DOI: https://doi.org/10.37075/BJIEP.2022.2.01
Bulgarian Journal of International Economics and Politics, 2022, Vol. 2, Issue 2, pp. 3-20

The War in Ukraine from 2022 and Its Impact on the Environment

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Received: 12.12.2022
Available online: 28.04.2023

Abstract

The present article aims to focus the attention on the Russian-Ukrainian war from February 24, 2022 and its impact on the environment. The analysis reveals the importance of climate issues in Ukraine for the past, present and future of the country by considering: a/the war as wake-up call for climate emergency; and b/ the desire of Kiev for accession to the EU as an opportunity for green transition and sustainable recovery.

It is claimed that the war in Ukraine from 2022 is an example of how military actions have a significant ecological footprint and how the post-war recovery could be a chance for low-carbon development of the economy and society of the second largest country in Europe, the seventh in terms of population and the eighth of military forces of the old continent. On the one hand, it emphasizes on the multidimensional role of the armed forces and defence sector that should be considered within the wider climate-security nexus. On the other hand, it shows that the pursuit of EU membership has a green transformative effect, considering the strategic targets of the Union to move towards Net Zero by 2050.

The analysis leads to the following conclusions: 1) The military conflict between Russia and Ukraine shows the widespread use of various types of weapons, which generates large amounts of carbon dioxide, by strongly affecting the climate of the entire continent; 2) The post-war recovery is a chance for Ukraine for better sustainable development of its economy, society and security; 3) The path of Ukraine to the EU would be a stimulus for the armed forces and defence sector, as causing and suffering the consequences of climate change, to increase the resilience of their capabilities and infrastructure, by investing in green and innovative technologies and at the same time by decreasing their environmental footprint without reducing their operational effectiveness.

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Keywords: War in Ukraine, Climate-security nexus, Defence, Climate change, Environment, EU
JEL: F5, Q54, P28

Introduction

The relevance of the topic concerns the Russian-Ukrainian war from February 24, 2022 and its impact on the environment. The importance of the subject is related to the analysis of the war from a different angle showing that the destructive conflict and the quest for rebuilding the peace in Europe should go hand in hand with the overall efforts at European and global level for overcoming the challenges related to climate change.

In 2019, four years after the adoption of the Paris agreement (where Ukraine also takes part), the Oxford dictionary has declared "climate emergency" as the word of the year. In the same period, in its Conclusions on Security and Defence in the context of the EU Global Strategy, the Council of the EU acknowledged for the first time the link between environmental issues and climate change for CSDP missions and operations, including its impact on military capability planning and development.

According to the World Economic Forum, among the highest "likelihood risks" of the next ten years are extreme weather, climate action failure and human-led environmental damage. Among the highest "impact risks" of the next decade are: climate action failure and other environmental risks (such as environmental biodiversity loss and ecosystem collapse; extreme weather events; human-made environmental damage; major geophysical disasters; natural resources crises); as well as weapons of mass destruction (World Economic Forum, 2021). Nevertheless, the perceptions about climate change as a threat in Eastern Europe are still different in comparison to the ones in Western Europe, which cause difference in their approaches and level of prioritization about the subject.

The present article aims to focus the attention on the war in Ukraine from the angle of the climate change-security nexus. The analysis will reveal the importance of climate issues in Ukraine for the past, present and future of the country by claiming that the war and military actions have a significant ecological footprint and that the accession to the EU has a transformative power, which could lead to the new impulse for green transition and sustainable post-war recovery of Kiev.

Ukraine is an interesting example for analysis as:

- on the one hand, the country is located in the Eastern part of Europe where climate change issues are not among the high priorities. Nevertheless the desire of Kiev for a European perspective leads to a transformation of political decisions in this field;
- on the other hand, the country is in a state of war that is challenging the local ecosystem, the citizens' health and the foresighted decision-making regarding the post-conflict period that could be a chance for low-carbon development of the economy, society and security.

This paper, written in early December 2022, examines a relatively new and rapidly evolving topic since February 2022, with a dual focus on the environmental impact of the full-scale war in Ukraine and the country's aspirations for EU accession, which can inspire and support Kiev in transitioning towards low-carbon and environmentally responsible practices during post-conflict recovery.

The impact of war on the climate is a global issue as one way or another it affects the whole ecosystem, and its effects can be felt far beyond the borders of any single country. However, it is also important to recognize that the impact of a conflict on the environment can be highly specific to the location and nature of the conflict. The conflict in Ukraine is the largest armed conflict in Europe since Second World War, and its impact on the environment is an issue of pressing concern for both the people of Ukraine and the broader international community. By analyzing the specific environmental impacts of the war in Ukraine, the paper aims to shed light on a crucial case study that can help inform our understanding of the broader global issue. Furthermore, the paper also highlights the potential for EU accession to help incentivize Ukraine to prioritize environmental issues and to move towards green transformation during the post-conflict recovery process.

For the purpose of this publication, a variety of research methods have been utilised, including methods of analysis and synthesis of both primary and secondary sources of information. In addition, the use of induction and deduction, as well as secondary data analysis, has been applied. Moreover, statistical modeling and model-based analysis have also been implemented in the research process to achieve the goals of this publication.

Although the war in Ukraine from February 2022 is a relatively new subject of analysis, the literature review shows that there are studies, albeit still limited in scope, which address different aspects of environmental issues and in particular, the environmental impacts of the war in the country. Some highlight the humanitarian and environmental catastrophe that the war in Ukraine has brought, particularly the disruption or destruction of natural areas, the long-term threat to the environment, and the implications for public health. They call for involvement of the international community, as the environment has no borders (Gardashuk, 2022).

Others provide a comparative analysis of ministerial announcements from selected European countries about the environmental impact of the war in Ukraine, by noting that while the Ukrainian ministry consistently posted information about the environmental damage caused by the war, the ministries of Eastern neighbouring countries (Poland, Hungary, Romania and Moldova), except Slovakia did not provide such information (Cynk, 2022).

There have been a number of other publications that address different aspects of environmental issues in Ukraine such as the environmental management in Kiev and energy security. The challenges of safe land use in the agricultural sector in the country are also a subject of analyses (Sannikov et al., 2022). A book on environmental performance reviews in Ukraine discusses the successes and efforts of the Ukrainian government in managing the environment and biodiversity during the economic transition. It highlights

the government's ratification of relevant international conventions and its commitments to uphold them (UN, 2000). Last but not least, the article *"Environmental damages due to war in Ukraine: A perspective"* emphasizes on the fact that the ongoing Russia-Ukraine conflict has severe negative consequences on people and the planet, including contamination of water sources, air pollution, deforestation, and risks of radiation leakage. The conflict may hamper efforts to deal with climate change, sustainable development goals, biodiversity conservation, and pollution control. Reforms in the International Criminal Court's mandate and new international norms to safeguard the environment during conflict are urgently needed to make the offenders accountable and prioritize environmental and human security (Rawtani et al., 2022).

The present publication builds on the existing literature by analyzing the environmental impact of military actions in Ukraine through the lens of chemistry, and exploring the potential for green transformation and sustainable post-war recovery in Ukraine as a result of its strife for EU membership. The picture of analysis is enriched by the inclusion of public documents and European institutions' resolutions, demonstrating an awakening in decision-makers about the importance of the link between defence and climate change as part of the wider "climate-security nexus".

The paper consists of three main part related to the climate issues in Ukraine before, during the war from 2022 and the future post-war recovery period, followed by conclusions about them.

Climate issues in Ukraine before the war

Ukraine is the second largest non-EU country in Eastern Europe and seventh in terms of population. Its geographical position, historical and economic backgrounds have an impact on the perceptions about climate change. Being on the other side of the "Iron curtain", governed by a totalitarian system, centrally planned and resource-draining economy, as many of the EU and non-EU countries from this part of the Old continent, Kiev also has different perceptions of the same climate emergency reality.

The perceptions in Eastern Europe about climate change are still different in comparison to those in Western Europe. The environmental issues have been often overshadowed at the expense of the pursuit of catching-up economic development.

According to the global data of Lloyd's Register Foundation World Risk Poll (2021), just 11% of people across the Western Europe region (covering Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Lithuania, Netherlands, Norway, Sweden, Switzerland, United Kingdom) and 7% across Southern Europe (covering Albania, Bosnia Herzegovina, Croatia, Cyprus, Greece, Italy, Malta, North Macedonia, Portugal, Serbia, Slovenia, Spain) did not recognise climate change as a very or somewhat serious threat. These figures were much higher in Eastern Europe (26%), a region covering Bulgaria, Czech Republic, Hungary, Kosovo, Moldova, Poland, Romania, Russia, Slovakia and Ukraine.

Table 1. Perceptions in Europe about climate threat

Percentage who did not view climate change as a threat, by region in 2019 vs. 2021

	2019			2021		
	% Not a threat	% Don't know	% Total*	% Not a threat	% Don't know	% Total*
Eastern Europe	10	16	26	11	16	26
Northern/Western Europe	7	3	11	8	2	10
Southern Europe	5	2	7	5	3	7

0-5 6-10 11-15 16-20 21-25 26-30 31-35 36-40 41-45 46-50

Survey question: Do you think that climate change is a very serious threat, a somewhat serious threat, or not a threat at all to the people in this country in the next 20 years? If you don't know, please just say so.
* Total may be ± 1% of the sum of the previous two columns due to rounding.

Source: Adabted by the authors from World Risk Poll (2020: 46/Chart 5.1)

The newly independent Ukraine in 1991 inherited from the Soviet Union an economic structure dominated by energy-, resource- and pollution-intensive sectors, with outdated technologies in the mining and metallurgical sectors, energy-inefficient housing and outdated transport systems (OECD, 2022; see also Government Statements, 2022).

The low priority given throughout the years on climate and environmental issues have made it difficult for Kiev to achieve green and sustainable economic developments. Just after the signing of the European Union-Ukraine Association Agreement in 2014, the Ukrainian government changed its approach by investing much more effort in overcoming the climate change and environmental challenges and by starting a process of green transformation of its economy. Kiev has appointed an inter-ministerial body for better implementation and policy coordination of the European Green Deal and the country has also adopted its strategic documents in the field: *Strategy for Environmental Safety and Climate Change Adaptation until 2030* (2021) followed by Operational Plan and National Environmental Action Plan until 2025. In line with the EU goal to make Europe climate-neutral by 2050 and to reduce the greenhouse gas (GHG) emissions to at least 55% below 1990 levels by 2030, in 2021, the Government of Ukraine has increased its level of ambition to reduce its GHG emissions by 65% by 2030 from the pre-industrial levels and to reach carbon neutrality by 2060.

The green transformation in Ukraine is an example of how the EU Neighbourhood policy and the deepening of relations between EU and its Eastern partnership countries lead to positive change and better sustainable development. It shows how the European Union has not only soft power but also a transformative power by:

- contributing to the positive and lasting transformation in non-EU countries;
- capacity building for self-reliance and sustainable development in third countries; helping their prosperity rather than making them dependent on the Union;
- implementing the paradigm of peace and respecting the principles of multilateral cooperation.

Kiev applied for EU membership in February 2022 and due to the force-majeure situation of Russian aggression in the country, Ukraine was granted EU candidate status in June 2022 by passing with unprecedented speed from the framework of partnership to the framework of future membership, from the coverage of the Neighbourhood policy to the one of the Enlargement policy.

In the process of EU accession the expectation towards the country will increase considerably, similar to the requirements set in the Green agenda for the Western Balkans (the so called five pillars related to decarbonisation and climate resilience, circular economy, depollution of air, water and soil; sustainable food systems and rural areas; biodiversity in terms of protection and restoration of ecosystems) (European Commission, 2022).

According to the Climate Change Knowledge Portal of the World Bank, the impacts from climate change make Ukraine increasingly vulnerable to: droughts, high temperatures, heat waves, heavy precipitation, mudflows, and floods. Climate change is expected to increase risks and severity of natural disasters in Ukraine, through more intense temperatures as well as rainfall patterns, prolonged heat waves, and water scarcity. In recent years, the number of natural disasters has increased in the region and in many cases, they have been considered as catastrophic, causing fatalities and leading to significant economic losses (World Bank Group, 2021).

In this regard, the impact of Russia's invasion of Ukraine should not impact the European and global efforts to combat climate change and to achieve sustainability, as is foreseen in the Paris agreement, UN Agenda 2030 and the European Green Deal. We should not forget the definition of sustainable development: "…development that meets the needs of the present, without compromising the ability of future generations to meet their own needs" (United Nations, 1987). Any postponement of the commitments at national, European and/or global level would deprive humanity of overcoming the existential threat of climate change and the young generations of having a future. In addition, the price of potential conflicts, humanitarian crises, population displacement and refugee crises due to climate change would be much higher than the expected current costs and efforts for sustainable and green transformation.

The war in Ukraine has a triple negative effect – on the entire environmental ecosystem of the country itself and Europe; on the speed of its green transition and sustainable development; on slowing down the progress on achieving the targets related to the carbon neutrality and the sustainable development goals (SDGs) at European and global level.

According to one of the world's most respected climate change scientists Lawrence M. Krauss: appealing only to emotions or relying on scare tactics should not be the ways to incite actions against climate change just as it would be wrong to push to inaction by denying evidence and scientific justification (Krauss, 2021).

In this regard, the second part of this article aims to expose the ecological footprint of the military actions in Ukraine by using the art of the science of chemistry.

Climate issues in Ukraine during the war

During the hostilities in Ukraine, both sides have been using different types of weapons with the corresponding ammunition. Assumptions have been made in the studies that most likely reflect the state of hostilities.

Norms of use of these ammunitions for one combat day, one week, one month and the already completed eight months of hostilities have been adopted.

At the beginning of the conflict, 150,000 Russian troops entered Ukraine. Based on this clear information, it is assumed that both sides are using 150,000 men each (300,000 in total), together with all the support of their actions, such as missile troops and aviation. The figures mentioned are our statistical data collected on the official number of personnel and armament of the warring parties in the conflict. They serve as the main basis for an approximation in the accepted model based analysis of the impact of hostilities on climate change.

With a large approximation, it can be assumed that a total of 20 solid divisions (300,000 men in total), were active on each combat day. One such division uses about 240 tons of gunpowder and 100 tons of TNT in its ammunition and for its artillery ammunition. The weight of the gunpowder charge of such a division in defence is about 20 tons. The total amount of gunpowder and TNT was then 360 tons for one Combat set (CS). In defence, the total amount can increase to 2 CS or 720 tons. Estimates for the various types of weapons and their quantities of explosives are provided in Table 2.

Table 2. Hot gases from some types of ammunition in Ukraine*

№	Armament	1 combat day		1 week		1 month		8 months		8 months
		ton	heated up gases m^3	ton	heated up gases m^3	ton	heated up gases m^3	ton	heated up gases m^3	heated up gases km^3
1	Fire arms	400	$2{,}1.10^{11}$	2,800	$1{,}47.10^{12}$	12,000	$6{,}3.10^{12}$	96,000	$5{,}75.10^{13}$	57,500
2	Artillery ammunition	3,400	$1{,}77.10^{12}$	23,800	$1{,}24.10^{13}$	112,000	$5{,}82.10^{13}$	896,000	$4{,}65.10^{14}$	$4{,}65.\ 10^{5}$
3	Drones	300	$1{,}56.10^{11}$	2,100	$1{,}1.10^{12}$	9,000	$4{,}68.10^{12}$	720,000	$3{,}75.10^{13}$	$3{,}75.10^{4}$
4	Reactive salvo fire systems	1,500	$7{,}8.10^{11}$	10,500	$5{,}46.10^{12}$	45,000	$2{,}34.10^{13}$	360,000	$1{,}8.10^{14}$	$1{,}8.10^{5}$
5	Anti-aircraft missile systems	1,500	$7{,}8.10^{11}$	10,500	$5{,}46.10^{12}$	45,000	$2{,}34.10^{13}$	360,000	$1{,}8.10^{14}$	$1{,}8.10^{5}$
6	Missile systems	2,000	$1{,}04.10^{12}$	14,000	$7{,}28.10^{12}$	60,000	$3{,}12.10^{13}$	480,000	$2{,}5.10^{14}$	$2{,}5.10^{5}$
7	Aerial bombs	2,000	$1{,}04.10^{12}$	14,000	$7{,}28.10^{12}$	60,000	$3{,}12.10^{13}$	480,000	$2{,}5.10^{14}$	$2{,}5.10^{5}$

Source: Created by the authors

* When detonating 1 kg of explosives, appr. 520,000 m^3 (5.2.105 m^3) heated gases from 3000-4000^{0}C to 500^{0}C are released during the explosion. It is assumed that a total of 300 battalion units are participating in the hostilities from Ukraine and Russia

The calculations are made on the basis of the following measurments: 1 km^3 has a side of 1000m x 1000m x 1000m = 1.10^3. 1.10^3. 1.10^3 = 1.10^9 m^3 = 1 km^3. In the case for the 400 tons of small arms ammunition used, $2.1.10^{11}$ heated air from 3000 - 4000^{0}C to 50^{0}C was obtained. Dividing $2.1.10^{11}$ by 1.10^9 m^3 gives approximately 210 km^3 of heated air from 3000 - 4000^{0}C to 50^{0}C.

For example, in the information for the small arms given in the table, 20 divisions of 20 tons of gunpowder charge are indicated as 400 tons for one combat day.

In the detonation of 1 kg of explosive, 1 m^3 of heated air mass is obtained. In the center of the explosion the temperatures rise up to 3000 - 4000^{0}C (Haralampiev, 2002: 12). At 50 m from the explosion center, it is about 50^{0}C. If assumed that the explosion takes place 50 m from the ground, then the volume of the heated air of this heated ball would be about 524,000 m^3.

$$V = \frac{4\pi R^3}{3} \qquad V = \frac{4.3,14.50^3}{3} = 524{,}000m^3$$

For both sides, regardless of whether they are offensive or defensive, the weapons used are equated on the basis of a basic amount of 1 kg of explosive substance (powders and TNT) and the heated air mass emitted by them in the surrounding space.

Adding up all the heated gases from the ammunition used for 8 months of combat gives an approximate volume of 1,5.10^6 km^3. Initially, this heated air is in the zone from the earth's surface to a height of 0 to 1 km. From here we can conclude that a square with the approximate dimensions of the country 1220 km is covered with this hot air.

There is no doubt that this volume of heated air changes the local, regional and territorial climate. Additional calculations show that thousands of tons of carbon dioxide are released, as well as acid gases for nitrogen and sulfur, which form acid rain over the territory of Ukraine and in the surrounding countries.

For the training activities of the troops of each country, huge areas of forests and arable land are needed. According to research data, the total area of land that is used by armies is about 1-5 percent of the entire earth's surface, and this means that a huge territory of 1,000,000 km^2. This means that it cannot be used for agriculture production.

The analysis shows that in order to conduct an exercise of a dense armored division or a mechanized division (in the composition of 10,000-15,000 personnel, up to 300-400 tanks, the same number of armored personnel carriers, up to 100 self-propelled guns and other units of combat equipment) an area is necessary up to 50,000 hectares. To achieve satisfactory efficiency, the territory grows to 70,000 hectares. For exercises in which air-to-air missiles are used, a test site with an area of 250,000 ha is required. Even larger are the territories on which the possible use of nuclear weapons is stimulated. These test sites most likely exist in nuclear weapon states and are up to 3500 km^2 (Gowin, 2019: 148, 157).

A large proportion of normal land areas in the world are used for military bases. The areas occupied by military bases and testing grounds are forever lost for economic land use. Most of these territories are turned into a desert by the explosions and machine chains, and a lot of material and human resources are needed to restore them.

Another dangerous source of environmental impact with radioactive waste is the hundreds of nuclear submarines that operate in various areas of the world's waters. It has been proven that a nuclear submarine emits about 240 g of radioactive isotopes in just 24 hours. Of these, mainly 181 g of plutonium, 40.3 g of cesium, 17.3 g of strontium

and in small quantities americium, radioactive carbon and tritium (Haralampiev, 2002: 19). The largest amount of plutonium 239 released has a very long half-life. It has not been proven, but it is assumed that in the majority of cases, submarines get rid of radioactive waste products by dumping them in the water. If we take into account the long half-life of plutonium, then with a high probability, the corresponding radiation damage to the living organisms and plant species of the world's oceans and seas will follow. The Black sea is becoming more and more a militarized area of contradictions and challenges, and this will have its ecological impact as well.

Here it is worth emphasizing that as a result of the ongoing war between Ukraine and Russia, many non-specific components have been introduced and are being introduced every day into the ecosystems, some of which are highly toxic. When conventional weapons are used, millions of scraps of metals and plastics, unexploded shells, bombs and mines remain in the soil, which threaten the existence of people and animals living in the area. As researchers, we assume that tons of metal scraps, plastics, and tens of thousands of tons of destroyed equipment are found on the territory of Ukraine so far. Tens of thousands of mines in mined areas pose a threat for tens of years.

These are thousands of tons of lead, iron, non-ferrous metals and many more chemical elements and compounds that are not characteristic of ecosystems. They will change the structure and functioning of natural and man-made ecological systems. As a result of military actions, the unity of plants and animals is thrown out of balance. The evolutionarily formed cycle of matter in the ecosystem of the Ukrainian territory and the lands annexed by Russia is being torn apart. The imported huge amounts of biogenic elements can hardly be included in the circulation, which is why the functioning of living matter in large areas is disturbed.

Research shows that lead is one of many chemical elements that also accumulate in ecosystems. The phenomenon is known as ecological build-up or bioaccumulation. This phenomenon is determined by the increasing accumulation of chemical elements and compounds along the ecological food chain. As is known, man is one of the final links of this chain, which is why the investigated chemical compound or element is introduced into his organism in toxic doses, regardless of the fact that its content in water or soil is minimal and cannot cause a toxic effect.

It was established that now, almost eight decades after the end of the Second World War (Battle of Kursk on the territory of Russia), the content of lead in the tissues of aquatic plants is nine times higher compared to its amount in the same types of plants, but taken from areas where no battles were fought. It is assumed that the content of this poisonous chemical element in the next units of the ecological food chain – plant-eating and predatory fish – is progressively increasing. This ecological effect is predicted to continue for many decades to come. In the same way, the accumulated thousands of tons of lead, iron, manganese, copper, and nickel on the territory of Ukraine will enduringly affect it.

It is obvious that a significant part of these munitions, as well as the techniques of launching them at the site of battles and as non-specific components, will disrupt the structure and functioning of ecosystems for many years.

The present research analyses also the issue related to the so-called "dirty bomb", with which both sides of the conflict blamed each other. The "dirty bomb" is a type of of radiological weapon. It uses the natural radioactivity of radioactive elements, the isotopes Strontium 90, Ruthenium 136, Cerium 144, Zirconium 45, etc., for military purposes. All these are waste products from the operation of the Nuclear Power Plant (NPP). The dispersion of these radioactive substances in the air causes the contamination of large areas and the destruction of life in them. The details of using this new type of "dirty" weapon have also been developed. Radioactive isotopes are expected to be scattered on targets using rockets or radio-controlled drones.

The potential severe environmental consequences of the use of radioactive substances for military purposes are also reported. It is possible Radiological Dispersal Devices to be used (RDD). RDD is any device that causes the purposeful dissemination of radioactive material without a nuclear detonation. For example: The cloud of radiation from a nuclear bomb could spread tens to hundreds of square miles, whereas a dirty bomb's radiation could be dispersed within a few blocks or miles of the explosion (Levi, 2002). We must emphasize that neutral substances irradiated in the active zones of nuclear reactors can be used for a dirty bomb. Even such a relatively safe by-product of reactor operation as tritium can be used under certain conditions for the needs of war. Tritium is chemically active and easily reacts with carbohydrates (sugar) or ammonium sulfate (a widely used chemical compound in the chemical industry and in agriculture). Creation of new chemical compounds, in the molecule of which tritium participates, and their use as a radiological weapon are associated with much greater ecological consequences, because the specified compounds are included in the ecological food chain, and the radioactivity in each subsequent unit increases significantly, in order to reach in the final units' lethal values for humans and higher animals, regardless of the fact that the content of the radioactive pollutant in the environment is in relatively small concentrations. Considering the migration of birds, mammals, amphibians, fish, insects, etc. and the passive transport of seeds and spores by air currents, the disappointing conclusion can be made that the use of "traditional" chemical substances for ecosystems as carriers of radioactive isotopes deepens the ecological consequences of the use of radiological weapons.

It is necessary to emphasize that the radiological weapon is insidious and has enormous consequences for man and living nature. Its insidiousness consists in the fact that the missile, which will pass over a certain territory, will not bring death with a conventional or nuclear weapon. However, it will bring a slow and painful death, the result of lethal irradiation of people, animals, and plants. Studies have shown that the decontamination of the area is a practically impossible task. Attempts to deactivate the soil are unsuccessful – the only option is to remove the surface soil layer containing the radioactive substance.

In a radiological war, just one cruise missile will lethally infect an area of 150 km^2, and removal of the topsoil will be impossible. When analyzing the ecological consequences of the use of this type of weapon of mass destruction, it must be emphasized that the radioactive substances used are of high resistance. For example, Cobalt 60 spread over an area will destroy life in that area for 50 years.

At some point during the hostilities in Ukraine, the possible use of tactical nuclear weapons was introduced. Essentially, a tactical nuclear weapon is a neutron weapon. For example, a neutron bomb with a power of one kiloton gives deadly radioactive radiation, which in a huge circle with a radius of 900 m from the epicenter of the explosion is of the order of 8000 rads, i.e. radiation lethal to almost all organisms living on Earth. In this round, soldiers fall victim to radiation sickness in just 5 minutes. At a distance of 1400 m from the epicenter of the explosion, it drops to 650 rads, which means that all people who are in this huge circle will die in two weeks. At a distance of 2,300 m from the place of detonation of the bomb, the radioactivity drops to 15 rads and it does not cause lethal radiation, but the probability of getting cancer or genetic defects that will be passed on to several generations is very high.

When analyzing the ecological consequences of radiation, its long-term effects on living organisms must be emphasized. In a nuclear explosion, of the 110 highly radioactive products released in significant concentrations, 80 have a half-life of more than one hour. Some of these products, for example those containing carbon 14, over many generations of plants and animals will have an impact on living organisms, since the half-life of this isotope is 5570 years.

At the heart of Sagan's team's development, which describes nuclear winter and what nuclear war might look like (see Francis, 2017), is the so-called "baseline" option; in a future war the nuclear munitions used will have a power of 5000 megatons, i.e. approximately 1/3 to 1/2 of the world's nuclear weapons stockpile. It is assumed that nuclear explosions will cover both large cities and military facilities, such as missile sites, military factories, etc.

The first consequence of nuclear explosions would be total darkness in areas located at great distances from the theater of nuclear catastrophe, due to the eclipse of the sun by the release of huge amounts of soot and dust. Subsequently, due to the dissipation of these atmospheric pollutants, the nuclear night will recede, but this process will be extremely slow, and in the mid-latitudes of the Northern Hemisphere, light intensity will be only one percent of normal, which means that plant photosynthesis will cease. And through photosynthesis, matter is cycled in ecosystems and the biosphere and the potential immortality of living matter on our planet is ensured. Forecasts show that the "nuclear night" will be long - at least several months, and a longer blackout period is possible. As a result, the temperature drop would be significant – up to 23^0C on average. The ecological consequences of this catastrophic drop in temperature will lead to the death of plants, animals and people.

In the war between Russia and Ukraine, such might be the power of nuclear weapons. This power of nuclear explosions will destroy major cultural and historical centers in Europe,

but will also claim hundreds of thousands of victims and cause severe environmental consequences. Soot and dust will be in such quantities that they will cause a nuclear winter over the entire planet that will last for several months. However, this prolonged period of ultra-low temperatures will be enough to kill off the last human living on Earth and destroy most of the ecosystems on land and in the world's oceans and seas.

There is also the mathematical model "Gaia", which proves what the consequences would be of using nuclear ammunition with a total power of 100-150 megatons, i.e. 50 times smaller than those in Sagan's scenario (Pittock, 1990).

It should be undelined that the plants for the production and processing of nuclear fuel, the nuclear reactors, the nuclear power plant, and the storage facilities for radioactive waste can be attacked with high-precision nuclear missiles.

Calculations show that two weeks after a ground-based 20 kiloton blast on a military target, 75,000 km^2 would turn into a nuclear hotbed and desert. In the event that a nuclear power plant (5,000-megawatt power plant) is hit with a high-precision nuclear weapon, the area of the territory with radioactivity that destroys all living things would increase 3 times and reach 225,000 km^2. After two months, these dangerous death zones will be 50,000 and 190,000 km^2, respectively, after two years – 20,000 and 100,000 km^2. The use of high-precision weapons at the NPP would most probably cause environmental consequences that are difficult to predict, since it is not known at which object of the nuclear energy the nuclear strike would be directed.

In addition, according to OECD, with a steady barrage of strikes on refineries, chemical plants, energy facilities, industrial depots or pipelines, the country's air, water and soil have been polluted by toxic substances, fires and building collapses, which can cause longer-term health threats like the risk of cancer and respiratory ailments. Military operations have also resulted in dramatically increased amount of waste and some of this waste is toxic, including shell fragments, medical waste, or building debris containing asbestos, PCB and heavy metals. Nature and ecosystems also suffer. Forests have been destroyed by fires from shelling and through misuse by the Russian forces. The Ukraine authorities estimate that, due to Russia's military activities, 900 protected natural areas of Ukraine have been affected and an estimated 1.2 million hectares, or about 30% of all protected areas of Ukraine, suffer from the effects of war (OECD, 2022).

The negative consequences of military actions in Ukraine will undoubtedly have a complex impact on the environment. The restoration of the infrastructure will also have to be tied to the country's international agreements regarding compliance with the reduction of greenhouse gases, the cleanliness of the air, soil and water.

Climate issues in Ukraine during the post-war period

The second part of the present article exposes how war and military actions have a severe ecological footprint. The last section of the publication will focus on the post-war period by showing that the sustainable recovery of Ukraine is vital for the future of its

economy, society and security and is related to the green transformative effect of the path of Kiev to the EU.

According to OECD, in the short term Ukraine should focus on eliminating and reducing the immediate risks that the war poses to human health and to the environment by mobilizing a comprehensive environmental clean-up effort, especially related to collection, safe disposal and treatment of the vast amount of military and other waste. In the longer term, post-war "green" reconstruction should not be seen as a desirable but optional "extra", but as an economic necessity for a fundamental transformation of Ukraine towards a green and net-zero economy (OECD, 2022).

During the post-war period, Ukraine would be at the crossroads between fast recovery and far-sighted strategic transition to sustainability. The country's desire to be part of the European Union and its already awarded status of a candidate-country presuppose a full alignment with the European Green Deal, New EU strategy on adaptation to climate change and the "Climate change and defence Roadmap". The climate change efforts are and will be reflected in the EU's bilateral relations and accession negotiations with the candidate countries. In addition, it is also expected that these countries should fully align with the EU Common Foreign and Security Policy (CFSP) and Common Security and Defence Policy (CSDP) as part of it.

In this regard, the recovery of the territory of Ukraine as recognised by international law shall be related not only the socio-economic aspects but also the climate-security nexus.

Military spending versus spending on social affairs, investments in peace and security versus climate change should not be anymore a question of choice or comparison. The security and climate change are horizontal issues that have to be taken into consideration in all future strategic and policy-making actions of Ukraine. Therefore, it is not about either-or, but about and.

In the last years climate change has been identified as a "threat multiplier", an "existential threat", a "threat fertilizer" and "shaping threat", thus the climate-security nexus becomes more and more important.

In 2019, the Council acknowledged for the first time the link between environmental issues and climate change for CSDP missions and operations, including its impact on military capability planning and development in its Conclusions on Security and Defence in the context of the EU Global Strategy (Council Conclusions, 2019). The EU Global strategy underlines that "climate change and environmental degradation exacerbate potential conflict, in light of their impact on desertification, land degradation, and water and food scarcity". Climate change is defined as "a threat multiplier that catalyses water and food scarcity, pandemics and displacement" (EUGS, 2016).

The New EU strategy on adaptation to climate change, 2021 outlines a long-term vision for the EU to become a climate-resilient society, fully adapted to the unavoidable impacts of climate change by 2050 (European Commission, 2021).

In the Strategic compass, it has been confirmed that climate change and environmental degradation are not only threats in themselves, but risk multipliers. The compass states

that "Global warming leads to more frequent and extreme weather events and natural disasters as well as degradation of eco-systems across the globe that increases vulnerability and exposure. This adds to the potential for social, economic and political instability and conflict in fragile countries" (Council of the EU, 2022).

The EEAS, the European Commission and the European Defence Agency elaborated a "Climate change and Defence Roadmap" (EEAS, 2020) which proposes concrete short-, medium-, and long-term actions across three main pillars: 1) operational dimension for better integrating the climate considerations into planning of CSDP civilian and military missions and operations; 2) capability development for integrating clean technologies in military equipment and defence infrastructure; 3) multilateralism and partnerships for sharing ideas/best practices and for closer cooperation and synergies in the area of climate resilience with relevant partner organisations and third countries (EU, 2020).

On the basis of the above-presented strategic documents, on the one hand, climate change is a "threat multiplier" that catalyses water and food scarcity, pandemics and displacement by increasing vulnerability and leading to the potential social, economic and political instability and conflicts, especially in fragile and conflict-ridden countries. On the other hand, it is a "shaping threat" having significant implications on the tactical, operational and strategic levels and reshaping geopolitics on various dimensions by triggering a competition for scarce resources and raw materials, by affecting the existing balance of power and EU economic and trade relations with the world, and by multiplying threats to global stability and security. Therefore, the armed forces and defence sector have a multidimensional role on climate change by causing and suffering the consequences of climate change. They have to increase the resilience of their capabilities and infrastructure by investing in green and innovative technologies and at the same time to decrease their environmental footprint without reducing their operational effectiveness.

Ukraine has already demonstrated before the war a strong commitment to environmental policy, pollution decrease, effective use of natural resources, nationally determined contribution and the reduction of greenhouse gas emissions of 65% until 2030 (see Bushovska, 2021). It would be an additional added value also to be included "the climate change-security-defence" aspects in the future and/or updated strategic documents in the field.

The multiple crises and the hard post-war transition to a completely new way of sustainable development should not potentially discourage the country and allow it preserve the post-Soviet design of its economy. The green reconstruction and recovery of the territory of Ukraine as recognised by international law is important in a long-term perspective not only for its post-war social-economic development, but also for its security and defence.

The turning point that makes the process of climate change irreversible is the most worrying for the experts of environment and security in Europe and the world. This is the moment when the decision makers would be forced to become firefighters to manage the consequences of climate change, instead of preventing them. In this regard, the approach

to climate change in one of the largest and most populated countries in Europe, eighth in possession of military forces, is vital not only for the country itself but for the sustainability of the whole continent (Statista, 2022).

Conclusion

The above-presented analysis, revealed the importance of climate issues for the past, present and future of Ukraine and its impact on Europe as well. Being in the past a part of the Soviet Union, in the present a victim of a large-scale military conflict and in the future a candidate for European Union membership, Ukraine should choose the path of a new model of sustainable development, taking into account the climate change-security nexus.

The three main conclusions that can be outlined, without pretense of being exhaustive, are as follow:

1. The post-war recovery is a chance for Ukraine for better sustainable development of its economy, society and security. On the one hand, the analysis showed how vulnerable the country was to climate change before the war and then how the war and the ecological footprint of military actions would further accelerate these climate-related challenges. On the other hand, it focused the attention on the pre-war design of the resource-draining economy of Kiev, the typical differences in perceptions about climate change as a threat in Eastern Europe and how namely the EU perspective is the transformative tool that would help Ukraine move towards low carbon, energy efficient and environmentally responsible behavior.
2. The military conflict between Russia and Ukraine shows the widespread use of various types of weapons, which also generate large amounts of carbon dioxide, which strongly affects the climate of the entire continent. At the same time, the war is slowing down the progress in climate emergency actions in Europe and the rest of the world. It is vital that:
   - on the one hand the existing setback in European and international efforts for green transformation and sustainability should be overcome as foreseen in the United Nations Agenda 2030 and the European Green Deal;
   - on the other hand Ukraine should eliminate and reduce the imminent risks that the war poses to the environment and citizens' health and to continue its path to Net Zero.
3. The path of Ukraine to the EU would be a stimulus not only for sustainable development of the economy and society but also for the armed forces and defence sector, as causing and suffering the consequences of climate change, to increase the resilience of their capabilities and infrastructure, by investing in green and innovative technologies and at the same time by decreasing their environmental footprint without reducing their operational effectiveness. Including "the climate

change-security-defence" aspects in the future and/or updated strategic documents of Ukraine would be an asset.

While the analysis focuses specifically on the conflict in Ukraine from February 2022, the findings and conclusions have broader implications for the global issue of the impact of war on the environment as well as for countries seeking to join the EU and leverage its transformative power.

In conclusion in the words of Yuval Noah Harari "a common enemy is the best catalyst for forging a common identity, and humankind now has at least three such enemies – nuclear war, climate change, and technological disruption" (Harari, 2018), so let us hope that in 2023 the entire international community will pay much more attention to the common enemies by building a strong common identity and striving for sustainability.

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