Ministry of Nature Protection of the Republic of Armenia

United Nations Development Programme
Global Environmental Facility

National Greenhouse Gas Inventory Report of the Republic of Armenia for 2014

Under the United Nations Framework Convention on Climate Change

Yerevan 2017

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ABBREVIATIONS

AFOLU	Agriculture, Forestry and Other Land Use
AMD	Armenian Dram
BOD	Biological oxygen demand
BUR	Biennial update report
CDM	Clean Development Mechanism
CJSC	Closed joint stock company
COD	Chemical oxygen demand
COP	Conference of the Parties
DOC	Degradable organic compound
DOM	Dead organic matter
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FC	Fluorinated compounds
GDP	Gross domestic product
GEF	Global Environment Facility
GHG	Greenhouse gas
GPG	Good practice guidance
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial process and product use
MCF	Methane conversion factor, methane correction factor
mln	Million
MRV	Measurement, reporting and verification
MSW	Municipal solid waste
NA	Not applicable
NCV	Net calorific value
NE	Not estimated
NIR	National Inventory Report
NMVOCs	non-methane volatile organic compounds
NO	Not occurring
NSS	National Statistical Service of the Republic of Armenia
ODS	Ozone depleting substances
QA/QC	Quality assurance and quality control
RA	Republic of Armenia
RE	Renewable energy
SW	Solid waste
SWD	Solid waste disposal
TNC	Third National Communication
TPES	Total primary energy supply
TPP	Thermal power plant
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
USSR	Union of Soviet Socialist Republics

Measurement Units

eq.	equivalent
Gcal	gigacalorie (10^9 calorie)
Gg	gigagram (10^9 g, or thousand t)
GWh	gigawatt hours (10^9 Wh)
MW	megawatt
PJ	petajoule (10^{15}J)
t	tonne

TJ	terajoule (10^{12}J)
toe	tonne of oil equivalent

Chemical Combinations

CFCs	Chlorofluorocarbons
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SF_6	Sulfur hexafluoride
CO	Carbon monoxide
NOx	Nitrous oxides
SO_2	Sulfur dioxide

Energy units' conversion

1 toe = 0.041868 TJ=0.01163 GWh
1 GWh = 3.6 TJ= 86 toe

SUMMARY

This greenhouse gas inventory report has been prepared within the framework of the Second Biennial Update Report (BUR2) of the Republic of Armenia.

The inventory of greenhouse gases covers the years 2013 and 2014.

The Armenia's National GHG Inventory is compiled according to the *2006 IPCC Guidelines for national greenhouse gas inventories*, including emissions and removals of four direct greenhouse gases - carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbons (HFCs) in a series of time from 2000 to 2014.

The NIR includes also estimates of so-called indirect greenhouse gases - carbon monoxide (CO), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2).

According to the key provisions in the Decision 1/CP.16 and following the guidelines in Annex III of Decision 2/CP.17 on reporting information on national GHG inventories in the BUR for non-Annex I countries, the Armenia's GHG NIR includes:

- Summary report of national GHG inventory
- Inventory sectorial tables according to the 2006 IPCC Guidelines
- Key category analysis (KCA)
- Uncertainty analysis
- Consistent time series for years 2000-2014
- Summary information table of inventories for previous submission years from 1990 to 2014.

According to the IPCC 2006 Guidelines the following sectors were considered:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste

Within the frames of the NIR 2014 report the following improvements were made to the GHG inventory:

- Introduction of higher Tier for 3 sub-categories
- Including data for 14 new sub-categories.

Armenia's greenhouse gas emissions in 2014 totaled 10,450.71 Gg $CO_{2\ eq.}$ (excluding Forestry and Other Land Use).

The total emissions in 2014 were approximately 59 % (15 million tonnes) below the 1990 emissions level. Compared to 2010, the emissions increased by 24 %. The emissions in 2014 were around 4 % (434.5 $CO_{2eq.}$) higher than those reported in 2012 NIR.

The tables below provide GHG emissions by gases and by sectors for 2014 and Summary information of inventories for previous submission years from 1990 to 2014.

Table S.1 Greenhouse gas emissions by gases and by sectors for 2014, Gg

Sectors	Net CO_2	CH_4	N_2O	HFCs $CO_{2eq.}$	Total $CO_{2eq.}$
Energy	5,370.26	76.88	0.09	NA	7,012.26
Industrial Processes[1]	250.79	NA	NA	NA	250.79
F gases[2]	NA	NA	NA	531.74	531.74
Agriculture	0.68	62.22	2.38	NA	2,044.73
Waste	4.36	25.69	0.22	NA	611.19
Total GHG Emissions	**5,626.09**	**164.79**	**2.69**	**531.74**	**10,450.71**
Forestry and Other Land Use	-480.26	NA	0.01	**NA**	-477.14
Net GHG Emissions	**5,145.82**	**156.82**	**2.70**	**531.74**	**9,973.57**

Table S.2 Greenhouse gas emissions by sectors from 1990 to 2014, Gg $CO_{2eq.}$

Sector	1990	2000	2010	2012	2013	2014	2014 emission change (%) compared to		
							1990 levels	2000 levels	2012 levels
Energy	22,712.16	4,298.27	5,827.53	6,914.72	6,895.22	7,012.26	-69.13	63.14	1.41
Industrial Processes and Product Use	630.33	142.72	555.00	675.81	729.94	782.53	24.15	448.30	15.79
Agriculture	1,989.21	1,326.67	1,462.26	1,827.11	2,015.43	2,044.73	2.79	54.12	11.91
Waste	438.99	532.94	582.61	598.55	603.49	611.19	39.23	14.68	2.11
Total Emissions	**25,770.69**	**6,300.60**	**8,427.40**	**10,016.19**	**10,244.08**	**10,450.71**	-59.45	65.87	4.34
Forestry and Other Land Use	-736.00	-454.33	-540.59	-512.68	-469.72	-477.14	-35.17	5.02	-6.93
Net Emissions	**25,034.69**	**5,846.28**	**7,886.80**	**9,503.51**	**9,774.36**	**9,973.57**	-60.16	70.60	4.95

[1] *Excluding F gases*
[2] *F gases refer to fluorinated greenhouse gases (HFC compounds)*

1. INTRODUCTION

1.1 Basic Information on Greenhouse Gas Inventory

1.1.1 Legal bases for preparation of the inventory

This greenhouse gas inventory report has been prepared within the framework of the Second Biennial Update Report (BUR2) of the Republic of Armenia to meet Armenia's reporting obligations to the United Nations Framework Convention on Climate Change (UNFCCC) in line with Decision 1/CP.16 and following the guidelines in Annex III of Decision 2/CP17.

1.1.2 National greenhouse gas inventories

The first GHG inventory report for 1990 was developed in the framework of the First National Communication submitted to the UNFCCC in 1998.

The second GHG Inventory for 2000 was developed in 2010.

The third GHG Inventory for 2010 was developed in 2014.

The GHG national inventory report prepared in the framework of the First Biennial Update Report covers the years 2011 and 2012.

The GHG national inventory report developed under Second Biennial Update Report covers the years 2013 and 2014.

1.1.3. Institutional mechanisms and processes for inventory development

The Ministry of Nature Protection of the Republic of Armenia (MNP) is responsible for coordinating the activities related to the development of national communications and biennial update reports, including GHG inventory, through division on Climate Change and Atmospheric Air Protection under Environmental Protection Policy Department.

Climate change is a challenge with many dimensions and hence a number of ministries are in charge of dealing with climate change related issues. Therefore in 2012 the Prime Minister of the Republic of Armenia adopted Decree N 955 "On the establishment of an Inter-agency Coordinating Council on the implementation of requirements and provisions of the UNFCCC and the approval of the composition and rules of procedures of the Inter-agency Coordinating Council".

The Council is composed of representatives of 13 ministries, 3 state agencies adjunct to the Government and 2 independent bodies - the Armenian Public Services Regulatory Commission and Armenian National Statistical Service. The chairperson of the Council is the Minister of Nature Protection. The Council ensures high-level support and policy guidance thus giving sustainability to the preparation of the national communications and biennial update reports.

To support the operations of the Council on the fulfilment of the reporting requirements including the process of producing GHG inventories, a working group was also established comprised from the representatives of the state agencies, ministries as well as climate change experts and consultants.

UNDP Country Office through the UNDP Climate Change Program Unit supports the MNP in fulfillment of its obligations under UNFCCC including development of national communications and biennial update reports. With this aim the GHG inventory expert group was formed with the involvement of experts engaged in preparation of the previous inventories and familiar with 2006 IPCC Guidelines and software trying to keep "institutional memory" and ensure continuity and quality of the assessment process. The expert group worked in close cooperation with the Climate Change and Atmospheric Air Protection Division of the Environmental Protection Policy Department of the MNP.

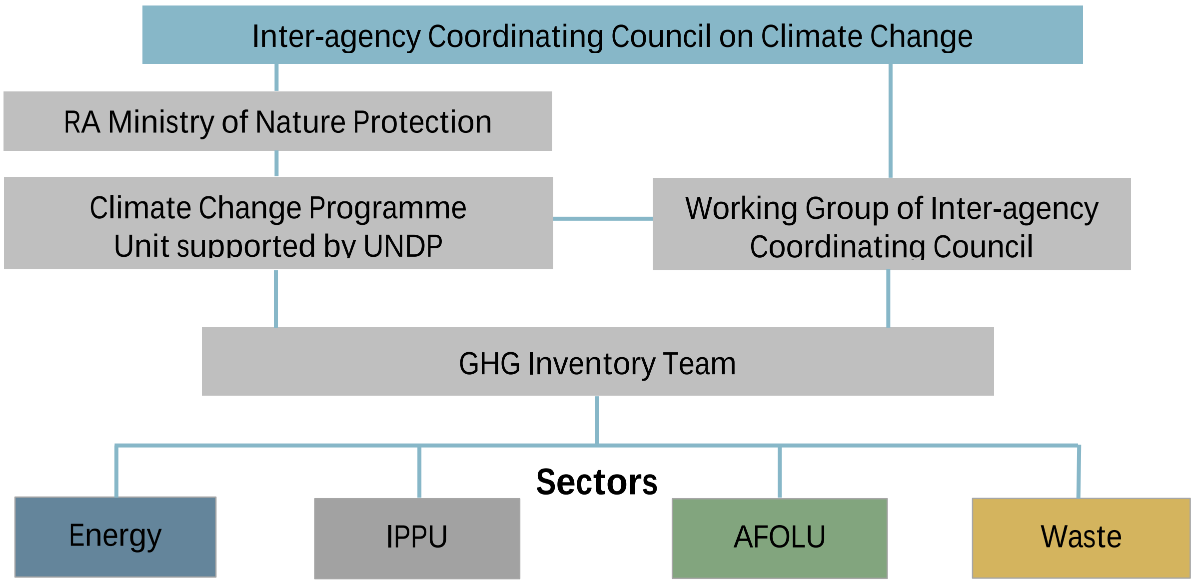


Figure 1.1 Organization chart of national inventory

1.1.4. Overview of inventory preparation process

Inventory preparation consists of the following main stages:

- Definition of the methods for calculation
- Data collection
- Data processing and emissions calculation
- Report preparation.

Definition of the methods for calculation means review of the calculation methods carried out by the relevant sectoral experts and consideration of the possible changes therein (where necessary). In each case, such methods selection depends on whether the considered category is a key or not and on the availability of the activity data for applying higher Tier approach.

Data collection and documentation comprises the following steps:

- Definition of requirements – means review and selection of data sources carried out by the relevant experts considering the calculation methods determined in the previous stage
- Requesting data from data providers carried out by the MNP
- Receipt of data
- Checking the received data for completeness and correctness by the relevant sectoral experts involved in the inventory preparation, including cross-checking and verification of data available from the different activity data sources and their underlying assumptions
- Update and development (if required) of country-specific emission factors

Report preparation includes the following steps:

- Compilation of submitted report to form a draft NIR
- Internal review by the GHG expert team followed by the review of the task leader expert
- Review of the draft NIR by the MNP and the working group of the Inter-agency Coordinating Council
- Circulation of the draft NIR among the stakeholder ministries and organizations for review
- Review and verification of the draft NIR by the Inter-agency Coordinating Council;
- Handover to the UNFCCC Secretariat
- Archiving

1.1.5 Overview of used methodology and data sources

Guidelines

GHG inventory was prepared according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC 2006 Inventory Software, developed for these Guidelines, was used for data entry, emission calculation, results analysis and conclusions.

"Good Practice Guidelines and Uncertainty Management in National Greenhouse Gas Inventories" (IPCC 2000), "Good Practice Guidelines for Land Use, Land Use Change and Forestry" (IPCC 2003) and "Air Pollutant Emission Inventory Guidebook" (EMEP/EEA, 2016), as well as if needed "1996 IPCC Revised Guidelines for National Greenhouse Gas Inventories" were also used during the preparation of the National Inventory.

The GHG inventory developed for reporting under BUR2 of the Republic of Armenia includes the following sectors:

- Energy
- Industrial Processes and Product Use (including F-gases)
- Agriculture, Forestry and Land Use
- Waste.

Global warming potentials

The estimated CH_4, N_2O, HFCs emissions were converted to CO_2 equivalent ($CO_{2eq.}$) using Global Warming Potentials (GWPs) values provided by the IPCC in its Second Assessment Report ("1995 IPCC GWP Values") based on the effects of GHGs over a 100-year time horizon (See Table 1.1).

Table 1.1 Global warming potential (GWP) values

GHG	GWP
CO_2	1
CH_4	21
N_2O	310
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-152a	140
HFC-143a	3,800
HFC-227ea	2,900

Methodologies

The GHG inventory was prepared according to the principles described below:

- Clear observation of the logic and structure of 2006 IPCC Guidelines;
- Priority given to the use of national data and indicators;
- Utilization of all possible sources of information;
- Maximum use of the capacities of national information sources.

During the preparation of the GHG inventory the highest priority was given to the estimation of the emissions of gases with direct greenhouse effect: CO_2, CH_4 and N_2O from the key categories as well as for emissions of hydrofluorocarbons (HFCs) compounds.

Estimations were also made for emissions of gases with indirect greenhouse effect: CO, NO_x, NMVOCs and SO_2.

Emission estimates were based on the sectoral approach applying Tier1, Tier 2 and Tier 3 methods.

Country-specific approaches were used for key categories wherever possible to produce more accurate emissions estimate than Tier 1 approach.

The Tier 3 method was used for estimating emissions of CO_2 in Energy Sector from electricity generation and in IPPU Sector from cement production, considering that both sub-categories were identified as key and disaggregated data were available.

The Tier 2 method was used for estimating emissions from the following key categories:

In Energy Sector:

- Emissions of CO_2 from stationary (with the exception of electricity generation) and mobile combustion of natural gas as well as for CH_4 emissions estimating from fugitive emissions of natural gas (The Tier 1 method was used for the emission estimates from liquid fuel combustion).

In IPPU Sector:

- The emissions of HFCs from refrigeration and air-conditioning were estimated applying the method 2A (estimation performed at a disaggregated level with country-specific data by sub-application and a default emission factor selected by sub-application from the 2006 IPCC Guidelines) considering that this sub-category was identified as key and data were available in each sublevel.
- The emissions of HFCs from the other applications were estimated by applying method 1a (estimation performed at an aggregated level, with country-specific data by application and default emission factor by application from the 2006 IPCC Guidelines).

In AFOLU Sector:

- Emissions of CH_4 from cattle enteric fermentation.
- Net CO_2 removals from Forest Land Remaining Forest Land.

In Waste Sector:

- CH_4 emissions from solid waste disposal.

Other emissions were estimated with the Tier 1 method with default estimation parameters from the 2006 IPCC Guidelines and country-specific activity data.

In addition to assessments based on Sectoral Approach the emissions of CO_2 from fuel combustion were also assessed by Reference Approach and the results were compared for checking purposes.

Activity data sources

Public Services Regulatory Commission of RA, the "Settlement Center" CJSC under the Ministry of Energy Infrastructures and Natural Resources of RA (which executes registration and measuring of power generation and supply through the country based on the indicators of the commercial meters) "Gazprom Armenia" CJSC and National Statistical Service, are the most important sources for determination of activity data for the Energy Sector.

National Statistical Service (NSS) has served as main fact sheet source of activity data for the other sectors as well. The information was also requested and received from the Ministry of Finance of RA (Customs Service), Ministry of Agriculture of RA, Ministry of Nature Protection of RA, Ministry of Economic Development and Investments of RA, State Committee of Real Estate Cadaster, State Revenue Committee, "ArmForest" SNCO, various private enterprises.

1.2 Key Category Analysis

The *2000 IPCC Good Practice Guidance* (Vol. 1, Chapter 4) specifies the methods –"Approaches" – to be applied in identifying key categories. These methods identify the relevant key categories with the help of analysis of the inventory for one year with regard to emissions levels for individual categories (Tier 1 level assessment), time-series analysis of inventory data (Tier 1 trend assessment) and detailed analysis of inventory data with error evaluation (Tier 2 level and trend assessment with consideration of uncertainties).

The key categories have been defined by applying the Approach 1 procedure, Level Assessment (for the last year reported) to 2014 Armenia's greenhouse gas emissions. In keeping with IPCC provisions, analyses have taken account of both emissions from sources and removals of greenhouse gases in sinks.

Level Assessment

Key categories were estimated in terms of their contribution to the absolute level of national emissions and removals. According to IPCC Guidelines, key categories are those that, when summed together in descending order of magnitude, add up to 95 percent of the total level.

The Approach 1 - Level Assessment for 2014 is provided below (see Table 1.2).

For the current report, the Approach 1 procedure identified 15 categories as key categories. Only few changes have occurred with respect to the results obtained in the 2012. The following new key categories have been added: CH_4 emissions from wastewater treatment and discharge (4.D) and CH_4 emissions from manure management (3.A.2).

Table 1.2 shows the absolute predominance of energy-related emissions - Energy Sector's 4 categories generate roughly more than half of all greenhouse gas emissions - as well as the considerable constancy of the relative shares of the various categories. Emissions from electricity generation and fugitive emissions from natural gas system are the largest both in 2014 and in 2012. Other significant emission sources in energy sector are transport fuels and household heating and cooking appliances that use mainly natural gas as their energy source.

Table 1.2 Approach 1 analysis – Level Assessment, 2014

A	B	C	D	E	F
IPCC catego-ry code	IPCC category	GHG	2012 emissions (Gg $CO_{2eq.}$)	Level assessment	Cumulative Total of the column E
1.A.1.a	**Electricity and Heat Production**	**CO_2**	**1,579.61**	**0.143**	**0.14**
1.B.2.b	**Fugitive Emissions of Natural Gas**	**CH_4**	**1,574.32**	**0.142**	**0.29**
1.A.3.b	**Road Transportation**	**CO_2**	**1,547.32**	**0.140**	**0.43**
1.A.4	**Other Sectors - Gaseous Fuels**	**CO_2**	**1,404.36**	**0.127**	**0.55**
3.A.1	**Enteric Fermentation**	**CH_4**	**1,209.54**	**0.109**	**0.66**
1.A.2	**Manufacturing Industries and Construction - Gaseous Fuels**	**CO_2**	**550.44**	**0.050**	**0.71**
3.B.1a	**Forest Land Remaining Forest Land**	**CO_2**	**-534.28**	**0.048**	**0.76**
2.F.1	**Refrigeration and Air Conditioning**	**HFCs**	**502.66**	**0.045**	**0.81**
3.C.4	**Direct N_2O Emissions from Managed Soils**	**N_2O**	**456.52**	**0.041**	**0.85**
4.A	**Solid Waste Disposal**	**CH_4**	**408.13**	**0.037**	**0.88**
2.A.1	**Cement Production**	**CO_2**	**223.40**	**0.020**	**0.90**
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	**190.17**	**0.017**	**0.92**
3.C.5	**Indirect N_2O Emissions from Managed Soils**	**N_2O**	**126.95**	**0.011**	**0.93**
4.D	**Wastewater Treatment and Discharge**	**CH_4**	**118.15**	**0.011**	**0.94**
3.A.2	**Manure Management**	**CH_4**	**96.99**	**0.009**	**0.95**
3.A.2	Manure Management	N_2O	86.03	0.008	0.96
3.C.6	Indirect N_2O Emissions From Manure Management	N_2O	67.99	0.006	0.97
1.A.2	Manufacturing Industries and Construction	CO_2	64.17	0.006	0.97
4.D	Wastewater Treatment and Discharge	N_2O	63.84	0.006	0.98
1.A.3.b	Road Transportation	CH_4	36.11	0.003	0.98
1.A.3.eii	Off-Road	CO_2	29.96	0.003	0.98
3.B.6.bii	Cropland Converted to Other Land	CO_2	26.90	0.002	0.99
1.A.3.b	Road Transportation	N_2O	24.49	0.002	0.99
2.A.4.d	Non-Cement Clinker Production	CO_2	20.16	0.002	0.99
2.F.2	Foam Blowing Agents	HFCs	17.11	0.002	0.99

1.3 Information on quality assurance and quality control

The ultimate aim of the QA/QC process is to ensure the quality of the inventory and to contribute to the improvement of inventory.

General inventory QC checks included routine check of the integrity, correctness and completeness of the data, as well as identification of errors. This was done by the sectoral experts and data manager.

Category-specific QC checks including technical reviews of the source categories, activity data, emission factors and methods were applied on a case-by-case basis focusing on key categories and on categories where significant methodological and data revision have taken place. This was done by the sectoral experts and task lead expert.

QC checks included internal review of the draft NIR by the MNP and by the working group of the Inter-agency Coordinating Council. The working group of the Inter-agency Coordinating Council comprising from representatives of the state agencies, ministries as well as climate change experts and consultants conducts technical analysis of the draft NIR (national trend tables) as contribution to the QC procedure.

The following step was handover of the draft NIR to the stakeholder ministries and organizations. Received comments and recommendations were taken into account.

The QA review was performed after the implementation of QC procedures concerning the finalized inventory. The draft NIR was submitted to and verified by the Inter-agency Coordinating Council for ensuring QA procedure followed by the final step of handover to the UNFCCC and inclusion the summary in the BUR.

1.4 Uncertainty assessment

Key sources uncertainty estimate was done using Approach 1 [Gen-1, Volume 1, Chapter 3, Equation 3.1]. The Equation 3.1 approximation was used to combine emission factor, activity data and other estimation parameter ranges by sub-category and greenhouse gas to assess the uncertainty in key sources emissions.

Table 1.3 Key sources uncertainty assessment

IPCC category code	IPCC category	GHG	2014			
			Emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty
			(Gg $CO_{2eq.}$)	(%)	(%)	(%)
1.A.1a	**Electricity and Heat Production –Gaseous Fuel**					
1.A.1.a.i	Electricity Generation – Gaseous Fuel	CO_2	962.89	3	3	4.24
1.A.1.a.ii	Combined Heat and Power Generation - Gaseous Fuel	CO_2	616.72	3	3	4.24
1.B.2.b	**Natural Gas Fugitive Emissions**					
1.B.2.b.iii.4	Transmission and Storage	CH_4	1060.35	7	5	8.6
1.B.2.b.iii.5	Distribution	CH_4	513.97	5	5	7.07
1.A.3.b	**Road Transportation**					
1.A.3.b	Road Transportation – Liquid Fuel	CO_2	594.33	20	5	20.62
1.A.3.b	Road Transportation – Gaseous Fuel	CO_2	952.99	5	3	5.83
1.A.4	**Other Sectors - Gaseous Fuel**					
1.A.4.a	Commercial/Institutional	CO_2	384.70	5	3	5.83
1.A.4.b	Residential	CO_2	1019.66	5	3	5.83
3.A.1	**Enteric Fermentation**	CH_4	624.32	10	20	22.36
1.A.2	**Manufacturing Industries and Construction – Gaseous Fuel**					
1.A.2.a	Iron and Steel	CO_2	36.65	5	3	5.83
1.A.2.b	Non-Ferrous Metals	CO_2	30.85	5	3	5.83
1.A.2.c	Chemicals	CO_2	14.65	5	3	5.83
1.A.2.d	Pulp, Paper and Print	CO_2	7.33	5	3	5.83
1.A.2.e	Food Processing, Beverages and Tobacco	CO_2	189.75	5	3	5.83
1.A.2.f	Non-Metallic Minerals	CO_2	229.63	5	3	5.83
1.A.2.h	Machinery	CO_2	2.52	5	3	5.83
1.A.2.i	Mining (Excluding Fuels) and Quarrying	CO_2	12.29	5	3	5.83
1.A.2.j	Wood and Wood Products	CO_2	0.03	5	3	5.83
1.A.2.k	Construction	CO_2	16.96	5	3	5.83
1.A.2.l	Textile and Leather	CO_2	0.64	5	3	5.83
1.A.2.m	Non-Specified Industry	CO_2	9.14	5	3	5.83
2.F.1	**Refrigeration and Air Conditioning**	HFCs	502.66	30	25	39.05
3.C.4	**Direct N_2O Emissions from Managed Soils**	N_2O	456.52	32	212	214.40
4.A	**Solid Waste Disposal**	CH_4	408.13	68.56	28.72	74.33
2.A.1	**Cement Production**	CO_2	223.40	19.5	3	19.73
1.A.4	**Other Sectors – Liquid Fuel**					
1.A.4.a	Commercial/Institutional	CO_2	2.80	15	5	15.81
1.A.4.b	Residential	CO_2	20.32	20	5	20.62
1.A.4.c.ii	Off-Road Vehicles and Other Machinery	CO_2	167.05	20	5	20.62
3.C.5	**Indirect N_2O Emissions from Managed Soils**	N_2O	126.95	32	229	231.22
4.D	**Wastewater Treatment and Discharge**					
4.D.1	Domestic Waste Water Treatment and Discharge	CH_4	86.72	36.4	58.31	68.74
4.D.2	Industrial Wastewater Treatment and Discharge	CH_4	31.42	75	58.31	95.00
3.A.2	**Manure Management**	CH_4	69.11	22	35	41.34

2. MAIN OUTCOMES OF GREENHOUSE GAS INVENTORY

Armenia's GHG emissions in 2014 totaled 10,450.71 Gg CO_2 equivalent (Table 2.1). The emissions were some 4 % (434.5 $CO_{2eq.}$) higher than those in 2012.

The Table 2.1 below provides greenhouse gases emissions estimate for 2013 and 2014.

Table 2.1 Greenhouse gas emissions by sectors and by gases for 2013 and 2014, Gg

Sectors	CO_2		CH_4		N_2O		HFC		$CO_{2eq.}$	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Energy	5,277.05	5,370.26	75.79	76.88	0.09	0.09	NA	NA	6,895.22	7,012.26
Industrial Processes	266.42	250.79	NA	NA	NA	NA	NA	NA	266.42	250.79
F-gases	NA	NA	NA	NA	NA	NA	463.52	531.74	463.52	531.74
Agriculture	0.29	0.68	60.67	62.22	2.39	2.38	NA	NA	2015.43	2,044.73
Waste	4.39	4.36	25.31	25.69	0.22	0.22	NA	NA	603.49	611.19
Total GHG Emissions	**5,548.16**	**5,626.09**	**161.77**	**164.79**	**2.69**	**2.69**	**463.52**	**531.74**	**10,244.08**	**10,450.71**
Forestry and Other Land Use	-472.85	-480.26	NA	NA	0.01	0.01	NA	NA	-469.72	-477.14
Net GHG Emissions	**5,075.31**	**5,145.82**	**161.77**	**164.79**	**2.70**	**2.70**	**463.52**	**531.74**	**9,774.36**	**9,973.57**

The data provided in Table 2.1 are summarized in Figure 2.1.

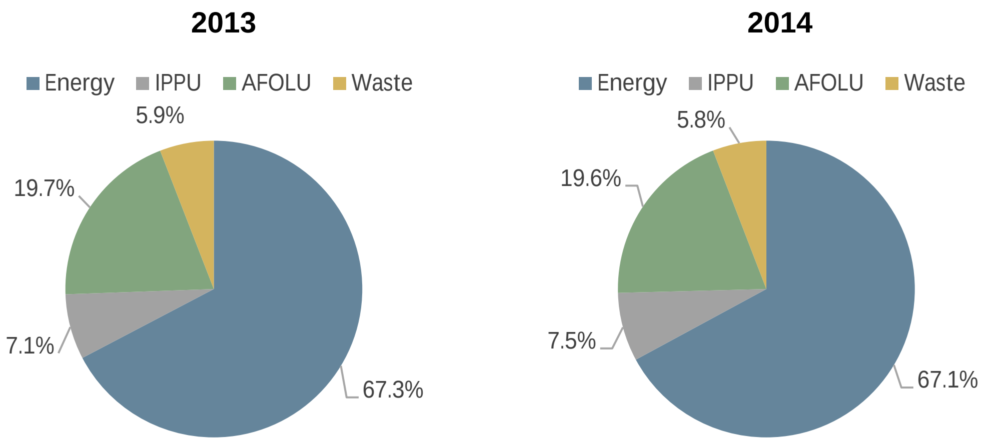


Figure 2.1 GHG emissions by sectors without Forestry and Other Land Use in 2013-2014, $CO_{2eq.}$

The Energy Sector is by far the largest producer of greenhouse gas emissions. In 2014, the Energy Sector accounted for 67.1% of Armenia's total greenhouse gas emissions. The Energy Sector includes emissions from all use of fuels to generate energy including fuel used in transport and the fugitive emissions related to the transmission, storage and distribution of natural gas. The second largest source of emissions was AFOLU Sector (without Forestry and Other Land Use) with share of 19.6% followed by IPPU and Waste Sectors – 7.5% and 5.8%, correspondingly.

Figure 2.2 provides greenhouse gas emissions by gases.

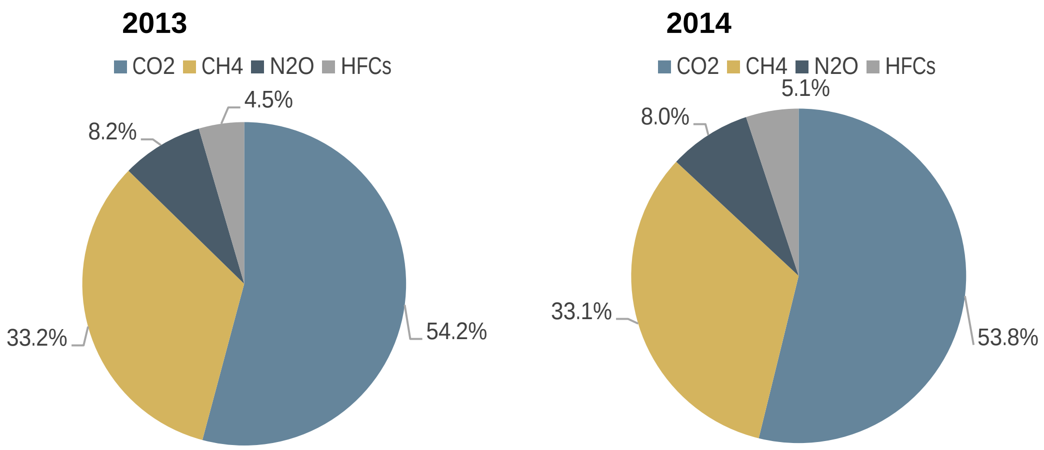


Figure 2.2 Greenhouse gas emissions by gases for 2013, 2014 (without Forestry and Other Land Use)

The most significant greenhouse gas of Armenia's inventory is carbon dioxide (CO_2), with share of 54.2 % and 53.8% of the total emissions in 2013 and 2014, correspondingly.

Figure 2.3 provides greenhouse gas emissions by sectors and by gases for 2014.

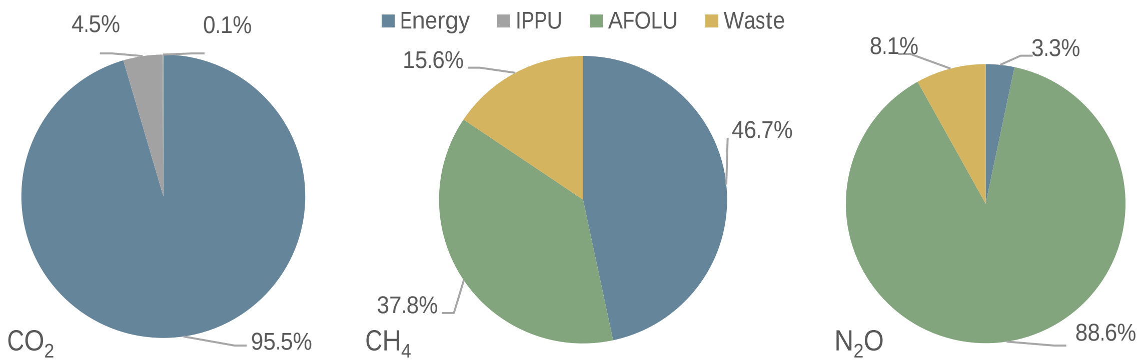


Figure 2.3 Greenhouse gas emissions by sectors and by gases for 2014 (without Forestry and Other Land Use)

The Energy Sector is mainly responsible for carbon dioxide emissions - it produced about 95.5% of all carbon dioxide emissions in 2014 (Fig. 2.3) because of the high emissions volume from thermal power plants, Residential and Road transportation subsectors.

CO_2 emissions from IPPU Sector are significantly less and make 4.5% of total carbon dioxide emissions, CO_2 emissions from Waste sector are negligible.

Methane emissions accounted for over 33% of the total emissions in 2014. Methane emissions are also mostly from the Energy Sector (46.7%) due to the fugitive emissions from the natural gas system. The second one with its share of methane emissions is AFOLU Sector (37.8%) due to the emissions from enteric fermentation and the Waste Sector is the third (15.6%).

Nitrous oxide emissions made up close 8% of the total emissions. Most of nitrous oxide emissions (88.6%) are from the AFOLU Sector mainly due to the direct and indirect emissions from managed soils.

F-gases (HFCs) accounted for roughly 5% of total greenhouse gas emissions, but their share has been growing continuously.

Summary report for national GHG inventory for 2014 is given in Table 2.2.

Emissions in CO_2 equivalent unit from Product uses as substitute for ozone depleting substances for 2014 are reported in Table 2.3

Table 2.2 Summary report for national GHG inventory for 2014

Category	Emissions (Gg)			Emissions $CO_{2eq.}$ (Gg)			Emissions (Gg)			
	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
Total Emissions and Removals	**5,145.824**	**164.786**	**2.695**	**531.743**	**NA, NO**	**NA, NO**	**12.4**	**22.322**	**10.155**	**39.010**
1 - Energy	**5,370.256**	**76.880**	**0.089**				**12.4**	**22.322**	**2.299**	**0.054**
1.A – Fuel Combustion activities	**5,369.093**	**1.912**	**0.089**				**12.4**	**22.322**	**2.299**	**0.054**
1.A.1 – Energy Industries	1,579.611	0.028	0.003				2.474	1.084	0.072	NE
1.A.2 – Manufacturing Industries and Construction	617.020	0.013	0.002				1.163	0.361	0.246	NE
1.A.3 – Transport	1,577.284	1.721	0.081				7.371	20.054	1.929	0.053
1.A.4 – Other Sectors	1,595.179	0.150	0.004				1.392	0.823	0.052	0.001
1.A.5 – Non-Specified	NO	NO	NO				NO	NO	NO	NO
1.B – Fugitive emissions from Fuels	**1.163**	**74.968**	**NA**				**NA**	**NA**	**NA**	**NA**
1.B.1 – Solid Fuels	NO	NO	NO				NO	NO	NO	NO
1.B.2 – Oil and Natural Gas	1.163	74.968	NA				NA	NA	NA	NA
1.B.3 – Other Emissions from Energy Production	NO	NO	NO				NO	NO	NO	NO
2 – Industrial Processes and Product Use	**250.792**	**NA, NO**	**NA, NO**	**531.743**	**NA, NO**	**NA, NO**	**NA,NO,NE**	**NA,NO,NE**	**10.155**	**39.010**
2.A – Mineral Industry	**250.792**	**NO**					**NO**	**NO**	**NO**	**NE, NA,NO**
2.A.1 – Cement Production	223.402						NA	NA	NA	NA
2.A.2 – Lime Production	NO						NO	NO	NO	NO
2.A.3 – Glass Production	7.231						NE	NE	NE	NE
2.A.4d –Non-Cement Clinker Production	20.160						NA	NA	NA	NA
2.A.5 – Other	NO	NO					NO	NO	NO	NO
2.B - Chemical Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.C – Metal Industry	**NA, NO**	**NA, NO**	**NA, NO**	**NA, NO**	**NA, NO**	**NA, NO**	**NA, NO**	**NA, NO**	**NA, NO**	**39.010**
2.C.1 – Iron and Steel Production	NO	NO	NO				NO	NO	NO	NO
2.C.2 – Ferroalloys Production	NA	NA	NA				NA	NA	NA	7.610
2.C.3 – Aluminum Production	NO	NO	NO		NO		NO	NO	NO	NO
2.C.4 – Magnesium Production	NO			NO	NO	NO	NO	NO	NO	NO
2.C.5 – Lead Production	NO						NO	NO	NO	NO
2.C.6 – Zinc Production	NO						NO	NO	NO	NO
2.C.7 – Other – Primary Copper Production	NA	NA	NA	NA	NA	NA	NA	NA	NA	31.400
2.D – Non-Energy Products from Fuels and Solvent Use	**NA, NE, NO**	**NA**	**NA**				**NO,NA,NE**	**NO,NA,NE**	**9.268**	**NO,NA,NE**
2.D.1 – Lubricant Use	NE						NE	NE	NE	NE

2.D.2 – Paraffin Wax Use	NO	NO	NO				NO	NO	NO	NO
2.D.3 – Solvent Use							NA	NA	7.418	NA
2.D.4 – Bitumen Use	NA	NA	NA				NA	NA	1.850	NA
2.E - Electronics Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.F – Product Uses as Substitutes for Ozone Depleting Substances	**NA, NO**	**NO**	**NO**	**531.743**	**NA, NO**		**NA**	**NA**	**NA**	**NA**
2.F.1 – Refrigeration and Air Conditioning	NA			502.660	NA		NA	NA	NA	NA
2.F.2 – Foam Blowing Agents	NA			17.109	NA		NA	NA	NA	NA
2.F.3 – Fire Protection	NA			0.531	NA		NA	NA	NA	NA
2.F.4 – Aerosols				11.444	NA		NA	NA	NA	NA
2.F.5 – Solvents				NO	NO		NO	NO	NO	NO
2.F.6 – Other Applications	NO	NO	NO	NO	NO		NO	NO	NO	NO
2.G – Other Product Manufacture and Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.H – Other	**NA, NO**	**NA, NO**	**NO**				**NA, NO**	**NA, NO**	**0.887**	**NA, NO**
2.H.1 – Pulp and Paper Industry	NO	NO					NO	NO	NO	NO
2.H.2 – Food and Beverages Industry	NA	NA					NA	NA	0.887	NA
2.H.3 – Other	NO	NO	NO				NO	NO	NO	NO
3 – Agriculture, Forestry and Other Land Use	**-479.589**	**62.217**	**2.389**				**NA**	**NA**	**NA**	**NA**
3.A – Livestock		**62.216**	**0.278**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
3.A.1 – Enteric Fermentation		57.597					NA	NA	NA	NA
3.A.2 – Manure Management		4.619	0.278				NA	NA	NA	NA
3.B – Land	**-480.265**	**NA**	**0.01**				**NA**	**NA**	**NA**	**NA**
3.B.1 – Forest Land	-539.780	NA	NA				NA	NA	NA	NA
3.B.2 – Cropland	0.779	NA	NA				NA	NA	NA	NA
3.B.3 – Grassland	14.525	NA	NA				NA	NA	NA	NA
3.B.4 – Wetlands	3.752	NA	0.01				NA	NA	NA	NA
3.B.5 – Settlements	13.564	NA	NA				NA	NA	NA	NA
3.B.6 – Other Land	26.895	NA	NA				NA	NA	NA	NA
3.C – Aggregate Sources and non-CO_2 emissions sources on land	**0.675**	**0.002**	**2.101**				**NA, NO**	**NA, NO**	**NA, NO**	**NA, NO**
3.C.1 – GHG emissions from biomass burning	NA	0.002	NA				NA	NA	NA	NA
3.C.2 – Liming	NO						NO	NO	NO	NO
3.C.3 – Urea Application	0.675						NA	NA	NA	NA
3.C.4 – Direct N_2O Emissions from Managed Soils			1.473				NA	NA	NA	NA
3.C.5 – Indirect N_2O Emissions from Managed Soils			0.410				NA	NA	NA	NA
3.C.6 – Indirect N_2O Emissions from Manure			0.219				NA	NA	NA	NA

Management										
3.C.7 – Rice Cultivation		NO	NO				NO	NO	NO	NO
3.C.8 – Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.D – Other	**NA, NO**	**NO**	**NO**				**NO**	**NO**	**NO**	**NO**
3.D.1 – Harvested Wood Products	NA						NO	NO	NO	NO
3.D.2 – Other	NO	NO	NO				NO	NO	NO	NO
4 – Waste	**4.365**	**25.689**	**0.217**				**NA**	**NA**	**NA**	**NA**
4.A – Solid Waste Disposal		19.435	NA				NA	NA	NA	NA
4.B – Biological Treatment of Solid Waste		NO	NO				NO	NO	NO	NO
4.C – Incineration and Open Burning of Waste	4.365	0.629	0.011				NO	NO	NO	NO
4.D – Wastewater Treatment and Discharge	NA	5.626	0.206				NA	NA	NA	NA
4.E – Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5 – Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo Items										
International Bunkers	**127.571**	**0.001**	**0.004**				**0.162**	**0.049**	**0.077**	**0.040**
1.A.3.a.i – International Aviation (International Bunkers)	127.571	0.001	0.004				0.162	0.049	0.077	0.040
1.A.3.d.i – International Water-Borne Navigation (International Bunkers)	NO	NO	NO				NO	NO	NO	NO
1.A.5.c – Multilateral Operations	NO	NO	NO				NO	NO	NO	NO

Table 2.3 Emissions from product uses as substitute for ozone depleting substances for 2014, $CO_{2eq.}$

Category	HFC-32	HFC-125	HFC-134a	HFC-152a	HFC-143a	HFC-227ea	Total HFCs
2.F - Product Uses as Substitutes for Ozone Depleting Substances	18.085	172.876	189.479	1.215	149.557	0.531	**531.743**
2.F.1 - Refrigeration and Air Conditioning	18.085	172.876	162.142	0	149.557	0	**502.660**
2.F.1.a - Refrigeration and Stationary Air Conditioning	18.085	172.876	85.213	0	149.557	0	**425.731**
2.F.1.b - Mobile Air Conditioning	0	0	76.929	0	0	0	**76.929**
2.F.2 - Foam Blowing Agents			16.398	0.711		0	**17.109**
2.F.3 - Fire Protection		0	0			0.531	**0.531**
2.F.4 – Aerosols			10.940	0.505		0	**11.444**

3. TRENDS OF GREENHOUSE GAS EMISSIONS

Figure 3.1 below provides greenhouse gas emissions trend by sectors for 1990 and 2000-2014, Gg $CO_{2eq.}$ (without Forestry and Other Land Use).

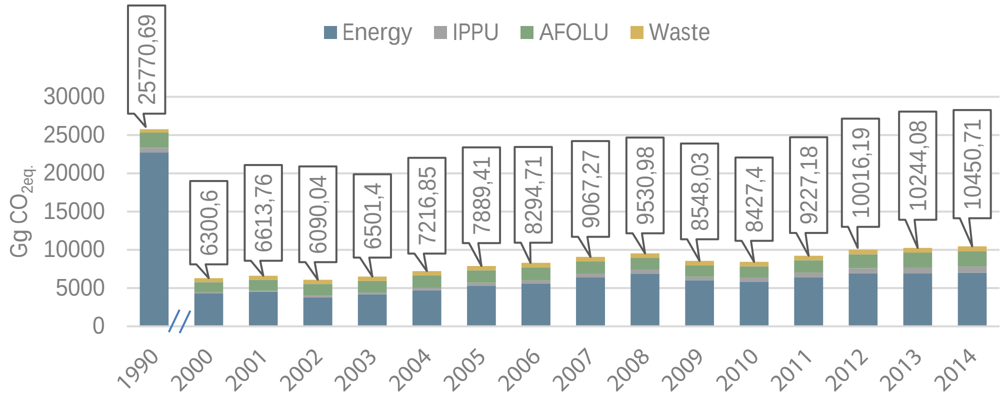


Figure 3.1 1990-2014 greenhouse gas emissions by sectors, Gg $CO_{2eq.}$

Figure 3.1 shows the contribution of the sectors to the total GHG emissions and highlights the absolute predominance of energy-related emissions. As a whole, Armenia's total GHG emissions in 2014 decreased by 59% since 1990. This was largely due to the collapse of the Soviet Union followed by a severe energy crisis and structural changes in economy.

Energy Sector emissions have decreased by 3.2 times compared with the year 1990, while Total Primary Energy Supply (TPES) decreased by 2.5 times, which is evidence of low-carbon development trends in Armenia resulted from the: structural changes in economy, i.e. decreased share of energy intensive industries and increased share of the service sector, wide use of eco-friendly fuel – natural gas for energy production (which replaced mazut) and in transport, recommissioning of Armenian Nuclear Power Plant and strongest growth of the small hydropower plants which number has increased nearly eightfold since 2000.

The increase of Energy Sector emissions since 2000 amounts to over 63 %. This is due to the economic growth, leading to the growth in traffic volume and improved household living conditions resulted in the wide use of natural gas in transport and for space heating. It became possible because of the unprecedented level of natural gas deliverability (nearly 95 %) reached in the country since 2004. During 2000-2014 road transport emissions steadily grew - increase by 145 %, and emissions attributable to energy used by households increased over fourfold.

In 2009, the financial and economic crisis affected the energy consumption, however in 2010 emissions increased again as a result of economic recovery.

Emissions resulted from electricity production have varied considerably due to changes in electricity exports and production of electricity by natural gas fired thermal power plants. Thus, the sharp increase of GHG emissions from Energy Sector in 2012 in comparison with 2010 was caused by a high export growth met by thermal power plants (thermal power plants generation in 2012 has been increased by 135% in comparison with 2010). This variation has been the principal feature of the trend of CO_2 emissions from energy sector since 2010.

In addition, energy sector emissions are influenced each year by the economic situation in the country's energy intensive industries, the weather conditions and the volumes of energy produced with hydropower plants.

In industrial processes the most significant emission sources were CO_2 emissions generated in cement production. A small amount of CO_2 emissions was also generated in non-cement clinker production and glass production. Emissions caused by the industrial processes are mostly affected by the economic situation in the country. Thus, after the decline of GHG emissions from IPPU Sector in 2009 because of the economic recession, which resulted in the decrease of construction volumes and, consequently cement production, in 2010 the construction volumes and cement production increased leading to the increase of GHG emissions.

Fluorinated gases, or F-gases, form a category of their own under industrial processes and accounted for over than 5% of total national greenhouse emissions and 68% of the greenhouse emissions of industrial processes in 2014. In the period from 2010 to 2014, the biggest change occurred in F-gases emissions, which doubled mainly due to the wide use of F-gases in refrigeration and cooling devices. The increase in IPPU Sector emissions since 2011is due primarily to the increase of F-gases emissions.

The increase in agricultural emissions since 2000, amounting to over 54%, is due primarily to increase in livestock populations and increase in emissions from managed soils and from fertilizer use.

Waste Sector emissions account for 5.8% of the country's total emissions in 2014. During 2000-2014 waste sector emissions increased by 14.7% due to the growth in methane emissions from solid waste disposal because of the increased population of the capital city Yerevan.

Time series for 2000-2014 greenhouse gas emissions by gases in Gg $CO_{2eq.}$ are provided below.

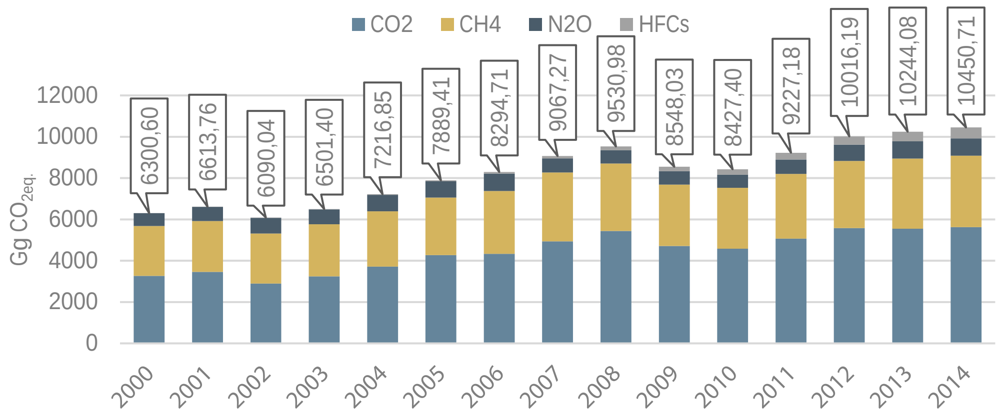


Figure 3.2 2000-2012 greenhouse gas emissions per gases, Gg $CO_{2eq.}$

Figure 3.2 shows the development of emissions of the various greenhouse gases since 2000. It must be noted that the emissions of each of these greenhouse gases is largely influenced by specific developments in a certain category.

Emissions of carbon dioxide – the great majority of which are caused by stationary and mobile combustion processes – predominate in the overall picture of greenhouse gas emissions making nearly 53.8% of total emissions. All other greenhouse gases together account for less than half of greenhouse-gas emissions. The energy sector produced roughly 95% of all carbon dioxide emissions in 2014.

The increase of overall emissions since 2000 amounts to over 66%. Mainly, this resulted from an increase of CO_2 emissions. In the period from 2005 to 2014, the biggest change occurred in F-gases emissions, which increased twelvefold. F-gases have been used to replace ozone depleting compounds in many refrigeration and cooling devices and applications, which is the main reason for the increase in F-gases.

The amount of CO_2 emissions is closely linked to trends in the energy sector. Increase of CO_2 emissions from Energy Sector is mainly caused by changes in electricity exports and consequent increase of thermal power generation, traffic volume growth and wide use of natural gas for space heating.

Methane emissions are caused mainly by transmission, storage and distribution of natural gas, animal husbandry in agriculture and waste landfilling; emissions from wastewater treatment are much lower and energy-related emissions play an almost negligible role. Methane emissions have been increased by 43% since 2000. This trend has been primarily the result of the increase of the natural gas consumption and increase of livestock populations.

The main emissions areas/sources of N_2O include agriculture – use of nitrogen-containing fertilizers and animal husbandry, smaller amounts of emissions are caused by wastewater treatment. Since 2000, N_2O emissions have increased by about 35%. Agriculture has the greatest influence on emissions increase as a result of the increase in livestock populations and increased use of nitrogen-containing fertilizers.

F-gases emissions volume has been growing continuously which is conditioned by substituting the ozone layer depletion substances with HFCs and rapid development of this sector since 2008. There is a sustainable annual average growth for all applications, however the growth dynamics is different.

HFCs emissions which are caused by refrigeration systems predominate in the overall picture of HFCs emissions with the share of 94.5% in 2014. The share of emissions from other applications is less than 6% altogether.

4. GREENHOUSE GAS EMISSIONS BY SECTORS

4.1 Energy

4.1.1 Overview of Energy Sector emissions assessment

The main power generation capacities in Armenia are nuclear power plant, natural gas consumed thermal power plants (including small cogeneration units), large hydropower plants as well as small renewables (small hydro, a biogas plant, a wind power plant), which provided 31.8%, 42.4%, 16.9%, 8.9% of total electricity generation in 2014. At present, renewable energy consists mainly of hydropower (small to large HPPs).

Armenia has interconnections with neighboring countries – Iran and Georgia, allowing for power exchange in both directions.

Armenia has no domestic resources of fossil fuel and imports all of its oil and gas. Vast majority of natural gas come from Russia - nearly 84% in 2014, Armenia also imports some natural gas from Iran in exchange for Armenia's supply of electricity to Iran. Oil is imported from a range of countries. Therefore it is the urgent need for Armenia to increase its indigenous energy production, improve transmission infrastructure and reduce its dependence upon external suppliers.

Armenia relies on electricity and gas to meet the majority of its energy consumption needs. Imported natural gas predominates in total primary energy supply in Armenia accounting for 63% of Armenia's TPES and 84.8% of the fossil fuel consumption in 2014. 80% of CO_2 emissions from fuel combustion in 2014 originates from natural gas. This is due to a very high gas deliverability level in the country - 94.6% and widespread use of natural gas for heating and cooking purposes, because it is less expensive than electricity, as well as widespread use of natural gas in transport as it is less expensive than petrol or diesel.

The Energy Sector is by far the biggest source of GHG emissions in the country. In 2014 its share of the total greenhouse emissions was 67.1% (7012.26 Gg CO_{2eq}). The energy sector emissions in 2014 made 30.9% of 1990 emissions level and were 1.4% higher than those in 2012.

Emissions from the Energy Sector consist of two main categories: fossil fuel combustion and fugitive emissions from natural gas. The majority of the sector's emission (78%) results from fossil fuel combustion.

The contribution of each source to the total of the sector is presented in Figure 4.1.

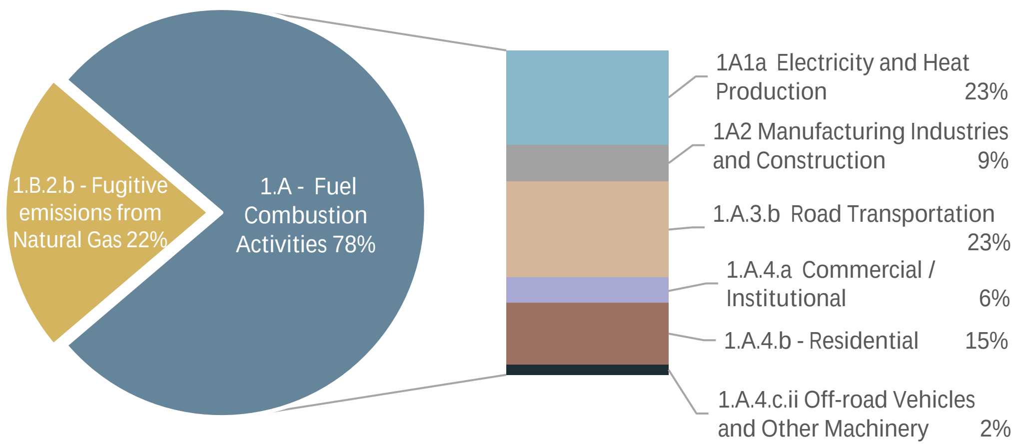
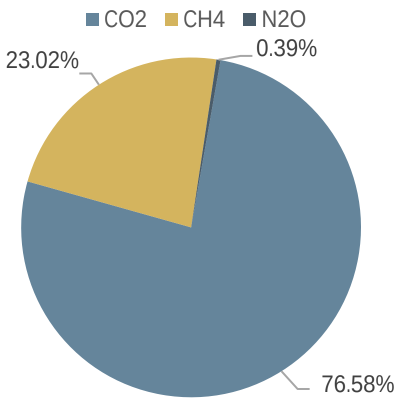


Figure 4.1. Greenhouse gas emissions by sources in Energy Sector in 2014 (Gg $CO_{2eq.}$)

Figure 4.1 shows that electricity production and road transport are the leading sources of GHG emissions within the sector generating 23% of the Energy Sector emissions in 2014 each, other significant emission source in Energy Sector is fugitive emissions of natural gas which share in 2014 is slightly less - 22%. Emissions attributable to energy use by households accounted to

15%, emissions from the fuels used by different industries made roughly 9%, followed by the emissions



from Commercial/Institutional category with the share of 6% and emissions from Off-road Vehicles and Machinery in agriculture with the share of 2%.

Energy is mainly responsible for carbon dioxide emissions, while it also contributes to methane emissions, nitrous oxide and other air pollutants such as CO, NOx, SO_2 and NMVOC. In 2014, 76.6% of the emissions from the Energy Sector were CO_2, 23% - CH_4 and 0.4% - N_2O (Figure 4.2.).

Figure 4.2. Greenhouse gas emissions by gases in Energy Sector in 2014 (Gg $CO_{2eq.}$)

Methodologies

Emission estimates from Energy Sector were based on the sectoral approach applying Tier 1, Tier 2 and Tier 3 methods - country-specific approaches were used wherever possible to produce more accurate emissions estimates than Tier 1 approach.

The Tier 3 method was used for estimating of CO_2 emissions from electricity generation at thermal power plants considering disaggregated power plant level data.

The Tier 2 method was used for estimating emissions of CO_2 from both stationary (with the exception of the thermal power plants) and mobile combustion of natural gas based on the activity data from national energy statistics and country-specific emission factors, derived from national fuel characteristics.

The Tier 2 method was also used for estimating emissions of CH_4 from fugitive emissions of natural gas.

The Tier 1 method was used for the emission estimates from liquid fuel combustion.

In addition to assessments based on Sectoral Approach the emissions of CO_2 from fuel combustion were also assessed by Reference Approach and the results were compared for checking purposes.

The methods applied for assessment of greenhouse gases emissions from Energy Sector are summarized in the Table 4.1.

Table 4.1. Summary on methods applied for assessment of greenhouse gas emissions from Energy Sector

Subcategory	Greenhouse gas	Level Assessment	Method, Approach	Activity Data	Emission Factor
1A FUEL COMBUSTION ACTIVITIES					
1A1a Main Activity Electricity and Heat Production (gaseous fuels)	CO_2	KC	T3	CS	CS
1A2 Manufacturing Industries and Construction (gaseous fuels)	CO_2	KC	T2	CS	CS
1A3b Road transportation	CO_2	KC	T1*, T2**	CS	D*; CS**
1A4 Other Sectors (gaseous fuels)	CO_2	KC	T2	CS	CS
1A4 Other Sectors (liquid fuels)	CO_2	KC	T1	CS	D
1B FUGITIVE EMISSIONS FROM FUELS					
1B2b Fugitive Emissions of Natural Gas	CH_4	KC	T2	CS	CS

** for liquid fuels*
*** for CNG*

Improvements

Within the frame of this inventory, the following improvements were made to the Energy Sector greenhouse gas emissions assessment:

- Greenhouse gas emissions were estimated for 10 new sub-categories - emissions from *Manufacturing Industries and Construction* category have been assessed by corresponding sub-categories from the 2006 IPCC Guidelines, a new sub-category 1a3eii *Off-road* in Transport category was considered as well.
- Higher Tier method was applied for 2 sub-categories - Electricity Generation and Combined Heat and Power Generation.

4.1.2 Energy Sector greenhouse gas source categories

As of 2014 the Energy Sector in Armenia includes the following source categories:

1 A Fuel Combustion Activities

1 A 1 Energy Industries

1 A 1 a Electricity and Heat Production

i Electricity Generation

ii Combined Heat and Power Generation

There are no enterprises in the country with the main activity of heat production. To avoid double accounting the existing boiler houses providing heat supply in various areas are considered in the respective categories.

1A2 Manufacturing Industries and Construction

1A2a Iron and Steel

1A2b Non-Ferrous Metals

1A2c Chemicals

1A2d Pulp, Paper and Print

1A2e Food Processing, Beverages and Tobacco

1A2f Non-Metallic Minerals

1A2h Machinery

1A2i Mining (excluding fuels) and Quarrying

1A2j Wood and Wood Products

1A2k Construction

1A2l Textile and Leather

1A2m Non-specified Industry

1A3 Transport

1A3a Civil Aviation

i International Aviation (International Bunkers)

1A3b Road Transportation:

1A3e Other Transportation

ii Off-road

1A4 Other Sectors

1A4a Commercial/institutional

1A4b Residential

1A4c iii Off-road Vehicles and Other Machinery

1 B Fugitive Emissions from Fuels

1B2biii4 Natural Gas Transmission and Storage

1B2biii5 Natural Gas Distribution.

All other sources indicated in 2006 IPCC Guidelines [Gen-1] for Energy Sector do not exist in Armenia and are not considered in this Inventory.

4.1.3 Activity data

Fossil fuel resources

Armenia has no domestic resources of fossil fuel and highly depends on fossil fuel imports. Total primary energy supply (TPES) of Armenia in 2014 was 3192.7 ktoe, nearly 69% of which is imported considering that production of nuclear energy is regarded as indigenous production. Natural gas accounted for 63% of Armenia's TPES in 2014.

With regard to fossil fuel consumption structure by fuel types, natural gas is accounting for 84.8% in 2014. In general, fossil fuel consumption structure is almost unchanged in recent years.

Figure 4.3 provides fossil fuel consumption structure in 2013 and 2014.

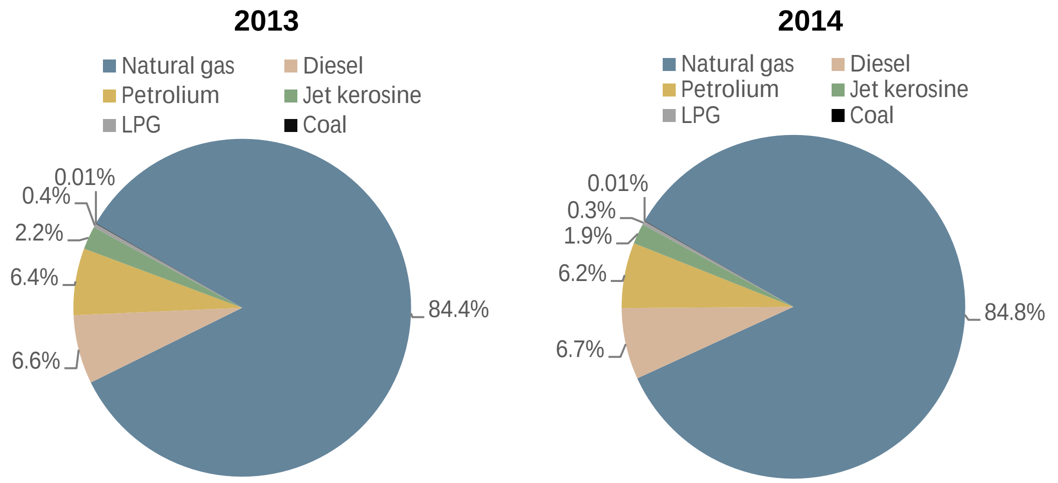


Figure 4.3. Fossil fuel consumption structure by type of fuel in 2013 and 2014

In 2014 the consumption of natural gas was 16.4% higher than in 2011 however in total fossil fuel consumption structure it has increased only by 2.9%.

With regard to fossil fuel consumption structure by sub-categories, in 2013 and 2014 energy production was the largest consumer with the share of 29.2% and 30.5%, respectively, followed by road transport – 27.3 and 28% and residential sector – 21.2% and 20%. The total share of these three sub-categories accounted for about 78% of the fossil fuel consumption in 2013 and 2014 (Figure 4.4).

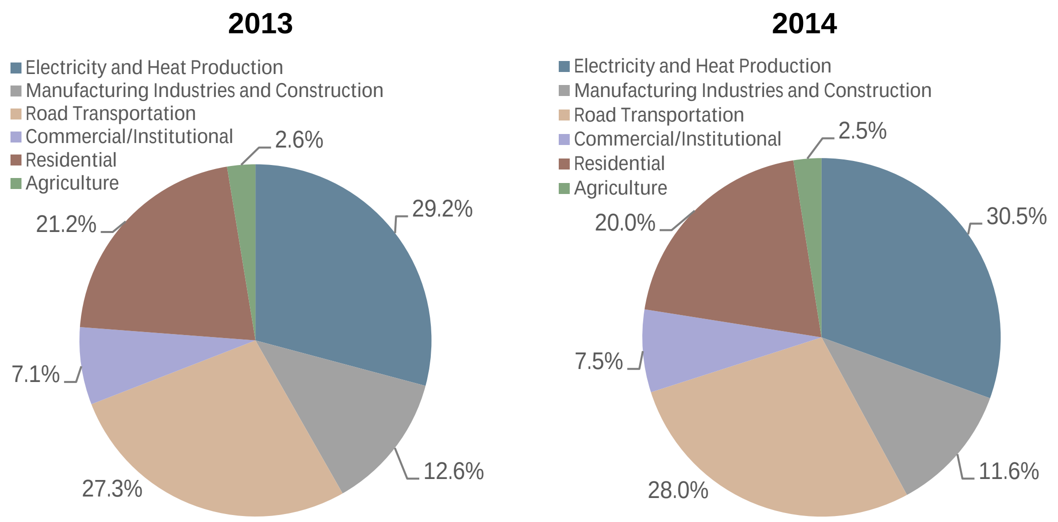


Figure 4.4. Fossil fuel consumption structure by sub-categories

Natural gas

Natural gas is widely used in the different sectors of economy and transportation. With gasification level of 94.6% Armenia is one of the leaders in the world.

The operation of the gas system in the Republic of Armenia is carried out by "Gazprom Armenia" CJSC. The company carries out import, transmission (operation of underground storage), distribution and sale of natural gas, as well as system management.

Natural gas balances (Annex 4) provided by "Gazprom Armenia" CJSC are the main activity data sources for assessing greenhouse gas emissions from natural gas combustion. Some activity data from gas balances required for the emissions estimate are provided in Table 4.2.

Table 4.2 Extract from natural gas balances for 2011-2014, (mln m^3)

Year	2011	2012	2013	2014
Imports	2,069.1	2,455.5	2,361.05	2,450.9
Gas turnover in storage facility *(extracted +, injected -)*	+46.4	-49.3	+24.27	-27.7
Own needs, (mln m^3)	7.8	13.5	7.01	9.2
Own needs, %	0.38	0.55	0.30	0.38
Losses, (mln m^3)	134.05	139	141.63	144.7
Losses, %	6.5	5.7	6.0	5.9
Consumption, including	1,973.6	2,253.7	2,236.68	2,269.3
Energy Generation	549.3	825.5	758.99	799.54
Road Transportation	362.4	418	454.96	481.7
Manufacturing Industries/Construction	326.2	317.7	301.36	278.2
Commercial/Institutional	184.9	150.5	182.43	194.45
Residential	550.8	542.0	538.93	515.4

The Table 4.2 shows that natural gas import in 2014 increased by 18.4%, consumption – by 15% compared with 2011. The natural gas annual consumption for electricity generation have varied considerably – up to 50%. This is mainly due to changes in electricity exports and production of electricity by natural gas based thermal power plants.

Natural gas consumption by transport has been growing steadily since 2010, during the period 2011-2014 it increased by 32.9%.

As it was mentioned above, since 2000 the natural gas distribution network has expanded rapidly and many residential consumers, who were looking for individual heating solutions due to the collapse of the district heating system have connected to the gas network. However, the growth of gas tariffs since 2010 has led to the fact that many consumers, especially in rural areas, switched to the use of biofuel. As of 2014, the natural gas consumption in the residential sector roughly made 23% of the final consumption of natural gas, mainly due to gas use for heating and hot water purposes.

Losses of natural gas in transmission and distribution system were reduced in 2014 compared to 2011 fell by 0.6% (upon the imported quantity).

Figure 4.5 illustrates the natural gas supply including transmission (including gas flow in storage facility, losses and own needs), distribution (including losses) and structure of sales (all percentages are calculated upon the quantity of the imported natural gas).

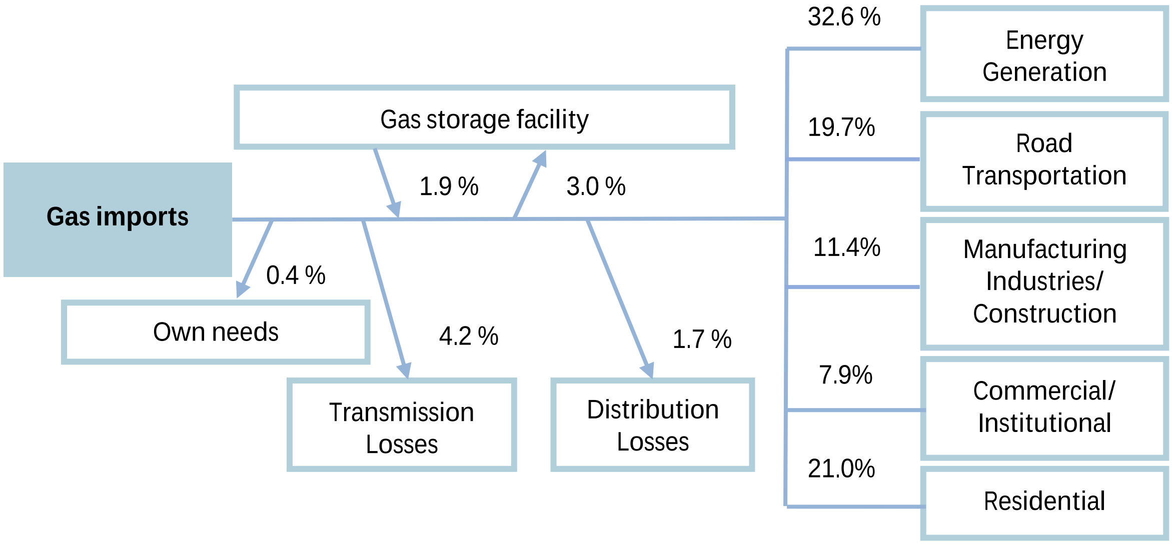


Figure 4.5. Natural gas supply structure in 2014

Oil products

The oil market in Armenia is not regulated. There are several private companies that import diesel and gasoline. The State Commission for Protection of Economic Competition of the RA is entitled for ensuring fare economic competition and protection of consumer rights.

The main reference for the calculation of GHG emissions from the oil products were the data on fuel import reported by the NSS. It is assumed that annually imported oil products are fully consumed in the same year as there are no large storages for liquid fuel in Armenia.

The quantities of oil products by fuel types imported in Armenia in 2011-2015 are summarized in Table 4.3.

Table 4.3 Oil products by fuel types imported in Armenia

Oil Products	Import, t				
	2011	2012	2013	2014	2015
Gasoline	131,588	130,332	132,218.6	129,120.0	130,484.4
Diesel Fuel	159,515	144,683	147,325.6	152,650.5	136,304.3
Jet Kerosene	39,648	40,473	45,900.4	40,458.4	30,939.3
Liquid Petroleum Gas (LPG)	7,359	6,909	7,397.0	6,763.3	6,913.8
Total	**338,110**	**322,397**	**332,841.6**	**328,992.2**	**304,641.8**

Table 4.3 shows that the quantities of the imported oil products are relatively steady, variation is in the range of 9.3-11.8%.

Due to the lack of official statistics on liquid fuel consumption by the sub-categories, it was estimated by the expert judgment (see page 29) based on the data on fuel import reported by the NSS and analysis of data provided by the Ministry of Agriculture and NSS.

The Figure 4.6 provides the liquid fuel flows in 2014 (all percentages were calculated upon the total amount of liquid fuel import).

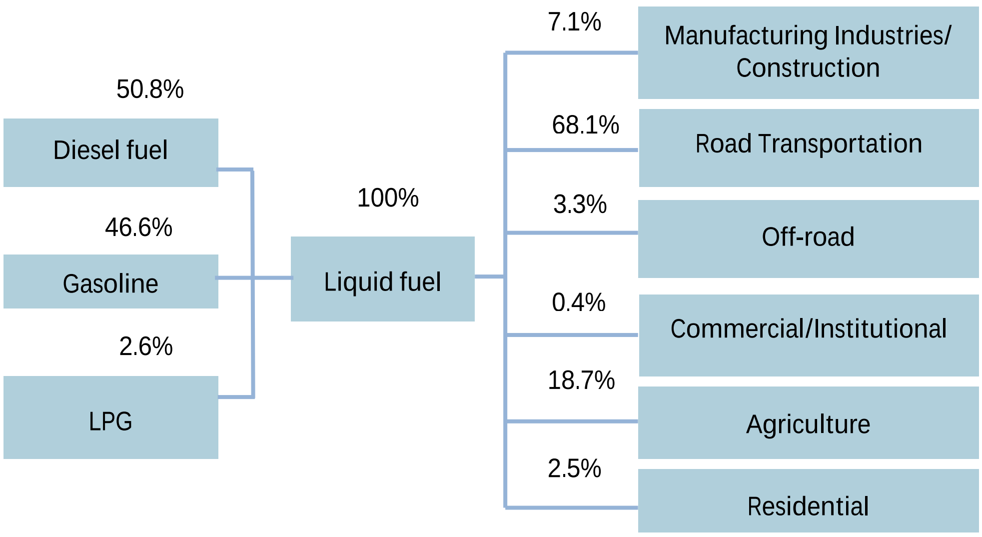


Figure 4.6 Liquid fuel flows in 2014

It is clear from the Figure 4.6 that diesel and gasoline are the main liquid fuels consumed in the country accounting for 50.8% and 46.6%, correspondingly. Road transport apparently is the largest consumer of the liquid fuel with the share of above 68% followed by the Off-road Vehicles and Other Machinery used on farm land and forests with the share of 18.7% and off-road and other mobile machinery in industry with the share of 7.1%. The consumption of the other categories is much lower.

Biomass

As it is mentioned in the Guideline [Gen-1] biomass data are generally more uncertain than other data in national energy statistics. This provision fully corresponds to realities of Armenia as the data on biomass burning from various sources vary considerably.

Fuelwood

Despite the mentioned above high natural gas access level in Armenia, the growth of gas tariffs since 2010 forced many consumers, mainly in rural areas, to switch to the use of biofuel including fuelwood. The quantity of fuelwood was estimated based on official data on volumes of harvested wood, fallen-wood and illegal logging provided by the Ministry of Agriculture ("Hayantar" SNCO) and the MNP.

The volumes of burned fuelwood were converted to energy units considering basic wood density for Armenia as of 0.557 t/m^3 [LUCFRef-4] and using wood default calorific value of 15.6 TJ/Gg [Gen-1, Volume 2, Table 1.2] and are provided in Table 4.4.

Table 4.4 Fuelwood combusted in 2011- 2014

Measurement Units	2011	2012	2013	2014
Volume (m^3)	65,740	85,960	71,551	65,621
Weight (t)	36,617	47,880	39,854	36,551
Energy (TJ)	571.23	746.92	621.72	570.20

Manure

Manure is largely used as fuel in rural areas of Armenia. Table 4.5 summarizes annual quantities of manure burned which were calculated based on number of cattle provided by the Ministry of Agriculture and ministry's experts assessment on annual manure excretion per animal, manure moisture rate (percent) and the share of manure used as fuel.

According to Ministry of Agriculture data (Annex 7, Table 1) in 2011-2014 the moist manure production per cattle was 8 tones in average per annum, 34.4 - 42.5% of which was left in pastures, 0.98% of the rest part of moist mass was stored in dry form to be used as fuel or fertilizer, 0.3 part of moist manure after drying was used as organic fertilizer, while 0.7 part was used for preparing fuel, 80 % of which was lost during drying process.

Heat produced from manure was calculated using the Net Calorific Value of 11.6 TJ/Gg [Gen-1, Volume 2, Table 1.2] for "Other Primary Solid Biomass".

Table 4.5 Quantity of manure produced, burned and heat received

Quantity of manure produced, burned and heat received	2011	2012	2013	2014
Total manure, Gg	5,635.1	6,211.7	6,681.7	6,783.9
Total burned, Gg	475.9	524.6	564.2	572.9
Heat, TJ	5,520.0	6,084.9	6,545.3	6,645.4

4.1.4 Emissions calculation

4.1.4.1 Fuel Combustion Activities (1A)

Sectoral Approach

Fuel Combustion Activities are further divided in two main categories: Stationary Combustion and Mobile Combustion.

Stationary Combustion includes Electricity and Heat Production, Manufacturing Industries and Construction and Other Sectors (Residential, Commercial/Institutional, Off-road Vehicles and Other Machinery in Agriculture).

This chapter describes GHG emissions assessment per categories for both Stationary and Mobile Combustion including the methods applied, activity data, emission factors, time series and uncertainty assessment.

Stationary Combustion

4.1.4.1.1 Main Activity Electricity and Heat Production (1A1a)

Description of the category

This category comprises emissions from natural gas combustion for electricity generation from thermal power plants - Hrazdan TPP, Hrazdan-5 TPP, Yerevan CCGT and 2 small cogeneration based district heating systems.

The source category *Main Activity Electricity and Heat Production* is a key category for CO_2 emissions in terms of level assessment.

Table 4.6 and Figure 4.7 provide electricity generation per type of power plants (Annex 5, EnRef-3, EnRef-4).

Table 4.6. Electricity generation structure per type of power plants, mln kWh

Power Plants	Year				
	2010	2011	2012	2013	2014
Nuclear	2,490	2,548	2,311	2,359.7	2,464.8
Thermal	1,443	2,395	3,398	3,173.1	3,288.6
Hydro	2,143	2,033	1,814	1,433.1	1,307.8
Small Renewables	416	458	513	744.1	688.9
Total	6,492	7,434	8,036	7,710	7,750.1

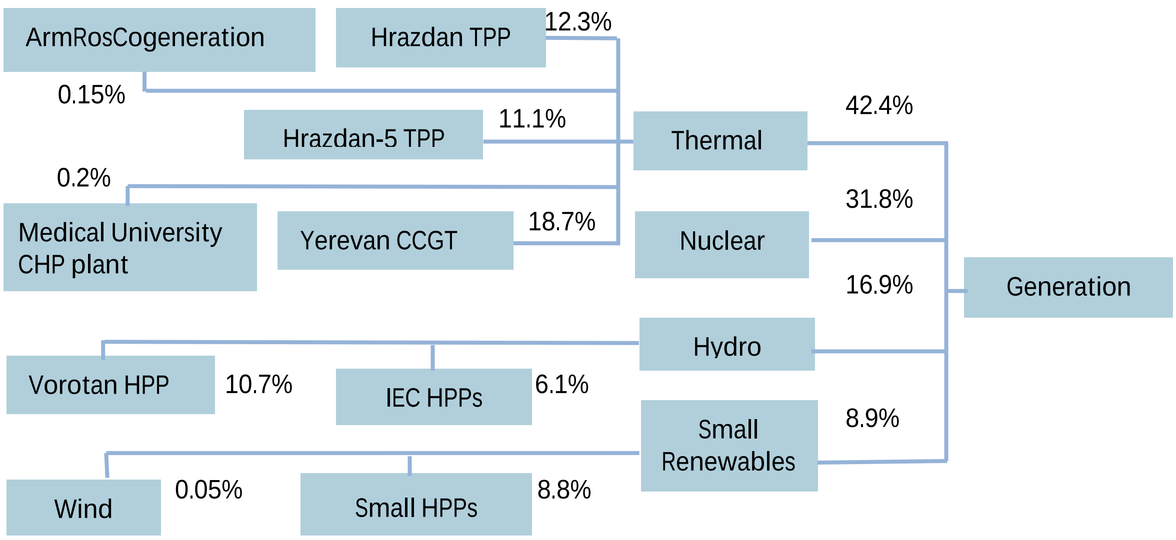


Figure 4.7. Electricity generation structure per type of power plants in 2014, mln kWh

Figure 4.7 shows that natural gas fired thermal power plants produced more than 42% of total electricity generation in 2014. Thermal plants operate to meet season peaks and when the nuclear power plant is offline for maintenance. Yerevan CCGT and Hrazdan-5 TPPs also generate electricity for export to Iran under the gas for electricity swap agreement.

Methodology

Gas supply system of the country has such structure that natural gas used by different consumers varies in its characteristics.

CO_2 emissions from stationary combustion of natural gas for *1A1ai Electricity_Generation* and *1A1aii Combined Heat and Power Generation* sub-categories were estimated using Tier 3 approach [Gen-1, Volume 2, Chapter 2.3.1.3] based on data at the individual plant level: natural gas consumption by each thermal power plant provided by PSRC and country-specific emission factors, considering natural gas composition in its delivered state to the each thermal power plant.

4.1.4.1.1.1 Electricity Generation (1A1ai)

Description of the sub-category

This sub-category comprises emissions from natural gas combustion for electricity generation from condensing power plants - Hrazdan TPP and Hrazdan-5 TPP.

Activity data

Natural gas consumption by each thermal power plant were derived from the PSRC (Annex 3) and were converted to common energy units (TJ) (Annex 2) considering net calorific values (NCVs) at individual plant level provided by Gazprom Armenia (Annex 1).

Emission factors

Country-specific emission factors were derived from detailed data on natural gas composition in its delivered state to the each thermal power plant, while for the small consumers (two CHP plants) country-specific emission factors were calculated based on characteristics of natural gas mixture.

The underlying data for the emission factors were provided by Gazprom Armenia (Annex 1).

The methodology for calculating country-specific emission factors along with the results of the calculation are provided in Annex 2. All indicators – NCVs, carbon content as well as calculated country-specific emission factors – are within 95% confidence interval.

4.1.4.1.1.2 Combined Heat and Power Generation (1A1aii)

Description of the sub-category

This sub-category comprises emissions from natural gas combustion from Yerevan CCGT and two small cogeneration based district heating systems.

The methodology, activity data sources and the approach for emission factor calculation are the same as for the *Electricity Generation* sub-category.

Emissions calculations results

Table 4.7 summarizes CO_2 emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories are calculated at plant level for 2011-2014.

Table 4.7 Plant level CO_2 emissions (Gg CO_2) for 2011-2014

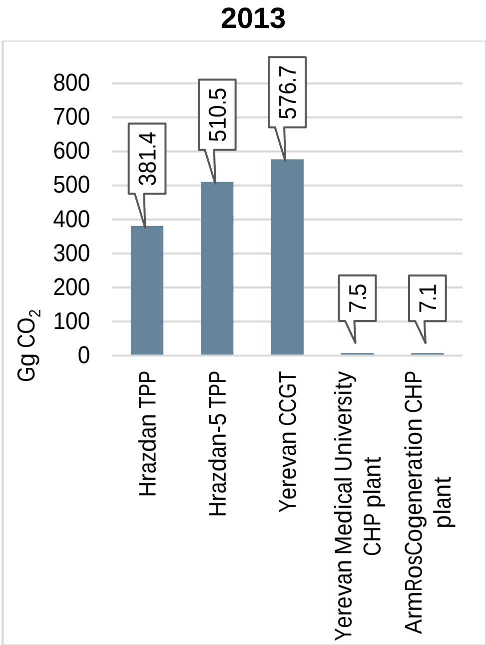
Stationary Combustion	Country-specific emission factor	Activity data		GHG emissions
	kg CO_2/TJ	TJ	mln m^3	Gg CO_2
2011				
Hrazdan TPP	56,798.0	6,352.74	184.026	360.82
Yerevan CCGT	57,004.9	12,352.12	360.318	704.13
Yerevan Medical University CHP plant	57,004.9	171.44	5.001	9.77
Total		**18,876.30**	**549.345**	**1,074.73**
2012				
Hrazdan TPP	56,851.7	7,962.90	230.683	452.70
Hrazdan-5 TPP	56,851.7	8,126.21	235.400	461.99
Yerevan CCGT	57,209.2	12,029.63	352.586	688.21
Yerevan Medical University CHP plant	57,209.2	107.10	3.139	6.13
ArmRosCogeneration CHP plant	57,209.2	126.04	3.694	7.21
Total		**28,351.87**	**825.503**	**1,616.23**
2013				
Hrazdan TPP	56,745.52	6,720.39	193.3202	381.35
Hrazdan-5 TPP	56,745.52	8,996.68	258.8004	510.52
Yerevan CCGT	56,993.61	10,344.33	299.2612	589.56
Yerevan Medical University CHP plant	56,993.61	134.74	3.898	7.68
ArmRosCogeneration CHP plant	56,993.61	128.10	3.706	7.30
Total		**26,324.24**	**758.9858**	**1,496.41**
2014				
Hrazdan TPP	56,706.16	9,619.33	275.5831	545.48
Hrazdan-5 TPP	56,706.16	7,360.96	210.8833	417.41
Yerevan CCGT	57,022.93	10,558.56	305.6441	602.08
Yerevan Medical University CHP plant	57,022.93	148.86	4.309	8.49
ArmRosCogeneration CHP plant	57,022.93	107.95	3.125	6.16
Total		**27,795.65**	**799.5445**	**1,579.61**

Table 4.8 provides CO_2 emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories per plants.

Table 4.8 CO_2 emissions from Electricity Generation and Combined Heat and Power Generation sub-categories per plants

Code	Category/Subcategory	Net CO_2	CH_4	N_2O	Total $CO_{2eq.}$
1A1a	Main Activity Electricity and Heat Production	1,579.61	0.0278	0.0028	1,581.06
1A1ai	Electricity Generation	962.89	0.0170	0.0017	963.77
1A1aii	Combined Heat And Power Generation	616.72	0.0108	0.0011	617.29

Figure 4.8 illustrates CO_2 emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories per plants.



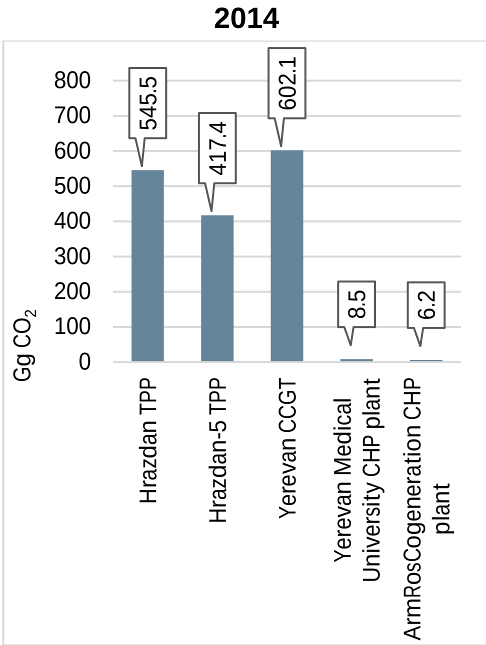


Figure 4.8 CO_2 emissions from Electricity Generation and Combined Heat and Power Generation sub-categories per plants

Uncertainty assessment

According to the Guideline, statistics of fuel combusted at large sources obtained from direct measurement or obligatory reporting are likely to be within 3% of the central estimate [Gen-1, Volume 2, Chapter 2.4.2]. Considering that in Armenia combustion data are obtained from direct measurement and obligatory are reported the uncertainty of activity data on fossil fuel combusted is within 3 %;

According to the Guideline, for fossil fuel combustion uncertainties in CO_2 emission factors are relatively low as these emission factors are determined by the carbon content of the fuel and thus there are physical constraints on the magnitude of their uncertainty [Gen-1, Volume 2, Chapter 2.4.1]. Therefore uncertainty in CO_2 emission factors is considered to be within 3 percent as well.

It is good practice to compare any country-specific emission factor with the default ones given in Tables 2.2 to 2.5 of Volume 2 of 2006 IPCC Guidelines [Gen-1]. A comparison with the IPCC default factors [Gen-1, Volume 2, Table 4.2.4] shows that the national emission factors for CO_2 lie within the range given for the default factors and could be regarded as consistent with the default value.

An overall uncertainty value for CO_2 emissions from *Main Activity Electricity and Heat Production (1A1a)* category could be regarded as 4.2%.

Time series

Figure 4.9 provides 2000-2014 time series of CO_2 emissions from *Main Activity Electricity and Heat Production category.*

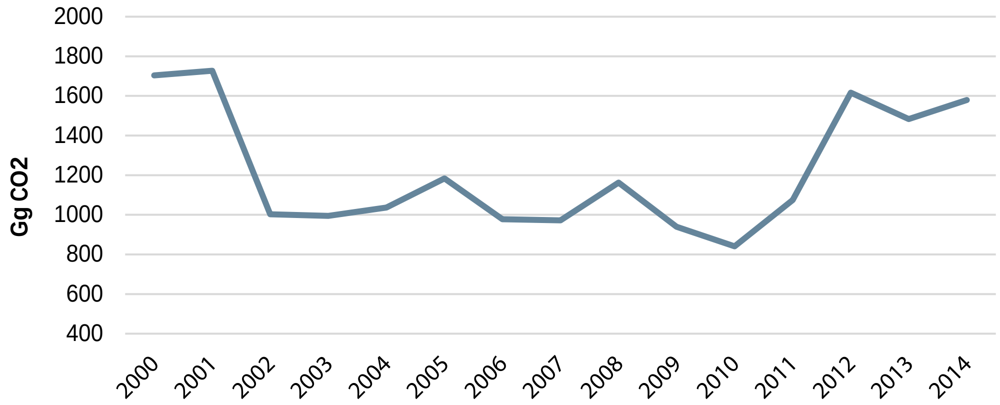


Figure 4.9 Time series of CO_2 emissions from Main Activity Electricity and Heat Production

The reduction of CO_2 emissions in the early 2000s was due to the increased electricity generation at hydropower plants, the annual variation in CO_2 emissions in 2002-2010 was relatively small, while CO_2 emissions growth in 2012 compared to 2010 was due to increased electricity generation by thermal power plants, mainly because of the increased electricity exports to Iran.

4.1.4.1.3 Manufacturing Industries and Construction (1A2)

Description of the category

This category consists of several sub-source categories defined in accordance with the IPCC categorization [Gen-1, Volume 2]. In this report emissions from 10 sub-categories of the *Manufacturing Industries and Construction* category have been specified for the first time.

The source category *Manufacturing Industries and Construction* is a key category (gaseous fuel) for CO_2 emissions in terms of level assessment.

This category comprises emissions from combustion of fuels for heat generation for own use in industries and emissions arising from off-road and other mobile machinery in industry.

Energy used for transport by industry have not been reported here, it is done under Transport (1A3) category. Emissions arising from off-road and other mobile machinery in industry have not been broken out as a separate sub-category but have been included in corresponding sub-categories.

Methodology

CO_2 emissions from combustion of natural gas were assessed by sub-categories applying Tier 2 method [Gen-1, Volume 2, Chapter 2.3.1.2] based on the data on the amount of natural gas combusted in the source sub-category (Annex 6) and applying country-specific emission factors for natural gas mixture (Annex 2). Emissions from diesel fuel and coal combustion were assessed applying Tier 1 approach.

Activity data

A different types of fuel are used in this category – mostly natural gas, followed by diesel fuel in a much smaller quantities, coal consumption is negligible. Within this inventory for the first time, in addition to natural gas combustion emissions, emissions resulting from the combustion of coal and diesel fuel were also estimated.

The amounts of natural gas and coal used by sub-categories were derived from the NSS (Annex 6). Diesel fuel consumption was estimated by the expert judgment due to the incompleteness of official statistics on diesel fuel consumption by the sub-categories. The estimate is based on the data on fuel import reported by the NSS and analysis of data provided by the Ministry of Agriculture and NSS.

The starting point for deriving activity data for calculation of GHG emissions from the diesel fuel were the data on its import reported by the NSS [Ref-2]. It is assumed that annually imported diesel is fully consumed in the same year as there are no large storages for liquid fuel in Armenia.

The quantity of diesel fuel imported in the country was allocated between Manufacturing Industries and Construction, Road Transportation (mainly heavy–duty trucks and buses), Other Transportation (Off-road), Residential sector and Agriculture (Off-road Vehicles and Other Machinery) sub-categories. The quantities of diesel used in Agriculture were assessed based on the volume of agricultural work performed (expert judgement), diesel consumption by Residential sub-category was provided by the NSS.

The quantities of diesel used in *Manufacturing Industries and Construction* were derived from the figures reported by the NSS per different sub-categories assuming that 40% were used for off-road activities in industry and 60% were used for transport with combustion emissions reported under transport. The rest of diesel imported in the country was considered under Transport category as well.

All fuel consumed were converted to common energy units (TJ) applying for natural gas NCVs of natural gas mixture provided by Gazprom Armenia (Annex 2) and for coal and diesel – default values provided by 2006 IPCC Guideline [Gen-1, Volume 2, Table 1.2].

Figure 4.10 provides consumption by fuel types specified by physical units and total energy consumption by sub-categories (TJ).

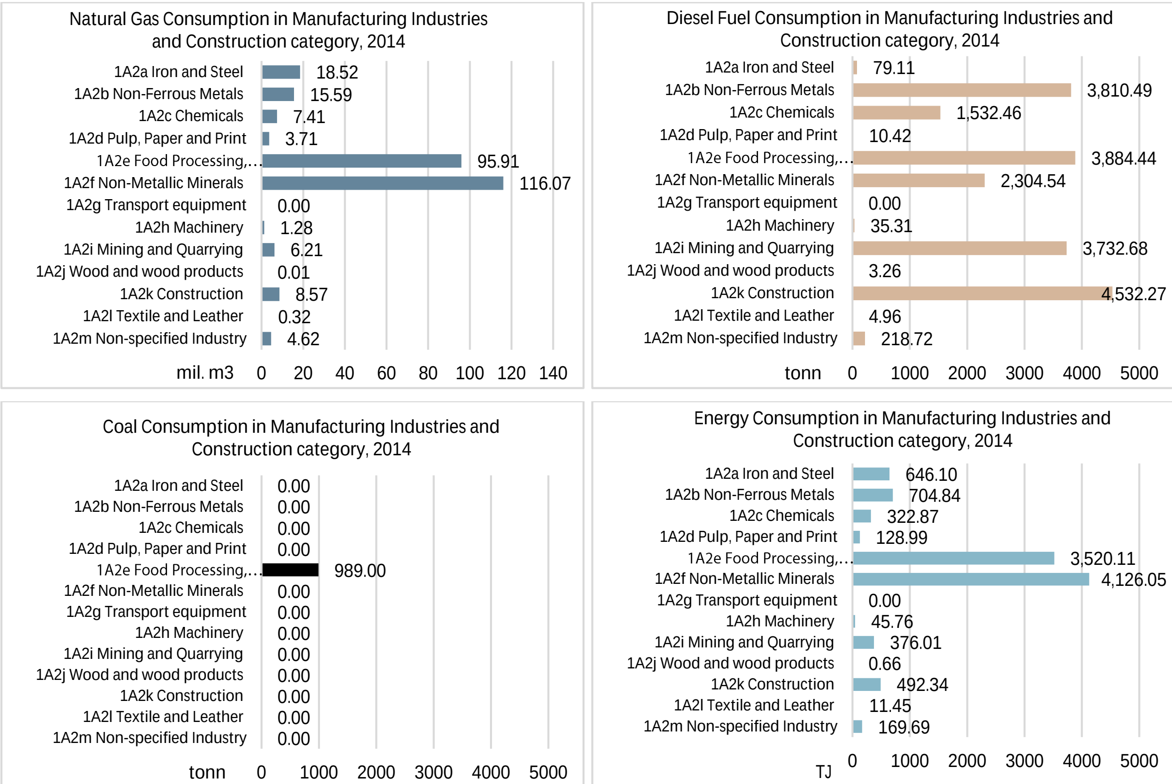


Figure 4.10 Natural gas, diesel fuel, coal and total energy consumption by sub-categories

Figure 4.10 shows that in Manufacturing Industries and Construction category *the Food Processing, Beverages and Tobacco* and *Non-Metallic Minerals* sub-categories are the largest consumers of natural gas. As for diesel, the main consumers are *Non-Ferrous Metals, Food Processing, Beverages and Tobacco, Mining and Construction* sub-categories.

Emission factors

Country-specific emission factors calculated for natural gas mixture (Annex 1 and Annex 2) were applied for estimating emissions from natural gas combustion while for diesel and coal default values provided by 2006 IPCC Guideline were applied [Gen-1, Volume 2, Table 1.4].

Emissions calculations results

The results of emissions assessment from Manufacturing Industries and Construction source category in 2014 are summarized in Table 4.9 and Figure 4.11.

Table 4.9. Emissions from *Manufacturing Industries and Construction* source category, 2014

Code	Category/sub-category	Net CO_2	CH_4	N_2O	Total $CO_{2eq.}$
1A2	**Manufacturing Industries and Construction**	617.02	0.01250594	0.00152313	617.76
1A2a	Iron and Steel	36.90	0.00065290	0.00006631	36.94
1A2b	Non-Ferrous Metals	42.990	0.00103255	0.00015241	43.06
1A2c	Chemicals	19.54	0.00045466	0.00006523	19.57
1A2d	Pulp, Paper and Print	7.36	0.00012989	0.00001312	7.37
1A2e	Food Processing, Beverages and Tobacco	204.54	0.00408381	0.00047125	204.77
1A2f	Non-Metallic Minerals	236.97	0.00432424	0.00046215	237.21
1A2h	Machinery	2.64	0.00004880	0.00000533	2.64
1A2i	Mining (excluding fuels) and Quarrying	24.15	0.00069566	0.00011758	24.20
1A2j	Wood and Wood Products	0.04	0.00000094	0.00000014	0.04
1A2k	Construction	31.40	0.00088211	0.00014668	31.47
1A2l	Textile and Leather	0.66	0.00001187	0.00000125	0.66
1A2m	Non-specified Industry	9.84	0.00018850	0.00002167	9.85

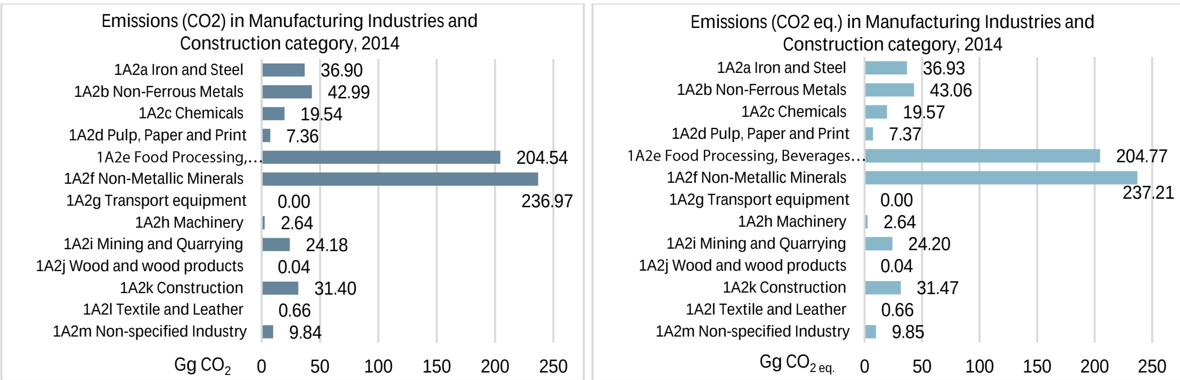


Figure 4.11. Emissions from Manufacturing Industries and Construction source category per sub-categories, 2014

Uncertainty assessment

The uncertainty of activity data on natural gas combusted is within 5% and for diesel fuel is 20% (expert judgement). Emission factors uncertainty for natural gas is 3% and for diesel fuel and coal is up to 5%. Therefore, uncertainty for emissions estimate from natural gas combustion could be regarded as 5.83% and from diesel fuel as 20.62%.

Consistent time series and recalculation

CO_2 emissions time series for 2000-2014 were recalculated to consider CO_2 emissions from diesel fuel and coal combustion and for ensuring time series consistency.

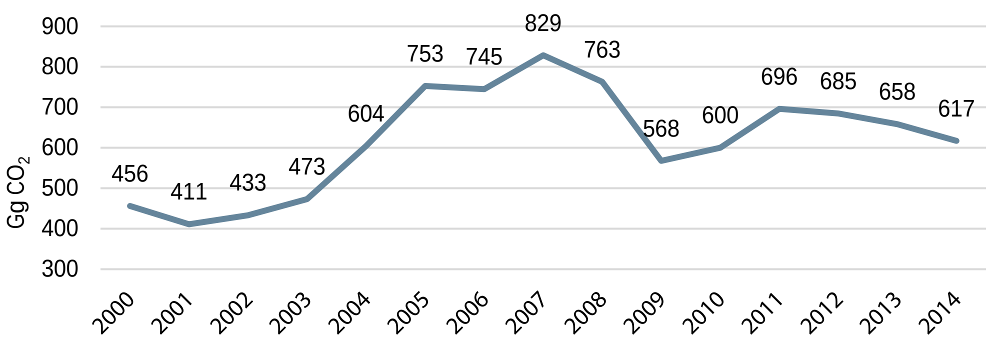


Figure 4.12 Manufacturing Industries and Construction CO_2 emissions time series from fuel combustion for 2000-2014, Gg CO_2

Figure 4.12 shows the emissions growth in 2000-2007 due to the Armenia's GDP growth followed by decrease of CO_2 emissions because of the economic downturn and then gradual recovery.

Mobile Combustion

4.1.4.1.4 Transport (1A3)

Description of the category

Mobile sources produce direct greenhouse gas emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from the combustion of various fuel types, as well as several other pollutants such as carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), sulphur dioxide (SO_2) and nitrogen oxides (NOx).

The following source categories exist in Armenia: *International Aviation (International Bunker)*, *Road Transportation* and *Off-road*.

Emissions from *Off-road* sub-category were estimated for the first time within this report.

Emissions estimated from *International Bunker* are not included in national total and are reported as memo item.

Railways are fully electrified in Armenia therefore emissions from Railways do not occur.

4.1.4.1.4.1 Road Transportation (1A3b)

Description of the category

The mobile source category *Road Transportation* includes all types of light-duty vehicles such as automobiles and light trucks, and heavy-duty vehicles such as tractor trailers and buses, and on-road motorcycles. These vehicles operate on many types of fuels - gasoline, diesel, compressed natural gas (CNG) and liquefied petroleum gas (LPG). Road transportation is the significant emission source in transport, accounting for more than 98.4 % of the *Transport* category's emissions in 2014.

The source category *Road Transportation* is a key category for CO_2 emissions in terms of level assessment.

In 2014, the greenhouse gas emissions from road transportation amounted to 1607.9 Gg CO_{2eq}. The emissions from *Road Transportation* have grown continuously since 2000: during the period 2000–2014 (with the exception of 2009 when the recession also resulted in lower CO_2 emissions from road transport) road transport emissions increased by about 145% due to the growth in traffic volume.

Fuel consumption structure in Road Transportation and in Off-road by fuel types is presented in Figure 4.13 (the percentages were calculated from the total energy equivalent of the all fuel consumed).

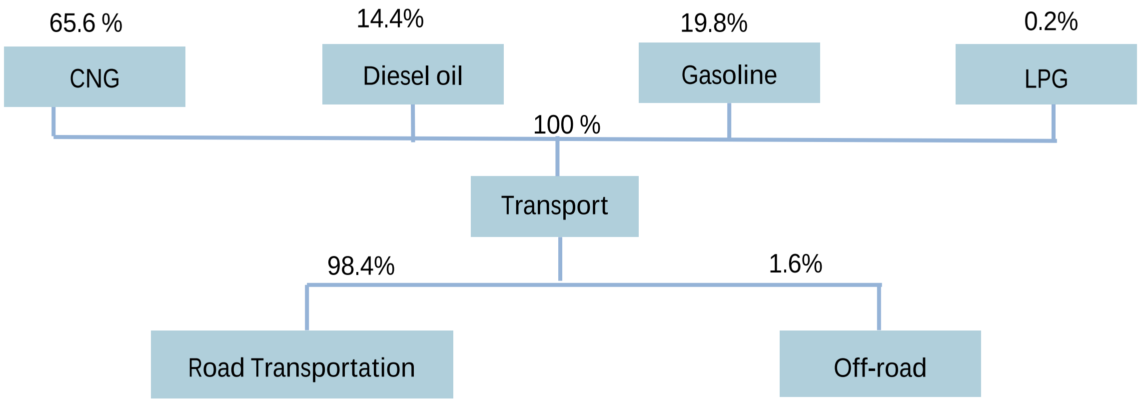


Figure 4.13 Fuel combustion structure in transport 2014

In Armenia fuel consumption structure in the road transport is quite specific, considering the absolute predominance of natural gas which accounted for above 65% of the total fuel consumption in the road transport in 2014. Currently there is a significant increase of the gas-filling stations number which has reached 373 operating units.

However 2006 IPCC software does not allow the separation of emissions from road transport by the fuel types which would allow to identify road transportation as a key emission source both from use of gaseous and liquid fuel separately.

Methodology

Emissions can be estimated from either the fuel consumed (represented by fuel sold) or the distance travelled by the vehicles [Gen-1, Volume 2, Chapter 3]. In general, the first approach (fuel sold) is appropriate for CO_2 emissions assessment. In this inventory report emissions were estimated from the fuel consumed assuming that the total fuel imported into the country [Ref-5] in a given year is sold in the same year.

Calculations of CO_2 emissions from CNG combustion were done applying Tier 2 method [Gen-1, Volume 2, Chapter 3] based on the quantities of compressed natural gas consumed by gas-filling stations (Annex 4), and country-specific emission factors for natural gas mixture (Annex 2).

CO_2 emissions from gasoline, diesel fuel and LPG combustion were calculated applying Tier 1 method based on the quantities of fuel consumed and by using default emission factors provided in 2006 IPCC Guideline [Gen-1, Volume 2, Chapter 3, Table 3.2.1].

Emissions of CH_4 and N_2O are more difficult to estimate accurately than those for CO_2 because emission factors strongly depend on vehicle technology.

However, CH_4 and N_2O emissions from fuel combustion in road transportation were calculated by applying Tier 1 method using country's activity data and emission factors from 2006 IPCC Guideline because of lack of the detailed information on this issue. Besides, the share of CH_4 and N_2O emissions is relatively small making up 3.8% of CO_2-equivalent emissions from the road transportation sector in 2014.

Estimation of indirect greenhouse gas emissions was done applying Tier 1 Approach using country's activity data and emission factors specified in EMEP/CORINAR, 2016 Guidebook.

Activity data

The amounts of natural gas consumed were taken from Gas balances provided by Gazprom Armenia (Annex 4), the amounts of consumed gasoline and LPG were provided by NSS.

The amount of diesel used in transport were estimated as described above. This amount was allocated between Road Transportation (mainly heavy-duty trucks and buses) and Other Transportation (Off-road) with prevailing share of Road Transportation.

All fuel consumed were converted to common energy units (TJ) applying for natural gas NCVs of natural gas mixture provided by Gazprom Armenia (Annex 2) and for gasoline, diesel and LPG– default values provided by 2006 IPCC Guideline [Gen-1, Volume 2, Table 1.2].

Emission factors

Country-specific emission factors calculated for natural gas mixture were applied for estimating emissions from CNG combustion (Annex 1 and Annex 2) while for gasoline, diesel and LPG default values provided by 2006 IPCC Guideline were applied [Gen-1, Volume 2, Table 1.2].

4.1.4.1.4.2 Off-road (1A3eii)

Description of the category

The sub-category includes combustion emissions from off-road activities not otherwise reported under 1 A4 c *Agriculture* or 1A2 *Manufacturing Industries and Construction*.

Methodology

CO_2 emissions from combustion of diesel were assessed applying Tier1 approach.

Activity data

The quantities of diesel consumed were estimated as described above.

Emission factors

Default values provided by 2006 IPCC Guideline were applied for estimating emissions from diesel combustion [Gen-1, Volume 2, Table 1.2].

Emissions calculations results from Transport category

The results of greenhouse gas emissions calculation from Transport category for 2014 are summarized in Table 4.10.

Table 4.10 Greenhouse gas *emissions from Transport category* for 2014, (Gg)

Code	Category/sub-category	Net CO_2	CH_4	N_2O	Total $CO_{2eq.}$
1A3	**Transport**	1,577.28	1.7213	0.0806	1,638.41
1A3a	Civil Aviation, *Memo Item*[3]	127.57	0.0009	0.0036	128.70
1A3ai	International Aviation (International Bunkers), *Memo Item*	127.57	0.0009	0.0036	128.70
1A3b	Road Transportation	1,547.32	1.7197	0.0790	1,607.93
1A3eii	Off-road	29.96	0.0016	0.0016	30.48

Uncertainty assessment

CO_2, N_2O and CH_4 contribute typically around 97, 2-3 and 1 percent of $CO_{2eq.}$ emissions from the Road Transportation category, respectively [Gen-1, Volume 2, Chapter 3.2.2]. Therefore, although uncertainties in N_2O and CH_4 estimates are much higher, CO_2 dominates the emissions from road transport.

For CO_2 the uncertainty in the emission factor for CNG is estimated 3%, for diesel fuel, gasoline and LPG – up to 5%.

Activity data are the primary source of uncertainty in the emission estimates mainly due to the lack of completeness. Activity data uncertainty for natural gas is estimated 5%, for gasoline and LPG – 15% and for diesel – 20%. Therefore, uncertainty for emissions estimate from CNG combustion could be regarded as 5.83%, from gasoline and LPG -15.8% and from diesel fuel – 20.62%.

Consistent time series and recalculation

CO_2 emissions time series for 2000-2014 were recalculated to consider reallocation of diesel fuel thus ensuring time series consistency (Figure 4.14).

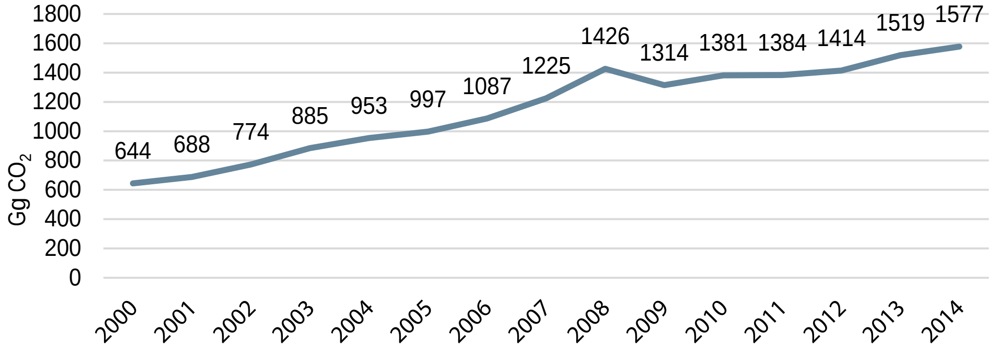


Figure 4.14 CO_2 emissions 2000-2014 time series for Transport sub-sector, Gg

Figure 4.14 shows that the Transport sub-sector emissions have grown continuously since 2000 with the exception of 2009 when the recession also resulted in lower CO_2 emissions from

[3] *According to the 2006 IPCC Guidelines [Gen-1] emissions from international bunkers are not included in total national greenhouse gas emissions, however, information on such emissions is reported in National inventory separately as memo item.*

transport: during 2000–2014 transport emissions increased by about 145% due to the growth in traffic volume.

Improvement foreseen

It is envisaged to estimate GHG emissions by types of vehicle.

4.1.4.1.5 Other Sectors (1A4)

The following source categories exist in Armenia: *Commercial/Institutional, Residential and Off-road Vehicles and Other Machinery in Agriculture*.

The source category *Other Sectors* is a key category (gaseous and liquid fuel) for CO_2 emissions in terms of level assessment.

4.1.4.1.5.1 Commercial/Institutional (1A4a)

Description of the category

This category comprises emissions from fuel combustion for space heating and cooking activities in commercial and institutional buildings. Natural gas and LPG are used as fuel in this sub-category.

Methodology

CO_2 emissions from natural gas combustion were assessed applying Tier 2 method by using country-specific emission factors (Annex 2) and data on natural gas consumption (Annex 4). CO_2 emissions from combustion of LPG were calculated applying Tier 1 method.

Activity data

The volumes of natural gas provided by "Gazprom Armenia" CJSC (Annex 4) and the volumes of LPG provided by NSS (Annex 6) were converted to common energy units (TJ) applying for natural gas NCV of natural gas mixture provided by Gazprom Armenia (Annex 2) and for LPG– default values provided by 2006 IPCC Guideline [Gen-1, Volume 2, Table 1.2].

Emission factors

Country-specific emission factors for natural gas mixture (Annex 1 and Annex 2) were applied for CO_2 emissions estimate from natural gas combustion, default values provided by 2006 IPCC Guideline were applied for estimating emissions from LPG combustion [Gen-1, Volume 2, Table 1.4].

4.1.4.1.5.2 Residential (1A4b)

Description of the sub-category

The sub-category comprises emissions from fuel combustion for space heating and cooking activities.

According to the data of the State Committee of the Real Estate Cadastre, the total area of the housing stock of the Republic of Armenia in 2014 made up 94.6 million m^2, including 51.1 million m^2 in urban communities (54.0%) and 43.5 million m^2 (46.0%) - in rural communities.

Table 4.11 Key indicators of RA Housing Fund

Multi-apartment buildings			Single family houses		Dormitory and temporary dwellings, thsd sq.m	Total area per resident, sq.m
Number	Number of apartments	Total area, thsd sq.m	Number	Total area, thsd sq.m		
18,974	435,427	27,534.2	426,593	66,805.8	311.5	31.3

The total space of the multi apartment buildings amounted to 27,534.2 thousand m^2 or 29.1 % of the total space of the housing stock. About 70% of the multi-apartment buildings are made of stone.

Multi-apartment buildings by the type of construction are presented in Figure 4.15 and the fuel consumption structure in the residential sector by fuel types (TJ) are shown in Figure 4.16.

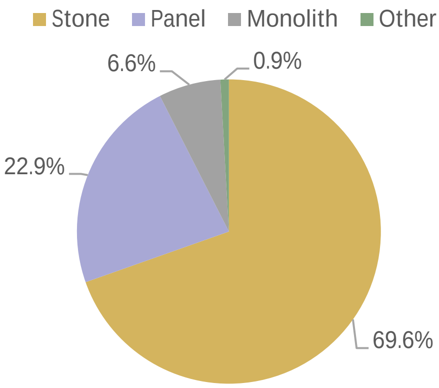


Figure 4.15 Multi-apartment buildings by the type of construction, 2014

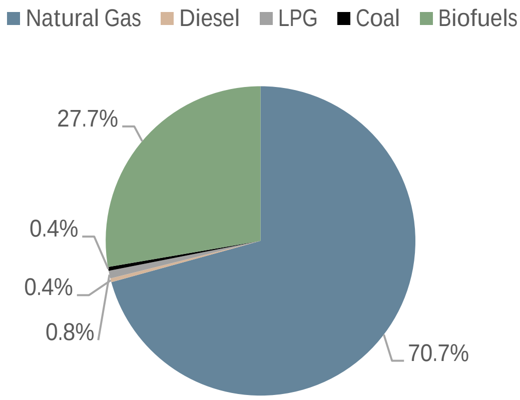


Figure 4.16 The consumed fuel by the types, 2014

The following fuel types are used by households in Armenia: natural gas, kerosene, LPG, fuelwood and manure. Natural gas is the main fuel consumed by households, making up to 71% of the total fuel consumed, followed by biofuel – 28%. Apparently, the consumption of the biofuel (manure and fuelwood) occurs in the rural areas.

Methodology

CO_2 emissions from natural gas combustion were assessed applying Tier 2 Approach by using country-specific emission factors (Annex 2) and data on natural gas consumption (Annex 4).

CO_2 emissions from combustion of the other fuels were calculated applying Tier 1 Approach.

Activity data

The activity data for natural gas consumption were taken from the Natural gas balances provided by Gazprom Armenia (Annex 4). The activity data for other fuel consumption were provided by NSS (Annex 6). Data on natural gas consumption were converted to energy units by applying NCV for gas mixture (Annex 2), other fuels were converted applying default valued provided by 2006 Guidelines [Gen-1, Volume 2, Table 1.2].

Emission factors

Country-specific emission factors for natural gas mixture (Annexes 1 and 2) were applied for CO_2 emissions estimate from natural gas combustion, default values provided by 2006 IPCC Guideline were applied for estimating emissions from other fuel combustion [Gen-1, Volume 2, Table 1.4].

4.1.4.1.5.3 Off-road Vehicles and Other Machinery (1A4cii)

Description of the sub-category

The sub-category includes combustion emissions from off-road vehicles and other machinery used on farm land and forests. Diesel and gasoline are used as fuel in this sub-category.

Methodology

CO_2 emissions from combustion of diesel and gasoline were calculated applying Tier 1 Approach using the quantities of fuel consumed (Ministry of Agriculture's expert judgement based on the volume of agricultural work) and default emission factors from 2006 IPCC Guideline.

Emissions estimate for Other Sectors (1A4) category

Table 4.12 summarizes the results of greenhouse gas emissions estimate for *Other Sectors* category for 2014.

Table 4.12 Greenhouse gas emissions from *Other Sectors* category, Gg

Code	Category/Subcategory	Net CO_2	CH_4	N_2O	Total $CO_{2eq.}$
1A4	**Other Sectors**	1,595.18	0.1504	0.0039	1,599.56
1A4a	Commercial/Institutional	387.50	0.0340	0.0007	388.42
1A4b	Residential	1,040.63	0.0934	0.0019	1,043.17
1A4cii	Off-road Vehicles and Other Machinery	167.05	0.0230	0.0014	167.96

Table 4.12 shows that Residential subsector produces a significant share of *Other Sectors* emissions, accounting for over 65% of the emissions of the sector.

According to 2006 IPCC Guidelines [Gen-1], emissions from combustion of biofuels are reported as information items but not included in the sectoral or national totals to avoid double counting.

Uncertainty assessment

Activity data uncertainty for natural gas is estimated 5%, for gasoline, LPG and coal – 15% and for diesel fuel – 20%.

Emission factors uncertainty for natural gas is estimated 3% and for gasoline, LPG and diesel – up to 5%.

Therefore, uncertainty for emissions estimate from CNG combustion could be regarded as 5.83%, from gasoline, LPG and coal -15.8% and from diesel fuel – 20.62%.

Consistent time series and recalculation for Other Sectors (1A4) category

CO_2 emissions 2000-2014 time series for *Other Sectors* category are shown in Figure 4.17.

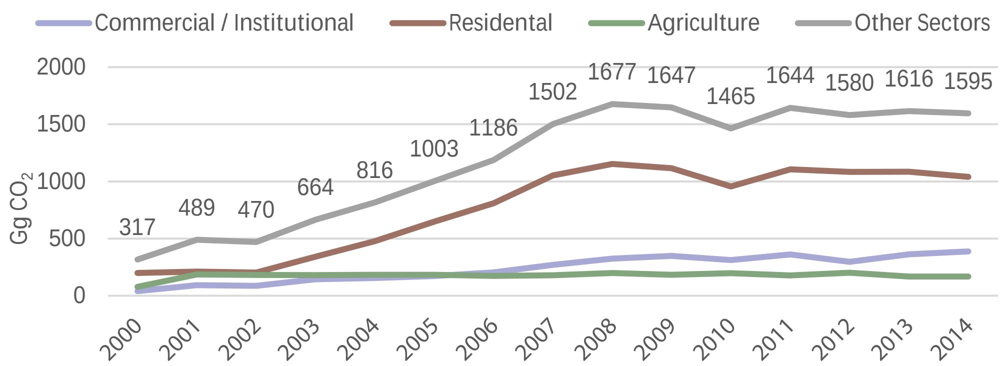


Figure 4.17 CO_2 emissions time series by sub-categories for Other Sectors category

Figure 4.17 shows that greenhouse gas emissions growth from *Other Sectors* category is due to emissions attributable to energy used by households: Residential sector's emissions have been growing steadily during the period 2000-2009 because of the improved households' living conditions and the unprecedented level of gasification (nearly 95%) in the country since 2004 that enabled use of natural gas for space heating. The recession in 2009-2010 also resulted in lower emissions from households. As for the recent years, some decrease of emissions from households is largely due to the growth of gas tariffs.

CO_2 emissions 2000-2014 time series for *Agriculture* were recalculated for ensuring time series consistency because of diesel fuel quantities reallocation. Greenhouse gas emissions in the *Agriculture* show minor annual variations throughout 2000-2014.

QA/QC procedures for Fuel Combustion Activities

Estimates of CO_2 emissions from fuel combustion prepared using the Sectoral Approach have been compared with the Reference Approach.

The results of Reference Approach estimate are summarized in the Table 4.13.

Table 4.13 CO_2 emissions from fuel combustion estimated using the Sectoral Approach

Types of Fuel			Actual emissions, Gg CO_2			
		Year	2011	2012	2013	2014
Liquid fossil	Secondary fuel	Gasoline	418.8	400.7	405.9	396.4
		Jet kerosine*	124.9	127.6	144.7	127.6
		Diesel fuel	489.7	460.7	447.0	462.1
		LPG	21.9	20.4	22.1	20.2
Total liquid fossil			**930.4**	**881.8**	**875.0**	**878.7**
Solid fossil		Other bitumen coal	10.2	9.5	3.8	3.1
Total solid fossil			**10.2**	**9.5**	**3.8**	**3.1**
Gaseous fossil		Natural Gas	4,055.7	4,590.4	4,630.1	4,716.4
Total Gaseous fossil			**4,055.7**	**4,590.4**	**4,630.1**	**4,716.4**
Total			**4,996.4**	**5,481.7**	**5,508,9**	**5,598,2**

**Memo item*

Comparison of Reference and Sectoral Approaches

The Reference Approach and Sectoral Approach often have different results because the Reference Approach is a top-down approach using a country's energy supply data and has no detailed information on how the individual fuels are used in each sector [Gen-1, Vol.2, Chapter 6].

Table 4.14 and Figure 4.18 present comparison of CO_2 emissions estimated using Reference and Sectoral Approaches.

Table 4.14 Comparison of CO_2 emissions estimated using Reference and Sectoral Approaches

Fuel Combustion Activity (1A)	2011	2012	2013	2014
Sectoral Approach, Gg	4,798.8	5,296.5	5,276.0	5,369.1
Reference Approach, Gg	4,996.4	5,481.7	5,508,9	5,598,2

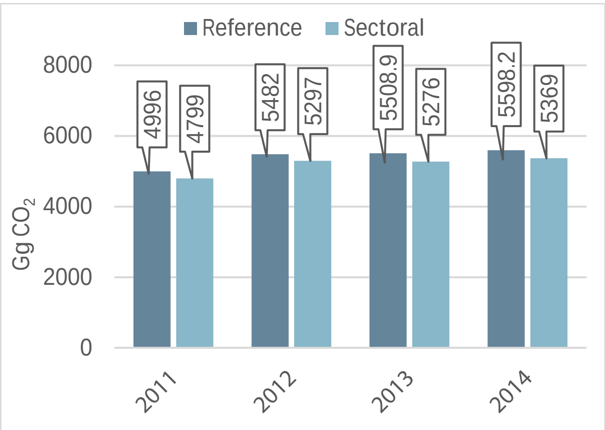


Figure 4.18 Comparison of CO_2 emissions estimated using Reference and Sectoral Approaches

Table 4.14 and Figure 4.18 show that emission values derived applying Reference Approach are bigger versus Sectoral Approach, the differences are 4.1%, 3.5%, 4.4%, 4.3% for 2011-2014 correspondingly, which is justified given that according to Guidelines [Gen-1, Volume 2, Chapter 6] fugitive emissions are included in Apparent Consumption in Reference Approach estimate.

Energy Sector CO_2 emissions time series from fuel combustion

Considering that a new sub-category has been considered and the quantity of gas diesel imported in the RA was allocated between Manufacturing Industries and Construction (Emissions arising from off-road and other mobile machinery), Road Transportation (heavy-duty trucks and buses), Other Transportation (Off-road) and Agriculture (Off-road Vehicles and Other Machinery), CO_2 emissions time series from fuel combustion were recalculated for the pervious years applying the same approaches for estimating diesel consumption by the sub-categories.

Table 4.15 and Figure 4.19 provide Energy Sector CO_2 emissions time series from fuel combustion by sub-categories for 2000-2014.

Table 4.15 Energy Sector CO_2 emissions time series from fuel combustion by sub-categories for 2000-2014

Subcategory / Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total	**3,120.5**	**3,314.8**	**2,679.4**	**3,017.2**	**3,410.1**	**3,936.7**	**3,995.2**	**4,528.9**	**5,028.0**	**4,469.0**	**4,287.1**	**4,798.8**	**5,296.5**	**5277.0**	**5,370.2**
Electricity and Heat Production	1,703.6	1,727.2	1,002.6	995.0	1,036.7	1,184.0	977.3	972.4	1,162.3	939.9	840.9	1,074.7	1,616.3	1,483.2	1,579.6
Manufacturing Industries and Construction	456.1	411.1	433.5	473.2	604.5	752.9	744.6	828.5	763.0	567.8	600.2	696.3	684.9	658.2	617.0
Transport	644.2	687.7	773.6	884.6	953.4	997.0	1,087.0	1,225.1	1,425.9	1,314.1	1,381.3	1,383.7	1,414.2	1,518.5	1,577.3
Other sectors:	316.6	489.1	469.8	664.5	815.5	1,002.7	1,186.3	1,502.2	1,676.8	1,647.2	1,464.6	1,644.1	1,580.1	1,616	1,595.2
Commercial / Institutional	*40.4*	*92.1*	*86.3*	*143.7*	*154.9*	*172.1*	*204.7*	*270.4*	*324.8*	*348.9*	*311.4*	*361.4*	*296.1*	*362.8*	*387.5*
Residential	*198.9*	*211.7*	*202.2*	*340.9*	*477.6*	*648.0*	*808.9*	*1,053.0*	*1,152.9*	*1,115.2*	*956.1*	*1,105.1*	*1,082.8*	*1,085.0*	*1,040.6*
Agriculture	*77.3*	*185.3*	*181.3*	*179.9*	*183.0*	*182.6*	*172.7*	*178.8*	*199.1*	*183.1*	*197.1*	*177.6*	*201.2*	*168.2*	*167.1*
Memo Items															
International Aviation	90.5	121	117.9	94.8	110	111.7	115.8	178.1	176	92.6	136.2	125	127.6	144.7	127.6
Memo Items: Biomass	731.1	732.4	716.8	703.0	679.7	655.3	613.7	439.4	432.0	422.7	586.4	616.0	692.2	724.1	728.4

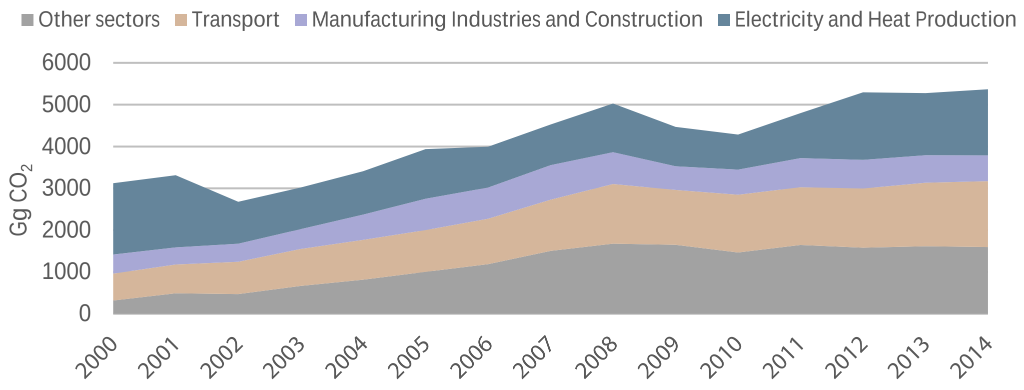


Figure 4.19 Energy Sector CO_2 emissions time series from fuel combustion by sub-categories for 2000-2014

Table 4.15 and Figure 4.19 show that the sharp increase in CO_2 emissions from Energy Sector was recorded in 2007-2008 which was due to the unprecedented level of gasification in the country (about 95%) and widespread use of natural gas especially by households for space heating and in road transport.

In 2009, the financial and economic crisis occurred, also affecting the energy consumption. In 2010, emissions increased again as a result of economic recovery.

The energy sector emissions have varied considerably due to changes in electricity exports and production of natural gas based condensing power. Thus, the sharp increase of GHG emissions from Energy Sector in 2012 in comparison with 2010 were resulted from a high export growth met by thermal power plants (thermal power plants generation in 2012 has been increased by 135% in comparison with 2010). In addition, the emissions are influenced each year by the economic situation in the country's energy intensive industries, the weather conditions and the volumes of energy produced with hydropower plants.

4.1.4.2 Fugitive emissions from fuels (1B)

4.1.4.2.1 Natural Gas Transmission and Storage (1B2biii4) and Natural Gas Distribution (1B2biii5)

Description of the sub-categories

Gas supply system

Armenia imports natural gas from Russia, via Georgia, and from Iran. The gas transmission system includes a main high pressure pipeline and an underground gas storage facility. The total length of the gas transmission system is 1685 km. The gas transmission system includes 107 gas distribution stations and 21 measuring units.

In recent years there was an unprecedented expansion of the natural gas distribution system. Currently gasification level is nearly 95%. The gas distribution system operates 14,600 km long high-, medium- and low-pressure pipelines. For operation of the gas distribution system there are 2600 gas control points, 6900 individual gas regulating units and 1399 head-count measuring units.

Fugitive emissions were estimated in the following sub-categories: *Natural Gas Transmission and Storage* (1B2biii4) and *Natural Gas Distribution* (1B2biii5).

All other sources indicated in 2006 IPCC Guidelines [Gen-1] for Energy Sector do not exist in Armenia and are not considered in this Inventory.

Fugitive emissions are a direct source of greenhouse gases due to the release of methane (CH_4). The source category *Fugitive Emissions from Natural Gas* is a key category for CH_4 emissions in terms of level assessment.

Methodology

Fugitive emissions from natural gas were assessed applying Tier 2 Approach. Considering characteristics (official data) of the delivered (mixture of) natural gas, country-specific emission factors were developed for estimation of fugitive emissions in the following sub-categories: *Natural Gas Transmission and Storage* (1B2biii4) and *Natural Gas Distribution* (1B2biii5).

The Methodology for calculating country-specific emission factors for fugitive emissions from natural gas transportation (including storage) and distribution systems was discussed and agreed with "Gazprom Armenia" CJSC. It was provided in details in NIR 2012.

Activity data

The volumes of marketable gas and utility sales delivered via the transmission and distribution system were derived based on the official statistics from Annual Gas Balances provided by "Gazprom Armenia" CJSC (Annex 4).

Emission factors

Country-specific emission factors were calculated using official statistics from Annual Gas Balances provided by "Gazprom Armenia" CJSC and based on the country-specific annual average characteristics of natural gas in transmission and distribution systems - net-calorific values (NCV), density and gas composition (Annex 1 and 2).

Emissions estimates

Table 4.16 provides country-specific emission factors, activity data and methane fugitive emissions estimates for 2011-2014.

Table 4.16 Country-specific emission factors, activity data and methane fugitive emissions estimates in 2011-2014

Year	Gas Supply System	Country-specific emission factors Gg/mln m^3	Activity data mln m^3	Methane fugitive emissions Gg	
2011	Transmission network	0.0231	2054.95	47.46	**71.43**
	Distribution network	0.0156	1534.92	23.97	
2012	Transmission network	0.0199	2443.00	48.61	**71.71**
	Distribution network	0.0144	1608.90	23.11	
2013	Transmission network	0.0211	2320.61	48.87	**73.96**
	Distribution network	0.0138	1821.93	25.09	
2014	Transmission network	0.0211	2394.60	50.49	**74.97**
	Distribution network	0.0122	2008.90	24.47	

Fugitive Emissions from Natural Gas for 2014 are summarized in Table 4.17

Table 4.17 Fugitive Emissions from Natural Gas in 2014, Gg

Code	Category/Subcategory	Net CO_2	CH_4	N_2O	Total $CO_{2eq.}$
1B2b	**Fugitive Emissions from Natural Gas**	1.163	74.97	NA	1,575.5
1B2biii4	Transmission and Storage	0.012	50.49	NA	1,060.4
1B2biii5	Distribution	1.151	24.48	NA	515.1

Comparison of methane fugitive emissions assessed by using 1996 IPCC Guidelines and country-specific emission factors

It should be noted, that methane fugitive emissions values that have been calculated by using country-specific emission factors are very close to those which could be obtained using methane emission factors provided for former USSR countries in 1996 IPCC Guidelines [Gen-8] (Tier 1 Approach), while they are significantly differ from those that estimated by using methane emission factors specified for developing countries in 2006 IPCC Guidelines [Gen-1, Volume 2, Chapter 4]. Table 4.18 provides comparison of methane fugitive emissions values.

Table 4.18 Comparison of methane fugitive emissions assessed by using 1996 IPCC Guidelines and country-specific emission factors

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Gas-supply system</th><th colspan="3">Methane fugitive emissions (Gg)</th></tr>
<tr><th>Assessed by using1996 IPCC Guidelines</th><th colspan="2">Assessed by using country-specific emission factors</th></tr>
<tr><td rowspan="2">2011</td><td>Transmission network</td><td rowspan="2">62.84</td><td>47.46</td><td rowspan="2">71.43</td></tr>
<tr><td>Distribution network</td><td>23.97</td></tr>
<tr><td rowspan="2">2012</td><td>Transmission network</td><td rowspan="2">72.01</td><td>48.61</td><td rowspan="2">71.71</td></tr>
<tr><td>Distribution network</td><td>23.11</td></tr>
<tr><td rowspan="2">2013</td><td>Transmission network</td><td rowspan="2">70.27</td><td>48.87</td><td rowspan="2">73.96</td></tr>
<tr><td>Distribution network</td><td>25.09</td></tr>
<tr><td rowspan="2">2014</td><td>Transmission network</td><td rowspan="2">71.91</td><td>50.49</td><td rowspan="2">74.97</td></tr>
<tr><td>Distribution network</td><td>24.47</td></tr>
</table>

Uncertainty assessment

Gas compositions considered to be accurate within ±5% on individual components and flow rates have errors of ±7% for transmission and storage and ±5% – for distribution. Combined uncertainty for *Transmission and Storage* sub-category is considered to be accurate within ±8.6% and for *Distribution* sub-category – within ±7.07%.

Time series

Methane fugitive emissions time series for 2000-2014 are presented in Figure 4.20.

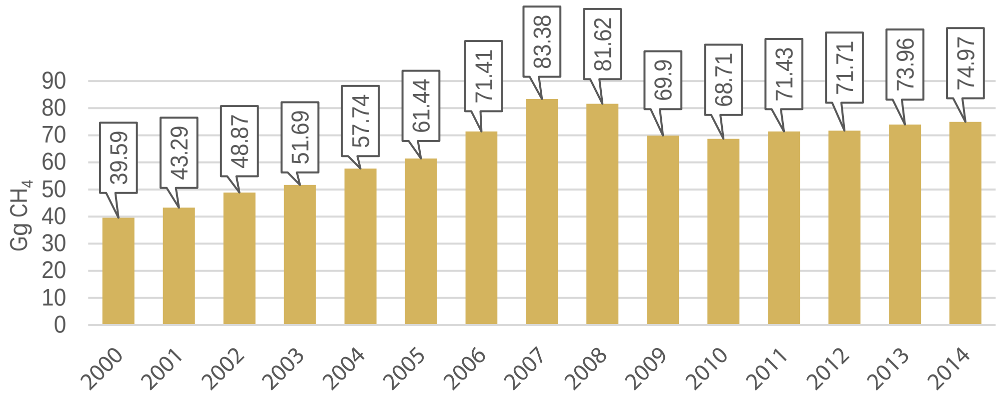


Figure 4.20 Methane fugitive emissions time series, Gg CH_4

Figure 4.20 shows that methane emissions have grown continuously since 2000 due to the natural gas distribution network gradual expansion. The biggest methane emissions were recorded in 2007-2008 when the level of gasification reached 94.6%. In 2009, the financial and economic crisis occurred, also affecting the natural gas consumption.

Gradual increase of methane emissions since 2010 was due to the electricity export growth to Iran met by thermal power plants.

Summary of greenhouse gas emissions from Energy Sector

The greenhouse gas emissions from Energy Sector by sub-categories and gases for 2013-2014 are summarized in Table 4.19.

Table 4.19 Greenhouse gas emissions from Energy Sector sub-categories by gases

Subcategory/ Greenhouse gas (Gg)	2013	2014
CO_2	**5,277.05**	**5,370.2**
Main Activity Electricity and Heat Production	1,483.2	1,579.6
Manufacturing Industries/Construction	658.2	617.0

Subcategory/ Greenhouse gas (Gg)	2013	2014
Transport	1,518.5	1,577.3
Other Sectors	1,616.0	1,595.2
Fugitive emissions from natural gas	1.0557	1.1632
CH_4	**75.7920**	**76.8797**
Main Activity Electricity and Heat Production	1.8277	0.0277
Manufacturing Industries/Construction	0.0132	0.0125
Transport	1.6356	1.7212
Other Sectors	0.1528	0.1503
Fugitive emissions from natural gas	73.9643	74.9678
N_2O	**0.0856**	**0.0888**
Main Activity Electricity and Heat Production	0.0026	0.0028
Manufacturing Industries/Construction	0.0016	0.0015
Transport	0.0774	0.0806
Other Sectors	0.0040	0.0039
Fugitive emissions from natural gas	NA	NA

Completeness of activity data

Complete official statistics on natural gas and electricity including production, import and consumption are currently available in the country.

However, the data on liquid fuel consumption by categories, in particular on diesel fuel, are incomplete as is described above.

Biomass data are generally more uncertain than other data in national energy statistics. This provision fully corresponds to realities of Armenia as the data on biomass burning obtained from various sources are considerably different.

Data accessibility and quality assurance

The required activity data on electricity and natural gas are available on the PSRC website or can be obtained from Settlement Centre or Gazprom Armenia.

The activity data on liquid fuel consumption are not available publically, but can be obtained from NSS. However these data both incomplete and are not detailed enough to be used for greenhouse gas inventory according to 2006 IPCC Guidelines.

Emissions from International Bunkers (1A3i)

According to 2006 IPCC Guidelines [Gen-1] emissions from international bunkers are not included in total national greenhouse gas emissions, however, information on such emissions is reported in National inventory separately as memo item.

Calculations are made on the basis of information on consumed fuel for 2011-2014 provided by the General Department of Civil Aviation of Armenia and NSS [Annex 6], by applying Tier 1 method.

Table 4.20 describes the consumed fuel and greenhouse gas emissions from international aviation by gases.

Table 4.20 Greenhouse gas emissions from *International Aviation* (bunker) by gases

Years	2011	2012	2013	2014
Consumption, (TJ)	1,748.48	1,784.86	2,024.21	1,784.21
Emissions, (Gg)				
CO_2	125.0	127.6	144.7	127.57
CH_4	0.001	0.001	0.0010	0.0009
N_2O	0.0035	0.0036	0.0040	0.0036
$CO_{2eq.}$	126.11	128.74	146.01	128.70

CO_2 emissions (Gg CO_2) from *International Bunkers* are presented in Figure 4.21.

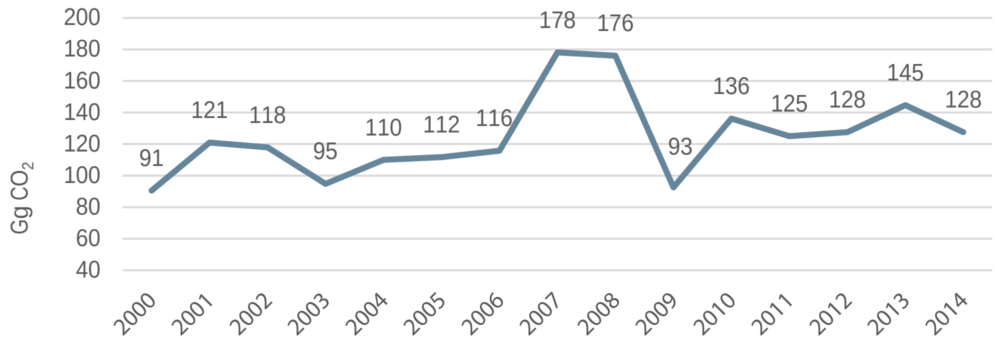


Figure 4.21 2000-2014 CO2 emissions (Gg CO2) from International Bunkers

Emissions from biomass

The greenhouse gas emissions from combustion of biofuels are calculated only from manure and fuelwood. According to 2006 IPCC Guidelines [Gen-1, Volume 2, Chapter 2], CO_2 emissions from combustion of biofuels are reported as information items but not included in the sectoral or national totals to avoid double counting. For biomass, only that part of the biomass that is combusted for energy purposes was estimated for inclusion as an information item in the Energy Sector. Table 4.21 and Figure 4.22 summarize the quantities of consumed fuelwood and manure in energy units and CO_2 emissions from burning, respectively.

Table 4.21 Biofuel consumption and greenhouse gas emissions from biomass burning

Year	2011	2012	2013	2014
Biofuel Consumption, TJ				
Fuelwood	571.2	746.9	621.7	570.2
Manure	5,520.0	6,084.9	6,545.3	6,645.4
Total	**6,091.3**	**6,831.8**	**7,166.0**	**7,215.6**
CO_2 emissions from biofuel, Gg				
Fuelwood	64.0	83.7	69.6	63.9
Manure	552.0	608.5	654.5	664.5
Total	**616.0**	**692.2**	**724.2**	**728.4**

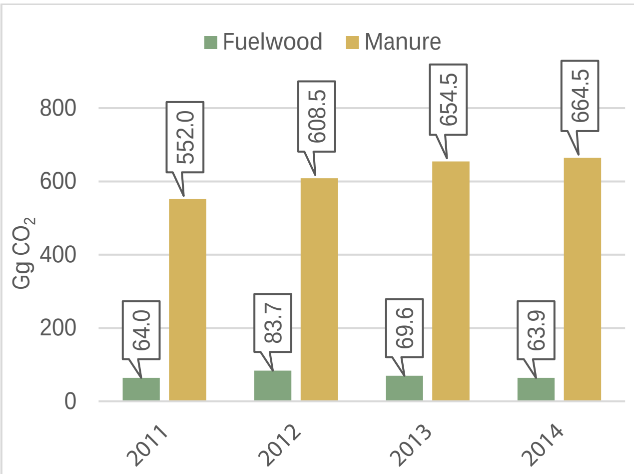


Figure 4.22 CO_2 emissions from biomass burning, (Gg CO_2)

4.1.5 Summary report on Energy Sector greenhouse gas emissions

Table 4.22 Energy Sectoral Table, 2014

Sectors/Categories	Emissions (Gg)			
	Net CO_2	CH_4	N_2O	Total $CO_{2eq.}$
1 – ENERGY SECTOR	**5,370.26**	**76.8798**	**0.0888**	**7,012.26**
1.A – FUEL COMBUSTION ACTIVITIES	**5,369.09**	**1.9119**	**0.0888**	**5,436.78**
1.A.1 – ENERGY INDUSTRIES	**1,579.61**	**0.0278**	**0.0028**	**1,581.06**
1.A.1.a – Electricity and heat production	1,579.61	0.0278	0.0028	1,581.06
1.A.1.a.i – Electricity generation	962.89	0.0170	0.0017	963.77
1.A.1.a.ii – Combined heat and power generation	616.72	0.0108	0.0011	617.29
1.A.2 – MANUFACTURING INDUSTRIES AND CONSTRUCTION	**617.02**	**0.0125**	**0.0015**	**617.76**
1.A.2.a – Iron and steel	36.90	0.0006529	0.0000663	36.94
1.A.2.b – Non-ferrous metals	42.99	0.0010325	0.0001524	43.06
1.A.2.c - Chemicals	19.54	0.0004547	0.0000652	19.57
1.A.2.d – Pulp, paper and print	7.36	0.0001299	0.0000131	7.37
1.A.2.e – Food processing, beverages and tobacco	204.54	0.0040838	0.0004712	204.77
1.A.2.f – Non-metallic minerals	236.97	0.0043242	0.0004622	237.21
1.A.2.h - Machinery	2.64	0.0000488	0.0000053	2.64
1.A.2.i - Mining (excluding fuels) and quarrying	24.15	0.0006957	0.0001176	24.20
1.A.2.j – Wood and wood products	0.04	0.0000009	0.0000001	0.04
1.A.2.k - Construction	31.40	0.0008821	0.0001467	31.47
1.A.2.l – Textile and leather	0.66	0.0000119	0.0000013	0.66
1.A.2.m – Non-specified industry	9.84	0.0001885	0.0000217	9.85
1.A.3 - TRANSPORT	**1,577.28**	**1.7212546**	**0.0805772**	**1,638.41**
1.A.3.a – Civil Aviation: *note**	127.57	0.0008921	0.0035684	128.70
1.A.3.ai – International aviation: *note**	127.57	0.0008921	0.0035684	128.70
1.A.3.b – Road transportation	1,547.32	1.7196776	0.0790002	1,607.92
1.A.3.e – Other transportation	29.96	0.0015769	0.0015769	30.48
1.A.3.e.ii – Off-road	29.96	0.0015769	0.0015769	30.48
1.A.4 – OTHER SECTORS	**1,595.18**	**0.1503748**	**0.0039300**	**1,599.56**
1.A.4.a – Commercial/institutional	387.50	0.0339538	0.0006791	388.42
1.A.4.b - Residential	1,040.63	0.0934324	0.0018716	1,043.17
1.A.4.c – Agriculture/forestry/fishing/fish farms	167.05	0.0229885	0.0013793	167.96
1.A.4.c.ii – Off-road vehicles and other machinery	167.05	0.0229885	0.0013793	167.96
1.B – FUGITIVE EMISSIOSN FROM FUELS	**1.16**	**74.968**	**NA**	**1,575.49**
1.B.2.b – Natural gas	1.16	74.968	NA	1,575.49
1.B.2.b.iii.4 – Transmission and storage	0.01	50.493	NA	1,060.37
1.B.2.b.iii.5 – Distribution	1.15	24.475	NA	515.12

4.2 Industrial Processes and Product Use

4.2.1 Overview of IPPU Sector emissions assessment

Emissions from this sector include non-energy related CO_2 emissions from the production of cement, non-cement clinker and glass production, SO_2 emissions from metal production, NMVOC emissions from solvent use, asphalt production and Food and Beverage industry as well as emissions of F–gases from refrigeration, air conditioning and other product use.

Emissions from the IPPU Sector amounted to 782.53 Gg $CO_{2eq.}$ in 2014 and were generated in Mineral Industry (cement and clinker production, glass production) - 250.79 Gg CO_2 and from F–gases - 531.74 Gg CO_{2eq} . Emissions from the IPPU Sector made up approximately 7.5% of Armenia's total greenhouse gas emissions in 2014.

The prevailing part of the CO_2 emissions comes from the cement production, accounted for 28.5% of the emissions from the sector and 2.1% of Armenia's total emissions. Emissions from non-cement clinker were 2.6 % of the total IPPU Sector emissions and from glass production – negligible.

Fluorinated greenhouse gases, or F-gases, form a category of their own under IPPU Sector. They accounted for over 5% of total national greenhouse gas emissions and nearly 68 % of the greenhouse gas emissions of IPPU Sector in 2014. HFC emissions which are caused by refrigeration systems predominate in the overall picture of HFC emissions with the share of 94.5 %. The share of emissions from other applications is about 5.5 % altogether.

4.2.2 IPPU Sector greenhouse gas source categories

"Industrial Processes and Product Use" (IPPU) sector of the national greenhouse gas inventory of Armenia includes the following emission source sub-categories:

(2A) Mineral Industry (CO_2 emissions)

(2A1) Cement production
(2A3) Glass Production
(2A4) Other Process Uses of Carbonates
    (2A4d) Non-cement Clinker Production

(2C) Metal Industry (SO_2 emissions)

(2C2) Ferroalloys Production
(2C7) Copper Production

(2D) Non-energy Products from Fuels and Solvent Use (NMVOC)

(2D3) Solvents Use
(2D4) Bitumen/Asphalt Production and Use

(2F) Product uses as Substitutes for Ozone Depleting Substances (HFCs)

(2F1) Refrigeration and Air Conditioning
(2F2) Foam Blowing Agents
(2F3) Fire Protection
(2F4) Aerosols
(2F5) Solvents

(2H) Other

(2H2)Food and Beverages Industry (NMVOC)

All other sources indicated in 2006 IPCC Guidelines [Gen-1, Volume 3] for IPPU Sector do not exist in Armenia and are not considered in this Inventory with the exception of *Lubricant Use* (2D1) sub-category that exist but not considered due to lack of data.

In IPPU Sector the emission estimation considers only process-related emissions and do not consider energy-related emissions. Energy-related emissions from these industries are accounted for in the Energy Sector and there is no double-counting of emissions between the Energy and IPPU Sectors.

There are no such industries in Armenia where it is difficult to separate emissions from fuel combustion and from technological processes (e.g. iron and steel production).

4.2.3 Improvements made

Within the frames of this inventory, the following improvements were made to the Industrial Processes sector greenhouse gas emissions assessment:

- GHG emissions were estimated for 2 new sub-categories - Glass Production and Non-cement Clinker Production

4.2.4 Key Categories

Cement production (2A1) and refrigeration and air-conditioning (2F1) are identified as the key source categories of greenhouse gas (carbon dioxide and HFCs respectively) emissions with level assessment. Emissions of carbon dioxide from cement production made 223.4 Gg CO_2 accounting for 2 % of the country's total emissions in $CO_{2eq.}$ and refrigeration and air-conditioning produced 502.66 Gg CO_{2eq} or 4.5 % of the total emissions.

4.2.5 Cement Production (2A1)

The category *Cement production* is a key category for CO_2 emissions in terms of emissions level. Cement is produced by two plants: "Hrazdan-Cement" CJSC and "Araratcement" CJSC.

Methodology

In cement manufacture, CO_2 is produced during the production of clinker. The method used for estimating CO_2 emissions from cement production is based on national circumstances considering that cement-producing plants produce more clinker than it is required for cement production in the reporting year. Some part of clinker can be exported or stored as a raw material for cement production in future (stockpiles).

Carbon dioxide emissions in *Cement production* sub-category were estimated on clinker quantities used in the reporting year for cement production. The emissions arising from the clinker production envisaged for export or as a raw material for future cement production were estimated in the other sub-category (*Non–cement clinker* sub-category).

Carbon dioxide emissions from cement production were calculated by applying Tier 3 approach which relies on plant specific data and is based on the collection of disaggregated data on the types (compositions) and quantities of carbonate(s) consumed to produce clinker, as well as the respective emission factor(s) of the carbonate(s) consumed. The Tier 3 approach includes an adjustment to subtract any uncalcined carbonate within CKD not returned to the kiln.

Emissions data collected on the plant level then were aggregated for reporting national emissions estimates.

Tier 3 approach applied was described in NIR 2012 (Ref-3).

Activity data

The activity data required for Tier 3 method are available only at individual plant level. The data according to the developed format was requested by MNP and received from 2 operating cement-producing plants - "Araratcement" CJSC and "Hrazdan-Cement" CJSC.

Data on cement and clinker production, quantity and composition of raw materials used by "Araratcement" CJSC [IndRef-1] and "Hrazdan-Cement" CJSC [IndRef-2] plants are provided below.

Table 4.23 Annual production and quantity of main row materials of "Araratcement" CJSC, thousand t

Year	Annual production		Quantity of main raw materials	
	Cement	Non-cement clinker	Clay	Lime
2013	397.492	86.913	148.61	534.47
2014	398.694	3.062	127.69	455.90

Quantity of recycled dust: in 2013- 180790 t/year, in 2014- 103370t/year, Dust capturing system efficiency: in 2013 -99.7%, in 2014 – 99.6%, Emissions from uncalcined CKD not recycled to the kiln: *2013 - 544 t, 2014 – 415.14 t*

Table 4.24 Chemical composition of main row materials for "Araratcement" CJSC, %

Chemical component	Raw material	
	Clay	Lime
SiO_2	31.15	1.2
Al_2O_3	10.84	0.46
Fe_2O_3	3.11	0.36
CaO	24.65	50.3-52.7
MgO	1.5	0.2

Table 4.25 Annual production and quantity of main row materials of "Hrazdan-Cement" CJSC, thousand t

Year	Annual production		Quantity of main raw materials		
	Cement	Non-cement clinker	Clay	Lime	Slag
2013	33.37	-	6.765	34.355	3.688
2014	23.34	-	10.91	94.58	4.044

Quantity of recycled dust: in 2013-7646 t/year, in 2014 - 10340 t/year Dust capturing system efficiency: in 2013- 96%, in 2014 - 96.3%:, Emissions from uncalcined CKD not recycled to the kiln: in 2013 - 318.6 ton, in 2014 - 397.3 ton

Table 4.26 Chemical composition of main row materials of "Hrazdan-Cement" CJSC, %

Chemical component	Raw material		
	Clay	Iron-containing slag	Lime
CaO	49.48	2.42	7.02
SiO_2	7.55	37.25	55.5
Al_2O_3	2.07	10.37	17.4
Fe_2O_3	0.89	46.4	6.2
MgO	0.85	0.85	1.46
SO_3	0.12	-	0.39

4.2.6 Non-Cement Clinker Production (2A4d)

In this sub-category carbon dioxide emissions arising from the clinker production that was not used in the reporting year for cement production but was envisaged for export or as a raw material for future cement production (stockpiles) were estimated. "Araratcement" CJSC exported some quantity of clinker in 2013 and in 2014, while "Hrazdan-Cement" CJSC stored most part of the clinker produced in 2014 for cement future production.

Calculation of carbon dioxide emissions from Cement and Non-Cement Clinker Production

The Tier 3 approach is a calculation based on the weights and compositions of all carbonate inputs from all raw material considering that limestone are the dominant (80-90 per cent) raw materials, the emission factor(s) for the carbonate(s) and the fraction of calcination achieved.

Raw-material-related CO_2 emissions were calculated with a country-specific emission factor from plant-specific data on raw materials used both for cement production and for non-cement clinker production [Gen-1, Volume 3, Chapter 2, Equation 2.3]. Data on the composition of raw materials provided by cement producers as CaO input were recalculated to $CaCO_3$:

CaO (56) $\longrightarrow$ $CaCO_3$ (100)

An example of calculation of carbonate for "Araratcement" in 2013 is provided below:

Clay: 148,613.4 t,

Content of calcium oxide: 24.65 %, or 148,613.4 x 0.2465= 36,633.2 t,

Lime: 534,470 t,

Content of calcium oxide: 51.5 % or 534,470 x 0.515 = 275,295.8 t, Total calcium oxide: 36,633.2 + 275,295.8= 311,929 t/year,

Total carbonate input: 311,929 x 100/56 = 557,016 t/year.

"Araratcement" and "Hrazdan-Cement" plants are provided in Table 4.27.

Table 4.27 Total carbonate input for "Araratcement" and "Hrazdan-Cement" plants, ton

Year	"Araratcement" CJSC	"Hrazdan-Cement" CJSC
2013	557,016	31,680
2014	485,240	85,957

Calculation of CO_2 emissions from clinker production for "Araratcement" and Hrazdan-Cement" plants for 2013 is provided in Table 4.28

Table 4.28 CO_2 emissions calculation from clinker production, 2013

Indicators	"Araratcement" CJSC	"Hrazdan-Cement" CJSC
EFi (tCO_2/t carbonate)	0.4397	0.4397
Mi (t)	568,387	31,680
Fi (degree)	1	1
M_d (t)	544.0	159.0
C_d (fraction)	1	1
F_d (fraction)	1	1
EF_d (t CO_2/t carbonate)	0.44	0.44
$M_к$ (t)	0	0
$X_к$ (fraction)	0	0
EF_k (t $C0_2$/t carbonate)	0	0
CO_2 (t)	244,920	13,930

Further, CO_2 emissions from the total clinker production have been divided according to the subsequent use of the clinker, i.e. between cement and non-cement clinker production.

Emissions arising from cement production were estimated considering that clinker fraction of blended cement is approximately 80-92% (estimation based on the analysis of composition of cement produced in recent years). Emissions arising from *Non-Cement Clinker Production* (export and stockpiles) were estimated by subtracting emissions referred to cement production from the total CO_2 emissions generated from total clinker production.

Tables 4.29 and 4.30 provide carbon dioxide emissions distribution by cement and non-cement clinker production for "Araratcement" and "Hrazdan-Cement", correspondingly.

Table 4.29 Carbon dioxide emissions distribution by Cement and Non-Cement Clinker Production for "Araratcement"

Year	Clinker, t			CO_2, Gg		
	For cement production	Non-cement	Total	From cement production	From Non-cement clinker	Total
2013	347,800	86,900	434,700	195.96	48.96	244.92
2014	366,795	3,060	369,855	211.6	1.76	213.36

Table 4.30 Carbon dioxide emissions distribution by Cement and Non-Cement Clinker Production for "Hrazdan-Cement" plant

Year	Clinker, t			CO_2, Gg		
	For cement production	Non-cement	Total	From cement production	From Non-cement clinker	Total
2013	27,997	-	27,997	13.93	-	13.93

2014	19,370	30,450	49,820	11.8	18.4	30.2

Emissions data estimated on the plant level then were aggregated for reporting national emissions estimates. Table 4.31 provides national emissions estimates of carbon dioxide emissions from cement and non-cement clinker production in the country.

Table 4.31 Carbon dioxide emissions from Cement and Non-Cement Clinker Production, Gg/year

Year	CO_2 emissions from cement production	CO_2 emissions from non-cement clinker	Total
2013	209.89	48.96	258.85
2014	223.4	20.16	243.56

Uncertainty assessment

Uncertainty estimates for cement production result predominantly from uncertainties associated with activity data, and to a lesser extent from uncertainty related to the emission factor for clinker.

For Tier 3, there is relatively little uncertainty associated with the emission factors of the source carbonates because they are based on stoichiometric ratios.

There may be some uncertainty associated with assuming, in Tier 3, that there is 100 percent calcination of carbonates in the CKD [Gen-1, Volume 3, Chapter 2].

Main uncertainness associated with cement production are provided below (expert judgement).

Uncertainty values	Uncertainty, %
1. Non-complete reporting on raw materials	3-7
2. Composition: overall chemical analysis pertaining to carbonate content (mass) & type	5-8
3. Reported (plant-level) data on clinker stockpiles	6-10
4. Assumption of level of calcination of carbonate destined to become clinker	1-5[4]

Time series

Since the emissions arising from *non-cement clinker* are separated for the first time and there is no possibility to carry out such a division for the previous years and to recalculate the time series, total CO_2 emissions from both cement production and non-cement clinker production are reported for the years 2000-2014 for ensuring a consistent time series.

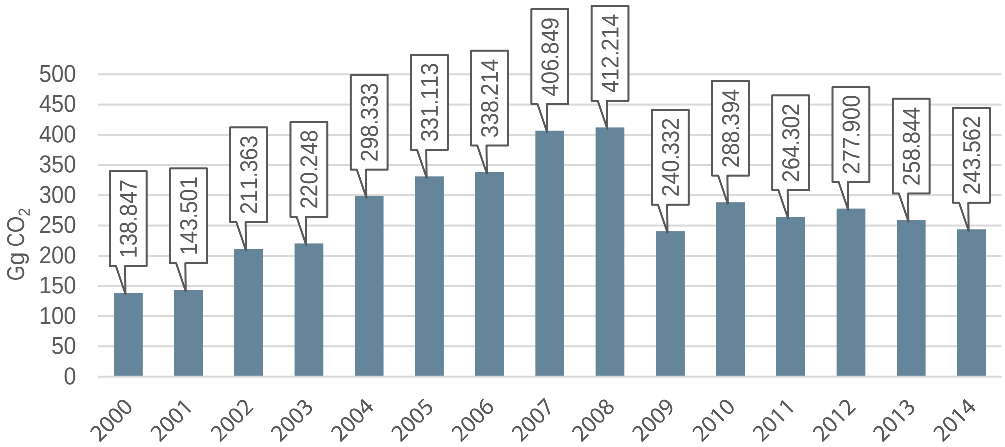


Figure 4.23 2000-2014 Total CO_2 emissions from cement and non-cement clinker production, Gg/year

[4] [Gen-1, Volume3, Table 2.3]

CO_2 emissions from cement and non-cement clinker production decreased markedly in 2009 due to the economic recession, which led to the decrease of construction volumes and, thus, cement demand and production. In 2010 there was some increase in construction volumes and cement production, however CO_2 emissions from cement and non-cement clinker production have declined in recent years.

4.2.7 Glass Production (2A3)

Armenia's glass industry produces container glass. Currently there is one glass producer in Armenia.

Methodology

The process-related CO_2 emissions under consideration here are released from the raw-material carbonates during the melting process in the furnace. The CO_2 emissions (the main pollutant) are calculated via a Tier 1 method [Gen-1, Volume3, Chapter 2, Equation 2.10].

$CO_2\ emissions = M_g \cdot EF \cdot (1 - CR)$
CO_2 emissions = emissions of CO_2 from glass production, t
M_g = mass of glass produced, t
EF = default emission factor for manufacturing of glass, t CO_2/t glass
CR = cullet ratio for process (either national average or default), fraction

Tier 1 applies a default emission factor, based on a 'typical' raw material mixture, to national glass production data. A 'typical' soda-lime batch might consist of sand (56.2 weight percent), feldspar (5.3 percent), dolomite (9.8 percent), limestone (8.6 percent) and soda ash (20.0 percent). Based on this composition, one metric tonnes of raw materials yields approximately 0.84 tonnes of glass, losing about 16.7 percent of its weight as volatiles, in this case virtually entirely CO_2.

According to the Equation 2.13 [Gen-1, Volume 3, Chapter 2], Tier 1 default emission factor for glass production

$EF = 0.167 / 0.84 = 0.20$ t CO_2 / t glass

Calculation of carbon dioxide emissions

Mass of glass produced and cullet ratio used [IndRef-3] are provided in the Table 4.32.

Table 4.32 Mass of glass produced and cullet ratio used

Years	Mass of glass produced, t	Cullet ratio,%
2013	49,000.00	22.7
2014	45,305.00	20.2

Based on these data, carbon dioxide emissions were calculated as follows and summarized in the Table 4.33:

2013:

$CO_2 = 49{,}000 \cdot 0.20 \cdot (1 - 0.227) = 7{,}575.4$ t or 7.5754 Gg

2014:

$CO_2 = 45{,}305 \cdot 0.20 \cdot (1 - 0.202) = 7{,}230.7$ t or 7.2307 Gg

Table 4.33 Carbon dioxide emissions from glass production

Year	CO_2 emissions, Gg
2013	7.5754
2014	7.2307

Uncertainty assessment

According to 2006 IPCC Guideline [Gen-1, Volume 3, Chapter 2.4.2.1], uncertainty associated with use of the Tier 1 emission factor and cullet may be on the order of +/- 60 %. In this report cullet ratio provided by the glass producer was used, therefore the level of uncertainty is lower.

4.2.8 Sulphur dioxide emissions

Main outputs from metal mining in RA are metal concentrates (except gold mining). A certain part of concentrate is exported. A part of copper concentrate is processed at Alaverdi copper smeltery and molybdenum concentrate is practically fully used in Armenia for ferromolybdenum production.
In this sub-chapter sulphur dioxide emissions arising from cooper and ferromolybdenum production were assessed.

Methodologies for the estimation of emissions of precursors are not given in 2006 IPCC Guidelines but it is recommended that emissions of these gases can be estimated using the EMEP/EEA Emission Inventory Guidebook. However the Guidebook doesn't provide the methodology for emission calculation from copper and ferromolybdenum production. The calculation of emissions from copper and ferromolybdenum production was done on the basis of production technology and chemical composition of raw materials.

4.2.8.1 Copper Production (2C7)

Primary copper in Armenia is produced by Alaverdi copper smeltery of "Armenia Copper Program" CJSC. Copper concentrate is used as a raw material. As a result of thermal treating sulphur content bound in the concentrate is fully transformed into sulphur dioxide. During the process some sulphur remains in slag.

Plant specific data required for estimating sulphur dioxide emissions from copper production were taken from "Armenia Copper Program" CJSC [IndRef-4]. These data are provided below.

Table 4.34 Copper concentrate average composition

	Year	Cu	S	S iO2	CaO	Fe	Zn	Pb	As
Copper concentrate, (%)	***2013***	22.01	33.07	7.70	1.28	27.34	0.56	0.45	0.21
	2014	21.29	35.27	6.94	1.32	28.38	0.47	0.41	0.14

The emissions of sulphur dioxide were calculated using the equitation proposed by the national experts:

$E_{SO2} = (Q_{con} \times P_{sul} + Q_{slag} \times S_{sul}) \times 2$, where:
E_{SO2} - annual emissions of sulphur dioxide, t/year
Q_{con} – annual quantities of copper concentrate, t
P_{sul} - sulphur content in concentrate, share,
Q_{slag} – the annual quantities of slag, t
S_{sul}- sulphur content in slag, share
2 - factor of sulphur recalculation to SO_2.

Sulphur dioxide emissions calculation:

2013: (49185 x 0.3307 - 35050 x 0.0193) x 2 = 31,178.0 t
2014: (46422 x 0.3527 - 35150 x 0.0192) x 2 = 31,396.0 t

Table 4.38 below provides annual quantities of produced copper, copper concentrate used for production and sulphur dioxide emissions for 2013-2014.

Table 4.35 Copper concentrate annual consumption, quantities of slag and Sulphur content in slag

Description	Year	
	2013	2014
Copper concentrate annual consumption, t/year	49184.89	46421.79
Quantities of slag, t/year	35050.0	35150.0
Sulphur content in slag, %	1.93	1.92

Table 4.36 Chemical composition of primary copper

Year	Cu	S	As	Bi	Ni	Sb
2013, (%)	99.22	0.028	0.0012	0.0006	0.013	0.010
2014, (%)	99.24	0.034	0.0011	0.0006	0.012	0.010

Table 4.37 Primary copper output from 1 ton of concentrate

Description	Year	
	2013	2014
Primary copper output from 1 ton of concentrate, (%)	22	21

Methodology

Emissions of sulphur dioxide were calculated in the following way (the equitation is proposed by the Project's experts):

$E_{SO2} = (Q_{con} \times P_{sul} + Q_{slag} \times S_{sul}) \times 2$, where:

E_{SO2} - annual emissions of sulphur dioxide, t/year

Q_{con} – annual quantities of copper concentrates

P_{sul} - sulphur content in concentrates, share,

Q_{slag} – the annual quantities of slag, t

S_{sul} - sulphur content in slag, share

2 - factor of sulphur recalculation to SO_2.

Sulphur dioxide emissions calculation:

2013: (49185 x 0.3307 - 35050 x 0.0193) x 2 = 31,178.0 t

2014: (46422 x 0.3527 - 35150 x 0.0192) x 2 = 31,396.0 t

Table 4.38 below provides annual quantities of produced copper, copper concentrate used for production and sulphur dioxide emissions for 2013-2014.

Table 4.38 Annual quantities of produced copper, used copper concentrate, and sulphur dioxide emissions

Year	Quantity of copper, t	Quantity of copper concentrate, t	Annual emissions of sulphur dioxide, Gg
2013	10,771	49,184.9	31.18
2014	9,814	46,421.8	31.40

Source: NSS

Sulphur dioxide emissions are emitted into the atmosphere without cleaning.

It should also be noted that the emissions calculated by the method above do not depend on the availability of the cleaning.

Uncertainty assessment

In this sub-category the main uncertainties may be due to variations in the composition of raw materials, in particular the sulfur content. Raw material is extracted from different mines and different layers of mines, and maybe the average content does not match the value used in calculations. However, the probability of these uncertainties is not high.

Time series

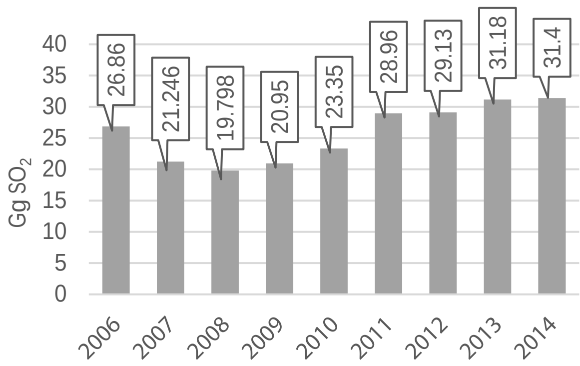


Figure 4.24 Sulphur dioxide emissions from Copper Production for 2006-2014

4.2.8.2 Ferromolybdenum Production (2C2)

In Armenia ferromolybdenum is produced by 2 plants: "Maqur Yerkat Plant" OJSC and "Armenian Molybdenum Production" LLC, which apply same technological schemes. Sulfur dioxide is produced from melting of molybdenum concentrate.

Methodology

Oxidization process of molybdenum concentrate is described by the following equation:

MoS_2 + 3.5 O_2 =MoO_3+2SO_2 + 228.5 kcal, (Technological regulations of the "Maqur Yerkat Plant" OJSC [IndRef-5] and "Armenian Molybdenum Production" LLC [IndRef-6])

Activity data

Data required for SO_2 emissions estimate were received from the plants - "Maqur Yerkat Plant" and "Armenian Molybdenum Production" LLC, and are provided in Table 4.39

Table 4.39 Activity data for SO_2 emissions calculation

Indicator	"Maqur Yerkat Plant"		"Armenian Molybdenum Production"	
	2013	2014	2013	2014
The quantities of FeMo produced, t	3,499	3,387.5	3,120	3,080
The quantities of consumed concentrate, t	6,887	6,975	4,590	4,650
Sulphur content in concentrate, share	0.33	0.33	0.325	0.325
The quantities of slag, t	3,151	2,158	1,248	1,232
Sulphur content in slag, share	0.003	0.003	-	-

Calculation of Sulfur dioxide emissions

"Maqur Yerkat Plant":

2013: $SO_2 = (Q_{conc} \times Cs - Q_{slag} \times S_s) \times 2$ = (6887 x 0.33 - 3151 x 0.003) x 2 = 4526.5 t
2014: SO_2 = (6975 x 0.33 - 2158 x 0.003) x 2 = 4590.6 t

"Armenian Molybdenum Production":

2013: $SO_2 = (Q_{conc} \times Cs - Q_{slag} \times S_s) \times 2$ = (4590 x 0.325) x 2 = 2983.5 t
2014: SO_2 = (4650 x 0.325) x 2 = 3022.5 t

Emissions data collected on the plant level then were aggregated for reporting national emissions estimates in Table 4.40.

Table 4.40 Sulphur dioxide emissions

Year	Quantity of molybdenum concentrate, t	Sulphur dioxide emission, t
2013	11,477	7,510.0
2014	11,625	7,613.0

Similar to copper case, the quantity of SO_2 emissions from ferromolybdenum production depends on the efficiency of gas-cleaning system. The level of cleaning at mentioned plants varies from 72 to 88%. The level of cleaning has no effect on emission factor but it influences the quantity of final emissions.

Uncertainty assessment

The technology of ferromolybdenum production is similar to those of copper production therefore the uncertainty can be assessed as not essential as well.

Time series

SO_2 emissions time series are presented in Figure 4.25

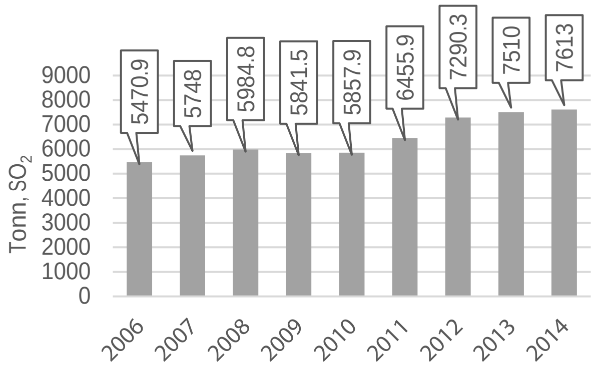


Figure 4.25 SO_2 emissions time series from Ferromolybdenum Production

The changes of SO_2 emissions from cooper and ferromolybdenum production are conditioned by the amount of the concentrate available in the market.

4.2.9 Non -Energy Products from Fuels and Solvent Use (2D)

This section provides emissions estimate from the first use of fossil fuels as a product for primary purposes other than i) combustion for energy purposes and ii) use as feedstock or reducing agent.

4.2.9.1 Asphalt Pavement (2D4)

Description of Source Category

This source category comprises the non-combustion emissions from the production of asphalt and its application such as paving operations. The production and use of asphalt results mainly in emissions of NMVOC.

Methodology and activity data

The emission factors for NMVOCs provided in EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016, SNAP 040611[Gen-2] were used. Activity data were taken from RA NSS Yearbooks [Ref-1].

The calculation was made applying Tier 1 Approach due to insufficient data for applying Tier 2 Approach.

$E_{pollutant} = AR_{production} \times EF_{pollutant}$, where
$E_{pollutant}$ - annual quantity of NMVOC emissions, t
$AR_{production}$ - the quantity of used bitumen, t
$EF_{pollutant}$ - default emission factor for NMVOC, 64 g/t bitumen [Gen-2].

Calculation of NMVOCs emissions

Table 4.41 provides the quantities of imported bitumen and NMVOCs emissions calculated by using 64 g/t bitumen emission factor for NMVOCs.

Table 4.41 NMVOCs emissions from the Use of Bitumen

Year	Quantity of bitumen imported, t	NMVOCs emission, t
2013	33,317.9	2.13
2014	28,972.1	1.85

Source: NSS

Time series

NMVOCs emissions time series from asphalt pavement are presented in Figure 4.26

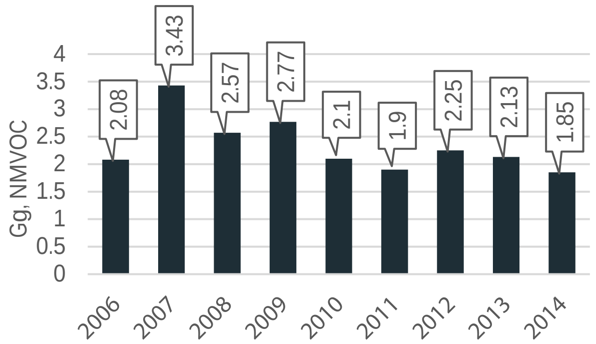


Figure 4.26 NMVOCs emissions time series from asphalt pavement

4.2.9.2 Solvent Use (2D3)

The use of solvents manufactured using fossil fuels as feedstocks can lead to evaporative emissions of various non-methane volatile organic compounds (NMVOC). NMVOCs emissions also occur during the use of Solvents. Methodologies for estimating these NMVOC emissions recommended in the EMEP/CORINAIR Emission Inventory Guidebook (EEA, 2016) were used [Gen-2].

Paint application

Calculations for NMVOCs from paint application were made by using emission factors (200 kg/t of paint used), from EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016 [Gen-2].

Calculations are based on data on quantities of produced, imported and exported paints, provided by the NSS [Ref-1, Ref-2].

Table 4.42 NMVOCs emissions from Use of Paints, t

Year	Emission of NMVOCs from use of paints
2013	4,447
2014	4,407

Time series

Figure 4.27 provides NMVOCs emissions time series from Use of Paints

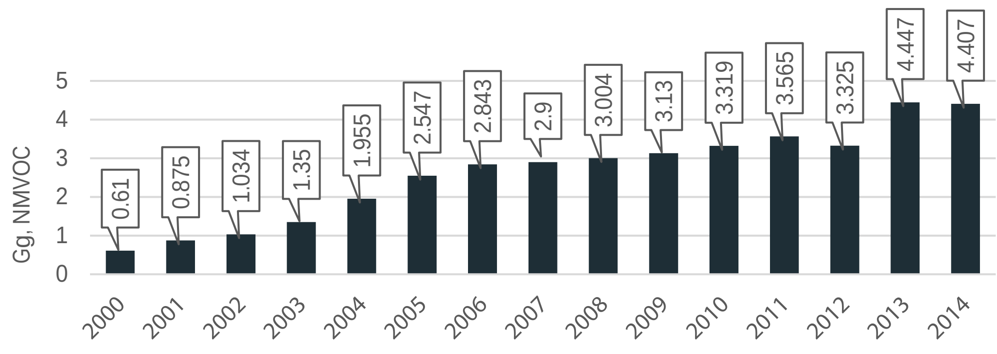


Figure 4.27 NMVOCs emissions time series from Use of Paints

Domestic solvent use

Emissions of NMVOCs from domestic solvent use were calculated by using the emission factor of 1kg per capita [Gen-2] and number of population, according to the NSS [Ref-1].

Table 4.43 Emissions of NMVOCS from domestic solvent use

Year	Emission of NMVOCS from domestic use of solvents, t
2013	3,017
2014	3,011

Time series

Figure 4.28 provides NMVOCs emissions time series from domestic solvent use.

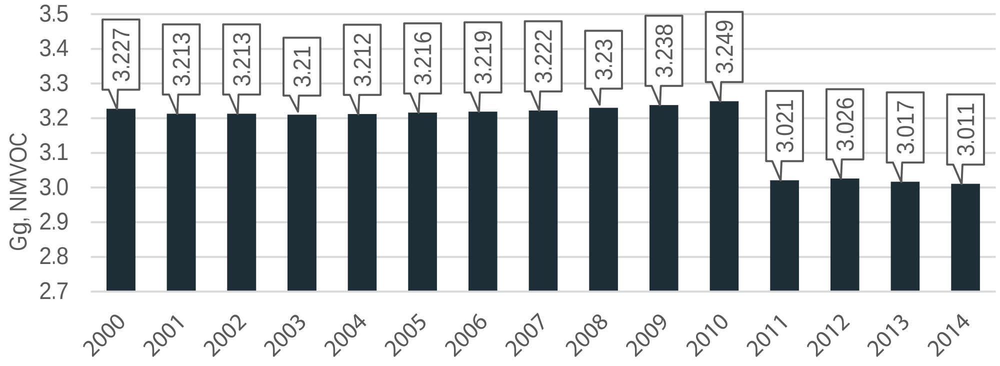


Figure 4.28 NMVOCs emissions time series from domestic solvent use

4.2.10 Food and Beverages (2H2)

Description of Source Category

This source category comprises NMVOCs emissions arising during cereal and fruit processing, as well as during meat, margarine, pastry and bread production.

Calculation of NMVOCs emissions

The emission factor provided in EMEP/EEA 2016 Guidebook was used which makes 2 kg NMVOCs for 1 ton product [Gen-2, Part B, 2H2, Table 3-1]. Production data were taken from the Yearbooks of the NSS [Ref -1].

Table 4.44 NMVOCs emissions from Production of Food and Alcoholic Beverages, t

Year	NMVOCs emissions
2013	890
2014	887

Time series

NMVOCs emissions time series from Food and Beverage are provided in Figure 4.29

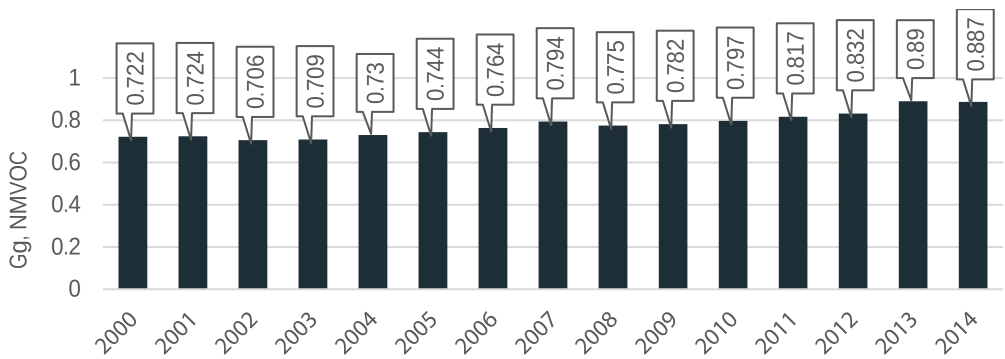


Figure 4.29 NMVOCs emissions time series from Food and Beverage

4.2.11 Assessment of emissions of fluorinated substitutes (F gases) for ozone depleting substances (ODS)

4.2.11.1 Overview of F-gases emissions assessment

In Armenia, as well as globally, F-gases are serving as alternatives to ozone depleting substances (ODS) which are being phased out under the Montreal Protocol. Armenia undertook commitments for ODS phase-out by having ratified the *Vienna Convention for the Protection of the Ozone Layer* and the *Montreal Protocol on Substances that Deplete the Ozone Layer*.

From F-gases Armenia largely uses hydrofluorocarbons (HFCs). Perfluorocarbons (PFCs) and SF6 are not used in the country.

Armenia has never had domestic production of HFCs. The country imports them as chemicals from UAE, sometimes from Iran and Turkey, while they come contained in products or equipment (sub-application) from a large number of other countries.

In general, Armenia started importing products and equipment containing HFCs after 2005 when the country launched its first country program for CFCs phase-out. In particular: Armenia adopted the Law on Substances that Deplete the Ozone Layer and sub-legislative acts for ensuring enforcement of the Law. Later, Armenia limited CFCs import and completely banned it in 2010. In parallel, the country has launched HCFCs phase-out program. All these measures resulted in a sharp increase of HFCs import since 2010.

F-gases form a separate category within the IPPU Sector. They are used in refrigeration and cooling devices, in air conditioning devices and as aerosols, as foam blowing agents and in fire protection and accounted for over 5 % of total national greenhouse gas emissions and nearly 68 % of the greenhouse gas emissions of IPPU sector in 2014.

HFC emissions which are caused by refrigeration and air conditioning (RAC) systems predominate in the overall HFCs emissions with the share of 94.5% in 2014. The emission share for other applications is much smaller and makes about 5.5% altogether: 3.22 % from Foam Blowing Agents, 2.15 % from Aerosols, and minor emissions, only 0.1 % of total HFC emissions from Fire Protection application.

From all HFCs, HFC-134a has the widest application area which is due to its multifunctional character: it is widely used as both an individual chemical and a blend (R-404A, R-410A, R-407C) component in all sub-applications of RAC which is the country’s HFCs key application area, and is also contained in aerosols as a propellant and in foam blowing as a foam blowing agent.

4.2.11.2 Source Categories description

The following application areas of HFCs exist in Armenia:

(2F) Product Uses as Substitutes for Ozone Depleting Substances

- **(2F1) Refrigeration and Air Conditioning**
  - (2F1a) Refrigeration and Stationary Air Conditioning
  - (2F1b) Mobile Air Conditioning
- **(2F2) Foam Blowing Agents**
- **(2F3) Fire Protection**
- **(2F4) Aerosols**

Emissions from solvents application have not been estimated due to the lack of the reliable data -the data on the solvents, received from the national customs service are of a general character and include no information on the content of HFCs in solvents.

Probably there is minor use of HFCs in some other sectors but they are not included in this report because of their negligible quantities.

4.2.11.2.1 Refrigeration and Air Conditioning (2F1)

RAC is a key application area in Armenia accounting for 94.5 % of total emissions in “Product Uses as Substitutes for Ozone Depleting Substances” category. It includes the following sub-applications: Refrigeration and Stationary Air Conditioning (2F1a) and Mobile Air Conditioning (2F1b).

Refrigeration and Stationary Air Conditioning sub-application includes domestic, commercial, industrial and transport refrigeration and stationary air-conditioning.

Mobile Air Conditioning sub-application includes mobile air-conditioning systems used in passenger cars, truck cabins, buses, and trains.

HFCs mostly used here include: HFC-134a and HFC blends - HFC-404A (HFC-125-44% / HFC-143a-52% / HFC-134a-4%), HFC-407C (HFC-32-23% / HFC-125-25% / HFC-134a-52%), HFC-410A (HFC-32-50% / HFC-125-50%).

HFCs generally replace CFC-12 formerly used in RAC equipment and HCFC-22 which is currently being phased out.

4.2.11.2.2 Foam Blowing Agents (2F2)

This application area accounts for 3.22 % of HFC total emissions in 2014 and is the second with its share of HFC emissions. HFCs are used in foam blowing as foam blowing agents.

Activities conducted under this report enabled to obtain data on HFC-134a, HFC -245fa, HFC -365mfc HFC -152a contained in the closed-cell foams imported into the country for further insulation applications. Here, they mainly substitute the formerly used CFC-11, as well as HCFC-141b contained in imported pre-blended polyol used in foam blowing.

4.2.11.2.3 Fire Protection (2F3)

HFC emissions caused within this application are negligible and account for 0.1 % of HFC total emissions in 2014.

There are two general types of fire protection (fire suppression) equipment that use HFCs as partial replacements for halons: portable (streaming) equipment, and fixed (flooding) equipment. In this application HFCs can be used as both propellants and active agents. Here they serve as alternatives to Halon-1211 formerly used in portable fire extinguishers, and Halon-1301 in fixed systems.

According to the survey results, from all HFCs typical of the application area only HFC-227ea was detected to be used in Armenia and its use was limited to fixed (flooding) fire-suppression systems.

4.2.11.2.4 Aerosols (2F4)

In this application HFCs are used as propellant or solvent including metered dosed inhalers (MDIs) used in medicine for patients with asthma, personal care products (e.g. hair care, deodorants, shaving cream), household products (e.g. air-fresheners, oven and fabric cleaners), aerosol paints.

The application is the third with its share of HFCs emissions accounting for 2.15 % in 2014.

The study mainly covers the HFCs used exclusively as a propellant in aerosols and not as a solvent. Propellants used in aerosols imported by Armenia include: HFC -134a, HFC227ea and HFC-152a. They generally substitute not only CFC-12 formerly used in this sector but also CFC-11, and sometimes CFC-114.

During the survey the inventory compilers have not discovered any other applications of HFCs in Armenia.

Main application areas for HFCs in the country are provided in Table 4.45.

Table 4.45 Main application areas for HFCs as ODS substitutes in Armenia

HFCs	Refrigeration and Air Conditioning	Aerosols (propellant)	Foam Blowing Agents	Fire Protection
HFC-134a	x	x	x	
HFC -32	x			
HFC -125	x			
HFC -143a	x			
HFC -227ea				x
HFC -245fa			x	
HFC -365mfc			x	
HFC -152a		x	x	

4.2.11.3 Data collection sources

Data for the emissions estimate have been collected from:

- RA Revenue State Committee [IndF.Ref-1]
- RA National Statistical Service [Ref-6], [Ref-1]
- National HCFCs Phase-out Management Plan for Armenia, Phase 2, 2015 [Ref-7]
- Studies and assessments from a number of companies and specialists/experts.

Data collection activities started with the study of the National HCFCs Phase-out Management Plan for Armenia, Phase 2, 2015, in order to get a good understanding of HFCs use in the country and their quantities [Ref-7].

The next step was studying the Nomenclature of Foreign Economic Activity of the CIS [Gen-3] and the Customs and Enforcement Officers Information Note jointly published by UNEP and WCO in 2012 [Gen-4]. Data collection and calculations were based on the inventory reports and studies on the use of ODS alternatives, made by other countries, a number of specialized IPCC communications and reports, as well as on several sources and materials from the internet [Gen-5; Gen-6; Ref-3; Ref-4; Ref-5].

Methodological issues

According to the 2006 IPCC Guidelines [Gen-1, Volume 3, Chapter 7], data collection and emissions assessment can be done by applying the methods and approaches described below.

Table 4.46 Overview of data requirements for different Tiers and Approaches

	Approach A (emission factor approach)	Approach B (mass-balance approach)
Tier 2 (emission estimation at disaggregated level)	• Data on chemical sales and usage pattern by sub-application [country-specific or globally/regionally derived] • Emission factors by sub-application [country-specific or default]	• Data on chemical sales by sub-application [country-specific or globally/regionally derived] • Data on historic and current equipment sales adjusted for import/export by sub-application [country-specific or globally/regionally derived]
Tier 1 (emission estimation at aggregated level)	• Data on chemical sales by application [country-specific or globally/regionally derived] • Emission factors by application [country-specific or (composite) default]	• Data on chemical sales by application [country-specific or globally/regionally derived] • Data on historic and current equipment sales adjusted for import/export by application [country-specific or globally/regionally derived]

HFC emissions assessment for all applications with the exception of RAC was implemented by applying Tier 1a method. In particular, for Aerosols such an assessment is considered to be preferable as half the chemical charge from all aerosol products escapes within the first year after manufacture and the remaining charge escapes during the second year.

It would have been reasonable to apply Tier 2a method or Tier 2b method for emissions assessment from *Foam Blowing Agents* and *Fire Protection* as in this case emission profiles vary substantially by sub-application. However, taking into consideration the absence of disaggregated activity data, again the preference was given to Tier 1a method.

In this report emissions from *Foam Blowing Agents* application were assessed based on the approach provided in Moldova's ODS Alternative Survey Report of 2016 [Gen-6] - the amounts of HFCs were calculated for each type of the foam product imported into the country. Though this approach for emissions calculation can't be considered as of a higher tier when compared to the one used in the previous reports, nevertheless, it allows getting a more realistic and complete view of the situation. As a result, while in the previous inventories Foam Blowing Agents application was in the third place with its share of emissions calculated based on the data provided by a single foam end-user, now it comes second with its emissions amount.

Since *RAC* is defined as a key application within the category and there are disaggregated activity data available for calculations, HFC emissions from RAC were estimated applying Tier 2a method (estimation performed at a disaggregated level with country-specific data by sub-application and a default emission factor selected by sub-application from the 2006 IPCC Guidelines).

4.2.11.4. Emission calculation equations and choice of emission factors

Due to unavailability of accurate measurements for estimating emission factors for applications and sub-applications, all calculations were made by using 2006 IPCC Guidelines default factors which, prior to using, were compared with estimates made by experts in order to avoid incorrectness [Gen-1, Volume 3, Chapter 7].

Emission factors are required for all methods following Approach A. In general terms, emission factors can be of two distinct types [Gen-1, Volume 3, Chapter 7]:

1. Emission factors derived from actual measurements of products or equipment at a national level during the various phases of their lifecycle (country-specific), or
2. Emission factors inferred from wider regional or global sub-application experience (e.g., default).

In all *RAC* sub-applications emissions were calculated using equations 7.10, 7.11, 7.12, 7.13, 7.14 described in Chapter 7 "Product Uses as Substitutes for Ozone Depleting Substances (F gases) emissions", Volume 3 "Industrial processes and product use" of 2006 IPCC Guidelines and the factors described in Table 7.9 in the same source [Gen-1]. Selection of a factor from the said range was guided by the country-specific characteristics of each sub-application.

Although the quantities of F-gases in general and HFCs in particular used in *Aerosols* were calculated by sub-application, it should be noted that calculation of emissions was made by applying Tier 1a method as the default emission factor used for the entire spectrum of aerosol products was 0.5. HFC emissions from *Aerosols* were calculated according to Equation 7.6 [Gen-1, Volume 3, Chapter 7].

For *Foam Blowing Agents* application two types of activity data are needed in order to prepare the emissions estimates:

1. the amount of chemical used in foam manufacturing in the country and not subsequently exported,
2. the amount of chemical contained in foam imported into the country.

In Armenia emissions occur only from imported closed-cell foam and were calculated according to the Equation 7.7 [Gen-1, Volume 3, Chapter 7].

Data on the quantities of the imported closed-cell foam were derived from the RA Customs Service. Afterwards, based on a number of foreign articles and studies, the quantities of the HFCs (by chemicals) contained in the imported foam were calculated by foam sub-applications [Gen-6; Gen-3; Ref-6; IndF.Ref-1]. The emission factor of the first year loss (EFAL) was considered to be equal to 0 assuming that the emissions had been released in the producing country before the foam crossed the borders of Armenia, and the annual emissions factor (EFAL) caused by the loss was estimated as 0.045 [Gen-1, Volume 3, Chapter 7.4, Table 7.7]. This approach allows getting a more complete overview of the emissions as compared to the calculations made in the previous years based on the data provided by a single foam end-user.

To ensure time series consistency, 2006-2012 emissions were recalculated using the new approach.

For *Fire Protection* application area emissions were calculated according to Equation 7.17 of the Guidelines [Gen-1, Volume 3, Chapter 7.6]. Only one factor was used for calculations - EF annual emissions from systems (except gas removal from the system for destruction or other purposes), which is equal to 0.04 according to the Guidelines [Gen-1, Volume 3, Equation 7.17].

The quantity of annual losses of the agent during its recovery and recharge from system to system (RRLt) is 0 for Armenia due to the fact that there are few such systems in the country and no data is available on the agent's recovery or recycling.

Estimated emissions (t) were entered into the Software for deriving final data in CO_2 equivalent.

For *Refrigeration and Air Conditioning* application area the IPCC Software allows to enter data only for 2 sub-applications, they are: (2F1a) *Refrigeration and Stationary Air Conditioning* and (2F1b) *Mobile Air Conditioning.* Therefore all the data collected for the following sub-applications: Domestic refrigeration, Commercial refrigeration, Industrial refrigeration, Transport refrigeration and Stationary air conditioning, were entered in the software under 2.F1.a sub-application, while those for Mobile Air-conditioning went under 2F1.b.

For incorporating the above-mentioned 5 sub-applications in a common software sub-application 2.F1.a, average annual emission factors were estimated for every chemical used in the sub-application.

The average factors are as follows for:

Chemical	Annual average emissions factor
Refrigeration and Stationary Air Conditioning (2F1a)	
HFC-134a	0.21
HFC-32	0.22
HFC-125	0.28
HFC-143a	0.36
Mobile Air Conditioning (2F1b)	
HFC-134a	0.27

4.2.11.5 Emissions assessment, time series

Table 4.47 provides HFCs emissions by application areas.

Table 4.47 HFCs emissions by application areas (Gg $CO_{2eq.}$), 2010-2014

Year	Refrigeration and Air Conditioning	Aerosols	Foam Blowing Agents	Fire protection	Total
2010	245.54	9.09	11.81	0.354	**255.38**
2011	308.21	10.13	13.23	0.426	**319.44**
2012	372.67	10.27	14.68	0.284	**397.913**
2013	435.92	10.91	16.18	0.5	**463.52**
2014	502.66	11.44	17.11	0.53	**531.74**

As indicated in the Table 4.47, in Armenia as well as in many other countries *RAC* sub-application causes the largest amount of HFC emissions within the Product Uses as substitutes for Ozone Depleting Substances category, accounting for 94.53 % of total HFC emissions in 2014, followed by *Foam Blowing Agents* with the share of 3.22 %. *Aerosols* accounted for 2.15 % and *Fire Protection* – for 0.1 % of total HFC emissions in 2014 (Figure 4.30).

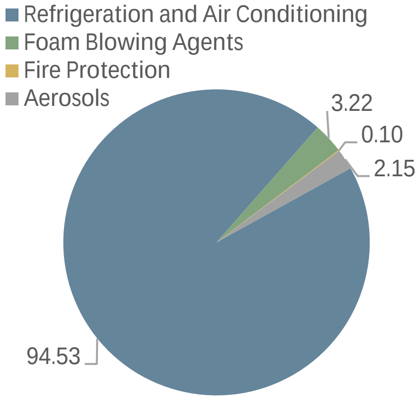


Figure 4.30 HFCs total emissions by application areas (Gg $CO_{2eq.}$), 2014

2004-2014 time series of HFCs emissions from RAC and Foam Production applications are shown in Figure 4.31.

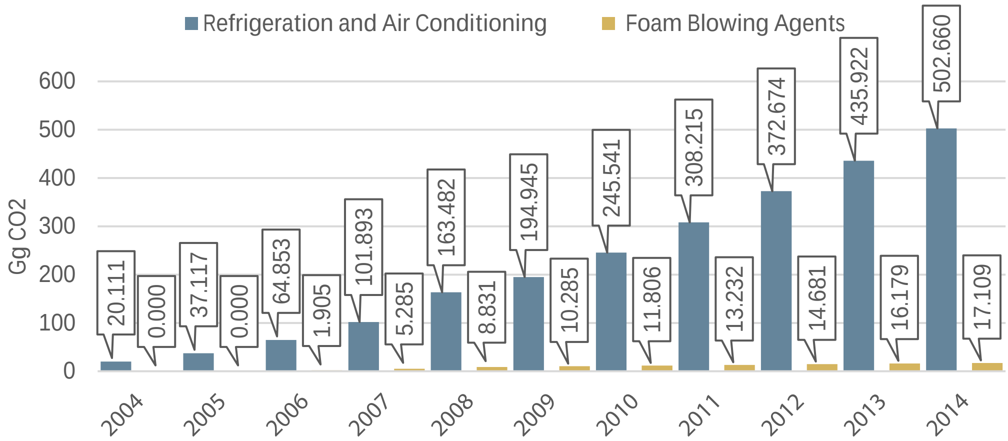


Figure 4.31 HFCs emissions from RAC and Foam Blowing Agents applications for 2004-2014, (Gg $CO_{2eq.}$)

Figure 4.31 shows sustainable annual growth of HFCs emissions both from *RAC* and *Foam Blowing Agents* applications. Such increase in RAC emissions is due to the fact that in Armenia as well as globally, in developing countries in particular, disregarding active campaign for using natural refrigerants (mainly ammonia, carbon dioxide, and carbon) as ODS alternative substances, HFCs are still considered as main substitutes for CFCs and HCFCs regulated under the Montreal Protocol.

The situation is quite different with regard to *Aerosols* application where a slight increase of emissions is observed (Table 4.47). This is because HFCs substitute only 2% of the formerly used CFC-12, CFC-11 and sometimes CFC-114. The remaining 98% of demand is met by hydrocarbons, dimethyl ether, carbon dioxide, nitric propellants and alternative non-synthetic substances. Global trends show that in this sub-category natural refrigerants would gradually come to replace HFCs as substitutes.

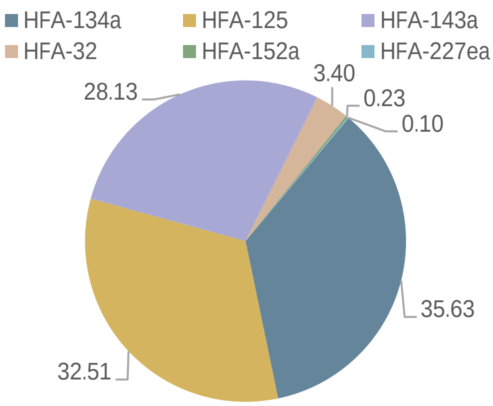


Figure 4.32 HFCs emissions by chemicals, %, 2014

The situation is similar with regard to *Fire Protection* and *Foam Blowing Agents* applications (Table 4.47). Not only did imports of HFCs in these application areas start relatively late - in 2004 and 2006 respectively, but they are also not the only ODS substitutes. Natural substances such as hydrocarbons and carbon dioxide are also used as substitutes in *Foam*

Blowing Agents, and nitrous oxide, carbon dioxide and pressurized air are used in Fire Protection.

HFC-134a is the most widely used HFC. It was due to its use as an individual chemical as well as a component contained in blends such as R-404A, R-410A, R-407C in the whole RAC application. HFC-134a is also used in Aerosols as a propellant and as a blowing agent in Foam Blowing Agents.

HFC emissions by chemicals for 2014 are given in Figure 4.32.

Figure 4.33 describes time series of HFCs emissions by chemicals, for 2000-2014.

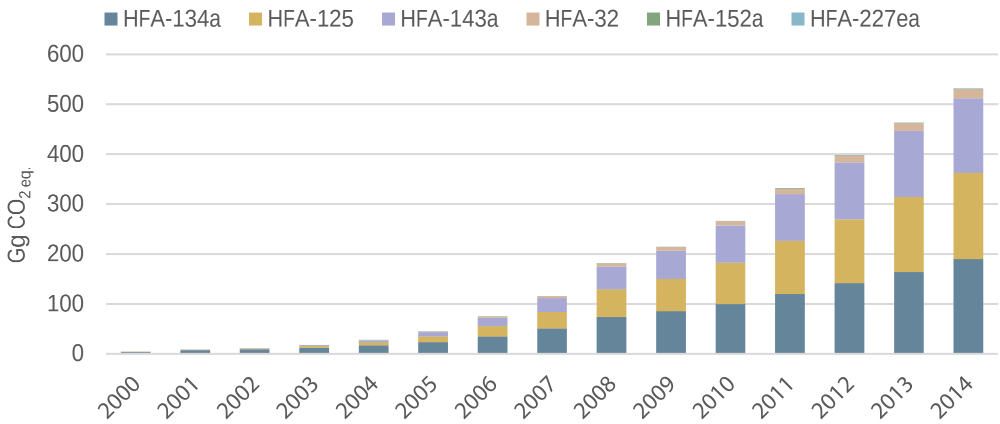


Figure 4.33 Emissions of HFCs by chemicals, 2000-2014

4.2.11.6 Completeness of data

As a result of data collection in this sector for the use of the Tier 2a method, almost 75% of the RAC application was covered. It was possible due to the availability of the relevant database and experience obtained by the experts in the course of the years.

Data for *Foam Blowing Agents* application area were estimated based only on the amount of the imported foams, provided by the national customs service. The data completeness for the area is assessed by the experts to be 60%.

According to expert judgment, 65% of *Aerosols* application was covered in the data collection process, including aerosols for personal care and household cleaning, as well as aerosol paints.

Calculations for *Fire Protection* application were made based on statistical data and expert judgment. Completeness of data here equals 50%.

4.2.11.7 Uncertainty assessment

In the *RAC* application area activity data were collected by sub-applications (Tier 2a) which already ensures their relatively low uncertainty. The statistical data collected were cross-checked with the information obtained from local manufacturers through verbal inquiries. As a result, activity data uncertainty for the application was estimated to be 30%.

For the RAC emissions calculations the inventory compilers used the default emission factors indicated in the Guidelines. Since the factors might differ from the country-specific ones, the average uncertainty of the emission factors was estimated as 25%.

Data for *Foam Blowing Agents* were collected and calculated by using Tier 1a method. The emissions were estimated based on the data provided by the national customs service with almost no information received from local consumers which would have allowed data cross-checking. Taking all this into account, uncertainty for the application was assessed rather high – 45-50%.

For *Aerosols* uncertainty was estimated to be 30% as per expert judgment.

In *Fire Protection* data uncertainty for developing countries makes more that 15% [Gen-1, Volume 3]. Taking into account the use of Tier 1a when collecting and calculating data for the application as well as lack of the data in the sector, the overall uncertainty for the application was estimated by the experts to be 40%.

4.2.11.8 Improvements foreseen

The main challenges faced while developing F-gases inventory are as follows: common customs codes used for the products covered by the inventory, which makes rigorous calculation of the imported chemicals/products difficult; lack of complete and reliable data on the chemicals' consumption within certain applications; as well as lack of the expert's experience in this relatively new field.

The data gaps are planned to be filled in to the extent possible while making the next inventory report by using the new knowledge and experience obtained in the course of the years.

The inventory experts would appreciate cooperating with international specialists in data collection for solvents application area and developing a country-specific data collection methodology for the sector, based on the existing international practice. The developed methodology would further allow making an inventory for that certain application area in the country as well.

4.2.11.9 Summary table of HFC emissions

The table 4.48 gives an overview of the HFCs emissions in 2014 by chemicals and applications.

Table 4.48 Armenia's HFCs emissions by chemicals and applications, 2014

Categories	HFC-32	HFC -125	HFC -134a	HFC -152a	HFC -143a	HFC -227ea	HFC -245fa	HFC -365mfc	Total HFCs
SAR GWPs (100 year time horizon) Conversion Factor (1)	650	2800	1300	140	3800	2900			
Emissions in original mass unit, t									
2.F - Product Uses as Substitutes for Ozone Depleting Substances	27.823	61.741	145.753	8.681	39.357	0.183	0.778	0.699	**283.355**
2.F.1 - Refrigeration and Air Conditioning	27.823	61.741	124.724	NA	39.357	NA			**253.645**
2.F.1.a - Refrigeration and Stationary Air Conditioning	27.823	61.741	65.548	NA	39.357	NA			**194.469**
2.F.1.b - Mobile Air Conditioning	NA	NA	59.176	NA	NA	NA			**59.176**
2.F.2 - Foam Blowing Agents			12.614	5.076		NA	0.778	0.699	**17.690**
2.F.3 - Fire Protection		NA	NA			0.183			**0.183**
2.F.4 - Aerosols			8.415	3.605		NA			**12.02**
Emissions in CO_2 equivalent unit, Gg									
2.F - Product Uses as Substitutes for Ozone Depleting Substances	18.085	172.876	189.479	1.215	149.557	0.531			**531.743**
2.F.1 - Refrigeration and Air Conditioning	18.085	172.876	162.142	NA	149.557	NA			**502.660**
2.F.1.a - Refrigeration and Stationary Air Conditioning	18.085	172.876	85.213	NA	149.557	NA			**425.731**
2.F.1.b - Mobile Air Conditioning	NA	NA	76.929	NA	NA	NA			**76.929**
2.F.2 - Foam Blowing Agents			16.398	0.711		NA			**17.109**
2.F.3 - Fire Protection		NA	NA			0.531			**0.531**
2.F.4 - Aerosols			10.940	0.505		NA			**11.444**

Table 4.49 IPPU Sectoral Table, 2014

Categories	Gg			Emissions $CO_{2eq.}$ (Gg)	Emissions (Gg)	
	CO_2	CH_4	N_2O	HFCs	NMVOCs	SO_2
2 Industrial Processes and Product Use	250.792	NA	NA	531.743	10.155	39.010
2A Mineral Industry	250.792			NA	NA	NA
2.A.1 Cement Production	223.402			NA	NA	NA
2.A.3 Glass Production	7.231			NA	NA	NA
2.A.4d Non-Cement Clinker Production	20.160			NA	NA	NA
2C Metal Industry					NA	39.010
2.C.2 Ferroalloys Production					NA	7.610
2.C.7 Other: Copper Production					NA	31.400
2.D Non-Energy Products from Fuels and Solvent Use					9.268	NA
2.D.3 Solvent Use					7.418	NA
2.D.4 Bitumen/Asphalt Production and Use					1.85	NA
2.F Product Uses as Substitutes for Ozone Depleting Substances				531.743	NA	NA
2.F.1 Refrigeration and Air Conditioning				502.660	NA	NA
2.F.1.a Refrigeration and Stationary Air Conditioning				425.731	NA	NA
2.F.1.b Mobile Air Conditioning				76.929	NA	NA
2.F.2 Foam Blowing Agents				17.109	NA	NA
2.F.3 Fire Protection				0.531	NA	NA
2.F.4 Aerosols				11.444	NA	NA
2.H Other					0.887	NA
2.H.2 Food and Beverages Industry					0.887	NA

4.3 Agriculture, Forestry and Other Land Use Sector

4.3.1 Sector description

According to the structure, activities and source categories in the 2006 IPCC "Guidelines for Inventories of Greenhouse Gases", the AFOLU Sector includes three categories: *3A Livestock*, *3B Land* and *3C Aggregated sources and non-CO_2 emissions sources on land*, with a lot of corresponding sub-categories. Emissions and removals were estimated and reported for the following categories and sub-categories:

(3A) Livestock: methane and nitrous oxide emissions including:

- (3A1) Enteric Fermentation (CH_4 emissions)
- (3A2) Manure Management (CH_4 and N_2O emissions)

(3B) Lands: following sub-categories of GHG emissions and removals are considered in Land category:

- (3B1) Forest Land
  - (3B1a) Forest Land Remaining Forest Land
  - (3B1b) Land Converted to Forest Land
- (3B2) Cropland
  - (3B2a) Cropland Remaining Cropland
  - (3B2b) Land Converted to Cropland
- (3B3) Grassland
  - (3B3a) Grassland Remaining Grassland
  - (3B3b) Land Converted to Grassland
- (3B4) Wetland
- (3B5) Settlement
- (3B6) Other Land

(3C) Aggregate sources and non-CO_2 emissions sources on land

- (3C1) GHG emissions from biomass burning
- (3C3) Urea application
- (3C4) Direct N_2O emissions from managed soils
- (3C5) Indirect N_2O Emissions from managed soils
- (3C6) Indirect N_2O Emissions from manure management.

4.3.2 Key Categories

The following categories were identified as key categories with the level assessment: *3A1 Enteric Fermentation* – CH_4; *3B1a Forest Land Remaining Forest Land* – CO_2; *3C4 Direct N_2O Emissions from Managed Soils* and *3C5 Indirect N_2O Emissions from Managed Soils*.

4.3.3 Improvements made

The following improvements have been made in the Agriculture, Forestry and Other Land Use Sector inventory:

- Emissions from 2 new categories were calculated:
  - Carbon dioxide and nitrogen emissions from Wetlands (*3B4ai Peatlands remaining peatlands*);
  - *Emissions from biomass burning in grasslands (3C1c).*
- In the sub-category *Direct N_2O Emission from managed soils* (3C4) a new source for the N_2O emission - "Urine and dung N deposited on pasture, range and paddock by grazing animals" was considered using the version 2.18 of the IPCC software package (this source was not included in the version of IPCC software package 2.12, which was used for the Armenia's 2012 National Inventory Report. Consequently, the *Direct N_2O Emissions from managed soils* time series for 2000-2012 have been recalculated for ensuring 2000-2014 time series consistency.
- Data on *Land Converted to Forest Land* for 2011 and 2012 have been adjusted.

4.3.4 "Agriculture" Sub-Sector

4.3.4.1 Overview of "Agriculture" sub-sector emissions assessment

Emissions from the agriculture sub-sector were 2044.7 Gg $CO_{2eq.}$ in 2014. Agricultural emissions include methane (CH_4) emissions from the enteric fermentation of domestic livestock, manure management and biomass burning, CO_2 emissions from urea application as well as nitrous oxide (N_2O) emissions from manure management and direct and indirect emissions from managed soils following additions of urea-containing fertilizer and crop residue.

The agriculture sub-sector accounted for 19.56 % of Armenia's total greenhouse gas emissions in 2014. The CH_4 emissions from enteric fermentation were 59.15 %, the CH_4 emissions from manure management were 4.74 %, the N_2O emissions from manure management were 7.54 % and the N_2O emissions from managed soils were 28.55 % of the total agricultural emissions. The share of emissions from the biomass burning is negligible.

The prevailing part of the CH_4 emissions from enteric fermentation – 90.3 %, are generated by cattle, however emissions generated by horses, pigs, sheep, goats, buffalos and asses are reported as well. Most of the N_2O emissions – 78.8 %, from the "Agriculture" sub-sector are direct and indirect N_2O emissions from managed soils.

4.3.4.2 Description of "Agriculture" sub-sector

Emissions and removals were estimated and reporting for the following categories and sub-categories done:

(3A) Livestock

- (3A1) Enteric Fermentation
  - (3A1a) Cattle
    - (3A1ai) Dairy Cows
    - (3A1ab) Other Cattle
  - (3A1b) Buffalo
  - (3A1c) Sheep
  - (3A1d) Goats
  - (3A1f) Horses
  - (3A1g) Mules and Asses
  - (3A1h) Swine
- (3A2) Manure Management
  - (3A2a) Cattle
    - (3A2ai) Dairy Cows
    - (3A2ab) Other Cattle
  - (3A2b) Buffalo
  - (3A2c) Sheep
  - (3A2d) Goats
  - (3A2f) Horses
  - (3A2g) Mules and Asses
  - (3A2h) Swine
  - (3A2i) Poultry

(3C) Aggregate sources and non-CO_2 emissions on land

- (3C1) GHG emissions from biomass burning
  - (3C1a) GHG emissions from biomass burning in forest land
  - (3C1c) GHG emissions from biomass burning in grasslands
- (3C3) Urea application
- (3C4) Direct N_2O emissions from managed soils

(3C5) Indirect N_2O emissions from managed soils

(3C6) Indirect N_2O emissions from manure management

4.3.4.3 Key sources

Methane emissions from enteric fermentation of domestic livestock is a key source of GHG emissions accounted for 10.9 % of the Armenia's total GHG emissions in 2014. Dairy cows and Other Cattle accounted for 90.3% of CH_4 emissions derived from enteric fermentation in 2014 and so those species of animals can be identified as significant.

Direct and Indirect N_2O Emissions from managed soils are also identified as key categories in terms of emissions level accounted for 4.1% and 1.1% of the total emissions in 2014, respectively.

4.3.4.4 Methodologies, activity data and emission factors

4.3.4.4.1 Livestock (3A)

4.3.4.4.1.1 Enteric fermentation (3A1)

Methodology

GHG emissions from cattle enteric fermentation were estimated according to the 2006 IPCC Guidelines [Gen-1, Volume 4] Tier 2 Approach applying national emission factors. The methodology for estimating annual average livestock population was described in details in the Third National Communication [Ref-4]. The methodology for calculation of country-specific emissions factors was described in Annex 2 of the NIR 2012.

Methane emissions from enteric fermentation of other animals were estimated according to the Tier 1 Approach by applying emission factor for developing countries provided in 2006 IPCC Guidelines.

Activity data

Livestock population

The number of livestock (Table 4.50) is the key indicator for estimating GHG emissions from enteric fermentation. The livestock annual average population was calculated by using available statistical information as well data provided by official statistics [AFOLURef-7].

The following data were obtained from official national statistics for calculating the average annual livestock population:

1. Data published by the NSS:

- Livestock population (by category and sub-categories) as of January 1 of each year
- Cattle and poultry sold for slaughter (total live-weight, thousand tons)
- Animals and poultry sold for slaughter by slaughter weight, in thousand tonnes, for each animal sub-category
- Exports and imports of domestic animals (quantity, live-weight)
- Annual average milk production.

2. Information provided by the RA Ministry of Agriculture on the average live-weight of domestic animals (kg), feed digestibility (%), growing cattle average weight gain per day (kg/day), milk fat content (%), number of slaughtered and lost livestock, etc.

Seasonal births or slaughters may cause the population size to expand or contract at different times of the year, which will require the population numbers to be adjusted accordingly. To this end, the cross-checking calculation of the livestock annual average population (use the data concerning the volume of meat and number of slaughtered and lost domestic animals) was implemented. Most animals in these growing populations are alive for only part of a complete year and their number is reflected in neither year-beginning nor in year-ending official statistical indicators. Animals should be included in the populations regardless if they were slaughtered for human consumption or die of natural causes.

One of the reasons of change in livestock population in 2013-2014 periods were import and export of livestock. As the imported quantity had already been taken into account, the number of exported animals was added while calculating the annual average population.

The following data were used to calculate livestock annual average population: population data at the beginning and at the end of year, livestock import and export data as well as evaluation data on the volumes of animals sold for slaughter and year-old growing livestock estimates. The monthly distribution of slaughtered cattle was done on the volume of the monthly produced meat.

For the calculation of the annual average population of poultry the following data were used: the number of headcount as of the beginning and at the end of the year, export and import data, as well as the number of broiler chickens grown and slaughtered during the year. The export data for poultry did not include 1-2 daily chicks.

In accordance with the methodological recommendations of the 2006 IPCC Guidelines "broiler chickens are typically grown approximately 60 days before slaughter. Estimating the annual average population as the number of poultry grown and slaughtered over the course of a year would greatly overestimate the population, as it would assume each bird lived the equivalent of 365 days. Instead, one should estimate the average annual population as the number of animals grown divided by the number of growing cycles per year." [Gen-1, Volume 4, Chapter 10, p. 10.8].

In 2014 the volume of poultry meat produced for slaughter was 8.8 thousand tons, and the total population of poultry - 7703.8 thousand heads. Based on this, the annual average number of broilers intended for slaughtering was calculated using the formula proposed in the guideline: Annual average number (60 days x 7,703,711) / 365 = 1,266,363. Similarly, the average annual number of poultry in 2013 was also calculated.

The annual average populations of buffalos, horses, mules and asses were calculated by using the average arithmetic mean of the livestock number by 1 January 2013, 2014 and 2015. The methodology for calculating the annual average number of domestic animals is provided in details in the Third National Communication's National Inventory Report [Ref-4].

As a result of the calculations, the following data were obtained (Table 4.50), which were used for calculating greenhouse gas emissions from livestock.

Table 4.50 Livestock annual average population, heads

	2012	2013	2014	2014 in comparison with 2012, %
Cattle, *from which*	776,462	835,212	847,991	109.2
Dairy Cows	311,908	359,462	365,676	117.2
Bulls	24,728	29,470	31,238	126.3
Growing cattle	439,826	446,280	451,076	102.6
Buffalo	502	631	731	145.6
Sheep	876,476	929,948	952,142	108.6
Goats	41,179	42,001	43,610	105.9
Horses	10,345	11,232	11,686	113.0
Mules and Asses	3,957	3,814	3,682	93.1
Swine	211,955	253,330	325,782	153.7
Poultry	4,876,201	5,274721	5,707249	117.0

Source: Expert assessment based on the NSS and RA Ministry of Agriculture data

As can be seen from Table 4.50, in 2014, as compared to the 2012 indicator, an increase in the number of all livestock categories population has been recorded, resulting in increased emissions both from enteric fermentation and manure management (Figure 4.34 and 4.35).

Quality Assurance/Quality Control

The primary condition for data collection is to ensure completeness and representation, i.e., when designing the GHG Inventory, all the major animal categories managed in the country should be considered. At the same time, before using the data, it is necessary to examine how the data was collected, processed and aggregated, and to what extent the data reflected the actual situation. For example, data on the number of domestic animals are published by the NSS of RA as of January 1 of each year, which does not reflect the number of livestock born, lost or committed for slaughter during the year for a certain period of the year. As a result of the additional calculations the most complete information on the number of animals was received. Thus, according to the Guidelines, the impact of production cycles and seasonal changes has been taken into account in calculating the annual average population of domestic animals.

To ensure data completeness and reduce uncertainties the following actions were done: the calculations were done using official statistics as well as the adjustment of the annual average number of domestic animals based on monthly data calculations on volume of meat, data on slaughter and loss of animals. Such approach enabled to have a more realistic view for livestock population.

Activity data uncertainty

According to the 2006 IPCC Guidelines the uncertainty associated with populations will vary widely depending on source, but should be known within ± 20%.

The possible uncertainty of cattle population is estimated as 4-6 % (expert judgement). At the same time, according to monitoring conducted by the Agriculture department of RA NSS, during the livestock population census deviation on population data were assessed up to 3 per cent as of January 1. As a result, the possible uncertainty of cattle population is estimated about from 8% to 10% uncertainty due to the existing deviations in data on livestock population. The uncertainty of the other livestock population is estimated ± 20%.

In order to check the quality and uncertainty of the data obtained by the method used for recycling of domestic animals, these results were compared with the Agricultural Census data in Armenia, 2014. During the agricultural census, the number of domestic animals was recorded as of October 10, 2014 [AFOLURef-8]. The comparison of these data with those published by the NSS (as of January 1 of each year) and the data obtained as a result of recalculation shows that the number of animals in the country is greater than the number of animals registered at the beginning of the year and much less different from data obtained by expert judgement (Table 4.50, Table 4.51 and Annex 7, Table 2). Thus, the animal population recalculation method has provided better quality data than published by the NSS as it takes into account all changes in the animal population during the year.

Table 4.51 Population of livestock and poultry at the 10.10.2014, heads

Cattle	Dairy Cows	Buffalo	Swine	Sheep and goats	Horses	Mules and Asses	Rabbit	Poultry
764,217	347,795	704	170,646	832,274	9,092	1,891	51,641	5,249,366

Emission factors

Enteric fermentation of cattle is a significant sub-category in the enteric fermentation category, which, in its turn, is the key source of emissions. The emissions from enteric fermentation of cattle were estimated by applying Tier 2 Approach using the animal's country-specific characteristics and national emission factors. Emissions from enteric fermentation of other animals were estimated according to Tier 1 Approach using default emission factors that are most appropriate for the country's livestock characteristics for each animal category.

The calculation of the national emission factors by Tier 2 Approach and the data necessary for estimation are provided in Annex 7 (Table 5), including, in particular: animal live weight, milk production per day (kg/day) and fat content (%), daily gross energy intake for cattle, feed digestibility (%), methane conversion factor (percentage of feed energy converted to methane), feeding situation: confined, grazing, pasture conditions, etc.

The national emissions factors from cattle enteric fermentation were calculated using the activity data and country-specific characteristics of the cattle in Armenia: for dairy cows-80.5 kg methane/head/year (2013) and 81.3 kg methane/head/year (2014), for bulls-63.1 kg methane/head/year, and for growing cattle- 44.8 kg methane/head/year (Table 4.52).

In estimating emissions from poultry the number of broilers is separated from the number of laying hens, which resulted in reducing uncertainties of emissions from poultry although increasing emissions.

Emission factors uncertainty

Emission factor estimates using the Tier 2 method are likely to be in the order of ±20% [Gen-1, Volume 4, Chapter 10, p. 10.33]. Therefore uncertainty of the emission factor for the cattle was estimated of ±20%.

As the emission factors for the Tier 1 method are not based on country-specific data, they may not accurately represent a country's livestock characteristics, and may be highly uncertain as a result. Emission factors estimated using the Tier 1 method are unlikely to be known more accurately than +30% and may be uncertain to +50% [Gen-1, Volume 4, Chapter 10, p. 10.33]. Therefore emission factors uncertainty for the other species were estimated ±40%.

There are significant differences between activity data and factors for Cattle offered by Tier 1 Approach [Gen-1] and activity data for livestock in Armenia. In particular, Tire 1 Method provides for cows: emissions factor - 68kg head/year, milk yield rate - 1650kg head/year or 4.5kg head/day, while for Armenia according to the data from RA NSS activity data for cows are: 2054kg head/year (2013) and 2102 kg head/year (2014) or about 5.7 kg head/day. Tier 1 Method provides 350kg of average live weight for dairy cows, while for Armenia according to the data from RA Ministry of Agriculture, average live weight of cows is 440kg and 445kg for 2013 and 2014 respectively. The difference is much greater for bulls, which ended up in a greater deviation in estimates made by using Tier 1 and Tier 2 Methods [Gen-1, Chapter 10, Volume 4].

Comparison of emission factors provided in Guideline [Gen-1, Volume 4, Table 10.11] with country-specific factors (see Table 4.52) shows that country-specific factors for cows are greater by 18.5-19.5%, for bulls- by 34-35%, because the values of activity data used for calculation of country-specific emission factors (weight, lactation etc.) are larger than those provided in the Guideline, while country-specific factors for growing cattle is smaller by 4.7% due to the difference between the value of activity data.

Table 4.52 Emission factors provided in 2006 IPCC Guideline and estimated country-specific emission factors (kg/head/year)

	Dairy cows		Bull		Growing cattle	
	Guideline	Country-specific	Guideline	Country-specific	National	Country-specific
2011	68	79	47	62	47	41
2012	68	80	47	63	47	43
2013	68	80.5	47	63.1	47	44.8
2014	68	81.3	47	63.3	47	44.8

The uncertainty of the emission factors can be reduced if the animal activity data, such as livestock population by categories and sub-categories, weight (kg), average weight gain per day (kg), milk production per day (kg/day) and fat content (%), feeding situation: confined, grazing, pasture conditions, daily gross energy intake for cattle, feed digestibility (%), per animal manure volume, manure management systems etc., will be updated as a result of the new measurements. At present, the RA Ministry of Agriculture is still using the data of the professional bulletins and the results of expert evaluations of the Soviet Union period.

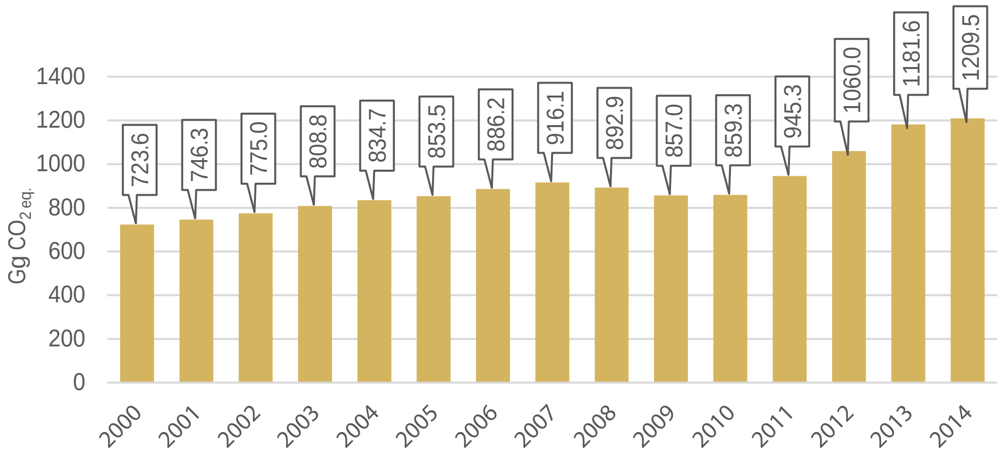


Figure 4.34 Methane emissions from livestock enteric fermentation 2000-2014, Gg $CO_{2eq.}$

As can be seen from the time series, starting from 2011, methane emissions have increased from the livestock enteric fermentation, which is caused by the growth of domestic animals (particularly cattle) population and performance data (live weight, milk production per day, etc.).

4.3.4.4.1.2 Manure Management (3A2)

Methodology, emission factors and activity data

Methane emissions

The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid, it decomposes anaerobically and can produce a significant quantity of CH_4. The temperature and the retention time of the storage unit greatly affect the amount of methane produced. When manure is handled as a solid (e.g., in stacks or pits) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced [Gen-1].

In Armenia, according to the data of the Ministry of Agriculture (Annex 7, Table 1) and expert judgement, up to 38% of manure is left in pastures, up to 1% is stored and used as a liquid (in farms) and the rest is handled as a solid and used as organic fertilizers and burned for fuel.

Methane emissions from manure management were calculated using Tier 1 Approach with country specific activity data (livestock population data by animal species/categories) and regional specific default emission factors by the average annual temperature because some emissions from manure management systems are highly temperature dependent and it is good practice to estimate the average annual temperature associated with the locations where manure is managed [Gen-1, Volume 4].

The following IPCC default emission factors were selected considering that annual average temperature in Armenia is below 10^{o} C [AFOLURef-10]:

- Methane emission factors for Asia [Gen-1, Volume 4, Table 10.14] were used for cattle, buffalos and pigs as animal raising practices of that region is the closest to Armenian conditions;
- Methane emission factors for developing countries [Gen-1, Volume 4,Table 10.15] were used for the other animal species.

The uncertainty in these emission factors is +30% [Gen-1, Volume 4, Table 10.15].

Activity data

Emissions from manure management are calculated for all categories of livestock. The following manure management systems used in Armenia have been considered in the estimation:

1. Pasture/Range/Paddock
2. Daily spread

3. Solid storage
4. Liquid/Slurry
5. Poultry manure with litter
6. Poultry manure without litter.

Uncertainty assessment

Activity data uncertainty

For countries that rely almost exclusively on one type of management system the uncertainty associated with management system usage data can be 10% or less [Gen-1, Volume 4, Chapter 10.4.4]. However, for countries where there is a variety of management systems used with locally different operating practices, the uncertainty range in management system usage data can be much higher. Considering that in Armenia there are six types of manure management systems, the activity data uncertainty was estimated to be 22%.

Emission factors uncertainty

The uncertainty range for the default factors is estimated to be +30% [Gen-1, Volume 4, Chapter 10.4.4].

As a result, the combined uncertainty was estimated to be 41.34%.

Nitrous oxide emissions

Direct N_2O emissions

Considering that this sub-category was not identified as the key category with the level assessment, nitrous oxide emissions from manure management were estimated using Tier 1 Approach and default emission factors provided for Asian Continent [Gen-1, Volume 4, Table 10.21]. The Tier 1 method entails multiplying the total amount of N excretion (from all livestock species/categories) in each type of manure management system by an emission factor for that type of manure management system [Gen-1, Volume 4, Equation 10.25]. Emissions are then summed over all manure management systems.

The Tier 1 method is applied using IPCC default N_2O emission factors, default nitrogen excretion data, and default manure management system data [Gen-1, Volume 4, Annex 10A.2, Tables 10A-4 to 10A-8 for default management 14 system allocations].

Indirect N_2O emissions

The Tier 1 calculation of N volatilization in forms of NH_3 and NOx from manure management systems is based on multiplication of the amount of nitrogen excreted (from all livestock categories) and managed in each manure management system by a fraction of volatilized nitrogen (see Equation 10.26). N losses are then summed over all manure management systems. The Tier 1 method is applied using default nitrogen excretion data, default manure management system data [Gen-1, Volume 4, Annex 10A.2, Tables 10A-4 to 10A-8] and default fractions of N losses from manure management systems due to volatilization [Gen-1, Volume 4, Table 10.22].

Time series

Figure 4.35 presents methane and nitrous oxide emissions time series from manure management.

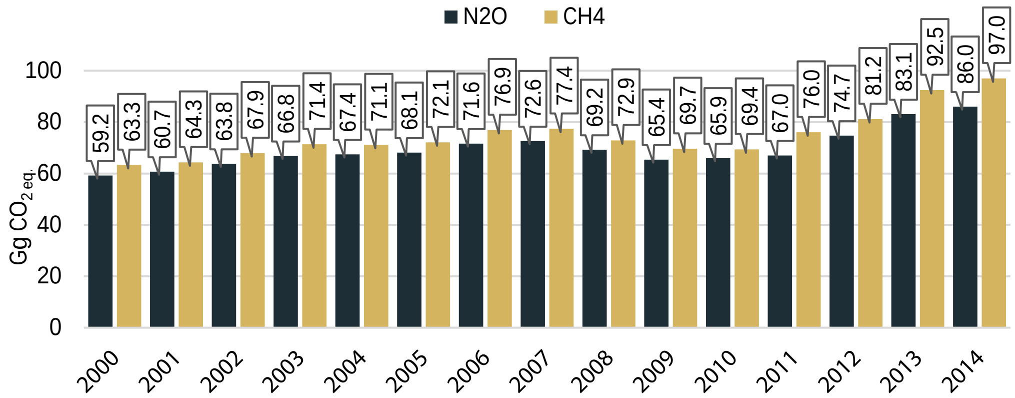


Figure 4.35 Methane and nitrous oxide emissions from manure management, 2000-2014, Gg CO_{2eq}.

4.3.4.5 Emissions from livestock category

The Table below provides methane and nitrous oxide emissions from Livestock Enteric Fermentation and Manure Management sub-categories.

Table 4.53 Methane and nitrous oxide emissions from Livestock Enteric Fermentation and Manure Management, Gg

Livestock categories	2012		2013		2014		2014 in comparison with 2012, %	
(Gg)	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
3.A - Livestock	**54.3422**	**0.2410**	**60.6699**	**0.2680**	**62.2157**	**0.2775**	**114.5**	**115.1**
3.A.1 - Enteric Fermentation	**50.4766**		**56.2669**		**57.5972**		114.1	
3.A.1.a – Cattle	45.4230		50.8788		52.0052		114.5	
3.A.1.a.i - Dairy Cows	24.9526		28.9367		29.7295		119.1	
3.A.1.a.ii - Other Cattle	20.4704		21.9422		22.2758		108.8	
3.A.1.b – Buffalo	0.0276		0.0347		0.0402		145.7	
3.A.1.c – Sheep	4.3824		4.6497		4.7607		108.6	
3.A.1.d – Goats	0.2059		0.2100		0.2181		105.9	
3.A.1.f – Horses	0.1862		0.2022		0.2103		112.9	
3.A.1.g - Mules and Asses	0.0396		0.0381		0.0368		92.9	
3.A.1.h – Swine	0.2120		0.2533		0.3258		153.7	
3.A.2 - Manure Management	**3.8655**	**0.2410**	**4.4030**	**0.2680**	**4.6186**	**0.2775**	**119.5**	**115.1**
3.A.2.a – Cattle	3.2717	0.1756	3.7109	0.1966	3.7734	0.2000	115.3	113.9
3.2.1.a.i - Dairy Cows	2.8072	0.1147	3.2352	0.1331	3.2911	0.1354	117.2	118.0
3.2.1.a.ii - Other Cattle	0.4646	0.0610	0.4758	0.0635	0.4823	0.0647	103.8	106.1
3.A.2.b - Buffalo	0.0005	0.0001	0.0006	0.0001	0.0007	0.0002	140.0	200.0
3.A.2.c - Sheep	0.0876	0.0428	0.0930	0.0454	0.0952	0.0465	108.7	108.6
3.A.2.d - Goats	0.0045	0.0019	0.0046	0.0019	0.0048	0.0020	106.7	105.3
3.A.2.f - Horses	0.0113	0.0020	0.0122	0.0021	0.0127	0.0022	112.4	110.0
3.A.2.g - Mules and Asses	0.0024	0.0005	0.0029	0.0005	0.0028	0.0005	116.7	100.0
3.A.2.h - Swine	0.4239	0.0128	0.5067	0.0153	0.6516	0.0196	153.7	153.1
3.A.2.i - Poultry	0.0635	0.0054	0.0720	0.0061	0.0773	0.0066	121.7	122.2

Comparison of 2014 emissions with those occurred in 2012 shows that in 2014 methane emissions from enteric fermentation increased by 14.5% and from manure management – by 19.5%, nitrous oxide emissions from manure management increased by 15.1%. This increase was due to the growth of livestock population and in particular - increase in the number of cattle (AFOLURef-1 and AFOLURef-7), accounted for over 90% of methane emissions from enteric fermentation.

2000-2014 time series of methane emission from livestock enteric fermentation and manure management are provided below.

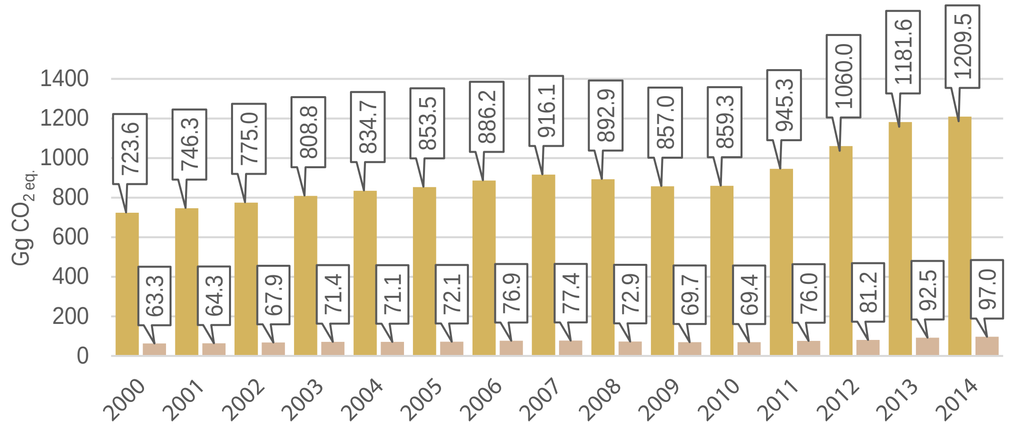


Figure 4.36 Methane emissions from livestock enteric fermentation and manure management, Gg CO_{2eq}

4.3.5 Forestry and Other Land Use sub-sector (3B)

4.3.5.1 Land Use categories

Greenhouse gas emissions and removals were estimated separately for each of six land-use categories according to the 2006 IPCC Guidelines [Gen-1]:

- 3B1 Forest land
  - 3B1a Forest land Remaining Forest land
  - 3B1b Land Converted to Forest land
- 3B2 Cropland
  - 3B2a Cropland Remaining Cropland
  - 3B2b Land Converted to Cropland
- 3B3 Grassland
  - 3B3a Grassland Remaining Grassland
  - 3B3b Land Converted to Grassland
- 3B4 Wetland
- 3B5 Settlement
- 3B6 Other Land.

Country's national land-use classification system does not match with IPCC categories as described above. According to Land Code of the Republic of Armenia the country's land stock is classified by purpose of use as follows:

1) Agricultural lands
2) Settlements
3) Industry, mining and other industrial purpose lands
4) Energy, transport, communication, public utilities infrastructures lands
5) Specially protected areas
6) Lands for special purpose
7) Forest
8) Wetlands
9) Reserve lands.

According to the IPCC Guideline the land-use classifications should be combined or disaggregated in order to represent the IPCC categories and countries should report on the procedure adopted for the reallocation. As the Armenia's national land-use classification system does not match 6 sub-categories described in 2006 IPCC Guideline, the following procedure was adopted for the reallocation:

- A certain part of agricultural lands as well arable lands and perennial plants from forest land were included in Cropland;
- Hay-lands and pastures from agricultural lands and forest as well as non-forested, non-water covered areas from specially protected areas were included in Grassland;
- No changes in Wetland category;
- Settlement lands excluding 50% of homestead lands and gardens, industry, mining and other production facilities lands excluding mining lands, lands for energy, communication, transport, public utilities infrastructure facilities; lands for health, recreation, and historical and cultural lands from specially protected areas were included in Settlement;
- The rest of agricultural and forest lands, mining and special purpose lands were included in Other Land.

Tables 4.54 and 4.55 present the harmonization of the country's national land-use classification system with 2006 IPCC Guideline Land Use categories.

Table 4.54 Harmonization of the national land-use classification with 2006 IPCC Guideline Land Use categories, ha, 2013

2013	Land Balance of RA, 1000 ha	IPCC Guideline Land Use categories, ha						
		3B1 Forestland	3B2 Cropland	3B3 Grassland	3B4 Wetland	3B5 Settlement	3B6 Other Land	Total, ha
1. Agricultural Lands	**2,051.0**	772	562,445	1,177,100	3,563		307,120	**2,051,000**
1.1. arable land	448.2		448,200					448,200
1.2. perennial plants	33.3		33,300					33,300
1.3. hayfield	121.8			121,800				121,800
1.4. pastures	1,055.3			1,055,300				1,055,300
1.5. other types of land	392.4	772	80,945		3,563		307,120	392,400
2. Settlements	**151.7**					151,700		**151,700**
3. Industry, Mining and Other Industrial Purpose Lands	**34.9**					7,852	27,048	**34,900**
4. Energy, Transport, Communication, Public Utilities Infrastructures Lands	**12.6**					12,600		**12,600**
5. Specially protected areas	**331.7**	59,059		96,606		17,800	158,235	**331,700**
5.1. nature protection	313.9	59,059		96,606			158,235	313,900
5.1.1. preserves	34.8	34,800						34,800
5.1.2. national parks	279.1	24,259		96,606			158,235	279,100
5.2. resorts	0.2					200		200
5.3. leisure	2.8					2,800		2,800
5.4. historical	14.8					14,800		14,800
6. Lands for special purpose	**31.6**						31,559	**31,559**
7. Forest	**334.3**	289,500	19,000	20,000			5,800	**334,300**
7.1. forest	289.5	289,500						289,500
7.2. bush	18.7		18,700					18,700
7.3. arable land	0.3		300					300
7.4. hayfield	9.1			9,100				9,100
7.5. pasture	10.9			10,900				10,900
7.6. other lands	5.8						5,800	5,800
8. Wetlands	**25.9**						25,900	**25,900**
9. Reserve lands	**0.6**						600	**600**
Total	**2,974.3**	**349,331**	**581,445**	**1,293,706**	**3,563**	**189,952**	**556,262**	**2,974,259**

Table 4.55 Harmonization of the national land-use classification with 2006 IPCC Guideline Land Use categories, ha, 2014

2014	Land Balance of RA, 1000 ha	IPCC Guideline Land Use categories, ha						
		3B1 Forestland	3B2 Cropland	3B3 Grassland	3B4 Wetland	3B5 Settlement	3B6 Other Land	Total, ha
1. Agricultural lands	**2,049.4**	793	557,260	1,175,900	3,563	0	311,884	**2,049,400**
1.1. arable land	447.5		447,500					447,500
1.2. perennial plants	33.7		33,700					33,700
1.3. hayfield	121.7			121,700				121,700
1.4. pastures	1,054.2			1,054,200				1,054,200
1.5. other types of land	392.3	793	76,060		3,563		311,884	392,300
2. Settlements	**151.8**					151,800		**151,800**
3.Industry, mining and other industrial purpose lands	**36.4**					8,174	28,226	36,400
4. Energy, transport, communication, public utilities infrastructures lands	**12.6**					12,600		**12,600**
5. Specially protected areas	**331.7**	58,906	0	95,136	0	18,341	159,317	**331,700**
5.1. nature protection	313.9	58,906	0	95,136	0	541	159,317	313,900
5.1.1. preserves	34.8	34,800						34,800
5.1.2. national parks	279.1	24,106		95,136		541	159,317	279,100
5.2. resorts	0.2					200		200
5.3. leisure	2.8					2,800		2,800
5.4. historical	14.8					14,800		14,800
6. Lands for special purpose	**31.6**						31,559	**31,559**
7. Forest	**334.3**	289,500	19,000	20,000	0	0	5,800	**334,300**
7.1. forest	289.5	289,500						289,500
7.2. bush	18.7		18,700					18,700
7.3. arable land	0.3		300					300
7.4. hayfield	9.1			9,100				9,100
7.5. pasture	10.9			10,900				10,900
7.6. other lands	5.8						5,800	5,800
8. Wetlands	**25.9**				0		25,900	**25,900**
9. Reserve lands	**0.6**		600					**600**
Total	**2,974.3**	**349,199**	**576,860**	**1,291,036**	**3,563**	**190,915**	**562,686**	**2,974,259**

Table 4.56 Land-use matrix, 2013 ha[5]

Initial / Final	Forest land	Cropland	Grassland	Wetland	Settlement	Other Land	Total Final
Forest land (forest covered)	348,559					772	**349,331**
Cropland		580,973	303		99	70	**581,445**
Grassland			1,293,706				**1,293,706**
Wetland				3,563			**3,563**
Settlement		388			189,464	100	**189,952**
Other Land		1,428	1,000			553,834	**556,262**
Total Initial	**348,559**	**582,789**	**1,295,009**	**3,563**	**189,563**	**554,776**	**2,974,259**
Total Changes	772	-1,344	-1,303	0	389	1,486	0

Table 4.57 Land-use matrix, 2014 ha[6]

Initial / Final	Forest land	Cropland	Grassland	Wetland	Settlement	Other Land	Total Final
Forest Land (Forest Covered)	348,406					793	**349,199**
Cropland		576,783			7	70	**576,860**
Grassland			1,291,036				**1,291,036**
Wetland				3,563			**3,563**
Settlement		95	480		190,340		**190,915**
Other Land		1,467				561,219	**562,686**
Total Initial	**348,406**	**578,345**	**1,291,516**	**3,563**	**190,347**	**562,082**	**2,974,259**
Total Changes	793	-1,485	-480	0	568	604	0

4.3.5.2 Calculation Methodology, Emission Factors and Activity Data in Forestry and Other Land Use Sub-Sector (3B)

4.3.5.2.1 Forest Land (3B1)

Sub-sector description

The forests account for about 11% of the territory of Armenia and are distributed unevenly: about 62.5% of the forests are located in the north-east, 13.5% in the central, 2.4% in the south and 21.6% in the south-east regions. The main tree species of forests in Armenia are pine, beech, oak and hornbeam, which together make up about 97% of wood, and the accessory species are ash, lime, maple, elm, birch and oriental trees. Armenia is characterized by the vertical zones of vegetation in the range of 550-2700 above sea-level, which has resulted in abundant biodiversity.

By November 2017, 75% of the forests in Armenia were supervised by the Ministry of Agriculture and 25% of forests which are specially protected areas of nature, was supervised by the Ministry of Nature Protection. Forest management, forest preservation and forest use activities were conducted by "Forestry" branches of "ArmForest" SNCO under the RA Ministry of Agriculture and by the SPANs under the RA Ministry of Nature Protection.

On November 2017 the Government of the RA approved the concept of reforms, strategy and action plan in the Forest Sector. According to the concept, the State Committee of Forests will be formed within the Ministry of Nature Protection with the aim of developing, investing and implementing state unified policy in the field of preservation, protection, reproduction and sustainable use of the forests in Armenia

Under supervision of the Committee state forest service will be formed which will implement inspection functions for the purpose of forest preservation.

[5] *Land balance for 2013, Real Estate Committee of the RA Government*
[6] *Land balance for 2014, Real Estate Committee of the RA Government*

As a result of changes it is expected to have a sustainable forest management system in Armenia and efficiency in fight against illegal logging. It is planned to implement the reforms in Forest Sector within 3 years, which will also contribute to the completeness and accuracy of GHG inventory data for this sub-sector.

For collecting data on areas of RA Forest Stock by lands type as well as regarding areas (ha) of forest lands covered by tree species, accumulated stock (cubic m), age, completeness and other necessary forest assessment data, forests and forest land allocation under "ArmForest" SNCO according to the existing Forest Management Plans of "Forestry" branches (LUCFRef-1, LUCFRef-5, LUCFRef-20), and the SPAN Management Plans (LUCFRef-2, LUCFRef-22) were studied. Former forest management plans (LUCFRef-10, LUCFRef-11) served as data sources for those "Forestry" branches and SPANs that do not have new (approved) Management Plans.

According to Forest Code of RA (LUCFRef-3) forest lands are defined as lands covered with forests, and intended for protection of animal and plant kingdom and nature protection as well as lands not covered with forests but intended for forestry needs which can be:

1. Areas under forests
2. Non-adherent forest cultures
3. Young forest plantings
4. Non-forest areas that are divided into: Rare forests (biological or anthropogenic), Fired or dead trees, Clear logged areas, Forest gaps.

The table below provides national level data of forest areas compiled from the forest management plans of the forest agencies.

Table 4.58 RA Forest Stock by land type

Year	Forest land, ha							Non Forest land, ha				Total
	Forest covered			Non-adherent forest cultures	Nurseries	Non-forest	Total forest lands	Hay-land	Pastures	Other Land (orchard, arable land and other)	Total non-forest land	
	Natural	Artificial	Total			Fired areas, totally logged areas, forest gaps, rare forests (anthropogenic, biological)						
2013	315,578.4	33,752.1	349,330.5	3,596.7	135	49,353.4	402,417.6	1,943.1	11,599.1	41,087.2	54,629.4	457,045
2014	315,558.4	33,640.1	349,198.5	3,605.7	135	49,353.4	402,292.6	1,913.1	11,599.1	41,087.2	54,599.4	456,892

According to 2006 IPCC Guidelines, Forest Land sub-sector is partitioned into two sub-categories:

Forest Land Remaining Forest Land (3B1a) - these lands (forests) should not have undergone land use change during 20 years prior to accounting year.

For this sub-category, such lands have been assessed that did not undergo land use change in the past 20 years. The area of said forests amounted to 348,558 ha and 348,405 ha in 2013 and 2014, respectively (Table 4.60).

Lands Converted to Forest Land (3B1b) - these lands are in transition stage and as a result of land use change during 20 years prior to accounting year they are converted to forest lands.

For this sub-category, such lands have been assessed that converted to forest lands as a result of land use change in the past 20 years. The area of said forests amounted to 772 ha and 793 ha in 2013 and 2014, respectively (Table 4.61).

4.3.5.2.1.1 Forest Land Remaining Forest land (3B1a)

According to 2006 IPCC Guidelines, GHG inventory for this sub-category involves estimation of changes in carbon stock from five carbon pools (i.e., above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter). However, because of lack of complete data, the estimation of changes in carbon stock were done for above-ground and below-ground biomass only.

This sub-category is a key category for CO_2 removals in terms of level assessment.

Methodology

The annual change in carbon stocks in biomass was estimated using the gain-loss method. The method requires the biomass carbon loss to be subtracted from the biomass carbon gain [Gen-1, Volume 4, Chapter 4, Equation 2.7]. Gains include total (above-ground and below-ground) biomass growth.

Annual gain in biomass (ΔC_G) is a product of mean annual biomass increment (G_{TOTAL}), area of land (A) and carbon fraction of dry matter (CF) (Volume 4, Chapter 2, Equation 2.9)

$$\Delta C_G = \Sigma ij \; (A \times G_{TOTAL} \times CF)$$

G_{TOTAL} is calculated by using values of annual aboveground biomass growth (GW), below-ground biomass to above-ground biomass ratio (R) and considering basic wood density (Volume 4, Chapter 2, Equation 2.10).

Biomass loss (ΔCL) is a sum of annual loss due to wood removals ($L_{removals}$), fuel wood gathering ($L_{fuelwood}$) and disturbances ($L_{disturbance}$), (Chapter 2, Equation 2.11).

As mostly country-specific data were used (wood annual average growth, basic wood density, etc.), calculated based on findings from the regional surveys (LUCFRef - 1, 2, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22), it can be concluded that the estimate was done by Tier 2 method [Gen-1, Volume 4, Chapter 2].

Activity data

To assess the amount of wood removed from the forest in 2013-2014, the data on harvested wood provided by "ArmForest" SNCO ("Forestry" branches) and SPANs ("Sevan", "Dilijan", and "Arevik" national parks), as well as illegal harvest discovered by various state institutions ("FSMC" SNCO, "ArmForest" SNCO, "NPI" under the Ministry of Nature Protection) as a result of annual inspections have been studied (LUCFRef-4, LUCFRef-21).

There is a decrease in forest areas in 2013 and 2014, as it was also observed in the previous years, caused by continuous forest clearing activities in "Sevan" National Park due to lake water level rise and by mining operations in "Teghut" area (LUCFRef-4).

The area of Forest Land Remaining Forest Land (A) within the country is 348,558 ha and 348,405 ha in 2013 and 2014, respectively.

The information on the wildfires is presented in Table 4.59.

Table 4.59 Wildfires in forest covered areas in 2013 and 2014

Year	The number of wildfires	Forest covered areas, ha	Not forest covered areas, ha	Total, ha	Loss of wood, cubic m
2013	21	64	36	100	-
2014	24	28	30	58	-

Emission factors

The average annual above-ground biomass growth for a specific woody vegetation type

GW = 0.835 tones d.m. /ha

The figure was derived from the regional surveys (LUCFRef - 1, 2, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22) and has been calculated based on biomass annual average growth per 1 ha of forest covered areas – 1.5 cubic meters (Annex 7, Table 8) and basic wood density - 0.557 oven-dry tonnes/moist cubic meter (Annex 7, Table 7):

GW = 1.5 cubic m/ha x 0.557 oven-dry tonnes/moist cubic m= 0.835 tonnes d.m./ha

GW estimate for Armenia shows that the figure is in the ecological zone of temperate mountain systems [Gen-1, Volume 4, Chapter 4, Table 4.9]:

Below-ground biomass to above-ground biomass ratio (R) provided for temperate climatic zone and temperate mountains systems ecological zone in 2006 IPCC Guidelines [Gen-1, Volume 4, Chapter 4, Table 4.4, referencing to Table 4.7 for above-ground biomass] was used for above-ground biomass of 75 - 150 t /ha

R = 0.23 tonne d.m. /(tonne d.m.)

Annual biomass increment

G_{TOTAL} = 0.835 tonnes d. m. /ha x (1+0.23) = 1.027 (Equation 2.10)

Carbon fraction of dry matter

CF = 0.48 tonne C/(tonne d.m.)

provided for temperate climatic zone [Gen-1, Volume 4, Chapter 4, Table 4.3] was used.

Estimate of carbon annual gain for 2014:

ΔC_G = 348,405 ha x 1.02 tonne d.m./ha x 0.48 tonne C/ (tonne d.m.) = 171,758 tonne C/annual

The annual change in carbon stocks in biomass

Table 4.60 Annual increase in biomass carbon stock

Indicators	2013	2014
Covered area, ha	348,558	348,405
Biomass annual average growth per 1 ha, cubic meters	1.5	1.5
Carbon annual gains, C t/year	171,834	171,758
Annual volume of harvested fuelwood, cubic m /including fallen wood	78,150	77,220
Annual volume of timber harvested (commercial fillings), cubic m	4,204	1,986
Burned areas, ha	64	28
Loss of wood due to fires, cubic m	-	-
Annual carbon loss, C t/year	27,086	26,047

Annual carbon loss in biomass due to the harvested fuelwood and timber is shown in Figure 4.37.

Figure 4.37 Carbon loss (ton) caused by harvested fuelwood and commercial felling

As it can be seen in the figure, in 2013 94.8% of annual carbon loss are caused by harvested fuelwood and 5.1% of that by harvested timber, whereas the contribution of fires is negligible – 0.1%. In 2014, 97.5% of annual carbon loss caused by harvested fuelwood and 2.5% of that by harvested timber.

Uncertainty assessment

The uncertainty of the activity data in the forestry is due to the lack of complete and accurate data on the changes in the forest covered areas.

Other sources of uncertainties could be errors made during cadaster mapping process and changes made but not yet registered in cadaster. As of 2014, the uncertainty of the forest covered area is approximately 5%.

The uncertainties in the forestry [Gen-1, Volume 4, Chapter 4] are largely due to the uncertainties of different factors - uncertainties of basic wood density and biomass expansion factors by stand age, species composition and structure.

The weighted average factors of both basic wood density and biomass expansion for Armenian Forestry are within the range of default parameters in the Guidelines.

In Armenia the uncertainties are mainly because of the lack of complete and accurate information on the natural losses in wood and on removals of fuelwood as a result of illegal felling. Moreover, the information on removals of fuelwood derived from various sources such as primary sources and surveys of households significantly differs.

Time series

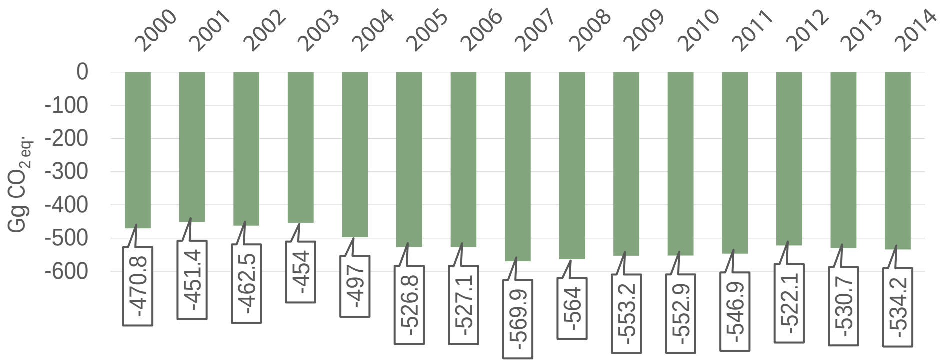


Figure 4.38 Carbon dioxide removals in Forest land Remaining Forest land sub-category in 2000-2014

Despite the decrease in forest areas, which is caused by forest clearing activities in “Sevan” National Park lakeside forest covered areas and by mining continuous operations in “Teghut” area, the removals increased in 2013 and 2014 due to the decrease in wood loss.

4.3.4.5.2.1.2 Land Converted to Forest land (3B1b)

Land converted to forest land sub-category covered 598.9 ha in 2010. In 2014 the area under this sub-category increased by 72 ha in 2013 compared to 2012 and by 21 ha in 2014 compared to 2013 (LUCFRef -1, LUCFRef -2, LUCFRef-4, LUCFRef-20, LUCFRef-22), due to the adherent forest cultures inclusion in this sub-category, constituting to 772 ha and 793 ha in 2013 and 2014, respectively (see Table 4.61).

Methodology

Tier 2 of biomass gain and loss method was applied to estimate GHG emissions and removals. GHG emissions estimate involves estimation of changes from dead organic matter as well.

Emission factors

The fraction of pine tree accounts for the prevailing part (about 66%) of the area covered by 14 tree species as well as of the cumulative stock, therefore the weighted average factors derived for carbon stock change in living biomass mainly refer to pine trees.

Below-ground biomass to above-ground biomass ratio (R) from 2006 IPCC Guidelines [Gen-1, Volume 4, Chapter 4, Table 4.4] selected by the temperate climatic zone and temperate mountains systems ecological zone was applied.

These areas do not yet have the status which would assume harvesting that result in carbon losses. Therefore the calculation was made considering only carbon gains which account for about 0.2% of annual total removals by all forest lands.

Table 4.61 Annual change in carbon stock of living biomass (including aboveground and belowground biomass)

Indicator	2013	2014
Covered area, ha	772	793
Biomass annual average growth per 1 ha, cubic m	1.5	1.5
Carbon annual gains, C t/year	380	391

Improvements foreseen

There is a lack of complete and reliable data on the recent changes in forest lands because of the 20-year absence of forest inventory. Thereby, activity data, in particular, on deforestation, afforestation, reforestation, and on disturbances caused by fire, insects and diseases have high uncertainty. Due to the absence of forest inventory, the information on forest is missing or incomplete, in particular – on the area occupied by tree species, on accumulated stock, on annual average growth, etc. - does not exist or is incomplete.

The availability of the arrangements enabling application of forest inventory on continuous basis will enable to reduce the uncertainty of estimates of GHG emissions/ removals from forest lands, as well enable estimation of changes in carbon stock from the other carbon pools as well.

4.3.5.2.2 - 4.3.5.2.6 Cropland, Grassland, Wetland, Settlement and Other Land

For Armenia, Land Use categories and changes there in are described in complex approach including the Land Use and character of conversion, areas, cultivated crops and biophysical criteria (e.g. climatic zonation). This approach not only enables to have a clear picture of each conversion in land use but also to follow further changes in such conversions.

Land Use change by years is made based on land balances and land change data provided by State Committee of Real Estate Cadaster under RA Government. Distribution of agricultural land according to the crop types in the categories "Cropland" and "Grassland" was made on the basis of the data of the actual agricultural crops sown areas on arable land according the agricultural statistics of NSS RA.

CO_2 emissions and removals were estimated based on carbon stock change in biomass and in dead organic matter, and in soil types - based on organic carbon stock change by using Gain-Loss Method.

4.3.5.2.2 Cropland (3B2)

Estimates for “Cropland” category in Land Use are made for 3B2a “Cropland Remaining Cropland” and 3B2b “Land Converted to Cropland” sub-categories.

Cropland includes all annual and perennial crops as well as temporary fallow land (i.e. land set at rest for one or several years before being cultivated again). Annual crops include cereals, oils seeds, vegetables, root crops and forages. Perennial crops include trees and shrubs, in combination with herbaceous crops (e.g., agroforestry) or as orchards, vineyards and plantations, except where these lands meet the criteria for categorization as Forest Land. Arable land which is normally used for cultivation of annual crops but which is temporarily used for forage crops or grazing as part of an annual crop-pasture rotation (mixed system) is included under cropland.

Cropland Remaining Cropland (3B2a)

Carbon stock change in biomass is estimated based on carbon Gain-Loss Method by using Tier 1 method considering land use type, area, cultivated crops and climatic zonal distribution. The inventory is made for all lands that have not undergone essential changes in terms of land use during recent 20 years by matching local and international classifications of lands with local soil types (Tables 4.54 and 4.55).

Lands are subdivided according to three global climatic zones available in Armenia: warm moderate dry, cold moderate dry and cold moderate humid. Annual crops were classified according to Armenian agricultural practices.

Land Converted to Cropland (3B2b)

2013-2014 Lands Inventories have reported on conversion of other land categories to Cropland (in 2013 - 476 ha, in 2014 – 7.3 ha). CO_2 emissions and removals are estimated based on changes of carbon stock in biomass by using the default Tier 1 method.

4.3.5.2.3 Grassland (3B3)

In 2013 the area of lands in "Grassland" category has increased by 200 ha resulted from conversion of "Other Land" categories and meanwhile was decreased by 1303 ha i.e. due to conversion of 303 ha from "Grassland" to "Cropland" and 1000 ha – to "Other Land". In 2014 there was no change in the area of lands in "Grassland" category.

In "Grassland" category carbon emissions/removals are mainly caused by changes in carbon stocks in above-ground and below-ground biomass and due to changes in soil C stocks caused by the management of grasslands and the change in management practices.

Emissions and removal from "Grassland" category are estimated for 3B3a "Grassland Remaining Grassland" and 3B3b "Land Converted to Grassland" sub-categories.

GHG emissions and removals for 3B3a "Grassland Remaining Grassland" sub-category were estimated by using Tier 1 method considering that in Armenia data on grassland management practices are not available. Therefore the approach provided in Guidelines [Gen-1, Volume 4, Chapter 6] on stability of biomass and absence of any change in it is was applied. Emissions and removal in this sub-category are estimated based on carbon stock change in mineral and organic soils.

Spatial inclusion of soil areas of this category are estimated by using three approaches recommended by the Guidelines [Gen-1, Volume 4] according to which soils are divided and included in the Inventory according to three climatic zones and soil types. Such division of soils for estimating emissions by using Tier 2 methodology is the first required condition which, however, is not sufficient and there is lack of information on grassland types, impact and management regimes and on other factors that make essential effect on both biomass and carbon stock Gain-Loss in it.

CO_2 emissions and removals in 3B3b "Land Converted to Grassland" sub-category are estimated based on carbon stock change in biomass and in dead organic matter as well as on carbon stock change in mineral and organic coils.

4.3.5.2.4 Wetlands (3B4)

In this category the greenhouse gas emissions were estimated from the 3.B.4.a.i "Wetlands Remaining Wetlands" sub-category by using Tier 1 method and the default values [Gen-1, Volume 4].The surface of peat extraction area in 2013 and 2014 comprised 3563 ha. The volume of peat extraction in 2013 was 2075.3 tons and in 2014 – 2274 tons (AFOLURef-9).

4.3.5.2.5 Settlement (3B5)

The land-use category Settlements includes soils, herbaceous perennial vegetation such as turf grass and garden plants, trees in rural settlements, homestead gardens and urban areas. Examples of settlements include land along streets, in residential (rural and urban) and commercial lawns, in public and private gardens, in golf courses and athletic fields, and in parks, provided such land is functionally or administratively associated with particular cities, villages or other settlement types and is not accounted for in another land-use category.

4.3.5.2.6 Other Land (3B6)

This category includes unmanaged reserve lands, bare soil, rock, ice, and all land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available. For example, this category includes other land plots intended for agricultural purposes but are still not used in agricultural production: salt, sands, canyons, gorges, rocky spaces, as well as roadside roads. If data are available, countries are encouraged to classify unmanaged lands by the above land-use categories (e.g., into Unmanaged Forest Land, Unmanaged Grassland, and Unmanaged Wetlands). This will improve transparency and enhance the ability to track land-use conversions from specific types of unmanaged lands into the categories above.

4.3.5.3 Emission /removals from "Forestry and Other Land Use" sub-sector

Assessment of 2013 and 2014 greenhouse gas emissions/removals from *Land* category in $CO_{2eq.}$ are provided below.

Table 4.62 Emissions/removals estimate from "Forestry and Other Land Use" sub-sector, 2013- 2014

IPCC Categories	2013 (Gg)			2014 (Gg)		
	Net CO_2 emissions/removals	Emissions		Net CO_2 emissions / removals	Emissions	
		CH_4	N_2O		CH_4	N_2O
3.B Land	**-472.845**	**NA**	**0.0101**	**-480.265**	**NA**	**0.0101**
3.B.1 Forest land	**-536.117**	**NA**	**NA**	**-539.780**	**NA**	**NA**
3.B.1.a Forest land Remaining Forest Land	-530.759			-534.275		
3.B.1.b Land Converted to Forest Land	-5.358			-5.504		
3.B.1.b.i Cropland converted to Forest Land	-5.358			-5.504		
3.B.2 Cropland	**8.782**	**NA**	**NA**	**0.779**	**NA**	**NA**
3.B.2.a Cropland Remaining Cropland	0.670			0.670		
3.B.2.b Land Converted to Cropland	8.112			0.109		
3.B.2.b.i Forest Land converted to Cropland	1.151			NO		
3.B.2.b.ii Grassland converted to Cropland	0.098			-7.438		
3.B.3.b.iv - Settlements converted to Grassland	0.223			0.907		
3.B.2.b.v Other Land converted to Cropland	6.640			6.640		
3.B.3 Grassland	**17.772**	**NA**	**NA**	**14.525**	**NA**	**NA**
3.B.3.a Grassland Remaining Grassland	14.525			14.525		
3.B.3.b Land Converted to Grassland	3.248			NO		
3.B.3.b.ii Cropland converted to Grassland	0.817			NO		
3.B.3.b.iv Settlements converted to Grassland	0.011			NO		
3.B.3.b.v Other Land converted to Grassland	2.420			NO		
3.B.4 Wetlands	**3.424**	**NA**	**0.0101**	**3.752**	**NA**	**0.0101**
3.B.4.a - Wetlands Remaining Wetlands	3.424		0.0101	3.752		0.0101
3.B.4.a.i - Peatlands remaining peatlands	3.424		0.0101	3.752		0.0101
3.B.5 Settlements	**7.113**	**NA**	**NA**	**13.564**	**NA**	**NA**
3.B.6 Other Land	**26.180**	**NA**	**NA**	**26.895**	**NA**	**NA**
3.B.6.b - Land Converted to Other Land	26.180			26.895		
3.B.6.b.ii - Cropland converted to Other Land	26.180			26.895		

4.3.5.4 Quality Control/Quality Assurance

The estimates of GHG inventory in "Forestry and Other Land Use" category are strongly influenced by the quality and consistency of data and information available in the country. The estimates in this Inventory are based on Land Balances approved for each year by the RA Government where Land categories are presented as the aggregate groups - 9 categories.

The harmonization between the country's national land-use classification system with 2006 IPCC Guideline Land Use categories and data calculation were made based on the official statistics of NSS RA and Ministry of Agriculture of RA.

Quality Control/Quality Assurance were implemented applying both internal and external review of inventory data and emissions assessment. Internal review have been implemented by the experts involved in the inventory preparation and external review was implemented by the other agencies through draft NIR circulation among stakeholder ministries and agencies.

4.3.5.5 Completeness of data and uncertainty assessment

Uncertainties in Forestry sub-sector is mostly due to the lack of complete and accurate information on changes in the forest covered areas. Lack of mechanism for forest inventory is the main challenge for forest management planning as well as on comprehensive reflection of current qualitative and quantitative changes in Forestry (in particular, on forest logging, afforestation, forest rehabilitation, burned forests, area exposed to infection and pests, etc.)

Uncertainties in Other Land Use are due to uncertainties in land areas; they are also due to the fact that the Government is publishing RA Land Balances as of July 1 of each year leaving some changes out of the balance of a given inventory year. Besides, materials for cadaster mapping implemented in the country and data published by NSS serve as primary sources for data included in Land Balances approved by the Government, however, as it is proven in practice, often there are differences in said data.

Other sources of uncertainties could be errors made during cadaster mapping process and changes made but not registered yet.

4.3.6 Aggregate sources and non-CO_2 emissions sources on land (3C)

Methodology and emission factors

This category provides estimation of nitrous oxide (N_2O) emissions from managed soils, including indirect N_2O emissions from additions of N to land due to deposition and leaching, emissions of carbon dioxide (CO_2) following additions of urea-containing fertilizers and methane emissions from biomass burning. The calculations were implemented by Tier 1 method.

4.3.6.1 Greenhouse gas emissions from Biomass Burning (3C1)

The calculations were made by Tier 1 method for two categories: Emissions from biomass burning in forest lands (3C1a) and Emissions from biomass burning in grassland (3C1c) by using the burned area data in forested lands and grasslands [AFOLURef-10].

4.3.6.2 Urea application (3C3)

Emissions from (3C3) Urea application sub-category were calculated by the Tier 1 method with data on the amount of urea applied to soils (the amount of imported synthetic N fertilizers) [Gen-3] assuming that all available urea in a particular year is immediately added to soils and applying the default emissions factors provided by the Guidelines [Gen-1, Volume 4].

4.3.6.3 Direct N_2O Emissions from Managed Soils (3C4)

The following N sources are included in the methodology for estimating direct N_2O emissions from managed soils:

- Synthetic N fertilizers (FSN) (the data on the amount of imported synthetic N fertilizers (8-digit level code - 3102 20 – 3102 90) [Gen-3] and the default emissions factors was used);
- Organic N applied as fertilizer (e.g. animal manure, compost, sewage sludge, rendering waste) (FON);
- Urine and dung N deposited on pasture, range and paddock by grazing animals (FPRP);
- N in crop residues (above and below ground), including from N-fixing crops and from

forages during pasture renewal (FCR).

4.3.6.4 Indirect N_2O Emissions from Managed Soils (3C5)

The following N sources of indirect N_2O emissions from managed soils are considered in this sub-category:

- synthetic N fertilizers (FSN);
- organic N applied as fertilizer (e.g., applied animal manure, compost, sewage sludge, rendering waste and other organic amendments) (FON);
- urine and dung N deposited on pasture, range and paddock by grazing animals (FPRP);
- N in crop residues (above- and below-ground), including N-fixing crops and forage/pasture renewal returned to soils (FCR).

Nitrous oxide (N_2O) emissions are calculated from the managed soils by Tier 1 method using the equation 11.9 [Gen - 1, Volume 4, Chapter 11].

In 2014 as compared to 2012, the volume of urine increased by 66% and the chemical nitrogen fertilizer by 15% (Annex 7, Table 6).

GHG emissions from the "Aggregate sources and non-CO_2 emissions sources on land" category are summarized in the Table 4.63.

Table 4.63 Emissions from "Aggregate Sources and Non-CO_2 Emissions Sources on Land" sub-category

IPCC Categories	2013 (Gg)			2014 (Gg)		
	Net CO_2 emission/ removal	Emissions		Net CO_2 emission/ removal	Emissions	
		CH_4	N_2O		CH_4	N_2O
3.C Aggregate Sources and Non-CO_2 Emissions Sources on Land	**0.295**	**0.0023**	**2.122**	**0.675**	**0.0015**	**2.101**
3.C.1 Emissions from Biomass Burning	**NA**	**0.0023**	**NA**	**NA**	**0.0015**	**NA**
3.C.1.A - Biomass Burning in Forest Lands		0.0016			0.0012	
3.C.1.C - Biomass Burning in Grasslands		0.0007			0.0003	
3.C.3 Urea Application	**0.295**			**0.675**		
3.C.4 Direct N_2o Emissions from Managed Soils			**1.499**			**1.473**
3.C.5 Indirect N_2O Emissions from Managed Soils			**0.417**			**0.410**
3.C.6 Indirect N_2O Emissions from Manure Management			**0.206**			**0.219**

Uncertainty assessment

Direct N_2O Emissions

Uncertainties in estimates of direct N_2O emissions from managed soils are caused by uncertainties related to the emission factors, natural variability, partitioning fractions, activity data, lack of coverage of measurements, spatial aggregation and lack of information on specific on-farm practices. Additional uncertainty will be introduced in inventory when emission measurements that are not representative of all conditions in a country are used. In general, the reliability of activity data will be higher than that of the emission factors [Gen-1, Volume 4, Chapter 11].

The activity data in Armenia relate to the amount of used inorganic fertilizer and manure management, the uncertainties of which are ± 10% and ± 32% respectively, and the total uncertainty of the activity data calculated by the method proposed in the Guidelines [Gen-1, Volume 1, Chapter 3] made up ± 32%. The uncertainties of emissions factors and the total uncertainty in estimates of direct N_2O emissions have been estimated by the method suggested in the Guidelines: the uncertainty of the emission factors was 212%, and the total uncertainty in estimates of direct N_2O emissions was 214%.

Indirect N_2O Emissions

Uncertainties in estimates of indirect N_2O emissions from managed soils are caused by uncertainties related to natural variability and to the emission, volatilization and leaching factors, activity data, and lack of measurements. Additional uncertainty will be introduced in an inventory when values for these factors that are not representative of all conditions in a country are used [Gen-1, Volume 4, Chapter 11].

The total uncertainty of the activity data was calculated by the method proposed in the Guidelines [Gen-1, Volume 1, Chapter 3] and made up 32%. The uncertainties of the volatilization and leaching factors and therefore, the total uncertainties in estimates of indirect N_2O emissions, were also calculated by the method recommended in the Guidelines. The uncertainty of the volatilization and leaching factors was 229%, and the total uncertainty in estimates of indirect N_2O emissions was 231%.

Time series

In this sub-category, the 2000-2012 time series were recalculated to ensure time series consistency because for the previous years the IPCC software version 2.12 was used where "Urine and Dung N Deposited on Pasture, Range and Paddock by Grazing Animals" was not considered.

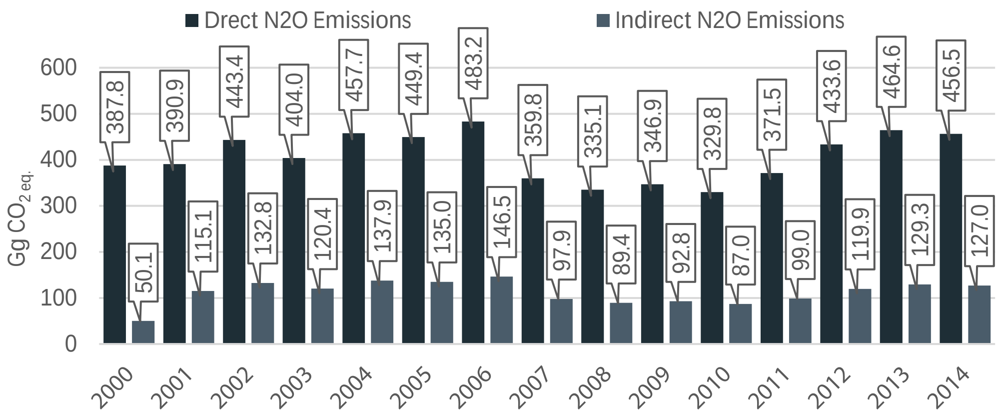


Figure 4.39 Direct and Indirect N_2O Emissions from Managed Soils, 2000-2014, Gg $CO_{2eq.}$

4.3.7 Emissions/removals estimate for Agriculture, Forestry and Other Land Use Sector

Table 4.64 Greenhouse gas emissions/removals from Agriculture, Forestry and Other Land Use Sector

IPCC Categories Code	Categories	2013 (Gg)			2014 (Gg)		
		Net CO_2 emission/ removal	Emissions		Net CO_2 emission/ removal	Emissions	
			CH_4	N_2O		CH_4	N_2O
3	**Agriculture, Forestry, and Other Land Use**	**-472.550**	**60.672**	**2.400**	**-479.589**	**62.217**	**2.389**
3.A	**Livestock**	**NA**	**60.670**	**0.268**	**NA**	**62.216**	**0.278**
3.A.1	**Enteric Fermentation**	**NA**	**56.267**	**NA**	**NA**	**57.597**	**NA**
3.A.1.a	Cattle		50.879			52.005	
3.A.1.a.i	Dairy Cows		28.937			29.729	
3.A.1.a.ii	Other Cattle		21.942			22.276	
3.A.1.b	Buffalo		0.035			0.040	
3.A.1.c	Sheep		4.650			4.761	
3.A.1.d	Goats		0.210			0.218	
3.A.1.f	Horses		0.202			0.210	
3.A.1.g	Mules and Asses		0.038			0.037	
3.A.1.h	Swine		0.253			0.326	
3.A.2	**Manure Management**	**NA**	**4.403**	**0.268**	**NA**	**4.619**	**0.278**
3.A.2.a	Cattle		3.711	0.197		3.773	0.200
3.A.2.a.i	Dairy Cows		3.235	0.133		3.291	0.135
3.A.2.a.ii	Other Cattle		0.476	0.064		0.482	0.065
3.A.2.b	Buffalo		0.001	0.0001		0.001	0.0002
3.A.2.c	Sheep		0.093	0.045		0.095	0.046
3.A.2.d	Goats		0.005	0.002		0.005	0.002
3.A.2.f	Horses		0.012	0.002		0.013	0.002
3.A.2.g	Mules and Asses		0.003	0.0005		0.003	0.0005
3.A.2.h	Cattle		0.507	0.015		0.652	0.020
3.A.2.i	Poultry		0.072	0.006		0.077	0.007
3.B	**Land**	**-472.845**	**NA**	**0.010**	**-480.265**	**NA**	**0.010**
3.B.1	**Forest land**	-536.117	NA	NA	-539.780	NA	NA
3.B.1.a	Forest Land Remaining Forest Land	-530.759			-534.275		
3.B.1.b	Land Converted to Forest Land	-5.358			-5.504		
3.B.1.b.i	Cropland converted to Forest Land	-5.358			-5.504		
3.B.1.b.ii	Grassland Converted to Forest Land	NO			NO		
3.B.1.b.iii	Wetlands Converted to Forest Land	NO			NO		
3.B.1.b.iv	Settlements Converted to Forest Land	NO			NO		
3.B.1.b.v	Other Land Converted to Forest Land	NO			NO		
3.B.2	**Cropland**	**8.782**	**NA**	**NA**	**0.779**	**NA**	**NA**
3.B.2.a	Cropland Remaining Cropland	0.670			0.670		
3.B.2.b	Land Converted to Cropland	8.112			0.109		
3.B.2.b.i	Forest Land Converted to Cropland	1.151			0.000		
3.B.2.b.ii	Grassland Converted to Cropland	0.098			-7.438		
3.B.2.b.iv	Settlements Converted to Cropland	0.223			0.907		
3.B.2.b.v	Other Land Converted to Cropland	6.640			6.640		
3.B.3	**Grassland**	**17.772**	**NA**	**NA**	**14.525**	**NA**	**NA**
3.B.3.a	Grassland Remaining Grassland	14.525			14.525		
3.B.3.b	Land Converted to Grassland	3.248			0.000		
3.B.3.b.i	Forest Land converted to Grassland	NO			NO		
3.B.3.b.ii	Cropland converted to Grassland	0.817			NO		
3.B.3.b.iv	Settlements Converted to Grassland	0.011			NO		
3.B.3.b.v	Other Land Converted to Grassland	2.420			NO		
3.B.4	**Wetlands**	**3.424**	**NA**	**0.01**	**3.752**	**NA**	**0.010**
3.B.4.a	Wetlands Remaining Wetlands	3.424	NA	0.01	3.752	NA	0.010

IPCC Categories Code	Categories	2013 (Gg)			2014 (Gg)		
		Net CO_2 emission/ removal	Emissions		Net CO_2 emission/ removal	Emissions	
			CH_4	N_2O		CH_4	N_2O
3.B.4.a.i	Peatlands Remaining Peatlands	3.424	NA	0.01	3.752	NA	0.010
3.B.5	**Settlements**	**7.113**	**NE**	**NE**	**13.564**	**NE**	**NE**
3.B.5.a	Settlements Remaining Settlements	NE	NE	NE	NE	NE	NE
3.B.5.b	Land Converted to Settlements	7.113	NE	NE	13.564	NE	NE
3.B.6	**Other Land**	**26.180**	**NA**	**NA**	**26.895**	**NA**	**NA**
3.B.6.a	Other Land Remaining Other Land	NA	NA	NA	NA	NA	NA
3.B.6.b	Land Converted to Other Land	26.180			26.895		
3.B.6.b.ii	Cropland Converted to Other Land	26.180			26.895		
3.C	**Aggregate Sources and Non-CO2 Emissions Sources on Land**	**0.295**	**0.002**	**2.122**	**0.675**	**0.002**	**2.101**
3.C.1	**Emissions from Biomass Burning**	**NE**	**0.002**	**NA**	**NE**	**0.002**	**NA**
3.C.1a	Biomass Burning in Forest Lands		0.0016			0.0012	
3.C.1.c	Biomass Burning in Grasslands		0.0007			0.0003	
3.C.3	**Urea Application**	**0.295**			**0.675**		
3.C.4	**Direct N_2O Emissions from Managed Soils**			**1.499**			**1.473**
3.C.5	**Indirect N_2O Emissions from Managed Soils**			**0.417**			**0.410**
3.C.6	**Indirect N_2O Emissions from Manure Management**			**0.206**			**0.219**

Table 4.65 Greenhouse gas emissions/removals (in the key source category classification format) from Agriculture, Forestry and Other Land Use Sector, 2013

IPCC Categories Code	IPCC Categories	GHG	2013, Gg $CO_{2eq.}$
3.A.1	**Enteric Fermentation**	**CH_4**	**1,181.606**
3.B.1.a	**Forest land Remaining Forest land**	**CO_2**	**-530.759**
3.C.4	**Direct N_2O Emissions from Managed Soils**	**N_2O**	**464.613**
3.C.5	**Indirect N_2O Emissions from Managed Soils**	**N_2O**	**129.337**
3.A.2	**Manure Management**	**CH_4**	**92.462**
3.A.2	**Manure Management**	**N_2O**	**83.087**
3.C.6	Indirect N_2O Emissions from manure management	N_2O	63.985
3.B.3.a	Grassland Remaining Grassland	CO_2	14.525
3.B.2.b	Land Converted to Cropland	CO_2	8.112
3.B.6.b	Land Converted to Other Land	CO_2	26.18
3.B.1.b	Land Converted to Forest land	CO_2	-5.358
3.B.4.a.i	Peatlands Remaining Peatlands	CO_2	3.424
3.B.3.b	Land Converted to Grassland	CO_2	3.248
3.B.4.a.i	Peatlands Remaining Peatlands	N_2O	3.124
3.B.2.a	Cropland Remaining Cropland	CO_2	0.670
3.C.3	Urea Application	CO_2	0.295
3.C.1	Emissions from Biomass Burning	CH_4	0.048

Table 4.66 Greenhouse gas emissions/removals (in the key source category classification format) from Agriculture, Forestry and Other Land Use Sector, 2014

IPCC Categories Code	IPCC Categories	GHG	2014, Gg $CO_{2eq.}$
3.A.1	**Enteric Fermentation**	**CH_4**	**1,209.540**
3.B.1.a	**Forest Land Remaining Forest Land**	**CO_2**	**-534.275**
3.C.4	**Direct N_2O Emissions from Managed Soils**	**N_2O**	**456.516**
3.C.5	**Indirect N_2O Emissions from Managed Soils**	**N_2O**	**126.954**
3.A.2	**Manure Management**	**CH_4**	**96.990**
3.A.2	**Manure Management**	**N_2O**	**86.033**
3.C.6	Indirect N_2O Emissions from Manure Management	N_2O	67.986
3.B.6.b	Land Converted to Other Land	CO_2	26.895
3.B.3.a	Grassland Remaining Grassland	CO_2	14.525
3.B.1.b	Land Converted to Forest Land	CO_2	-5.504
3.B.4.a.i	Peatlands Remaining Peatlands	CO_2	3.752
3.B.4.a.i	Peatlands Remaining Peatlands	N_2O	3.124
3.C.3	Urea Application	CO_2	0.675
3.B.2.a	Cropland Remaining Cropland	CO_2	0.670
3.B.2.b	Land Converted to Cropland	CO_2	0.109
3.C.1	Emissions from Biomass Burning	CH_4	0.026

4.4 Waste

4.4.1 Summary of emissions estimate

Methane (CH_4) emissions from landfills, CO_2, CH_4 and N_2O emissions from the combustion of waste and CH_4 and N_2O emissions from wastewater treatment and discharge are reported under Waste Sector.

The Waste Sector emissions amounted to 603.49 Gg $CO_{2eq.}$ (5.89%) and 611.19 Gg $CO_{2eq.}$ (5.85%) of Armenia's total emissions in 2013 and 2014, correspondingly. Landfill emissions accounted for 66.78% of the all waste sector emissions (3.7% of the country's total emissions), while the emissions from the combustion of waste are insignificant and accounted for 3.43%. The emissions from the waste water treatment accounted for 29.78% of the sector emissions in 2014.

4.4.2 Waste Sector description

The Waste Sector of greenhouse gases of the national inventory of Armenia includes the following categories and sub-categories:

- (4A) Solid Waste Disposal (CH_4 emissions)
- (4C) Incineration and Open Burning of Waste
  - (4C2) Open Burning of Waste (CO_2, CH_4, N_2O emissions)
- (4D) Wastewater Treatment and Discharge (CH_4, N_2O emissions)
  - (4D1) Domestic Wastewater Treatment and Discharge (CH_4, N_2O)
  - (4D2) Industrial Wastewater Treatment and Discharge (CH_4)

Other sources provided in IPCC 2006 Guidelines do not exist in Armenia.

4.4.3 Key Categories

Solid Waste Disposal and *Wastewater Treatment and Discharge* are identified as the key source categories of greenhouse gas (CH_4) emissions with level assessment. CH_4 emissions from *Solid Waste Disposal* accounted for 3.72% and 3.7% of the country's total emissions in $CO_{2eq.}$ in 2013 and in 2014, respectively, and CH_4 emissions from *Wastewater Treatment and Discharge* accounted for 1.05% and 1.07% in 2013 and 2014, respectively.

4.4.4 Methane emissions from Solid Waste Disposal (4A)

Choice of method

To estimate CH_4 emissions from *Solid Waste Disposal* (SWDS), the First Order Decay (FOD) method was applied, considering the recommendation provided by the IPCC 2006 Guidelines [Gen-1, Volume 5]. This method assumes that the degradable organic component (DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are formed. If conditions are constant, the rate of CH_4 production depends solely on the amount of carbon remaining in the waste. As a result, emissions of CH_4 from waste deposited in a disposal site are highest in the first few years after deposition, then gradually decline as the degradable carbon in the waste is consumed by the bacteria responsible for the decay.

Half-lives for different types of waste vary from a few years to several decades or longer. The FOD method requires data to be collected or estimated for historical disposals of waste over a time period of 3 to 5 half-lives in order to achieve an acceptably accurate result. It is therefore good practice to use disposal data for at least 50 years as this time frame provides an acceptably accurate result for most typical disposal practices and conditions. In Armenia the lack of activity data does not allow to make such accurate assessment for the Soviet period (up to 90s).

Under these conditions the following approach was applied. The calculations were made in two options. In the first option the calculations were made for the time period starting from the year 1990. In this case the methane emissions value can be underestimated as of present, but in the course of time the methane emissions values will be corrected in parallel with availability of more data.

In the other option, the calculations were made for the time period starting from the year 1950 while expert judgement was used when empirical data are not available. As a result, the methane emissions values were not underestimated but uncertainty level was high.

Methane emissions from *Solid Waste Disposal* provided in Table 4.71 have been calculated applying the second option, considering that more accurate data would be available throughout time.

Choice of emission factors and parameters

The following values were applied for the calculations:

- Per capita waste generation rate for MSW selected for Yerevan is 0.315 tonnes/capita/year [WRef-5], for Gyumri and Vanadzor - 0.274 tonnes/capita/year [WRef-6] and for other cities - 0.219 tonnes/capita/year [WRef-6]. As the IPCC 2006 Inventory Software allows to input only one value MSW generation, so the weighted average emission factor was calculated. The calculation was done as follows: based on the above mentioned factors and population number of cities, the total generated waste was calculated; the result was divided by the urban population number to obtain the average rate of the waste generation per capita (MSW) that is 0.278 tonnes/capita/year for 2013 and 0.279 tonnes/capita/year for 2014. (The IPCC default value for the Russian Federation is 0.340 tonnes/capita/year).
- For the fraction of MSW disposed into dumpsites, the following factors were used: 0.9 [WRef-5 /3. 5. 1/ and WRef-6] for Yerevan, Gyumri and Vanadzor; 0.75 [WRef-6] for other cities. In this case also the average value of this factor was calculated, equaling to 0.86 (IPCC default value for the Russian Federation is 0.9).
- To define the amount of the degradable organic carbon (DOC) in MSW (Gg C/Gg MSW) mass disposed into dumpsites reliable local data on MSW morphology are required.

  Increase in fraction of degradable carbon in MSW (food waste, paper, cardboard) generated in the country was observed in recent decades. According to the available data [WRef-1] the value of this factor is equal to 0.17 which is very close to default value 0.18 provided in the Guidelines [Gen-1, Volume 5, IPCC Waste Model].

  Fraction of degradable organic carbon in waste (DOC_f) was selected 0.5 [Gen-1, Volume 5, Chapter 3, 3.2.3., Fraction of Degradable Organic Carbon which Decomposes DOC_f, page 3.13], fraction of methane in landfill gas (F) is 0.5 [Gen-1, Volume 5, Chapter 3, page 3.15].

  The default value 0.05 $year^{-1}$ of the IPCC 2006 Guidelines was selected for decay rate constant (k) [Gen-1, Volume 5, Chapter 3, Table 3.3]. It complies with SW half-life decay 13.86 year period [Gen-1, Volume 5, IPCC Waste Model].

  The IPCC 2006 Guidelines default value 6.0 month is selected for delay time (t) [Gen-1, Volume 5, Chapter 3, Delay time, Page 3.19].

Activity data

The number of urban population was taken from official statistics [Ref-9, Ref-10].

For assessing methane emissions from solid waste disposal sites (SWDS) they were classified by cities of RA, by using Methane Correction Factor (MCF) default values [Gen-1, Volume 5, Table 3.1].

- Capital City of Yerevan - up to 2006 100% of solid waste and since 2006 70% of solid waste was disposed to the anaerobic managed SWDS ("Nubarashen" SWD site is the largest in RA); *MCF = 1.0*
- Capital City of Yerevan – since 2006 30% of solid waste was disposed to Jrvezh, Spandaryan and Sasunik unmanaged SWDS having depths of greater than or equal to 5 meters;

  MCF = 0.8
- Gyumri and Vanadzor cities – unmanaged SWDS having depths of greater than or equal to 5 meters; *MCF = 0.8*

- Other 45 cities and towns of the country – unmanaged shallow SWDS, having depths of less than 5 meters; *MCF = 0.4.*

According to the monitoring reports of "Nubarashen" CDM project, 1.033 Gg CH_4 (21.07 Gg $CO_{2eq.}$) and 0.91 Gg CH_4 (19.08 Gg $CO_{2eq.}$) were captured and flared in 2013 and 2014, respectively [WRef-2].

Taking into consideration that country-specific data were used as activity data and for the parameters mainly default values were used, it can be considered that Tier 2 method was applied while in previous inventories Tier 1 method was used.

Completeness

From the waste types mentioned in Guidelines, MSW was considered - other types of waste are not generated in Armenia, except for industrial waste. However, taking into consideration the fact that industrial waste is mostly disposed in MSW dumping sites and the waste generation country-specific data were used in calculations, it can be inferred that industrial waste was included and this type of waste was also taken into account.

Developing consistent time series

Emission calculation was done by IPCC 2006 Guidelines software, thus for all the years included in the time series the calculation was done using the FOD methodology. For MSW calculation official statistics on urban population were used. The FOD model requires historical data back to 1950. For this period the MSW generation rate was changed. To consider these changes the observed period was divided into 3 parts: Soviet (1950-1990), transition (1991-2001) and sustainable market period (since 2002). For the Soviet period the MSW generation rate was 0.210 tonnes/capita/year, which is taken from the Soviet period normative documents (Building Code (СНиП) 2.07.01-89). For 2002-2014 the MSW generation rate was calculated by applying a method described in the "Choice of emission factor" section. For the 1991-2001 period, the MSW generation rates were calculated by applying the interpolation method.

Time series of methane emissions from SWDS are given in Figure 4.40

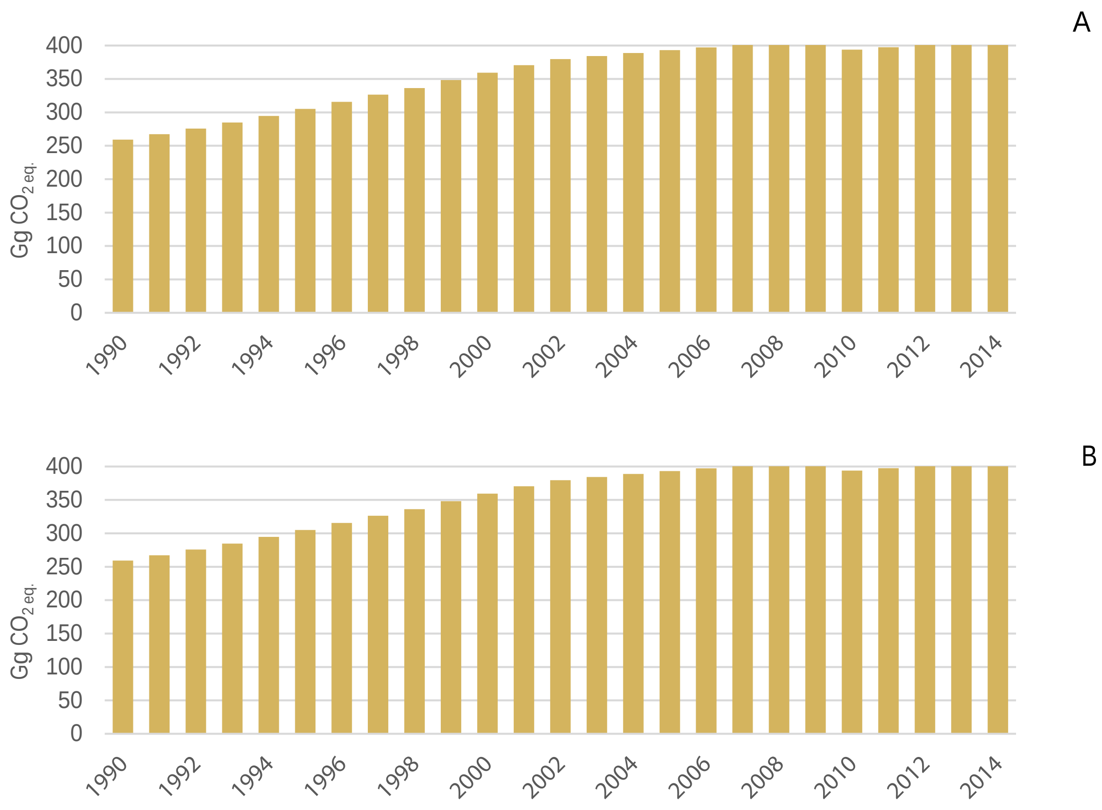


Figure 4.40 Methane emissions from SWDSs, calculated since 1950 (A) and since 1990 (B), Gg CO_{2eq}.(without CDM project methane capture in Nubarashen)

As it was expected, figures calculated since 1990 are underestimated.

The methane emissions percentage distribution according to the landfill classification is presented in Figure 4.41.

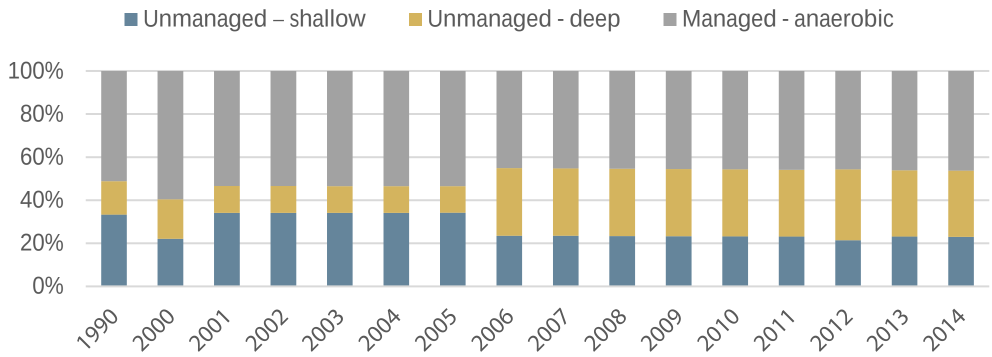


Figure 4.41 Methane emissions percentage distribution according to landfill classification

The observed sharp change in 2006 is due to the fact that 30% of the Yerevan waste was disposed in new dumpsites, which are considered as "unmanaged deep".

Uncertainty assessment

There are two areas of uncertainty in the estimate of CH_4 emissions from SWDS:

- Uncertainty attributable to the method
- Uncertainty attributable to the data (activity data and parameters).

However, it is important to remember that the FOD method is a simple model of a very complex and poorly understood system [Gen-1, Volume 5, Chapter 3]. However, uncertainty is mainly caused by the activity data and emission factors.

In the Table 4.67 the uncertainty estimates selected from IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 3, Table 3.5] are provided.

Table 4.67 Estimates of uncertainties associated with the default activity data and parameters

Activity data and parameters	Uncertainty range
Total Municipal Solid Waste (MSW_T)	30%
Fraction of MSWT sent to SWDS (MSW_T)	±30%
Total uncertainty of Waste composition	±50%
Degradable Organic Carbon (DOC)	±20%
Fraction of Degradable Organic Carbon Decomposed (DOC_f)	±20%
Methane Correction Factor (MCF) = 1.0 = 0.8 = 0.4	 -10%, +0% ±20% ±30%
Fraction of CH_4 in generated Landfill Gas (F) = 0.5	±5%
Methane Recovery (R)	±10%

Activity data, emission factors and general uncertainty were calculated according to the IPCC 2006 Guidelines [Gen-1, Volume 1, Equation 3.1]:

- Activity data: 68.56%
- Emission factors: 28.72%
- General uncertainty: 74.33%

4.4.5 Open Burning of Waste (4C2)

Open burning of waste generates carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions.

There are no data on the amount of waste open burned and emission factors in Armenia. Calculations were made according to Equations 5.4, 5.5, 5.7 [Gen-1, Chapter 5, Volume 5]. The amount of waste open burned was calculated based on the number of rural population which was 1109.4 thousand and 1103.0 thousand in 2013 and 2014, respectively [Ref-8].

For per capita MSW generation factor, the value of 0.40 kg/capita/day or 0.146 tonnes/capita/year was chosen for rural population [WRef-6, Table 2].

Default values were applied for waste parameters (dry matter content, carbon content and other input parameters) [Gen-1, Volume 5, Chapter 5].

B_{frac} - the fraction of MSW for which carbon content is converted to CO_2, B_{frac} is *0.6* [Box 5.1, page 5.17].

dm_i - total dry matter content in the MSW is 0.78 [Gen-1, Volume 5, Chapter 5, page 5.17].

CF_i - carbon content in the waste type is 0.34 [Gen-1, Volume 5, Chapter 5, page 5.17-18].

FCF_i - fraction of fossil carbon in the waste type *i* of the MSW is 0.08 [Gen-1, Volume 5, Chapter 5, page 5.19-20].

OF_i - oxidation factor is 0.58 [Gen-1, Volume 5, Chapter 5, Table 5.2, page 5.18].

Calculated greenhouse gas emissions are given in the Table 4.71.

Figure 4.42 presents greenhouse gas emissions time series from open burning of waste.

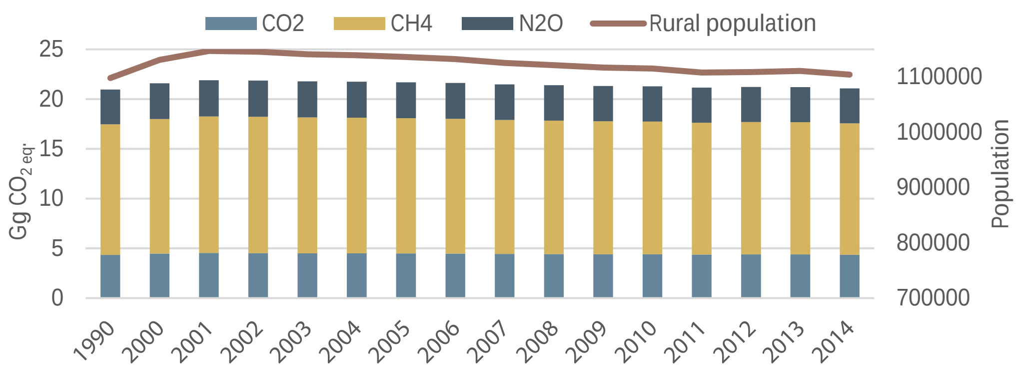


Figure 4.42 Greenhouse gas emissions from open burning of waste

4.4.6 Wastewater Treatment and Discharge (4D)

Greenhouse gas emissions sources from wastewater are:

- *Domestic Wastewater Treatment and Discharge* (4D1) - CH_4 and N_2O emissions
- *Industrial Wastewater Treatment and Discharge* (4D2) - CH_4 emissions.

Given the lack of reliable data and country-specific parameters, methane emissions calculation was done by the IPCC 2006 Guidelines Tier 1 approach [Gen-1].

Country-specific data used for the calculations were taken from the official statistics (NSS and the Ministry of Nature Protection).

The default values of the following factors have been reviewed and updated as well as the following input data were clarified:

- I - correction factor for additional industrial Biochemical Oxygen Demand (BOD) discharged into sewers (for collected the default is 1.25) [Gen-1, Volume 5, Chapter 6, page 6.14]. It expresses the BOD from industries and establishments (e.g., restaurants, butchers and etc.) that is co-discharged with domestic wastewater.
- The activity data that are needed for estimating N_2O emissions are nitrogen content in the wastewater effluent, country population and average annual per capita protein

generation (kg/person/year). Per capita protein generation consists of intake (consumption) which is taken from the country relevant publications of the United Nations Food and Agriculture Organization (FAO) [WRef-9].

- Dynamic range of distribution of different population groups has been clarified. Recalculation was done on the basis of the 2001 and 2011 Census.
- Wastewater emissions from the sugar production (officially published data for 2004-2014) have been considered while calculating methane emissions from the industrial wastewater.

Taking into consideration the above mentioned changes, recalculation was done for the entire time series to ensure their consistency.

4.4.6.1 Methane emissions from Domestic Wastewater

Because the methodology is on a per person basis, emissions from commercial wastewater are estimated as part of domestic wastewater [Gen-1, Volume 5, Chapter 6].

According to the IPCC 2006 Guidelines, assessment of methane emissions from domestic and commercial wastewater and methodology selection was done for different groups of population (rural population, urban high, and urban low income groups) in terms of the wastewater discharge/treatment system types existing in the country.

The practices for domestic and commercial wastewater discharge/treatment are not changed over the period of 1990-2014 in Armenia. In large cities and towns the domestic and commercial wastewater is discharged by the existing sewer system, in the rural communities - mostly by the latrines and holes. There is no centralized biological treatment of domestic and commercial wastewater, sludge removal and methane capturing.

Estimation of methane emissions from the domestic and commercial wastewater are done by three steps based on the Guideline's equations [Gen-1, Volume 5, Chapter 6, Sections 6.1, 6.2, 6.3].

Choice of emission factors

Methane emissions were estimated applying Tier 1 method and the following default values of emission factors were used:

Bo - maximum CH_4 producing capacity (kg CH_4/kg BOD): Bo = 0.6 [Gen-1, Volume 5, Table 6.2].

MCF= 0.1[Gen-1, Volume 5, Chapter 6, Table 6.3].

I = 1.25 for collected domestic and commercial wastewater. [Gen-1, Volume 5, page 6.14].

Choice/collection of activity data

Population statistics are available from RA NSS official website [Ref-8], these data are also published in the RA NSS yearbooks.

Based on the Guidelines default data, as well as domestic and commercial wastewater discharge/treatment practices existing in RA, the following degree of utilization of treatment or discharge pathway has been used for different population groups.

- Large cities (Yerevan, Gyumri, Vanadzor) the sewer fraction: 0.95 (95%), public and other latrines: 0.05 (5%),
- Other towns of the country the sewer fraction: 0.5 (50%), public and other latrines: 0.5 (50%),
- Rural communities the sewer fraction: 0.05 (5%), public and other latrines: 0.95 (95%) (expert judgement, Ref-4, WRef-4).

$MCF_j = 0.1$ was selected for removals through the sewer system which complies with removal of collected and untreated domestic and commercial wastewater that are eventually discharged in rivers, lakes and river mouths [Gen-1 Volume 5, Chapter 6, Table 6.3].

In the case of latrines, *the default value 0.1 was also selected for MCF_J* factor which complies with the arid climate areas where the level of subterranean water is below the depth of latrines or holes of small family (3-5 persons) [Gen-1 Volume 5, Chapter 6, Table 6.3].

BOD =18250 kg/1000person/year (which is equal to 50g/person/day). The IPCC 2006 Guidelines does not recommend any values for the selection of this calculation parameter for South Caucuses countries or former Soviet Republics. For that reason the default values recommended by the IPCC 1996 Revised Guidelines [Gen-8] for former Soviet Republics were used – 18250 kg/1000 person/year (50g/person/day). This value was also used for the previous NIRs calculations. It is worth mentioning that in some publications available at the Russian and Armenian websites the value of 60g/person/day was used, however considering that these publications are not official, the value of 50g/person/day was used.

From the other side the NSS publishes the BOD annual quantity in wastewater. However, these data are not complete and therefore cannot be used for the calculations yet.

The calculations were done by using both Excel spreadsheets and the IPCC 2006 Software.

Times series consistency

1990-2014 time series of methane emissions from domestic and commercial wastewater along with population dynamics are provided in Figure 4.43.

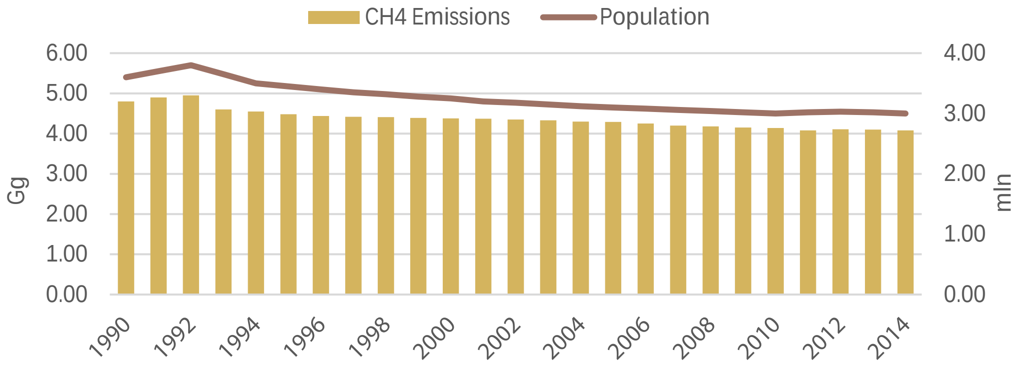


Figure 4.43 Methane emissions from domestic and commercial wastewater and population dynamics

Figure 4.44 shows the trend in methane emissions from the domestic and commercial wastewater by different population groups: population of large cities (Yerevan, Gyumri, Vanadzor), urban and rural population. The large cities are the key source of methane emissions from domestic and commercial wastewater. Decrease of emissions are mainly caused by the migration processes in the country.

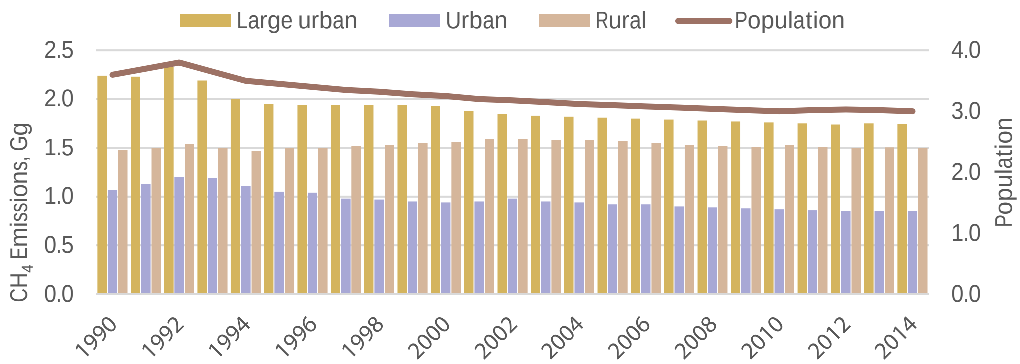


Figure 4.44 Methane emissions from domestic wastewater by population groups, 1990-2014

Uncertainty assessment

Uncertainty estimates of methane emissions from domestic and commercial wastewater were done according to the IPCC 2006 Guidelines [Gen-1, Volume 5, Table 6.7]. According to the

Guidelines the most uncertain data is the degree of utilization of treatment/discharge pathway for each income group ($T_{i,j}$). The uncertainty range is ±3% - ±50%. The uncertainty range of Bo is ±30%.

According to the Guideline, the uncertainty range of the human population for calculation of methane emissions from the wastewater is considered to be ±5%, BOD per person is ±30%, for the sewer access for different groups of people is ±15%.

The activity data, emission factor and total uncertainties calculated according to the IPCC 2006 Guidelines [Gen-1, Volume 1, Equation 3.1] are as follows: for activity data is 36.4%, for emission factors is 58.31% and total uncertainty is 68.74%.

4.4.6.2 Industrial Wastewater

Methane emissions

Methane emissions from the industrial wastewater were estimated by three steps according to the IPCC 2006 Guidelines [Gen-1, Volume 5, Equations 6.4, 6.5 and 6.6].

Choice of emission factors

According to the Tier 1 method the following default values for calculation of methane emissions from industrial wastewater were used.

MCF = 0.1 (for collected and untreated industrial wastewater that are eventually discharged in rivers, lakes and river mouths) [Gen-1, Volume 5, Chapter 6, Table 6.3].

Bo = 0.25 kg CH_4/kg BOD [Gen-1, Volume 5, Chapter 6, page 6.21].

Choice of activity data

2006 IPCC Guidelines suggests to consider several industry types with corresponding default values [Gen-1, Volume 5, Chapter 6, Table 6.9]. Table 4.68 provides industrial wastewater data relevant to Armenia that have been selected from Table 6.9 [Gen-1, Volume 5, Chapter 6].

Table 4.68 Industrial wastewater data

Industry type	Wastewater generation, W_i, m^3/ton	COD, kg/m^3
Milk, Dairy Products, including Cheese	7	2.7
Fruits, Vegetable Preserves, Juices	20	5.0
Alcohol Refining	24	11.0
Paper, Cardboard	162	9.0
Meat, Meat Products, Canned Meat	13	4.1
Beer	6.3	2.9
Wines: Champagne	23	1.5
Detergents, Cleansing and Starching Agents	9	10.0
Plastics	0.6	3.7
Vegetable and Other Oils	3.1	0.5
Soap	1.0	0.5
Fish Processing	8	2.5
Sugar Processing	4	3.2

The required activity data were obtained from NSS publications [WRef-8].

Table 4.69 presents the industrial outputs per industry types which generate wastewater, 2000-2014.

Table 4.69 Industrial outputs (thousand tonnes/year), 2000-2014

Industry sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Alcohol Refining	12.37	15.64	17.13	18.42	20.22	22.84	22.10	26.92	29.25	25.12	25.77	24.41	28.78	35.95	29.76
Beer & Malt	7.94	9.97	7.08	7.31	8.83	10.75	12.62	11.63	10.53	10.83	15.35	14.74	13.80	20.05	23.95
Dairy Products	196.04	202.63	212.79	226.03	354.75	315.91	328.91	370.41	388.24	359.09	374.58	355.40	359.94	405.93	435.37
Fish Processing	0.00	0.08	0.27	0.23	0.14	0.09	0.01	0.18	0.12	0.03	0.05	7.10	9.35	0.06	0.03
Meat & Poultry	41.66	39.47	39.78	42.78	44.98	48.27	55.30	60.85	63.87	63.03	59.46	66.14	71.85	78.80	88.99
Plastics & Resins	0.00	0.15	0.23	0.92	2.14	3.10	6.47	9.36	6.69	9.05	10.14	25.31	24.89	24.98	26.95
Pulp & Paper	0.00	0.24	0.65	1.61	1.61	1.81	1.72	1.35	2.00	2.14	3.37	10.48	10.66	13.53	17.68
Soap & Detergents	0.00	0.00	0.00	0.05	0.20	0.06	0.02	0.06	0.01	0.05	0.08	0.09	0.09	0.17	0.10
Starch Production	0.00	0.59	0.56	0.44	0.65	3.18	3.55	2.80	2.27	2.33	2.33	2.11	1.89	2.33	1.58
Vegetable Oils	0.00	0.26	1.46	2.18	0.39	0.68	3.38	0.90	2.01	2.20	2.22	1.70	3.26	5.19	3.98
Vegetables, Fruits &Juices	20.63	55.31	81.70	53.53	47.97	47.47	53.42	54.54	62.93	52.80	57.71	72.06	71.15	92.25	112.3
Wine & Vinegar	4.09	6.92	7.10	2.65	2.83	7.21	4.32	4.19	3.76	4.84	6.37	6.75	6.24	7.22	6.77
Sugar	-	-	-	-	0.72	1.89	2.21	3.29	3.83	0.87	32.51	72.16	69.27	69.63	89.19

The following default values were used in the calculations:
COD_i, kg COD/m^3 - default values [Gen-1, Volume 5, Chapter 6, Table 6.9].
W_i, m^3/ton - default values [Gen-1, Volume 5, Chapter 6, Table 6.9]
$S_i = 0$ kg COD/yr [Gen-1, Volume 5, Chapter 6]. The emissions from the sludge are not considered.
$R_i = 0$ kg CH_4/yr [Gen-1, Volume 5, Chapter 6]. Methane discharge/removal from industrial wastewater is not considered.

Time series consistency

Time series of methane emissions from industrial wastewater are presented below in Figure 4.45.

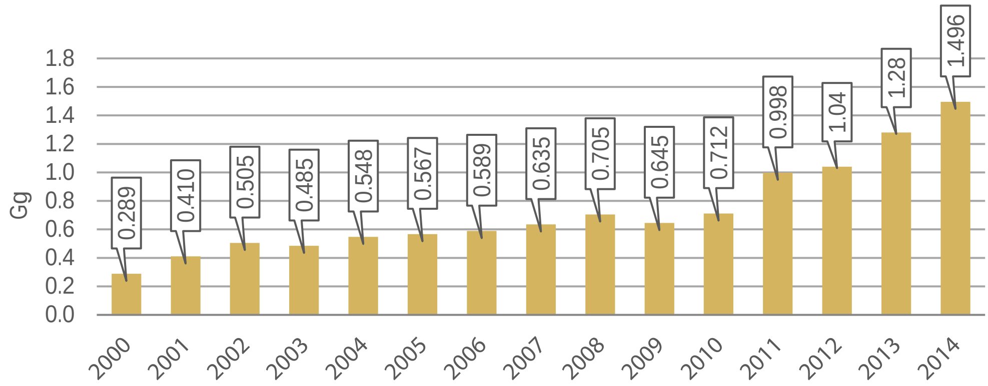


Figure 4.45 Methane emissions from industrial wastewater, for 2000-2014, Gg

As it is obvious from the picture, the methane emissions from industrial wastewater is steadily increasing for the period of 2000-2014 with the exception of 2003 and 2009: for 2003 it is due to the unfavorable agriculture and food safety conditions observed in 2002 and for 2009 - due to the impact of the 2008-2009 global financial crisis.

The share of methane emissions from industrial wastewater per industry type is given in the Figure 4.46. It's obvious that the increase of methane emissions in 2013-2014 is due to the increase of methane emissions from industrial wastewater from "Pulp & Paper".

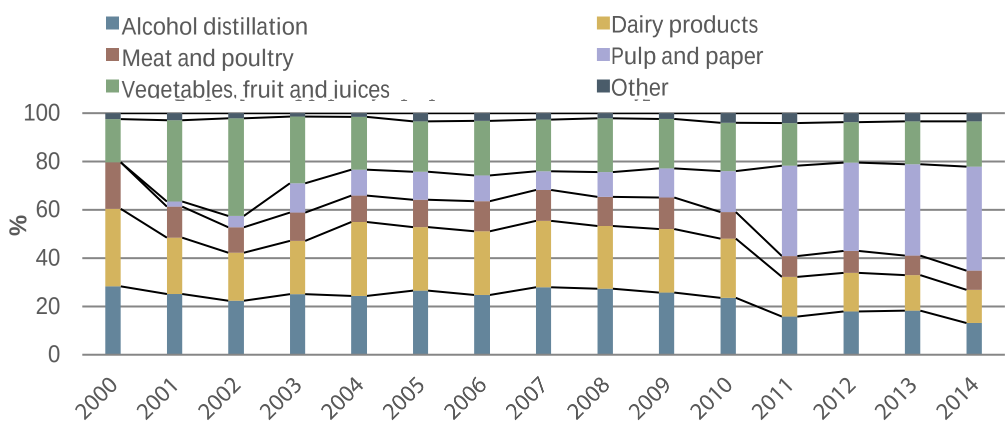


Figure 4.46 Shares of methane emissions from industrial wastewater per industry types for 2000-2014, (%)

Methane emissions from the wastewater for 1990-2014 are summarized in the Figures 4.47.

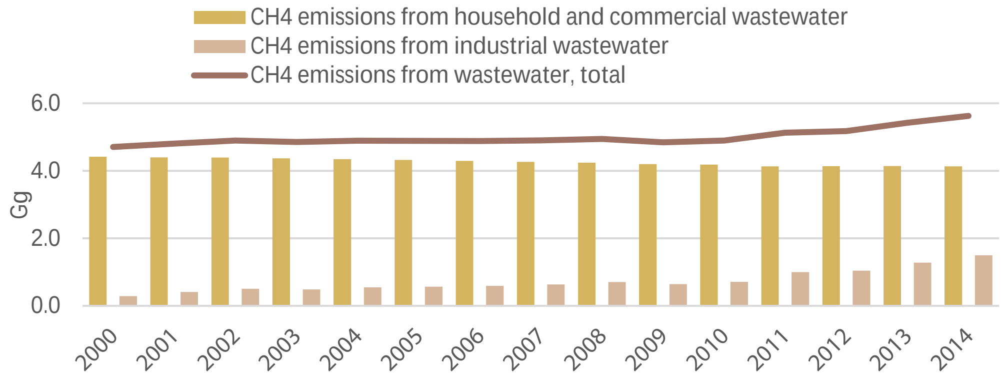


Figure 4.47 Methane emissions from different categories of wastewater, 2000-2014, Gg

It is obvious from Figure 4.47 that methane emissions from domestic and industrial wastewater predominate in total wastewater emissions.

Uncertainty Assessment

Uncertainty estimates of methane emissions from industrial wastewater were done according to the IPCC 2006 Guidelines [Gen-1] based on the default values of uncertainty range presented in the Table 6.10. The most uncertain data to estimate methane emissions from industrial wastewater are COD per industry type. These data can be very uncertain as the same sector might use different waste handling procedures at different plants. An uncertainty value can be attributed directly to kg COD/tonne of product. –50 %, +100% is suggested [Gen-1].

The uncertainty range of the maximum CH_4 producing capacity (B_o) is ±30%, methane correction factor (MCF) is from 0 to 1, product volume is 25% [Gen-1].
The activity data, emission factor and total uncertainties calculated according to the IPCC 2006 Guidelines [Gen-1, Volume 1, Equation 3.1] are as follows: for activity data is 75.00%, for emission factors is 58.31% and total uncertainty is 95.00%.

Nitrous oxide emission from Wastewater

2006 IPCC Guidelines suggest the same approach for the nitrous oxide emissions estimate from the wastewater both for the developing and developed countries. According to the proposed method the calculations are based on the country total population number and the per capita 'consumed' protein. Nitrous oxide emissions from wastewater are estimated based on Equations 6.7 and 6.8 [Gen-1, Volume 5, Chapter 6].

The following default values were used for the calculations [Gen-1, Volume 5, Chapter 6, Table 6.11]:

$EF_{EFFLUENT}$ - N_2O emission factor (kg N_2O-N/kg N) is 0.005.

F_{NPR} - Fraction of nitrogen in protein (kg N/kg protein) is 1.6.

$F_{NON\text{-}CON}$ - Factor to adjust for non-consumed protein. Taking into account that there is waste and wastewater disposal in Armenia $F_{NON\text{-}CON}$ = 1.40 value was used in the calculations.

$F_{IND\text{-}COM}$ - Factor to allow for co-discharge of industrial and commercial protein into the sewer, $F_{IND\text{-}COM}$ = 1. 25

Nitrogen removed with sludge $N_{SLUDGE} = 0$ **-** As in the previous two sections referring to the wastewater, as well as in this section, based on the wastewater treatment and discharge practice in the country, nitrogen removal from sludge generated from wastewater is not considered.

Annual per capita protein consumption **(**kg/person/yr) – For this value the Guidelines recommend to calculate FAO protein indicator consumed by a person in the certain country for the certain period. In the previous NIRs the UN FAO Middle East indicator (0.76g/person/day) was used as there is no data on consumed protein for Armenia.

The FAO data published for Armenia were used in this inventory report. These data are presented in the Table 4.70 and served a basis for recalculation for the whole period (1990-2014) (WRef-9).

Table 4.70 Consumed protein (g/person/day)

Years	1999-01	2000-02	2001-03	2002-04	2003-05	2004-06	2005-07	2006-08	2007-09	2008-10	2009-11	2012-14
Consumed protein (g/person/day)	66	66	68	71	74	78	81	84	85	85	85	85

The consumed protein (g/person/day) by years exceed the values used in the previous inventory reports, leading to the increased of nitrogen oxide emissions from wastewater.

Time series consistency and uncertainty assessment

To ensure time series consistency, nitrogen oxide emissions from wastewater have been recalculated for the whole period considering the national data on consumed protein by a person in a certain year (person/year).

Time series of the nitrogen oxide emissions from wastewater depending on protein consumption and population number are given in the Figures 4.48 and 4.49.

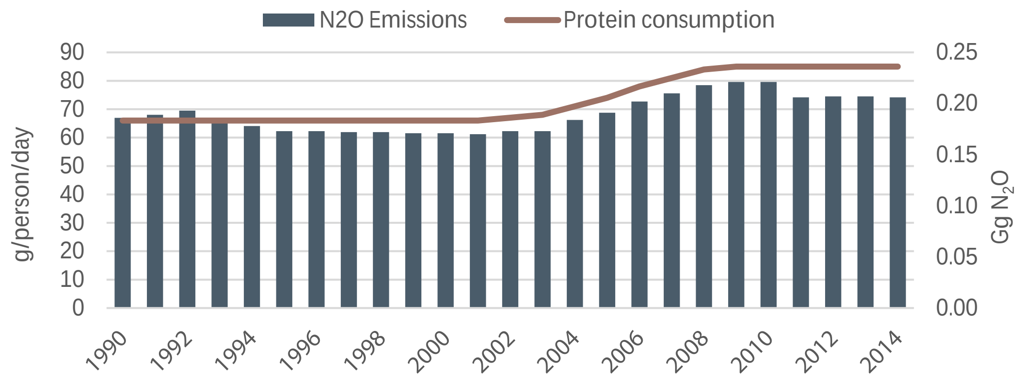


Figure 4.48 Nitrogen oxide emissions from wastewater and protein consumption, 1990-2014

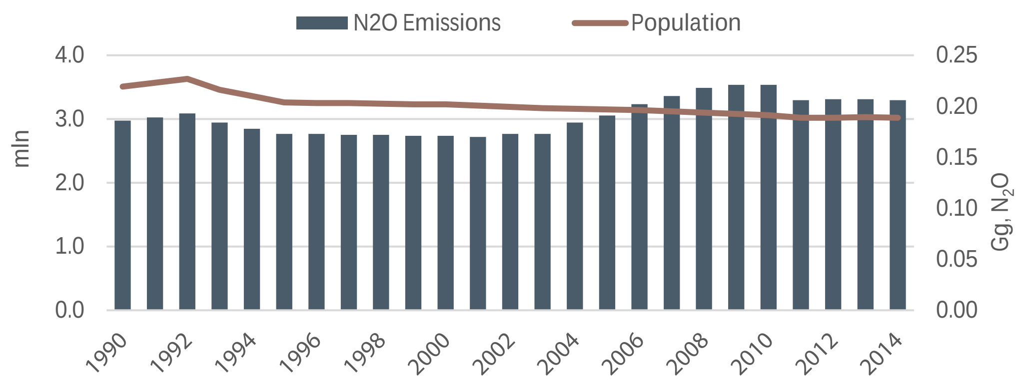


Figure 4.49 Nitrogen oxide emissions from wastewater and population number, 1990-2014

Currently there is no sense to estimate the uncertainty of the nitrogen oxide emissions from wastewater as the corresponding studies are very limited while the recommended range for the emission factors is very large, in particular N_2O emission factor (kg N_2O-N/kg N) uncertainty range is - $EF_{EFFLUENT}$: 0.0005 - 0.25 [Gen-1, Volume 5, Table 6.11]

Quality Assurance/ Quality Control

The calculations were also done by the Excel and compared to the results received by running the 2006 IPCC Inventory Software.

Time series consistency was checked and ensured by comparative analysis with emissions estimates in the previous inventories.

4.4.7 Possible improvements

Solid Waste Disposal

Since 2015 the internationally recognized organizations such as "Sanitek" and "Eco Group" have been involved in the waste removal activity. This fact allows to assume that over time data enabling development of the country-specific emission factors will become available. The other possible improvement relates to the clarified population number.

Wastewater Treatment and Discharge

The NSS and the MNP are moving towards improvement of the legislative framework and full enforcement of the existing legal acts.

The main possibility of the methane emissions data improvement from domestic and commercial wastewater depends on the availability of the reliable data on the population number including distribution between urban and rural population as well as on their access to the sewer system. The RA NSS publishes the data on the share of the households with access to the sewer system per rural and urban households (Armenia's Millennium Challenge indicators). After clarification of the household number and average number of the household members the national data will be used in the calculations.

The MNP collects statistics reports from the operating companies. However, these data are incomplete since not all entities provide such reports and provided ones are often incomplete, therefore improvement of this process is required.

4.4.8 Emissions from Waste Sector

GHG emissions from Waste Sector is given in the Table 4.71.

Table 4.71 GHG emissions from Waste Sector

Emission Sources	Emissions, Gg					
	2013			2014		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
4. Waste	**4.391**	**25.311**	**0.218**	**4.365**	**25.689**	**0.217**
4A Solid Waste Disposal	NA	19.255	NA	NA	19.435	NA
4C Incineration and Open Burning of Waste	4.391	0.633	0.011	4.365	0.629	0.011
4C2 Open Burning of Waste	4.391	0.633	0.011	4.365	0.629	0.011
4D Wastewater Treatment And Discharge	NA	5.423	0.207	NA	5.626	0.206
4D1 Domestic Wastewater Treatment and Discharge	NA	4.143	0.207	NA	4.130	0.206
4D2 - Industrial Wastewater Treatment and Discharge	NA	1.280	NA	NA	1.496	NA

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ANNEXES

Energy

Annex 1. Data on natural gas main characteristics for 2013 and 2014 provided by "GAZPROM ARMENIA" CJSC (letter N 02-21/196 dated 23.01.2017) in response to the RA Ministry of Nature Protection letter (N 2/05.1/20024-17 dated 13.01.2017)

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Հայաստանի Հանրապետության
բնապահպանության նախարարի
առաջին տեղակալ
պարոն Ս.Պապյանին

Հարգելի պարոն Պապյան

Ի պատասխան Ձեր առ 16.01.2017թ. № 2/05.1/20024 գրության տրամադրում ենք տեղեկատվություն Ռուսաստանի Դաշնությունից և Իրանի Իսլամական Հանրապետությունից Հայաստանի Հանրապետություն ներկրված բնական գազի միջին տարեկան ֆիզիկա-քիմիական ցուցանիշների արժեքները 2013 և 2014թթ. համար, այդ թվում բաղադրամասերը, խտությունը, ջերմարարությունը:

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Natural Gas Annual Average Characteristics provided by "GAZPROM ARMENIA"

1. Natural gas imported from the Russian Federation

Components, mol % Annual average	2013	2014
Oxygen O_2	0.0099	0.0105
Carbon Dioxide CO_2	0.6257	0.6116
Nitrogen N_2	1.2610	1.1675
Ethane C_2H_6	4.9551	5.2100
Propane C_3H_8	0.9167	1.0168
Isobutane i-C_4H_{10}	0.0860	0.0826
N-butane n-C4H10	0.1081	0.0984
Pentane C_5H_{12} and C_5+	0.0942	0.0390
Methane CH_4	91.9869	91.7637
Density (kg/m^3)	0.7259	0.7278
Indicators		
Net Calorific Value (average), kcal/m^3 (standard conditions t=20˚C, P=101.325 kPa)	8303	8337
Net Calorific Value (average), MJ/ m^3	34.76	34.91
Wobbe index MJ/ m^3	49.56	49.75
Mass concentration of hydrogen sulphide, g/m^3	0.0011	0.0013
Mass concentration of mercaptan sulfur, g/m^3	0.0025	0.0034
Mass concentration of mechanical impurities, g/m^3	0	0

2. Natural gas imported from the Islamic Republic of Iran

Components, mol % Annual average	2013	2014
Oxygen O_2	0.0196	0.0172
Carbon Dioxide CO_2	0.6158	0.6693
Nitrogen N_2	4.2609	4.2848
Ethane C_2H_6	3.3317	3.2842
Propane C_3H_8	1.2583	1.0491
Isobutane i-C_4H_{10}	0.2176	0.1669
N-butane n-C4H10	0.2974	0.2288
Pentane C_5H_{12} and C_5+	0.0976	0.0944
Methane CH_4	89.9012	90.2053
Density (kg/m^3)	0.7448	0.7391
Indicators		
Net Calorific Value (average), kcal/m^3 (standard conditions t=20˚C, P=101.325 kPa)	8076	8020
Net Calorific Value (average), MJ/ m^3	33.81	33.58
Wobbe index MJ/ m^3	47.72	47.64
Mass concentration of hydrogen sulphide, g/m^3	0.0014	0.0016
Mass concentration of mercaptan sulfur, g/m^3	0.0043	0.0058
Mass concentration of mechanical impurities, g/m^3	0	0

3. Natural gas mixture

Components, mol % Annual average	2013	2014
Oxygen O_2	0.0122	0.013
Carbon Dioxide CO_2	0.6191	0.605
Nitrogen N_2	1.9563	2.076
Ethane C_2H_6	4.5638	4.663
Propane C_3H_8	0.9992	1.072
Isobutane i-C_4H_{10}	0.1179	0.108
N-butane n-C4H10	0.1544	0.138
Pentane C_5H_{12} and C_5+	0.0606	0.053
Methane CH_4	91.5165	91.271
Density (kg/m^3)	0.7305	0.7312
Indicators		
Net Calorific Value (average), kcal/m^3 (standard conditions t=20˚C, P=101.325 kPa)	8256	8251
Net Calorific Value (average), MJ/ m^3	34.57	34.55

Wobbe index MJ/ m^3	49.16	49.14
Mass concentration of hydrogen sulphide, g/m^3	0.0012	0.0013
Mass concentration of mercaptan sulfur, g/m^3	0.0029	0.0038
Mass concentration of mechanical impurities, g/m^3	0	0

Annex 2. Calculation of country-specific CO_2 emission factor for stationary combustion of natural gas

CO_2 emissions from stationary combustion for electricity and thermal energy generation were calculated based on natural gas characteristics: composition, density, net calorific value of natural gas (per weight) and carbon content.

Below the sequence of the calculation steps is provided:

1. Carbon (C) content (mol, %) was calculated per natural gas components:

Methane (CH_4) 12/16 = 0.75

Ethane (C_2H_6) 24/30 = 0.8

Propane (C_3H_8) 36/44 = 0.8182

Isobutene (i-C_4H_{10}) 48/58 = 0.8276

N-butane (n-C_4H_{10}) 48/58 =0.8276

Pentane (C_5H_{12} and C_5+) 60/72 =0.8333

Carbon Dioxide (CO_2) 12/44 =0.2727

2. Carbon (C) content (mol, %) was calculated per components' share:

% of C per Methane share = 0.75 x CH_4 %

% of C per Ethane share = 0.8 x C_2H_6 %

% of C per Propane share = 0.8182 x C_3H_8 %

% of C per Isobutane share = 0.8276x C_4H_{10} %

% of per N-Butane share= 0.8276 x n-C_4H_{10} %

% of C per Pentane share = 0.8333 x C_5H_{12} and C_5 + %

% of C per Carbon Dioxide share = 0.2727 x CO_2 %

3. The total of Carbon content per components makes the carbon content (%) in 1 m^3 of natural gas.

4. The carbon content value (%) obtained in the point 3 was multiplied by the annual average data on the natural gas density (see Annex 1) to get the weight (g) of carbon content in 1 m^3 of natural gas (g/m^3).

5. The calorific value of the natural gas in kcal/m^3 (Annex 1) was recalculated to MJ/m^3 multiplying by 4.1868/1000.

6. To express the carbon content of the natural gas in kg/GJ, the carbon content value in g/m^3 (see point 4) was multiplied by 1000 and divided on natural gas annual average calorific value in MJ/m^3 (see point 5). This was done to compare it with the reference values provided in the 2006 Guideline.

7. According to 2006 IPCC Guideline, to get the CO_2 emission factor from natural gas stationary combustion in kg/TJ, the carbon content in kg/GJ given in point 6 should be multiplied by 1000 and 44/12.

CO_2 country-specific emission factors for natural gas imported from RF, mixture natural gas and natural gas imported from Iran are given in the Table below.

Carbon content values and country-specific CO_2 emission factors calculated based on the imported natural gas characteristics

Imported natural gas	Density	Net calorific values (NCV) [Default value: 48 TJ/Gg, confidence intervals limits: 46.5 - 50.4]			Carbon content [Default value: 15.3 kg/GJ; upper and lower intervals limits: 14.8 -15.9]			CO_2 emission factors [Default value: 56100 kg/TJ; 95 % confidence intervals limits: 54300-58300]
	kg/m^3	$kcal/m^3$	MJ/m^3	TJ/Gg	%	kg/m^3	kg/GJ	kg/TJ
2011								
Imported from RF	0.7231	8245	34.52	47.74	73.95	0.5347	15.49	56,798.02
Mixture	0.7260	8188	34.28	47.22	73.41	0.5330	15.55	57,004.85
Imported from Iran	0.7351	7999	33.49	45.56	71.73	0.5273	15.75	57,735.59
2012								
Imported from RF	0.7239	8245	34.52	47.68	73.95	0.5352	15.51	56,851.70
Mixture	0.7275	8149	34.12	46.90	73.41	0.5323	15.60	57,209.21
Imported from Iran	0.7374	8020	33.58	45.54	71.73	0.5293	15.76	57,801.53
2013								
Imported from RF	0.7259	8303	34.76	47.89	74.1141	0.5380	15.48	56,745.52
Mixture	0.7305	8256	34.57	47.32	73.5506	0.5373	15.54	56,993.61
Imported from Iran	0.7448	8076	33.81	45.40	71.7963	0.5347	15.81	57,987.50
2014								
Imported from RF	0.7278	8337	34.91	47.96	74.1718	0.5398	15.47	56,706.16
Mixture	0.7312	8251	34.55	47.24	73.4735	0.5372	15.55	57,022.93
Imported from Iran	0.7391	8020	33.58	45.43	71.7284	0.5301	15.79	57,890.73

Annex 3. Data on Natural Gas consumption by Thermal Power Plants for 2013 and 2014, received from the PSRC (letter N RN/3.2-32/24-17 dated 19.01.2017) in response to the RA Ministry of Nature Protection letter (N 1/05.1/10037-17, dated 16.01.2017)

ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ
ՀԱՆՐԱՅԻՆ ԾԱՌԱՅՈՒԹՅՈՒՆՆԵՐԸ ԿԱՐԳԱՎՈՐՈՂ ՀԱՆՁՆԱԺՈՂՈՎ
ՆԱԽԱԳԱՀ

ՀՀ, ԵՐԵՎԱՆ, ՍԱՐՅԱՆ 22, ՀԵՌ. (374-10) 522522, ՖԱՔՍ (374-10) 525563

« ______ » ________________ 2017 թ.

№ ________________

Հայաստանի Հանրապետության
բնապահպանության նախարար
պարոն Արծվիկ Մինասյանին

Ի պատասխան Ձեր
16.01.2017թ. №1/05.1/10037-17 գրության

Հարգելի պարոն նախարար,

Ձեզ է ուղարկվում ջերմային էլեկտրակայանների կողմից 2013 և 2014 թթ. սպառված վառելիքի ծախսի և ջերմարարության վերաբերյալ տեղեկատվությունը (կցվում է):

?????? ????????
Jan 19 2017 5:06 PM

Ռ. Նազարյան

Natural Gas consumption by Thermal Power Plants and Net calorific values (2013, 2014)

N	Thermal Power Plant	Measurement unit	2013	2014
1	Hrazdan TPP OJSC	thousand m^3	193,320.2	275,583.1
		kcal/m^3	8,221.5	8,290.2
2	"Gazprom Armenia" CJSC Hrazdan-5 TPP	thousand m^3	258,800.4	210,883.3
		kcal/m^3	8,264.0	8,302.0
3	Yerevan CCGT	thousand m^3	299,261.2	305,644.1
		kcal/m^3	8,253.0	8,260.0
4	Yerevan Medical University CHP plant	thousand m^3	3,898.0	4,309.0
		kcal/m^3	8,294.3	8,309.4
5	ArmRosCogeneration CJSC CHP plant	thousand m^3	3,706.0	3,125.0
		kcal/m^3	8,301.4	8,328.3

Annex 4. Main indicators of gas supply system for 2013 and 2014, mln m^3

	2013	2014
Imported Natural Gas, including:	**2361.05**	**2450.9**
From Russian Federation	1956.33	2061.7
From the Islamic Republic of Iran	404.73	389.2
Taken from gas pipelines and Gas Underground Storage Facility (GUSF)	**58.19**	**45.7**
Gas for own needs in the transmission system	**3.21**	**5.2**
Gas losses in the transmission system, including:	**98.63**	**102**
Technological inevitable losses in gas pipelines	98.62	102
Accidental losses	0.01	0.02
Injected into gas pipelines and GUSF	**33.92**	**73.4**
The volume of gas transmitted	**2283.47**	**2315.9**
Other consumers	414.75	260.4
Distribution system	1868.72	2055.5
Gas for own needs in the distribution system	**2.92**	**3.1**
Recovered gas	**0.88**	**0.9**
Gas losses in the distribution system	**43**	**42.7**
Natural gas sales in the distribution system, including:	**1821.92**	**2008.8**
Residential	538.93	515.4
Energy Generation	252.29	594.1
Industry	275.26	252.1
Compressed natural gas (CNG) stations	454.96	481.7
Budgetary organizations	49.89	49.1
Heating companies	0	0
Other consumers	250.59	116.3

Annex 5. Main indicators for power system for 2013 and 2014, mln kWh

Electricity generated and delivered	2013	2014
Electricity generation, including:	**7710**	**7750**
ANPP	2359.7	2464.8
Hrazdan TPP	660.1	957
"Gazprom Armenia" CJSC Hrazdan-5 TPP	1079	857.5
Yerevan CCGT	1405.7	1447.9
International energy corporation HPP	467.9	474.7
Vorotan HPP	965.2	833.1
Dzoraget Hydro	76.3	0
Combined Heat and Power Production (Cogeneration)	28.3	26.2
Power plants using renewable energy resources (up to 10 MW in 2013), (up to 30 MW in 2014)	667.8	688.9
Generating plants own needs, including:	**329.1**	**361.4**
ANPP	192.1	199.2
Hrazdan TPP	16.2	51.8
"Gazprom Armenia" CJSC Hrazdan-5 TPP	38.8	29.9
Yerevan CCGT	48	49.1
International energy corporation HPP	9.3	9.4
Vorotan HPP	6.9	6.5
Dzoraget Hydro	1.4	0
Combined Heat and Power Production (Cogeneration)	0.2	0.2
Power plants using renewable energy resources (up to 10 MW in 2013), (up to 30 MW in 2014)	16.2	15.4
Electricity supply from generation plants, including:	**7381**	**7388.6**
ANPP	2167.6	2265.6
Hrazdan TPP	643.9	905.2
"Gazprom Armenia" CJSC Hrazdan-5 TPP	1040.2	827.6
Yerevan CCGT	1357.7	1398.8
International energy corporation HPP	458.6	465.3
Vorotan HPP	958.3	826.6
Dzoraget Hydro	74.9	0
Combined Heat and Power Production (Cogeneration), including:	28.1	26
Yerevan Medical University CHP plant	14.4	14.5
ArmRosCogeneration CHP plant	13.8	11.5
Power plants using renewable energy resources (up to 10 MW in 2013), (up to 30 MW in 2014), including:	651.6	673.5
Lori-1 wind plant (up to 10 MW)	2.3	3.7
Lusakert Biogas Plant (up to 10 MW)	1.4	0
Small HPPs (up to 10 MW in 2013), (up to 30 MW in 2014)	647.9	669.8
Import including:	**147.7**	**205.8**
The Islamic Republic of Iran	63.5	50.9
Inflow to high voltage network	**7528.6**	**7594.4**
Loss of High Voltage Networks	**138.7**	**138.9**
Delivery from High Voltage Networks including:	**7389.9**	**7455.5**

Electricity generated and delivered	2013	2014
The Islamic Republic of Iran	1225.7	1195.1
Total losses in distribution networks including:	**810**	**789.9**
Technological losses	635.2	617.3
Commercial losses	174.8	172.6
Electricity supplied by Armenian Electric Networks CJSC (by consumers' groups)	**5267**	**5352**
Residential	1950	1933.5
Budgetary organizations	228.3	231.1
Industry	1208.6	1243.7
Transport	124.4	115.5
Irrigation	151.4	172.4
Water supply and sanitation	78.3	74.6
Other consumers	1526	1581.2

Annex 6. Data on consumed energy per fuel type, received from the RA NSC (letter 18-7-1-64, dated 20.01.2017) in response to the RA Ministry of Nature Protection letter (N 1/05.1/10024, dated 12.01.2017).

ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ
ԱԶԳԱՅԻՆ ՎԻՃԱԿԱԳՐԱԿԱՆ ԾԱՌԱՅՈՒԹՅՈՒՆ

ՀՀ Բնապահպանության նախարար
պարոն Ա. Մինասյանին

"20" 01 2017թ. № 18-7-1-64

Ձեր "____" ________ 20 թ. № _____

Հարգելի պարոն Մինասյան

Ի պատասխան Ձեր՝ 12.01.2017թ. № 1 /05.1/ 10024 գրության, սույնով ՀՀ Ազգային վիճակագրական ծառայությունը (ՀՀ ԱՎԾ) Ձեզ է տրամադրում ՀՀ ԱՎԾ-ում առկա տեղեկատվությունը գրությանը կից 1 և 2 հավելվածներով հայցվող ցուցանիշների վերաբերյալ:

Միաժամանակ տեղեկացնում ենք Ձեզ առ այն, որ ՀՀ ԱՎԾ-ն էներգահաշվեկշռի կազմման ուղղությամբ իրականացվող աշխատանքները սկսել է 2015թ.-ից (2014թ. տվյալներով), որով պայմանավորված հավելված 2-ով հայցվող տեղեկատվությունը ներկայացված է 2014 և 2015թթ. համար:

Առդիր 3 էջ

Հարգանքով

նախագահ Ա. Մնացականյան

Կատարողներ՝
Գյուղատնտեսության վիճակագրության բաժին հեռ. (011) 56 46 72
Արդյունաբերության և էներգետիկայի
վիճակագրության բաժին հեռ. (011) 52 35 43

4198
20 01 17

ք. Երևան, 0010
Հանրապետության պող.,
Կառավարական տուն 3

☎: (37411) 52-42-13, Ֆաքս: (37411) 52-19-21
Էլ. փոստ: info@armstat.am
http:// www. armstat.am

Categories/Subcategories	Coal	Natural Gas	Diesel	Gasoline	LPG	Fuelwood	Manure and other biofuel	Jet kerosine	CNG
	ton	thsd m^3	thsd liter	thsd liter	thsd m^3	ton	ton	ton	thsd m^3
Manufacturing Industries and construction, including:	989	278227	57496.9	29389.9	740.7	763	-	-	8641.6
Iron and Steel	-	18524.4	237.7	129	0.7	-	-	-	182.3
Chemicals	-	7406.8	569.9	222.3	0.1	-	-	-	439.6
Non-Ferrous Metals	-	15593	11449.8	104.7	3	635	-	-	-
Non-Metallic Minerals	-	116068.7	7102.9	1250.8	193.7	100	-	-	407.9
Transport equipment	-	-	-	-	-	-	-	-	
Machinery	-	1275.3	158.5	508.2	14.2	-	-	-	351.5
Mining (excluding fuels) and Quarrying	-	6211.6	11500.4	1123.7	285.4	-	-	-	345.1
Food Processing, Beverages and Tobacco	989	95910.1	11677.8	5708.6	27.6	18	-	-	3082.4
Pulp, Paper and Print	-	3705.1	31.6	79.7	2.1	-	-	-	81.3
Wood and wood products	-	15	9.8	118.2	157	10	-	-	19.5
Textile and Leather	-	323.8	14.9	58.4		-	-	-	159
Construction	-	8573.4	14083.4	19836.8	46.8	-	-	-	3220.9
Non-specified Industry	-	4619.8	660.2	249.5	10.1	-	-	-	352.1
Civil Aviation	-	-	636	244.8		-	-	40458	-
Road Transportation including:	-	-	18779.4	670.5	2.9	-	-	-	34216
Light-duty trucks (up to 3.5t)	-	-	-	-	-	-	-	-	-
Heavy-duty trucks (over than 3.5t)	-	-	-	-	-	-	-	-	-
Passenger cars	-	-	-	-	-	-	-	-	-
Buses	-	-	-	-	-	-	-	-	-
Microbuses	-	-	-	-	-	-	-	-	-
Commercial/Institutional	-	-	-	-	-	-	-	-	-
Residential	175.3	491750	2371.3	20015	4701 (ton)	1783.3 (thsd m^3)	109185	-	188882
Agriculture	-	-	-	-	-	-	-	-	-

Agriculture

Annex 7. Activity data on Agriculture Sector for 2013 and 2014 received from the Ministry of Agriculture (letter N RM/GO-1/388-17 dated 23.01.2017) in response to the RA Ministry of Nature Protection letter (N 2/05.1/20016-17, dated 13.01.2017)

ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ ԳՅՈՒՂԱՏՆՏԵՍՈՒԹՅԱՆ
ՆԱԽԱՐԱՐԻ ՏԵՂԱԿԱԼ

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ՀՀ ԲՆԱՊԱՀՊԱՆՈՒԹՅԱՆ ՆԱԽԱՐԱՐԻ
ԱՌԱՋԻՆ ՏԵՂԱԿԱԼ
ՊԱՐՈՆ Ս. ՊԱՊՅԱՆԻՆ

Ի պատասխան Ձեր 13.01.2017 թվականի
N 2/05.1/20016-17 գրության

Հարգելի պարոն Պապյան,

Ազգային կադաստրի «Գյուղատնտեսություն» բաժնի մշակման նպատակով ներկայացվում են «Գյուղատնտեսություն» բաժնի համար անհրաժեշտ ելակետային տվյալները:

Առդիր՝ 2 էջ:

ՀԱՐԳԱՆՔՈՎ՝

Ռ. ՄԱԿԱՐՅԱՆ

Կատարող՝
բուսաբուծության և բույսերի
պաշտպանության վարչություն
Գ.Օսիպյան
Հեռ. (011 52 37 93)

0010, ք. Երևան, Կառավարական տուն 3 հեռ. (374 10) 52 02 07, ֆաքս. (374 10) 52 46 10
էլ. փոստ agro@minagro.am

Table 1. Agriculture sector data

Indicator	2013	2014
1. Livestock	*x*	*x*
Cows average live weight, kg	443	445
Bulls average live weight, kg	522	525
Growing cattle average live weight, kg	201	202
Growing cattle etalon weight, kg	230	235
Growing cattle daily average growth of weight, kg/day	0.470	0.470
Cows digestion energy, %	61	61
Bulls digestion energy, %	57	57
Growing cattle digestion energy, %	59	59
Milk fatness, %	3.7	3.7
2. Livestock regime	*x*	*x*
Nursery, day	210-240	210-240
Grazing, day	125-155	125-155
3. Manure dumplings for 1 cow, tonnes/year	8	8
4. Manure amount in the pasture, %	34.4-42.5	34.4-42.5
5. Lands	*x*	*x*
5.1 Grassland area, ha	121,700	121,100
including manageable grassland area, ha	121,700	121,100
5.2 Pasture area, ha	1,054,200	1,051,300
including manageable pasture area, ha	-	-
5.3 One-year crops burnt area, ha	-	-
5.4 Unmanageable (not used) land area, ha	130,300	115,500
5.5 Separation and wind protection area, ha	-	-
5.6 Burnt meadows and pastures area, ha	-	-
5.7 Watershed area, including	13,433	12,431
5.7.1 Peat soils used for turf extraction, ha	3,563	3,563
5.7.2 Reservoir area for energy intake and irrigation, ha		
5.7.3 Territory of land used for fishing (ground-based artificial lakes), ha	3,532.6	3,532.6
6. Used fertilizer, tonne, of which	*x*	*x*
6.1 Mineral or chemical nitrogen fertilizer, tonne	37,906.2 t	31,770.15 t
6.2 Mineral or chemical phosphorus fertilizer, tonne		1,173.65 t
6.3 Mineral or chemical potassium fertilizer, tonne		592.2 t

Table 2. Number of Livestock and Poultry[7], as of January 1 (heads)[8]

	2013	2014	2015
Cattle, including	661,003	677,584	688,553
Dairy cows	303,277	309,616	313,872
Bulls	26,282	29,322	31,081
Growing cattle	331,444	338,646	343,600
Buffalos	531	731	720
Sheep and goats, of which	703,751	717,574	745,770
Sheep	674,731	687,074	713,879
Goats	29,020	30,500	31,891
Horses	10,777	11,686	11,430
Swine, of which	145,044	139,799	142,432
Sows which have farrowed and are nursing young	31,324	26,006	27,144
Mules and Asses	3,945	3,682	3,408
Poultry, of which	4,050,001	4,101,197	4,145,494
Laying hens	2,689,025	2,485,439	2,731,935

[7] *Statistical Yearbook of Armenia 2015, p. 307.*
[8] *Statistical Yearbook of Armenia 2015, p. 307:*

Table 3. Livestock Production[9], 1000 tonne

	2013	2014
Animals and poultry sold for slaughter (in slaughter weight),	83.4	93.1
Of which		
veal and beef	53.6	59.0
Pork	12.6	16.2
Lamb and goat's meat	9.0	9.1
Poultry meat	8.2	8.8
Milk	657.0	700.4

Table 4. Data on livestock and poultry slaughter and loss for 2013, 2014

	Unit	2013	2014
Slaughter data for livestock			
Cattle, including	head	314,207	345,863
Dairy cows	head	47,131	51,879
Growing cattle	head	267,077	293,984
Sheep and goats	head	517,976	523,732
Swine	head	322,732	414,942
Poultry	thousand heads	7,178,458	7,703,711
Losses			
Cattle	head	14,278	15,377
Sheep and goats	head	22,466	24,938
Swine	head	8,845	9,553
Poultry	head	285,299	286,726

Source: RA Ministry of Agriculture (data received form the RA Ministry of Agriculture in response to the letter (dated 13.01.2017 N 2/05.1/20016-17) of the RA Ministry of Nature Protection

[9] *Statistical Yearbook of Armenia 2015, p. 308-310.*

Table 5. Activity data for calculation of greenhouse gas emission factors from Enteric Fermentation

Cows	2013	
Activity data		
Average live weight, kg		443
Digestion factor, %		61
Fat content, %		0.037
Milk production per day (kg/day)		5.63
Maintenance		
NE_m (MJ/day) =Cf_i x $(Weight)^{0.75}$	NEm=0.335 x $443^{0.75}$=32.35	32.35
Activity		
NE_a(MJ/day) = C_a x NE_m	NE_a= 0 x 32.35=0 nursery regime	0.00
	NE_a= 0.37 x 32.35=11.97 grazing regime	11.97
Lactation		
NE_l(MJ/day) =kg milk/day x (1.47+0.4 x Fat)	NE_l=5,63x (1.47+0.4x3.70)=16.61	16.61
Pregnancy		
NE_p (MJ/day)=$C_{pregnancy}$ x NE_m	NE_p=0.1 x 32.35=3.23	3.23
NEm/DE		
NE_m/DE=1.123-(4.092 x 10^{-3}x DE) + [1.126 x 10^{-5} x $(DE)^2$]-25.4/DE)	NE_m/DE=1.123-(4.092 x 0.001 x 61) + (1.126 x 0.00001 x 61 x 61) - (25.4/61) = 0.4989	0.4989
Gross energy		
GE = (NE_m +NE_a+NE_l+NE_p) NE_{ma}/ DE]/(DE/100)	GE=[(32.35+0+ 16.61+3.23+0)/0,4989]/0,61= 171.50 MJ/head/day nursery regime	171.50
	GE=[(32.35+11.97 + 16.61+3.23+0)/0,4989]/0,61 = 210.83 MJ/head/day grazing regime	210.83
Emission Factor		
EF=GE x Y_m x 365 days/year)/ (55.65 MJ/kg CH_4)	EF=[(171.50 x 0.07 x 210 + 210.83 x 0.06 x 155)/55.65]=80.5 kg methane/head/year	**80.5**

Cows	2014	
Activity data		
Average live weight, kg		445
Digestion factor, %		61
Fat content, %		0.37
Milk production per day (kg/day)		5.76
Maintenance		
NE_m (MJ/day) =Cf_i x $(Weight)^{0.75}$	NEm=0.335 x $445^{0.75}$=32.35	32.46
Activity		
NE_a(MJ/day) = C_a x NE_m	NE_a= 0 x 32.35=0 nursery regime	0.00
	NE_a= 0.37 x 32.46=11.39 grazing regime	12.01
Lactation		
NE_l(MJ/day) =kg milk/day x (1.47+0.4 x Fat)	NE_l=5,76x (1.47+0.4x3.70)=16.99	16.99
Pregnancy		
NE_p (MJ/day)=$C_{pregnancy}$ x NE_m	NE_p=0.1 x 32.46=3.25	3.25
NEm/DE		
NE_m/DE=1.123-(4.092 x 10^{-3}x DE) + [1.126 x 10^{-5} x $(DE)^2$]-25.4/DE)	NE_m/DE=1.123-(4.092 x 0.001 x 61) + (1.126 x 0.00001 x 61 x 61) - (25.4/61) = 0.4989	0.4989
Gross energy		
GE = [(NE_m+ NE_a+NE_l+NE_p)NE_{ma}/DE]/(DE/100)	GE=[(32.46+0+ 16.99+3.25)/0,4989]/0,61= 173.155 MJ/head/day nursery regime	173.15
	GE=[(32.46+12.01 + 16.99+3.25+0)/0,4989]/0,61= 212.62 MJ/head/day grazing regime	212.62
Emission Factor		
EF=GE x Y_m x 365 days/year)/ (55.65 MJ/kg CH_4)	EF=[(173.16 x 0.07 x 210 + 212.62 x 0.06 x 155)/55.65]=81.3 kg methane/head/year	**81.3**

Bulls	2013	
Activity data		
Average live weight, kg		522
Digestion factor, %		57
Maintenance		
NE_m (MJ/day) =Cf_i x (Weight)$^{0.75}$	NE_m= 0.322 x $522^{0.75}$=35.16	35.16
Activity		
NE_a(MJ/day) = C_a x NE_m	NE_m= 0 x 35.06=0 nursery regime	0.00
	NE_m= 0.36 x 35,16=12.66 grazing regime	12.66
NEm/DE		
NE_{ma}/DE=1.123-(4.092 x 10^{-3}x DE) + [1.126 x 10^{-5} x $(DE)^2$]-25.4/DE)	NE_m/DE=1.123-(4.092 x 0.001 x57.0) + (1.126 x 0.00001 x 57.0 x57.0) - (25.4/57.0) = 0.4807	0.4807
Gross energy		
GE = [(NE_m+ NE_a)NE_{ma}/DE]/(DE/100)	GE=[(35.16+0)/0,48]/0,570= 128. MJ/head/day nursery regime	128.33
	GE=[(35.16+12.66)/0,48]/0,57=174.53 MJ/head/day grazing regime	174.53
Emission Factor		
EF=GE x Y_m x 365 days/year)/ (55.65 MJ/kg CH_4)	EF=[(128.33 x 0.07 x 210 + 174.53 x 0.06 x 155)/55.65]=63.1 kg methane/head/year	**63.1**

Bulls	2014	
Activity data		
Average live weight, kg		525
Digestion factor, %		57
Maintenance		
NE_m (MJ/day) =Cf_i x (Weight)$^{0.75}$	NE_m= 0.322 x $525^{0.75}$=35.32	35.32
Activity		
NE_a(MJ/day) = C_a x NE_m	NE_m= 0 x 35.06=0 nursery regime	0.00
	NE_m= 0.36 x 35.32=12.71 grazing regime	12.71
NEm/DE		
NE_{ma}/DE=1.123-(4.092 x 10^{-3}x DE) + [1.126 x 10^{-5} x $(DE)^2$]-25.4/DE)	NE_m/DE=1.123-(4.092 x 0.001 x57.0) + (1.126 x 0.00001 x 57.0 x57.0) - (25.4/57.0) = 0.4807	0.4807
Gross energy		
GE = [(NE_m+ NE_a)NE_{ma}/DE]/(DE/100)	GE=[(35.32+0)/0,48]/0,570= 128.89 MJ/head/day nursery regime	128.89
	GE=[(35.32+12.71)/0,48]/0,57=175.28 MJ/head/day grazing regime	175.28
Emission Factor		
EF=GE x Y_m x 365 days/year)/ (55.65 MJ/kg CH_4)	EF=[(128.89 x 0.07 x 210 + 175.28 x 0.06 x 155)/55.65]=63.3 kg methane/head/year	**63.3**

Growing cattle	2013	
Activity data		
Average live weight, kg		201
Mature weight, kg		350
Average weight gain per day kg/head		0.47
Digestion factor, %		59
Maintenance		
NE_m (MJ/day) =Cf_i x (Weight)$^{0.75}$	NE_m=0.322 x $201^{0.75}$=17,12	17.12
Activity		
NE_a(MJ/day) = C_a x NE_m	NE_m= 0 x 17,12=0 nursery regime	0.0000
	NE_m= 0.47 x 17,12=8.05 grazing regime	8.05

Growing cattle	2013	
Growth		
NE_g(MJ/day) =4.18 x {0.0635 x [0.891 x (BW x 0.96) x (478/(C x MW))]$^{0.75}$ x (WG x 0.92)$^{1.097}$}	NE_g(MJ/day) =4.18 x {0.0635 x [0.891 x (201 x 0.96) x (478/(1,2 x 350)]$^{0.75}$ x (0,47 x 0.92)$^{1.097}$}=5.54	5.5355
NE_{ma}/DE		
NE_{ma}/DE=1.123-(4.092 x 10^{-3}x DE) + [1.126 x 10^{-5} x (DE)^2]-25.4/DE)	NE_{ma}/DE=1.123-(4.092 x 0.001 x 59) + (1.126 x 0.00001 x 59 x 59) - (25.4/59) = 0.49	0.4903
NEg/DE		
NE_g/DE=1.164-(5.160 x 10^{-3}x DE) + [1.308 x 10^{-5} x (DE)^2]-37.4/DE)	NEg/DE=1.164-(5,160 x 0.001 x 59) + (1.308 x 0.00001 x 59 x 59) - (37,4/59) = 0.27	0.2712
Gross energy		
GE = [(NEm+NEa)/(NEma/DE)+NEg/(NEg/DE)]/(DE/100)]	GE=[(17,12+0)/0.49/0.59+5.53/0,27]/0,59= 93.8 MJ/head/day nursery regime	93.8001
	GE=[(17,12+8.05)/0,49+5.53/0,27]/0,59= 121.6 MJ/head/day grazing regime	121.6259
Emission Factor		
EF=GE x Ym x 365 days/year)/ (55.65 MJ/kg CH4)	EF=[(93.8 x 0.07 x 233+ 121.6 x 0.06 x 132)/55.65]=45 kg methane/head/year	**44.8**

Growing cattle	2014	
Activity data		
Average live weight, kg		202
Mature weight, kg		350
Average weight gain per day kg/head		0.47
Feed digestibility, %		59
Maintenance		
NE_m (MJ/day) =Cf_i x (Weight)$^{0.75}$	NE_m=0.322 x $201^{0.75}$=17,12	17.12
Activity		
NE_a(MJ/day) = C_a x NE_m	NE_m= 0 x 17,12=0 nursery regime	0.0000
	NE_m= 0.47 x 17,12=8.05 grazing regime	8.05
Growth		
NE_g(MJ/day) =4.18 x {0.0635 x [0.891 x (BW x 0.96) x (478/(C x MW))]$^{0.75}$ x (WG x 0.92)$^{1.097}$}	NE_g(MJ/day) =4.18 x {0.0635 x [0.891 x (201 x 0.96) x (478/(1,2 x 350)]$^{0.75}$ x (0,47 x 0.92)$^{1.097}$}=5.54	5.54
NE_{ma}/DE		
NE_{ma}/DE=1.123-(4.092 x 10^{-3}x DE) + [1.126 x 10^{-5} x (DE)^2]-25.4/DE)	NE_{ma}/DE=1.123-(4.092 x 0.001 x 59) + (1.126 x 0.00001 x 59 x 59) - (25.4/59) = 0.49	0.4903
NEg/DE		
NE_g/DE=1.164-(5.160 x 10^{-3}x DE) + [1.308 x 10^{-5} x (DE)^2]-37.4/DE)	NEg/DE=1.164-(5,160 x 0.001 x 59) + (1.308 x 0.00001 x 59 x 59) - (37,4/59) = 0.27	0.27
Gross energy		
GE=[(NE_m+NE_a)/(NE_{ma}/DE)+NE_g/(NE_g/DE)]/(DE/100)]	GE=[(17,12+0)/0.49/0.59+5.53/0,27]/0,59= 93.8 MJ/head/day nursery regime	93.80
	GE=[(17,12+8.05)/0,49+5.53/0,27]/0,59= 121.63 MJ/head/day grazing regime	121.63
Emission Factor		
EF=GE x Y_m x 365 days/year)/ (55.65 MJ/kg CH_4)	EF=[(93.8 x 0.07 x 233+ 121.6 x 0.06 x 132)/55.65]=45 kg methane/head/year	**44.8**

Table 6. Volume of imported mineral or chemical fertilizers, nitrogenous (AFOLURef-4)

Commodity chapter, group, subgroup name and 8-digit level code	Unit	Import					
		quantity	volume, ton	quantity	volume, ton	quantity	volume, ton
		2012		2013		2014	
Mineral or chemical fertilizers, nitrogenous				X	58593.9	X	48635.7
31021010	kgN	255691.5	555.7	166259.6	360.5	393717.2	865.6
31021090	kgN	-	-	14960.7	41.1	20246.0	55.6
31022100	kgN	292.0	0.9	962.5	4.4	4656.3	15.3
31023010	kgN	36.0	0.4	720.0	4.0	2474.8	15.5
31023090	kgN	14421769.2	41903.3	19987036.2	58102.6	16515567.8	47271.4
31024010	kgN	3869.6	26.3	11527.1	54.1	57231.5	236.8
31025010	kgN	0.5	0.0	333.0	0.9	0.1	0.0
31025090	kgN	1032.0	5.3	299.0	1.5	4182.8	26.0
31026000	kgN	1674.0	10.8	3804.0	24.0	19460.2	125.5
31029000	kgN	299.8	1.7	120.0	0.8	3861.6	24.1
Total		14428973	555.7	20004802	402	16607435	921

Table 7. Basic wood density

Tree Species	Factor	Source	Type	Factor	Source
Pine-tree	0.415	LUCFref.19.	Elm-tree	0.535	LUCFref.15.
Juniper	0.447	LUCFref.16.	Lime-tree	0.366	LUCFref.13.
Yew	0.474	LUCFref.8.	Birch-tree	0.459	LUCFref.8.
Fir-tree	0.365	LUCFref.19.	Plane-tree	0.522	LUCFref.18.
Oak-tree	0.57	LUCFref.19.	Walnut tree	0.49	LUCFref.19.
Beech	0.538	LUCFref.7.	Pear tree	0.564	LUCFref.8.
Hornbeam	0.64	LUCFref.19.	Poplar	0.423	LUCFref.17.
Ash-tree	0.648	LUCFref.15.	Willow	0.38	LUCFref.19.
Maple	0.557	LUCFref.14.	Acacia	0.65	LUCFref.19.
			Hackberry	0.53	LUCFref.9.

Table 8. Average annual biomass growth per 1 ha of forest covered areas

Dominating tree species	Average annual biomass growth (cubic meter/ha year) Revised 2010 [LUCFref.1., LUCFref.2., LUCFref.6.,LUCFref.10., LUCFref.11.,LUCFref.12., LUCFref.20.,LUCFref.22.]
Coniferous trees	
Pine-tree	1.97
Juniper	0.19
Yew	0.48
Broad-leaved trees	
Seed oak-tree	1.18
Stump-sprig oak	0.43
Beech	1.76
Seed hornbeam	1.58
Stump-sprig hornbeam	1.09
Ash-tree	1.4
Maple	0.99
Elm-tree	0.9
Bastard acacia	0.35
Birch tree	0.16
Lime-tree	1.5
Aspen	1.46
Poplar	2.1
Willow	0.25
Oriental beech	0.87
Pear-tree	0.37
Apple tree	0.39
Walnut tree	0.78
Plane-tree	1.1
Almond tree	0.06
Oleaster	0.52
Apricot tree	0.05
Plum tree	0.8
Other species	-
Average (RA forests)	**1.5**