POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2023 ✦ Volume 26 ✦ Issue 3 ✦ 131–148

DOI: 10.33223/epj/166688

Yevheniia Duliba[1], Nataliia Chudyk[2]

Good lessons based on bad experience: confronting risks and governing nuclear safety in Ukraine

Abstract: Based on a review of scholarly literature and statements of IAEA and Ukrainian institutions, we try to attempt to analyze the current problems in nuclear energy of Ukraine during the war based on the example of the seized Zaporizhzhia nuclear power plant, which demonstrates the impact of this situation over global nuclear safety. Our study also outlines some solutions to this ongoing crisis and highlights that there is an urgent need for a new strategic vision at the global level with regard to nuclear safety and environmental protection.

The "trial and error" approach is not the desired practice of ensuring nuclear safety in the world and therefore the world must today apply the lessons learned during the war in Ukraine to better protect people and the environment.

The current situation in the world is complex and requires reasonable considerations, taking into account social, economic, environmental and geopolitical aspects. The introduction of minimum International Atomic Energy Agency (IAEA) safety standards that are illegally enforceable, the revision of the provisions of the IAEA statute and its amendment by providing the organization with the function of maintaining the harmonization of nuclear requirements, the need to improve the existing IAEA standards in terms of taking measures during the construction of nuclear power

✉ Corresponding Author: Yevheniia Duliba; e-mail: dulibayevheniia@gmail.com

[1] Department of Constitutional Law and Field-Related Disciplines, Institute of Law, National University of Water and Environmental Engineering, Ukraine; ORCID iD: 0000-0003-2651-4977; e-mail: dulibayevheniia@gmail.com

[2] Department of Constitutional, Administrative and Financial Law Faculty of Law, West Ukrainian National University, Ukraine; ORCID iD: 0000-0003-0649-2715; e-mail: Natali_ternopil@ukr.net

plants to protect them from missile attacks, as well as during the operation of NPPs are all analyzed as necessary steps required to solve the issues of improving nuclear safety in Ukraine, Europe, and the world. The cooperation of Ukraine with such states as the USA, Japan, South Korea, France, and the United Kingdom, and the creation of the coalition could help to put pressure on United Nations and IAEA at the international level to withdraw all troops and ammunition supplies from Zaporizhzhia NPP.

Keywords: nuclear safety, nuclear power plant, war in Ukraine, energy, IAEA standards

Introduction

One of the most topical issues of the twenty-first century has become the provision of the reliability and safety of energy generation necessary to ensure the proper functioning of the economy as well as to fulfill the growing needs of the population.

The political recognition of the importance of energy for development was originally defined in the Sustainable Development Goals (SDGs) also known as the Global Goals adopted by the United Nations in 2015, as a shared blueprint of action for people and the planet for peace and prosperity. The SDG7 was provided in order to "ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations 2015). Meanwhile, the progress of all other SDGs directly depends on the provision of a sustainable energy supply.

Nuclear energy is a stable source of energy that can solve the energy trilemma of supplying baseload, clean and affordable power (Ho et al. 2019). Nowadays, various countries are considering or have recognized nuclear energy as a stable source of energy, which is crucial in reducing carbon emissions in the fight against climate change (Baker 2019).

Meanwhile, no technology would be completely free of risk to people or the environment. Nuclear power plants (NPPs) are potential facilities of increased danger, so malfunctions take place almost daily. The consequences of accidents can affect large areas and be of an ecological regional and economic global character.

Back to 2013, Woo (2013), considering nuclear safety in the context of the physical protection system in NPPs, has not only described eight possible cases of terror attacks to NPPs that can happen in normal operation but also how to get prepared for them. Both possible cases are related to armed attacks, in particular, the scenario of a frontal assault with small arms and the scenario of an attack with rockets or medium artillery. Woo (2013) offered his vision of the advanced physical protection system construction in NPPs, highlighting the importance of strengthening the IAEA's role, introducing a unified approach to nuclear safety and the strengthening of carrying security and safety. However, his conclusions were based on suggestions and the implementation of these scenarios seemed non-existent.

While the invasion of the territory of Ukraine and the subsequent full-scale war is contrary to Article 56 of the Additional Protocol to the Geneva Conventions of 12 August 1949 (United

Nations 1977), Russia launched an attack on the nuclear power facilities of Ukraine (the missile strike near the South Ukrainian NPP, attacking the 'Source of Neutrons' International Bar Association of the National Science Center 'Kharkiv Institute of Physics and Technology', and the storage of spent nuclear fuel in the Chornobyl NPP), as well as seizing the Chornobyl NPP and the Zaporizhzhia NPP. Such actions of Russia have led to the destabilization of the world nuclear order and have generated crucial consequences of a political and regular character.

Based on the fact that nowadays, 431 nuclear reactors are operating in the world (IAEA 2023), seven reactors started their work in 2022, and the construction of ten reactors in China, Egypt, and Turkey is underway (WNISR 2023; IAEA 2023). Additionally, about thirty countries are considering, planning or starting nuclear power programs (World Nuclear Association 2023), and the war in Ukraine has demonstrated the significance of ensuring nuclear safety in Ukraine Europe, and the world and the improvement of existing IAEA standards.

The issue of nuclear safety in Ukraine is relevant and attracts the wide attention of academic communities, there is an insignificant number of scientists on the given subject. Budjeryn (2022), Bollfrass and Herzog (2022) were among the first to discuss the war in Ukraine and its impact on the world nuclear order. Smith (2022) has highlighted the unprecedented situation and an array of possible threats in his work titled "Playing with Fire: military attacks against a civilian nuclear power station."Some authors, for example, Boulton (2022), has considered the war in Ukraine in the wider context of the possession and potential use of nuclear weapons and concluded the urgency of effective nuclear arms control measures. Duliba (2022) has highlighted the problems of nuclear safety in Ukraine and has outlined ways to solve them. Furthermore, Chepeliev et al. (2023) discussed the impact of war and safety considerations on the future of nuclear energy in Ukraine. We attempt to analyze the current problems in nuclear energy in Ukraine during the war on the example of seized Zaporizhzhia NPP and demonstrate the impact of this situation over global nuclear safety and outline some solutions to this ongoing crisis.

The research uses such methods as the dialectical method of scientific knowledge, the method of comparative analysis, the method of formal-legal analysis and the situational method.

The urgency of the chosen issue lies in the fact that nuclear power plants are directly vulnerable within military situations. Each NPP is certainly designed under the concept of in depth defense for the prevention of severe accidents; this is comprised of multiple layers of protection aimed at reducing risks to both the public and workers (IAEA 1996). However, any NPP has been designed to provide protection against military attacks. Moreover, there are no NPPs built with a sufficient margin of safety to resist bombardment or protect against any other military attacks. Furthermore, until now, all accidents at NPPs have occurred in the conditions of a peaceful society and occurred due to human error or natural disasters.

1. The energy sector of Ukraine is on the front line of the war

The united energy system of Ukraine is one of the largest energy networks in Europe, which covers seven regional energy systems (Dniprovsk, Western, Crimean, Southern, South-West, North, and Central), which are interconnected by system-forming and main lines of electricity transmission. The structure of the national energy system includes various power plants (thermal power plants and thermoelectric stations, hydroelectric power plants, pumped hydroelectric energy storage, nuclear power plants, renewable-energy power plants, mail-line, and distribution networks that are linked by the general mode of production, transmission, and distribution of electric and thermal energy (Ministry of Energy of Ukraine 2022) (Fig. 1). However, nuclear energy has provided about 50% of the electricity generation in Ukraine (Energy Universe 2022).

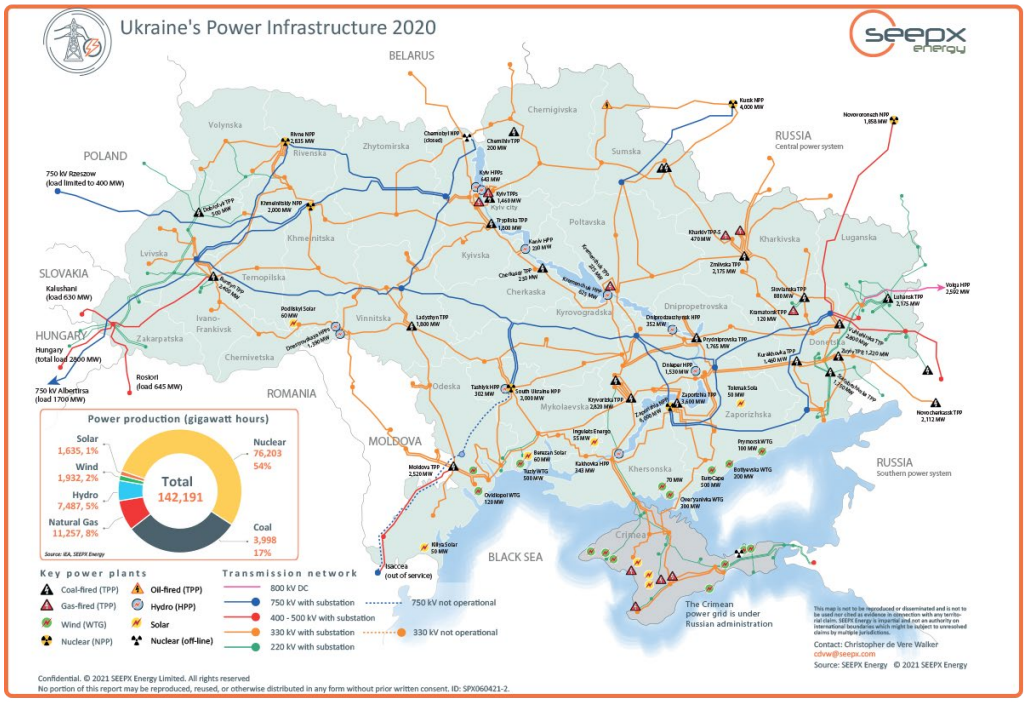

Fig 1. The United energy system of Ukraine
Source: SEEPX Energy

Rys. 1. Zjednoczony system energetyczny Ukrainy

Ukraine has a highly developed nuclear-power infrastructure, which includes five nuclear power plants with fifteen reactors with a total installed capacity of 13,835 MWe: Zaporizhzhia NPP (Donetsk Energodar of Zaporizhzhya region), Rivne NPP (city Varash Rivne region), Khmelnyt-

sky NPP (city Netyshyn Khmelnytsky region), South-Ukrainian NPP (Yuzhnoukrainsk, Mykolaiv region), Chornobyl NPP (city Chornobyl, Kyiv region).

From the beginning of its development, Ukraine's energy system was synchronized with the United Energy System of Russia and operated in parallel with the power systems of Russia, Belarus, and Moldova, being largely dependent on Russia in the event of emergencies (Ministry of Energy of Ukraine 2022).

The signing of the Association Agreement with the EU in 2014 (Agreement EU 2014), and subsequently Agreement on Ukraine's accession to the European Network of Transmission System Operators for Electricity (ENTSO-E) in 2017 (ENTSO-E, 2017), became the starting point for the integration of the united energy system of Ukraine into the electricity system of continental Europe.

At the time of signing this agreement in 2017, Ukraine had already had electrical interconnections with neighboring EU countries, in particular with Poland, Slovakia, Hungary, and Romania. However, the only thermal power plant, Burshtyn Island in the Ivano-Frankivsk region of Ukraine, is synchronized with the European network.

Synchronization with the European energy network ENTSO-E should be the result of long-term labor and reforms in the domestic energy sector, the implementation of several technological and regulatory requirements (the certification of system operators in accordance with European standards, modernization of software and hardware control, performing two split tests – carrying out tests of own electric network of isolated operational tests) (ENTSO-E 2017).

The first isolated operational test began on the night of February 24, 2022, when the Ukrainian power system was disconnected from Russia and Belarus and had to join them in three days (Ministry of Energy of Ukraine 2022).

However, after the beginning of the war, Ukraine officially refused to join Russia and Belarus again and began negotiations on the urgent synchronization with ENTSO-E. The Ukrainian energy system showed stable operation in an isolated mode for three weeks in the conditions of war and on March 16, 2022, Ukraine became part of the EU single energy system (Ministry of Energy of Ukraine 2022).

On March 31, 2022, the Board of Governors of the World Association of Organizations Operating Nuclear Power Plants (WANO) reviewed the application of the State Enterprise "NNEGC Energoatom" and decided on the transfer of the Ukrainian NPP, the operator of which is the State Enterprise "NNEGC Energoatom," to the Paris Center of the All-Ukrainian NPP (Verkhovna Rada of Ukraine 2022). Before this period, Ukrainian nuclear power plants have been under Moscow Center and the partnership inspection program, as a result of which, representatives of the Moscow Center visited Ukrainian nuclear power plants every four years for an objective analysis of the activity of nuclear power plants and prepared reports with recommendations for increasing the nuclear safety and security of the nuclear power plant (WANO, 2022). The transition from Moscow to the Paris Center of the WANO will provide the disconnection of Russian representatives from the Ukrainian NPPs.

After synchronization with ENTSO-E, Ukraine began exporting electricity to Poland, Slovakia, Romania, and Moldova, helping Europe to reduce the consumption of Russian energy resources (Ministry of Energy of Ukraine 2022).

However, the energy sector has become the front line in Russia's war against Ukraine. Large-scale Russian missile attacks on energy infrastructure facilities in October 2022 (255 strikes on 112 objects of the energy infrastructure of Ukraine (Office of the Prosecutor General 2023)) could not pass unmonitored for Ukraine. These attacks led to a hard drop in the frequency of the energy system. For the first time in the history of Ukraine, the energy system suffered a systemic incident – a complete blackout. The simultaneous loss of off-site power at all Ukrainian NPPs led to the start of the operation of diesel generators, as a forced step, which allowed the maintaining and safe operation of nuclear facilities in the absence of external power supply to its resumption (IAEA 2022d).

The event described above underlines the fact that the situation with nuclear safety in Ukraine has become "increasingly precarious, challenging and potentially dangerous" (IAEA 2022d).

We want to state the fact that NPP may currently be applied for various uses during the war. In the case of the Zaporizhzhia NPP, Ukrainian forces could not resist Russian armored vehicles and tanks, as well as various weapons, including rocket-propelled grenades. The military may deliberately use the territory of NPPs as a shield against attacks or blackmail. For instance, the seizure of the Zaporizhzhia NPP made Russia realize that Ukraine would not go to the NPP because it is naturally interested in protecting its population and preserving the environment.

The complexity of the situations around the NPPs is also specified by the fact that the combatants do not have in-depth knowledge of the operation of the NPPs, the requirements for its stable operation and knowledge about the significance of the safety of certain parts of the NPP and complex safety requirements, they are also unable to assess the side effects of their combat actions (WNISR 2023). It is supposed that damage to the electricity supply in the spent nuclear fuel storage at the Chornobyl NPP has demonstrated a lack of knowledge of the Russian military that in the case of the prolonged de-energizing of storage could lead to overheating and evaporating radioactive substances (IAEA 2022b; The State Nuclear Regulatory Inspectorate of Ukraine 2022).

NPPs constantly require regular maintenance for their safe operation. Damage to the NPPs infrastructure results in damage to some elements of the plant, the need to replace or repair them, and can further lead to the shortage of spare parts and consumables. For example, the IAEA Support and Assistance Mission to Zaporizhzhia NPP observed and reported damage at different locations (one turbine lubrication oil tank; the roofs of various buildings such as the building for the spent fuel transporter vehicle; the special building that houses the fresh nuclear fuel and the solid radioactive waste storage facility; the new training building; the building in which the central alarm station of the physical protection system is placed; the container in which the radiation monitoring system is located in the vicinity of the dry spent fuel storage facility (IAEA 2022c).

The following issues are among the responsibilities of the staff: daily maintenance, the prevention of abnormal operation, and the repair of system failures to ensure the safe functioning of the system at the appropriate level of the NPP. Furthermore, traditionally, during an emergency, the NPP depends on the actions of the NPP staff, who are involved in the deployment of technical resources and the application of established procedures (Guarnieri and Travadel 2014). Howe-

ver, regrettably, today the work of the Zaporizhzhia NPP's staff and their full abilities to perform duties intended to control and minimize consequences are limited. Having been seized, the staff of the Zaporizhzhia NPP have faced and are still facing unprecedented problems in carrying out daily operations and maintaining nuclear safety standards under the pressure of the Russian military; workers suffer stress, which may lead to certain omissions or mistakes. The safe performance of their work without interference is also a requirement for the successful functioning of the NPP.

Awareness of the fact that "the responsibility for nuclear safety is entirely carried by the state that has jurisdiction over a nuclear installation" (United Nations 1994a) and military actions are taking place around the Zaporizhzhia NPP, and this plant has been repeatedly subjected to military attacks, the State Nuclear Regulatory Inspectorate of Ukraine has made changes to the licenses for the operation of power units 1 and 2 of the Zaporizhzhia NPP. Due to these, the power units are operated in a cold shutdown status, which provides the safety of the nuclear reactors and presupposes the stopping of electric power generation. This is optimal under the conditions of occupation of Zaporizhzhia NPP. In case of a nuclear emergency, this position enables a reduction in the level of radioactivity potentially released in the event of an accident with damage to the active zone, which in turn reduces the potential consequences for the population and the environment. However, Ukraine cannot guarantee nuclear safety during this war, and cannot solve safety for all nuclear facilities now. In addition, today Russia does not guarantee the safety of Ukrainian nuclear facilities, as a member of the IAEA, which has assumed international obligations to support effective and comprehensive nuclear safety. The current situation in the world is complex and requires reasonable considerations, taking into account social, economic, environmental, and geopolitical aspects. The cold war, which was thought to have ended, has resumed in the middle of Europe and has become a turning point in European-American-Russian relations. War in Ukraine has caused the emergence of international geopolitical blocs because not all states agreed with the condemnation of Russia's actions.

The events in nuclear energy in Ukraine deserve a considerable rethinking of the existing standards of nuclear safety and the building of a completely new paradigm of nuclear safety in the world. The radiation risks undertaken by Ukraine may have a transboundary impact and could become a significant issue in Europe and the rest of world.

2. IAEA and standards of nuclear safety

Today, the international community must seek effective solutions while the critical infrastructure of Ukraine, including NPPs, is under threat. The IAEA plays a leading role in the search for these solutions, in promoting international cooperation and in coordinating international efforts to strengthen global nuclear safety, in achieving the purposes of its creation. In particular, it is accelerating and enlarging the contribution of atomic energy to peace, health,

and prosperity throughout the world, and ensuring that assistance provided by it or at its request or under its supervision or control is not used in such a way as further any military purpose (IAEA 1956).

Establishing or adopting standards of safety (the fundamental principles, requirements, and guidelines to ensure nuclear safety) for the protection of health and the minimization of danger to life and property, and the provision of the application of these standards is among other IAEA functions.

The goal of the introduction of the IAEA standards was to create a certain order and destabilize the disorder. The IAEA safety standards reflect the international consensus in nuclear safety and human and environmental protection from the harmful effects of ionizing radiation. The IAEA safety standards are not legally enforceable in the Member States and are applied at their discretion.

The IAEA has adopted several nuclear safety standards in the area of the construction and operation of NPPs. The IAEA Basic Safety Principles for Nuclear Power Plants 75-INSAG-3 Rev. 1 INSAG-12 (1999) provide information on six fundamental safety principles (three related to safety management, three related to defense in depth), and nine technical principles, which provide a general framework for several specific safety principles (IAEA 1999). The IAEA Safety Requirements No GS-R-2 "Preparedness and Response for a Nuclear or Radiological Emergency" (2002), incorporates requirements for emergency preparedness for and response to a nuclear or radiological emergency (IAEA 2015).

Among the IAEA standards, there is the Safety Guide No. NS-G-1.5 "External Events Excluding Earthquakes in the Design of Nuclear Power Plants" (2003) describes the requirements for both the design basis of external human-induced events and the design basis of external natural events (aircraft crashes, external fire, explosions, asphyxiant and toxic gases, corrosive and radioactive gases and liquids, electromagnetic interference, floods, extreme winds, extreme meteorological conditions, biological phenomena, volcanism, collisions of floating bodies with water intakes and uhs components). Furthermore, in this IAEA standard, the term "missile" is used but only in the context of the description of the moving object in general (primary rocket (aircraft) or secondary missiles (engines and landing gear)), with the excluding from the consideration of any military missiles (bombs or missiles) and heavy artillery attacks (IAEA 2003). However, this publication has been superseded by the Specific Safety Guide No. SSG-68 "Design of Nuclear Installations Against External Events Excluding Earthquakes" (2021), where the term "missile" also is used to describe a moving object in general, and military missiles, whether explosive or not, are specifically excluded from consideration. The main reason of this expulsion is because "military projectiles have velocities higher than Mach 1 and are therefore usually beyond the range of applicability of the techniques described in this Safety Guide". For non-explosive military projectiles with characteristics lying within the quoted ranges of applicability, the techniques described may be used of this Specific Safety Guide (IAEA 2021).

In 2022, the IAEA adopted several safety standards related to the operation of NPPs: recommendations on controlling activities relating to modifications to NPPs (SSG 70) (IAEA 2022e); an operating organization for NPPs (SSG 72) (IAEA 2022f);; core management and fuel han-

dling for NPPs (SSG 73) (IAEA 2022g); Maintenance, Testing, Surveillance and Inspection in Nuclear Power Plants (SSG 74) (IAEA 2022h); Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (SSG 75) (IAEA 2022i); Conduct of Operations at Nuclear Power Plants (SSG 76) (IAEA 2022j).

It also worth paying attention to the IAEA General Conference resolutions adopted on nuclear safety. The IAEA General Conference resolution GC (55)/RES/9 (2011) underlines the significance of all Member States to implement emergency preparedness and response mechanisms and develop mitigation measures at the national level (Resolution IAEA General Conference 2011). The IAEA General Conference resolution GC (56)/RES/9 (2012) has emphasized the need to resolve the issue of compatibility in the development of national and international emergency response mechanisms and procedures consistent with the agency's safety standards (Resolution IAEA General Conference 2012). The IAEA General Conference resolution GC (59)/RES/9 highlights "…the significance of the establishment, implementation, regular exercise and continuous improvement of national emergency preparedness and response measures, taking into account the IAEA Safety Standards", and encourages Member States to strengthen their national, bilateral, regional and international emergency preparedness and response mechanisms (Resolution IAEA General Conference 2015).

Events in Ukraine in the first days of the war have led to the outlining of seven indispensable pillars of nuclear safety and security (IAEA 2022a). Analysis of these pillars has demonstrated that Ukraine can provide these seven pillars in all NPPs, except the seized Zaporizhzhia NPP. There are a lot of questions regarding how to implement these pillars in the seized plant. In situations in which Ukraine can't guarantee the physical integrity of the facilities, the operation of all safety and security systems and equipment, making decisions and the working of operating staff under pressure, the availability of secure off-site power supply from the grid for all nuclear sites, an effective on-site and off-site radiation monitoring system, emergency preparedness and response measures.

In resolution IAEA General Conference GC (66)/RES/6 (2022), all Member States have been called to maintain nuclear safety and security regarding peaceful nuclear facilities and materials in all circumstances and without prejudice to the views of Member States and noted the importance of following the IAEA Director "General's seven indispensable pillars of nuclear safety and security" (Resolution IAEA General Conference 2022).

However, these pillars were not achieved concerning the Zaporizhzhia NPP as Russia has ignored them and has continued to pose a threat to the nuclear safety of Ukraine and Europe.

The mission of the IAEA and the permanent presence of its representatives at Zaporizhzhia NPP are the IAEA steps towards the improvement of the situation, which can play a crucial role in reducing nuclear danger, providing an opportunity to significantly increase transparency and helping to more accurately assess the situation at the plant.

3. What are the good lessons for the world?

The global nuclear order was certainly tense before the 24th of February (Bollfrass and Herzog 2022) and issues of nuclear safety and the necessity for determining a set of nuclear safety and radiation protection measures for NPPs have been always relevant (Prăvălie and Bandoc 2018).

The annexation of the Autonomous Republic of Crimea, which is a part of Ukraine, and Russia's violation of the memorandum on security assurances in connection with Ukraine's accession to the Treaty on the Non-Proliferation of Nuclear Weapons (Budapest Memorandum on Security Guarantees 1994) have created "potential cracks in the credibility of extended deterrence" and influenced the world nuclear order (Fitzpatrick 2014).

The war in Ukraine has become the most notable conflict in Europe since World War II and has a number of geopolitical (Kuzemko et al. 2022; Wiertz et al. 2023; Roland 2023; von Hippel 2023); economic (Deng et al. 2022; Izzeldin et al. 2023; Pandey and Kumar 2023), medical (Brągiel and Gambin 2023) consequences.

This protracted energy geopolitical conflict can lead to long-term consequences for global safety and nuclear deterrence. Today, we have the opportunity to observe how the war in Ukraine has raised crucial issues not only with regard to the world nuclear order but also in the context of international nuclear energy management, the need to change geopolitical relations, and policies aimed at energy independence (Nastos 2022).

Today's war in Ukraine has discernible, multifaceted nuclear undernotes (Budjeryn 2022). The constant shelling of nuclear energy facilities and the long-term destruction of NPP's facilities have demonstrated how essential it is to change the paradigm of global nuclear safety and develop a better plan for nuclear safety.

The history of IAEA's activity reflects the facts, which shows that nuclear emergencies all over the world have become catalysts for change in nuclear safety in general, and amendments to the IAEA standards. Firstly, the accidents at Three Mile Island NPP (USA, 1979) and Chornobyl NPP (Ukraine, 1986) led to the adoption of new concepts in nuclear safety (Guarnieri and Travadel 2014). Secondly, the Chornobyl NPP accident led to the creation of the World Association of Nuclear Operators (WANO) as a result of reconsidering the importance of the safety and reliability of NPPs in the world, the cooperation and exchange of information and the emulation of best practices (WANO 2023). Thirdly, the desire to develop a common approach to nuclear safety and ensure an independent capacity to study nuclear safety at the EU level led to the establishment of the Western European Nuclear Regulatory Association (WENRA), which, among other measures, began to work on enhancing the harmonization of regulatory requirements in Europe (WENRA 2023).

The de-occupation of the Zaporizhzhia NPP and its return to being under the control of Ukraine is a priority for Ukraine, as well for the IAEA, the EU and the rest of the world. Unfortunately, experience has demonstrated that after leaving any cities or facilities of Ukraine, the Russian military always mined them. Regrettably, the situation with Zaporizhzhia NPP needs

to be addressed diplomatically. Again, the IAEA should play a crucial role here. We think that Ukraine needs cooperation with those States of the world that understand what nuclear energy is (such as the USA, Japan, Sound Korea, France, and the United Kingdom) and create a coalition at the international level and try to make the United Nations and the IAEA withdraw all the troops and ammunition supplies from Zaporizhzhia NPP. Nuclear safety governance should move towards a more robust regime that includes elements of international monitoring and verification (Taebi and Mayer 2017).

Based on the fact that today, each Member State decides on the application of the standards of the IAEA in its sole discretion, it would be necessary to ensure nuclear safety in the world by way of the implementation of the full responsibility of the IAEA standards. The standards from the design to the decommissioning of nuclear power plants cannot be applied at the discretion of the Member States. These should be such minimum nuclear safety standards that everyone must comply with in order to maintain world nuclear safety and nuclear order.

The International Civil Aviation Organization can serve as a good example of how this works in practice. International Civil Aviation Organization is supported by minimum international standards of international air transportation, aviation safety, security and efficiency.

The new international standard can be adopted only after archiving diplomatic consensus of all Member States around the best results and advice and discussing a new standard›s scope and details. Each state establishes minimal standards in the native legislation (ICAO 2023). During its existence, the IAEA has tried to introduce legally binding standards for Member States and expanded its nuclear safety duties. However, neither the IAEA Board of Directors nor any Member States has ever agreed to this position. The IAEA Board of Directors involves thirty-five Member States. Their position is based on the fact that the introduction of the minimum safety standards could call into question one of the principles of the functioning of the IAEA such as the principle of responsibility of Member States for ensuring nuclear safety in their territory, and the impossibility of the improvement of standards.

It is worth mentioning that today, most states of the world are either a party or state signatories to many international legal documents related to nuclear safety. The introduction of the IAEA legally binding minimum standards on Member States correlates with the provisions of the convention on nuclear safety since most IAEA member states have agreed to call this argument for themselves by signature, ratification, accession or acceptance (United Nations 1994b). Moreover, in the preamble of the convention on nuclear safety, the parties expressed their recognition that the "Convention entails a commitment to the application of fundamental safety principles for nuclear installations" (United Nations 1994a).

The "trial and error" approach is not the desired practice for ensuring nuclear safety in the world and therefore the world must today apply the lessons learned from the war in Ukraine to better protect the people and the environment. We believe that the threat to the nuclear safety of Ukraine has led to the understanding that we need to reconsider and change the paradigm of global nuclear safety. We believe that based on the fact that the IAEA safety standards reflect the international consensus in the field of nuclear safety and the protection of humans and the environment from the harmful effects of ionizing radiation, the introduction of minimum legally

binding IAEA standards will create a certain order and the destabilization of disorder. Moreover, there is a real need to make changes to Safety Guide No. NS-G-1.5 "External Events Excluding Earthquakes in the Design of Nuclear Power Plants" and the need to include the impact of military missiles and artillery attacks.

Conclusions

The drastic experience of Ukraine in the context of ensuring nuclear safety on the example of the seized Zaporizhizhia NPP has to be a lesson for the world. The situation around Zaporizhzhia NPP should be the catalyst for changes in nuclear safety in general, and amendments to the IAEA statute and IAEA standards.

The "trial and error" approach is not the desired practice for ensuring nuclear safety in the world and therefore the world must today apply the lessons learned from the war in Ukraine in order to better protect the people and the environment. Both the IAEA's statute and the IAEA's standards need to be improved.

The following steps are considered to be essential:

1. The minimum IAEA safety standards should be legally enforceable and introduced for all Member States to ensure the sustainable development of our planet. These standard should cover everything from the design to the decommissioning of nuclear power plants and cannot be applied at the discretion of the Member States. The introduction of minimum legally binding IAEA standards will create a certain order and destabilization of disorder. Moreover, there is a real need to improve the existing IAEA standards in terms of taking measures during the construction of nuclear power plants in order to protect them from missile attacks, as well as during the operation of NPPs, and making changes to Safety Guide No. NS-G-1.5, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants" and the need to include the impact of military missiles and artillery attacks.

2. There is a requirement for the revision of the provisions of the IAEA statute and its amendment by providing the organization with the function of maintaining the harmonization of nuclear requirements.

3. There is a requirement for the cooperation of Ukraine with such states as the USA, Japan, Sound Korea, France, and the United Kingdom and the creation of the coalition could help at the international level to make the United Nations and IAEA withdraw all troops and ammunition supplies from the Zaporizhzhia NPP.

References

Agreement EU 2014. Association Agreement between the European Union and its Member States, of the one part, and Ukraine, of the other part. [Online]. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A22014A0529%2801%29 Accessed: 2022-02-28].

Baker, K. 2019. Governance, depoliticization, and nuclear power in Britain and the United States. *Policy Studies* 43(2), DOI: 10.1080/01442872.2019.1665643.

Bollfrass, A.K. and Herzog, S. 2022. The War in Ukraine and Global Nuclear Order. *Survival* 64(4), pp. 7–32, DOI: 10.1080/00396338.2022.2103255.

Boulton, F. 2022. The nature and consequences of a nuclear war: lessons for prevention from Ukraine. *Medicine, Conflict and Survival* 38(3), pp. 184–202, DOI: 10.1080/13623699.2022.2093571.

Brągiel, A. and Gambin, M. 2023. Depressive symptoms and psychological pain experienced by Polish adults in the context of both the war in Ukraine and the COVID-19 pandemic. *Journal of Affective Disorders Reports* 12, DOI: 10.1016/j.jadr.2023.100487.

Budjeryn, M. 2022. Distressing a system in distress: global nuclear order and Russia's war against Ukraine. *Bulletin of the Atomic Scientists* 78(6), pp. 339–346, DOI: 10.1080/00963402.2022.2132742.

Chepeliev et al. 2023 – Chepeliev, M., Diachuk, O., Podolets, R. and Semeniuk, A. 2023. What is the future of nuclear power in Ukraine? The role of war, techno-economic drivers, and safety considerations. *Energy Policy* 178, DOI: 10.1016/j.enpol.2023.113612.

Deng et al. 2022 – Deng, M., Leippold, M., Wagner, A.F. and Wang, Q. 2022. Stock Prices and the Russia-Ukraine War: Sanctions, Energy and ESG, *Swiss Finance Institute Research Paper Series* 22––29, DOI: 10.2139/ssrn.4080181.

Duliba, Y.E. 2022. Nuclear safety: a global challenge in the context of the war in Ukraine. *Journal of Energy & Natural Resources Law*, DOI: 10.1080/02646811.2022.2145018.

Energy Universe 2022. *Electricity production in Ukraine in 2021*. [Online] https://vse.energy/news/peknews/electro/1935-power-generation-202112 [Accessed: 2022-02-28] (*in Ukrainian*).

ENTSO-E 2017. *Future interconnection of Ukraine and Moldova with the Continental Europe Power System.* [Online] https://www.entsoe.eu/publications/system-operations-reports/#future-interconnection-of-ukraine-and-moldova-with-the-continental-europe-power-system [Accessed: 2022-02-28].

Fitzpatrick, M. 2014. The Ukraine Crisis and Nuclear Order. *Survival* 56(4), pp. 81–90, DOI: 10.1080/00396338.2014.941552.

Guarnieri, F. and Travadel, S. 2014. Engineering thinking in emergency situations: A new nuclear safety concept. *Bulletin of the Atomic Scientists* 70(6), pp. 79–86, DOI: 10.1177/0096340214555109.

Ho et al. 2019 – Ho, M., Obbard, E., Burr, P.A. and Yeoh, G. 2019. A review on the development of nuclear power reactors. *Energy Procedia* 160, pp. 459–466, DOI: 10.1016/j.egypro.2019.02.193.

IACO 2023. *About ICAO.* [Online]. https://www.icao.int/about-icao/AirNavigationCommission/Pages/how-icao-develops-standards.aspx [Accessed: 2022-02-28].

IAEA 1956. *The Statute of the IAEA.* [Online] https://www.iaea.org/sites/default/files/statute.pdf [Accessed: 2022-02-28].

IAEA 1996. INSAG-10 – Defence in Depth in Nuclear Safety. [Online] https://www-pub.iaea.org/mtcd/publications/pdf/pub1013e_web.pdf [Accessed: 2022-02-28].

IAEA 1999. INSAG-12 – Basic safety principles for nuclear power plants: 75-INSAG-3 rev. 1. [Online] https://www-pub.iaea.org/MTCD/Publications/PDF/P082_scr.pdf [Accessed: 2022-02-28].

IAEA 2002. GS-R-2- Preparedness and response for a nuclear or radiological emergency: Safety Guide. [Online] https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1133_scr.pdf [Accessed: 2022-02-28].

IAEA 2003. NS-G-1.5 – External Events Excluding Earthquakes in the Design of Nuclear Power Plants: Specific Safety Guide. [Online] https://www.iaea.org/publications/6733/external-events-excluding-earthquakes-in-the-design-of-nuclear-power-plants [Accessed: 2022-02-28].

IAEA 2015. GSR Part 7 – Preparedness and Response for a Nuclear or Radiological Emergency: General Safety Requirements. [Online] https://www.iaea.org/publications/10905/preparedness-and-response-for-a-nuclear-or-radiological-emergency [Accessed: 2022-02-28].

IAEA 2021. SSG-68 – Design of Nuclear Installations Against External Events Excluding Earthquakes: Specific Safety Guide. [Online] https://www-pub.iaea.org/MTCD/publications/PDF/PUB1968_web.pdf [Accessed: 2022-02-28].

IAEA 2022a. *IAEA Director General Calls for Restraint, Reiterates Need to Ensure Safety of Ukraine's Nuclear Facilities and Their Staff.* [Online] https://www.iaea.org/newscenter/news/iaea-director-general-calls-for-restraint-reiterates-need-to-ensure-safety-of-ukraines-nuclear-facilities-and-their-staff [Accessed: 2022-02-28].

IAEA 2022b. Update – 8. IAEA Director General Statement on situation in Ukraine. [Online] https://www.iaea.org/newscenter/pressreleases/update-8-iaea-director-general-statement-on-situation-in-ukraine [Accessed: 2022-02-28].

IAEA 2022c. *Nuclear Safety, Security and Safeguards In Ukraine. 2nd Summary Report by the Director General*. [Online] https://www.iaea.org/sites/default/files/22/09/ukraine-2ndsummaryreport_sept2022.pdf [Accessed: 2022-02-28].

IAEA 2022d. Update – 132. IAEA Director General Statement on Situation in Ukraine. [Online] https://www.iaea.org/newscenter/pressreleases/update-132-iaea-director-general-statement-on-situation-in-ukraine [Accessed: 2022-02-28].

IAEA 2022e. SSG70 – Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants: Specific Safety Guide. [Online] https://www.iaea.org/publications/14901/operational-limits-and-conditions-and-operating-procedures-for-nuclear-power-plants [Accessed: 2022-02-28].

IAEA 2022f. SSG72 – The Operating Organization for Nuclear Power Plants: Specific Safety Guide. [Online] https://www.iaea.org/publications/14903/the-operating-organization-for-nuclear-power-plants [Accessed: 2022-02-28].

IAEA 2022g. SSG73 – Core Management and Fuel Handling for Nuclear Power Plants: Specific Safety Guide. [Online] https://www.iaea.org/publications/14904/core-management-and-fuel-handling-for-nuclear-power-plants [Accessed: 2022-02-28].

IAEA 2022h. SSG74 – Maintenance, Testing, Surveillance and Inspection in Nuclear Power Plants: Specific Safety Guide. [Online] https://www.iaea.org/publications/14905/maintenance-testing-surveillance-and-inspection-in-nuclear-power-plants [Accessed: 2022-02-28].

IAEA 2022i. SSG75 – Recruitment, Qualification and Training of Personnel for Nuclear Power Plants: Specific Safety Guide. [Online] https://www.iaea.org/publications/14906/recruitment-qualification-and-training-of-personnel-for-nuclear-power-plants [Accessed: 2022-02-28].

IAEA 2022j. SSG76 – Conduct of Operations at Nuclear Power Plants: Specific Safety Guide. [Online] https://www.iaea.org/publications/14907/conduct-of-operations-at-nuclear-power-plants [Accessed: 2022-02-28].

IAEA 2023. *Nuclear Power Capacity Trend.* [Online] https://pris.iaea.org/PRIS/WorldStatistics/WorldTrendNuclearPowerCapacity.aspx [Accessed: 2022-02-28].

Izzeldin et al. 2023 – Izzeldin, M., Muradoğlu Y.G., Pappas, V., Petropoulou, A. and Sivaprasad, S. 2023. The impact of the Russian-Ukrainian war on global financial markets. *International Review of Financial Analysis* 87, DOI: 10.1016/j.irfa.2023.102598.

Kuzemko et al. 2022 – Kuzemko, C., Blondeel, M., Dupont, C. and Brisbois, M.C. 2022. Russia's war on Ukraine, European energy policy responses & implications for sustainable transformations. *Energy Research & Social Science* 93, DOI: 10.1016/j.erss.2022.102842.

Memorandum on security assurances in connection with Ukraine's accession to the Treaty on the Non-Proliferation of Nuclear Weapons, December 1994, 05. [Online] https://treaties.un.org/Pages/showDetails.aspx?objid=0800000280401fbb [Accessed: 2022-04-28].

Ministry of Energy of Ukraine 2022. *Integration into the European electricity network ENTSO-E.* [Online]. https://www.mev.gov.ua/reforma/intehratsiya-u-yevropeysku-elektromerezhu-entso-e [Accessed: 2022-02-28] (*in Ukrainian*).

Ministry of Energy of Ukraine 2022. *The history of energy.* [Online] https://www.mev.gov.ua/storinka/istoriya-enerhetyky [Accessed: 2022-02-28] (*in Ukrainian*).

Nastos, G. 2022. European Union's Energy Security in the Aftermath of Russia's War in Ukraine: From Dependence to Independence. *HAPSc Policy Briefs Series* 3(2), pp. 153–160, DOI: 10.12681/hapscpbs.33795.

Office of the Prosecutor General 2023. *Press conference of Andriy Kostin about the work of the Prosecutor General's Office for the year of full-scale aggression of the Russian Federation.* [Online] https://www.gp.gov.ua/ua/posts/preskonferenciya-andriya-kostina-pro-roboti-prokuraturi-za-rik-povnomasstabnoyi-agresiyi-rf [Accessed: 2022-02-28] (*in Ukrainian*).

Pandey, D.K. and Kumar, R. 2023. Russia-Ukraine War and the global tourism sector: A 13-day tale. *Current Issues in Tourism* 26(5), pp. 692–700, DOI: 10.1080/13683500.2022.2081789.

Prăvălie, R. and Bandoc, G. 2018. Nuclear energy: Between global electricity demand, worldwide decarbonisation imperativeness, and planetary environmental implications. *Journal of Environmental Management* 209, pp. 81–92, DOI: 10.1016/j.jenvman.2017.12.043.

Resolution General Conference IAEA 2011. Resolution GC(55)/RES/9, September 2011, 22. Measures to strengthen international cooperation in nuclear, radiation, transport and waste safety [Online] https://www.iaea.org/sites/default/files/gc/gc55res-9_en.pdf [Accessed: 2022-02-28].

Resolution General Conference IAEA 2012. Resolution GC(56)/RES/9, September 2012, 20. Measures to strengthen international cooperation in nuclear, radiation, transport and waste safety. [Online] https://www.iaea.org/sites/default/files/gc/gc56res-9_en.pdf [Accessed: 2022-02-28].

Resolution General Conference IAEA 2015. Resolution GC(59)/RES/9 of September 2015, 17. Measures to strengthen international cooperation in nuclear, radiation, transport and waste safety. [Online] https://www.iaea.org/sites/default/files/gc/gc59resdec-2015_en.pdf [Accessed: 2022-02-28].

Resolution General Conference IAEA 2022. Resolution GC(66)/RES/6 of September 2022, 30. Nuclear and radiation safety. [Online] https://www.iaea.org/sites/default/files/gc/gc66-res6.pdf [Accessed: 2022-02-28].

Roland, G. 2023. The war in Ukraine and its consequences for the international order and North East Asia. *Asia and the Global Economy* 3(1), DOI: 10.1016/j.aglobe.2023.100056.

Smith, D.C. 2022. Playing with fire: military attacks against a civilian nuclear power station. *Journal of Energy & Natural Resources Law* 40(2), pp. 159–164, DOI: 10.1080/02646811.2022.2057727.

Taebi, B. and Mayer, M. 2017. By accident or by design? Pushing global governance of nuclear safety. *Progress in Nuclear Energy* 99, pp. 19–25, DOI: 10.1016/j.pnucene.2017.04.014.

The State Nuclear Regulatory Inspectorate of Ukraine 2022. *On the situation at the Chornobyl NPP and the state of safety of other nuclear facilities*. [Online] https://snriu.gov.ua/news/pro-situaciyu-na-chornobilskij-aes-ta-stan-bezpeki-inshih-yadernih-ustanovkah [Accessed: 2022-02-28] (*in Ukrainian*).

United Nations 1977. Protocols Additional to the Geneva Conventions of 12 August 1949. [Online] www.icrc.org/en/doc/assets/files/other/icrc_002_0321.pdf [Accessed: 2022-02-28].

United Nations 1994a. The Convention on Nuclear Safety (CNS). [Online] https://www.iaea.org/topics/nuclear-safety-conventions/convention-nuclear-safety [Accessed: 2022-02-28].

United Nations 1994b. Participants of the Convention on Nuclear Safety (CNS). [Online] https://treaties.un.org/pages/showDetails.aspx?objid=08000002800a52b4 [Accessed: 2022-04-28].

United Nations 2015. *Take Action for the Sustainable Development Goals*. [Online] https://www.un.org/sustainabledevelopment/sustainable-development-goals/[Accessed: 2022-02-28].
Verkhovna Rada of Ukraine 2022. *The situation on the nuclear facilities of Ukraine on March 31, 2022*. [Online] https://www.rada.gov.ua/news/razom/221143.html [Accessed: 2022-02-28] (*in Ukrainian*).
Von Hippel, D. 2023. Implications of the 2022–2023 Situation in Ukraine for Possible Nuclear Weapons Use in Northeast Asia. *Journal for Peace and Nuclear Disarmament,* DOI: 10.1080/25751654.2023.2201367.
WANO 2022. *Who Are Our Members?* [Online] https://www.wano.info/members/who-are-our-members [Accessed: 2022-02-28].
WANO 2023. *Our history*. [Online] https://www.wano.info/about-us/our-history [Accessed: 2022-02-28].
WENRA 2023. *Wenra's Mission*. [Online] https://www.wenra.eu/about [Accessed: 2022-02-28].
Wiertz et al. 2023 – Wiertz T., Kuhn, L. and Mattissek, A. 2023. A turn to geopolitics: Shifts in the German energy transition discourse in light of Russia's war against Ukraine. *Energy Research & Social Science* 98(2), DOI: 10.1016/j.erss.2023.103036.
WNISR 2022. *Nuclear Power 2022. Did We Pass "Peak Nuclear" Years Ago? IAEA Revises Statistics.* [Online] https://www.worldnuclearreport.org/Did-We-Pass-Peak-Nuclear-Years-Ago.html [Accessed: 2022-02-28].
WNISR 2023. *The World Nuclear Industry Status Report 2022.* [Online] https://www.worldnuclearreport.org/IMG/pdf/wnisr2022-v3-hr.pdf [Accessed: 2022-02-28].
Woo, H.T. 2013. Analytic study for physical protection systems (PPS) in nuclear power plants (NPPs). *Nuclear Engineering and Design* 265, pp. 932–937, DOI: 10.1016/j.nucengdes.2013.09.025.
World Nuclear Association 2023. *Plans For New Reactors Worldwide.* [Online] https://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx [Accessed: 2022-02-28].

Yevheniia Duliba, Nataliia Chudyk

Dobre lekcje ze złych doświadczeń: konfrontacja z ryzykiem i zarządzanie bezpieczeństwem jądrowym na Ukrainie

Streszczenie

Na podstawie przeglądu literatury naukowej, oświadczeń MAEA i ukraińskich instytucji, w artykule podjęto próbę analizy obecnych problemów w energetyce jądrowej Ukrainy w czasie wojny na przykładzie zajętej elektrowni jądrowej Zaporoże, która pokazuje wpływ tej sytuacji na globalne bezpieczeństwo jądrowe. Studium ukazane w artykule nakreśla również niektóre rozwiązania tego trwającego kryzysu i uświadamia, że istnieje pilna potrzeba nowej strategicznej wizji na poziomie globalnym w zakresie bezpieczeństwa jądrowego i ochrony środowiska.

Podejście „prób i błędów" nie jest pożądaną praktyką zapewniania bezpieczeństwa jądrowego na świecie i dlatego dziś świat musi zastosować lekcje wyciągnięte podczas wojny na Ukrainie, aby lepiej chronić ludzi i środowisko.

Obecna sytuacja na świecie jest złożona i wymaga rozsądnych rozważań, uwzględniających aspekty społeczne, gospodarcze, środowiskowe i geopolityczne. Wprowadzenie minimalnych standardów bezpieczeństwa MAEA, które można wyegzekwować w sposób niezgodny z prawem, rewizja postanowień statutu MAEA i jego zmiana poprzez zapewnienie organizacji funkcji utrzymania harmonizacji wymagań jądrowych, potrzeba poprawy istniejących standardów MAEA w zakresie podejmowania środków podczas budowy elektrowni jądrowych w celu ich ochrony przed atakami rakietowymi, a także podczas eksploatacji elektrowni jądrowych, są analizowane jako niezbędne kroki w celu rozwiązania kwestii poprawy bezpieczeństwa jądrowego na Ukrainie, w Europie i na świecie. Współpraca Ukrainy z takimi państwami jak USA, Japonia, Korea Południowa, Francja czy Wielka Brytania oraz utworzenie koalicji może pomóc na poziomie międzynarodowym wywrzeć presję na ONZ i MAEA, aby wycofały wszystkie wojska i zapasy amunicji z elektrowni jądrowej w Zaporożu.

Słowa kluczowe: energia, bezpieczeństwo jądrowe, elektrownia jądrowa, wojna na Ukrainie, standardy MAEA