# REPUBLIC OF MOLDOVA'S GREENHOUSE GAS INVENTORY. QUALITY ASSURANCE / QUALITY CONTROL AND INVENTORY UNCERTAINTY

**Vladimir BREGA[1], Marius ȚĂRANU[2], V. SCORPAN[2], Valeriu BRAŞOVEANU[1]**

*[1]Institute of Ecology and Geography, [2]Climate Change Office besides ME Republic of Moldova*

**Abstract:** This work has been developed within the Project "Republic of Moldova: Ennobling Activities for the Preparation of the (UNFCCC)" with financial support of the Global Environment Facility (GEF), from November 2005 through September 2008. Emissions of direct ($CO_2$, $CH_4$, $N_2O$, HCF and $SF_6$) and indirect ($NO_x$, CO, NMVOC, $SO_2$) greenhouse gases were estimated based on methodologies contained in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. The evolution of total direct greenhouse gas emissions expressed in $CO_2$ equivalent, revealed a decreasing trend in the Republic of Moldova, reducing by circa 72.3 percent: from 42886.0 Gg $CO_2$ equivalent in 1990 to 11883.5 Gg $CO_2$ equivalent in 2005. Emissions of $CH_4$ have decreased by circa 39.5 percent: from 4766.1 Gg $CO_2$ eq. in 1990, to 2883.8 Gg $CO_2$ eq. in 2005, while emissions of $N_2O$ decreased by circa 58.1 percent: from 3354.7 1 Gg $CO_2$ eq. in 1990, to 1404.1 Gg $CO_2$ eq. in 2005. Halocarbons emissions (in particular HFCs, as no PFCs emission have been registered so for in the Republic of Moldova) and sulphur hexafluoride ($SF_6$) emissions commenced in 2000, considered as a reference year for F - gases in the Republic of Moldova.

**Keywords:** greenhouse gas inventory, quality assurance, climate change

## Introduction

The United Nations Framework Convention on Climate Change (UNFCCC), Article 4(1)(a) and Article 12(1)(a) require each non-Annex I Parties to report to the Conference of Parties (COP) to the UNFCCC, information on its emissions by sources and removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol (greenhouse gas inventories).

The period 2003-2005 marks the development of the Moldova's National GHG Inventory in the frame of UNDP-GEF Regional Project "Capacity Building for Improving the Quality of Greenhouse Gas Inventories (Europe/CIS region)". It comprises the second inventory since Republic of Moldova's decision to ratify the UNFCCC on 16$^{th}$ of March 1995 (the first inventory was part of the First National Communication of the Republic of Moldova that was due to the UNFCCC Secretariat on November 13$^{th}$ of 2000) [4].

The UNFCCC requires Parties to move towards more rigorous and transparent reporting of their GHG emissions, calculation methodologies and verification procedures for the inventory.

This GHG inventory has taken a significant step in that direction by incorporating methodological detail in the body and annexes of the inventory document and reporting on efforts to develop a Quality Assurance and Quality Control Plan for the next inventory to be developed in the frame of the Second National Communication. This inventory is also a step in a progression towards more comprehensive reports that allow Republic of Moldova to track its progress in meeting its commitments under the UNFCCC.

## Material and methods

The current inventory includes an inventory of anthropogenic (human-induced) emissions by sources, and removals by sinks, of GHG not controlled by the Montreal Protocol. The inventory is based on international reporting methods agreed to by the Parties to the UNFCCC and according to the procedures of the Intergovernmental Panel on Climate Change (IPCC) [1]. The activity data needed for inventory is available in the Statistical Yearbooks, Energy Balances and other sectoral statistic publications of the National Bureau of Statistics (NBS). Other relevant AD are collected at request, from various partner organizations (Ministry of Transports and Roads, Ministry of Economy and Trade, Ministry of Agriculture and Food Industry, Ministry of Defence, Academy of Sciences of Moldova, Forest Agency "Moldsilva, Land Relations and Cadastre Agency, State Ecological Inspectorate.

**Results and discussion**

This work has been developed within the Project "Republic of Moldova: Ennobling Activities for the Preparation of the (UNFCCC)" with financial support of the Global Environment Facility (GEF), from November 2005 through September 2008. Emissions of direct ($CO_2$, $CH_4$, $N_2O$, HCF and $SF_6$) and indirect ($NO_x$, CO, NMVOC, $SO_2$) greenhouse gases were estimated based on methodologies contained in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000). Atmospheric Emissions Inventory Guidebook (CORINAIR, 1996, 1999, 2005), and 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

The activity data sources Greenhouse Gas Categories were documented by inserting references to these into the inventory document text. Estimation methods and emission factors sources (table1) and their selection justification are documented in the corresponding Good Practice Guidance.

**Table 1**

Emission factors and other relevant parameters used to estimate GHG emissions from the Energy Sector of the Republic of Moldova

| Fuel type | Net Calorific Value, (TJ/kt) (country specific) | | Net Calorific Value (TJ/kt) | | Emission factors (t C/TJ) | | Fraction of carbon oxidized | |
|---|---|---|---|---|---|---|---|---|
| | Ranges according to the NBS | Value used | IPCC, 1997 | IPCC, 2006 | IPCC, 1997 | IPCC, 2006 | IPCC, 1997 | IPCC, 2006 |
| Coal | 15.40 -29.13 | | 18.58 | | | | 0.98 | 1 |
| Anthracite | 22.83 -29.13 | | 18.58 | 26.7 | 26.8 | 26.8 | 0.98 | 1 |
| Brown Coal, | 6.31 - 15.37 | | 14.65 | 11.9 | 27.6 | 27.6 | 0.98 | 1 |
| Donetsk | 25.70 | 25.70 | | | 26.8 | | 0.98 | 1 |
| Kuznetsk | 25.44 | 25.44 | | | 26.8 | | 0.98 | 1 |
| Ukraine | 6.31 - 11.68 | 11.68 | | | 27.6 | | 0.98 | 1 |
| Kansk-Acinsk | 15.14 | 15.14 | | | 25.8 | | 0.98 | 1 |
| Brown Coal | 17.75 | 17.75 | | 20.7 | 25.8 | 26.6 | 0.98 | 1 |
| Coking Coal | 26.41 -29.05 | 26.41 | 18.58 | 28.2 | 25.8 | 25.8 | 0.98 | 1 |
| Diesel Oil | 42.54 | 42.54 | 43.33 | 43.0 | 20.2 | 20.2 | 0.99 | 1 |
| Fuel for Oven | 42.54 | 42.54 | | | 21.1 | | 0.99 | 1 |
| Residual Fuel Oil | 39.02 -40.20 | 40.20 | 40.19 | 40.4 | 21.1 | 21.1 | 0.99 | 1 |
| Fuel for Engines | 41.96 | 41.96 | | | 20.0 | | 0.99 | 1 |
| including Jet Engines | 43.13 | | | | 19.5 | | 0.99 | 1 |
| Aviation Gasoline | 43.72 | 43.72 | 44.80 | 44.3 | 18.9 | 19.1 | 0.99 | 1 |
| Gasoline | 43.72 | 43.72 | 44.80 | 44.3 | 18.9 | 18.9 | 0.99 | 1 |
| Kerosene | 43.13 | 43.13 | 44.75 | 43.8 | 19.6 | 19.6 | 0.99 | 1 |
| Lubricants | 42.19 | 42.19 | 40.19 | 40.2 | 20.0 | 20.0 | 0.99 | 1 |
| Bitumen | 39.61 | 39.61 | 40.19 | 40.2 | 22.0 | 22.0 | 0.99 | 1 |
| Other Oil Products | 40.19 | 40.19 | 40.19 | 40.2 | 20.0 | 20.0 | 0.99 | 1 |
| Natural Gas | 33.15 - 34.03 | 33.86 | 33.70 | 48.0 | 15.3 | 15.3 | 0.995 | 1 |
| Liquefied Petroleum | 46.06 | 46.06 | 47.31 | 47.3 | 17.2 | 17.2 | 0.99 | 1 |
| Fuel Wood | 12.32 | 12.32 | 15 | 15.6 | 29.9 | 30.5 | 0.98 | 1 |
| Agricultural | 14.67 | 14.67 | 15.2 | | 29.9 | | 0.98 | 1 |

GHG emissions from the 1A3b 'Road Transportation' source category were estimated following a Tier 1 methodological approach (based on AD on fuel consumption and default values of EFs). It was not possible yet to use Tier 2 and Tier 3 methods because of lack of activity data on total vehicle km travelled disaggregated for each vehicle type (for the moment the vehicle km travelled are kept only for some vehicle types included into the State Register of Transport). Default EFs values available in the Revised 1996 IPCC Guidelines (IPCC, 1997) and 2006 IPCC Guidelines were used for non-$CO_2$ emissions estimation (tables 2-4).

**Table 2**
Emission factors used for estimating non-$CO_2$ emissions originated from 1A3b 'Road Transportation' (kg/TJ)

| Type of fuel | $CH_4$ | $N_2O$ | NOx | CO | NMVOC |
|---|---|---|---|---|---|
| Gasoline | 33 | 3.2 | 600 | 8000 | 1500 |
| Diesel Oil | 3.9 | 3.9 | 800 | 1000 | 200 |
| Natural Gas | 92 | 3 | 600 | 400 | 5 |

**Table 3**
Emission factors used for estimating non-$CO_2$ emissions originated from 1A1 'Energy Industries' source category (kg/TJ)

| GHG | Coal | Natural Gas | Oil Products | Fuel Wood | Other Biomass |
|---|---|---|---|---|---|
| $CH_4$ | 1 | 1 | 3 | 30 | 30 |
| $N_2O$ | 1.5 | 0.1 | 0.6 | 4 | 4 |
| $NO_x$ | 300 | 150 | 200 | 100 | 100 |
| CO | 20 | 20 | 15 | 1000 | 1000 |
| NMVOC | 5 | 5 | 5 | 50 | 50 |

**Table 4**
Republic of Moldova's GHG Emissions by Gas and Sector, 2005

| Greenhouse Gas Categories | $CO_2$ | $CH_4$ | $N_2O$ | HFC | $SF_6$ | $CO_2$ |
|---|---|---|---|---|---|---|
| | Gg | Gg $CO_2$ eq | Gg $CO_2$ eq | Gg $CO_2$ eq | Gg$CO_2$ eq | Gg $CO_2$ eq |
| **Total** | **7,576.577** | **2,883.818** | **1,404.05** | **18.719** | **0.284** | **11,883.45** |
| **1. Energy** | **6,986.138** | **693.3471** | **45.3232** | **no** | **no** | **7,724.808** |
| A. Fuel combustion activities | 6,984.257 | 41.3382 | 45.3180 | | | 7,070.913 |
| 1. Energy industries | 2,986.571 | 1.2256 | 1.9774 | | | 2,989.774 |
| 2. Manufacturing industries and construction | 396.3804 | 0.2149 | 0.3989 | | | 396.9942 |
| 3. Transport | 1,610.949 | 7.5024 | 36.0651 | | | 1,654.516 |
| 4. Other sectors | 1,872.308 | 32.2659 | 6.5339 | | | 1,911.108 |
| 5. Other (other works and needs in energy) sector | 118.0475 | 0.1295 | 0.3426 | | | 118.5196 |
| B. Fugitive emissions from fuels | 1.8809 | 652.0090 | 0.0052 | | | 653.8950 |
| 1. Solid fuels | no | no | no | | | no |
| 2. Oil and natural gas | 1.8809 | 652.0090 | 0.0052 | | | 653.8950 |
| **2. Industrial processes** | **541.4561** | **19.8167** | **1.6246** | **18.7189** | **0.2839** | **581.9002** |
| A. Mineral products | 416.8380 | 0.0068 | 0.0000 | | | 416.8448 |
| B. Chemical industry | no, ne | no, ne | no, ne | | | no, ne |
| C. Metal production | 83.8512 | 19.8098 | 1.6246 | | | 105.2857 |
| D. Other production | 40.7669 | no, ne | no, ne | | | 40.7669 |
| E. Production of CxHly and $SF_6$ | | | | no | no | no |
| F. Consumption of CxHly and $SF_6$ | | | | 18.7189 | 0.2839 | 19.0028 |
| **3. Solvents and other products use** | **48.9833** | **0.0000** | **0.0189** | **0.0000** | **0.0000** | **49.0022** |
| A. Paint application | 17.9812 | | | | | 17.9812 |
| B. Degreasing and dry cleaning | 1.2401 | | | | | 1.2401 |
| C. Chemical products, manufacture and processing | 0.2931 | | | | | 0.2931 |
| D. Other | 29.4689 | | 0.0189 | | | 29.4878 |
| **4. Agriculture** | | **863.4353** | **1,264.35** | **no** | **no** | **2,127.790** |
| A. Enteric fermentation | | 792.8592 | | | | 792.8592 |
| B. Manure management | | 70.5761 | 565.1074 | | | 635.6835 |
| C. Rice cultivation | | no | | | | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| D. Agricultural soils | | | 699.2474 | | | 699.2474 |
| E. Prescribed burning of savannas | | no | no | | | no |
| F. Field burning of agricultural residues | | ie | ie | | | ie |
| **5. LULUCF** | **-1,381.40** | **0.2445** | **0.1007** | **no** | **no** | **-1,381.06** |
| A. Forest land | -2,246.23 | 0.0164 | 0.0134 | | | -2,246.20 |
| B. Cropland | 1,684.281 | 0.2281 | 0.0873 | | | 1,684.596 |
| C. Grassland | -819.456 | ne | ne | | | -819.4560 |
| D. Wetlands | ne | ne | ne | | | ne |
| E. Settlements | ie | ne | ne | | | ne, ie |
| **6. Waste** | | **1,307.219** | **92.7379** | **no** | **no** | **1,399.957** |
| A. Solid waste disposal on land | | 1,186.206 | 0.0000 | | | 1,186.206 |
| B. Wastewater Handling | | 121.0136 | 92.7379 | | | 213.7515 |
| C. Waste Incineration | no, ne | no, ne | no, ne | | | no, ne |
| **7. Other** | **no, ne** | **no, ne** | **no, ne** | **no, ne** | **no, ne** | **no, ne** |
| International bunkers | 63.9592 | 0.0203 | 0.6589 | | | 64.6384 |
| $CO_2$ emissions from biomass | 295.0374 | | | | | 295.0374 |

Abbreviations: ie - included elsewhere; ne - not estimated; no - not occurring.

For other sectors, the emissions ratios were assessed by the procedures applied for energy and transport sectors.

Besides the inventory results, the NIR contains additional relevant data, as well as the analysis of recent trends in GHG emissions and removals in the Republic of Moldova (in the period team during 1990-2008), the analysis of key categories, additional sectored information used in emission inventory, data regarding activities related to inventory quality control and uncertainty management.

The evolution of total direct greenhouse gas emissions expressed in $CO_2$ equivalent, revealed a decreasing trend in the Republic of Moldova, reducing by circa 72.3 percent: from 42886.0 Gg $CO_2$ equivalent in 1990 to 11883.5 Gg $CO_2$ equivalent in 2005. Emissions of $CH_4$ have decreased by circa 39.5 percent: from 4766.1 Gg $CO_2$ eq. in 1990, to 2883.8 Gg $CO_2$ eq. in 2005, while emissions of $N_2O$ decreased by circa 58.1 percent: from 3354.7 1 Gg $CO_2$ eq. in 1990, to 1404.1 Gg $CO_2$ eq. in 2005 [5, 6]. Halocarbons emissions (in particular HFCs, as no PFCs emission have been registered so for in the Republic of Moldova) and sulphur hexafluoride ($SF_6$) emissions commenced in 2000, considered as a reference year for F - gases in the Republic of Moldova (fig. 1).

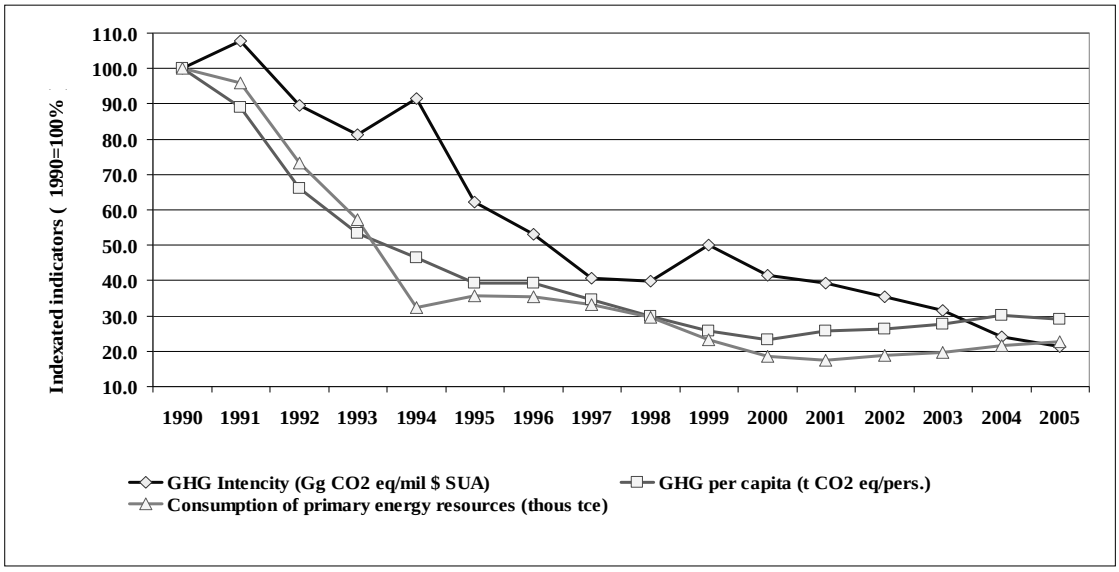


**Fig. 1.** Trends in GHG emissions per Capita and per Unit GDP, 1990-2005

Sectoral breakdown of the Republic of Moldova's GHG Emissions is shown in fig. 2. In 2005 approximately 59.5 percent of the total national direct GHG emissions originated from fossil fuel combustion, while fugitive emissions from oil and natural gas accounted for 5.5 percent of the total, so the share of energy, representing a decrease of this sector against reporting year.

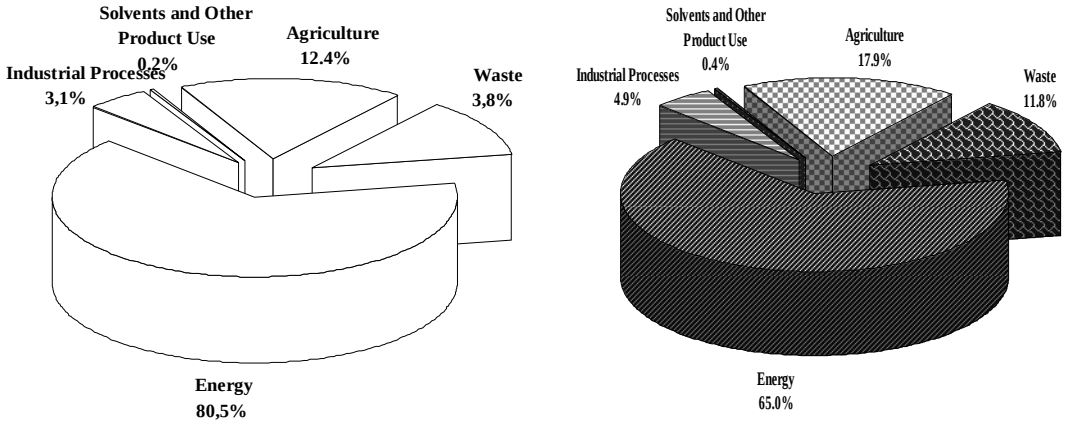


**Fig. 2.** Sectoral breakdown of the Republic of Moldova's GHG Emissions in 1990 and 2995

Republic of Moldova developed a Quality Assurance and Quality Control Plan and the Procedures Manual for Quality Assurance and Quality Control. The key attributes of the Quality Assurance and Quality Control Plan include detailed Tier 1 (general procedures) and Tier 2 (source-specific) procedures [2, 3] and standard verification and quality control forms and checklists, that serve to standardize the process of implementing quality assurance and quality control activities meant to ensure the quality of the national inventory; peer review carried out by experts not directly involved in the national inventory development process; data quality check, as well as the documentation and archiving of all materials used in inventory preparation process.

The overall inventory uncertainty was estimated using a Tier 1 methodological approach (IPCC, 2000). An estimate of the overall quantitative uncertainty ±16.0 percent level uncertainty and ±3.9 percent trend uncertainty, are shown in table 5. Combined uncertainties analysis of the GHG emissions from the Energy Sector (by source categories) as a percentage of total direct sectoral emissions were estimated at circa ±16.9 percent (±5.6 percent for $CO_2$, ±188.1 percent for $CH_4$ and ±30.4 percent for $N_2O$). The uncertainties introduced in trend in sectoral emissions were estimated at ±3.1 percent (±1.4 percent for $CO_2$, ±34.3 percent for $CH_4$ and ±4.3 percent for $N_2O$).

**Table 5**

Estimated overall national inventory quantitative uncertainty (%)

| Indicator | $CO_2$ | $CH_4$ | $N_2O$ | Total |
|---|---|---|---|---|
| Level Uncertainty | ±14.1 | ±48.6 | ±22.0 | ±16.0 |
| Trend Uncertainty | ±3.3 | ±17.6 | ±5.3 | ±3.9 |

Despite the greenhouse gases national cadaster prepared by 1998 in accordance with the IPCC manual reviewed in 1998 is quite complete and accurate, the uncertainty assessment and determination of prime measures for inventory quality have not been made. In this context, at least, the preparation and elaboration of a manual for inventory with an emphasis on the uncertainty and the inventory quality assessment are quite usable.

Due to a comparative world analysis, taking into account a number of regional and local factors, we began to prepare such manual in the basis of the manual developed by the US Environment Protection Agency (US EPA).

In respect to uncertainty assessment, the transport and waste module have been taken into account with priority. For transport, the main uncertainties are the selection of specific emission ratios. By RM legislation and regulation in force, the selection of specific emission ratios are made by used fuels. Thus, the inventory procedure, at this stage, was made by level 1. In the next step, the inventory pattern by the procedure of level 2 is to be made at the state of harmonization of the regulations in respect to automotive transport with the methodology for registering the category and mileage of transport in the RM by the classification of motor vehicles in accordance with EU legislation. These uncertainties intersect with uncertainties of the following activities: statistic data interpretation, energy balances, the number and type of motor vehicles etc.

It could be mentioned that the methods EMEP CORINAIR, IPCC elaborated within the Convention for Climate Change and other regulations to calculate, verify the inventory quality have a numbers of gaps. As a result of the uncertainty in how to classify the pollution sources by categories, the specific emissions ratios have been presented in wide limits and in order to select them, the local specific have not been taken into account. These and other uncertainties have led to the fact that environmental information in national and international environmental reports varies up to 30% in number.

In this context, recently elaborated manual for inventory with uncertainties and inventory quality assessment will diminish these errors.

**References**

1. IPCC/OECD/IEA - *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. The Reference Manual,* J. T. Houghton et al., Volumes 1, 2, 3, Paris, France, Intergovernmental Panel on Climate Change, Organisation for Economic Co-operation and Development, and International Energy Agency, 1997 (download at <http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm>)

2. *** Quality assurance / quality control and uncertainty management plan for the U. S. Greenhouse Gas Inventory: Procedures Manual for Quality Assurance / Quality Control and Uncertainty Analysis U. S. Environmental Protection Agency Office of Atmospheric Programs (6204N) Greenhouse Gas Inventory Program Washington D. C. 20460, EPA 430-R-02-007B.Version 1.0, June 2002

3. Quality assurance / Quality control and uncertainty management plan for the U.S. Greenhouse Gas Inventory background on the U. S. Greenhouse Gas Inventory Process U. S. Environmental Protection Agency Office of Atmospheric Programs (6204N) Greenhouse Gas Inventory Program Washington D. C. 20460 EPA 430-R-02-007A. Version 1.0, June 2002

4. *** Prima Comunicare Națională a Republicii Moldova prezentată Convenției Cadru a Națiunilor Unite privind Schimbările Climaterice, Chișinău 2000

5. Brega V., Buburuz D., Țăranu M. - *Energetic potential cultures and the enviromental risks,* Ecoterra, nr. 19, 2008

6. *** Raportul Național de Inventariere al Republicii Moldova: 1990-2005. Surse de emisii şi sechestrare a gazelor cu efect de seră/Ministerul Ecologiei şi Resurselor Naturale, Programul ONU pentru Mediu; Autori: Țăranu M., Scorpan V., Bîcova E., Brega V., Tărîță A., Bacean I., Păgînu V., Talmaci I., Banaru A., Țugui T., Calos S.-Ch., Editura „Continental Grup", 364 p., 2009

**Contact data**

Vladimir BREGA: Academy of Sciences from Moldova, Institute of Ecology and Geography; Academiei str., 1, MD-2028, Chişinău, Republic of Moldova; e-mail: bregaradu@rocketmail.com