REPUBLIC OF ARMENIA
MINISTRY OF ENVIRONMENT

National Greenhouse Gas Inventory Report of Armenia 1990-2017

Submission of the Ministry of Environment
of the Republic of Armenia under
United Nations Framework Convention on Climate Change

2020

The National GHG Inventory Report has been developed under the coordination of the Ministry of Environment of the Republic of Armenia with the funding of the Global Environmental Facility and support of the United Nations Development Programme in Armenia within the framework of the "Armenia's Third Biennial Update Report to the UNFCCC" project

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ABBREVIATIONS

AD	Activity data
AFOLU	Agriculture, Forestry and Other Land Use
BUR	Biennial update report
CDM	Clean Development Mechanism
CJSC	Closed Joint-Stock Company
COP	Conference of the Parties
CS	Country specific
D	Default
EF	Emission factor
F gases	Fluorinated greenhouse gases
FAO	United Nations Food and Agriculture Organization
FOD	First Order Decay
GDP	Gross Domestic Product
GEF	Global Environment Fund
GHG	Greenhouse gas
GWP	Global Warming Potential
HPP	Hydropower plant
ICA	International Consultation and Analysis
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
KCA	Key Category Analysis
LLC	Limited liability company
LPG	Liquid petroleum gas
MOE	Ministry of Environment
MSW	Municipal solid waste
NA	Not applicable
NCV	Net calorific value
NE	Not estimated
NIR	National Inventory Report
NO	Not occurring
NMVOC	Non methane volatile organic compounds
ODS	Ozone depleting substances
PSRC	Public Services Regulatory Commission
QA/QC	Quality assurance/ Quality control
RA	Republic of Armenia
RAC	Refrigeration and Air Conditioning
SAR	IPCC Second Assessment Report
SC	Statistics Committee
SRC	State Revenue Committee
SWDS	Solid waste disposal sites
TACCC	Transparency, Accuracy, Consistency, Completeness, Comparability
TASR	Technical analysis summary report
TPES	Total Primary Energy Supply
TPP	Thermal Power Plant
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Units of Measurement

mm	millimeter
cm	centimeter
m	meter
km	kilometer
m^3	cubic meter
km^2	square kilometer
ha	hectare
g	gram
Gg	gigagram (10^9 g, or thousand t)
t	ton
toe	tones oil equivalent
GJ	gigajoule (10^9 J)
TJ	terajoule (10^{12} J)
kWh	kilowatt hour (10^3 Wh)
MW	megawatt (10^6 W)
GWh	gigawatt hour (10^9 Wh)
m/sec	meters per second
^0C	degree Celsius

Chemical Combinations

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

Energy Units Conversion

1 toe = 41.868 GJ= 11.63 MWh
1 GWh = 3.6 TJ = 86 toe

Standard conversions

1 tonne (t) = 1 megagram (Mg)
1 kilotonne / thousand tonnes (kt) =1 gigagram (Gg)

SUMMARY

Armenia's 1990-2017 National Inventory Report (NIR) has been prepared under coordination of the Ministry of Environment of the Republic of Armenia within the framework of "Armenia's Third Biennial Update Report to the UNFCCC" UNDP-GEF/00112638 Project under the United Nations Framework Convention on Climate Change.

The Republic of Armenia developed Greenhouse Gas (GHG) Inventory from 1990-2017 in accordance with the *2006 IPCC (Intergovernmental Panel on Climate Change) Guidelines for national greenhouse gas inventories*.

The national GHG inventory includes carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HFC_s) and sulfur hexafluoride (SF_6) and they are expressed in units of mass and in carbon dioxide equivalent ($CO_{2\ eq.}$) using the Global Warming Potentials (GWP_s) in the IPCC Second Assessment Report (SAR).

The national GHG inventory includes also estimates of carbon monoxide (CO), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2).

According to 2006 IPCC Guidelines, GHG NIR includes the following sectors:

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

Given 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 1990-2017
- Summary information table of inventories for previous submission years from 1990 to 2017.

Within the frames of the 2017 NIR certain improvements were made to the GHG inventory to align it more with TACCC principles (Transparency, Accuracy, Consistency, Completeness, and Comparability), in particular:

- Emissions of the sulfur hexafluoride (SF_6) have been estimated for the first time
- GHG emissions of 6 new sub-categories were included
- Higher Tier for 5 sub-categories was introduced
- Key Category Analysis was done both by Level and Trend assessment
- Uncertainties have been assessed for all sub-categories of emissions and removals
- Time series for years 1990-2017 were recalculated to ensure their consistency considering the latest changes in terms of the improved methodologies and completeness and accuracy of activity data

Armenia's greenhouse gas emissions in 2017 amounted 10,624 Gg $CO_{2\ eq.}$ (excluding *Forestry and Other Land Use*).

Total emissions in 2017 were 3% higher than those in 2016, approximately 59% (15.2 million tonnes) below the 1990 emissions level and about 69% higher than 2000 emissions level.

Table 1 provides GHG emissions by gases and by sectors for 2017.

Table 1. Greenhouse gas emissions by gases and by sectors for 2017, Gg

Sector	Net CO_2	CH_4	N_2O	HFCs $CO_{2\ eq}$	SF_6 $CO_{2\ eq.}$	Total $CO_{2\ eq.}$
Energy	5,361.5	80.6	0.11	NA	NA	7,087.4
Industrial Processes[1]	262.6	NA	NA	NA	NA	262.6
F-gases[2]	NA	NA	NA	685.3	2.6	687.9
AFOLU (without Forestry and Other Land Use)[3]	2.7	48.2	3.1	NA	NA	1,965.4
Waste	4.3	25.9	0.2	NA	NA	620.7
Total GHG Emissions	**5,631.1**	**154.8**	**3.4**	**685.3**	**2.6**	**10,624**
Forestry and Other Land Use	-471.0	NA	0.001	NA	NA	-470.6
Net GHG Emissions	**5,160.1**	**154.8**	**3.4**	**685.3**	**2.6**	**10,153.5**

Table 2 provides summary information of inventories for previous submission years from 1990 to 2017. AFOLU sector is considered with and without *Forestry and Other Land Use* (*Land* category).

[1] Excluding F-gases
[2] F gases refer to hydrochlorofluorocarbons (HFCs) and sulfur hexafluoride (SF_6)
[3] *Forestry and Other Land Use* refers to *Land* category

Table 2. Greenhouse gas emissions by sectors from 1990 to 2017, Gg $CO_{2\ eq.}$

Sector	1990	1995	2000	2005	2010	2012	2014	2016	2017	2017 emission change (%) compared to		
										1990 levels	2000 levels	2016 levels
Energy	22,719.4	4,819.1	4,255.1	5,252.6	5,809.6	6,891.8	7,041.5	6,623.4	7,087.4	-68.8	66.56	7.0
Industrial Processes and Product Use	631.2	122.7	152.9	395.1	587.2	712.6	815.1	796.2	950.5	50.6	521.9	19.4
AFOLU (without Forestry and Other Land Use)	2,085.7	1,932.3	1,374	1,621.6	1,534.9	1,874.9	2,058.8	2,283.6	1,965.4	-5.8	43.1	-13.9
Waste	418.8	454.5	513.8	557.4	564.8	581.4	598.7	608.7	620.7	48.2	20.8	2.0
Total Emissions (without Forestry and Other Land Use)	**25,855**	**7,328.6**	**6295.8**	**7,826.6**	**8,496.6**	**10,060.7**	**10,514**	**10,311.9**	**10,624**	**-58.9**	**68.8**	**3.0**
Forestry and Other Land Use	-736.9	-514.4	-467.8	-523.7	-550.1	-510.1	-476.0	-488.0	-470.6	-36.1	0.6	-3.6
Total Net Emissions	**25,118.1**	**6,814.2**	**5,828.0**	**7,302.9**	**7,946.5**	**9,550.7**	**10,038.0**	**9,823.9**	**10,153.5**	**-59.6**	**74.2**	**3.4**

1. BASIC INFORMATION ON GHG INVENTORY

1.1 National inventory arrangements

Since the ratification of UNFCCC, Government of Armenia once every five years approves a list of measures as well as assigns responsible agencies for implementing the country's commitments under international environmental conventions, including the UNFCCC.

The list of measures to be implemented during 2017-2021 to fulfill obligations and provisions arising from the UNFCCC and Paris Agreement, including development of GHG Inventories every 2 years was approved by Government Protocol Decree N 49-8 of December 8, 2016.

The Ministry of Environment is the statutory entity responsible for the development and implementation of state policy addressing climate change issues and is responsible for fulfilling commitments under UNFCCC, including development of national communications, biennial update reports and GHG Inventories.

National climate change policies and actions are coordinated by the *Inter-agency Coordinating Council for Implementation of Requirements and Provision of the UN Framework Convention on Climate Change*, which was established in 2012 by the Prime Minister's Decree. The Council has the authority to coordinate reporting on climate change and ensure coherent policies for achievement of Armenia's commitments under UNFCCC and is the decision-making body that approves the final drafts such as the national GHG inventory.

The Council is chaired by the Minister of Environment and is composed of representatives of ministries, state agencies, including the Statistics Committee and independent bodies (the Public Services Regulatory Commission and the National Academy of Sciences). Technical cooperation is ensured through *Working Group* under the *Council* that consists of professionals nominated by their respective ministries and agencies.

Given the changes in the Government structure, the Inter-agency Coordinating Council composition is currently being revised.

The United Nations Development Programme (UNDP) through its Climate Change Program supports the Ministry of Environment, as an authorized national entity, in fulfilling the country's obligations under UNFCCC. The support includes the preparation of national communications, biennial update reports and GHG inventories.

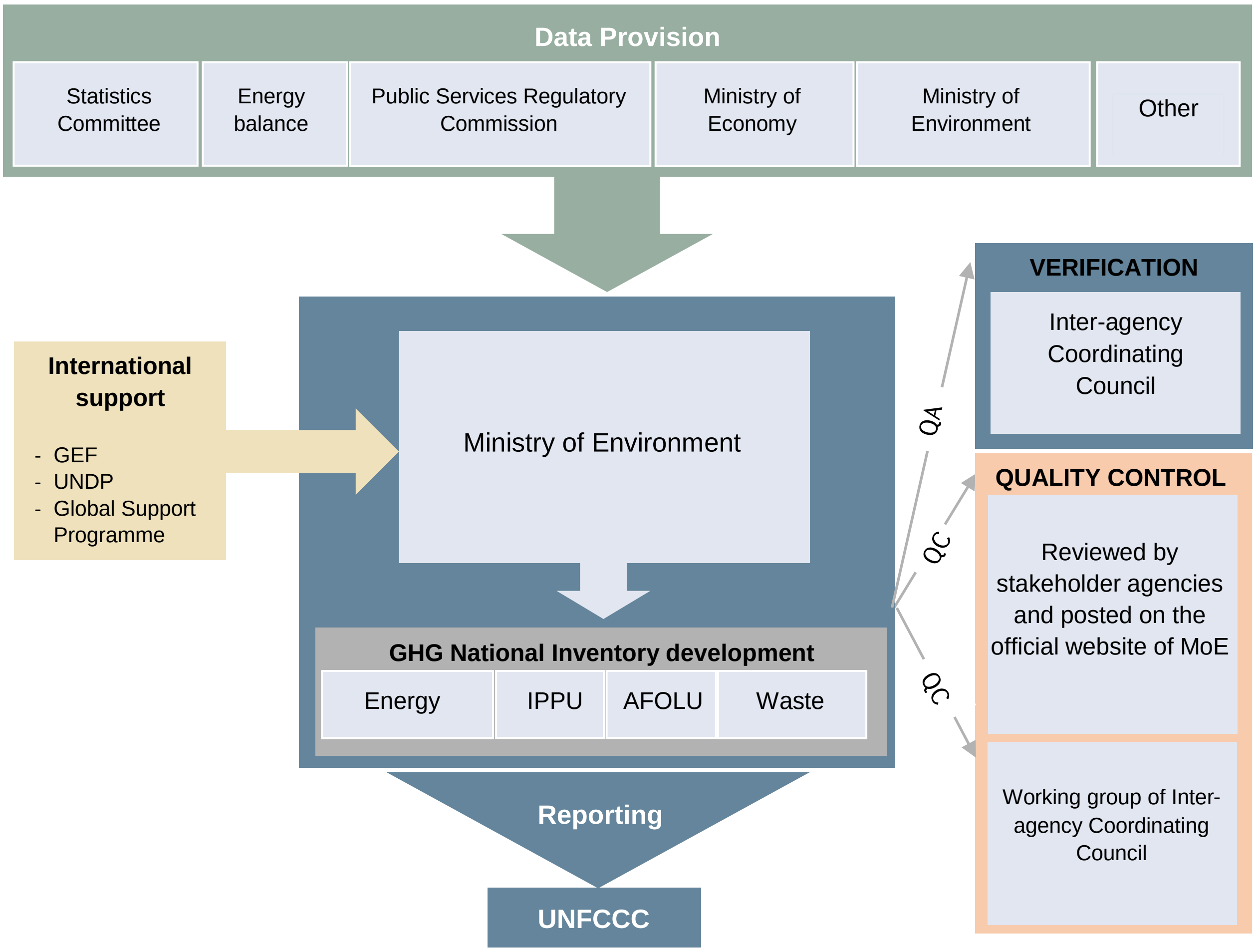


Figure 1.1 Institutional arrangements of GHG Inventory development in Armenia

Organizational Changes to Arrangements

During the compilation period of the Third Biennial Update Report, certain changes in the organizational structure for national inventory arrangements occurred. Notably, Climate Policy Department in Ministry of Environment was established in 2020, acting as coordinating unit for fulfilling Armenia's commitments under the UNFCCC, including coordination of the processes associated with the preparation of national communications, biennial update reports and national inventories. Previously those functions were performed by the Division of Climate Change and Atmospheric Air Protection Policy under Environment Protection Policy Department of MoE.

Since the Second Biennial Update Report (BUR2) was submitted, some operational improvements contributing to the quality of Armenia's Inventory reports were implemented with the objective to achieve more transparency, accuracy, comparability, consistency and completeness (TACCC) in the inventory.

Since BUR2 was submitted, the improvements in the inventory were focused on:

- *Improving activity data collection process:*
  - "Questionnaires" by sectors were developed to clarify requirements for activity data.
  - Close collaboration has been established between the GHG Inventory development expert team and the Statistics Committee (SC) to improve the accuracy/quality and consistency of data collected by SC within Household Survey.

As a result, Household Survey questionnaires were revised to include additional questions regarding the amount of fuelwood consumed to enable the analysis of that data and to improve accuracy.

- *Improving the accuracy of activity data on emissions and removals:*
  - In contrast to the previous inventories, the activity data on liquid fuel consumption per categories were not estimated by expert judgment but were provided by the Statistics Committee.
  - The activity data (AD) of the Agriculture sector has been reviewed and adjusted by qualified national expert, followed by discussions with the officials from the Ministry of Economy (Agriculture sector's experts). Similarly, the activity data for manure burnt in energy sector has been revised.

  As a result, accuracy of certain activity data on Agriculture and Energy sectors was improved. Emissions from enteric fermentation and manure management as well as CH_4 and N_2O emissions from fuel combustion in residential sector were calculated using adjusted activity data, time series were recalculated to ensure consistency.
- *Improving the completeness of the inventory:*
  - Energy Sector expert was involved to identify data sources and availability, as well as country-specific circumstances for estimating SF_6 emissions from electrical equipment.

  As a result, the activity data on SF_6 emissions were collected and analyzed and for the first time SF_6 consumption–related emissions assessment was done, as well as time series were developed starting from the first year of import of SF_6 containing electrical equipment to Armenia.
- *Improving the quality control processes:*
  - Close collaboration has been established between the GHG Inventory development expert team and the specialists responsible for development of the Energy balance to provide cross-checks and ensure consistency of the data used for both the GHG Inventory and the Energy balance.
- *National capacity building for GHG Inventory development:*
  - Inventory officials, stakeholder representatives and expert team members participated in a 5-day workshop on "Quality Assurance of the National Greenhouse Gas Inventory Management System and National Greenhouse Gas Inventories of Armenia" organized in Yerevan in November 2019 by the UNFCCC Secretariat with the collaboration of the FAO.
  - 4 officials from MoE participated to the capacity building trainings organized by the UNFCCC.
  - GHG inventory expert team participated in a workshop on conducting uncertainty assessment of emissions/removals and conducting key category analysis according to the 2006 IPCC Guidelines in December 2019 organized by "Armenia's Third Biennial Update Report to the UNFCCC" UNDP-GEF/00112638" Project.
  - National experts of different sectors participated in the training of GHG Management Institute organized by the UNFCCC. Five of them have passed the qualification exam and were included in the list of technical experts of the Convention, having the right to be involved in the technical review of GHG inventories submitted by Annex I Parties and technical analysis of biennial update reports submitted by non-Annex I Parties.

1.2 Overview of inventory preparation process

Whenever applicable, the following are considered prior to starting the inventory preparation process: a) improvement requirements that have emerged from past quality control and quality assurance; b) results of previous inventory reviews (including key category analysis and uncertainty assessment); and c) planned improvements listed in the previous NIR. This process precedes the inventory preparation process as it serves as the basis for the formulation of data collection requirements.

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, method selection depends on whether the considered category is a key or not and on the availability of the 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.
- Use of publicly available national data; Statistics Committee serves as main source of data:
  - Since 2015, Statistics Committee is publishing the Energy balance, which is the most important source of activity data for the Energy Sector.
- The collection of the rest of the required activity data is carried out by the Ministry of Environment, through official inquiry to data providers, as there are no formal institutional arrangements for collection/reporting of GHG inventory activity data on a regular basis so far.
- Receipt of data.
- Quality Assurance and Quality Control (QA/QC) of activity data.
- Data archiving: all activity data received from the data providers along with the corresponding inquiry letters of the Ministry of Environment sent to the data providers are being archived, both as hard copies and in electronic format.

Data processing and emissions calculation:

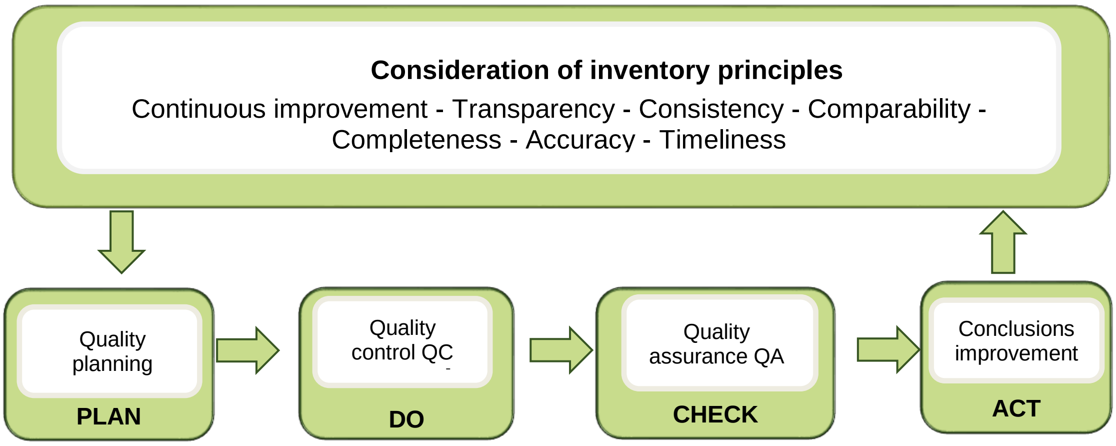
- Selection of emission factors, which includes update and development (if required) of country-specific emission factors
- QC of emissions estimates
- Preparation of report sections (texts), and
- Approval by the relevant experts
  - In each case, the relevant expert responsible for QC also has responsibility for issuing expert level approvals
  - Approvals for written texts and calculation results, prior to any further use of such texts and results.

Report preparation includes the following steps:

- Aggregation of emissions data for the national trend tables and preparation of data tables for the NIR
- Compilation of submitted sectorial report texts to form a draft NIR
- QA/QC of the draft NIR
- Review and verification of the draft NIR by the Inter-agency Coordinating Council
- Handover to the UNFCCC Secretariat
- Archiving

1.3 Quality management

The quality requirements set for the national inventory - transparency, accuracy, completeness, consistency and comparability - are fulfilled by implementing the QA/QC procedures.



The ultimate goal of the QA/QC process is to ensure the quality of inventory and to contribute to the improvement of inventory across all sectors.

The QC procedures used in Armenia's GHG Inventory follow Quality assurance /Quality control procedures provided in the Chapter 6 of Volume 1 of 2006 IPCC Guidelines, and serve to the following objectives:

1.Continuous Improvement	1.1 Treatment of conclusions from previous reviews is systematic. In particular, in the frames of 2017 NIR the following was treated: • Recommendations from the team of technical experts that conducted the technical analysis of Armenia's second BUR, depicted in corres-ponding technical analysis summary report (TASR) • Findings/Recommendations from the "Quality Assurance of the National Greenhouse Gas Inventory Management System and National Greenhouse Gas Inventories" workshop organized by the UNFCCC Secretariat in collaboration with FAO 1.2 Improvements foreseen in the previous NIR are carried out
2.Transparency	2.1 Archiving of the inventory is systematic 2.2 Internal documentation of calculations supporting emissions estimates are saved
3. Accuracy	3.1 Calculation is correct 3.2 Inventory uncertainties are estimated
4. Completeness	4.1 The inventory covers all the emission sources, sinks and gases
5. Consistency	5.1 The time series are consistent

	5.2 Same methodologies have been used for all years and data have been used in a consistent manner
6. Comparability	6.1 The methodologies and formats used in the inventory meet comparability requirements
7. Timeliness	7.1 Inventory reports submitted within the set times

General inventory quality control checks (2006 IPCC Guidelines, Chapter 6, Table 6.1. General Inventory QC procedures) include routine checks of the integrity and completeness of the data, cross-check of activity data available from the different sources and their underlying assumptions done by the relevant sectoral experts, check for consistency in data between categories, check of time series consistency and finally - documentation and archiving of the inventory data and quality control actions.

Category-specific QC procedures include technical reviews of the activity data, emission factors and methods applied on a case-by-case basis focusing on key categories and on categories where significant methodological and data revisions have taken place, comparison of estimates to previous estimates. If there are significant changes or departures from expected trends, estimates are rechecked and difference is explained if any. QC procedures for country-specific emission factors include comparison with IPCC default factors and comparison of emission factors between countries.

Experts on each inventory sector implement and document the QC procedures, which precedes to the internal review of GHG National Inventory by the task leader.

QC checks include internal review of the draft NIR by the Ministry of Environment and by the working group of the Inter-agency Coordinating Council. The working group of the Inter-agency Coordinating Council, which is comprised by 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.

QC procedure also includes the review of the draft NIR by stakeholder state agencies and companies.

The results of the review are then presented to the relevant sectoral experts for any changes or clarifications (if necessary and after appropriate consultations).

The QA reviews are performed after the implementation of all QC procedures for the finalized inventory. The actions include basic reviews of the draft report, peer reviews, Global Support Program's expert reviews.

The QA process is finalized when the draft NIR is submitted to and verified by the Inter-agency Coordinating Council, followed by the final step of submission to the UNFCCC and archiving.

1.4 Archiving

Description of archiving system

The Archiving System is an important component of the inventory development process. It is key for sustaining the National Inventory System of the Republic of Armenia, simultaneously serving for the transparency of national inventories and facilitating the development of subsequent inventories.

Information used to create the inventory is being archived in a single location (in both electronic and hard copy storage) in order for the future inventory staff to have access to all relevant files in case of necessity, such as responding to reviewer questions, including questions about methodologies.

All emission factors and activity data at detailed level are archived, as well as relevant documentation on how these factors and data have been acquired, calculated and consolidated to develop the inventory.

The archived information also takes account of internal documentation on QA/QC procedures, external and internal reviews, as well as planned inventory improvements.

All electronic data used for the inventory are stored on the Climate Change Programme Unit server located at RA, Yerevan, Governmental Building #3, Room 533 and automatically duplicated in the Google drive cloud storage.

Archiving procedures

The archiving procedures of the documents and files are as follows:

- Inventory cycle documents and files are stored both electronically and in hard copies.
- The archive system can be accessed only by the Inventory coordinator, the expert on Inventory database management and the IT specialist of the Climate Change Programme Unit.
- Most documents are stored both as drafts and final versions.
- The information is kept both on the hard drive and external HDD, which is handed to the MoE. In addition, the information on the server is automatically duplicated in the Google drive cloud storage. The data in the Google drive, if necessary, can be provided to other professionals (for example, reviewers) in "read-only" mode.
- The information initially received from different sources is kept both in hard copy and electronic format.
- The files are named based on the name of the relevant document and date of receipt.
- In order to reflect subsequent updates, the file names are changed by providing the date of last update.

Data retention

At the end of each inventory cycle, spreadsheets used by experts for inventory calculations and other electronic files are provided to the database manager.

The main components of the archive include:

- IPCC 2006 software package database (mbd file) used for data collection
- Data and calculation spreadsheets (mainly excel files) and other electronic files for each category used by experts to create inventory estimates
- Key category analysis and uncertainty assessment spreadsheets
- Internal and external review comments and responses
- Latest drafts and final electronic versions of the inventory documents (National Inventory Report), in Armenian and in English

The database manager archives the files on the hard drive as well as on an external memory support, while also ensures automatic data backup in the Google Drive cloud.

The archived data is stored in folders, mentioning the inventory year, for easy use.

1.5 Improvements in Armenia's GHG inventory

The main improvements to 1990-2017 GHG National Inventory are listed below according to TACCC (transparency, accuracy, completeness, consistency and comparability) principles and have been made considering the following:

- Recommendations from the team of technical experts that conducted the technical analysis of Armenia's second BUR in the frames of ICA process, depicted in corresponding technical analysis summary report (TASR).
- Findings/recommendations from the "Quality Assurance of the National Greenhouse Gas Inventory Management System and National Greenhouse Gas Inventories" workshop organized by the UNFCCC Secretariat in 2019 in Yerevan.
- Improvements foreseen in the previous NIR.

Improvements of transparency

1. TASR paragraph 39: Information on the land classification and compliance to 2006 IPCC Guidelines is provided in the GHG National Inventory report (see chapter 4.3.5.1).
2. TASR paragraph 39: The data on GHG inventories for 1990 and 1995 have been recalculated and are provided in the NIR (see Executive summary, chapter 3).
3. TASR paragraph 42: Information on documentation and archiving was provided in NIR (see Chapter 1.4).
4. TASR paragraph 48: The uncertainty assessment for the complete inventory for both level and trend has been performed for all categories.

KCA with trend and with and without *FOLU* (*Land* category) was performed.

Improvements of accuracy

6. Some activity data on Agriculture sector were checked and adjusted. Emissions from enteric fermentation and manure management have been calculated based on adjusted activity data, and time series have been recalculated to ensure consistency.
7. The emissions from enteric fermentation and manure management from the *Buffalo* and *Sheep* subcategory were assessed applying Tier 2 methodology.
8. CH_4 and N_2O emissions from manure burned in Energy Sector were calculated using refined activity data.
9. The assessment of GHG emissions from wetlands was clarified, using 2013 Revised Supplementary Methods and Good Practice Guidance.

Improvements of completeness

New subcategories were observed. The emissions for several gases and categories that were not assessed in previous inventory, have been estimated in this inventory. These include:

10. Energy Sector:
    - CH_4 and N_2O emissions from charcoal burning were estimated using data from the Energy balance. Entire time series for Energy Sector have been recalculated to ensure time series consistency in the light of the above-mentioned changes in (1.A.4b) category

11. IPPU Sector:

CO_2 emissions were estimated from the following subcategories:

- (2A2) *Lime Production*
- (2D1) *Lubricant Use*
- (2D2) *Paraffin Wax Use*

SF_6 emissions were estimated from:

- (2G1b) *Use of Electrical Equipment* subcategory

12. AFOLU sector:

- TASR paragraph 38: The information on livestock statistics used as AD is clearly reported in the NIR (see chapter 4.3.4.3.1.1) and the list of other cattle has been extended to include rabbits and other furry animals in enteric fermentation and manure management categories (3.A.1 and 3.A.2).
- *Emissions from biomass burning in croplands* (3C1b) were estimated.

Improvements of consistency

13. All emissions and removals have been estimated for the period of 1990-2017 using consistent methodologies from 2006 IPCC Guidelines (Executive summary, Chapter 3). QC procedures were applied to ensure the consistency of time series.

The recalculations resulted in overall increase of GHG emissions by 0.3% in 1990 and by 1.1% in 2014 in GHG emission estimates for BUR3 compared to BUR2.

Figure 1.2 and 1.3 show the differences of GHG emission estimates by sectors and gases according to BUR3 and BUR2 estimates.

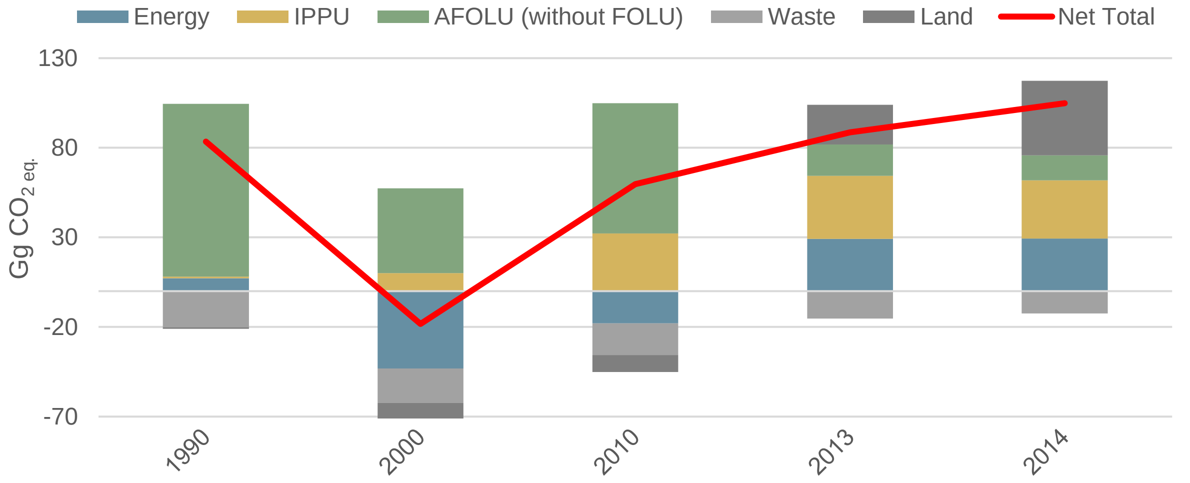


Figure 1.2 The changes of GHG emissions and removal estimates by sectors between BUR3 and BUR2, Gg $CO_{2\ eq.}$

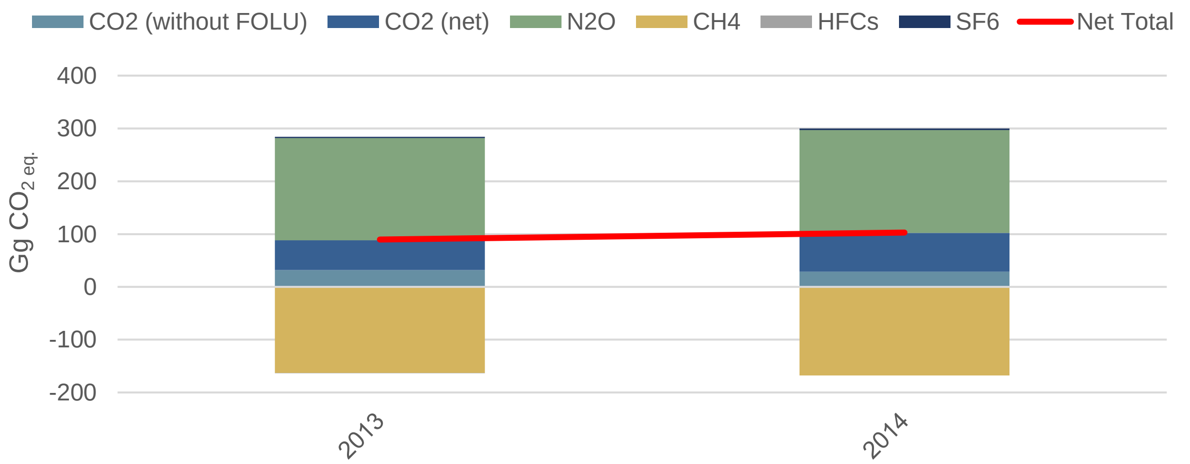


Figure 1.3 The changes of GHG emissions and removal estimates by gases between BUR3 and BUR2, Gg $CO_{2\ eq.}$

Improvements of comparability

14. TASR paragraph 36: All emissions from clinker production have been reported under the category (2.A.1) *Cement Production*.

15. Reallocation of unmanaged land in line with 2006 IPCC Guidelines have been done, which was described in details (Chapter 4.3.5.1).

1.6 Overview of used methodology

Guidelines

GHG inventory was prepared according to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. *The IPCC Inventory Software version 2.69.7235* was used for the direct GHGs 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 *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetland*, as well as if needed "*1996 IPCC Revised Guidelines for National Greenhouse Gas Inventories*" were also used during the preparation of the National Inventory for default values of certain parameters.
Regarding the emissions of precursor gases, these were estimated mostly using the methodology *"Air Pollutant Emission Inventory Guidebook" (EMEP/EEA, 2009, 2016*), except for emissions derived from biomass burning (category 3C1; NOx and CO) which were estimated using the *2006 IPCC Guidelines and the IPCC Inventory Software*.

Global warming potentials

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
SF_6	23,900

The estimated CH_4, N_2O, HFCs and SF_6 emissions were converted to CO_2 equivalent ($CO_{2\ eq.}$) 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 (Table 1.1).

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 CO_2, CH_4 and N_2O from the key categories, as well as for emissions of hydrofluorocarbons (HFCs) compounds and sulfur hexafluoride (SF_6).

Estimations were also made for CO, NO_x, NMVOCs and SO_2 emissions.

Emission estimates were based on the sectoral approach applying Tier 1, 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 by natural gas fired TPPs,
- 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:

- 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.

  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 enteric fermentation and manure management of cattle, buffalo and sheep.
- 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.

1.7 Activity data sources

Energy Sector is by far the largest producer of GHG emissions in the country while the Energy balances published by the SC are the main data sources for determination of activity data for category 1.A “Fuel Combustion Activities”. An Energy balance provides an overview of the links within Armenia's energy sector, and it supports breakdowns in accordance with fuels and categories. The data for Energy balances come from a wide range of other sources.

Therefore, development and improvement of the Energy balances on a continuous basis is extremely important in order to improve accuracy, consistency and completeness of the National GHG Inventory.

Amendments to the Energy Saving and Renewable Energy Law, which were adopted in 2016, have set out the mandatory requirement for running, development and publication of the RA Energy balance on annual basis by the SC and the Ministry of Energy Infrastructures and Natural Resources. Thus, the Energy balances of Armenia for 2015, 2016 and 2017 have been published by the SC. However, considering that the elaboration of Energy balances is a rather new process and with the aim to improve consistency of data provided in the Energy balance and used for GHG Inventory, activity data for GHG Inventory have been collected from the initial data sources, including the Public Services Regulatory Commission (PSRC) and "Gazprom Armenia" CJSC, and have been cross-checked with those provided in the Energy balance. Besides, the expert team involved in the preparation of GHG inventory collaborates with the Energy balance compilers for ensuring accuracy and consistency of the data reported.

The Statistics Committee is the most important data source for determination of activity data for estimation of emissions from the other sectors. Data were provided also by the Ministry of Territorial Administration and Infrastructure, Ministry of Economy, Ministry of Environment, Public Services Regulatory Commission, State Revenue Committee, Cadastre Committee, as well as various private enterprises.

2. MAIN OUTCOMES OF GREENHOUSE GAS INVENTORY

Armenia's GHG emissions without Forestry and Other Land Use ((3.B) *Land*) in 2017 totaled 10,624 Gg CO_2 equivalent (Table 2.1). The emissions were 3% (313 Gg $CO_{2\,eq.}$) higher than those in 2016 and approximately 59 % (15,231 Gg $CO_{2\,eq.}$) below the 1990 emissions level.

Table 2.1 Greenhouse gas emissions by sectors and by gases, 2017, Gg

Sectors	CO_2	CH_4	N_2O	HFCs $CO_{2\,eq.}$	SF_6 $CO_{2\,eq.}$	Total $CO_{2\,eq.}$
Energy	5.361,5	80.6	0.11	NA	NA	7,087.4
Industrial Processes[4]	262.6	NA	NA	NA	NA	262.6
F - gases[5]	NA	NA	NA	685.3	2.6	687.9
AFOLU (without Forestry and Other Land Use[6])	2.7	48.2	3.1	NA	NA	1,965.4
Waste	4.3	25.9	0.2	NA	NA	620.7
Total Emissions (without Forestry and Other Land Use)	**5,631.1**	**154.8**	**3.4**	**685.3**	**2.6**	**10,624**
Forestry and Other Land Use	-471.0	NA	0.001	NA	NA	-470.6
Total Net Emissions	**5,160.1**	**154.8**	**3.4**	**685.3**	**2.6**	**10,153.5**

Shares of GHG emissions by the IPCC sectors are provided in Figure 2.1

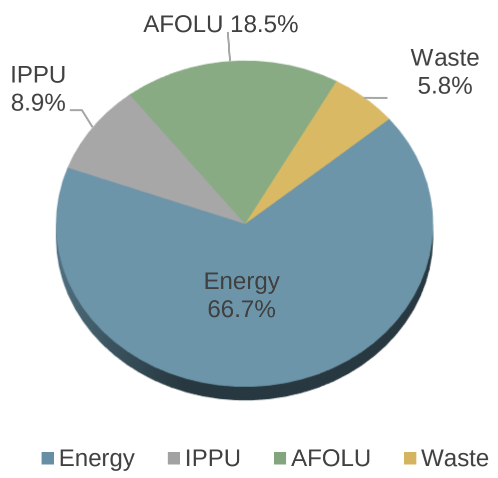


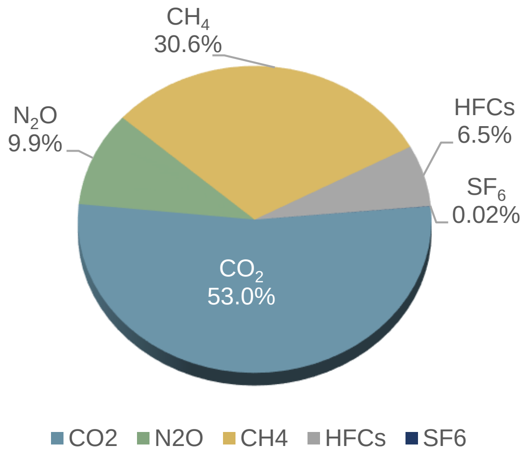
Figure 2.1 GHG emissions by sectors (without *Forestry and Other Land Use*), 2017, $CO_{2\,eq.}$

The Energy Sector is by far the largest producer of greenhouse gas emissions. In 2017, the Energy Sector accounted for 66.7% of Armenia's total GHG 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 a share of 18.5%, followed by IPPU and Waste Sectors – 8.9% and 5.8%, respectively.

Figure 2.2 provides greenhouse gas emissions by gases.

[4] Excluding F gases
[5] F gases refer to hydrochlorofluorocarbons (HFCs) and sulfur hexafluoride (SF_6)
[6] *Forestry and Other Land Use* refers to *Land* category



The most significant greenhouse gas of Armenia's inventory is carbon dioxide (CO_2), with a share of about 53% of the total emissions in 2017, followed by methane (CH_4) – about 30.6%. Nitrous oxide (N_2O) accounted for 9.9% of the total emissions in 2017 and HFCs accounted for roughly 6.5% of all GHG emissions. The share of SF_6 is negligible.

Figure 2.2 Greenhouse gas emissions by gases, 2017

Figure 2.3 provides greenhouse gas emissions by sectors and by gases for 2017.

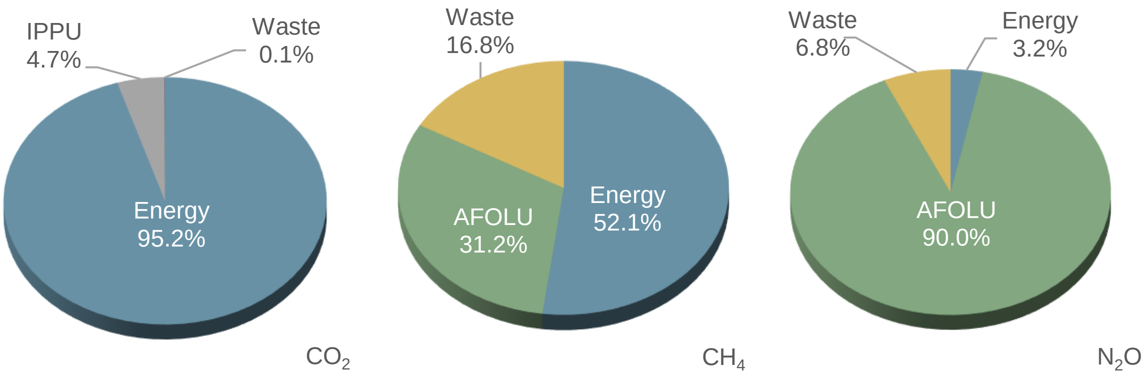


Figure 2.3 Greenhouse gas emissions by sectors and by gases, 2017 (without *Forestry and Other Land Use*)

The Energy Sector is mainly responsible for carbon dioxide emissions - it produced over 95% of all carbon dioxide emissions, because of high emissions volume from thermal power plants, road transportation and residential sector.

CO_2 emissions from IPPU Sector are significantly less and made about 4.7% of total carbon dioxide emissions, CO_2 emissions from Waste sector are negligible.

Methane emissions accounted for nearly 31% of the total emissions in 2017. Methane emissions are also mostly from the Energy Sector (about 52%) due to the fugitive emissions from the natural gas system. The second one with its share of methane emissions is AFOLU Sector (without *Forestry and Other Land Use*) -over 31% mainly due to the emissions from enteric fermentation, while the Waste Sector is the third (nearly 17%).

Nitrous oxide emissions made up close to 10% of the total emissions. Most of nitrous oxide emissions (about 90%) are from the Agriculture Sector mainly due to the direct and indirect N_2O emissions from managed soils.

F-gases (HFCs and SF_6) accounted for roughly 6.5% of total GHG emissions, but their share has been growing continuously.

Summary report for national GHG inventory for 2017 is given in Table 2.2.

Emissions of HFCs on gas-by-gas basis from Product Uses as Substitutes for Ozone Depleting Substances for 2017 are reported in Table 2.3 in CO_2 equivalents. These emissions in the units of mass are provided further in Table 4.36.

Table 2.2 Summary report for national GHG inventory for 2017

Categories	Emissions and Removals (Gg)				Emissions $CO_{2\ eq.}$ (Gg)			Emissions (Gg)			
	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
Total National Emissions and Removals	5,698.103	-538.028	154.753	3.405	685.337	NO	2.594	13.272	34.010	10.026	48.558
1 - Energy	5,361.500		80.576	0.109				13.066	26.869	2.737	0.181
1A - Fuel Combustion Activities	5,361.311		3.106	0.109				13.066	26.869	2.737	0.181
1.A.1 - Energy Industries	1,297.949		0.023	0.002				2.033	0.891	0.059	0.006
1.A.2 - Manufacturing Industries and Construction	469.861		0.010	0.001				0.962	0.263	0.186	0.044
1.A.3 - Transport	1,723.689		1.810	0.087				8.676	24.823	2.415	0.013
1.A.4 - Other Sectors	1,869.811		1.263	0.018				1.395	0.892	0.077	0.117
1.A.5 - Non-Specified	NO		NO	NO				NA,NO	NA,NO	NO	NA,NO
1B - Fugitive emissions from fuels	0.189		77.470	NA,NO				NO	NO	NO,NE	NO
1.B.1 - Solid Fuels	NO		NO	NO						NO	
1.B.2 - Oil and Natural Gas	0.189		77.470					NO	NO	NE	NO
1.B.3 - Other emissions from Energy Production	NO		NO	NO				NO	NO	NO	NO
1C - Carbon dioxide Transport and Storage	NO							NO	NO	NO	NO
2 - Industrial Processes and Product Use	262.574		NA,NO	NA,NO	685.337	NO	2.594	NA,NO	NA,NO	7.289	48.377
2A - Mineral Industry	258.336										
2.A.1 - Cement production	224.551										
2.A.2 - Lime production	28.352										
2.A.3 - Glass Production	5.433										
2.A.4 - Other Process Uses of Carbonates	NE,NO										
2.A.5 - Other	NO										
2B - Chemical Industry	NO		NO	NO	NO	NO	NO	NO		NO	NO
2C - Metal Industry	NA,NO		NA,NO		NO	NO	NO	NO,NA	NO,NA	NO,NA	48.377
2.C.1 - Iron and Steel Production	NO		NO								NO
2.C.2 - Ferroalloys Production	NA		NA	NA							7.054
2.C.3 - Aluminum production	NO					NO			NO		NO
2.C.4 - Magnesium production	NO						NO				
2.C.5 - Lead Production	NO										
2.C.6 - Zinc Production	NO										
2.C.7 – Other - Copper Production											41.323
2D - Non-Energy Products from Fuels and Solvent Use	4.237								NO	6.403	

Categories	Emissions and Removals (Gg)				Emissions $CO_{2\ eq.}$ (Gg)			Emissions (Gg)			
	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
2.D.1 - Lubricant Use	3.991										
2.D.2 - Paraffin Wax Use	0.246										
2.D.3 - Solvent Use										6.401	
2.D.4 - Other - Bitumen/Asphalt Production and Use									NO	0.0021	
2E - Electronics Industry					NO	NO	NO				
2F - Product Uses as Substitutes for Ozone Depleting Substances					685.337	NO					
2.F.1 - Refrigeration and Air Conditioning					653.921	NO					
2.F.2 - Foam Blowing Agents					23.008						
2.F.3 - Fire Protection					0.636	NO					
2.F.4 - Aerosols					7.773	NO					
2.F.5 - Solvents					NO	NO					
2.F.6 – Other Applications					NO	NO					
2G - Other Product Manufacture and Use						NO	2.594				
2.G.1 - Electrical Equipment						NO	2.594				
2.G.2 - SF_6 and PFCs from Other Product Uses						NO	NO				
2.G.3 - N_2O from Product Uses				NO							
2.G.4 - Other											
2H - Other								NA,NO		0.886	
2.H.1 - Pulp and Paper Industry								NO		NO	
2.H.2 - Food and Beverages Industry										0.886	
2.H.3 - Other										NO	
3 - Agriculture, Forestry, and Other Land Use	69.744	-538.028	48.235	3.065				0.205	7.141	NA, NO,NE	NA,NO,NE
3A - Livestock			48.011	0.185							
3.A.1 - Enteric Fermentation			46.357								
3.A.2 - Manure Management			1.653	0.185							
3B - Land	67.024	-538.028	NO	0.001				NA,NO		NA,NO	
3.B.1 - Forest land	NO	-530.445						NO		NO	
3.B.2 - Cropland	0.712	-7.438									
3.B.3 - Grassland	18.366	0						NO		NO	
3.B.4 - Wetlands	18.317	NO	NO	0.001							NO
3.B.5 - Settlements	NO	-0.145									

Categories	Emissions and Removals (Gg)				Emissions $CO_{2\ eq.}$ (Gg)			Emissions (Gg)			
	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
3.B.6 - Other Land	29.629	NO									
3C - Aggregate sources and non-CO_2 emissions sources on land	2.720		0.224	2.878				0.205	7.141	NA,NO,NE	NA,NO,NE
3.C.1 - Emissions from biomass burning			0.224	0.008				0.205	7.141	NE	NE
3.C.2 - Liming	NO										
3.C.3 - Urea application	2.720										
3.C.4 - Direct N2O Emissions from managed soils				2.165							
3.C.5 - Indirect N2O Emissions from managed soils				0.586							
3.C.6 - Indirect N2O Emissions from manure management				0.12							
3.C.7 - Rice cultivation			NO					NO		NO	
3.C.8 - Other			NO	NO							
3D - Harvested Wood Products	NE	NE						NO			NO
4 - Waste	4.284		25.942	0.231				NE	NE	NE	NE
4A - Solid Waste Disposal			20.296								
4B - Biological Treatment of Solid Waste			NE	NE							
4C - Incineration and Open Burning of Waste	4.284		0.617	0.011				NE	NE		NE
4D - Wastewater Treatment and Discharge			5.028	0.22						NE	
4E - Other	NO		NO	NO				NO	NO	NO	
5 - Other	NE		NE	NE				NE	NE	NE	NE
5A – Indirect N_2O Emissions from the Atmospheric Deposition of Nitrogen in NO_2 and NH_3	NE		NE	NE				NE	NE	NE	NE
Memo Items											
International Bunkers	168.676		0.0012	0.005				0.218	0.065	0.103	0.054
1.A.3.a.i - International Aviation (International Bunkers)	168.676		0.0012	0.005				0.218	0.065	0.103	0.054
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

Notation Keys:
NO (not occurring) - used for activities or processes that do not occur for a particular gas or source/sink category within a country, NE (not estimated) – for existing emissions and removals which have not been estimated, NA/grey cells (not applicable) – is used for activities in a given source/sink category which do not result in emissions or removals of a specific gas, or there is no IPCC or EMEP/CORINAIR methodology.

Table 2.3 Emissions from product uses as substitute for ozone depleting substances for 2017, CO_{2} eq.

Categories	HFC-32	HFC-125	HFC-134a	HFC-152a	HFC-143a	HFC-227ea	Total HFCs
Emissions in CO2 equivalent unit (Gg CO_2)							
2.F - Product Uses as Substitutes for Ozone Depleting Substances	25.091	230.710	237.126	1.438	190.336	0.636	685.337
2.F.1 - Refrigeration and Air Conditioning	25.091	230.710	207.785	0	190.336	0	653.921
2.F.1.a - Refrigeration and Stationary Air Conditioning	25.091	230.710	114.118	0	190.336	0	560.255
2.F.1.b - Mobile Air Conditioning	0	0	93.667	0	0	0	93.667
2.F.2 - Foam Blowing Agents			21.9127	1.095		0	23.008
2.F.3 - Fire Protection		0	0			0.636	0.636
2.F.4 - Aerosols			7.430	0.343		0	7.773

Key Categories

The key categories are those categories of GHG emissions or removals that should be assigned priority in the process and the system of the national inventories, because they have significant impact on absolute values or trends of the country's greenhouse gases. Thus, the main efforts in the process of national inventory of greenhouse gases should be directed towards the improvement of the accuracy of the estimates of the key categories and the reduction of uncertainty of their emissions or removals.

The methodology for the assessment of key categories is described in 2006 IPCC Guidelines for National Greenhouse Gas Inventories [Gen-1, Volume 1, Chapter 4]. The approach 1 from this chapter has been used for selecting the key categories for Armenia's GHG inventory. The analysis has been performed for absolute values of emissions and removals (level assessment) based on 2017 inventory, as well as for the trends based on 2000 and 2017 inventories. Since in 1990 the structure and management principles of Armenia's economy were absolutely different as compared to the present time, using 1990 as a base year for trend analysis would identify those categories that underwent the most structural changes following the breakup of the Soviet Union and would not be informative for assessing current trends and processes of emission changes. Hence, 2000 has been used as a base year for trend assessment.

The 2006 IPPC Guidelines suggests an aggregation level of analysis for Approach 1 (Table 4.1, page 4.8, Volume 1, Chapter 4) but inventory compilers modified this list to reflect particular national circumstances and to consider more detailed disaggregation level. Thus, the subcategories *1A4b Residential - Gaseous Fuels* CO_2; *3A1a Enteric Fermentation-Cattle-*CH_4; *1A3b Road Transportation - Liquid Fuels* CO_2*; 1A4a Commercial / Institutional - Gaseous Fuels* CO_2 *and 3A1b-j Enteric Fermentation - Other* - CH_4 were identified as key by the level and trend assessment.

The identified key categories are presented in Table 2.4, whereas calculations, which are the basis for level and trend assessments, are given in Annexes 1.1 and 1.2 respectively. The key category analysis has been performed with and without *Land* (3.B) category. However, excluding the *Land* category didn't change the final list of key categories, thus it is not presented. The GHG inventory team found the obtained list of key categories as satisfactory and well depicting the current priorities. Thus, no additional categories have been added using qualitative criteria.

Table 2.4 Key categories of Armenia's GHG inventory according to Level (2017) and Trend (2000-2017) assessments

IPCC Category code	IPCC Category	Greenhouse gas	Method (Level, Trend)	Tier level
1.B.2.b	**Fugitive emissions from Natural Gas transportation and distribution**	**CH_4**	Level, Trend	T2
1.A.1	**Energy Industries - Gaseous Fuels**	**CO_2**	Level, Trend	T3
1.A.4.b	**Residential- Gaseous Fuels**	**CO_2**	Level, Trend	T2
1.A.3.b	**Road Transportation - Gaseous Fuels**	**CO_2**	Level, Trend	T2
3.A.1.a	**Enteric Fermentation - Cattle**	**CH_4**	Level, Trend	T2
1.A.3.b	**Road Transportation - Liquid Fuels**	**CO_2**	Level, Trend	T1
3.C.4	**Direct N2O Emissions from managed soils**	**N_2O**	Level, Trend	T1
2.F.1	**Refrigeration and Air Conditioning**	**HFCs**	Level, Trend	T2a
1.A.4.a	**Commercial/institutional - Gaseous Fuels**	**CO_2**	Level, Trend	T2
3.B.1.a	**Forest land Remaining Forest land**	**CO_2**	Level, Trend	T2

IPCC Category code	IPCC Category	Greenhouse gas	Method (Level, Trend)	Tier level
4.A	**Solid Waste Disposal**	**CH_4**	Level, Trend	T2
1.A.2	**Manufacturing Industries and Construction - Gaseous Fuels**	**CO_2**	Level, Trend	T2
4.D	**Wastewater Treatment and Discharge**	**CH_4**	Level	T1
2.A.1	**Cement production**	**CO_2**	Level	T3
3.C.5	**Indirect N2O Emissions from managed soils**	**N_2O**	Level	T1
3.A.1.b-j	**Enteric Fermentation - Other**	**CH_4**	Level, Trend	T2 (for buffalo and sheep), T1 (others)
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	Level, Trend	T1
4.D	**Wastewater Treatment and Discharge**	**N_2O**	Level	T1
1.A.2	**Manufacturing Industries and Construction - Liquid Fuels**	**CO_2**	Trend	T1

There are 19 key categories in Armenia's GHG inventory - 14 of which have been identified with both level and trend assessments, 4 - with only level assessment and 1 more - with trend assessment.

Total value of emissions of key categories in 2017 is 9,735 Gg $CO_{2\ eq.}$ and they comprise 95.9% of overall net emissions.

In recent years significant improvements have been made in accuracy of several key categories. As a result, out of 19 identified key categories, 12 are estimated using the higher tiers, including the 5 top key categories in both level and trend assessment (fugitive emissions, CO_2 emissions from the combustion of gaseous fuels in energy industries and other categories, enteric fermentation for cattle). For CH_4 emissions from Enteric Fermentation – Other, Tier 2 has been applied for buffalo and sheep, which represent 91.8% of emissions in this category.

Overall, the net emissions form these 12 categories that have been estimated using higher tiers comprised 87.6% of total net national emissions in 2017.

However, there are still several key categories that have significant shares in the level and trend uncertainty of inventory, making them priority sectors for next inventory cycles. These are *Direct and Indirect N_2O Emissions from Managed Soils* (3.C.4 and 3.C.5), N_2O emissions from W*astewater Treatment and Disch*arge (4.D), and CO_2 emissions from *Liquid fuel use in road transportation* (1.A.3.b).

Uncertainty Assessment

The uncertainty assessment is one of the main components of the inventory development process. Performance of this analysis is stipulated by the UNFCCC Reporting Guidelines on national communications (Decision 17/CP.8, annex, paragraph 24) and is one of the specific functions performed by the national inventory systems.

The uncertainty assessment is not intended to bring into question the inventory estimations. On the contrary, together with key category analysis, it helps to improve the accuracy of inventory by planning priorities for improvements and making decisions on selection of methodologies.

There are two methods of uncertainty estimation stipulated by the 2006 IPCC Guidelines. For uncertainty assessment of the Armenia's GHG inventory the Approach 1: the propagation of error has been used. The methodology is described in detail in 2006 IPCC Guidelines for National Greenhouse Gas Inventories [Gen-1, Volume 1, Chapter 3, Section 3.2.3.1.]

The uncertainty analysis of Armenia's inventory covers all source categories and all direct greenhouse gases. In some cases, the sub-categories have been aggregated to eliminate the interrelation and ensure that data is available at appropriate level both for 2017 and 2000 years. The categories are disaggregated in such a way that they match categories used in key category analysis and therefore serve their purpose of identification of such categories that will require special attention during the next inventory process to improve their accuracy and reduce uncertainty.

The uncertainty has been assessed based on the level in 2017 GHG inventory data, as well as trend, where the base year was selected to be 2000. 2000 has been chosen as a base year instead of 1990 because difference between inventory estimates of 2000 and 2017 better represents the current and possible future trends of Armenia's inventory, than the difference between 1990 and 2017. The difference between 1990 and 2017 shows downward trend due to the breakdown of Soviet Union and consequent restructuring of inventory, whereas the difference between 2000 and 2017 shows an upward trend, which is more characteristic to the current and possible future development of Armenia's emissions and removals. In addition, 2000 is the first year, where the activity data is relatively accurate compared to previous years.

The uncertainty estimation for the activity data and country specific emission factors is based on expert's analysis of data sources, whereas uncertainty levels of default emission factors are based on suggested values from 2006 IPCC Guidelines. When 2006 IPCC Guidelines give uncertainty assessment for components of activity data and emission factors, they have been combined using error propagation equations. A detailed description of selected emission factors and activity data is given in sectoral chapters.

The calculations for the uncertainty assessment are presented in Annex 1.3.

The calculations' results revealed that the level of emissions uncertainty is within 17.9%, and the uncertainty of trend is 16.7%.

The highest contribution to variance by category in 2017 have *Direct and Indirect N_2O Emissions from managed soils* (3.C.4 and 3.C.5), CH_4 and N_2O emissions for the use of natural gas in *Road Transportation* (1.A.3.b), N_2O emissions from *Wastewater Treatment and Discharge* (4.D) and CH_4 emissions from *Solid Waste Disposal* (4.A).

The highest contributors in the uncertainty of trend have CH_4 and N_2O emissions for the use of natural gas in *Road Transportation* (1.A.3.b), CH_4 emissions from *Solid Waste Disposal* (4.A), *Direct N_2O Emissions from managed soils* (3.C.4) and HFC emissions from *Refrigeration and Air conditioning* (2.F.1).

As it can be seen, in all cases the highest uncertainties are related to non-CO_2 emissions. For CO_2 emissions, the categories with highest uncertainty contribution both in level and trend are the liquid fuel use in *Road Transportation* (1.A.3.b) and *Forest Land Remaining Forest Land* (3.B.1.a). Consequently, the main efforts for reducing uncertainty should be directed towards these categories in future inventory processes.

3. TRENDS OF GREENHOUSE GAS EMISSIONS

Figure 3.1 below provides greenhouse gas emissions trend by sectors for 1990-2017 (without *Forestry and Other Land Use*).

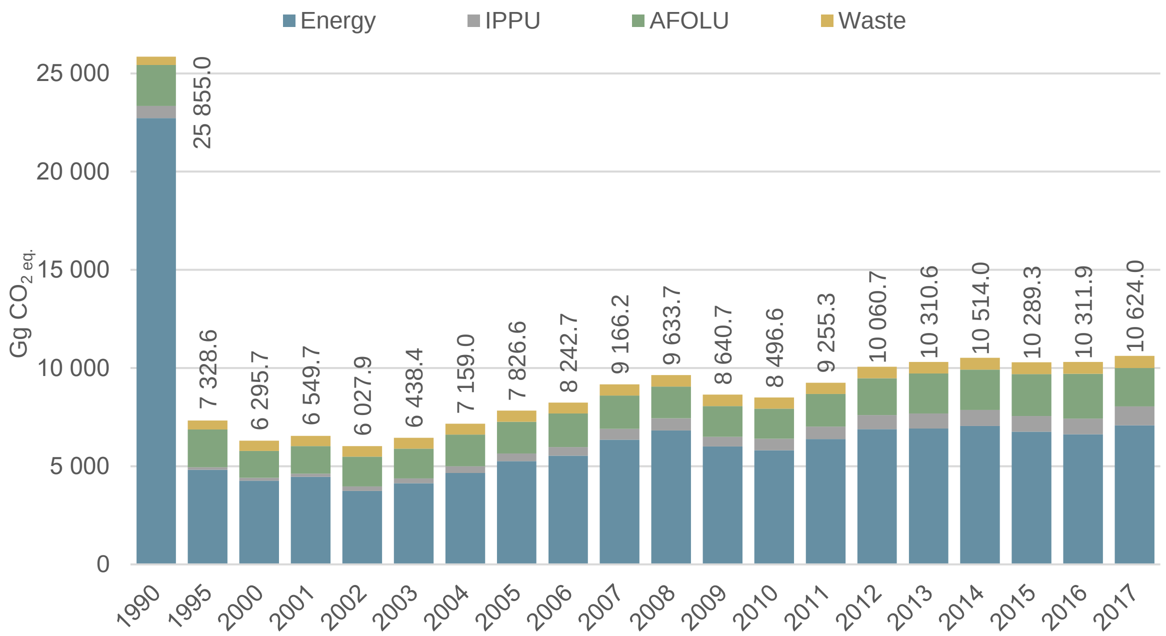


Figure 3.1 1990-2017 greenhouse gas emissions by sectors *(without Forestry and other land use)*, Gg $CO_{2\ eq.}$

The Figure 3.1 shows 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 2017 decreased by nearly 59% compared to 1990, indicating that the greenhouse gas intensity of the economy has decreased. 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 to the year 1990, while Total Primary Energy Supply (TPES) decreased by 2.4 times, import of natural gas – by 1.8 times and electricity production – by 1.3 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 coal and mazut) and in transport, recommissioning of Armenia's Nuclear Power Plant and strongest growth of the small hydropower plants.

The increase of Energy Sector emissions since 2000 (except for 2009-2010) amounts to nearly 67% due to:

- Economic growth, leading to the growth in traffic volume, which resulted in road transport emissions' growth. During 2000-2017 road transport emissions have increased by more than 150%.
- Improved household living conditions resulted in the wide use of natural gas for space heating. It became possible because of the unprecedented level of natural gas deliverability reached in the country. During 2004-2017, emissions attributable to energy used by households increased over fivefold.
- Increased production of electricity by natural gas fired thermal power plants.

In 2009, the financial and economic crisis affected the energy consumption, however, since 2011 emissions increased again as a result of economic recovery.

Emissions resulted from Energy Sector 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. Thus, increase of Energy Sector emissions in 2017 compared with those in 2016 is due to GDP growth in 2017 and cold winter.

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 lime and glass production, as well as from lubricant and paraffin wax use.

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. Increase of CO_2 emissions in 2017 compared to those in 2016 resulted from the growth of construction volumes as well.

The increase in IPPU Sector emissions since 2011 is primarily due to the increase of F-gases' emissions. Fluorinated gases, or F-gases, form a category of their own under industrial processes and accounted for roughly 6.5% of total national greenhouse gas emissions and over than 72% of the greenhouse gas emissions of IPPU sector in 2017. In the period from 2010 to 2017, the biggest change occurred in F-gases emissions, which increased 2.6 times mainly due to the wide use of F-gases in refrigeration and cooling devices.

The decline in emissions in AFOLU sector in the 1990s was due to the liquidation of state-owned livestock farms which led to a sharp reduction in livestock and, accordingly, to a continuing reduction in emissions until 2000.

The increase in AFOLU sector emissions since 2000 (except for the period of economic crisis in 2009-2010), was due primarily to increase in livestock populations and increase in emissions from managed soils and from fertilizer use. The decrease of agricultural emissions in 2017 compared to those in 2016 was due to decrease in the number of cattle.

The share of Waste Sector emissions in the country's total emissions is relatively stable. Waste Sector emissions accounted for 5.8% of the country's total emissions in 2017. During 2000-2017, Waste Sector emissions increased by about 21% due to the growth in methane emissions from solid waste disposal because of high inertia and cumulative effect of organic matter decomposition process in anaerobic conditions.

Time series for 1990-2017 greenhouse gas emissions by gases in Gg $CO_{2\ eq.}$ are provided below (without *Forestry and Other Land Use*).

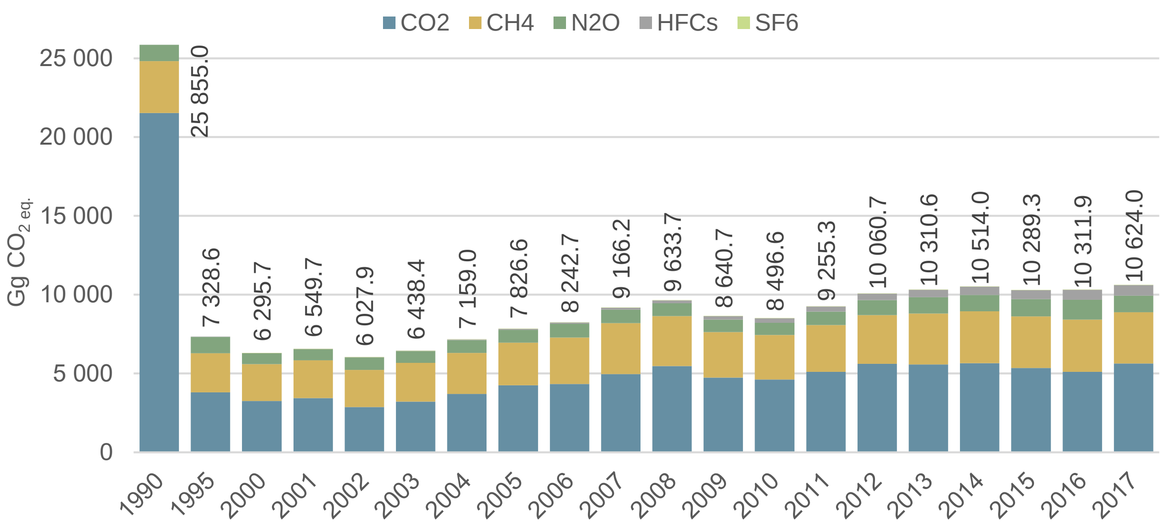


Figure 3.2 Greenhouse gas emissions by gases, Gg $CO_{2\ eq.}$

Figure 3.2 shows the development of emissions of the various greenhouse gases since 1990. 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 51% of total emissions. All other greenhouse gases together account for less than half of greenhouse gas emissions. Energy Sector produced the vast majority - roughly 95% of all carbon dioxide emissions in 2017.

The increase of overall emissions in 2017 as compared to 2000 amounted to over 69%. Mainly, this resulted from an increase of CO_2 emissions.

In the period from 2005 to 2017, the biggest change occurred in F-gases emissions, which increased fifteen-fold. 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 a negligible role. Methane emissions increased by nearly 39% since 2000. This trend has been primarily the result of the increase of the natural gas consumption and increase of livestock populations.

The main emission 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 51%. 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 2005. There is a sustainable annual average growth for all applications, however the growth dynamics is different. HFC_s emissions, which are caused by refrigeration systems, predominate in the overall picture of HFCs emissions with the share of 95% in 2017.

The share of SF_6 emissions is negligible, though they have grown continuously.

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, wind and solar power plant), which provided 33.7%, 18.1%, 37.0% and 11.1% of total electricity generation in 2017, respectively. As of 2017, renewable energy consisted mainly of hydropower (small to large HPPs) however, in recent years solar energy has been growing rapidly.

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 is imported from Russia - nearly 84% in 2017. Armenia also imports some natural gas from Iran in exchange for Armenia's supply of electricity to Iran. Oil is imported mainly from Russia.

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 61% of Armenia's TPES and 85% of the fossil fuel (including jet fuel) consumption in 2017.

Over 83% of CO_2 emissions from fuel combustion (without international bunker) in 2017 originated from natural gas. This is due to a very high gas deliverability level in the country - 96% 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 gasoline.

The Energy Sector is by far the biggest source of GHG emissions in the country - in 2017 its share of the total greenhouse gas emissions was 67% (7,087.4 Gg $CO_{2\ eq.}$). The Energy Sector emissions in 2017 made 31.2% of 1990 emissions' level and were 7.0% higher than those in 2016.

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 emissions (77%) results from fossil fuel combustion.

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

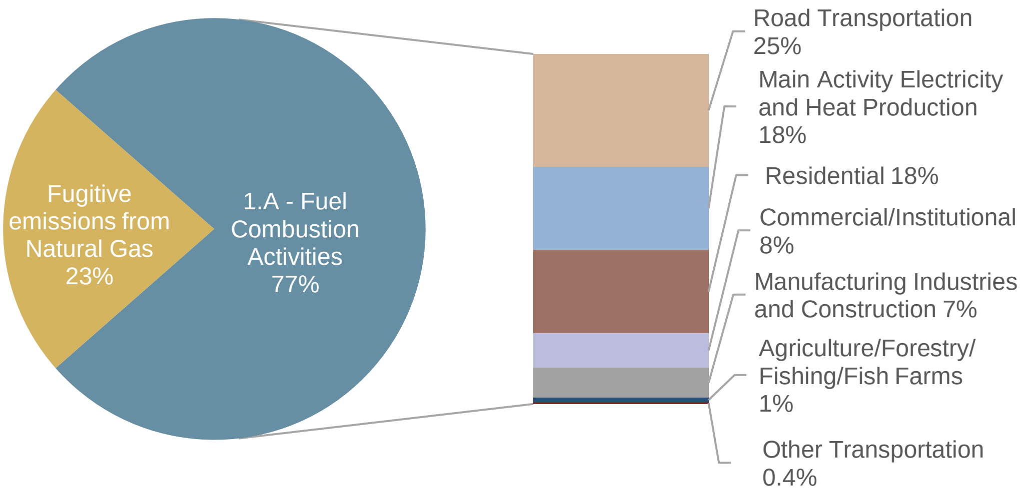


Figure 4.1 Greenhouse gas emissions by sources in Energy Sector in 2017, $CO_{2\ eq.}$

Figure 4.1 shows that road transport, fugitive emissions, electricity production and households are the leading sources of GHG emissions within the sector.

Road transport generated 24.8% of the Energy Sector emissions in 2017, other significant emission source in Energy Sector was fugitive emissions of natural gas, share of which in 2017 was slightly less – 23.0%. Emissions attributable to electricity production and energy use by households accounted to 18.3% each, emissions from the fuels used by Commercial/Institutional category and different industries made 7.6% and 6.6% correspondingly, while emissions from Off-road Vehicles and Machinery in agriculture accounted only for 1%.

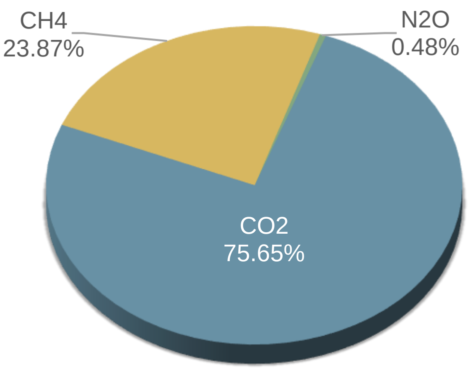


Figure 4.2 Greenhouse gas emissions by gases in Energy Sector in 2017, $CO_{2\ eq.}$

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 2017, 76% of the emissions from the Energy Sector were CO_2, 24% - CH_4 and 0.5% - N_2O (Figure 4.2.).

Methodologies for GHG emissions assessment

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 emissionś estimates than Tier 1 approach:

- *The Tier 3 method* was used for estimating 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 CO_2 emission estimates from liquid and solid fuel combustion and for emissions of CH_4 and N_2O from 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. Other emissions were estimated with the Tier 1 method with default estimation parameters from the 2006 IPCC Guidelines and country-specific activity data.

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

Subcategory	GHG	Key Source	Method, Approach	Activity Data	Emission Factor
1A FUEL COMBUSTION ACTIVITIES					
1A1a Main Activity Electricity and Heat Production (gaseous fuel)	CO_2	Level, Trend	T3	CS	CS
1A2 Manufacturing Industries and Construction (gaseous fuel)	CO_2	Level, Trend	T2	CS	CS
1A2 Manufacturing Industries and Construction (liquid fuel)	CO_2	Trend	T1	CS	D
1A3b Road transportation (gaseous fuel)	CO_2	Level, Trend	T2	CS	CS
1A3b Road transportation (liquid fuel)	CO_2	Level, Trend	T1	CS	D
1A4a Commercial/Institutional (gaseous fuel)	CO_2	Level, Trend	T2	CS	CS
1A4b Residential (gaseous fuels)	CO_2	Level, Trend	T2	CS	CS
1A4 Other Sectors (liquid fuels)	CO_2	Level, Trend	T1	CS	D
1B FUGITIVE EMISSIONS FROM FUELS					
1B2b Fugitive Emissions of Natural Gas	CH_4	Level, Trend	T2	CS	CS

The emissions of other air pollutants such as CO, NOx, SO_2 and NMVOC form energy sector have been estimated as well, using the methodologies and emission factors from “Air Pollutant Emission Inventory Guidebook” (EMEP/EEA, 2016) and same activity data used for estimating three main GHGs. The emissions of these pollutants are presented in Table 2.2.

Improvements done

Improvements to the GHG emissions assessment of the Energy Sector are done on a continuous basis, driven by previous QA/QC procedures, as well as improvements proposed as a result of previous GHG Inventory review.

Improvements of 2017 National GHG Inventory include:

- The quantity of manure used for fuel have been adjusted (detailed description is given in the section "Biomass emissions").

- Emissions from biomass burning included other solid biomass and charcoal (Energy balance data) in addition to fuelwood and Animal waste.
- Methane (CH_4) and Nitrous oxide (N_2O) emissions from biomass burning have been included in the National GHG Inventory and time series have been recalculated.
- Time series of GHG emissions from biomass burning (CO_2 as memo item) have been recalculated.

4.1.2 Energy Sector greenhouse gas source categories

As of 2017, the Energy Sector of 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 for commercial delivery. To avoid double counting the existing boiler houses providing heat supply for own use 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 2017 was 3313.0 ktoe, nearly 68% of which is imported considering that production of nuclear energy is regarded as indigenous production. Natural gas accounted for 61% of Armenia's TPES in 2017.

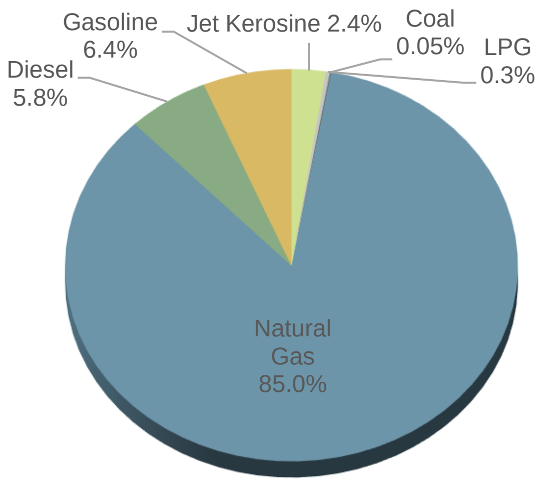


Figure 4.3 Fossil fuel consumption structure by type of fuel in 2017

With regard to fossil fuel consumption structure by fuel types, natural gas is accounting for 85% in 2017. In general, fossil fuel consumption structure remained almost unchanged in recent years. Figure 4.3 provides fossil fuel consumption structure in 2017.

Natural gas

Natural gas is widely used in the different sectors of economy and transportation. With natural gas access level of 96% Armenia is one of the leaders in the world.

"Gazprom Armenia" CJSC is a monopoly in charge of the operation and management of the gas supply system in the Republic of Armenia including import, transmission (operation of underground storage), distribution and sale of natural gas.

Natural gas balances (Annex 2.1, EnRef-1) 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 estimates are provided in Table 4.2.

Table 4.2 Extract from natural gas balances for 2011-2017, (mln m^3)

Year	2011	2012	2013	2014	2015	2016	2017
Imports	2,069.1	2,455.5	2,361.1	2,450.9	2371.8	2236.5	2,378.7
Gas turnover in storage facility *(extracted +, injected -)*	+46.4	-49.3	+24.3	-27.7	-33.0	+1.9	-23.5
Own needs, (mln m^3)	7.8	13.5	7.01	9.2	8.1	7.3	9.1
Own needs, %	0.38	0.55	0.30	0.38	0.34	0.33	0.38
Losses, (mln m^3)	134.05	139	141.63	144.7	138.8	142.6	148.2
Losses, %	6.5	5.7	6.0	5.9	5.9	6.4	6.2
Consumption, including	1,973.6	2,253.7	2,236.7	2,269.3	2191.9	2088.5	2,197.9
Energy Generation	549.3	825.5	759.0	799.54	654.4	603.7	637.5
Road Transportation	362.4	418	455.0	481.7	484.6	467.3	477.5

Year	2011	2012	2013	2014	2015	2016	2017
Manufacturing Industries/Construction	326.2	317.7	301.4	278.2	207.7	191.2	200.3
Commercial/Institutional	184.9	150.5	182.4	194.45	318.6	245.3	261.1
Residential	550.8	542.0	538.9	515.4	526.6	581.0	621.5

The Table 4.2 shows that natural gas import in 2017 increased by 6.4%, consumption – by 5.2% compared with 2016.

At the same time net calorific value (NCV) of imported/supplied natural gas mixture (kcal/m^3) in 2017 increased by 3.4% compared to 2016 and carbon content of imported/supplied natural gas mixture increased by 3.8%.

Figure 4.4 provides CO_2 country-specific emission factors for natural gas mixture for 2011-2017, kg CO_2 /TJ

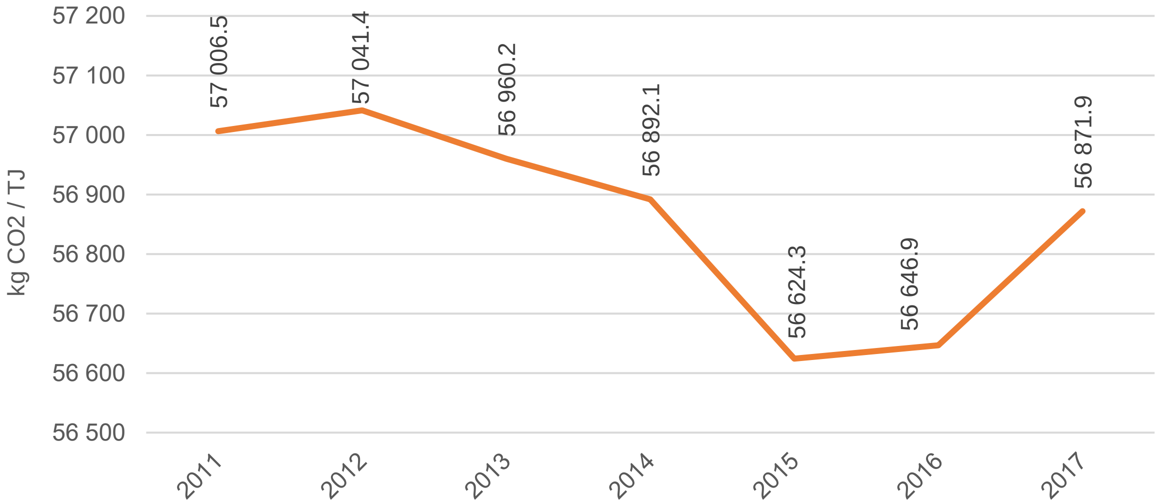


Figure 4.4 CO_2 country-specific emission factors for natural gas mixture, 2011-2017, kg CO_2 /TJ

The variations in the annual volumes of natural gas imports are mainly due to the changes in the volumes of exported electricity produced by natural gas fired thermal power plants – the variations in the annual consumption of natural gas for electricity generation reach up to 50% (relatively stable over the last three years).

There was an increase in gas consumption in 2017 in all categories compared with 2016 due to economic growth and weather conditions (cold winter), meanwhile in 2017 residential sector had the highest gas consumption for 2011-2017 period caused by the cold winter.

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 consumed provided by the SC.

Considering that Armenia does not have domestic fossil fuel resources, refining and large storage facilities for liquid fuel, it is assumed that the entire volume of imported oil products is fully consumed during the same year.

The quantities of oil products by fuel types imported in Armenia in 2011-2017 are summarized in Table 4.3.

Table 4.3 Oil products by fuel types for 2011-2017 (tonnes)

Oil Products	Import, t						
	2011	2012	2013	2014	2015	2016	2017
Gasoline	131,588	130,332	132,219	129,120	130,381	140,556	142,213
Diesel Fuel	159,515	144,683	147,326	152,651	128873	126,660	134,506
Jet Kerosene	39,648	40,473	45,900	40,458	30,927	44,055	54,394
Liquid Petroleum Gas (LPG)	7,359	6,909	7,397	6,763	6,914	4,054	6,146
Total	**338,110**	**322,397**	**332,842**	**328,992**	**297,095**	**315,324**	**337,259**

Table 4.3 shows that the quantities of the imported/consumed oil products are relatively steady for 2011-2017 period.

According to an agreement signed between Russian Federation and the Republic of Armenia in 2013, the delivery of oil products from Russia is indefinitely exempt from customs duties, and is imported to Armenia without collecting customs duties in Russia.

Gasoline and diesel are the main liquid fuels consumed in the country accounting for 50.9% and 46.7%, correspondingly.

Road transport apparently is the largest consumer of the liquid fuel with the share of 82.3% followed by the Off-road Vehicles and Other Machinery used on farm land and forests with the share of 7.0% and Off-road and other mobile machinery in industry with the share of 6.8%. The consumption by the other categories is much lower.

Liquid fuel consumption by subcategories was estimated based on official data from the SC (Annex 2.2).

The quantity of diesel fuel imported in the country was consumed by 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 made by the SC), diesel consumption by Residential sub-category was provided by the SC as well. Gasoline is almost entirely consumed in transport sector.

Biomass

As it is mentioned in the IPCC Guidelines [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 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 biomass fuels including fuelwood. The quantity of fuelwood was estimated based on official data on volumes of harvested wood, fallen-wood and illegal logging (LUCFRef-4).

It should be noted, that there is a significant difference between data on fuelwood consumption provided by the official statistics and those from the Household survey implemented by the SC. Currently GHG Inventory team closely collaborates with the SC to ensure consistency of these data.

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 2011-2017

Measurement Units	Fuelwood combustion volumes						
Year	2011	2012	2013	2014	2015	2016	2017
Volume (m^3)	65,740	85,960	71,551	65,621	76,600	70,246	82,743
Weight (t)	36,617	47,880	39,854	36,551	42,666	39,127	46,088
Energy (TJ)	571.23	746.92	621.72	570.20	665.59	610.38	718.97

Manure

Manure is largely used as fuel in rural areas of Armenia.

Emissions from manure combustion have been recalculated using revised data on annual manure excretion per animal and revised data on share of manure used as fuel provided by the Ministry of Economy (Agriculture department).

Table 4.5 summarizes the annual amounts of manure burned, which were assessed according to official data (Annex 3.4) and the revised methodology, considering the following:

- manure production per cattle
  - per one cow – 8t excretion, from which manure – 5.6t
  - per one calf – 4.0t
  - on average – 4.8t
- average annual livestock numbers (the detailed methodology on Average annual livestock numbers' estimate was provided in the National GHG Report of the Armenia's Third National Communication)
- cattle regimes - in confined area and pasture days
- on average 38.5% of manure left in pastures
- 0.98 part of the remaining was stored in dry form to be used as fuel or fertilizer
- 0.47 part of moist manure after drying was used as organic fertilizer, while 0.53 part was used for preparing fuel
- 80% of the mass is lost during drying.

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 in 2011-2017

Quantity of manure produced, burned and heat received	2011	2012	2013	2014	2015	2016	2017
Total manure, Gg	3,371.3	3,716.3	3,997.5	4,058.6	4,108.2	4,027.7	3,489.7
Total burned, Gg	215.6	237.6	255.6	259.5	262.7	257.5	223.1
Heat, TJ	2,500.4	2,756.3	2,964.8	3,010.2	3,047.0	2,987.3	2,588.2

Other Biomass

In 2017, for the first time GHG emissions estimate from Biomass burning included other solid biomass and charcoal, in addition to fuelwood and manure.

The values of the other biomass burned were taken from the officially published RA Energy balance for the last three years - 2015, 2016 and 2017.

For the previous years these data have been received using extrapolation.

Quantity of other solid biomass produced, burned and heat received	2015	2016	2017
Total other solid biomass, burned, Gg	25.18	21.31	28.94
Heat, TJ	292.03	247.19	335.74

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

Quantity of charcoal produced, burned and heat received	2015	2016	2017
Total charcoal, burned, Gg	0.03	0.04	0.08
Heat, TJ	1.02	1.29	2.43

Heat produced from Charcoal was calculated using the Net Calorific Value of 29.5 TJ/Gg [Gen-1, Volume 2, Table 1.2] for “Charcoal”.

GHG emissions time series from Solid Biomass burning were recalculated to ensure time series consistency considering revised activity data on manure burned and inclusion of charcoal and other solid biomass burned.

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 and trend assessment.

Table 4.6 provides electricity generation per type of power plants (Annex 2.3, EnRef-2).

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

Power Plants	Year							
	2010	2011	2012	2013	2014	2015	2016	2017
Nuclear	2,490	2,548	2,311	2,360	2,465	2,788	2,381	2,620
Thermal	1,443	2,395	3,398	3,173	3,289	2,801	2,582	2,872
Hydro	2,143	2,033	1,814	1,433	1,308	1,369	1,394	1,407
Small Renewables	416	458	513	744	689	840	960	864
Total	6,492	7,434	8,036	7,710	7,750	7,798	7,315	7,763

In 2017, the increase of annual electricity production was mainly driven by:

- the increase of electricity Import /Export saldo by approximately 17% (or 166 GWh)
- the increase in domestic consumption by 5.5% (or 293 GWh),

The share of gas fired TPPs in power generation mix in 2017 was more than 37%. 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

Considering both that Armenia imports natural gas from two countries and natural gas supply system structure specifics, 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 the PSRC and country-specific emission factors, considering natural gas composition in its delivered state to the each thermal power plant.

Activity data

Natural gas consumption by each thermal power plant were derived from the PSRC (Annex 2.4) and were converted to common energy units (TJ) (Annex 2.5) considering net calorific values (NCVs) at individual plant level provided by Gazprom Armenia (Annex 2.6).

Emission factors

Country-specific emission factors were derived from detailed data on natural gas composition in its delivered state to 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 2.6).

The methodology for calculating country-specific emission factors along with the results of the calculation are provided in Annex 2.5.

All indicators – NCVs, carbon content, as well as calculated country-specific emission factors are within 95% confidence interval (Annex 2.5.).

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.

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.

According to the Energy balance, in 2017 centralized heat production was carried out only by “Armruskogeneratsia” CJSC, comprising only 8.5 million kWh (or 0.1% of electricity production in the country).

All production is based on natural gas combustion.

Emissions calculations results

Table 4.7 summarizes plant level CO_2 emissions calculation from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories in 2011-2017.

Table 4.7 Plant level CO_2 emissions (Gg CO_2) for 2011-2017

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	56,851.70	7,962.90	230.683	452.70
Hrazdan-5 TPP	56,851.70	8,126.21	235.400	461.99
Yerevan CCGT	57,209.21	12,029.63	352.586	688.21
Yerevan Medical University CHP plant	57,209.21	107.10	3.139	6.13
ArmRosCogeneration CHP plant	57,209.21	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

Stationary Combustion	Country-specific emission factor	Activity data		GHG emissions
	kg CO_2/TJ	TJ	mln m^3	Gg CO_2
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**
2015				
Hrazdan TPP	56,419.72	5,671.08	162.5091	319.96
Hrazdan-5 TPP	56,419.72	5,185.41	148.5919	292.56
Yerevan CCGT	56,655.00	11,656.56	336.8126	660.40
Yerevan Medical University CHP plant	56,655.00	134.22	3.8782	7.60
ArmRosCogeneration CHP plant	56,655.00	89.15	2.576	5.05
Total		**22,736.41**	**654.3678**	**1,285.58**
2016				
Hrazdan TPP	56,415.80	4,515.82	129.5443	254.76
Hrazdan-5 TPP	56,415.80	5,750.06	164.9505	324.39
Yerevan CCGT	56,715.56	10,455.88	303.8872	593.01
Yerevan Medical University CHP plant	56,715.56	72.82	2.1165	4.13
ArmRosCogeneration CHP plant	56,715.56	111.03	3.227	6.30
Total		**20,905.62**	**603.7255**	**1,182.60**
2017				
Hrazdan TPP	56,697.39	3,299.70	91.144	187.08
Hrazdan-5 TPP	56,697.39	8,186.01	226.112	464.13
Yerevan CCGT	56,951.34	11,175.67	315.180	636.47
Yerevan Medical University CHP plant	56,951.34	77.19	2.177	4.40
ArmRosCogeneration CHP plant	56,951.34	103.29	2.913	5.88
Total		**22,841.86**	**637.526**	**1,297.96**

The increase of country specific emission factors (kg CO_2 /TJ) is due to increase of carbon content in natural gas imported from Russia and Iran (in 2016, from Russia - 15,386 kg/GJ, from Iran - 15,772 kg/GJ, while in 2017, from Russia - 15,463 kg/GJ, Iran - 15,787 kg/GJ) (Annex 2.5, Table 2.5-1).

Table 4.8 summarizes 2017 emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories and per greenhouse gases.

Table 4.8 Emissions from (1A1a) *Main Activity Electricity and Heat Production* sub-category in 2017

Code	Category/Subcategory	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A1a	Main Activity Electricity and Heat Production	1,297.9	0.0228	0.0023	1,299.1
1A1ai	Electricity Generation	651.2	0.0114	0.0011	651.8
1A1aii	Combined Heat And Power Generation	646.7	0.0113	0.0011	647.3

Figure 4.5 illustrates CO_2 emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories per plants in 2017.

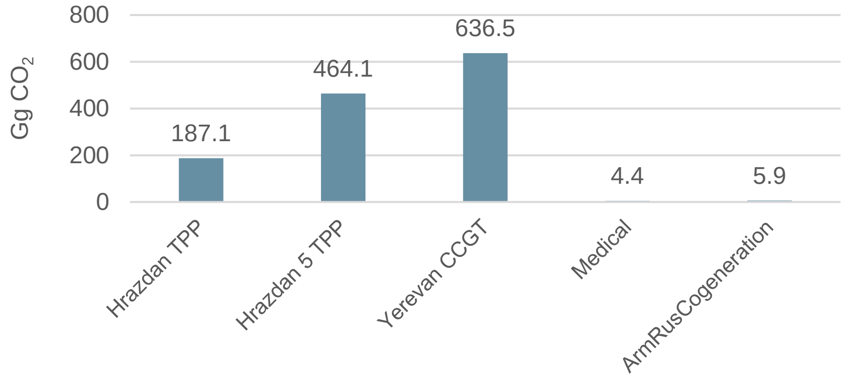


Figure 4.5 CO_2 emissions from Electricity Generation and Combined Heat and Power Generation sub-categories per plants in 2017

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 are obligatory 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% 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 4.24% (Annex 1.3).

Time series

Figure 4.6 provides 1990-2017 time series of CO_2 emissions from *Main Activity Electricity and Heat Production* category.

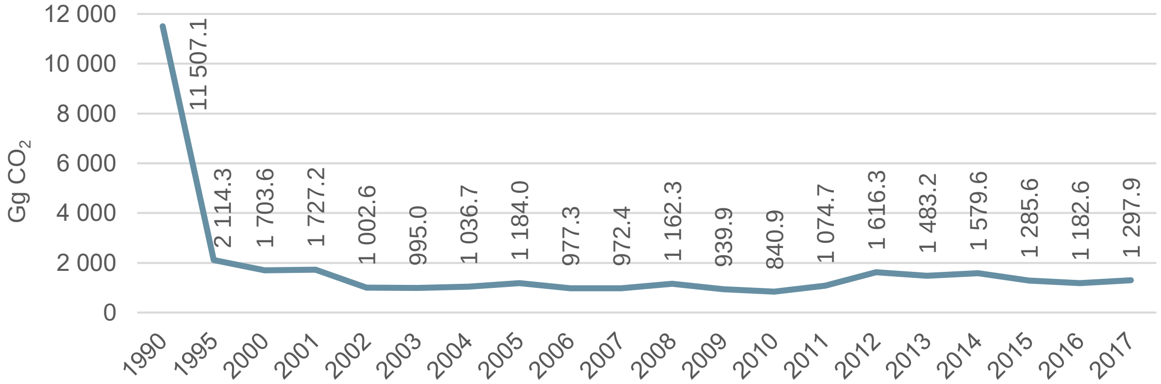


Figure 4.6 Time series of CO_2 emissions from Main Activity Electricity and Heat Production, Gg, 1990-2017

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 during 2002-2010 was relatively small, while CO_2 emissions growth in 2012 compared to 2010 was due to the increased electricity generation by thermal power plants, mainly because of the increased electricity exports to Iran.

The reason for the reduction of CO_2 emissions in 2014-2016 was the reduction of electricity export.

4.1.4.1.2 Manufacturing Industries and Construction (1A2)

Description of the category

According to 2006 IPCC Guidelines [Gen-1, Volume 2] the Energy Sector includes activities related to fuel combustion in manufacturing and construction. This category consists of several sub-source categories defined in accordance with the 2006 IPCC Guideline [Gen-1, Volume 2].

The source category *Manufacturing Industries and Construction* is a key category (gaseous fuel) for CO_2 emissions in terms of level and trend assessment (and for liquid fuel - CO_2 emissions, in terms of trend 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 2.2) and applying country-specific emission factors for natural gas mixture (weighted average) (Annex 2.5).

Emissions from diesel fuel and LPG combustion were assessed applying Tier 1 approach.

Activity data

Different types of fuel are used in this category – mostly natural gas, followed by diesel fuel in a much smaller quantities, while LPG consumption is negligible.

The amounts of natural gas, diesel fuel and LPG used by sub-categories were derived from the Statistics Committee of the Republic of Armenia (SC) (Annex 2.2) - for cross-checking of the data provided in Energy balance.

All fuel consumed were converted to common energy units (TJ) applying for natural gas NCVs of natural gas mixture provided by Gazprom Armenia (Annex 2.5) and for LPG and diesel – default values provided by 2006 IPCC Guideline [Gen-1, Volume 2, Table 1.4].

Figure 4.7 provides consumption by fuel types specified by physical units and total energy consumption by sub-categories (TJ).

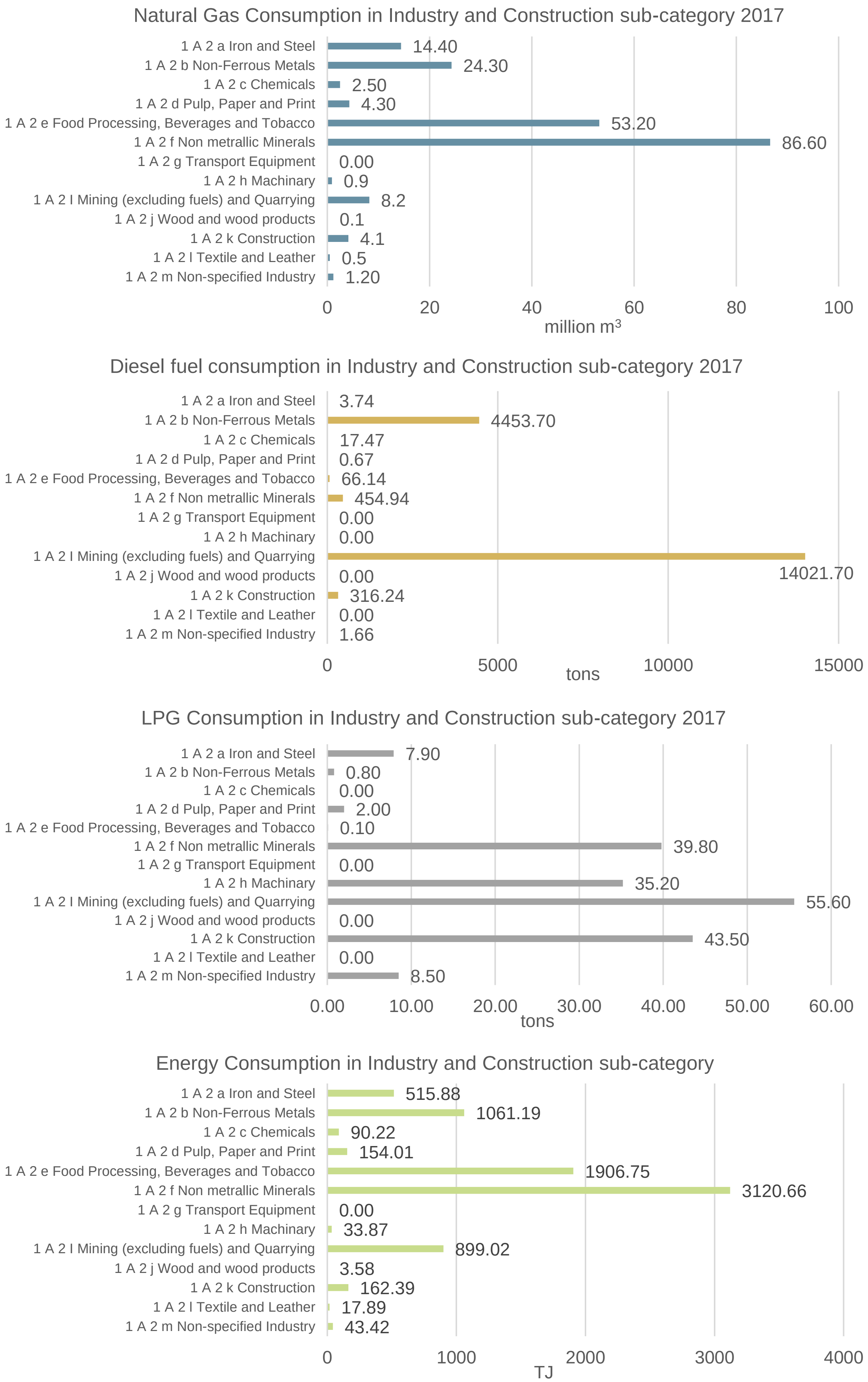


Figure 4.7 Natural gas, diesel fuel, LPG and total energy consumption by sub-categories

Figure 4.7 shows that in *Manufacturing Industries and Construction* category the largest consumers of natural gas were (1A2f) *Non-Metallic Minerals* and (1A2e) *Food Processing, Beverages and Tobacco* sub-categories.

As for diesel, the main consumers were (1A2i) *Mining and Quarrying* and *(1A2b) Non-Ferrous Metals* sub-categories.

LPG main consumers were (1A2i) *Mining and Quarrying*, (1A2k) *Construction*, (1A2f) *Non-Metallic Minerals* and (1A2h) *Machinery* sub-categories.

The leaders in terms of total energy consumption (TJ) are (1A2f) *Non-Metallic Minerals* and (1A2e) *Food Processing, Beverages and Tobacco* sub-categories.

Natural gas makes 89.5% of the fuel consumed in *Manufacturing Industries and Construction* category, diesel - 10.4% and LPG is only 0.1%.

Emission factors

Country-specific emission factors (Annex 2.5) calculated for natural gas mixture (Annex 2.6) were applied for estimating emissions from natural gas combustion, while for diesel and LPG default values provided by 2006 IPCC Guideline were applied [Gen-1, Volume 2, Table 1.4].

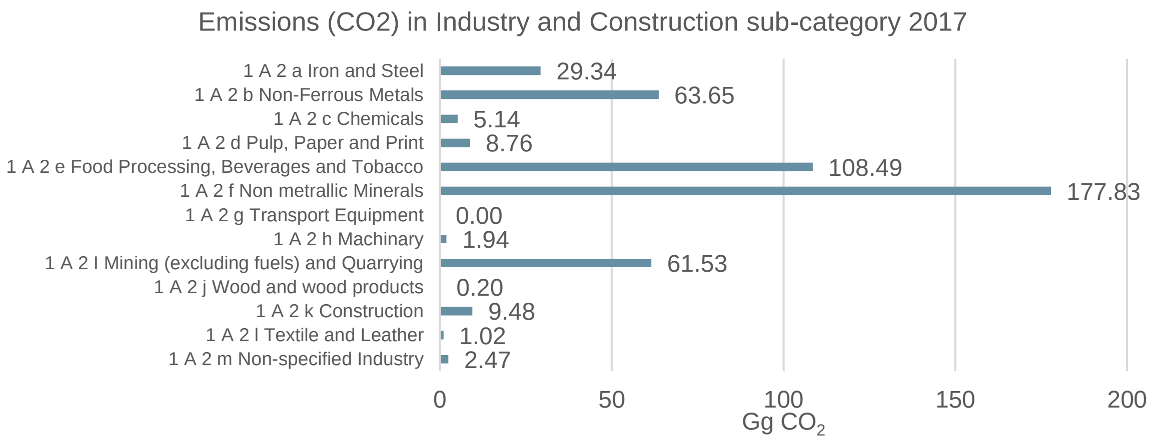
Emissions calculations results

The results of emissions assessment from *Manufacturing Industries and Construction* source category in 2017 are summarized in Table 4.9.

Table 4.9 Emissions from *Manufacturing Industries and Construction* category, Gg, 2017

Code	Category/sub-category	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A2	**Manufacturing Industries and Construction**	469.9	0.0097	0.0012	470.4
1A2a	Iron and Steel	29.3	0.0005	0.0001	29.4
1A2b	Non-Ferrous Metals	63.7	0.0014	0.0002	63.7
1A2c	Chemicals	5.1	0.0001	0.0000	5.1
1A2d	Pulp, Paper and Print	8.8	0.0002	0.0000	8.8
1A2e	Food Processing, Beverages and Tobacco	108.5	0.0019	0.0002	108.6
1A2f	Non-Metallic Minerals	177.8	0.0032	0.0003	178.0
1A2h	Machinery	1.9	0.0000	0.0000	1.9
1A2i	Mining (excluding fuels) and Quarrying	61.5	0.0021	0.0004	61.7
1A2j	Wood and Wood Products	0.2	0.0000	0.0000	0.2
1A2k	Construction	9.5	0.0002	0.0000	9.5
1A2l	Textile and Leather	1.0	0.0000	0.0000	1.0
1A2m	Non-specified Industry	2.5	0.0000	0.0000	2.5

Figure 4.8 provides GHG emissions from fuel combustion in *Manufacturing Industries and Construction* source category per sub-categories in 2017



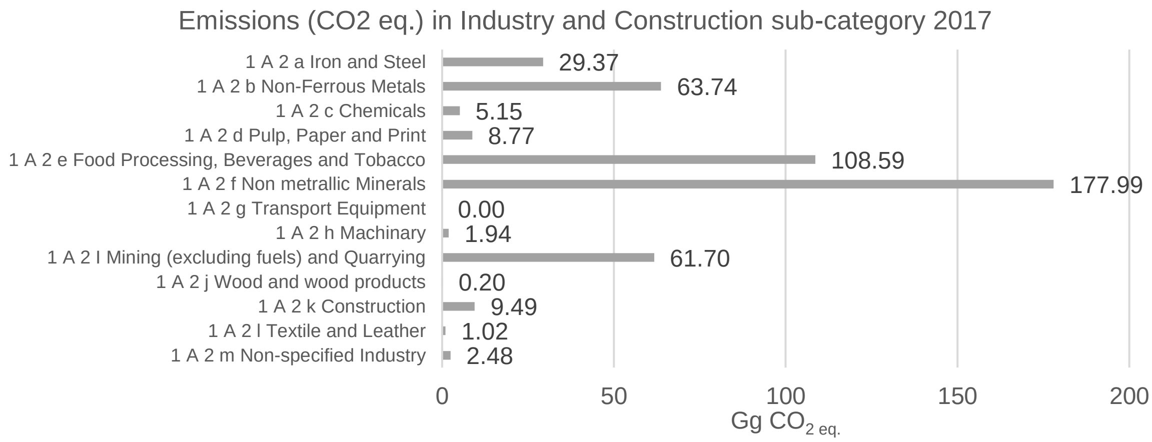


Figure 4.8. Emissions from Manufacturing Industries and Construction source category per sub-categories, 2017 (Gg CO_2 and Gg $CO_{2\ eq.}$)

Uncertainty assessment

The uncertainty of activity data on natural gas combusted is within 5% and for diesel fuel and LPG is 20% (expert judgement).

Emission factors uncertainty for natural gas is 3% and for diesel fuel and LPG 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

GHG emissions time series for *Manufacturing Industries and Construction* category are presented in Figure 4.9.

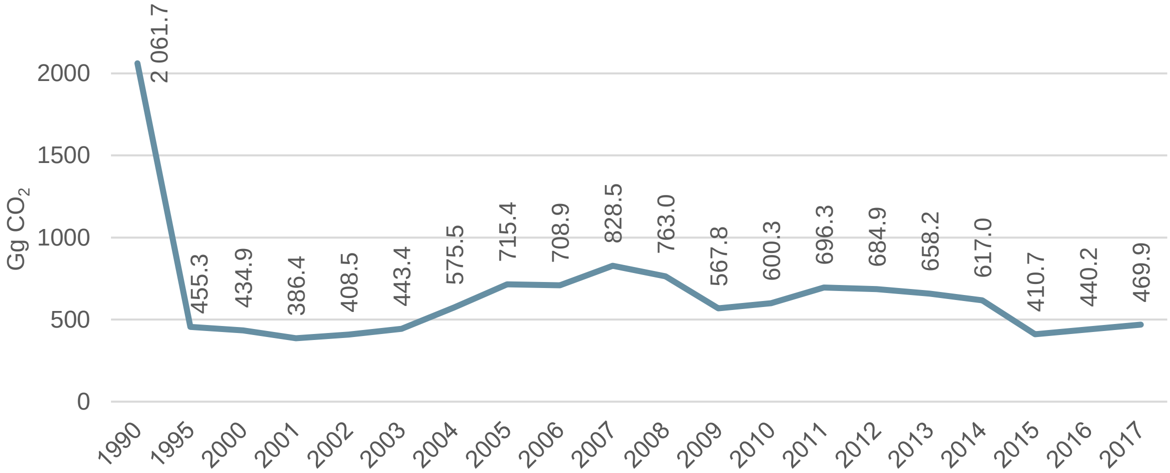


Figure 4.9 Manufacturing Industries and Construction CO_2 emissions time series from fuel combustion for 1990-2017, Gg CO_2

Figure 4.9 shows the emissions growth in 2000-2007 due to the GDP growth followed by decrease of CO_2 emissions because of the economic downturn and gradual recovery afterwards.

2017 emissions growth in comparison to 2016 is also driven by economic growth.

Mobile Combustion

4.1.4.1.3 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*.

The emissions from pipeline transport doesn't occur in Armenia, since there are no pumping stations for gas transportation.

Emissions estimated from *International Aviation* are not included in national total and are reported as memo item. Emissions form international marine bunker do not occur in Armenia since it is a landlocked country.

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

4.1.4.1.3.1 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). The use of lubricants as an additive in 2-stroke engines is negligible.

In Armenia fuel consumption structure in the road transport is quite specific, considering the absolute predominance of natural gas which accounted for above 62% of the total fuel consumption in the road transport in 2017. Currently there is a significant increase of the gas-filling stations number which has reached 379 operating units.

Road Transportation is responsible for the prevailing part of the emissions in *Transport* category - more than 98% in 2017.

In 2017, the greenhouse gas emissions from road transportation amounted to 1,758.1 Gg $CO_{2\ eq}$.

For Key Categories Analysis the emissions from the road transport were separated by type of fuel consumed (gaseous and liquid fuel) and both categories were identified as the key ones (CO_2 emissions) in terms of both level and trend assessment.

The emissions from *Road Transportation* have grown continuously since 2000: during the period 2000–2017 (with the exception of 2009 when the recession also resulted in lower CO_2 emissions from road transport) road transport emissions increased by about 150% due to the growth in traffic volume (the latter being driven by a rise in living standards).

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 liquid fuel imported into the country 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 2.1), and country-specific emission factors for natural gas mixture (weighted average) (Annex 2.5).

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.

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 only 3.6% of CO_2 equivalent emissions from the road transportation sector in 2017.

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

Activity data

The amounts of natural gas consumed were taken from Gas Balances provided by Gazprom Armenia (Annex 2.1), the amounts of consumed gasoline, diesel and LPG were provided by SC (Annex 2.2).

All fuel consumed were converted to common energy units (TJ) applying for natural gas NCVs of natural gas mixture provided by Gazprom Armenia (Annex 2.5) 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 (Annex 2.5) calculated for natural gas mixture (weighted average) were applied for estimating emissions from CNG combustion (Annex 2.6) while for gasoline, diesel and LPG default values provided by 2006 IPCC Guideline were applied [Gen-1, Volume 2, Table 1.2].

4.1.4.1.3.2 Off-road (1A3eii)

Description of the category

The sub-category includes combustion emissions from off-road activities not otherwise reported under 1A4c *Agriculture* or 1A2 *Manufacturing Industries and Construction*. All fuel consumed in this category is diesel.

Methodology

CO_2 emissions from combustion of diesel were assessed applying Tier 1 approach.

Activity data

The quantities of diesel consumed were estimated at 10% of the diesel fuel consumed in *Transport* category.

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 2017 are summarized in Table 4.10.

Table 4.10 Greenhouse gas emissions from *Transport* category, 2017, Gg

Code	Category/sub-category	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A3	**Transport**	1,723.7	1.8098	0.0873	1,788.8
1A3a	Civil Aviation, *Memo Item*[7]	*168.7*	*0.0012*	*0.0048*	*170.2*
1A3ai	International Aviation (International Bunkers), *Memo Item*	*168.7*	*0.0012*	*0.0048*	*170.2*
1A3b	Road Transportation	1,693.6	1.8083	0.0857	1,758.1
1A3eii	Off-road	30.1	0.0016	0.0016	30.6

[7] 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.

Uncertainty assessment

CO_2, N_2O and CH_4 contribute typically around 96.3, 2.2 and 1.5 percent of $CO_{2\ eq.}$ emissions from the *Road Transportation* sub-category, respectively [Gen-1, Volume 2, Chapter 3.2.2]. Therefore, although uncertainties in N_2O and CH_4 estimates are too high, their impact on total GHG inventory uncertainty is negligible.

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, LPG and diesel fuel – 20%.

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

Assessment of uncertainties was made using the Approach 1 - the propagation of error.

Consistent time series

CO_2 emissions time series for 1990-2017 for *Transport* category are presented in Figure 4.10.

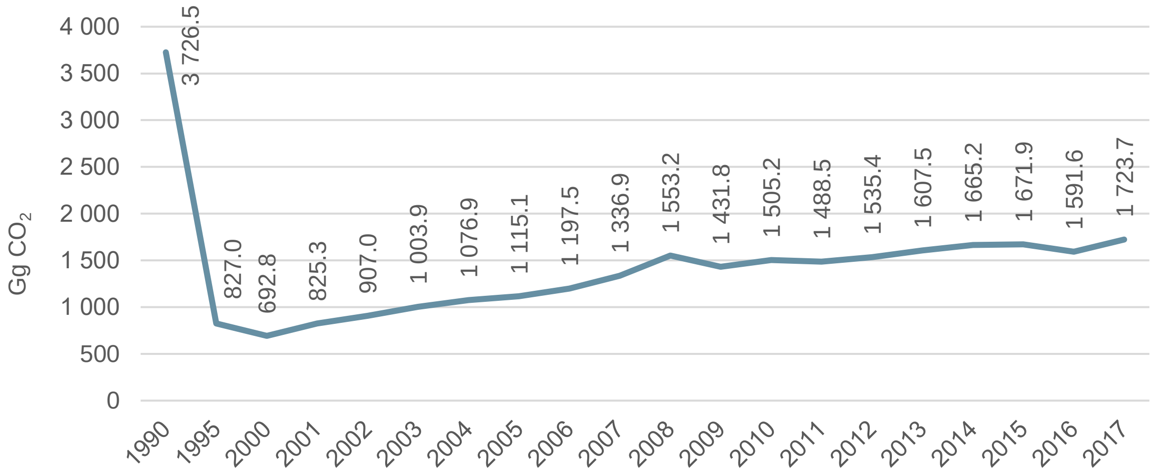


Figure 4.10 CO_2 emissions time series for *Transport* category, 1990-2017, Gg

Figure 4.10 shows that the *Transport* category emissions have grown continuously since 2000 with the exception of 2009, when the recession also resulted in lower CO_2 emissions from transport and some decline in 2016: during 2000–2017 transport emissions increased by about 150% due to the growth in traffic volume.

4.1.4.1.4 Other Sectors (1A4)

This category includes *Commercial/Institutional, Residential, Off-road Vehicles* and *Other Machinery in Agriculture* sub-categories.

The source categories *Commercial/Institutional* and *Residential* are the key categories (gaseous fuel, CO_2 emissions) in terms of both level and trend assessment.

Other sectors sub-category is the key (liquid fuel, CO_2 emissions) in terms of level and trend assessment.

4.1.4.1.4.1 Commercial/Institutional (1A4a)

Description of the sub-category

This sub-category comprises emissions from fuel combustion for space heating and cooking activities in commercial and institutional buildings. Natural gas, LPG and coal 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 for natural gas mixture (Annex 2.5) and data on natural gas consumption (Annex 2.1).

CO_2 emissions from combustion of LPG and coal were calculated applying Tier 1 method.

Activity data

The volumes of natural gas provided by "Gazprom Armenia" CJSC (Annex 2.1) and the volumes of LPG and coal provided by SC (Annex 2.2) were converted to common energy units (TJ) applying for natural gas NCV of natural gas mixture (weighted average) provided by Gazprom Armenia (Annex 2.5) and for LPG and Coal default values provided by 2006 IPCC Guideline [Gen-1, Volume 2, Table 1.2].

Emission factors

Country-specific emission factors for natural gas mixture (weighted average) (Annex 2.5 and Annex 2.6) 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 and Coal combustion [Gen-1, Volume 2, Table 1.4].

4.1.4.1.4.2 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 Cadastre Committee, the total area of the housing stock of the Republic of Armenia in 2017 made up 94.9 million m^2, including 53.7 million m^2 in urban communities (56.6%) and 41.2 million m^2 (43.4%) 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		
19,195	443,023	28,280,813	396,948	66,305,298	273,507	31.9

The total space of the multi apartment buildings makes about 30% of the total space of the housing stock. About 70% of the multi-apartment buildings are made of stone.

The following fuel types are used by households in Armenia: natural gas, diesel, LPG, coal, fuelwood and manure. Natural gas is the main fuel consumed by households, making up to 85.8% of the total fuel consumed, followed by biofuel – 14.1%. Apparently, the consumption of the biomass (manure, fuelwood and other biomass) 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 2.5) and data on natural gas consumption (Annex 2.1).

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

CH_4 and N_2O emissions from manure burned were included in GHG Inventory.

Activity data

The activity data for natural gas consumption were taken from the natural Gas Balances provided by Gazprom Armenia (Annex 2.1). The activity data for other fuel consumption were provided by SC (Annex 2.2).

Data on natural gas consumption were converted to energy units by applying NCV for gas mixture (weighted average) (Annex 2.5), other fuels were converted applying default values provided by 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.2].

Emission factors

Country-specific emission factors for natural gas mixture (Annex 2.5) were applied for CO_2 emissions estimate from natural gas combustion, default values provided by 2006 IPCC Guidelines were applied for estimating emissions from other fuel combustion [Gen-1, Volume 2, Table 1.4].

Emissions from biomass

The greenhouse gas emissions from combustion of biofuels in Residential sector are calculated from manure, fuelwood, other solid biomass and charcoal.

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, while methane (CH_4) and nitrogen oxide (N_2O) are included in the National GHG Inventory.

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 4.12 summarizes the quantities of consumed fuelwood, manure, other solid biomass and charcoal in energy units and CO_2, CH_4 and N_2O emissions from biofuel burning for 2015-2017.

Table 4.12 Biomass consumption and greenhouse gas emissions from biomass burning in 2015-2017, Gg

Year	2015	2016	2017
Biomass Consumption, TJ			
Fuelwood	665.6	610.4	719.0
Manure	3,047.0	2,987.3	2,588.2
Solid biomass	292.0	247.2	335.7
Charcoal	1.0	1.3	2.4
Total	**4,005.6**	**3,846.1**	**3,645.4**
CO_2 emissions from biofuel (memo item), Gg			
Fuelwood	74.54	68.36	80.52
Manure	304.70	298.73	258.82
Solid biomass	29.20	24.72	33.57
Charcoal	0.11	0.14	0.27
Total	**408.55**	**391.95**	**373.18**
CH_4 emissions from biofuel, Gg			
Fuelwood	0.1997	0.1831	0.2157
Manure	0.9141	0.8962	0.7765
Solid biomass	0.0876	0.0742	0.1007
Charcoal	0.0003	0.0004	0.0005
Total	**1.2017**	**1.1539**	**1.0934**
N_2O emissions from biofuel, Gg			
Fuelwood	0.002662	0.002441	0.002876
Manure	0.012188	0.011949	0.010353
Solid biomass	0.001168	0.000989	0.001342
Charcoal	0.000004	0.000005	0.000002
Total	**0.016023**	**0.015385**	**0.014574**

Figure 4.11 provides CO_2 emissions time series from biomass burning, Gg CO_2

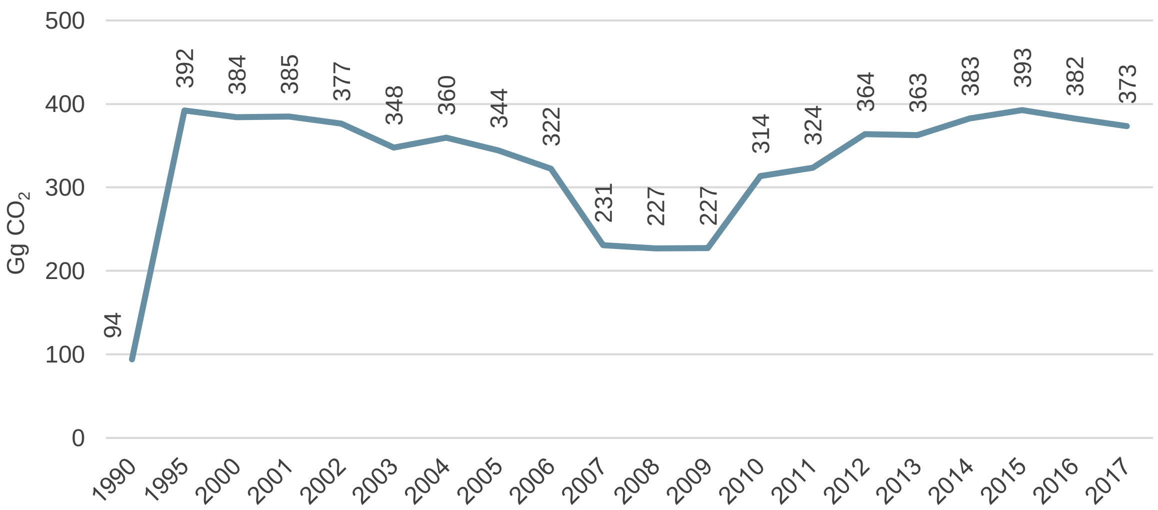


Figure 4.11 CO_2 emissions from biomass burning, 1990-2017, Gg CO_2

4.1.4.1.4.3 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 is used as fuel in this sub-category.

Methodology

CO_2 emissions from combustion of diesel were calculated applying Tier 1 Approach using the quantities of fuel consumed (Annex 2.2) and default emission factors from 2006 IPCC Guidelines [Gen-1, Volume 2, Table 2.3.1.1].

Activity data

The data on the volume of diesel fuel was provided by SC, which was estimated based on the amount of fuel required for agricultural work (Annex 2.2).

The volume of diesel fuel was converted to energy units, using the 2006 IPCC Guidelines' default factors [Gen-1, Volume 2, Table 1.2].

Emission factors

Default emission factors of 2006 IPCC Guidelines were used for assessing GHG emissions from diesel fuel combustion [Gen-1, Volume 2, Table 1.4].

Emissions estimate for (1A4) Other Sectors category

Table 4.13 summarizes the results of greenhouse gas emissions estimate for *Other Sectors* category for 2017.

Table 4.13 Greenhouse gas emissions from *Other Sectors* category, Gg, 2017

Code	Category/Subcategory	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A4	**Other Sectors**	1,869.81	1.2633	0.0183	1,902.00
1A4a	Commercial/Institutional	537.24	0.0473	0.0010	538.54
1A4b	Residential	1,268.54	1.2074	0.0168	1,299.11
1A4c	Agriculture/ Forestry/Fishing	64.02	0.0086	0.0005	64.37
1A4cii	Off-road Vehicles and Other Machinery	64.02	0.0086	0.0005	64.37

Table 4.13 shows that the *Residential* sub-sector produces the largest share of *Other Sectors* emissions - over 68%.

According to 2006 IPCC Guidelines [Gen-1], 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.

Uncertainty assessment

Activity data uncertainty for natural gas is estimated 5%, for LPG and diesel fuel – 20% and for coal – 40%. Emission factors uncertainty for natural gas is estimated 3%, for LPG and diesel – up to 5% and for coal - 10%. Therefore, uncertainty for emissions estimate from CNG combustion could be regarded as 5.83%, from LPG and diesel fuel - 20.62% and from coal – 41.23%.

Estimation of combined uncertainties are implemented by Approach 1- error propagation method. Calculations and results are presented in Annex 1.3.

Consistent time series for (1A4) *Other Sectors* category

CO_2 emissions 1990-2017 time series for *Other Sectors* category are shown in Figure 4.12.

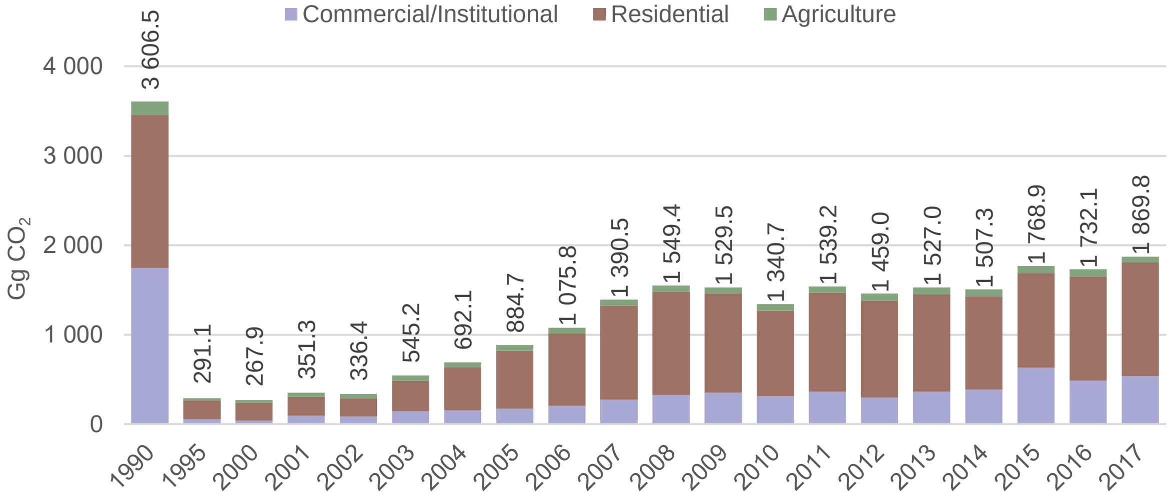


Figure 4.12 CO_2 emissions time series by sub-categories for *Other Sectors* category, Gg

Figure 4.12 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 widespread access to gas supply system (nearly 96%) 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.

Increases in emissions from households in 2017 was due to weather conditions: the average winter temperature in 2017 was quite low compared to previous years.

Emissions from *Commercial/ Institutional* sub-category have grown after 1995, although some variations in the emissions level observed.

Greenhouse gas emissions in the *Agriculture* sub-category show minor annual variations throughout 2000-2017.

Energy Sector CO_2 emissions time series from fuel combustion

Figure 4.13 and Table 4.14 provide Energy Sector CO_2 emissions time series from fuel combustion by sub-categories for 1990-2017.

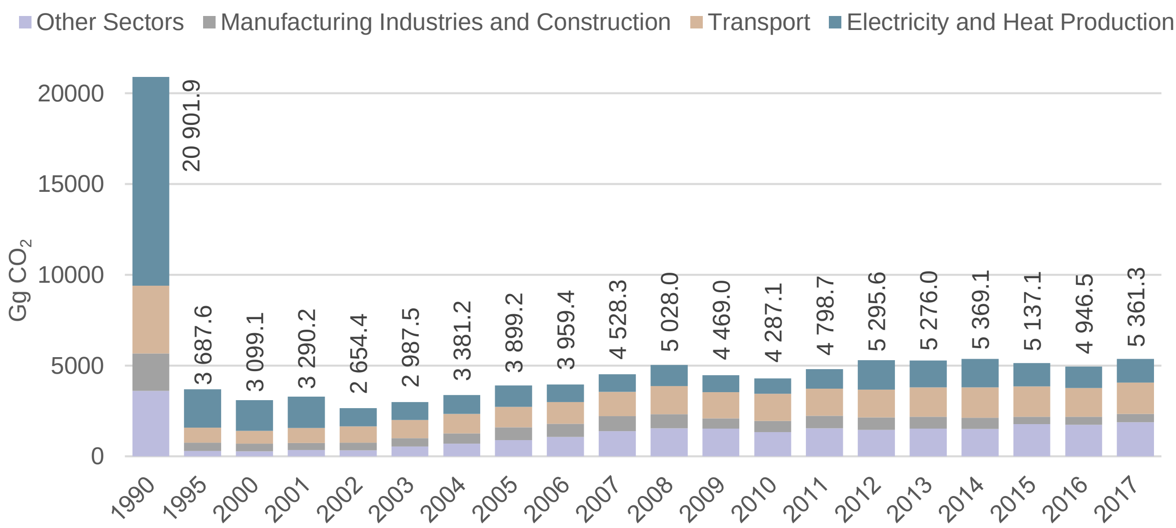


Figure 4.13 Energy Sector CO_2 emissions time series from fuel combustion by sub-categories, 1990-2017, Gg

Table 4.14 Energy Sector CO_2 emissions time series from fuel combustion by sub-categories, Gg

Subcategory / Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2106	2017
Total	**20,902**	**3,688**	**3,099**	**3,899**	**4,287**	**4,799**	**5,296**	**5,276**	**5,369**	**5,137**	**4,947**	**5,361**
Electricity and Heat Production	11,507	2,114	1,704	1,184	841	1,075	1,616	1,483	1,580	1,286	1,183	1,298
Manufacturing Industries and Construction	2,062	455	435	715	600	696	685	658	617	411	440	470
Transport	3,727	827	693	1,115	1,505	1,488	1,535	1,608	1,665	1,672	1,592	1,724
Other sectors:	3,606	291	268	885	1,341	1,539	1,459	1,527	1,507	1,769	1,732	1,870
Commercial/ Institutional	1,746	52	40	172	311	361	296	363	387	630	487	537
Residential	1,712	211	199	648	956	1,105	1,083	1,085	1,041	1,059	1,167	1,269
Agriculture	149	28	29	65	73	73	80	79	79	79	79	64
Memo Items												
International Aviation	409	90	91	112	136	125	128	145	128	96	137	169
Memo Items: Biomass	94	392	384	344	314	324	364	363	383	393	382	373

As it comes from Table 4.14 and Figure 4.13, the sharp increase in CO_2 emissions from Energy Sector was recorded in 2007-2008, which was due to the widespread access to the gas supply system in the country (about 96%) 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 2011, emissions increased again as a result of the economic recovery.

The Energy Sector emissions have varied considerably due to changes in electricity exports and production of natural gas fired condensing power plants. Thus, the sharp increase of GHG emissions from Energy Sector in 2012 in comparison with those in 2010 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). 2014 CO_2 emissions exceed those of 2012, but declined again in 2015 and 2016.

CO_2 emissions increase in 2017 was caused by the economic situation in the country, the weather conditions and the volume of exported electricity produced by TPPs.

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 results of Reference Approach. Energy balance served as a basis for the Reference approach.

The results of Sectoral Approach estimate per type of fuel are summarized in the Table 4.15.

Table 4.15 CO_2 emissions from fuel combustion estimated using the Sectoral Approach, Gg CO_2

Types of Fuel			Actual emissions, Gg CO_2						
		Year	2011	2012	2013	2014	2015	2016	2017
Liquid fossil	Secondary fuel	Gasoline	418.8	400.7	405.9	396.4	400.3	431.5	436.6
		Jet kerosene*	124.9	127.6	144.7	127.6	95.9	136.6	168.7
		Diesel fuel	489.7	460.7	447.0	462.1	410.6	403.6	428.6
		LPG	21.9	20.4	22.1	20.2	20.6	12.1	18.3
Total liquid fossil			**930.4**	**881.8**	**875.0**	**878.7**	**831.5**	**847.2**	**883.5**
Solid fossil		Other bitumen coal	10.2	9.5	3.8	3.1	2.5	4.6	3.9
Total solid fossil			**10.2**	**9.5**	**3.8**	**3.1**	**2.5**	**4.6**	**3.9**
Gaseous fossil		Natural Gas	3,858.1	4,405.2	4,397.2	4,487.4	4,303.1	4,094.7	4,473.9
Total Gaseous fossil			**3,858.1**	**4,405.2**	**4,397.2**	**4,487.4**	**4,303.1**	**4,094.7**	**4,473.9**
Total			**4,798.8**	**5,296.5**	**5,276.0**	**5,369.1**	**5,137.2**	**4,946.5**	**5,361.3**

**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 (Energy balance) and has no detailed information on how the individual fuels are used in each sector [Gen-1, Volume 2, Chapter 6].

Table 4.16 and Figure 4.14 present comparison of CO_2 emissions estimated using Reference and Sectoral Approaches. As it can be seen, the differences within the period considered are not significant and amount 4.1%, 3.5%, 4.4%, 4.3%, 4.8%, 5.1%, 4.8%, for the years 2011-2017, respectively.

Table 4.16 Comparison of CO_2 emissions estimated using Reference and Sectoral Approaches, Gg CO_2

Fuel Combustion Activity (1A)	2011	2012	2013	2014	2015	2016	2017
Sectoral Approach, Gg	4,798.8	5,296.5	5,276.0	5,369.1	5,137.2	4,946.5	5,361.3
Reference Approach, Gg	4,996.4	5,481.7	5,508.9	5,598.2	5,381.6	5,199.6	5,616.0

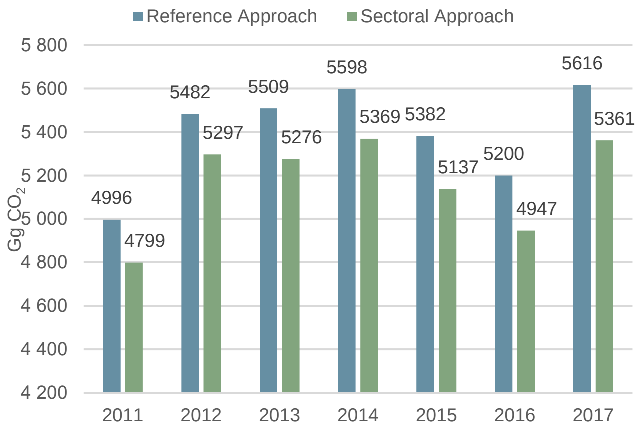


Figure 4.14 Comparison of CO_2 emissions estimated using Reference and Sectoral Approaches

Table 4.16 and Figure 4.14 show that emission values derived applying Reference Approach are higher versus those derived from Sectoral Approach, which is justified given that according to Guidelines [Gen-1, Volume 2, Chapter 6] the natural gas losses which are sources of fugitive emissions are included in Apparent Consumption in Reference Approach estimate.

4.1.4.2 Fugitive emissions from fuels (1B2b)

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 1,682.2 km. The gas transmission system includes 110 gas distribution stations and 21 measuring units.

In recent years there was an unprecedented expansion of the natural gas distribution system. Currently access to the gas supply system in the country is nearly 96%.

The gas distribution system operates 15,335 km long high-, medium- and low-pressure pipelines. For operation of the gas distribution system there are 2,610 gas control points, 7,279 individual gas regulating units and 1,429 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, Volume 2] 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 (CH_4 emissions) in terms of level and trend assessment.

In Armenia, methane fugitive emissions mainly occur during the operation of natural gas systems (emergency leaks, leaks from operating regulations, technological losses).

Methodology

Fugitive emissions from natural gas were assessed applying Tier 2 Approach [Gen-1, Volume 2, Chapter 4].

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, which was developed in the frames of Armenia’s First Biennial Update Report (Ref-3).

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 2.1).

Emission factors

Country-specific emission factors were calculated for CH_4 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 2.6).

For CO_2 the default value from 2006 IPCC Guidelines has been used [Gen-1, Volume 2, Chapter 4, Table 4.2.5].

Emissions estimates

Given that fugitive emissions from natural gas is the key source category in this Report they were assessed applying Tier 2 Approach provided in 2006 IPCC Guidelines [Gen -1].

Country-specific emission factors developed for fugitive emissions from natural gas transportation (including storage) and distribution systems (see Table 4.17) were discussed and agreed with “Gazprom Armenia” CJSC.

Calculation of country-specific emission factors and volumes of marketable gas and utility sales delivered via transmission and distribution system was made by using official data from Annual Balances provided by “Gazprom Armenia” CJSC [EnRef-1, Annex 2.1] and based on natural gas annual average characteristics (gas composition, density, Net Calorific Value) in gas transmission and distribution systems (Annex 2.6).

Calculation of country-specific emission factors for fugitive emissions in gas transmission system- F_{trans}

$F_{trans} = [(P-T)-k_{trans}*T] *\rho_{trans}* CH_{4tr} / T$ (Gg/mln.m^3)

Where:

P(Produced Gas) = Quantity of imported gas (18) + quantity of gas taken from Gas Underground Storage Facility (2) (million m^3)

T(Transmission marketable gas) = Quantity of transmitted gas (6) + quantity of gas injected in Gas Underground Storage Facility (5) + quantity of gas used for own needs (3) (mln m^3)

k_{trans} = 0.011 Factor conditioned by transmission system metering devices errors

ρ_{trans} (Density) = Gas density in transmission system (Gg/mln m^3)

CH_{4tr} (Content) = Methane content in transmitted gas

Calculation of country-specific emission factors for fugitive emissions in gas distribution system - F_{dist}

$F_{dist} = [(T_{trans}-T_{sales} -D)-k_{dist}*D_{sales}] *\rho_{dist}* CH_{4dis} / D_{sales}$ (Gg/mln m^3)

Where:

T_{trans} = Quantity of transmitted gas (6) (mln m^3)

T_{sales} = Gas sales in transmission system (6.1) (mln m^3)

D (Distribution marketable gas) = Gas sales in distribution system (10) + Gas consumed for own needs in distribution system (7) + recovered gas (8) (mln m^3)

k_{dist} =0.003 = Factor conditioned by distribution system metering devices errors

Dsales (Distribution utility sales) = Gas sales in distribution system (10) (mln m^3)

ρ_{dist} (Density) = Gas average density in distribution system (Gg/mln m^3)

CH_{4dis} (Content) = Methane content in distributed gas

Table 4.17 provides country-specific emission factors, activity data and methane fugitive emissions estimates for 2011-2017.

Table 4.17 Country-specific emission factors, activity data and fugitive emissions estimates for methane in 2011-2017

Year	Gas Supply System	Country-specific emission factors	Activity data	Methane fugitive emissions	
		Gg/mln m^3	mln m^3	Gg	
2011	Transmission network	0.0230950	2,054.95	47.46	**71.43**
	Distribution network	0.0156172	1,534.92	23.97	
2012	Transmission network	0.0198961	2,443.00	48.61	**71.71**
	Distribution network	0.0143617	1,608.90	23.11	
2013	Transmission network	0.0210598	2,320.61	48.87	**73.96**
	Distribution network	0.0137726	1,821.93	25.09	
2014	Transmission network	0.0210862	2,394.60	50.49	**74.97**
	Distribution network	0.0121832	2,008.90	24.47	
2015	Transmission network	0.0221299	2,285.90	50.59	**72.25**
	Distribution network	0.0119016	1,820.10	21.66	
2016	Transmission network	0.0239219	2,184.20	52.25	**75.27**
	Distribution network	0.0124810	1,844.10	23.02	
2017	Transmission network	0.0236837	2,327.70	55.13	**77.47**
	Distribution network	0.0115081	1,941.40	22.34	

Fugitive Emissions from Natural Gas (1B2b) per greenhouse gases are summarized in Table 4.18.

[8] The brackets indicate respective row in gas supply balance sheet

Table 4.18 Fugitive Emissions from Natural Gas in 2017, Gg

Code	Category/Subcategory	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1B2b	**Fugitive Emissions from Natural Gas**	0.1887	77.4703	NA	1,627.07
1B2biii4	Transmission and Storage	0.0033	55.1285	NA	1,157.70
1B2biii5	Distribution	0.1854	22.3418	NA	469.36

Uncertainty assessment

Natural gas composition considered to be accurate within ±5% on individual components and flow rates have errors of ±5% for transmission and storage and distribution.

Combined uncertainty for *Transmission/Storage and Distribution* sub-category is considered to be accurate within ±7.07% (Annex 1.3)

Time series

Methane fugitive emissions time series for 1990-2017 are presented in Figure 4.15.

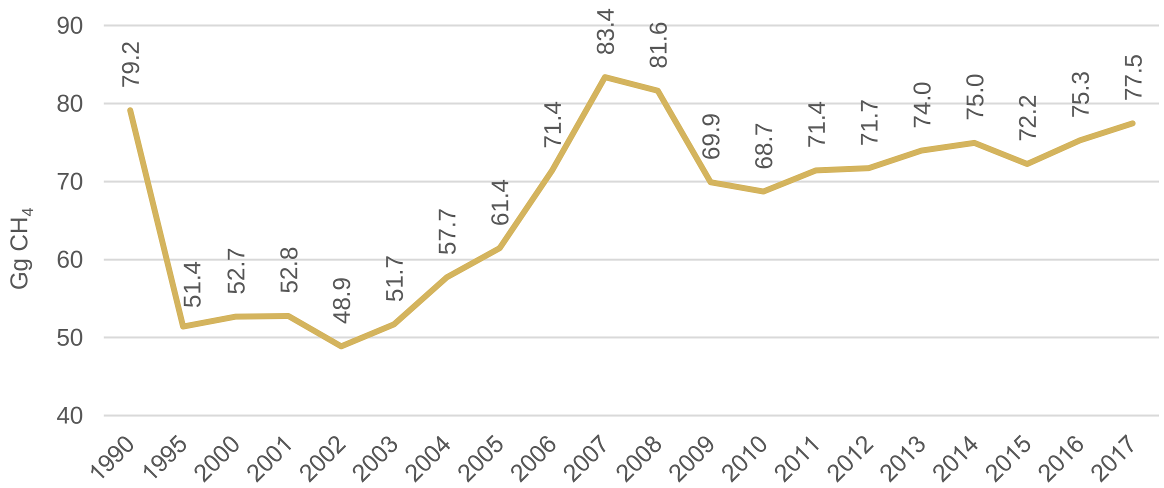


Figure 4.15 Methane fugitive emissions time series, 1990-2017, Gg CH_4

Figure 4.15 shows that methane emissions have grown continuously since 2000, due to the natural gas distribution network's gradual expansion. The biggest methane emissions were recorded in 2007-2008 because of the unprecedented level of natural gas deliverability reached in the country. 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.

4.1.5 Summary of greenhouse gas emissions from Energy Sector by sub-categories and gases

The greenhouse gas emissions from Energy Sector by sub-categories and gases for 2017 are summarized in Table 4.19.

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

Subcategory/ Greenhouse gas (Gg)	2017
CO_2	**5,361.50**
Main Activity Electricity and Heat Production	1,297.95
Manufacturing Industries/Construction	469.86
Transport	1,723.69
Other Sectors	1,869.81
Fugitive emissions from natural gas	0.1887
CH_4	**80.5760**
Main Activity Electricity and Heat Production	0.0228
Manufacturing Industries/Construction	0.0097
Transport	1.8098
Other Sectors	1.2633
Fugitive emissions from natural gas	77.4704
N_2O	**0.1091**
Main Activity Electricity and Heat Production	0.0023
Manufacturing Industries/Construction	0.0012
Transport	0.0873
Other Sectors	0.0183
Fugitive emissions from natural gas	NA

(1A3ai) Emissions from International Bunkers (memo)

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 2011-2017 provided by SC (Annex 2.2), by applying Tier 1 method.

The volumes of fuel were converted to common energy units (TJ) applying default values provided by 2006 IPCC Guideline for jet kerosene [Gen-1, Volume 2, Table 1.2].

Default values provided by 2006 IPCC Guidelines for jet fuel [Gen-1, Volume 2, Table 1.4] were applied for emissions estimate.

Table 4.20 provides the consumed fuel and emissions from international aviation by gases.

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

Years	2011	2012	2013	2014	2015	2016	2017
Consumption, (TJ)	1,748.48	1,784.86	2,024.21	1,784.21	1,370.07	1,951.64	2,409.66
Emissions, (Gg)							
CO_2	125.0	127.6	144.7	127.57	95.90	136.61	168.68
CH_4	0.001	0.001	0.0010	0.0009	0.0007	0.0010	0.0012
N_2O	0.0035	0.0036	0.0040	0.0036	0.0027	0.0039	0.0048
$CO_{2\ eq.}$	**126.11**	**128.74**	**146.01**	**128.70**	**96.77**	**137.85**	**170.20**

CO_2 emissions (Gg CO_2) from *International Bunkers* in 1990-2017 are presented in Figure 4.16.

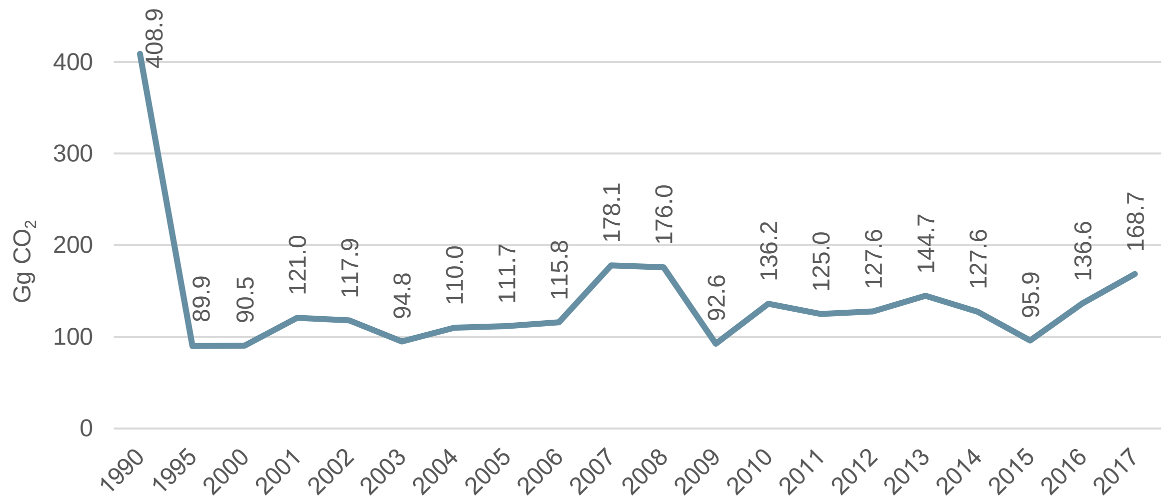


Figure 4.16 CO_2 emissions (Gg CO_2) from *International Bunkers* in 1990-2017, Gg CO_2

Completeness of activity data

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

Since 2015 Energy balances are officially published, being the main sources of activity data for the Energy Sector. The GHG National Inventory team works closely with energy balances' compiling experts to ensure accuracy and consistency of data.

However, the data on liquid fuel consumption by categories, in particular on diesel fuel, provided by the SC are based on expert estimates and have a rather high uncertainty.

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, in particular this refers to data on fuelwood consumption provided by the official statistics and derived from Household survey.

In order to improve the completeness and reliability of the activity data, the National GHG Inventory team members work closely with the SC experts.

Data accessibility and quality assurance

To ensure accuracy and consistency of activity data, they are collected from different available sources and cross-checked whenever possible.

The required activity data on electricity and natural gas are available on the PSRC website or can be obtained from Settlement Centre, “Gazprom Armenia” CJSC, Energy balances and the SC.

Quality assurance of activity data includes check for consistency in data between source categories (activity data, constants that are common to multiple source categories), for example: for the purpose of assessing the emissions from fuelwood these data are checked with those applied, while assessing carbon losses in forest lands as a result from fuelwood removals.

4.1.6 Summary of GHG emissions in Energy Sector

The summary of emissions from Energy Sector for 2017 are given in Table 4.21, whereas Table 4.22 and Figure 4.17 show the complete time series for Energy Sector. Emissions of precursors are given in Table 2.2.

Table 4.21 Energy Sectoral Table, 2017

Sectors/Categories	Emissions (Gg)			
	Net CO_2	CH_4	N_2O	Total CO_2 eq.
1 - ENERGY SECTOR	**5,361.50**	**80.5761**	**0.1091**	**7,087.43**
1A - FUEL COMBUSTION ACTIVITIES	**5,361.31**	**3.1057**	**0.1091**	**5,460.37**
1A1 - ENERGY INDUSTRIES	**1,297.95**	**0.0228**	**0.0023**	**1,299.14**
1A.1.a - Electricity and heat production	1,297.95	0.0228	0.0023	1,299.14
1A.1.a.i - Electricity generation	651.21	0.0115	0.0011	651.80
1A.1.a.ii - Combined heat and power generation	646.74	0.0114	0.0011	647.33
1A.2 - MANUFACTURING INDUSTRIES AND CONSTRUCTION	**469.86**	**0.0097**	**0.0012**	**470.44**
1A.2.a - Iron and steel	29.34	0.0005	0.0001	29.37
1A.2.b - Non-ferrous metals	63.65	0.0014	0.0002	63.74
1A.2.c - Chemicals	5.14	0.0001	0.0000	5.15
1A.2.d - Pulp, paper and print	8.76	0.0002	0.0000	8.77
1A.2.e - Food processing, beverages and tobacco	108.49	0.0019	0.0002	108.59
1A.2.f - Non-metallic minerals	177.83	0.0032	0.0003	177.99
1A.2.h - Machinery	1.94	0.0000	0.0000	1.94
1A.2.i - Mining (excluding fuels) and quarrying	61.53	0.0021	0.0004	61.53
1A.2.j - Wood and wood products	0.20	0.0000	0.0000	0.20
1A.2.k - Construction	9.48	0.0002	0.0000	9.48
1A.2.l - Textile and leather	1.02	0.0000	0.0000	1.02
1A.2.m - Non-specified industry	2.47	0.0000	0.0000	2.47
1A.3 - TRANSPORT	**1,723.69**	**1.8099**	**0.0873**	**1,788.76**
1.A.3.a - Civil Aviation:	168.68	0.0012	0.0048	170.20
1.A.3.ai - International aviation: *(memo item)*	168.68	0.0012	0.0048	170.20
1.A.3.b - Road transportation	1,693.59	1.8083	0.0857	1,758.14
1.A.3.e - Other transportation	30.10	0.0016	0.0016	30.63
1.A.3.e.ii - Off-road	30.10	0.0016	0.0016	30.63
1.A.4 - OTHER SECTORS	**1,869.81**	**1.2633**	**0.0183**	**1,902.02**
1.A.4.a - Commercial/institutional	537.24	0.0473	0.0010	538.54
1.A.4.b – Residential	1,268.54	1.2074	0.0168	1,299.11
1.A.4.c - Agriculture/forestry/fishing/fish farms	64.02	0.0086	0.0005	64.37
1.A.4.c.ii - Off-road vehicles and other machinery	64.02	0.0086	0.0005	64.37
1.B - FUGITIVE EMISSIOSN FROM FUELS	**0.1888**	**77.4704**	**NA**	**1,627.07**
1.B.2.b - Natural gas	0.1888	77.4704	NA	1,627.07
1.B.2.b.iii.4 - Transmission and storage	0.0034	55.1285	NA	1,157.70
1.B.2.b.iii.5 - Distribution	0.1854	22.3418	NA	469.36

Note: Emissions from all sub-categories not shown in this table are not occurring in Armenia

	Emissions (Gg)		
Categories	**CO_2**	**CH_4**	**N_2O**
Memo Items (3)			
International Bunkers	168.676	0.0012	0.005
1.A.3.a.i - International Aviation (International Bunkers) (1)	168.676	0.0012	0.005
Information Items			
CO_2 from Biomass Combustion for Energy Production	373.193		

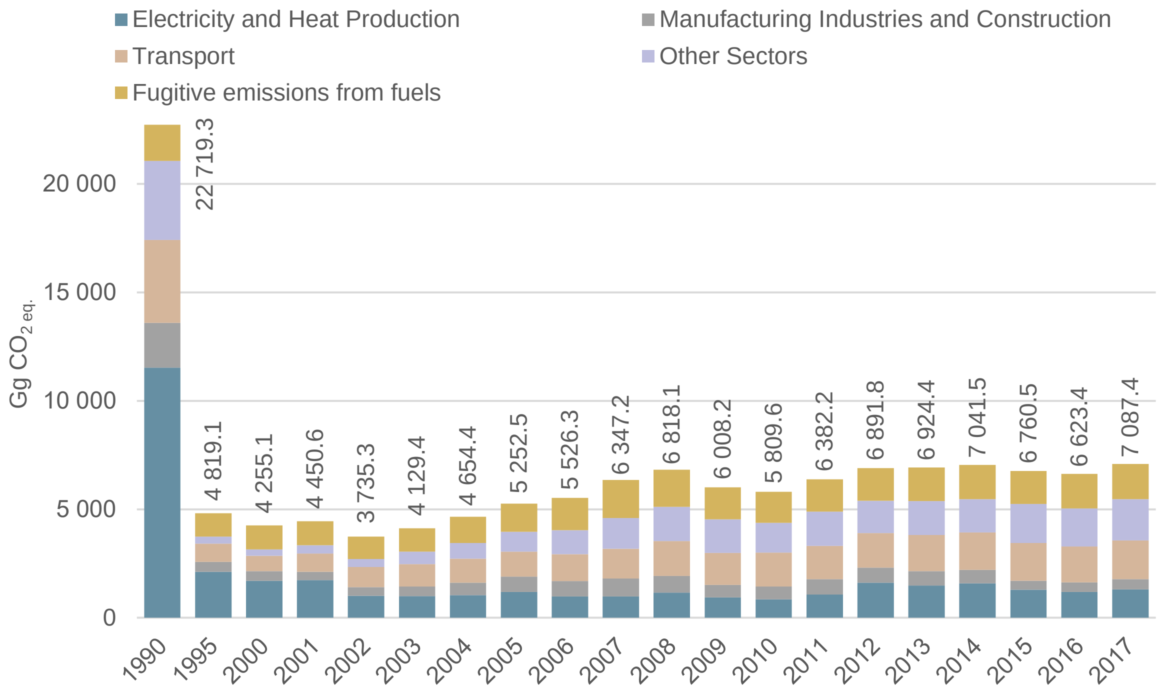


Figure 4.17 Energy Sector emissions time series, 1990-2017, Gg $CO_{2\ eq.}$

Table 4.22 Time series of GHG emissions from Energy Sector, Gg $CO_{2\ eq.}$

Subcategory / Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2106	2017
Total	**22,719**	**4,819**	**4,255**	**5,253**	**5,810**	**6,382**	**6,892**	**6,924**	**7,042**	**6,761**	**6,623**	**7,087**
Electricity and Heat Production	11,535	2,117	1,705	1,185	842	1,076	1,618	1,485	1,581	1,287	1,184	1,299
Manufacturing Industries and Construction	2,065	456	435	716	601	697	686	659	618	411	441	470
Transport	3,810	847	710	1,148	1,556	1,541	1,591	1,668	1,728	1,742	1,653	1,789
Other sectors:	3,647	319	298	913	1,368	1,568	1,491	1,560	1,540	1,803	1,765	1,902
Commercial/ Institutional	1,752	53	40	173	313	362	297	364	388	632	488	539
Residential	1,745	239	228	676	982	1,133	1,113	1,116	1,072	1,091	1,198	1,299
Agriculture	149	28	29	65	74	73	81	80	80	80	79	64
Fugitive emissions from fuel	1,662	1,079	1,107	1,290	1,443	1,500	1,506	1,553	1,575	1,517	1,581	1,627
Memo Items												
International Aviation	413	91	91	113	137	126	129	146	129	97	138	170
Memo Items: Biomass	94	392	384	344	314	324	364	363	383	393	382	373

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 Mineral Industry - cement, lime and glass production, CO_2 emissions generated from lubricant and paraffin use, emissions of F-gases (HFCs) from refrigeration, air conditioning and other product use, as well as emissions of SF_6 from use of electrical equipment.

Emissions from this sector include SO_2 emissions from metal industry, NMVOC emissions from solvent use, asphalt production and Food and Beverage industry as well.

Emissions from the IPPU Sector amounted to 950.5 Gg $CO_{2\ eq.}$ in 2017, making up approximately 8.9% of Armenia's total greenhouse gas emissions.

The prevailing part of CO_2 emissions were generated in Mineral Industry - 258.3 Gg CO_2, while CO_2 emissions generated from lubricant use and paraffin use were much smaller - 4.24 Gg CO_2. The most significant CO_2 emissions' source was emissions generated in the production of cement, which accounted for 23.6% of the emissions from the sector and 2.1% of Armenia's total emissions.

Fluorinated greenhouse gases or F-gases form a category of their own under IPPU Sector.

F-gases emissions made 687.9 Gg $CO_{2\ eq.}$ with prevailing share - 685.3 Gg $CO_{2\ eq}$. from Product Uses as Substitutes for Ozone Depleting Substances, while SF_6 emissions from use of electrical equipment were negligible - only 2.6 Gg $CO_{2\ eq}$.

Emissions of HFCs from Product Uses as Substitutes for Ozone Depleting Substances accounted for over 6.5% of total national greenhouse gas emissions and nearly 72% of the greenhouse gas emissions of IPPU Sector in 2017. HFCs emissions, which are caused by refrigeration systems, predominate in the overall picture of HFCs emissions with the share of 95.4% in 2017. The share of emissions from other applications is about 4.6% 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
- (2A2) Lime production
- (2A3) Glass Production

(2C) Metal Industry (SO_2 emissions)

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

(2D) Non-energy Products from Fuels and Solvent Use (CO_2 and NMVOC)

- (2D1) Lubricant Use (CO2 emissions)
- (2D2) Paraffin Wax Use (CO2 emissions)
- (2D3) Solvents Use (NMVOC emissions)
- (2D4) Bitumen/Asphalt Production and Use (NMVOC emissions)

(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

(2G) Other Product Manufacture and Use (SF_6 emissions)

(2G1b) Use of Electrical Equipment

(2H) Other

(2H2) Food and Beverages Industry (NMVOC emissions)

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.

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

Within the frames of 2017 NIR the following improvements were made to the IPPU sector GHG Inventory:

GHG emissions were estimated for 4 new sub-categories:

- (2A2) Lime production (CO_2 emissions)
- (2D1) Lubricant Use (CO_2 emissions)
- (2D2) Paraffin Wax Use (CO_2 emissions)
- (2G1b) Use of Electrical Equipment (SF_6 emissions)

4.2.4 Key Categories

(2A1) Cement production is identified as the key source category (CO_2 emissions) with level assessment and *(2F1) Refrigeration and Air-conditioning* is identified as the key source category (HFCs emissions) with both level and trend assessments.

4.2.5 (2A1) Cement Production

In Armenia cement is produced by two plants: "Araratcement" CJSC and "Hrazdan Cement Corporation" LLC.

Methodology

Carbon dioxide emissions from cement production were calculated by applying Tier 3 approach [Gen-1, Volume 3, Chapter 2, Equation 2.3] 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 cement kiln dust (CKD) not returned to the kiln.

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

Activity data

The activity data required for Tier 3 method are available only at individual plant level.

Plant level data were requested by the Ministry of Environment in the format required for the assessment of emissions developed by the GHG Inventory expert team and have been received from 2 operating cement-producing plants - “Araratcement” CJSC and “Hrazdan Cement Corporation” LLC.

QC of the activity data have been done including technical review of the integrity, correctness and completeness of the data. The discrepancies were discussed with the manufacture’s representatives, subsequently clarified and used for the calculations.

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

Table 4.23 Annual production and quantity of main row materials of “Araratcement” CJSC, thousand t, 2017

Year	Annual production		Quantity of main raw materials	
	Cement	Clinker	Clay	Limestone
2017	270.576	220.114	114.936	429.501

Quantity of recycled dust: 64,945.7 t/year, Dust capturing system efficiency: 99.7%. Amount of uncalcined CKD not recycled to the kiln: 195.4 t

Table 4.24 The average composition of Calcium oxide in “Araratcement” CJSC primary raw material, %

Chemical component	Raw material	
	Clay	Lime
CaO	23.34	51.27

Table 4.25 Annual production and quantity of main row materials of “HrazdanCement Corporation” LLC, thousand t

Year	Annual production		Quantity of main raw materials		
	Cement	Clinker	Clay	Limestone	Slag
2017	59.621	50.475	8.090	81.454	2.063

Quantity of recycled dust: 7029 t/year. Dust capturing system efficiency: 98.1%. Amount of uncalcined CKD not recycled to the kiln: 136.0 ton.

Table 4.26 The average composition of Calcium oxide in “HrazdanCement Corporation” LLC primary raw material, %

Chemical component	Raw material		
	Clay	Iron-containing slag	Limestone
CaO	6.31	3.89	48.32

Calculation of carbon dioxide emissions from Cement Production

The Tier 3 Approach 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. Emissions are then calculated using Equation 2.3 [Gen-1, Volume 3, Chapter 2].

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)

Calculation of carbonate for “Hrazdan Cement Corporation” LLC in 2017:

Clay: 8,090 t; Content of calcium oxide: 6.31 %, or 8,090 x 0.0613 = 510.5 t

Limestone: 81,454 t; Content of calcium oxide: 48.32 % or 81,454 x 0.4832 = 39,358.6 t

Slag: 2,063 t; Content of calcium oxide: 3.89% or 2,063 x 0.0389 = 80.3 t

Total calcium oxide: 510.5 + 39,358.6 + 80.3 = 39,949.4 t/year

Total carbonate input: 39,949.4 t x 100/56 = 71,338.2 t/year

Calculation of carbonate for “Araratcement” CJSC in 2017:

Clay: 114,969 t; Content of calcium oxide: 23.34 %, or 114,969 x 0. 2334 = 25,833.8 t

Limestone: 429,501 t; Content of calcium oxide: 51.27 % or 429,501 x 0.5127 = 220,205.2 t

Total calcium oxide: 25,833.8 + 220,205.2 = 246,039 t/year

Total carbonate input: 246,039 t x 100/56 = 439,355.4 t/year

Total carbonate input for “Araratcement” and “Hrazdan Cement” are provided in Table 4.27.

Table 4.27 Total carbonate input for “Araratcement” and “HrazdanCement Corporation” plants, Gg

Year	“Araratcement” CJSC	“HrazdanCement Corporation” LLC
2017	439.355	71.338

Calculations of CO_2 emissions for “Hrazdancement” and “Araratcement” plants for 2017 are provided in Table 4.28 and Table 4.29, correspondingly.

Table 4.28 CO_2 emissions factors and calculation of CO_2 emissions for “Hrazdan Cement Corporation”, 2017

Indicators	Value
EFi (tCO_2/t carbonate)	0.4397
Mi (t)	71,338
Fi (degree)	1
M_d (t)	136
C_d (fraction)	1
F_d (fraction)	1
EF_d (t CO_2/t carbonate)	0.4397
M_K (t)	0
X_K (fraction)	0
EF_k (t $C0_2$/t carbonate)	0
CO_2 (t)	31,367.3

Table 4.29 CO_2 emissions factors and calculation of CO_2 emissions for “Araratcement”, 2017

Indicators	Value
EFi (tCO_2/t carbonate)	0.4397
Mi (t)	439,355
Fi (degree)	1
M_d (t)	195.4
C_d (fraction)	1
F_d (fraction)	1
EF_d (t CO_2/t carbonate)	0.4397
M_K (t)	0
X_K (fraction)	0
EF_k (t $C0_2$/t carbonate)	0
CO_2 (t)	193,184.4

Table 4.30 Carbon dioxide emissions from "Araratcement" and "Hrazdan Cement", Gg/year

Year	CO_2 emissions from cement production		
	"Araratcement"	"Hrazdan Cement Corporation"	Total
2017	193.184	31.367	224.551

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

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 small 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 uncertainties associated with cement production are provided below (expert judgement) [Gen-1, Volume3, Table 2.3].

Table 4.31 Uncertainty assessment

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[9]

Time Series

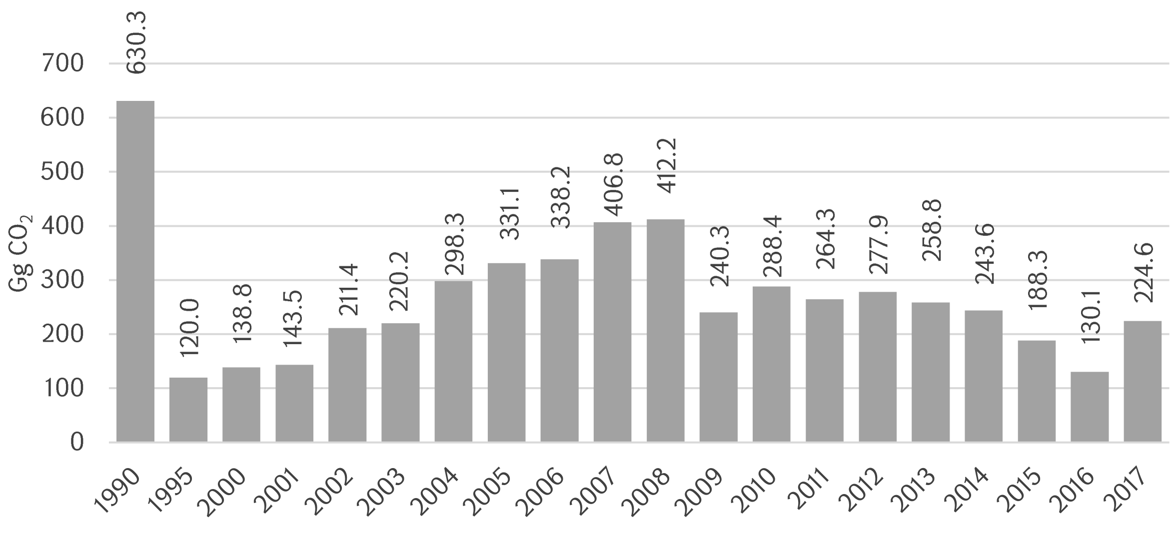


Figure 4.18 CO_2 emissions from *Cement production*, Gg CO_2

[9] 2006 IPCC Guidelines [Gen-1, Volume 3, Table 2.3]

CO_2 emissions from cement production are mainly driven by changes in construction volume.

Thus, in 2000-2008 as a result of economic and, consequently, construction growth CO_2 emissions from cement production have been on a growing trend, which was followed by a sharp decline in 2009 due to the economic downturn. In 2010, due to the construction recovery CO_2 emissions from cement production increased and since 2012 the variation of CO_2 emissions is due to the changes in construction volumes.

4.2.6 (2A2) Lime Production

Calcium oxide (CaO or quicklime) is formed by heating limestone to decompose the carbonates. This is usually done in shaft or rotary kilns at high temperatures and the process releases CO_2.

Methodology

Carbon dioxide emissions from lime production were calculated by applying Tier 1 approach. The Tier 1 method is based on applying a default emission factor to national level lime production data [Gen-1, Volume 3, Chapter 2]:

$CO_2 = EF \times M$,

Where:

EF - emission factor for lime production

EF = 0.75 tonnes CO_2/tonne lime produced [Gen-1, Volume 3, Chapter 2, Equation 2.8]

M = lime production data, 37,803 t in 2017

Activity data

The quantities of lime produced were provided by the Statistics Committee (Ref-6).

Calculation of carbon dioxide emissions from Lime Production

In 2017: M = 37,803 t

CO_2 = 37,803 x 0.75 = 28,352 t or 28.352 Gg

Uncertainty Assessment

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

Default Uncertainty Values for Estimation of CO_2 Emissions from Lime Production [Gen-1, Volume 3, Chapter 2.3, Table 2.5] is 4-8% (Uncertainty in assuming an average CaO in lime).

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 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, Volume 3, Chapter 2, Equation 2.10].

$$CO_2\ emissions = M_g \cdot EF \cdot (1-CR)$$

Where:

CO_2 = 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 = 27% (national, provided by glass producer), 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 is:

$$EF = 0.167 / 0.84 = 0.20 \text{ t } CO_2 / \text{t glass}$$

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, %
2017	37,214	27.0

Based on these data, carbon dioxide emissions were calculated as follows:

$$CO_{2\ Emissions} = 37{,}214 \cdot 0.20 \cdot (1-0.27) = 5{,}433 \text{ t or } 5.433 \text{ Gg}$$

Uncertainty assessment

According to 2006 IPCC Guideline [Gen-1, Volume 3, Chapter 2.4.2.1], uncertainty associated with the use of 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.

CO_2 emissions time series from Mineral Industry category

CO_2 emissions time series from *Mineral Industry* category are presented in Figure 4.19.

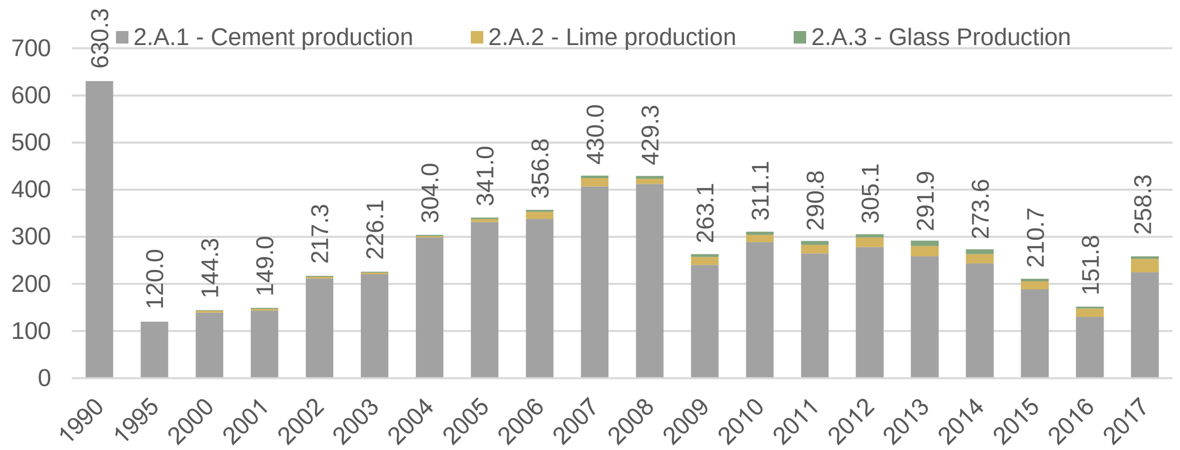


Figure 4.19 CO_2 emissions time series from *Mineral Industry,* Gg CO_2

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 copper and ferromolybdenum production were assessed.

Methodologies for the estimation of emissions of precursors are not provided 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 Ferromolybdenum Production (2C2)

Methodology

In 2017 ferromolybdenum was produced by 3 plants which applied same technological schemes. The molybdenum concentrate used in ferromolybdenum production in Armenia contains no carbon practically and raw materials for the production of ferromolybdenum (batch, mixture) do not contain carbon (coal, coke) as well, which is a source of greenhouse gas generation (CO_2, CH_4), So there are no emissions of CO_2 and CH_4.

However, Sulfur dioxide is produced from melting of molybdenum concentrate.

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

$$MoS_2 + 3.5\ O_2 = MoO_3 + 2SO_2 + 228.5\ kcal$$

SO_2 emissions were calculated using the equation proposed by the national experts for copper production, as the technology of ferromolybdenum production is similar to those of copper production:

$$SO_2\ Emissions = (Q_{conc} \times C_s - Q_{slag} \times S_s) \times 2$$

Based on the plant specific data for the previous years, the weighted average national emission factor of 1.07 t CO_2 par 1 t of ferromolybdenum produced was calculated.

Thus:

SO_2 Emissions = 6,588 x 1.07 = 7,054.0

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.

Activity data

The quantity of ferromolybdenum produced were taken from the Statistics Committee Yearbook (Ref-1) and made 6,588 tonnes.

Uncertainty assessment

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

4.2.8.2 Copper Production (2C7)

Activity data

Primary copper in Armenia is produced by Alaverdi copper smeltery of "Armenian Copper Programme" 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 provided by "Armenian Copper Programme" CJSC [IndRef-4] in response to the inquiry of the Ministry of Environment.

Data for 2017 are provided below:

- annual quantities of copper concentrate: 50,898.7 t
- sulphur content in concentrate, share: 39.23%
- the annual quantities of slag: 30,850 t
- sulphur content in slag, share: 2.25%:

Methodology

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

(50898.6 x 0.3923 - 30850 x 0.0225) x 2 = 41,323.2 t

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 cleaning processes.

Uncertainty assessment

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

Sulphur dioxide emissions time series from *Ferromolybdenum Production* (2C2) and *Copper Production* (2C7) sub-categories

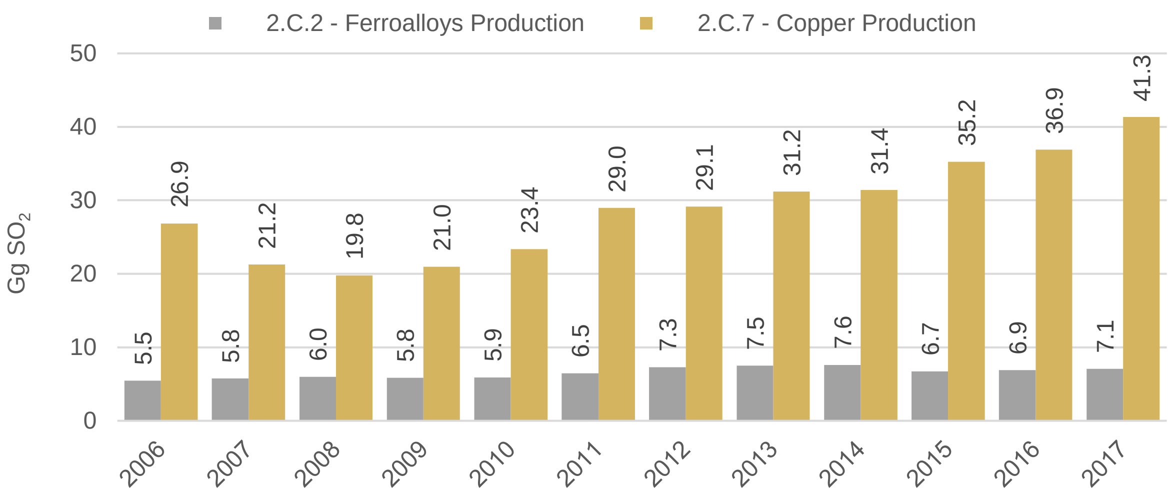


Figure 4.20 Sulphur dioxide emissions time series from Ferromolybdenum Production and Copper Production sub-categories, Gg

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

4.2.9.1 (2D1) Lubricant Use

Description of the sub-category

Lubricants are mostly used in industrial and transportation applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. They can be subdivided into (a) motor oils and industrial oils, and (b) greases, which differ in terms of physical characteristics (e.g., viscosity), commercial applications, and environmental fate.

The use of lubricants in engines is primarily for their lubricating properties and associated emissions are therefore considered as non-combustion emissions to be reported in the IPPU Sector [Gen-1, Volume 3, Chapter 5.2].

Activity data

Activity data were taken from the Energy balance (non-energy consumption) and cross-checked by the import values.

Methodology

Emissions from the use of lubricants were estimated applying Tier 1 method. Tier 1 method relies on applying one default *Oxidised During Use* (ODU) factor to total lubricant activity data.

CO_2 emissions are calculated according to Equation 5.2 [Gen-1, Volume 3, Chapter 5.2] with aggregated default data for the limited parameters available and the ODU factor based on a default composition of oil and greases in total lubricant figures (in TJ units):

$$CO_2\ Emissions = LC \times CC_{Lubricant} \times ODU_{Lubricant} \times 44/12$$

Where:

$CO_2\ Emissions$ = CO_2 emissions from lubricants, tonne CO_2

LC = total lubricant consumption, TJ

$CC_{Lubricant}$ = carbon content of lubricants (default), tonne C/TJ (= kg C/GJ)

$ODU_{Lubricant}$ = ODU factor (based on default composition of oil and grease), fraction

$44/12$ = mass ratio of CO_2/C

Choice of Emission Factors

Having only total consumption data for all lubricants (i.e., no separate data for oil and grease), the weighted average ODU factor for lubricants as a whole is used as default value in the Tier 1 method. Assuming that 90 percent of the mass of lubricants is oil and 10 percent is grease, applying these weights to the ODU factors for oils and greases yields an overall (rounded) ODU factor of 0.2 [Gen-1, Volume 3, Chapter 5.2, Table 5.2]. This ODU factor can then be applied to an overall carbon content factor, which may be country-specific or the default value for lubricants to determine national emission levels from this source when activity data on the consumption of lubricants is known (Equation 5.2).

Emissions Estimate

Thus for 2017:

$$CO_2\ Emissions = 272.142\ TJ * 20\ t/TJ * 0.2 * 44/12 = 3{,}991.416\ t = 3.991\ Gg$$

Uncertainty assessment

Emissions Factor Uncertainties

The default ODU factors are very uncertain, as they are based on limited knowledge of typical lubricant oxidation rates. 2006 IPCC Guidelines suggest (Expert judgment) using a default uncertainty of 50 percent.

According to 2006 IPCC Guidelines the carbon content coefficients are based on two studies of the carbon content and heating value of lubricants, from which an uncertainty range of about ±3 percent is estimated.

Activity Data Uncertainties

Much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used in individual countries. Considering that Armenia has well-developed energy statistics - Energy balances, which serve as activity data source, a default value of 5 percent was used according to the 2006 IPCC Guidelines.

4.2.9.2 Paraffin Wax Use (2D2)

The category includes such products as petroleum jelly, paraffin waxes and other waxes. Waxes are used in a number of different applications. Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others.

Activity data

Basic data on non-energy products used in the country were taken from the Energy balance split on the energy/non-energy use and were cross-checked by the import values.

Methodology

Emissions from the use of paraffin were estimated applying Tier 1 method. Tier 1 method relies on applying default emission factors to activity data.

CO_2 emissions are calculated according to Equation 5.4 [Gen-1, Volume 3, Chapter 5.3] with aggregated default data for the limited parameters available:

$$CO_2\ Emissions = PW \times CC_{Wax} \times ODU_{Wax} \times 44/12$$

Where:

CO_2 Emissions = CO_2 emissions from waxes, tonne CO_2

PW = total wax consumption, TJ

CC_{Wax} = carbon content of paraffin wax (default), tonne C/TJ (= kg C/GJ)

ODU_{Wax} = ODU factor for paraffin wax, fraction

44/12 = mass ratio of CO_2/C

Choice of Emission Factors

According to the 2006 IPCC Guidelines [Gen-1, Volume 3, Chapter 5.3] it can be assumed that 20 percent of paraffin waxes are used in a manner leading to emissions, mainly through the burning of candles, leading to a default ODU factor of 0.2 (Equation 5.4).

Emissions Estimate

Thus in 2017:

CO_2 emissions = 16.7472 TJ*20 t/TJ * 0.2 *44/12 = 245.6256 t = 0.2456 Gg

Uncertainty assessment

Emission Factor Uncertainties

The default emission factors are highly uncertain, because knowledge of national circumstances of paraffin wax fates is limited.

The default carbon content coefficient is subject to an uncertainty range of ±5 percent (U.S.EPA, 2004). However, the ODU factor is highly dependent on specific-country conditions and policies and the default value of 0.2 exhibits an uncertainty of about 100 percent [Gen-1, Volume 3, Chapter 5.3.3].

Activity Data Uncertainties

Much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used and discarded in individual countries.

Considering that Armenia has well-developed energy statistics - Energy balances, which serve as activity data source, a default value of 5 percent was used according to the 2006 IPCC Guidelines [Gen-1, Volume 3, Chapter 5.3.3].

4.2.9.3 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 SC [Ref-1, Ref-2].

NMVOCs emissions from paint application in 2017 made 3.501 Gg.

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 SC [Ref-1].

Emissions of NMVOCs from domestic solvent use in 2017 made 2.9 Gg.

4.2.9.4 Bitumen/Asphalt Production and Use (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 NMVOCs.

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 SC [Ref-2].

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, 16 g/t bitumen [Gen-2].

Table 4.33 provides NMVOCs emissions calculated using the quantities of imported bitumen and the asphalt mix produced on its basis

Table 4.33 NMVOCs emissions from the Use of Bitumen

Year	Quantity of bitumen imported, t	Quantity of asphalt mix, t	NMVOCs emission, t
2017	32,186.0	128,744.2	2.1

4.2.9.5 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 tonne product [Gen-2, Part B, 2H2, Table 3-1].

Production data were taken from the Yearbooks of the SC [Ref -1].

NMVOCs emissions from *Food and Beverage* in 2017 made 0.886 Gg.

Time series

NMVOCs total emissions from *Non-Energy Products from Fuels and Solvent Use* (2D) category and *Food and Beverage* (2H2) sub-category are provided in Figure 4.21.

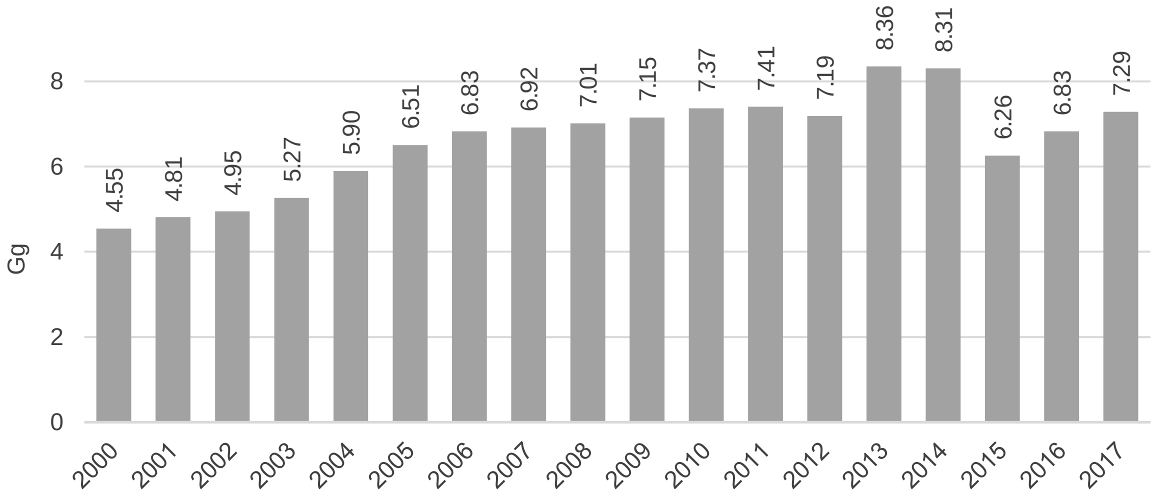


Figure 4.21 NMVOCs emissions time series from *Non-Energy Products from Fuels and Solvent Use* (2D) category and *Food and Beverage* (2H2) sub-category, Gg

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

4.2.10.1 Overview of emissions of fluorinated substitutes for ozone depleting substances

The emissions of F-gases occur in Armenia largely from Hydrofluorocarbons (HFCs). Perfluorocarbons (PFCs) are not used in the country.

SF_6 emissions are reported under *(2G) Other Product Manufacture and Use* category.

In Armenia, as well as globally, Hydrofluorocarbons (HFCs) are used 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*.

On March 28, 2019, the Republic of Armenia ratified the Kigali amendment to the Montreal Protocol “on Substances that Deplete the Ozone Layer” of the Vienna Convention “On Protection of the Ozone Layer", by which Armenia is committed to reduce the use of Hydrofluorocarbons.

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 while in small quantities such import started since 2000. 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 CFC 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.

In 2017, HFCs emissions made nearly 6.5% of the country’s total emissions and over 72% of the greenhouse gas emissions of the IPPU sector in 2017. HFC emissions, which are caused by refrigeration systems, predominate in the overall picture of HFCs emissions with the share of over 95.4% in 2017. The share of emissions from other applications is about

4.6% altogether: 3.4% from Foam Blowing Agents, 1.1% from Aerosols, and minor emissions, only 0.1% of total HFCs emissions - from Fire Protection application.

From all HFCs, HFC-134a has the widest application area, 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 HFC key application area, and is also contained in aerosols as a propellant and in foam blowing as a foam blowing agent.

Table 4.34 HFCs application areas 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	

4.2.10.2 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 a solvent.

HFCs emissions assessment for all applications with the exception of RAC was implemented by applying Tier 1A method.

4.2.10.3 Refrigeration and Air Conditioning (RAC) (2F1)

Description of Application Area

RAC is a key source category in Armenia accounting for 95.4% of total emissions in *Product Uses as Substitutes for Ozone Depleting Substances* category in 2017, where HFCs are used as refrigerants.

The application area 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 refrigeration, commercial refrigeration, industrial refrigeration, transport refrigeration and stationary air-conditioning.

Mobile Air Conditioning sub-application includes air-conditioning systems used in vehicles.

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

Methodology

Since *RAC* is defined as a key application within the category and there are disaggregated activity data available for calculations, HFCs emissions from *RAC* were estimated applying Tier 2a – Emission-factor approach (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).

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 emission factors provided 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.

In a Tier 2a calculation, refrigerant emissions at a year t from each of the six sub-applications of refrigeration and air conditioning systems are calculated separately. These emissions result from:

$E_{containers,t}$ = emissions related to the management of refrigerant containers

$E_{charge,t}$ = the emissions of refrigerant due to the charging process of new equipment are related to the process of connecting and disconnecting the refrigerant container to and from the equipment when it is initially charged

$E_{lifetime,t}$ = annual emissions from the banks of refrigerants associated with the six sub-applications during operation (fugitive emissions and ruptures) and servicing

$E_{end-of-life,t}$ = amount of HFC emitted at system disposal in year t, kg

All these quantities are expressed in kilograms and have been calculated for each type of HFC used in the six different sub-applications.

$E_{total,t} = E_{containers,t} + E_{Charge,t} + E_{lifetime,t} + E_{end-of-life,t}$ [Equation 7.10, Gen-1, Volume 3, Chapter 7].

Refrigerant management of containers

The emissions related to the refrigerant container management comprise all the emissions related to the refrigerant transfers from bulk containers down to small capacities.

$E_{containers,t} = RM_t * C/100$ [Gen-1, Volume 3, Chapter 7, Equatation 7.11]

Where:

$E_{containers,t}$ = emissions from all HFC containers in year t, kg

RM_t = HFC market for new equipment and servicing of all refrigeration application in year t, kg

c = emission factor of HFC container management of the current refrigerant market, percent, estimated to be 10 percent for all sub-applications [Gen-1, Volume 3, Chapter 7, Equatation 7.11].

Refrigerant charge emissions of new equipment

The emissions of refrigerant due to the charging process of new equipment are related to the process of connecting and disconnecting the refrigerant container to and from the equipment when it is initially charged.

$E_{charge, t} = 0$ for all sub-applications with the exception of large and medium commercial and industrial refrigeration because large and medium commercial and industrial refrigeration equipment is imported not charged with refrigerant.

Emissions during lifetime (operation and servicing)

Annual leakage from the refrigerant banks represent fugitive emissions, i.e., leaks from fittings, joints, shaft seals:

$E_{ifetime,t} = B_t * x/100$ [Gen-1, Volume 3, Chapter 7, Equation 7.13].

Where:

$E_{lifetime, t}$ = amount of HFC emitted during system operation in year t, kg

B_t = amount of HFCs banked in existing systems in year t (per sub-application), kg

x = annual emission rate (i.e., emission factor) of HFC of each sub-application bank during operation, accounting for average annual leakage and average annual emissions during servicing, percent.

Emissions at end-of-life

The amount of refrigerant released from scrapped systems depends on the amount of refrigerant left at the time of disposal, and the portion recovered.

It was disregarded for all sub-applications with the exception of *Transport Refrigeration and Mobile air-conditioning* as HFC-based *RAC* equipment being disposed in Armenia in year t is insignificant because such equipment was first imported into Armenia in 2000 - in small quantities, and mainly – from 2014, while lifetime of such equipment is estimated to be at least 15 years.

Activity Data

Data on the quantities of imported fluorinated substitutes for ODS (F-gases), as well as on goods containing them classified by the country of origin have been received from the RA Government Adjunct State Revenue Committee (SRC) in response to the official inquiry of the RA Ministry of Environment.

Customs codes of the local customs system sometimes indicate very broad category of goods and the information obtained in the reference issued by the SRC didn’t allow to track the type of chemical in the product, its amount and date of import. This is the reason the data received was analyzed by the panel of experts taking into account the country’s relevant market features, existing demand, technical fit-out and many other factors for each application area.

To get the activity data as accurate as possible the inventory compilers also held inquiries among the chemicals’ importers and retailers, well-experienced specialists working in the area, as well as end-users.

The data provided by the SRC on the amount of the refrigerants imported into the country as individual chemicals were cross-checked with the existing demand for refrigerants needed for charging and maintaining the equipment imported into the country. The demand in its turn equals to the sum of the amount of an individual HFC released into the atmosphere within the reporting year and the amount of refrigerants charged into newly-installed equipment.

There are also some small companies and workshops in the country that manufacture stand-alone, medium-sized and large commercial refrigeration equipment. However, since they get their product just by putting together individual components imported into the country, it was decided not to hold separate calculations of the amount of HFCs used in the manufacturing process, instead involve this amount in the estimations derived from the quantities of the refrigeration equipment imported into the country within the reporting period.

Emissions estimates

Domestic Refrigeration

It was estimated by the expert judgement that 80% of the all refrigeration equipment imported into Armenia are domestic refrigerators, 47.5% of which are based on HC-600a and 52.5% - on HFC-134a. The average amount of the refrigerant contained in each domestic refrigerator was estimated by expert judgement to be 120 g.

Based on the assumption that the domestic refrigerators imported earlier are more likely to use R-134a, the share of the R-134a-based refrigerators for each coming year was assessed to be 2.5% less than for the preceding year.

According to the data provided by the SRC, in 2017 41,545 units of refrigeration equipment were imported into Armenia in total. 80% of them, which is 33,236, make domestic refrigerators of which only 52.5% or 17,449 (i.e. 2.5% less than for the previous year) units are charged with R-134a. Therefore, the amount of R-134a contained in the domestic refrigerators imported into Armenia in 2017 counts as follows:

17,449 x 0.120 = 2093.9 kg

B_t = estimated based on the total quantity of domestic refrigerators imported in Armenia in 2000-2017 and is equal to 61,888.1 kg.

x = estimated to be 2% based on the expert judgement due to improper handling and maintenance of the equipment.

$E_{lifetime,t}$ = 1,237.8 kg

As Armenia has no production of domestic refrigerators:

$RM_t = E_{lifetime,t}$, i.e. it equals to HFC market for servicing of all refrigeration application in year t, kg

RM_t = 1,237.8 kg

Thus:

$E_{containers,t}$ = 123.8 kg

Finally:

$E_{total,t} = E_{containers,t} + E_{lifetime,t}$ = 123.8 + 1,237.8 = 1,361.6 kg

Stand-alone commercial applications

18% of refrigeration equipment imported into the country are stand-alone commercial systems: 50% of which work on R-134a and 50% on R-404A. The average refrigerant charge of each equipment was estimated to be 1 kg.

Bt = was estimated based on the amount of commercial refrigeration equipment imported in Armenia in the period of 2000-2017 and makes 150,981.6 kg

x = was estimated to be 15% [Gen-1, Volume 3, Table 7.9].

$E_{lifetime,t}$ = 22,647.2 kg

In this sub-application $RM_t = E_{lifetime,t}$ = 22,647.2 kg

Thus,

$E_{containers,t}$ = 2264.7 kg

Finally:

$E_{total\ ,t} = E_{containers,t} + E_{lifetime,t}$ = 24,911.9 kg

50% or 12,455.95 kg of emissions calculated for this sub-application fall to share of R-134a and 50% or 12,455.95 kg to that of refrigerant blend R-404A (HFC-125-44%/HFC-143a-52%/HFC-134a-4%).

Large and medium commercial and industrial refrigeration

2% of all the imported refrigeration equipment are large and medium-sized commercial and industrial refrigeration equipment, which arrive in the country with no refrigerant charged in.

After installation, 20% of them were charged with R-134a and 80% - with R-404A. Average refrigerant charge for each equipment was estimated to be 15 kg.

According to the data provided by RA GA SRC, in 2017 in total 41,545 units of refrigeration equipment were imported into Armenia, of which 2% or 831 units were large and medium-sized commercial and industrial refrigeration equipment. Therefore, in 2017 at the moment of installation the total refrigerant charge of the imported large and medium-sized commercial and industrial refrigeration equipment was estimated to be 831 * 15 = 12,465 kg of which 20% or 2493 kg was R-134a and the remaining 80% or 9972 was HFC-404A.

B_t = was estimated based on the amount of large and medium-sized commercial and industrial refrigeration equipment imported into Armenia in 2000-2017 and makes 234,019.9 kg

x = was estimated to be 35 % [Gen-1, Volume 3, Table 7.9].

$E_{lifetime,t}$ = 81,907 kg

$E_{Charge,t}$ = emissions related to the refrigerant charge in year t: connection and disconnection of the refrigerant container and the new equipment to be charged

$E_{Charge,t} = M_t * k/100$ [Gen-1, Volume 3, Equation 7.12]

Where:

M_t = amount of HFC charged into new equipment in year t, kg, equals to 12,465 kg

k = emission factor of assembly losses of the HFC charged into new equipment, percent: it was estimated to be 3% [Gen-1, Volume 3, Table 7.9]

Thus:

$E_{Charge,t}$ = 374 kg

RM_t = HFC market for new equipment and servicing of all refrigeration application in year t, kg, as in this case large and medium commercial and industrial refrigeration equipment is charged after its installation

$RM_t = Mt + E_{lifetime,t}$ = 12,465 + 81,907 = 94,372 kg

$E_{containers,t}$ = 9,437.2 kg

Finally:

$E_{total\ ,t} = E_{containers,t} + E_{Charge,t} + E_{lifetime,t}$ = 91,718.2 kg

20% or 18,343,6 kg of emissions from this subapplication accounts for R-134a and the remaining 80% or 73,374.6 kg for the blend refrigerant R-404A (HFC-125-44% / HFC-143a-52% / HFC-134a-4%).

Air Conditioning

From all air-conditioning equipment imported into the country in 2017 20% work on R-134a, 30% - with R-407C and 50% - with R-410A.

Taking into consideration that this sub-application includes window air-conditioners, split air-conditioning systems, chillers, central systems with heat exchangers and others, the average refrigerant charge for each air conditioning equipment is estimated by expert judgement to be 3 kg.

As per the data provided by the SRC, in total 14,655 units of air-conditioning equipment were imported in Armenia in 2017.

Therefore, the air-conditioning equipment imported in 2017 contained 14,655 * 3 = 43,965 kg HFCs.

Bt = estimated based on the amount of air-conditioning equipment imported into Armenia in 2000-2017 and equals to 523,810.4 kg

x = based on experts judgements was estimated to be 20 % due to improper handling and maintenanace of air-conditioning equipment

$E_{lifetime,t}$ = 104,762.1 kg

In this sub-application $RM_t = E_{lifetime,t}$, thus:

$E_{containers,t}$ = 10,476.2 kg

Finally:

$E_{total,t}$ = 115,238.3 kg

For this sub-application 20% or 23,047.7 kg of all the emissions account for R-134a, 30 % or 34,571.5 kg for blend R-407C (HFC-32-23% / HFC-125-25% / HFC-134a-52%) and 50% or 57,619.1 kg for blend for 410A (HFC-32-50% / HFC-125-50%).

Transport Refrigeration

As per expert judgements, 5% of trucks imported into Armenia are fitted with refrigeration equipment. 50% of them work on R-134a and the other 50% on R-404A. The average refrigerant charge for each transport refrigeration equipment was estimated to be 7 kg.

According to the data provided by the RA GA SRC, 715 trucks were imported into Armenia in 2017. 5% or 36 units of which are fitted with refrigeration equipment: thus the total amount of HFCs contained in transport refrigeration equipment makes 36 * 7 = 252 kg.

Bt = estimated based on the amount of transport refrigeration equipment imported into Armenia in 2000-2017 and equals to 16,931.8 kg

x = was estimated to be 50% [Table 7.9, Gen-1, Volume 3, Chapter 7]

$E_{lifetime,t}$ = 8,465.9 kg

In this sub-application $RM_t = E_{lifetime,t}$, thus:

$E_{containers,t}$ = 846.6 kg

$E_{end-of-life,t}$ - For this sub-application it can't be estimated using Equation 7.14 [Gen-1, Volume 3, Chapter 7], as data on the trucks imported in year t by the year of manufacture is not available.

Considering the national circumstances and specifics, it was estimated by expert judgement, to be 10% of the amount of HFCs banked in existing systems of transport refrigeration in year t , that is:

$E_{end-of-life,t}$ = 1693.2 kg

Finally:

$E_{total,t}$ = 11,005.7 kg

50% or 5502.85 kg of the total emissions from this sub-application fall on R-134a and the other 50% or 5502.85 kg on the blend refrigerant R-404A (HFC-125-44% / HFC-143a-52% / HFC-134a-4%).

Mobile air-conditioning

As per expert judgements, 80% of cars imported into Armenia have air-conditioning systems based on R-134a. The average refrigerant charge for each mobile air-conditioner was estimated to be 900 g.

According to the data provided by the SRC, in 2017 in total 3,256 cars and trucks were imported into Armenia. 80% or 2,605 units of which are fitted with air-conditioners. It means that total amount of the R-134a contained in the mobile air-conditioners imported into Armenia in 2017 made:

2,605 * 0.9 = 2,344.5 kg.

B_t = estimated based on the amount of mobile air-conditioners imported into Armenia in 2000-2017 and equals to 269,912.4 kg

x = 20 % [Table 7.9, Gen-1, Volume 3]

$E_{lifetime,t}$ = 53,982.5 kg

$RM_t = E_{lifetime,t}$, thus:
$E_{containers,t}$ = 5,398.3 kg

$E_{end-of-life,t}$ - for this sub-application it can't be estimated using Equation 7.14 [Gen-1, Volume 3, Chapter 7], as data on the passenger cars, truck cabins and buses imported in year t by the year of manufacture is not available.

Considering the national circumstances and specifics, it was estimated by expert judgement, to be 5% of the amount of HFCs banked in existing systems of mobile air conditioning in year t , that is:

$E_{end-of-life,t}$ = 13,495.6 kg

Finally:

$E_{total,t}$ = 72,876.4 kg

Data Entry into the 2006 IPCC Software

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

For *Refrigeration and Air Conditioning* application area the Software allows to enter data only for 2 sub-applications, namely:

- (2F1a) Refrigeration and Stationary Air Conditioning
- (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 subcategory, while those for *Mobile Air-conditioning* went under 2F1.b. For incorporating the above-mentioned 5 sub-applications in a common sub-category 2.F1.a, average annual emission factors were estimated for every chemical used in the sub-category. The estimation was as follows: the total amount of annual banks estimated for a certain chemical in each of 5 sub-applications was divided by the total amount of annual emissions estimated for the same chemical in the same sub-applications. Afterwards the arithmetical mean value of the annual averaged factors was calculated for each year of the reporting period.

The average factors are as follows:

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

Uncertainty Assessment

In the *RAC* application area activity data were collected by sub-applications (Tier 2a approach) 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 *RAC* emissions calculations the inventory compilers used the default emission factors provided in the Guidelines. Since the factors might differ from the country-specific ones, the average uncertainty of the emission factors was estimated as 25%.

Time series

HFCs emissions from the *RAC* application are provided in the Figure 4.22.

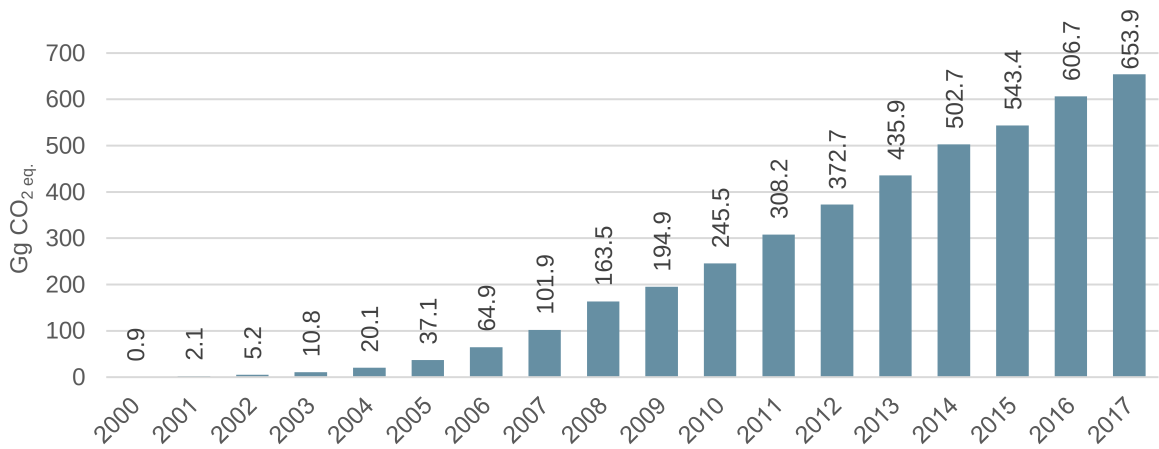


Figure 4.22 HFCs emissions time series from the *RAC* application, Gg CO_2 eq., 2000-2017

As it comes from the Figure 4.23, the emissions from *RAC* application have grown continuously and markedly - in the period from 2006 to 2017 they increased almost tenfold as F-gases have been used to replace ozone depleting compounds in many refrigeration and cooling devices and applications. This is due to the fact that in Armenia as well as globally and in developing countries particularly, HFCs are still being considered as main substitutes for CFCs and HCFCs regulated under the Montreal Protocol, despite the active campaign for using natural refrigerants (mainly ammonia, carbon dioxide, and carbon) as ODS alternative substances.

4.2.10.4 Foam Blowing Agents (2F2)

Application Area Description

This application area accounts for nearly 3.4% of HFC total emissions in 2017 and is the second with its share of HFC emissions in the country. 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 formerly used CFC-11, as well as HCFC-141b contained in imported foam.

Methodology

Due to the lack of disaggregated activity data on the application, Tier 1a approach was applied for emissions assessment.

In this report emissions from *Foam Blowing Agents* application were estimated based on the approach provided in Moldova's ODS Alternative Survey Report of 2017 [Gen-4]: 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, it allows getting a more realistic and complete view of the situation.

Activity Data

Emissions estimate was done based on the amount of the imported foam product provided by the RA GA SRC.

Emissions Estimate

In Armenia emissions occur only from imported closed-cell foam and were calculated according to Equation 7.7 [Gen-1, Volume 3, Chapter 7.4]:

General emission-factor approach (a) for foams:

$Emissions_t = Mt \cdot EFFYL + Bank_t \cdot EFAL + DLt – RDt$

First, the amount of the imported closed-cell foam was estimated being derived from the data provided by the RA GA SRC. 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-5; IndF.Ref-1]. The emission factor of the first year loss (EFFYLL) 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].

Uncertainty Assessment

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 this into account, uncertainty for the application was assessed rather high: 45-50%.

Time series

HFCs emissions from the *Foam Blowing* are provided in the Figure 4.23.

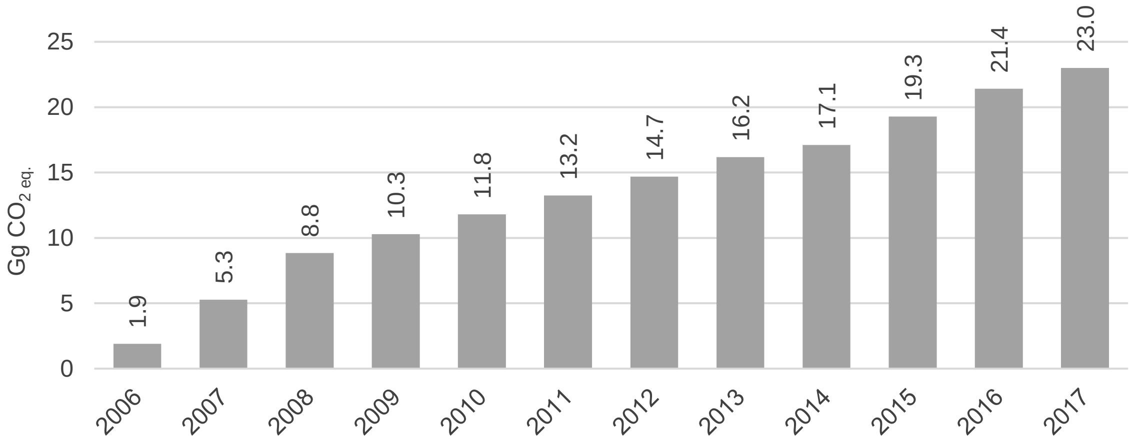


Figure 4.23 HFCs emissions time series from the *Foam blowing*, Gg $CO_{2\ eq.}$

As it can be seen from the Figure 4.23, the emissions from the *Foam Blowing Agents* application are not so high compared with those from the *RAC* application. The reason is that HFCs are not the only optimal substitutes for the ODS used here. Natural substances such as hydrocarbons and carbon dioxide are also used as alternatives in *Foam Blowing Agents*.

4.2.10.5 Fire Protection (2F3)

Application Area Description

HFC emissions caused within this application are insignificant and account for 0.1% of HFCs total emissions in 2017. HFCs can be used in fire extinguishers and other fire suppression equipment as both propellants and active agents at the same time. In this application area HFCs come as alternatives to Halon-1211 formerly used in portable fire extinguishers and Halon-1301 in fixed systems.

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

Methodology

For *Fire Protection* application area emissions were calculated according to Equation 7.17 [Gen-1, Volume 3, Chapter 7.6].

$$Emissions_t = Bank_t \cdot EF + RRL_t$$

$Bank_t$ = bank of agent in fire protection equipment in year t, tonnes

EF = fraction of agent in equipment emitted each year, which is equal to 0.04 according to the Guidelines [Gen-1, Volume 3, Chapter 7.6.2.2].

RRLt = Recovery Release or Loss: emissions of agent during recovery, recycling or disposal at the time of removal from use of existing fire protection equipment in year t, is estimated to be 0 (zero) for Armenia due to few number of such fixed systems in the country and lack of data on the agent’s recovery or recycling.

Activity Data

Emissions in this application were estimated based on the data published by the Statistics Committee of the Republic of Armenia, as well as market research findings and judgements, estimations of a number of companies and specialists/experts.

Uncertainty Assessment

In *Fire Protection* application data uncertainty for developing countries makes more than 15% [Gen-1]. 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%.

Time series

HFCs emissions from the *Fire Protection* are provided in the Figure 4.24.

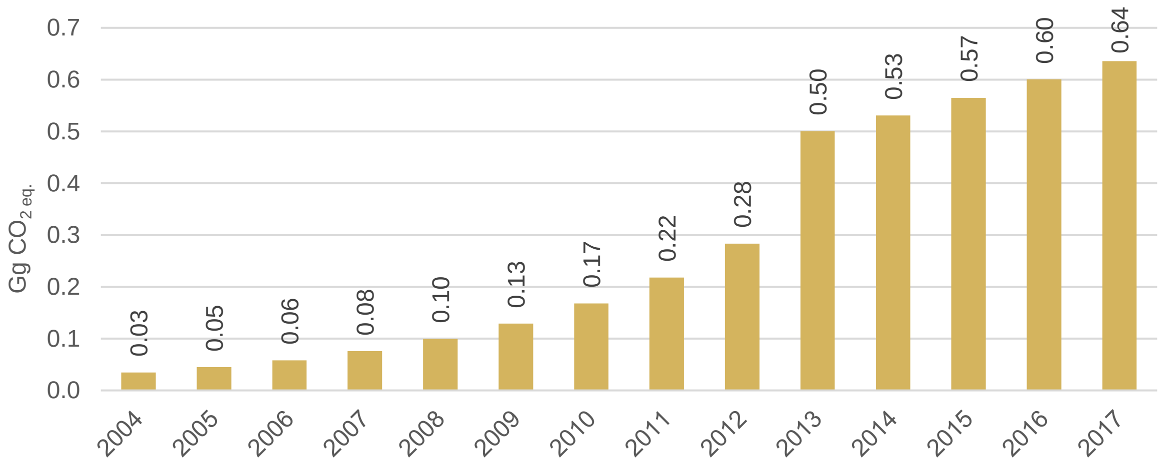


Figure 4.24 HFCs emissions time series from the *Fire Protection*, Gg $CO_{2\ eq.}$

HFCs emissions from the *Fire Protection* application are insignificant, because such natural substances as nitrous oxide, carbon dioxide and pressurized air serve as alternative ODS substitutes as well.

4.2.10.6 Aerosols (2F4)

Application Area Description

Here HFCs are used as propellants or solvents. The following sub-applications exist in Armenia: Metered Dose Inhalers (MDIs), Personal Care Products (e.g. hair care, deodorants, shaving cream), Household Products (e.g. air-fresheners, oven and fabric cleaners) and Industrial Products (e.g. special cleaning sprays, aerosol paints). In terms of HFC emissions this application ranks third in the country with a share of 1.1% of total HFC emissions recorded in 2017.

The survey mainly covered the usage of HFCs exclusively as a propellant in aerosols and not as a solvent. Propellants used in aerosols imported by Armenia include: HFC-134a and HFC-152a, which mainly substitute not only CFC-12 formerly used in this sector but also CFC-11, and sometimes CFC-114. By the survey no any other HFCs was discovered.

Methodology

HFCs emissions from *Aerosols* were calculated according to the Equation 7.6 of the Guideline [Gen-1, Volume 3, Chapter 7.3.2.1].

$Emissions_t = St \cdot EF + St{-}1 \cdot (1 - EF)$

Where:

$Emissions_t$ = emissions in a year *t*, tonnes

S_t = quantity of HFC contained in aerosol products sold in a year *t*, tonnes

S_{t-1} = quantity of HFC contained in aerosol products sold in a year *t*–1, tonnes

EF = emission factor (= fraction of chemical emitted during the first year), fraction

A default emission factor of 50 percent of the initial charge per year for the broad spectrum of aerosol products was used when assessed at the application level (Tier 1a) [Gen-1, Volume 3, Chapter 7.3.2.2]

Activity Data

The emissions assessment was done based on the aerosol products import data provided by the Customs Service of the RA State Revenue Committee [IndF.Ref-1].

The entire amount of the imported products, the average gross weight (the weight with a container) and the net weight (the weight without a container), were estimated based on the local market survey results and the experts judgements.

Uncertainty Assessment

As per experts judgement the uncertainty for *Aerosols* was estimated to be 30%.

Time series

HFCs emissions from the *Aerosols* are provided in the Figure 4.25.

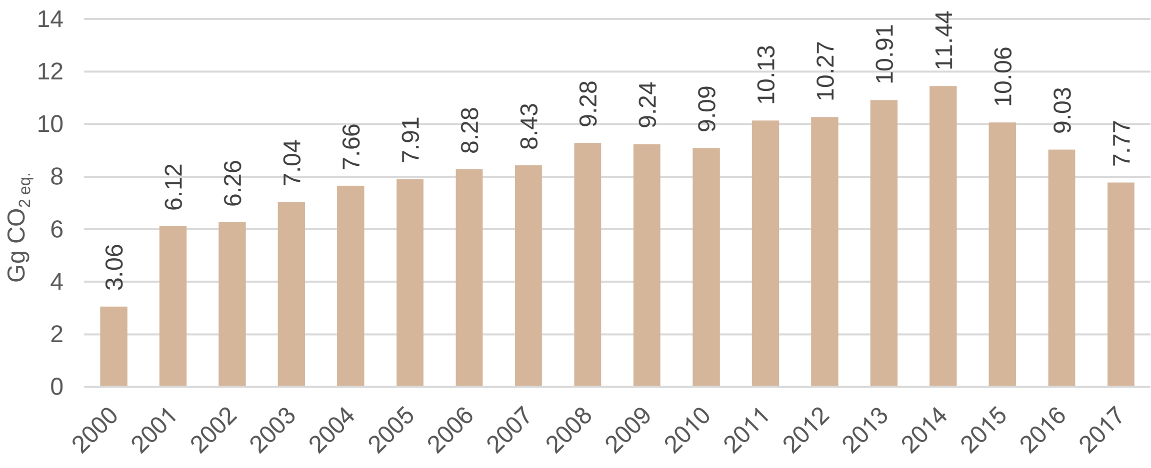


Figure 4.25 HFCs emissions from the *Aerosols*, Gg $CO_{2\ eq.}$

4.2.10.7 Emissions of fluorinated substitutes and time series for ODS substitutes category, by applications and chemicals

Table 4.35 and Figure 4.26 provide HFCs emissions by applications.

Table 4.35 HFCs emissions by application areas, Gg $CO_{2\ eq.}$

Year	Refrigeration and Air Conditioning	Aerosols	Foam Blowing Agents	Fire Protection	Total
2000	0.895	3.060	0	0	3.955
2001	2.102	6.120	0	0	8.222
2002	5.152	6.263	0	0	11.415
2003	10.822	7.038	0	0	17.861
2004	20.125	7.657	0	0.035	27.817
2005	37.126	7.909	0	0.045	45.080
2006	64.85	8.28	1.91	0.06	75.10
2007	101.89	8.43	5.29	0.08	115.69
2008	163.48	9.28	8.83	0.10	181.69
2009	194.95	9.24	10.29	0.13	214.61
2010	245.54	9.09	11.81	0.17	266.61
2011	308.22	10.13	13.23	0.22	331.80
2012	372.67	10.27	14.68	0.28	397.90
2013	435.92	10.91	16.18	0.50	452.60
2014	502.66	11.44	17.11	0.53	531.74
2015	543.44	10.06	19.29	0.57	573.36
2016	606.67	9.03	21.40	0.60	637.70
2017	653.92	7.77	23.01	0.64	685.34

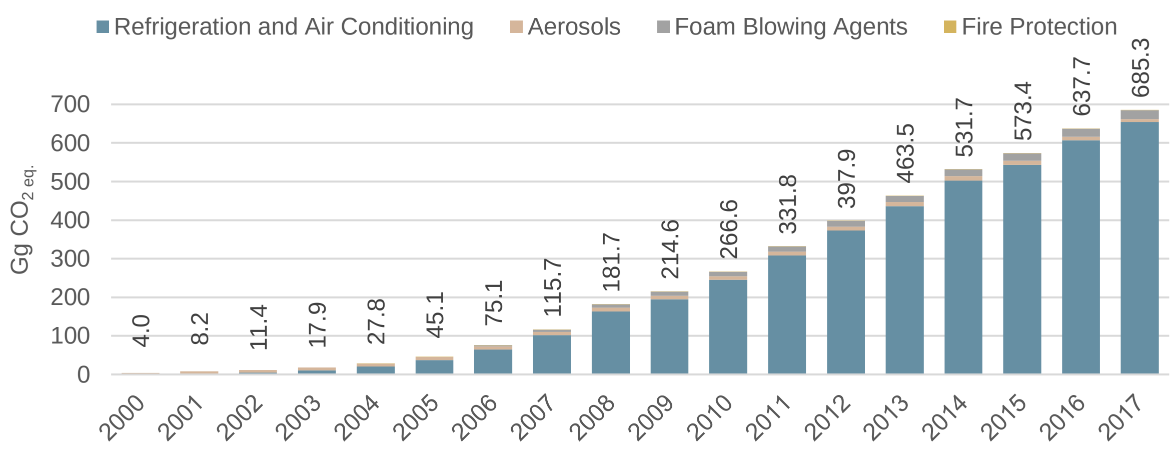


Figure 4.26 HFCs emissions by applications, Gg $CO_{2\ eq.}$

As seen in the Figure 4.26, there is an obvious sustainable annual growth of HFCs emissions from two applications - *RAC* and *Foam Blowing Agents*. Each application, however, has different growth rates.

Rapid increase in *RAC* emissions is due to the fact that in Armenia, as well as globally, and in developing countries particularly, HFCs are still being considered as main substitutes for CFCs and HCFCs regulated under the Montreal Protocol, despite the active campaign for using natural refrigerants (mainly ammonia, carbon dioxide, and carbon) as ODS alternative substances.

The situation is a bit different with *Foam Blowing Agents* application, where emissions are not so high. The reason is that HFCs are not the only optimal substitutes for the ODS used here. Natural substances such as hydrocarbons and carbon dioxide are also used as alternatives in *Foam Blowing Agents*.

The situation is similar for *Fire Protection* application. Along with them, such natural substances as nitrous oxide, carbon dioxide and pressurized air come as alternative ODS substitutes.

The picture is totally different in case of *Aerosols*. 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 application natural refrigerants will gradually come to replace HFCs as substitutes.

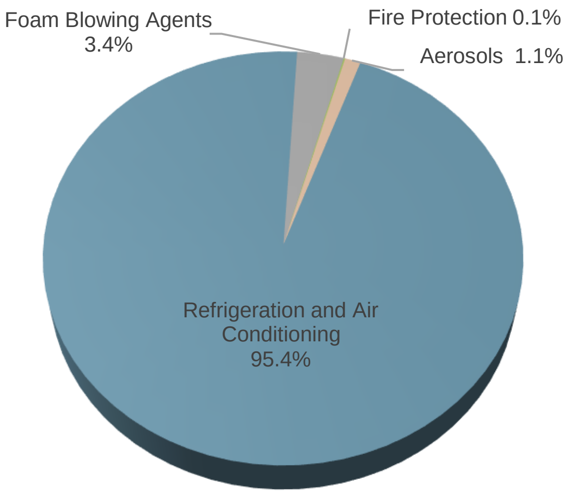


Figure 4.27 HFCs total emissions by application areas, 2017

As seen in the Table 4.35 and Figure 4.27, for Armenia, as well as for many other countries, *RAC* is a key category. It accounts for 95.4% of total HFCs emissions for 2017, followed by *Foam Blowing Agents* with the share of 3.4%. *Aerosols* accounted for 1.1% and *Fire Protection* – for 0.1% of total HFCs emissions for 2017.

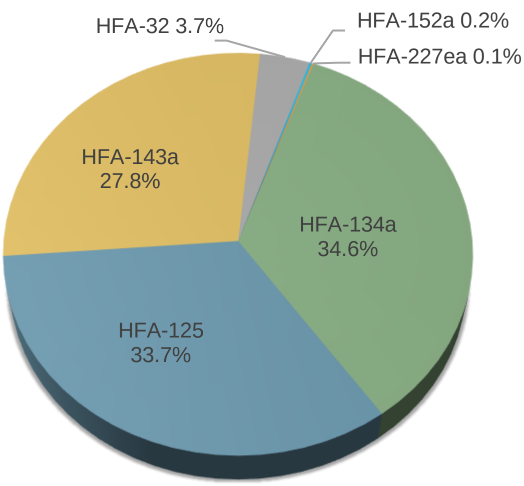


Figure 4.28 HFCs emissions by chemicals, 2017

HFC-134a is the most widely used HFC (Figure 4.28). It is 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*.

Figure 4.29 provides time series of HFC emissions by chemicals.

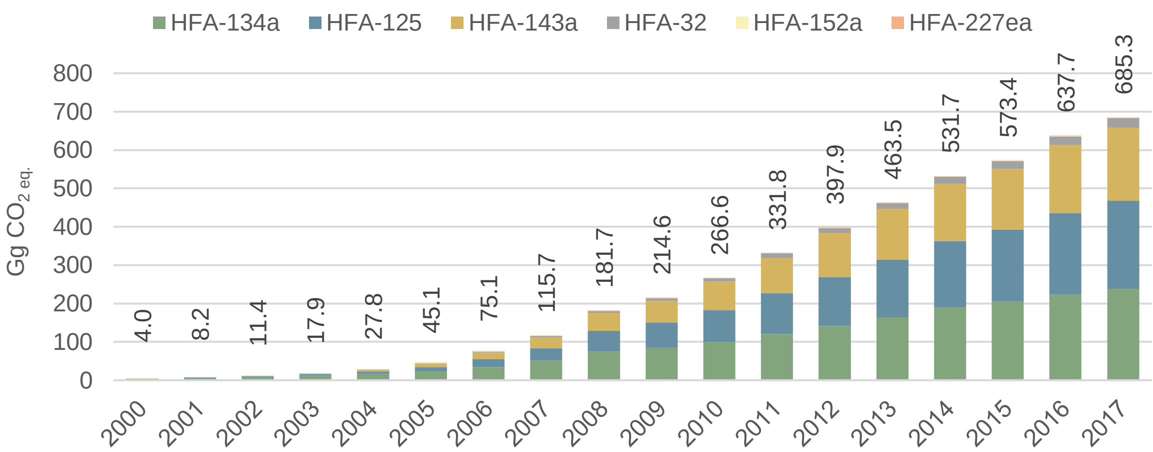


Figure 4.29 HFCs emissions by chemicals, Gg CO_2 eq.

4.2.10.8 Completeness of data

Using Tier 2a method, by expert judgement, almost 75% of the *RAC* application was successfully covered while making the data collection in the sector. It was possible due to the availability of the relevant database and experience obtained by the exerts 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 MDIs, personal care and household products, as well as aerosol paints.

Calculations for *Fire Protection* application were made based on statistical data and expert judgment. Completeness of data here was assessed to be 50% by expert judgement.

The number of HFC-based refrigeration equipment (apart from transport), stationary air-conditioners and fire suppression equipment disposed in Armenia within the reporting period was considered insignificant and was not included in the calculations.

4.2.10.9 Summary table of HFCs emissions

The Table 4.36 gives an overview of the HFC emissions in 2017, (tonnes and Gg $CO_{2\ eq.}$) by chemicals and applications.

Table 4.36 Armenia's HFC emissions (in tonnes and Gg $CO_{2\ eq.}$) by chemicals and applications, 2017

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 According to Second Assessment Report of IPCC	650	2800	1300	140	3800	2900			
Emissions in tonnes									
2.F - Product Uses as Substitutes for Ozone Depleting Substances	38.602	82.396	182.405	10.273	50.088	0.220	1.1529	1,0368	
2.F.1 - Refrigeration and Air Conditioning	38.602	82.396	159.834	NO	50.088	NO			
2.F.1.a - Refrigeration and Stationary Air Conditioning	38.602	82.396	87.783	NO	50.088	NO			
2.F.1.b - Mobile Air Conditioning	NO	NO	72.051	NO	NO	NO			
2.F.2 - Foam Blowing Agents			16.856	7.823		NO	1.1529	1.0368	
2.F.3 - Fire Protection		NO	NO			0.220			
2.F.4 - Aerosols			5.715	2.450		NO	NO		
2.F.5 - Solvents									
Emissions in CO_2 equivalent unit (Gg)									
2.F - Product Uses as Substitutes for Ozone Depleting Substances	25.091	230.709	237.126	1.438	190.3361	0.636			**685.337**
2.F.1 - Refrigeration and Air Conditioning	25.091	230.709	207.784	NO	190.336	NO			**653.921**
2.F.1.a - Refrigeration and Stationary Air Conditioning	25.091	230.709	114.118	NO	190.336	NO			**560.254**
2.F.1.b - Mobile Air Conditioning	NO	NO	93.667	NO	NO	NO			**93.667**
2.F.2 - Foam Blowing Agents			21.912	1.095		NO			**23.008**
2.F.3 - Fire Protection		NO	NO			0.636			**0.636**
2.F.4 - Aerosols			7.430	0.343		NO			**7.773**
2.F.5 - Solvents									

4.2.11 Other Product Manufacture and Use (2G)

Description of the category

Sulfur hexafluoride (SF_6) is a powerful greenhouse gas with high global warming potential (GWP; 23,900)[7].

According to the 2006 IPCC Guidelines [Gen-1, Volume 3], emissions of SF_6 are derived mainly from four sources:

- Magnesium production: Chapter 4, Metal Industry Emissions
- Semiconductor and flat panel display production: Chapter 6, Electronics Industry Emissions
- Manufacture and use of electrical equipment: Chapter 8, Other Product Use
- Other sources (accelerators, military, etc.): Chapter 8, Other Product Use

There is no magnesium smelting, semiconductor manufacturing as well as other sources of SF_6 emissions in Armenia. In Armenia emissions of SF_6 are originated from electrical equipment used in electricity transmission and distribution` 2G1 category.

Globally, electrical equipment constitutes the largest source of SF_6 emissions. The excellent insulating and arc-extinguishing characteristics of SF_6 have led to its widespread use in electrical equipment.

4.2.11.1 Electrical Equipment (2G1)

Sulphur hexafluoride (SF_6) is used for electrical insulation and current interruption in equipment used in the transmission and distribution of electricity. Emissions occur at each phase of the equipment's life cycle, including manufacturing, installation, use, servicing, and disposal. Most of the SF_6 used in electrical equipment is used in gas insulated switchgear and substations (GIS) and in gas circuit breakers (GCB), though some SF_6 is used in high voltage gas-insulated lines (GIL), outdoor gas-insulated instrument transformers and other equipment.

The aforementioned applications may be divided into two categories of containment. The first category is "Sealed Pressure Systems" or "Sealed-for-life Equipment", which is defined as equipment that does not require any refilling (topping up) with gas during its lifetime. Distribution equipment normally falls into this category.

The second category is "Closed Pressure Systems", which is defined to include equipment that requires refilling (topping up) with gas during its lifetime. Transmission equipment normally falls into this category.

Both categories of equipment have lifetimes of more than 30 to 40 years. [Gen-1, Volume 3, Chapter 8].

Estimating of SF_6 emissions from electrical equipment was done only for *Use of Electrical Equipment* (2G1b) subcategory as Armenia has no manufacturing of *Electrical Equipment* and started importing electrical equipment containing SF_6 since 1999.

4.2.11.1.1 Use of Electrical Equipment (2G1b)

Description of the sub-category

As a result of the study of national data on SF_6 containing electrical equipment operated at Armenia's power system facilities, it has been identified that in Armenia emissions of SF_6 are derived mainly from gas circuit breakers (GCB) (HV closed - pressure equipment) and in less amount - from gas-insulated switchgears (GIS) (MV sealed pressure equipment). Due to the ongoing reconstruction of the existing substations and the construction of new facilities, old equipment is being replaced with SF_6 containing new equipment.

Figure 4.30 shows the dynamics of putting equipment into operation for the period from 1999 to 2018. Currently, there is a steady increase in the use of GCBs (closed - pressure equipment) in existing and new substations in Armenia.

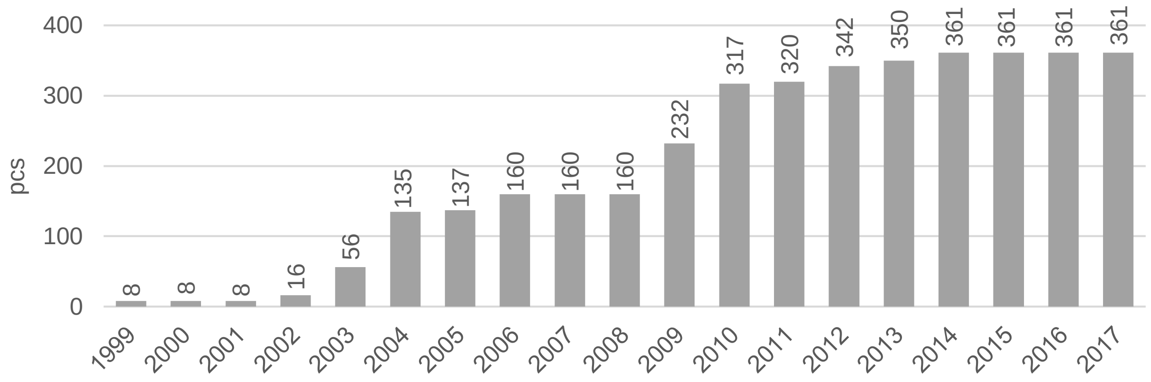


Figure 4.30 Growth dynamics of SF_6 containing HV GCBs (closed-pressure equipment) use in Armenia

Methodology

Emissions of SF_6 from use of electrical equipment were estimated using a Tier 1 method (the default emission-factor approach) [Gen-1, Volume 3, Chapter 8, Equation 8.1]:

Total Emissions = Manufacturing Emissions + Equipment Installation Emissions+ Equipment Use Emissions + Equipment Disposal Emissions

Manufacturing emissions and *Equipment Disposal Emissions* are omitted as Armenia has no manufacturing of Electrical Equipment and started importing electrical equipment containing SF_6 since 1999 while the lifetime of such electrical equipment range from 30 to 40 years.

Equipment installation emissions are omitted as they are included in the emission factor for emissions from Use [Gen-1, Volume 3, Chapter 8.2.2].

Thus:

Total Emissions = Equipment Use Emissions

Equipment Use Emissions = Use Emission Factor x Total nameplate capacity of installed equipment

The “use emission factor” includes emissions due to leakage, servicing, and maintenance as well as failures.

Activity data

Data on SF_6 containing electrical equipment was provided by the Ministry of Energy Infrastructure and Natural Resources in response to the inquiry sent by the Ministry of Environment with the detailed “questionnaire” on data required. These data were provided for the whole period starting from the year of importing SF_6 containing electrical equipment.

Data on SF_6 containing equipment for electricity transmission and distribution include data on high-voltage GCB installed in the power plants, as well as data on MV gas-insulated switchgears (GIS) for ensuring own needs of the power plants.

QA/QC of activity data was done by the Energy Sector specialist not directly involved in the inventory compilation/development process by comparison with independently compiled data sets and through discussions with data providers followed by adjustments as needed.

Emission Factors

For sealed pressure electrical equipment (MV Switchgear) containing SF_6 default emission factors provided for Europe and equaling to 0.002 have been used [Gen-1, Volume 3, Chapter 8, Table 8.2].

Default emission factor includes leakage, major failures/arc faults and maintenance losses.

For closed pressure electrical equipment (HV switchgear) containing SF_6 default emission factors provided for Europe and equaling to 0.026 have been used [Gen-1, Volume 3, Chapter 8, Table 8.3].

SF_6 emissions were estimated based on the above-mentioned default emission factors values and nameplate capacity of all equipment installed.

Emissions calculation results

Emissions calculations results for closed pressure electrical equipment are provided in the Table 4.37.

The final amount of SF_6 in all electrical equipment for a given year n changes annually due to the new additions and refilling if any.

Table 4.37 SF_6 emissions from closed pressure electrical equipment

Year	Total nameplate installed (banked) capacity, tonne	Refilling, tonne	SF_6 emissions in $CO_{2\ eq.}$, tonnes
1999	0.068	0.0000	42.26
2000	0.068	0.0003	42.47
2001	0.068	0.0003	42.47
2002	0.1924	0.0003	119.77
2003	0.7915	0.0010	492.44
2004	1.9675	0.0040	1,225.06
2005	2.0145	0.0098	1,257.92
2006	2.4551	0.0101	1,531.86
2007	2.4551	0.0123	1,533.23
2008	2.4551	0.0123	1,533.23
2009	2.9601	0.0123	1,847.03
2010	3.7484	0.0150	2,338.59
2011	3.7739	0.0190	2,356.88
2012	3.9125	0.0191	2,443.09
2013	4.0725	0.0198	2,542.94
2014	4.1638	0.0206	2,600.17
2015	4.1638	0.0210	2,600.46
2016	4.1638	0.0210	2,600.46
2017	4.1638	0.0208	2,600.32

As for the Sealed Pressure distribution equipment, which is defined as equipment that does not require any refilling with gas during its lifetime, the emissions of SF_6 from such equipment are negligible.

Table 4.38 SF_6 emissions from Sealed Pressure distribution equipment

Year	Total nameplate installed (banked) capacity, tonne	SF6 emissions, $CO_{2\ eq.}$, tones
2003	0.02	0.87
2004	0.02	0.87
2005	0.02	0.87
2006	0.04	1.74
2007	0.04	1.75
2008	0.04	1.75
2009	0.04	1.75
2010	0.13	5.99
2011	0.13	5.99
2012	0.13	6.01
2013	0.13	6.01
2014	0.13	6.01
2015	0.13	6.01
2016	0.13	6.01
2017	0.13	6.01

Time Series

SF_6 emissions from closed pressure electrical equipment have grown continuously due to the ongoing reconstruction of the existing substations and the construction of new facilities with SF_6 containing gas circuit breakers (GCB) (Figure 4.31).

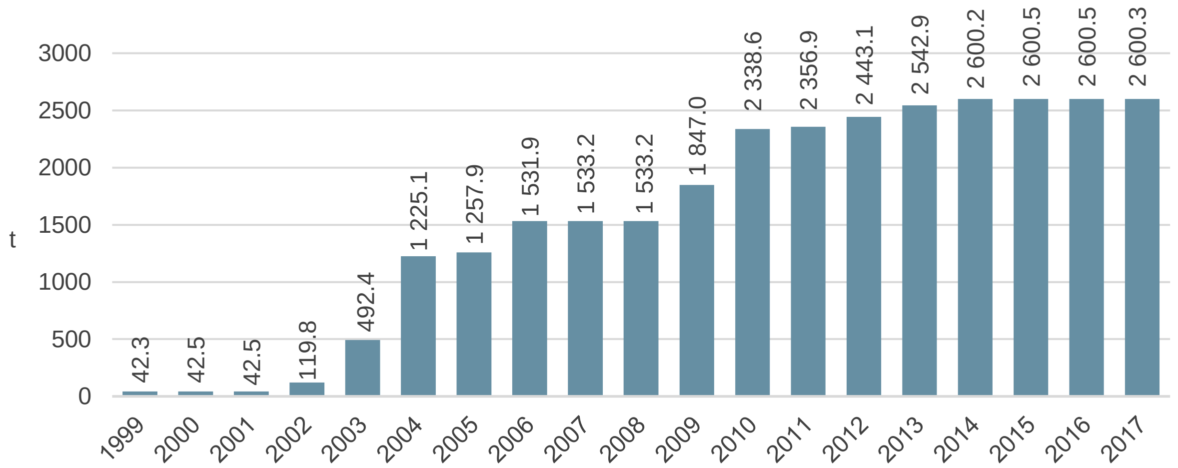


Figure 4.31 SF_6 emissions time series from closed pressure electrical equipment, $CO_{2\ eq.}$, tones

Uncertainty assessment

Uncertainties in the Default Emission Factors for Use of Closed-Pressure Electrical Equipment are estimated ±30 % [2006 IPCC Guidelines, Volume 3, Chapter 8, Table 8.5].

Uncertainties in AD were estimated ±10%.

Table 4.39 shows GHG emissions in IPPU sector in 2017, whereas Table 4.40 and Figure 4.32 show the complete time series for IPPU sector.

Information on the emissions of precursors is given in Table 2.2.

Table 4.39 GHG emissions in IPPU Sector, 2017

Categories	(Gg)			$CO_{2\ eq.}$ (Gg)	
	CO_2	CH_4	N_2O	HFCs	SF_6
2 – Industrial processes and product use	262.574	NA,NO	NA,NO	685.337	2.594
2.A – Mineral Industry	258.336				
2.A.1 – Cement Production	224.551				
2.A.2 – Lime production	28.352				
2.A.3 – Glass Production	5.433				
2.B – Chemical Industry	NO	NO	NO	NO	NO
2.C – Metal Industry	NA,NO	NA,NO		NO	NO
2.C.2 Production of Ferroalloys	NA	NA			
2.C.7 – Other: Primary Copper Production					
2.D – Non-Energy Production Fuel and Solvent Use (6)	4.237				
2.D.1 – Use of Lubricants	3.991				
2.D.2 – Use of solid paraffin	0.246				
2.D.3 – Use of Solvents					
2.D.4 - Other (3), (8)					
2.E – Electronics Industry				NO	NO
2.F - Use of substitutes for ozone depleting substances				685.337	
2.F.1 – Refrigeration and Air Conditioning				653.921	
2.F.1.a – Refrigeration and Stationary Air Conditioning				560.255	
2.F.1.b – Mobile Air Conditioning				93.667	
2.F.2 – Foam Blowing Agents				23.008	
2.F.3 – Fire Protection				0.636	
2.F.4 - Aerosols				7.772	
2.G – Production and Use of Other Products			NA,NO		2.594
2.G.1 – Electrical Equipment					2.594
2.G.1.b – Use of Electrical Equipment					2.594
2.H - Other					
2.H.2 – Food and Beverage Industry					

Note: Emissions from all sub-categories not shown in this table are not occurring in Armenia. Emissions of PFCs, NOx and CO are not occurring in Armenia from this sector.

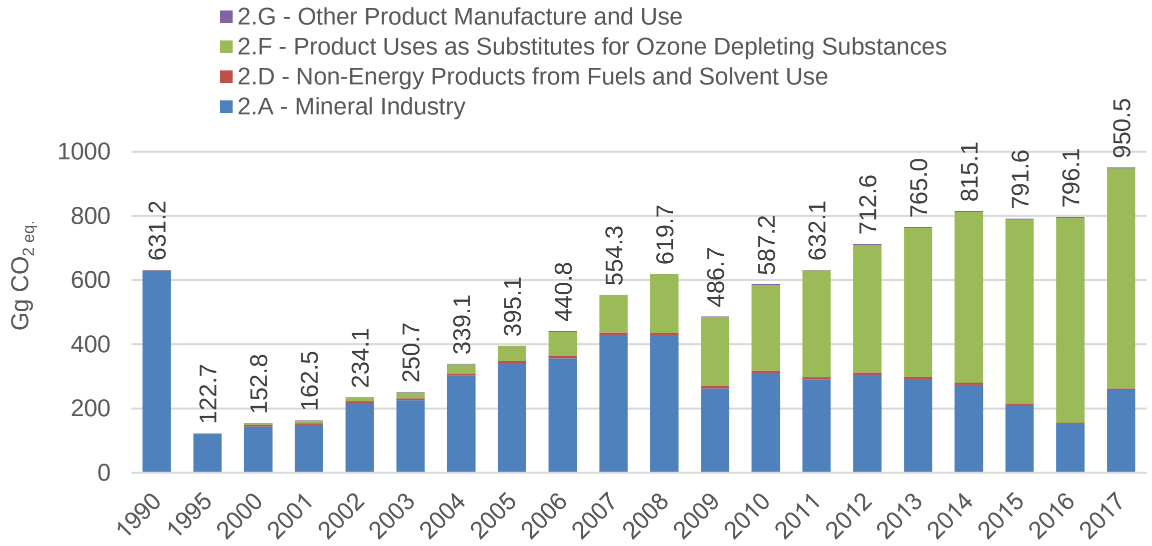


Figure 4.32 IPPU Sector emissions time series, 1990-2017, Gg $CO_{2\ eq.}$

Table 4.40 Time series of GHG emissions from IPPU Sector, Gg $CO_{2\ eq.}$

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
2.A - Mineral Industry	630.3	120.0	144.3	341.0	311.1	290.8	305.1	291.9	273.6	210.7	151.8	258.3
2.D - Non-Energy Products from Fuels and Solvent Use	0.8	2.7	4.5	7.7	7.1	7.1	7.1	7.1	7.1	4.9	4.1	4.2
2.F - Product Uses as Substitutes for Ozone Depleting Substances	-	-	4.0	45.1	266.6	331.8	397.9	463.5	531.7	573.4	637.7	685.3
2.G - Other Product Manufacture and Use	-	-	-	1.3	2.3	2.4	2.4	2.5	2.6	2.6	2.6	2.6
Total	**631.2**	**122.7**	**152.8**	**395.1**	**587.2**	**632.1**	**712.6**	**765.0**	**815.1**	**791.6**	**796.1**	**950.5**

4.3 Agriculture, Forestry and Other Land Use Sector

4.3.1 Sector description

Armenia's Agriculture, Forestry and Other Land Use Sector includes the following source categories and subcategories [Gen-1]:

(3A) Livestock:

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

(3B) Lands:

- (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 the key ones both with the level and trend assessment: *(3A1) Enteric Fermentation from Cattle* (CH_4), *(3B1a) Forest Land Remaining Forest Land* (CO_2) and *(3C4) Direct N_2O Emissions from Managed Soils*.

(3C5) Indirect N_2O Emissions from Managed Soils and *(3.A.1.b-j) Enteric Fermentation - Other (CH_4)* were identified as the key ones in terms of only Level and *(3.B.6.b) Land Converted to Other Land (CO_2)* - with Trend assessment.

4.3.3 Improvements made

Within the frames of the 2017 NIR the following improvements have been made in the Agriculture, Forestry and Other Land Use Sector inventory:

- *Improved accuracy:*
  - Improved accuracy of certain activity data on cattle, in particular: live weight of cows, digestive energy, live weight of growing cattle, the quantities of excreta per cattle.
  - The shares of manure used as fuel and fertilizer have been adjusted.
  - Applying Tier 2 method and improved parameters for assessing the emissions from

enteric fermentation and manure management, namely:

✓ Methane emissions from enteric fermentation from *Buffalo* and *Sheep* sub-categories were assessed applying Tier 2 Approach.

✓ Methane and nitrogen oxide emissions from manure management for *Cattle,* Buffalo and *Sheep* sub-categories were assessed applying Tier 2 Approach.

- The land structure in the *Grassland* category has been adjusted for organic soils (there are no organic soils in Armenian grassland).

- *Improved transparency:*
  - Reallocation of all national land use categories in line with 2006 IPCC Guidelines.
  - Based on the "Procedure for Classification of the Land Area Coverage of the Republic of Armenia" which was approved by the GoA Decision # 431-N of April 11, 2019, the national classification of lands has been adapted to the 6 categories of Land Use provided in 2006 IPCC Guidelines [Gen-1] (Land Classification is presented in Section 4.3.5.1).
- *Improved completeness:*
  - New subcategory - *Emissions from biomass burning in croplands* (3.C.1.b.) has been considered.
  - Emission estimates in *GHG emissions from biomass burning category* (3.C.1) include nitrogen oxide and carbon oxide emissions.

4.3.4 Agriculture

4.3.4.1 Overview of *Agriculture* sector emissions assessment

In 2017 *Agriculture* sector emissions amounted to 1965.4 Gg $CO_{2\ eq.}$ (18.5% of total emissions) - a decrease of about 14% compared to the previous year.

Emissions from the *Agriculture* sector include methane (CH_4) emissions from enteric fermentation of domestic livestock, manure management and biomass burning, nitrous oxide (N_2O) emissions from manure management, biomass burning and from managed soils, as well as CO_2 emissions from urea application.

Of the total agricultural emissions, CH_4 emissions from enteric fermentation accounted for 49.5% and from manure management 1.8%, while N_2O emissions from manure management (3A2 and 3C6) accounted for 4.8% and from soils - 43.4%.

The prevailing part (87%) of CH_4 emissions from enteric fermentation are generated by cattle while the prevailing part of N_2O emissions – about 90%, are from managed soils.

4.3.4.2 Description of *Agriculture* sector

According to the 2006 IPCC Guidelines [Gen-1], *Agriculture* sector includes the following categories and subcategories:

3A Livestock:

- (3A1) Enteric Fermentation (CH_4)
  - 3A1a Cattle

    3A1ai Dairy Cows

    3A1aii Other Cattle

- 3A1b Buffalo
- 3A1c Sheep
- 3A1d Goats
- 3A1f Horses
- 3A1g Mules and Asses
- 3A1h Swine
- 3A1j Others (Rabbits and Fur bearing animals)

- (3A2) Manure Management (CH_4 and N_2O)
  - 3A2a Cattle
    - 3A2ai Dairy Cows
    - 3A2aii Other Cattle
  - 3A2b Buffalo
  - 3A2c Sheep
  - 3A2d Goats
  - 3A2f Horses
  - 3A2g Mules and Asses
  - 3A2h Swine
  - 3A2i Poultry
  - 3A2j Others (Rabbits and Fur bearing animals)

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

Emissions in this category are caused by the burning of biomass and the use of fertilizers (gases CH_4 and N_2O).

The following categories were reviewed:

- 3C1 GHG emissions from biomass burning
  - 3C1a Emissions from biomass burning in forest land
  - 3C1b Emissions from biomass burning in cropland
  - 3C1c 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 Methodologies, activity data and emission factors

4.3.4.3.1 Livestock (3A)

4.3.4.3.1.1 Enteric fermentation (3A1)

Methodology

GHG emissions from cattle, buffalo and sheep enteric fermentation were estimated according to the 2006 IPCC Guidelines Tier 2 Approach [Gen-1, Volume 4] by applying country-specific emission factors.

Methane emissions from enteric fermentation of other animals were estimated by Tier 1 Approach applying emission factors for developing countries [Gen 1, Volume 4].

Activity data

Livestock population

The number of livestock (Table 4.41) is the key indicator for estimating GHG emissions from enteric fermentation. The livestock annual average population was calculated by using publicly available statistical information as well data provided by official statistics in response to the inquiry of the Ministry of Environment [Annex 3.1].

As a whole, for calculating the average annual livestock population and emission factors of the cattle, the following activity data was used according to the sources:

1. Data published by the Statistics Committee (SC) of RA:
    - Livestock population (by category and sub-categories) as of January 1 of each year
    - Cattle and poultry sold for slaughter (total live-weight, thousand tonnes, annually)
    - Animals and poultry sold for slaughter by slaughter weight, in thousand tonnes, for each animal sub-category including by commercial organizations and households; on monthly basis,
    - Data on the number of cattle slaughtered and lost in commercial organizations;
    - Exports and imports of domestic animals (quantity, live-weight)
    - Annual average milk production.
2. Data on the average live-weight of domestic animals (kg), feed digestibility (%), growing cattle average weight gain per day (kg/day), manure dumping and the shares of manure used for burning and as fertilizer provided by the RA Ministry of Agriculture (RA Ministry of Economics since 2019).

The following activity data were used to calculate livestock annual average population by species/categories:

- population data at the beginning and at the end of year, livestock import and export data as well as estimates of the number of slaughtered, lost and born livestock,
- data on sales of meat and slaughtered animals, as most of the animal raised for meat production (calves, lambs, swine, birds, rabbits) are alive just for a limited time during the year and their number is neither reflected in the official statistics of the beginning-of-the-year nor at the end of the year.
- distribution of slaughtered cattle and swine by months based on monthly volumes of meat produced, while the livestock population of lost cattle by months was distributed proportionally;
- new born animals were distributed on monthly bases, based on the practice of organizing animal births in Armenia.

Thus, the average annual numbers of cattle and swine were calculated as arithmetic average by monthly values for 12 months, and not as arithmetic average at the beginning and end of the year. This calculation approach results in difference between official statistics on livestock population as of January 1 (SC and FAO data) and data on livestock average population used in GHG Inventory.

For the calculation of the annual average population of poultry the following data were used: the number of livestock population 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 2017 the total population of poultry for slaughter was 6696.8 thousand heads. Based on this, the annual average number of broilers intended for slaughtering was calculated using the Equation 10.8 proposed in the Guideline:

$$AAP = (Days\ alive) \cdot \frac{NAPA}{365}$$ *[Gen-1, Volume 4, Chapter 10, p. 10.8].*

Where:

AAP = annual average population

NAPA = number of animals born annually

As a result, the average annual number of slaughtered (broilers) birds in 2017 was 1,100.8 thousand heads.

The average annual number of poultry was calculated by summing the average annual number of birds with the number of birds killed during the year.

Similarly, the average annual rabbit livestock population for 2017 was calculated. Many households in Armenia are engaged in rabbit breeding for meat, fur, and fennel. Domestic rabbits are premature and characterized by intense growth. They can multiply year-round. They reach adulthood in 3-4 months. The duration of pregnancy is 28-32 days. A single rabbit can bear 3-6 times a year (each yields 6-8, sometimes up to 15 or more cubs). The live weight of newborn rabbit is 60-70 grams, it doubles on the 6th day and increases 9-10 times in 30 days.

The average annual number of slaughtered rabbits was calculated using equation 10.1 [Gen-1, Volume 4, Chapter 10, page 10.8] by using the following data:

- Maternal rabbit head count - 70% of rabbits' arithmetic average at the beginning and at the end of the year (Appendix 3.1).
- The number of cubs born per mother rabbit - 6 points
- The life expectancy of slaughtered rabbits - 120 days.
- This data is then added to the arithmetic average of rabbits at the beginning and at the end of the year. According to the estimates, in 2017 the average annual number of rabbits was 66,604.

The annual average populations of buffalos, horses, mules and asses were calculated by using the average arithmetic number of the livestock by 1 January 2017 and 2018.

The methodology for calculating the annual average number of livestock population was provided in details in the Third National Communication's National Inventory Report [Ref-4, AFOLURef-1].

As a result of the calculations, the following data were obtained (Table 4.41), which were used for calculating greenhouse gas emissions from livestock.

Table 4.41 Livestock annual average population, heads

Livestock	2016	2017	2017 in comparison with 2016, %
Cattle, ***from which***	**841,530**	**729,117**	**87**
Dairy Cows	360,461	329,232	91
Bulls	*29,206*	*29,017*	*99*
Growing cattle	451,862	370,868	82
Buffalo	**703**	**719**	**102**
Sheep, *from which*	**983,369**	**909,043**	**92**
Ewes	492,312	465,273	95
Other sheep	491,057	443,771	90
Goats, ***from which***	**40,717**	**34,671**	**85**
Nanny goats	20,723	17,927	87
Other goats	19,994	16,744	84
Horses	**11,017**	**10,340**	**94**
Mules and Asses	**2,450**	**1,949**	**80**
Swine, *from which*	**404,384**	**395,128**	**98**
Sows	34,360	32,123	93
Other swine	370,024	363,005	98
Rabbits	**67,625**	**66,604**	**98**
Fur bearing animals	**4,817**	**9,502**	**197**
Poultry	**4,794,469**	**5,211,134**	**109**
Broiler	2,083,464	2,552,527	123
Laying hens	2,711,005	2,658,607	98

Source; Expert calculation according to the information of the RA Statistics Committee and Ministry of Economy

As it can be seen from Table 4. 41, there was a decrease in the number of livestock in 2017 in comparison with 2016 (with the exception of buffalo and fur-bearing animals whose impact on the volume of GHG emissions from *Agriculture* is insignificant).

Quality Assurance/Quality Control

Completeness and accuracy of activity data are essential for emissions assessment, which means that all the categories of animals managed in the country should be considered.

At the same time, before using the data, it is necessary to analyze how the data was collected, processed and aggregated by the statistical body or relevant ministry, and to what extent the data reflected the actual situation. For example, as was stated above, data on the number of domestic animals are published by the SC 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. To this purpose, additional data were collected and analyzed enabling to get complete information on the livestock annual population which means that according to the Guidelines [Gen-1], 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.

For the purpose of verifying the accuracy of the data calculated by the methodology used for defining livestock population, 2014 census data on agriculture results were compared with those received applying the said methodology. During the general census of agriculture, the number of livestock population was registered as that of October 10, 2014. It was revealed that census data on annual livestock population was higher than those published by the SC of RA (as of January 1 of each year) while difference between census data and data calculated by applying the said methodology was much less.

Activity data uncertainty

According to the 2006 IPCC Guidelines the uncertainty associated with populations will vary widely depending on source, but shouldn't exceed the ± 20% range.

The possible uncertainty of cattle population is estimated as 4.2% (expert judgement). At the same time, according to the monitoring conducted by the Agriculture department of RA SC, during the livestock population census deviation on population data were assessed up to 3% as of January 1. As a result, the possible uncertainty of cattle population is estimated about from ±8% to ±10% due to the existing deviations in data on livestock population.

Emission factors

The emissions from enteric fermentation of cattle as well as of buffalo and sheep were estimated by applying Tier 2 Approach using the animals' country-specific characteristics and emission factors.

Emissions from enteric fermentation of other animals were estimated by 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 along with data required for the estimation, are provided in Annexes 3.1 - 3.7, including: 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.

As a result, the following country-specific emission factors for cattle have been obtained (Table 4.42):

- Cows - 68.9 kg methane/head/year
- Bulls - 70.1 kg methane/head/year
- Growing cattle - 42.3 kg methane/head/year
- Buffalo - 71.8 kg methane/head/year
- Sheep - 5.6 kg methane/head/year

which means that the country-specific emissions factors for cattle calculated using more accurate activity data have decreased. Thus, the country-specific emission factor for dairy cows in 2016 was 82.7 kg methane/head/year, while it decreased making 68.2 kg methane/head/year when recalculated with new accurate data.

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]. Therefore, uncertainty of the emission factor for the cattle was estimated ±20%.

The differences between default emission factors provided in the Guideline [Gen-1] and the national ones are caused by differences in regional characteristics (activity data). Thus, in the Guideline for Asia average milk production of 1,650 kg per head/yr (4.5 kg per day), with an average live weight of dairy cows of 350 kg (table 10A.1) and default emission factor of 68 kg methane/year are provided for cattle [Gen-1, Volume 4, Table 10.11]. While in Armenia, in 2017 according to SC of RA data, the average annual milk production of cows was 2,260 kg per head or approximately 6.2 kg / day and according to data provided by the Ministry of Economy the average live weight of cows in 2017 was 407 kg.

In case of buffalo, bulls and young, the differences are much greater, which has led to a greater variance between the country-specific emission factor and the default ones [Gen-1, Volume 4, Chapter 10].

The Table 4.42 provides a comparison of the default emission factors [Gen-1, Volume 4, Table 10.11, Asia] and country-specific ones.

Table 4.42 Comparison of Emission Factors (kg/head/year), 2017

Cows		Bulls		Growing cattle		Buffalo		Sheep	
Guide-line	Country-specific	Guide-line	Country-specific	Guide-line	Country-specific	Guide-line	Country-specific	Guide-line	Country-specific
68	68.9	47	70.1	47	42.3	55	71.8	5	5.6

Time Series

Consistent time series have been developed for 1990-2017 applying new methodology for defining activity data for the whole period.

According to the adjusted data on the cattle activity, the country-specific emission factor for enteric fermentation has decreased. As a result of the recalculation of the time series methane emissions have decreased by about 10% for all years. Thus, in 2016 methane emissions from enteric fermentation amounted to 1218.9 Gg $CO_{2\ eq.}$, while recalculated ones made 1095.3 Gg $CO_{2\ eq.}$ or about 10% less.

The decrease in number of livestock in 2017 as compared to 2016 resulted in the lower CH_4 emissions from enteric fermentation and emissions from manure management (Figures 4.33 and 4.34).

Time series of methane emissions (Gg $CO_{2\ eq.}$) from livestock enteric fermentation from 1990 to 2017 are presented in Figure 4.33.

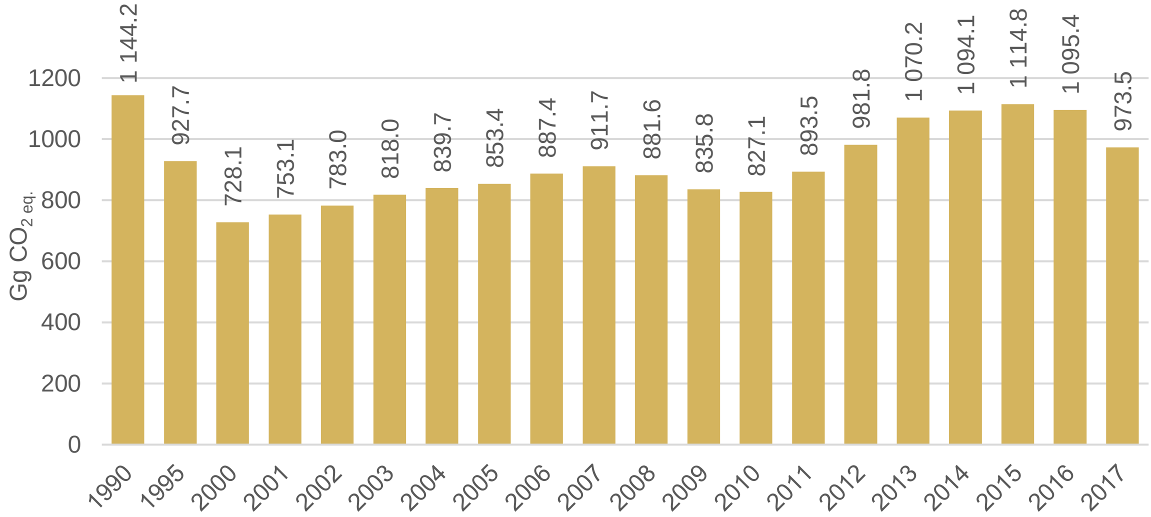


Figure 4.33 Methane emissions from livestock enteric fermentation, Gg $CO_{2\ eq.}$

As it can be seen from the time series, during 1990-2017 period three stages of change in the volumes of emissions from enteric fermentation are visible. This was mainly due to the changes in number of livestock (change in other factors affecting emissions from 1990-2017 was insignificant, except for milk output which was on a growing trend).

- In 1990s the structural changes in agriculture have resulted in decrease of farm size and decrease in the numbers of domestic livestock which have led to corresponding decrease of emissions from livestock.
- During 2000-2007 the economic growth in the country has also contributed to the development of livestock breeding in agriculture and corresponding increase of emissions. The crisis of 2008-2010 has affected agriculture as well, which is visible in a lower emission.
- Emissions increase during 2011-2015, followed by a decrease in the number of livestock and corresponding decrease of emissions since 2016.

4.3.4.3.1.2 Manure management (3A2)

Methodology and emission factors

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.

Emissions from manure management have been calculated with adjusted (more accurate) data.

Adjustment of activity data in case of manure management refers not only to the quantity of the manure produced but also to the change in the portions of manure burned as dung and used as fertilizer: now 53% as fuel and 47% as fertilizer, instead of former 70% as fuel and 30% as fertilizer.

It is worth to be mentioned that the quantities of manure used as fuel calculated with the adjusted data correspond to the quantities of manure in the Energy balance of Armenia obtained as a result of the Household Survey conducted by the SC of RA.

Methane emissions

There are two main types of activity data for estimating CH_4 emissions from manure management: (1) animal population data; and (2) manure management system usage data.

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, Volume 4, Chapter 10].

In Armenia, according to the data of the Ministry of Economics (AFOLUREF-7) and expert judgement, up to 38.5% 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 as fuel.

Methane emissions from manure management for the cattle, buffalos and sheep were calculated using Tier 2 methodology as these particular livestock species/categories with the exception of buffalos are responsible for the significant share of the country's emissions. Detailed information on animal characteristics and manure management practices were used to develop emission factors specific to the conditions of the country. In the meantime, considering that country-specific data is available for only a portion of the variables, country-specific emission factors were calculated using the data in Tables 10A-4 through 10A-9 [Gen-1, Volume 4] to fill gaps [Gen-1, Volume 4, Chapter 10, p.10.42].

Methane emissions from manure management for other livestock categories were calculated using Tier 1 methodology with country specific activity data and using methane emission factors for developing countries considering that annual average temperature in Armenia is below 10°C (AFOLURef-8, AFOLURef-9).

Uncertainty assessment

The uncertainty of the emissions from manure management is due to the uncertainty of the activity data (the number of animals per species and management systems usage data) and the uncertainty of the emission factors.

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, Page 50]. 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 25%.

Emission factors uncertainty

The uncertainty range for the default emission factors is estimated to be +30% [Gen-1, Volume 4, Chapter 10 p.4.4].

As a result, the combined uncertainty of methane emissions was estimated to be 39%.

Time series

The consistence time series have been calculated for the 1990-2017 period with adjusted activity data.

While time series trends have remained unchanged, as they are largely dependent on changes in livestock number, methane emissions have decreased up to 60% compared to the calculations with not adjusted activity data.

Time series of methane emissions (Gg $CO_{2\ eq.}$) from manure management are presented in Figure 4.34.

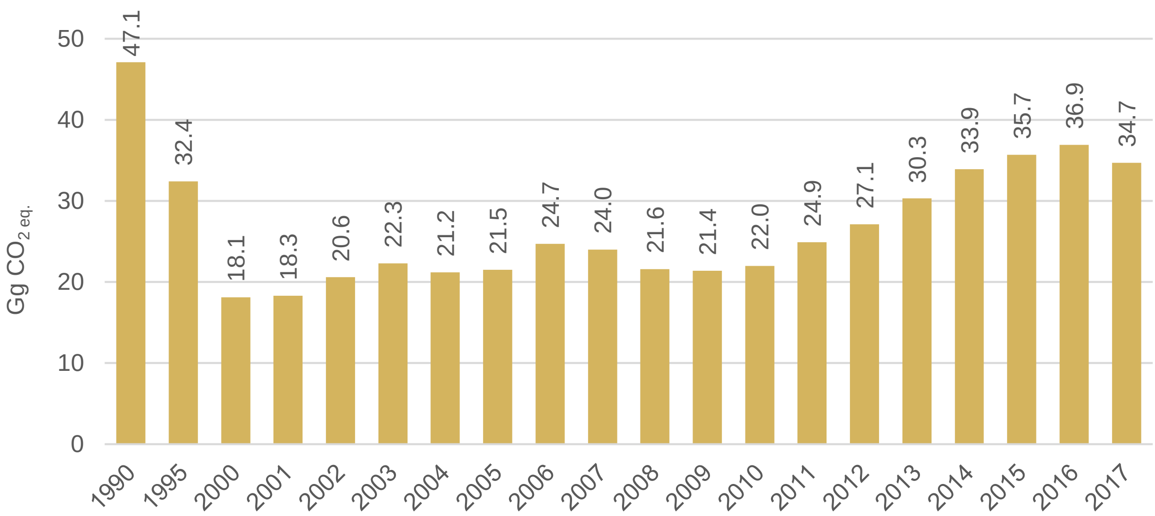


Figure 4.34 Methane emissions from manure management, 1990-2017, Gg $CO_{2\ eq.}$

Nitrous oxide emissions

Direct N_2O emissions

Nitrous oxide emissions from manure management of the cattle, buffalos and sheep were calculated using Tier 2 methodology, and for other livestock categories - using Tier 1 methodology with country specific activity data and using the default emission factors per manure management system [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 [Annex 10A.2, Tables 10A-4 to 10A-8 for default management system allocations].

The Tier 2 method follows the same calculation equation as Tier 1 but includes the use of country-specific data for some or all of these variables, for example, the use of country-specific nitrogen excretion rates for livestock categories. Annual N excretion rates for livestock categories was calculated applying Equation 10.31 [Gen-1, Volume 4] and using country-specific data.

Indirect N_2O emissions

The Tier 1 and Tier 2 calculations 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 (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-9] and default fractions of N losses from manure management systems due to volatilization [Gen-1, Volume 4, Table 10.22].

In the case of cattle, buffaloes and sheep, country-specific nitrogen excretion factors were used.

Time series

Consistent time series have been calculated for the 1990-2017 period with adjusted activity data.

Time series trends have remained unchanged as they are largely dependent on changes in livestock number, while nitrogen oxide emissions have decreased up to 30% compared to the calculations with not adjusted activity data.

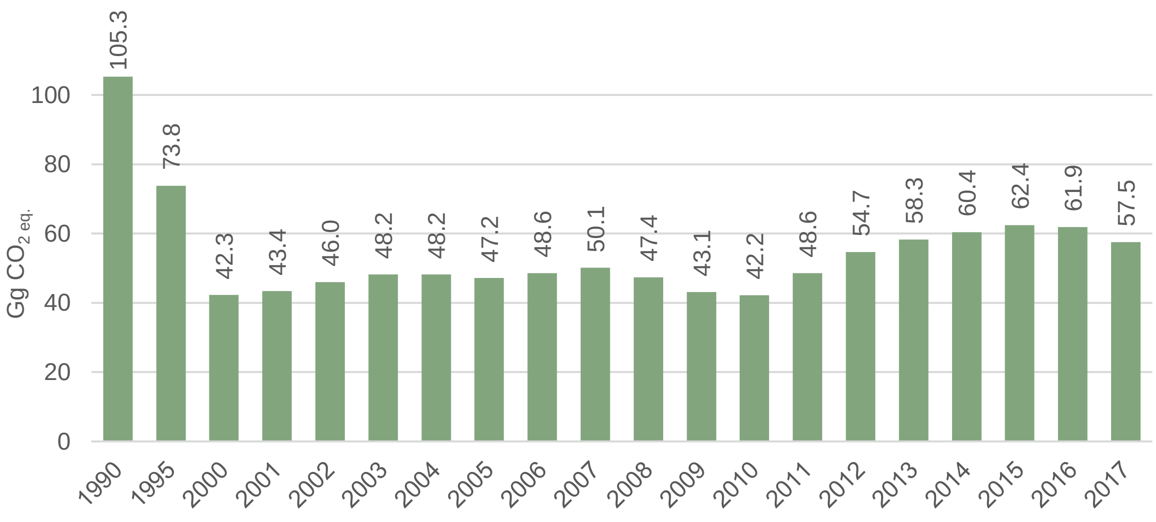


Figure 4.35 Nitrous oxide emissions from manure management, 1990-2017, Gg $CO_{2\ eq.}$

4.3.4.3.1.3 Emissions from livestock category

Table 4.43 below provides methane and nitrous oxide emissions from *Livestock Enteric Fermentation* and *Manure Management*.

Table 4.43 Methane and nitrous oxide emissions from *Livestock Enteric Fermentation* and *Manure Management*, Gg

Livestock	2017	
Categories	**CH_4**	**N_2O**
3.A Livestock	**48.011**	**0.185**
3.A.1 Enteric Fermentation	**46.357**	**NA**
3.A.1.a Cattle	**40.430**	
3.A.1.a.i Dairy Cows	22.704	
3.A.1.a.ii Other Cattle	17.725	
3.A.1.b Buffalo	0.052	
3.A.1.c Sheep	5.090	
3.A.1.d Goats	0.173	
3.A.1.f Horses	0.186	
3.A.1.g Mules and Asses	0.019	
3.A.1.h Swine	0.395	
3A1j Other (Rabbits, Fur bearing animals)	0.012	
3.A.2 Manure Management	**1.653**	**0.185**
3.A.2.a Cattle	0.588	0.014
3.2.1.a.i Dairy Cows	0.321	0.007
3.2.1.a.ii Other Cattle	0.267	0.007
3.A.2.b Buffalo	0.001	0.000
3.A.2.c Sheep	0.172	0.148
3.A.2.d Goats	0.004	0.003
3.A.2.f Horses	0.011	0.000
3.A.2.g Mules and Asses	0.001	0.000
3.A.2.h Swine	0.790	0.010
3.A.2.i Poultry	0.075	0.011
3A2j Other (Rabbits, Fur bearing animals)	0.012	0.000

In comparison to 2016, in 2017:

- Methane emissions from enteric fermentation of livestock decreased by 11%.
- Nitrogen oxide emissions from manure management decreased by 7.5% and methane emissions by 6.0%.

Decrease of emissions from Livestock is due to decrease in number of livestock and especially cattle (which is responsible for about 87% of methane emissions) (Table 4.41, AFOLURef-2, AFOLURef-3), namely: compared to 2016 in 2017 the number of cattle decreased by 13%, from which the number of cows decreased by 9%, bulls - by 1% and young – by 17%. With the exception of furry animals (increase by 197%) and birds (increase by 109%), number of other livestock was reduced as well: swine – by 2%, sheep - by 8% and goats - by 15%.

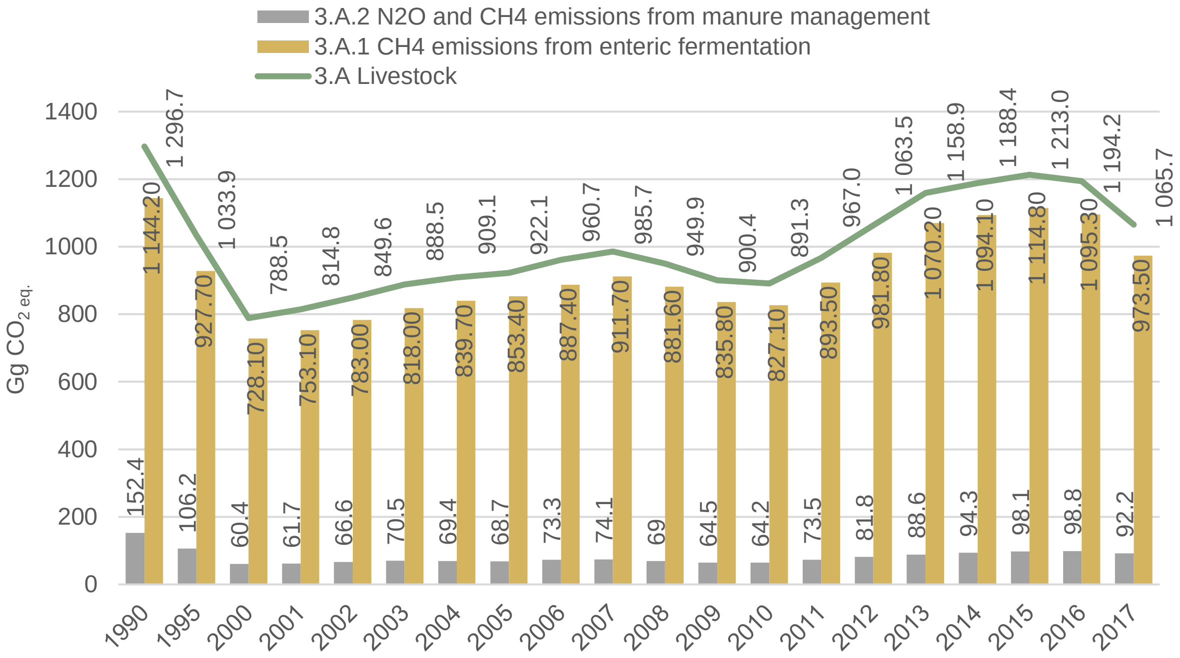


Figure 4.36 GHG emissions from *Livestock* 1990-2017, Gg $CO_{2\ eq.}$

4.3.5 Lands (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 the 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) Industrial, sub-soil use and other industrial purpose lands
4) Energy, transport, communication, public utility infrastructure lands
5) Specially protected areas

6) Special significance
7) Forest
8) Water land
9) Reserve lands.

According to the IPCC Guideline [Gen-1, Volume 4] 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 considering the "Procedure for the Classification of the Land Coverage of the Republic of Armenia" approved by the GoA Resolution 431-N of April 11, 2019:

1. The following were included in the *Forest Land*:

- 100% of forest land,
- Forests of specially protected areas,
- Shelter forests from agricultural land.

2. The following were included in the *Cropland*:

- From agricultural lands: 100% of arable land and 100% of perennial plants,
- From forest land: 100% of arable land,
- From Settlements: 60% of home garden plots and gardening lands

3. The following were included in the *Grassland*:

- From agricultural lands: 100% of hay-land, 100% of pasture and 20% of other lands,
- From Settlements: mixed construction and general use lands, public and other lands,
- From specially protected areas: Non-Forest land and Non-flooded areas,
- From areas of special significance: Non-Forest land and Non-flooded areas,
- From forest lands: 100% of hay-land and arable land and 20% of other land.

4. The following were included in the *Wetlands:*

- From subsoil use lands those used for peat extraction,
- Areas of lakes, reservoirs, hydro-technical and other water engineering facilities

5. The following were included in *Settlements:*

- From Settlements 100% of lands for housing construction, 40% of home garden plots and gardening lands
- From Industrial, sub-soil use and other industrial purpose lands with the exception of subsoil use lands: lands without vegetation
- Energy, transport, communication, public utility infrastructure lands
- From Specially protected areas: lands intended for healthcare, recreation, as well as of cultural and historical significance

6. In *Other Lands* were included lands without vegetation (shores of lakes and rivers, sandstones, bare rocks and mother rocks), in particular:

- From agricultural lands: 80% of other lands,
- From forest land: 80% of other lands,
- A portion of sub-soil use lands and lands of Special significance,
- From specially protected areas: areas of lakes and ponds,
- Offshore land areas, river and canal areas,
- Reserve lands.

Table 4.44 presents the harmonization of the country's national land-use classification with 2006 IPCC Guidelines Land Use categories, as of 2017.

Table 4.44 Harmonization of the national land-use classification[8] with 2006 IPCC Guidelines Land Use categories, ha, 2017

National land-use classification	RA Land Balance, ha	IPCC Guidelines Land Use categories, ha						
		3B1 Forestland	3B2 Cropland	3B3 Grassland	3B4 Wetland	3B5 Settlement	3B6 Other Land	Total, ha
1. Agricultural	**2,044,464.8**	**793**	**480,913**	**1,249,979**			**312,780**	**2,044,464.8**
1.1. arable land	445,564.5		445,565					445,564.5
1.2. perennial plants	35,348.3		35,348					35,348.3
1.2.1 orchards	21,052.6		21,053					21,052.6
1.2.2 grape vines	14,268.1		14,268					14,268.1
1.2.3 other perennial plants	27.5		28					27.5
1.3. hay-land	121,040.1			121,040				121,040.1
1.4. pastures	1,051,536.54			1,051,537				1,051,536.5
1.5. other types of lands	390,975.3	793		77,402			312,780	390,975.3
2. Settlements	**151,866.7**		**56,746.9**	**52,685.9**		**42,434**		**151,866.7**
2.1 housing construction	99,180.8					4,602.7		4,602.7
2.1.1 home garden plots	89,889.3		53,933.6			35,955.7		89,889.3
2.1.2 gardening lands	4,688.8		2,813.3			1,875.5		4,688.8
2.2 public building	7,806			7,806				7,806
2.3 Mixed construction	2,428.6			2,428.6				2,428.6
2.4 Common use lands	18,447.5			18,447.5				18,447.5
2.5 Other Lands	24,003.8			24,003.8				24,003.8
3. Industrial, sub-soil use and other industrial purpose lands	**38,428.5**				**489**	**23,447.9**	**14,491.6**	**38,428.5**
3.1 industrial facilities	9,991.5					9,991.5		9,991.5
3.2 agricultural production facilities	12,781					12,781		12,781
3.3 storages	675.4					675.4		675.4
3.4 Land allocated for the use of subsoil	14,980.6				489		14,491.6	14,980.6
4. Energy, transport, communication, public utilities infrastructures lands	**12,953.5**					**12,953.5**		**12,953.5**
4.1 energy	2,382.7					2,382.7		2,382.7
4.2 communication	146.1					146.1		146.1
4.3 transport	9,097					9,097		9,097

National land-use classification	RA Land Balance, ha	IPCC Guidelines Land Use categories, ha						
		3B1 Forestland	3B2 Cropland	3B3 Grassland	3B4 Wetland	3B5 Settlement	3B6 Other Land	Total, ha
4.4 Utility Infrastructure Objects	1,327.7					1,327.7		1,327.7
5. Specially protected areas	**335,578.2**	**59,013**	**15,952**	**117,389**		**18,439.7**	**124,784.8**	**335,578.2**
5.1 nature protection	317,679.5	59,013	15,952	117,389		541	124,784.8	317,680
5.2 healthcare	233.6					234		234
5.3 recreation	2,802.4					2,802		2,802
5.4 cultural and historical	14,862.7					14,862.7		14,862.7
6. Special significance	**30,524.1**			**18,314.46**		**12,209.6**		**30,524.1**
7. Forestry	**334,025.0**	**289,194.3**	**18,938.6**	**21,259.3**			**4,632.8**	**334,025**
7.1 forest	289,194.3	289,194.3						289,194.3
7.2 bush	18,682.8		18,682.8					18,682.8
7.3 arable land	255.8		255.8					255.8
7.4 hay-land	9,203.3			9,203.3				9,203.3
7.5 pasture	10,897.8			10,897.8				10,897.8
7.6 other lands	5,791			1,158.2			4,632.8	5,791
8. Water	**25,798.9**				**9,363.6**		**16,435.3**	**25,798.9**
8.1. rivers	8,298.9						8,298.9	8,298.9
8.2. reservoirs	7,007				7,007			7,007
8.3. lakes	5,838.5				810		5,028.5	5,838.5
8.4. canals	3,107.9						3,107.9	3,107.9
8.5. Hydro-technical and other water engineering facilities	1,546.6				1,546.6			1,546.6
9. Reserve	**620.4**						**620.4**	**620.4**
9.1. salts								
9.2. sands								
9.3. swamps								
9.4. other unused lands	620.4						620.4	620.4
Total	**2,974,260.1**	349,000.2	572,550.0	1,435,623.9	9,852.6	109,484.7	473,744.9	2,974,260.1

The Table 4.45 presents Land-Use conversion matrix

Table 4.45 Land-use matrix of RA, ha, 2017

Final\Initial	Forest land	Cropland	Grassland	Wetland	Settlement	Other Land	Total Final
Forest Land (Forest Covered)	349,000.2	940.4					349,940.6
Cropland		572,620					572,620.0
Grassland		122	1,459,627.5				1,459,749.5
Wetland				9,852.6			9,852.6
Settlement					110,305.7		110,305.7
Other Land	26.8	1,467				470,298	471,791.7
Total Initial	**349,027.0**	**575,149.4**	**1,459,627.5**	**9,852.6**	**110,305.7**	**470,298**	**2,974,260.1**
Net Changes	**-26.8**	**-2,529.4**	**0**	**0**	**0**	**0**	**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 was 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 was formed which will implement inspection functions for the purpose of forest preservation.

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 land types 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, 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 glades.

Table 4.46 provides Forest stock data by land types compiled from the forest management plans of the forest agencies.

Table 4.46 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 others)	Total non-forest land	
	Natural	Artificial	Total			Fired areas, totally logged areas, forest glades, rare forests (anthropogenic, biological)						
2017	315,514.4	33,485.8	349,000.2	3,458.1	135	49,353.4	401,946.7	1,913.1	11,599.1	41,087.2	54,599.4	456,546.1

According to 2006 IPCC Guidelines [Gen-1], *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, lands that did not undergo land use change in the past 20 years have been assessed. The area of these type of forests was estimated 348,060 ha in 2017 (Table 4.48).

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 were converted to forest lands as a result of land use change in the past 20 years. The area of these type of forests was estimated 940.4 ha in 2017 (Table 4.49).

4.3.5.2.1.1 Forest Land Remaining Forest Land (3B1a)

According to 2006 IPCC Guidelines [Gen-1], 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 and trend 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) [Gen-1, 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 (BCEFR) [Gen-1, 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 2017, 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 2017, as it was also observed in the previous years, caused by continuous forest clearing activities in “Sevan” National Park (LUCFRef-4).

The area of *Forest Land Remaining Forest Land* (A) within the country was 348,060 ha in 2017 (Table 4.48).

The information on the wildfires is presented in the Table 4.47.

Table 4.47 Wildfires areas, 2017

Year	Forest covered areas, ha	Non- forest covered areas, ha	Total, ha	Loss of wood, cubic m
2017	895	2,063	2,958	-

In 2017, the trees damaged before cessation of growth were stored per suitability (timber, fuelwood, dry wood (part of liter)) in accordance with the procedure established by law.

Emission factors

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

GW = 0.835 tonnes d.m. /ha

The GW 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 3.9) and basic wood density - 0.557 oven-dry tonnes/moist cubic meter (Annex 3.8).

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. annual /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 2017:

ΔC_G = 348,138 ha x 1.02705 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

The area of 349,000.2 ha in Table 4.46 represents the area of forest land category. In preparation for the greenhouse gas emission and removal estimation, this area should be further sub-divided into the area that has remained in the land-use category and area that has been affected by a land-use conversion (940.4 ha that was converted from cropland to the forest land) in the previous 20 years (Table 4.49).

Thus, the area which has been remained in this category equals to 349,000.2 ha - 940.4 ha = 348, 059.8 ha.

Table 4.48 Annual increase in biomass carbon stock

Indicators	2017
Covered area, ha	348,060
Biomass annual average growth per 1 ha, cubic meters	1.5
Carbon annual gains, C t/year	171,588
Annual volume of harvested fuelwood, cubic m /including fallen wood	85,373
Annual volume of timber harvested (commercial felling), cubic m	3314
Burned areas, ha	895
Annual carbon loss, C t/year	29,165

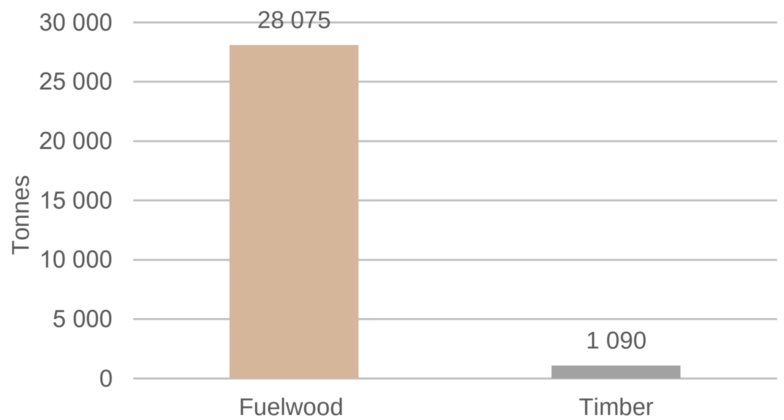


Figure 4.37 Carbon loss (tonne) caused by harvested fuelwood and commercial felling

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

As it can be seen from the figure, in 2017, 96.3% of annual carbon loss are caused by harvested fuelwood and 3.7% - by harvested timber.

Time series

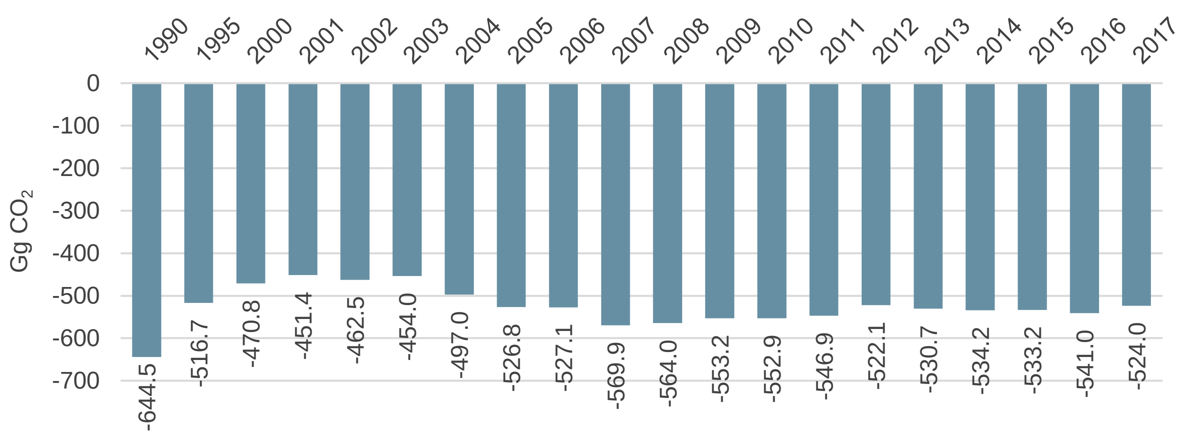


Figure 4.38 Carbon dioxide removals in *Forest Land Remaining Forest Land* sub-category

Decrease in removals in 2017 is due to continuous clean-up of coastal areas of Sevan National Park and the increased volume of the harvested wood.

4.3.5.2.1.2 Land Converted to Forest Land (3B1b)

This subcategory refers to areas converted to forest land as a result of afforestation activity and natural afforestation during the last 20 years.

In 2017 the area under this sub-category made 940.4 ha or increased by 51.4 ha compared to those in 2016 (LUCFRef -1, LUCFRef -2, LUCFRef-4, LUCFRef-20, LUCFRef-22), due to the adherent forest cultures inclusion in this sub-category (Table 4.49).

For comparison, Land converted to forest lands sub-category covered 598.9 ha in 2010.

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 62%) of the area covered by 14 tree species as well as of the cumulative stock (Table 4.49), therefore the weighted average factors derived for carbon stock change in living biomass mainly refer to pine trees.

Table 4.49 Area of tree species under *Lands Converted to Forest Land* sub-category, 2017

N/N	Species	Area, ha
1	Pine-tree	584.4
2	Oak-tree	70
3	Ash-tree	112
4	Maple	34
5	Birch-tree	2.9
6	Poplar	5.5
7	Pear	31.6
8	Apple-tree	60.1
9	Walnut tree	15.6
10	Sea-buckthorn	3.6
11	Locust	2.3
12	Siberian pea shrub	10.5
13	Plum tree	0.9
14	Other species	7
	Total	**940.4**

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 0.3% of annual total removals by all forest lands.

Table 4.50 Annual change in carbon stock of living biomass (including aboveground and belowground biomass)

Indicator	2017
Covered area, ha	940.4
Biomass annual average growth per 1 ha, cubic m	1.5
Carbon annual gains, C t/year	464

Improvements required

There is a lack of complete and reliable data on the recent changes in forest lands because of the above 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.

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 as will enable the 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 therein 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 Cadastre Committee under RA Government. Distribution of agricultural land according to the crop types in the categories *Cropland* and *Grassland* was based on the agricultural crops sown areas data published by RA SC.

CO_2 emissions and removals were estimated based on carbon stock change in the 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)

Emissions assessment for *Cropland* category 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 harmonizing national classification of lands with 2006 IPCC Guidelines Land Use categories (Table 4.45).

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.

The Tier 1 method assumes that the dead wood and litter stocks are not present in Cropland or are at equilibrium as in agroforestry systems and orchards. Thus, there is no need to estimate the carbon stock changes for these pools [Gen-1, Volume 4, Chapter 5].

CO_2 emissions and removals have been calculated due to changes of carbon stocks in biomass and in mineral soils. There are no organic soils in Armenia, so no emissions were calculated from such type of soil.

Land Converted to Cropland (3B2b)

In 2017 there was no land-use conversion to Cropland from other categories.

4.3.5.2.3 *Grassland* (3B3)

The area of *Grassland* has been adjusted both for 2017 and previous years in accordance with the "Procedure for the Classification of the Land Coverage of the Republic of Armenia" approved by the GoA Resolution 431-N of April 11, 2019 (AFOLURef-6, 7, 8, 9).

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.

Considering that *Grassland* is not a key source and data on grassland management practices are not available, the Tier 1 assumption of no change in biomass was applied [Gen-1, Volume 4, Chapter 6]. The assumption in Tier 1 is that the biomass in all *Grassland Remaining Grassland* is stable.

Emissions and removal in this sub-category are estimated based on carbon stock change in mineral soils.

Grassland areas were stratified by IPCC climate regions and soil types by using three approaches recommended by the Guidelines [Gen-1, Volume 4]. Such stratification 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 soils.

4.3.5.2.4 *Wetlands* (3B4)

In Armenia Wetlands cover around 1800 km^2, slightly more than 6% of the country’s territory. Of them 90% is open water (lakes, ponds, rivers, reservoirs, canals), 8% is temporarily flooded area (including saline lands), and only 2% are permanent marshes, fens and peatlands. The area of peatlands (mires) is estimated 42 km^2, or only 0.14% of the territory of the country.

Methodology

Emissions assessment was done using 2006 IPCC Guidelines [Gen-1], 2013 Supplement to 2006 Guidelines: Wetlands [Gen-6] and 2013 Reviewed Additional Methods and Best Practice Guide [Gen-7].

Methodologies are provided for [Gen-1, Volume 4, Chapter 7]:

- Peatlands cleared and drained for production of peat for energy, horticultural and other uses
- Reservoirs or impoundments for energy production, irrigation, navigation, or recreation

In Armenia wetlands, peatlands, water storage reservoirs and Lake Sevan meet these criteria.

Total CO_2 emissions from wetlands are estimated as the sum of emissions from two types of managed wetlands [Gen-1, Volume 4, Equation 7.1]:

$$CO_{2\_W} = CO_{2w\_peat} + CO_{2w\_flood}$$

Where:

CO_{2_W} = CO_2 emissions from Wetlands, Gg CO_2 yr^{-1}

CO_{2w_peat} = CO_2 emissions from Peatlands managed for peat production Gg CO_2 yr^{-1}

CO_{2w_flood} = CO_2 emissions from Flooded Land Gg CO_2 yr^{-1}

Tier 1 approach [Gen-1, Volume 4, Chapter 7, Equation 7.3] was applied for CO_2 – C emissions estimated from managed peatlands.

The 2006 IPCC Guideline provides Equation 7.10 on estimation of CO_2 emissions from *Land Converted to Flooded Land* for the year of flooding. This criterion applies only to Marmarik Reservoir.

Activity data

The activity data sources are the SC , Archive of Geological Fund SNCO of the Ministry of Territorial Administration and Infrastructure, scientific literature, site visits and interviews.

Peatlands

Peat occurs on 1.5% of the territory of Armenia. Peatlands are of lowland origin and formed from sedges with 10-40% addition of reeds.

The area of peat mines is 489 ha, and more than 1,065 ha is occupied by peat occurrences. Peat stocks estimated 1,005,375 tones. High uncertainty and even controversy exists in available data on the volume of extracted peat. Armenian peat is used as fertilizer, fuel, in balneology and is subject of export. The official data on peat extractions varies significantly by years.

In 2017, the volume of peat extracted was 9905.7 tonnes [AFOLURef-8, AFOLURef-9].

Flooded land

Flooded lands in Armenia are almost entirely restricted to reservoirs for the production of hydroelectricity, irrigation and potable water.

As of 2017, there are no CO_2 emissions from flooded lands.

Emissions calculation and time series

Figure 4.39 provides CO_2 emissions from Armenian wetlands as sum of emissions from peatlands and flooded land.

For the years, where the water level changes were negative (2012, 2014, 2017), the emissions from flooded lands, were assumed to be zero.

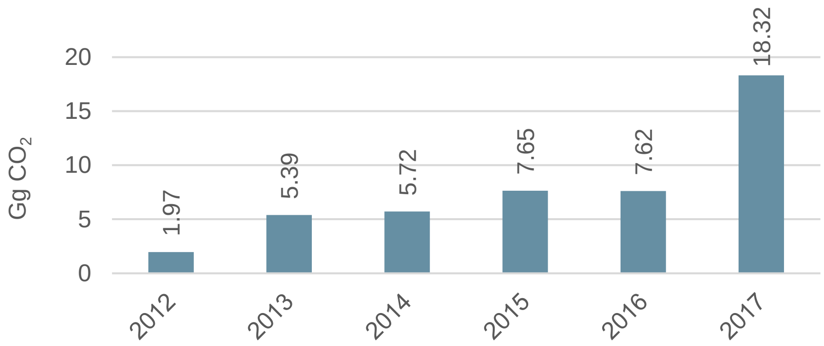


Figure 4.39 Annual emissions of CO_2 from *Wetlands*, Gg CO_2

4.3.5.2.5 *Settlements* (3B5)

According to the Guideline [Gen-1, Volume 4, Chapter 8] *Settlements* include all developed land - i.e. residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size, unless it is already included under other land-use categories. The land-use category *Settlements* include 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.

Settlements is not a key category and emissions assessment was done applying Tier 1 method which assumes no change in carbon stocks in live biomass in *Settlements Remaining Settlements*, in other words, that the growth and loss terms balance.

4.3.5.2.6 *Other Land* (3B6)

Other land category includes unmanaged reserve lands, bare soil, rock, ice, and all land areas that do not fall into any of the other five categories, i.e. lands without vegetation.

Other Land is often unmanaged, and in that case changes in carbon stocks and non-CO_2 emissions and removals are not estimated.

For Land Converted to Other Land, the change in carbon stocks in biomass are estimated. Average change in carbon stocks on per area basis is estimated to be equal to the change in carbon stocks due to the removal of living biomass from the initial land uses. According to Tier 1 method the amount of above-ground biomass that is removed is estimated by multiplying the area (e.g., forest area) converted annually to Other Land by the average carbon content of biomass in the land prior to conversion (BBEFORE) [Gen-1, Volume 4, Chapter 9]. In this case, BAFTER is set to zero by default. The default assumption for the Tier 1 calculation is that all carbon in biomass (less harvested wood products removed from the area) is released to the atmosphere immediately (i.e., in the first year after conversion) through decay processes either on- or off-site.

4.3.5.3 Emission /removals from *Land* category

In 2017, as in the previous years, *Lands* category as a whole acted as a CO_2 sink: the net removals were -443.68 $CO_{2\ eq.}$ (Table 4.51), as forests in Armenia act as a CO_2 sink.

Table 4.51 Emissions/removals estimate from *Land* category, 2017 [10]

	CO_2 emissi-ons, Gg	CO_2 removals, Gg	CH_4 emissi-ons, Gg	N_2O emissions Gg	Total emissions Gg $CO_{2\ eq.}$
Categories	**67.02**	**-538.03**		**0.00138**	**-470.58**
A. Forest land	**NO**	**-530.44**			**-530.44**
1. Forest land Remaining Forest land	NO	-523.92			
2. Land Converted to Forest land	NO	-6.53			
B. Cropland	**0.71**	**-7.44**			**-6.73**
1. Cropland Remaining Cropland	0.67	NO			
2. Land Converted to Cropland	NO	-7.40			
C. Grassland	**18.37**	**NO**			**18.37**
1. Grassland Remaining Grassland	NO	NO			
2. Land Converted to Grassland	18.37	NO			
D. Wetlands	**18.32**	**NO**		**0.00138**	**18.75**
1. Wetlands Remaining Wetlands	18.32	NO		**0.00138**	
2. Land Converted to Wetlands	NO	NO		NO	
E. Settlements	**NO**	**-0.15**			**-0.15**
1. Settlements Remaining Settlements	NO	NO			
2. Land Converted to Settlements	NO	-0.15			
F. Other land	**29.63**	**NO**			**29.63**
1. Land Converted to Other land	NO	NO			
2. Cropland Converted to Other Land	29.63	NO			

In Table 4.52 presents the GHG net emissions from the *Land* category for 2017, in $CO_{2\ eq.}$.

Table 4.52 Emissions/removals estimate from *Land* category, 2017

IPCC categories	Net CO_2 emissions/removals	Emissions	
		CH_4	N_2O
3.B Land	-471.003		0.00138
3.B.1 Forest land	-530.445		
3.B.1.a Forest land Remaining Forest land	-523.917		
3.B.1.b Land Converted to Forest land	-6.527		
3.B.1.b.i Cropland Converted to Forest land	-6.527		
3.B.2 Cropland	-6.726		
3.B.2.a Cropland Remaining Cropland	0.670		
3.B.2.b Land Converted to Cropland	-7.396		
3.B.2.b.i Forest Land converted to Cropland	NO		
3.B.2.b.ii Grassland converted to Cropland	-7.438		
3.B.2.b.iii Wetlands converted to Cropland	NO		
3.B.3.b.iv Settlements converted to Cropland	0.042		

[10] According to 2003 IPCC Good Practice Guidance “Land Use, Land Use Change and Forestry” [Gen-8]

IPCC categories	Net CO_2 emissions/removals	Emissions	
		CH_4	N_2O
3.B.2.b.v Other Land converted to Cropland	NO		
3.B.3 Grassland	18.366		
3.B.3.a Grassland Remaining Grassland	NO		
3.B.3.b Land Converted to Grassland	18.366		
3.B.3.b.i Forest Land converted to Grassland	NO		
3.B.3.b.ii Cropland converted to Grassland	18.366		
3.B.3.b.iii Wetlands converted to Grassland	NO		
3.B.3.b.iv Settlements converted to Grassland	NO		
3.B.3.b.v Other land converted to Grassland	NO		
3.B.4 Wetlands	18.317		0.00138
3.B.4.a Wetlands Remaining Wetlands	18.317		0.00138
3.B.4.a.i Peatlands remaining peatlands	18.317		0.00138
3.B.5 Settlements	-0.145		
3.B.5.a - Settlements Remaining Settlements	NE		
3.B.5.b - Land Converted to Settlements	-0.145		
3.B.5.b.ii - Cropland converted to Settlements	NO		
3.B.5.b.iii Grassland converted to Settlements	-0.145		
3.B.6 Other land	29.63		
3.B.6.b - Land Converted to Other land	29.63		
3.B.6.b.i - Forest land converted to Other Land	3.449		
3.B.6.b.ii - Cropland converted to Other Land	26.18		

4.3.5.4 Quality Control/Quality Assurance

The estimates of GHG inventory in *Land* category are strongly influenced by the quality and consistency of data and information available in the country. The estimates in this category 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 the SC and Ministry of Economy of the Republic of Armenia.

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

4.3.5.5 Completeness of data and uncertainty assessment

Uncertainties in *Forestry* category is mostly due to the lack of complete and accurate information on changes in the forest covered areas. The lack of mechanism for forest inventory is the main challenge for forest management planning, as well as it has a negative impact 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 the uncertainties in land areas; they in turn are also due to the fact that the Government is publishing RA Land Balances as of July 1 each year, as a result, some changes are left out of the balance of a given inventory year. Besides, materials for cadaster mapping implemented in the country and data published by SC of RA serve as primary sources for data included in Land Balances approved by the Government, however, as it is proven in practice, many differences are encountered in the said data.

Other sources of uncertainties could be errors made during cadaster mapping process, as well as 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 the 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 three sub-categories: *Emissions from biomass burning in forest lands (3C1a), Emissions from biomass burning in croplands (3C1b),* and *Emissions from biomass burning in grasslands (3C1c)* (AFOLURef-8, AFOLURef-9).

Under Tier 1, non-CO_2 emissions are estimated using the fuel consumption provided in Table 2.4, appropriate emission factors (Table 2.5) and combustion factor (Table 2.6) [Gen-1, Volume 4, Chapter 2].

4.3.6.2 Urea application (3C3)

CO_2 emissions from urea fertilization were estimated by the Tier 1 method with Equation 11.13 [Gen-1, Volume 4, Chapter 11] by using data on the amount of urea applied to soils (the first two rows in Table 4.53), 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, Chapter 11].

In 2017 as compared to 2016, the volume of urea has increased by 2.6 times.

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 (Table 4.53,10-digit level code - 3102210000 – 3102900000) and the default emissions factors were 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).

Direct N_2O emissions from managed soils are estimated using Equation 11.1 with country specific activity data and default emission factors (EF), which are needed to estimate direct N_2O emissions from managed soils (Table 11.1) [Gen-1, Volume 4, Chapter 11] :

- the first EF (EF_1) refers to the amount of N_2O emitted from the various synthetic and organic N applications to soils, including crop residue and mineralization of soil organic carbon in mineral soils due to land-use change or management.
- the second EF (EF_2) refers to the amount of N_2O emitted from an area of drained/managed organic soils,
- the third EF (EF_3PRP) estimates the amount of N_2O emitted from urea and dung N deposited by grazing animals on pasture, range and paddock.

Table 4.53 Volume of imported mineral or chemical fertilizers, nitrogenous [AFOLURef- 5]

Commodity chapter, group, subgroup name and 10-digit level code	Unit	Import, 2017	
		quantity	volume, tonne
Mineral or chemical fertilizers, nitrogenous		X	90,106.3
3102101000	kgN	1,611,402.7	**3,482.0**
3102109000	kgN	77,942.51	**226.9**
3102210000	kgN	2,491.68	11.0
3102301000	kgN	1,224	3.6
3102309000	kgN	426.45	4.0
3102401000	kgN	32,709,057.9	85,256.0
3102501000	kgN	128	1.6
3102509000	kgN	3,500.08	3.5
3102600000	kgN	161,520	1,012.8
3102900000	kgN	36,815.55	104.9
Total		**32,915,163.6**	**3,709**

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:

- mineral or chemical N fertilizers (FSN);
- organic N applied as fertilizer (e.g., animal manure, compost, sewage sludge, rendering waste and other organic amendments) (FON);
- urea 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) indirect emissions from the managed soils are estimated by Tier 1 method, using Equation 11.9, with country specific activity data and default emission factors [Gen - 1, Volume 4, Chapter 11, Table 11.3].

The most common nitrogenous fertilizer in Armenia is ammonium salt (NH_4NO_3), which contains 34.6% nitrogen in the form of ammonium and nitrate ions. Ammonium salts have a leading role in nitrogen fertilizers, as half of the nitrogen is in the form of readily moveable nitrate and the other half in the form of hard-moving ammonium. It is used both in the form of basic fertilization during preliminary cultivation and in the form of fertilization and nutrition of saplings. Ammonium salts can be used for fertilizing all agricultural crops. For example, the proportion of nitrogen fertilizers for cereal crops ranges between 30-90 kg/ha, for vegetable crops during the whole vegetation period the proportion is 60-120 kg/ha of nitrogen in case of fertilization with 20-30 tons / ha of manure, for potato 60-90 kg/ha for fruits 60-90 kg/ha, sometimes up to 120 kg/ha, and for berries - 45-60 kg/ha, depending on the degree of soil fertility, etc.

The increase in agricultural prices in Armenia in recent years, the expansion of export opportunities, state support (e.g. subsidies for fertilizers), and the increase in farm incomes have contributed to increased volumes of inorganic fertilizer use in crops, which caused the increase of N_2O emissions from the managed soils (Figure 4.40).

In 2017 as compared to 2016, the amount of chemical nitrogen fertilizer decreased by 35% which was the reason for decrease of N_2O Emissions from Managed Soils in 2017.

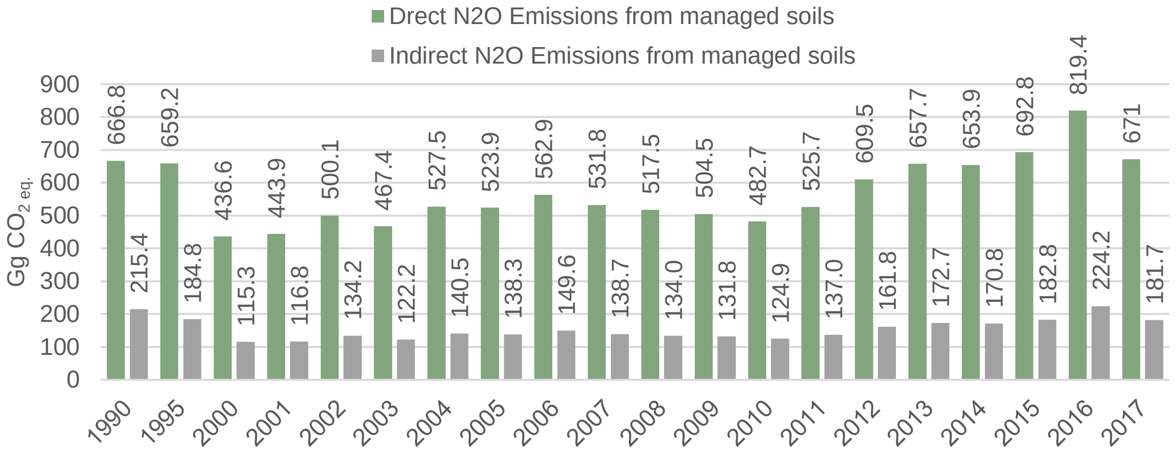


Figure 4.40 Time Series of *Direct and Indirect N_2O Emissions from Managed Soils*, Gg $CO_{2\ eq.}$

GHG emissions from the *Aggregate sources and non-CO_2 emissions sources on Land* category in 2017 are summarized in the Table 4.54.

Table 4.54 Emissions from *Aggregate Sources and Non-CO_2 Emissions Sources on Land*, 2017

IPCC Categories	2017 (Gg)				
	Net CO_2 emissions /removals	Emissions			
		CH_4	N_2O	NOx	CO
3.C Aggregate sources and non-CO_2 emissions sources on land	**2.720**	**0.224**	**2.878**	**0.205**	**7.141**
3.C.1 Emissions from biomass burning		0.224	0.008	0.205	7.141
3.C.1.a Biomass burning in forest lands		0.037	0.002	0.024	0.853
3.C.1.b Biomass burning in cropland		0.175	0.005	0.162	5.962
3.C.1.c Biomass burning in grasslands		0.012	0.001	0.020	0.326
3.C.3 Urea application	2.720				
3.C.4 Direct N_2O Emissions from managed soils			2.165		
3.C.5 Indirect N_2O Emissions from managed soils			0.586		
3.C.6 Indirect N2O Emissions from manure management			0.120		

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

Table 4.55 provides GHG emissions/removals from AFOLU sector in 2017 while Figure 4.41 show the complete time series for AFOLU sector.

Information on the emissions of precursors is given in Table 2.2.

Table 4.55 Greenhouse gas emissions/removals from Agriculture, Forestry and Other Land Use Sector, 2017, Gg

IPCC Category Codes	Categories	Emissions, Gg		
		Net CO_2 emissions/ removals	CH_4	N_2O
3	**Agriculture, Forestry, and Other Land Use**	**-468.284**	**48.235**	**3.065**
3.A	**Livestock**		**48.011**	**0.185**
3.A.1	**Enteric Fermentation (1)**		46.357	
3.A.1.a	Cattle		40.430	
3.A.1.a.i	Dairy Cows		22.704	
3.A.1.a.ii	Other Cattle		17.725	
3.A.1.b	Buffalo		0.052	
3.A.1.c	Sheep		5.090	
3.A.1.d	Goats		0.173	
3.A.1.f	Horses		0.186	
3.A.1.g	Mules and Asses		0.019	
3.A.1.h	Swine		0.395	
3A1j	Other (Rabbits, Fur bearing animals)		0.012	
3.A2	**Manure Management (2)**		1.653	0.185
3.A.2.a	Cattle		0.588	0.014
3.A.2.a.i	Dairy Cows		0.321	0.007
3.A.2.a.ii	Other Cattle		0.267	0.007
3.A.2.b	Buffalo		0.001	0.00004
3.A.2.c	Sheep		0.172	0.148
3.A.2.d	Goats		0.004	0.003
3.A.2.f	Horses		0.011	0.0001
3.A.2.g	Mules and Asses		0.001	0.000005
3.A.2.h	Swine		0.790	0.010
3.A.2.i	Poultry		0.075	0.011
3A2j	Other (Rabbits, Fur bearing animals)		0.012	0.000
3.B	**Land**	**-471.004**		**0.00138**
3.B.1	**Forest land**	**-530.445**		
3.B.1.a	Forest land Remaining Forest land	-523.917		
3.B.1.b	Land Converted to Forest land	-6.527		
3.B.1.b.i	Cropland Converted to Forest land	-6.527		
3.B.1.b.ii	Grassland Converted to Forest land	NO		
3.B.1.b.iii	Wetlands Converted to Forest land	NO		
3.B.1.b.iv	Settlements Converted to Forest land	NO		
3.B.1.b.v	Other Land Converted to Forest land	NO		
3.B.2	**Cropland**	**-6.726**		
3.B.2.a	Cropland Remaining Cropland	0.667		
3.B.2.b	Land Converted to Cropland	-7.396		
3.B.2.b.i	Forest Land converted to Cropland	NO		
3.B.2.b.ii	Grassland converted to Cropland	-7.438		
3.B.2.b.iii	Wetlands converted to Cropland	NO		
3.B.2.b.iv	Settlement converted to Croplands	0.042		
3.B.2.b.v	Other Land converted to Cropland	NO		
3.B.3	**Grassland**	**18.366**		
3.B.3.a	Grassland Remaining Grassland	NO		
3.B.3.b	Land Converted to Grassland	18.366		
3.B.3.b.i	Forest Land converted to Grassland	NO		
3.B.3.b.ii	Cropland converted to Grassland	18.366		

IPCC Category Codes	Categories	Emissions, Gg		
		Net CO_2 emissions/ removals	CH_4	N_2O
3.B.3.b.iii	Wetlands converted to Grassland	NO		
3.B.3.b.iv	Settlements converted to Grassland	NO		
3.B.3.b.v	Other Land converted to Grassland	NO		
3.B.4	**Wetlands**	**18.317**		**0.00138**
3.B.4.a	Wetlands Remaining Wetlands	18.317		0.00138
3.B.4.a.i	Peatlands remaining peatlands	18.317		0.00138
3.B.5	**Settlements**	**-0.145**		
3.B.5.a	Settlements Remaining Settlements	NE		
3.B.5.b	Land Converted to Settlements	-0.145		
3.B.5.b.ii	Cropland converted to Settlements	NO		
3.B.5.b.iii	Grassland converted to Settlements	-0.145		
3.B.6	**Other land**	**29.629**		
3.B.6.a	Other land Remaining Other land	NO		
3.B.6.b	Land Converted to Other land	29.629		
3.B.6.b.i	Forest Land Converted to Other land	3.449		
3.B.6.b.ii	Cropland Converted to Other land	26.18		
3.C	**Aggregate sources and non-CO_2 emissions sources on land**	**2.720**	**0.224**	**2.878**
3.C.1	Emissions from biomass burning		0.224	0.008
3.C.1a	Biomass burning in forest lands		0.037	0.002
3.C.1.b	Biomass burning in cropland		0.175	0.005
3.C.1.c	Biomass burning in grasslands		0.012	0.001
3.C.3	Urea application	2.720		
3.C.4	Direct N_2O Emissions from managed soils (3)			2.165
3.C.5	Indirect N_2O Emissions from managed soils			0.586
3.C.6	Indirect N_2O Emissions from manure management			0.120
3.D.1	Harvested wood products	NE		

Note: Emissions from all sub-categories not shown in this table are not occurring in Armenia. 0.000 in this table mean that emission estimates are close to zero.

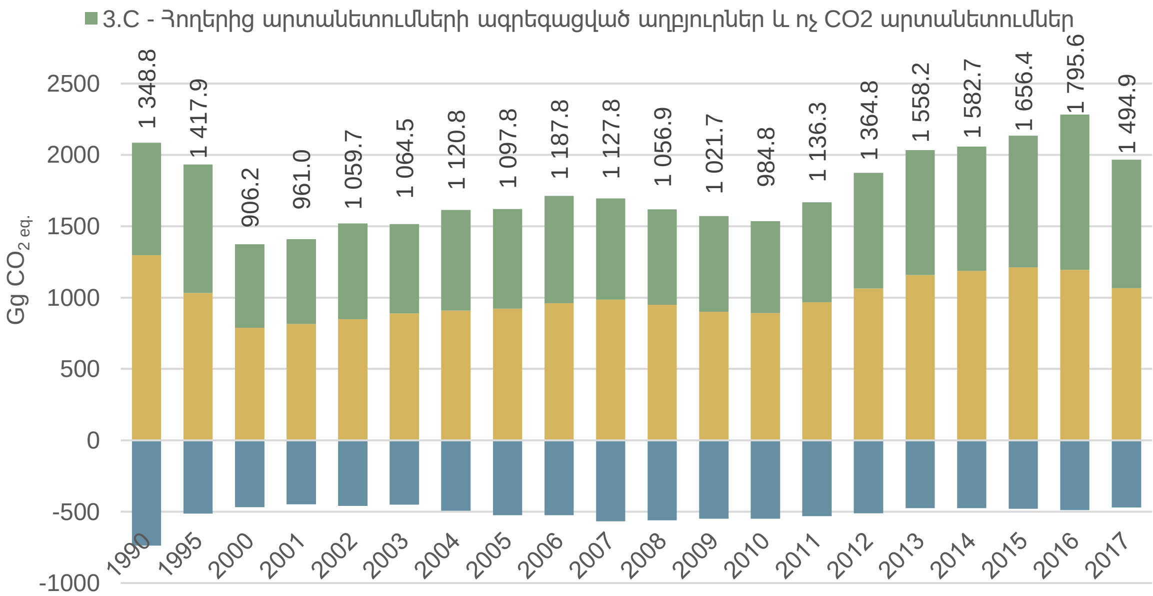


Figure 4.41 AFOLU Sector emissions time series, 1990-2017, Gg $CO_{2\ eq.}$

Table 4.56 Time series of GHG emissions from AFOLU Sector, Gg CO_{2} eq.

Category / Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3A - Livestock	1,296.7	1,033.9	788.5	922.1	891.3	967.0	1,063.5	1,158.9	1,188.4	1,213.0	1,194.2	1,065.7
3B - Land	-736.9	-514.4	-467.8	-523.7	-550.1	-532.3	-510.1	-474.9	-476.0	-478.9	-488.0	-470.6
3C - Aggregate sources and non-CO_2 emissions sources on land	789.0	898.4	585.5	699.5	643.6	701.7	811.4	874.2	870.4	922.4	1,089.4	899.7
Total	1,348.8	1,417.9	906.2	1,097.8	984.8	1,136.3	1,364.8	1,558.2	1,582.7	1,656.4	1,795.6	1,494.9

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 open burning 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 620.7 Gg $CO_{2\ eq.}$ or 5.84% of Armenia's total emissions in 2017. Landfill emissions accounted for 68.7% of Waste sector emissions (4% of the country's total emissions), while the emissions from the open burning of waste are insignificant and accounted for 3.3%. The emissions from the waste water treatment accounted for 28% of the sector emissions in 2017.

4.4.2 Waste Sector description

The Waste Sector of the national greenhouse gases 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)

There are small amounts of emissions from biological treatment of waste and incineration of medical waste, but due to their small quantities they have not been estimated.

There is no methodology for estimating emissions of precursors in EMEP/CORINAIR other than for open burning of waste and for NMVOC emissions from wastewater. However, these emissions have not been estimated.

4.4.3 Key Categories

Solid Waste Disposal is identified as the key source category of greenhouse gas (CH_4) emissions both with level and trend assessment, while *Wastewater Treatment and Discharge* is identified as the key source category *of* greenhouse gases *(CH_4 and N_2O) emissions with the level assessment.*

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 starting from the year 1950 and instead of the missing data, expert assessments were done. As a result, methane emissions were not underestimated but uncertainty was high.

Methane emissions from *Solid Waste Disposal* provided in the summary table have been calculated applying the second option, considering that throughout the time more accurate data would be available.

Emission factors and parameters

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.

In recent decades, an increase in fraction of degradable carbon in MSW (food waste, paper, cardboard) generated in the country was observed. 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, MSW Section].

- Fraction of degradable organic carbon which decomposes (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 months is selected for delay time (t) [Gen-1, Volume 5, Chapter 3, Delay time, page 3.19].

For assessing methane emissions from solid waste disposal sites (SWDS), classification was made by the cities of RA, by using Methane Correction Factor (MCF) default values [Gen-1, Volume 5, Table 3.1].

- Capital City of Yerevan - until 2006, 100% of solid waste and since 2006 70% of solid waste was disposed to the anaerobic managed SWDS[11] ("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.

[11] With depth of more than 5 m

- Other 45 cities and towns of the country – unmanaged shallow SWDS, having depths of less than 5 meters; MCF = 0.4.

Activity data

To obtain the total waste generation in the country, we have followed 2006 IPCC Guidelines provision, that if there is no reliable data on waste collection in rural areas, especially in developing countries, then the calculation is based on the number of urban population [Gen-1, Volume 5, Chapter 2, Tables 2.1, 2A.1].

The following values were applied for the calculations:

- The number of urban population was taken from official statistics [Ref-9, Ref-10].
- 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 of MSW generation, so the average value of this 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 0.279 tonnes/capita/year for 2017. (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).

According to the assessments of “SHIMIZU Co., Ltd.”, in frames of “Nubarashen” CDM project, 0.285 Gg CH_4 (5.985 Gg $CO_{2\ eq.}$) were captured and flared in 2017 [WRef-2].

Considering that country-specific data were used as activity data, while default values were mainly used for the parameters, it can be treated that Tier 2 method was applied for emissions assessment.

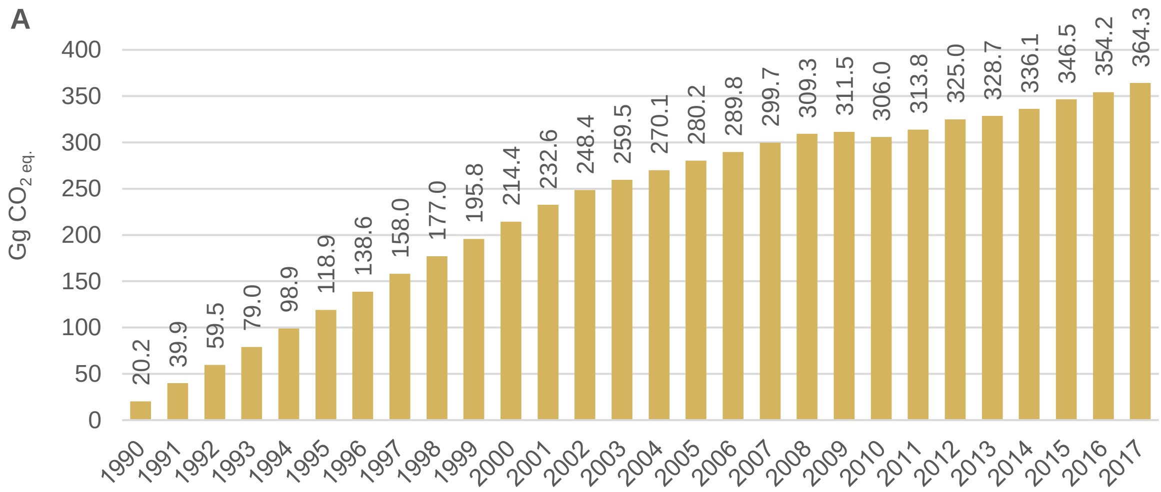
Completeness

From the waste types mentioned in the Guidelines, MSW was considered, as 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.

Consistent time series

Emissions calculation was done by IPCC 2006 Guidelines software, thus for all the years included in the time series, the calculation was done by using the FOD methodology. For MSW calculation official statistics on urban population were used. The FOD model requires historical data back to 1950, while the per capita MSW generation rate has changed during this period. 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 4.42.



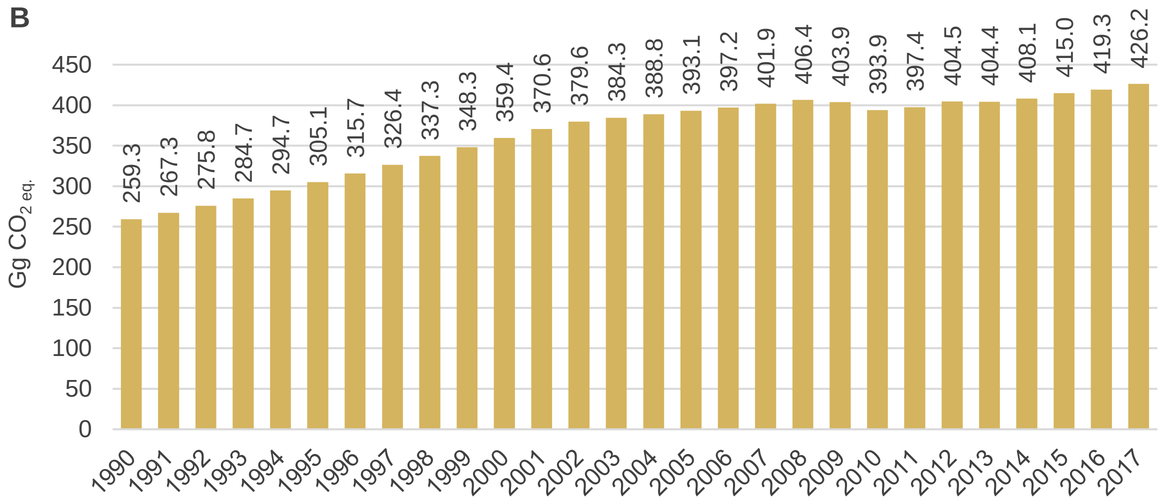


Figure 4.42 Methane emissions from SWDSs, calculated since 1990 (A) and since 1950 (B), Gg $CO_{2\ eq.}$ (without CDM project methane capture in Nubarashen)

As it was expected, figures calculated since 1990 are underestimated.

The methane emissions distribution (percentage) according to the landfill classification is presented in Figure 4.43.

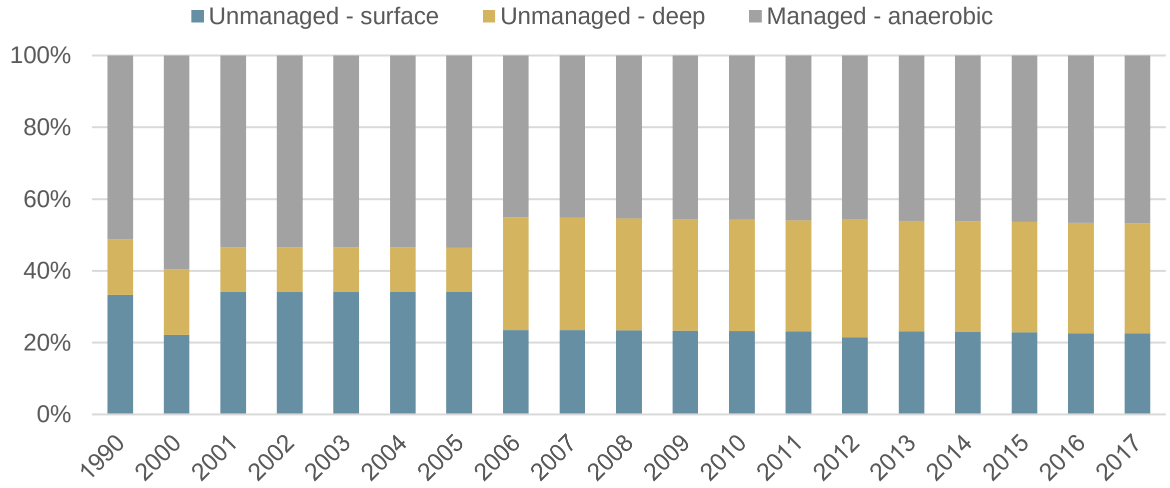


Figure 4.43 Methane emissions distribution (percentage) according to landfill classification

The observed sharp change in 2006 is due to the fact that 30% of the Yerevan waste started to be 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 4.57 the uncertainty estimates selected from IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 3, Table 3.5] are provided.

Table 4.57 Uncertainty of 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: 70%
- Emission factors: 30%
- General uncertainty: 76%

4.4.5 *Open Burning of Waste* (4C2)

In the rural areas, vegetable waste (dried leaves, grass, etc.) generated by orchards and plots is burned on site, and household waste is mainly accumulated in one of the nearby canyons and is periodically burned.

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, Volume 5, Chapter 5]. The amount of waste open burned was calculated based on the number of rural population, which was 1084.7 thousand in 2017 [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* [Gen-1, Volume 5, Chapter 5, Table 5.1, p. 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 dry 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].

CH_4 emission factor is 6500 g / t MSW wet weight [Gen-1, Volume 5, Chapter 5.4.2, page 5.20].

N_2O emission factor is 150 g N_2O / t MSW dry weight [Gen-1, Volume 5, Chapter 5.4, page 5.22].

Calculated greenhouse gas emissions are given in the Table 4.61.

Figure 4.44 presents greenhouse gas emissions time series from open burning of waste.

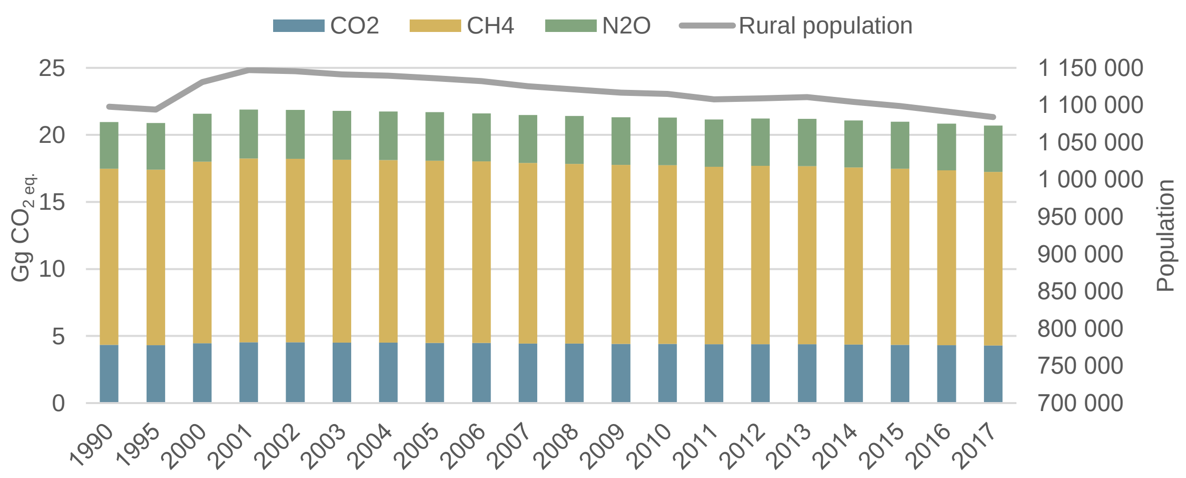


Figure 4.44 Greenhouse gas emissions from open burning of waste

4.4.6 *Wastewater Treatment and Discharge* (4D)

Greenhouse gas emissions sources from wastewater are:

- (4D1) Domestic Wastewater Treatment and Discharge - CH_4 and N_2O emissions,
- (4D2) Industrial Wastewater Treatment and Discharge - 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 (Statistics Committee and the Ministry of Environment).

4.4.6.1 *Methane Emission from Domestic and Commercial Wastewaters* (4D1)

Currently, Armenia has a limited sewer service area. There are only few wastewater treatment plants, 6 in total number, which perform mechanical treatment only. For that reason, they were not taken into consideration in calculations.

The practices for domestic and commercial wastewater discharge/treatment are not changed over the period of 1990-2017 in Armenia. In large cities and towns, the domestic and commercial wastewater were discharged mostly 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 Equations 6.1, 6.2, 6.3 of the 2006 Guidelines [Gen-1, Volume 5, Chapter 6].

Choice of Emission Factors

Methane emissions were estimated by applying Tier 1 method and the following default values of emission factors were used:

- **Bo = 0.6 (kg CH_4/kg BOD) _ Maximum methane producing capacity** for domestic wastewater [Gen-1, Volume 5, Chapter 6, Table 6.2].
- **I = 1 Correction factor for additional industrial BOD discharged into sewers** (for collected the default is 1.25, **for uncollected the default is 1.0**) [Gen-1, Volume 5, page 6.14]. I = 1 is selected because methane emissions from organic residues of industrial origin have been calculated in the *Industrial Wastewater* (4D2) category
- **MCF_J _ Methane correction factor (fraction)** indicates the extent to which the CH_4 producing capacity (Bo) is realised in each type of treatment and discharge pathway and system.
  - **MCF** $_{\text{Sea, river and lake discharge}}$ = *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]. Methane emissions from anaerobic processes in mechanical treatment systems are insignificant, and they were not taken into account in the calculations.
    - **MCF** $_{\text{Latrine}}$= *0.1* In the case of latrines was selected for MCF 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].
- **Emission factor *EFj = Bo • MCFj*** *(*kg CH_4/kg BOD)
  - ***EF*** $_{\text{Sea, river and lake discharge}}$= ***Bo*** **•MCF** $_{\text{Sea, river and lake discharge}}$=0.06 *(*kg CH_4/kg BOD)
  - ***EF***$_{\text{Latrine}}$ = ***Bo*** **• MCF** $_{\text{Latrine}}$ =0.06 *(*kg CH_4/kg BOD)

Choice/collection of activity data

The activity data for this source category is the total amount of organically degradable material in the wastewater (TOW). This parameter is a function of human population **(P)** and **BOD** generation per person.

P - country population in inventory year, (person) [Ref-1], which is classified by the size of income group where:

- population in large cities (Yerevan, Gyumri, Vanadzor) with centralized and branched sewerage system is considered as high-income population group,
- other urban population – as middle-income population group,
- rural population - as low-income population group [Gen-1, Volume 5, Chapter 6].

Tj - degree of utilization of treatment/discharge pathway or system

- For large cities (Yerevan, Gyumri, Vanadzor) the share of sewerage is 0.95 (95%), public and other latrines - 0.05 (5%),
- For other cities the share of sewerage is 0.5 (50%), public and other latrines - 0.5 (50%),
- In rural areas the share of sewerage is 0.05 (5%), public and other latrines - 0.95 (95%) (expert assessment, Ref-4, WRef-4).

***BOD* - country-specific per capita BOD in inventory year, g/person/day**

The value of 18250 kg/1000persons/year (50g/person/day) recommended in [Gen-9, Page 6.23] for former USSR countries was used as the most appropriate for Armenia. The same value was also used in calculations made for all former GHG National Inventories for Armenia.

Sludge removal and **methane recovered**. **S** = **R** = 0, as in Armenia no sludge is removed and no methane is captured from domestic and commercial wastewater.

The calculations were done by using both Excel spreadsheets and the IPCC 2006 Software.

Times series

1990-2017 time series of methane emissions from domestic and commercial wastewater, along with population dynamics, are provided in Figure 4.45. To ensure consistency of the time series, the entire series was recalculated using the revised I = 1 coefficient.

Figure 4.45 shows that the reduction of methane emissions from domestic and commercial wastewater is due to the decrease in the country's population.

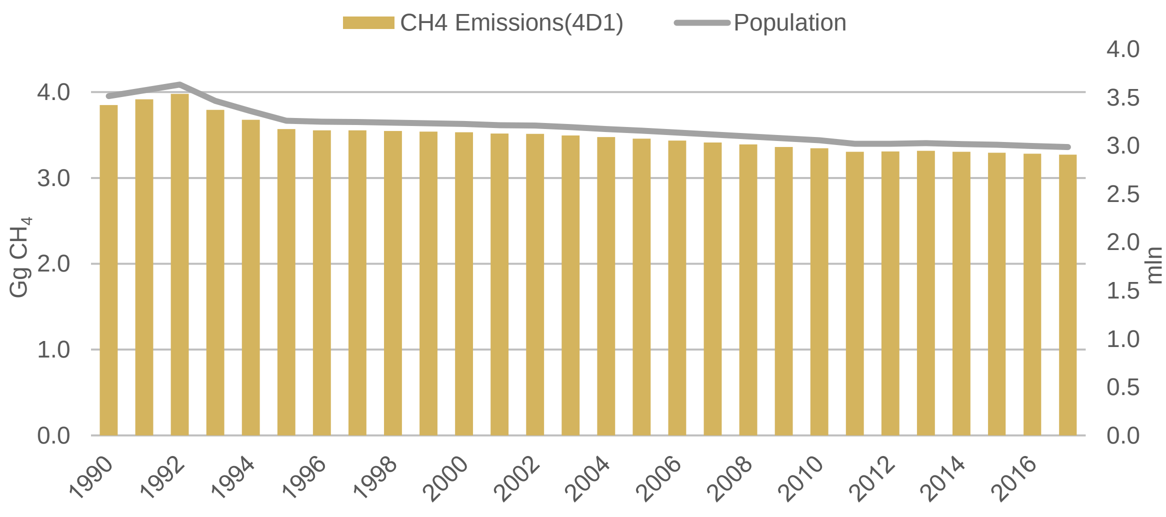


Figure 4.45 Methane emissions from domestic and commercial wastewater (Gg) and population dynamics

Figure 4.46 shows the trend in methane emissions from the domestic and commercial wastewater by different population groups: population of the large cities (Yerevan, Gyumri, Vanadzor), urban and rural population.

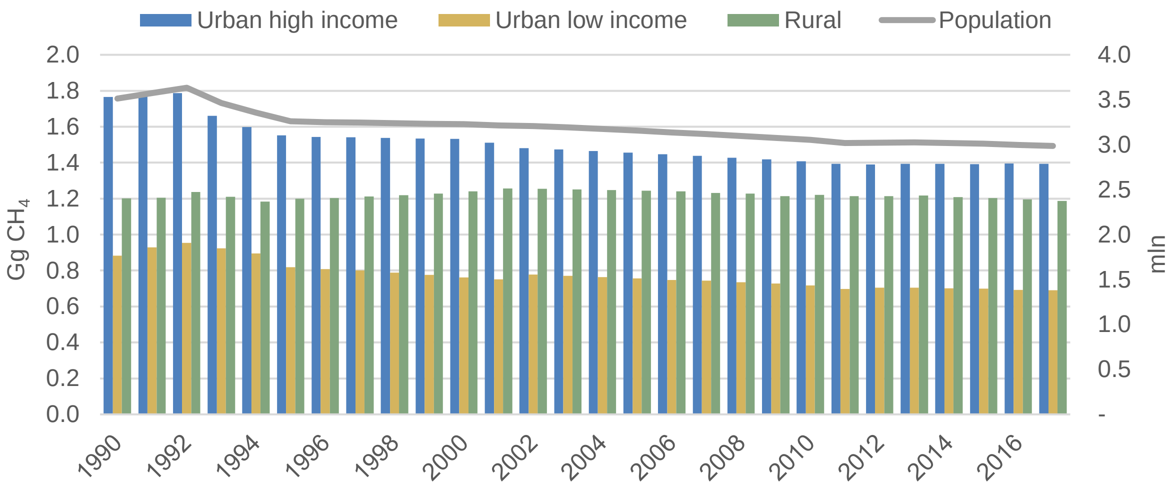


Figure 4.46 Methane emissions from domestic and commercial wastewater by population groups, Gg

The large cities are the main sources of methane emissions from domestic and commercial wastewater.

Decrease of emissions are mainly caused by the immigration process

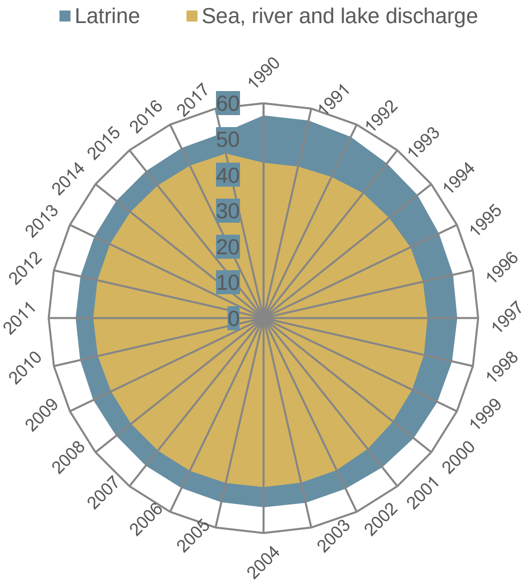


Figure 4.47 provides break-down of the emissions from said sources in annual total methane emissions from domestic and commercial wastewaters. For the entire period under consideration, methane emissions from urban sewer systems has exceeded 50% of annual total emissions from domestic and commercial wastewater.

Figure 4.47 Methane emissions from sewers and latrines, %

Uncertainty assessment

Uncertainty assessments 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 Guidelines, 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, emissions factor and total uncertainties calculated according to the IPCC 2006 Guidelines [Gen-1, Volume 1, Equation 3.1] are as follows: activity data 36.4%, emissions factors 58.31% and total uncertainty 68.74%.

4.4.7 *Industrial Wastewater* (4D2)

4.4.7.1 Methane emissions

The discharge of industrial wastewater into a water resource is prohibited if the quantitative and qualitative criteria of these wastewaters do not meet the general and individual requirements for the allowable leakage limit approved by the Agency for Management and Protection of Water Resources of the Republic of Armenia.

Methane emissions from the industrial wastewater were estimated applying Tier 1 Approach 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

The following default values [Gen-1] for calculation of methane emissions from industrial wastewater were used:

- **MCF _ Methane correction factor (fraction)** ***MCF = 0.1*** (for collected and untreated industrial wastewater that are eventually discharged in sea, rivers and lakes) [Gen-1, Volume 5, Chapter 6, Table 6.8].
- **Bo = 0.25 (kg CH_4/kg COD) _ Maximum methane producing capacity** [Gen-1, Volume 5, Chapter 6, Page 6.21].
- **Chemical oxygen demand CODi** (industrial degradable organic component in wastewater), kg COD/m^3) [Gen-1, Volume 5, Chapter 6, Table 6.9].
- **W_i-Wastewater generated (by product), m^3/t product,** [default values, Gen-1, Volume 5, Chapter 6, Table 6.9]).

Choice of activity data

The activity data for this source category is the amount of organically degradable material in the wastewater (TOW). This parameter is a function of industrial output (product) P (tonnes/yr), wastewater generation W (m^3/tonne of product), and degradable organics concentration in the wastewater COD (kg COD/m^3). For determination of TOW, the industrial sectors that generate wastewater with large quantities of organic carbon were identified.

Table 4.58 provides industrial wastewater data relevant to Armenia that were selected from Table 6.9 [Gen-1, Volume 5, Chapter 6].

Table 4.58 *Industrial wastewater* data

Industry type	Wastewater generation, Wi, m^3/t	COD, kg/m^3
Milk, Dairy Products, including Cheese	7	2.7
Fruits, Vegetables, 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
Wine, 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

Table 4.59 presents the quantities of output from which the wastewater were generated, by production type and by year. The required activity data were obtained from RA SC publications [WRef-8].

Table 4.59 Production volumes (thousand t/year) by years, 2000-2017

Industry sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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	29.47	33.77	42.32
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	20.89	18.72	20.66
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	504.41	519.87	518.57
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	0.34	0.34	0.32
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	85.96	92.09	116.77
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	25,00	27.37	37.97
Pulp & Paper (combined)	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	14.91	16.97	19.54
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	0.161	0.19	0.39
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	1.40	1,91	3.91
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	2.44	2,045	1.56
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	108.95	103.62	128.88
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	6.59	7.52	9.72
Sugar Refining	-	-	-	-	0.72	1,89	2,21	3,29	3,83	0,87	32,51	72,16	69,27	69,63	89,19	53.23	54.12	48.63

Time series

Time series of methane emissions from industrial wastewater are presented below in Figure 4.48.

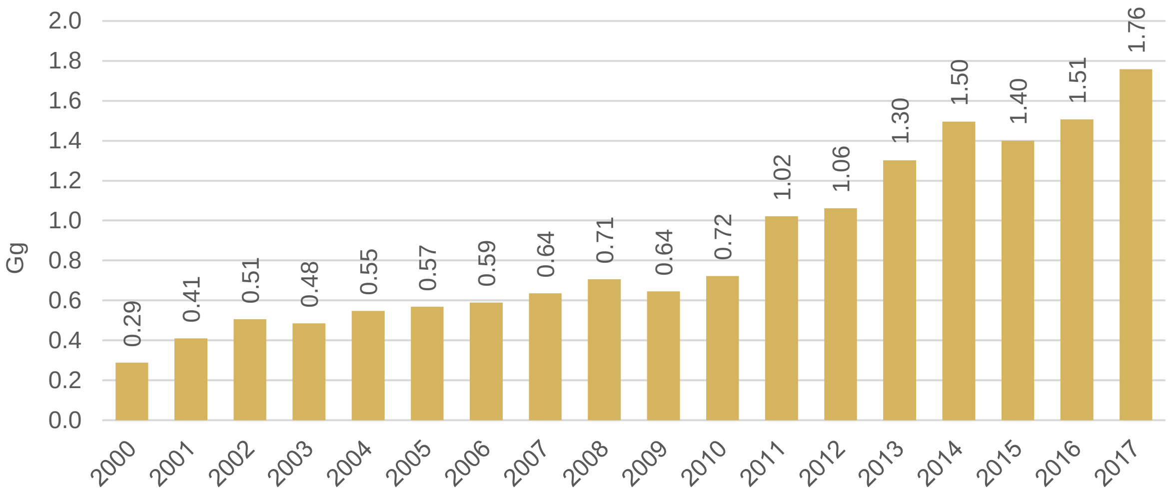


Figure 4.48 Methane emissions from industrial wastewater, Gg

As it can be seen from the Figure 4.48, methane emissions from industrial wastewater are on a growing trend for the period of 2000-2017, with the exception of 2003, 2009-2010 and 2015, given the following causes:

- In 2003 and 2015 - due to the unfavorable agriculture and food safety conditions.
- In 2008-2009 - due to the impact of the global financial crisis.

The shares of methane emissions from *industrial wastewater* per industry type, are given in the Figure 4.49.

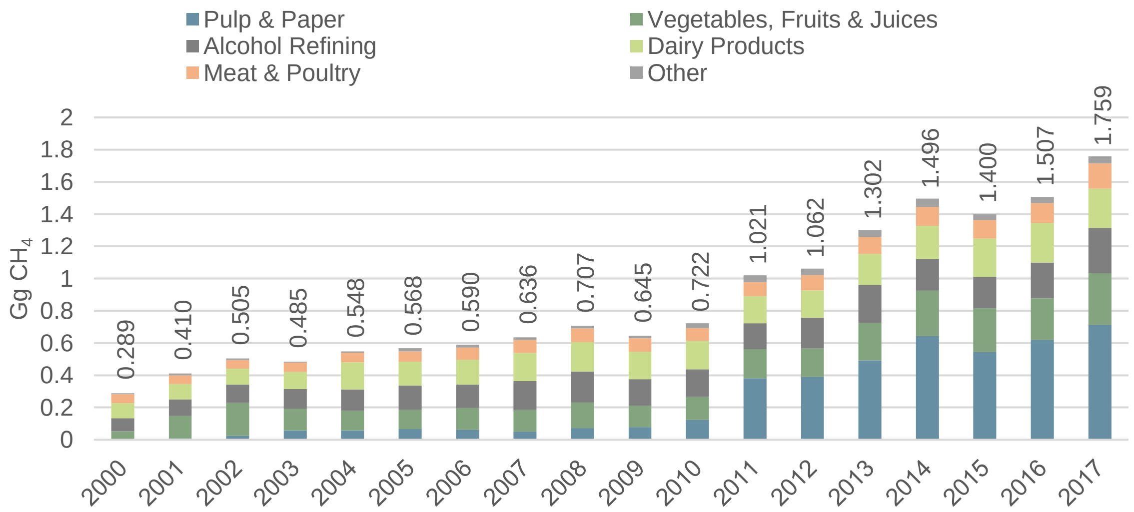


Figure 4.49 Methane emissions from industrial wastewater per industry types, Gg

It is obvious that the increase of methane emissions in 2011-2017 is due to the increase of methane emissions from industrial wastewater from "Pulp & Paper" production.

Methane emissions from wastewater are summarized in the Figure 4.50.

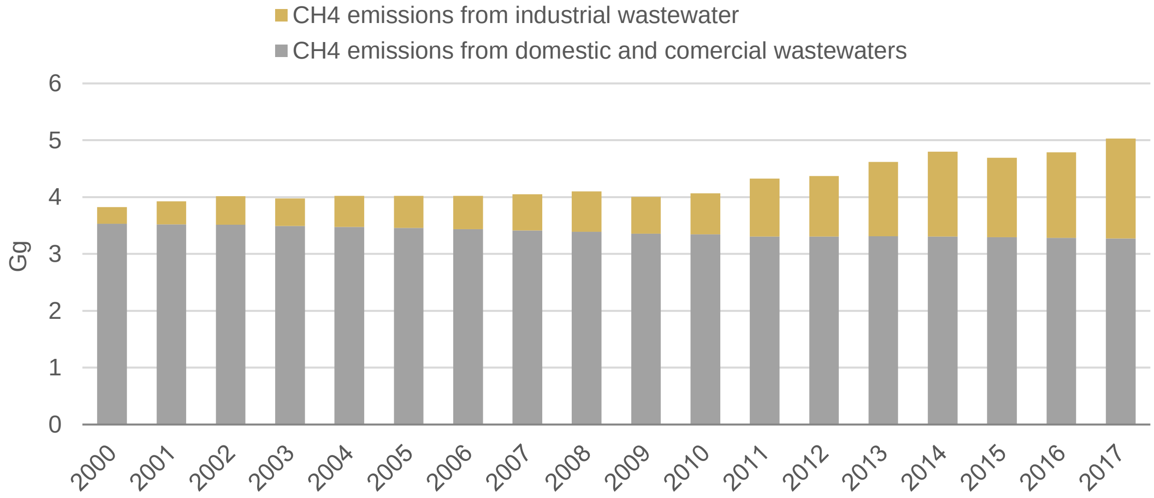


Figure 4.50 Methane emissions per sub-categories, Gg

It is obvious from Figure 4.50, that methane emissions from domestic and commercial wastewaters predominate in total wastewater emissions.

4.4.7.2 Nitrous oxide emission from Wastewater

2006 IPCC Guidelines suggest the same approach for the nitrous oxide emissions assessment from the wastewater, both for the developing and developed countries. According to the proposed method, the calculations are based on the country's 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]:

$EF_{EFFLUENT}$ = 0.005 (kg N_2O-N/kg N) - Nitrous oxide emission factor

F_{NPR} = 1.6(kg N/kg protein) - Fraction of nitrogen in protein

$F_{NON\text{-}CON}$ - **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.

$F_{IND\text{-}COM}$ = 1. 25 - Factor to allow for co-discharge of industrial and commercial protein into the sewer.

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 UN FAO protein indicator consumed by a person in the certain country for a certain period of time.

The UN FAO data on Armenia [WRef-9] were used in this inventory report. These data are presented in the Table 4.60 and served as basis for recalculation of the whole period (1990-2017).

Table 4.60 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	2010-12	2011-13	2013-17
Per capita consumption protein (g/person/day)	65.3	65.3	67	70.3	74	77.3	79.7	83	84.3	84.7	84.3	85.3	87.7	91

Time series 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 4.51 and 4.52.

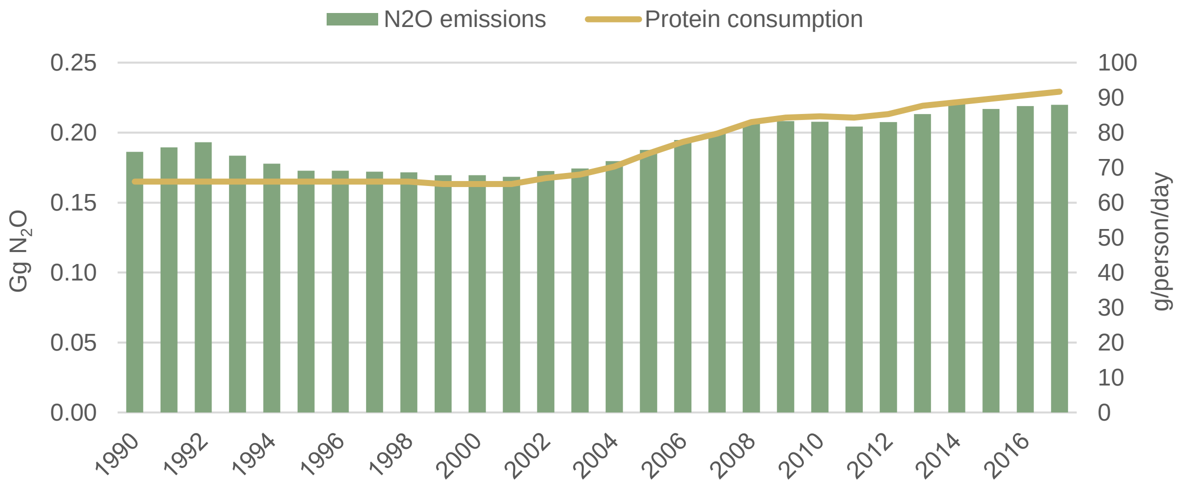


Figure 4.51 Nitrogen oxide emissions from wastewater (Gg) and protein consumption

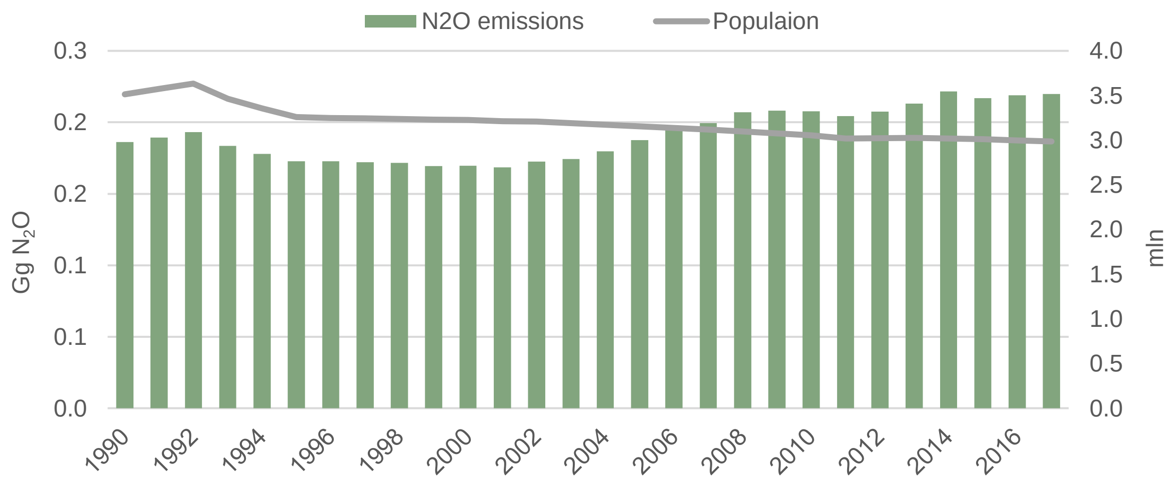


Figure 4.52 Nitrogen oxide emissions from wastewater (Gg) and population number

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 - $E_{FEFFLUENT}$: 0.0005 - 0.25 [Gen-1, Volume 5, Table 6.11].

Quality Assurance/ Quality Control

The sources of activity data and their reliability were clarified prior to the calculations.

During the calculations, quality control was done both for the activity data and main parameters of calculation, followed by the quality control of the results of calculation and analysis of time series.

The calculations were also done by the Excel and compared to the results received by the running 2006 IPCC Inventory Software.

Possible Improvements

One of the main opportunities for improving data on greenhouse gas emissions from *Domestic and commercial wastewater* (4D1) is due to the clarification of the actual number of the population. By the decree of the Government of the Republic of Armenia, it is envisaged to conduct a census in 2020, which will determine the actual number of the population, the number of the population in urban and rural settlements, and access to the sewer system.

Estimates of greenhouse gas emissions from industrial wastewater can be improved through introducing a new system for collecting administrative statistics from the existing organizations.

In the Table 4.61 GHG emissions from Waste Sector are summarized, whereas Table 4.62 and Figure 4.53 show the complete time series for Waste Sector.

Table 4.61 Waste Sector emissions, 2017

Emission Sources	GHG Emissions, Gg		
	CO_2	CH_4	N_2O
4. Waste	4.284	25.942	0.231
4A Solid Waste Disposal		20.297	
4B Biological Treatment of Waste		NE	NE
4C Incineration and Open Burning of Waste	4.284	0.617	0.011
4C1 Incineration	NE	NE	NE
4C2 Open Burning of Waste	4.284	0.617	0.011
4D Wastewaters Treatment and Discharge		5.029	0.220
4D1 Domestic Wastewater Treatment and Discharge		3.270	0.220
4D2 Industrial Wastewater Treatment and Discharge		1.759	

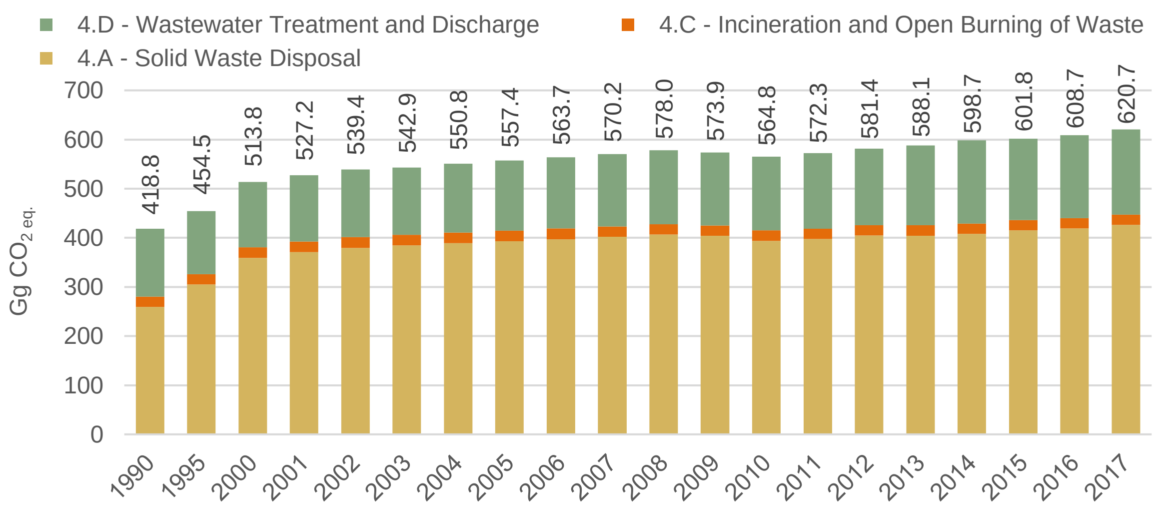


Figure 4.53 Waste Sector emissions time series, 1990-2017, Gg $CO_{2\ eq.}$

Table 4.62 Time series of greenhouse gas emissions from Waste Sector, Gg $CO_{2\ eq.}$

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
4A Solid Waste Disposal	259.3	305.1	359.4	393.1	393.9	397.4	404.5	404.4	408.1	415.0	419.3	426.2
4C Incineration and Open Burning of Waste	21.0	20.9	21.6	21.7	21.3	21.1	21.2	21.2	21.1	21.0	20.8	20.7
4D Wastewater Treatment and Discharge	138.6	128.5	132.9	142.6	149.6	153.7	155.6	162.6	169.5	165.9	168.6	173.8
Total	**418.8**	**454.5**	**513.8**	**557.4**	**564.8**	**572.3**	**581.4**	**588.1**	**598.7**	**601.8**	**608.7**	**620.7**

BIBLIOGRAPHY

International

Gen-1 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Gen-2 “Air Pollutant Emission Inventory Guidebook” (EMEP/EEA, 2016, 2009)
Gen-3 Nomenclature of Foreign Economic Activity of the CIS, fifth publication
Gen-4 Republic of Moldova – ODS Alternative Survey Report, Chisinau, 2016
Gen-5 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC 2000: Emissions of SF_6 from use of electrical equipment
Gen-6 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetland
Gen-7 2013 Revised Supplementary Methods and Good Practice Guidance
Gen-8 2003 IPCC Good Practice Guidance “Land Use, Land Use Change and Forestry”
Gen-9 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories

National

Ref-1 RA Statistical Yearbook, RA SC, 2018, (http://armstat.am)
Ref-2 Foreign Trade of Armenia in 2017, RA SC, 2018
Ref-3 Armenia’s First Biennial Update Report under the UNFCCC, 2016., National Greenhouse Gas Inventory Report of the Republic of Armenia for 2011-2012
Ref-4 Third National Communication on Climate Change under UNFCCC, 2014
Ref-5 RA Foreign Trade by Products, http://www.customs.am/Content.aspx?itn=csCIForeignTradeByProducts
Ref-6 Socio-economic indicators for 1999-2017, http://armstat.am/am/
Ref-7 HCFCs Phase-out Management Plan for Armenia, Phase 2, 2015
Ref-8 (http://armstatbank.am)
Ref-9 Population Statistics http://www.populstat.info/
Ref-10 http://www.cisstat.com/

Energy

EnRef-1 Main indicators of gas supply system, 2017 http://www.psrc.am/images/docs/reports/gas/2017/4-er/%D5%A3%D5%A1%D5%A6-%D5%AD%D5%B8%D6%80%D5%A1%D5%B6%D5%A1%D6%80%D5%A4-2017.pdf
EnRef-2 Main indicators of power system, 2017 http://www.psrc.am/images/docs/reports/electric/2017/4-er/Himnakan_bnutagrer_2017-4.pdf

Industrial processes and product use

IndRef-1 Data provided by “Araratcement” CJSC, N S-01/215 dated 13 August 2019, in response to the RA Ministry of Environment inquiry, N 02/05-1/20124 dated 29.07.2019
IndRef-2 Data provided by “Hrazdancement” CJSC, N99 dated 02.09.2019, in response to the RA Ministry of Environment inquiry, N 02/05-1/20121 dated 29.07.2019
IndRef-3 Data provided by “Saranist” LLC in response to the RA Ministry of Environment inquiry, N 02/05-1/20123 dated 29.07.2019
IndRef- 4 Data provided by “Armenian Copper Program” CJSC, N LU-062 dated 06.08.2019 LLC in response to the RA Ministry of Environment inquiry, N 02/05-1/20120 dated 29.07.2019

F-gases

IndF.Ref-1 Official Response from the First Deputy of RA Government Adjunct State Revenue Committee, N 2010710142 in response to the RA Ministry of Environment inquiry N 1/05.1/11889-19 dated 29.07.2019

Agriculture

AFOLURef-1 GHG National Inventory Report of the Republic of Armenia; 2010, pp. 89-109.

AFOLURef-2 Food safety and poverty in January-December 2017 and January-December 2018, RA SC, Yerevan 2019.

AFOLURef-3 Statistical Yearbook of Armenia, 2018. RA SC, Yerevan 2018.

AFOLURef-4 Livestock Statistics as of 1st January for 2017 and 2018, Statistical Bulletin, RA SC

AFOLURef-5 Foreign Trade of RA for 2017 (According to the Commodity Nomenclature of External Economic Activity at 10-digit level), Statistical Handbook, RA SC, Yerevan 2018.

AFOLURef-6 Land balance for 2017, Real Estate Committee of the RA Government.

AFOLURef-7 Official letters of the Ministry of Agriculture and the Statistics Committee of the RA in response to the inquiry of the Ministry of Environment No. 1/05.1/11853-19 dated 29.07.2019.

AFOLURef-8 Environment and Natural Resources in the Republic of Armenia for 2017, Statistical Handbook, RA SC, Yerevan 2018.

AFOLURef-9 Environmental Statistics of Armenia for 2017 and Indicators for 2013-2017, Statistical Handbook, RA SC, Yerevan 2018.

Forest Lands

LUCFref-1 Forest Management Plan, “ArmForest” SNCO of the Ministry of Agriculture of the Republic of Armenia, “Dsegh Forestry” Branch, Yerevan 2009, 155 pages.

LUCFref-2 Forest Management Plan, “ArmForest” SNCO of the Ministry of Agriculture of the Republic of Armenia, “Meghri Forestry” Branch, Yerevan 2009, 139 pages.

LUCFref-3 RA Forest Code. 2005

LUCFref-4 Letters from the State Forest Committee, the Bioresource Management Agency and the Department of Biodiversity and the Forest Policy, in response to the inquiry of the Ministry of Environment of the Republic of Armenia No. 0043/51916. dated 24.07.2019

LUCFref-5 Distribution of forests and forest lands fixed by “ArmForest” SNCO as of 2010 according to “Forestry Branches”. Order N 102-S of the Ministry of Agriculture dated 04.06.2010.

LUCFref-6 Ghulijanyan A. H. Dendrobodiversity of North-Eastern Armenia and the Biomass Change Dynamics of the Most Valuable Species, Institute of Botany of the NAS RA, Doctoral Thesis, Yerevan 2009, 266 pages.

LUCFref-7 Arzumanyan G. A. Mamikonyan M. C. Physic-mechanical properties of BUKA production in Armenia. DAN Arm. USSR, 1961, XXXIII, 3, p. 119-127.

LUCFref-8 Arzumanyan G. A., Khurshudyan P. A. The physic-mechanical properties of the timber of yew, pear and birch growing in Armenia. Abs. Acad. Science Arm.SSR, 1961, XIV, 5, p. 31-40.

LUCFref-9 Palandzhyan V. A. O unprotected properties of the Caucasian carcass. Abs. Acad. Science Arm.SSR, 1955, VIII, 6, p. 77-85.

LUCFref-10 Project organizations and development of easy-to-use, low-cost writing; Taxonomic description of Radiation Lesions. Tbilisi, 1991-1992, 176 s, AparanCogo, 160 s, Lesotho.

LUCFref-11 Project organizations and development of easy-to-use software; Taxonomic description of Leninakan lesions. Tbilisi, 1982-1983, 150 p.

LUCFref-12 Project organizations and development of easy-to-use, low-cost writing; Taxonomic description of Aparan's leprosy. Tbilisi, 1991-1992, 160 p.

LUCFref-13 Khurshudyan P. A. Physico-mechanical properties of the timber of linden tree from NORTHERN Armenia. Abs. Acad. Science Arm.SSR, 1952, V, 6, p. 59-67.

LUCFref-14 Khurshudyan P. A. The physic-mathematical properties of the timber of some sort of maple trees growing in Armenia. Abs. Acad. Science Arm.SSR, 1953, VI, 7, p. 35-49.

LUCFref-15 Khurshudyan P. A. The physic-mechanical properties of the timber of ash tree from the South Armenia. Abs. Acad. Science Arm.SSR, 1954, VII, 10, p. 49-56.

LUCFref-16 Khurshudyan P. A. The physic-mechanical properties of the timber of two types of juniper trees growing in Armenia. Abs. Acad. Science Arm.SSR, 1959, XII, 5, p. 65-76.

LUCFref-17 Khurshudyan, P. A. Physic-mechanical properties of aspen timber growing in Armenia, , NAS Arm. SSR,1960,XIII,9,p. 51-60

LUCFref-18 Khurshudyan P.A, On the main technical properties of sycamore wood from Tsavskaya grove. NAS SSR,1962,XV,11,p. 31-38

LUCFref-19 Ugolev B. A, Wood Science and Forestry. 2nd ed., Publishing Centre ‘’Academy’’ M, 2006, p. 272.

LUCFref-20 http://hayantar.am

LUCFref-21 http://forest-monitoring.am

LUCFref-22 http://www.mnp.am

Waste

WRef-1 Biomass և bioenergy use plan. Ministry of Energy and Natural Resources of the Republic of Armenia, Yerevan, 2012

WRef-2 Nubarashen Landfill Gas Capture and Power Generation Project in Yerevan, 4th monitoring report, Monitoring report form (Version 04.0), http://www.nature-ic.am/Content/posts/3722/Monitoring-Report.pdf

WRef-4 A. Marjanyan, Preparatory works for 3rd National Communication, Waste sector of 2012 National Greenhouse Gas Inventory

WRef-5 Advisory Study on the Municipal Solid Waste Management in Yerevan, Fichtner, Final report, 2009

WRef-6 Strategic Development Plan, Road Map and Long Term Investment Plan for the Solid Waste Management Sector in Armenia. Asian Development Bank, Final report, 2013

WRef-7 RA Development Strategy for the Solid Waste Management System in 2017-2036

WRef-8 Output of Main Commodities in the Industrial Organizations (in Kind) in Armenia, 2018 (armstat.am) (https://www.armstat.am/file/article/bnexen_12_2018.pdf)

WRef-9 Food security statistics country profiles, Armenia in: http://www.fao.org/economic/ess/ess-fs/ess-fadata/en

WRef-8 “In-kind Output of Basic Products from Industrial Organizations in Armenia”, 2016-2017, (www.armstat.am)

ANNEXES

Annex 1. Key Category Analysis and Uncertainty Assessment

Annex 1.1 Key Category Analysis - Level Assessment

A	B	C	D	E	F	G
IPCC Category codes	IPCC Category	Greenhouse gas	2017 Ex,t (Gg $CO_{2\ eq}$)	|Ex,t| (Gg $CO_{2\ eq}$)	Lx,t	Cumulative Total of Column F
1.B.2.b	**Fugitive emissions from Natural Gas transportation and distribution**	**CH_4**	**1,626.88**	**1,626.88**	**14.45%**	**14.45%**
1.A.1	**Energy Industries - Gaseous Fuels**	**CO_2**	**1,297.95**	**1,297.95**	**11.53%**	**25.98%**
1.A.4.b	**Residential- Gaseous Fuels**	**CO_2**	**1,264.95**	**1,264.95**	**11.24%**	**37.22%**
1.A.3.b	**Road Transportation - Gaseous Fuels**	**CO_2**	**971.86**	**971.86**	**8.63%**	**45.86%**
3.A.1.a	**Enteric Fermentation - Cattle**	**CH_4**	**849.02**	**849.02**	**7.54%**	**53.40%**
1.A.3.b	**Road Transportation - Liquid Fuels**	**CO_2**	**721.73**	**721.73**	**6.41%**	**59.81%**
3.C.4	**Direct N2O Emissions from managed soils**	**N_2O**	**671.00**	**671.00**	**5.96%**	**65.77%**
2.F.1	**Refrigeration and Air Conditioning**	**HFC_s**	**653.92**	**653.92**	**5.81%**	**71.58%**
1.A.4.a	**Commercial/institutional - Gaseous Fuels**	**CO_2**	**531.42**	**531.42**	**4.72%**	**76.30%**
3.B.1.a	**Forest land Remaining Forest land**	**CO_2**	**-523.92**	**523.92**	**4.65%**	**80.96%**
4.A	**Solid Waste Disposal**	**CH_4**	**426.22**	**426.22**	**3.79%**	**84.74%**
1.A.2	**Manufacturing Industries and Construction - Gaseous Fuels**	**CO_2**	**407.67**	**407.67**	**3.62%**	**88.36%**
2.A.1	**Cement production**	**CO_2**	**224.55**	**224.55**	**1.99%**	**90.36%**
3.C.5	**Indirect N2O Emissions from managed soils**	**N_2O**	**181.67**	**181.67**	**1.61%**	**91.97%**
3.A.1.b-j	**Enteric Fermentation - Other**	**CH_4**	**124.48**	**124.48**	**1.11%**	**93.08%**
4.D	**Wastewater Treatment and Discharge**	**CH_4**	**105.60**	**105.60**	**0.94%**	**94.02%**
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	**69.49**	**69.49**	**0.62%**	**94.63%**
4.D	**Wastewater Treatment and Discharge**	**N_2O**	**68.16**	**68.16**	**0.61%**	**95.24%**
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	62.19	62.19	0.55%	96.02%
3.A.2	Manure Management	N_2O	57.48	57.48	0.51%	96.53%
1.A.3.b	Road Transportation	CH_4	37.97	37.97	0.34%	96.87%
3.C.6	Indirect N2O Emissions from manure management	N_2O	37.26	37.26	0.33%	97.20%
3.A.2	Manure Management	CH_4	34.72	34.72	0.31%	97.51%
1.A.3.e	Other Transportation	CO_2	30.10	30.10	0.27%	97.78%

A	B	C	D	E	F	G
IPCC Category codes	IPCC Category	Greenhouse gas	2017 Ex,t (Gg $CO_{2\ eq}$)	|Ex,t| (Gg $CO_{2\ eq}$)	Lx,t	Cumulative Total of Column F
3.B.6.b	Land Converted to Other land	CO_2	29.63	29.63	0.26%	98.04%
2.A.2	Lime production	CO_2	28.35	28.35	0.25%	98.30%
1.A.3.b	Road Transportation	N_2O	26.58	26.58	0.24%	98.53%
2.F.2	Foam Blowing Agents	HFCs	23.01	23.01	0.20%	98.74%
1.A.4	Other Sectors - Biomass	CH_4	22.96	22.96	0.20%	98.94%
3.B.3.b	Land Converted to Grassland	CO_2	18.37	18.37	0.16%	99.11%
3.B.4.a.i	Peatlands remaining peatlands	CO_2	18.32	18.32	0.16%	99.27%
4.C	Incineration and Open Burning of Waste	CH_4	12.96	12.96	0.12%	99.39%
2.F.4	Aerosols	HFCs	7.77	7.77	0.07%	99.45%
3.B.2.b	Land Converted to Cropland	CO_2	-7.40	7.40	0.07%	99.52%
3.B.1.b	Land Converted to Forest land	CO_2	-6.53	6.53	0.06%	99.58%
2.A.3	Glass Production	CO_2	5.43	5.43	0.05%	99.63%
3.C.1	Emissions from biomass burning	CH_4	4.70	4.70	0.04%	99.67%
1.A.4	Other Sectors - Biomass	N_2O	4.52	4.52	0.04%	99.71%
4.C	Incineration and Open Burning of Waste	CO_2	4.28	4.28	0.04%	99.75%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	4.24	4.24	0.04%	99.78%
1.A.4	Other Sectors - Solid Fuels	CO_2	3.95	3.95	0.04%	99.82%
4.C	Incineration and Open Burning of Waste	N_2O	3.44	3.44	0.03%	99.85%
1.A.4	Other Sectors - Gaseous Fuels	CH_4	3.32	3.32	0.03%	99.88%
3.C.3	Urea application	CO_2	2.72	2.72	0.02%	99.90%
2.G	Other Product Manufacture and Use	SF6	2.59	2.59	0.02%	99.93%
3.C.1	Emissions from biomass burning	N_2O	2.38	2.38	0.02%	99.95%
1.A.4	Other Sectors - Gaseous Fuels	N_2O	0.98	0.98	0.01%	99.96%
1.A.1	Energy Industries - Gaseous Fuels	N_2O	0.71	0.71	0.01%	99.96%
3.B.2.a	Cropland Remaining Cropland	CO_2	0.67	0.67	0.01%	99.97%
2.F.3	Fire Protection	HFCs	0.64	0.64	0.01%	99.98%
1.A.3.e	Other Transportation	N_2O	0.49	0.49	0.00%	99.98%
1.A.1	Energy Industries - Gaseous Fuels	CH_4	0.48	0.48	0.00%	99.98%
3.B.4.a.i	Peatlands remaining peatlands	N_2O	0.43	0.43	0.00%	99.99%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	N_2O	0.22	0.22	0.00%	99.99%

A	B	C	D	E	F	G
IPCC Category codes	IPCC Category	Greenhouse gas	2017 Ex,t (Gg $CO_{2\ eq}$)	|Ex,t| (Gg $CO_{2\ eq}$)	Lx,t	Cumulative Total of Column F
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.19	0.19	0.00%	99.99%
1.B.2.b	Natural Gas	CO_2	0.19	0.19	0.00%	99.99%
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.17	0.17	0.00%	99.99%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.15	0.15	0.00%	100.00%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CH_4	0.15	0.15	0.00%	100.00%
3.B.5.b	Land Converted to Settlements	CO_2	-0.15	0.15	0.00%	100.00%
1.A.4	Other Sectors - Solid Fuels	CH_4	0.06	0.06	0.00%	100.00%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.05	0.05	0.00%	100.00%
1.A.3.e	Other Transportation	CH_4	0.03	0.03	0.00%	100.00%
Total			**10.153.47**	**11.229.44**	**100%**	

Annex 1.2 Key Category Analysis - Trend Assessment

A	B	C	D	E			F	G	H
IPCC Category code	IPCC Category	Green-house gas	2000 Year Estimate Ex0 (Gg $CO_{2\ eq}$)	2017 Year Estimate Ext (Gg $CO_{2\ eq}$)	2000 Year Estimate (absolute) |Ex0| (Gg $CO_{2\ eq}$)	2017 Year Estimate (absolute) |Ext| (Gg $CO_{2\ eq}$)	Trend Assessment (T_{xt})	% Contri-bution to Trend	Cumula-tive Total of Column G
1.A.1	**Energy Industries - Gaseous Fuels**	**CO_2**	**1,696.99**	**1,297.95**	**1,696.99**	**1,297.95**	**0.245**	**23.95%**	**23.95%**
1.A.4.b	**Residential- Gaseous Fuels**	**CO_2**	**170.43**	**1,264.95**	**170.43**	**1,264.95**	**0.143**	**13.98%**	**37.93%**
1.A.3.b	**Road Transportation - Gaseous Fuels**	**CO_2**	**55.20**	**971.86**	**55.20**	**971.86**	**0.129**	**12.65%**	**50.57%**
2.F.1	**Refrigeration and Air Conditioning**	**HFCs**	**0.90**	**653.92**	**0.90**	**653.92**	**0.096**	**9.42%**	**59.99%**
1.A.4.a	**Commercial/institutional - Gaseous Fuels**	**CO_2**	**35.16**	**531.42**	**35.16**	**531.42**	**0.069**	**6.79%**	**66.78%**
3.B.1.a	**Forest land Remaining Forest land**	**CO_2**	**-470.82**	**-523.92**	**470.82**	**523.92**	**0.059**	**5.81%**	**72.60%**
1.A.3.b	**Road Transportation - Liquid Fuels**	**CO_2**	**626.80**	**721.73**	**626.80**	**721.73**	**0.055**	**5.35%**	**77.94%**
1.B.2.b	**Fugitive emissions from Natural Gas transportation and distribution**	**CH_4**	**1,106.49**	**1,626.88**	**1,106.49**	**1,626.88**	**0.044**	**4.34%**	**82.29%**
3.A.1.a	**Enteric Fermentation - Cattle**	**CH_4**	**634.96**	**849.02**	**634.96**	**849.02**	**0.038**	**3.71%**	**86.00%**
4.A	**Solid Waste Disposal**	**CH_4**	**359.38**	**426.22**	**359.38**	**426.22**	**0.030**	**2.89%**	**88.89%**
1.A.2	**Manufacturing Industries and Construction - Gaseous Fuels**	**CO_2**	**345.63**	**407.67**	**345.63**	**407.67**	**0.029**	**2.81%**	**91.70%**
1.A.2	**Manufacturing Industries and Construction - Liquid Fuels**	**CO_2**	**89.23**	**62.19**	**89.23**	**62.19**	**0.014**	**1.35%**	**93.04%**
3.C.4	**Direct N2O Emissions from managed soils**	**N_2O**	**436.57**	**671.00**	**436.57**	**671.00**	**0.013**	**1.29%**	**94.34%**
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	**62.27**	**69.49**	**62.27**	**69.49**	**0.006**	**0.56%**	**94.90%**
3.A.1.b-j	**Enteric Fermentation - Other**	**CH_4**	**93.09**	**124.48**	**93.09**	**124.48**	**0.006**	**0.54%**	**95.44%**
4.D	Wastewater Treatment and Discharge	CH_4	80.26	105.60	80.26	105.60	0.005	0.49%	95.94%
3.B.6.b	Land Converted to Other land	CO_2	-0.02	29.63	0.02	29.63	0.004	0.43%	96.37%
1.A.3.b	Road Transportation	CH_4	7.30	37.97	7.30	37.97	0.004	0.36%	96.73%
4.D	Wastewater Treatment and Discharge	N_2O	52.60	68.16	52.60	68.16	0.003	0.34%	97.07%
2.A.2	Lime production	CO_2	3.95	28.35	3.95	28.35	0.003	0.31%	97.38%
3.C.5	Indirect N2O Emissions from managed soils	N_2O	115.32	181.67	115.32	181.67	0.003	0.28%	97.66%
1.A.4	Other Sectors - Biomass	CH_4	24.20	22.96	24.20	22.96	0.003	0.28%	97.93%
2.A.1	Cement production	CO_2	138.85	224.55	138.85	224.55	0.003	0.25%	98.18%
3.A.2	Manure Management	N_2O	42.33	57.48	42.33	57.48	0.002	0.23%	98.42%
3.B.4.a.i	Peatlands remaining peatlands	CO_2	1.97	18.32	1.97	18.32	0.002	0.21%	98.63%
3.C.6	Indirect N2O Emissions from manure management	N_2O	28.49	37.26	28.49	37.26	0.002	0.18%	98.81%

A	B	C	D	E			F	G	H
IPCC Category code	IPCC Category	Green-house gas	2000 Year Estimate Ex0 (Gg $CO_{2\ eq}$)	2017 Year Estimate Ext (Gg $CO_{2\ eq}$)	2000 Year Estimate (absolute) |Ex0| (Gg $CO_{2\ eq}$)	2017 Year Estimate (absolute) |Ext| (Gg $CO_{2\ eq}$)	Trend Assessment (T_{xt})	% Contribution to Trend	Cumulative Total of Column G
1.A.1	Energy Industries - Liquid Fuels	CO_2	6.57	0.00	6.57	0.00	0.002	0.17%	98.98%
1.A.3.e	Other Transportation	CO_2	10.84	30.10	10.84	30.10	0.002	0.16%	99.14%
4.C	Incineration and Open Burning of Waste	CH_4	13.52	12.96	13.52	12.96	0.002	0.15%	99.29%
1.A.3.b	Road Transportation	N_2O	9.99	26.58	9.99	26.58	0.001	0.13%	99.43%
1.A.4	Other Sectors - Solid Fuels	CO_2	0.04	3.95	0.04	3.95	0.001	0.06%	99.48%
1.A.4	Other Sectors - Biomass	N_2O	4.76	4.52	4.76	4.52	0.001	0.05%	99.54%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	4.55	4.24	4.55	4.24	0.001	0.05%	99.59%
4.C	Incineration and Open Burning of Waste	CO_2	4.47	4.28	4.47	4.28	0.001	0.05%	99.64%
3.A.2	Manure Management	CH_4	18.12	34.72	18.12	34.72	0.000	0.05%	99.69%
4.C	Incineration and Open Burning of Waste	N_2O	3.59	3.44	3.59	3.44	0.000	0.04%	99.73%
2.A.3	Glass Production	CO_2	1.50	5.43	1.50	5.43	0.000	0.04%	99.77%
3.C.3	Urea application	CO_2	0.00	2.72	0.00	2.72	0.000	0.04%	99.81%
1.A.4	Other Sectors - Gaseous Fuels	CH_4	0.38	3.32	0.38	3.32	0.000	0.04%	99.84%
2.G	Other Product Manufacture and Use	SF_6	0.04	2.59	0.04	2.59	0.000	0.04%	99.88%
2.F.4	Aerosols	HFCs	3.06	7.77	3.06	7.77	0.000	0.04%	99.92%
3.C.1	Emissions from biomass burning	CH_4	3.68	4.70	3.68	4.70	0.000	0.02%	99.94%
1.A.1	Energy Industries - Gaseous Fuels	N_2O	0.92	0.71	0.92	0.71	0.000	0.01%	99.95%
1.A.4	Other Sectors - Gaseous Fuels	N_2O	0.11	0.98	0.11	0.98	0.000	0.01%	99.97%
1.A.1	Energy Industries - Gaseous Fuels	CH_4	0.62	0.48	0.62	0.48	0.000	0.01%	99.97%
3.B.2.a	Cropland Remaining Cropland	CO_2	0.67	0.67	0.67	0.67	0.000	0.01%	99.98%
3.B.4.a.i	Peatlands remaining peatlands	N_2O	0.43	0.43	0.43	0.43	0.000	0.00%	99.99%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.23	0.15	0.23	0.15	0.000	0.00%	99.99%
1.A.3.e	Other Transportation	N_2O	0.18	0.49	0.18	0.49	0.000	0.00%	99.99%
3.C.1	Emissions from biomass burning	N_2O	1.42	2.38	1.42	2.38	0.000	0.00%	99.99%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	N_2O	0.19	0.22	0.19	0.22	0.000	0.00%	100.00%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.08	0.05	0.08	0.05	0.000	0.00%	100.00%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CH_4	0.13	0.15	0.13	0.15	0.000	0.00%	100.00%

A	B	C	D	E			F	G	H
IPCC Category code	**IPCC Category**	**Green-house gas**	**2000 Year Estimate Ex0 (Gg $CO_{2\ eq}$)**	**2017 Year Estimate Ext (Gg $CO_{2\ eq}$)**	**2000 Year Estimate (absolute) |Ex0| (Gg $CO_{2\ eq}$)**	**2017 Year Estimate (absolute) |Ext| (Gg $CO_{2\ eq}$)**	**Trend Assessment (T_{xt})**	**% Contri-bution to Trend**	**Cumula-tive Total of Column G**
1.A.4	Other Sectors - Solid Fuels	CH_4	0.00	0.06	0.00	0.06	0.000	0.00%	100.00%
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.14	0.19	0.14	0.19	0.000	0.00%	100.00%
1.A.1	Energy Industries - Liquid Fuels	N_2O	0.02	0.00	0.02	0.00	0.000	0.00%	100.00%
1.A.4	Other Sectors - Solid Fuels	N_2O	0.00	0.02	0.00	0.02	0.000	0.00%	100.00%
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.09	0.17	0.09	0.17	0.000	0.00%	100.00%
1.A.3.e	Other Transportation	CH_4	0.01	0.03	0.01	0.03	0.000	0.00%	100.00%
1.A.1	Energy Industries - Liquid Fuels	CH_4	0.01	0.00	0.01	0.00	0.000	0.00%	100.00%
1.B.2.b	Natural Gas	CO_2	0.11	0.19	0.11	0.19	0.000	0.00%	100.00%
2.F.2	Foam Blowing Agents	HFCs	0	23.01	0.00	23.01	-	0.00%	100.00%
3.B.3.b	Land Converted to Grassland	CO_2	0	18.37	0.00	18.37	-	0.00%	100.00%
3.B.2.b	Land Converted to Cropland	CO_2	0	-7.40	0.00	7.40	-	0.00%	100.00%
3.B.1.b	Land Converted to Forest land	CO_2	0	-6.53	0.00	6.53	-	0.00%	100.00%
2.F.3	Fire Protection	HFCs	0	0.64	0.00	0.64	-	0.00%	100.00%
3.B.5.b	Land Converted to Settlements	CO_2	0	-0.15	0.00	0.15	-	0.00%	100.00%
Total			**5,827.98**	**10,153.47**	**6,769.65**	**11,229.44**	**1.02**	**1**	

Annex 1.3 Uncertainty Assessment of the level (2017) and trend (2000-2017) of Armenia's GHG inventory

IPCC Cate-gory code	IPCC Category	GHG	Base year Emissi-ons or remo-vals (2000)	Last year emissi-ons or remo-vals (2017)	Activity data uncer-tainty	Emissi-on factor uncer-tainty	Combi-ned Uncer-tainty	Contribu-tion to Variance by category in last year (2017)	Type A Sensiti-vity	Type B Sensiti-vity	Uncerta-inty in trend in national emissions introdu-ced by emission factor	Uncerta-inty in trend in national emissions introduced by activity data	Uncerta-inty introdu-ced into the trend in total national emissions
			Gg $CO_{2\ eq.}$	Gg $CO_{2\ eq.}$	%	%	%		%	%	%	%	%
1.A.1	Energy Industries - Gaseous Fuels	CH_4	0.62	0.48	3%	100%	100%	0.00000	0.0104%	0.0082%	0.0104%	0.0003%	0.0000%
1.A.1	Energy Industries - Gaseous Fuels	CO_2	1,696.99	1,297.95	3%	3%	4%	0.00003	28.4210%	22.2461%	0.8526%	0.9438%	0.0162%
1.A.1	Energy Industries - Gaseous Fuels	N_2O	0.92	0.71	3%	500%	500%	0.00000	0.0154%	0.0121%	0.0771%	0.0005%	0.0001%
1.A.1	Energy Industries - Liquid Fuels	CH_4	0.01	0.00	5%	100%	100%	-	0.0002%	0.0000%	0.0002%	0.0000%	0.0000%
1.A.1	Energy Industries - Liquid Fuels	CO_2	6.57	0.00	5%	3%	6%	-	0.1964%	0.0000%	0.0059%	0.0000%	0.0000%
1.A.1	Energy Industries - Liquid Fuels	N_2O	0.02	0.00	5%	1000%	1000%	-	0.0005%	0.0000%	0.0047%	0.0000%	0.0000%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CH_4	0.13	0.15	5%	100%	100%	0.00000	0.0012%	0.0026%	0.0012%	0.0002%	0.0000%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	345.63	407.67	5%	3%	6%	0.00001	3.3472%	6.9873%	0.1004%	0.4941%	0.0025%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	N_2O	0.19	0.22	5%	1000%	1000%	0.00000	0.0018%	0.0038%	0.0180%	0.0003%	0.0000%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.08	0.05	20%	100%	102%	0.00000	0.0014%	0.0009%	0.0014%	0.0003%	0.0000%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	89.23	62.19	20%	5%	21%	0.00000	1.6025%	1.0659%	0.0801%	0.3015%	0.0010%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.23	0.15	20%	1000%	1000%	0.00000	0.0042%	0.0027%	0.0416%	0.0008%	0.0000%
1.A.3.b	Road Transportation - Gaseous Fuels	CH_4	1.87	33.02	5%	1500%	1500%	0.00237	0.5100%	0.5659%	7.6501%	0.0400%	0.5853%
1.A.3.b	Road Transportation - Gaseous Fuels	N_2O	0.90	15.89	5%	2500%	2500%	0.00152	0.2455%	0.2724%	6.1381%	0.193%	0.3768%
1.A.3.b	Road Transportation - Liquid Fuels	CH_4	5.43	4.96	20%	300%	301%	0.00000	0.0773%	0.0850%	0.2320%	0.0240%	0.0005%
1.A.3.b	Road Transportation - Liquid Fuels	N_2O	9.09	10.68	20%	300%	301%	0.00001	0.0888%	0.1831%	0.2663%	0.0518%	0.0007%
1.A.3.b	Road Transportation - Gaseous Fuels	CO_2	55.20	971.86	5%	3%	6%	0.00003	15.0049%	16.6571%	0.4501%	1.1778%	0.0159%
1.A.3.b	Road Transportation - Liquid Fuels	CO_2	626.80	721.73	20%	5%	21%	0.00021	6.3681%	12.3700%	0.3184%	3.4988%	0.1217%
1.A.3.e	Other Transportation - Liquid Fuels	CO_2	10.84	30.10	20%	5%	21%	0.00000	0.1918%	0.5159%	0.0096%	0.1459%	0.0002%
1.A.3.e	Other Transportation - Liquid Fuels	CH_4	0.01	0.03	20%	100%	102%	0.00000	0.0002%	0.0006%	0.0002%	0.0002%	0.0000%
1.A.3.e	Other Transportation - Liquid Fuels	N_2O	0.18	0.49	20%	1000%	1000%	0.00000	0.0031%	0.0084%	0.0313%	0.0024%	0.0000%
1.A.4	Other Sectors - Biomass	CH_4	24.20	22.96	100%	100%	141%	0.00001	0.3301%	0.3935%	0.3301%	0.5565%	0.0042%
1.A.4	Other Sectors - Biomass	N_2O	4.76	4.52	100%	1000%	1005%	0.00002	0.0650%	0.0774%	0.6500%	0.1095%	0.0043%

IPCC Category code	IPCC Category	GHG	Base year Emissions or removals (2000)	Last year emissions or removals (2017)	Activity data uncertainty	Emission factor uncertainty	Combined Uncertainty	Contribution to Variance by category in last year (2017)	Type A Sensitivity	Type B Sensitivity	Uncertainty in trend in national emissions introduced by emission factor	Uncertainty in trend in national emissions introduced by activity data	Uncertainty introduced into the trend in total national emissions
			Gg CO_2 eq.	Gg CO_2 eq.	%	%	%		%	%	%	%	%
1.A.4	Other Sectors - Gaseous Fuels	CH_4	0.38	3.32	5%	100%	100%	0.00000	0.0455%	0.0568%	0.0455%	0.0040%	0.0000%
1.A.4	Other Sectors - Gaseous Fuels	N_2O	0.11	0.98	5%	1000%	1000%	0.00000	0.0134%	0.0168%	0.1344%	0.0012%	0.0002%
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.14	0.19	20%	100%	102%	0.00000	0.0008%	0.0033%	0.0008%	0.0009%	0.0000%
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.09	0.17	20%	1000%	1000%	0.00000	0.0002%	0.0029%	0.0022%	0.0008%	0.0000%
1.A.4	Other Sectors - Solid Fuels	CH_4	0.00	0.06	40%	100%	108%	0.00000	0.00010%	0.0010%	0.0009%	0.0006%	0.0000%
1.A.4	Other Sectors - Solid Fuels	CO_2	0.04	3.95	40%	10%	41%	0.00000	0.0665%	0.0677%	0.0066%	0.0383%	0.0000%
1.A.4	Other Sectors - Solid Fuels	N_2O	0.00	0.02	40%	1000%	1001%	0.00000	0.0003%	0.0003%	0.0033%	0.0002%	0.0000%
1.A.4.a	Commercial/institutional - Gaseous Fuels	CO_2	35.16	531.42	5%	3%	6%	0.00001	8.0564%	9.1082%	0.2417%	0.6440%	0.0047%
1.A.4.a	Commercial/institutional - Liquid Fuels	CO_2	5.19	2.66	20%	5%	21%	0.00000	0.1096%	0.0457%	0.0055%	0.0129%	0.0000%
1.A.4.b	Residential - Liquid Fuels	CO_2	28.44	2.81	20%	5%	21%	0.00000	0.8025%	0.0481%	0.0401%	0.0136%	0.0000%
1.A.4.b	Residential- Gaseous Fuels	CO_2	176.95	1264.95	5%	3%	6%	0.00005	16.3836%	21.6805%	0.4915%	1.5330%	0.0259%
1.A.4.c	Agriculture/forestry/fishing/fish farms - Liquid Fuels	CO_2	28.63	64.02	20%	5%	21%	0.00000	0.2411%	1.0973%	0.0121%	0.3104%	0.0010%
1.B.2.b	Natural Gas	CH_4	1,106.49	1626.88	5%	5%	7%	0.00013	5.1969%	27.8837%	0.2598%	1.9717%	0.0396%
2.A.1	Cement production	CO_2	138.85	224.55	5%	20%	21%	0.00002	0.3036%	3.8487%	0.0612%	0.2721%	0.0008%
2.A.2	Lime production	CO_2	3.95	28.35	5%	6%	8%	0.00000	0.3677%	0.4859%	0.0221%	0.0344%	0.0000%
2.A.3	Glass Production	CO_2	1.50	5.43	5%	40%	40%	0.00000	0.0483%	0.0931%	0.0193%	0.0066%	0.0000%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	4.55	4.24	5%	50%	50%	0.00000	0.0634%	0.0726%	0.0318%	0.0051%	0.0000%
2.F.1	Refrigeration and Air Conditioning	HFCs	0.90	653.92	30%	25%	39%	0.00063	11.1810%	11.2078%	2.7953%	4.7551%	0.3042%
2.F.2	Foam Blowing Agents	HFCs	0.00	23.01	50%	25%	56%	0.00000	0.3943%	0.3943%	0.0986%	0.2788%	0.0009%
2.F.3	Fire Protection	HFCs	0.00	0.64	40%	25%	47%	0.00000	0.0109%	0.0109%	0.0027%	0.0062%	0.0000%
2.F.4	Aerosols	HFCs	3.06	7.77	30%	25%	39%	0.00000	0.0417%	0.1332%	0.0104%	0.0565%	0.0000%
2.G	Other Product Manufacture and Use	SF_6	0.04	2.59	5%	30%	30%	0.00000	0.0432%	0.0445%	0.0130%	0.0031%	0.0000%
3.A.1.a	Enteric Fermentation - Cattle	CH_4	634.96	849.02	10%	20%	22%	0.00035	4.4324%	14.5518%	0.8865%	2.0579%	0.0502%
3.A.1.b-j	Enteric Fermentation - Other	CH_4	93.09	124.48	20%	40%	45%	0.00003	0.6503%	2.1335%	0.2601%	0.6034%	0.0043%
3.A.2	Manure Management	CH_4	18.12	34.72	25%	30%	39%	0.00000	0.0530%	0.5951%	0.0159%	0.2104%	0.0004%
3.A.2	Manure Management	N_2O	42.33	57.48	25%	30%	39%	0.00000	0.2806%	0.9852%	0.0842%	0.3483%	0.0013%
3.B.1.a	Forest land Remaining Forest land	CO_2	-470.82	-523.92	5%	105%	105%	0.000293	5.1047%	8.9796%	5.3660%	0.6350%	0.2920%

IPCC Category code	IPCC Category	GHG	Base year Emissions or removals (2000)	Last year emissions or removals (2017)	Activity data uncertainty	Emission factor uncertainty	Combined Uncertainty	Contribution to Variance by category in last year (2017)	Type A Sensitivity	Type B Sensitivity	Uncertainty in trend in national emissions introduced by emission factor	Uncertainty in trend in national emissions introduced by activity data	Uncertainty introduced into the trend in total national emissions
			Gg CO_2 eq.	Gg CO_2 eq.	%	%	%		%	%	%	%	%
3.B.1.b	Land Converted to Forest land	CO_2	-0.00	-6.53	5%	105%	105%	0.00000	0.1119%	0.1119%	0.1176%	0.0079%	0.0001%
3.B.2.a	Cropland Remaining Cropland	CO_2	0.67	0.67	5%	50%	50%	0.00000	0.0086%	0.0115%	0.0043%	0.0008%	0.0000%
3.B.2.b	Land Converted to Cropland	CO_2	0.00	-7.40	5%	50%	50%	0.00000	0.1268%	0.1268%	0.0634%	0.0090%	0.0000%
3.B.4.a.i	Peatlands remaining peatlands	CO_2	1.97	18.32	5%	50%	50%	0.00000	0.2550%	0.3139%	0.1275%	0.0222%	0.0002%
3.B.4.a.i	Peatlands remaining peatlands	N_2O	0.43	043	5%	50%	50%	0.00000	0.0055%	0.0073%	0.0027%	0.0005%	0.0000%
3.B.5.b	Land Converted to Settlements	CO_2	0.00	-0.15	5%	50%	50%	0.00000	0.0025%	0.0025%	0.0012%	0.00002%	0.0000%
3.B.6.b	Land Converted to Other land	CO_2	-0.02	29.63	5%	50%	50%	0.00000	0.5083%	0.5078%	0.2542%	0.0359%	0.0007%
3.C.1	Emissions from biomass burning	CH_4	3.68	4.70	5%	105%	105%	0.00000	0.0295%	0.0806%	0.0310%	0.0057%	0.0000%
3.C.1	Emissions from biomass burning	N_2O	1.42	2.38	5%	105%	105%	0.00000	0.0018%	0.0407%	0.0019%	0.0029%	0.0000%
3.C.3	Urea application	CO_2	0.00	2.72	5%	10%	11%	0.00000	0.0466%	0.0466%	0.0047%	0.0033%	0.0000%
3.C.4	Direct N2O Emissions from managed soils	N_2O	436.57	671.00	30%	210%	212%	0.01955	1.5542%	11.5005%	3.2639%	4.8792%	0.3446%
3.C.5	Indirect N2O Emissions from managed soils	N_2O	115.32	181.67	30%	230%	232%	0.00171	0.3350%	3.1137%	0.7705%	1.3210%	0.0234%
3.C.6	Indirect N2O Emissions from manure management	N_2O	28.49	37.26	25%	30%	39%	0.00000	0.2133%	0.6387%	0.0640%	0.2258%	0.0006%
4.A	Solid Waste Disposal	CH_4	359.38	426.22	70%	30%	76%	0.00102	3.4401%	7.3052%	1.0320%	7.2318%	0.5336%
4.C	Incineration and Open Burning of Waste	CO_2	4.47	4.28	40%	40%	57%	0.00000	0.0603%	0.0734%	0.0240%	0.0415%	0.0000%
4.C	Incineration and Open Burning of Waste	CH_4	13.52	12.96	40%	40%	57%	0.00000	0.1823%	0.2221%	0.0729%	0.1257%	0.0002%
4.C	Incineration and Open Burning of Waste	N_2O	3.59	3.44	40%	40%	57%	0.00000	0.0484%	0.0590%	0.0194%	0.0334%	0.0000%
4.D	Wastewater Treatment and Discharge	CH_4	80.26	105.60	36%	58%	68%	0.00005	1.5903%	1.8099%	0.3424%	0.9214%	0.0097%
4.D	Wastewater Treatment and Discharge	N_2O	52.60	68.16	35%	500%	501%	0.00113	0.4046%	1.1683%	2.0232%	0.5783%	0.0443%
		Totals	**5,834.50**	**10,153.47**				**0.03201**					**0.02804**
				Percentage Uncertainty in total inventory:				**17.9%**				**Trend Uncertainty:**	**16.7%**

Annex 2. Energy

Annex 2.1 Main indicators of gas supply system, 2017, provided by Gazprom Armenia CJSC

ГАЗПРОМ АРМЕНИЯ

Закрытое акционерное общество
«Газпром Армения»
(ЗАО «Газпром Армения»)

ЗАМЕСТИТЕЛЬ ГЕНЕРАЛЬНОГО ДИРЕКТОРА ГЛАВНЫЙ ИНЖЕНЕР

Тбилисское шоссе, 43. Ереван, Республика Армения, 0091
тел.. (374 10) 294-888, 294-753, факс (374 10) 294-728
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«Գազպրոմ Արմենիա»
փակ բաժնետիրական ընկերություն
(«Գազպրոմ Արմենիա» ՓԲԸ)

ԳԼԽԱՎՈՐ ՏՆՕՐԵՆԻ ՏԵՂԱԿԱԼ ԳԼԽԱՎՈՐ ՃԱՐՏԱՐԱԳԵՏ

0091, ՀՀ, Երևան, Թբիլիսյան խճուղի 43
հեռ `(374 10) 294-888, 294-753, ֆաքս`(374 10) 294-728
Էլ.փոստ`inbox@gazpromarmenia.am, gazpromarmenia.am

«06» 08 2019 թ. № 02-24/3507

ՀՀ շրջակա միջավայրի
նախարարի տեղակալ
տիկին Ի. Ղափլանյանին

Ի պատասխան Ձեր 29.07.2019թ.
№ 2/05.1/20119 գրության

Հարգելի տիկին Ղափլանյան

Ձեզ է ներկայացվում ՀՀ գազափոխադրման համակարգում՝ 2017 և 2018թ.թ. ընթացքում, ՌԴ-ից ու ԻԻՀ-ից ներկրված և «Երևանի ԳՐԿ-2»-ից մատակարարված բնական գազի բաղադրամասերի և ֆիզիկաքիմիական պարամետրերի տարեկան միջին ցուցանիշների վերաբերյալ:

Առդիր՝ Տեղեկատվություն - 1 թերթից:

Հարգանքով՝ Ա. Հակոբյան

ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ ՇՐՋԱԿԱ
ՄԻՋԱՎԱՅՐԻ ՆԱԽԱՐԱՐՈՒԹՅԱՆ
ՔԱՐՏՈՒՂԱՐՈՒԹՅՈՒՆ
Մուտք No 35944
«12» 08 2019թ.

Դ. Հակոբյան
010. 29-47-62

Main indicators of gas supply system, mln m^3

		2017
1	Imported Natural Gas, including:	2,378.7
1.1	From Russian Federation	1,996.0
1.2	From the Islamic Republic of Iran	382.7
2	Taken from gas pipelines and Gas Underground Storage Facility (GUSF)	57.7
3	Gas for own needs in the transmission system	4.9
4	Gas losses in the transmission system. including:	108.7
4.1	Technological inevitable losses in gas pipelines	107.8
4.2	Accidental losses	0.9
5	Injected into gas pipelines and GUSF	81.2
6	The volume of gas transmitted	2,241.7
6.1	Other consumers	256.5
6.2	Distribution system	1,985.2
7	Gas for own needs in the distribution system	3.4
8	Recovered gas	0.8
9	Gas losses in the distribution system	39.5
10	Natural gas sales in the distribution system, including:	1,941.5
10.1	Residential	621.5
10.2	Energy Generation	422.0
10.3	Industry	210.0
10.4	Compressed natural gas (CNG) stations	477.5
10.5	Budgetary organizations	56.2
10.6	Heating companies	0
10.7	Other consumers	154.3
11.	Average Net Calorific Value of Natural Gas (kcal/m3)	8,381

Annex 2.2 Activity Data in Energy Sector. Data on consumed energy per fuel types. 2017. received from RA SC

ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ
ՎԻՃԱԿԱԳՐԱԿԱՆ ԿՈՄԻՏԵ
(ԱՐՄՍՏԱՏ)

« ____» __________ 20____ թ. №

Ձեր « ____ »__________ 20____ թ. №

ՀՀ ՇՐՋԱԿԱ ՄԻՋԱՎԱՅՐԻ ՆԱԽԱՐԱՐ
ՊԱՐՈՆ Է. ԳՐԻԳՈՐՅԱՆԻՆ

Հարգելի պարոն Գրիգորյան

Ի պատասխան Ձեր 29.07.2019թ. թիվ 1/05.1/11853-19 գրության, ՀՀ վիճակագրական կոմիտեն (Արմստատ) Ձեզ է տրամադրում հայցվող վիճակագրական տեղեկատվությունը համաձայն Ձեր գրությանը կից հավելվածների:

Միաժամանակ, Արմստատ-ը տեղեկացնում է, որ 2017-2018թթ.-ին սպանդի ենթարկված գյուղատնտեսական կենդանիների գլխաքանակի և կորուստների (անկումների) վերաբերյալ տվյալները (*հավելված 1՝ «Գյուղատնտեսություն» բաժնի համար անհրաժեշտ ելակետային տվյալները*) վիճակագրական հաշվառման մշտադիտարկման դաշտում ընդգրկված գյուղատնտեսությամբ զբաղվող առևտրային կազմակերպությունների և անհատ ձեռնարկատերերի մասով է: Ինչ վերաբերում է ֆիզիկական անձանց (բնակչության) կողմից սպանդի ենթարկված գյուղատնտեսական կենդանիների գլխաքանակի և կորուստների (անկումների) վերաբերյալ տվյալներին *(նույն հավելված)*, ապա Արմստատ-ի կողմից նման կտրվածքով վիճակագրական հաշվառում չի իրականացվում: Հաշվի առնելով,որ ՀՀ էկոնոմիկայի նախարարությունը վարում է մսի արտադրության մասով վարչական ռեգիստր, խնդրո առարկա ցուցանիշների համար Արմստատ-ն առաջարկում է դիմել ՀՀ էկոնոմիկայի նախարարությանը:

2018թ.-ին սպառված վառելիքի քանակն ըստ տեսակների վերաբերյալ տվյալների մասով (հավելված 2՝ «Էներգետիկա» բաժնի համար անհրաժեշտ ելակետային տվյալները) Արմստատ-ը տեղեկացնում է, որ համաձայն «2019 թվականի վիճակագրական ծրագրի» Մաս 1, 1.2.1 Արդյունաբերություն ենթահատվածի, 121013 ծածկագրով («Էներգակիրների արտադրության, սպառման և պահուստների մասին») վիճակագրական աշխատանքի մշակման ավարտը նախատեսված է ս.թ. օգոստոսի 15-ին (տես՝ https://www.armstat.am/file/doc/99513873.pdf հղումը) և պատրաստ լինելուն պես Արմստատ-ը կտրամադրի խնդրո առարկա ցուցանիշները:

Առդիր՝ 3 ֆայլ:

Հարգանքով

Recoverable Signature

Նախագահ
Ս.Մնացականյան

X

ՍՏԵՓԱՆ ՄՆԱՑԱԿԱՆՅԱՆ

Signed by: MINATSAKANYAN STEPAN 1107570328

Կատ.՝ Վիճակագրական տեղեկատվության տարածման բաժին, հեռ.՝ (011) 523 356
Միջազգային վիճակագրական համագործակցության բաժին (011) 589 545

ք. Երևան, 0010
Հանրապետության պողոտա,
Կառավարական 3 շենք

☎: (+37411) 52-42-13, Ֆաքս: (+37411) 52-19-21
Էլ. փոստ: info@armstat.am
https://www.armstat.am, http://www.armstatbank.am

Consumed energy by types of fuels. 2017

Categories/Subcategories	Coal	Natural Gas	Diesel		Gasoline	LPG	Fuelwood	Manure and other biofuel
	ton	million m³	thousand liter		ton	ton	ton	ton
2017			For energy purposes	Transport				
Manufacturing Industries and construction. including:	-	200.3	23,240.7	57,534.7	-	193.4	87.1	-
Iron and Steel	-	14.4	4.5	261.0	-	7.9	-	-
Chemicals	-	2.5	21.0	1,124.7	-	-	-	-
Non-Ferrous Metals	-	24.3	5,353.0	8,635.9	-	0.8	80.0	-
Non-Metallic Minerals	-	86.6	546.8	5,972.7	-	39.8	-	-
Transport equipment	-	-	-	-	-	-	-	-
Machinery	-	0.9	-	343.9	-	35.2	-	-
Mining (excluding fuels) and Quarrying	-	8.2	16,853.0	15,013.1	-	55.6	-	-
Food Processing. Beverages and Tobacco	-	53.2	79.5	7,462.3	-	0.1	-	-
Pulp. Paper and Print	-	4.3	0.8	91.8	-	2.0	-	-
Wood and wood products	-	0.1	-	14.9	-	-	2.6	-
Textile and Leather	-	0.5	-	99.3	-	-	4.5	-
Construction	-	4.1	380.1	17,743.8	-	43.5	-	-
Non-specified Industry	-	1.2	2.0	771.3	-	8.5	-	-
Civil Aviation	-	-		-	54,394.2*		-	-
Road Transportation including:	-	477.5**		94,473.8***	142,213.3	4,761.9	-	-
Commercial/Institutional	1,294.6	261.3		-	-	892.9	-	-
Residential	323.7	621.5		601.6***	-	297.6	199,788.0	209,405.3
Agriculture	-	-		20,093.8***	-	-	-	-

**Jet Kerosene. Gasoline fuel for jet engines*

***Compressed Natural Gas*

**** ton*

Annex 2.3 Main indicators of power system for 2017, mln kWh

Electricity generated and delivered	2017
Electricity generation, including:	**7,762.9**
ANPP	2,619.6
Hrazdan TPP	316.9
“Gazprom Armenia” CJSC Hrazdan-5 TPP	992.6
Yerevan CCGT	1,543.6
International energy corporation HPP	466.0
ContourGlobal HPP	941.2
Combined Heat and Power Production (Cogeneration)	18.6
Power plants using renewable energy resources (up to 30 MW)	864.3
Own needs of the generating plants, including:	**353.3**
ANPP	208.2
Hrazdan TPP	21.6
“Gazprom Armenia” CJSC Hrazdan-5 TPP	38.1
Yerevan CCGT	50.5
International energy corporation HPP	9.1
ContourGlobal HPP	6.7
Combined Heat and Power Production (Cogeneration)	0.4
Power plants using renewable energy resources (up to 30 MW)	18.7
Electricity supply from generation plants, including:	**7,409.6**
ANPP	2,411.4
Hrazdan TPP	295.4
“Gazprom Armenia” CJSC Hrazdan-5 TPP	954.5
Yerevan CCGT	1,493.1
International energy corporation HPP	456.9
ContourGlobal HPP	934.6
Combined Heat and Power Production (Cogeneration), including:	18.3
Yerevan Medical University CHP plant	7.0
ArmRosCogeneration CHP plant	11.2
Power plants using renewable energy resources (up to 30 MW), including:	845.5
“High Voltage Networks” CJSC Lori-1 wind plant	2.0
“Arats” LLC (Kajaran) wind plant	0.07
Autonomous producers up to 150 kW capacity	0.14
Solar PVs	0.4
Small HPPs	843.0
Import including:	**319.5**
Artsakh	64.6
The Islamic Republic of Iran	75.1
Georgia	179.8
Inflow to high voltage network	**6,865.3**
Losses of High Voltage Networks	**129.1**
Delivery from High Voltage Networks, including:	**7,600.0**
Domestic consumption	6,160.4
Artsakh	87.9
The Islamic Republic of Iran	1,224.3
Georgia	127.4
Total losses in distribution networks, including:	**539.5**
Electricity supplied by Armenian Electric Networks CJSC (by consumers' groups)	**5,620.9**
Residential	1,905.7
Budgetary organizations	233.9
Industry	1,440.1
Transport	101.7
Irrigation	158.4
Water supply and sanitation	67.2
Other consumers	1,713.9

Annex 2.4 Data on Natural Gas consumption by Thermal Power Plants provided by the Public Services Regulatory Commission

ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ
ՀԱՆՐԱՅԻՆ ԾԱՌԱՅՈՒԹՅՈՒՆՆԵՐԸ ԿԱՐԳԱՎՈՐՈՂ ՀԱՆՁՆԱԺՈՂՈՎ

ՀԱՆՁՆԱԺՈՂՈՎԻ ԱՆԴԱՄ

ՀՀ, ԵՐԵՎԱՆ, ՍԱՐՅԱՆ 22, ՀԵՌ.(374-10) 566471, ՖԱՔՍ (374-10) 525563

« 17 » սեպտեմբերի 2019 թ.

№ ՀԾԿՀ/34.3-ՀՆ-1/2555-19

ՄԱԶԾ Հայաստան
կլիմայի փոփոխության ծրագրի համակարգող
տիկին Դիանա Հարությունյանին

Ի պատասխան Ձեր 11.09.2019թ.
№BUR3-001 գրության

Հարգելի տիկին Հարությունյան,

Ձեզ է ուղարկվում 2017-2018թթ. ջերմային էլեկտրակայանների սպառած բնական գազի ծախսի վերաբերյալ տեղեկանքը:

Առդիր՝ 1 էջ:

Invalid signature

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ՍԵՐԳԵՅ ԱՂԻՆՅԱՆ

Ս.Աղինյան

Կատարող՝ Մ. Մոմջյան ☎ 010-52-85-90 (329)

N	Thermal Power Plant	Measure-ment unit	2013	2014	2015	2016	2017
1	Hrazdan TPP OJSC	thsd m^3	193,320.2	275.583.1	162,509.1	129,544.3	91,143.7
2	“Gazprom Armenia” CJSC Hrazdan-5 TPP	thsd m^3	258,800.4	210,883.3	148,591.9	164,950.5	226,112.5
3	Yerevan CCGT	thsd m^3	299,261.2	305,644.1	336,812.6	303,887.2	315,180.4
4	Yerevan Medical University CHP plant	thsd m^3	3,898.0	4,309.0	3,878.2	2,116.5	2,176.9
5	ArmRosCogenerati on CJSC CHP plant	thsd m^3	3,706.0	3,125.0	2,576.0	3,227.0	2,913.0

Annex 2.5 Calculation of country-specific CO_2 emissions factors 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 2.6) 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 emissions factors for natural gas imported from RF. mixture natural gas and natural gas imported from Iran. are given in the Table below.

Table 2.5-1 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/m³	kcal/m³	MJ/m³	TJ/Gg	%	kg/m³	kg/GJ	kg/TJ
2011								
Imported from Russian Federation	0.7231	8,245	34.52	47.74	73.9512	0.5347	15.49	56,798.02
Mixture GDS-2	0.7260	8,188	34.28	47.22	73.4107	0.5330	15.55	57,004.85
Mixture (weighted average)	0.7258	8,190	34.29	47.25	73.4579	0.5331	15.55	57,006.52
Imported from Iran	0.7351	7,999	33.49	45.56	71.7326	0.5273	15.75	57,735.59
2012								
Imported from RF	0.7239	8,245	34.52	47.68	73.9512	0.5352	15.51	56,851.70
Mixture GDS-2	0.7275	8,149	34.12	46.90	73.4107	0.5323	15.60	57,209.21
Mixture (weighted average)	0.7265	8,200	34.33	47.25	73.5062	0.5341	15.56	57,041.37
Imported from Iran	0.7374	8,020	33.58	45.54	71.7326	0.5293	15.76	57,801.53
2013								
Imported from RF	0.7259	8,303	34.76	47.89	74.1141	0.5380	15.48	56,745.52
Mixture GDS-2	0.7305	8,256	34.57	47.32	73.5506	0.5373	15.54	56,993.61
Mixture (weighted average)	0.7291	8,264	34.60	47.45	73.7167	0.5375	15.53	56,960.17
Imported from Iran	0.7448	8,076	33.81	45.40	71.7963	0.5347	15.81	57,987.50
2014								
Imported from RF	0.7278	8,337	34.91	47.96	74.1718	0.5398	15.47	56,706.16
Mixture GDS-2	0.7312	8,251	34.55	47.24	73.4735	0.5372	15.55	57,022.93
Mixture (weighted average)	0.7296	8,287	34.69	47.55	73.7837	0.5383	15.52	56,892.11
Imported from Iran	0.7391	8,020	33.58	45.43	71.7284	0.5301	15.79	57,890.73
2015								
Imported from RF	0.7234	8,335	34.90	48.24	74.2282	0.5370	15.39	56,419.72
Mixture GDS-2	0.7259	8,266	34.61	47.68	73.6668	0.5347	15.45	56,655.00
Mixture (weighted average)	0.7252	8,266	34.66	47.79	73.8069	0.5353		56,624.28
Imported from Iran	0.7350	7,974	33.39	45.42	71.5373	0.5258	15.75	57,747.46
2016								
Imported from RF	0.7245	8,326	34.86	48.11	74.0303	0.5363	15.39	56,415.80
Mixture GDS-2	0.7239	8,218	34.41	47.53	73.5192	0.5322	15.47	56,715.56
Mixture (weighted average)	0.7264	8,270	34.62	47.66	73.6357	0.5349	15.45	56,646.87
Imported from Iran	0.7360	7,987	33.44	45.43	71.6580	0.5274	15.77	57,829.30
2017								
Imported from RF	0.7535	8,647	36.20	48.05	74.2943	0.5598	15.46	56,697.39
Mixture GDS-2	0.7460	8,469	35.46	47.53	73.8257	0.5507	15.53	56,951.34
Mixture (weighted average)	0.7513	8,548	35.79	47.64	73.8852	0.5551	15.51	56,871.87
Imported from Iran	0.7397	8,030	33.62	45.45	71.7511	0.5307	15.79	57,883.94

Annex 2.6 Natural Gas Composition and Annual Average Characteristics provided by "GAZPROM ARMENIA"

Natural gas imported from the Russian Federation

Composition. mol % Annual average	2017
Oxygen O_2	0.0097
Carbon Dioxide CO_2	0.1390
Nitrogen N_2	1.5882
Ethane C_2H_6	7.9975
Propane C_3H_8	1.9953
Isobutene i-C_4H_{10}	0.1384
N-butane n-C4H10	0.1176
Pentane C_5H_{12} and C_5+	0.0405
Methane CH_4	87.9738
Density (kg/m^3)	0.7535
Characteristics	
Net Calorific Value (average). kcal/m^3 (standard conditions t=20˚C. P=101.325 kPa)	8,647
Net Calorific Value (average). MJ/ m^3	36.20
Wobbe index MJ/ m^3	50.65
Mass concentration of hydrogen sulphide. g/m^3	0.0014
Mass concentration of mercaptan sulfur. g/m^3	0.0042
Mass concentration of mechanical impurities. g/m^3	0

Natural gas imported from the Islamic Republic of Iran

Composition. mol % Annual average	2017
Oxygen O_2	0.0098
Carbon Dioxide CO_2	0.6732
Nitrogen N_2	4.2709
Ethane C_2H_6	3.4648
Propane C_3H_8	1.0219
Isobutane i-C_4H_{10}	0.1796
N-butane n-C4H10	0.2520
Pentane C_5H_{12} and C_5+	0.0796
Methane CH_4	90.0481
Density (kg/m^3)	0.7397
Characteristics	
Net Calorific Value (average). kcal/m^3 (standard conditions t=20˚C. P=101.325 kPa)	7,974
Net Calorific Value (average). MJ/ m^3	33.39
Wobbe index MJ/ m^3	47.35
Mass concentration of hydrogen sulphide. g/m^3	0.0018
Mass concentration of mercaptan sulfur. g/m^3	0.0058
Mass concentration of mechanical impurities. g/m^3	0

Natural gas mixture (Yerevan GDS-2)

Compositionj. mol % Annual average	2017
Oxygen O_2	0.0089
Carbon Dioxide CO_2	0.2321
Nitrogen N_2	2.0438
Ethane C_2H_6	6.7487
Propane C_3H_8	1.6705
Isobutane i-C_4H_{10}	0.1374
N-butane n-C4H10	0.1411
Pentane C_5H_{12} and C_5+	0.0385
Methane CH_4	88.9789
Density (kg/m^3)	0.7460

Characteristics	
Net Calorific Value (average). kcal/m^3 (standard conditions t=20˚C. P=101.325 kPa)	8,469
Net Calorific Value (average). MJ/ m^3	35.46
Wobbe index MJ/ m^3	49.93
Mass concentration of hydrogen sulphide. g/m^3	0.0015
Mass concentration of mercaptan sulfur. g/m^3	0.0048
Mass concentration of mechanical impurities. g/m^3	0

Natural gas mixture (weighted average)

Composition. mol % Annual average	2017
Oxygen O_2	0.0097
Carbon Dioxide CO_2	0.2249
Nitrogen N_2	2.0198
Ethane C_2H_6	7.2683
Propane C_3H_8	1.8387
Isobutane i-C_4H_{10}	0.1450
N-butane n-C4H10	0.1392
Pentane C_5H_{12} and C_5+	0.0468
Methane CH_4	88.3075
Density (kg/m^3)	0.7513
Characteristics	
Net Calorific Value (average). kcal/m^3 (standard conditions t=20˚C. P=101.325 kPa)	8,548
Net Calorific Value (average). MJ/ m^3	35.79
Wobbe index MJ/ m^3	50.12
Mass concentration of hydrogen sulphide. g/m^3	0.0015
Mass concentration of mercaptan sulfur. g/m^3	0.0045
Mass concentration of mechanical impurities. g/m^3	0

Annex 3. AFOLU

Annex 3.1 Number of Livestock and Poultry, as of January 1 (heads)[12]

Indicator	2017
Cattle, including:	655,771
Dairy cows	295,974
Bulls	25,971
Growing cattle	333.823
Buffalos	715
Sheep and goats, including:	727,082
Sheep	699,561
Goats	27,521
Horses	10,631
Swine, including:	175,549
Sows which have farrowed and are nursing young	32,634
Mules and Asses	2,104
Rabbits.	30,704
Fur bearing animals	4,817
Poultry. including:	3,814,205
Laying hens	2,689,103

Annex 3.2 Production of main livestock products[13], 1000 tonne

Indicator	2017
Animals and poultry sold for slaughter (in slaughter weight). including:	109.0
Veal and beef	70.8
Pork	16.8
Lamb and goat's meat	10.8
Poultry	10.6
Milk Produced	758.2

Annex 3.3 Data on livestock and poultry slaughter and loss (according to the data of commercial organizations), heads[14], 2017

Indicator	2017
Slaughtered pets, of which:	
1.1 Cattle, head, of which:	507
Cows	145
Other age group animals	362
1.2 Sheep and goats, head	157
1.3 Swine, head	6,799
1.4 Bird, a thousand heads	6,696.8
2.Loss	
2.1 Cattle, head, of which:	376
Cows	274
Other age group animals	102
2.2 Sheep and goats, heads	93
2.3 Swine, heads	1,377
2.4 Bird, a thousand heads	637.0

[12] Food Security and Poverty, 2017-2018 January-June, Statistical Bulletins, NSS RA 2018, 2019, pp. 49-53.
[13] Statistical Yearbook of the Republic of Armenia 2018, NSS RA 2018, page 314.
[14] Source: Statistics Committee of the Republic of Armenia (Information received from the Statistics Committee of the Republic of Armenia in response to letters sent by the Ministry of Environment of RA (Letter No. 1 / 05.1 / 11853-19 dated 29.07.2019).

Annex 3.4 Activity data for the Agriculture Sector[15]

Indicator	2017
1. Cattle	***x***
Cows average live weight, kg	407
Bulls average live weight, kg	528
Growing cattle average live weight, kg	164
Growing cattle etalon weight, kg	322 (19 month)
Growing cattle daily average growth of weight, kg/day	0.470
Cows digestion energy, %	67
Bulls digestion energy, %	57
Growing cattle digestion energy, %	60
Milk fatness, %	3.7
2. Livestock regime`	***x***
Nursery, day	210-240
Grazing, day	125-155
3. Exertion for 1 cow, tonnes/year	8 t., from which manure; 5.6 t.
4. Manure left in the pasture, %	34.4-42.5
5. Lands	***x***
5.1 Grassland area, ha	121.0
From which manageable grassland area, ha	
5.2 Pasture area, ha	1050.8
From which manageable pasture area, ha	
5.3 One-year crops burnt area, ha	
5.4 Unmanageable (not used) land area, ha	
5.5 Separation and wind protection area, ha	
5.6 Burnt meadows and pastures area, ha	
5.7 Watershed area. from which	
5.7.1 Peat soils used for turf extraction, ha	
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	
6. Used fertilizer, tonne, from which:	***x***
6.1 Mineral or chemical nitrogen fertilizer, tons	40,793.9
6.2 Mineral or chemical phosphorus fertilizer, tons	
6.3 Mineral or chemical potassium fertilizer, tons	

[15] Source: Statistics Committee of the Republic of Armenia (Information received from the Statistics Committee of the Republic of Armenia in response to letters sent by the Ministry of Environment of RA (Letter No. 1 / 05.1 / 11853-19 dated 29.07.2019).

Annex 3.5 Activity data for the calculation of the emission factor from enteric fermentation

COWS

	Indicator	2017	Source:
1	Number of cows, head	329,232	Expert calculation
2	Average live weight, kg	407	Ministry of Agriculture of the RA
3	Milk Fat Content, %	3.7	Ministry of Agriculture of the RA
4	Milk Production per day (kg/day)	2.260	Statistical Yearbook[16]
5	Digestion Energy, %	67	Ministry of Agriculture of the RA
6	***Livestock regime`*** Confined area, day	210	Ministry of Agriculture of the RA
7	Grazing, day	155	Ministry of Agriculture of the RA
8	Work performed (days)	X	Cows are not used for work
9	Weight loss, kg / day	0	2006 IPCC Guidelines for National Greenhouse Gas Inventories
10	Methane Generation Coefficient (Y_m) - Confined area	0.07	2006 IPCC Guidelines for National Greenhouse Gas Inventories, (Volume 4. Table 4.8)
11	Methane Generation Coefficient (Y_m) - Pasture Mode	0.06	2006 IPCC Guidelines for National Greenhouse Gas Inventories, (Volume 4. Table 4.8)
12	**Emission Factor**	**68.9**	

Annex 3.6 Activity data for the calculation of the methane emission factor from enteric fermentation

BULLS

	Indicator	2017	Source:
1	Number of bulls, head	29,017	Expert calculation
2	Average live weight, kg	528	Ministry of Agriculture of the RA
3	Digestion factor. %	57	Ministry of Agriculture of the RA
4	***Livestock regime`*** Confined area, day	210	Ministry of Agriculture of the RA
5	Grazing, day	155	Ministry of Agriculture of the RA
6	Work performed (days)	X	Bulls are not used for work
7	Weight loss	0	2006 IPCC Guidelines for National Greenhouse Gas Inventories
8	Methane Generation Coefficient (Ym) - Confined area	0.07	2006 IPCC Guidelines for National Greenhouse Gas Inventories. (Volume 4. Table 4.8)
9	Methane Generation Coefficient (Ym) - Pasture Mode	0.06	2006 IPCC Guidelines for National Greenhouse Gas Inventories. (Volume 4. Table 4.8)
10	Emission factor (EF)	**70.1**	

[16] Statistical Yearbook 2018, RA SC, Yerevan 2018

Annex 3.7 Baseline data for the calculation of the methane emission factor from enteric fermentation

GROWING CATTLE

	Indicator	2017	Source:
1	Number of *growing cattle*, head	370,868	Expert calculation
2	Average live weight, kg	164	Ministry of Agriculture of the RA
3	Adult (etalon) weight (kg), kg	322	Ministry of Agriculture of the RA
4	Growing cattle daily average growth of weight, kg/day	0.47	Ministry of Agriculture of the RA
5	Digestion factor, %	60	Ministry of Agriculture of the RA
6	***Livestock regime`*** Confined area, day	210	Ministry of Agriculture of the Republic of Armenia
7	Grazing, day	155	Ministry of Agriculture of the Republic of Armenia
8	Methane Generation Coefficient (Ym) - Confined area	0.07	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Gen-3. Table 4.8
9	Methane Generation Coefficient (Ym) - Pasture Mode	0.06	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Gen-3. Table 4.8
10	Emission factor (EF)	**42.3**	

Annex 3.8 Basic wood density

Tree Species	Factor	Source
Pine-tree	0.415	LUCFref-19
Juniper	0.447	LUCFref-16
Yew	0.474	LUCFref-8
Fir-tree	0.365	LUCFref-19
Oak-tree	0.57	LUCFref-19
Beech	0.538	LUCFref-7
Hornbeam	0.64	LUCFref-19
Ash-tree	0.648	LUCFref-15
Maple	0.557	LUCFref-14
Elm-tree	0.535	LUCFref-15
Lime-tree	0.366	LUCFref-13
Birch-tree	0.459	LUCFref-8
Plane-tree	0.522	LUCFref-18
Walnut tree	0.49	LUCFref-19
Pear tree	0.564	LUCFref-8
Poplar	0.423	LUCFref-17
Willow	0.38	LUCFref-19
Acacia	0.65	LUCFref-19
Hackberry	0.53	LUCFref-9

Annex 3.9 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**