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ANALYSIS OF THE ECONOMIC AND ENVIRONMENTAL POLICY OF UKRAINIAN DEFENCE INDUSTRY ENTERPRISES

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Introduction. The regulation of economic and environmental impacts of the entire military-industrial complex is a cross-sectoral and international problem. At the same time, research in this area is rather fragmented, which reduces the effectiveness of systematic reviews of the security and defence sector in the context of the green economy. The relevance of the issue of greening the defence industry is significantly enhanced by the need to regulate and operate domestic defence industries in the context of the country's military operations.

Aim and tasks. The aim of the study is to substantiate the economic mechanism for regulating the greening of enterprises of the defence industry of Ukraine.

Results. The economic and environmental security requirements for defence industry enterprises are studied, as the activity of polluting sources of enterprises, including defence enterprises in Ukraine, has generally decreased, in 2021, emissions of pollutants into the atmosphere from stationary sources decreased by 9.0% compared to 2020, to almost 2.2 million tonnes, ammunition was disposed of (235.29 thousand tonnes of ammunition were disposed of from 2014 to 2020) and liquid rocket fuel (16.7 thousand tonnes of melange). In 2021, enterprises, organisations and institutions spent UAH 41.3 billion on environmental protection, compared to UAH 43.7 billion in 2020. Of the total environmental costs in 2021, 68% were current expenses and 32% were capital investments. The strategic directions of greening the defence industry enterprises have been identified, including the introduction of resource-saving technologies, environmental monitoring of environmental impact and reduction of the negative impact of the defence industry units.

Conclusion. The realisation of the greening potential will help protect the country's natural resource potential under the influence of the defence industry. A system of measures should be developed to ensure the protection and restoration of natural systems at a certain cost. Given the importance of the defence industry for the country in the context of current external threats and armed conflicts in certain parts of the territory, it is necessary to develop a strategic vision of environmental security with the involvement of all relevant organisations and taking into account the degree of responsibility and motivation for eco-oriented management.

Keywords: greening, analysis, dynamics, defence industry, pollutant emissions, environment.

1. Introduction.

Strengthening environmental protection, implementing eco-friendly technologies, saving resources, and improving life safety are global challenges and conditions for the future survival of humanity. Nowadays, the environmental transformation of the defence industry is particularly important for the protection of Ukraine's environment. The state of military activities and the defence industry depends on the level of development of the country's economy and is a factor that has a significant impact on all spheres of society, including the environmental situation. The impact of the military-industrial complex (MIC) activities is often transboundary and affects neighboring countries' interests (Quist et al., 2003).

In the current environment, Ukraine's economy is in a systemic crisis due to the effects of military operations and the COVID-19 pandemic. The country's economic development is to some extent constrained by its poor environmental situation. Overall, only 6% of Ukraine's territory is considered environmentally friendly. Every year, up to UAH 10 billion (\$264,500) is spent from the Ukrainian budget to overcome the consequences of emergencies (Orel et al., 2022). About 7 million tonnes of various hazardous substances are released into the atmosphere annually. The average density of air emissions in Ukraine is about 11 t/km² (Ministry of Defence of Ukraine, 2022). In terms of water reserves available for use, Ukraine belongs to low-income countries (in low-water years, 0.67 thousand m³ of river runoff per person).

The territory of Ukraine is characterised by a very high rate of agricultural development, which far exceeds ecologically sound limits. Only 18% of the country's territory is covered by forests (Bochkova et al., 2020). Ukraine's defence industry includes state-owned enterprises of various ministries that are involved in the development and production of weapons and armaments, namely the state-owned concern Ukroboronprom (137 enterprises), 103 enterprises of the Ministry of Defence of Ukraine (2022), as well as private enterprises, mostly members of the public union League of Defence Enterprises of Ukraine, which unites 69 enterprises, and other enterprises and organisations.

It is non-state enterprises that currently produce more than half of the state defence order (60-70%) (Defense Policy, 2022). Despite significant economic, technological and other problems, Ukrainian enterprises are present on the global arms market in the aircraft, armoured vehicles and ammunition segments. Regulation of the environmental impact of all components of the military-industrial complex is an international and cross-sectoral issue. At the same time, research in this area is fragmented, which reduces the effectiveness of systematic reviews of the security and defence sector in the context of the green economy (Redkva et al., 2022). The relevance of the issue of promoting the greening of the defence industry is growing significantly due to the need to regulate the activities of the domestic defence industry.

2. Literature review.

Greening reflects the tendency of the world society to strengthen environmental protection, introduction of environmentally friendly technologies, resource conservation and increase of environmental safety requirements. In addition, the obligation to comply with environmental standards and restrictions on the use of natural resources in the conduct of economic activity should be based on the preventive nature of environmental protection measures greening of material production based on the complexity of solving environmental problems of use and reproduction of renewable natural resources (EU4Environment, 2022).

The implementation of these principles is disrupted in the context of hostilities and conflicts. In economic activity, war is an almost continuous phenomenon that has a huge impact on the environment. The ecology of war covers the three phases of war – preparation, actual war, and post-war operations – and argues that biophysical and socio-economic systems are interconnected (Machlis & Hanson, 2008). According to Adamczyk (2014), the field of environmental protection includes the following issues: prevention of environmental pollution, reduction of raw material and energy consumption, and mitigation of climate change. Eryigit and Özcüre (2015) argue that the field of environmental protection includes the prevention of environmental pollution, reduction of raw material and energy consumption, and reduction of climate change (Eryigit et al., 2015).

The traditional view of economic and environmental policy by Jaffe et al. (1995) there is a long-term environmental policy that usually forces enterprises to invest in some deposits to prevent and reduce pollution in production, without being seen as an added cost or a deterrent to production.

A commonly accepted view of economic and environmental policy by Jaffe et al. (1995) and Ambec et al. (2013) is that it is considered a burden of economic activity. Despite the debate on long-term sustainability, compliance with environmental policies often forces firms to invest some savings.

Machlis & Hanson (2008) argue that the development and advancement of military environmental science is both a scientific and a moral imperative. Scientific reasons include the wide impact of war on the environment, the complexity of the interaction of war with combined natural and social systems, and the distinctive characteristics of war, namely its premeditation, destructiveness, and intensity of environmental impact. Moral reasons include the contribution of science to warfare technologies and the need to counterbalance the excesses of these activities, the contribution to combat ecology can reduce ecosystem degradation and the potential of war ecology to promote security (Dwight, 2008).

However, research on the economics of natural resource use and the environment related to warfare is deeply limited and fragmented. The economics, ecology, and policy of the defense industry treat socio-economic and biophysical systems as interconnected. A review of scientific research shows complex economic links between such enterprises and ecosystem change.

3. Aim and tasks.

The purpose of the study is to substantiate the economic mechanism for regulating the greening of enterprises of the defence industry of Ukraine. The objectives of the study are to analyse the dynamics of pollutant emissions from stationary sources of pollution in Ukraine and the dynamics of environmental protection costs in the country, as well as to summarise the areas of greening the defence industry in the context of strategic development goals.

4. Methodology.

Atmospheric air is deemed to be actually polluted when pollutants or mixtures of such substances are released into the atmosphere during military operations or as a result of emergencies. The fact of emissions of pollutants or such mixtures into the atmosphere and their volumes are determined by persons authorised to exercise state supervision in the field of environmental protection.

If information on the mass of the combusted substance is available, fugitive emissions (M_i emission) of each pollutant or mixture of such substances from the source of emission are calculated using the following formula (1) (Williams, et al., 2015; WHO, 2015):

$$M_i \text{ emission} = q_i \times M_{ci} \quad (1)$$

where, i – a pollutant or a mixture of substances (CO, NO_x, etc.); q_i – specific emission factor of the pollutant or mixture of substances; M_{ci} – mass of combusted substance, t.

The calculation of uncontrolled emissions for each pollutant or mixture of such substances in the absence of information on the mass of the burnt substance (M_i emission) into the atmosphere from the emission source is carried out by the formula (2):

$$M_i \text{ emission} = q_i \times p_o \times S \quad (2)$$

where, i – a pollutant or a mixture of such substances (CO, NO_x, etc.); q_i – specific emission factor of a pollutant or a mixture of such substances; p_o – the coefficient of average density of substances equal to 0.03; S – fire area, sq. m.

The calculation of the mass of fugitive emissions of each pollutant or mixture of such substances (M_i emission) into the air from the source of emission when establishing the fact of forest and other plantations fire is carried out according to formula (3):

$$M_i \text{ emission} = q_i \times S \quad (3)$$

where, i – a mixture of pollutants (CO, NO_x, etc.); q_i – specific pollutant emission rate; S – the area of the fire, ha.

If information is available on the emissions M_i of each pollutant or mixture of such substances and its density, based on the conclusions of laboratory tests and any inspections, the values will be taken from the available data when calculating the amount of damage. Specific emission refers to the emissions per unit mass of a combustible substance or mixture of such substances, expressed by the symbol q . Specific emission values are in t/t. If there is information on the volume of the combustible substance, it is converted to the mass of the combustible substance, taking into account the density depending on the type of substance.

Determination of the amount of damage caused by unorganised emissions of pollutants or mixtures of such substances into the air during emergencies and martial law

The amount of damages is calculated by authorised persons exercising state supervision in the field of environmental protection, in particular, but not exclusively, materials confirming the fact of air pollution are calculated according to the formula (4):

$$D = M_i \text{ emission} \times Tr \times Cdc \times E_i \times Ce \times Cne \quad (4)$$

where, D – share of the damage, hryvnias; M_i emission is the mass of an unorganised release of a pollutant or a mixture of such substances into the atmosphere as a result of emergency situations or during martial law, t; Tr – the tax rate for fugitive emissions of pollutants or a mixture of such substances into the atmosphere, UAH/t; C danger class – coefficient of the danger class of pollutants or mixtures of such substances; E_i – environmental impact factor depending on the duration of the event; Ce – coefficient depending on the scale of events; Cne – coefficient depending on the nature of the origin of the event. D – total damage is calculated as the amount of damage from uncontrolled emissions into the atmosphere based on the total indicator of each pollutant or mixture of such substances.

The calculation of the amount of damage caused by uncontrolled emissions of pollutants or mixtures of such substances into the atmosphere as a result of emergencies and/or curfew periods is controlled in the field of environmental protection by the authorised bodies exercising state supervision.

5. Results.

The economic and environmental situation in Ukraine is significantly affected by the activities of the military-industrial complex, which is a major polluter of the environment (Report, 2004). The defence capability of the state is primarily determined by the level of development and technical equipment of the Armed Forces of Ukraine. All other aspects of the activities of the Armed Forces of Ukraine, especially the requirements for environmental safety of the army, defence facilities and military activities, should take into account that military readiness for the defence of the country requires the deployment of military units and military exercises.

However, the level of armament of military units and the state of the domestic defence industry are long outdated, especially in terms of environmental impact. More than 90% of the available weapons and military equipment (WME) in the Armed Forces and other military formations are morally obsolete, and about 80% of WME is physically outdated (Obnyavko, 2015).

During the years of Ukraine's independence, there has been an unjustified reduction in armaments and military equipment and their sales on the world market, mainly aircraft, armoured vehicles, air defence systems, and ammunition. However, with the outbreak of the military conflict in eastern Ukraine, the export of weapons and military equipment has significantly decreased, as weapons and equipment have become necessary for defence, and while in 2012 the revenue from arms sales was USD 1,498 million, in 2018 it was only USD 1,437 million. In 2018, it was only USD 224 million (Ministry of Defence of Ukraine, 2022).

The Ministry of Defence of Ukraine (2022) estimates that in 2020-2022, imported weapons and military equipment will amount to 10% of the State Defence Order (SDO). The rearmament with new weapons and military equipment is massive only for one item – the supply of ATGMs and missiles produced by the Luch State Design Bureau, while the rest of the new weapons and military equipment are single purchases or prototypes.

The AFU is in dire need of high-precision weapons, including unmanned aerial vehicles (UAVs), but the demand for such weapons exceeds the capabilities of the domestic defence industry (Grechanik et al., 2023). The way out of the crisis in the defence capability of the state as a whole should be

primarily associated with the technical re-equipment of the army. In general, the level of defence spending, in particular, on the execution of orders by the military-industrial complex, has been growing since the beginning of the military conflict in Donbas (Fig. 1).

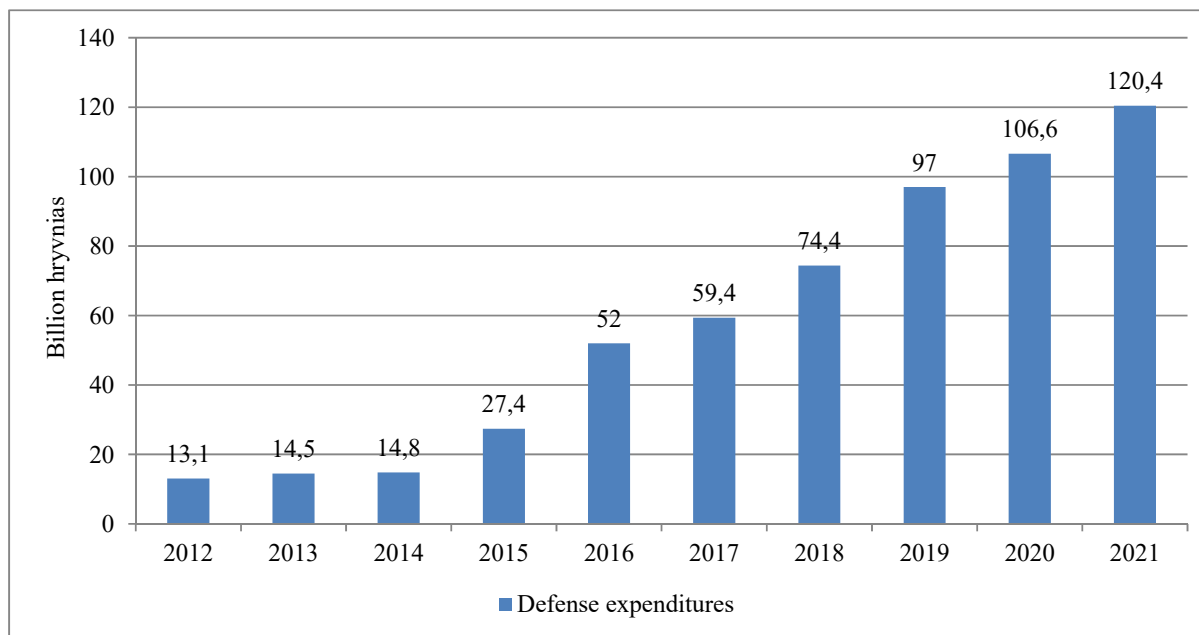


Fig. 1. Defence spending in Ukraine.

Source: based on State Statistics Service of Ukraine, (2022).

Since independence, the Ukrainian army has lost the state's interest in maintaining its combat capability. The available weapons and military equipment have been outdated for more than twenty years. Thus, in 2021, the share of weapons and military equipment with a service life of more than 20 years is 92%, while the share of weapons with a service life of up to 10 years

is only 1.2% (Table 1). Unfortunately, the situation has not changed dramatically in recent years, with new models of weapons and military equipment hardly ever being used to rearm the Armed Forces, and with the wear and tear of weapons and military equipment exceeding 90%.

Table 1. Total service life of weapons and military equipment of the Armed Forces of Ukraine in 2021.

Indicator	Up to 10 years	Up to 15 years	From 15 to 20 years	From 20 to 25 years	Over 25 years
Distribution of weapons and military equipment in accordance with the term of service life, %	1,2	1,8	5,0	38,7	53,3

Source: based on Defence Polic (2022).

The level of military equipment and the defence industry has long been out of step with the times, including in terms of environmental impact. However, given the ongoing hostilities in Ukraine and the need to upgrade the country's military potential, the activities of the country's defence industry will be intensified (Koval et al., 2022).

The Ukrainian navy ships were built without taking into account environmental standards, so they are not equipped with domestic water treatment systems. Even before the occupation of Crimea, it was established that each ship of the Black Sea Fleet in the main

base, Sevastopol Bay, discharges 2.5 to 6 m³ of bilge and ballast water and oil products into the sea per day (OECD, 2022). To this must be added pollution from half-submerged and rusting warships.

In the Armed Forces of Ukraine, environmental protection is limited to the disposal of ammunition (235.29 thousand tonnes of ammunition were disposed of between 2014 and 2020) and liquid rocket fuel (16.7 thousand tonnes of melange), but the melange disposal programme was completed in 2014 (Figure 2) (Obnyavko, 2015).

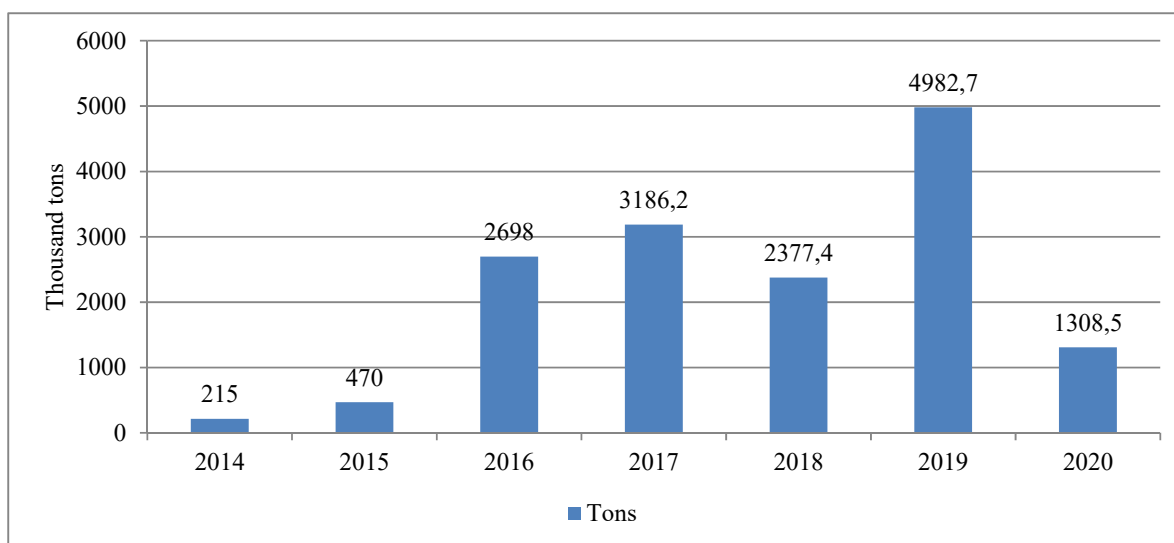


Fig. 2. Dynamics of liquid rocket fuel utilisation in 2014-2020.

Source: based on State Statistics Service of Ukraine (2022).

In 2011-2013, the utilisation of ammunition was 240.5 per cent, 272.4 per cent, and 264.9 per cent, respectively, compared to 1999. These dynamics contributed to the creation of an ammunition shortage with the outbreak of hostilities in the eastern part of the country, and since 2014, ammunition disposal has declined sharply.

Currently, Ukraine has some work on environmental policy within the Armed Forces of Ukraine (AFU) and the defence industry. For example, the Centre for Military Ecology of the Ministry of Defence of Ukraine has been operating since 2001. One of the main tasks of this Centre in the current environment is to support and implement the Programme for the

Rehabilitation of Territories Contaminated by Military Activities.

The Annual National Programme under the auspices of the NATO-Ukraine Commission for 2021 was approved by the Decree of the President of Ukraine No. 189/2021 of 11 May 2021. The Programme is harmonised with the main strategic documents of Ukraine, in particular the Law of Ukraine "On National Security of Ukraine", the National Security Strategy of Ukraine, the Strategic Defence Bulletin of Ukraine, the Programme of Activities of the Cabinet of Ministers of Ukraine, and the Sustainable Development Goals of Ukraine for the period up to 2030 (Mandryk et al., 2017).

Implementation of the Programme will be an effective response to the challenges faced by Ukraine in the context of changes in the global security environment and will bring it closer to compliance with the basic principles laid down in the North Atlantic Treaty of 1949, in particular economic standards. The programme focuses on the state's efforts to ensure the health, safety and well-being of its citizens as a key national security issue. When developing the environmentalisation of their armed forces and other military organisations, Ukraine should draw on the experience of developed countries, in particular the United States, as the world's leading military-industrial complex, which pays great attention to environmentalisation.

According to US experts, environmental safety documents prepared by military experts are also important for planning the production activities of industrial enterprises that fulfil orders from the Ministry of Defence, as they are taken into account when allocating financial resources at each stage of the programme. According to the DRI documents, the implementation of the environmental safety concept in the area of responsibility of the Ministry of Defence is entrusted to the Deputy Minister for Acquisition of Arms, Technologies and Logistics, who manages all programmes for the creation of advanced weapons systems, development of new technologies, and supports cooperation with industry. The Office of this Deputy Minister is the key body of the Ministry of Defence that implements measures to reform the system of acquisition of weapons and military equipment in accordance with the concept of WME and ensure environmental safety throughout the entire life cycle of weapons and military equipment (State Emergency Situations Service of Ukraine. (2019).

The governments of NATO and European Union (EU) countries, together with the management of industrial companies, came to the conclusion that it was necessary to create an environmental control system based on common approaches and practical standards of the EU and NATO. Such a measure would take into account the peculiarities and specifics of each country's national legislation on environmental protection and restoration and ensure its effectiveness.

On the initiative of the NATO Committee on the Challenges of Modern Society (CCMS), which was agreed with the governments of the USA, UK and EU countries, NATO created a joint system for organising and implementing environmental control measures, of which the Environmental Management System (EMS) – environmental safety management of the armed (Marler, 2013). Environmental training for armed forces personnel, based on the so-called "green approach" adopted by NATO and EU countries, is carried out within the framework of the NATO-wide concept of "Sustainable Environmental Development", which is equally applicable to both civilian and military activities (Hakim et al., 2022).

One of the NATO bodies that synthesises environmental assessments in areas where troops are deployed is the NATO Environmental Protection Working Group (EPWG). This group was established by the Joint Services Department of the NATO Military Standards Agency to develop common approaches, procedures and practices in the field of the environment, which should become an integral part of the activities of NATO forces in the performance of their direct peacetime tasks.

The EPWG's functions include the following key activities:

- monitoring compliance with the adopted standards and their improvement;
- organising training for personnel assigned to implement environmental programmes and providing them with support in terms of professional development;
- monitoring of environmental protection measures in the course of the troops' daily activities;
- verification of the effectiveness of the EMS system elements at each military facility (garrisons, infrastructure) in terms of environmental control and environmental safety.

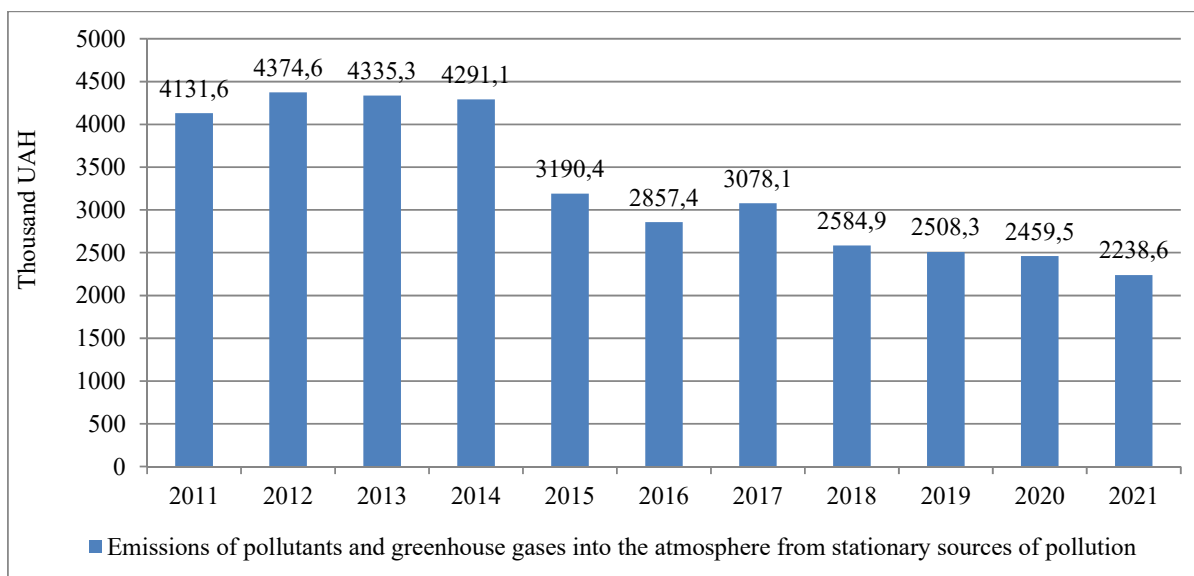
In addition, the EPWG deals with issues of environmental security in the context of non-traditional threats and environmental stresses, which involve strengthening the cooperation of NATO and the EU in joint actions aimed at countering global environmental threats (Austin et al., 2000). Thus, the strategic goals for the development of environmentalisation in the Armed Forces of Ukraine are presented in Table 2.

Table 2. Assessment of the economic potential of greening the armed forces in the context of strategic development goals.

Strategic goals of of the Armed Forces of Ukraine	Areas and measures of greening
Reducing the negative impact of the activities of the Armed Forces of Ukraine	Implementation of the necessary protective measures against environmentally hazardous waste from production, reduction of noise levels near airfields, wave pollution, excessive heat, electromagnetic radiation from military exercises at training grounds, firing ranges, training centres, military camps, etc. Reducing the number of military personnel in contact with sources of noise, wave pollution, supernatural heat, electromagnetic radiation, military training ranges and shooting ranges. Equipping firing ranges with bullet traps for the disposal of used ammunition. Equipping premises near airfields with noise insulation.
Implementation of resource-saving technologies in the activities	Saving fuel and reducing emissions from warships and vehicles by adjusting engines, introducing smooth driving techniques, and improving maintenance.
Environmental monitoring of environmental impact	Establishment of special environmental protection services directly at military facilities. Developing a mechanism of responsibility of military leadership for environmental damage. Developing a system of financial incentives for the implementation of greening. Involvement of public authorities and civil society organisations in maintaining environmental balance in the locations of military facilities. Development and implementation of environmentally friendly plans for military exercises.

It should be noted that comprehensive greening of the MIC is possible only if all actors of the complex are simultaneously involved in this process. The timely transition of the Armed Forces and the defence industry to the principles of sustainable development is the key to the successful integration of the MIC into the national sustainability system. The issue of ecology and the introduction of green technologies is very relevant for Ukraine. As a

result of the economic crisis and the military conflict in the eastern part of the country, the activity of polluting sources (enterprises, including defence companies, military units, etc.) in Ukraine has generally decreased, and in 2021, emissions of pollutants from stationary sources decreased by 9.0% compared to 2020, to almost 2.2 million tonnes (Fig. 3) (State Statistics Service of Ukraine, 2022).

**Fig. 3. Dynamics of pollutant emissions from stationary sources in Ukraine in 2011-2021.**

Source: based on Service of Statistics of Ukraine (2022).

In 2021, Ukraine generated 462.4 million tonnes of waste (including from the defence industry), which is 4.7% more than in 2020 (Fig. 4).

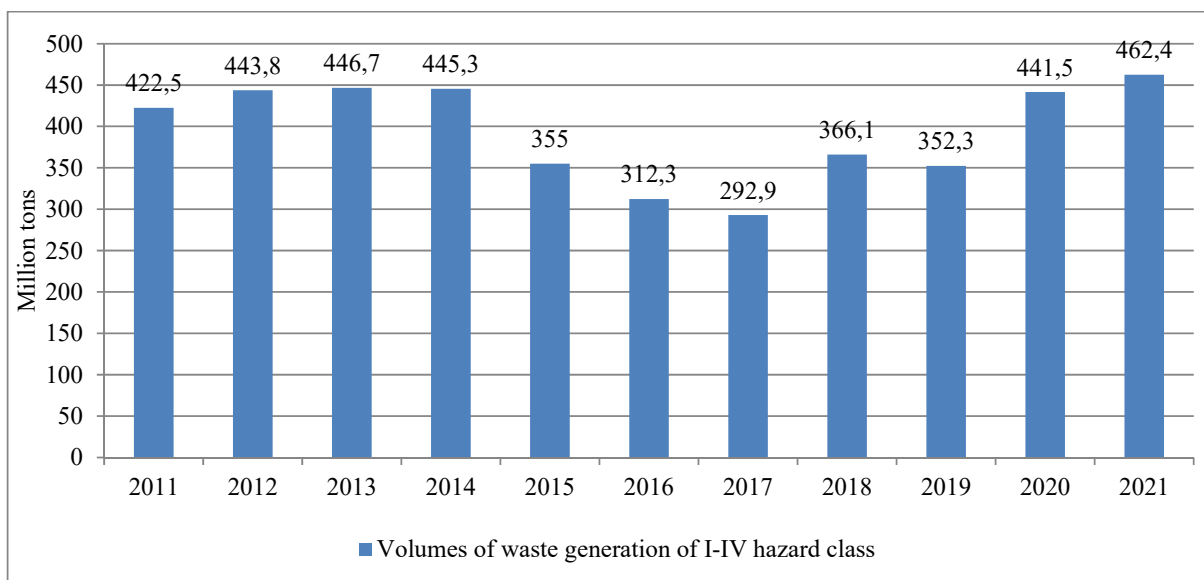


Fig. 4. Dynamics of waste generation in Ukraine in 2011-2021.

Source: based on State Statistics Service of Ukraine (2022).

Environmental protection costs are constantly growing (Fig. 5), although in 2021, enterprises, organisations and institutions spent UAH 41.3 billion (excluding VAT) on environmental protection compared to UAH 43.7 billion in 2020. Of the total environmental expenditures in 2021, 68% were current expenditures and 32% were capital investments (Service of Statistics of Ukraine, 2022).

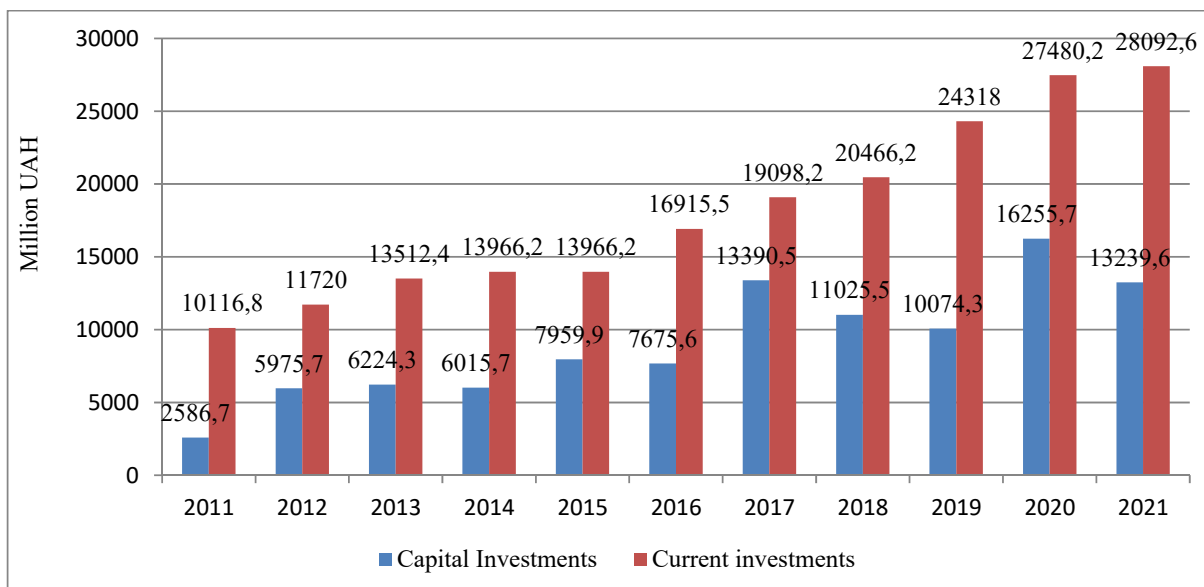


Fig. 5. Dynamics of costs for environmental protection in Ukraine (million hryvnias, in actual prices).

Source: developed by the authors based on Statistical Service of Ukraine (2022).

Environmental issues are not a priority at defence enterprises. Most enterprises do not have a special service or unit for environmental management. Therefore, it is advisable to study the experience of implementing greening, in particular, in NATO member states, where the NATO Group on Acquisition Practices, known as AC/313, operates. This group is one of the

leading analytical working bodies of NATO that directly supports the activities of the Conference of National Armaments Directors (CNAD), which is the highest authority in the structure of the bloc and manages the process of acquiring weapons and military equipment for the joint armed forces. Strategic goals for the development of Ukraine's defence industry are shown in Figure 6.

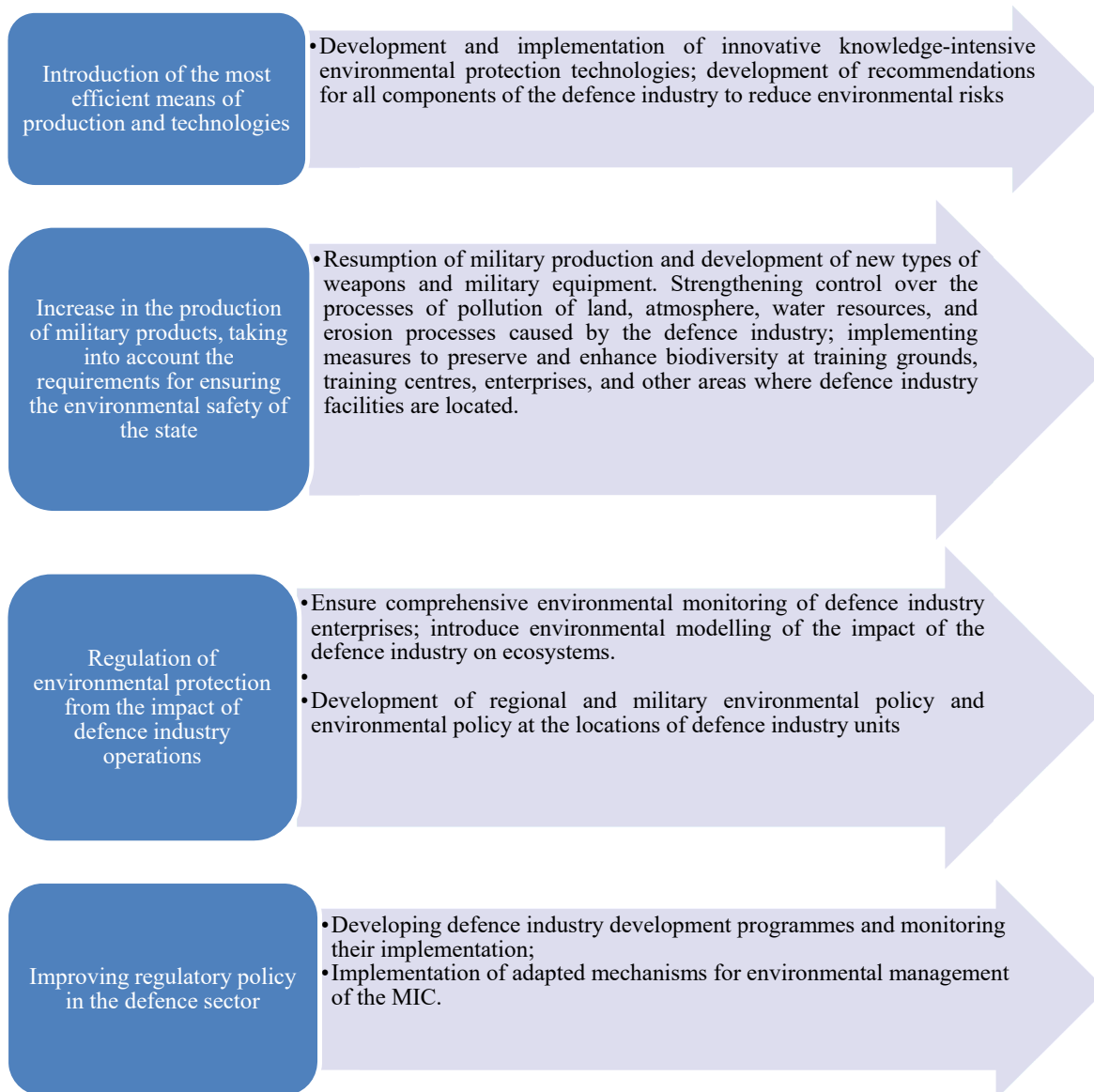


Fig. 6. Directions of greening the defense-industrial complex in the context of strategic development goals.

Source: based on Saha et al. (2022).

The main tasks of environmentally oriented development of the MIC include (Becker et al., 2022):

- comprehensive surveys to assess the level of soil, air and water pollution in the area of influence of military complexes;
- identify, develop and implement specific measures to eliminate and prevent the harmful effects of the activities of military formations and defence enterprises;
- to develop and implement recommendations for eliminating factors harmful to the environment (use of advanced technologies for the disposal of ammunition, toxic substances, production of environmentally safe military equipment and weapons);
- to introduce effective mechanisms of liability of defence enterprises for environmental damage and to help minimise harmful environmental impact.

Implementation of the greening directions should significantly increase the level of greening of the defence industry, the competitiveness of defence enterprises and the products they produce, facilitate the country's access to international markets for weapons and military equipment, provide employment in Ukraine and the preconditions for poverty reduction, and intensify the greening policy of the economy as a whole.

6. Conclusions.

The greening of Ukraine's defence industry should be seen as a component of national and international environmental regulation, the implementation of which is possible only if countries develop a common worldview and determine a common vector for further environmentally friendly development.

The analysis of economic and environmental problems existing in the activities of various components of the national industrial complex has shown that all these problems have an extremely unfavourable mechanical, chemical and biological impact on nature.

The armed forces management system traditionally needs to pay more attention to the implementation of a strategy to reduce the threat to the environment from ammunition depots, bases, fuel and waste storage facilities in military camps, and to implement systemic programmes to raise environmental awareness among military personnel and to form an appropriate environmental culture. The environmental work of defence enterprises and other branches of the military industry should be carried out not only in the direction of preventive management of the risk of harmful environmental impact, but also in the direction of eliminating existing environmental problems.

The realisation of the greening potential depends on targeted economic, legal, technical and environmental, organisational and educational activities. Thus, in order to protect the country's natural resource potential under the influence of the defence industry, it is necessary to develop a system of measures that ensure the protection and restoration of natural systems at a certain cost. Given the importance of the defence industry for Ukraine in the context of current external threats and armed conflicts in certain parts of the territory, it is necessary to develop a strategic vision of environmental security with the involvement of all relevant organisations. Developing a common view of the problem, taking into account the degree of responsibility and motivation for environmentally oriented management.

It is beneficial to understand the complex greening of all components of the defence industry as a continuous and purposeful process of fundamental introduction of new technologies, technological, economic, organisational, information and other solutions that provide an intermediate opportunity to achieve the maximum possible balance of military, economic and environmental goals, ensure the protection of ecosystems and create conditions for their self-renewal, significantly increase the efficiency of the use of resources of all kinds and improve the quality of products and services.

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