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ECONOMIC MECHANISMS OF ENVIRONMENTAL MANAGEMENT: EVOLUTION AND CURRENT TRENDS WITH PROSPECTS FOR UKRAINIAN REALITIES

ЕКОНОМІЧНІ МЕХАНІЗМИ ЕКОЛОГІЧНОГО МЕНЕДЖМЕНТУ: ЕВОЛЮЦІЯ ТА СУЧАСНІ ТЕНДЕНЦІЇ З ПЕРСПЕКТИВАМИ ДЛЯ УКРАЇНСЬКИХ РЕАЛІЙ

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Abstracts. *In view of the ongoing climate degradation, the article analyses and compares the most commonly used mechanisms for preventing negative environmental impacts resulting from human activities. In this respect, administrative and economic mechanisms are considered, which have a significantly different nature. Based on the consideration of the specific features of these approaches, the advantages of economic methods that provide incentives for individual enterprises to implement the necessary environmental protection measures, as opposed to purely administrative and restrictive measures inherent in command-and-control approach.*

Among the economic mechanisms of environmental management of climate change, as one of the most painful problem of our time, the main attention is paid to the principle of direct financial taxation and the method of market trading in emission quotas, which is commonly known as cap and trade systems. The advantages and disadvantages of these approaches to limiting anthropogenic greenhouse gas emissions are presented and analysed, and the range of application of these basic economic instruments in different countries of the world is demonstrated.

It is noted that the Association Agreement between Ukraine and the European Union provides for the introduction in the coming years of a national greenhouse gas trading system adapted to the pan-European system that has been in place since 2005. In this regard current state of the national ETS system implementation is analysed with the first essential step of which being the putting in force a carbon emissions monitoring, reporting and verification system.

Keywords. *Environmental management, economic mechanisms, carbon emissions, carbon trading, carbon taxation, carbon allowances, carbon credits.*

Анотація. *З огляду на триваючу деградацію клімату, у статті проаналізовано та порівняно найбільш поширені механізми запобігання негативному впливу на навколишнє середовище внаслідок людської діяльності. У цьому контексті розглядаються адміністративні та економічні механізми, які мають суттєво різну природу. На основі розгляду особливостей цих підходів показано переваги економічних методів, які забезпечують стимулювання окремих підприємств до впровадження необхідних природоохоронних заходів, на відміну від суто адміністративних та обмежувальних заходів, притаманних командно-адміністративному підходу.*

Серед економічних механізмів екологічного управління зміною клімату, як однією з найболючіших проблем сучасності, основна увага приділяється принципу прямого фінансового

оподаткування та методу ринкової торгівлі квотами на викиди, який отримав широку популярність під назвою «система торгівлі квотами» (cap and trade). Представлено та проаналізовано переваги та недоліки цих підходів до обмеження антропогенних викидів парникових газів, а також продемонстровано сферу застосування цих основних економічних інструментів у різних країнах світу.

Зазначається, що Угода про асоціацію між Україною та Європейським Союзом передбачає запровадження у найближчі роки національної системи торгівлі квотами на викиди парникових газів, адаптованої до загальноєвропейської системи, яка діє з 2005 року. У зв'язку з цим проаналізовано поточний стан впровадження національної системи СТВ, першим важливим кроком якої є введення в дію системи моніторингу, звітності та верифікації викидів вуглецю.

Ключові слова. *Екологічний менеджмент, економічні механізми, викиди вуглецю, торгівля квотами, вуглецеве оподаткування, квоти на викиди вуглецю, вуглецеві кредити.*

Introduction. Limited volume of natural resources available and negative processes of their degradation and depletion accelerated in the modern era by hugely intensified human production activity are becoming an increasing threat not only to further overall economic development but in general sense to future generations well-being**.** This axiomatic statement is well recognized already and led to formulation of global sustainability concept to be implemented to address growing challenges in this respect and to mitigate possible unpleasant consequences. Environmental component of sustainable development as well as other main pillars of this concept including economic and social one in this respect requires scientifically grounded and practically proven regulations that should be adopted, implemented and followed at all necessary levels including corporate, industry, national, regional and international.

Such multi-level approach is of particular importance for environmental part of sustainability concept with obvious externality nature when potentially harmful for ecology human activity caused by any operator are born also by other parties that are not involved in operation processes. It means that environmentally negative factors appearing locally at the operator's facilities spread their influence over much broader geographical area and consequently influencing other parties and their interests. This is particularly true for global climate system change issue that is becoming increasingly recognized as one of the main factors of negative impact on the environmental component of sustainable development.

The first official statement at the international level on the threat of global warming was made back in 1976 by the World Meteorological Organisation (WMO). Scientifically grounded evidence of a significant anthropogenic impact on the climate associated with human activity was first presented to the international community three years later at the 1st World Climate Conference in Geneva.

The Intergovernmental Panel on Climate Change (IPCC), established by the decision of this first global climate forum, has become the world's premier scientific body aimed to study, analyse and systematise data on worldwide climate change processes with further grounding of projected scenarios for their development in the short and long term sense. The periodic reports provided by the IPCC are invariably the subject of wide discussion, as they contain the most substantiated conclusions on the global processes of climate change occurring in the planet's ecosystem, with the identification of prospects for their further development.

Latest among them IPPC Sixth Assessment Report and Synthesis Report published in 2023 summarize in particular the state of art in climate change, its widespread impacts and risks, and climate change mitigation and adaptation as a results of measures provided at all levels. Among main conclusions arising from these reports are the following (*IPPC*, 2023:18):

- human activities in first hand through emissions of greenhouse gases, have unequivocally caused global warming, with worldwide surface temperature 1.1°C above of the level end of 19-th century.

- global greenhouse gas emissions have continued to increase resulted in widespread and rapid adverse changes in the atmosphere, ocean, cryosphere and biosphere that have occurred affecting every region across the globe;
- despite progress in planning and implementation of regulatory measures to mitigate climate changes across all sectors and regions, adaptation gaps exist, and will continue to grow at current rates of implementation.

Unfavorable situation in place with global climate warming and prospects of its further aggravation necessitate general analysis of existing approaches to tackle this phenomenon and their efficiency with prospects for implementation in Ukrainian realities. In this sense it can be considered as **main goal of the publication** intended to delve into evolution and current trends of economical mechanisms of environmental management with application to climate change phenomenon mainly.

Literature review. In general case institutional measures to tackle environmental challenges could be split in 3 main streamlines (*Percival R V.,* et al, 2024: 21):

-administering through implementation, directives, standards and norms aimed to regulate impact of human activity;

-taxation by introducing direct taxation of environmentally harmful operations;

-trading systems via application of market approach to mitigate environmentally negative aspects.

The traditional approach used to regulate the anthropogenic impact on the climate system is to implement administrative measures that limit the activities of hazardous industries in terms of the level of environmental pollution permissible for them. The main algorithm of this approach is defined by a concise formulation as *'command and control - CAC'.* In this context, the 'command' part refers to the establishment of directive provisions in the form of laws, standards, regulations and other binding administrative documents. The content of the other part, 'control', is to monitor compliance with the established requirements and impose sanctions in case of violation. Such sanctions may take various forms, including administrative penalties, criminal liability, fines, and various organisational measures, including, as a last resort, the suspension of the company's operations.

In general terms, this approach can be described as direct legislative regulation of an industry or type of activity that defines what is permissible and what is illegal. The level of harmfulness that is permissible is established by the relevant state policy-making bodies and is fixed in the standards, norms and regulatory documents issued by them.

Historically this approach was the first to appear being still widely used for different ecology related applications especially in developing countries like China and India, where they form the backbone of environmental regulation frameworks (*Blackman A.,* et al, 2018: 3). It has been actively spreading since the 60s and 70s of the last century due to its simplicity and obviousness and has been implemented in many countries around the world (*Bocher M. A.,* 2012: 4). Being most prevalent approach at that time it was also attracted by the possibility of fairly prompt application of appropriate administrative measures aimed at protecting the environment (*Singhal P.* , 2018: 29).

By that time, the public understanding of the limited natural resources and the need to ensure the principles of sustainable socio-economic development at all echelons of social life had not yet reached the modern level. However, since the 1980s, its criticism has gradually spread, mainly due to the lack of flexibility and the formation of internal motivation of enterprises to be more economical with natural capital.

Environmental regulation in force in Ukraine bears a clear signs of post-soviet era with its administrative principles of economy governance. It reflected in dominance of command-and-control approach firmly followed till the end of previous century in all aspects of country live including ecological issues. Visible changes appeared only beginning of this century with joining the Kyoto Protocol and even more remarkably since 2014, to align with European Union (EU) standards as part of the EU–Ukraine Association Agreement (*Yakymenko I.*, 2024: 37).

While reported evidences encompassing 32 developing countries demonstrated that CAC policies can play a positive role in reducing pollutant emissions and improve environmental outcomes, particularly for easily identifiable pollution sources (*Blackman A.,* et al, 2018: 3). At the same time implementation of these measures is alligned with certain trade-offs: while they mitigate

lower emissions, they can suppress enterprise productivity and increase compliance costs without sufficient compensation effect from innovations provided.

The general view of the low efficiency of the administrative approach to environmental management, especially for complex environmental issues that cover a large number of sources of problems, has been significantly reinforced by the results of analytical work on their economic comparison with less costly incentive-based approaches. An economic analysis of the results of applying different approaches to preventing air pollution in New York State (*Burton E.I.,* et al, 1973: 5) and San Luis (*Atkinson S.E.,* 1974: 2) through computer modelling of the processes involved has shown a significant economic advantage of the incentive principles of environmental regulation. Depending on the degree of air pollution, the advantage in the economic efficiency of incentive principles per unit of emission reduction estimated within the ranges from 2 to 4. A similar estimate was obtained as a result of a generalised comparison of the costs of reducing anthropogenic impact on the environment using administrative and economic incentive approaches in the United States and some European countries (*Harrington W.,* 2004: 15).

At the same time it should be noted that all measures related to command-and-control principle of environmental policy could be referred as economically incentivizing only in respect of financial penalties that operator should bear when breaking established pollution limits. In this sense in line with the article main purpose most attention is given to regulatory more flexible and economically more efficient approaches of environmental policy, i.e. taxation and trading systems.

Main research results and discussion. While administrative methods of environmental management are focused on the use of various regulatory and restrictive instruments, incentive-based approaches are grounded on economic principles of creating interest in reducing the anthropogenic burden on the environment. In first hand, it is environmental taxation, the main idea of which is to impose taxes on pollution, which stimulates companies to reduce the level of pollution induced.

The conceptual idea of pollution taxation lies in the essence of the process itself, since the polluter causes harm not only to itself, but to the entire environment as a whole, i.e. to others. This manifests not only the internal, but also the external side of any pollution, which is called externality effect. Based on this, it is quite obvious that the polluter should pay for the total losses that it causes by its production, adding these costs to the cost of its products. Conversely, this will stimulate the producer to reduce the level of pollution, which will lead to a reduction in the level of the corresponding tax. Revenues that may be expected from environmental taxation for instance carbon taxes could be directed to implement pollution limiting actions to decrease more distortive taxes leading to 'double dividend' effect (*Freire-González J.,* 2018: 14).

The theoretical justification for the concept of environmental taxation was first provided by Arthur Pigou in 1920 in his work (*Pigou A.,* 1920: 22), where he showed that internal and general costs differ in the level of external costs that should be compensated by appropriate taxation. This approach seems quite obvious, but the main difficulties in its effective application lie in the lack of reliable tools for costing environmental impact, and thus a reasonable determination of the level of taxation. Therefore, despite the fact that this concept has been comprehensively generalised in the form of the 'polluter pays' principle, its practical application invariably encounters the issue of how to optimally determine the level of this payment, which is complicated by the lack of necessary basic information.

Based on advantages of direct taxation environmental economists have been promoting this approach as key environmental policy instrument already for several decades second half of last century. Gradually it appears as complimentary approach to command-and control principle of environmental policy being pioneered by such European Nordic States like Finland (1990), Norway (1991), Sweden (1992) and Denmark (1992) with gradual spreading over other countries (*Andersen, M*., 2004: 1). According to the World Bank statistics, as of mid 2022, 36 jurisdictions have introduced already carbon taxes covering 5.7% of global GHG emissions (*WB*, 2022: 33). In this list of countries Ukraine is also present with carbon taxation introduced starting from 2011.

The general situation with the uncertainty of the cost of polluting and in first hand its external component, together with the national economic specifics, including a cautious attitude to the possible depressive impact on corresponding industries, gives rise to a certain subjectivity in setting the level

of environmental taxation in different countries. As a result carbon tax rates among these countries vary in a broad range, between US$0.08 per ton of CO2 equivalent (CO2e) in Poland and US$129.89 in Sweden (*Schratzenstaller M.*, 2023: 27). For Ukraine the fee associated with emission of carbon dioxide into atmosphere from 2022 amounts UAH 30 (US$ 0.73) per metric ton (*State statistics*, 2023: 19). And that is a remarkable increase from previously mandated from 2011 level of UAH 0.24 (US$ 0.006)/t.

This range of taxation levels demonstrated above refers to so-called 'carbon tax', which is imposed on the main fossil fuels such as oil, coal and natural gas, as their consumption accounts for the bulk of greenhouse gas emissions. Such a large discrepancy cannot be explained by the level of economic development of individual countries alone (*Prabhuti R, Soral G.*, 2025: 24). To a large extent, this is a manifestation of the general attitude to climate change that exists in a particular country.

Such wide variation in the level of carbon taxation confirms the difficulty of establishing an economically justified level of taxation. This also makes it complicated to adopt a uniform level of carbon taxation at the regional and international level. Regarding current general status of climate degradation abatement and commitments in this respect under Paris Climate Agreement and European Green Deal countries with low level of carbon levies should provide necessary balanced measures to achieve more tangible reductions of anthropogenic emissions to meet obligations assumed.

The main advantages of taxation as an economic mechanism for regulating the negative impact on the climate system include direct impact on emitters and the simplicity of administration of the taxation process itself, as well as its transparency. It does not require complex organisational structures, development of detailed procedures and control over their implementation, which may cause significant additional costs.

At the same time, the principle of taxation does not allow for direct impact and regulation of the level of harmful emissions, since the decision to pay the tax or implement measures to reduce emissions remains with the emitting company. This is a significant general limitation inherent in the principle of taxation as an economic mechanism of environmental management.

The ways and efficiency of using the financial flows generated through the introduction of taxation remain a significant issue as well. These flows are generated in business being guided to government institutions where they are distributed. This creates a tempting possibility of their misuse for purposes other than environmental protection.

The lack of flexibility in responding to natural fluctuations in such factors as inflation, the state of the currency market, crisis phenomena, and others inherent in the taxation approach also provided an additional reason to seek different concept of economic regulation of the anthropogenic burden on the ecosystem. The main competing principle to the environmental taxation of emissions of harmful substances appeared to be the approach based on setting emission limits and market trading of permits for these emissions, abbreviated as 'cap and trade'.

The theoretical basis of this approach is the concept of property rights, which was used as a basis by Ronald Coarse in its development (*Coarse R.,* 1960: 7). He was the first to prove that the most economically feasible approach to environmental management is a market mechanism that minimizes the costs of achieving the environmental goal. A few years later, John Dales formulated the conceptual idea that emission rights granted by the state to enterprises can be subject to market trading (*Dale J.,* 1968: 11). In this case, the state should organize this process and control its implementation.

The effectiveness of this approach was first demonstrated in the late 60s of the last century based on the results of a series of computer modelling studies of different approaches to reducing air pollution in several US cities (*Burton E.*, 1974: 5). Calculations were performed for various mechanisms to prevent further air pollution in order to compare the costs of their implementation. The results obtained in all cases demonstrated a clear economic advantage of a flexible market-based approach to reducing air pollution which has gradually evolved into a holistic cap-and-trade concept as the most economically attractive mechanism for achieving the set level of environmental pollution control.

In contrast to direct emissions taxation, which sets a tax level and does not control the emissions reductions that are achieved, this approach fixes the level of emissions that are permissible through quotas, while the allowances themselves can be traded at prices that are freely determined on the market. Those companies that have surplus allowances can sell them on the open market at their discretion, while companies that exceed their emission targets can buy the missing allowances on the market instead of paying fines. This creates a financial market for emission allowances, or in other words, trading in these allowances.

One of the main advantages of this approach to reducing the burden on the ecosystem is the possibility of achieving the overall result at a lower cost, as emission reductions can be made where it is most economically feasible, and enterprises that lack permits can purchase the appropriate number of permits on the free market.

The first practical attempt to apply an emissions trading system was made in the United States as part of a program to combat the so-called 'acid rain' introduced by the Clean Air Act in 1990. Its implementation reduced emissions of NO2 and SO2 , which are the main cause of acid rain, by 3 million tons per year by 1995 (*Coniff R.*. 2009: 9).

The positive experience of this trading system for emission quotas for these harmful substances was the impetus for its introduction in the formation of the international mechanism for the implementation of the UN Framework Convention on Climate Change (UNFCCC). The legally binding quantitative commitments of the countries participating in this convention are contained in the Kyoto Protocol, which was signed in 1997 as a supplement to the main text of the UNFCCC. According to Annex B to this protocol, the commitments of 38 industrialised countries and countries with economies in transition to reduce greenhouse gas emissions by 2012 were set in the range of 5-8% compared to their level in 1990, which was adopted as the baseline. Along with other post-soviet countries Ukraine appeared to be in an advantageous position, as due to the sharp decline in industrial production in these countries after 1990, anthropogenic emissions of harmful gases into the atmosphere decreased significantly.

The Kyoto Protocol provides for flexible mechanisms to implement the countries' commitments to reduce greenhouse gas emissions. The use of these mechanisms enables interested countries to obtain or purchase additional emission allowances, adding them to the cap set by the Kyoto Protocol. Since the mechanisms provided for by the Protocol are related to investment projects aimed at reducing emissions or direct purchase of additional allowances, these mechanisms are referred as economic or market-based.

These mechanisms include the following:

- Joint Implementation Mechanism (JI) that provides for investment projects aimed at reducing emissions between developed countries and countries with economies in transition;
- The Clean Development Mechanism (CDM) oriented to the implementation of projects in developing countries at the expenses of developed countries or at the expenses of developing countries themselves;
- The Emission Trading Mechanism (ETM) focused on the direct purchase and sale of emission quotas between countries.

Thus, the market mechanisms envisaged by the Kyoto Protocol have opened a direct economic route for the purchase and sale of achieved emission reductions from countries with a surplus of greenhouse gas emissions to countries with their shortage.

The Protocol's first commitment period started in 2008 and ended in 2012. All 36 countries that fully participated in the first commitment period complied with the Protocol objectives. The greatest emission reductions were seen in the former East-European Bloc countries because the dissolution of the Soviet Union reduced their emissions in the early 1990s. Collectively, these countries through implementation flexible mechanisms of Kyoto Protocol surpassed their aggregate commitment, reducing emissions by an average of 2.4 GtCO2e per year (*Shishlov I.*, et al., 2016: 28). Even though these countries significantly reduced their emissions during the first Kyoto commitment period, other large developing countries with fast growing economies like China, India, Thailand, Indonesia, Egypt, and Iran increased their emissions so much that the global emissions increased by 32% from 1990 to 2010 (*UNEP*, 2012: 31).

A second commitment period was agreed in 2012 to extend the agreement to 2020, known as the Doha Amendment to the Kyoto Protocol, in which 37 countries had binding targets. It achieved modest emissions reductions among participating developed countries, with new rules limiting surplus allowances and a stronger focus on forest carbon sinks. However, the withdrawal or non-participation of major emitting economies including Canada, China, Egypt, India, Iran, Japan, USA and unresolved legal issues around emissions units limited its global impact. Ukraine actively participated in first commitment period of Kyoto protocol with total number of JI-type projects above 300 but refrained from being officially involved in its second phase (*Yakubovsky V.,* 2014: 36).

In general, the Kyoto Protocol resulted in measurable emissions reductions and fostered technological innovation, but its economic costs and design limitations tempered its overall effectiveness. At the same time it laid down the groundwork for future climate policy, highlighting the need to balance environmental goals with economic realities and broader participation.

With all drawbacks and lack of efficiency of measures provided by the Kyoto Protocol both stages as a next main step of United Nations Framework Convention on Climate Change efforts became a Paris Climate Agreement negotiated by 196 countries and signed in 2016 (*UNFCC*, 2016: 32). Nowadays it should be considered as a landmark international treaty focused at limiting global warming to well below 2°C, with efforts to keep it to 1.5°C above pre-industrial level till this century end and beyond (Fig,1). And to stay below such level of global warming, emissions need to be cut by roughly 50% by 2030 (*Schleussner, C.-Fr.,* et al, 2022: 26).

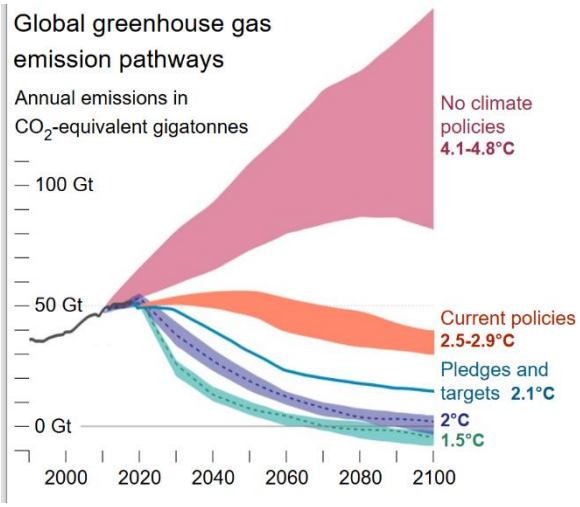

Fig.1. Global greenhouse gas emission main pathways. Source: Ritchie H., Roser *M.*, 2017: 25.

Under the Paris Agreement, each participating country must determine, plan, and regularly report on its contributions. In contrast to the Kyoto Protocol no mechanism forces a country to set specific emissions targets emphasizing voluntary national commitments, but each 5-years long target should go beyond previous targets without any distinction between developed and developing countries.

It means that each country is free to set its own climate targets called Nationally Determined Contributions, or NDCs, which are reviewed and compared internationally to encourage greater ambition through transparency and peer pressure. At the same time current situation demonstrates that national pledges announced are not sufficient to keep warming below 2°C and without stronger action, projected warming is 2.6–3.1°C by 2100 (Fig.1).

Being widely recognized as a historic step in global climate governance the Paris Agreement which introduced a flexible, inclusive framework for climate action and spurred international cooperation, current commitments fall short of its temperature goals, and stronger, faster actions are needed to avoid further dangerous global warming.

The adoption of the UN Framework Convention on Climate Change, its Kyoto Protocol and Paris Accords with quantitative commitments of countries to prevent further degradation of the climate system has become a kind of impetus for further actions to create emissions trading systems (ETS) at the regional, national and sub-national levels.

Like a tax on emissions, an ETS injects the cost of emitting greenhouse gases into business decision making. Unlike taxes, which control the price of emissions but not their quantity, an ETS

controls the quantity of emissions but leaves the price to vary based on the supply and demand of allowances, subject to a limit on their total amount. Hence, carbon emissions trading is a common flexible and market-oriented concept that countries may use to attempt to meet their pledges under the Paris Agreement.

In its core essence emissions trading sets a quantitative total limit on the emissions produced by all emitters involved, which correspondingly determines the prices of emissions. Under emission trading, a polluter having more emissions than their quota has to purchase the right to emit more from emitters with fewer emissions. Consequently, emitter with extra carbon quota amount has an opportunity to sell in at the open carbon market.

As mentioned above the use of emissions trading as a pollution control mechanism was first introduced in the United States under the Clean Air Act, which led to a significant reduction in emissions of sulphur oxide, that causes smog and acid rain, and reduced cost of addressing the associated environmental consequences when using command-and-control tools (*Common M.,* 2006: 8).

Such positive experience led to rapid expansion of emission trading system adoption as a mechanism of environmental regulation at subnational, national and regional level over last 20 years. Two main streams of carbon markets originated during this period: those that trade emissions allowances and those that trade carbon credits. The former are often called “compliance” markets because the firms that usually operate within them are required to do so by regulation. The latter are often called the “voluntary” carbon markets because most entities that purchase carbon credits voluntarily, usually in support of a climate commitment or claim.

As of today, there are 37 emission trading systems and 33 crediting mechanisms in force around the world, with another 22 at various stages of consideration and development (*WB,* 2025b: 35). Carbon trading systems in operation at subnational, national and international level cover already 23 % of global GHG emissions to compare with additional 5 % covered by carbon taxes. Hence, totally worldwide GHG emissions coverage by these two carbon pricing mechanisms equals 28 %. In absolute figures it gives almost 15 billion metric tons of carbon dioxide equivalent emissions (tCO2e) out of the global total emission level of just over 52 billion tCO2e (*WB,* 2025a: 34). To underline the scale of the jurisdictions implemented carbon pricing mechanisms it could be mentioned that they represents roughly 2/3 of global GNP. Among carbon emission trading systems in place to-day most widescale are European Union Emission Trading Scheme (EU-ETS) and Chinese ETS (Table).

In general appearance of EU ETS the first stage of which was launched in 2005 under Directive 2003/87/EC of the European Parliament served as a strong impetus and example for others. As of 2025, this trading system being a central pillar of the European climate policy covers more than 11,000 emitters. It operates in 27 EU countries across the European continent plus Iceland, Liechtenstein and Norway, which are responsible for approximately half of all greenhouse gas emissions of the continent.

The European trading system is based on the quota principle, which was previously preliminary tested in the UK and Denmark. In accordance with the quantitative commitments made, each country develops a national quota plan that should cover all emitters of harmful emissions in the relevant industries

At the initial stage, the list of economic sectors covered by Directive 2003/87/EC included energy, production and processing of ferrous metals, minerals and pulp and paper production. Subsequently, Directive 2009/29/EC added a number of other metallurgical and chemical industries and air transport to this list. As a result, the European Greenhouse Gas Emissions Trading Scheme is considered now as fundamental element of the EU's entire climate change policy.

In contrast to the Kyoto mechanisms, which are project-oriented, the EU-ETS implements the principle of object orientation. This means that each production facility included in the emissions trading system must provide verified by independent body annual reports on its emissions for the reporting period in line with the allocated quotas and purchased permits. At the same time, operators have the opportunity to freely sell or purchase emission permits at prices freely formed on the market, as well as accumulate them or carry them over to subsequent periods.

The establishment and development of the European trading system was not easy, as the main powerful industrial circles, whose interests were directly affected by this system, actively opposed its implementation. As a result, the initial level of emission permits was set too high, which led to a significant reduction in the cost per unit of emissions. The impact of the global economic crisis 2007-2009 and COVID-19 pandemic which induced certain decline in production, was also noticeable.

Table.

Carbon trading systems globally as of April 2025. Source: built based on (*WB,* 2025a: 34) results.

ETS	Year start	Jurisdiction	Main price rate, USD/tCO2	Share of emissions covered, %	Gov-nt revenue Received, USD
Alberta TIER	2007	Canada	USD 66.2	59 %	USD 412 mln
Australia SM	2023	Australia	USD 21.8	26 %	USD 1264 mln
Austria ETS	2022	Austria	USD 48.5	36 %	-
British Columbia	2016	Canada	USD 66.2	26 %	-
Beijing Pilot ETS	2013	China	USD 12.2	17 %	USD 1 mln
California ETS	2012	USA	USD 29.3	76 %	USD 4400 mln
Canada Federal	2019	Canada	USD 66.2	3 %	-
China National	2021	China	USD 11.8	51 %	-
Chongqing Pilot	2014	China	USD 5.5	14 %	USD 3 mln
Colorado ETS	2023	USA	-	3 %	-
EU ETS	2005	EU	USD 70.4	40%	USD 41703 mln
Fujian ETS	2016	China	USD 4.7	16 %	-
Germany ETS	2021	Germany	USD 48.5	39 %	USD 13933 mln
Guangdong Pilot	2013	China	USD 5.4	12 %	-
Hubei Pilot	2014	China	USD 5.4	20 %	-
Indonesia ETS	2023	Indonesia	USD 0.7	24 %	-
Kazakhstan ETS	2013	Kazakhstan	USD 0.9	43 %	-
Korea ETS	2015	Korea, Rep.	USD 6.5	79 %	USD 134 mln
Massachusetts ETS	2018	USA	USD 9.3	9 %	USD 19 mln
Mexico ETS	2020	Mexico	-	36 %	-
Montenegro ETS	2022	Montenegro	USD 25.9	43 %	USD 14 mln
New Brunswick ETS	2021	Canada	USD 66.2	54 %	-
New Zealand ETS	2008	New Zealand	USD 32.0	44 %	USD 293 mln
Newfoundland ETS	2019	Canada	USD 66.2	36 %	USD 0.4 mln
Nova Scotia ETS	2019	Canada	USD 66.2	36 %	USD 13 mln
Ontario ETS	2022	Canada	USD 66.2	26 %	-
Oregon ETS	2021	USA	-	48 %	-
Quebec ETS	2013	Canada	USD 41.5	76 %	USD 1.055 mln
Regional GHG	2009	USA	USD 23.3	14 %	USD 1.456 mln
Saitama ETS	2011	Japan	USD 1.0	16 %	-
Shanghai Pilot ETS	2013	China	USD 10.8	21 %	USD 13 mln
Shenzhen Pilot ETS	2013	China	USD 6.5	37 %	-
Switzerland ETS	2008	Switzerland	USD 64.7	13 %	USD 50 mln
Tianjin ETS	2013	China	USD 5.3	16 %	-
Tokyo ETS	2010	Japan	USD 4.0	19 %	-
UK ETS	2021	United Kingdom	USD 57.2	27 %	USD 3250 mln
Washington ETS	2023	USA	USD 50.0	71 %	USD 811 mln

During current forth period of EU-ETS covering years 2021-2030 its further modernization is planned including reforms of previously established Market Stability Reserve which plays a critical role in stabilizing European carbon market. Such a reform is also aimed to form the backbone of a global carbon market and to reach an ambitious goal for Europe to become the world's first climate-neutral continent by 2050 (*EU-ETS*, 2021: 13).

Summarizing assessment the EU-ETS effectiveness in reducing emissions using a rigorous, machine-learning assisted systematic review and meta-analysis demonstrated that it has delivered measurable emissions reductions effect quantified at about 7% and drove technological changes in particular in the energy sector (*Döbbeling-Hildebrandt N.,* et al., 2024: 12). No significant impact on profits and employment had been detected with an increase in revenues and fixed assets for regulated companies.

The relatively rapid development of the European greenhouse gas emissions trading system has largely stimulated interest in the creation of other national, regional and subnational trading systems. In many cases, they were based on the principles and structure of the European model, which has been well tested already.

The list of the main trade systems existing as of 2025 presented in Table is not exhaustive. It should be supplemented by fairly new or planned trade systems and schemes, the total number of which reaches 22 (*Cayol G., Monar D. C.,* 2025: 6). However, these systems and schemes which are not included in the Table do not yet finalised organisational and economic criteria for their operation.

These emissions trading systems are so-called regulatory or compliance systems, i.e. regulated and implemented by relevant policy documents at the international, national or subnational levels. To them should also be added a rather impressive list of existing voluntary systems, the total number of which has already exceeded 30. The largest among them by volume are run by Verra, Gold Standard, Climate Action Reserve (CAR) and American Carbon Registry (ACR). Together they accounted for 77% of all credits issued in the credit market in 2023 (*MSCI*, 2024: 19).

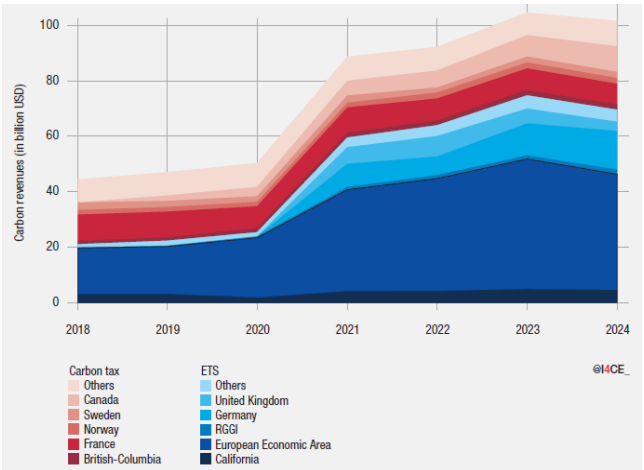

Fig.2. Evolution of Global Carbon Revenues. Source: (*Cayol G., Monar D. C.*, 2025: 6).

First of all, the existing number of greenhouse gas emissions trading systems currently in operation, covering a wide geographical area of the globe, is impressive. Moreover, this list is constantly growing, which puts on the agenda the difficult question of gradually merging or linking individual systems and creating a single global carbon market.

The steady spread of greenhouse gas emissions trading systems in the world, which has become most prominent in recent years, is a direct proof of the interest in their use. Financial incentives are also essential. Last two years total carbon pricing revenues exceeded $100 billion (Fig.2). By 2024, governments will have collected 2.3 times the amount of carbon revenues in 2018, with ETS generating around 67% of the total sum (*Cayol G., Monar D. C.,* 2025: 6).

Such an impressive increase in global carbon revenues is induced not only by carbon emissions coverage by different crediting mechanisms but also by gradual growth of carbon allowance and credits prices. As demonstrated by Fig.3 carbon allowances with all fluctuations steadily grew in prices for all main trading systems. Unstable character of this tendency is influenced not only by carbon market volatility but also regulatory rules changes that took place during carbon trading systems operation to adapt their performance to main climate objectives established.

As mentioned above one of the ETS main advantage is their flexibility and focus on achieving a specific environmental result. The flexible economic nature of the very principle of such systems, based on the free formation of the market price per unit of emissions, leads to its significant fluctuations over time (fig.3).

In general carbon trading as an economic mechanism clearly occupy growing place in ongoing efforts in climate change mitigation. More and more governments and local administrations at subnational level especially in fast growing economies are planning to implement different types of flexible trading mechanism to combat climate degradation. With the current coverage by pricing instruments in place with 28 % of global GHG emissions there is still plenty of space for further growth. According to top-down estimates of the Independent High-Level Expert Group on Climate Finance, USD 6.3-6.7 trillion are needed each year for global climate investments by 2030 (*Cayol G., Monar D.,* 2025: 6).

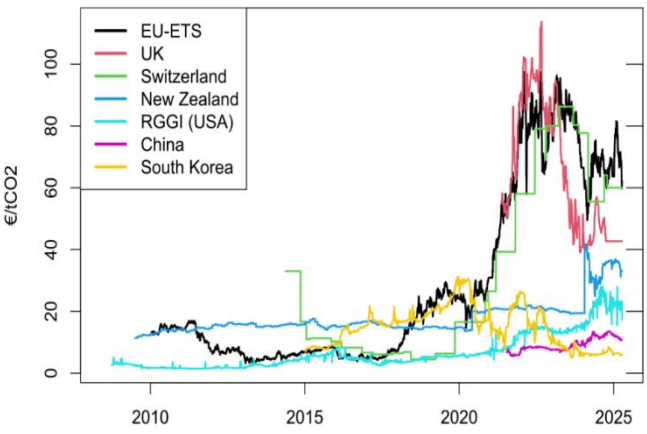

Fig.3. Allowances prices evolution for several ETS. Source: *Hedgehoque,* 2025: 16

This picture in evolving in general of unfavorable situation with low economic growth projections and rising volatility in trade and financial markets are placing additional pressures on public budgets. In this context, carbon pricing offers promising opportunity through mobilizing additional financial resources to secure development outcomes even during periods of uncertainty.

But carbon trading mechanisms development is not without controversy. The main caveats to using trading systems as a basic instrument in international environmental policy on climate change are as follows. First of all, it is a rather complicated mechanism that requires further improvement. One of the main problems is the rather significant fluctuation in the cost of emission units. Its excessive value limits the possibilities of free trade exchange. On the other hand, their very low prices do not stimulate the implementation of emission limitation measures being the main purpose of using such systems. The main tool for improving trading systems in this regard is the introduction of restrictions on both the excessively high price of emission units and their minimum level. In some regulatory emissions trading systems, such restrictions are already used, in particular, in Japan and China (*ICAP,* 2024: 17).

Another reason for criticising emissions trading systems is their low overall efficiency and geographical unevenness and imbalance. Since the cheapest emission reduction units are in less economically developed countries (Table), it is obvious that developed countries are trying to ensure that their obligations are met the expenses of low-income countries. With such geographical 'flows', there is no real emissions reduction in the economically and industrially developed countries that are the largest emitters, which is not socially fair. To take this into account, additional regulatory measures are needed to limit the possibility of such 'flows' or to introduce economic levers to balance such cross-border transactions.

For Ukraine, the issues of economic mechanisms of environmental management primarily related to climate change are not secondary and remote in time. Active participation in first stage of Kyoto protocol project oriented mechanisms gave an opportunity to gain some experience in market oriented approaches to climate mitigation. They are also a priority in the entire environmental block of the Association Agreement with the European Union signed and ratified by the Ukrainian Parliament in 2014 and entered into force from September 01, 2017. This Agreement envisages the introduction of a national greenhouse gas emissions trading system adapted to the relevant European system and outlines steps for the implementation of a national ETS, including:

- adopting national legislation and designating a competent authority;
- establishing a system for identifying relevant installations and GHGs;
- developing a national allocation plan to distribute allowances;
- establishing a system to issue allowances to be traded domestically and
- establishing monitoring, reporting, verification (MRV) and enforcement systems, as well as public consultations procedures.

Such a system should be implemented within 2 years from the date of entry into force of the Association Agreement and is overdue now as a result of military time of unrest. At the same time first solid step in establishing national ETS has been done by establishing national MRV system of carbon emissions with its scope partially covering activities similar to EU ETS (*Law No. 4187*., 2025: 20). the MRV procedures as adopted in the framework law on MRV have been applied by regulated installations. To establish national ETS, Ukraine plans to develop separate legislation based on at least three years data from the MRV system. National ETS is now planned to be launched in a pilot mode in 2025.

With implementation of national ETS system Ukraine will join global cohort of countries where full mixture of command-and-control and economical mechanisms instruments in environmental management are used with gradual historical prevailing of the last group of approaches as being more flexible and adaptive. Within this group of instruments emission trading systems should play growing role.

Conclusions. While the world faces the escalating impacts of climate change, the urgent need for effective mitigation strategies is becoming more evident. Addressing this negative tendency governments and other regulatory institutions around the globe are looking to implement most proper climate policy frameworks based on existing components with evolving track of wider reliance to economically more efficient pricing mechanisms.

To-days overall picture of environmental management instruments in use shows complex palette of earlier established command-and-control methods and economically more incentivizing instruments. These main approaches to regulating anthropogenic impact on the environment discussed above clearly demonstrate the advantage of economic levers that provide flexible and more effective incentives for enterprises to implement appropriate environmental protection measures. Among such economic methods of environmental management, the most theoretically sound and widely tested are direct taxation and emissions trading systems. Joint implementation of these methods already led to coverage of 28 % of global carbon emissions where 23 % share belongs to ETSs.

Whereas direct taxation methods are characterised by simplicity and transparency, along with the lack of direct influence on the level of emission reductions to be achieved. In contrast, emissions trading systems have an advantages of flexibility and greater economic feasibility with somewhat more complex organisational design and operation.

With the signing of the Association Agreement with the European Union, Ukraine got on the path of developing and implementing its own national carbon dioxide emissions trading system that would be fully adapted to the pan-European trading system. This process will require significant additional organisational and methodological efforts in the near future.

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