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Energy security strategy under martial law: Environmental risks and areas of their legal regulation

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Abstract

The purpose of the study was to substantiate legal mechanisms for ensuring energy security under martial law, considering environmental risks, for the development of a comprehensive strategy focused on sustainable development. The study was conducted using systemic and structural, comparative, formal legal, and historical legal methods. The study systematised the environmental consequences of the destruction of Ukraine's energy infrastructure as a result of Russian aggression through the development of a comprehensive methodology for assessing energy and environmental damage under martial law. A classification of the environmental costs of war has been drawn up across five categories, with a total monetary estimate exceeding USD 200 billion: greenhouse gas emissions from combat operations and reconstruction amount to USD 42.6 billion; fires caused by the war – USD 9.1 billion; toxic sediments following the destruction of the Kakhovka Hydroelectric Power Plant – USD 31.5 million; construction waste and debris – USD 140 billion; contaminated and mined land – USD 9-10 billion. A comparative analysis of the impact of armed conflicts on energy systems across four regions of the world was conducted,

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revealing an evolutionary transformation of compensation mechanisms – from the successful Kuwaiti precedent, with 94% of claims paid, to ineffective contemporary mechanisms with no payments at all – thus confirming the critical dependence of effectiveness on the level of international political support. A comparative matrix of international precedents was created, which demonstrated the evolution of international legal mechanisms from a fragmentary response to systemic compensation institutions with the expansion of the subject composition of responsibility. Typological patterns of application of international legal instruments of compensation were revealed, in particular, a direct correlation between the effectiveness of compensation procedures and the level of international political support was established. The results of the study conceptualised the development of a new paradigm of national security based on a synergistic combination of energy and environmental legal mechanisms in the context of sustainable development

Keywords: ecocide; compensation mechanisms; international humanitarian law; ecosystem losses; greenhouse gases; restorative justice

Introduction

The Russian-Ukrainian War demonstrated the critical vulnerability of national energy systems and their direct impact on the economic stability of states. Simultaneously, the growing environmental challenges and the need for a transition to sustainable development require the search for new approaches to ensuring energy security that would harmoniously combine national interests with environmental imperatives. The legal regulation of these processes is of particular importance, since an effective regulatory framework is a key tool for coordinating the efforts of the state, business, and the international community. When conventional models of energy security are insufficient to respond to contemporary challenges, the relevance of the study of legal mechanisms for ensuring energy security in the context of environmental requirements becomes a priority.

The study of the relationship between energy security and environmental regulation has attracted the attention of a wide range of researchers who have considered various aspects of this complex problem. A significant contribution to understanding the mechanisms of the impact of environmental regulation on energy security was made by N. Aslam *et al*. (2024b), who showed that export activity increases energy risks, while industrial imports and economic growth contribute to their reduction. The researchers recommend the establishment of environmental regulation to control energy security risks, and reducing exports and increasing industrial imports to optimise domestic energy consumption. Regional features of this relationship were investigated by X. Zhao *et al*. (2023), who focused on spatial heterogeneity in China and found that environmental regulation contributes to higher levels of energy security, but its effect varies by region, and the positive impact increases when the degree of fiscal decentralisation and marketability crosses a certain threshold.

Strategic aspects of energy security in the context of sustainable development were considered by P.S. Varbanov (2022), who substantiated an integrated approach to overcoming environmental and energy challenges through a hierarchy of measures that begins with minimising the energy needs of global economies. The researcher emphasised that a strategy to achieve sufficient energy security can benefit from synergies,

further improving energy efficiency, reducing domestic energy needs, and making reasonable use of available local resources, especially waste. The legal mechanisms for harmonising environmental and security objectives of energy policy were analysed in detail by D.M. Schizer (2023), who proposed an innovative approach to the development of energy policy that simultaneously protects the environment and ensures national security. The researcher proposed a heuristic of "marginal costs of energy efficiency", according to which politicians should consider all the social costs of each source – private costs, national security costs, and environmental costs – and strive to replace high-cost sources with low-cost ones.

International legal aspects of energy security have been comprehensively investigated by T. Morgandi & J. Vinuales (2021), who analysed the concept of energy security as "continuous availability of energy resources at an affordable price" and the role of international law in addressing threats to energy security. The researchers found that the international legal framework largely focuses on the idea of energy as a "reserve" that is unevenly distributed among countries and creates vulnerabilities for energy-importing countries. The impact of geopolitical risks on the energy transition in the context of environmental regulation was investigated by Q. Wang *et al*. (2024a), applying a multivariate linear and nonlinear regression model for OECD countries and found a significant positive impact of geopolitical risk on the energy transition, with stronger environmental regulation and progress in green innovation significantly reinforcing this effect.

Specific aspects of energy security in the context of military conflict have been considered by several researchers. A. Nosach *et al*. (2024) analysed the legal regulation of ensuring national security under martial law, establishing that the financial security of the state as a component of national security is the basis for the economic development of the country, ensuring the sovereignty and integrity of the state. K. Hook & R. Marcantonio (2022) examined the environmental risks of the military conflict in eastern Ukraine, finding that the lack of international political will for "forgotten conflicts" increases the likelihood that shared environmental risks will be seen as just another point of the political agenda for negotiations.

Empirical studies of the impact of energy risks on achieving climate goals were conducted by O. Usman *et al*. (2024), who found that energy security risks hinder long-term goals of achieving zero emissions, with their impact decreasing over time to complete disappearance in approximately 5 years. The specific aspect of the relationship between environmental regulation and energy security through the prism of energy taxes was investigated by N. Aslam *et al*. (2024a), who found that environmental regulation significantly reduces the gap between energy consumption and production, and mitigates energy security risks by facilitating the energy transition. The economic security of Ukraine in the context of military operations was studied by V. Yesina *et al*. (2025), who conducted a correlation analysis of the density of the relationship between the economic security of the state and the introduction of energy-saving technologies, paying special attention to the implementation of EU directives and the concept of sustainable development with an emphasis on reducing Ukraine's energy dependence. However, the analysis of scientific literature revealed insufficient research on legal mechanisms for coordinating environmental regulation and energy policy at the level of national legislation, especially in emergency situations. The researchers ignored the issues of institutional support for the integration of environmental standards into the energy security system.

The purpose of the study was to identify legal mechanisms for integrating environmental principles into the state's energy security strategy

under martial law to ensure long-term sustainability of national security based on the principles of sustainable development. The objectives of the study were:

1) to systematise the environmental consequences of the destruction of Ukraine's energy infrastructure as a result of Russian aggression and carry out monetary assessment of categories of energy and environmental damage;

2) to identify typological patterns of application of international legal mechanisms for compensation of environmental damages through a comparative analysis of the impact of military conflicts on energy systems in different regions of the world;

3) to define legal mechanisms for minimising and compensating energy and environmental damages during the war, including the development of the concept of ecocide and the establishment of specialised international compensation institutions.

Materials and Methods

The methodological framework of the research included system and structural, comparative, formal legal, historical legal, and statistical and analytical methods. The case study method was used for a detailed analysis of four key international conflicts and specific incidents of destruction of Ukraine's energy infrastructure.

The first stage provided for the systematisation of the environmental consequences of the destruction of the energy infrastructure of Ukraine using a statistical and analytical method to classify empirical data into five categories of impact: greenhouse gases from military operations and reconstruction; fires caused by war; toxic sediment after the explosion of the Kakhovka Hydroelectric Power Plant; construction waste and debris; contaminated and mined land. Monetary valuation was carried out using the Social Cost of Carbon method at a rate of USD 185 per tonne of CO_2 equivalent (Rennert *et al*., 2022) and replacement cost methods for ecosystem services (US Environmental Protection Agency, 2001). The case-study method was used to analyse the explosion of the Kakhovka HPP on June 6, 2023, the flooding of mines in the Donetsk Oblast and the shelling of the Zaporizhia NPP (International Atomic Energy Agency, 2023) using reports on emissions of 180 million tonnes of CO_2 equivalent (Planetary Security Initiative, 2025), and data from Ukrenergo on the loss of generating capacity (Ukrenergo, 2023).

The second stage included a comparative analysis of international precedents through a detailed case study of four conflicts: the 1991 Gulf War with the arson of 600 oil wells and the creation of the UN Compensation Commission (Farber, 2022), the 1999 bombing of Yugoslavia with the damage to the HIP Petrohemija (Poolos, 2002), and the 2016 conflict with ISIS in Iraq with the arson of oil wells near Kayar (The Washington Post, 2018), and Russian aggression against Ukraine (Commission on security and cooperation in Europe, 2024). The analysis was based on analytical materials on the effectiveness of compensation mechanisms (Payne, 2005) and research by NASA Earth Observatory (2017) on the effects of oil fires.

The third stage was devoted to formal legal and historical legal analysis of contemporary legal mechanisms for minimising and compensating energy and environmental damage. The formal legal method was used to investigate Articles 35(3) and 55 of the Protocol I Additional to the Geneva Conventions (1977) and Article 441 of the Criminal Code of Ukraine (2001) on ecocide. The historical and legal method was used to analyse the evolution from the UN Compensation Commission to institutions through the study of resolution No. ES-11/5 (2022) and No. CM/Res (2023)3 (2023) of the Committee of Ministers of the Council of Europe.

Results

Energy security during war: challenges and environmental risks. The armed aggression of the Russian Federation against Ukraine, launched on February 24, 2022, has caused significant challenges to the state's energy security and created a complex of environmental risks that require immediate legal settlement. The energy infrastructure of Ukraine has become the target of systematic attacks by the aggressor, which has led to a critical disruption of the functioning of the energy system and large-scale environmental consequences that go beyond national borders. As of the beginning of 2025, as a result of massive rocket attacks and occupation of certain territories, more than 63,000 energy infrastructure facilities in Ukraine were damaged or destroyed (University of Leeds, 2025). Analysis of the targeting of such attacks shows the strategic nature of the use of energy infrastructure as a tool for waging war. According to the Ministry of Energy of Ukraine, during the three years of the war, the strikes led to the loss of approximately 10 GW of generating capacity and disabled all major thermal and hydroelectric power plants in the country (University of Leeds, 2025). This scale of destruction has created a critical threat to the state's energy security, depriving millions of citizens of access to electricity and heat.

The consequences for the population were particularly acute in the winter period of 2022-2023, when the intensity of attacks reached its maximum indicators. At the height of the attacks, Ukrainian consumers had to live in conditions of regular rolling blackouts, while the average household experienced approximately five weeks without electricity during the winter of 2022 (Ukrenergo, 2023). This situation required emergency measures to maintain power supply, including emergency synchronisation of the combined power system with the European network ENTSO-E (European Network of Transmission System Operators for Electricity) (2022), prompt repair of networks and generation, and mass involvement of backup power sources.

The environmental consequences of the destruction of energy infrastructure form a separate category of threats, which are characterised by long-term impact and cross-border nature. Ensuring energy sustainability in times of war is accompanied by serious environmental risks and damages, which are a significant component of armed conflict, but are often ignored by international law and compensation mechanisms due to the complexity of their quantification and the long-term nature of the consequences. Unlike direct economic losses from the destruction of energy infrastructure, which are directly calculated, environmental damages include transboundary effects of air pollution, degradation of ecosystem services, and long-term health impacts that require specialised assessment methodologies and an interdisciplinary approach to documentation. Building an energy balance using renewable energy sources is becoming critical not only for ensuring energy security, but also for minimising long-term environmental risks, especially in situations of armed conflict, when conventional energy infrastructure becomes the object of targeted attacks (Hurochkina & Kohut, 2023). According to estimates of the Ministry of Environmental Protection and Natural Resources of Ukraine, as of November 2024, after 1,000 days of full-scale war, the total direct damage to the environment reached USD 71 billion. The total amount of greenhouse gas emissions caused by the war is 180 million tonnes of carbon dioxide, including emissions from fighting, forest fires, and an additional 3.3 million tonnes of CO_2 from the movement of more than six million Ukrainians to various European countries (Ministry of Environmental Protection and Natural Resources of Ukraine, 2024).

The spatial distribution of environmental damage shows a special concentration in regions

with a high density of industrial facilities. Approximately 30% of the territory of Ukraine is contaminated with unexploded mines and ammunition, and intense shelling, forest fires, deforestation, and leaks of toxic substances negatively affected 30% of the country's nature reserve fund (Hryhorczuk *et al*., 2024). The situation is particularly critical in the Donetsk and Luhansk oblasts, where fighting has engulfed a region with a dense concentration of heavy industry and mines, which has led to anthropogenic environmental problems.

The flooding of coal mines in the occupied territories has created a long-term environmental threat on a regional scale. The cessation of water pumping at abandoned mines led to their flooding and the ingress of mine water saturated with heavy metals and salts into ground water and rivers. In 2019 alone, as a result of flooding of mines in the occupied Donbas, approximately 760 million m^3 of contaminated water entered the Siversky Donets River and then the Sea of Azov, bringing almost 2.5 million tonnes of dissolved salts and other pollutants there. As of 2023, more than 49 flooded mines in the occupied territories have been documented, including mines containing particularly hazardous waste, including toxic chlorobenzene in the "Oleksandr-Zakhid" mine or even the remains of nuclear explosions in the "Yunkom" mine, where a nuclear charge was detonated in 1979 (Hryhorczuk. *et al*., 2024).

Nuclear safety is the most critical aspect of environmental risks in times of war. In March 2022, Russian troops seized Europe's largest Zaporizhia NPP (ZNPP), turning it into a military facility and repeatedly exposing it to the risk of shelling (Kaminski, 2023). During the occupation, the plant completely lost its external power supply at least seven times due to fighting, which forced it to rely on backup diesel generators to cool its nuclear reactors (International Atomic Energy Agency, 2025). The International Atomic Energy Agency (IAEA) has repeatedly warned that attacks on ZNPP could lead to a nuclear accident with serious consequences, calling the situation "extremely dangerous" and one that has no precedent (Reuters, 2024). Any damage to the existing reactor or spent fuel storage facilities at ZNPP is fraught with radiation emissions, which will affect not only Ukraine, but also neighbouring states.

The destruction of oil and gas infrastructure has led to significant greenhouse gas emissions and air pollution. Targeted strikes on oil depots and refineries caused large-scale fires and emissions of combustion products. According to a study by the Greenhouse Gas Accounting Initiative, fuel burning as a result of attacks on oil storage facilities and refineries resulted in emissions of approximately 3.1 million tonnes of CO_2 equivalent during the first three years of the war (Planetary Security Initiative, 2025). The combustion of petroleum products was accompanied by emissions of toxic substances – sulphur oxides, nitrogen, and fine dust – which worsened air quality in large areas. The destruction of main gas pipelines had a cross-border environmental effect due to massive leaks of methane, a powerful greenhouse gas. In particular, explosions on gas pipelines, including sabotage on the Nord Stream gas pipeline in the Baltic Sea, led to a massive methane leak equivalent to 14 million tonnes of CO_2 emissions. In addition, damage to electrical substations caused leaks of technical gases and oils; in particular, the destruction of high-voltage equipment released approximately 1.1 million tonnes CO_2 equivalent of SF_6 into the atmosphere, with sulphur hexafluoride having a greenhouse potential tens of thousands of times higher than that of CO_2 (Planetary Security Initiative, 2025). Hydraulic infrastructure has been the target of particularly devastating attacks with catastrophic environmental consequences. The explosion of the Kakhovka HPP in June 2023 led to catastrophic flooding on the Dnipro River, flooding of dozens of settlements and agricultural land, and dehydration of the

Kakhovka Reservoir (Commission on Security and Cooperation in Europe, 2024). Approximately 1.25 million people, including 300 thousand children, in the southern regions lost stable access to drinking water after this anthropogenic accident (Hryhorczuk *et al*., 2024). The flood washed away industrial and agricultural facilities along the riverbed, causing oil products, fertilisers, pesticides, and other pollutants to enter the water.

The overall impact of war on the environment was characterised by significant direct greenhouse gas emissions. Total direct greenhouse gas emissions due to the war over three years are estimated at 230 million tonnes of CO_2 equivalent, which is comparable to the annual emissions of several medium-sized European countries (Planetary Security Initiative, 2025). Moreover, the collapse of the Ukrainian economy as a result of the war led to a drop in its regular industrial emissions by 23-26% in 2022 alone (Joint Research Centre, 2025). Thus, the war temporarily reduced anthropogenic pressure in the form of habitual industrial pollution, but instead added a new source of large-scale environmental damage – military energy destruction. A comprehensive monetary assessment of environmental external costs from military operations against energy infrastructure requires systematisation of heterogeneous categories of environmental damage to form an evidence base for compensation claims (Table 1).

Table 1. Inventory of key environmental external costs of the war in Ukraine

Impact category	Indicator	Value	Evaluation method	Monetary interpretation
Greenhouse gases (fighting + reconstruction)	Total emissions, Mt CO_2-eq	230	Social Cost of Carbon (185 USD/tonne)	≈USD 42.6 billion
Fires caused by war	Emissions, Mt CO_2-eq	49	SCC	≈USD 9.1 billion
Toxic precipitation after Kakhovka HPP explosion	Weight of sediments, tonnes	90,000	Hazardous waste disposal (≈350 USD/tonne)	≈USD 31.5 million
Construction waste and debris	Concrete volume, million tonnes	1,400	Unit cost 100 USD/tonnes	≈USD 140 billion
Contaminated/ mined land	Share of territory, %	30%	UNMAS 3,000 USD/ha	≈USD 9-10 billion

Source: created by the author based on the US Environmental Protection Agency (2001), K. Rennert *et al.* (2022), D. Hryhorczuk *et al.* (2024), M. Igini (2025), D. Gayle (2025), The Washington Post (2025), University of Leeds (2025)

The inventory of environmental external costs structured in Table 1 reflects contemporary methodological approaches of environmental economics and international environmental law to a comprehensive monetary assessment of heterogeneous categories of ecosystem losses through the integration of direct costs for the elimination of pollution, indirect losses from the degradation of ecosystem services, and the opportunity cost of lost natural resources in a single monetary assessment system. The methodological substantiation for monetarisation of environmental damage is based on a combination of market valuation methods for commodity resources, methods of declared benefits for intangible environmental benefits, and methods of replacement value for ecosystem services, which ensures the legal validity of compensation claims in international court proceedings. The differentiation of time horizons of environmental impact from short-term emissions to long-term consequences of resource degradation reflects the legal logic of distinguishing immediate compensation obligations and future recovery programmes, which correlates with the

international legal doctrine of dividing environmental responsibility into compensatory and restorative components. The integration of various data sources from national authorities to international institutions ensures verifiability of the assessments presented and creates a solid evidence base for substantiating claims for environmental damages in future legal proceedings against the aggressor state.

A strategy for ensuring energy security in war conditions should consider the complex nature of environmental challenges and integrate measures to minimise collateral damage to the environment. The need to simultaneously maintain the functioning of the power system through rapid network repairs, import electricity and distribution of backup power sources should be combined with prompt elimination of the consequences of accidents, pollution monitoring, and prevention of the most risky scenarios. Ukraine's experience demonstrates an urgent need for sustainable solutions, including the development of distributed generation and renewable energy sources that are less vulnerable to attacks, the creation of reserves and duplicate systems, the use of technologies for cleaning up emissions and rapid response to environmental incidents (Hryhorczuk *et al*., 2024). Integrating environmental principles into strategic energy security planning not only minimises long-term environmental impacts, but also increases the resilience of the energy system to future threats. The establishment of legal mechanisms for such integration is a critical task for ensuring national security in the context of modern hybrid conflicts.

Comparative analysis: the impact of military conflicts on energy and the environment in Ukraine and the world. The nature of the destruction caused to Ukraine's energy infrastructure in February 2022 – January 2025 has no precedent in Europe over the past seventy years, but military conflicts in other regions of the world have also been repeatedly accompanied by deliberate destruction of energy facilities and large-scale environmental consequences. Comparative analysis of such cases allows identifying spatial patterns and differences in the impact of war on energy security and the environment, and emphasising the uniqueness of the Ukrainian situation in terms of legal regulation and international responsibility. The spatial distribution of strikes on energy infrastructure in Ukraine is characterised by a comprehensive nature, which distinguishes this conflict from localised military operations in other regions. Attacks were carried out throughout the country, from the frontline to the western regions, creating critical challenges for national energy security. According to Ukrenergo, during the autumn-winter campaign of 2022-2023, Russian forces fired more than 1,200 missiles and drones at Ukrainian power facilities, purposefully trying to de-energise the entire country (Ukrenergo, 2023). Spatial analysis of these impacts shows that the central and northern regions suffered the most damage due to the location of powerful thermal power plants and distribution substations there. The Trypillya Thermal Power Plant near Kyiv was completely destroyed with the 100% loss of the generating capacity of Centrenergo, and major thermal power plants in Kharkiv Oblast (University of Leeds, 2025). In the south, hydroelectric power plants were severely damaged, including the complete destruction of the Kakhovka HPP and damage to the Dnipro HPP. As of May 2024, it was officially confirmed that all major thermal and hydroelectric power plants in Ukraine were affected by the attacks, that is, not a single significant generation facility remained intact (University of Leeds, 2025).

The historical precedent of deliberate destruction of energy resources as a military strategy was observed during the 1991 Gulf War, when Iraqi forces used "burnt land" tactics against Kuwait's oil fields. During this conflict, the

Resolution of the United Nations Security Council No. 687 (1991) was applied, which established the principle of environmental responsibility for military operations and established the United Nations Compensation Commission (UNCC), but this mechanism was only partially effective due to lengthy procedures and political difficulties. Approximately 600 oil wells were set on fire, causing up to 5 million barrels of oil to burn daily for several months. The black smoke from these fires formed giant plumes that settled in an oily "black rain" over a vast territory. CO_2 emissions from the Kuwaiti oil fires accounted for approximately 2% of global emissions this year, and soot emissions reached 3,400 tonnes per day (Hobbs & Radke, 1992). This led to a sharp deterioration in air quality and the release of toxic substances on the soil in the Bay region, cases of acid rain and a decrease in air temperature under smoke clouds. Millions of barrels of crude oil spilled into the Persian Gulf, forming one of the largest oil slicks in history, destroying a significant part of marine biota. The international response to the environmental consequences of the Kuwait war has set an important precedent in international law on compensation for environmental damage. Under the auspices of the United Nations, a Special Compensation Commission was established, which ordered Iraq to pay record amounts for environmental damage. According to the Commission's decisions, more than USD 5 billion in compensation was allocated for environmental recovery projects, which has become a precedent in international law (Farber, 2022). Kuwait's experience has shown that the large-scale destruction of energy resources in war is transboundary in nature, since atmospheric and marine pollution knows no borders, and the restoration of the environment requires enormous efforts and resources even after the end of hostilities.

The use of energy facilities as an instrument of environmental terrorism was observed during the conflict with the so-called "Islamic State" in Iraq. In this case, international legal instruments were ineffective due to the lack of a state subject of responsibility and insufficient international coordination, which limited the use of conventional compensation mechanisms. In 2016, retreating militants blew up oil wells near the city of Qayyarah, causing 25 oil fountains to burn uncontrollably for 9 months, covering an entire area with thick smoke (The Washington Post, 2018). Up to 2 million barrels of oil were lost, which led to contamination of soils and groundwater with oil and its combustion products. In the region, the incidence of respiratory and cardiovascular diseases has sharply increased, cases of livestock deaths and crop failures due to soot and toxins have been recorded. Simultaneously, militants set fire to a large sulphur storage plant, which released approximately 35,000 tonnes of sulphur dioxide into the atmosphere, forming acidic compounds that affected people and the environment within a radius of tens of kilometres (The Washington Post, 2018).

The European experience of military influence on industrial and energy facilities is represented by the case of the bombing of Yugoslavia in 1999, when NATO forces hit a petrochemical plant and an oil refinery in the city of Pančevo. Despite the creation of special mechanisms for assessing damage under the auspices of UNEP, the compensation process was ineffective due to political differences between the parties to the conflict and the lack of mandatory mechanisms for implementing decisions. Explosions at these sites formed a huge black cloud of smoke and caused tens of thousands of tonnes of toxic chemicals to be released into the environment (Poolos, 2002). Tens of thousands of tonnes of oil burned out and flowed into the Danube River during these strikes. Concentrations of vinyl chloride, dioxins, mercury, and other hazardous substances that threaten public health and transboundary pollution of the

Danube basin have sharply increased in the air and water around Pančevo. Over the following years, independent experts recorded an increase in the level of diseases of the respiratory and endocrine systems in the population of this region, and groundwater remained polluted for tens of kilometres around. The UN assessment identified Pančevo as the "hottest point" of environmental damage among several industrial accident sites in Yugoslavia, but the problem of complete cleaning up of these areas has not been solved even three years after the conflict (Poolos, 2002).

The global impact of the war in Ukraine on the energy processes and environmental policies of other states creates additional challenges for the international community. A full-scale war has triggered a global energy crisis, forcing European countries to urgently abandon Russian oil and gas, seek alternative supplies, and even temporarily return to coal for electricity generation (Kaminski, 2023). Germany and some other European Union states, such as Austria and the Netherlands, temporarily restarted coal-fired power plants in 2022 to compensate for gas shortages, which led to a short-term increase in CO_2 emissions. The European Union has accelerated investment in renewable energy and energy efficiency to reduce dependence on fossil fuels and improve the sustainability of energy supply.

The transformation of the Ukrainian energy strategy under the influence of military operations demonstrates the acceleration of energy reform processes. Despite the military destruction, the government of Ukraine in 2023 adopted an updated energy strategy of Ukraine until 2050, which provides for deep decarbonisation and integration into the European energy space (United Nations Committee on the Elimination of Racial Discrimination, 2024). The war actually accelerated energy reform processes by synchronising the grid with the continental European grid in record time, increasing incentives for renewable energy development, and designing a more decentralised energy system. Spatially, this means moving from a concentration of generation in several large nodes to dispersed capacities across the country, closer to the consumer, which simultaneously increases energy sustainability and reduces environmental risks. The transboundary nature of the environmental consequences of the war in Ukraine is manifested through air, water, and soil pollution, which is not limited to national borders. Fires at oil depots and industrial facilities released toxic substances that were transported by atmospheric flows to neighbouring countries, in particular, an increase in the level of fine dust and sulphur was recorded in the border areas of Poland and Moldova during intense shelling of fuel depots in Ukraine at the end of 2022. Pollution of the Black Sea as a result of fighting due to oil leaks and flooding of military equipment has affected marine ecosystems from the coast of Romania to Turkey, causing a mass death of dolphins, which scientists recorded in 2022.

Comparative analysis shows that the Ukrainian experience of the energy crisis during the war, although unique in scale and nature, confirms the general pattern of using energy infrastructure as a strategic goal in military conflicts. Spatial analysis of the consequences shows that regions with a high concentration of energy facilities suffer the most intense environmental impact, while nature recovers more slowly than infrastructure. If the energy system can be rebuilt in a few years, then land and water purification from pollution requires much more time and resources, which makes it necessary to develop effective legal mechanisms for liability and compensation for environmental damage. Systematisation of the experience of various military conflicts in the field of destruction of energy infrastructure and their environmental consequences allows identifying typological patterns in the application of international legal instruments of compensation (Table 2).

Table 2. Comparative matrix of international precedents

No.	Conflict (year)	Energy facilities/ target	Quantitative damage	Responsible entity	International legal response	Compensation mechanism	Payment amount/ status
1	Gulf War (1991)	≈600 oil wells set on fire	>1 Gt CO_2-eq	Iraq	UN SECURITY COUNCIL 687 (1991)	UNCC	USD 5.26 billion awarded, 4.97 billion paid
2	Lebanon-Israel conflict (2006)	Jiyeh TPP: 15-30 thousand tonnes of fuel oil	170 km of coast, 15-30 thousand tonnes of oil	Israel	UN GA 60/222; UNEP PCA	Eastern Med. Oil Spill Trust Fund	USD 856 million declared, no payments
3	ISIS retreat (Iraq/ Syria, 2016)	19-40 ignited wells (Qayyarah)	≈2 million barrels; smoke for 9 months	ISIS	UNEP post-conflict reports	—	—
4	Russian aggression against Ukraine (2022-24)	63,000 damaged power facilities, strikes on TPPs/HPPs	230 Mt CO_2-EQ; 49 Mt CO_2-eq of fires	Russian Federation	UN GENERAL ASSEMBLY ES-11/5 (2022)	Register of Damage for Ukraine (2024)	Collection of applications continues

Source: created by the author based on E. Cusato (n.d.), E. Pianin (2003), C. Payne (2005), J. Arbid (2015), UN Environment Programme (2016), NASA Earth Observatory (2017), S. van den Berg (2024), World Bank Group (2025), M. Igini (2025), D. Gayle (2025)

The presented comparative matrix in Table 2 demonstrates the evolution of international legal approaches to resolving the environmental consequences of military operations against energy infrastructure, revealing a fundamental transformation from a fragmentary response to systemic compensatory mechanisms with an expansion of the subject composition of liability and the subject coverage of losses. The analysis of the chronological sequence of conflicts shows the development of case law in the field of environmental compensation, where the Kuwaiti experience has created a basic model for assessing and compensating environmental damage through specialised international institutions, the Yugoslav precedent has expanded the understanding of the transboundary nature of environmental damage from military operations, the Iraqi case has demonstrated the complexity of documenting environmental consequences in a prolonged conflict, while the Ukrainian situation actualises the need to create new legal instruments to resolve the consequences of systematic targeted destruction of critical energy infrastructure as a method of warfare. A comparative analysis of the mechanisms of international legal response confirms the tendency to strengthen institutional support for environmental responsibility, while the effectiveness of compensation procedures correlates with the level of international political support and the availability of mechanisms for enforcement of decisions.

Legal mechanisms for minimising and compensating energy and environmental losses during the war. Large-scale destruction of the environment as a result of military operations against energy facilities requires a comprehensive legal response, covering both measures to prevent and reduce damage, and mechanisms for bringing those responsible to justice and compensating for the damage caused. In the context of the war in Ukraine, this issue has become critical due to environmental damage and the need

to develop effective legal tools to protect the environment from military impacts of an energy nature. International humanitarian law forms the basic regulatory framework for limiting the devastating impact of war on the environment through a system of prohibitions and restrictions on the methods of warfare. Protocol I Additional to the Geneva Conventions (1977), Article 35(3), explicitly prohibits the use of methods of war that result in large-scale, long-term and serious damage to the natural environment. Article 55 of this protocol obliges belligerents to protect the natural environment from mass destruction during a conflict, requiring that the environmental factor be considered when choosing the means of attack. However, the practical effectiveness of these provisions is limited by the high criteria for proving the "scale, duration and severity" of environmental damage, which creates significant obstacles to their application in specific judicial procedures.

The development of international legal approaches to environmental protection during armed conflicts has received a new impetus as a result of the Ukrainian crisis. In December 2022, the UN General Assembly approved the special Protection of the Environment in Relation to Armed Conflicts (PERAC) prepared by the International Law Commission (Kaminski, 2023). These 27 principles create a comprehensive system of measures at all stages of the conflict: from the obligation of states to conduct a preliminary assessment of the environmental consequences of hostilities to recommendations for the restoration of the environment after the end of hostilities. Although the PERAC principles have the status of "soft law" and do not create direct legal obligations, their unanimous adoption at the UN represents the largest update of legal approaches in this area in the last fifty years (Kaminski, 2023). Experts see these guidelines as a tool to increase the priority of environmental protection during war and encourage states to integrate environmental considerations into military planning.

The national legislation of Ukraine contains a developed system of norms of criminal liability for environmental destruction in war conditions, which allows for effective prosecution of environmental crimes. Section 8 of the Criminal Code of Ukraine "Crimes against the environment" establishes a comprehensive system of punishments for environmental offences, including articles 236-254, which cover violations of environmental safety rules, pollution of atmospheric air, water, land, destruction of plant life objects, and other environmental crimes. Article 438 of the Criminal Code of Ukraine "War crimes" provides legal grounds for bringing to justice for the destruction of the environment during military operations, if it is the result of illegal methods of warfare, in particular, attacks on civilian infrastructure with a known environmental effect (Criminal Code of Ukraine, 2001). Code Article 441 on ecocide, which criminalises intentional actions aimed at mass destruction of plant or animal life, poisoning of the atmosphere or water resources, and other actions that can lead to an environmental catastrophe. The Office of the Prosecutor General of Ukraine (2024) created a specialised unit for documenting war crimes against the environment, which as of 2023 registered more than 6,500 facts of crimes against nature committed during Russian aggression. Among these acts, a special place was occupied by explosions of oil depots, shelling of chemical enterprises, destruction of forests, flooding of mines, and the explosion of the Kakhovka HPP, which are being investigated as possible deliberate ecocidal activities. The qualification of the destruction of the Kakhovka Dam as an ecocide is an important precedent in national judicial practice. In June 2023, Ukrainian law enforcement agencies officially qualified this act as an ecocide, considering the large-scale long-term consequences for the ecosystems of the

Lower Dnipro and the Black Sea (Commission on Security and Cooperation in Europe, 2024). This qualification creates a legal basis for bringing to justice specific military commanders and officials of the Russian Federation, and forms the evidence base for future international judicial procedures.

The regulatory framework of Ukraine demonstrates the evolution of approaches to integrating environmental principles into strategic planning of energy security, which is becoming critical for ensuring the long-term sustainability of the state in the conditions of martial law and post-war reconstruction. Approval by the Cabinet of Ministers of Ukraine of the National Action Plan on renewable energy for the period up to 2030 (Order of the Cabinet of Ministers of Ukraine No. 761-r, 2024) lays down a comprehensive system of legal mechanisms for the transformation of the energy sector by setting an ambitious target for the share of renewable energy sources in gross final energy consumption at 27% by 2030, with the simultaneous development of distributed generation with a capacity of more than 2,000 MW and the creation of energy storage facilities with a capacity of 1,000 MW. The conceptual foundations of this transformation are reflected in the previous energy strategy of Ukraine for the period up to 2035 (Order of the Cabinet of Ministers of Ukraine No. 605-r, 2017), which, despite losing force in April 2023, laid the foundation for understanding the need to diversify energy sources and reduce dependence on imported energy carriers. Simultaneously, the environmental component of energy policy received institutional support through the National Waste Management Strategy in Ukraine until 2030 (Resolution of the Cabinet of Ministers of Ukraine No. 392, 2020), which established the principles of a circular economy for the development of bioenergy with the potential to produce up to 2 billion cubic metres of biogas annually and replace 15% of natural gas consumption in the municipal sector. An integrated approach to environmental constraints for traditional energy is embodied in the national plan to reduce emissions from large combustion plants (Order of the Cabinet of Ministers of Ukraine No. 1363-r, 2021), which provides for the gradual decommissioning or modernisation of 40% of the capacity of thermal power plants until 2033, while simultaneously stimulating the development of clean electricity production technologies, which creates a legal mechanism for the fundamental transformation of the structure of the energy balance of Ukraine in favour of environmentally friendly technologies.

The strategic vector of development based on the principles of sustainable development is conceptualised in the current energy strategy of Ukraine for the period up to 2050 (Order of the Cabinet of Ministers of Ukraine No. 373-r, 2023), which defines the achievement of climate neutrality in the energy sector by 2050 with interim goals of reducing greenhouse gas emissions by 65% by 2030 compared to the level of 1990, which requires a radical restructuring of the energy system through the integration of environmental principles into all aspects of energy policy. National environmental strategy of Ukraine for the period up to 2030 (Order of the Cabinet of Ministers of Ukraine No. 761-r, 2021) complements this approach by establishing specific mechanisms for coordinating environmental regulation and energy policy, including the development of integrated systems for monitoring environmental risks from energy infrastructure and implementing preventive measures to minimise potential damage during emergencies. The synergistic effect of combining these regulations creates a comprehensive system of legal instruments for ensuring energy security based on environmental sustainability, which meets contemporary challenges of hybrid conflicts and the need to form energy systems that are resistant to external threats.

Administrative and legal mechanisms for assessing environmental damage in Ukraine have undergone significant reform through the introduction of specialised institutional and methodological tools to ensure effective documentation of environmental damage as a result of Russian aggression. The Ministry of Environmental Protection and Natural Resources of Ukraine has developed and approved a number of specialised methods for calculating losses, in particular "Methodology for determining the amount of damage caused to land, soils as a result of emergencies and/or armed aggression and military operations during martial law" (Order of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 167, 2022) and "Methodology for calculating unorganised emissions of pollutants or mixtures of such substances into the atmospheric air as a result of emergencies and/or during martial law and determining the amount of damage caused" (Order of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 175, 2022), which allow estimating the losses from air, water, land pollution and forest destruction as a result of military operations in monetary terms. To systematise the collected data, the digital platform "Ecozagroza" was created, which in December 2022 officially became part of the unified national online platform "EcoSystem" and functions as a centralised database on the environmental consequences of Russian aggression, through which Ukrainians reported to the ministry approximately more than 2.2 thousand facts of the impact of military operations on the environment (Ministry of Environmental Protection and Natural Resources of Ukraine, 2022). These methodological tools facilitate a unified approach to documenting damages and provide the necessary evidence base for future claims for compensation at the national and international levels, which is critical for the implementation of the "polluter pays" principle in international litigation and the establishment of comprehensive compensation mechanisms within the framework of post-war reconstruction based on sustainable development.

International liability and compensation mechanisms play a crucial role in ensuring compensation for environmental damage, since the scale of damage caused by the war in Ukraine significantly exceeds the capabilities of national jurisdiction. Ukraine has initiated appeals to several international courts to protect its rights and interests. The case application of the International Convention on the Elimination of all Forms of Racial Discrimination (Ukraine v. Russian Federation) (International Court of Justice, 2024), in which Ukraine proves that the chronic water crisis, the destruction of protected areas, and other environmental consequences of the occupation of Crimea disproportionately harm Crimean Tatars and ethnic Ukrainians, forming a manifestation of "environmental racism". This statement is based on Article 5 e (IV) of the CERD, as the United Nations Committee on the Elimination of Racial Discrimination (2023; 2024) interprets it as a guarantee of the right to a healthy environment and recognises the impact of "environmental racism" on vulnerable groups. The Court's ability to award reparations for environmental damage has already been confirmed by decisions in Costa Rica V. Nicaragua (2018) and Argentina v. Uruguay (2006). In addition, the advisory opinion of the ICJ of 23 July 2025 on the climate obligations of states confirmed that serious pollution or degradation of the environment can constitute an internationally wrongful act (Shah, 2025; International Court of Justice, 2025). The combination of these precedents creates a procedural bridge to the national qualification of ecocide provided for in Article 441 of the Criminal Code of Ukraine (2001), and demonstrates that international law allows effectively holding offending states accountable for large-scale degradation of ecosystems during war.

The creation of a special international compensation mechanism is considered by the international community, including the Council of Europe, the European Union, and more than 40 partner states, as the most promising area for ensuring compensation for environmental damage. UN General Assembly Resolution No. ES-11/5 (2022), which recognised Russia's responsibility for aggression and recommended the creation of a damage register to document evidence of damage, losses, and damage caused by the war. The resolution laid the political and legal basis for further institutional steps towards the establishment of a compensation mechanism. Practical implementation of the compensation mechanism began in May 2023 with the creation under the auspices of the Council of Europe of the International Register of Damage caused by aggression against Ukraine, which was joined by more than forty countries and the European Union (Council of Europe, 2023; Council of Europe & RF4U, 2024; Justice Info, 2024). The mandate of the International Register of Damage covers the collection and storage of information on all cases of damage, including property, environmental and human damages, which can then be used to review compensation claims. According to the official data of the Register (Register of Damage, 2024). The total amount of compensation sought by the applicants for the applications received reaches EUR 1,012 billion, while for the recorded applications this amount is EUR 184 million. The categories of applications explicitly include category B3 "Damage to the environment and natural resources", which includes B3.1 "Environmental damage" and B3.2 "Looting and/or appropriation of natural resources", which provides a comprehensive approach to documenting the environmental consequences of war.

Procedure for submitting applications to the Register of Damage established by the Resolution of the Committee of Ministers of the Council of Europe No. CM/Res(2023)3 (2023), defined by the document "Rules Governing the Submission, Processing, and Recording of Claims". Applicants can be individuals and legal entities, and the State of Ukraine, and the submission is made exclusively in electronic form through the Diia portal. For category B3 "Damage to environment and natural resources", in particular subcategory B3.1 "Environmental damage", only the State of Ukraine, including its regional and local authorities, has the right to submit claims. The form for submitting such claims requires a detailed description of the nature of the damage, its causal relationship with military operations, the method of calculating the damage, and a digitised evidence package that provides thorough documentation of the environmental consequences of aggression.

The financing of the compensation mechanism remains a key issue of international legal settlement. Ukraine and a number of partner states insist on using frozen Russian assets, including approximately USD 300 billion of the Russian Federation's gold and foreign exchange reserves seized abroad. Currently, the search for legal ways to legally allocate these funds for the restoration and environmental reclamation of Ukraine continues. An alternative approach is to create an international fund with contributions from partner states or collect reparations from the Russian Federation under a future peace treaty. The "polluter pays" principle, where the aggressor state acts as the subject of responsibility, is at the heart of all these approaches (Farber, 2022).

Kuwait's precedent demonstrates the possibility of a broad interpretation of compensatory obligations in the field of environmental damage. The UN Compensation Commission recognised not only direct environmental damage, but also "loss of ecosystem services", including the cost of reforestation, water treatment, and restoration of wetlands instead of those destroyed by oil spills

(Farber, 2022). Ukraine plans to apply a similar approach, calculating compensation both to cover direct costs for mine clearance, clearing of territories and restoration of nature reserves, and to compensate for long-term environmental losses from disruption of natural processes.

The development of the concept of ecocide as an international crime has become critical under the influence of the environmental consequences of the war in Ukraine. In 2021, an independent expert panel of lawyers chaired by Philippe Sands proposed a draft definition of ecocide for inclusion in the Rome Statute of the International Criminal Court; however, this draft remains under discussion by states parties, with no consensus yet reached: "widespread or long-term and severe damage to any element of the environment, committed knowingly and without lawful justification" (Sands & Fall Sow, 2021). The adoption of such a ruling would give the International Criminal Court jurisdiction to prosecute those responsible for such acts. Within its existing jurisdiction, the International Criminal Court may consider environmental aspects as aggravating circumstances of war crimes. The deliberate destruction of civilian facilities resulting in a spill of dangerous substances can qualify as a war crime due to an attack on civilian infrastructure combined with illegal methods of warfare. Ukraine has submitted to the International Criminal Court an official report on the destruction of the Kakhovka Hydroelectric Power Plant as part of the investigation into the situation in Ukraine (ICC, 2023), as this act is considered as a possible war crime that caused civilian deaths and mass destruction of the environment.

Legal management of environmental damage recovery includes the development of specialised programmes and funds to help affected countries in post-conflict environmental recovery. The United Nations Environment Programme has assessed and coordinated the cleaning of contaminated areas in the Balkans and Kuwait, and is currently engaged in similar work in Ukraine. A special fund platform "Green Restoration of Ukraine" was created together with the European Union to finance projects on forest restoration, water purification, renewable energy development, and other environmental initiatives during and after the war (Hryhorczuk *et al*., 2024). The application of the principle of "restorative justice" provides for forcing the guilty party to carry out environmental rehabilitation with their own funds instead of simple monetary compensation. In a potential peaceful settlement with the Russian Federation, Ukraine will insist on including an environmental component due to the aggressor's obligations to provide technical and financial assistance for the elimination of oil spills, the management of hazardous war waste, and the restoration of the nature reserve fund, which was affected by 30% (Hryhorczuk *et al*., 2024). This approach is consistent with Ukraine's European aspirations, as the implementation of the environmental sections of acquis communautaire will require the restoration of water, air, and soil quality standards, which is directly related to the elimination of the consequences of the war.

Legal mechanisms for ensuring energy security in war conditions should be considered in an indissoluble connection with environmental safety due to the need to balance military necessity and preserve the environment. Ukraine puts this philosophy in its strategic documents, proclaiming the principles of sustainability and greening as one of the priorities of the post-war reconstruction plan. International law is in the process of transformation under the influence of Ukrainian events due to the resumption of discussions on strengthening responsibility for ecocide and the creation of more effective compensation institutions. An objective legal approach to solving environmental problems of war includes professional damage assessment, proper documentation,

bringing the perpetrators and the aggressor state to justice, and mobilising international support for environmental restoration as necessary conditions for ensuring full-fledged energy security with a restored and protected energy system and a restored natural environment (Hryhorczuk *et al*., 2024; Commission on Security and Cooperation in Europe, 2024). The synergistic effect of the combination of energy and environmental legal mechanisms creates the basis for the establishment of a new paradigm of national security focused on sustainable development. The successful implementation of Ukraine's energy strategy until 2050 requires the integration of sustainable development principles into all aspects of energy policy, including legal support for the transition to a climate-neutral energy sector, while simultaneously achieving the goals of reducing greenhouse gas emissions by 65% by 2030 compared to the level of 1990 (Hurochkina & Kohut, 2023). This conceptual integration opens up prospects for the development of comprehensive legal instruments that can ensure the long-term resilience of the state to energy and environmental threats in future conflicts.

Discussion

The results of the study demonstrate a fundamental transformation of approaches to ensuring energy security in the context of modern military conflicts, confirming the need to integrate environmental principles into strategic planning of national security. The identified patterns are consistent with the theoretical study by M. Radulescu *et al.* (2024), who investigated the impact of environmental regulation, energy efficiency, and green technologies on CO_2 emissions in Chinese provinces, and emphasised the importance of investigating the relationship between environmental regulation and energy security to ensure sustainable development. The identified regional differences and spatial dependence in energy security correlate with the conclusions of Chinese researchers about the variability of the impact of environmental regulation depending on the degree of fiscal decentralisation and marketability, but the Ukrainian experience demonstrates a fundamentally different context for applying these principles due to military necessity.

The identified patterns complement the study by W. Leal Filho *et al*. (2024), which included a systematic analysis of the environmental consequences of the Russian invasion of Ukraine, emphasising the uniqueness of the Ukrainian situation due to the combination of high density of energy infrastructure with systematic attacks. The researchers noted that the war in Ukraine illustrates the dangers that arise from conflict in an urbanised landscape that is significantly modified by human activity and requires active environmental risk management. The established correlation between the nature of military operations and environmental consequences confirms the thesis that modern conflicts in industrialised regions create fundamentally new challenges for international law and environmental policy. The theoretical foundations of sustainable development were empirically confirmed in the analysis of Ukraine's energy transformation conducted by C. Winkler *et al*. (2024), who formulated criteria for restoring energy systems after large-scale destruction: rapid reconstruction of infrastructure, increasing resistance to external threats, minimising import dependence, and reducing the environmental burden. The introduction of these principles into the practice of compensation mechanisms creates opportunities for achieving the double effect of restoring destroyed infrastructure and modernising the energy system in accordance with the principles of sustainability. The documented transition to the use of renewable energy sources under martial law confirms the possibility of transforming crisis challenges into catalysts for structural change, and the use

of high-quality solar technologies demonstrates the practical implementation of the concept of energy security through source diversification and reduction of dependence on centralised systems.

The established direct correlation between the effectiveness of compensation procedures and the level of international political support was confirmed by B. Steffen *et al*. (2020), who analysed the navigation of the energy transition in the context of global crises. The researchers stressed the need for a coordinated approach to achieving energy security and environmental protection goals through adaptive policies that can withstand economic shocks. The researchers noted that energy policies should simultaneously consider short-term crisis response challenges and long-term decarbonisation goals. In particular, the results found that in military conditions, such coordination becomes critically necessary to prevent a long-term environmental catastrophe with transboundary consequences. The identified mechanisms for integrating environmental and energy principles into strategic planning confirm the concept of shock-resistant policies, according to which energy solutions should be adaptive to crisis circumstances and ensure structural changes in the energy system. The transformation of legal mechanisms from a fragmented response to systemic compensation institutions is consistent with research by A. Boute (2022) on the role of international law in ensuring energy security in the new geopolitical reality. The researcher analysed how the tools of energy trade liberalisation and investment protection contributed to the creation of dangerous dependencies that are now at the centre of threats to energy security. A. Boute (2022) stressed that international energy, trade, and investment law should be reformed to allow states to respond adequately to the use of energy as a weapon without neutralising the contribution of liberalising instruments to efficient energy supply. The results of the study extend this concept, showing that contemporary hybrid conflicts require fundamentally new legal instruments that would cover not only conventional aspects of energy security, but also comprehensive environmental responsibility. The observed evolution of legal regulation in the context of renewable energy creates new opportunities to simultaneously reduce geopolitical risks and environmental threats.

Documented 230 million tonnes of CO_2-equivalent of direct greenhouse gas emissions due to war-correlate with the results of Q. Wang *et al*. (2024) on the impact of geopolitical risks on the energy transition. Chinese researchers have found that geopolitical risks have a significant positive impact on the energy transition, especially in the face of increased environmental regulation and green innovation development. The results of the study revealed a paradoxical situation where war simultaneously creates large-scale environmental damage and accelerates energy transformation due to the need for rapid synchronisation with European networks and the development of distributed generation. The established non-linear relationship between geopolitical risks and energy transition at different levels of environmental regulation confirms the thesis that stronger green innovation enhances the role of geopolitical risks in promoting energy transformation. The analysis of international precedents shows that effective provision of national security in crisis conditions requires a systematic approach to economic and legal instruments. The study by Y. Kuchmak *et al*. (2024) argued that economic security is a critical component of national security, directly affecting the stability of state development. The researchers identified nine key structural components of Ukraine's economic security: industrial, demographic, energy, foreign economic, investment and innovation, macroeconomic, food, social and financial security. Special attention should be paid to the researchers' conclusion that it is

necessary to strengthen the legal framework and ensure transparency of the financial environment as a basis for overcoming systemic problems. The findings on environmental compensation mechanisms extend this conceptual framework, integrating the environmental component into the overall national security system and reaffirming the importance of international cooperation to effectively address cross-border challenges.

The development of the concept of ecocide as an international crime is consistent with the study by D. Liu (2021) on the creation of environmental damage assessment systems and compensation mechanisms. D. Liu (2021) established a system for estimating the cost of compensation for environmental damage caused by air pollution with an accuracy of 92.3% and a confidence level of 95%. The established high consistency between the developed assessment models and the actual situation confirms the feasibility of applying integrated approaches to quantification of environmental damage. The transboundary nature of the environmental impacts of war complements the research by M. Nevitt (2024) on the relationship between energy security, climate, and military conflicts. The researcher analysed how Russian aggression against Ukraine has created an "environmental war" with far-reaching consequences for long-term progress in the field of environment, energy, and climate security. M. Nevitt (2024) emphasised that the war has had a significant impact on global energy markets, as Europe has finally severed its energy ties with Russia and accelerated the transition to renewable energy. Documented cases of Black Sea pollution and atmospheric transfer of toxic substances to neighbouring countries confirm the thesis that the environmental consequences of military conflicts are not limited to national borders and require a coordinated international response. The identified positive effects of renewable energy consumption and investment in green technologies correlate with the author's conclusions that the Russian-Ukrainian crisis creates a unique opportunity to accelerate international decarbonisation and climate efforts.

The established need to integrate environmental principles into strategic planning of energy security finds theoretical substantiation in interdisciplinary research on risk management. The results develop the concept, demonstrating that in the context of contemporary hybrid conflicts, the environmental component becomes not an additional factor, but the basis for ensuring the long-term sustainability of energy systems. The identified effectiveness of the creation of specialised compensation mechanisms confirms the importance of institutional support for environmental responsibility and demonstrates the evolution from ad hoc mechanisms to systematic approaches with expanded mandates. The documented transformation of the Ukrainian energy strategy demonstrates the practical implementation of theoretical concepts of energy and environmental policy integration through accelerated synchronisation with the European network and focus on the development of renewable energy sources.

Conclusions

The study conducted a systematic analysis of the environmental consequences of the destruction of Ukraine's energy infrastructure due to Russian aggression, based on official statistical data covering over 63,000 damaged energy facilities, losses of approximately 10 GW of generating capacity, and an assessment of total environmental damages exceeding USD 56.4 billion. Key cases of environmental harm were examined in detail, including the destruction of the Kakhovka Hydroelectric Power Plant, the flooding of mines in occupied territories, and attacks on the Zaporizhzhia Nuclear Power Plant. A thorough comparative analysis of international precedents of military influence on energy systems was carried out, covering

the conflicts in the Persian Gulf with the arson of 600 oil wells, the bombing of Yugoslavia with the destruction of industrial facilities, and the conflict with ISIS in Iraq, which allowed identifying typological patterns and the evolution of the use of international legal instruments to compensate for environmental damage. The paper examined the transformation of legal mechanisms for minimising and compensating energy and environmental losses from a fragmented response through ad hoc tribunals to the establishment of systemic compensation institutions with expanded mandates. The paper analysed the development of the concept of ecocide as an international crime and the creation of specialised compensation mechanisms, in particular, the International Register of Damage under the auspices of the Council of Europe with the participation of more than forty countries. There is a critical need to integrate environmental principles into strategic energy security planning through the development of distributed generation, renewable energy sources and technologies for rapid response to environmental incidents to ensure the sustainability of energy systems to future threats.

The results of the study revealed systemic patterns of environmental consequences of military operations against energy infrastructure through the creation of a five-category classification of losses with a monetary estimate of more than USD 200 billion, including greenhouse gases from military operations (USD 42.6 billion), fires (USD 9.1 billion), toxic sediments (USD 31.5 million), construction waste (USD 140 billion) and contaminated land (USD 9-10 billion). A comparative analysis of the four international conflicts established an evolutionary transformation of compensation mechanisms from the successful Kuwaiti precedent with 94% of the funds compensated (USD 4.97 billion out of USD 5.26 billion) to the ineffective Lebanese-Israeli mechanism without any payment, which confirmed the critical dependence of effectiveness on the level of international political support. The study of the national legal response of Ukraine revealed the creation of specialised institutional mechanisms, including the registration of more than 6,500 environmental crimes through the GPU division and the qualification of the explosion of the Kakhovka HPP as an ecocide, which is an important precedent in international judicial practice. The establishment of innovative legal instruments at the international level through the adoption of 27 UN PERAC principles and the creation of an International Register of Damage under the auspices of the Council of Europe, with an anticipated 6-8 million claims, demonstrated an institutional transformation from fragmented responses to systemic compensation mechanisms with expanded mandates for energy-environmental damages.

The study has some limitations related to the incompleteness of official statistical information on the long-term environmental consequences of war and limited access to documents of the occupied territories, which could provide a more accurate assessment of environmental damage from flooded mines and industrial facilities. Promising areas of further research are the development of specialised methodologies for assessing ecosystem losses from military operations, analysis of the effectiveness of innovative financial mechanisms for compensating environmental losses, and research of legal aspects of using frozen assets of the aggressor state for environmental restoration of affected territories.

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Conflict of Interest

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Стратегія енергетичної безпеки в умовах воєнного стану: екологічні ризики та напрями їх правового врегулювання

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Анотація

Метою роботи було обґрунтування правових механізмів забезпечення енергетичної безпеки в умовах воєнного стану з урахуванням екологічних ризиків для формування комплексної стратегії, орієнтованої на сталий розвиток. Дослідження здійснювалось із застосуванням системно-структурного, компаративного, формально-юридичного та історико-правового методів. У ході дослідження систематизовано екологічні наслідки руйнування енергетичної інфраструктури України внаслідок російської агресії через розробку комплексної методології оцінки енергетично-екологічних збитків в умовах воєнного стану. Створено класифікацію екологічних витрат війни за п'ятьма категоріями з монетарною оцінкою загальною вартістю понад 200 мільярдів доларів Сполучених Штатів Америки: парникові гази від бойових дій та реконструкції становлять 42,6 мільярда доларів, пожежі спричинені війною – 9,1 мільярда доларів, токсичні осади після підриву Каховської гідроелектростанції – 31,5 мільйона доларів, будівельні відходи та уламки – 140 мільярдів доларів, забруднені та заміновані землі – 9-10 мільярдів доларів. Проведено порівняльний аналіз впливу воєнних конфліктів на енергетичні системи у чотирьох регіонах світу, який виявив еволюційну трансформацію компенсаційних механізмів від успішного кувейтського прецеденту з 94 % виплаченими коштами до неефективних сучасних механізмів без жодної виплати, що підтвердило критичну залежність результативності від рівня міжнародної політичної підтримки. Створено порівняльну матрицю міжнародних прецедентів, яка продемонструвала еволюцію міжнародно-правових механізмів від фрагментарного реагування до системних компенсаційних інститутів з розширенням суб'єктного складу відповідальності. Виявлено типологічні закономірності застосування міжнародно-правових інструментів компенсації, зокрема встановлено пряму кореляцію між ефективністю компенсаційних процедур та рівнем міжнародної політичної підтримки. Результати дослідження концептуалізували формування нової парадигми національної безпеки, що базується на синергетичному поєднанні енергетичних та екологічних правових механізмів у контексті сталого розвитку

Ключові слова: екоцид; компенсаційні механізми; міжнародне гуманітарне право; екосистемні втрати; парникові гази; відновлювальне правосуддя