

IMPACT AND VULNERABILITIES OF CLIMATE CHANGE IN THE REPUBLIC OF MOLDOVA

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Abstract. *Climate change has become a threat to sustainable development for all developing countries, and measures to mitigate and adapt to this phenomenon must become a priority in national policies. Therefore, the Republic of Moldova is directly affected by Climate Change, being more vulnerable to adverse effects. As a result, Climate Change presents a serious danger for the achievement of the Millennium Development Goals, which the Republic of Moldova has assumed. At the same time, Climate Change can generate opportunities for the transformation of the economy, providing greater sustainability and thus paving the way to reducing poverty and achieving the Millennium Development Goals. Excessive consumption of natural resources of the growth generation emissions of greenhouse gases, causing in the last century the warming of the Earth and the disruption, finally, of the global climate system. These problems put the scientific community in front of the dilemma of finding the compromise between economic development and its effects on climate change. Finding this compromise will mean the sustainable development of mankind. Studies show that the impact of global warming is directly proportional to the standard of living of the population, and it affects the inhabitants of poor countries the most, which, in fact, have polluted the least. The problem of Climate Change can only be solved with synergistic efforts of all the states of the world, that is why the Framework Convention of the United Nations Organization on Climate Change (CONUSC) was created. This study was developed within the State Program 20.80009.0807.22 "Development of the mechanism for formation of the circular economy in the Republic of Moldova" funded from the state budget through the National Agency for Research and Development of the Republic of Moldova.*

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JEL: *Q01, Q53, Q54*

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Introduction. The most important measures to mitigate climate change are reflected in strategic documents at national and international level. According to the Paris Agreement of 2015, ratified by the Republic of Moldova through Law no. 78/201757, an action plan was established to limit global warming below 2°C.

In order to achieve the objective of the Paris Agreement, 2015, all its signatory Parties are to communicate to CONUSC, through Nationally Determined Contributions (NDC), about the efforts undertaken at the national level in order to reduce GHG emissions. The Republic of Moldova presented to CONUSC the first CND on September 25, 2015 (EEA, 2022).

Therefore, according to the 2030 Agenda for Sustainable Development, sustainable development objectives and target indicators to be achieved are set. Thus, targets related to air quality can be found in Objective 3, "Health and well-being", which aims to minimize the mortality rate determined by the quality of the surrounding air, and Objective 11, "Sustainable cities and communities", which establishes the minimization of harmful substances emitted into the air by road transport.

At the same time, the provisions of the Association Agreement between the Republic of Moldova and the European Union, in chapter 16 "Environment", provides in art. 89 lit. (b) cooperation between the Parties also includes the development of a sectoral strategy regarding air quality – its draft is in the process of being promoted for approval. Likewise, Annex XI to the RM-EU Association Agreement establishes the European directives in the field of air protection and the term in which they must be transposed into national legislation (EA, 2023). These are:

- ✓ Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe,
- ✓ Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 on arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air,
- ✓ Council Directive 1999/32/EC of April 26, 1999 on reducing the sulfur content of certain liquid fuels,
- ✓ Directive 94/63/EC of December 20, 1994 on the control of emissions of volatile organic compounds (VOC) resulting from the storage of fuels and their distribution from terminals to fuel distribution stations,
- ✓ Directive 2004/42/EC of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds caused by the use of organic solvents in certain paints and varnishes and in vehicle refinishing products,
- ✓ Directive 2001/81/EC of the European Parliament and of the Council of October 23, 2001 on national emission ceilings for certain atmospheric pollutants.

However, the country's most important strategic planning document is the "Moldova 2030" National Development Strategy, which includes among its priorities the development of a sustainable and ecological economy, as well as adaptation to climate change in all economic sectors. The vision outlined in Moldova 2030 is anchored in two strategic international commitments. The first is the Association Agreement with the European Union, signed in 2014, and the second major international commitment is outlined in the 2030 Agenda for Sustainable Development. Namely, the Sustainable Development Goal (SDG) 8.4, located by the Government of the Republic of Moldova in 2017, specifies that the authorities are committed to progressively improve, until 2030, the efficiency of resources in consumption and production processes in order to decouple economic growth from degradation the environment. In addition, SDG 12 is dedicated to responsible consumption and production. Thus, according to the commitments,

Moldova will fully incorporate the principles of sustainable development and effective management of national resources in the elaboration of national policies and regulations. Meanwhile, it will encourage industries and businesses to adopt resource-efficient production and share responsibility for eliminating toxic waste and pollutants.

Results and discussion. The Republic of Moldova has committed to reach more ambitious targets for reducing GHG emissions by 2030. Thus, the unconditional target is to increase from 64-67% to 70% compared to the level recorded in the reference year (1990), and the conditional target will advance accordingly from 78% to about 88% compared to the level recorded in 1990. The new targets for reducing GHG emissions will be introduced in the Low Emission Development Program of the Republic of Moldova until 2030 and the Action Plan for its implementation.

Table 1. Sectoral targets for reducing GHG emissions,%

Sectors:	Until the year 2025		Until the year 2030	
	unconditional	conditioned	unconditional	conditioned
Energy	83	87	81	87
transport	56	58	52	55
Buildings	76	78	74	77
Industry	34	37	27	31
Agriculture	48	50	44	47

Source: *National Inventory Report 1990-2020, Chisinau June 30, 2022, www.clima.md*

In the Republic of Moldova, a higher concentration of pollutants is observed only in the municipality of Chisinau and near large power plants. However, the overall air pollution situation in Moldova turned out to be favorable, especially compared to other European countries, including Ukraine, Romania and others. The national air monitoring system is updated daily, using information from only 17 monitoring stations, not being fully covered. Thus, the municipalities of Chisinau, Balti, Bender, Tiraspol and Rîbnița are covered by the respective monitoring system, 2 other automatic monitoring stations are located in Rezina and Leova.

The most important greenhouse gas in the atmosphere is water vapor (H₂O), responsible for about 2/3 of the total greenhouse effect. The water content in the atmosphere is not directly influenced by human activities, being rather determined by the natural water cycle, expressed more simply as a difference between evaporation and precipitation. Carbon dioxide (CO₂) is responsible for the greenhouse effect in proportion to 30%, and methane (CH₄), nitrogen oxide (N₂O) and ozone (O₃), all three in proportion to 3%. Republic of Moldova, from 1750 to the end of 2021, the concentration of CO₂ increased by about 148.4%, the concentration of CH₄ - by 264.2%, and the concentration of N₂O by about 123.9%, (Tab.2). These trends can be largely attributed to human activities, particularly the burning of fossil fuels and the continued deforestation of forested areas.

Table 2. Tropospheric concentration (in the Northern Hemisphere), concentration change rate and tropospheric lifetime of direct greenhouse gases

Greenhouse gases	Tropospheric concentration pre-industrial (1850-1900)	Tropospheric concentration at the end of 2021	Global warming potential for a 100-year horizon (IPCC, 2014)	Lifetime tropospheric (years)
Carbon dioxide (CO ₂)	280 ppm	415,7ppb	1	50-200
Methane etanul (CH ₄)	722ppb	1907,2ppb	28	12,4
Nitrous oxide (N ₂ O)	270ppb	334,6ppb	265	121

Notes: ppm - concentration in parts per million by volume; ppb - concentration in parts per billion by volume

Source: National Inventory Report 1990-2020, Chisinau June 30, 2022, www.clima.md

Therefore, the air in the Republic of Moldova is polluted above the admissible norms determined by emissions from the transport sector. On average, the transport sector accounts for 95% of the total volume of harmful substances emitted into the air. According to statistical data provided by the National Bureau of Statistics, in 2020 more than 95 thousand tons of CO₂ (carbon dioxide) were emitted into the atmosphere from road transport, or less by 7.8 thousand tons compared to 2010. Respectively, hydrocarbons and sulfur dioxide increased by 1.5 times in 2020 compared to 2010.

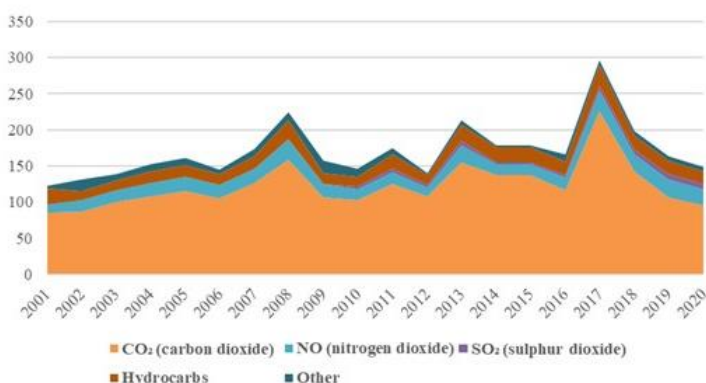


Figure 1. Air pollutant emissions from road transport, thousands of tons/year¹¹

Source: Developed by the author based on the data provided by statistica.md

In the period 1990-2020, the dynamics of total direct greenhouse gas emissions, expressed in CO2 equivalent, revealed a decreasing trend in the Republic of Moldova, reducing by about 69.8%: from 45,248 Mt CO2 equivalent in 1990 to 13,662 Mt CO2 equivalent in 2020, net direct greenhouse gas emissions decreased in the same period by about 68.7%: from 43,591 Mt CO2 equivalent in 1990 to 13,658 Mt CO2 equivalent in 2020. Carbon dioxide contributes the more to the total emissions of greenhouse gases directly in the Republic of Moldova. Figure 2 demonstrates how the share of direct greenhouse gases in the structure of total national GHG emissions varied in the years 1990 and 2020.

According to the statistical data provided by the National Bureau of Statistics, nitrogen dioxide concentrations in Moldova are generally low. This air pollutant comes mainly from cars and other motor vehicles, but also oil and metal refining, electricity generation, light and food industry. It affects the resistance of the respiratory system to bacterial and viral infections. The highest values were recorded in Chisinau and around the border with Ukraine, especially where the Cuciurgan power plant is located, as well as around the municipalities of Tiraspol and Rîbnița. Chisinau, Bender and Balti regions have the highest average levels of nitrogen dioxide pollution.

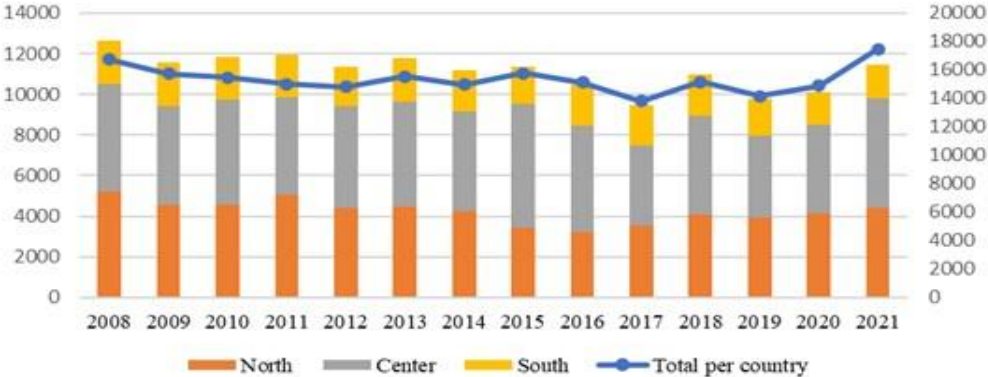


Figure 2. Air pollutant emissions from stationary sources of economic agents in territorial profile, thousands of tons/year

Source: Developed by the author based on the data provided by statistica.md

Between 2009 and 2020, the total volume of emissions into the atmosphere was halved: from 15,744 to 15,053 thousand tons annually. However, there are differences between the evolution of emissions from stationary and mobile sources. These sources emit large amounts of hydrocarbons, carbon oxides, nitrogen and sulfur oxides, etc., depending on different factors: the quality of the fuel used, the technical condition of the vehicles, the number of transport units operated, etc.

Emissions from stationary sources increased until 2016, after which they registered a slight decrease, while emissions from mobile sources reached their

maximum value in 2018, after which they registered decreases up to 148.7 thousand tons per year.

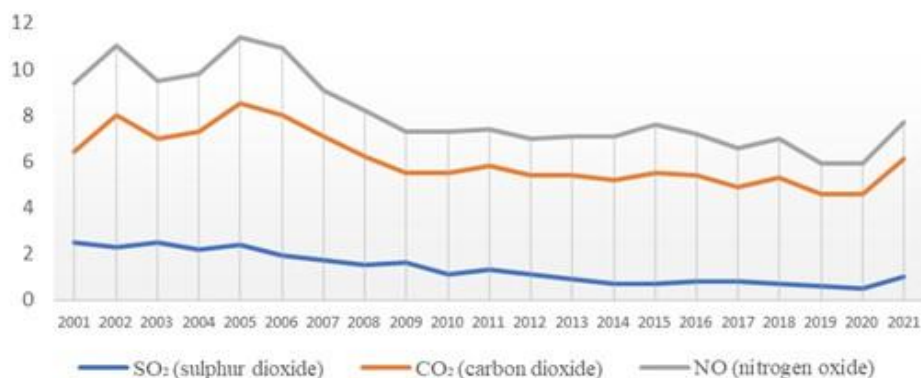


Figure 3. Total emissions of the main pollutants from stationary and mobile sources, thousands of tons/year

Source: *Developed by the author based on the data provided by statistica.md*

The assessment of greenhouse gas emissions was carried out for five sectors: (1) "Energy", (2) "Industrial processes and product use", (3) "Agriculture", (4) "Land use, change in the category of land use and forestry" (FTSCFTS) and (5) "Waste". The interpretation of the GHG emission inventory results within the "FTSCFTS" sector is somewhat different from the others: positive numbers indicating that the sector is a net source of emissions, and negative numbers establishing that the sector is a net source of carbon sequestration.

Photochemically active gases such as carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs) are not considered greenhouse gases, but indirectly contribute to the greenhouse effect in atmosphere. All these gases are qualified as precursors of ozone in the atmosphere, influencing the formation and disintegration of ozone in the atmosphere. They mainly persist in the exhaust gases generated by transport units, they also come from the burning of fossil fuel at stationary sources, from the use of solvents and other household products, etc.

Thus, the emissions from the following gases-precursors of ozone and aerosols: NO_x, CO, VOCNM and SO₂ were included in the national inventory of greenhouse gases of the Republic of Moldova. In the period 1990-2020, the total emissions of nitrogen oxides decreased by about 74.4%: from 95.55 kt in 1990 to 24.47 kt in 2020, the total emissions of carbon monoxide decreased by about 49.3%: by to 278.79 kt in 1990, to 141.37 kt in 2020, emissions of non-methane volatile organic compounds decreased by about 21.2%: from 141.57 kt in 1990 to 111.56 kt in 2020, and sulfur dioxide emissions decreased by about 97.1%: from 150.11 kt in 1990 to 4.29 kt in 2020 (Tab. 4).

Table 3. Dynamics of indirect greenhouse gas emissions (NO, CO and NMVOC) and SO₂ in the Republic of Moldova, in the period 1990-2020, kt

	1990	1995	2000	2005	2010	2015	2020
NO₂	95,5512	30,8466	14,8007	19,9620	21,4697	21,8663	24,4709
CO	278,7930	76,6445	39,9908	54,4534	53,0984	86,7007	141,3672
COVNM	141,5732	46,5154	22,9213	42,1519	40,8386	54,1274	111,5648
SO₂	150,1134	31,9788	4,5137	5,1861	5,3806	4,8979	4,2932

Source: *National Inventory Report 1990-2020, Chisinau June 30, 2022, www.clima.md*

The amount of pollutants captured (neutralized) includes all types of pollutants captured (neutralized) at dust capture (gas purification) installations from the total volume of pollutants emitted by stationary sources. In 2021, around 96.4 thousand tons were captured by the purification facilities of polluting substances, formed at stationary sources of atmospheric air pollution of economic agents, down 19.5% compared to 2010. the year 2013 saw the highest level of pollutants captured - 194.7 thousand tons.

In this sense, to evaluate the level of emissions from the source, it is necessary to use mobile monitoring stations, but the Republic of Moldova does not have such equipment. Air pollution monitoring is carried out by the State Hydrometeorological Service, which has a surveillance network consisting of 17 stationary monitoring stations, located in 5 industrialized centers of the Republic (Chisinau - 6 stations, Bălți - 2 stations, Bender - 4 stations, Tiraspol – 3 stations, Rîbnița – 2 stations), where air samples of 8-9 pollutants are collected (solid suspensions, SO₂, CO, NO₂ and 4-5 specific pollutants). In addition to these stations, the State Hydrometeorological Service also has 2 automatic atmospheric air quality control stations, including at the cross-border level (Mateuți village, Rezina district; Leova city) with the frequency of continuous monitoring 24/24 hours. The results of the air samples collected at the 17 stations do not reflect the real air quality situation, because they are collected only 3 times a day and the delivery of atmospheric air quality data is delayed by one day. Moreover, they do not cover all regions of the country and do not provide real data online. Thus, the current monitoring system does not provide information to the public regarding the level of air pollution in real time, throughout the country.

In order to mitigate the problem of air pollution, urgent and immediate actions are needed through the involvement of central and local public authorities, the private sector and civil society. Unfortunately, until 2023, the objectives proposed by the authorities of the Republic of Moldova for the recovery of the situation in the targeted field have not been fully achieved. In this context, we consider it appropriate to focus efforts on achieving the following medium-term objectives:

- improving the monitoring, assessment and integrated management system of air quality;
- improving the air quality forecast system, by providing data related to a possible deterioration of its quality;
- control of pollutant emissions and pollution levels by applying techniques

and technologies to retain pollutants and/or by introducing less polluting technologies;

- the development and implementation of measures to temporarily reduce pollutant emissions at some major sources;
- the use of fuels and fuels that generate low pollutant emissions;
- limiting/excluding the use of equipment and products that contain substances that destroy the ozone layer;
- developing measures aimed at reducing greenhouse gas emissions, including by harnessing energy from non-traditional sources;
- reducing the amount of stored biodegradable waste;
- the development and implementation of medium and long-term plans, at national, regional and local level, for the continuous reduction of pollutant emissions in the atmosphere in all fields of activity;
- reducing the pollutant emissions generated by road traffic by improving the technical condition of motor vehicles in circulation and adopting fiscal measures to favor the replacement of old motor vehicles in circulation, with high pollutant emissions, with new motor vehicles with a low level of pollutant emissions.

The implementation of the strategic objectives in the field of atmosphere protection, contained in the European legislation, transposed into the national legislation, as well as the obligations arising from the international conventions and treaties to which the Republic of Moldova is a party, involves institutional and financial efforts.

Conclusions and recommendations. Capitalizing on the potential to mitigate GHG emissions in the Republic of Moldova largely depends on how the barriers that stand in the way of implementing actions to reduce and sequester carbon emissions could be overcome. Financial, technical and capacity constraints, specific to each sector, are described in the Environmental Strategy for the years 2014-2023, the Low Emission Development Program (PDER - 2030) and in the Action Plan for its implementation.

Therefore, the current state of air quality, sectoral problems and the need for air protection require the development of measures to reduce pollutant emissions at the source, as well as directions of action to avoid, prevent or reduce the impact of air pollution on environmental components, ecosystems and human health, including in the context of fulfilling the commitments of the Republic of Moldova regarding the ratification of international treaties:

- Creating an integrated air quality management system;
- Delimitation of the territory of the Republic of Moldova in areas or agglomerations that reflect their level of pollution;
- Stationary sources, installations or activities that generate pollutant emissions into the atmosphere will be inventoried and classified into three categories according to the level of pollutant emissions: large, medium and small;
- Temporary tolerance margins will be added for areas and agglomerations where the concentration of pollutants in the ambient air exceeds the target

values or air quality limits;

- If necessary, air quality plans will be developed, following environmental quality rehabilitation plans and programs. These plans will be provided at the stage of issuing environmental permits;
- Harmonization of national air quality legislation with EU legislation and standards.

The norms regarding the emission limits of atmospheric pollutants are outdated and do not correspond to EU standards. Allowable limit values for atmospheric emissions of major pollutants should be introduced gradually, starting with large thermal and electric power plants and progressively extended to other sources of pollution and pollutants. Furthermore, pollution taxes have no deterrent effect on polluters and are applied to too many substances. For these reasons, the system needs to be revised. It must also increase the amount of payments for emissions of important pollutants.

Following the above, capitalizing on the potential to mitigate GHG emissions in the Republic of Moldova depends to a large extent on how the barriers that stand in the way of implementing actions to reduce and sequester carbon emissions could be overcome. Financial, technical and capacity constraints, specific to each sector, are described in the Environmental Strategy for the years 2014-2023, the Low Emission Development Program (PDER - 2030) and in the Action Plan for its implementation. Following the above, we note that important steps are being taken in the Republic of Moldova towards the transition to a circular economy and international practices have begun to be successfully implemented in our country.

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