

УДК 347.7

DOI <https://doi.org/10.32782/chern.v3.2022.3>

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## THE NUCLEAR ENERGY IN UKRAINE: HOW TO STIMULATE ITS DEVELOPMENT BY LEGISLATIVE MEANS?

The article covers burning questions about the future of nuclear energy in Ukraine. The key aim of the paper is to propose tangible solutions to promote atomic energy, regarded by the author as one of the milestones of a decarbonized future for the Ukrainian power mix. The article examines nuclear energy law as a part of bigger legal, social, and economic context. Therefore, in the current article, we analyze the legislative base for decarbonized energy in general as well as the foundations of Ukrainian, European, and American energy policies. In the article, nuclear power plants are understood more in the sense of classic electricity producers rather than hazardous objects. The critical question is how to promote investments in Ukrainian atomic energy. Thus, the aspects related both to electricity markets and production costs are covered, whereas problems with nuclear safety regulations are not covered. The role of the State Nuclear Regulatory Inspectorate is examined more in the vein of its decision-making impact on energy policies, such as the development of SMRs. Even though there has been enough research on Ukrainian nuclear energy law, there were few papers proposing recommendations on how to holistically the situation. Rather than merely considering the status quo in Ukrainian atomic energy, the article suggests concrete ways to improve it. Even though the legislative means are at the core of the analysis, the article also partly includes economic, political, and technical aspects of the nuclear energy development in Ukraine. Such a decision was made to evaluate and understand more clearly a social-economic context in which proposed legal rules are to take place. Therefore, the research will be helpful for policymakers from governmental bodies in charge of energy policy.

*Key words:* Nuclear power plants, SMR (small modular reactors), electricity market, sustainable investments, electricity exports.

### **Карвацький В. АТОМНА ЕНЕРГЕТИКА В УКРАЇНІ: ЯК ЗАКОНОДАВЧИМИ ЗАСОБАМИ СТИМУЛЮВАТИ РОЗВИТОК?**

У статті досліджуються ключові питання перспектив розвитку атомної енергетики в Україні. Основна мета статті – на основі аналізу нинішнього стану розвитку сформулювати конкретні пропозиції щодо розвитку атомної енергетики, яка розглядається як один із векторів декарбонізації майбутнього для української енергетики. У статті аналізується право атомної енергії як частина загального правового, соціального-економічного контексту. У статті аналізується законодавча основа декарбонізованої енергетики загалом, а також порівнюються засади української, європейської та американської енергетичної політики. Робиться висновок про те, що атомні електростанції визначаються швидше як класичні виробники електроенергії, аніж як небезпечні об'єкти. Ключове питання полягає у тому, якими засобами сприяти інвестиціям в українську атомну енергетику. Тобто, вивчаються аспекти, пов'язані як з ринками електроенергії, так і з витратами на виробництво, які не охоплюються правилами атомної безпеки. Роль Державної інспекції ядерного регулювання розглядається більшою мірою в контексті її впливу на прийняття рішень щодо енергетичної політики, такої як розробка SMR. Незважаючи на проведення досліджень українського законодавства у галузі атомної енергетики, є потреба у працях, які формулюють цілісне бачення проблем у цій сфері та пропонують конкретні шляхи для її удосконалення. Окрім аналізу законодавчих засобів, у статті також вивчаються окремі економічні, політичні та технічні аспекти розвитку атомної енергетики в Україні. Це обумовлюється потребою оцінити та чіткіше зрозуміти соціально-економічний контекст, у якому мають діяти запропоновані правові норми.

*Ключові слова:* атомні електростанції, SMR (малі модульні реактори), ринок електроенергії, стійкі інвестиції, експорт електроенергії.

**Introduction.** Ukraine, as well as all other world states, must inevitably complete a “green transition” to a decarbonized economic system, also involving the usage of a low-carbon (called “green”) energy. Our country has already reiterated numerous times its commitments to a low-carbon future, including signing the 2015 Paris Climate Agreement and producing documents such as the national 2017 Energy Strategy [6] and 2050 Low Emission Development Strategy [7].

On the global and European scale, there are numerous approaches to the question of which technologies should be prioritized while phasing out fos-

sil fuels (oil, gas, and coal). Whereas countries such as Germany are historically big opponents of nuclear energy, others, such as France, define it as the key pillar in the future of their energy mixes.

Nuclear energy is a pivotal and indispensable element of the Ukrainian power mix. Before the full-scale Russian aggression, it provided up to 52-55% of national electricity generation. Despite existing critics of the dangers of nuclear energy, it appears to be a much safe energy mix than coal (25-27% of the energy mix). Whereas nuclear energy for 0.03 deaths from accidents and air pollution per

1 TWh (annual consumption of 27 000 people in the EU), coal results in 24.6 deaths. Furthermore, it is also anything but easy to replace the capabilities of nuclear energy with solar or wind energy. The thing is that due to different capacity factors of various sources for electricity production, one needs three times more solar energy to make up for 1 GW of nuclear energy.

Nuclear energy also has a big chance to become vital for the Ukrainian economy and foreign exchange earnings. Whereas production costs at Ukrainian NPPs are small enough, "Energoatom" (Ukrainian state-owned operator of NPPs) may make enough profit via exporting electricity to the EU. As a rule, market prices for electricity in neighboring countries are three times higher than in Ukrainian ones. Nevertheless, Ukrainian nuclear energy has enough problems, including ones related to a soon-to-reach end of the operating lifecycle (30-40 years) of many national NPPs.

#### Main body

First, one must legally distinguish nuclear energy from renewable energy sources (RES) such as solar or wind. Even though both nuclear and traditional renewables are low carbon, they have far too different economic logic behind their functioning.

The governments worldwide, including in Ukraine, adopted initiatives aimed at incentivizing small-scale generation of RES. In 2009 Ukrainian parliament passed a Law on Ukraine "On the Amendments to the certain legislative acts concerning the instauration of the feed-in tariff" [2], introducing mark-up for enterprises, producing electricity out of RES. Their electricity was to be obligatory bought by a newly created "Guaranteed Buyer". Therefore, companies had all incentives to invest in RES, hoping to cover their capital

expenses in 4-5 years. The feed-in tariff has primarily helped the Ukrainian energy sector, increasing green energy's contribution to the power mix from below 1 to 12% in early 2022. Nevertheless, any similar measures are impossible to do in the case of atomic energy. Compared to thousands of small-scale decentralized green energy facilities, there are only 4 NPPs in Ukraine. The largest of it, Zaporizhzhia NPP, is currently under illegal Russian occupation, even though it still provides electricity to the national grid.

Those four NPPs are all state-owned, which additionally signals the value of nuclear energy to the Ukrainian state. It seems almost impossible to imagine the construction of the new big NPP to be owned by a private company – such a legislation change does not have much support among energy experts and policymakers.

Consequently, the National Nuclear Energy Generating Company of Ukraine "Energoatom" and other state agencies (Ministry of Energy or State Nuclear Regulatory Inspectorate) are critical decision-makers in shaping energy policy in the nuclear field. Namely, according to Articles 3 and 4 of the Cabinet of Minister's ruling on the State Nuclear Regulatory Inspectorate [5], the mentioned authority has the power to A) ensure the formation and realization of the state's nuclear safety energy policy; B) issue the documents permitting activities in the field of nuclear energy use; C) execute state supervision over compliance with legislation, conditions of permitting documents, nuclear and radiation safety norms and rules, physical protection requirements.

The most burning issue in sustaining Ukrainian nuclear energy growth is the approaching end of the lifetime of many nuclear reactors. Theoretically, there are two ways Kyiv may follow to solve the problem. Ukraine can extend reactors' lifespan by technically modifying them or building NPPs & new reactors. Compared to the 8-month construction time of solar power stations, nuclear ones become operational only in 5-7 years, starting from the original decision to start the construction. One should also understand that today's decisions in nuclear energy will be the ones shaping the power mix in the 2030s.

The critical technological and economic objective of the Ukrainian nuclear field is to gradually replace the old soviet WWER (water-water energetic reactor) with the newly presented American AP1000. The thing is that reactors AP1000, compared to WWERs, represent the third, more advanced generation of nuclear reactors. They have a higher level of thermal efficiency; are

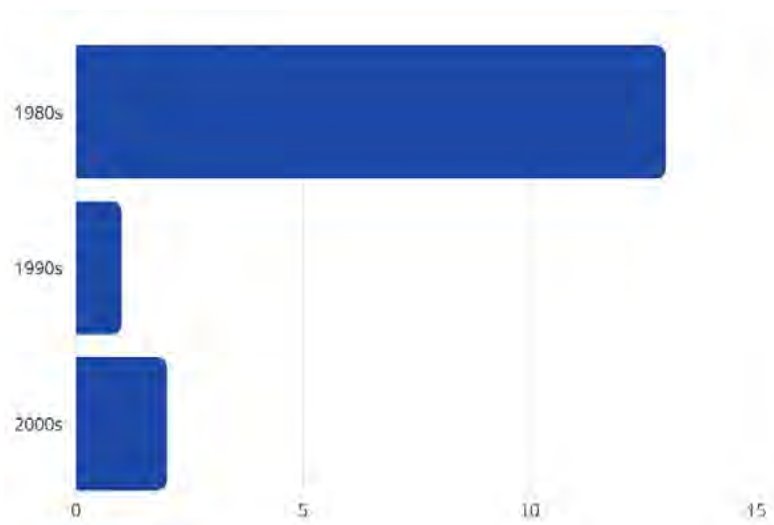


Figure 1. The chronological entry of Ukrainian nuclear power plants into operations

considered safer; their more standardized designs decrease their production & construction time and associated capital & maintenance costs.

So, what should the state namely do to promote nuclear energy? Simple solutions such as merely highlighting the need to invest more money from the Ukrainian budget in AP1000s will not work. The thing is that for the energy transition to happen, the state needs to invest in various technologies, including biomethane, energy storage, and hydrogen. Even if Ukraine makes nuclear energy a priority, the lack of finance in other parts of the power mix will merely cause problems related to electricity demand management.

Nevertheless, the need to secure more funding by legislative means is still evident. In light of this, we are confident that draft bill #4347 [4] should be reviewed and modified by the Ministry of Energy. This draft bill foresees the creation of a special budgetary "Climate and Energy" foundation to fund projects related to decarbonization. However, the primary income source proposed by the legislation will be 50% of the carbon dioxide tax.

In our opinion, there is no reason to limit a funding plan of such a foundation to simply carbon dioxide, given the modest price of carbon dioxide emissions (30 UAH), while leaving all other greenhouse gases aside. The cost of other climate-harming gases (HFC2, PFC2, and SFC6) is more than 200 times higher per ton. Given their even more significant negative impact on the environment, such a decision is also justified from the environmental perspective.

However, it is not a silver bullet, and one cannot rely merely on our national funding. In the realm of involving foreign players in constructing new big reactors, we see two main interdependent elements Ukraine should consider getting the needed funding from foreign governments and companies. The first element is to capitalize on existing legal-political paradigms of the relations between Ukraine and its partners. Whereas political cooperation is not the main subject of our article, we still need to take politics as a shaping legal power in the nuclear field. Nuclear energy is widely perceived not only as an economic topic but also as one having a direct influence on national security.

Thus, the newly passed by the American Parliament International Nuclear Energy Act of 2022 [10], apart from proposing ways how to develop their nuclear energy, is written to be coherent with American foreign interests. Namely, the Act introduces the "Nuclear Security Program," aimed to "reduce the reliance of the United States and ally or partner nations on nuclear fuels from the Russian Federation and the People's Republic of China".

If the American partner complies with technical and economic considerations, he can benefit from credit funding (6 billion USD Civil Credit Program),

introduced by the 2021 Infrastructure Investment Jobs Act [9]. In this realm, we recommend the government create a permanent intergovernmental commission on energy cooperation between Ukraine and the United States of America. Even though, after 2014, numerous bodies such as Ukraine-U.S. working groups at the Ministry of Energy were operating on an ad hoc basis, a unique communication center was never created. The fact that officials in charge of communication with foreign partners from numerous governmental bodies, including a state-owned oil & gas company "Naftogaz," do not have one coordination point harms the governmental initiative. We believe that an intergovernmental commission is the most needed format to use, as representatives of numerous bodies (Ministry of Energy, Energoatom, State Nuclear Regulatory Inspectorate, Ministry of Finance, Ukrainian Embassy in the U.S.) may coordinate their policies together.

Such an approach to develop the nuclear sector in partnership with the U.S. already showed its first results in August 2021. During Ukrainian President Volodymyr Zelensky's visit to the United States, Kyiv and Washington signed Joint Statement on the U.S.-Ukraine Strategic Partnership. Even though a joint statement did not mention nuclear cooperation, a vital memorandum was signed by Energoatom (state atomic power plants operator) and American private nuclear leader Westinghouse as a part of Zelensky's visit. The parties agreed on Westinghouse's participation in constructing a new AP1000 block in Khmelnytskyi NPP, with four others coming. To transform a memorandum into a contract, consistent political cooperation is needed.

The same ideas of nuclear energy cooperation should be voiced as a priority in the relations also between Ukraine and the European Union. The fact that atomic energy was added into the so-called "European Union Taxonomy" (a list of environmentally sustainable economic activities, created by the Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088) [11] opens additional communication opportunities for the Deputy Prime Minister's Office for European and Euro-Atlantic Integration.

Nevertheless, one should also remember that Ukraine is not the unique partner of the U.S. and the European Union. Despite the tangible benefits for European investors, such as a close location to the EU or the far lower price of electricity in Ukraine, compared to European EU markets, Kyiv still needs to make nuclear energy economics far more compatible on the global scale.

Therefore, our second element to getting more foreign funding for Ukrainian nuclear energy is to create a highly efficient market environment.

First, the Ukrainian electricity market [3] should finally get away from PSO (Public Service Obligations) mechanism to enable all its stakeholders to be guided by merely market logic. In 2017 Ukrainian parliament, fulfilling its commitments within Ukraine-EU Association Agreement, finally passed a law "On the electricity market." Before the law was passed, all electricity-generating enterprises were selling the electricity to a monopolistic state entity (SE Energorynok) by regulating prices on each generation plant type (coal, nuclear, etc.). The prices were fixed by an electricity markets regulator NEURC (National Energy and Utilities Regulatory Company) [1]. Then SE Energorynok was selling the electricity to regional electricity distribution companies, and then finally, end-consumers got their electricity from "Oblenergos."

However, not willing to drastically raise electricity prices for residential consumers, the government created a distorted market via PSOs to keep electricity prices fixed for Ukrainian citizens (1,44 UAH before 250 kWh per month; 1,68 UAH after 250 kWh per month). Within the PSO mechanism, two leading state-owned electricity market players (Energoatom and Ukrhydroenergo, hydro energy company) were selling their electricity at meager prices to the SE Guaranteed Buyer. At particular parts of the day, the electricity was sold even at prices lower than the production costs.

Given that this model had many weak points, in 2021, it was modified into a "financial PSO" paradigm. The main differences consist in the mechanism of which Energoatom and Ukrhydroenergo continue to cover the price differences between a market-based electricity price and a final price paid by the residential consumer. Instead of selling the electricity directly to the state at meager prices, Energoatom and Ukrhydroenergo became more interdependent players.

Now top SOEs may freely sell their electricity at the market prices. Such a possibility finally brings sense to the existence of "Energoatom Trading", a trading subsidiary of the national nuclear energy management company. Afterward, SOEs still need to support SE Guaranteed Buyer, however, by giving a significant part of their revenues, not directly by electricity.

Nevertheless, a "financial PSO" model still hinders Energoatom's financial results and possible governmental plans of transforming it into a publicly listed company. According to Energoatom, depending on the month, it must give 40-50% of its revenues to SE Guaranteed Buyer. Alternatively, these funds can be transferred either for research & development capabilities of Energoatom or co-investments in the NPPs' modernization. Thus, a government should continue the path toward creating a fully functional electricity market, where low-in-

come consumers get aid from the government in the form of targeted subsidies.

Secondly, suppose foreign companies decide to invest in Ukrainian nuclear energy assets. In that case, they should have clear possibilities to sell a part of the generated electricity on European markets at a much higher price to make up their investment costs. Following that, in March 2022, Ukraine finally became a member of ENTSO-E (European Network of Transmission System Operators), the state got the opportunity to export electricity to European countries freely. Before, the Ukrainian energy system was connected with Moldova, Belarus, and Russia, with only a tiny part of the country (Burstyn Energy Island) having the technical possibility to export electricity.

The critical governmental priority should be increasing cross-border interconnection capabilities to export more electricity. Because of drastic industrial production falls, Ukraine found itself in a surplus of electricity. The capacity (800 MW) should be expanded to at least 2-3 GW, particularly by modernizing the Khmelnytskyi NPP - Rzeszow powerline (750 KW) for export to Poland.

When compared to some foreign energy systems, the state's monopoly for the control over NPPs may be considered a bottleneck for developing a nuclear energy sector. Whereas not questioning such a state's approach to either existing or big future reactors (1 GW+), we propose to change it when it comes to Small Modular Reactors (SMR) with a lower capacity (300-500 MW). An SMR technology is still nascent, meaning that reactors' prototypes are only doing technological tests before their entry into operation. However, multiple Western states (U.S., Canada, United Kingdom) have been actively preparing for SMR's emergence in the years to come.

In 2021 U.S. President issued an executive order on promoting SMR [8]. The order defined an "SMR as an advanced nuclear reactor of electric generation capacity less than 300 megawatts electric. Because of the smaller size, small modular reactors can generally be designed for factory fabrication and modular construction to take advantage of economies of serial production and shorter construction times". Three years before, the Canadian government prepared a roadmap to develop SMRs to launch the first state-owned SMR in 2026 and the first commercially owned one in 2030. Whereas 2030 may seem a bit far in time now, as stressed before, the construction time of a regular NPP takes 5-7 years. So, if Ukraine takes essential decisions to renovate its nuclear fleet, it will still feel tangible results in the target years, similar to if it implements an SMR strategy.

Compared to standard 1 GW nuclear plants, SMRs have several advantages. As the U.S. President's order definition entails, because the details

to SMRs may be produced at home and a serial scope, their production time is shorter, and production cost is lower. Compared to standard plants, SMRs are more flexible and dispatchable, meaning it is easier for nuclear energy operators to lessen or put up their capabilities. This feature has pivotal importance in creating a stable decarbonized energy mix. The thing is that historically the peak hours demand was covered up by coal, as you can add up the coal in the power station manually when you want to do it. Neither nuclear nor solar/wind, which is very dependent on weather conditions, are not manually dispatchable. A cold start time of a 1 GW nuclear plant is 24 hours. This is not the case with the SMR; therefore, Energoatom will be capable of pulling up its capacities more freely in times of need.

Therefore, Ukraine undoubtedly needs to develop a small modular reactor development outlook. SMRs should also be allowed by the government to be privately owned. In that case, they may become one of the main topics of the investment discussions between Ukrainian energy authorities and companies with their foreign counterparties.

We propose to include the following steps in the Ukrainian SMR Strategy. Firstly, finance from the government funds the creation of the installment of the first SMR in Ukraine. It will act as a signal of strong governmental support for the development of SMRs. Secondly, create a flexible system of "green loans" with lower interest rates and higher repayment returns for Ukrainian companies. UkrGasBank [12], one of the four state-owned banks, already has a solid portfolio in financing sustainable development assets. Therefore, we propose to name in future this bank responsible also for more flexible finance for SMRs.

When it comes to dealing with foreign companies, we recommend engaging them to invest in future Ukrainian SMR assets, proposing the mechanism of PPAs (Power Purchase Agreement). Via PPAs, an European electricity generation or even industrial company will get control of a guaranteed amount of electricity, one corresponding to its property shares in the SMR. Afterward, a company may either use the electricity for its own needs (e.g., when one thinks about a big industrial producer located in a nearby country) or, after having purchased an SMR's electricity at break-even costs, the electricity to the European consumers at higher prices.

Finally, in cooperation with the UkrEnergo and the Ministry of Energy should create a map for suitable technically and non-dangerous connection places for SMRs. To fully realize SMR's potential in providing flexibility to the power mix, they should be placed accordingly to manage customers' electricity demand more effectively.

**Conclusions.** Nuclear energy must play a pivotal role in the decarbonized future of the Ukrainian energy mix. Even though NPPs can help the state now, without concrete legislative actions, a national nuclear fleet will lose many capabilities in future decades. The issue of construction of new modern nuclear reactors as well as new advanced atomic plants such as SMR is pivotal. Whereas the government should understand nuclear energy development, the key aim is to make the field more investments-friendly on a global scale. Domestically, creating a national Energy and Climate Fund may serve as an additional investment income source. Equally, the reforms on the electricity markets, including the role of Energoatom, will make a nuclear monopolist more financially stable and increase its attractiveness as a possible cooperation partner for the European Union States.

The idea of increasing interconnection capacities of the electricity network is equally of extreme importance to attracting foreign investors. Only with stable access to generated electricity, the companies will be willing to invest in national nuclear energy assets. It is pointed out that a model of PPA (Power Purchase Agreements) is the one to implement, as it may at the same time allow engaging both companies willing to import electricity for their consumption (e.g., big industrial plants in neighboring countries) or for future resell (big European electricity traders or generation companies).

The government shall comprehend the SMR technology as an essential element for the energy transition. Therefore, an SMR development strategy should be created to prepare the power mix for their addition to the energy system in the 2020s. Whereas it is advisable to fund a first national SMR, a set of market mechanisms such as flexible "green loans" should be implemented.

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