operable nuclear reactors at Paks, with a combined net capacity of 1.9 GWe, while nuclear energy covered 46.8% of the country's electricity needs in 2021. Similarly, Romania has two operable nuclear reactors at Cernavodă and Slovenia one at Krško, with a combined net capacity of 1.3 GWe and 0.7 GWe respectively, with nuclear energy covering 18.5% and 36.9% of the electricity needs of each country respectively **(3)**. Nuclear power remains a viable option for

growth because it offers important base load capacity and supports the EU's decarbonization policies, as analysed in IENE's "SEE Energy Outlook 2021/2022" study **(4)**.

Over the last 15 years, IENE has closely monitored developments in the region's nuclear power sector. In this context, the Institute has successfully organised two regional conferences. Under the general title "The Nuclear Option for SE Europe: A Critical Appraisal" **(5)**, the first such conference was convened in Sofia on May 19, 2009 and the second one in Bucharest on May 6, 2015. **(6)**

Table 1: Operational Nuclear Power Plants in SE Europe

Country	Name	Type of reactor	Capacity (MWe)	Operation since
Bulgaria	Kozloduy 5	PWR	1003	1987
	Kozloduy 6	PWR	1003	1991
Hungary	Paks 1	PWR	479	1982
	Paks 2	PWR	477	1984
	Paks 3	PWR	473	1986
	Paks 4	PWR	473	1987
Romania	Cernavoda 1	PHWR	650	1996
	Cernavoda 2	PHWR	650	2007
Slovenia/Croatia	Krsko	PWR	688	1981

Note: Cernavodă NPP in Romania has the only PHWR CANDU reactors operating in Europe.

Source: World Nuclear Association

The zero emissions from operating NPPs contribute most effectively to the region's efforts to curtail GHG emissions. This means that nuclear energy has an important role to play in the SE European energy and electricity mix over the next decades.

Table 2: Nuclear Power Plants (Under Construction, Planned and Proposed) in Turkey

Country	Name	Type of reactor	Capacity (MWe)	Start construction	Planned operation
Turkey	Akkuyu 1	VVER	1200	April 2018	2023
	Akkuyu 2	VVER	1200	April 2020	2024
	Akkuyu 3	VVER	1200	March 2021	2025
	Akkuyu 4	VVER	1200	(2022)	2026
	Sinop 1	ATMEA1	1150	uncertain	-
	Sinop 2	ATMEA1	1150	uncertain	-
	Sinop 3	ATMEA1	1150	uncertain	-
	Sinop 4	ATMEA1	1150	uncertain	-
	Igneada 1-4	AP1000x2, CAP1400x2	2x1250 2x1400	unknown	-

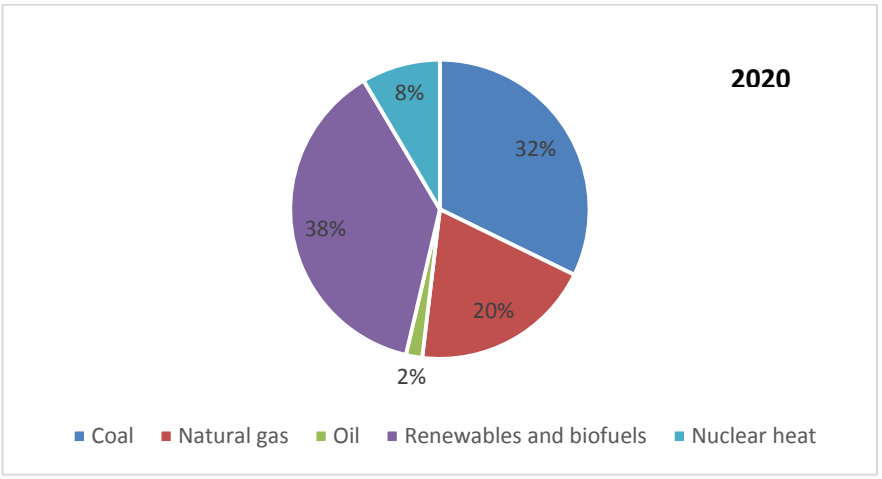
Source: World Nuclear Association

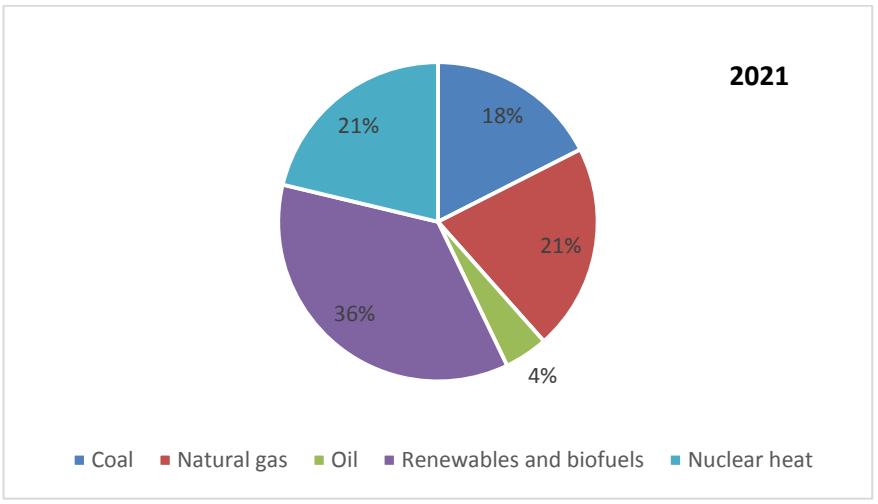
Following the tragic accident at Fukushima's NPP in March 2011 and operational security reviews, which have since been conducted by the SEE countries that host NPPs, the use of nuclear power in the region is unlikely to diminish over the next decade. Neither Bulgaria nor Romania nor Hungary are likely to shut down the Cernavoda, Kozloduy 5-6 and Paks 1, 2, 3, and 4 power plants respectively on account of safety concerns.

The same applies for Croatia and Slovenia, which, between them, share the Krško NPP. Both governments are very well aware of the fact that a decrease in the participation of nuclear power in their electricity generated portfolio cannot be easily replaced by renewables or natural gas.

As shown in Figure 3, nuclear energy has almost tripled its share in the SE European electricity mix between 2020 and 2021. This can be explained by a substantial fall in the shares of coal, natural gas as well as moderate drop in renewables and biofuels in 2021, compared to 2020, taking into consideration that the share of nuclear heat remained at similar levels.

Figure 3: Gross Electricity Production by Energy Source in SE Europe, 2020 and 2021





Source: Eurostat

A New Dawn for Nuclear Energy?

There is little doubt that nuclear energy can help make the energy sector's journey away from unabated fossil fuels faster and more secure. Energy security concerns and the recent surge in energy prices, notably in the wake of Russia's invasion of Ukraine, have highlighted the value of a diverse mix of non-fossil and domestic energy sources.

In the near term, utilising existing nuclear energy infrastructure could help make European countries more energy independent. While new nuclear plants take years to build, about half of EU countries already generate nuclear power. France has the most operable nuclear reactors, followed by Belgium and Spain, while France recently announced plans for the construction of new nuclear reactors **(7)**, Belgium reached recently an agreement on the extension of two nuclear reactors for another ten years **(8)** and Spain wants the European Commission to allow it to set prices for nuclear and hydroelectric power as it seeks to decouple the cost of electricity production from gas and to curb windfall profits **(9)**.

As suggested by the International Energy Agency **(10)**, these countries could boost the power generation of existing reactors relatively quickly, helping to reduce reliance on gas from Russia. Additionally, delaying the closure of five nuclear reactors scheduled to shut down in 2022 and 2023 could reduce the EU's gas demand by nearly 1 billion cubic meters per month.

In addition, nuclear energy is preferable in environmental terms compared to gas. It is a zero-emission clean energy source and the second-largest source of low-carbon electricity globally. It also has a low land footprint, producing more electricity on less land than any other clean energy source. So why has nuclear not been adopted on a larger scale? One reason is the safety fears.

Nuclear energy has long been a controversial topic in Europe because of the Chernobyl and Fukushima disasters. Safety fears remain one of the biggest barriers to the more mainstream adoption of nuclear energy. However, despite high-profile disasters, nuclear has emerged as one of the safest energy sources. An Oxford University analysis **(11)** shows nuclear power results in 99% fewer deaths than coal, oil and gas, carrying almost the same risk as wind power. Potential risks of nuclear energy are still real, but the death toll from nuclear disasters still remains far lower than those who suffer each year from air pollution caused by fossil fuels.

Following the Fukushima disaster in 2011, caused by a tsunami disabling the power supply and cooling of three reactors, Germany sped up plans to shut down all its nuclear plants. Its last three nuclear operators are slated to be closed down later this year, despite calls to reconsider the country's nuclear energy policy. Several analysts argue that given the current energy crisis, such decisions should be revisited. **(12)**

Another roadblock is the large-scale investment needed to build nuclear infrastructure. It has been difficult to attract finance for nuclear plants. However, financing nuclear projects is now easier in Europe since the European Commission has included nuclear energy as a transition activity in its sustainable taxonomy and such decision could pave the way for increased funding for research into nuclear technology and address some of the challenges associated with nuclear energy.

Undoubtedly, greater investment could speed up the development of small modular reactors, which are cheaper and easier to develop and operate than traditional nuclear power plants. Having one-third of the generating capacity of traditional nuclear power reactors, the modular reactors have reduced fuel requirements.

Despite being one of the cleanest and safest sources of energy, nuclear energy is hamstrung by regulation. European governments should consider decreasing red tape for nuclear plant licensing processes. Subsidising nuclear energy and supporting innovative reactor designs will also help make it a viable energy source. Moreover, existing safety concerns should be addressed by educating the public about the safety of nuclear energy and its positive impact on reducing dependence on fossil fuels.

Storage and Disposal of Nuclear Waste

The safe handling, storage and disposal of nuclear fuel are hugely important in the area of nuclear power generation, and include the areas of long-term storage, retrievability and recoverability requirements, and safe decommissioning. Radioactive waste management in the EU has its legal basis through the EURATOM treaty[1] and the adopted "Waste Directive" (2011/70/EURATOM[2]). The Directive provides for Responsible and Safe management of spent fuel and radioactive waste. It builds on a series of internationally accepted principles, in particular that present and future generations shall be protected without imposing undue burdens on future generations. Consequently, the end-point for radioactive waste management is disposal, providing passive and robust safety features. Support to the technical implementation of the nuclear waste directive is provided to Member States and EC stakeholders. Dedicated facilities produce high quality experimental data, aiming at reducing uncertainties associated with safe handling, long-term storage and final disposal in a geologic repository of nuclear waste, and at implementing safe decommissioning.

A remaining key challenge is the long term disposal of high-level waste. The amount and type of such waste depends on the respective national nuclear programme and the type of fuel cycle used. The current two main spent fuel management options are reprocessing and direct disposal in deep geological repositories, or a mixture of both. In addition, decommissioning of nuclear facilities has reached industrial maturity. A challenge is that a large number of nuclear facilities reach the end of their useful life in the coming decades

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A12012A%2FTXT
[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011L0070

and so large amounts of decommissioning waste will arise **(13)**. However, it is worth noting that energy companies usually sign long-term contracts, covering the full management of nuclear cycle, including the fuel use, its storage and disposal.

The Case of Small Modular Reactors (SMR)

The challenge of net zero has stimulated a burst of development in SMR technologies. SMRs, generally defined as advanced nuclear reactors with a capacity of less than 300 MW, have strong political and institutional support, with substantial grants in the United States, and increased support in Canada, the United Kingdom and France. This support makes it possible to attract private investors, bringing new players and new supply chains to the nuclear industry.

Being smaller can help SMRs fit in. Lower capital costs, inherent safety and waste management attributes and reduced project risks may improve social acceptance and attract private investment for research and development, demonstration and deployment. SMRs could also reuse the sites of retired fossil fuel power plants, taking advantage of existing transmission, cooling water and skilled workforces. Other opportunities include co-location with industry to provide electricity, heat and hydrogen.

Policy and regulatory reforms are needed to stimulate investment. The successful long-term deployment of SMRs hinges on strong support from policy makers and regulators to leverage private sector investment. Adapting and streamlining licensing and regulatory frameworks to take SMR attributes into account is key. International harmonisation of licensing and definitions are essential to developing a global market. Securing private financing will require a robust and technology-neutral policy framework, including in the area of taxonomies and environmental, social and governance that will have a growing influence on financial flows.

Decisions are needed now for SMRs to play a meaningful part in energy transitions. While only a small number of units are likely to start operating this decade, with recent momentum SMRs could start playing a significant role in energy transitions in the 2030s, provided that regulatory and investment decisions are made now, and commercial viability is demonstrated. This is true both for small evolutionary reactors that could achieve economic competitiveness more readily, but also for the advanced reactor models.

Discussion

This Monthly Analysis is intended to highlight the rising importance of nuclear energy in the global energy transition debate and to aid analysis of the arguments both for and against the adoption of nuclear energy. Climate change motivations are applicable in nearly all cases, whilst energy security and foreign relationship

motivations are prominent.

In the decades ahead, it can be expected that nuclear energy for electricity generation purposes will remain a significant component of the global energy mix, with countries choosing to continue or begin using nuclear energy for various reasons. The current war in Ukraine will have, and indeed already has had, an effect on how countries view their energy security. This has affected governments' decisions to replace coal, oil and natural gas in their energy mix. As a result, more reliance has been placed on maintaining the current share of nuclear, accelerating the development of renewables, and accessing domestic sources of hydrocarbons, particularly natural gas.

Since Russia's invasion in Ukraine, there has been increasing pressure to rapidly reduce the reliance on Russian gas imports to Europe and maximise the use of nuclear energy. Therefore, it can be expected that attention towards extending the lifetimes of ageing reactors will increase in Europe in the short term and that plans to construct new NPPs will appear as long term solutions to decreasing dependence on Russian imports. At the time of writing, it is too soon to offer expectations beyond this for what exactly the crisis may mean for the role of nuclear energy and for the global energy transition as a whole, but that there will be an effect is indisputable.

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IENE SEE ENERGY BRIEF MONTHLY ANALYSIS - Issue No. 378 – ISSN:179-9163

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Monthly Analysis is published by the INSTITUTE OF ENERGY FOR SOUTH-EAST EUROPE (IENE)

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