A statistical study of climate change in Ukraine under martial law

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ABSTRACT

The article concentrates on the development of theoretical and methodological foundations of statistical research in the field of national environmental and economic accounting, which forms the basis for the development of indicators of climate change under martial law and shapes the adaptation to these changes. Given Russia's military aggression against Ukraine, the national statistical system is faced with an urgent task of ensuring the continuity of the production of complete and high quality statistical information.

The issue of forming a methodology for the production of statistical information in the field of ecology, i.e. climate change statistics, remains unresolved. Outlining ways to address this issue is an important condition for the improvement of modern state statistics of Ukraine and the development of statistical theory and practice, as this largely determines the quality of the information-related support for environmental management at all levels.

The statistical estimation of the dynamics and structure of greenhouse gas emissions on the basis of the economic activity of enterprises was performed. It was pointed out that among the various related branch methods of obtaining information, the system of environmental and economic accounting is the most relevant and source of high quality data. One of the aspects of solving the complex problem of forming methodological bases for collecting statistical environmental information is the creation of a national system of indicators of climate change and preparing statistical informational products using administrative data sources.

The paper studies issues of producing ecological information relating to Ukraine according to statistical data. Moreover, the main problems which arise during the construction of national environmental accounts were characterised. Finally, the paper identified the key factors which influence to the largest extent the quality of statistical data and calculations, and which are necessary for the transformation and development of the statistical estimation of climate change under Russian military aggression.

Key words: climate change statistics, environmental and economic accounting, natural environment, statistical evaluation, ecological processes.

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1. Introduction

So far, the war in Ukraine has led to large-scale destruction and mass deaths. Of course, there will be much more of them, as the military conflict continues. Any war causes enormous damage to the environment and the current situation is no exception. Although the fighting is still ongoing, it has already led to a significant deterioration in the environment and agricultural land, as the destruction of the chemical industry, oil refineries, fuel storage facilities and fossil fuel consumption during hostilities has led to huge greenhouse gas emissions (hereinafter - GHG) into the atmosphere of the planet. But in addition to emissions of hazardous substances, we should expect long-term losses due to the collapse of global efforts and measures to slow down the pace of climate change on the planet.

Due to the ongoing hostilities, it is now difficult to assess the damage done to the country's natural environment, so improving the organizational and methodological framework for statistical production of climate change indicators to assess existing losses is one of the main tasks today.

An integrated approach is needed to effectively produce statistical information on environmental processes during a military conflict. Today, the priority issue is to ensure the ability of the environmental and economic system of the country to develop in conditions of war, and this requires high-quality statistical information that will enable a full and reliable assessment of environmental losses.

As a result, there is an increasing need to modify the system of collecting and processing statistical information in order to assess climate change and to increase the requirements for existing statistics, including those regarding natural capital. Appropriate changes to metadata should be made using a proper set of rules. Faced with reality, we need to adapt to changes and their consequences, primarily through the rational management of water resources, reducing the use of other natural resources. But we will be able to control all this only when we have high-quality statistics to make informed decisions in a state of war and to develop an effective environmental policy. The next step should be the development of new technologies that will facilitate both adaptation to climate change and the implementation of effective mitigation measures.

Thus, our task is to conduct a qualitative statistical assessment in today's conditions, to develop and improve existing approaches to building a system of indicators of natural capital accounting, which, in turn, characterize climate change and adaptation to these changes. Improving the methodological and methodical foundations of statistical accounting and assessment of environmental indicators of climate change requires a clear and comprehensive statistical approach. Statistical analysis and evaluation can provide a complete picture of the functioning of such

a complex phenomenon, help develop measures to reduce the negative impact on the environment, and, consequently, mitigate the negative effects of climate change on our planet.

The purpose of the research is to substantiate the basics of national statistical production and evaluation of information on climate change under martial law, the formation of environmental and economic governance mechanisms and their proper application.

2. Theoretical and methodological problems of statistical study of the national climate change statistics

Despite the extreme urgency of the problems of ecology and environmental protection, today both in Ukraine and abroad there is no unambiguous definition of the concept "natural capital". This term belongs to the economist E.F. Schumacher, who introduced this concept in 1973 in the book "Small is Beautiful: A Study of Economics As If People Mattered". There are many definitions of this term. A typical example was developed by the Natural Capital Coalition after a lengthy consultation process: natural capital is another term for a stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soil, useful minerals) which, if combined, benefit people (SEEA).

One of the authoritative sources in this field is the Glossary of Statistical Terms of the Organization for Economic Co-operation and Development (OECD). It defines natural capital as natural assets which act as natural resources and environmental services for economic production (Glossary of Environment statistics). The UN Glossary of Environmental Statistics defines natural capital as natural assets in their role in providing natural resources and environmental services for economic production (Environment glossary).

Climate change is defined in Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC). According to it, the term "climate change" means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. The term "climate system" is interpreted by the Convention as "the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions". In addition, the UNFCCC defines the term "adverse effects of climate change" as "changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare" (United Nations). In turn, NASA experts believe that climate change will affect people around

the world. Rising global temperatures are expected to raise sea levels and change both precipitation and other regional climatic conditions. Regional climate change will affect forests, crop yields, drinking water supplies, as well as human and animal health and almost all types of ecosystems. Deserts will expand to existing ridges, and the areas of national parks and national forests will be constantly changing (GlobalMaps; Global climate change).

Today, the world community is facing an acute problem of increasing the concentration of hazardous substances, especially GHG, in the surface layers of the atmosphere. Scientists around the world are conducting numerous studies to identify effective ways to implement alternative energy sources, calculate quantitative indicators of GHG emissions, develop various scenarios and algorithms to combat the negative impact of human economic activity on the natural environment (Khvesyk, 2010; Bun, 2004). The leading role in reducing the level of anthropogenic GHG emissions in national plans and programs is given to energy, energy conservation and energy efficiency, development of renewable energy sources, and, in the long run, replacing fossil fuels in power plants, in the process of combustion of which the significant amounts of carbon dioxide (CO2) are released.

The main sources of carbon dioxide emissions are extraction, processing, storage, transportation and consumption (combustion) of carbon-containing fuels (coal, oil and natural gas), internal fermentation of animals and livestock waste, agriculture (rice cultivation, which produces significant amounts of methane), the use of nitrogen fertilizers (with the subsequent formation of nitrogen oxides) (SEEA).

In recent decades, even before the onset of hostilities, climatic conditions in Ukraine have been changing significantly, causing increased risks to human health and life, natural ecosystems and sectors of the economy. Thus, warming leads to: sudden changes in weather; increase in frequency and intensity of dangerous natural hydrometeorological phenomena both in a warm season (showers, thunderstorms, squalls, hail, long hot periods), and in cold (heavy snowfalls, ice, difficult deposits); increasing the frequency and intensity of droughts and expanding the areas covered by them; reduction of river runoff in the south and south-east of Ukraine, increase in the intensity of floods on the rivers of the west of the country (Prykarpattia and Zakarpattia (Subcarpathia and Transcarpathia)), especially in the Dniester river basin; changes in the annual distribution of river runoff.

Combating climate change is a global challenge, which requires broad international cooperation, the consensus of which is reflected in a number of successive international agreements: UNFCCC (United Nations, 1996), the Kyoto Protocol (Kyoto Protocol) and the Paris Agreement (Verkhovna Rada of Ukraine, 2016). Given that the tools provided for in the first two agreements failed to achieve a significant reduction in GHG emissions, 195 countries signed the Paris Agreement, which entered into force on

November 04, 2016 (Verkhovna Rada of Ukraine, 2016). According to the goal of keeping global average temperature increase below 2°C of pre-industrial level, the Paris Agreement parties must balance sources of GHG emissions and removals in the second half of this century or in fact achieve net zero global GHG emissions by 2100.

Ukraine's goals are consistent with the global goals of the Paris Agreement, and joint international action will be crucial to achieving them. International cooperation will significantly reduce decarbonisation costs and create economic opportunities for people and enterprises, while reducing the risks and consequences of climate change. In addition, in order to improve the current climate policy, the Cabinet of Ministers of Ukraine by orders of 07.12.2016 № 932-r and of 06.12.2017 № 878-r approved the Concept for the Implementation of State Policy in the Field of Climate Change until 2030 and the Action Plan for its implementation (Cabinet of Ministers of Ukraine, 2017). This Concept defines the tasks in the following areas: increasing the institutional capacity of formation and implementation of state policy in the field of climate change; prevention of climate change by reducing anthropogenic emissions with increasing GHG absorption and ensuring a gradual transition to low-carbon development of the state; adapting to climate change, increasing resilience and reducing the risks associated with climate change.

Climate change is a threat and poses a huge challenge to society. Better understanding of all aspects of it through monitoring, modelling, analysis and reporting is crucial to identify best practices. Demands for environmental information in modern society are high, so government statistics bodies play an important role as major producer of high quality data.

In the long run, adaptation to climate change in Ukraine will have the same priority degree as climate change prevention, and will cover aspects such as proper policy planning and improvement in the context of expanding the knowledge base, scientifically based determination of needs and costs, implementation of innovative approaches and creating conditions for attracting foreign investment (Khvesyk, 2013; Stepanenko, 2016).

Scientific research often gives a picture of a particular issue at a particular point in time. Such research is certainly important for understanding this issue and ways to address it, but it does not always provide an understanding of how this phenomenon is developing in dynamics. This is where official statistics are of particular value, given that the development of long consecutive time series is the main competence of the national statistical system (NSS) of the country (Osaulenko, 2008; Osaulenko, 2020).

Official statistics involves the development of methods for adjusting data for comparability of changes over time, for example, by taking into account seasonality, price variation, temperature, etc. When such adjustments are made, the influence of a known source on data change is eliminated and only changes caused by unknown

sources of impact and natural changes remain. This type of data processing is important in the study of climate change because by definition it is an issue that requires assessment over time, and therefore benefits from the use of long time series available in the NSS. The statistical system also has methodologies, techniques and procedures to develop statistics that are internationally comparable. This is done through a global institutional infrastructure that harmonizes definitions, classifications and data collection processes between countries. In addition, the main goal of the statistical system is to create quality statistics for the needs of society. Official systems of the countries of the world have developed their own methods of data collection to improve their reliability and timeliness, so statistical agencies can help, in particular, to satisfy requests for timely information on climate change (SEEA; Eurostat, 2021).

Scientific research emphasizes the importance of statistical assessment of socio-economic aspects of climate change and its impact for sustainable development (Verkhovna Rada of Ukraine, 2010). In this context, the NSS of Ukraine provides statistics for the creation of GHG emission inventories (cadastres) in order to provide a broader and more reasonable assessment of the socio-economic aspects of climate change. Recently, official statistics has increasingly focused on the issues of the environment and climate, giving preference to the development and improvement of methodologies and processes for compiling environmental accounts for the economic measurement of natural resources, energy, waste, water resources and emissions to the atmosphere, as well as environmental protection costs (State Statistics Service of Ukraine, 2018, 2019, 2020). However, despite the many competencies of the statistical system for measuring climate change, existing official statistics does not always use its potential to assess climate change.

The UN Statistical Commission has adopted a system of environmental and economic accounting (hereinafter – SEEA) at the global level. This new standard provides important support for the development of statistics on climate change by strengthening work on environmental and economic accounting. The SEEA contains internationally agreed concepts, definitions, classifications, accounting rules and tables for the production of comparable statistic data on the environment and its interrelation to the economy (SEEA).

Considering climate change statistics as a tool for influencing decision-making in this area, we will determine how to improve statistical accounting relative to climate and climate change. A change from a statistical standpoint is the difference between two observations (usually an absolute or relative difference between the values of indicators at different points in time). Qualitative measurement of change requires consistent and comparable data collected over a long period of time. In general, existing official statistics are not developed to analyse climate change. Therefore, the NSS needs to be transformed to better respond to the need for data and assessment regarding

climate change. This will certainly require new ways of disseminating official statistics, collecting data, and also may lead to organizational changes in the statistical system.

The statistical system of Ukraine currently offers a lot of data on different areas of socio-economic and environmental life of the country, but often does not pay much attention to preventing duplication of data and measuring the relationship between these areas of statistics. Defining and modelling interactions is the work of economists, scientists, analysts, experts of state ministries, etc., who are outside the statistical system (Mishchenko, 2007; Lavryk et al., Dorohuntsov, 2007). The main elements of these definitions are: human-caused climate change (not related to natural causes); climate as a system consisting of several components (atmosphere, hydrosphere, etc.), their interaction; taking into account the fact that climate change ultimately affects both the natural environment and the socio-economic aspects of human life.

The main cause of climate change due to human activities, which is the basis of development and technological progress, is GHG emissions into the atmospheric air. Thus, Article 2 of the UNFCCC, outlining the main purpose of the Convention, clearly states this reason: "The ultimate objective of this Convention and all related legal instruments ...is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (United Nations, 1996).

How can a statistical system, which has many particular qualities of accounting and data collection that are important in the context of climate change (Cabinet of Ministers of Ukraine, 2001), help to measure it? Official statistics adhere to international principles and standards in this area, which are formulated as a result of numerous discussions on climate change and are characterized by a number of important features. First of all, official statistics mainly measure the activities of legal entities (enterprises), individuals and households. Monitoring the state of the natural environment, climate changes and adaptation to these changes is usually carried out outside the statistical system. However, when data on the environment and climate are related to sectors of the economy and households that affect the environment, these data may fall into the scope of official statistics. The latter also often contains links to the geographical region. In some countries, statistics receive exact spatial coordinates using geo-links. This practice needs to be actively developed further, as the spatial dimension is too important in the context of climate change.

The development of new statistics to support the analysis of climate change within the statistical system, such as monitoring progress towards the ecological structure of

consumption and production, will be a challenge for the NSS. As climate change statistics cover many sectors, it is necessary to outline and study the field of statistics related to these changes, as well as to create a structure in the statistical bodies which will be responsible for this area.

Intensification of extreme weather and climate events will cause an increase in negative impact on ecosystems, economic sectors, health and welfare of population. As a result, actions to adapt to climate change must be paramount and tailored to specific circumstances in different areas of human activity. It is now clear that the issues of the quality of our habitat cannot be approached only in any one of aspects, but must be comprehensive. The current model of environmental development is futureless for humanity in terms of security, as it exacerbates the environmental and economic problems of various spheres of activity. The ecological condition of the environment continues to deteriorate, and therefore the preservation of nature, in particular the reduction of emissions of hazardous substances from all sources of pollution, should become a priority for every state and society.

The formation and implementation of the country's socio-economic development strategy and state environmental policy must be coordinated and interconnected, as the health of the nation, environmental and social growth are closely and inextricably linked. The modern national economy is impossible without taking into account the environmental component. Over the past year, Ukraine has approved a number of important measures in the field of environmental policy, including the Action Plan for the Implementation of the Concept of the State Climate Change Policy; the Low Carbon Development Strategy of Ukraine until 2050 was worked out, and work on legislation to monitor greenhouse gas emissions has started (Ministry of Energy and Environmental Protection of Ukraine, 2018). High-quality statistical data will provide the basis for effective decision-making regarding climate action. State statistics bodies play a key role in national efforts to promote the development of official statistics for climate assessment and national reporting. Thus, the main task of this development is the scientific substantiation of the following statistical estimates:

- GHG emissions;
- drivers of climate change (emissions in the industrial sector, energy, agriculture, etc.);
- social, economic and environmental after-effects of climate change;
- adaptation to the obtained consequences.

The outlined direction of the research is related to the 13th Sustainable Development Goal (hereinafter referred to as the SDG) on climate change mitigation. To do this at the national level it is necessary to develop a methodology for compiling the main list of indicators related to climate change, approved by the Conference of European Statisticians in 2017 (Supporting countries to achieve the SDGs). The developed national list of indicators of SDG 13 does not fully correspond to

the global indicators of SDG (G), and therefore, the search for available sources of information is still ongoing (Figure 1).
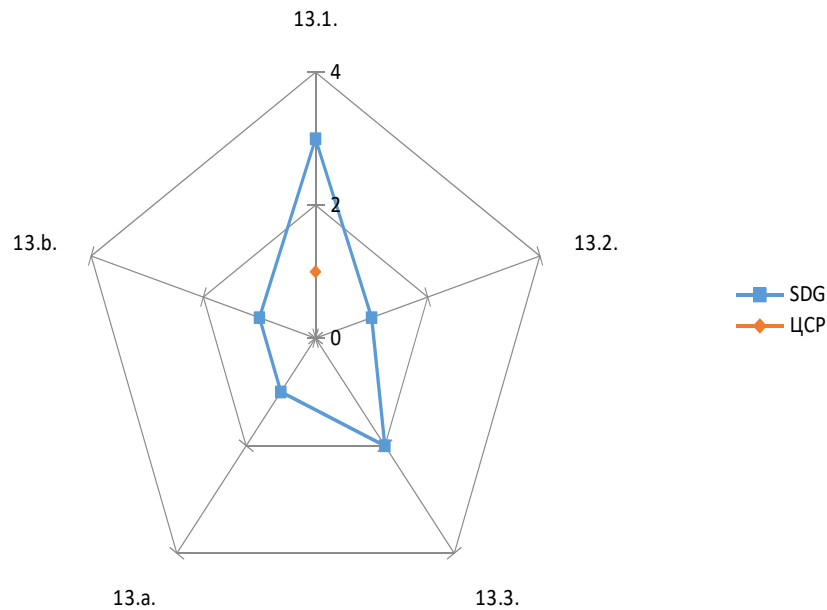

Figure 1. Comparison of national and global SDG

Source: developed by the author.

As climate change affects the natural environment and society directly through complex interactions and cause-effect relationship, the conceptual basis for the production of climate change statistics should cover the widest possible range of data and be as comprehensive as possible. Climate change, on the one hand, is due to, on the other hand, affects a wide range of anthropogenic activities. In fact, only a few human activities are not related to climate change in any way or on some aspects do not contribute to positive climate change.

As a result, the scope of statistics related to climate change is:

1) environmental, social and economic data measuring the anthropogenic causes of climate change (Figure 2);
2) the impact of climate change on anthropogenic and natural systems;
3) society's efforts to prevent effects;
4) society's efforts to adapt to these effects.

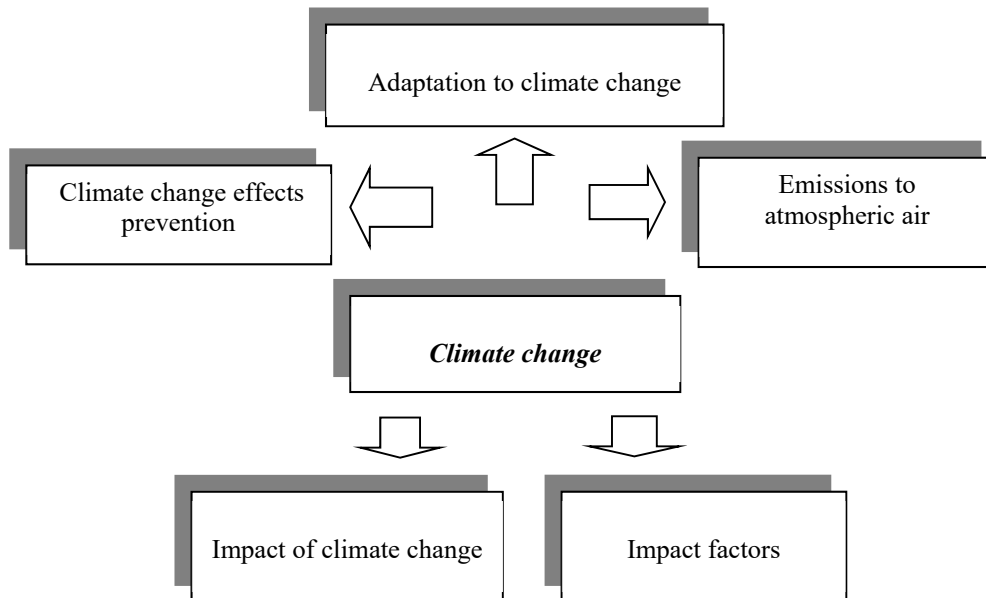**Figure 2.** Coverage of statistics related to climate change
Source: developed by the author.

3. National approaches to statistical assessment of climate change indicators under martial law

A key element in building national climate change statistics is to define basic responsibilities for quality assurance and the availability of climate change statistics, namely, the development of statistics for GHG inventory and building relationships with key users and producers of climate information, including users and producers within the NSS itself.

Exploring the capabilities of the statistical system will help to identify the subject areas related to climate change, and will provide coverage of all relevant areas in the work of the NSS. In current conditions, the following approaches to statistical accounting can be used:

- Drivers, Pressures, State, Impact and Response model of intervention, (hereinafter DPSIR);
- United Nations Environmental and Economic Accounting System (SEEA);
- United Nations Framework for the Development of Environmental Statistics (UNFDES);
- Approach to natural capital accounting;
- Impact, mitigation and adaptation.

The purpose of creating national approaches to statistical accounting is to identify the area which is best suited to structuring climate change statistics. It should be recognized that each area has its own purpose and benefits, and the areas are not independent of each other. Thus, the approach to the accounting of natural capital is closely related to the system of environmental and economic accounting, which is a statistical implementation of many, but not all areas (Osaulenko, 2020). SEEA, in turn, covers the concept of natural capital. At the same time, the structures of impact, mitigation and adaptation are identical, the main difference between them is the direct use of terminology of climate change policy.

It should be emphasized that an important feature of the SEEA is its approval by the UN Statistical Commission, which puts this system in the same category as the widely used system of national accounts (hereinafter – SNA). The SNA is an international statistical standard and system, which uses the NSS to calculate gross domestic product and other macroeconomic variables, with SEEA linking environmental statistics to economic statistics. This status makes the SEEA an attractive basis for use in measuring climate change statistics, as the NSS of European countries have already agreed to use it in the development of environmental reports (Osaulenko, 2020).

Climate change statistics can be studied and structured according to the so-called model of the DPSIR. This model is used, for example, by the European Environment Agency to structure the relationship between the environment and socio-economic activities. The DPSIR is based on a systematic approach to the assessment of environmental phenomena. Although the model seems quite simple, it may also involve a more complex accounting system. The organization of climate change statistics, based on the DPSIR model, will help to structure information from different areas, which will allow to analyse various aspects of climate change, including a wide range of socio-economic events, GHG emission sources, actions relating to adaptation and mitigation of climate change.

In turn, the impact of climate change can be seen as direct or indirect. In the first case, the impact is analysed from the standpoint of natural phenomena, for which data on water, air, land resources, biodiversity and ecosystems are relevant. The second should take into account the socio-economic impact of physical change, such as the impact on agriculture, forestry, human health and the economy. In this case, the role of the NSS is more important, as environmental data are often provided not by it, but by environmental institutions and organizations.

The United Nations Environmental and Economic Accounting System (SEEA) is a multi-purpose system for measuring the share of the environment in the economy and the impact of the economy, human activities on the environment. In practice, the SEEA covers an integrated set of basic statistics which can be regrouped into various

indicators useful for climate change analysis. This system is flexible in the sense that its implementation can be adapted to policy priorities and needs, while providing a common framework between countries and coherence with the concepts, structures, rules and principles of the SNA. Although the SEEA is not primarily intended for climate change analysis, it contains a number of components related to its various aspects, namely:

1) accounting for physical flows of materials and energy;
2) accounting for stocks of environmental assets and changes in them;
3) accounts of economic activities and operations related to the environment.

With regard to climate change, the SEEA accounts of emissions to atmospheric air contain data on the origin and purpose of these emissions, including GHGs. Thus, energy flow accounts provide relevant information on the supply and use of energy (both renewable and non-renewable). Water flow accounts are especially important for understanding the impact of climate change on changes in water availability and use. Solid waste stream accounts contain data on waste sources, their incineration and methane emissions in landfills, which is one of the powerful sources of GHG. Currently these modules are still under development and most countries are unable to provide full statistics and time series useful for environmental policy purposes.

The introduction of SEEA into the national statistical system will help to create a basis for the collection and analysis of indicators related to climate change, as those which characterize, among others:

- energy use and GHG emissions per unit of GDP by industry;
- actions regarding GHG emissions calculated on the basis of consumption;
- actions to separate the economy and the environment.

The main SEEA accounts measure the size of environmental assets (ecosystems, land and natural resources) and the annual changes of these reserves. Asset accounting is important for quantification of the impact of climate change on various environmental assets. Accounts are valued both physically and (where possible) in value terms and are compiled for energy, land, soil, timber and water resources that may change as a result of climate change. For example, as precipitation regimes vary, the availability of water resources and their geographical distribution will change.

SEEA accounts measure activities and operations the main purpose of which are:

1) prevention, reduction and elimination of pollution and other forms of environmental degradation;
2) conservation and maintenance of natural resources, and therefore protection against depletion;
3) influence on the behaviour of producers and consumers in relation to the environment.

The SEEA provides recommendations on measuring environmental taxes, subsidies, permits and licenses related to energy production and use, GHG emissions and ecological innovations. These data are the basis for analysing the relationship between GHG emissions, energy use and emissions permits, as well as for monitoring GHG emissions trading. SEEA limits the scope of activities that are considered environmental, environmental protection and resource management activities.

National environmental and economic statistical accounting is represented by two SEEA accounts. They are: 1) the account of emissions into the atmosphere; 2) auxiliary (satellite) cost account for the protection of the national natural environment.

First of all, it should be noted that the Decision No 1578/2007/EC of the European Parliament and of the Council of 11 December 2007 on the Community Statistical Programme 2008 to 2012 determines the need to produce high quality statistical information and accounts on the environment and to supplement existing indicators with data, including environmental and social aspects, in order to implement a coherent and comprehensive environmental policy (State Statistics Service of Ukraine, 2019, 2020). That is why environment and economic accounting (hereinafter - EEA) has been introduced as a statistical tool in order to monitor the pressure exerted by the economy on national natural environment, and to study ways to reduce it.

Taking into account the existing international and European experience, the organization of creation, analysis and dissemination of environmental and economic accounting is entrusted to the State Statistics Service of Ukraine. The purpose of the introduction of the account of emissions into the atmosphere is the formation of statistical information on the amount of pollutants and GHG entering the air from the production activities of residents within the economic territory of the country to provide data for environmental and economic analysis.

The introduction and maintenance of a national EEA ensures complete and high-quality accounting of the condition and use of the national natural environment. The environmental account of emissions into the atmosphere registers the flows of gaseous and dispersed materials, describing these emissions by their sources and types of economic activity in terms of both production and consumption. Atmospheric emissions include emissions of GHGs and air pollutants, taking into account the principle of residency. This principle can be formulated as follows: an economic unit is considered to be a resident unit of a country if the centre of its economic interest is located in the economic territory of that country, i.e. if this unit carries out economic activity in this territory for a long period (one or more years).

It should be noted that the first experimental calculations in the official statistics of Ukraine were conducted in 2015 on the basis of data for 2013 in compliance with international standards for accounting and dissemination of data on emissions of pollutants and GHG into the air in a way compatible with SNA. The development of

this account provided data on emissions of pollutants and GHG in the atmosphere air from enterprises and households activities.

The basic standard for creating an account is the International Standard of the System of Environmental-Economic Accounting 2012 - Central Framework, (SEEA) Regulation (EU) No 691/2011 of the European Parliament and of the Council of 6 July 2011 On European Environmental Economic Accounts (European Commission, 2019). The legal basis for the creation of the account on emissions is the Law of Ukraine "On State Statistics", the annual plan of state statistical surveys, which is approved by the order of the Cabinet of Ministers of Ukraine, and the procedure defined by metadata, which are approved by the orders of the State Statistics Service (Cabinet of Ministers of Ukraine, 2017). This account reflects data on 11 types of pollutants and GHGs released into the atmosphere by stationary and mobile sources of pollution by type of economic activity (KVED-2010 (Classification of economic activities). In addition to data on emissions, the account reflects economic indicators relative to output, gross added value and the number of employed population according to KVED-2010. The data sources for compiling the above account are:

- the State Statistics Service data "Protection of atmospheric air" on emissions of pollutants and solid suspended particles into the atmosphere from the production activities of stationary sources;
- the SNA data on final consumption expenditures of households, output, gross added value according to KVED-2010;
- the State Statistics Service data "Labor Force Survey" on the number of employed population according to KVED-2010.

For the purpose of maintaining the quality of statistical information, the environmental account for atmospheric air protection (hereinafter – EAAAP) is compared with national emission inventories. The data provided on a disaggregated basis may correspond to emission sources by type of economic activity and supplement national emission inventories (State Statistics Service of Ukraine, 2020).

In accordance with international and European requirements, information on emissions of pollutants into the atmospheric air is presented in terms of types of economic activities for the following substances:

- greenhouse gas emissions (CO_2, N_2O, CH_4, HFC, PFC and SF_6);
- emissions of pollutants (NO_x, CO, NMVOC, SO_2, NH_3);
- emissions of solid suspended particles (less than 10 μm and 2.5 μm).

In national inventories, GHG air emissions and pollutants are broken down by process and source, classified by technologies. Unlike environmental accounts, national emission inventories are largely based on the principle of territoriality, i.e. they cover emissions from the country's geographical area. It should be noted that the national accounting of pollutant emissions is conducted in terms of 109 economic activities

(KVED-2010) in accordance with Regulation (EU) № 691/201 of the European Parliament and the Council (Compilation Guide, 2013).

The generally recognized at the international level and adapted for Ukraine features of the calculations are the following:

- statistical data on air emissions are recorded at the time of emissions;
- emissions from cultivated plants, soils and forests are not taken into account in the calculations;
- landfill emissions are taken into account only in part of the actual entry of pollutants into the air (captured gases are not taken into account);
- emissions of non-economic origin, which occurred, for example, in wetlands, due to forest fires, volcanic eruptions, etc., are not taken into account;
- emissions from livestock due to fermentation (methane production), as well as from manure processing are taken into account if they relate to the economic activities of residents;
- repeated emissions due to natural processes in the atmosphere are not taken into account;
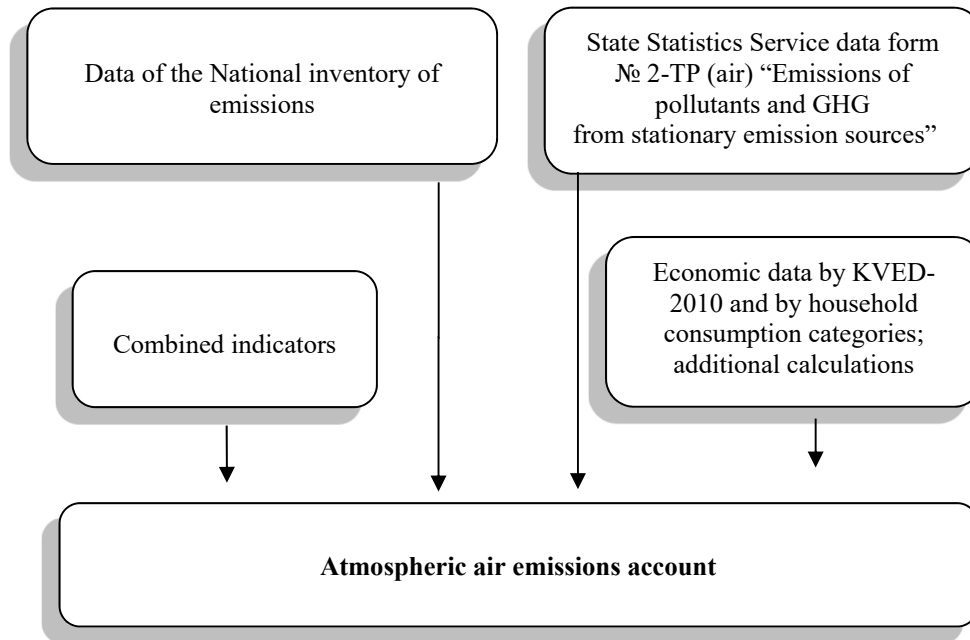- CO2 emissions from biomass are included as a separate item.

Figure 3. Chart for collecting national information to compile an account of emissions into the atmospheric

Source: developed by the author.

It should be noted that the national results on air protection differ from the results defined in the emission inventories. These differences are due to differences between the principles of presidency and territoriality and the definition / coverage of national results in the emission inventory. For example, emissions from international shipment are excluded from the results of inventories consistent with the structure and principles of accounting for SEEA (United Nations, (2014).

In the context of the quality of statistical information, given the national differences in the list of pollutant emissions, it is necessary to emphasize the differences between the national system of indicators and the accounts of air pollutant emissions collected by the United Nations Economic Commission for Europe. For this purpose, within the framework of the air emissions account, an appropriate section entitled "Combined Indicators" has been created (see Figure 3). In addition, it should be noted that in all accounting systems, emissions are usually determined by estimation (i.e. calculation) rather than measurement. At the same time, all accounting systems consider anthropogenic, i.e. human-caused, emissions into the atmosphere, and, as a rule, do not take into account emissions from natural sources.

Concepts for coverage of emission sources are defined: national inventories cover GHG emissions and their absorption within the national territory and coastal areas over which the country has jurisdiction. In this case, emissions from the use of fuel by road transport are included in the emissions of the country in which the fuel is sold, not the country in which the vehicle is used, as fuel sales statistics are widely available and usually much more accurate.

In turn, the UNFCCC inventory covers six types of GHGs, for which certain quantitative targets have been set: CO_2; N_2O; CH_4; HFC; PFC; SF_6. The first three are individual substances, and the rest are groups of substances called F-gases (fluorine-containing gases). In 2015, another substance was added which is not currently included in the emissions accounts: nitrogen trifluoride (NF_3).

Emissions of all GHGs can be summed up taking into account their global warming potential, and for each type of GHG emissions are recalculated using specific global warming coefficients that reflect the gas potential in CO_2 equivalents. CO_2 emissions from biomass are recorded as a "Reference" item in the UNFCCC inventory. It should be noted that the UN inventories for information purposes also cover emissions of NO_x, CO, NMVOC and SO_2, but this information is not used to monitor the achievement of environmental policy objectives. In order to evaluate it, the relevant registration of these substances is carried out in the inventory of the Convention on Long-range Transboundary Air Pollution (United Nations Statistics Division).

According to the data of the State Statistics Service of Ukraine, during 2020, 109.1 million tons of carbon dioxide were released into the country's air due to the production activities of enterprises, which is 12.2 million (or 12.2%) less than in 2019 (Figure 4), according to (State Statistics Service of Ukraine, 2021).
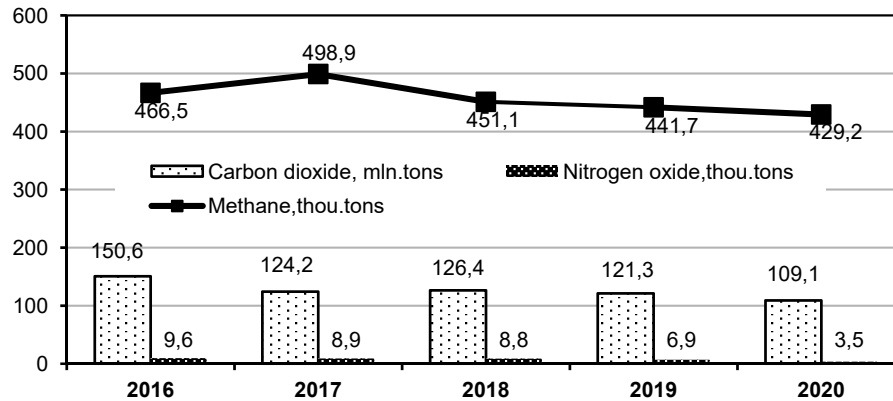

Figure 4. Dynamics of emissions of the main types of greenhouse gases into the atmospheric air of Ukraine

Source: built by the author according to (State Statistics Service of Ukraine, 2021).

CO_2 emissions from the production activities of stationary sources of pollution occur in the following main sectors of the economy (sections KVED-2010):

- supply of electricity, gas, steam and conditioned air;
- process industry;
- mining industry and quarrying;
- agriculture

The largest volumes of CO_2 were emitted by enterprises of section D "Supply of electricity, gas, steam and conditioned air" – 56.2 million tons, which is 52% of all emissions volume (Figure 5, according to (State Statistics Service of Ukraine, 2021).
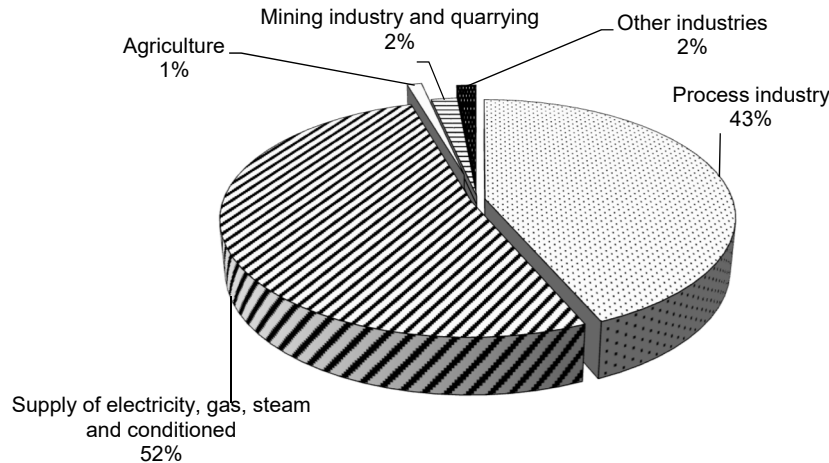
Figure 5. Structure of carbon dioxide emissions by main sections of KVED-2010, Ukraine, 2020, million tons

Source: built by the author according to (State Statistics Service of Ukraine, 2021).

The largest amount of 9470.2 thousand tons of CO_2 emissions (8.6% of total emissions in the country) came into the air in 2020 from the metallurgical plant "Arcelor Mittal Kryvyi Rih", as well as from the Zaporiuzhzhia metallurgical plant "Zaporizhstal" - 6631.8 thousand tons (respectively 6.1%). It should also be noted that the five largest industrial enterprises, which are among the 10 largest polluters in Ukraine, are located in Donbas area, where active, fierce fighting is currently taking place. They are:

  1) Kurakhiv thermal power plant;
  2) Mariupol Metallurgical Plant named after Ilyich;
  3) Azovstal metallurgical plant;
  4) Slavic thermal power plant "Donbasenergo";
  5) Vuglegirsk Centrenergo Coal Mine Thermal Power Plant.

During 2020, the above-mentioned enterprises generated a total of 19,361.5 thousand tons of CO_2 into the country's air, which is 17.7% of all national emissions.

As a result of the study, it was found that the largest GHG emissions, namely, of carbon dioxide, per capita were generated in the Zaporizhzhia region – 7740.0 kg, Ivano-Frankivsk – 7479.9 kg, Dnepropetrovsk – 6480.7 kg (Figure 6).
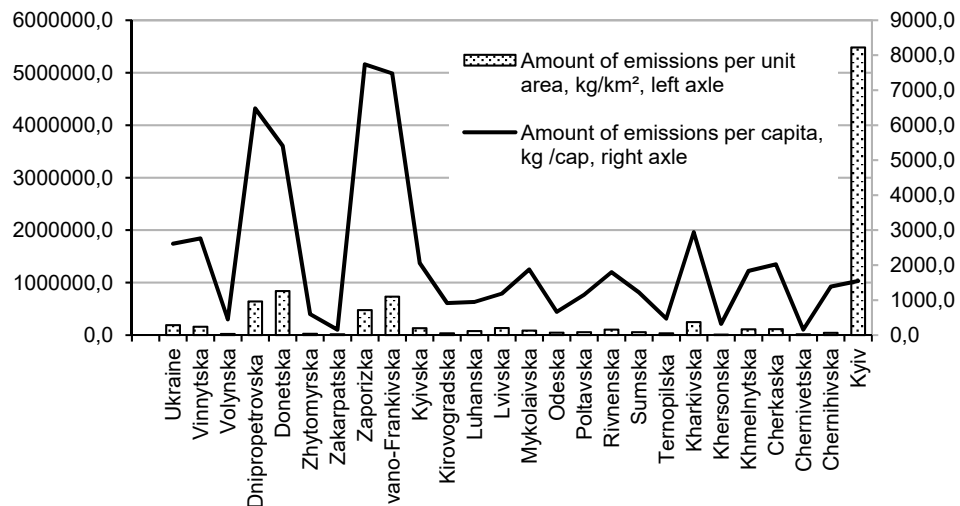
Figure 6. GHG emissions by regions (oblasts) per unit area and per capita, 2020

Source: built by the authors according to (State Statistics Service of Ukraine, 2021).

It should be noted that the national SEEA is represented by another account: that is the account of the natural environment protection costs, which is formed in accordance with the statistical classification of environmental protection activities and costs (CEPA 2000), which identifies nine environmental areas for its description:

- protection of atmospheric air and problems of climate change;
- waste water treatment;
- waste treatment;
- protection and rehabilitation of soil, groundwater and surface water;
- reduction of noise and vibration exposure (except for labour protection measures);
- conservation of biodiversity and habitat;
- radiation safety (except for measures to prevent accidents and catastrophes);
- research works in the field of environmental protection;
- other areas of environmental protection activities.

Typically, environmental protection costs are described by the structure of environmental protection costs according to the classification of environmental measures by type of costs: capital investment, including overhaul costs, and running costs. However, these indicators do not determine the place and role of the natural environment in the economic life of the country. This goal can be achieved only with the help of cost indicators, the methods and methodology of which will be comparable to those used for valuation of other sectors of the economy. Such indicators form the basis of the natural environment protection cost account, providing a detailed study of the environment as an economic component of the SNA.

In national accounts, environmental activities are seen as a system of consistent and interconnected accounts that characterize the operations regarding the production of environmental services, the creation, distribution and use of income, the accumulation of capital and the acquisition of financial instruments. Institutional residents are grouped into the sectors of non-financial corporations, financial corporations, general government bodies, private households, non-profit institutions which serve households, with their further breakdown by subsector. In the framework of the implementation of strategic directions for further improvement of environmental statistics and in accordance with international standards, in particular the EU Regulation №691 / 2011 on European environmental and economic accounts module "Environmental Protection Expenditure Accounts" (EPEA), countries are encouraged to introduce national auxiliary (satellite) accounts of costs for the protection of natural environment.

Data in the EPEA account regarding the protection of the natural environment costs are presented by the following institutional sectors of the economy: state government, corporations, private households and other world. At the same time, non-profit organizations which serve private households are not separately identified and are included in general government bodies. The corporation sector is divided between corporations as the main producers of environmental protection services and producers of the market services of the natural environment protection as "ancillary activities" and "other corporations", the production activities of households are included in corporations as market producers.

To facilitate monitoring and reporting on climate change, a working group under the auspices of the Conference of European Statisticians (CES) of the United Nations Economic Commission for Europe has developed a set of relevant indicators [30]. The creation of such a set for measuring and monitoring changes over time will be based on the core competence of national statistical offices to ensure the high quality of a consistent dynamic series.

The purpose of the use of the global set of statistics and indicators of climate change by UN is to create a framework with relevant indicators that will guide countries in preparing their own sets, especially for countries with less developed statistical systems. The global set is designed to meet the needs of all countries and contains an exhaustive list of metadata-related indicators (including definitions, input variables, aggregations, measurement categories and data links). In total, the CES set covers five main areas; these are 44 indicators that affect climate change and are distributed as follows:

- emissions of pollutants: 9 indicators;
- drivers: 9 indicators;
- impact of climate change: 13 indicators;

- climate change mitigation: 8 indicators;
- adaptation to climate change: 5 indicators.

The CES set of indicators provides a basis for the development of national sets of indicators related to climate change, which aim to show the general issues of climate change, the most acute policy issues and help to meet the immediate information needs. It contains indicators that cover the above factors and offers relevant indicators which help to interpret the core set in national and global contexts.

4. Conclusions

Thus, climate change research is a complex and complicated process, in which qualitative statistical data on emissions of hazardous substances, including greenhouse gases, as well as other inter-sectoral data and statistical calculations, are absolutely important. Improving and modifying the collection, processing of data and additional calculations is a requirement of today and should provide up-to-date and timely information for environmental policy decisions.

On the whole, in order to further achieve the effectiveness of environmental impact assessment, the implementation of the following methods and measures deserves attention:

1) Engaging the necessary experts through partnerships.
2) Familiarizing the staff with GHG emission inventory methodologies and explaining the need for appropriate cooperation between inventory compilers and official statisticians.
3) Expanding knowledge, developing methodologies and tools for obtaining and using geographic data throughout the whole statistical system, including through the organization of appropriate cooperation with specialists in geospatial information.
4) Ensuring the effective international exchange of knowledge and skills between NSSs.

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