THE ASSESSMENT OF CO_2 EMISSIONS FROM ENERGY INDUSTRY FOR THE PERIOD OF 1990-2002 IN MOLDOVA

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The paper presents the results of an assessment focused on evaluation of CO_2 emissions those originates from Energy Industry for 1990-2002 period in the Republic of Moldova. The aim of the assessment was to develop a GHG inventory of a higher quality by improving the methodologies and finding new and improved activity data. The CO_2 emission estimates from Energy Industry for the period 1990-1998 have been recalculated due to new activity data becoming available (the Energy Balances of the Republic of Moldova for 1990, 1993-2002 years offered by the National Bureau of Statistics). The obtained results revealed that CO_2 emissions from Energy Industry declined by 84.1% within 1990-2002. The inter-annual changes of CO_2 emissions from this source category for some years are large, being more than 10%. The reasons for the large fluctuations are due mainly to permanent annual declined in the production in comparison with the base year of 1990, characteristic up to 2000 year (the 1993 and 1996 were the only years since 1990 when an inter-annual increase was observed in the CO_2 emissions, of 8.0% and respectively 1.9%, however during the next periods the decrease continued), as well as because of the increase of the natural gas share in the structure of fuel consumed in the thermal and electric energy production, especially at Moldovan Thermoelectric Power Plant (MTPP). A significant increase (of 28.6%) in CO_2 emission was registered only in 2001. To be noted that since 2000 the GDP has a stable increase trend in the Republic of Moldova, however this trend was not followed by such index as fuel consumption and energy production within Energy Industry (respective by CO_2 emissions originated from fuel combustion).

Key words: Greenhouse Gas Emissions (GHG), GHG Inventory**,** Energy Industry

INTRODUCTION

Generally, the 'Energy Industry' source category includes greenhouse gas emissions from stationary fuel combustion sources in the production, processing, and refining energy. In the Republic of Moldova, the category includes only the subcategory 'public electricity and heat production'. There is minor domestic fossil fuels production, therefore the sub-categories related with the processing and refining of fossil fuels are missing.

The Republic of Moldova's electric supply grid includes four thermal power plants and two hydropower plants. Total electricity production of hydropower plants is relatively small. The Moldavan Thermoelectric Power Plant (MTPP) has a condensation cycle, while the Combined Heat and Power Plants (CHP): CHP-1 and CHP-2 in Chisinau and CHP-North in Balti have cogeneration cycle. The thermal power plants work on the combustion of the following fossil fuels: coal, heavy fuel oil and natural gas. Currently, the great share of fuel used at power plants is of the natural gas, while the share of remaining fuels is insignificant. Thus, in the Republic of Moldova, the main parts of CO_2 emissions in 'Energy Industries' category is generated by the thermal power plants.

METHODOLOGICAL ISSUES

CO_2 emissions are calculated ground of the data of fuel consumption for electricity and heat production. The calorific values for conversion to energy units are those offered by the State Ecological Inspectorate of the Republic of Moldova (SEI) and the National Bureau of Statistics (NBS). Emission factors (EFs) used is those recommended in the Revised 1996 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories [1].

While preparing the First National Communication (FNC) [2], the activity data on consumed fuel and their quality were collected from different sources: directly from the power plants, as well as from former Custom Department and Department of Statistics and Sociology (since 2005 they changed the name into the Custom Service and National Bureau of Statistics). Currently, the Energy Balances (EB) for 1990 and 1993-2002 years prepared by the National Bureau of Statistics of the Republic of Moldova [3] were taken as the base source for calculation of CO_2 emission estimates from the Energy Industry (to be noted that the EBs for 1991 and 1992 years were not prepared).

While preparing the GHG Inventory for 1990-2002 periods, the IPCC Tier 1 method was used. The Decision Tree for selecting the optimal method of estimation CO_2 emissions from stationary fuel combustion is presented below (Fig. 1). IPCC Inventory Guidelines require the public electricity and heat production sector to include only emissions generated by public utilities. Emissions associated with industrial generation should be allocated to the industry category that produces the energy under the appropriate industrial sector in the energy section regardless of whether the energy is for sale or internal use.

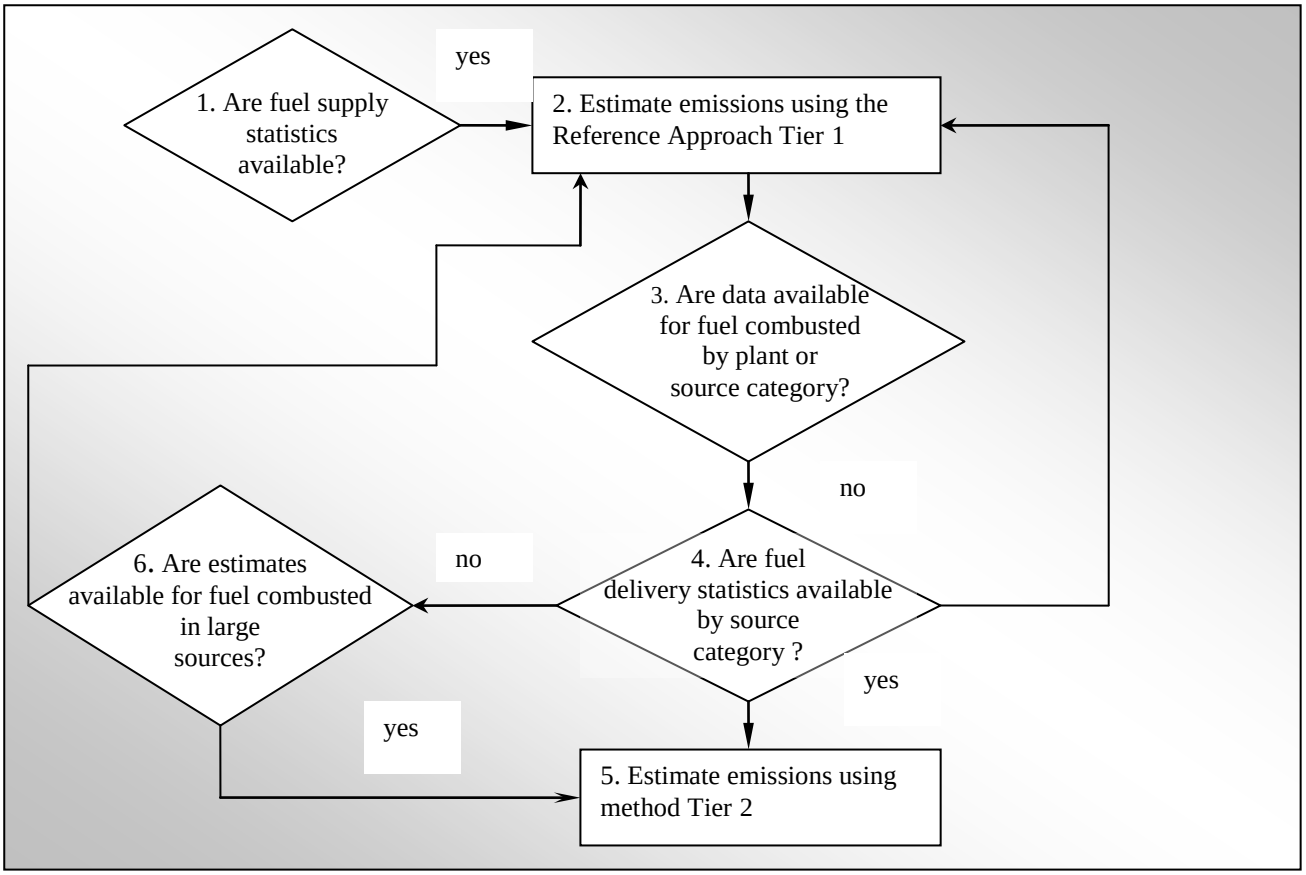

Fig. 1 - Decision tree for selecting the method of estimation CO_2 emissions from stationary combustion

The rationale for this is that the IPCC recognizes that it is difficult to disaggregate emissions in cogeneration facilities (i.e., to separate the electricity component from the heat component of fuel use). Statistics fuel use data in the Energy Balance does distinguish industrial electricity generation data, and aggregates the data into one category titled 'electricity generation'.

As a result, the GHG inventory does not allocate industrial electricity generation emissions to specific industrial sub-sectors, these emissions are lumped together and reported with 'Public Electricity and Heat' generation. In the Republic of Moldova, the total CO_2 emissions were calculated by using the (1):

*CO_2 (Gg) emissions = Σ (Fuel Combustion $_j$ (for each sector) x Conversion Factor (TJ/units) x Carbon emission factor $_j$ (t C/TJ) – Carbon Stored x Fraction Oxidized $_j$*44/12),* where j - type of fuel (1)

The activity data on fuel consumption within the Energy Industries were taken from the Energy Balances for 1990 and 1993-2002, as well as directly from the MTPP for 1990-1998, while for 1999-2002 period, being calculated based on the amount of electricity produced at the MTPP and on amount of fuel consumption for a power production unit (an average of 360 grams of coal equivalent per a kWh of electricity produced) (Table 1).

Table 1 - Fuel Consumption in Energy Industries for production of: electricity (e), heat (h), total energy (Σ), in kilotons and million m^3, according the Energy Balances prepared by the National Bureau of Statistics of the Republic of Moldova for 1990 and 1993-2002 years and data obtained from Moldovan Thermoelectric Power Plant (MTPP)

Type of fuel	**1990***			**1993**			**1994**			**1995**		
	e	h	Σ	e	h	Σ	e	h	Σ	e	h	Σ
Diesel Oil	62	0	62	0	9	9	0	8	8	1	7	8
Residual Fuel Oil	2119	0	2119	658	547	1205	255	304	559	55	280	335
Coal	2657	0	2657	1620	90	1720	1687	30	1717	883	18	901
Natural Gas	3239	0	3239	1012	793	1804	1168	711	1879	1216	712	1928
Type of fuel	**1996**			**1997**			**1998**			**1999**		
	e	h	Σ	e	h	Σ	e	h	Σ	e	h	Σ
Diesel Oil	1	6	7	1	4	5	1	2	3	1	2	3
Residual Fuel Oil	58	251	309	35	178	213	48	141	189	9	90	99
Coal	806	20	826	282	18	300	182	16	198	0	7	7
Natural Gas	1412	727	2139	1339	743	2082	1010	749	1759	1015	553	1568
Type of fuel	**2000**			**2001**			**2002**			**1990-2002,%**		

	e	h	Σ	e	h	Σ	e	h	Σ	Σ
Diesel Oil	1	3	4	1	2	3	0	2	2	-96,77
Residual Fuel Oil	3	40	43	6	33	39	2	28	30	-98,58
Coal	0	0	0	0	0	0	0	2	2	-99,92
Natural Gas	966	354	1320	1347	381	1728	1175	371	1546	-52,28

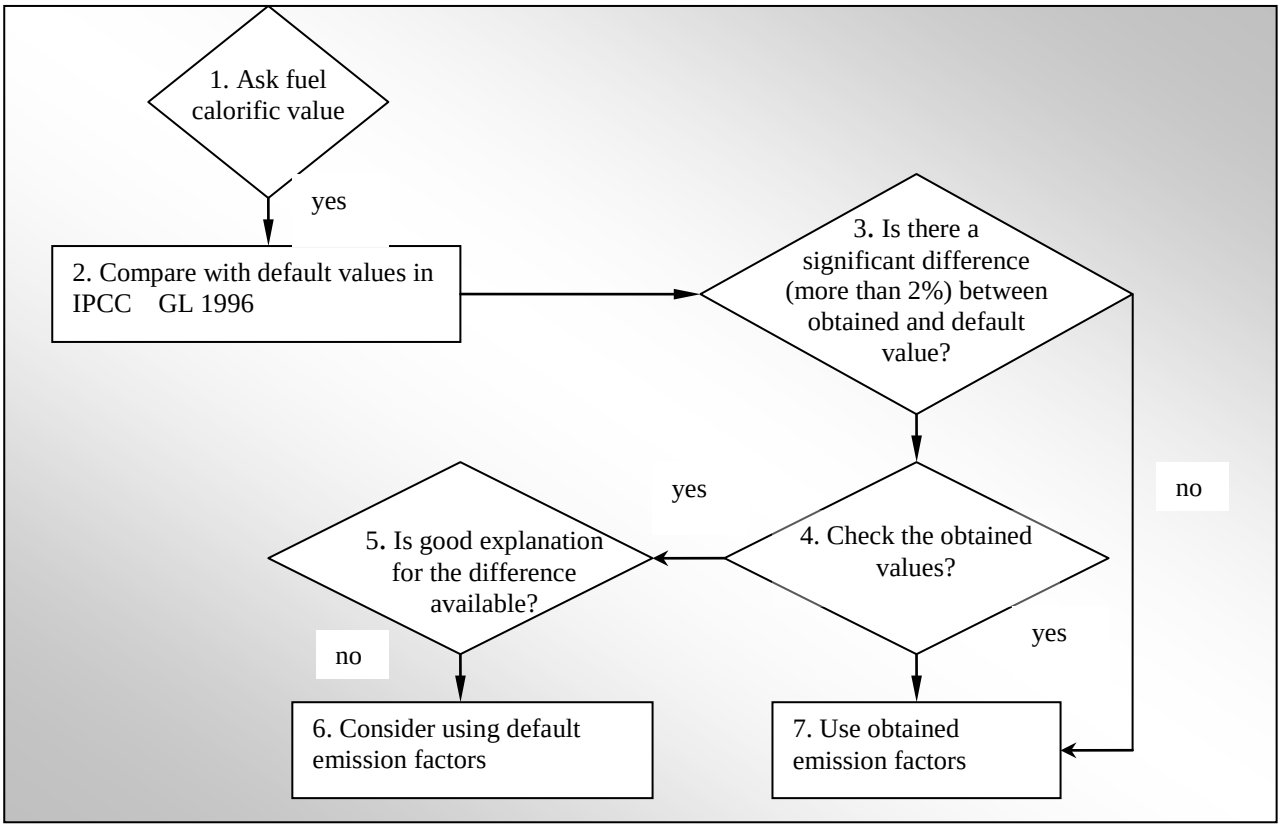

Fig. 2 - Decision Tree for selecting Calorific Values and Carbon Emission Factors

Following the recommendation of the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories [4], the decision tree represented in the Fig. 2 was used for selecting the optimal Calorific Values and Carbon Emission Factor. The national conversion factors used are presented in Table 2 below.

Almost of the fuels used within the Energy Industries in the Republic of Moldova are imported. The data on direct import of fuel it is available within the database of the Customs Service of the Republic of Moldova, these data are also delivered to the National Bureau of Statistics, being published within the Statistical Yearbooks and Energy Balances of the Republic of Moldova. Thus, the completeness of emission estimates within the sector directly depends on the quality of the statistical data included into the Energy Balances of the Republic of Moldova. As mentioned above, the Energy Balance for 1990 year contain data for the whole territory of the country; within the 1991-1992 period the Energy Balances were not prepared (for these years data have been collected on the ground, preferentially there were used departmental data), while since 1993 year the Energy Balances prepared by the Department of Statistics and Sociology of the Republic of Moldova (actual NBS) comprise data only for the right bank of the Dniester (data for MTPP situated on the left bank of the river are not included).

Table 2 - National conversion factors used in the Energy Balances of the Republic of Moldova.

Type of fuel	Range	National Conversion Factor	Selected NCV from IPCC 1996 Guidance for comparison
	TJ	**TJ/ kt**	**TJ / 1000 t**
Coal	15,40 - 29,13		18.58
Antracite	22,83 - 29,13		18.58
Brown coal	6,31 - 15,37		14.65

Donetsc coal	25,70	25,70	
Kuznetsk coal	25,44	25,44	
Ukrainean brown coal	6,31 - 11,68	11,68	
Kansk-Acinsk coal	15,14		
BKB & Patent fuel	17,75	17,75	
Coke	26,41 - 29,05	26,41	18.58
Diesel oil	42,54	42,54	43.33
Fuel for ovens	42,54	42,54	
Residual fuel oil	39,02 - 40,20	40,2	40.19
Fuel for engines	41,96	41,96	
Fuel for jet engines	43,13		
Aviation gasoline	43,72	43,72	44.80
Gasoline	43,72	43,72	44.80
Kerosine	43,13	43,13	44.75
Lubricants	42,19	42,19	40.19
Bitumen	39,61		40.19
Other oil products	29,34	29,34	
Natural gases, million cub meters	33,15 - 34,03		
Natural gas	33,86	33,86	33.704
LPG	46,06	46,06	47.31
Firewood, tce	7,80		15
Wood residues, inclusive	29,34	29,34	15
bark	12,32	12,32	
Agricultural residues, inclusive	29,34	29,34	
Wheat straw	14,67	14,67	15.2
Maize stalk	9,68		14.7

RESULTS AND DISCUSSION

GHG emissions calculations and recalculations

The CO_2 emissions originated from Energy Industries were recalculated according the recommendations of the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories [3]. National factors on conversion the mass units in the energy units were used accordingly the information received from National Bureau of Statistics. The registered difference in CO_2 emissions from this source category between the recalculated version of the inventory and the inventory comprised in the FNC for some years under the assessment are large: for 1990 it is +46.07%; for 1993 it is +27.65%; for 1994 it is +27.77%; for 1995 it is +-30.77%; for 1996 it is +20.88%; for 1997 it is +15.62% and for 1998 it is +11.69% (Table 3).

This primary is due to more precise and completed data activity data became available - the Energy Balances of the Republic of Moldova for 1990, 1993-2002 years were used for the recalculated version of the GHG inventory, instead of departmental data used while preparing the first GHG inventory comprised in the FNC. To be noted also, that the further differences for the rest of the period represents mainly the share of the CO_2 emissions originated from Moldavian Thermal Power Plant (MTPP is situated on the left bank of the Dniester in the separatist region of Transnistria and those authorities did not offer any official statistic data, inclusive on fuel consumption). Thus, the sharp difference of CO_2 emissions from 1990 (19,106.26 Gg) to 2002 years (3,029.72 Gg) is mainly due to the fact that since 1994 at MTPP, which has the highest contribution in the structure of the CO_2 emissions (around 75%), there was initiated the process of replacing the coal and residual fuel oil consumption with natural gases.

Table 3 - CO_2 emissions originated from Energy Industry, for 1990-2002 periods

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
CO_2,Gg (Recalcul.)	19106,26	11894,52	10372,63	11199,15	9371,15	6840,97	6970,64
CO_2,Gg (FNC)	13080,45	11894,52	10372,63	8773,43	7451,08	5231,26	5766,60
Difference, %	46,07	0,00	0,00	27,65	25,77	30,77	20,88
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**1990-2002, %**
CO_2,Gg (Recalcul.)	5319,29	4387,68	3296,01	2639,95	3395,25	3029,72	-84,14
CO_2,Gg (FNC)	4600,53	3928,36	-	-	-	-	-69,97
Difference, %	15,62	11,69	-	-	-	-	-

Uncertainties and time-series consistency

Generally, the uncertainties for the energy industry category are largely dependent on the collection procedures used for the underlying activity data as well as how representative the EFs are for specific fuel properties; commercial fuel volumes and properties are as usual well known while there is greater uncertainty surrounding both the reported quantities and properties of non-market fuels.

In the Republic of Moldova the accuracy in determining emissions is almost entirely determined by the availability of the delivery of the fuel combustion statistics for the main source categories, the major uncertainty in this situation arises from: the adequacy of the statistical coverage of all source categories and the adequacy of the coverage of all fuels.

The statistic data on fuel combustion at large sources could be obtained from direct measurement or by reporting, and are likely to be generally within 5% of the central estimates.

The activity data is a subject to random errors in the data collection and it might be expected that in the Republic of Moldova the random error is about 3-5% of annual value consumption.

The estimates for the energy industries category are consistent over time (especially since 1993, when the Energy Balances are prepared for the territory of the Republic of Moldova situated on the right bank of Dniester river), being calculated using the same methodology.

Quality Assurance/Quality Control and Verification

As an additional QA/QC procedure specific to the energy industry category was the comparison of the data for 'Public Electricity and Heat Production' category available within the Energy Balances of the Republic of Moldova against a data set collected independently by the national inventory team within the Climate Change Office besides the Ministry of Ecology and Natural Resources directly from the sources in collaboration with the Ministry of Industry and Infrastructure of the Republic of Moldova.

Generally, the applied QA/QC and verification procedures are referring to the check of activity data and emission factors, inclusive: check data from energy balances in mass units; check data from energy balances in energy units; the calorific values are cross-checked with IEA values; energy statistics are compared with data directed in international organizations etc.

Planned improvements

One of major goals for further improvements would be obtaining more precise activity data from MTPP for the period of 1999-2002. Also, by disaggregating emissions in cogeneration facilities (i.e., to separate the electricity component from the heat component of fuel use) it would be possible apply the higher Tier 2 method with adequate accuracy. Another planned activity it is the annual check of national values for the coefficients used as conversion factors from mass units in energy units.

CONCLUSIONS

The CO_2 emission estimates from Energy Industry for the period 1990-1998 have been recalculated due to new activity data becoming available from the Energy Balances of the Republic of Moldova for 1990, 1993-2002 years offered by the National Bureau of Statistics.

The registered difference in CO_2 emissions from this source category between the recalculated version of the inventory and the inventory comprised in the FNC for some years under the assessment are large: for 1990 it is +46.07%; for 1993 it is +27.65%; for 1994 it is +25.77%; for 1995 it is +30.77%; for 1996 it is +20.88%; for 1997 it is +15.62% and for 1998 it is +11.69%. It might be assumed that the registered differences for 1990 and 1993-1998 years are due to more precise and completed data available in the Energy Balances of the Republic of Moldova.

By using the new data available in the Energy Balances of the Republic of Moldova, the obtained results revealed that the CO_2 emissions originated from fuel combustion within Energy Industry decreased between 1990 and 2002 by approximate 84% (Table 4).

The inter-annual changes of CO_2 emissions from this source category for some years under the assessment are large, being more than 10%: between 1990 and 1991 it is -37.75%; between 1992 and 1993 it is -12.79%; between 1993 and 1994 it is -16.32%; between 1994 and 1995 it is -27.00%; between 1996 and 1997 it is -23.69%; between 1997 and 19989 it is -17.51%; between 1998 and 1999 it is -24.88%; between 1999 and 2000 it is -19.90%, between 2000 and 2001 it was +28.61% and between 2000 and 2001 it was -10.77%.

The reasons for these large fluctuations are difficult to be explained. However, it could be assumed that the permanent annual declined in the production, in comparison with the base year of 1990, characteristic up to 2000 year it is due primarily to the economic crisis specific to the national economy within this period.

The 1993 and 1996 were the only years since 1990 when an inter-annual increase was observed in the CO_2 emissions, of 7.97% and respectively 2.53%, however during the next periods (1997-2000) the decrease continued.

A significant increase (28.61%) in CO_2 emission was registered only in 2001. To be noted that since 2000 the GDP has a stable increase trend in the Republic of Moldova [5], however this trend was not followed by such index as fuel consumption within Energy Industry (respective by CO_2 emissions originated from the their combustion).

Table 4 - The dynamic of CO_2 emissions originated from Energy Industry, for 1990-2002 periods

Source	1990	1991	1992	1993	1994	1995	1996
CO_2 emissions, Gg	19106,26	11894,52	10372,63	11199,15	9371,15	6840,97	6970,64
Change compared with 1990, %	100	-37,75	-45,71	-41,38	-50,95	-64,20	-63,52
Inter-annual change, %	100	-37,75	-12,79	7,97	-16,32	-27,00	1,90
Inter-annual change of GDP, %	100	-17,50	-29,10	-1,20	-30,90	-1,40	-5,90
Source	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	
CO_2 emissions, Gg	5319,29	4387,68	3296,01	2639,95	3395,25	3029,72	
Change compared with 1990, %	-72,16	-77,04	-82,75	-86,18	-82,23	-84,14	
Inter-annual change, %	-23,69	-17,51	-24,88	-19,90	28,61	-10,77	
Inter-annual change of GDP, %	1,60	-6,50	-4,40	2,10	6,10	7,80	

REFERENCES

[1] IPCC (1997), *Greenhouse Gas Inventory Reporting Instructions*, Vol. 1; and *Greenhouse Gas Inventory Reference Manual*, Vol. 3, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change, Bracknell, U.K. Chapter 3.

[2] *First National Communication of the Republic of Moldova under the United Nations Framework Convention on Climate Change (2000)*, implemented by the Ministry of Environment and Territorial Development in cooperation with UNDP Moldova under the GEF financial assistance. Chisinau, 2000, 74 p.

[3] *Energy Balances of the Republic of Moldova for 1990 and 1993-2002 year,s* prepared by the former Department of Statistics and Sociology of the Republic of Moldova (actual National Bureau of Statistics).

[4] IPCC/OECD/IEA (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Organisation for Economic Co-operation and Development, and International Energy Agency, Tokyo.

[5] *The Economic Growth and Poverty Reducing Strategy (2004-2006)*. Government of the Republic of Moldova. Chisinau, 2004, available also on: http://www.scers.md/strategy_en/.

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