REPUBLIC OF ARMENIA
MINISTRY OF ENVIRONMENT

National Greenhouse Gas Inventory Report of Armenia 1990-2019

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

2023

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 Environment Facility and support of the United Nations Development Programme in Armenia within the framework of the "Building Armenia's national transparency framework under Paris Agreement" project. "Hydrometeorology and Monitoring Center" SNCO of the Ministry of Environment of the RA contributed to the Inventory development.

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ABBREVIATIONS

AFOLU	Agriculture, Forestry and Other Land Use
BUR	Biennial update report
CCGT	Coal and Gas Combined-Cycle Gas Turbine
CFC	Chlorofluorocarbons
CIS	Commonwealth of Independent States
CJSC	Closed Joint-Stock Company
DOM	Dead organic matter
EDF	Energy Delivery Factor
EE	Energy efficiency
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme (of EEA)
FEC	Final energy consumption
FES	Fuel-energy supplies
FOD	First Order Decay
FOLU	Forestry and Other Land Use
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HH	Households
HMC SNCO	"Hydrometeorology and Monitoring Center" SNCO of the Ministry of Environment of the RA
HPP	Hydropower plant
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
KCA	Key Category Analysis
LCFL	Land Converted to Forest Land
LLC	Limited liability company
LNG	Liquified natural gas
LPG	Liquified petroleum gas
MOE	Ministry of Environment (previously, Ministry of Nature Protection)
NA	Not applicable: an activity or a category exists, but does not contribute to the emissions of a given type
NAS	National Academy of Sciences
NE	Not estimated: emissions/removals exist, but are not assessed
NGDS	Natural gas distribution station
NMVOC	Non methane volatile organic compounds
NO	Not occurring: a given activity or process does not exist in the country
ODS	Ozone depleting substances
PFC	Perfluorocarbons
PSRC	Public Services Regulatory Commission
QA/QC	Quality assurance/ Quality control
RA	Republic of Armenia
REC	Refrigeration and Air Conditioning
RF	Russian Federation

RSW	Residential solid waste
RSWDS	Residential solid waste disposal sites
RSWGR	Residential solid waste generation rate
SC	Statistics Committee
SHPP	Small hydropower plant
SNCO	State Non-Commercial Organization
SPNA	Specially protected nature areas
SRC	State Revenue Committee
TACCC	Transparency, Accuracy, Completeness, Comparability, Consistency
TASR	Technical analysis summary report
TPP	Thermal power plant
UN	United Nations
UN FAO	UN Food and Agriculture Organization
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USSR	Union of Soviet Socialist Republics

Abridgements

thsd	thousand
eq.	equivalent
mln	million
toe	tones oil equivalent

Units of Measurement

g	gram
Gg	gigagram (10^9 g, or thousand t)
t	ton
m	meter
m^3	cubic meter
mm	millimeter
cm	centimeter
km	kilometer
km^2	square kilometer
ha	hectare
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
NOx	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

SUMMARY

The National Inventory Report (NIR) 1990-2019 of the Republic of Armenia is prepared under coordination of the country's Ministry of Environment in the framework of "Building Armenia's national transparency framework under Paris Agreement" UNDP-GEF/00110252 project.

The Republic of Armenia developed its Greenhouse Gas (GHG) Inventory for 1990-2019 period in accordance with the 2006 IPCC (Intergovernmental Panel on Climate Change) Guidelines for national greenhouse gas inventories.

The National GHG Inventory includes an assessment of the emissions/removals of five greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HFC_s) and sulfur hexafluoride (SF_6) – expressed in the units of mass and in carbon dioxide equivalent ($CO_{2\ eq.}$) and relying on the values of the Global Warming Potentials (GWP_s) recommended by in the IPCC Second Assessment Report (SAR).

The National GHG Inventory includes also the emission estimates of precursors: carbon monoxide (CO), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2).

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

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

and includes:

- Summary report of National GHG Inventory,
- Inventory sectoral tables according to the 2006 IPCC Guidelines,
- Key category analysis (KCA),
- Uncertainty analysis,
- Consistent time series for years 1990-2019,
- Summary information table of inventories for previous submission years from 1990 to 2019.

The National GHG Inventory developed in the framework of the present report is improved in the following main areas to make it more transparent, accurate, comparable, consistent and complete (TACCC principles):

- GHG emissions are assessed for 7 new sub-categories,
- Methods of higher Tiers are introduced for 2 sub-categories,
- Time series for years 1990-2019 were recalculated to ensure their consistency taking into account the latest changes in terms of the improved methodologies and completeness and accuracy of the activity data.

In 2019, GHG emissions made 11,150.8 Gg $CO_{2\ eq.}$ (without the *Lands* category), which exceed the level of 2017 (546.9 Gg $CO_{2\ eq.}$) by 5.2%.

Table 1 shows GHG emissions distribution by gas and by sector in 2019.

Table 1. GHG emissions by gas and by sector in 2019, Gg

Sector	CO_2	CH_4	N_2O	HFCs CO_2 eq.	SF_6 CO_2 eq.	Total CO_2 eq.
Energy	5,896.6	57.2	0.1	NA	NA	7,138.3
Industrial Processes and Product Use[1]	312.5	NA	NA	NA	NA	312.5
F gases[2]	NA	NA	NA	969.5	3.3	972.8
AFOLU (without Forestry and Other Land Use)[3]	-0.2	44.9	3.7	NA	NA	2,098.3
Waste	4.7	26.2	0.2	NA	NA	628.7
Total GHG Emissions	**6,213.7**	**128.3**	**4.1**	**969.5**	**3.3**	**11,150.8**
Forestry and Other Land Use	-373.4	NA	0.0014	NA	NA	-373.0
Net GHG Emissions	**5,840.3**	**128.3**	**4.1**	**969.5**	**3.3**	**10,777.8**

Table 2 provides GHG emissions by sector in 1990-2019.

In 2019, GHG emissions fell below the level of 1990 by 57% (14,663 Gg) and exceeded the level of 2000 by 79.9%.

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

Table 2. GHG emissions by sector in 1990-2019, Gg $CO_{2\ eq.}$

Sector	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019	2019 emission change (%) compared to		
												1990 levels	2000 levels	2017 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	6,822.3	7,138.5	-68.6	67.8	0.7
Industrial Processes and Product Use	630.9	122.5	152.6	395.8	588.6	713.9	816.5	797.4	951.9	1174.2	1285.3	103.7	742.3	35.02
AFOLU (without Forestry and Other Land Use)	2,045.5	1,874.4	1,276.8	1,551.8	1,524.1	1,873.2	2,048.1	2,258.4	1,941.9	1,829.9	2,098.3	2.6	64.3	8.1
Waste	418.8	454.5	513.8	560.3	567.2	584.4	601.3	611.4	622.7	628.7	628.7	50.1	22.4	0.97
Total GHG Emissions	**25,814.5**	**7,270.5**	**6,198.4**	**7,760.4**	**8,489.5**	**10,063.3**	**10,507.4**	**10,290.6**	**10,603.9**	**10,455.0**	**11,150.8**	**-56.8**	**79.9**	**5.2**
Forestry and Other Land Use	-736.9	-514.4	-467.8	-523.7	-550.1	-516.2	-477.6	-487.9	-470.4	-455.2	-373.0	-49.4	-20.3	-20.7
Net GHG Emissions	**25,077.6**	**6,756.1**	**5,730.6**	**7,236.7**	**7,939.4**	**9,547.1**	**10,029.7**	**9,802.7**	**10,133.5**	**9,999.8**	**10,777.8**	**-57.0**	**88.1**	**6.4**

1. BASIC INFORMATION ON THE GREENHOUSE GAS INVENTORY

1.1 The Institutional structure of the Inventory compilation

The Ministry of Environment is the state authorized body responsible for the development and implementation of the state policies aimed at addressing climate change issues, also for implementing the country's commitments under the UNFCCC and the Paris Agreement.

National climate change policies and assumed commitments 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. In 2021, the decision N955 was repealed and replaced by Prime Minister's ordinance N719 to ensure a higher extent of political leadership, to expand the coordination mechanisms to include the commitments under the Paris Agreement, and to improve the Council's structure and procedures further. The tasks of the Council are, among others, to coordinate the implementations of the commitments and provisions assumed by the Republic of Armenia that arise from the Convention and the Paris Agreement, and to evaluate the respective performance and results.

The Chairman of the Council is the Deputy Prime Minister of the Republic of Armenia. In order to ensure the effectiveness of the Council's work, to provide professional and expert support (advice, recommendations, conclusions, opinions, reports) on individual sectoral and inter-sectoral issues, permanent and temporary interdepartmental working groups are established under the Council.

The United Nations Development Programme (UNDP) Country Office in Armenia through its Climate Change Program supports the Ministry of Environment, as the authorized national coordinator, in their effort to implement the country's commitments under the UNFCCC and the Paris Agreement. The support includes building Armenia's national transparency framework under the Paris Agreement.

Organizational changes

The major effort to support the establishment of the enhanced transparency framework is provided through the "*Building Armenia's national transparency framework under Paris Agreement*" UNDP-GEF project. In the framework of this project, a Letter-Agreement was signed between the UNDP Armenia and the "Hydrometeorology and Monitoring Center" (HCM) of the Ministry of Environment of the Republic of Armenia in order to involve a partner to implement the activities of the said UNDP-GEF project, including the submission of the country reports under the Convention and the Paris Agreement, such as the National GHG Inventory 2018-2019.

In the framework of this Letter-Agreement, the GHG emissions/removals of the *Industrial Processes and Product Use* sector, excluding F-gases, the *Forestry and Other Land Use* sub-sector and the *Waste* sector, are assessed by the HMC SNCO.

1.2 Overview of the Inventory compilation process

The National Greenhouse Gas Inventory Improvement Plan (NIIP) was analyzed prior to the start of the Inventory compilation activities. The purpose of the National Inventory Improvement Plan is to guide the next Inventory compilation process towards higher transparency, accuracy, completeness, consistency, comparability (TACCC) by identifying and prioritizing the actions to improve the national GHG system.

The following items that ensure from the previous revisions are incorporated into the National Inventory Improvement Plan:

- International consultation and analysis, that is, the Technical Analysis of the Third Biennial Update Report (TASR);

- Recommendations made at the seminar on "Quality Assurance of the National GHG Inventory Management Systems and National GHG Inventories of Developing Countries" organized by the UNFCCC Secretariat in 2019;
- Also, the actions that follow from the recommendations of the national experts.

It should be noted that the UNFCCC Secretariat provided additional targeted technical assistance to the Republic of Armenia for the development of the country's National GHG Inventory Improvement Plan (NIIP), which is a key component of the National GHG Inventory Management System (GHG-IMS) and aims to help the country prepare for the effective implementation of the Enhanced Transparency Framework (ETF) under the Paris Agreement. With the support of an international expert, the national plan for improving the GHG inventory was developed, which served as the basis for introducing improvements to the National GHG Inventory 1990-2019 of the Republic of Armenia.

Analysis of the National GHG Inventory Improvement Plan precedes the Inventory preparation process, because it serves as the foundation for formulating the data collection requirements.

Inventory preparation consists of the following main stages:

- Identification of the estimation methods
- Data collection
- Data processing and emissions estimation
- Report preparation

Identification of the estimation methods means review of the estimation methods implemented by the relevant sectoral experts and consideration of the possible changes therein (where necessary). In each case, the selection of a method depends on whether the considered category is a key one or not and on the availability of the data to enable application of a higher Tier approach.

Data collection and documentation includes 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 the publicly available national data; the Statistical Committee serves as the main source of data: since 2015, they publish the country’s energy balance, which is the most important source of activity data for the Energy sector;
- Collection of the rest of the required activity data is implemented by the Ministry of Environment through official inquiries, because no formal institutional arrangements function so far for regular collection/reporting of GHG inventory activity data;
- Receipt of the data;
- Quality Assurance and Quality Control (QA/QC) of activity data;
- Data archiving: all activity data received along with the respective inquiry letters from the Ministry of Environment to the data provider organizations are to be archived, both as printed/hard copies and in electronic format.

Data processing and emissions estimation:

- Update the country-specific emission factors and obtain their new values (if necessary);
- QC of emissions estimates;
- Preparation of sectoral reports (texts);
- 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: necessary prior to any further use of such texts and results.

Report preparation includes the following steps:

- Aggregation of emissions data for the country-specific trend tables and preparation of data tables for the NIR;
- Compilation of submitted sectorial report texts to produce a draft NIR;
- QA/QC procedure implementation for the draft NIR;
- Review and verification of the draft NIR by the Inter-agency Coordinating Council;
- Submitting the document to the UNFCCC Secretariat;
- Archiving.

1.3 Quality management

The quality requirements specified for the National Inventory - transparency, accuracy, completeness, comparability, consistency - are met through implementation of the QA/QC procedures.

The ultimate goal of the Quality Assurance / Quality Control (QA/QC) process is to ensure the quality of the Inventory and to contribute to the improvement of Inventory across the sectors.

The QC procedures used in Armenia's GHG Inventory follow QA/QC procedures provided by the Chapter 6 of Volume 1 of the 2006 IPCC Guidelines.

General quality control checks of the Inventory (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 comparability of the data between the 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 significant changes or departures from expected trends are identified, 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, also climate change experts and consultants, conducts technical analysis of the draft NIR (national trend tables) as a contribution to the QC procedure.

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

The results of the review are subsequently 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 provisions of the draft report, independent 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 the system

The Archiving System is an important component of the inventory development process that serves the maintenance of the Inventory system and the transparency of the national Inventories, while facilitating the development of subsequent inventories.

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

All emission factors and activity data are archived in most detail possible, also the relevant documentation on how these factors and data are 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 regular 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.

Archiving procedures

Below are presented the archiving procedures used for the available Inventory documents and files:

- The available documents and files of the Inventory cycle are stored both electronically and in printed/hard copies;
- The archive system can be accessed 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 server's hard drive and external HDD, which is handed to the MoE. In addition, the information kept 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 files are named and coded by sources and by receipt date;
- In order to reflect subsequent updates, the file names are changed by providing the date of latest update.

Starting from the data of 2017, the structure of the archiving system is coded for reference with the following logic:

L (numbering): Letters, D (numbering): Estimation files, DB (numbering): databank based on the IPCC 2006 software package, S (numbering): Sectoral reports, F (numbering): Final reports, Q (numbering): QA/QC protocols, M (numbering): Methodological files.

The use of bibliography in the National Inventory Reports is also coded. The reference numbers are applied with the following logic: International literature: Gen-1 - Gen-***, Country-specific literature: Ref-1 - Ref-***, Sectoral literature: Energy: EnRef-1 - EnRef-***, Industrial processes: IndRef-1 - IndRef-***, F-gases: IndF.Ref-1 - IndF.Ref-***, Agriculture: AFOLURef-1 - AFOLURef -***, Forestry: LUCFRef-1 - LUCFRef-***, Waste: WRef-1 - WRef-***.

Reference coding of the experts' estimation files is performed per the relevant Excel sheets with the following logic:

Energy: ExE***, Industrial processes: ExI***, F-gases: ExF***, Agriculture: ExA***, Forestry and Land Use: ExL***, Waste: ExW***.

Information about the archive’s reference codes is recorded in an Excel file (status archive.xls) and stored in the root folder of the archive.

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 server’s hard drive and replicated them to an external memory device, also ensures automatic and smooth data backup process to the Google Drive cloud.

The archived data is stored in folders by year of the Inventories, to facilitate the use.

1.5 Improvements to the National GHG Inventory

Below are presented the major improvements made to the National GHG Inventory between 1990 and 2019, in accordance with the principles of Transparency, Accuracy, Completeness, Comparability, Consistency (TACCC) and based on the National Greenhouse Gas Inventory Improvement Plan, which includes the recommendations of the technical expert group conducting the technical analysis for the Third Biennial Update Report of Armenia as reflected in the Technical Summary Report (TASR), and improvements recommended as a result of the peer reviews.

Transparency improvement

1. *TASR point 35.* The emissions and removals from the *Land* category are presented by land use category and the annual change in carbon stocks – by pool. The improvement relies on the tables in Annex 3A.2 of the 2003 IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry.
2. *TASR point 98(f).* The presentation covers the nitrogen losses due to leakage and leaching from storing of solid and liquid manure, as well as those volatilized in the form of ammonia and nitrogen oxides.
3. *TASR point 44.* The presented estimations of direct and indirect N_2O emissions cover those related to the mineralization resulting from the loss of organic matter in the *Cropland Remaining Cropland* and *Grassland Remaining Grassland* sub-categories.

Accuracy improvement

4. Relying on the expert judgement results, the activity data of *(2D2) Paraffin Wax Use* sub-category are adjusted and the time series of the respective CO_2 emissions are re-estimated accordingly.
5. Based on the expert judgement results, the bitumen content in the asphalt mixture is adjusted to underpin the NMVOC emissions estimation from *(2D4) Bitumen/asphalt use* sub-category.
6. As recommended by the expert team, the time series of emissions of gases with an indirect greenhouse effect, NMVOC, from *(2H2) Food and Beverages Industry* sub-category are assessed using *the Tier-2 method* of the EMEP/EEA manual and

accounting for the respective technological features, and the time series are re-estimated.

7. By the expert team's recommendation, the emissions of gases with an indirect greenhouse effect, NMVOC, from *(2D3) Solvent use* sub-category are estimated using the emission factor provided in the 2019 EMEP/EEA manual.
8. As recommended by the expert team, the emissions from enteric fermentation and manure management are assessed separately for the imported high-breed cows, bulls and the young (calves) in the *Cattle* sub-category.
9. By the expert team's recommendation, the activity data of sheep are disaggregated and three subcategories are considered: mother sheep, other sheep and the young (lambs).
10. As recommended by the expert team, the activity data of the *Industrial Wastewater Treatment and Discharge* sub-category are adjusted and the time series are re-estimated.

Completeness improvement

New categories are considered, namely:

11. In the Energy sector, the GHG emissions from two new sub-categories are assessed:

- (1A4ci) *Stationary;*
- (1A2g) *Transport Equipment.*

12. In the IPPU sector, the emissions of CO_2 are assessed for this new sub-category:

- (2C1) *Iron and Steel Production.*

13. In the AFOLU sector:

- TASR point 47. For the first time, the emissions and removals from (3D1) *Harvested Wood Products* sub-category are assessed;
- TASR Annex 1. CO_2 emissions from (3B5a) *Settlements Remaining Settlements* sub-category are assessed and the respective time-series are re-estimated.

14. The Waste sector:

- TASR Annex 1. For the first time, the emissions of CO_2, CH_4 և N_2O from (4C1) *Waste Incineration* sub-category are assessed;
- TASR Annex 1. The issue of GHG emissions from (4B) *Biological Treatment of Solid Waste* category is studied with the key finding that no similar program is implemented in the country.

Consistency improvement

15. GHG emissions and removals in 1990-2019 period are assessed using a methodology consistent with the 2006 IPCC Guidelines (Summary, Chapter 3) and are re-estimated.

    Noteworthily, the largest impact on the emission values' change in the time series is due to the inclusion of the new category (3D1) *Harvested Wood Products* into the analysis.

16. To ensure consistency across the sub-categories under *(1A4) Other Sectors* category, the time series of 1990-2019 are re-estimated for *(1A4a) Commercial/Institutional* and *(1A4c) Agriculture/Forestry/Fishing/Fish Farms*.
17. The time series of CO_2 emissions from *(2D2) Paraffin Wax Use* sub-category are re-estimated due to the recent availability of more accurate data.
18. The time series of CO_2 emissions from *(2D3) Solvent use* sub-category are re-estimated for 1990-2017 due to the changed emission factor.

19. The time series of NMVOC emissions from *(2D4) Bitumen/asphalt use* sub-category are re-estimated for 1995-2017 to account for the recently improved data accuracy of the bitumen content in the asphalt mixture.
20. The time series of NMVOC emissions from *(2H2) Food and Beverages Industry* sub-category are re-estimated.
21. The time series of methane emissions from *(4D2) Industrial Wastewater Treatment and Discharge* sub-category are re-estimated.

The re-estimations yielded lower values of GHG emission compared to the results of BUR3: their volumes of 1990 decreased by 0.16% and of 2017 – by 0.19%.

1.6 The applied methodology

Guidelines

GHG inventory was prepared according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC 2006 Inventory Software version 2.69.7235 was used for data entry, emissions estimation, results analysis and conclusions.

For the default values of certain parameters, the National Inventory refers also to the following sources: "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), 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetland, also "Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe" and "Air pollutant emission inventory guidebook" of the European Environment Agency (EMEP/EEA, 2019).

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[4] based on the effects of GHGs over a 100-year time horizon (Table 1.1).

Applied methodologies

The GHG inventory is developed 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 preparation of the GHG Inventory, the highest priority was given to the emissions estimation of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) compounds and sulfur hexafluoride (SF_6).

Emissions of CO, NO_x, NMVOCs and SO_2 are also assessed.

[4] 1995 IPCC GWP Values

Emission estimates were based on the sectoral approach with application of the Tier-1, Tier-2 and Tier-3 methods.

Advanced and country-specific approaches were used for key categories of emissions wherever possible to obtain more accurate estimates than in the case of the Tier 1 approach application.

The Tier 3 method was used to estimate the emissions from the following key sources:

- Energy Sector: CO_2 emissions from electrical energy generation by natural gas fired TPPs,
- IPPU Sector: CO_2 emissions form the cement production,

The Tier-2 method was applied to estimate the emissions from the following key categories.

In Energy Sector:

- Emissions of CO_2 from stationary (with the exception of electrical energy generation) and mobile combustion of natural gas, also of CH_4 emissions from fugitive emissions of natural gas.

In IPPU Sector:

- Emissions of HFCs from refrigeration and air-conditioning were estimated applying the 2A method, because this sub-category is identified as a key one and the necessary data are available for each sub-level.

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:

- Methane CH_4 emissions from solid waste disposal.

The emissions from all the remaining sources are evaluated using the Tier-1 method.

1.7 The sources of activity data

The majority of GHG emissions in Armenia originate from the Energy sector. That is why the energy balances of Armenia, officially published by the Ministry of Energy, are the most important source of data for estimation of GHG emissions from the Energy sector.

The GHG Inventory working group cooperates with the experts compiling the Energy Balance to ensure accuracy, reliability and comparability of the data.

The main source of data for the assessment of emissions from other sectors was the Statistical Committee of the RA. Data were also provided by the Ministry of Territorial Administration and Infrastructure, the Ministry of Economy, the Ministry of Environment, the Public Services Regulatory Commission, the State Revenue Committee, the State Cadastre of Real Estate, and private industrial/manufacturing enterprises.

2. MAIN OUTCOMES OF GREENHOUSE GAS INVENTORY

Armenia's GHG emissions in 2019 totaled 11,150.8 Gg CO_2 equivalent (Table 2.1). The emissions were 5.2% (546.9 Gg $CO_{2\ eq.}$) higher than those in 2017.

Table 2.1 Greenhouse gas emissions by sector and by gas, 2019, Gg

Sector	CO_2	CH_4	N_2O	HFCs $CO_{2\ eq.}$	SF_6 $CO_{2\ eq.}$	Total $CO_{2\ eq.}$
Energy	5,896.6	57.2	0.1	NA	NA	7,138.5
Industrial Processes[5]	312.5	NA	NA	NA	NA	312.5
F gases[6]	NA	NA	NA	969.5	3.3	972.8
AFOLU (without Forestry and Other Land Use)[7]	-0.2	44.9	3.7	NA	NA	2,098.3
Waste	4.7	26.2	0.2	NA	NA	628.7
Total GHG Emissions	**6,213.7**	**128.3**	**4.1**	**969.5**	**3.3**	**11,150.8**
Forestry and Other Land Use	-373.4	NA	0.0014	NA	NA	-373.0
Net GHG Emissions	**5,840.3**	**128.3**	**4.1**	**969.5**	**3.3**	**10,777.8**

Figure 2.1 summarizes the data presented in Table 2.1.

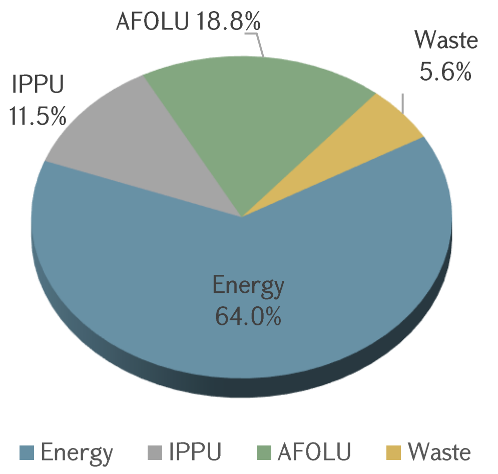


Figure 2.1 GHG emissions by sector (without *Forestry and Other Land Use*), 2019, $CO_{2\ eq.}$

The dominant share of Armenia's total GHG emissions makes 64% and comes from the Energy sector. The Energy sector includes emissions from burning 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 is the AFOLU sector with a share of 18.8%, followed by the IPPU and Waste sectors: 11.5% and 5.6%, respectively.

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

Figure 2.2 provides the distribution of the greenhouse gas emissions by gas.

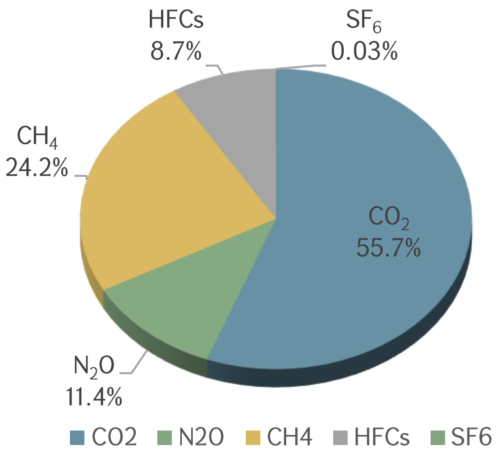


Figure 2.2 GHG emissions' distribution by gas, 2019

The most significant greenhouse gas of Armenia's inventory is carbon dioxide (CO_2), with a share of about 56% of the total emissions in 2019, followed by methane (CH_4) – about 24.2%. The shares of fluorocarbons are much smaller and make 11.4% և 8.7%, respectively, while the share of SF_6 is negligible.

Figure 2.3 provides greenhouse gas emissions by sector per the type of gas.

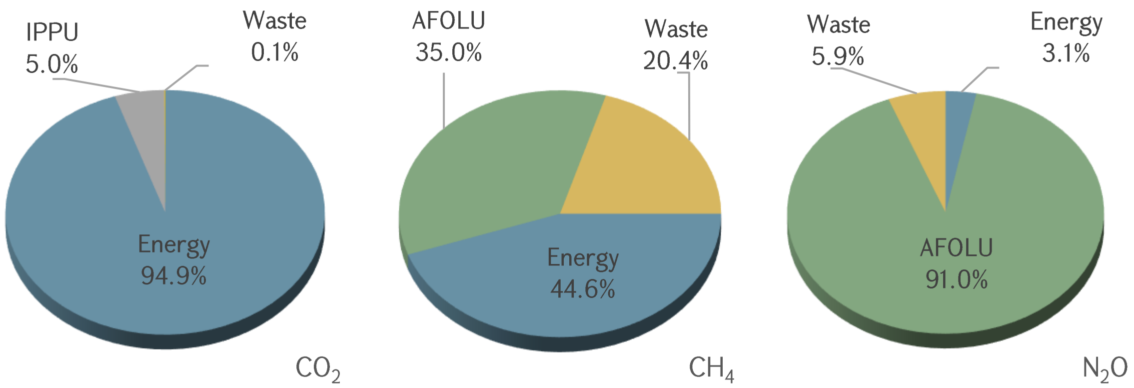


Figure 2.3 Greenhouse gas emissions by sector per the type of gas, 2019 (without *Forestry and Other Land Use*)

The Energy sector is mainly responsible for carbon dioxide emissions: it produced about 95% of all carbon dioxide emissions, because of high emission volumes from thermal power plants, road transportation and residential sub-categories.

CO_2 emissions from the IPPU sector made about 5% of total carbon dioxide emissions, while CO_2 emissions from the Waste sector are negligible.

The share of methane emissions made nearly 25% of the total emissions in 2019. Methane emissions are also mostly from the Energy sector (about 47%) consequent to the fugitive emissions from the natural gas system. The second large share of methane emissions comes from the AFOLU sector (without *Forestry and Other Land Use*) and makes over 35% mainly due to the emissions from enteric fermentation. The Waste sector holds the third place with nearly 17% share in total emissions.

Nitrous oxide emissions made up close to 12% of the total emissions in 2019. The Agriculture sector grossly dominates the nitrous oxide emissions with its share reaching 91%, mainly because of the direct and indirect N_2O emissions from managed soils.

Emissions of F-gases (HFCs and SF_6) accounted for roughly 9% of total GHG emissions in 2019, but their share has been growing continuously.

Summary report of National GHG Inventory in 2019 is given in Table 2.2. Emissions of HFCs on gas-by-gas basis and by uses for year 2019 are summarized in Table 2.3 and reported in CO_2 equivalent. These emissions, expressed in the units of mass (ton), are provided further in Table 4.36.

Table 2.2 Summary report of National GHG Inventory in 2019

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	6,306.114	-465.700	128.262	4.100	969.532	NO	3.287	17.811	40.866	16.507	8.526
1 - Energy	5,896.759		57.239	0.128				17.630	34.455	3.556	0.226
1.A - Fuel Combustion Activities	5,896.644		3.786	0.128				17.630	34.455	3.556	0.226
1.A.1 - Energy Industries	1,364.946		0.024	0.002				2.152	0.943	0.063	0.007
1.A.2 - Manufacturing Industries and Construction	436.930		0.009	0.001				0.874	0.244	0.174	0.039
1.A.3 - Transport	2,071.437		2.199	0.102				13.096	31.994	3.203	0.016
1.A.4 - Other Sectors	2,023.330		1.554	0.022				1.508	1.274	0.116	0.164
1.A.5 - Non-Specified	NO		NO	NO				NA, NO	NA, NO	NO	NA, NO
1.B - Fugitive emissions from fuels	0.115		53.453	NA, NO				NO	NO	NA, NE	NO
1.B.1 - Solid Fuels	NO		NO	NO						NO	
1.B.2 - Oil and Natural Gas	0.115		53.453					NO	NO	NE	NO
1.B.3 - Other emissions from Energy Production	NO		NO	NO				NO	NO	NO	NO
1.C - Carbon dioxide Transport and Storage	NO							NO	NO	NO	NO
2 - Industrial Processes and Product Use	312.504		NA, NO	NA, NO	969.532	NO	3.287	NA, NO	NA, NO	12.951	8.300
2.A - Mineral Industry	305.608										
2.A.1 - Cement production	258.954										
2.A.2 - Lime production	39.590										
2.A.3 - Glass Production	7.064										
2.A.4 - Other Process Uses of Carbonates	NE, NO										
2.A.5 - Other	NO										
2.B - Chemical Industry	NO		NO	NO	NO	NO	NO	NO		NO	NO
2.C - Metal Industry	1.185		NA, NO		NO	NO	NO	NA, NO	NA, NO	NA, NO	8.300
2.C.1 - Iron and Steel Production	1.185		NO								NO
2.C.2 - Ferroalloys Production	NA		NA	NA							8.300
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											NO
2.D - Non-Energy Products from Fuels and Solvent Use	5.711								NO	9.201	
2.D.1 - Lubricant Use	5.588										
2.D.2 - Paraffin Wax Use	0.123										
2.D.3 - Solvent Use										9.190	

	Emissions and Removals (Gg)				Emissions $CO_{2\ eq.}$ (Gg)			Emissions (Gg)			
Categories	CO_2 emissions	CO_2 removals	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
2.D.4 - Other - Bitumen/Asphalt Production and Use									NO	0.011	
2.E - Electronics Industry					NO	NO	NO				
2.F - Product Uses as Substitutes for Ozone Depleting Substances					969.532	NO					
2.F.1 - Refrigeration and Air Conditioning					927.867	NO					
2.F.2 - Foam Blowing Agents					28.860						
2.F.3 - Fire Protection					0.707	NO					
2.F.4 - Aerosols					12.097	NO					
2.F.5 - Solvents					NE	NO					
2.F.6 - Other Applications					NO	NO					
2.G - Other Product Manufacture and Use						NO	3.287				
2.G.1 - Electrical Equipment						NO	3.287				
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											
2.H - Other								NA, NO		3.750	
2.H.1 - Pulp and Paper Industry								NO		NO	
2.H.2 - Food and Beverages Industry										3.750	
2.H.3 - Other										NO	
3 - Agriculture, Forestry, and Other Land Use	86.639	-465.700	44.864	3.731				0.181	6.411	NA,NO,NE	NA,NO,NE
3.A - Livestock			44.649	0.177							
3.A.1 - Enteric Fermentation			42.887								
3.A.2 - Manure Management			1.762	0.177							
3.B - Land	86.639	-460.031	NO	0.001				NA, NO		NA, NO	
3.B.1 - Forest land	NO	-453.305						NO		NO	
3.B.2 - Cropland	NO	-6.726									
3.B.3 - Grassland	18.366							NO		NO	
3.B.4 - Wetlands	31.917	NO	NO	0.001							NO
3.B.5 - Settlements	6.727	NO									
3.B.6 - Other Land	29.629	NO									
3.C - Aggregate sources and non-CO2 emissions sources on land	5.507		0.215	3.553				0.181	6.411	NA, NO, NE	NA, NO, NE
3.C.1 - Emissions from biomass burning			0.215	0.008				0.181	6.411	NE	NE
3.C.2 - Liming	NO										
3.C.3 - Urea application	5.507										

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.C.4 - Direct N2O Emissions from managed soils				2.668							
3.C.5 - Indirect N2O Emissions from managed soils				0.760							
3.C.6 - Indirect N2O Emissions from manure management				0.116							
3.C.7 - Rice cultivation			NO					NO		NO	
3.C.8 - Other			NO	NO							
3.D - Other	NA	-5.669						NO			NO
3.D.1 - Harvested Wood Products	NA	-5.669						NO			NO
4 - Waste	4.706		26.159	0.241				NE	NE	NE	NE
4.A - Solid Waste Disposal			20.105								
4.B - Biological Treatment of Solid Waste			NE	NE							
4.C - Incineration and Open Burning of Waste	4.706		0.610	0.011				NE	NE		NE
4.D - Wastewater Treatment and Discharge			5.444	0.230						NE	
4.E - Other (please specify)	NO		NO	NO				NO	NO	NO	
5 - Other	NE		NE	NE				NE	NE	NE	NE
5.A - Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3	NE		NE	NE				NE	NE	NE	NE
Memo Items											
International Bunkers	217.503		0.0015	0.006				0.276	0.083	0.131	0.069
1.A.3.a.i - International Aviation (International Bunkers)	217.503		0.0015	0.006				0.276	0.083	0.131	0.069
1.A.3.d.i - International water-borne navigation (International bunkers)	NO		NO	NO				NO	NO	NO	NO
1.A.5.c - Multilateral Operations	NO		NO	NO				NO	NO	NO	NO

Table 2.3 Emissions of hydrofluorocarbons in 2019

Category	HFC-32	HFC-125	HFC-134a	HFC-152a	HFC-143a	HFC-227ea	Total HFC
Emissions in CO_2 equivalent unit (Gg CO_2)							
2.F - Product Uses as Substitutes for Ozone Depleting Substances	42.403	344.725	344.508	1.941	235.247	0.707	969.532
2.F.1 - Refrigeration and Air Conditioning	42.403	344.725	305.492	0	235.247	0	927.867
2.F.1.a - Refrigeration and Stationary Air Conditioning	42.403	344.725	164.388	0	235.247	0	786.763
2.F.1.b - Mobile Air Conditioning	0	0	141.105	0	0	0	141.105
2.F.2 - Foam Blowing Agents			27.452	1.408		0	28.860
2.F.3 - Fire Protection		0	0			0.707	0.707
2.F.4 - Aerosols			11.564	0.533		0	12.097

Key categories

Key category analysis (KCA) is performed in accordance with the 2006 IPCC Guidelines [Gen-1, Volume 1, Chapter 4] by application of Approach 1.

The trend assessment is performed based on the National Inventories per years 2000 and 2019 and considered their data trends. The adopted base year for trend assessment is 2000, because the structure and management principles of Armenia's economy of 1990 were absolutely different from the ones of the present time. Therefore, using 1990 as a base year for trend analysis would not produce an accurate perception of the current trends.

The key categories identified via the analysis 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 expert team of GHG Inventory found the resulting list of key categories as satisfactory and depicting the current priorities accurately. Therefore, no other qualitative criteria were considered.

Table 2.4 Key categories according to Level (2019) and Trend (2000-2019) assessments

IPCC Cate-gory code	IPCC Category	Green-house gas	Method (Level, Trend)	Tier level
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	**Transport - Gaseous Fuels**	**CO_2**	Level, Trend	T2
1.B.2.b	**Fugitive emissions of Natural Gas**	**CH_4**	Level, Trend	T2
2.F.1	**Refrigeration and Air Conditioning**	**HFCs**	Level, Trend	T2a
1.A.3.b	**Transport - Liquid Fuels**	**CO_2**	Level, Trend	T1
3.C.4	**N_2O direct emissions from managed soils**	**N_2O**	Level, Trend	T1
3.A.1.a	**Enteric Fermentation – Cattle**	**CH_4**	Level, Trend	T2
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
4.A	**Solid Waste Disposal**	**CH_4**	Level, Trend	T2
1.A.2	**Manufacturing Industries and Construction - Gaseous Fuels**	**CO_2**	Level, Trend	T2
2.A.1	**Cement production**	**CO_2**	Level, Trend	T3
3.C.5	**N_2O indirect emissions from managed soils**	**N_2O**	Level, Trend	T1
1.A.4.c	**Agriculture/Forestry/Fishing/Fish Farms**	**CO_2**	Level, Trend	T2
3.A.1.b-j	**Enteric Fermentation - Other**	**CH_4**	Level, Trend	T2 (for buffalo and sheep), T1 (others)
4.D	**Wastewater Treatment and Discharge**	**CH_4**	Level, Trend	T1
4.D	**Wastewater Treatment and Discharge**	**N_2O**	Level, Trend	T1
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	Level, Trend	T1
1.A.2	**Manufacturing Industries and Construction - Liquid Fuels**	**CO_2**	Level, Trend	T1
1.A.3.b	**Road Transportation**	**CH_4**	Level, Trend	T1

The analysis of the key categories identified 21 of them in Armenia's GHG inventory, with 15 revealed by both level and trend assessments, 3 - with only level assessment and 2 more - with trend assessment.

The total value of emissions in the key categories makes 10,233.74 Gg $CO_{2\ eq.}$ in 2019 and they comprise 95% of overall net emissions.

Out of 21 identified key categories, 13 are estimated using the higher tier methods (2^{nd} and 3^{rd}), including the 5 top key categories in both level and trend assessment (*Energy Industries, Residential, Transport, Fugitive Emissions, Refrigeration and Air Conditioning*).

Overall, the net emissions form these 13 categories that are estimated using higher tiers comprise 81.6% of total net national emissions in 2019.

However, there are still several key categories that have significant shares in the level and trend uncertainty of inventory, making them the 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

Together with key category analysis, uncertainty assessment helps to improve the accuracy of inventory by planning priorities for improvements and by informing the decisions on methodology selection.

According to the 2006 IPCC Guidelines, two methods of uncertainty estimation are applicable. For uncertainty assessment of the Armenia's GHG Inventory, the Approach 1: the propagation of error is employed [Gen-1, Volume 1, Chapter 3, Section 3.2.3.1].

The uncertainty analysis of Armenia's Inventory covers all emission/removal categories and all direct greenhouse gases. In some cases, the sub-categories are aggregated to ensure that data is available at an appropriate level for both 2019 and 2000. In other cases, the categories are disaggregated into sub-categories in such a way that they match the categories used in key category analysis. This approach serves the 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 is assessed based on the level in 2019 GHG inventory data, as well as trend, where the base year is selected to be 2000. Year 2000 is adopted as the base year instead of 1990 because the difference between the Inventory estimates of 2000 and 2019 better represents the current and possible future trends of Armenia's Inventory, than the difference between 1990 and 2019. The difference between 2000 and 2019 shows an upward trend, which is more characteristic of 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 the suggested values from the 2006 IPCC Guidelines. The calculations for the uncertainty assessment are presented in Annex 1.3.

The calculations' results revealed that the level of emissions uncertainty is within 17.96%, and the uncertainty of trend is 19.86%.

The highest contributions to variance by category in 2019 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), HFC emissions from *Refrigeration and Air Conditioning* (2.F.1), 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), HFC emissions from *Refrigeration and Air conditioning* (2.F.1), CH_4 emissions from *Solid Waste Disposal* (4.A), and *Direct N_2O Emissions from managed soils* (3.C.4).

Evidently, the highest uncertainties are related to non-CO_2 emissions in all cases. 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 depicts the time series of greenhouse gas emissions by sector for 1990-2019 (without *Forestry and Other Land Use*).

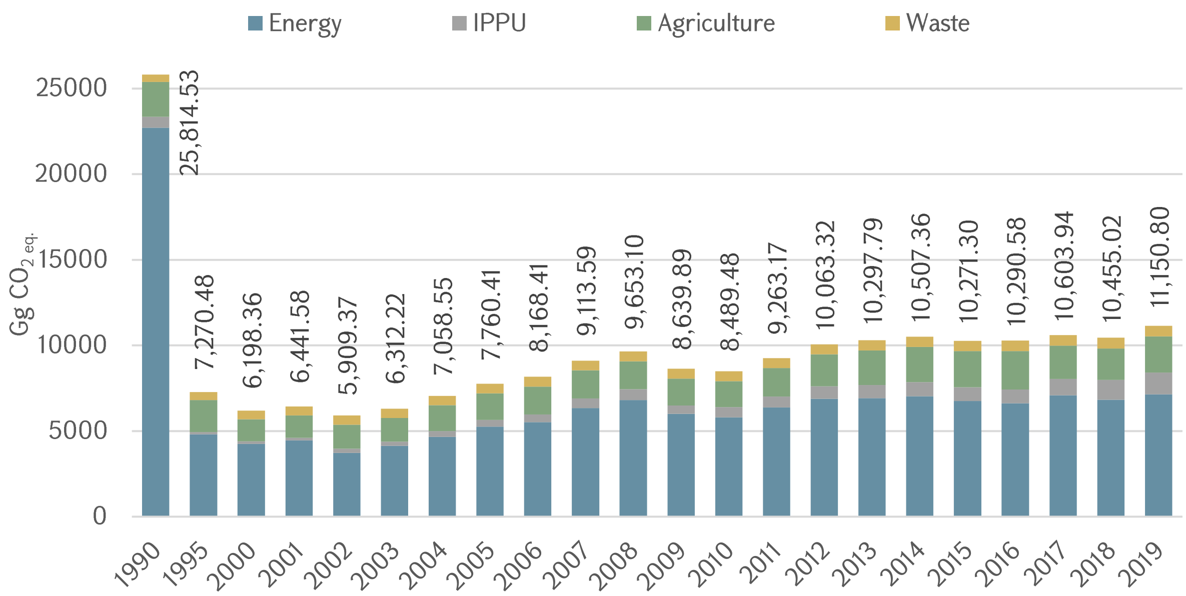


Figure 3.1 Time series of greenhouse gas emissions by sector in 1990-2019 (without *Forestry and Other Land Use*), Gg $CO_{2\ eq.}$

Figure 3.1 shows contribution of the sectors to the total GHG emissions. It demonstrates that different sectors' comparative shares are relatively stable, while emissions from the Energy sector persist in their absolute dominance throughout the record.

In general, Armenia's total GHG emissions in 2019 decreased by nearly 57% compared to 1990, mainly because of the reduction of emissions from the Energy sector.

The rate of reduction of GHG emissions from the Energy sector (for 1990-2019 period) is somewhat different from the rate of reduction in the level of Total Primary Energy Supply (TPES) (decoupling) consequent to structural changes in the economy, to the larger-scale use of an ecologically cleaner fuel – natural gas (no consumption of coal and fuel oil) in *Energy Industries, Transport* and *Residential* sub-categories, to the relaunch of the nuclear power plant, the unprecedented growth of small hydropower in the 2000s, and the favorable trends in solar energy development in recent years.

The rise of emissions from the Energy sector since 2000 (except for 2009-2010) makes 67.8%, which is mainly because of the following:

- Economic growth, leading to the rise in the volume of road transportation (number of automobiles), which resulted in the emission increase from the Transport sector. Within 2000-2019, road transport emissions showed a three-fold growth;
- Improved household living standards consequent to the unprecedented gasification in the country and the expansion in natural gas volumes used for space heating. As a result, emissions attributable to energy used by households demonstrated a sixfold surge within 2004-2019;
- Increase in fuel consumption (mainly due to gasification) in the *Commercial/Institutional* and *Agriculture/Forestry/Fishing/Fish Farms* subcategories.

In 2009, the financial and economic crisis affected the energy consumption; however, since 2011 emissions from the Energy sector experienced an upward trend again as a result of the economic recovery.

Emissions from the Energy sector show annual variations mainly because of the changes in exports volume of electrical energy. Thus, the sharp increase of GHG emissions from the Energy sector in 2012 in comparison with 2010 is attributed to a higher rate of export growth and, respectively, a notable rise in the electrical energy generation by the thermal power plants (about 135%). This variation has been the principal feature of the trend of CO_2 emissions from the Energy sector since 2010.

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

The increase in emissions from the Energy sector in 2019 is mainly because of the increase in the emissions from the *Road Transportation* sub-category (more automobiles) and from the *Residential* sub-category due to the improvement in the living standards of households. On the other hand, noteworthily, despite the increase in the imports volume of natural gas in 2018 and 2019, the fugitive emissions decreased significantly thanks to the repair works carried out in the system.

In industrial processes, the most significant emission source are CO_2 emissions generated in cement production. A small amount of CO_2 emissions is also generated in lime and glass production, secondary steel production, as well as from lubricant and paraffin wax use.

Emissions caused by the industrial processes are mostly affected by the changes in the production volumes. Thus, after the decline of GHG emissions from the IPPU sector in 2009, which ensued from the decrease of construction volumes and, consequently, cement production because of the economic recession, both of them increased in 2010 leading to the rise in GHG emissions. Increase of CO_2 emissions in 2019 compared to those in 2017 resulted from the growth of construction volumes as well.

The increase in the emissions from the IPPU sector since 2011 is primarily because of the steady growth in the emissions of HFCs. In 2019, HFCs accounted for 8.7% of the country's total emissions and more than 75.4% of the Industrial Processes and Product Use sector. In 2010-2019 period, the emissions of HFCs increased by about 3.6 times, mainly due to the large-scale use of HFCs in refrigeration and air conditioning applications and the sharp increase in the number of refrigeration equipment imported into Armenia, especially in 2018 and 2019.

The decline in emissions in the AFOLU sector in the 1990s was consequent to the liquidation of state-owned animal husbandry farms which resulted in the plummeting numbers of livestock and, accordingly, to a continuing reduction in emissions until 2000.

The increase in the emissions from the AFOLU sector in the 2000s (except for the period of economic crisis in 2009-2010), was primarily due to the increase in cattle heads and rise of emissions from managed soils because of fertilizer use. Since 2010, there has been a noticeable cyclical increase in emissions from the AFOLU sector (without *Forestry and Other Land Use*), which is due to two main sources of the emissions: methane from intestinal fermentation of animals and direct release of nitrogen suboxide from inorganic fertilizers, with certain fluctuations. While the decrease in the number of farm animals and, in particular, cattle heads, contributed to the reduction of methane emissions in the reporting year 2019, the sharp increase in the number of inorganic fertilizers used in the same year resulted in a significant rise of not only in N_2O emissions from managed lands, but also in total emissions from the entire AFOLU sector.

The share of emissions from the Waste sector in the country's total emissions is relatively stable and made 5.6% in 2019. Within 2000-2019, the Waste sector emissions went up by about 22% because of the growth in methane emissions from solid waste disposal. This increase comes from the high inertia and cumulative effect of decomposition process of organic matter in anaerobic conditions, that is, from the circumstance that the waste disposed as early as several decades ago (according to best practice, no less than 50 years) still contributes to the emissions of a given year.

Time series for 1990-2019 greenhouse gas emissions are presented in Figure 3.2 (without *Forestry and Other Land Use* sub-sector).

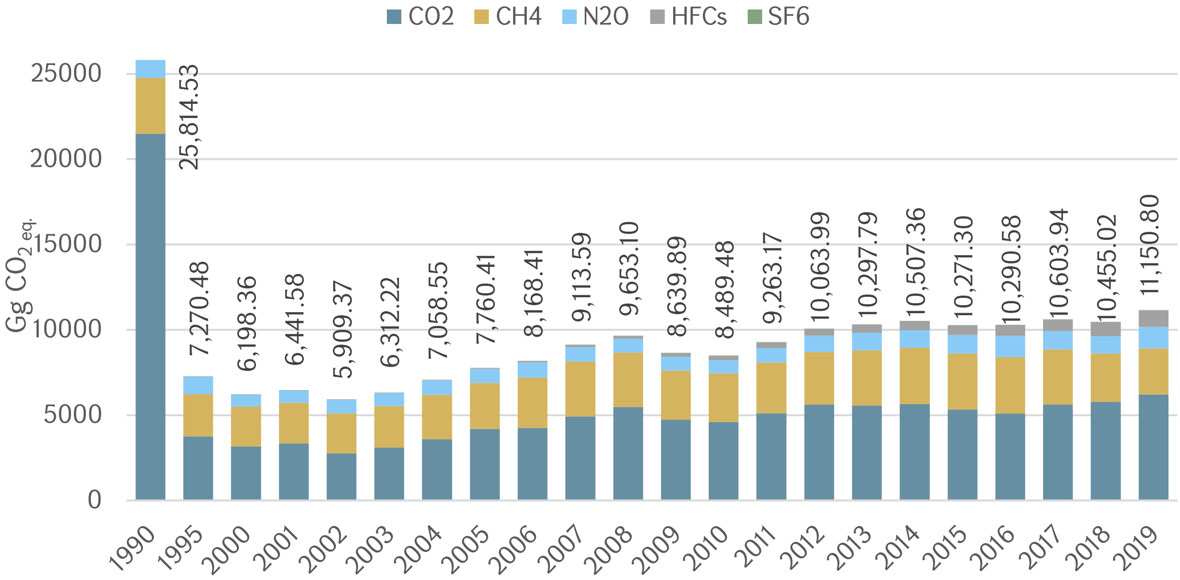


Figure 3.2 The time series of greenhouse gas emissions by gas, Gg $CO_{2\ eq.}$

Figure 3.2 shows the unfolding 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, with the prevalent share of them caused by stationary and mobile combustion processes, dominate the overall pattern of greenhouse gas emissions, making nearly 55.7% of total emissions in 2019 (the shares of the other gasses make less than half). The Energy sector produced the vast majority, roughly 95%, of all carbon dioxide emissions in 2019.

The increase of the country's overall emissions in 2019 as compared to 2000 amounted to over 79.9%. Mainly, this resulted from an increase of CO_2 emissions.

The HFCs demonstrate the highest rates of the emissions' growth, with the increase of about 3.6 times compared to year 2010 (after 2010, the records show a sharp increase in the quantities of imported HFCs).

The bulk of the HFC total emissions originate from refrigeration systems, 95.7%. The share of emissions from all other applications is relatively small, 4.3%.

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. HFCs emissions, which are caused by refrigeration systems, predominate in the overall picture of HFCs emissions with the share of 95% in 2017.

The emissions of SF_6 are negligible, though they demonstrate a growth trend.

The amount of CO_2 emissions is closely linked to the trends in the Energy sector. In recent years, the fluctuations of CO_2 emissions from the Energy sector are mainly due to the fluctuations in the export volumes of electrical energy and, consequently, in its generation by thermal power plants. Other main causes include the increase of transportation vehicles on the roads and the large-scale use of natural gas by households for space heating purposes.

Methane CH_4 emissions are caused mainly by transmission, storage and distribution of natural gas, animal husbandry in agriculture and waste landfilling. The decrease in emissions over the last three years is because of the reduction of fugitive emissions of natural gas in 2018-2019 coming from the repair works carried out in previous years, also the decrease in cattle heads.

The emissions of N_2O come mainly from agriculture via the use of nitrogen-containing fertilizers and from animal husbandry, smaller amounts of emissions are caused by wastewater treatment. Since 2000, N_2O emissions increased by about 82%, in recent years – mainly due to the extensive use of nitrogen-containing fertilizers.

4. INVENTORY BY SECTOR

4.1 Energy

4.1.1 Overview of the Energy sector emissions assessment

The main power generation capacities in Armenia are the nuclear power plant, large hydropower plants, natural gas consuming thermal power plants (including small cogeneration units), as well as small power plants based on renewable energy sources (small hydro, wind and solar power), which provided 28.8%, 18.5%, 39.9% and 12.7% of total electricity generation in 2019, respectively. As of 2019, renewable energy was represented mainly by hydropower (small to large HPPs); however, in recent years solar energy has been growing rapidly (their generation made 5.2 GWh in 2018 and 13.4 GWh in 2019).

Armenia has no domestic supplies of fossil fuels and energy of industrial scale and the whole of such fuels is imported from Russia and Iran. For instance, 85% of the imports came from the RF in 2019. In these circumstances, the energy security requirements necessitate prioritization of the large-scale use of renewable energy sources and the implementation of energy saving measures, which is consistent with the challenges of climate change.

Armenia relies on electricity and gas to meet the majority of its energy consumption needs. Imported natural gas predominates in total primary energy supply in Armenia accounting for 63% of Armenia's TPES and 84% of the fossil fuel (including jet kerosine) consumption in 2019. Over 82% of CO_2 emissions from fuel combustion (without international bunker) in 2019 originated from natural gas. This is due to a very high gas deliverability level in the country, reaching 96%, and to the fact that 1 kWh of thermal energy generated from natural gas is cheaper than 1 kWh electrical energy. Natural gas is widely used also for the road transportation purposes.

The Energy sector is by far the biggest source of GHG emissions in the country: its share in the total greenhouse gas emissions reached 64%, in 2019.

In 2019, the emissions from the Energy sector made 7,138.5 Gg $CO_{2\ eq.}$ or 31.4% of its emissions' level in 1990 and were 0.7% higher than those in 2017.

Emissions from the Energy sector consist of two main categories: fossil fuel combustion and fugitive emissions from natural gas.

The contributions of each category/sub-category to the total GHG emissions from the Energy sector in 2019 are presented in Figure 4.1.

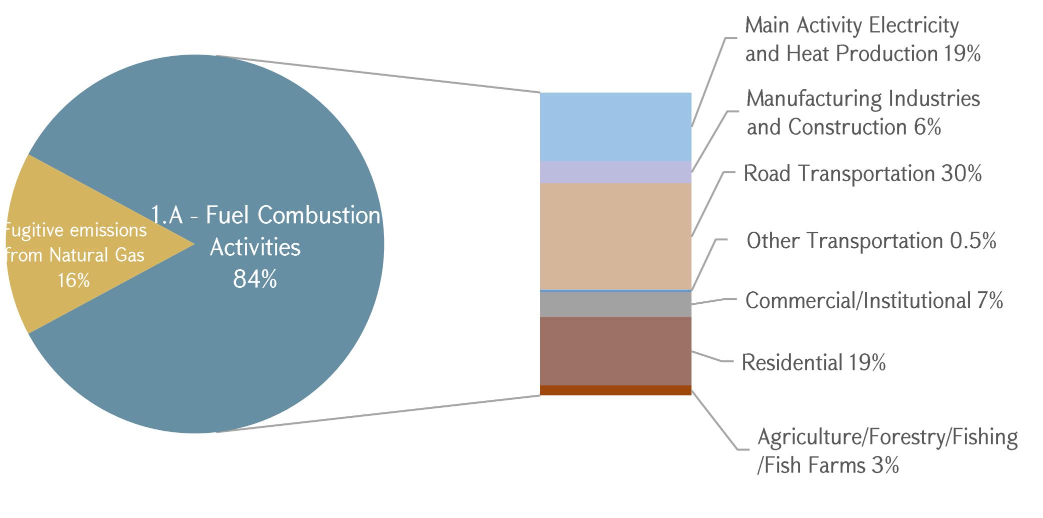


Figure 4.1 GHG emissions from the Energy sector in 2019, $CO_{2\ eq.}$

The bulk of the emissions from the Energy sector comes from road transportation, electrical energy generation, residential sectors and fugitive emissions of natural gas. As of 2019, the road transportation's share in the total emissions from the Energy sector was the largest and reached 29.7%, the shares of electrical energy generation and residential sectors were equal and made 19.1% each, while fugitive emissions of natural gas amounted to 15.7%. The next by share were the *Commercial/Institutional* category and *Industries/Construction* sub-sectors with 7.1% and 6.1% respectively, while emissions from Off-road Vehicles and Other Machinery in agriculture and emissions from stationary combustion of natural gas in greenhouses accounted for 2.8%.

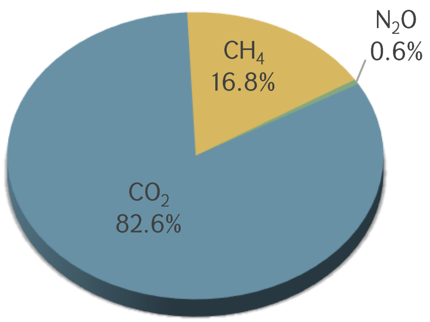


Figure 4.2 Emissions from the Energy sector by greenhouse gas in 2019, $CO_{2\ eq.}$

The main greenhouse gas in the Energy sector is carbon dioxide (CO_2). In 2019, it made about 82.6% of the total emissions from the Energy sector, about 16.8% – methane (CH_4) and a small amount of about 0.6% – nitrous oxide (N_2O). Negligible amounts of other GHGs of indirect effect are also emitted, such as carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and non-methane volatile organic compounds (VOCs).

Methodology applied for GHG emissions assessment

Estimate of the emissions from the Energy sector are based on the Sectoral approach. Where possible, country-specific approaches are used for the key categories to produce more accurate estimates of GHG emissions.

In general, Tier 1, Tier 2 and Tier 3 methods are applied, namely:

- *The Tier 3 method* is applied for estimation of CO_2 emissions due to electrical energy generation by thermal power plants via natural gas combustion, per each plant;
- *The Tier 2 method* is 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;
- The fugitive emissions of natural gas (CH_4) are also assessed with application of *the Tier 2 method*;
- The emissions from liquid fuel combustion are estimated using *the Tier 1 method*.

To verify the emissions' assessment under the *Fuel Combustion Activities* category yielded by application of the Sectoral approach, the emissions of CO_2 from fossil fuel combustion are also assessed using the Reference approach, and the results are compared.

The methods applied for assessment of greenhouse gases emissions from the Energy sector are summarized in the table below. Emissions under the categories omitted from the table are estimated using *the Tier 1 method* with default estimation parameters from the 2006 IPCC Guidelines and country-specific activity data.

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

Subcategory	GHG	Key category, by assessment	Method	Activity Data	Emission Factor
1A FUEL COMBUSTION ACTIVITIES					
1 A 1 Energy Industries (gaseous fuels)	CO_2	Level, Trend	T3	CS	CS
1 A 2 Manufacturing Industries and Construction (gaseous fuels)	CO_2	Level, Trend	T2	CS	CS
1 A 2 Manufacturing Industries and Construction (liquid fuels)	CO_2	Trend	T1	CS	D
1 A 3 b Road Transportation (gaseous fuels)	CO_2	Level, Trend	T2	CS	CS
1 A 3 b Road Transportation (liquid fuels)	CO_2	Level, Trend	T1	CS	D

Subcategory	GHG	Key category, by assessment	Method	Activity Data	Emission Factor
1 A 4.a Commercial/Institutional (gaseous fuels)	CO_2	Level, Trend	T2	CS	CS
1 A 4.b Residential (gaseous fuels)	CO_2	Level, Trend	T2	CS	CS
1 A 4 Other sectors (liquid fuels)	CO_2	Level, Trend	T1	CS	D
1 A 4.c Agriculture / Forestry / Fishing / Fish Farms	CO_2	Level, Trend	T2	CS	CS
1B FUGITIVE EMISSIONS FROM FUELS					
1 B 2 b Fugitive Emissions of Natural Gas	CH_4	Level, Trend	T2	CS	CS

Improvements achieved in the assessment of the greenhouse gas emissions from the Energy sector

Improvements to the GHG emissions assessment of the Energy sector are done on a continuous basis, driven by QA/QC procedures performed for the previous inventories, proposals yielded per the expert assessment findings and implemented, as well as the availability of the necessary data.

Improvements of 2017 National GHG Inventory are as follows.

Accuracy improvement:

- The time series of 1990-2019 are re-estimated for the *Commercial/Institutional* (1A4a) and *Agriculture/Forestry/Fishing/Fish Farms* (1A4c) sub-categories of the *Other Sectors* (1A4) category, to ensure their consistency. The re-estimations are performed with the appropriate method in order to ensure the accuracy of the activity data in the time series (a detailed description is provided in "Other Sectors" section of the present Report).

Completeness improvement:

- GHG emissions are assessed for two new sub-categories:
  - The *Transport Equipment* (1A2g) sub-category of the *Manufacturing Industries and Construction* (1A2) category;
  - The *Stationary* (1A4ci) section of the *Agriculture/Forestry/Fishing/Fish Farms* (1A4c) sub-category within the *Other Sectors* (1A4) category. The assessment of GHG emissions in the new subcategory is made possible thanks to the effort by "Gazprom Armenia" CJSC in 2019 to keep a separate record of the natural gas consumption in greenhouse farms and make the findings available, as well as to include them in the energy balance of the RA and publish them in 2021.

4.1.2 Greenhouse gas source categories in the Energy Sector

The Energy sector of Armenia's National GHG Inventory involves the following categories and sub-categories of the emission sources.

1 A Fuel Combustion Activities

1 A 1 ENERGY INDUSTRIES

1 A 1 a i Electricity Generation

1 A 1 a ii Combined Heat and Power Generation (CHP)

There are no specialized organizations in the country with the main activity of thermal energy generation and supply. To avoid double counting, the available boiler houses that supply heat to various users are considered in their respective categories.

1 A 2 MANUFACTURING INDUSTRIES AND CONSTRUCTION

1 A 2 a Iron and Steel

1 A 2 b Non-Ferrous Metals
1 A 2 c Chemicals
1 A 2 d Pulp, Paper and Print
1 A 2 e Food Processing, Beverages and Tobacco
1 A 2 f Non-Metallic Minerals
1 A 2 g Transport Equipment
1 A 2 h Machinery
1 A 2 i Mining (excluding fuels) and Quarrying
1 A 2 j Wood and Wood Products
1 A 2 k Construction
1 A 2 l Textile and Leather
1 A 2 m Non-specified industry

1 A 3 TRANSPORT

1 A 3 a Civil Aviation
1 A 3 b Road Transportation
1 A 3 e ii Off-road Transportation

1 A 4 OTHER SECTORS

1 A 4 a Commercial/Institutional
1 A 4 b Residential
1 A 4 c Agriculture/Forestry/Fishing/Fish Farms
1 A 4 c i Stationary
1 A 4 c ii Off-road Vehicles and Other Machinery

1B Fugitive Emissions from Fuels

1 B 2 b iii 4 Transmission and Storage, natural gas
1 B 2 b iii 5 Distribution, natural gas

4.1.3 Activity Data

General pattern of the use of fossil fuel-energy supplies

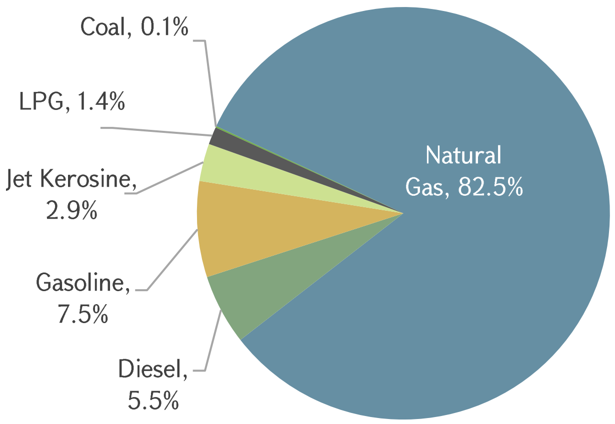


Figure 4.3 Fossil fuel consumption structure by type of fuel in 2019

Figure 4.3 provides fossil fuel consumption structure in 2019. Natural gas constitutes the bulk of the fossil fuels' total consumption with the share of 82.5%. In general, the consumption structure of fossil fuel-energy supplies has remained almost unchanged in recent years.

Natural Gas

The natural gas supply and sales in the domestic market of the RA, as well as operation of its transmission system is implemented the monopoly "Gazprom Armenia" CJSC. Wide-scale gasification resulted in the availability of natural gas for consumption in 644 settlements. With natural gas access level of 96% Armenia is one of the leaders in the world.

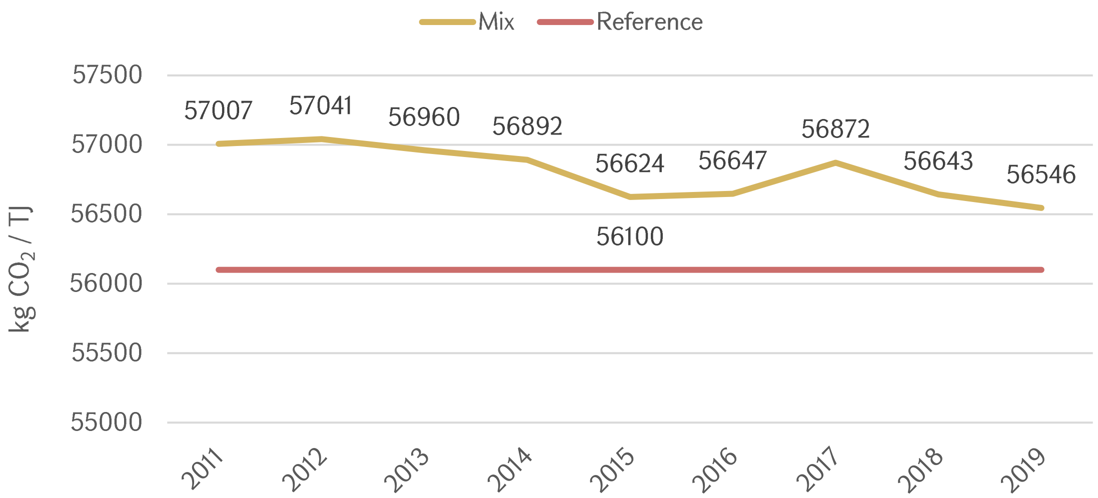
Table 4.2 provides natural gas balances in 2011-2019 (Annex 2.1, EnRef-1) that serves as the basis for estimation of the emissions originating from natural gas combustion in different sub-categories.

Table 4.2 Natural gas balances in 2011-2019, mln m³

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Imports	2,069.1	2,455.5	2,361.1	2,450.9	2,371.8	2,236.5	2,378.7	2,463.4	2,545.4
Gas turnover in storage facility *(extracted +, injected -)*	+46.4	-49.3	+24.3	-27.7	-33.0	+1.9	-23.5	20.8	18.6
Own needs, (mln m^3)	7.8	13.5	7.01	9.2	8.1	7.3	9.1	6.7	4.9
Own needs, %	0.38	0.55	0.30	0.38	0.34	0.33	0.38	0.27	0.19
Losses, (mln m^3)	134.05	139	141.63	144.7	138.8	142.6	148.2	123.9	114.2
Losses, %	6.5	5.7	6.0	5.9	5.9	6.4	6.2	5.0	4.5
Consumption, including	1,973.6	2,253.7	2,236.7	2,269.3	2,191.9	2,088.5	2,197.9	2,353.6	2,444.8
Energy Generation	549.3	825.5	759.0	799.5	654.4	603.7	637.5	767.9	691.7
Transport	362.4	418	455.0	481.7	484.6	467.3	477.5	552.7	577.2
Manufacturing Industries/Construction	326.2	317.7	301.4	278.2	207.7	191.2	200.3	200.9	194.1
Commercial/Institutional	157.2	127.9	149.6	159.5	261.3	201.1	199.8	212.7	239.5
Residential	550.8	542.0	538.9	515.4	526.6	581.0	621.5	554.1	668.7
Agriculture/Forestry/Fishing/ Fish Farms	27.7	22.6	32.8	35.0	57.3	44,1	61.3	65.3	73.5

Table 4.2 shows that natural gas imports (mln m^3) increased by 7.0% and consumption – by 11.2% in 2019 compared to the data of 2017. The rise in consumption is recorded mainly in *Transport* and *Residential*, as well as the *Energy Industries* categories. Net calorific value (kcal/m^3) of the imported/supplied natural gas mixture (weighted average) decreased by 2.5%, while the carbon content (kgC/m^3) of the mixture decreased by 3.7%.

Figure 4.4 provides natural gas mixture's CO_2 emission factors (kg CO_2 /TJ) and country-specific fugitive CH_4 emission factors (kg CH_4 /m^3) in 2011-2019.



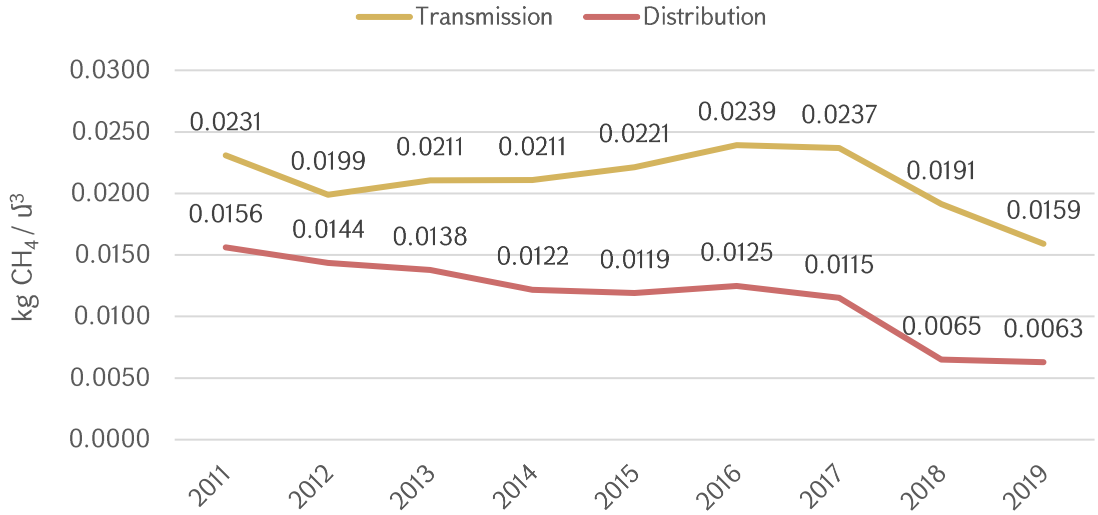


Figure 4.4 Natural gas mixture's CO_2 emission factors (kg CO_2 /TJ) and country-specific fugitive CH_4 emission factors (kg CH_4 /m^3) in 2011-2019

As can be seen from Figure 4.4, CO_2 emission factors (kg CO_2/TJ) of natural gas for all years are higher than the reference value recommended by the IPCC. Natural gas country-specific CO_2 emission factors (according to annual averages) vary depending on the carbon content of natural gas, calorific value of internal combustion, and other parameters.

The national CH_4 fugitive emission factors of natural gas (kg CH_4 /m3) show a decreasing trend in the distribution network throughout the period, and in the transmission network in the last two years.

The variations in the annual imports of natural gas are mainly because of the changes in the exports of electrical energy generated by burning natural gas in thermal power plants: the fluctuations in the annual consumption of natural gas for electricity generation reach up to 50% (although relatively stable in the recent years).

An increase in natural gas consumption is recorded in all sub-categories except *Manufacturing Industries and Construction* in 2019 compared to 2017 – due to economic growth and weather conditions (cold winter), with the Residential sector scoring its highest consumption of natural gas within 2011-2019, caused by 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 monitors the prices of diesel and gasoline to prevent entry barriers and excessive profit margins in any segment of the market.

Armenia does not have domestic fossil fuel-energy supplies, their refining industries or large storage facilities for liquid fuel.

The quantities of oil products imported into Armenia in 2011-2019 are summarized in Table 4.3 (final consumption for energy purposes).

Table 4.3 Balance of oil products in kind within 2011-2019 (ton)

Oil product	Imports, t								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoline	131,588	130,332	132,219	129,120	130,381	140,556	142,213	138,553	175,446
Diesel	159,515	144,683	147,326	152,651	128,873	126,660	134,506	113,739	132,658
Jet kerosine	39,648	40,473	45,900	40,458	30,927	44,055	54,394	61,877	68,980
Liquified gas	7,359	6,909	7,397	6,763	6,914	4,054	6,146	16,004	30,197
Total	**338,110**	**322,397**	**332,842**	**328,992**	**297,095**	**315,324**	**337,259**	**330,173**	**407,281**

As shown in Table 4.3, the quantities of the imported/consumed oil products are relatively stable for 2011-2018 period. However, the imports of oil products demonstrate an increase in 2019, particularly in terms of gasoline and liquefied petroleum gas (LPG), with LPG imports more than doubling in 2018 and 2019.

According to an agreement signed between the 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 into Armenia without collecting customs duties in Russia.

Gasoline (43.1%) and diesel fuel (32.6%) are the major import items of oil products.

Naturally, the *Road Transportation* is the bulk consumer of the liquid fuel with the share of 73.9% followed by the *Civil Aviation* with 16.9%, the *Manufacturing Industries and Construction* sub-category with 4.2% and the *Off-road Vehicles and Other Machinery* section of the *Agriculture / Forestry / Fishing / Fish Farms* sub-category with 3.7%. The consumption by the other categories is much lower.

Liquid fuel consumption by subcategory is estimated for years 2018 and 2019 based on the official data of the country's energy balance published by the Statistics Committee on their web-site (Annex 2.2).

The diesel fuel imported into the country is consumed in *Manufacturing Industries and Construction, Road Transportation* (mainly trucks and buses), *Other Transportation* (Off-road), *Residential* sectors and in *Agriculture/Forestry/Fishing/Fish Farms* (Off-road Vehicles and Other Machinery). The amount of diesel fuel consumed in the *Agriculture / Forestry / Fishing / Fish Farms* category is adopted according to the energy balance, where it is estimated based on the volume of agricultural work performed (expert assessments by the SC), the amount of diesel fuel consumption in the residential sector is also adopted according to the energy balance.

As for gasoline, it is almost entirely consumed in the road transportation sector.

Biomass

Fuelwood

Natural gas access rate is high in Armenia and reached 96%; however, fuelwood consumption still continues in rural areas, because of its affordability.

The quantity of burned fuelwood is converted to energy units based on the official data of the volumes of harvested wood, fallen-wood and illegal logging [LUCFRef.1, LUCFref.2, LUCFref.4].

It should be noted, that there is a significant difference between the official data on fuelwood consumption volumes (published by MOE) and the energy balance data (yielded via 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 are converted to energy units and provided in Table 4.4. The conversion is based on the average basic wood density 0.557 t/m^3 as adopted for estimations in Armenia and uses the default calorific value 15.6 TJ/Gg of wood as set forth by the 2006 IPCC Guidelines.

Table 4.4 Fuelwood consumption volumes in 2011-2019

Unit of Measure	Burned fuelwood volumes								
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Volume (m^3)	65,740	85,960	71,551	65,621	76,600	70,246	82,743	90,146	152,271
Weight (t)	36,617	47,880	39,854	36,551	42,666	39,127	46,088	50,212	84,815
Energy (TJ)	571.23	746.92	621.72	570.20	665.59	610.38	718.97	783.30	1,323.11

Manure

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

The emissions from the burning of manure are estimated in accordance with the methodology described in detail in the GHG National Inventory report of the RA for 1990-2019, that is, using the adjusted data, where the applied amount of manure remaining in a pasture is adopted as 27% instead of 38.5%, in line with the official data (AFOLURef-3).

Table 4.5 summarizes the annual amounts of manure burned as fuel (AFOLURef-3).

Heat generated of manure is estimated with the Net Calorific Value of 11.6 TJ/Gg as set forth by the 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.2] for “Other Primary Solid Biomass”.

Table 4.5 Quantity of manure produced, burned and thermal energy generated in 2011-2019

Quantity of manure produced, burned and heat received	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total manure produced, Gg	3,371.3	3,716.3	3,997.5	4,058.6	4,108.2	4,027.7	3,489.7	3,213.2	3,140.3
Total manure burned, Gg	215.6	237.6	255.6	259.5	262.7	257.5	223.1	243.7	238.1
Total thermal energy generated, TJ	2,500.4	2,756.3	2,964.8	3,010.2	3,047.0	2,987.3	2,588.2	2,826.5	2,762.3

Other biomass

The estimates of the GHG emissions from biomass burning included also pomace, other solid bioresidue and charcoal.

The values of the other biomass burned are found in the officially published Energy balance of the RA.

Energy generated from burning other solid biomasses	2015	2016	2017	2018	2019
Total pomace and other solid bio-residue, Gg	25.18	21.31	28.94	37.82	37.59
Total thermal energy generated, TJ	292.03	247.19	335.74	438.75	436.09

The Net Calorific Value of pomace and other solid bio-residue is adopted at 11.6 TJ/Gg as set forth by the 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.2] for “Other Primary Solid Biomass”.

Energy generated from burning charcoal	2015	2016	2017	2018	2019
Total charcoal, Gg	0.03	0.04	0.08	0.28	1,57
Total thermal energy generated, TJ	1.02	1.29	2.43	8.17	46.35

The Net Calorific Value of charcoal is adopted at 29.5 TJ/Gg as set forth by the 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.2] for “Charcoal”.

4.1.4 Emission estimation

4.1.4.1 Fuel Combustion Activities (1A)

Sectoral approach

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

Stationary Combustion includes *Electricity Generation, Manufacturing Industries and Construction,* as well as other sectors: *Residential, Commercial/Institutional,* and *Off-road Vehicles and Other Machinery* and *Horticulture Greenhouses* in Agriculture.

The presentation below covers estimates of GHG emissions per the categories of both Stationary and Mobile Combustion, and includes the methods applied, activity data, emission factors, findings of emission estimates, uncertainty assessment and time series of GHG emissions.

Stationary Combustion

4.1.4.1.1 Main Activity Electricity and Heat Production (1A1a)

Description of the category

This category includes emissions originating from burning of natural gas by thermal power plants, namely, Hrazdan CHP, Hrazdan-5 and Yerevan CHP CJSC (steam-gas cycle power generation unit), as well as by combined heat and power plants of smaller capacity, namely, "ArmRosCogeneration" CJSC and the Energy Center of the Yerevan State University.

The category *Main Activity Electricity and Heat Production* is the major source of emissions [gaseous fuels, carbon dioxide (CO_2)] in terms of level and trend assessment.

Table 4.6 provides the volumes of electrical energy generation by type of power plants (Annex 2.3, EnRef-2).

Table 4.6 Electrical energy generation by type of power plants, mln kWh

Power Plants	Year									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Nuclear	2,490	2,548	2,311	2,360	2,465	2,788	2,381	2,620	2,076	2,198
Thermal	1,443	2,395	3,398	3,173	3,289	2,801	2,582	2,872	3,376	3,047
Hydro	2,143	2,033	1,814	1,433	1,308	1,369	1,394	1,407	1,314	1,415
Small Renewables	416	458	513	744	689	840	960	864	1,011	972
Total	6,492	7,434	8,036	7,710	7,750	7,798	7,315	7,763	7,777	7,632

While the domestic consumption experienced a certain increase of 1.4% (or 83.6 GWh) in 2019, the electricity generation demonstrated a reduction in its annual output as compared to 2017. This is attributed to the following:

- a decrease in the electrical energy's import and export balance by about 14.4% (or 161.6 GWh), mainly due to the reduction of export volumes;
- a reduction of losses, with the total losses in 2017 amounting to 668.6 GWh or 8.6% of the total output, while in 2019 – to 548 GWh or 7.2%.

The share of gas fired TPPs in power generation mix in 2019 is about 40%. The thermal power plants operate to meet the season peaks, especially in the winter season, and whenever 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

CO_2 emissions for the sub-categories *Electricity Generation* and *Combined Heat and Power Generation* are estimated using *the Tier 3 method* per each individual plant [Gen-1, Volume 2, Chapter 2.3.1.3].

The structure of the country's gas distribution system is such that the natural gas consumed by different users varies by its unique physical and chemical parameters (indicators). Emissions are estimated per the volumes of natural gas consumed by each individual plant and per the country-specific emission factors, taking into account the characteristics of natural gas consumed by each given plant.

Activity data

Natural gas consumption by each thermal power plant (the records of the metering units) are provided by the PSRC (Annex 2.4) and are converted to thermal energy units, TJ (Annex 2.5), applying the net calorific values of the natural gas consumed in each power plant as provided by "Gazprom Armenia" CJSC (Annex 2.6).

Emission factors

The country-specific emission factors are estimated on the basis of the physical and chemical parameters of natural gas imported from RF, mixture (Yerevan gas distribution station 2) and from Iran (Annex 2.6: Data provided by "Gazprom Armenia" CJSC). The method of calculation of country-specific emission factors and the results of calculations are given in Annex 2.5.

All country-specific indicators: net calorific values, carbon content and estimated CO_2 emission factors are within the 95% confidence interval as set forth by the 2006 IPCC Guidelines (Annex 2.5).

Electricity Generation (1A1ai)

Description of the sub-category

This sub-category includes emissions from natural gas combustion for electrical energy generation by condensing power plants: Hrazdan TPP and Hrazdan-5 TPP.

Combined Heat and Power Generation (1A1aii)

Description of the sub-category

This sub-category covers Yerevan CHP CJSC (steam-gas cycle power generation unit), and combined heat and power plants of smaller capacity, namely, "ArmRosCogeneration" CJSC and the Energy Center of the Yerevan State University.

According to the energy balance, centralized generation of thermal energy (and its supply to other users) is carried out only by “ArmRosCogeneration” CJSC in 2019. This totaled to 7.6 mln kWh (or less than 0.1% of electrical energy generation in the country), with the energy delivery of 2.3 mln kWh or 30%.

All production is based on natural gas combustion.

Emissions estimation results for the category *Main Activity Electricity and Heat Production* (1A1a)

Table 4.7 provides estimations of plant-level CO_2 emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories in 2011-2019, with application of the country-specific emission factors.

Table 4.7 Country-specific emission factors (kg CO_2/TJ), activity data (TJ, mln m^3) and CO_2 emissions (Gg CO_2) in 2011-2019, by the power plants in operation

Stationary Combustion	Country-specific emission factors	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 in 2011		**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 in 2012		**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 in 2013		**26,324.24**	**758.9858**	**1,496.41**

Stationary Combustion	Country-specific emission factors	Activity data		GHG emissions
	kg CO_2/TJ	TJ	mln m^3	Gg CO_2
2014				
Hrazdan TPP	56,706.16	9,619.33	275.583	545.48
Hrazdan-5 TPP	56,706.16	7,360.96	210.883	417.41
Yerevan CCGT	57,022.93	10,558.56	305.644	602.08
Yerevan Medical University CHP plant	57,022.93	148.86	4.309	8.49
ArmRosCogeneration CHP plant	57,022.93	107.95	3.125	6.16
Total in 2014		**27,795.65**	**799.5445**	**1,579.61**
2015				
Hrazdan TPP	56,419.72	5,671.08	162.509	319.96
Hrazdan-5 TPP	56,419.72	5,185.41	148.592	292.56
Yerevan CCGT	56,655.00	11,656.56	336.813	660.40
Yerevan Medical University CHP plant	56,655.00	134.22	3.878	7.60
ArmRosCogeneration CHP plant	56,655.00	89.15	2.576	5.05
Total in 2015		**22,736.41**	**654.3678**	**1,285.58**
2016				
Hrazdan TPP	56,415.80	4,515.82	129.544	254.76
Hrazdan-5 TPP	56,415.80	5,750.06	164.950	324.39
Yerevan CCGT	56,715.56	10,455.88	303.887	593.01
Yerevan Medical University CHP plant	56,715.56	72.82	2.116	4.13
ArmRosCogeneration CHP plant	56,715.56	111.03	3.227	6.30
Total in 2016		**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 in 2017		**22,841.86**	**637.526**	**1297.96**
2018				
Hrazdan TPP	56,356.67	3,196.52	92.185	180.15
Hrazdan-5 TPP	56,356.67	12,933.10	372.980	728.87
Yerevan CCGT	56,755.47	10,231.84	298.538	580.71
Yerevan Medical University CHP plant	56,755.47	57.08	1.665	3.24
ArmRosCogeneration CHP plant	56,755.47	87.74	2.560	4.98
Total in 2018		**26,506.27**	**767.928**	**1,497.94**
2019				
Hrazdan TPP	56,362.62	5,025.54	143.186	283.25
Hrazdan-5 TPP	56,362.62	7,821.61	222.851	440.85
Yerevan CCGT	56,526.24	11,234.59	322.749	635.05
Yerevan Medical University CHP plant	56,526.24	67.32	1.934	3.81
ArmRosCogeneration CHP plant	56,526.24	35.2,5	1.013	1.99
Total in 2019		**24,184.31**	**691.733**	**1,364.95**

The decrease of country-specific emission factors (kg CO_2 /TJ) in 2019 compared to 2017 is due to decrease of carbon content in the natural gas imported from Russia and Iran: in 2017, from Russia - 15,46 kg/GJ, from Iran - 15,79 kg/GJ, while in 2019, from Russia - 15,37 kg/GJ, Iran - 15,42 kg/GJ (Annex 2.5, Table 2.5-1).

Table 4.8 summarizes GHG emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories by greenhouse gas in 2019.

Table 4.8 Emissions estimation results for *Energy Industries (1A1)* category in 2019, Gg

Code	Category/Subcategory	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A1a	Main Activity Electricity and Heat Production	1364.9	0.0242	0.0024	1366.2
1A1ai	Electricity Generation	724.1	0.0128	0.0013	724.8
1A1aii	Combined Heat And Power Generation	640.8	0.0113	0.0011	641.4

Figure 4.5 summarizes CO_2 emissions from *Electricity Generation* and *Combined Heat and Power Generation* sub-categories by power plant in 2019.

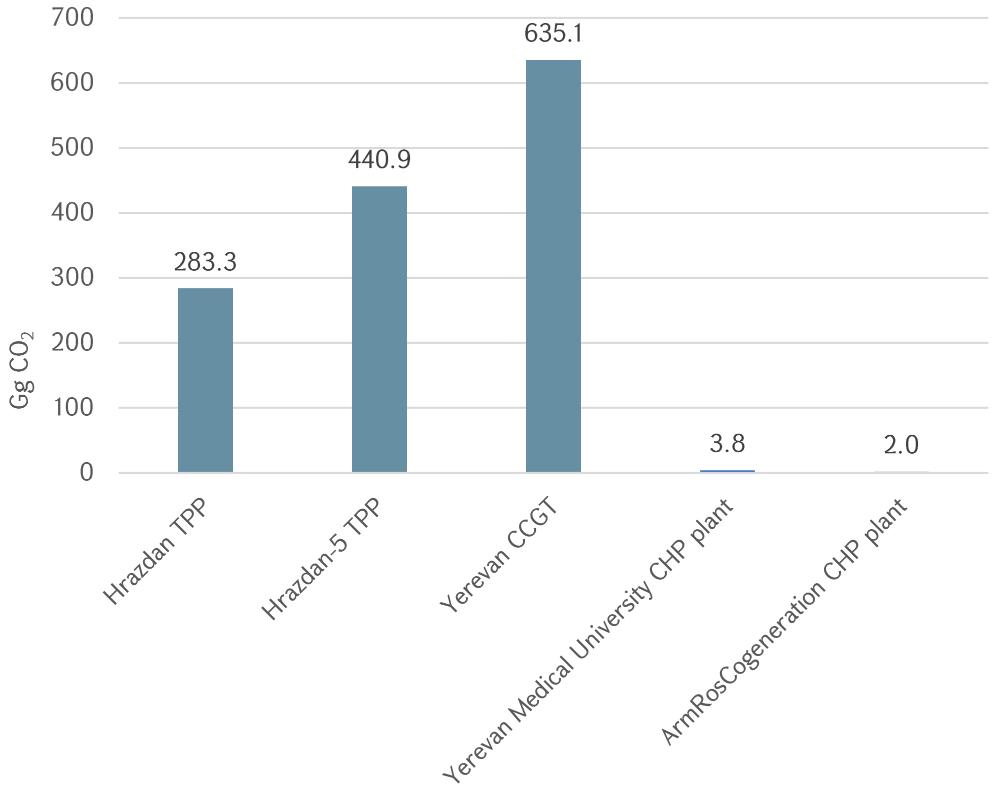


Figure 4.5 CO_2 emissions from the *Combined Heat and Power Generation* sub-category by power plant in 2019

Uncertainty assessment

In the sub-category *Main Activity Electricity and Heat Production* (1A1a), the uncertainty of Activity Data and Emission Factors is estimated to be up to 3% each, while the overall uncertainty of GHG emissions is estimated to be 4.24% at most. The uncertainties are estimated by the method of Approach 1: propagation of error. The calculations and their results are presented in Appendix 1.3.

Time series

The time series of GHG emissions (Gg CO_2) from the *Main Activity Electricity and Heat Production* category in 1990-2019 are demonstrated in Figure 4.6.

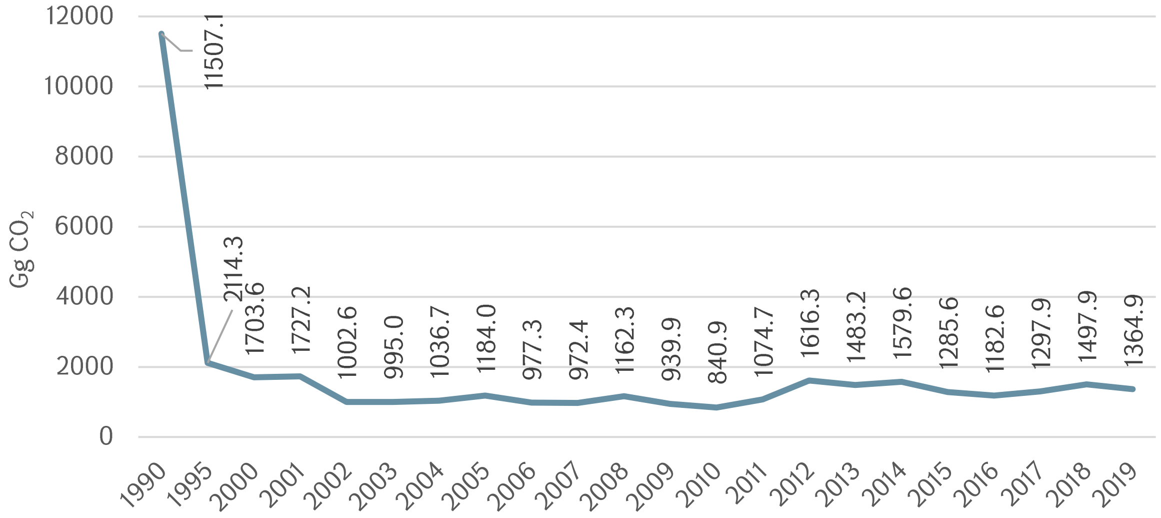


Figure 4.6 Time series of CO_2 emissions from the *Main Activity Electricity and Heat Production* category in 1990-2019

The reduction of CO_2 emissions in the early 2000s is consequent to the increased electricity generation at hydropower plants, the CO_2 emissions were relatively stable during 2002-2010, and since 2012 the fluctuations in CO_2 emissions were induced by the variations in the electricity generation by thermal power plants, mainly because of the electricity exports, but also due to the changes in the domestic consumption.

Thus, the volumes of electricity produced in thermal power plants were 2,871.7 GWh or 37% of the total output in 2017, 3,375.6 GWh or 43.4% of the total output in 2018 and 3,046.8 GWh or 39.9% of the total output in 2019. These are because of the changing import/export balance of the electrical energy, which made 1,120.1 GWh in 2017, 1,423.5 GWh in 2018 and 958.5 GWh in 2019, as well as due to the varying domestic consumption volumes, which totaled to 5,620.9 GWh in 2017, 5,388.3 GWh in 2018 and 5,802 GWh in 2019.

4.1.4.1.2 Manufacturing Industries and Construction (1A2)

Description of the category

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

This category is the main source of emissions in the case of a gaseous fuel [carbon dioxide (CO_2)] in terms of both level and trend assessments, while in the case of a liquid fuel it is the main source in terms of trend assessment only [GHG gas: carbon dioxide (CO_2)] .

This category comprises emissions from combustion of fuels for thermal energy generation for own use in industries and emissions arising from using off-road and other mobile machinery in industry. Energy used for transport by industry is not reported here, as it is covered under the *Transport* (1A3) category.

Methodology

CO_2 emissions from combustion of natural gas are assessed with application of *the Tier 2 method* [Gen-1, Volume 2, Chapter 2.3.1.2], by sub-categories, using the consumption data of the natural gas (Annex 2.2) and with the country-specific emission factors for natural gas mixture (weighted average) (Annex 2.5). Emissions from diesel fuel and LPG combustion are assessed applying *the Tier 1 method*.

Activity data

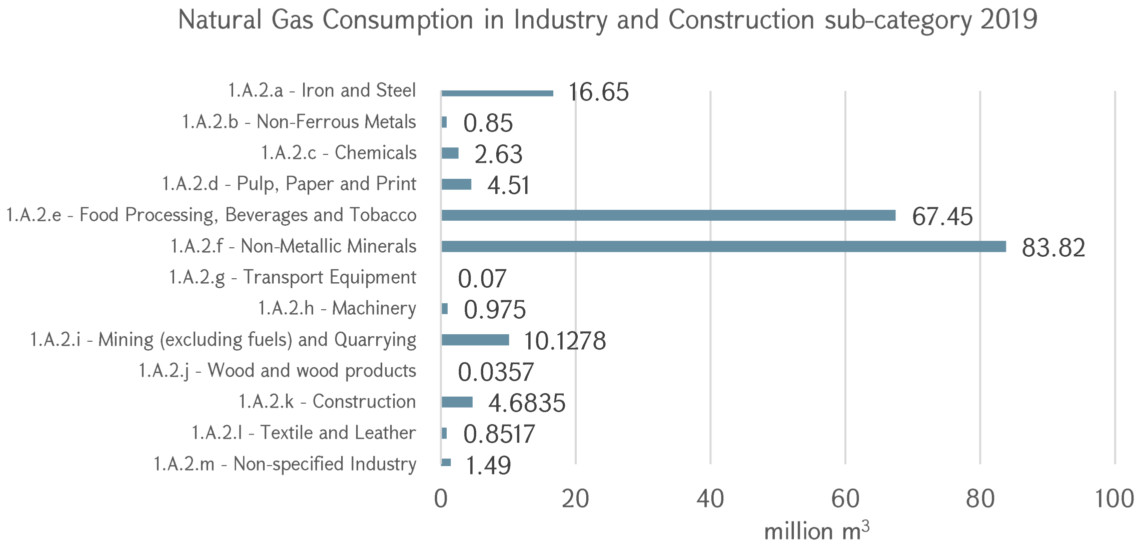
Under this sub-category, the following types of fuel are used: natural gas, diesel fuel and LPG.

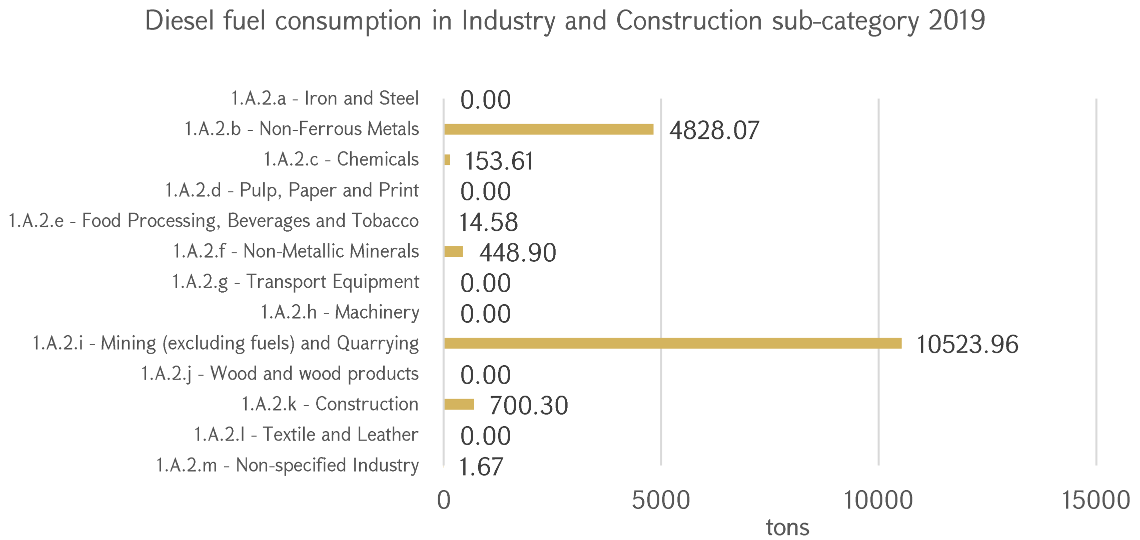
The consumption volumes of natural gas, diesel fuel and LPG are adopted by the energy balance (Annex 2.2).

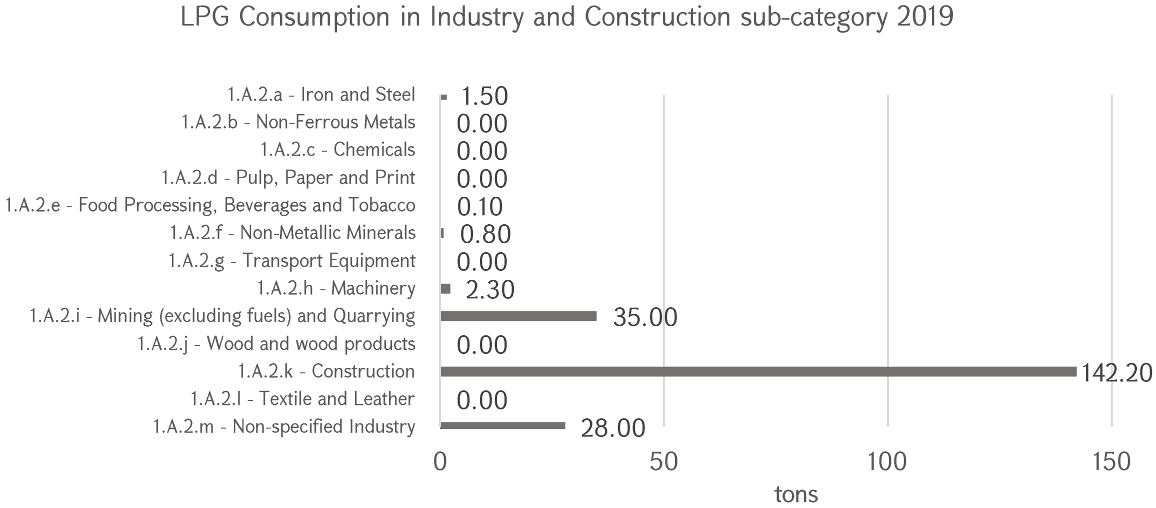
The diesel fuel imported into Armenia is consumed in the following sub-categories: *Manufacturing Industries and Construction, Road Transportation* (mainly trucks and buses), *Other Transportation* (off-road activities), *Residential* and *Agriculture (Off-road Vehicles and Other Machinery).*

The volumes of different fuels – natural gas and diesel fuel – consumed in all sections of the sub-category *Manufacturing Industries and Construction* (Annex 2.2) are converted to thermal energy units, using the net calorific values characteristic of natural gas mixture (weighted average) (Annex 2.5), and applying the reference values of the emission factors for diesel fuel and LPG as set forth by the 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.4].

Figure 4.7 shows the amounts of fuel burned in this sub-category [natural gas (mln m^3), diesel fuel (tons) and LPG (tons)] and total energy consumption (TJ) by sub-category.







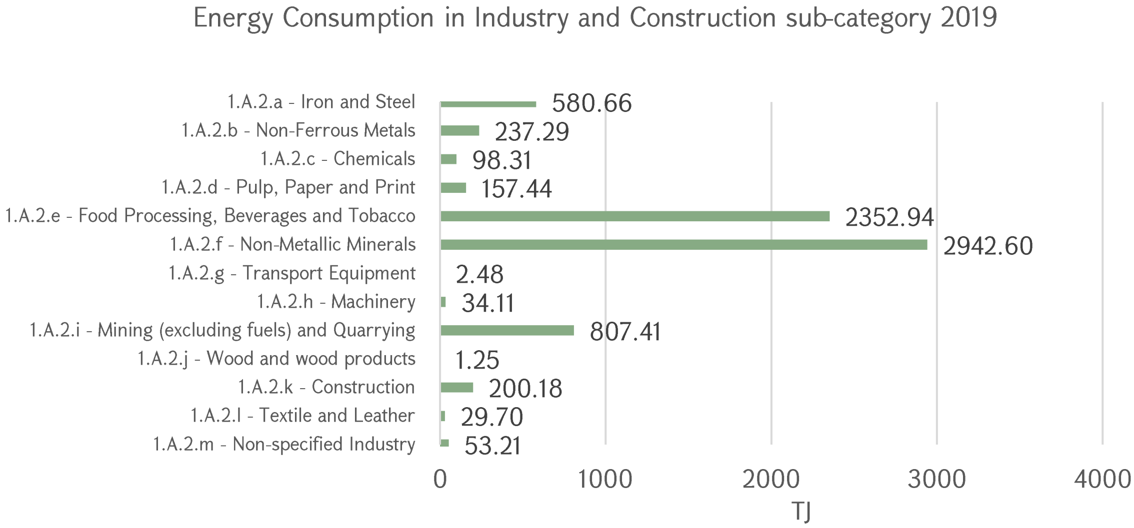


Figure 4.7 Amounts of fuel burned in the *Manufacturing Industries and Construction* category [natural gas (mln m^3), diesel fuel (tons) and LPG (tons)] and total energy consumption (TJ) in 2019, by sub-category.

It is evident from Figure 4.7 that the major consumers of natural gas are (1A2f) *Non-Metallic Minerals* and (1A2e) *Food Processing, Beverages and Tobacco* sub-categories. The main consumers of diesel fuel are (1A2i) *Mining and Quarrying* և (1A2b) *Non-Ferrous Metals* sub-categories. The key consumers of LPG are (1A2i) *Mining and Quarrying* and (1A2k) *Construction* sub-categories. Meantime, charcoal is not used in 2018 and 2019. The leaders in terms of total energy consumption (TJ) are (1A2f) *Non-Metallic Minerals* and (1A2e) *Food Processing, Beverages and Tobacco* sub-categories.

In the *Manufacturing Industries and Construction* sub-category, natural gas constitutes the bulk of the consumed fuel (90.31% in 2019, 93.49% in 2018), diesel fuel is also used (9.56% in 2019, 6.46% in 2018).

Emission factors

In the case of natural gas, country-specific emission factors (Annex 2.5) are applied based on the physical and chemical parameters of natural gas mixture (weighted average) (Annex 2.6) – in all sections of the *Manufacturing Industries and Construction* sub-category.

For the GHG emissions from diesel fuel and LPG, the reference values of the emission factors are applied as set forth by the 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.4].

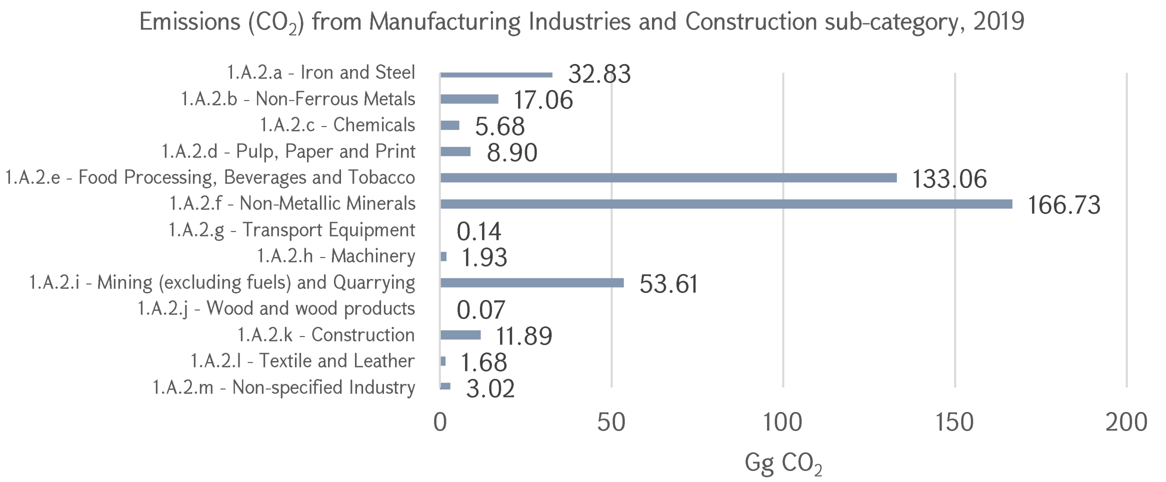
Emissions estimation results

Estimation results of GHG emissions from the *Manufacturing Industries and Construction* sub-category in 2019, by gas, are presented in Table 4.9.

Table 4.9 Emissions estimation results for the *Manufacturing Industries and Construction* sub-category in 2019, Gg

Code	Category/sub-category	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A2	**Manufacturing Industries and Construction**	436.9	0.0090	0.0011	437.5
1A2a	Iron and Steel	32,8	0.0006	0.0001	32.9
1A2b	Non-Ferrous Metals	17.1	0.0007	0.0001	17.1
1A2c	Chemicals	5.7	0.0001	0.0000	5.7
1A2d	Pulp, Paper and Print	8.9	0.0002	0.0000	8.9
1A2e	Food Processing, Beverages and Tobacco	133.1	0.0024	0.0002	133.2
1A2f	Non-Metallic Minerals	166.8	0.0030	0.0003	166.9
1A2g	Transport Equipment	0.1	0.0000	0.0000	0.1
1A2h	Machinery	1.9	0.0000	0.0000	1.9
1A2i	Mining (excluding fuels) and Quarrying	53.6	0.0017	0.0003	53.7
1A2j	Wood and wood products	0.07	0.0000	0.0000	0.1
1A2k	Construction	12.2	0.0003	0.0000	12.2
1A2l	Textile and Leather	1.7	0.0000	0.0000	1.7
1A2m	Non-specified Industry	3.0	0.0000	0.0000	3.0

Figure 4.8 provides GHG emissions from fossil fuel combustion in the *Manufacturing Industries and Construction* category per its sub-categories in 2019 (Gg CO_2 and Gg $CO_{2eq.}$).



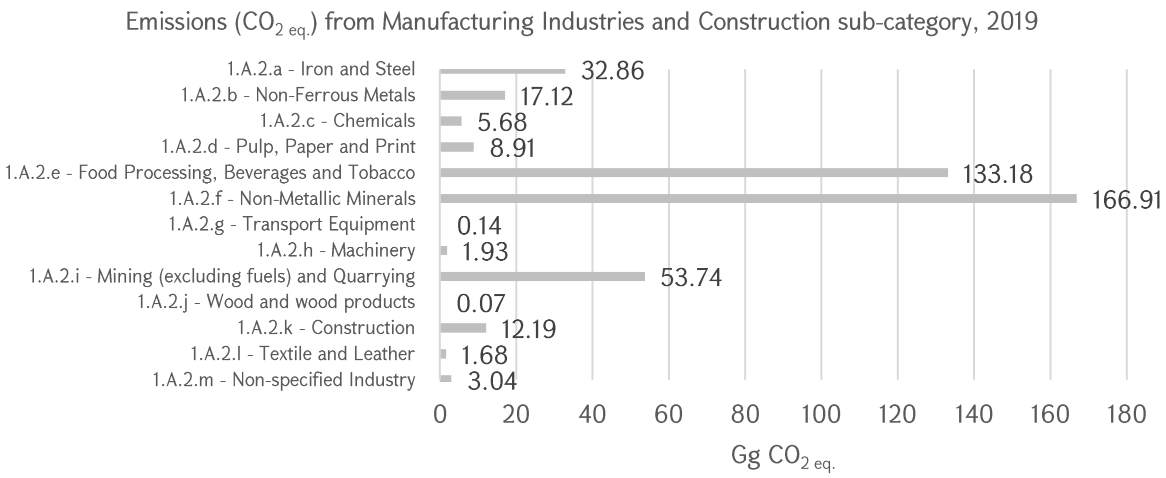


Figure 4.8 GHG emissions from the *Manufacturing Industries and Construction* category in 2019, by sub-category (Gg CO_2 and Gg $CO_{2eq.}$).

Uncertainty assessment

In the *Manufacturing Industries and Construction* category, the uncertainty of activity data on natural gas burned is assessed at 5%, while for diesel fuel it is up to 20%.

Emission factors uncertainty for natural gas is 3% and for diesel fuel it reaches 5%. Therefore, overall uncertainty for GHG emissions estimate for natural gas combustion could be adopted at 5.83% and for diesel fuel – at 20.62%.

Time series of GHG emissions

The time series of GHG emissions from the *Manufacturing Industries and Construction* category in 1990-2019 are presented in Figure 4.9.

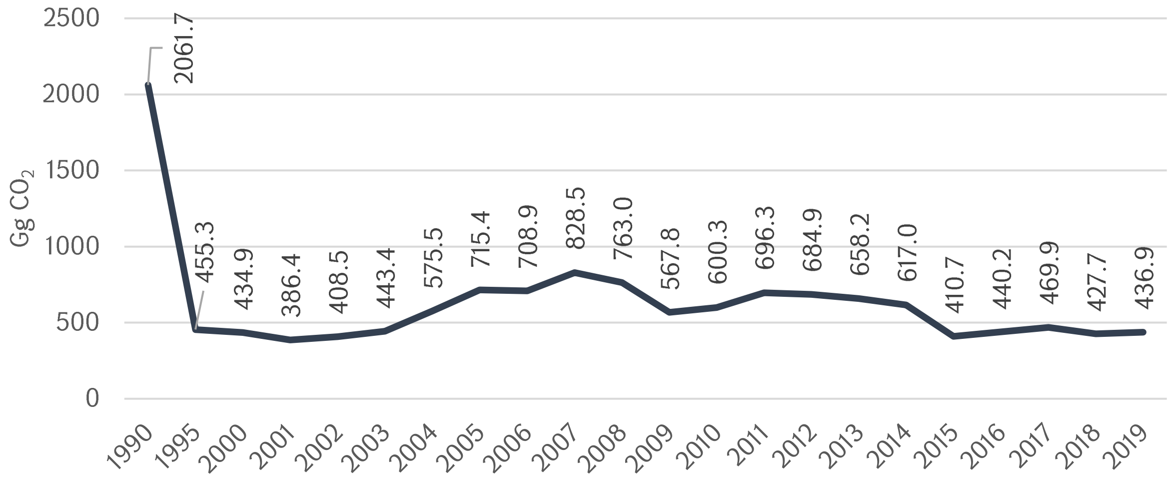


Figure 4.9 Time series of CO_2 emissions from the *Manufacturing Industries and Construction* (1A2) category in 1990-2019, Gg CO_2

It is evident from Figure 4.9 that the emissions rose in line with the economic growth of 2000-2007, then plummeted due to the global economic crisis of 2008, and showed gradual recovery afterwards.

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, also carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), sulphur dioxide (SO_2) and nitrogen oxides (NOx) emissions.

The following emission source sub-categories of the *Transport* category exist in Armenia: *International Aviation (International Bunker)*, *Road Transportation* and *Off-road Transportation*.

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

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

4.1.4.1.3.1 Road Transportation (1A3b)

The mobile source category *Road Transportation* includes light passenger automobiles, light and heavy trucks of all types, as well as buses, tractors and other self-propelled vehicles with diesel engines.

In Armenia fuel consumption structure in the road transportation is peculiar: gasification's impact is significant in this sector too and the share of LNG reached 60.3% in the total fuel consumption in the Road Transportation sector in 2019 (64.6% in 2018). Currently, 358 auto gas filling compressor stations operate in the country.

Transportation vehicles consume also gasoline (23.3% in 2019, 20.8% in 2018), diesel fuel (12.9% in 2019, 12.5% in 2018), liquified petroleum gas (LPG) (3.6% in 2019, 2.0% in 2018).

Over 98% of the emissions from the *Transport* category in 2019 originated in *Road Transportation*.

In 2019, the greenhouse gas emissions from the *Road Transportation* sub-category rose to 2,116.8 Gg $CO_{2\ eq.}$, exceeding the level of 2017 by 20% in an unprecedented surge.

Back in 2017, in order to analyze the main sources of emissions for the National GHG Inventory Report, the *Road Transportation* sub-category was separated by the type of fuel consumed – gaseous and liquid – to take into account the peculiarity of Armenia's gross consumption of liquified natural gas (LNG), and even with this assessment technique the *Road Transportation* manifested itself as a major source of GHG emissions for both gaseous and liquid fuels, both in level and trend estimates [GHG: Carbon Dioxide (CO2)].

The emissions from the *Road Transportation* grew continuously since 2000: during the period of 2000–2019 (with the exception of 2009 when the economic recession also affected auto-transport and resulted in a decline of CO_2 emissions from the road transportation, and of 2016 that showed a certain decrease in the sector's emissions), the emissions from the road transportation increased by about 200% due to the growth in traffic volume, driven by a rise in the living standards.

Methodology

Estimations of CO_2 emissions from mobile combustion of fossil fuels are performed applying *the Tier 2 method* with the Sectoral approach [Gen-1, Volume 2, Chapter 3] based on the country-specific emission factors for natural gas mixture (weighted average) (Annex 2.5) and the quantities of the consumed natural gas (Annex 2.1).

GHG emissions from gasoline, diesel fuel and LPG combustion are estimated applying *the Tier 1 method*.

CH_4 and N_2O emissions from fuel combustion in road transportation are estimated by applying *the Tier 1 method* using country's activity data and emission factors from the 2006 IPCC Guidelines, because the lack of detailed country-specific information on transportation vehicles and traffic prevents the application of higher tier methods. Besides, the share of CH_4 and N_2O emissions from fuel combustion is relatively small and makes only 3.6% of CO_2 equivalent emissions from the *Road Transportation* sector.

Estimation of the indirect greenhouse gas emissions from fuel combustion is performed applying *the Tier 1 method* with the Sectoral approach using the country's activity data and the emission factors as specified by 2019 EMEP/EEA Guidebook.

Activity data

The volumes of various fuels – natural gas, diesel fuel, gasoline and LNG (Annex 2.2: The Energy Balance and Annex 2.6: Data provided by "Gazprom Armenia" CJSC) – are converted to thermal energy units using net calorific values characteristic of natural gas mixture (weighted average) in the case of natural gas (Annex 2.5), while is case of diesel fuel, gasoline and LPG the reference values of the emission factors set forth by the 2006 IPCC Guidelines are applied.

Emission factors

In the case of natural gas, country-specific emission factors (Annex 2.5) are applied based on the physical and chemical parameters of natural gas mixture (weighted average) (Annex 2.6), while is case of diesel fuel, gasoline and LPG the reference values of the emission factors set forth by the 2006 IPCC Guidelines are applied [Gen-1, Volume 2, Table 1.2].

4.1.4.1.3.2 Off-road Transportation (1A3eii)

Description of the category

The sub-category includes fuel combustion emissions from off-road activities not otherwise reported under the *Agriculture/Forestry/Fishing/Fish Farms* (1A4c) or *Manufacturing Industries and Construction* (1A2) sub-categories. All the fuel consumed in this category is diesel.

Methodology

GHG emissions from combustion of diesel fuel are assessed applying *the Tier 1 method*.

Activity data

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

Emission factors

The reference values of the emission factors provided by the 2006 IPCC Guidelines are applied for estimating emissions from diesel combustion [Gen-1, Volume 2, Table 1.2].

Emissions estimation results from the Transport category

The results of greenhouse gas emissions estimation from the *Transport* (1A3) category for 2019 are summarized by gas (Gg) in Table 4.10.

Table 4.10 Emissions estimation results from the *Transport* category in 2019, Gg

Code	Category/sub-category	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A3	**TRANSPORT**	2,071.4	2.1989	0.1023	2,149.3
1A3a	Civil Aviation, *Memo Item*[8]	*217.5*	*0.0015*	*0.0061*	*219.4*
1A3ai	International Aviation (International Bunkers), *Memo Item*	*217.5*	*0.0015*	*0.0061*	*219.4*
1A3b	Road Transportation	2,039.5	2.1973	0.1006	2,116.8
1A3eii	Off-road	32.0	0.0017	0.0017	32.5

Uncertainty assessment

In the *Transport* category, the uncertainty of the activity data is estimated to be 5% for natural gas, and up to 20% for gasoline, LPG and diesel. The uncertainty of emission factors is assessed as up to 3% for natural gas, and up to 5% for diesel fuel, gasoline and LPG. Therefore, the overall uncertainty of GHG emissions is estimated to be 5.83% for natural gas and 20.62% for gasoline, LPG and diesel fuel. The uncertainties are estimated by the method of Approach 1: propagation of error (Annex 1.3).

Time series of GHG emissions

The time series of CO_2 emissions from the *Transport* category in 1990-2019 are presented in Figure 4.10.

[8] 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.

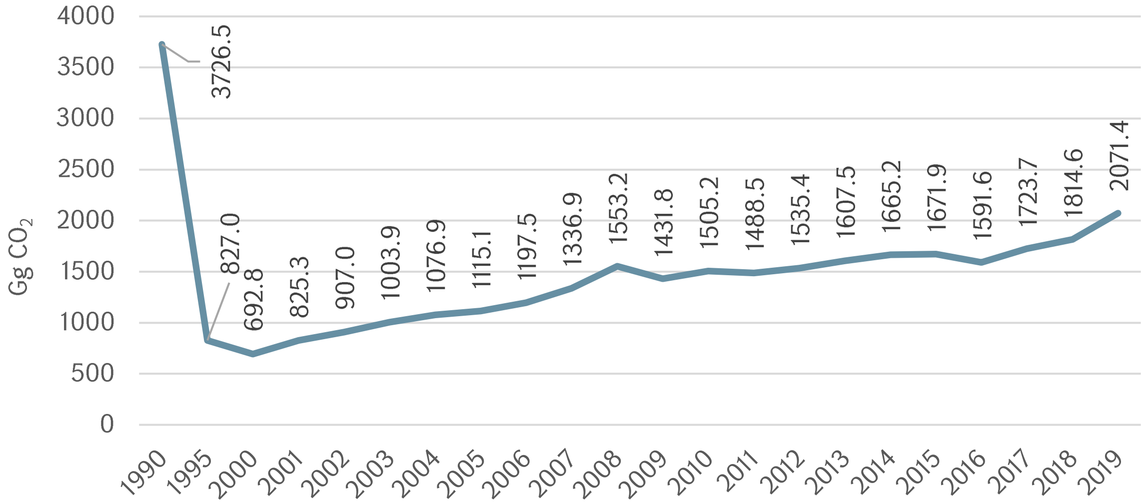


Figure 4.10 The time series of CO_2 emissions from the *Transport* category in 1990-2019, Gg

It is evident from Figure 4.10 that the time series of CO_2 emissions show the continuous growth due to regular development, except for the decline in 2009 caused by the global economic crisis, and a certain decline in 2016. Within 2000-2019, emissions in the category increased by about 200%.

4.1.4.1.4 Other Sectors (1A4)

This category includes *Commercial/Institutional, Residential,* and *Agriculture/Forestry/ Fishing/Fish Farms* sub-categories.

The sub-categories *Residential* and *Commercial/Institutional* are key sources of GHG emissions [gaseous fuel, greenhouse gas: carbon dioxide (CO_2)] in terms of both level and trend assessment, while the *Agriculture/Forestry/ Fishing/Fish Farms* sub-category is a major source in terms of trend assessment only.

The *Other Sectors* category is a key source of GHG emissions [liquid fuel, greenhouse gas: carbon dioxide (CO_2)] in terms of both level and trend assessment.

4.1.4.1.4.1 Commercial/Institutional (1A4a)

Description of the sub-category

Commercial organizations that are not covered by other sub-categories and institutional structures such as budgetary organizations are addressed here. Natural gas, LNG and coal are the types of consumed fuel in this sub-category.

Within the framework of this Inventory, the *Commercial/Institutional* sub-category is revised, the GHG emissions from natural gas combustion in horticultural greenhouses are disaggregated and included in the *Stationary* (1A4ci) section of the *Agriculture/ Forestry/Fishing/Fish Farms* (1A4c) sub-category. The time series of *Commercial/Institutional* subcategory for 1990-2019 are re-estimated to ensure consistency.

Methodology

CO_2 emissions from natural gas combustion are assessed applying *the Tier 2 method* with the Sectoral approach [Gen-1, Volume 2, Chapter 2] by using country-specific emission factors for natural gas mixture (weighted average) (Annex 2.5) and data on natural gas consumption (Annex 2.1). CO_2 emissions from LPG and coal combustion are estimated applying *the Tier 1 method*.

Activity data

The volumes of natural gas provided by "Gazprom Armenia" CJSC (Annex 2.1: Data provided by "Gazprom Armenia" CJSC) and the volumes of LPG and coal provided by SC (Annex 2.2: The Energy Balance) are converted to thermal energy units (TJ), using net calorific values characteristic of natural gas mixture (weighted average) in the case of natural gas (Annex 2.5), while is case of diesel fuel and coal the reference values of the emission factors set forth by the 2006 IPCC Guidelines are applied [Gen-1, Volume 2, Table 1.2].

Emission factors

In the case of natural gas, country-specific emission factors are applied based on the physical and chemical parameters of natural gas mixture (weighted average) (Annex 2.5 and Annex 2.6), while is case of diesel fuel and coal the reference values of the emission factors set forth by the 2006 IPCC Guidelines are applied [Gen-1, Volume 2, Table 1.4].

4.1.4.1.4.2 Residential (1A4b)

Description of the sub-category

According to the summary data provided by the Cadastre Committee, the total area of the country's housing stock in 2019 made 96.5 million m^2, including 54.2 million m^2 in urban communities (56.1%) and 42.3 million m^2 (43.9%) in rural communities.

Table 4.11 Key indicators of the RA housing stock

Multi-apartment buildings			Residential homes (single family)		Dormitories and temporary dwellings, total area	Total area per resident, sq.m
Number	Number of apartments	Total area	Number	Total area		
unit	unit	thsd sq.m	unit	thsd sq.m	thsd sq.m	sq. m
19,175	**444,026**	**28,611,946**	**450,100**	**67,656,331**	**273, 446**	**32.6**

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 (TJ) consumed by households in the RA, making up to 83.5% of the total fuel consumed, followed by biofuel with 16.3%. Naturally, the consumption of manure, fuelwood, pomace and other solid bio-residue occurs mainly in the rural areas.

Methodology

CO_2 emissions from natural gas combustion are assessed applying *the Tier 2 method* with the Sectoral approach by using country-specific emission factors (Annex 2.5) and data on natural gas consumption (Annex 2.1).

GHG emissions from combustion of all other types of fuel are estimated applying *the Tier 1 method*.

The emissions of methane (CH_4) and nitrous oxide (N_2O) from the burned manure are included in the National GHG Inventory.

Activity data

The volumes of natural gas (Annex 2.1: Data provided by "Gazprom Armenia" CJSC) and the volumes of the other fuels (Annex 2.2: The Energy Balance) are converted to thermal energy units, using net calorific values characteristic of natural gas mixture (weighted average) in the case of natural gas (Annex 2.5), while is the case of the other fuels the reference values of the emission factors set forth by the 2006 IPCC Guidelines are applied [Gen-1, Volume 2, Table 1.2].

Emission factors

In the case of natural gas, country-specific emission factors (Annex 2.5) are applied based on the physical and chemical parameters of natural gas mixture (weighted average) (Annex 2.6), while is case of the other fuels the reference values of the emission factors set forth by the 2006 IPCC Guidelines are used [Gen-1, Volume 2, Table 1.4].

Emissions from biomass

The greenhouse gas emissions from combustion of biofuels in the Residential sector are estimated from combustion of fuelwood, manure, pomace, other solid bio-residue and charcoal.

According to the 2006 IPCC Guidelines, CO_2 emissions from combustion of biofuels are not added to the total of the country-specific GHG emissions; instead, they are reported in a separate section as information items, while the emitted methane (CH_4) and nitrous oxide (N_2O) are included into the National GHG Inventory [Gen-1, Volume 2]. This allows to avoid double counting.

For biomass, only that part of the biomass that is combusted for energy purposes is estimated for inclusion as an information item in the Energy sector.

Table 4.12 summarizes the quantities of consumed fuelwood, manure, charcoal, pomace and other solid bio-residue, and the emissions of CO_2, CH_4 and N_2O from biofuel combustion for 2015-2019, while Figure 4.11 presents the time series of CO_2 emissions from combustion in the *Biomass* category in 1990-2019.

Table 4.12 Energy value (TJ) of the biofuel consumption and GHG emissions form its combustion in 2015-2019, Gg

Year	2015	2016	2017	2018	2019
Biomass Consumption, TJ					
Fuelwood	665.6	610.4	719.0	783.3	1,323.1
Manure	3,047.0	2,987.3	2,588.2	2,826.5	2,763.3
Pomace and other solid bio-residue	292.0	247.2	335.7	438.7	436.1
Charcoal	1.0	1.3	2.4	8.2	46.3
Total	**4,005.6**	**3,846.1**	**3,645.4**	**4,056.7**	**4,567.9**
CO_2 emissions from biofuel, Gg					
Fuelwood	74.54	68.36	80.52	87.73	148.19
Manure	304.70	298.73	258.82	282.65	276.23
Pomace and other solid bio-residue	29.20	24.72	33.57	43.87	43.61
Charcoal	0.11	0.14	0.27	0.91	5.19
Total	**408.55**	**391.95**	**373.18**	**415.17**	**473.22**
CH_4 emissions from biofuel, Gg					
Fuelwood	0.1997	0.1831	0.2157	0.2350	0.3969
Manure	0.9141	0.8962	0.7765	0.8480	0.8287
Pomace and other solid bio-residue	0.0876	0.0742	0.1007	0.1316	0.1308
Charcoal	0.0003	0.0004	0.0005	0.0016	0.0093
Total	**1.2017**	**1.1539**	**1.0934**	**1.2162**	**1.3657**
N_2O emissions from biofuel, Gg					
Fuelwood	0.002662	0.002441	0.002876	0.003133	0.005292
Manure	0.012188	0.011949	0.010353	0.011306	0.011049
Pomace and other solid bio-residue	0.001168	0.000989	0.001342	0.001755	0.001744
Charcoal	0.000001	0.000001	0.000002	0.000008	0.000046
Total	**0.016019**	**0.015379**	**0.014572**	**0.016194**	**0.018086**

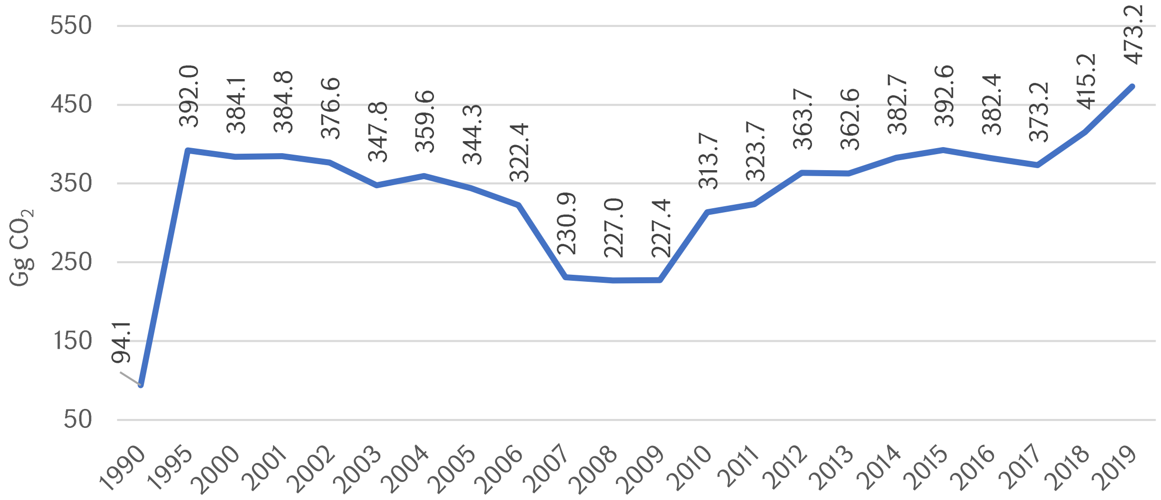


Figure 4.11 Time series of CO_2 emissions from biomass burning in 1990-2019, Gg CO_2

It is evident from Figure 4.11 that there was a sharp increase in CO_2 emissions from biomass combustion in 2018-2019, which is due to the increase in the use of firewood, specifically in 2019, by about 2 times according to the official data.

4.1.4.1.4.3 *Agriculture/Forestry/Fishing/Fish Farms* (1A4c)

The *Off-road Vehicles and Other Machinery* (1A4cii) section of the *Agriculture/Forestry/ Fishing/Fish Farms* (1A4c) sub-category uses diesel fuel and kerosine, while *Stationary* (1A4ci) section consumes natural gas.

This category is a key source of GHG emissions [carbon dioxide (CO_2)] in terms of both level and trend assessment.

Stationary (1A4ci)

Within this Inventory, the GHG emissions from the *Stationary* (1A4ci) subcategory are assessed for the first time. These are generated by burning natural gas in greenhouses and were previously included into the *Commercial/Institutional* subcategory.

The assessment of GHG emissions in a separate, new subcategory is made possible by "Gazprom Armenia" CJSC in 2019, due to keeping a separate record of the natural gas consumption in greenhouses and its inclusion into and publication within the energy balance of the Republic of Armenia.

Methodology

In order to ensure the consistency of time series and the completeness and accuracy of activity data, the following are taken into account for this re-estimation:

- The fact of setting of setting a preferential tariff for natural gas sales to greenhouse farms operating in the agricultural sector by the PSRC from January 01 of 2017 (for the period of November 01 to March 31 inclusive);
- The rates and progress of gas supply restoration in the country and its achieved availability in 1998-2016;
- Non-existent gas supply in 1992-2004;
- Availability of district heating in the 1990s and its dismantling in the early 2000s.

To estimate the GHG emissions from natural gas combustion in the years covered by the time series, the country-specific emission factors (Annex 2.5) are applied based on the physical and chemical parameters of natural gas mixture (weighted average) in those years (Annex 2.6).

Activity data

The volumes of natural gas consumption in 2019 are adopted according to the energy balance, while for the other years these are estimated according to the methodology identified above.

Emission factors

The volumes of natural gas are converted to thermal energy units, using net calorific values characteristic of natural gas mixture (weighted average) (Annex 2.5).
The country-specific emission factors (Annex 2.5) are applied to natural gas, based on the physical and chemical parameters of natural gas mixture (weighted average) (Annex 2.6).

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

Methodology

CO_2 emissions from combustion of diesel fuel and kerosine are assessed applying *the Tier 1 method* [Gen-1, Volume 2, Table 2.3.1.1].

Activity data

The data on the volume of diesel fuel is adopted in accordance with the energy balance, which are assessed based on the amount of fuel required for agricultural work (Annex 2.2).

The volumes of diesel fuel are converted to energy units, using the reference values of the emission factors as set forth by the 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.2].

Emission factors

Reference values of the emission factors set forth by the 2006 IPCC Guidelines are adopted for the assessment of GHG emissions from diesel fuel combustion [Gen-1, Volume 2, Table 1.4].

Emissions estimate for *Other Sectors* sub-category *(1A4)*

Table 4.13 summarizes the results of greenhouse gas emissions estimates for *Other Sectors* (1A4) sub-category by gas.

Table 4.13 Results of GHG emissions estimates for *Other Sectors* (1A4) sub-category in 2019, Gg

Code	Category/Sub-category	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1A4	**Other Sectors**	2023.33	1.5540	0.022	2062.8
1A4a	Commercial/Institutional	503.78	0.0446	0.001	505.0
1A4b	Residential	1323.31	1.4897	0.020	1361.0
1A4c	Agriculture/ Forestry/Fishing	196.23	0.0197	0.0007	196.9

It is evident from Table 4.13 that the *Residential* sub-sector produces the largest share of emissions from the *Other Sectors* sub-category: over 66%. According to the 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 in the *Other Sectors* (1A4) sub-category is estimated at 5% for natural gas, at 20% for LPG and diesel fuel, and at 40% for coal.

Emission factors' uncertainty is estimated at up to 3% for natural gas, at up to 5% for LPG and diesel, and 10% for coal.

Therefore, overall uncertainty for GHG emissions estimate for natural gas combustion could be adopted at 5.83%, for gasoline, LPG and diesel fuel – at 20.62%, and for coal – at 41.23%. For uncertainty assessment, the Approach 1: the propagation of error is employed. The estimations and their results are presented in Annex 1.3.

Time series of GHG emissions for *Other Sectors* (1A4) sub-category

The time series of GHG emissions (Gg CO_2) from the *Other Sectors* (1A4) sub-category in 1990-2019 are shown in Figure 4.12, in total and by sub-category.

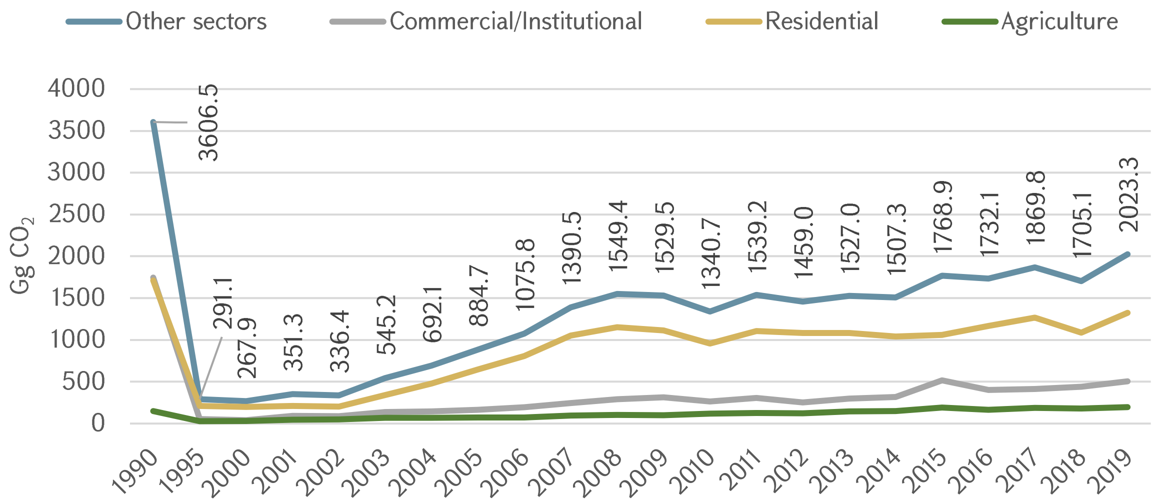


Figure 4.12 Time series of GHG emissions from the *Other Sectors* (1A4) sub-category (Gg CO_2)

It is evident from Figure 4.12 that the growth of the GHG emissions from the *Other Sectors* sub-category is mainly attributable to the increasing emissions from the *Residential* sub-category, where the impact of the global economic crisis is also visible via the drop in 2009. The higher emissions from the Residential sector in 2017 and in 2019 are attributable to the weather conditions, as the outdoor air temperature in the winter season is lower compared to the previous years.

Emissions from *Commercial/Institutional* sub-category show continuous growth, although some variations in the emissions level are observed.

The time series of the CO_2 emissions from the *Agriculture/Forestry/Fishing/Fish Farms* sub-category are relatively stable throughout 2000-2019.

Time series of CO_2 emissions from the Energy sector due to fuel burning activities

Figure 4.13 and Table 4.14 provide the time series of CO_2 emissions from the Energy sector due to fuel combustion in 1990-2019, by sub-category.

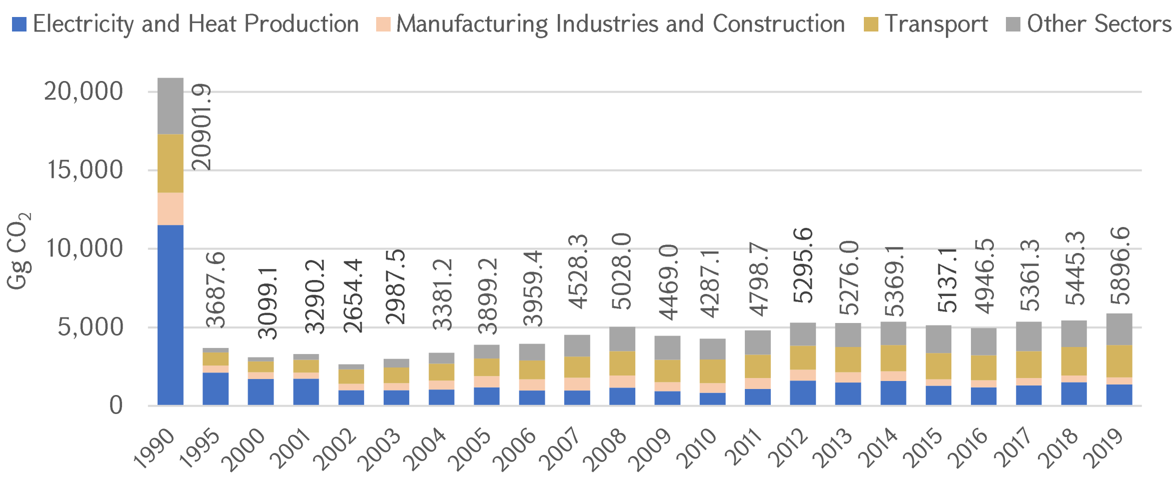


Figure 4.13 Time series of CO_2 emissions from the Energy sector in 1990-2019, by sub-category, Gg

Table 4.14 Time series of CO_2 emissions from the Energy sector due to fuel burning activities in 1990-2019, by sub-category, Gg

Subcategory / Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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	5,445	5,897
Energy Industries	11,507	2,114	1,704	1,184	841	1,075	1,616	1,483	1,580	1,286	1,183	1,298	1,498	1,365
Manufacturing Industries and Construction	2,062	455	435	715	600	696	685	658	617	411	440	470	428	437
Transport	3,727	827	693	1,115	1,505	1,488	1,535	1,608	1,665	1,672	1,592	1,724	1,815	2,071
Other Sectors, *including:*	3,606	291	268	885	1,341	1,539	1,459	1,527	1,507	1,769	1,732	1,870	1,705	2,023
Commercial/Institutional	1,746	52	40	164	265	307	252	298	318	518	400	412	439.0	504
Residential	1,712	211	199	648	956	1105	1083	1085	1041	1059	1167	1269	1,086	1,323
Agriculture/Forestry/Fishing/Fish Farms	149	28	29	73	120	127	124	144	148	192	165	189	180	196
Memo item: International Aviation (Bunkers)	409	90	91	112	136	125	128	145	128	96	137	169	195	218
Information Item: Biomass	94	392	384	344	314	324	364	363	383	393	382	373	373	415

The estimation outputs presented above show a significant increase in GHG emissions recorded in 2007 and 2008. This is consequent to the unprecedented expansion of gasification in the country then that resulted in a surge of natural gas consumption, especially by households. No smaller growth is recorded in natural gas and oil products' use in the Transport sector.

The decline of emissions in 2009 is a consequence of the global economic crisis. Emissions increased again in 2011 as a result of economic recovery.

The significant fluctuations in GHG emission since 2010 are mainly consequent to the changes in the natural gas consumption by the thermal power plants for electrical energy generation because of the unstable exports. Thus, the sharp increase in emissions recorded in the Energy sector in 2012 comes from higher exports of electrical energy produced by the thermal power plants (135% of their output in 2010). In 2014, the CO_2 emissions exceeded their levels of 2012, however, in the following years 2015 and 2016 a reduction in emissions is noted again. In 2017, an increase in CO_2 emissions is recorded, almost equaling the one in 2014, which is the highest within 1995-2017. This is a result of the combined effect of several factors: economic growth, rise in the export volumes, cold winter. In 2018 and in 2019, the emissions increase: due to the increase in electrical energy exports, therefore, in its generation by the thermal power plants, and a higher fuel consumption in the Transport sector in 2018, and mainly because of a higher natural gas consumption in the Residential sub-category and the unprecedented rise in emissions from the Transport in 2019, over 20% higher than in 2017.

Each year, the following factors have a certain influence on the emissions: the economic activity index, the economic situation in the country's energy-intensive industries, weather conditions, the volumes of energy generation by hydropower plants and the increase in the living standards of the population. The last-mentioned factor leads to an increase in fuel consumption for apartment heating and for transportation vehicles. Currently, low-carbon development mechanisms and energy efficient equipment do not compensate for the GHG emissions growth rates.

QA/QC procedures for Fuel Combustion Activities

Assessments of CO_2 emissions from fuel combustion yielded by the Sectoral approach for the category 1A are replicated using the Reference approach for result comparison. Energy balance served as the basis for the Reference approach to emissions estimation.

The results of CO_2 emissions estimate by the Sectoral approach per type of fuel are summarized in the Table 4.15.

Table 4.15 CO_2 emissions from fuel combustion in 2011-2019 assessed with the Sectoral approach, Gg CO_2

Type of Fuel			Actual emissions, Gg CO_2								
		Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Liquid fossil	Secondary fuel	Gasoline	418.8	400.7	405.9	396.4	400.3	431.5	436.6	425.4	538.6
		Jet kerosene*	*124.9*	*127.6*	*144.7*	*127.6*	*95.9*	*136.6*	*168.7*	*195.1*	*217.5*
		Diesel fuel	489.7	460.7	447.0	462.1	410.6	403.6	428.6	362.4	425.4
		LPG	21.9	20.4	22.1	20.2	20.6	12.1	18.3	47.8	90.1
Total liquid fossil			**930.4**	**881.8**	**875.0**	**878.7**	**831.5**	**847.2**	**883.5**	**835.6**	**1,054.1**
Solid fossil	Other bitumen coal		10.2	9.5	3.8	3.1	2.5	4.6	3.9	4.7	10.5
Total solid fossil			**10.2**	**9.5**	**3.8**	**3.1**	**2.5**	**4.6**	**3.9**	**4.7**	**10.5**
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	4,605.0	4,831.8
Total gaseous fossil			**3,858.1**	**4,405.2**	**4,397.2**	**4,487.4**	**4,303.1**	**4,094.7**	**4,473.9**	**4,605.0**	**4,831.8**
Total			**4,798.8**	**5,296.5**	**5,276.0**	**5,369.1**	**5,137.2**	**4,946.5**	**5,361.3**	**5,445.3**	**5,896.6**

Note: *Since jet kerosine is completely consumed in international bunkers, its emissions are not included in the total emissions of the country. It is a memo item.*

Comparison of Reference and Sectoral approaches

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

The IPCC approach to the emissions' record encourages the use of fuel statistics collected by an officially recognized national body, as this is usually the most comprehensive and readily available source of activity data. The present estimations employ the officially published data of the Energy Balance 2019.

Table 4.16 and Figure 4.14 present a comparison of CO_2 emission volumes in 2011-2019 estimated using Reference and Sectoral approaches. Evidentially, the differences are not essential; specifically, they do not reach 5% for the whole period and amount 3.5% and 3% for years 2018 and 2019 [Gen-1, Volume 2, Chapter 2, Table 2.17].

Table 4.16 Comparison of CO_2 emissions from fuel combustion estimated with the Reference and Sectoral approaches, Gg CO_2

Fuel Combustion Activity (1A)	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sectoral approach	4,798.8	5,296.5	5,276.0	5,369.1	5,137.2	4,946.5	5,361.3	5,445.3	5,896.6
Reference approach	4,996.4	5,481.7	5,508.9	5,598.2	5,381.6	5,199.6	5,616.0	5,640.9	6,078.4

For the purposes of this comparative analysis, CO_2 emissions from fuel combustion are included in the assessment (those covered in other sections of the GHG Inventory, particularly fugitive emissions, are not a part of the estimation).

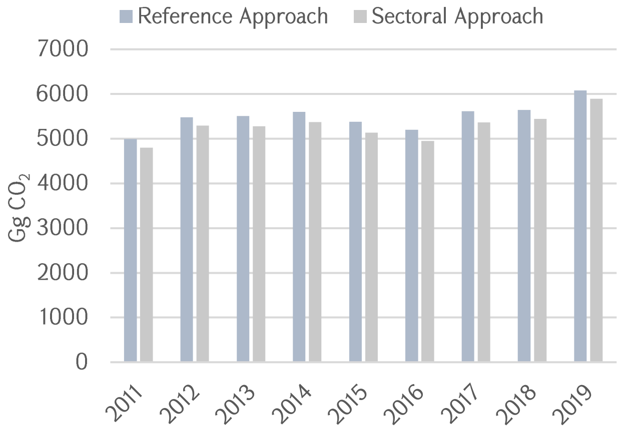


Figure 4.14 Comparison of the *Reference* and *Sectoral* approaches

The emissions obtained using the *Reference* approach are higher than those yielded from the *Sectoral* approach. This is legitimate and comes from the 2006 IPCC Guidelines, because natural gas losses are included in the estimation of the *Reference* approach as a part of consumption.

4.1.4.2 Fugitive emissions from natural gas (1B2b)

4.1.4.2.1 Fugitive emissions from the Natural Gas Transmission and Storage (1B2biii4) sub-category and Fugitive emissions from the Natural Gas Distribution (1B2biii5) sub-category

Description of the sub-categories

Gas supply system

Armenia imports natural gas from Russia, by transit route through Georgia's territory, 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 1,683 km. The gas transmission system includes 116 gas distribution stations and 21 metering units.

In recent years, there was an unprecedented expansion of the natural gas distribution system. Currently, the access to the gas supply system in the country nears 96% and covers 644 settlements. The gas distribution system operates 19,350 km long high-, medium- and low-pressure pipelines. For operation of the gas distribution system there are 2,642 gas control points, 8,568 individual gas regulating units and 1,433 head-count measuring units.

Fugitive emissions from the natural gas related systems are estimated in the following sub-categories:

Natural Gas Transmission and Storage (1B2biii4) and

Natural Gas Distribution (1B2biii5).

The other sources indicated in the 2006 IPCC Guidelines [Gen-1, Volume 2] for the Energy sector do not exist in Armenia.

The sub-category *Fugitive emissions from natural gas* (1B2b) is the major source of emissions [gaseous fuels, carbon dioxide (CO_2)] in terms of both level and trend assessment.

In Armenia, methane fugitive emissions mainly occur during the operation of natural gas related systems (emergency leaks, leaks due to the measures implemented in accordance with the operating regulations, technological losses).

Methodology

Fugitive emissions from natural gas are assessed applying the Tier 2 method [Gen-1, Volume 2, Chapter 4] with application of the country-specific emission factors using the official data on physical and chemical parameters of the supplied natural gas [mixture (weighted average)].
The estimation methodology of the country-specific emission factors is discussed and consented with “Gazprom Armenia” CJSC. National Inventory Report 2011-2012 contains its detailed presentation as developed in the framework of Armenia’s First Biennial Update Report [Ref-7].

Activity data

Estimations of the activity data of natural gas transmission and distribution systems is performed using the official statistics from the annual balances provided by “Gazprom Armenia” CJSC (Annex 2.1).

Emission factors

The country-specific factors of methane fugitive emissions are estimated using the official statistics from the annual balances provided by “Gazprom Armenia” CJSC and based on the annual average physical and chemical parameters of natural gas in its transmission and distribution systems: gas composition, density, net calorific values (Annex 2.6).

Emissions estimation results

The country-specific factors of methane fugitive emissions (Gg/mln m^3), activity data (mln m^3) and methane fugitive emissions (Gg CH_4) from the gas supply system of Armenia in 2011-2019 are presented in Table 4.17.

Table 4.17 Country-specific factors of methane fugitive emissions, activity data and methane fugitive emissions from the gas supply system of Armenia in 2011-2019

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	
2018	Transmission network	0.0191360	2,427.20	46.45	**60.46**
	Distribution network	0.0065002	2,156.10	14.01	
2019	Transmission network	0.0159096	2,488.90	39.60	**53.45**
	Distribution network	0.0062909	2,202.49	13.85	

The fugitive emission volumes, when estimated using the country-specific emission factors, are quite close to values yielded by *the Tier 1 method* with the factors set forth by 1996 IPCC Guidelines, and differ significantly from the results of estimations that use the factors specified by the 2006 IPCC Guidelines.

Estimation results of GHG emissions from the *Fugitive Emissions from Natural Gas* (1B2b) sub-category in 2018 and 2019, by gas, are presented in Table 4.18.

Table 4.18 Estimation results of GHG emissions from the *Fugitive Emissions from Natural Gas* (1B2b) sub-category in 2018 and 2019, Gg

2018

Code	Category/Sub-category	Net CO_2	CH_4	N_2O	Total CO_2 eq.
1B2b	**Fugitive Emissions from Natural Gas**	0.1121	60.4620	NA	1269.81
1B2biii4	Transmission and Storage	0.0021	46.4470	NA	975.39
1B2biii5	Distribution	0.1100	14.0150	NA	294.42

2019

Code	Category/Sub-category	Net CO_2	CH_4	N_2O	Total CO_2 eq.
1B2b	**Fugitive Emissions from Natural Gas**	0.1145	53.4530	NA	1122.63
1B2biii4	Transmission and Storage	0.0022	39.5974	NA	831.55
1B2biii5	Distribution	0.1123	13.8556	NA	291,08

Uncertainty assessment

The uncertainty of activity data in the *Transmission and Storage* and *Distribution* sub-categories of *Fugitive Emissions from Natural Gas* category is estimated at 5%. For each emission factor, the uncertainty is assessed at up to 5%. This yields the overall uncertainty of 7.07% for GHG emissions from the *Transmission and Storage* and *Distribution* sub-categories. The uncertainties are estimated using the Approach 1: the propagation of error. The estimations and their results are presented in a separate section of the present report.

Time series of GHG emissions

The time series of GHG emissions (Gg CH_4) in the *Fugitive Emissions from Fuels* (1B) category in 1990-2019 are presented in Figure 4.15.

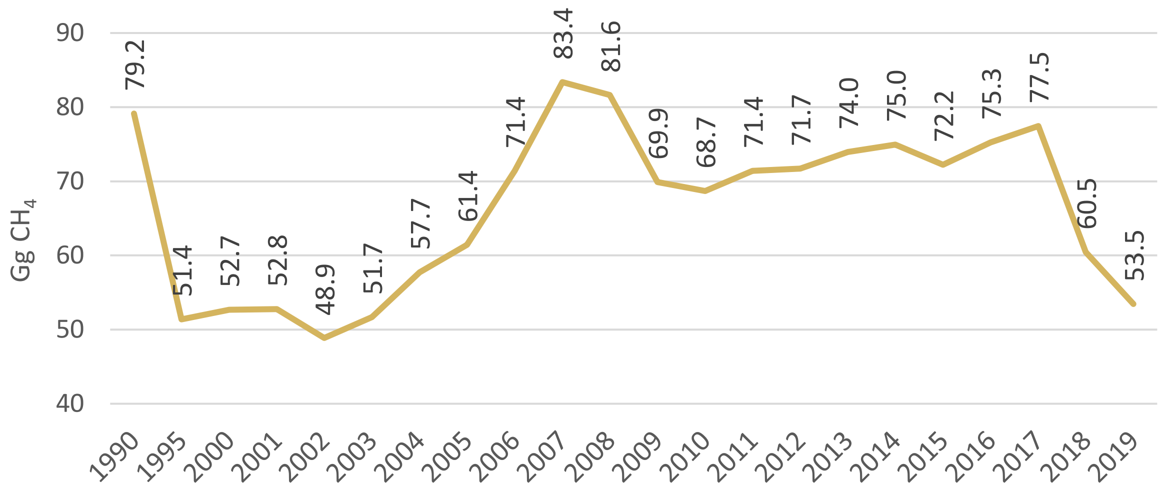


Figure 4.15 Time series of CH_4 emissions in the *Fugitive Emissions from Fuels* (1B) category in 1990-2019

It is evident from Figure 4.15 that the fugitive emissions from natural gas recorded a steady increase in the early 2000s because of the expansion of gasification effort in the country, and continue to rise after 2010 consequent to the increase in the natural gas imports as necessary for the growing exports of electrical energy. As in all the previous time series, this category also shows a significant decline due to the global economic crisis impact in 2009.

In 2018 and 2019, despite the increase in the natural gas imports, the fugitive emissions decreased significantly because of the renovation works implemented in the previous years.

4.1.5 Summary of GHG emissions from the Energy sector

Table 4.19 shows the GHG emissions from the Energy sector in 2019, by sub-category and by gas.

Table 4.19 GHG emissions from the Energy sector in 2019, by sub-category and by gas

Sub-category/ Greenhouse gas (Gg)	2019
CO_2	**5,896.76**
Main Activity Electricity and Heat Production	1,364.95
Manufacturing Industries/Construction	436.93
Transport	2,071.44
Other Sectors	2,023.33
Fugitive emissions from natural gas	0.1145
CH_4	**57.2391**
Main Activity Electricity and Heat Production	0.0242
Manufacturing Industries/Construction	0.0090
Transport	2.1989
Other Sectors	1.5540
Fugitive emissions from natural gas	53.4530
N_2O	**0.1280**
Main Activity Electricity and Heat Production	0.0024
Manufacturing Industries/Construction	0.0011
Transport	0.1023
Other Sectors	0.0222
Fugitive emissions from natural gas	NA

Emissions from International Bunkers (1A3ai) (memo item)

According to the 2006 IPCC Guidelines, the 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 a memo item.

Estimations of GHG emissions from the *International Bunker* sub-category is performed using the activity data provided in the energy balances (Annex 2.2), by *the Tier 1 method*, as a memo item.

The volumes of fuel are converted to thermal energy units with application of the reference values of emission factors for jet kerosene as provided by the 2006 IPCC Guidelines [Gen-1, Volume 2, Table 1.2]. The reference values of the emission factors for jet kerosene from the 2006 IPCC Guidelines are adopted for the estimations [Gen-1, Volume 2, Table 1.4].

Table 4.20 provides the fuel consumption and the resulting emissions from the *International Aviation* sub-category, by gas.

Table 4.20 GHG emissions from *International Aviation* (bunker)

Years	2011	2012	2013	2014	2015	2016	2017	2018	2019
Consumption (TJ)	**1,748.48**	**1,784.86**	**2,024.21**	**1,784.21**	**1,370.07**	**1,951.64**	**2,409.66**	**2,728.76**	**3,042.01**
Emissions (Gg)									
CO_2	125.0	127.6	144.7	127.57	95.90	136.61	168.68	195.11	217.50
CH_4	0.001	0.001	0.0010	0.0009	0.0007	0.0010	0.0012	0.0014	0.0015
N_2O	0.0035	0.0036	0.0040	0.0036	0.0027	0.0039	0.0048	0.0055	0.0061
CO_2 eq.	**126.11**	**128.74**	**146.01**	**128.70**	**96.77**	**137.85**	**170.20**	**196.83**	**219.42**

The time series of CO_2 emissions (Gg CO_2) from the *International Bunkers* memo item (1A3ai) in 1990-2019 are presented in Figure 4.16.

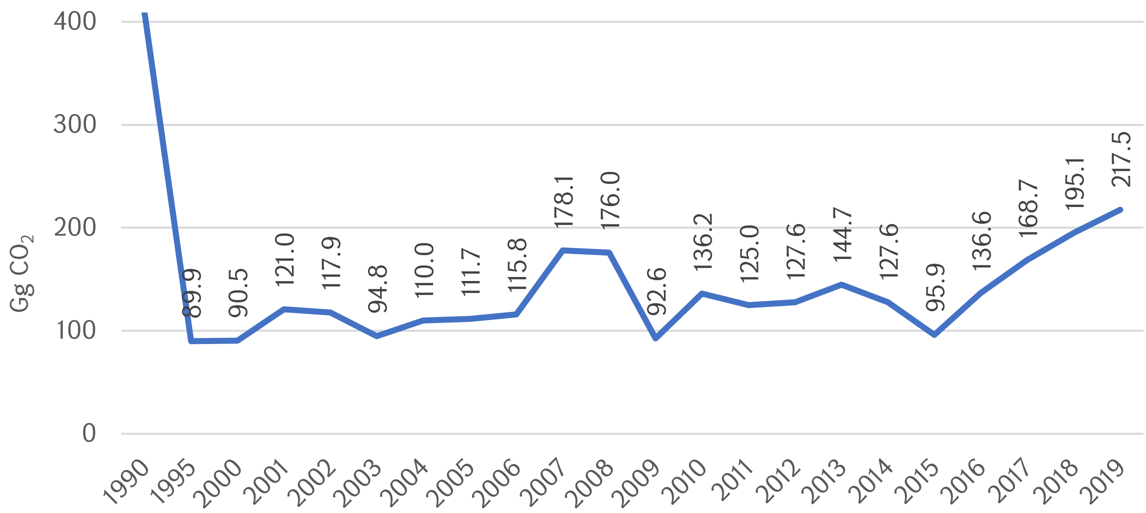


Figure 4.16 Time series of CO_2 emissions from the *International Bunkers* memo item (1A3ai) in 1990-2019, Gg CO_2

Completeness and accuracy of the activity data

Comprehensive official statistics is available in the country on production/generation, transmission/transportation, distribution and sales of natural gas and electrical energy (albeit the data on certain consumer groups is still aggregate).

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

However, the consumption data on certain types of liquid fuel is incomplete and does not include all the necessary areas of activity.

The official data on the quantities of fuelwood consumed and the data yielded from the Household Survey vary widely, and the experts currently work towards ensuring consistency of these data.

In order to improve the completeness and reliability of the activity data, the National GHG Inventory team works closely with the SC and the energy balances' compiling experts.

QA/QC procedures for Activity data

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

The assumptions and criteria underlying the selection of activity data, emission factors and other evaluation parameters are checked. Comparability of the data between the categories is verified. For each category, the current inventory estimates are compared to the previous year's estimates, and if significant changes or deviations from the expected trends are observed, the estimates are rechecked and the differences interpreted.

At the same time, the consistency of the activity data common for different emission sources is checked. For instance, to estimate emissions from fuelwood and manure burning, the consistency is checked of fuelwood and manure data in the AFOLU sector with the data used to estimate carbon loss in forest soils and emissions from manure management.

4.1.6 GHG emissions of the Energy sector

GHG emissions of the Energy sector in 2019 are presented in Table, while Table 4.22 and Figure 4.17 show the time series of GHG emissions from the Energy sector. Table 2.2 provides the data on precursor emissions.

Table 4.21 GHG emissions from the Energy sector in 2019

Sectors/Categories	Emissions (Gg)			
	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1 - ENERGY	**5,896.76**	**57.2391**	**0.1280**	**7,138.47**
1.A - FUEL COMBUSTION ACTIVITIES	**5,896.64**	**3.7860**	**0.1280**	**6,015.84**
1.A.1 - ENERGY INDUSTRIES	**1,364.95**	**0.0242**	**0.0024**	**1,366.20**
1.A.1.a - Main Activity Electricity and Heat Production	1,364.95	0.0242	0.0024	1,366.20
1.A.1.a.i - Electricity Generation	724.10	0.0128	0.0013	724.77
1.A.1.a.ii - Combined Heat and Power Generation	640.85	0.0113	0.0011	641.44
1.A.2 - MANUFACTURING INDUSTRIES AND CONSTRUCTION	**436.93**	**0.0090**	**0.0011**	**437.46**
1.A.2.a - Iron and Steel	32.83	0.0006	0.0001	32.86
1.A.2.b - Non-Ferrous Metals	17.06	0.0007	0.0001	17.12
1.A.2.c - Chemicals	5.68	0.0001	0.0000	5.68
1.A.2.d - Pulp, Paper and Print	8.90	0.0002	0.0000	8.91
1.A.2.e - Food Processing, Beverages and Tobacco	133.06	0.0024	0.0002	133.18
1.A.2.f - Non-Metallic Minerals	166.76	0.0030	0.0003	166.91
1.A.2.g - Transport Equipment	0.14	0.0000	0.0000	0.14
1.A.2.h - Machinery	1.93	0.0000	0.0000	1.93
1.A.2.i - Mining (excluding fuels) and Quarrying	53.61	0.0017	0.0003	53.74
1.A.2.j - Wood and wood products	0.07	0.0000	0.0000	0.07
1.A.2.k - Construction	12.17	0.0003	0.0000	12.19
1.A.2.l - Textile and Leather	1.68	0.0000	0.0000	1.68
1.A.2.m - Non-specified Industry	3.04	0.0001	0.0000	3.04
1.A.3 - TRANSPORT	**2,071.44**	**2.1989**	**0.1023**	**2,149.33**
1.A.3.a - Civil Aviation	217.50	0.0015	0.0061	219.42
1.A.3.a.i - International Aviation (International Bunkers)	217.50	0.0015	0.0061	219.42
1.A.3.a.ii - Domestic Aviation	2,039.47	2.1973	0.1006	2,116.81
1.A.3.e - Other Transportation	31.97	0.0017	0.0017	32.53
1.A.3.e.ii - Off-road	31.97	0.0017	0.0017	32.53
1.A.4 - OTHER SECTORS	**2023.33**	**32.6334**	**6.8789**	**2062.84**
1.A.4.a - Commercial/Institutional	503.78	0.9359	0.3118	505.03
1.A.4.b - Residential	1,323.31	31.2828	6.3587	1360.95

Sectors/Categories	Emissions (Gg)			
	Net CO_2	CH_4	N_2O	Total $CO_{2\ eq.}$
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	196.24	0.4147	0.2084	196.86
1.A.4.c.i - Stationary	144.95	0.2692	0.0795	145.30
1.A.4.c.ii - Off-road Vehicles and Other Machinery	51.29	0.0069	0.0004	51.56
1.B - FUGITIVE EMISSIONS FROM FUELS	**0.1145**	**53.4530**	**NA**	**1,122.63**
1.B.2.b - Natural Gas	0.1145	53.4530	NA	1,122.**63**
1.B.2.b.iii.4 - Transmission and storage	0.0022	39.5974	NA	831.55
1.B.2.b.iii.5 - Distribution	0.1123	13.8556	NA	291.08

	Emissions (Gg)						
Categories	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
MEMO ITEMS							
International Bunkers	217.504	0.0015	0.0061	0.276	0.083	0.131	0.069
1.A.3.a.i - International Aviation (International Bunkers)	217.504	0.0015	0.0061	0.276	0.083	0.131	0.069
INFORMATION ITEMS							
CO_2 from Biomass Combustion for Energy Production	473.229						

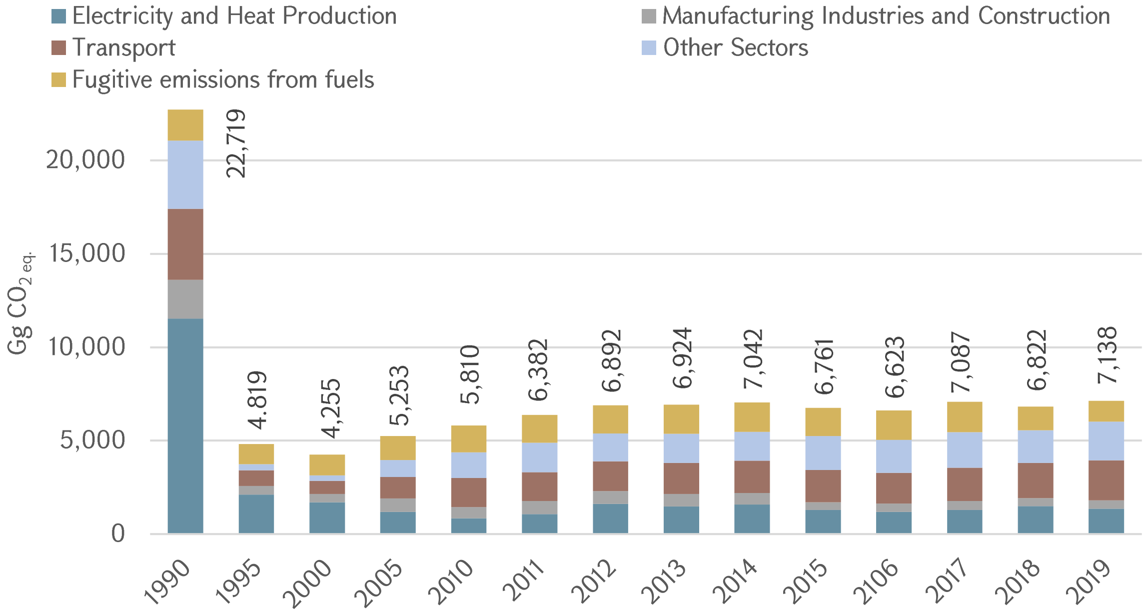


Figure 4.17 Time series of GHG emissions from the Energy sector, Gg $CO_{2\ eq.}$

Table 4.22 Time series of GHG emissions from the Energy sector in 1990-2019, Gg $CO_{2\ eq.}$

Sub-category / Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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**	**6,822**	**7,138**
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	1,499	1,366
Manufacturing Industries and Construction	2,065	456	435	716	601	697	686	659	618	411	441	470	428	437
Transport	3,810	847	710	1,148	1,556	1,541	1,591	1,668	1,728	1,742	1,653	1,789	1,885	2,149
Other sectors:	3,647	319	298	913	1,368	1,568	1,491	1,560	1,540	1,803	1,765	1,902	1,706	2,026
Commercial/ Institutional	1,752	53	40	164	266	308	253	299	319	519	401	413	440	505
Residential	1,745	239	228	676	982	1,133	1,113	1,116	1,072	1,091	1,198	1,299	1,119	1,361
Agriculture	149	28	29	74	120	128	125	145	149	193	166	189	180	197
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	1,270	1,123
Memo Items														
International Aviation	413	91	91	113	137	126	129	146	129	97	138	170	197	219
Memo Items: Biomass	94	392	384	344	314	324	364	363	383	393	382	373	415	473

Table 2.2 Summary report of the Energy sector in 2019

Categories	Emissions and Removals				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											
1 - Energy	5,896.758		57.2391	0.1280				17.630	34.456	3.556	0.225
1.A - Fuel Combustion Activities	5,896.644		3.7861	0.1280				17.630	34.456	3.556	0.225
1.A.1 - Energy Industries	1,364.946		0.0242	0.0024				2.152	0.943	0.063	0.007
1.A.2 - Manufacturing Industries and Construction	436.930		0.0090	0.0011				0.874	0.244	0.174	0.039
1.A.3 - Transport	2,071.437		2.1989	0.1023				13.096	31.994	3.203	0.016
1.A.4 - Other Sectors	2,023.330		1.5540	0.0222				1.508	1.274	0.116	0.164
1.A.5 - Non-Specified	NO		NO	NO				NA, NO	NA, NO	NO	NA, NO
1.B - FUGITIVE EMISSIONS FROM FUELS	0.1145		53.4530	NA, NO				NO	NO	NA, NE	NO
1.B.1 - Solid Fuels	NO		NO	NO						NO	
1.B.2 - Oil and Natural Gas	0.1145		53.4530					NO	NO	NE	NO
1.B.3 - Other emissions from Energy Production	NO		NO	NO				NO	NO	NO	NO
1.C - CARBON DIOXIDE TRANSPORT AND STORAGE	NO							NO	NO	NO	NO
Memo Items											
International Bunkers	217.5034		0.0015	0.006				0.276	0.083	0.131	0.069
1.A.3.a.i - International Aviation (International Bunkers)	217.5034		0.0015	0.006				0.276	0.083	0.131	0.069
1.A.3.a.i - International Aviation (International Bunkers)	NO		NO	NO				NO	NO	NO	NO
1.A.5.c - Multilateral Operations	NO		NO	NO				NO	NO	NO	NO

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, from metals productions – steel production, CO_2 emissions generated from lubricant and paraffin wax use, emissions of F-gases (HFCs) from refrigeration, air conditioning, foam production 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 1174.2 Gg $CO_{2\ eq.}$ In 2018 making up 11.2 % of the Armenia's total emissions, and in 2019 – 1285.3 Gg CO_2 eq. or 11.5 % of the total emissions.
The prevailing part of CO_2 emissions were generated in Mineral Industry (cement, lime and glass production) making 305.61 Gg in 2019, whereas CO_2 emissions from the use of lubricants and solid paraffin, steel production were much smaller making up 5.71 Gg and 1.18 Gg, respectively.

The most significant CO_2 emissions' source was emissions generated in the production of cement - 258.95 Gg CO_2, which accounts for 20.1 % of emissions from the IPPU sector and 2.3 % of Armenia's total emissions.

Fluorinated greenhouse gases or F-gases form a category of their own under IPPU Sector. F-gases emissions made 972.8 Gg $CO_{2\ eq.}$ in 2019, with prevailing share - 969.5 Gg $CO_{2\ eq}$. from Product Uses as Substitutes for Ozone Depleting Substances – HFCs emissions - while SF_6 emissions from use of electrical equipment were negligible - 3.3 Gg $CO_{2\ eq.}$

Emissions of HFCs from Product Uses as Substitutes for Ozone Depleting Substances accounted for 8.7 % of total national emissions and about 75.4 % of the greenhouse gas emissions of IPPU Sector in 2019, the share of SF_6 emissions is negligible.

The prevailing part of total HFC emissions is caused by the refrigeration systems – 95.7 %. The share of emissions from other applications is much lower (4.3%) than the rest of applications together.

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** (CO_2 and SO_2 emissions)
  - (2C1) Iron and Steel Production (CO_2 emissions)
  - (2C2) Ferroalloys Production (SO_2 emissions)
  - (2C7) Copper Production (SO_2 emissions)
- (2D) **Non-energy Products from Fuels (CO_2 emissions) and Solvent Use (CO_2 and NMVOC)**
  - (2D1) Lubricant Use (CO_2 emissions)
  - (2D2) Paraffin Wax Use (CO_2 emissions)
  - (2D3) Solvents Use (NMVOC emissions)
  - (2D4) Bitumen/Asphalt Production and Use (NMVOC emissions)

- (2F) Product uses as Substitutes for Ozone Depleting Substances (HFCs emissions)
- (2G) Other Products Manufacture and Use (SF_6 emissions)
  - (2G1b) Use of Electrical Equipment
- (2H) Other Product Manufacture and Use (NMVOC emissions)
  - (2H2) Food and Beverages Industry.

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 production).

4.2.3 Improvements done

Within the frames of 2018-2019 NIR the following improvements were made to the IPPU sector GHG Inventory:

Accuracy improvement

- Time series of CO_2 emissions of the *Paraffin Wax Use* (2D2) sub-category have been recalculated due to the improvement of activity data.
- Emissions from *Solvents Use* (2D3) sub-category with indirect greenhouse effect (NMVOC) for 1990-2017 have been recalculated due to the change of emission factor.
- NMVOC emissions from the *Bitumen/Asphalt Use* (2D4) sub-category for 1995-2017 have been recalculated and the bitumen content in asphalt mixture has been reassessed.
- NMVOC estimates from the *Food and Beverages* (2H1) sub-category were improved through application of the Tier 2 methodology of EMEP/EEA guidebook considering the technological peculiarities and the time series have been recalculated.

Completeness Improvement

- For the first time greenhouse gases (CO_2) generated from the steel production of the *Iron and Steel Production* (2C1) sub-category have been calculated for the period of 2001-2019 years.

4.2.4 Key Categories

(2A1) Cement production is identified as the key source category (CO_2 emissions) with level assessment (CO_2).

4.2.5 Cement Production (2A1)

Methodology

Carbon dioxide emissions from cement production were calculated by applying Tier 3 approach [Gen-1, Volume 3, Chapter 2, Equation 2.3] indicated in 2006 IPCC Guidelines based on plant specific data, which considering the characteristics of raw material and technological procedures, provides more accurate results. Emissions data collected on the plant level were then aggregated for reporting national emissions estimates.

During cement production, the Greenhouse Gas emissions (CO_2) are practically generated only when annealing the raw material in the clinker kiln. The calculation is implemented with the equations introduced in the guideline [Gen-1, Volume 3, Chapter 2, Equation 2.3] based on the accurate/precise data on the activities of individual plant (productions).

Tier 3 calculation approach considers the chemical composition of the raw material and based thereon the precise carbonate amount is calculated, which is the source of carbon dioxide generation. Besides, the captured dust amount to be returned to the kiln is also taken into account.

Activity data

The activity data for emissions assessment were received directly from the producing organizations [IndRef-1, IndRef-2]. The data were analyzed by the experts, the enhanced discrepancies were discussed with the manufacture's representatives, subsequently clarified and used for the calculations.

Data on cement production, quantity and composition of raw materials used by cement producing plants, as well as those on emissions are provided below:

Table 4.23 Production and quantity of the main raw materials, 2018-2019, thousand t (Production 1)

Year	Annual production		Quantity of main raw materials	
	Cement	Clinker	Clay	Limestone
2018	309.528	405.968	139.615	491.609
2019	444.441	344.620	149.967	476.016

Quantity of captured dust for 2018 – 74.295.3 t/year, 2019 – 106.668.7 t/year, kiln dust capturing system efficiency for 2018-2019 - 99.7 %. Quantity of emitted dust (loss) for 2018 - 223.56t, 2019 - 320.97 t.

Table 4.24 The average composition of Calcium oxide in primary raw material, % (Production 1)

Chemical component	Raw material	
	Clay	Limestone
CaO	24.65	58.7

Table 4.25 Cement and Clinker production per years, thousand t (Production 2)

Year	Annual production		Quantity of main raw materials				
	Cement	Clinker	Limestone	Clay	Iron containing slag	Perlite	Gypsum
2018	93.501	70.181	117.156	6.632	3.702	27.149	8.526
2019	29.655	14.756	25.824	1.952	0.77	5.990	2.127

Quantity of captured dust for 2018 – 11.023 t/year, 2019 – 2.651.4 t/year, kiln dust capturing system efficiency for 2018 - 98.74 % and for 2019 - 98.68 %. Quantity of emitted dust (loss) for 2018 - 140.66t, 2019 - 35.47 t.

Table 4.26 The average composition of Calcium oxide in primary raw material, % (Production 2)

Year	Chemical component	Limestone	Iron containing slag	Clay	Perlite	Gypsum
2018	CaO	46.93	3.27	3.49	0.47	26.99
2019	CaO	49.12	1.73	4.22	0.59	27.4

Calculation of carbon dioxide emissions from Cement Production

According to the equation [Gen-1, Volume 3, Chapter 2, Equation 2.3], the quantity of the used carbonate is required for calculation. In the data provided by the plants the content of CaO in the primary raw material is available.

Given that carbonate accounts for 80-90% of the carbonate in raw ores, the calculations have been done on that premise.

Since the calcium content in the raw material is reported in the form of oxide by the companies of Production 1 and Production 2, it has been recalculated to express it in carbonate form.

Recalculation is implemented per the chemical formula:

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

Carbonate determining calculation for the Production 2 is introduced below:

2018

- Limestone – 117,156 t, average content of calcium oxide - 46.93%, or 117,156 x 0.4693 = 54,981.3 t
- Clay – 6,632 t, calcium oxide content - 3.49%, or 6,632 x 0.0349 = 231.46 t
- Iron containing slag – 3,702 t, content of calcium oxide - 3.27%, or 3,702x 0.0327 = 121.06 t
- Perlite – 27,149t, content of calcium oxide - 0.47%, or 2,7149x 0.0047 = 127.60 t
- Gypsum – 8,526 t, content of calcium oxide - 26.99%, or 8,526x 0.2699 = 2,301.17 t
- Total calcium oxide – 54,981.3 + 231.46 + 121.06 + 127.60 + 2,301.17 = 57,762.59 t/year
- Estimated carbonate 57,762.59 x 100/56 = 103,147.5 t/year.

2019

- Limestone – 25,824 t, average content of calcium oxide - 49.12%, or 2,5824 x 0.4912 = 12,684.75 t
- Clay – 1,952 t, content of calcium oxide - 4.22%, or 1,952 x 0.0422 = 82.37 t
- Iron containing slag – 770 t, content of calcium oxide - 2.83%, or 770x 0.0283 = 21.79t
- Perlite - 5,990t, content of calcium oxide - 0.59%, or 5,990x 0.0059 = 35.34 t
- Gypsum – 2,127t, content of calcium oxide - 27.4%, or 2,127x 0.274 = 582.8 t
- Total calcium oxide – 12,684.75 + 82.37 + 21.79 + 35.34 + 582.8 = 13,407.05 t/year
- Estimated carbonate – 13,407.05 x 100/56 = 23,941.2 t/year.

The quantity of carbonate for "Production 1" is also calculated in the same way:

2018

- Clay – 139,615 t, content of calcium oxide - 24.65%, or 139,615 x 0.2465 = 34,415.09 t
- Limestone – 491,609 t, average content of calcium oxide - 58.7%, or 491,609 x 0.587 = 288,574.48 t,
- Total calcium oxide – 34,415.09 + 288,574.48 = 322,989.6 t/year,
- Estimated carbonate 322,989.6 x 100/56 = 576,767.1 t/year.

2019

- Clay – 149,967 t, content of calcium oxide - 24.65%, or 149,967 x 0.2465 = 36,966.86 t
- Limestone – 476,016 t, average content of calcium oxide - 58.7%, or 476,016 x 0.587 = 279,421.39 t,
- Total calcium oxide - 36,966.86 + 279,421.39 = 316,388.86 t/year,
- Estimated carbonate - 316,388.86 x 100/56 = 564,979.0 t/year.

Table 4.27 Estimated carbonate quantities, t/year

Year	Production 1	Production 2
	Total carbonate	Total carbonate
2018	576.77	103.147
2019	564.98	23.941

Taking into account the input data, the calculation results of carbonate quantities and above stated interpretations related to formula, the emission factors of carbon dioxide have been determined.

Calculations of GHG emissions for 2018-2019 are given in Tables 4.28 and 4.29, and the generated carbon dioxide emissions are summarized in Table 4.30.

Table 4.28 CO_2 emissions factors and calculation results, 2018-2019 (Production 2)

Indicators	2018	2019
EFi (t CO_2/t carbonate)	0.43971	0.43971
Mi (t)	103,147.5	23,941.2
Fi (degree)	1	1
MR_d (t)	140.66	35.47
C_d (fraction)	1	1
F_d (fraction)	1	1
EF_d (t CO_2 /t carbonate)	0.4397	0.4397
$M_к$ (t)	0	0
$X_к$ (fraction)	0	0
EF_k (t CO_2 /t carbonate)	0	0
CO_2 (t)	45,355	10,527

Table 4.29 CO_2 emissions factors and calculation results, 2018-2019 (Production 1)

Indicators	2018	2019
EFi (t CO_2/t carbonate)	0.43971	0.43971
Mi (t)	576,767.1	564,979.0
Fi (degree)	1	1
M_d (t)	223.56	1,333.2045
C_d (fraction)	1	1
F_d (fraction)	1	1
EF_d (t CO_2 /t carbonate)	0.4397	0.4397
$M_к$ (t)	0	0
$X_к$ (fraction)	0	0
EF_k (t CO_2 /t carbonate)	0	0
CO_2 (t)	253,610	248,427

Table 4.30 Carbon dioxide emissions from the cement production, Gg/year

Year	CO_2 emissions from cement production		
	Production 1	Production 2	Total
2018	253.610	45.355	298.965
2019	248.427	10.527	258.954

The total quantity of carbon dioxide emissions from cement production made up 298.958 Gg for 2018 and for 2019 it was 258.948 Gg.

Uncertainty assessment

Uncertainty estimates for CO_2 emissions from cement production result predominantly from uncertainties associated with activity data – uncertainties in raw materials and their carbon content.

The analysis of cement plant data indicated that the discrepancies yearly observed in the proportions of cement production and GHG quantities are not accounted for the raw material composition and the carbonate content.

Losses in raw materials and fluctuations in carbonate content are particularly influential. Lack of data on the reserve balance at the beginning and end of the year also has a considerable impact.

There may be some uncertainty associated with assuming that there is 100 percent calcination of carbonates in the cement kiln dust. Anyhow its effect is negligible.

Various uncertainty values and expert assessment of their impact are introduced below.

Table 4.31 Uncertainties of GHG calculations in cement production

N	Uncertainty values	Uncertainty, %
1	Non-complete reporting on raw material quantities and high fluctuations in the factor of estimated losses	3 - 7
2	Inaccurate determination of carbonate content in various raw materials	5 - 8
3	Lack of data on residual quantities of raw material, cement and clinker in the stock	6 - 10
4	Inaccuracy of assumptions about the calcination of carbonates in raw materials	1 - 5[9]

Time Series

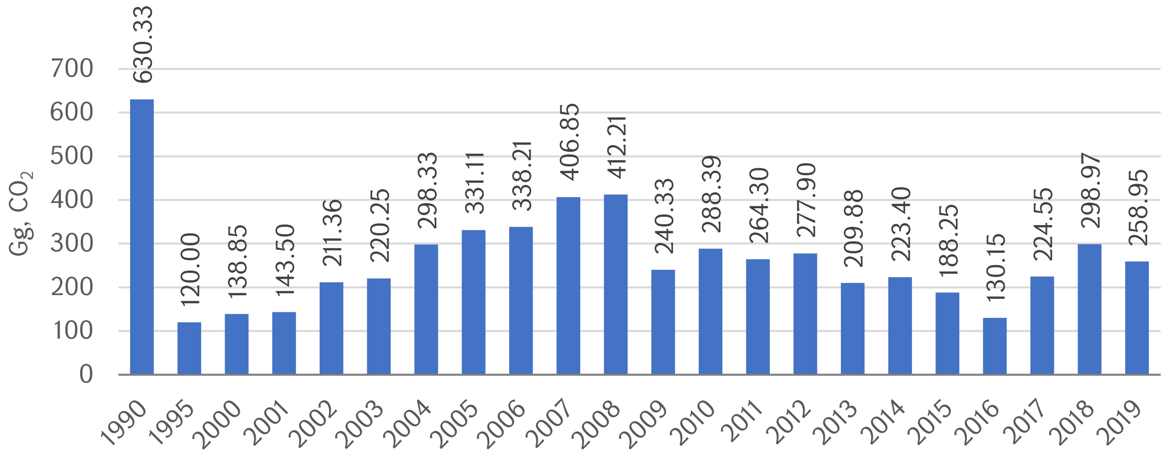


Figure 4.18 CO_2 emissions from cement production, Gg CO_2

CO_2 emissions from cement production are mainly driven by changes in construction volumes. 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, a certain increase in construction volumes and cement production, consequently in emissions was recorded.

In 2018 and 2019 emission growth was observed against the previous 5 years related to the increase in construction volumes. In this view, it is noteworthy that some clinker produced in 2018 was not used for cement production in that year and was instead stored and used for cement production in 2019. As a result, CO_2 emission rates in 2018 were higher than those in 2019, since the emissions are generated just during the period of clinker production.

Compared to 1990, the emission reduction in 2018 and 2019 made 52.6 % and 58.9 %, respectively.

4.2.6 Lime production (2A2)

Lime is produced based on the carbonate-containing raw material through annealing method, as a result of which carbon dioxide emissions are generated.

Calculation methodology

Since there are limited production data, the calculation has been implemented through Tier 1 approach, which is based on applying a default emission factor to national level lime production data [Gen-1, Volume 3, Chapter 2, Equation 2.6]:

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

$CO_2 = EF \times M$,

where:

EF - emission factor for lime production,

EF = 0.75 t CO_2 /1 t lime produced [Gen-1, Vol.3, Chapter 2, Equation 2.8],

M - lime quantity produced in the reporting year:

2018 - 41,813 t,

2019 - 52,786.9 t.

Activity data

The activity data for emissions assessment were provided by the Statistical Committee [Ref-1].

Calculation of carbon dioxide emissions from Lime Production

Hence,

$CO_2 = EF \times M$,

In 2018 - CO_2 = 41,813 x 0.75 = 31,360 t or 31.360 Gg

In 2019 - CO_2 = 52,786.9 x 0.75 = 39,590 t or 39.590 Gg

Table 4.32 Carbon dioxide emissions from lime production, Gg/year

Year	CO_2 emissions from lime production
2018	31.36
2019	39.59

The total carbon dioxide emissions from lime production were 31.36 Gg in 2018 and 39.59 Gg in 2019.

Time series

CO_2 emissions are summarized in Figure 4.19 from the subcategory of *(2A2) Lime Production.*

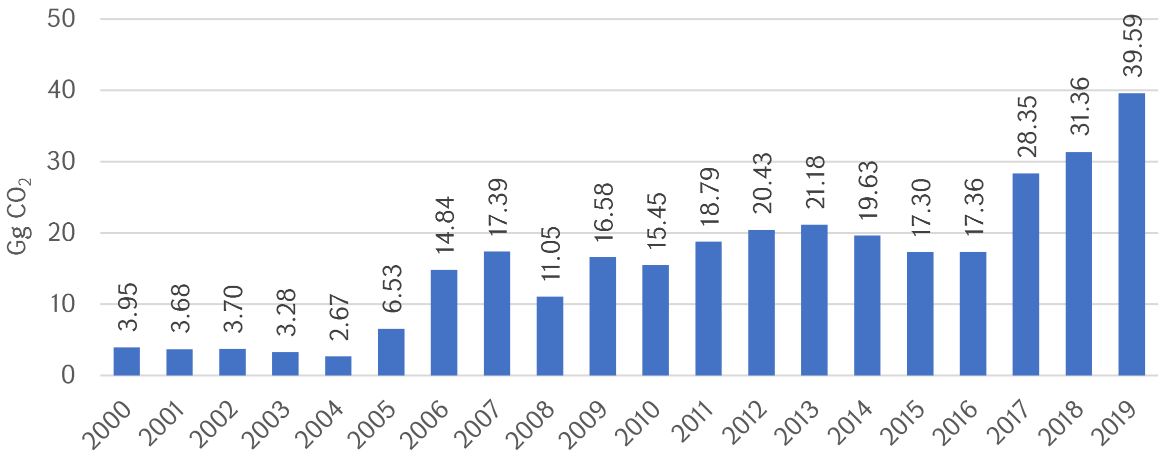


Figure 4.19 CO_2 emissions from lime production, Gg CO_2

The carbon dioxide emissions from lime production demonstrate dynamic growth. In 2019 the highest value of carbon dioxide emissions from lime production was recorded.

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%.

4.2.7 Glass Production (2A3)

Armenia's glass industry produces container glass. Currently there is one glass producer in Armenia. The activity data for emissions assessment were provided directly by the producer company [IndRef-6].

Methodology

During the glass production thermal treatment (melting) of raw materials and also partly that of glass waste/cullet is carried out, which results in the carbonate decomposition in the raw material and carbon dioxide generation.

The CO2 emissions (the main pollutant) are calculated via a Tier 1 method [Gen-1, Volume 3, Chapter 2, Equation 2.10]. During the calculation, guideline's default emission factor and ratio of cullet in the raw mix provided by the producer, are used.

$$CO_2 \text{ emissions} = Mg \cdot EF \cdot (1-CR)$$

where:

CO_2 = emissions of CO_2 from glass production, t

Mg = mass of glass produced, t

EF = default emission factor per the quantity of manufactured glass, t CO_2/t glass

CR = cullet ratio for process (provided by glass producer).

Tier 1 applies a default emission factor based on a 'typical' raw material mixture, to national glass production data, which has the following composition:

- Silicim dioxide - 56.2 weight percent
- Feldspar - 5.3%
- Dolomite - 9.8%
- Limestone - 8.6%
- Soda ash - 20%.

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.

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 in 2018 and 2019 are provided in Table 4.33.

Table 4.33 Indicators required for the calculation of GHG emissions from glass production

Year	Mass of glass produced, t	Cullet ratio in the raw material, %
2018	48,212	30.4
2019	50,529	30.1

CO_2 emissions for 2018-2019 have been calculated using these data:

In 2018 - CO_2 = 48,212 x 0.20 x (1−0.304) = 6,711 t or 6.711 Gg

In 2019 - CO_2 = 50,529 x 0.20 x (1−0.301) = 7,064 t or 7.064 Gg

Table 4.34 Carbon dioxide emissions from the glass production, Gg/year

Year	CO_2 emissions
2018	6.711
2019	7.064

Time series

CO_2 emissions from the sub-category of *(2A3) Glass production* are summed up in Figure 4.20.

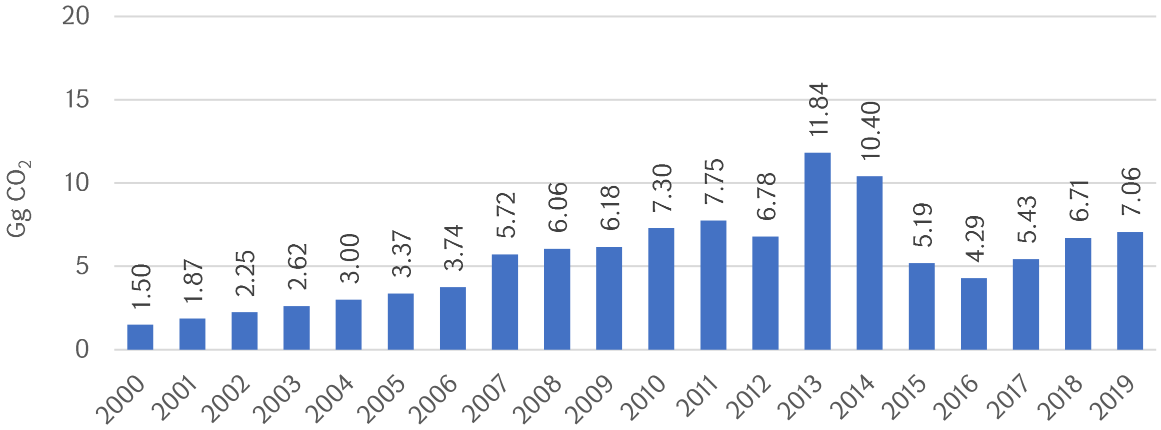


Figure 4.20 CO_2 emissions from glass production, Gg CO_2

The highest values of carbon dioxide emissions from glass production were recorded in 2013 and 2014. The carbon dioxide emissions from glass production make only 4-5 % of those of *(2A) Mineral Industry* sector.

Uncertainty assessment

Calculation of GHG emissions from the glass production was implemented with Tier 1 approach according to the data of the producing organization.

According to 2006 IPCC Guidelines [Gen-1, Volume 3, Chapter 2.4.2.1] uncertainties associated with the use of Tier 1 approach are considerable and related to default emissions factor and cullet ratio, which may be on the order of +/-60%. Nevertheless, the cullet ratio provided by the glass producer was used in the current report, therefore the level of uncertainty is much lower.

CO_2 emissions time series from *(2A) Mineral Industry category*

CO_2 emissions time series from Mineral Industry category are presented in Figure 4.21.

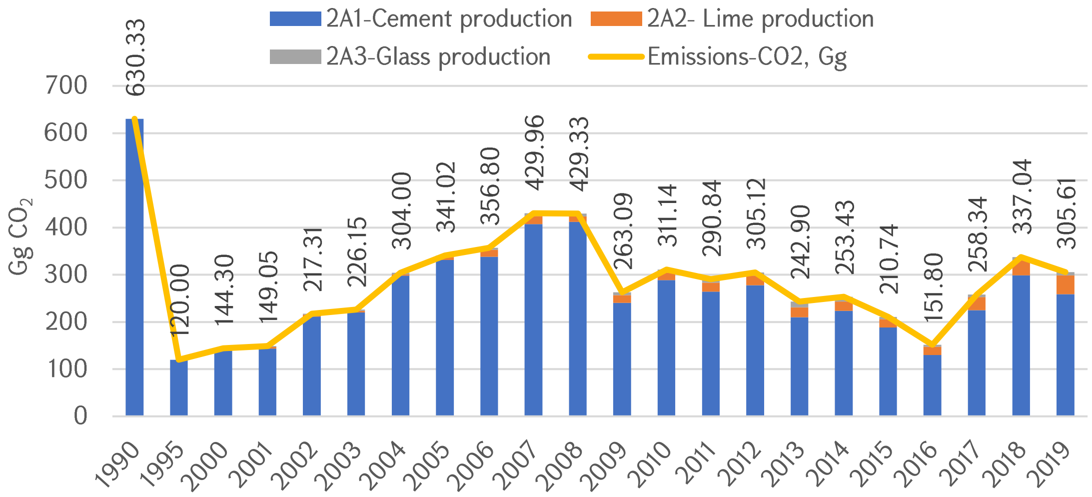


Figure 4.21 CO_2 emissions from mineral industry: cement, lime and glass production, Gg CO_2

4.2.8 Metals production (2C)

4.2.8.1 *Iron and steel production* (2C1) (CO_2 emissions)

For the first time CO_2 emissions from the secondary steel production were included in the report. Steel production in electric induction furnaces is usually carried out on the basis of scrap steel, which is melted by means of carbon electrodes under the influence of electricity. The process-related CO_2 emissions are mainly caused by the consumption of carbon electrodes and the use of carbon additives.

Calculation methodology

Carbon dioxide emissions generated in the steel production were calculated via Tier 1 approach of IPCC 2006 Guideline [Gen-1, Volume 3, Chapter 4] according to the product quantity. The calculations were made with the equation 4.4 recommended in the Guideline [Gen-1, Volume 3, Chapter 4].

Activity data

Activity data for emissions estimation - annual steel ingots - were taken from SC publications [Ref-1].

CO_2 emissions calculation

For calculation 4.4 equation [Gen-1, Volume 3, Chapter 4, Equation 4.4] was applied, in case of which it was considered that steel smelting in the country is performed in electric induction furnaces and hence, the calculation formula will look as follows:

CO_2 *emission* = *EAF* x EF_{EAF}

where:

EAF - quantity of cast steel in electric arc (induction) furnaces, t

EF_{EAF} - assumed emission factor,

EF_{EAF} - *0.08 tCO2/t steel,* which is related to the emissions of steel produced in the electric arc furnaces [Gen-1, Volume 3, Chapter 4, Table 4.1].

In the reporting period 17.458 t (in 2018) and 14.810.2 t (in 2019) steel ingot was produced. Thus:

In 2018 - CO_2 emission = 17,458.0 x 0.08 = 1,397 t or 1.397 Gg

In 2019 - CO_2 emission = 14,810.2 x 0.08 = 1,185 t or 1.185 Gg

Table 4.35 Carbon dioxide emissions from steel production, Gg/year

Year	Annual amount of produced steel, t	CO_2 emissions, Gg
2018წ.	17,458.0	1.397
2019წ.	14,810.2	1.185

Time series

Time series are introduced starting from 2001 due to the lack of official statistical data.

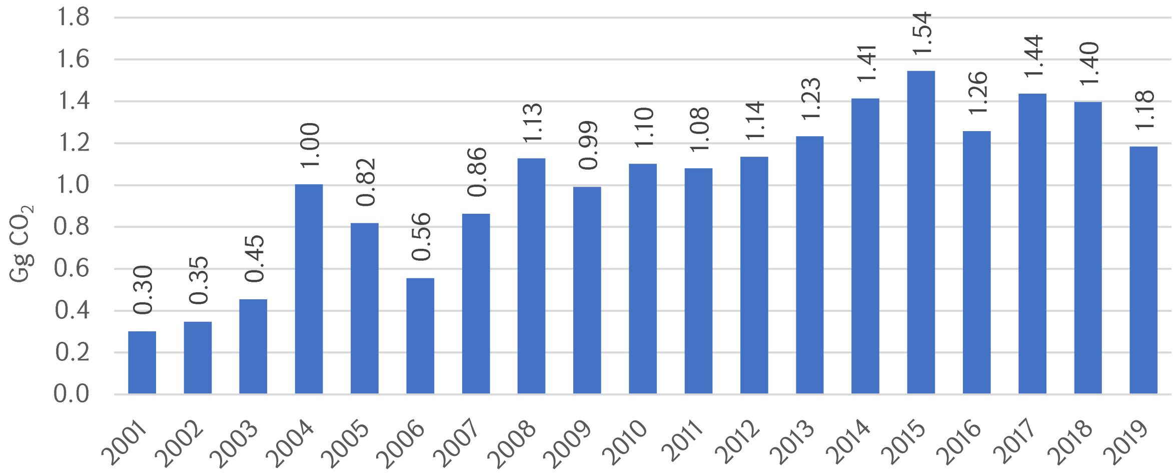


Figure 4.22 CO_2 emissions from the secondary steel production, Gg CO_2

Uncertainty assessment

Uncertainty estimates of GHG emissions (CO_2) from steel production are related to the uncertainties of activity data and default emission factor. In case of applying Tier 1 approach in CO_2 calculation of steel production, the guideline offers the following uncertainty values [Gen-1, Volume 3, Chapter 4, Table 4.4].

Default emission factor	± 25%
National activity data	± 10%

4.2.8.2 Ferromolybdenum Production (2C2) (SO_2 emissions)

As a result of metal mines processing in Armenia, molybdenum concentrate is currently obtained as the main product, which is practically completely used for the extraction of ferromolybdenum.
In the current sector sulfur dioxide emissions (as a gas with indirect greenhouse effect) from the ferromolybdenum production have been assessed.
According to 2006 IPCC Guidelines, emissions of the gases with indirect greenhouse effect should be estimated using the EMEP/EEA Emission Inventory Guidebook, anyhow the latter doesn't provide methodology for estimating emissions from ferromolybdenum production. Thus, in this case indicators of technological procedures, material balance and chemical formulae have been used.

Methodology and calculation of sulfur dioxide emissions

The technological processes of ferromolybdenum and copper production in RA are similar. Sulfur dioxide (SO_2) is produced from melting of molybdenum concentrate.

Calculation of SO_2 emissions was made by the national experts with the formula offered for copper production, since the technology of ferromolybdenum production is similar to that of copper production.

Average value of indicators calculated for each plant in previous years was applied for calculation, based on which the average weighting factor per the estimates of 1.07 t SO_2 1 t produced ferromolybdenum was calculated.

Activity data

The quantity of ferromolybdenum produced were taken from the Statistical Committee Yearbook [Ref-2] and directly from the producing organizations [IndRef-3, IndRef-4, IndRef-5] and it was 7,292 t in 2018, 7,712 t in 2019.

2018 SO_2 = 7,292 x 1.07 = 7,802.4 t = 7.8024 Gg

2019 SO_2 = 7,712 x 1.07 = 8,254.9 t = 8.2549 Gg

Table 4.36 SO_2 emissions from Ferromolybdenum Production, Gg

Year	SO_2 emissions from Ferromolybdenum Production, Gg
2018	7.8024
2019	8.2549

The factors calculated in the above stated way are not dependent on the application of cleaning processes.

The amount of sulfur dioxide emissions from ferromolybdenum production depends on the efficiency of gas cleaning system, however, due to the lack of controllable data on the efficiency of those systems, emission reduction resulting from the work of gas cleaning system has not been considered in the current report.

Time series

Time series are presented from 2002 due to lack of official statistical data.

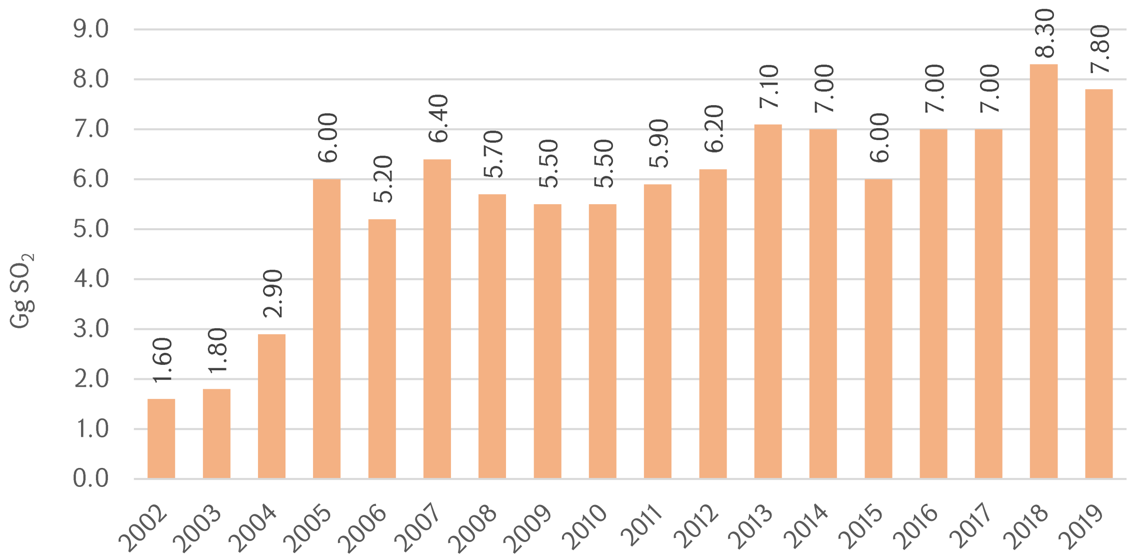


Figure 4.23 SO_2 emissions from Ferromolybdenum Production, Gg

Uncertainty assessment

Uncertainties in the production of ferromolybdenum can be estimated as insignificant.

4.2.8.3 Copper production (2C7)

Activity data

Primary copper in Armenia was produced in one copper smeltery, which has stopped its activity since the 3rd quarter of 2018. Copper concentrate was used as a raw material. As a result of thermal treatment sulfur content bound in the concentrate is fully transformed into sulfur dioxide. During the process some sulfur remains in slag, which is deposited and collected in a special collector.

Previously the data on the concentrate and slag were provided directly by the organization and as it was not possible to get data immediately from the organization for the current inventory, the quantity of the produced copper was taken from the Yearbook of SC [Ref-2] and for 2018 it was 8,831 t, and in 2019 there was not any production.

Methodology

Sulfur dioxide emission was calculated with the mean factor of the last three years derived in the result of the methodology developed by the national experts.

$$ER_{SO2} = Q \times P$$

where:

ER_{SO2} - annual emission of sulfur dioxide, t/year

Q is the quantity of the produced copper, 8,831t

P is the average emission factor, 3.103

Sulfur dioxide emissions calculation

The calculation was made according to the above stated formula:

In 2018 - **8,831 x 3.103 = 27,402.6 t = 27.4 Gg/year**

Uncertainty assessment

As mentioned above, the calculations have been conducted considering the amounts of copper production and the average value of emission factors for the previous three years. Here the main uncertainties can be related to the factor.

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

4.2.9.1 *Lubricant Use* (2D1)

Description of the sub-category

Lubricants are mostly used in industrial and transportation sectors. They can be subdivided into motor oils and industrial oils, and 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.

Activity data

The main data on non-energy product use in the country were taken from the energy balance distributed per the energy and non-energy application purposes [Ref-4].

Methodology

Emissions from the use of lubricants were estimated using the Tier 1 method. Tier 1 method relies on applying one default *Oxidized 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].

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

where:

CO_2 - CO_2 emissions from lubricant use, t

LC – lubricant quantity, TJ

$CC_{lubricant}$ - carbon content of lubricants (default), tonne C/TJ

$ODU_{lubricant}$ - ODU factor

44/12 - CO_2/C molecular weight ratio.

Emission factor

Emission factor is composed of the specific carbon content factor (tons C / TJ) multiplied by the ODU factor. Further multiplication of 44/12 (CO_2 /C mass ratio) gives the emission factor (expressed in tons of CO_2/TJ). Carbon content for lubricants per the Guidelines is 20.0 kg C/GJ for low temperatures [Gen-1, Volume 2, Chapter 1, Table 1.3].

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].

Emissions estimates

For 2018-2019 the carbon dioxide emissions make:

In 2018 - CO_2 = 326.6 TJ x 20 t/TJ x 0.2 x 44/12 = 4,790 t = 4.790 Gg/year

In 2019 - CO_2 = 381 TJ x 20 t/TJ x 0.2 x 44/12 = 5,588 t = 5.588 Gg/year

Time series

CO_2 emissions are summarized in Figure 4.24 from the sub-category of *(2D1) Lubricants Use.*

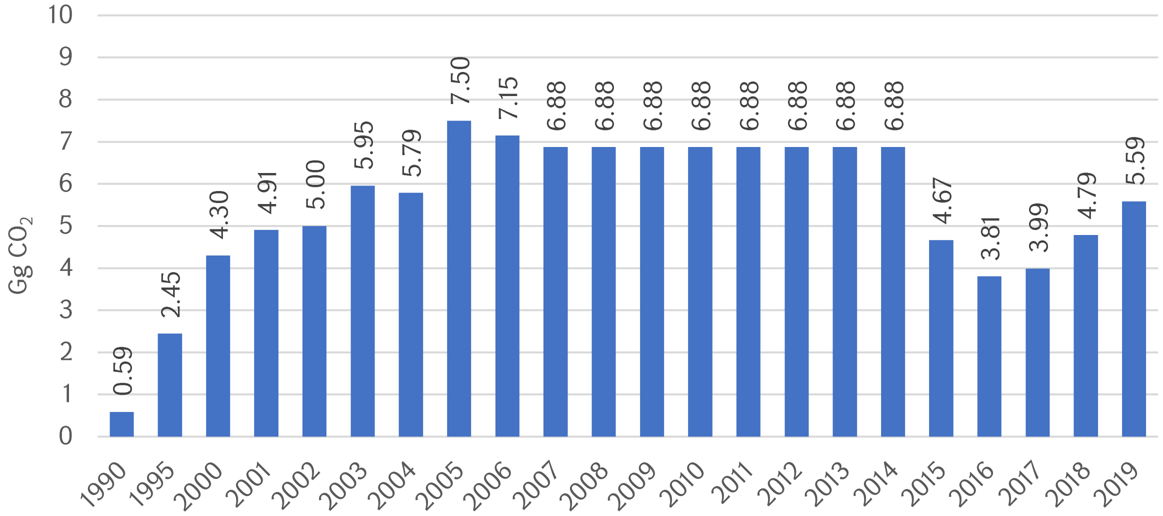


Figure 4.24 CO_2 emissions from the lubricants use, Gg CO_2

The maximum value of carbon dioxide emissions from the (2D1) lubricants use sector was observed in 2005. Compared to 1990, carbon dioxide emissions have increased about 10 times.

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 the country. According to the Guideline, in the presence of accurate energy statistics, the uncertainty is 5%, which was adopted for Armenia, taking into account the existence of the Energy Balance [Gen-1, Volume 3, Chapter 5].

If the quantity of lubricants used in two-stroke engines is unknown (which should be calculated according to the total consumption of that source), the uncertainty of the activity data will increase and become non-objective (biased, too high). In countries where the majority of lubricants are consumed by two-stroke engines, the lower bound of the uncertainty of activity data in this sector will be much higher, as it can be determined through the specific weight/share of consumption by two-stroke engines in the total national consumption.

4.2.9.2 Paraffin Wax Use (2D2)

Description of sub-category

Paraffins are used in many industries. Paraffin waxes are used to make candles, corrugated boxes, paper coating, glue boards, food products, mastics, detergents, etc.

Activity data

Basic data on non-energy products used in the country were taken from the Energy balance [Ref-4].

Methodology

Emissions from the use of paraffin were estimated using the 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].

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

where:

CO_2 - CO_2 emissions from waxes, t

PW - total wax consumption/quantity, TJ

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

$ODU_{paraffin}$ - ODU factor for paraffin wax, fraction

44/12 - mass ratio of CO_2/C molecular weight.

Emission factor

Calculations have been made per Tier 1 methodology. According to the 2006 IPCC Guidelines 20.0 kg C/GJ factor was used [Gen-1, Volume 2, Chapter 1, Table 1.3]. 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 [Gen-1, Volume 3, Chapter 5].

Emissions Estimate

For 2018-2019 carbon dioxide emissions make:

In 2018 - CO_2 = 8.4 TJ x 20t/TJ x 0.2 x 44/12 = 123 t = 0.123 Gg/year

In 2019 - CO_2 = 8.4 TJ x 20t/TJ x 0.2 x 44/12 = 123 t = 0.123 Gg/year

Time series

In Figure 4.25 CO_2 emissions from the sub-category (*2D2) Praffin Wax Use* are summarized.

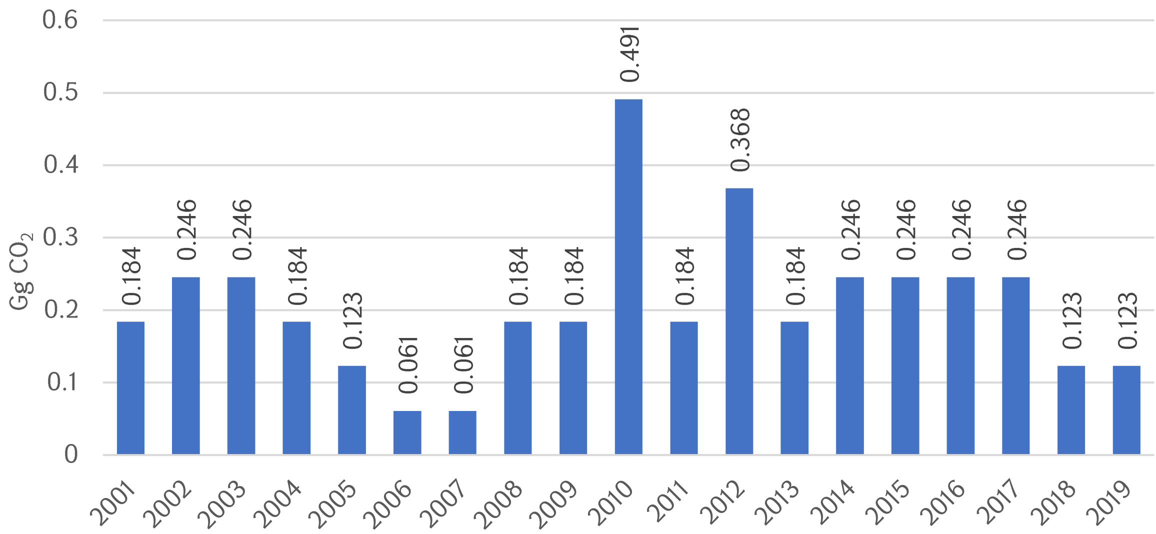


Figure 4.25 CO_2 emissions from Paraffin Wax Use, Gg CO_2

Uncertainty assessment

Emission Factor Uncertainties

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

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].

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 [Gen-1, Volume 3, Chapter 5].

4.2.9.3 Solvent Use (2D3)

NMVOCs are produced during the use of solvents. Currently, there is no methodology provided by IPCC for calculation of GHG emissions with indirect effect caused by the solvents use. That is why methodologies for estimating these NMVOC emissions recommended in the EMEP/CORINAIR Emission Inventory Guidebook (EEA, 2016) were used [Gen-2].

Domestic Solvent Use

NMVOC emissions from the domestic use of solvents have been calculated using the factor introduced in the methodology of EMEP/EEA 2019 (1.2 kg per Capita) [Gen-2]. Time series have been recalculated.

NMVOC emissions from the domestic use of solvents made 3.57 Gg in 2018, and in 2019 - 3.56 Gg.

Time series

Time series of NMVOC emissions from the sub-category of *(2D3a) Solvents use* have been recalculated. The NMVOC emissions from the sub-category of *(2D3a) Solvents use* are summarized in Figure 4.26.

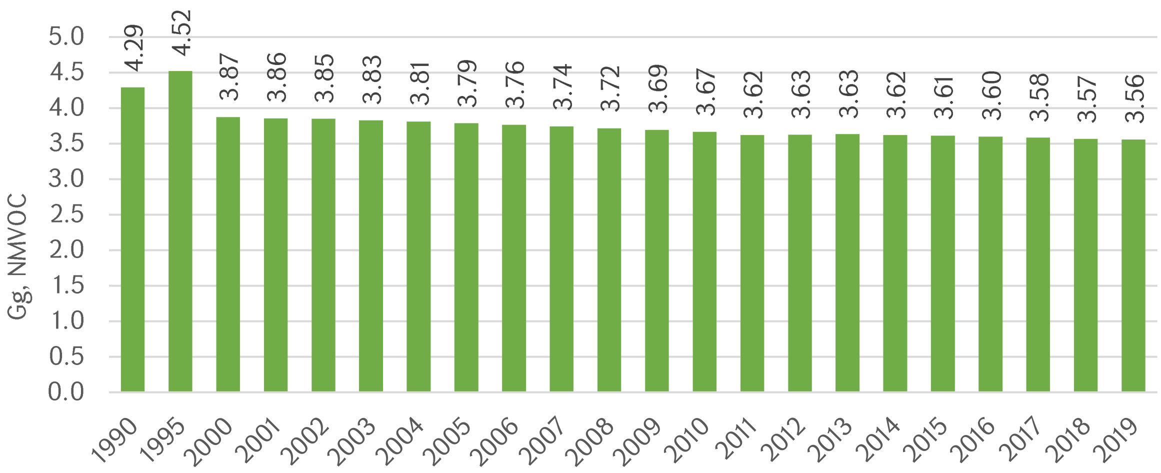


Figure 4.26 NMVOC emissions from the domestic use of solvents, Gg

Paint application

Calculations for NMVOC emissions 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 RA SC [Ref-2, Ref-3].

NMVOC emissions from paint use made 4.76 Gg in 2018 and 5.63 Gg in 2019.

Time series

The time series are introduced starting from 2000 due to lack of official statistical data.

NMVOC emissions from the source category of *(2D3d) Paint application* are summarized in Figure 4.27.

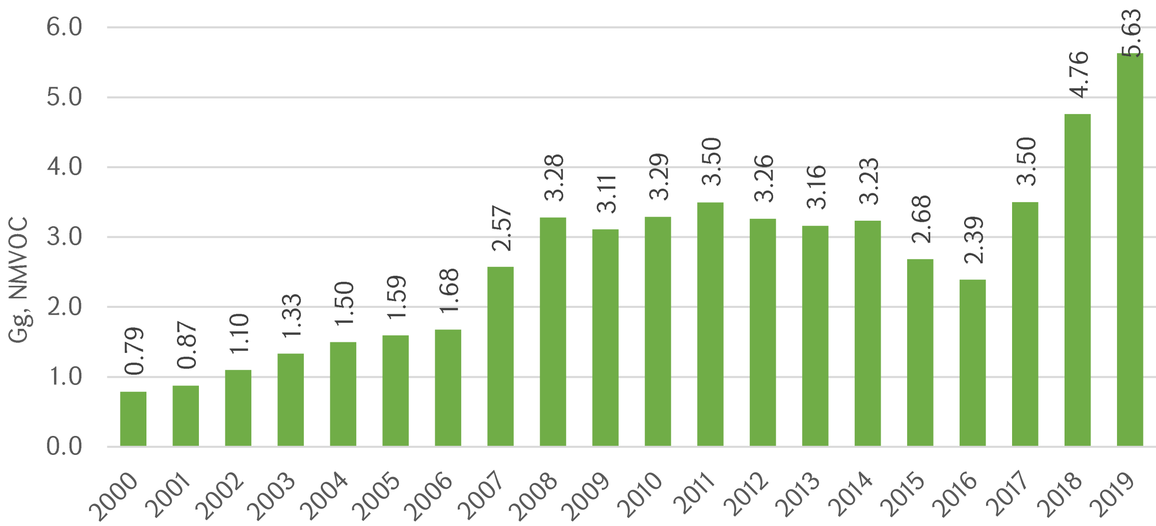


Figure 4.27 NMVOC emissions from paint application, Gg

The maximum emission value of non-methane volatile organic compounds from the paint application (2D3) category was observed in 2019, which is 7.1 times higher than 2000.

4.2.9.4 Asphalt Covering (2D4)

Description of the Sub-Category

During the preparation of asphalt mix bitumen is melted and asphalt mix is prepared, which is transported in a hot state to the site of constructed or repaired road and spread along the mentioned road. Throughout this process NMVOC emissions are generated.

Methodological issues

The emission factors for NMVOCs provided in EMEP/EEA Air Pollutant Emission Inventory Guidebook [Gen-2] were used.

The bitumen volumes are taken from the publication of SC [Ref-3].

The calculation was made applying Tier 1 Approach (Tier 1).

$E_{pollutant} = AR_{production} \times EF_{pollutant}$

where:

$E_{pollutant}$ is 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 (EMEP/EEA) [Gen-2].

Bitumen content in the asphalt mix has been identified. According to GOST 9128-2013 appendix G (Г), the content of bitumen in the asphalt mix makes maximum 9 %.

Thus:

In 2018 - $AR_{production}$ = 11 x 39,552 = 435,067 t

In 2019 - $AR_{production}$ = 11 x 63,276 = 696,035 t

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

Table 4.37 NMVOCs emissions from the Use of Bitumen, Gg/t

Year	Quantity of bitumen, t	Quantity of asphalt mix, t	NMVOCs emission, Gg
2018	39,552	435,067	0.0070
2019	63,276	696,035	0.0111

Time series

The time series of NMVOC emissions from the sub-category of *(2D4) Asphalt Covering* has been recalculated.

NMVOC emissions from the sub-category *(2D4) Asphalt Covering* are summarized in Figure 4.28.

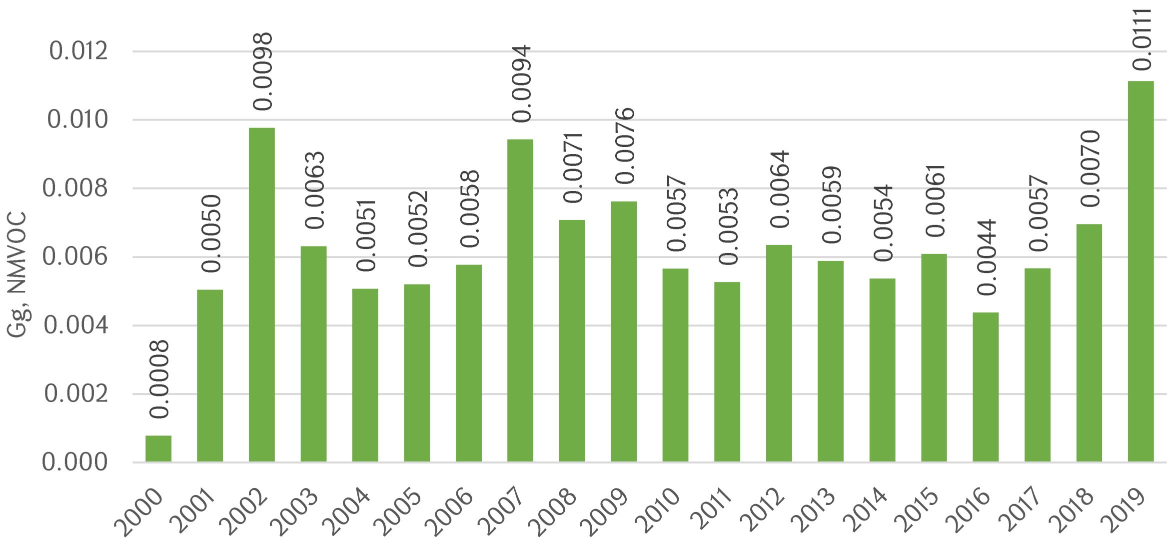


Figure 4.28 NMVOC emissions from the asphalt covering, Gg

4.2.9.5 Food and Beverages (2H2)

Description of Source Category

Non-methane volatile organic compounds are emitted in fermentation processes when processing cereals and fruits, as well as when producing meat, bread and pastry.

The calculations have been made using Tier 2 approach [Gen-2] given in the Guidebook of Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe and European Environment Agency (EMEP/EEA) through the following formula considering the technological peculiarities:

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant}$$

where:

$E_{pollutant}$ – NMVOC emissions

$AR_{production,technology}$ – product quantity per type

$EF_{technology,pollutant}$ – emission factor for the specific technology.

Calculation of NMVOCs emissions

Production data for calculation were taken from the Yearbooks of the SC [Ref-2]. Due to the changes in the statistical data formats, the quantity of confectionery in 2019 was calculated by the aggregation of cakes, pastry, biscuits, honey-cakes and other similar products.

Emission factors provided in Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe and the European Environment Agency (EMEP/EEA, 2019) Guidebook was used [Gen-2].

The values of factors are given below.

Table 4.38 Food and beverage production. NMVOC emissions factors

Product type	Measuring unit	Emission factor
Meat	kg/t	0.3
Bread	kg/t	4.5
Confectionery	kg/t	1
Wine	kg/100l	0.08
Beer	kg/100l	0.035
Liqueur-Vodka	kg/100l	15
Cognac	kg/100l	3.5
Whiskey	**kg/100l**	7.5

Table 4.39 Food and beverage production. Product quantity

Product type	Measuring unit	Product quantity	
		2018	2019
Meat	t	86900	84000
Bread	t	263000	270000
Confectionery	t	23324	15212
Wine	100l	96720	127500
Beer	100l	235710	262580
Liqueur-Vodka	100l	50090	60640
Cognac	100l	308260	433040
Whiskey	100l	8060	7130

Time series

Time series of NMVOC emissions from the source category of *(2H2) Food and Beverages* has been recalculated.

NMVOC emissions from the sub-category of *(2H2) Food and Beverages* are summarized in Figure 4.29.

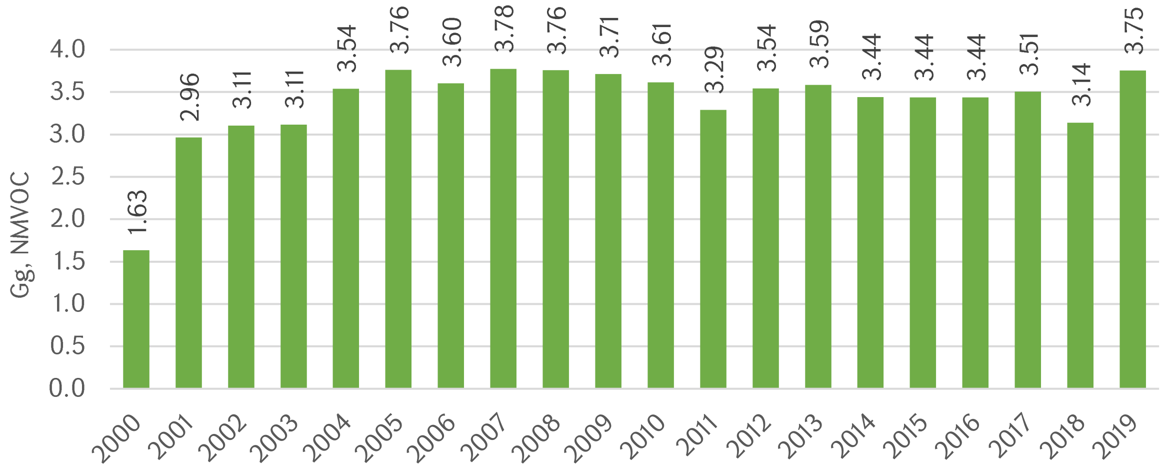


Figure 4.29 NMVOC emissions from Food and beverage source category, Gg

Quality assurance and quality control

At the initial stage of calculations, the reliability of activity data was checked.

During the calculations, the values of main calculation parameters were determined, as well as the quality of estimated results was checked.

The technological processes of production enterprises were examined. For the selection of appropriate methodologies, as well as for data quality control the production enterprises were directly requested.

Calculations were also conducted with the Excel program and compared with the results of IPCC software computations.

If required, the time series were recalculated to ensure comparability.

Table 4.40 Time series of GHG emissions for IPPU sector, Gg CO_2

Categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
2.A - Mineral Industry	**630.33**	**120.00**	**144.30**	**341.02**	**311.14**	**210.74**	**151.80**	**258.34**	**337.04**	**305.61**
2.A.1 – Cement Production	630.33	120.00	138.85	331.11	288.39	188.25	130.15	224.55	298.97	258.95
2.A.2 – Lime production			3.95	6.53	15.45	17.30	17.36	28.35	31.36	39.59
2.A.3 – Glass Production			1.498	3.370	7.302	5.195	4.291	5.433	6.711	7.064
2.C – Metal Industry				**0.82**	**1.10**	**1.54**	**1.26**	**1.44**	**1.40**	**1.18**
2.C.1 - Steel Production				0.82	1.10	1.54	1.26	1.44	1.40	1.18
2.D – Non-Energy Production Fuel and Solvent Use	**0.835**	**2.692**	**4.549**	**7.748**	**7.122**	**4.913**	**4.053**	**4.237**	**4.913**	**5.711**
2.D.1 – Use of Lubricants	0.589	2.446	4.303	7.502	6.876	4.667	3.807	3.991	4.790	5.588
2.D.2 – Use of Solid Paraffin	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.246	0.123	0.123
Total	**631.16**	**122.69**	**148.85**	**349.58**	**319.37**	**217.20**	**157.11**	**264.01**	**343.35**	**312.50**

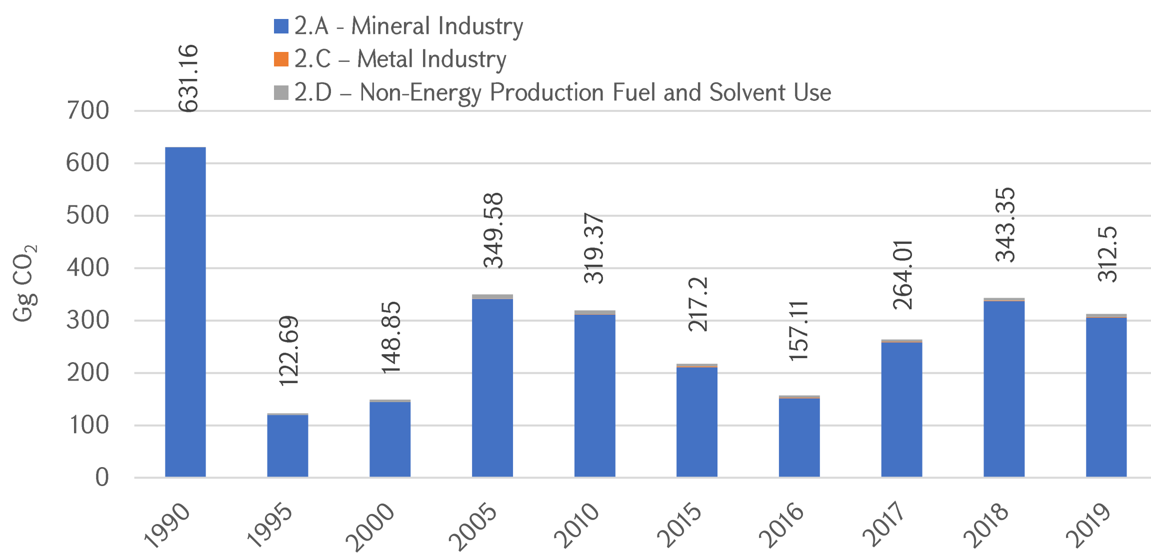


Figure 4.30 Time series of CO_2 emissions, Gg CO_2

Table 4.41 Time series of indirect greenhouse gas (NMVOC) emissions in IPPU sector, Gg

Categories	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2.D.3.a - Domestic use of solvents	3.85	3.83	3.81	3.79	3.76	3.74	3.72	3.69	3.67	3.62	3.63	3.63	3.62	3.61	3.60	3.58	3.57	3.56
2.D.3.d - Use of paints	1.10	1.33	1.50	1.59	1.68	2.57	3.28	3.11	3.29	3.50	3.26	3.16	3.23	2.68	2.39	3.50	4.76	5.63
2.D.4 - Asphalt Production and Use	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
2.H.2 – Food and Beverage Industry	3.11	3.11	3.54	3.76	3.60	3.78	3.76	3.71	3.61	3.29	3.54	3.59	3.44	3.44	3.44	3.51	3.14	3.75
NMVOC emissions	**8.07**	**8.28**	**8.85**	**9.15**	**9.05**	**10.10**	**10.76**	**10.52**	**10.58**	**10.42**	**10.44**	**10.38**	**10.30**	**9.74**	**9.43**	**10.60**	**11.47**	**12.95**

Table 4.42 Time series of SO_2 emissions in IPPU sector, Gg

Categories	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2.C.2 - Production of Ferroalloys	1.60	1.80	2.90	6.00	5.20	6.40	5.70	5.50	5.50	5.90	6.20	7.10	7.00	6.00	7.00	7.00	7.80	8.30
2.C.7 - Primary Copper Production	0.00	0.00	0.00	0.00	26.86	21.25	19.80	20.95	23.35	28.96	29.13	31.18	31.40	35.24	36.88	41.32	27.40	0.00
SO_2 emissions	**1.60**	**1.80**	**2.90**	**6.00**	**32.06**	**27.65**	**25.50**	**26.45**	**28.85**	**34.86**	**35.33**	**38.28**	**38.40**	**41.24**	**43.88**	**48.32**	**35.20**	**8.30**

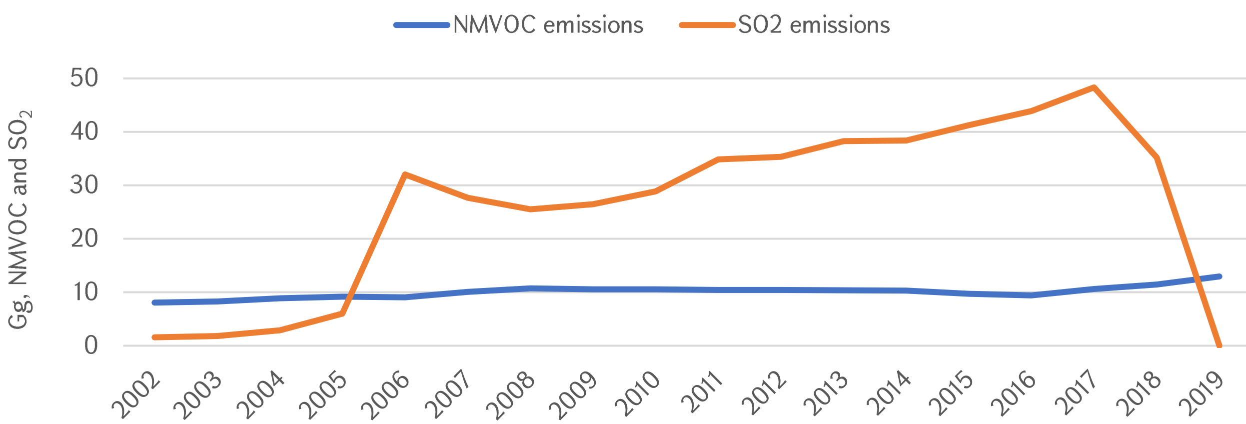


Figure 4.31 Time series of NMVOC and SO_2 emissions, Gg

Drastic reduction of SO_2 emissions in 2019 is related to the absence of copper production.

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

4.2.10.1 Overview of emissions assessment

In the sector of Industrial processes F-gases form a special category. Among the latter Hydrofluorocarbons (HFCs) are widespread in Armenia. Perfluorocarbons (PFCs) are not used in the country. Information on SF6 emissions is introduced in the relevant sector.

In Armenia, as well as globally, Hydrofluorocarbons (HFCs) are used as alternatives to ozone depleting substances (ODS) - CFCs and HCFCs - which are being phased out under the Montreal Protocol. Ratifying the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer, Armenia is committed to gradually refuse the use of ozone depleting substances.

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 starting from 2024.

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 imports 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.

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 2019 HFCs emissions made 9 % of the country’s total emissions and over 75 % of those of “Industrial Processes and Product Use” sector. The prevailing part of the total HFC emissions is caused by refrigerating and air conditioning systems, which made over 95.7 % in 2019. The share of emissions from other applications was totally 4.3 %: from Foam Blowing Agents – 3 %, Aerosols – 1.2 %, while the emissions from Fire Protection Application was negligible – only 0.1 % of the total HFC emissions.

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 4.43 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 Applications of Substitutes for Ozone Depleting Substances (F-gases) in Armenia

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 reliable data. The data on the solvents, received from the national customs service are of a general character and include no information on the content of HFCs in solvents.

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

4.2.10.3 Key source categories

The refrigeration and air conditioning category is the main source of emissions according to level and trend assessment.

4.2.10.4 Refrigeration and Air Conditioning (2F1)

Description of Application Area

RAC is a key source category in Armenia accounting for 95.6% of total emissions in Product Uses as Substitutes for Ozone Depleting Substances category in 2019, 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 an emission factor from the mentioned 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 in the t reporting year

$E_{charge,t}$ = emissions of refrigerant due to the charging process of new or already functioning equipment in t reporting year

$E_{lifetime,t}$ = 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

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

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

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, Equation 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, Equation 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 represents fugitive emissions, i.e., leaks from fittings, joints, shaft seals.

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

where:

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

Bt = 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 (decommissioning)

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 mainly from 2004, while lifetime of such equipment is estimated to be at least 15-20 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 [IndF.Ref-1] and import years have been received from the RA State Revenue Committee (SRC) in response to the official inquiry of the RA Ministry of Environment.

Quality control

Customs codes of the local customs (CIS) system sometimes indicate a 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.

Surveys were conducted among the chemicals' importers and retailers, well-experienced specialists working in the area, as well as end-users.

The data provided by the RA SRC on the amount of the refrigerants imported into the country as individual chemicals were cross-checked through the data published by the RA SC [Ref-5].

The SRC data on the container refrigerant amounts imported to the country were 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 number 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

According to the expert judgment 80% of the all refrigeration equipment imported into Armenia in 2019 are domestic refrigerators, 52.5% of which are based on HC-600a and 47.5% - on HFC-134a. The average amount of the refrigerant contained in each domestic refrigerator was estimated by expert judgment 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 2019, 82,118 units of refrigeration equipment were imported into Armenia in total, 80 % of which or 65.694 units are domestic refrigerators of which only 47.5 % or 31.205 units are charged with HFC-134a. Therefore, the amount of R-134a contained in the domestic refrigerators imported into Armenia in 2019 counts as follows: 31,205 x 0.120 = 3,744.6 kg.

Bt = total quantity of refrigerants in the equipment existing in the country as of t reporting year, which was calculated based on the total quantity of domestic refrigerators imported in Armenia in 2000-2019 and is equal to 70.133 kg,

x = the average annual emission factor during the operation of the equipment, including the maintenance, which was estimated 2 %, due to improper handling and maintenance of the equipment.

$E_{lifetime,t}$ = 1,402.7 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 = 1,402.7 kg

Thus:

$E_{containers,t}$ = 140.3 kg

Finally:

$E_{total,t} = E_{containers,t} + E_{lifetime,t}$ = 140.3 + 1,402.7 = 1,543 kg.

Stand-alone commercial refrigerators

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 refrigerants. The average refrigerant charge of each equipment was estimated to be 1 kg.

B_t = was estimated based on the amount of commercial refrigeration equipment imported in Armenia in the period of 2000-2019 and makes 182,640 kg.

x = average emissions factor during the operation of the equipment, including the maintenance and was estimated as 15 % [Gen-1, Volume 3, Table 7.9] $E_{lifetime,t}$ = 27,396 kg In this sub-application $RM_t = E_{lifetime,t}$ = 27,396 kg

Thus:

$E_{containers,t}$ = 2,739.6 kg

Finally:

$E_{total,t} = E_{containers,t} + E_{lifetime,t}$ = 30,135.6 kg

50% or 15,067.8 kg of emissions calculated for this sub-application fall to share of R-134a, and the other 50 % or 15.067.8 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 SRC, in 2019 in total 82,118 units of refrigeration equipment were imported into Armenia, of which 2% or 1,642 units were large and medium-sized commercial and industrial refrigeration equipment. Therefore, in 2019 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 1,642 * 15 = 24,630 kg of which 20% or 4,926 kg was R-134a and the remaining 80% or 19,704 kg 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 2000-2019 and makes 286,783.9 kg.

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

$E_{lifetime,t}$ = 100,374.4 kg

$E_{Charge,t}$ = emissions related to the new or existing equipment refrigerant charge in year t

$E_{Charge,t}$ = Mt * 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 24.630 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:

$E_{Charge,t}$ = 738.9 kg

RM_t = in this case, since the equipment are charged after installation, sum of total HFC charged in the new large and mid-sized commercial and industrial equipment installed in t year and the emissions from the refrigerant bank (total amount) during the operation of old and new equipment in the reporting year, i.e.:

$RM_t = M_t + E_{lifetime,t}$ = 24,630 + 100,374.4 = 125,004.4 kg

$E_{containers,t}$ = 12,500.4 kg

Finally:

$E_{total,t} = E_{containers,t} + E_{Charge,t} + E_{lifetime,t}$ = 113,613.7 kg

20% or 22,722.7 kg of emissions from this subapplication accounts for R-134a and the remaining 80% or 90,891 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 2019, 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 judgment to be 3 kg.

As per the data provided by the SRC, in total 59,088 units of air-conditioning equipment were imported in Armenia in 2019. Therefore, the air-conditioning equipment imported in 2019 contained 59,088 * 3 = 177,264 kg HFCs.

B_t = estimated based on the amount of air-conditioning equipment imported into Armenia in 2000-2019 and equals to 866,161.4 kg.

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

$E_{lifetime,t}$ = 173,232.3 kg

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

$E_{containers,t}$ = 17,323.2 kg

Finally:

$E_{total,t}$ = 190,555.5 kg

For this sub-application 20% or 38,111.1 kg of all the emissions account for R-134a, 30% or 57,166.7 kg for blend R-407C (HFC-32 - 23% / HFC-125 - 25% / HFC-134a - 52%) and 50% or 95,277.7 kg for blend HFC-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 SRC, 7,786 trucks were imported into Armenia in 2019. 5% or 389 units of which are fitted with refrigeration equipment: thus, the total amount of HFCs contained in transport refrigeration equipment makes 389 * 7 = 2,723 kg.

B_t = estimated based on the amount of transport refrigeration equipment imported into Armenia in 2000-2019 and equals to 20,926.7 kg.

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

$E_{lifetime,t}$ = 10,463.3 kg

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

$E_{containers,t}$ = 10,46.3 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 trucks imported in year t by the year of manufacture is not available. Instead, 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:

$E_{end-of-life,t}$ = 2092.7 kg

Finally:

$E_{total,t}$ = 13602.3 kg.

50% or 6,801.15 kg of the total emissions from this sub-application fall on R-134a and the other 50% or 6,801.15 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 and trucks 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 2019 86,617 cars and trucks were imported into Armenia, 80 % or 77,294 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 2019 made: 77,294 * 0.9 = 69,564.6 kg.

B_t= estimated based on the number of mobile air-conditioners imported into Armenia in 2000-2019 and equals to 381,636.9 kg.

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

$E_{lifetime,t}$ = 76,327.4 kg

RM_t = $E_{lifetime,t}$, thus:

$E_{containers,t}$ = 7,632.7 kg

$E_{end\text{-}of\text{-}life,t}$ = is the total amount of refrigerant emitted into the atmosphere as a result of phasing out the equipment in the t year; for this sub-application it can't be estimated using Equation 7.14, as data on the passenger cars, truck cabins and buses imported in year t by the year of manufacture is not available. Instead, 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:

$E_{end\text{-}of\text{-}life,t}$ = 19,081.8 kg

Finally:

$E_{total,t}$ = 103,041.9 kg

Data Entry into the IPCC Software

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

It should be mentioned that for Refrigeration and Air Conditioning application area the Software allows to enter data only for 2 sub-applications, namely:

- (2.F1.a) Refrigeration and Stationary Air Conditioning,
- (2.F1.b) Mobile Air Conditioning.

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 average factors have been estimated on the following principle: 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 sub-application (2F1a)	
HFC-134a	0.21
HFC-32	0.22
HFC-125	0.26
HFC-143a	0.34
Mobile Air Conditioning sub-application (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, which might differ from the country-specific ones. Thus, the average uncertainty of the emission factors was estimated as 25%.

Time series

HFCs emissions from the RAC application are provided in Figure 4.32.

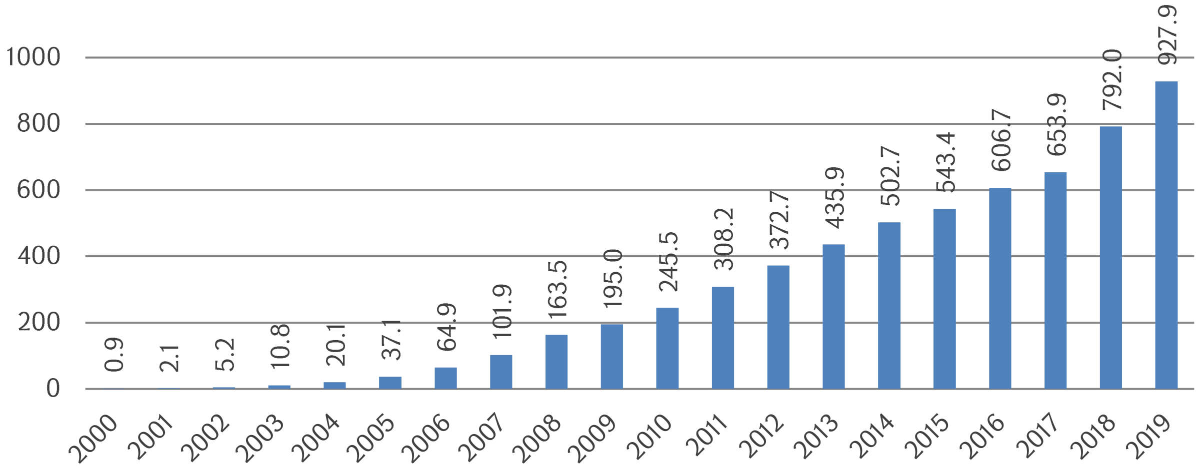


Figure 4.32 HFCs emissions time series from the RAC application, Gg $CO_{2\ eq.}$, 2000-2019

As it comes from Figure 4.32, the emissions from RAC application have grown continuously and markedly - in the period from 2006 to 2019 they increased more than 14 times. 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.

In 2018 and 2019, the sharp increase of emissions from the RAC application is related to the abrupt increase in the import of refrigeration equipment into Armenia.

4.2.10.5 Foam Blowing Agents (2F2)

Application Area Description

This application area accounts for nearly 3% of HFC total emissions of 2019. HFCs are used in foam blowing as foam blowing agents. This application is the second with its share of HFC emissions in the country.

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 finished polyol and foam products.

Methodology

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

Emissions from Foam Blowing Agents application were estimated based on the approach provided in Moldova's ODS Alternative Survey Report of 2016 [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 SRC.

Emissions Estimate

Emissions from the rigid/closed-cell foam in the sector of foam application have been calculated according to the Guideline Equation 7.7 [Gen-1, Volume 3, Chapter 7.4].

$$Emissions_t = M_t \cdot EFFYL + Bank_t \cdot EFAL + DL_t - RD_t.$$

The amount of imported closed-cell foam in the reporting year was estimated being derived from the data provided by the RA SRC and then, 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 [Ref-5; IndF.Ref-1].

Considering that only imported finished product was calculated, only one emission factor has been used. 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%.

Emissions time series

HFC emissions from the *Foam Blowing* are provided in the Figure 4.33.

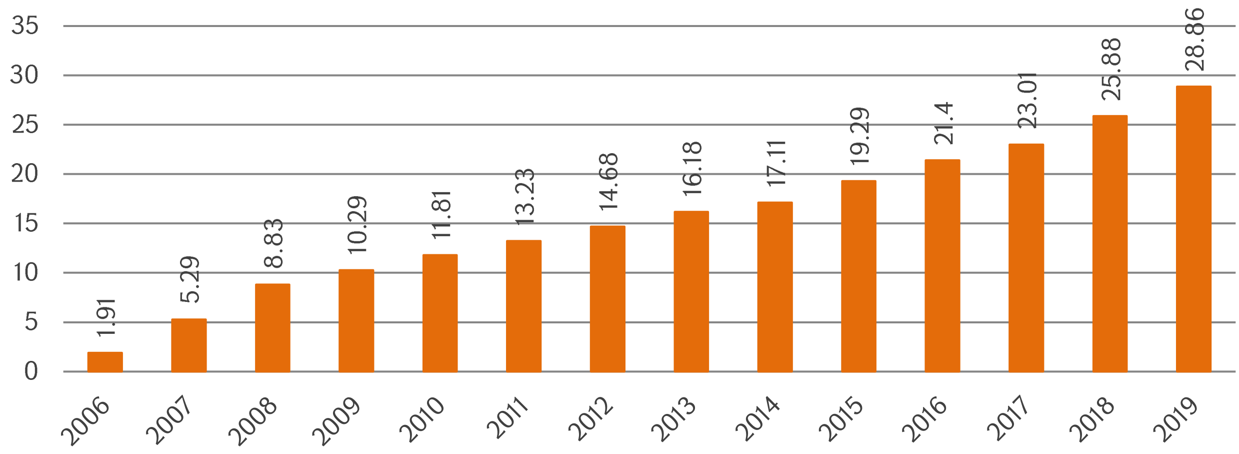


Figure 4.33 HFCs emissions time series from the Foam blowing, Gg $CO_{2\ eq.}$, 2006-2019

As it can be seen from Figure 4.33, 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.*

4.2.10.6 Fire Protection (2F3)

Application Area Description

HFC emissions caused within this application are insignificant and account for 0.1% of HFCs total emissions in 2019. 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].

RRL_t = 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 area were estimated based on the data published by the Statistical 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 4.34.

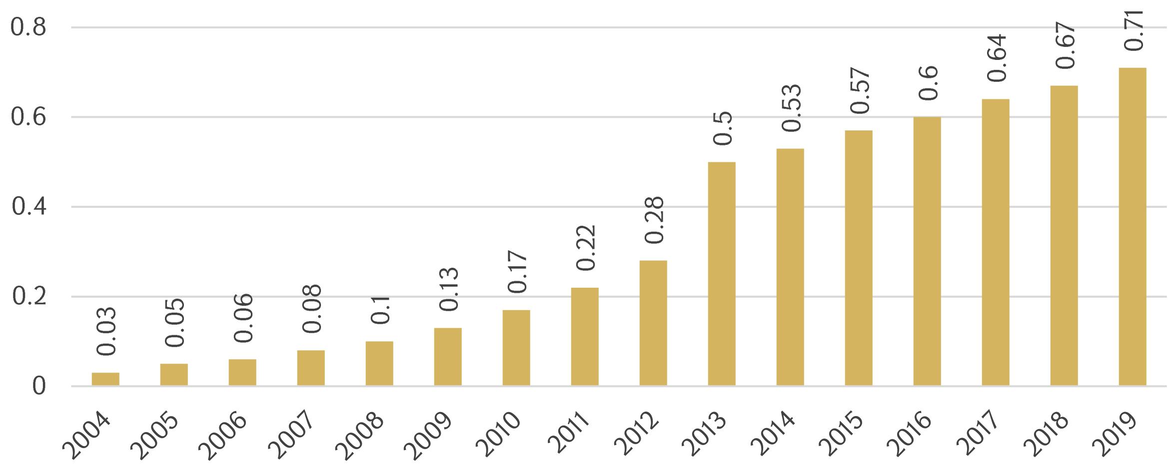


Figure 4.34 HFCs emissions time series from the Fire Protection, Gg $CO_{2\ eq.}$, 2004-2019

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.

4.2.10.7 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), 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 1.3% of total HFC emissions recorded in 2019.

The surveys 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. The latter substitute not only CFC-12 formerly used in this sector but also CFC-11, and sometimes CFC-114.

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].

$$Emissions_t = S_t \bullet EF + S_t{-}1 \bullet (1 - EF)$$

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

Since the emissions for ths application area were estimated through Tier 1a level, a default emission factor of 50 percent of the initial charge per year for aerosolol prducts was used (0.5) [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 SRC [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* sector was estimated to be 30%.

Emissions time series

HFCs emissions from the *Aerosols* are provided in the Figure 4.35.

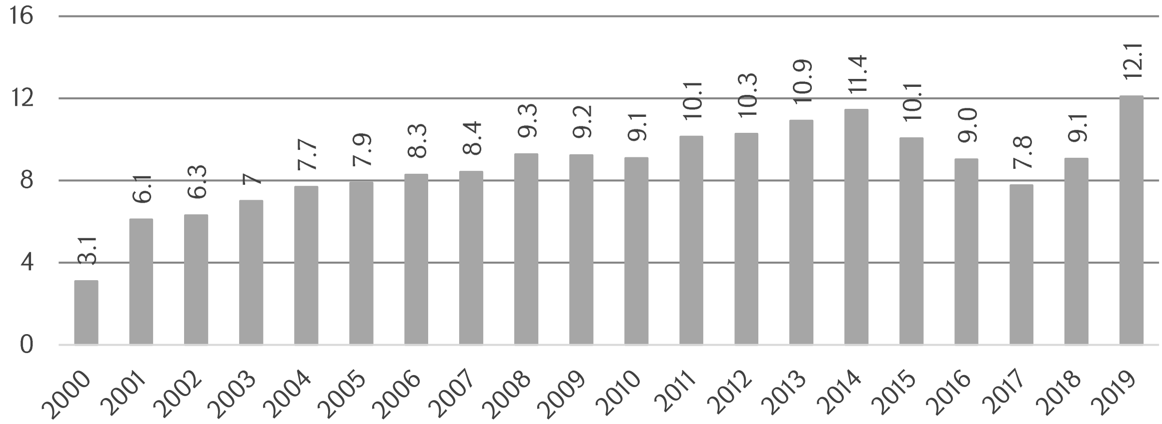


Figure 4.35 HFCs emissions from the Aerosols, Gg $CO_{2\ eq.}$, 2000-2019

4.2.10.8 Emissions assessment results, time series by applications and chemicals

Table 4.44 and Figure 4.36 provide HFC emissions by applications.

Table 4.44 HFCs emissions by application areas, Gg $CO_{2\ eq.}$, 2000-2019

Year	Refrigeration and Air Conditioning	Aerosols	Foam Blowing Agents	Fire Protection	Total
2000	0.89	3.06	0	0	3.95
2001	2.1	6.12	0	0	8.22
2002	5.15	6.26	0	0	11.41
2003	10.82	7.04	0	0	17.86
2004	20.13	7.66	0	0.035	27.82
2005	37.13	7.91	0	0.045	45.08
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
2018	792.00	9.47	25.88	0.67	828.02
2019	927.87	12.1	28.86	0.71	969.53

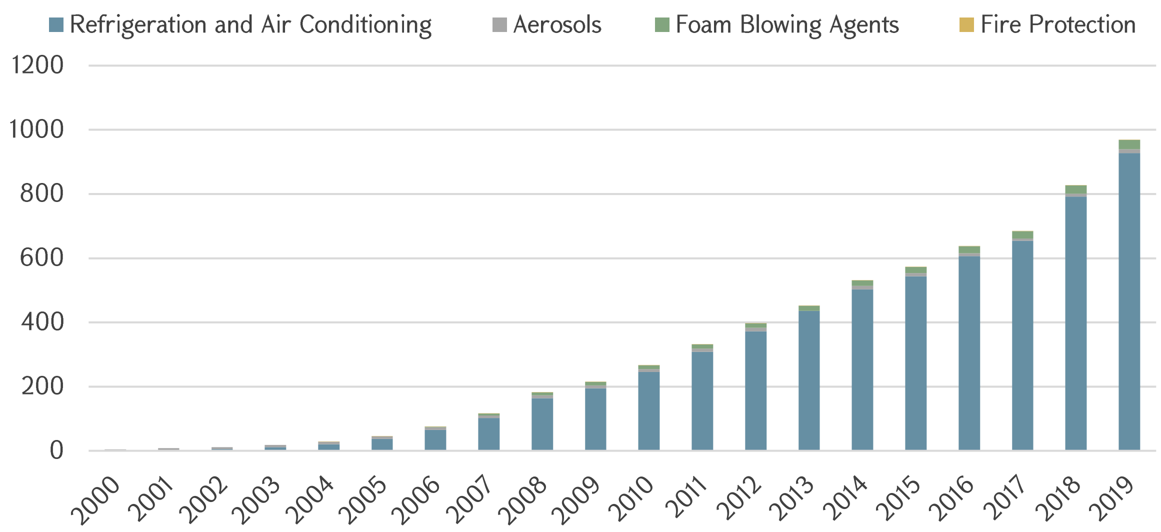


Figure 4.36 HFCs emissions by applications, Gg $CO_{2\ eq.}$, 2000-2019

As it can be seen from Figure 4.36, 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 drastic increase of RAC emissions in 2018 and 2019 is related to the abrupt growth in the quantity of imported refrigeration equipment into Armenia.

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 same is true 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.

As seen in the Table 4.49, for Armenia, as well as for many other countries RAC is a key category in terms of emission of HFCs as ODS substitutes. It accounts for 95.7 % of total HFCs emissions for 2019, followed by *Foam Blowing Agents* with the share of 3%. *Aerosols* and *Fire Protection* accounted for 1.3 % and 0.1 % of the total HFCs emissions, respectively (Figure 4.37).

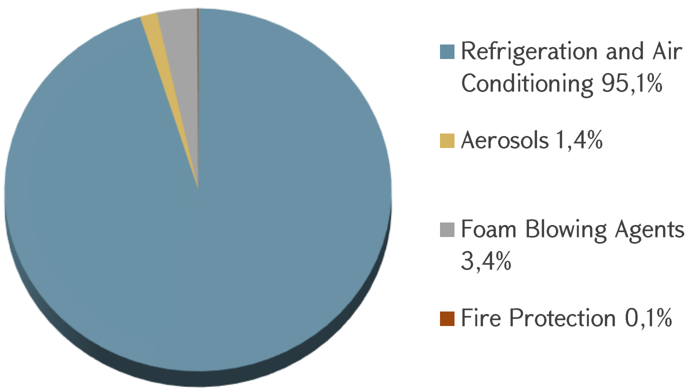


Figure 4.37 HFCs total emissions distribution by application areas, Gg $CO_{2\ eq.}$, 2019

HFC-134a is the most widely used HFC. As already mentioned above, it is due to its mutiprofile 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 contained in *Aerosols* as a propellant and as a blowing agent in *Foam Blowing Agents.*
Distribution of total HFC emissions of 2019 by chemicals is introduced in Figure 4.38.

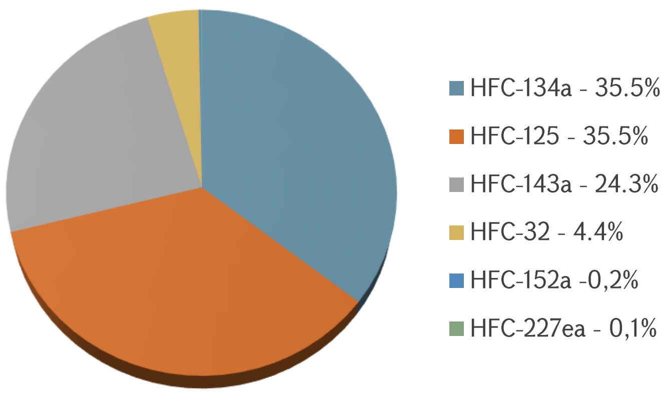


Figure 4.38 HFC emissions by chemicals, Gg $CO_{2\ eq.}$, 2019

Time series of HFC emissions per chemicals for the period of 2000-2019 are depicted in Figure 4.39.

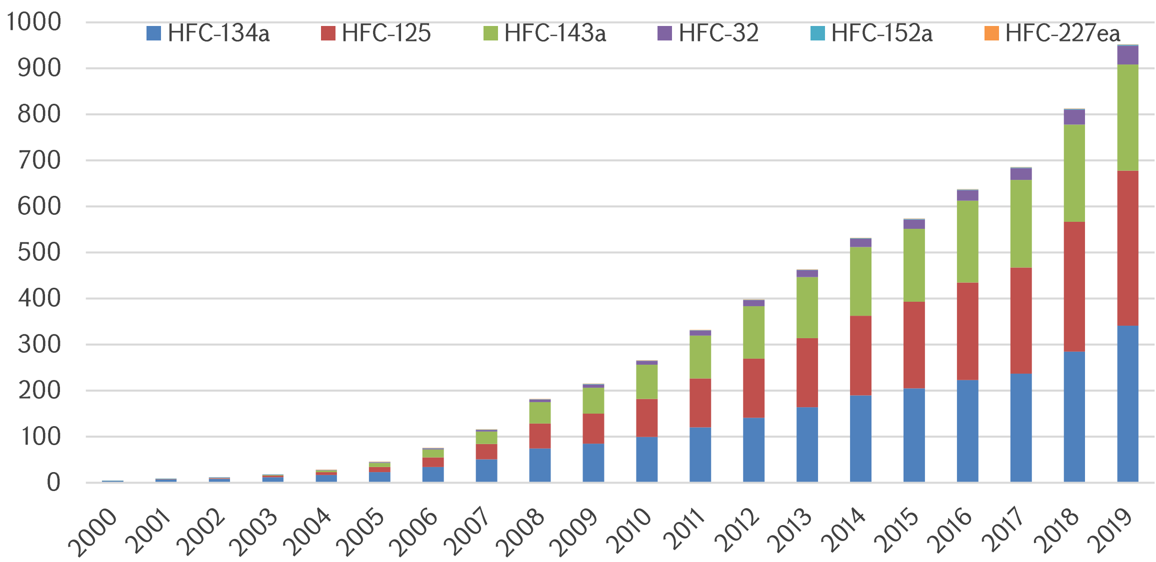


Figure 4.39 Time series of HFC emissions by chemicals, Gg $CO_{2\ eq.}$, 2000-2019

4.2.10.9 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 experts in the course of the years.

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

According to expert assessment, 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 evaluation and completeness of data here was assessed to be 50%.

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.

4.2.10.10 Summary table of HFCs emissions

The Table 4.45 gives an overview of the HFC emissions in 2019 (tonnes and Gg $CO_{2\ eq.}$) by chemicals and applications.

Table 4.45: Armenia's HFC emissions (in tonnes and Gg $CO_{2\ eq.}$) by chemicals and applications, 2019

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	65.236	123.116	265.006	13.865	61.907	0.244	2.017	1.814	
2.F.1 - Refrigeration and Air Conditioning	65.236	123.116	234.994	NO	61.907	NO			
2.F.1.a - Refrigeration and Stationary Air Conditioning	65.236	123.116	126.451	NO	61.907	NO			
2.F.1.b - Mobile Air Conditioning	NO	NO	108.542	NO	NO	NO			
2.F.2 - Foam Blowing Agents			21.117	10.055		NO	2.017	1.814	
2.F.3 - Fire Protection		NO	NO			0.244			
2.F.4 - Aerosols			8.895	3.81		NO	NO		
2.F.5 - Solvents									
Emissions in CO_2 equivalent unit (Gg)									
2.F - Product Uses as Substitutes for Ozone Depleting Substances	42.403	344.725	344.508	1.941	235.247	0.707			**969.531**
2.F.1 - Refrigeration and Air Conditioning	42.403	344.725	305.492	NO	235.247	NO			**927.867**
2.F.1.a - Refrigeration and Stationary Air Conditioning	42.403	344.725	164.387	NO	235.247	NO			**786.762**
2.F.1.b - Mobile Air Conditioning	NO	NO	141.105	NO	NO	NO			**141.104**
2.F.2 - Foam Blowing Agents			27.452	1.408		NO			**28.86**
2.F.3 - Fire Protection		NO	NO			0.707			**0.707**
2.F.4 - Aerosols			11.563	0.533		NO			**12.097**
2.F.5 - Solvents									

4.2.11 Other Product Manufacture and Use (2G)

Only the sub-category of SF_6 *emissions from the electrical equipment use (2G1)* from the category of *Other product manufacture and use* reported in IPCC Guidelines 2006 [Gen-1, Volume 3] is available in Armenia. There is no other sub-category/source applied in Armenia.

4.2.11.1 SF_6 emissions from electrical equipment (2G1)

Category description

In Armenia the Sulphur hexafluoride (SF_6) is used for electrical insulation and current interruption in equipment used in the transmission and distribution of electricity due to perfect insulating and arc extinguishing/suppressing characteristics of SF_6.

In the category of *(2G1) SF_6 emissions from the electrical equipment use* only the SF_6 emissions caused in the result of operation of gas insulating switchgear *(2G1b)* were estimated for two reasons:

- there is no production of electrical equipment in the country *(2G1a)* and,
- waste disposal emissions *(2G1c)* are absent, as gas insulating switchgear have been used in the country since 1999 and the lifetime/term doesn't exceed 35 years [Gen-1, Volume 3, Chapter 8].

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.

Consistent with IPCC Guideline, 2006 [Gen-1, Volume 3, Chapter 8], SF_6 containing electrical equipment can 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. This category mainly includes power transmission equipment - medium and high voltage circuit breakers.

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

4.2.11.2 Description of SF_6 Emissions from the Use of Electrical Equipment (2G1b) 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 SF_6 is derived mainly from high and mid voltage 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 the lifetime of which exceeds 35 years (according to the manufacturer certificate and warranty obligations).

Throughout the entire observation period (1999-2019), the use of gas circuit breakers in Armenia sustainably grew, considering both the existing and new substations.

Figure 4.40 indicates the dynamics of changes in the number of the mid and high voltage gas circuit breakers (closed-pressure equipment) in Armenia, while Figure 4.41 shows the growth of SF_6 content in mid and high voltage circuit breakers.

Figure 4.42 and 4.43 illustrate the dynamics of the change in the number of gas-insulated switchgears (sealed pressure equipment) and dynamic growth of SF_6 content therein for Armenia.

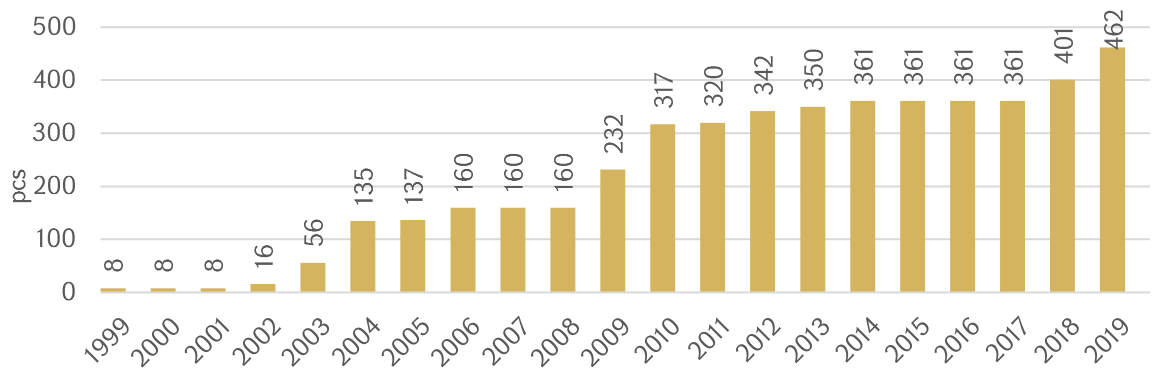


Figure 4.40 Operational dynamics of high voltage Gas Circuit Breakers (closed-pressure equipment)

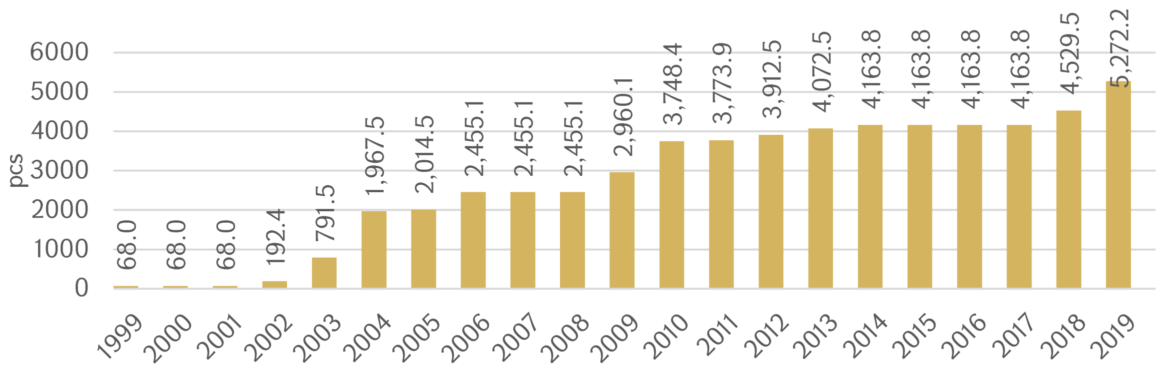


Figure 4.41 Growth dynamics of SF6 content in high voltage Gas Circuit Breakers (closed-pressure equipment)

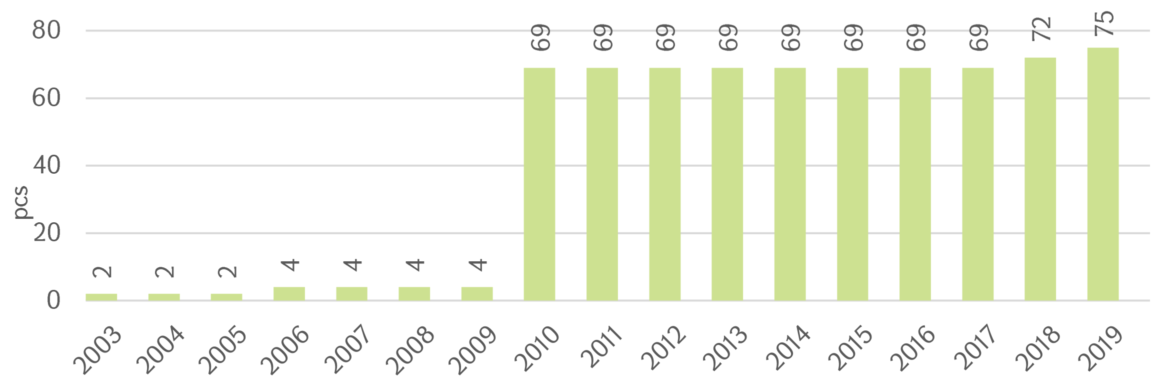


Figure 4.42 Operational dynamics of gas-insulated switchgears/sealed pressure equipment

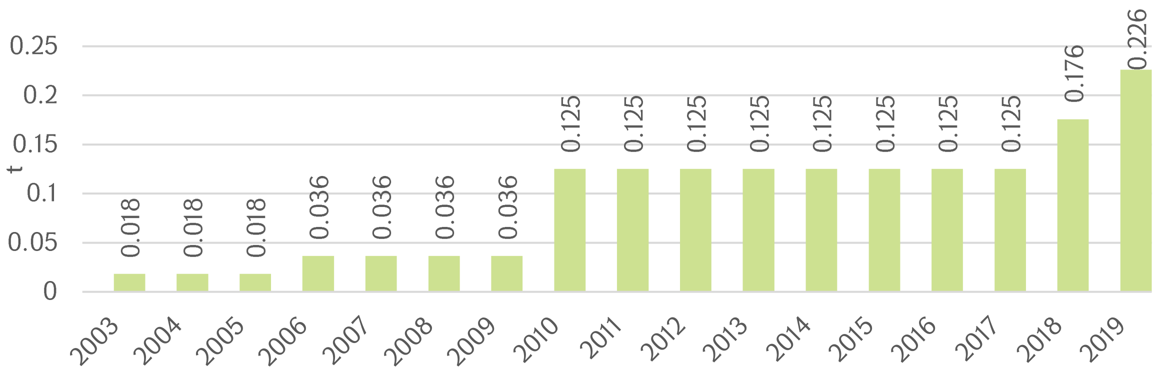


Figure 4.43: Growth dynamics of SF_6 in the sealed pressure equipment

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], [Gen-5].

SF_6 Total Emissions = Manufacturing Emissions + Equipment Installation Emissions+ Equipment Use Emissions + Equipment Disposal Emissions

Considering that Armenia has no manufacturing of Electrical Equipment and started importing electrical equipment containing SF_6 since 1999 while the lifetime of such electrical equipment does not exceed 35 years, manufacturing emissions and Equipment Disposal Emissions are omitted [Gen-1, Volume 3, Chapter 8] and the SF_6 operational emissions were assessed based on the total content of SF_6 in the installed equipment according to the nameplate data of the equipment. When assessing the operational emissions, the equipment installation emissions were taken into account.

As a result, the equation 8.1 looks as follows:

Equipment use emissions = Use Emission factor x SF_6 bank

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

In the emissions calculation the use of SF_6 both in the equipment installed in energy producing stations of Armenia’s energy system, as well as in high voltage and gas insulating switchgear equipment has been considered.

Activity data

Data on SF_6 containing electrical equipment for 2018 and 2019 was provided by the Ministry of Territorial Administration and Infrastructure per the RA energy system objects and years, including data on information producing country and SF_6 content in the installed equipment in line with equipment nameplate data [IndF.Ref-2].

Quality control

Activity data quality control and quality assurance (QA/QC) was performed by a specialist in the energy sector, through analysis of acquired data and related materials, discussions and adjustments with information providers, and comparison with publicly available equipment passport data produced by the given manufacturer.

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]. This default emission factor enables to consider all emissions generated from the installed equipment (including 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].

SF6 emissions were estimated based on the above-mentioned default emission factors values and nameplate capacity of all equipment installed, which are introduced in Tables 4.46 and 4.47.

Emissions calculation results

SF_6 emissions calculations results for closed pressure electrical equipment are provided in the Table 4.46.

Table 4.46 SF_6 emissions from closed pressure electrical equipment

Year	Total nameplate installed (banked) capacity, tonne	SF_6 Refilling, tonne	SF_6 emissions in $CO_{2\ eq.}$, tonne
1999	0.0680	0.0000	42.26
2000	0.0680	0.0003	42.47
2001	0.0680	0.0003	42.47
2002	0.1924	0.0003	119.77

Year	Total nameplate installed (banked) capacity, tonne	SF_6 Refilling, tonne	SF_6 emissions in $CO_{2\ eq.}$, tonne
2003	0.7915	0.0010	492.44
2004	1.9675	0.0040	1225.06
2005	2.0145	0.0098	1257.92
2006	2.4551	0.0101	1531.86
2007	2.4551	0.0123	1533.23
2008	2.4551	0.0123	1533.23
2009	2.9601	0.0123	1847.03
2010	3.7484	0.0150	2338.59
2011	3.7739	0.0190	2356.88
2012	3.9125	0.0191	2443.09
2013	4.0725	0.0198	2542.94
2014	4.1638	0.0206	2600.17
2015	4.1638	0.0210	2600.46
2016	4.1638	0.0210	2600.46
2017	4.1638	0.0208	2600.32
2018	4.5295	0.0226	2828.70
2019	5.2722	0.0264	3292.52

The emissions of SF_6 from Sealed Pressure distribution equipment of the energy system are presented in Table 4.47.

Table 4.47 SF_6 emissions from Sealed Pressure distribution equipment

Year	*Total nameplate installed (banked) SF_6 capacity, tonne*	*SF_6 emissions, $CO_{2\ eq.}$, tonne*
2003	0.018	0.87
2004	0.018	0.87
2005	0.018	0.87
2006	0.036	1.74
2007	0.036	1.75
2008	0.036	1.75
2009	0.036	1.75
2010	0.125	5.99
2011	0.125	6.01
2012	0.125	6.01
2013	0.125	6.01
2014	0.125	6.01
2015	0.125	6.01
2016	0.125	6.01
2017	0.125	6.01
2018	0.176	8.40
2019	0.226	10.82

As the data of Table 4.47 show, SF_6 emissions from Sealed Pressure distributing equipment (installed in distribution networks) are negligible.

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 4.44).

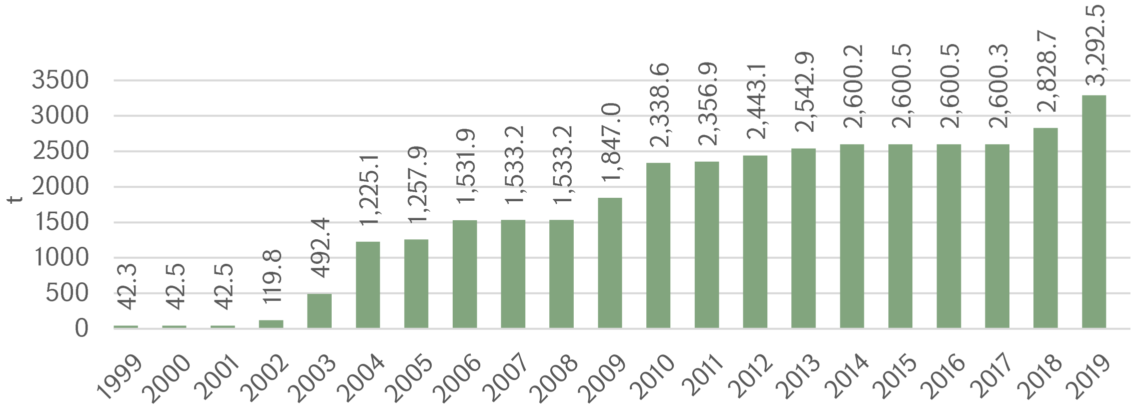


Figure 4.44 SF_6 emissions time series from closed pressure electrical equipment, $CO_{2\ eq.}$, tonne

SF_6 emissions time series from the Sealed Pressure Distributing equipment are introduced in Figure 4.45.

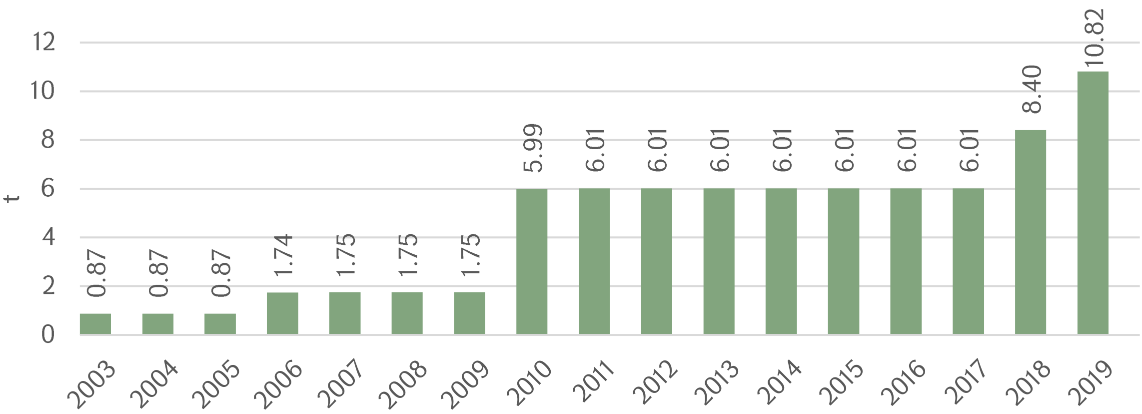


Figure 4.45 SF_6 emissions time series from Sealed Pressure Distributing equipment, $CO_{2\ eq.}$, tonne

Uncertainty assessment

Uncertainties in the Default Emission Factors for Use of Closed-Pressure Electrical Equipment are estimated ±30% (uncertainties in emission factors at the operational stage, including leakage, arc failure and maintenance losses) [2006 IPCC Guidelines, Volume 3, Chapter 8, Table 8.5; Gen-5].

Uncertainties in AD were estimated ±10%.

Table 4.48 GHG emissions in IPPU Sector, 2019

Categories	(Gg)			$CO_{2\ eq.}$ (Gg)	
	CO_2	CH_4	N_2O	HFCs	SF_6
2 - Industrial processes and product use	312.504	NA, NO	NA, NO	969.532	3.287
2.A - Mineral Industry	305.608				
2.A.1 - Cement Production	258.954				
2.A.2 - Lime production	39.590				
2.A.3 - Glass Production	7.064				
2.B - Chemical Industry	NO	NO	NO	NO	NO
2.C - Metal Industry	1.185	NA, NO		NO	NO
2.C.1 - Iron and Steel Production	1.185				
2.C.2 - Production of Ferroalloys	NA	NA			
2.C.7 - Other: Primary Copper Production					
2.D - Non-Energy Production Fuel and Solvent Use	5.711				
2.D.1 - Use of Lubricants	5.588				
2.D.2 - Use of solid paraffin	0.123				
2.D.3 - Use of Solvents					
2.D.4 - Other					
2.E - Electronics Industry				NO	NO
2.F - Use of substitutes for ozone depleting substances				969.532	
2.F.1 - Refrigeration and Air Conditioning				927.867	
2.F.1.a - Refrigeration and Stationary Air Conditioning				786.763	
2.F.1.b - Mobile Air Conditioning				141.105	
2.F.2 - Foam Blowing Agents				28.860	
2.F.3 - Fire Protection				0.707	
2.F.4 - Aerosols				12.097	
2.G - Production and Use of Other Products			NA,NO		3.287
2.G.1 - Electrical Equipment					3.287
2.G.1.b - Use of Electrical Equipment					3.287
2.H - Other					
2.H.2 – Food and Beverage Industry					

Table 4.49 IPPU Sector emissions time series, Gg $CO_{2\ eq.}$

Categories	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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	337.0	305.6
2.C - Metal Industry	0.0	0.0	0.0	0.8	1.1	1.1	1.1	1.2	1.4	1.5	1.3	1.4	1.4	1.2
2.D - Non-Energy Products from Fuels and Solvent Use	0.6	2.4	4.3	7.6	7.4	7.1	7.2	7.1	7.1	4.9	4.1	4.2	4.9	5.7
2.F - Product Uses as Substitutes for Ozone Depleting Substances			4.0	45.1	266.6	331.8	397.9	969.5	531.7	573.4	637.7	685.3	828.0	969.5
2.G - Other Product Manufacture and Use			0.0	1.3	2.3	2.4	2.4	2.5	2.6	2.6	2.6	2.6	2.8	3.3
Total	**630.9**	**122.5**	**152.6**	**395.8**	**588.6**	**633.1**	**713.8**	**1272.2**	**816.5**	**793.2**	**797.4**	**951.9**	**1174.2**	**1285.3**

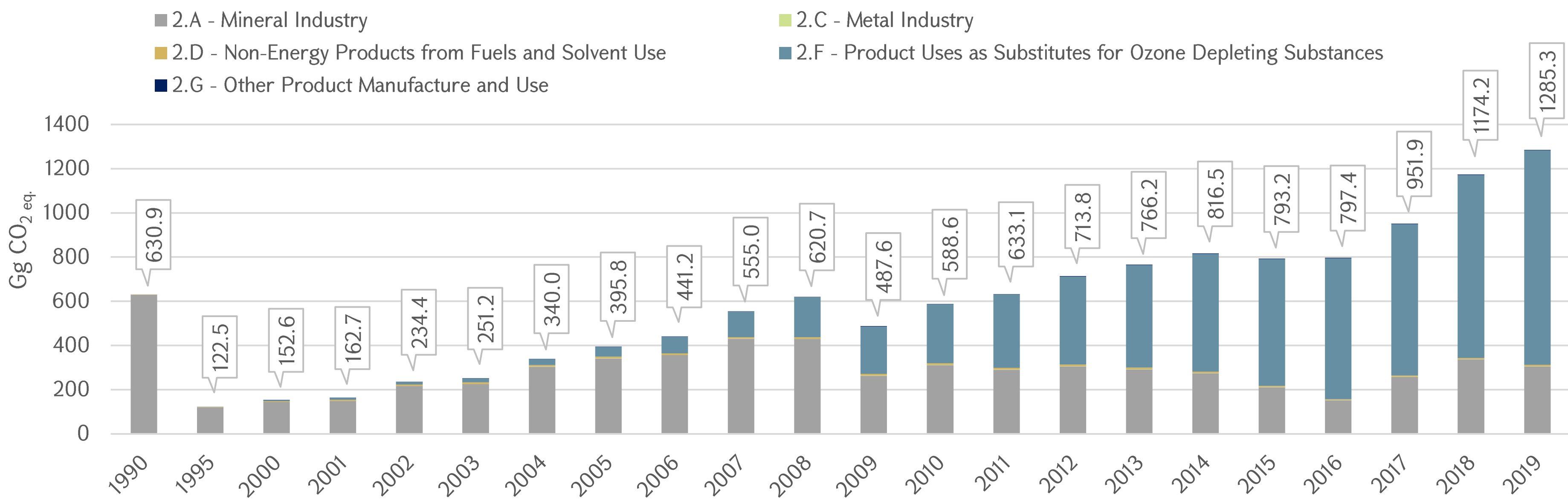


Figure 4.46 IPPU Sector emissions time series, 1990-2019, Gg $CO_{2\ eq.}$

4.3 Agriculture, Forestry and Other Land Use sector

4.3.1 Sector description

In accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [Gen-1], the Agriculture, Forestry and Other Land Use sector in Armenia includes the following categories and sub-categories of GHG emissions/removals.

(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) Wetlands
- (3B5) Settlements
- (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.
- (3D1) Harvested Wood Products

4.3.2 Key categories

The following categories were identified as the key sources of GHG emissions/removals in this sector in terms of both level and trend assessment: *(3A1) Enteric Fermentation from Cattle* (CH_4), *(3B1a) Forest Land Remaining Forest Land* (CO_2), *(3C4) Direct N_2O Emissions from Managed Soils*, and *(3C5) Indirect N_2O Emissions from Managed Soils*.

4.3.3 Improvements achieved

In the *Agriculture, Forestry and Other Land Use* sector, the following improvements are introduced to ensure higher completeness, accuracy and transparency of the National GHG Inventory.

Transparency improvement:

- Emissions and removals from the *Lands* category are presented according to Good Practice Guidance 2003 for the *Land Use, Land-Use Change and Forestry* sector [Gen-7];
- The presentation covers the nitrogen losses due to leakage and leaching from storing of solid and liquid manure, as well as those volatilized in the form of ammonia and nitrogen oxides;
- The presented estimations of direct and indirect N_2O emissions cover those related

to the mineralization resulting from the loss of organic matter in the *Cropland Remaining Cropland* and *Grassland Remaining Grassland* sub-categories.

Accuracy improvement:

- In the cattle category, emissions from enteric fermentation and manure management of imported high-breed cows, bulls and the young (calves) are estimated separately for 2018 and 2019. The basis for the activity data is the data on imports of high-breed animals as reflected in the foreign trade statistics [Ref-5] (See Appendix 3.1, Table 3.1.3), as well as expert assessments of the activity data;
- The category of sheep is presented with three subcategories: mother sheep, other sheep and the young (lambs).

Completeness improvement:

- For the first time, emissions/removals from the *Harvested wood products* (3D1) category are assessed;
- CO_2 emissions from the Settlements Remaining Settlements (3B5a) sub-category are assessed.

4.3.4 Agriculture

4.3.4.1 Summary of the emissions assessment

In 2018 and 2019, the emissions of the *Agriculture* sub-sector in CO_2 equivalent were 1,829.9 Gg and 2,098.3 Gg (17.4% and 18.8% of the total emissions). In comparison with 2017, a decrease of about 5.7% appears in 2018, while an increase of 8.1% is recorded in 2019.

Emissions from the *Agriculture* sub-sector include methane (CH_4) from enteric fermentation of the farm animals, methane (CH_4) and nitrous oxide (N_2O) from manure management, aggregated sources of emissions and non-CO_2 emissions from *Land* category (N_2O և CH_4), as well as CO_2 emissions from the *Harvested wood products* sub-category.

In the total volume of emissions from the *Agriculture* sub-sector, the emissions of methane (CH4) make 49.3% and 42.9% from enteric fermentation of the farm animals, 1.9% and 1.7% – from manure management, the direct and indirect emissions of nitrogen oxides from agricultural lands make 44.6% and 50.6%, and the remaining 4.2% and 4.8% are N_2O emissions from manure management (3A2 and 3C6), respectively in 2018 and 2019.

About 87% of CH_4 emissions from enteric fermentation of the livestock is generated by cattle, while the prevailing part of direct and indirect N_2O emissions – from managed soils.

Cattle enteric fermentation is a major source of greenhouse gases (CH4) and is responsible for 8.1% and 7.7% of the country's total emissions in 2018 and 2019, respectively.

4.3.4.2 Description of the sector

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

- (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-CO2 emissions on land

- (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
- (3D1) Harvested Wood Products

4.3.4.3 Estimation methodology, selection of emission factors, baseline data

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 are estimated by *the Tier 2 method* according to the 2006 IPCC Guidelines [Gen-1, Volume 4] by applying country-specific emission factors.

Methane emissions from enteric fermentation of other categories of farm animals are estimated by *the Tier 1 method* applying emission factors for developing countries [Gen 1, Volume 4].

Activity data

Livestock population

The number of farm animals (Table 4.41) by category is the key indicator for estimating GHG emissions from enteric fermentation. The annual average population of livestock is estimated based on the officially published data as well as the statistics provided by the relevant state authorized bodies (Annex 3.1), [AFOLURef-1, AFOLURef-6].

To estimate the average annual population of livestock, specifically, large and small cattle, and their emission factors, the following baseline data is used according to the emission 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, quarterly

and annually);

- Export and import of live cattle (quantities), according to the EEU Commodity Nomenclature of External Economic Activity at 10-digit level;
- Average annual milk output per cow;
- Average annual wool clip per sheep.

2. The RA Ministry of Economy provides the data on the care regime of farm animals, their average live-weight, feed digestibility, live-weight of young cattle and their average weight gain per day, cow fertility rate, also manure dumping and its distribution by use.

According to the categories, for the estimation of the average annual number of livestock, the following factors were taken into account:

- The population data in the beginning and at the end of a year, livestock import and export data, also estimated number of slaughtered and lost livestock, as well as the young farm animals born within a year;
- Estimated annual volumes of meat sales by animal category and, based on that, the numbers of slaughtered animals, as most of the animal raised for meat production (calves, lambs up to one year of age, swine, birds, rabbits) and they are alive just for a limited time within a year, so their numbers are reflected in the official statistics neither in the beginning of the year nor at the year-end;
- The numbers of slaughtered large and small cattle and swine are distributed by quarter based on the quarterly volumes of meat produced, while the livestock population of lost cattle was distributed proportionally, by month;
- The newly born animal numbers are distributed on a monthly basis, relying on the practice of organizing animal births in Armenia.

That is, the average annual numbers of large and small cattle and swine are calculated as arithmetic average by quarterly values, not by the data in the beginning and at the end of a year (previously, the data on slaughter was available on a monthly basis and the arithmetic average relied on 12 values, disaggregated by months). This is the cause of the differences between the average arithmetic indicators estimated relying on the animal numbers in the beginning and the end of a year and the averages calculated for the 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, also 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 on "Emissions from livestock and manure collection, storage and application" of the 2006 IPCC Guidelines "broiler chickens are typically grown approximately 60 days before slaughter. One should estimate the average annual population as the number of animals grown divided by the number of growing cycles per year".

In 2018 and 2019, poultry meat production was 12.3 and 12.4 thousand tons in slaughter weight, while the total number of birds sold for slaughter was estimated at 7,784.8 and 7,848.1 thousand heads, respectively. Based on this, the average annual numbers of broilers intended for slaughter are estimated using the formula recommended by the Guidelines:

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

where:

AAP *is* annual average population

NAPA *is* number of animals born annually

As a result, the average annual number of slaughtered (broilers) birds in 2018 and 2019 was 1,279.7 and 1,290.1 thousand heads, respectively. The average annual number of poultry is calculated by adding the number of birds slaughtered during a year to the average arithmetic of the number of birds in the beginning and at the end of a year.

The average annual rabbit livestock population for 2018 and 2019 is estimated similarly. Many households in Armenia are engaged in rabbit breeding for meat, fur, and fennel. Domestic rabbits are premature and characterized by intense growth. They reach adulthood in 3-4 months and can multiply year-round. The duration of pregnancy is 28-32 days. One mother rabbit can bear 3-6 times a year (each yields 6-8, sometimes 15 or more cubs). The live weight of newborn rabbit is 60-70 grams, it doubles on the sixth day and increases 9-10 times in 30 days.

The average annual number of slaughtered rabbits was calculated using equation 10.1 of the 2006 IPCC Guidelines [Gen-1, Volume 4, Chapter 10, page 10.8] by using the following data:

- Mother rabbits' number is assessed at 70% of rabbits' arithmetic average in the beginning and at the end of the year (Annex 3.1, Table 3.1.4);
- The number of newborns per mother rabbit is 6 kittens;
- The life expectancy of slaughtered rabbits is 120 days;
- This data is then added to the arithmetic average of rabbits in the beginning and at the end of the year.

The annual average populations of buffalos, horses, asses, mules and fur-bearing animals are estimated using the arithmetic averages of the animals' populations in the beginning and at the end of years 2018, 2019 and 2020.

The assessment of the average annual numbers of farm animals accounts for the growth/decrease rates of the indicator in the current reporting period compared to the previous levels.

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

The number of cattle in 2018 and 2019 is assessed by the groups of local and high-breed animals. The number of high-breed animals is estimated based on the official statistical data on animal imports in 2014-2019.

The estimations yielded the following data, further used to obtain the greenhouse gas emissions from livestock.

Table 4.50 Annual average population of livestock, heads

Livestock category	2018	2019	2018 to 2017 ratio, %	2019 to 2018 ratio, %
Cattle local, of which:	672,008	660,314	92.2%	98.3%
Dairy Cows	299,928	288,522	91.1%	96.2%
Bulls	28,310	28,600	97.6%	101.0%
Young cattle	343,770	341,092	92.7%	99.2%
Cattle high-breed, of which:	8,023	13,089	-	163.1%
Dairy Cows	4,743	7,216	-	152.1%
Bulls	96	101	-	105.2%
Young cattle	3,184	5,772	-	181.3%
Buffalos	696	680	96.9%	97.7%
Sheep and goats, of which:	876,995	879,340	93.6%	100.2%
Sheep, of which:	845,950	847,043	93.7%	100.1%
Ewes	441,271	441,206	94.8%	100.0%
Other sheep	185,571	186,446	91.2%	100.5%
Lambs	219,108	219,391	93.7%	100.1%
Goats, of which:	31,045	32,298	90.0%	101.9%
Nanny goats	16,238	16,089	90.6%	99.1%
Other goats	14,807	16,209	88.4%	109.5%
Horses	10,399	11,058	100.6%	106.3%
Mules and Asses	1,697	1,555	87.1%	91.6%
Swine, of which:	418,850	477,530	106.5%	115.5%
Sows	35,492	41,084	110.5%	115.8%
Other swine	383,358	436,446	105.6%	113.8%
Rabbits	66,432	77,774	99.7%	117.1%
Fur bearing animals	16,066	10,637	169.1%	66.2%
Poultry, heads, of which	5,425,299	5,527,809	104.1%	101.9%
Broiler	2,864,652	2,851,680	107.8%	99.5%
Laying hens	2,560,647	2,676,129	100.3%	104.5%

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

It is evident from the table that there was a decrease in the numbers of large and small cattle, also mules and asses in 2018 and 2019, compared to the indicators of the previous year. At the same time, the numbers of pigs, horses and rabbits increased, while the number of fur-bearing animals reduced in 2019 after its surge in 2018. The number of birds fluctuated with peaks in 2018 and in 2020 and a reduction in 2019. The average annual numbers of livestock are estimated using the animals' population data from the officially published statistics as of January 01 of each year (Annex 3.1, Table 3.1.1). The livestock population is the main factor determining both annual volumes and time series dynamics of GHG emissions. Within 1990-2019, five stages of changes in animal numbers were recorded (see the section on time series).

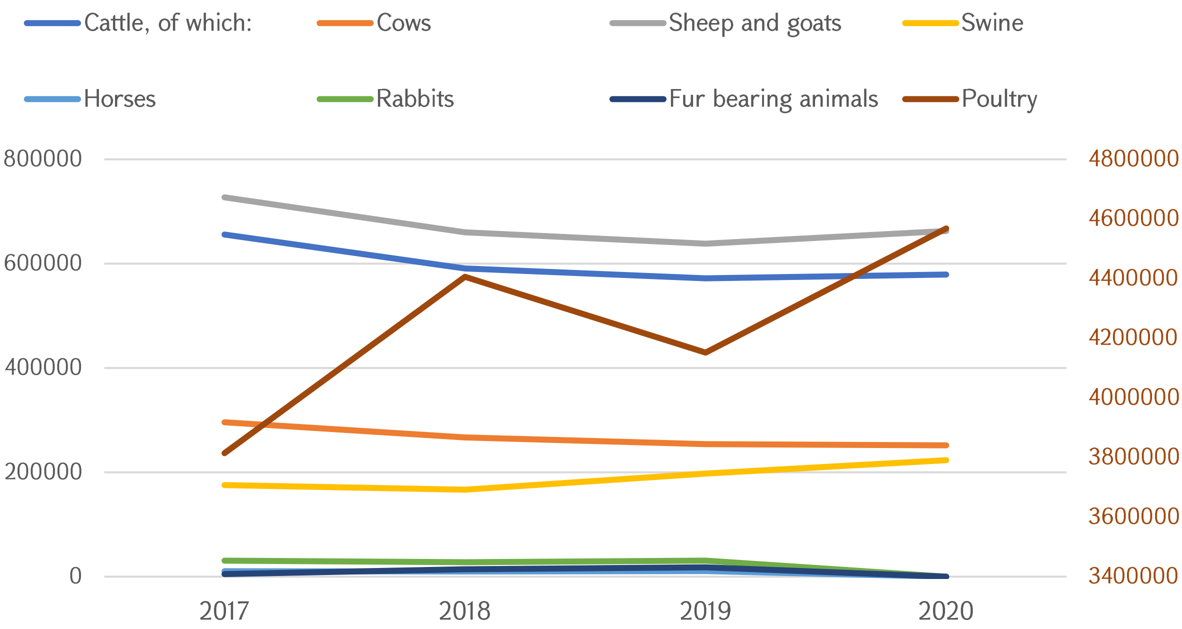


Figure 4.47 Dynamics of the livestock population in 2017-2020, as of January 01, heads

Quality Assurance/Quality Control procedures

Ensuring completeness and accuracy is the principal requirement towards the data collection, that is, all the categories of animals available in the country should be considered in this category for the Inventory compilation purposes.

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 stated above, the 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. Additional estimations allow to supplement the data and obtain more complete information on the livestock annual population. According to the Guidelines, the impact of production cycles and seasonal changes has been taken into account in calculating the annual average population of domestic animals.

An essential tool of QA/QC procedure is the comparison of estimation results using *the Tier 1 method* and *the Tier 2 method* – for the purpose of reducing the uncertainties.

For the purpose of verifying the accuracy of the data calculated by the methodology used for defining farm animals' population, within the previous Inventory compilation, the indicators of the estimated numbers of agricultural animals were compared with the data of the first comprehensive census of Agriculture carried out in Armenia in 2014. During the comprehensive census of Agriculture, the number of livestock population was registered as 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.

The data on the activity of farm animals received from the Ministry of Economy of the RA in an official letter, specifically, cattle live weight, digestibility energy, live weight of the young and of the mature, are cross-checked by comparing them with the adjusted and consented data as a result of the earlier series of discussions with the experts of the Ministry *(the minutes of the joint meeting of the experts of the Program and the Ministry of Agriculture of the RA held on June 18, 2019)*.

Activity data uncertainty

According to the 2006 IPCC Guidelines, the uncertainties associated with livestock populations will vary widely depending on data source, but shouldn't exceed the ± 20% range.

The deviation between the estimated livestock population and the numbers of slaughtered animals makes 4.2%. On the other hand, according to the monitoring conducted previously by the Agriculture department of RA SC, during the livestock population census, deviations on population data were assessed up to 3% as of January 01. As a result, the uncertainty of livestock population is estimated about from ±8% to ±10%.

Emission factors

Emissions from enteric fermentation of cattle, also of buffalo and sheep, are estimated as the key source of emissions, using *the Tier 2 method* with the adjusted country-specific characteristics and emission factors.

Emissions from the enteric fermentation of other animals are evaluated using *the Tier 1 method*.

As a result, the following country-specific emission factors of cattle enteric fermentation are obtained:

- cows local: 69.4 kg methane/head/year,
- cows high-breed: 80.1 kg methane/head/year,
- bulls local: 70.3 kg methane/head/year,
- bulls high-breed: 59.3 kg methane/head/year,
- young local: 42.3 kg methane/head/year,
- young high-breed: 39.0 kg methane/head/year,
- buffalos: 71.8 kg methane/head/year,
- ewes: 7.3 kg methane/head/year,
- other sheep: 4.8 kg methane/head/year,
- lambs: 3.1 kg methane/head/year:

During the development of the 2019 GHG Inventory, cattle activity data for years 2018 and 2019 was used – adjusted as a result of a series of discussions between scientists-experts and specialists of the Ministry of Agriculture of the RA (specifically, cattle live weight, digestibility energy, live weight of the young and the mature).

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

In accordance with the Guidelines, the uncertainty is assessed at ±20% with *the Tier 2 method* [Gen-1, Volume 4, Chapter 10].

The differences between default emission factors for cattle as provided in the Guidelines and the country-specific ones are caused by differences in animal characteristics (activity data). For instance, in the Guidelines for Asia as a part of world the average milk output is 1,650 kg per head/year or 4.5 kg per day, with an average live weight of dairy cows of 275-350 kg and default emission factor of 68 kg methane/year. By the circumstances in Armenia, according to SC of RA data of 2018 and 2019, the average annual cow milk output was 2,310 և 2,365 kg per head or approximately 6.3 - 6.5 kg/day, while according to the consented assessment by the scientists-experts and specialists of the Ministry of Agriculture, the average live weight of cows is 407 kg.

In case of buffalo and bulls the differences are much greater, which has led to a greater variance between the country-specific emission factor and the ones set forth by the 2006 IPCC Guidelines [Gen-1, Volume 4, Chapter 10].

The Table 4.51 below provides a comparison of the emission factors specified by the Guidelines [Gen-1, Volume 4, Table 10.11, Asia] and country-specific ones.

Table 4.51 Comparison of Emission Factors (kg/head/year)

Cows		Bulls		Young cattle		Buffalo		Sheep	
Guideline	Country-specific	Guideline	Country-specific	Guideline	Country-specific	Guideline	Country-specific	Guideline	Country-specific
68	69.4	47	70.3	47	42.3	55	71.8	5	5.1

Time series

The time series are compiled for 1990-2019 period. The emission factor from enteric fermentation of cattle increased from 68.9 to 69.4 kg methane/head/year in 2018 and 2019, which is due to the increase in average daily milk output and fertility rate. However, the reduction in the number of farm animals in 2017, 2018 and 2019 resulted in lower emission volumes from enteric fermentation and from manure management (Figures 4.48 and 4.49).

The time series of emissions (Gg $CO_{2\ eq.}$) from livestock enteric fermentation in 1990 to 2019 are presented in Figure 4.48.

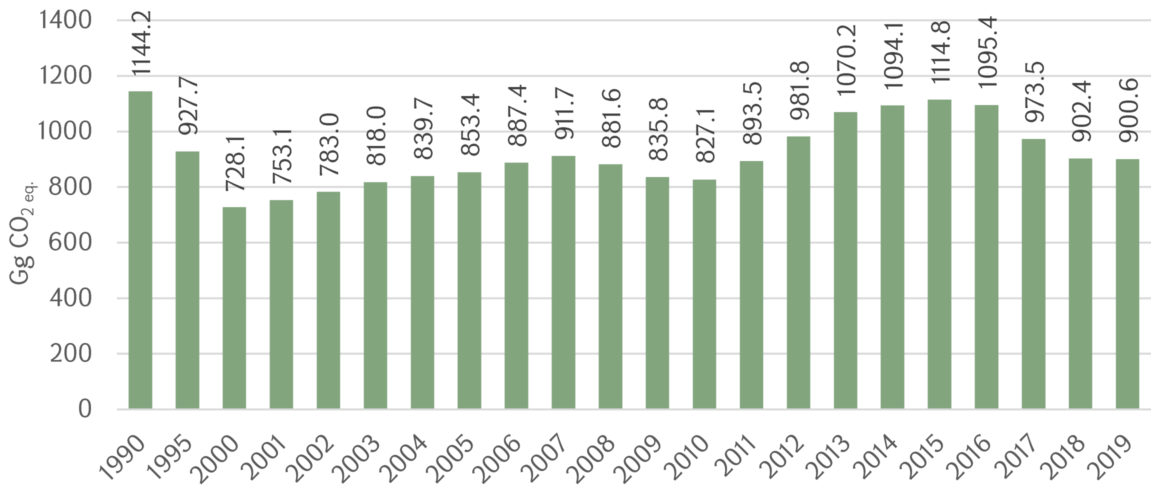


Figure 4.48 Methane emissions from livestock enteric fermentation, Gg $CO_{2\ eq.}$

The reduction of methane emissions from the intestinal fermentation of farm animals in 2018 and 2019 is mainly due to the reduction of the number of livestock, in particular, the number of cattle. Although an increase in the number of bulls and some other farm animals was recorded in 2019 compared to the previous year, nevertheless, the reduction in the number of cows and calves by 3.8% and 0.8%, respectively, contributed to the reduction of methane emissions from enteric fermentation.

It is evident from the time series, that five stages of change in the volumes of emission volumes from enteric fermentation of farm animals are recorded in 1990-2019 period. This was mainly consequent to the relevant changes in the number of livestock (change in the other factors affecting emissions was insignificant in 1990-2019, except for milk output which was on a growing trend).

- In 1990s the after liquidation of state livestock farms and privatization of animals the livestock population numbers plummeted in the country leading to the respective decrease of emissions from livestock, which held up to 2000.
- During 2000-2007 the economic activity in the country contributed also to the development of livestock breeding in agriculture, interrupted in 2008-2010 by the

global economic crisis. Therefore, the record shows emissions growing up to 2007 and decreasing in 2008-2010.

- Due to the recovery of the economy and the favorable socio-economic conditions created in the country in 2011-2016, an increase in the number of farm animals was recorded; in particular, the number of cattle was 571.4 thousand heads in 2011 and reached 688.6 thousand heads by 2016. As a result of the increase in the number of animals, an increase in the volume of emissions from enteric fermentation of animals was also recorded.
- From 2016, the number of animals and the volume of emissions entered another phase of reduction; for instance, the head count of the cattle was 579.3 thousand as of January 1, 2020. This indicator decreased by -15.9% compared to 2016.

4.3.4.4.1.2 Manure management (3A2)

Estimation methodology and selection of emission factors

Activity data

Emissions from manure management are estimated for all categories of livestock.

The following manure management systems applied in Armenia are included in the Guidelines and are considered for the emission assessment:

1. Pasture/Range/Paddock
2. Daily spread
3. Solid storage
4. Liquid/Slurry
5. Poultry manure with litter
6. Poultry manure without litter.

Methane emissions

The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on the type of manure collection, storage and application system.

When manure is stored or treated as a liquid, it decomposes anaerobically and can produce a significant quantity of methane. If this system is used, the temperature and the retention time of the storage unit significantly affect the amount of methane produced. When manure is handled as a solid or when it is deposited in the pastures and rangelands, it tends to decompose under more aerobic conditions and less methane is produced.

In the circumstances of Armenia, according to the data of the Ministry of Economy (AFOLUREF-7), up to 27% of manure is left in the pastures (anaerobic decomposition), up to 1% is stored and used as a liquid (agricultural collective farms/farms that use manure for biogas production or use as a fertilizer) and the rest is handled as a solid in livestock farms and used as organic fertilizers and burned as solid fuel. Therefore, decomposition of 1% of manure produced by all categories of farm animals occurs in anaerobic, and of 99% – in aerobic conditions.

Methane emissions from manure management of cattle, buffalos and sheep are estimated using *the Tier 2 method*, and of the other livestock categories – using *the Tier 1 method*, both with application of country-specific characteristics (baseline data) and emission factors set forth by the Guidelines.

For estimations with the Tier 1 method, emission factors for developing countries are used as set forth by the Guidelines [Gen-1, Volume 4, Table 10.15].

Both the geographical location of the country and the average annual temperature are important when estimating emissions from enteric fermentation of farm animals and manure management. The average annual temperature in the Republic of Armenia is below 10°C and it is classified as a country with a cold climate.

Time series

The time series are compiled for 1990-2019 period and show the methane emissions (Gg $CO_{2\ eq.}$) from livestock manure management as presented in Figure 4.49.

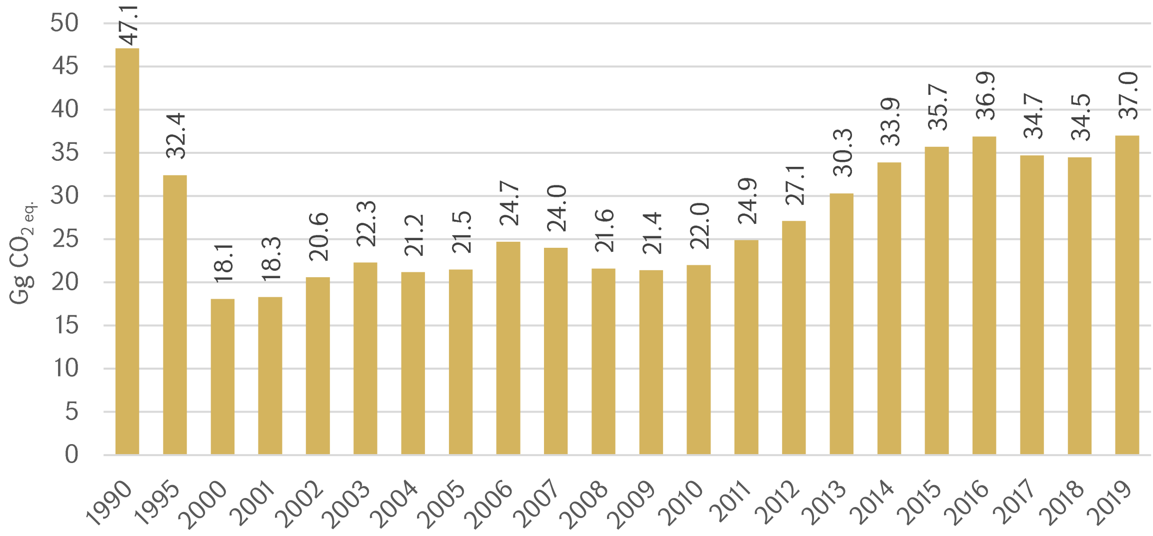


Figure 4.49 Methane emissions (Gg $CO_{2\ eq.}$) from livestock manure management

Methane emissions from manure management decreased by 0.3% in 2018 compared to last year; however, the volume of emissions increased by 6.9% in 2019. The emissions' growth in 2019 is caused mainly by the increase in the swine population (115.5%), also rabbits (117.1%) and birds (101.9%).

Nitrous oxide emissions

N_2O direct emissions

Nitrous oxide emissions from manure management of cattle, buffalos and sheep are estimated using *the Tier 2 method*, and for the other livestock categories – using *the Tier 1 method*, both with application of the emission factors set forth by the Guidelines [Gen-1, Volume 4, Table 10.21]. For estimations using *the Tier 1 method*, data on the number of animals by category for each type of manure collection, storage and application system are used – with the respective emission factors were used. The estimation is performed by multiplying the nitrogen released from each type of manure collection, storage and application system by the respective emission factor.

N_2O indirect emissions

Under *the Tier 1 method* and *the Tier 2 method*, the estimations of N volatilization in forms of NH_3 and NOx from the systems of manure collection, storage and application are performed by multiplication of the amount of nitrogen from each system of manure collection, storage and application by the specific weight of volatilized nitrogen. Subsequently, N losses are summed over all manure management systems. *The Tier 1 method* is applied using country-specific characteristics of livestock and the emission factors recommended by the Guidelines [Gen-1, Volume 4, Table 10.22].

Time series

The time series from 1990-2019 are presented below.

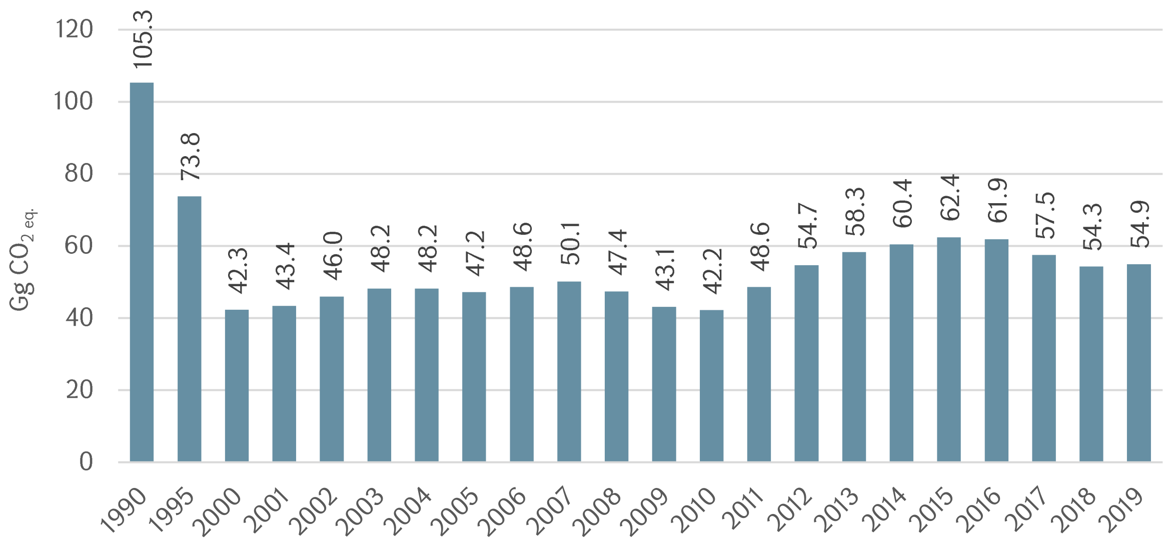


Figure 4.50 Nitrous oxide emissions from livestock manure management

Nitrous oxide emissions from manure management decreased by 5.6% in 2018 compared to the previous year, but the emissions increased by 1.1% in 2019. The emissions' growth in 2019 comes from the increase in certain livestock populations, such as swine (115.5%), rabbits (117.1%) and birds (101.9%).

4.3.4.4.1.3 General pattern of emissions from the *Livestock* sub-category

Table 4.52 below provides methane and nitrous oxide emissions from the *Livestock Enteric Fermentation* and *Manure Management* sub-categories.

Table 4.52 Emissions of methane and nitrous oxide from *Livestock Enteric Fermentation* and *Manure Management*, Gg

Livestock Categories	2018		2019	
	CH_4	N_2O	CH_4	N_2O
3.A Livestock	44.617	**0.175**	44.649	**0.177**
3.A.1 Enteric Fermentation	42.972		42.887	
3.A.1.a Cattle	37.355		37.194	
3.A.1.a.i Dairy Cows	20.690		20.567	
3.A.1.a.ii Other Cattle	16.666		16.627	
3.A.1.b Buffalo	0.050		0.049	
3.A.1.c Sheep	4.773		4.777	
3.A.1.d Goats	0.155		0.161	
3.A.1.f Horses	0.187		0.199	
3.A.1.g Mules and Asses	0.017		0.016	
3.A.1.h Swine	0.419		0.478	
3A1j Other (Rabbits, Fur bearing animals)	0.016		0.013	
3.A.2 Manure Management	1.645	**0.175**	1.762	**0.177**
3.A.2.a Cattle	0.543	0.013	0.540	0.013
3.2.1.a.i Dairy Cows	0.292	0.006	0.290	0.006
3.2.1.a.ii Other Cattle	0.251	0.007	0.250	0.007
3.A.2.b Buffalo	0.001	0.000	0.001	0.000
3.A.2.c Sheep	0.152	0.138	0.152	0.138
3.A.2.d Goats	0.003	0.003	0.004	0.003
3.A.2.f Horses	0.011	0.000	0.012	0.000
3.A.2.g Mules and Asses	0.001	0.000	0.001	0.000
3.A.2.h Swine	0.838	0.010	0.955	0.012
3.A.2.i Poultry	0.080	0.012	0.084	0.012
3A2j Other (Rabbits, Fur bearing animals)	0.016	0.00	0.013	0.000

Comparison of the select indicators in 2018 and 2019 with their values in previous years shows that:

- Methane emissions from enteric fermentation of farm animals reduced by -7.2% and -0.2%, respectively.

- Nitrous oxide emissions from manure management reduced by - 5.6% in 2018 and increased by 1.1% in 2019, compared to the previous year's indicator;
- Methane emissions from manure management reduced by -0.3% in 2018 and increased by 6.9% in 2019, compared to the previous year's indicator;

The reduction and increase in emissions come from the changes in the livestock populations, and especially cattle (which accounted for 87.2% of methane emissions) [Table 4.50, AFOLURef-1, Ref-2].

A summary time series of GHG emissions from livestock enteric fermentation and manure management is shown in the figure below.

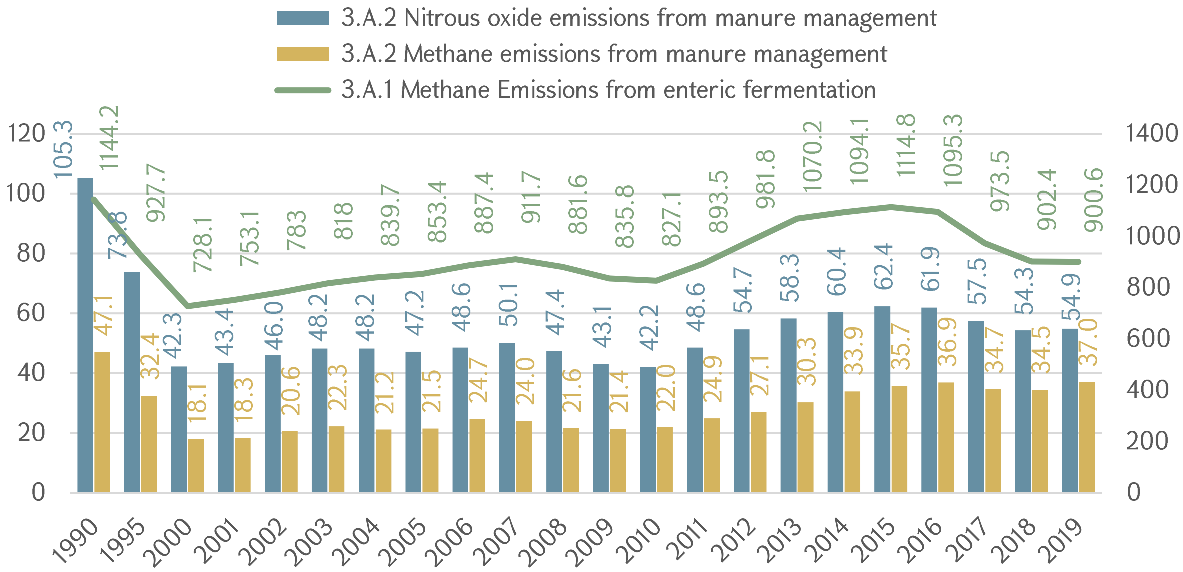


Figure 4.51 GHG emissions from the *Livestock* sub-category in 1990-2019, Gg $CO_{2eq.}$

4.3.5 Lands (3B)

4.3.5.1 Land Use categories

Greenhouse gas emissions and removals are estimated separately for the following six categories of land use according to the 2006 IPCC Guidelines for National GHG Inventories [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) Wetlands
- (3B5) Settlements
- (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 RA, the classification of the country's land fund is organized around its target uses (categories and sub-categories) as follows:

1) Agriculture
2) Settlements
3) Industrial, for entrails-use and other production
4) Energy, transport, communication, public utility infrastructure
5) Specially protected areas
6) Special importance
7) Forest
8) Water
9) Reserve

In order to estimate GHG emissions and removals from the *Lands* sub-category, the national classification of soils is revised in accordance with the categories listed in the 2006 IPCC Guidelines.

Relying on "The Procedure for the Classification of the Land Coverage of the Republic of Armenia" (approved by the GoA decision #431-N of April 11, 2019), the following steps are implemented to align the national classification of lands with the one of the 2006 IPCC Guidelines:

1. The following are included in the *Forest Land*:
   - 100% of forest land;
   - Forests of specially protected areas;
   - Shelter forests from agricultural land.
2. The following are 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 are 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 pastures and 20% of other land.
4. The following are 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 are 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 importance.
6. In the *Other Lands* sub-category, lands without vegetation are included (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 importance;
- From specially protected areas: areas of lakes and ponds;
- Offshore land areas, river and canal areas;
- Reserve lands.

The report “On the availability and distribution of the land fund of the RA (the land balance) as of July 01 of 2018 and 2019" by the Cadastre Committee demonstrates the conversions taken place between all the categories of the national land classification.

The conversions between land categories identified by the National GHG Inventory are presented in Tables 4.53 to 4.56 according to Annex 3.3.

Lands converted into the category of agricultural lands from other categories made 1292 ha in 2018 and 34.4 ha in 2019. It should be taken into account that the amount of real transformations was 230 ha in 2018, because 1115 ha were added as a result of adjustments and changes to the relevant documentation. Conversions from agricultural land to other categories made 680 ha in 2018 and 293 ha in 2019 [AFOLURef-2].

Table 4.53 Lands conversion into Agricultural category as of 2018

Previous category	Agricultural use, hectare
Settlements	42
Industrial, for entrails-use and other production	6
Energy, transport, communication, public utility infrastructure	16
Specially protected areas	140
Forest	23
Special importance	1062
Water	3

Table 4.54 Agricultural lands conversion into other categories as of 2018

Previous category	Category of conversion, ha				
	Settlem ents	Industrial, for entrails-use and other production	Energy, transport, communication, public utility infrastructure	Specially protected areas	Forest
Agricultural use	40	450	110	50	30

Table 4.55 Lands conversion into Agricultural category as of 2019

Previous category	Agricultural use, hectare
Settlements	1.1
Industrial, for entrails-use and other production	21
Energy, transport, communication, public utility infrastructure	-
Specially protected areas	2.3
Special importance	10

Table 4.56 Agricultural lands conversion into other categories as of 2019

Previous category	Category of conversion, ha				
	Settle ments	Industrial, for entrails-use and other production	Energy, transport, communication, public utility infrastructure	Specially protected areas	Forest
Agricultural use	56	148	75	7	7

In the matrix of land use and conversions, it is necessary to record only the conversions from the settlements, the industry, for entrails-use use and other production, the energy, communication, transport and communal infrastructures categories (70 ha in 2018 and 24.3 ha in 2019), because the conversions from other categories took place on the land plots which were already included in the categories of cultivated land or meadows, according to the National Land Use Classification aligned with the land categories of the 2006 IPCC Guidelines (according to "The Procedure for the Classification of the Land Coverage of the Republic of Armenia", approved by the GoA decision #431-N of April 11, 2019).

By the same logic, conversions of lands from agricultural to other categories refer again to the conversions from the category of meadows to the category of settlements (600 ha in 2018 and 279 ha in 2019). Table 4.57 below shows the alignment of the National Land Use Classification with the Guidelines categories, taking into account the conversions between the land categories.

Table 4.57 Alignment of the national classification of land use with the categories set forth by the 2006 by the Guidelines, as of 2018, in hectares, in accordance with "The Procedure for the Classification of the Land Coverage of the Republic of Armenia" (approved by the GoA decision #431-N of April 11, 2019) [AFOLURef-2,3,4,5] and the Land Balance 2018 by the State Committee of the Real Estate Cadastre

2018	Land balance	3B1 Forest lands	3B2 Croplands	3B3 Grasslands	3B4 Wetlands	3B5 Settle-ments	3B6 Other lands	Total
1. Agricultural	**2044464.8**	793	480913	1249979	0	0	312780	2044464.8
1.1 arable land	445564.5		445565					445564.5
1.2. perennial plants	35348.3		35348					35348.3
1.2.1 orchards	21052.6		21053					21052.6
1.2.2 grape vines	14268.1		14268					14268.1
1.2.3 other perennial plants	27.5		28					27.5
1.3 hay-land	121040.1			121040				121040.1
1.4 pastures	1051536.54			1051537				1051536.5
1.5 other types of lands	390975.3	793		77402			312780	390975.3
2. Settlements	**151866.7**		56746.9	52685.9		42433.9		151866.7
2.1 housing construction	99180.8		56746.9			42433.9	0	99180.8
2.1.1 home garden plots	89889.3		53933.6			35955.7		89889.3
2.1.2 gardening lands	4688.8		2813.3			1875.5		4688.8
2.1.3 other lands						4602.7		
2.2 public building	7806			7806				7806
2.3 Mixed construction	2428.6			2428.6				2428.6
2.4 Common use lands	18447.5			18447.5				18447.5
2.5 Other Lands	24003.8			24003.8				24003.8
3. Industrial, sub-soil use and other industrial purpose lands	**38428.5**	0	0	0	3563	23447.9	11417.6	38428.5
3.1 industrial facilities	9991.5					9991.5		9991.5
3.2 agricultural production facilities	12781					12781		12781
3.3 storages	675.4					675.4		675.4
3.4 Land allocated for the use of subsoil	14980.6				3563		11417.6	14980.6
4. Energy, transport, communication, public utilities infrastructures lands	**12953.5**	0	0	0	0	12953.5	0	12953.5
4.1 energy	2382.7					2382.7		2382.7
4.2 communication	146.1					146.1		146.1
4.3 transport	9097					9097		9097
4.4 utility infrastructure objects	1327.7					1327.7		1327.7
5. Specially protected areas	**335578.2**	60904	15952	115498	0	18439.7	124784.8	335578.2
5.1 nature protection	317679.5	60904	15952	115498	0	541	124784.8	317680
5.1.1 reserves	35239	14150	5231	15858				35239
5.1.2 sanctuaries	47955.8	22675	3360	21921				47956
5.1.3 national parks	234484.7	24079	7360	77720		541	124784.8	234485

2018	Land balance	3B1 Forest lands	3B2 Croplands	3B3 Grasslands	3B4 Wetlands	3B5 Settle-ments	3B6 Other lands	Total
5.2 healthcare	233.6					234		234
5.3 recreation	2802.4					2802		2802
5.4 cultural and historical	14862.7					14863		14863
6. Special significance	**30524.1**	0	0	18314.46	0	12209.64	0	30524.1
7. Forestry	**334025.0**	289194.3	18938.6	21259.3	0	0	4632.8	334025
7.1 forest	289194.3	289194.3						289194.3
7.2 bush	18682.8		18682.8					18682.8
7.3 arable land	255.8		255.8					255.8
7.4 hay-land	9203.3			9203.3				9203.3
7.5 pasture	10897.8			10897.8				10897.8
7.6 other lands	5791			1158.2			4632.8	5791
8. Water	**25798.9**	0	0	0	9363.6	0	16435.3	25798.9
8.1 rivers	8298.9						8298.9	8298.9
8.2 reservoirs	7007				7007			7007
8.3 lakes	5838.5				810		5028.5	5838.5
8.4 canals	3107.9						3107.9	3107.9
8.5 hydro-technical and other water engineering facilities	1546.6				1546.6			1546.6
9. Reserve	**620.4**	0	0	0	0	0	620.4	620.4
9.1 salts	0							0
9.2 sands	0							0
9.3 swamps	0							0
9.4 other unused lands	620.4						620.4	620.4
Total	**2974260.1**	**350891.2**	**572550.0**	**1457736.5**	**12926.6**	**109484.7**	**470671.1**	**2974260.1**

Table 4.58 Alignment of the national classification of land use with the categories set forth by the 2006 by the Guidelines, as of 2019, in hectares, in accordance with "The Procedure for the Classification of the Land Coverage of the Republic of Armenia" (approved by the GoA decision #431-N of April 11, 2019) [AFOLURef-2,3,4,5] and the Land Balance 2019 by the State Committee of the Real Estate Cadastre

2019	Land balance	3B1 Forest lands	3B2 Croplands	3B3 Grasslands	3B4 Wetlands	3B5 Settle-ments	3B6 Other lands	Total
1. Agricultural	**2044206.2**	793.0	481213.1	1249599.7	0.0	0.0	312600.4	2044206.2
1.1 arable land	444854.3		444854.3					444854.3
1.2. perennial plants	36358.9		36358.9					36358.9
1.2.1 orchards	21849.9		21849.9					21849.9
1.2.2 grape vines	14477.4		14477.4					14477.4
1.2.3 other perennial plants	31.5		31.5					31.5
1.3 hay-land	121098.7			121098.7				121098.7
1.4 pastures	1051143.9			1051143.9				1051143.9
1.5 other types of lands	390750.5	793.0		77357.1			312600.4	390750.5
2. Settlements	**151904.5**		56746.9	52695.9		42461.7		151904.5
2.1 housing construction	99208.6					42461.7	0.0	42461.7
2.1.1 home garden plots	89893.0		53933.6			35959.4		89893.0
2.1.2 gardening lands	4688.9		2813.3			1875.6		4688.9
2.1.3 other lands						4626.7		
2.2 public building	7842.7			7842.7				7842.7
2.3 Mixed construction	2434.1			2434.1				2434.1
2.4 Common use lands	18456.1			18456.1				18456.1
2.5 Other Lands	23963.0			23963.0				23963.0
3. Industrial, sub-soil use and other industrial purpose lands	**38576.3**	0.0	0.0	0.0	3563.0	23462.6	11550.7	38576.3
3.1 industrial facilities	10005.5					10005.5		10005.5
3.2 agricultural production facilities	12782.9					12782.9		12782.9
3.3 storages	674.2					674.2		674.2
3.4 Land allocated for the use of subsoil	15113.7				3563.0		11550.7	15113.7
4. Energy, transport, communication, public utilities infrastructures lands	**13046.9**	0.0	0.0	0.0	0.0	13046.9	0.0	13046.9
4.1 energy	2474.6					2474.6		2474.6
4.2 communication	146.5					146.5		146.5
4.3 transport	9096.9					9096.9		9096.9
4.4 utility infrastructure objects	1328.9					1328.9		1328.9
5. Specially protected areas	**335571.7**	60904.7	15951.7	115497.3	0.0	18433.2	124784.8	335571.7
5.1 nature protection	317679.5	60904.7	15951.7	115497.3	0.0	541.0	124784.8	317679.5
5.1.1 reserves	35239.0	14150.2	5231.3	15857.6				35239.0
5.1.2 sanctuaries	47955.8	22675.3	3360.4	21920.1				47955.8
5.1.3 national parks	234484.7	24079.2	7360.0	77719.7		541.0	124784.8	234484.7

2019	Land balance	3B1 Forest lands	3B2 Croplands	3B3 Grasslands	3B4 Wetlands	3B5 Settle-ments	3B6 Other lands	Total
5.2 healthcare	233.6					233.6		233.6
5.3 recreation	2794.0					2794.0		2794.0
5.4 cultural and historical	14864.6					14864.6		14864.6
6. Special significance	**30511.1**	0.0	0.0	18301.5	0.0	12209.6	0.0	30511.1
7. Forestry	**334024.1**	289193.7	18938.3	21259.3	0.0	0.0	4632.8	334024.1
7.1 forest	289193.7	289193.7						289193.7
7.2 bush	18682.5		18682.5					18682.5
7.3 arable land	255.8		255.8					255.8
7.4 hay-land	9203.3			9203.3				9203.3
7.5 pasture	10897.8			10897.8				10897.8
7.6 other lands	5791.0			1158.2			4632.8	5791.0
8. Water	**25798.9**	0.0	0.0	0.0	9363.6	0.0	16435.3	25798.9
8.1 rivers	8298.9						8298.9	8298.9
8.2 reservoirs	7007.0				7007.0			7007.0
8.3 lakes	5838.5				810.0		5028.5	5838.5
8.4 canals	3107.9						3107.9	3107.9
8.5 hydro-technical and other water engineering facilities	1546.6				1546.6			1546.6
9. Reserve	620.4	0.0	0.0	0.0	0.0	0.0	620.4	620.4
9.1 salts	0.0							0.0
9.2 sands	0.0							0.0
9.3 swamps	0.0							0.0
9.4 other unused lands	620.4						620.4	620.4
Total	**2974260.1**	**350891.4**	**572850.0**	**1457353.7**	**12926.6**	**109614.1**	**470624.4**	**2974260.1**

The matrix of the changes taken place in the categories of lands is presented in Tables 4.59 and 4.60.

Table 4.59 Land use matrix of Armenia in 2018, hectare

Previous / Final	3B1 Forest lands	3B2 Croplands	3B3 Grasslands	3B4 Wetlands	3B5 Settle-ments	3B6 Other lands	Total Final
Forest lands	**350,891.2**						**350,891.2**
Croplands		**573,330.0**			70.0		**573,400.0**
Grasslands			**1,456,928.4**				**1,456,928.4**
Wetlands				**9,852.6**			**9,852.6**
Settlements			600.0		**109,535.7**		**110,135.7**
Other lands						**473,052.2**	**473,052.2**
Total Previous	**350,891.2**	**573,330.0**	**1,457,528.4**	**9,852.6**	**109,605.7**	**473,052.2**	**2,974,260.1**
Resulting Change	0.0		-600.0	0.0	-70.0	0.0	0.0

Table 4.60 Land use matrix of Armenia in 2019, hectare

Previous / Final	3B1 Forest lands	3B2 Croplands	3B3 Grasslands	3B4 Wetlands	3B5 Settle-ments	3B6 Other lands	Total Final
Forest lands	**350,891.2**	0.2					**350,891.4**
Croplands		**573,857.7**			24.3		**573,882.0**
Grasslands			**1,456,928.4**				**1,456,928.4**
Wetlands				**9,852.6**			**9,852.6**
Settlements			279.0		**110,111.4**		**110,390.4**
Other lands						**472,315.3**	**472,315.3**
Total Previous	**350,891.2**	**573,857.9**	**1,457,207.4**	**9,852.6**	**110,135.7**	**472,315.3**	**2,974,260.1**
Resulting Change	0.0	-0.2	-279.0	0.0	-24.3	0.0	0.0

4.3.5.2 Calculation methodology, emission factors selection and source data

4.3.5.2.1 Forest Lands (3B1)

The Republic of Armenia stands out for its highly pronounced vertical zonation and continental climate, where long-term anthropogenic (negative) activities, as well as changes in natural and climatic factors, have had a negative impact on the development of forest ecosystems and their vertical boundaries.

Sub-sector description

RA forests and forest lands are under the jurisdiction of the RA Ministry of Environment.

Forest management, preservation and forest use activities are implemented both in the "Forestry" branches of ArmForest SNCO of the State Forest Committee and in the forests included in SPNA system.

To disclose RA Forest Stock per land types (forest covered areas, non-adherent forest cultures, rare/light forest, grasslands, pastures, etc.), as well as to collect index data on forest lands covered by tree species, accumulated stock (m^3), age, completeness and other necessary forest assessment indexes, information provided by "Forestry" branches of ArmForest SNCO (LUCFRef-1), and SPNAs [LUCFref.2], as well as forest land allocation under "ArmForest" SNCO according to the existing and outdated Forest Management Plans [LUCFref.21] of "Forestry" branches, and the SPNA Management Plans [LUCFRef-22] were studied.

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/nurseries
4. Non-forest areas that are divided into:
   4 a. Rare forests (biological or anthropogenic)
   4 b. Fired or dead trees,
   4 c. Clear logged areas,
   4 d. Forest glades.

Table 4.61 provides Forest stock data by land types compiled from the forest management plans:

Table 4.61 Forest stock by land types

Year	Forest lands, ha					Non-forest lands, ha				Total
	Forest covered			Non-forest						
	Total	Non-adherent forest cultures	Տնկարաններ	Fired areas, totally logged areas, forest glades, rare forests (anthropogenic, biological)	Total forest lands	Grasslands	Pastures	Other Land (orchard, arable land and others)	Total non-forest lands	
2018	350,891.21	3,791	135.9	51,296.8	406,799.8	2,943.2	24,617.49	75,207.96	102,768.65	509,568.46
2019	350,891.41	3791	135.9	51,296.6	406,799.8	2,943.2	24,617.49	75,207.96	102,768.65	509,568.46

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 changes 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.

Areas under forests made 350,891.21 hectares in 2018, while in 2019 - 350,891.41ha (Table 4.65). The data have been acquired from ArmForest SNCO and SPNAs.

Lands Converted to Forest Land (3B1b). These lands are in transition stage and as a result of land use change during the 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. During 2018-2019, no transfer of forest cultures to forest stands took place (Table 4.66).

4.3.5.2.1.1 Forest Land Remaining Forest Land (3B1a)

Consistent with 2006 IPCC Guidelines [Gen-1], GHG inventory for this sub-category involves estimation of changes in carbon stock from live biomass, dead organic substances, soil. However, because of lack of complete data, the estimation of changes in carbon stock were done for above-ground and below-ground/live biomass/ biomass only.

This sub-category is a key source for carbon absorption/loss, which accounts for 99.7 % of the annual carbon absorption and 100% of annual carbon loss.

Methodology

The annual change in carbon stocks in biomass was estimated using the gain-loss method.

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].

$$\Delta C_G = \Sigma ij \, (A \bullet G_{TOTAL} \bullet CF)$$

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, construction timber removals, fuel wood gathering, and disturbances.

As mostly country-specific data were used (wood annual average growth, basic wood density, etc.), calculated based on findings from the regional surveys (LUCFRef - 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 2018-2019, the data on harvested wood provided by “ArmForest” SNCO (“Forestry” branches) and SPNAs (“Sevan”, “Dilijan” National Parks), “Biosphere complex” SNCO, as well as illegal harvest/logging discovered by various state institutions (“ArmForest” SNCO, SPNAs, Environmental Protection and Mining Inspection Body) as a result of annual inspections, have been studied [LUCFref.1, LUCFref.2, LUCFref.4].

Emission factors

The average annual above-ground biomass growth for a specific woody vegetation type (GW):

$GW = 0.835$ d.m.t/ha

The GW was derived from the regional surveys and has been calculated based on biomass annual average growth of forest covered and tree species areas [Ref-8, LUCFref. 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22].

It has been calculated based on biomass annual average growth per 1 ha of forest covered areas – 1.5m^3 (Annex 3.3, Table 3.3.2) and basic wood density - 0.557 oven-dry tonnes/moist cubic meter according to tree varieties (Annex 3.3, Table 3.3.1).

$GW = 1.5$ m^3/ha x 0.557 oven-dry tonnes/moist m^3 = 0.835 tonnes d.m./ha.

GW estimated factor for Armenia per the default values of the Guidelines shows that the figure is in the ecological zone of temperate mountain systems [Gen-1, Volume 4, Chapter 4, Table 4.9].

$R = 0.23$ tonne d.m. /(tonne d.m.) for above-ground mass 75-150 t/ha

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.

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

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

Carbon fraction in dry matter 0.48 tonne C/ (tonne d.m) is taken from IPCC 2006 Guidelines [Gen-1, Volume 4, Chapter 4, Table 4.3], which has been chosen per temperate climatic zone.

As a result, in the forest lands remaining lands sub-catergory for 2018-2019 we have the following:

ΔC_G (2018) = (350,891.21 - 940.4) ha x 1.02705 tonne dry matter/ha x 0.48 tonne C/ (tonne dry matter) = 172,520.1 tonne C/annual

ΔC_G (2019) = (350,891.41 - 940.4) ha x 1.02705 tonne dry matter/ha x 0.48 tonne C/ (tonne dry matter) = 172,520.2 tonne C/annual.

The annual change in carbon stocks

The estimation of annual change in carbon stock in biomass for 2018-2019 is introduced below.

Table 4.62 Annual increase in biomass carbon stock (includes the above-ground and below-ground biomass)

Estimation year	2018
Covered area, ha	349,950.81
Biomass annual average growth per 1 ha, m^3	1.5
Carbon annual gains, C t/year	172,520.15
Annual volume of harvested fuelwood and detected illegal logging /including fallen wood, m^3	90,146.41
Annual volume of timber harvested, m^3	4,018.18
Annual carbon loss, C t/year	30,966.3

Estimation year	2019
Covered area, ha	349,951.01
Biomass annual average growth per 1 ha, m^3	1.5
Carbon annual gains, C t/year	172,520.2
Annual volume of harvested fuelwood and detected illegal logging /including fallen wood, m^3	152,270.57
Annual volume of timber harvested, m^3	1,815.98
Annual carbon loss, C t/year	5,0671.8

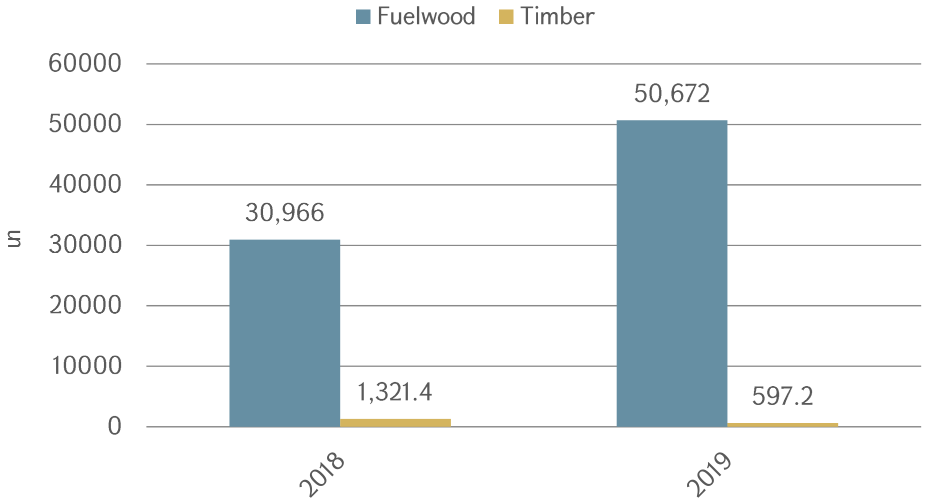


Figure 4.52 2018-2019 annual carbon loss in biomass due to the harvested fuelwood and timber including illegal logging/commercial felling

As the Figure data indicate 95.8% carbon loss in 2018 is due to harvested fuelwood and 4.2 %- due to harvested timber, while in 2019 this index makes 98.9 % and 1.1 %, respectively.

Time series

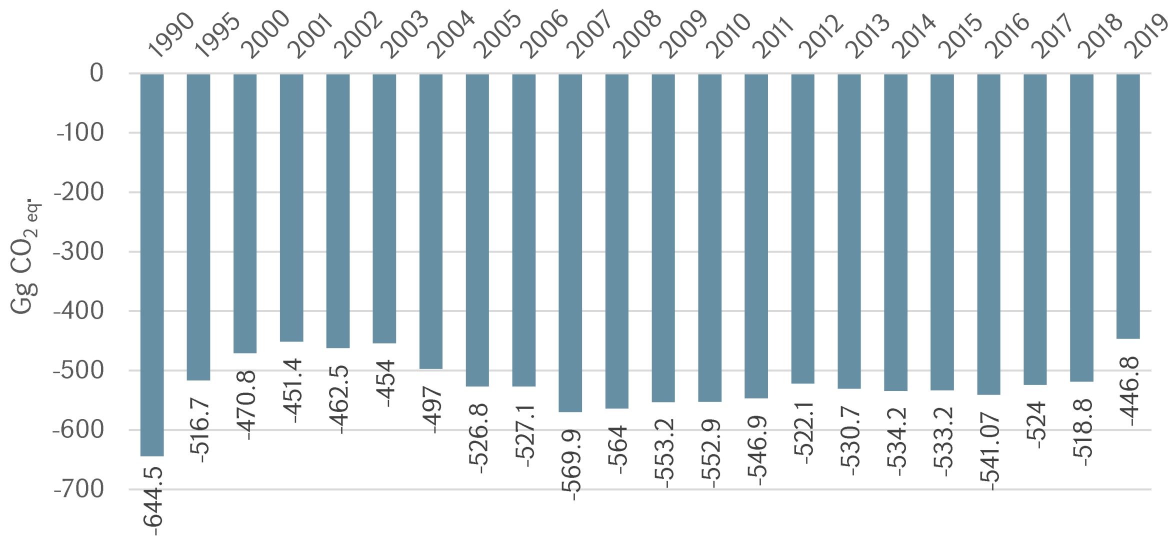


Figure 4.53 Carbon dioxide removals in *Forest Land Remaining Forest Land* sub-category

Decrease in removals in 2019 is due to increased volume of the harvested wood and commercial felling.

4.3.5.2.1.2 Land Converted to Forest Land (3B1b)

Land Converted to Forest Land subcategory [Gen-1] refers to non-forest areas and lands (grasslands, pastures, etc.) converted to forest land as a result of afforestation activity (forest cultures establishment) and natural afforestation, which takes up the previous 20 years of the reporting 2018 and 2019 years.

The subcategory hasn't undergone any changes since 2017 [Ref-8, LUCFref.5] (see Table 4.63).

Methodology

GHG emissions and removals have been estimated by applying Tier 2 of biomass gain and loss method.

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 4.63), therefore the weighted average factors derived for carbon stock change in living biomass mainly refer to pine trees.

Table 4.63 Area of tree species under *Lands Converted to Forest Land* sub-category, 2019

N/N	Species	Covered 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.

As already mentioned *"Lands Converted to Forest Lands"* subcategory has a 20-year history and this category is the result of afforestation activities carried out in the pastures of Forest Stock. Hence, these areas do not yet have the status, which would assume harvesting that results 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 4.64 Annual change in carbon stock of living biomass (including aboveground and belowground biomass)

Year	2018
Covered area, ha	940.4
Biomass annual average growth per 1 ha, m^3	1.5
Carbon annual gains, C t/year	463.6
Year	**2019**
Covered area, ha	940.4
Biomass annual average growth per 1 ha, m^3	1.5
Carbon annual gains, C t/year	463.6

Improvements required

Considering the circumstance that complete assessment and inventory activities of the RA forests have been absent for the last 20-25 years, information on woodstock, area occupied by tree species, on accumulated stock, on annual average growth, etc. is missing.

Activity data, in particular, on deforestation, afforestation, reforestation, and on disturbances caused by fire are lacking. However, upon the procedures stated by the law, in forest areas the trees damaged by fire prior to their growth termination, are harvested per their usability (timber, fuelwood, fallen wood) in the following years.

Data on biomass loss in the areas affected by pests and diseases are also uncertain. The highest uncertainties are related to the forest cover area, wood volume removed from the forests and fire-induced wood loss.

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.

4.3.5.2.2 - 4.3.5.2.6 Cropland, Grassland, Wetlands, Settlements and Other Land

For Armenia, Land Use categories and conversions between them are described by a complex approach, including the Land Use and the character of conversion, areas of the lands, cultivated crops and biophysical indicators (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 year is made based on land balances and land conversion data provided by the Cadastre Committee. Distribution of agricultural land according to the crop types in the categories *Cropland* and *Grassland* is based on the agricultural crops sown areas data published by the SC of the RA.

CO_2 emissions and removals are assessed based on the carbon stock change in the biomass and in dead organic matter, and in natural soils – based on organic carbon stock change by using Gain-Loss Method.

4.3.5.2.2 Cropland (3B2)

Emissions assessment for *Cropland* category are performed 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 grains, cereals, root vegetables, truck crops, melons and gourds, technical and forage crops. Perennial crops include areas covered by trees and shrubs that do not meet the threshold criteria for the *Forest Land* category, perennials (fruit, berry and grape orchards) and plantations. The 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)

This category is not a major source of emissions/removals. Carbon stock change in biomass is estimated based on carbon Gain-Loss Method using *the 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 aligning national classification of lands with the Land Use categories of the 2006 IPCC Guidelines

Lands are subdivided according to three global climatic zones available in Armenia: warm moderate dry, cold moderate dry and cold moderate humid. In their turn, the annual crops are classified from the viewpoint of the GHG Inventory compilation and in accordance with Armenian agricultural practices. CO_2 emissions and removals are estimated that are consequent to the changes of carbon stocks in biomass and of organic carbon in mineral natural soils. There are no organic soils in Armenia, so no emissions are calculated from this sub-category.

The Tier 1 method assumes that the carbon stocks are not present in dead wood and plant litter in Cropland or are at an equilibrium; therefore, there is no need to assess the carbon stock changes for these pools.

Land Converted to Cropland (3B2b)

As a result of the inventory preparations in 2018 and 2019, according to the data of the

Cadastre Committee, the conversions fto the category of agricultural lands from other categories made 230 ha and 35 ha, respectively.

4.3.5.2.3 Grassland (3B3)

This category is not a major source of emissions/removals. The lands' area under the *Grassland* sub-category was adjusted both in 2018 and in 2019 in accordance with "The Procedure for the Classification of the Land Coverage of the Republic of Armenia" (approved by the GoA decision #431-N of April 11, 2019).

GHG emissions/removals from the *Grassland* category are mainly caused by changes of carbon stocks in biomass and natural soils (organic matter), caused by the management practices of pastures and meadows and by changes in those practices.

Emissions and removals from the *Grassland* sub-category are assessed for 3B3a *Grassland Remaining Grassland* and 3B3b *Land Converted to Grassland* sub-categories.

Greenhouse gas emissions and removals for the *Grassland Remaining Grassland* sub-category are estimated *using the Tier-1 method*. Considering the fact that, firstly, there is no data on the management practices and intensity of use of grassland in Armenia, and secondly, this category is not the main source of GHG emissions, the estimations rely on the assumption of the stability of the biomass or the absence of any change, as recommended by the Guidelines. Emissions and removals in this subcategory are estimated based on the carbon stocks changes in mineral natural soils.

The scope of the territorial coverage of the land plots' areas in this category is estimated by the three tier methods set forth by the Guidelines, using which the plots are stratified and included in the Inventory according to the three climatic zones and soil types. Such a stratification of plots is the first of the required conditions to perform the emission assessment by *the Tier-2 method*, but it is not sufficient, because there is a lack of information on the types of pastures, intervention and management regimes and other factors that significantly affect both biomass and the growth of carbon stocks' 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 organic carbon stock change in mineral natural soils.

4.3.5.2.4 Wetlands (3B4)

In Armenia, wetlands cover around 1800 km^2, which is 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, swamps and peatlands. The area of peatlands (mires) is estimated at 42 km^2, or only 0.14% of the country's territory.

The total area of wetlands is 9,852.6 ha, of which the area of peatlands used for peat extraction is 489 ha.

Methodology

The emissions' assessment relies on the 2006 IPCC Guidelines [Gen-1] and the 2013 Supplement to the 2006 Guidelines: Wetlands [Gen-3].

In this sub-category, GHG emissions are assessed for 3.B.4.a.i Peatlands Remaining peatlands and 3.B.4.a.ii Flooded Land Remaining Flooded Land categories, using *the Tier-1 method*.

Total CO_2 emissions from the *Wetlands* category 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 managed Peatlands, Gg CO_2 yr-1

CO_2w_flood = CO_2 emissions from Flooded areas, Gg CO_2 yr-1

The emissions are assessed using the Tier 1 method of the 2006 IPCC Guidelines, based on the country-specific activity data and on the emission factors recommended by the Guidelines.

Activity data

The activity data sources are the SC, Archive of Geological Fund SNCO of the Ministry of Territorial Administration and Infrastructure, scientific literature, field visits and interviews.

Peatlands

Peat occurs on 1.5% of the territory of Armenia. Peatlands are of lowland origin and are 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 mires. Peat stocks are estimated at 1,005,375 tones. Armenian peat is used as fertilizer, fuel, in balneology and an exports item.

The official data on peat extractions varies significantly by year.

In 2018, the volume of peat extracted made 5,807.25 tons and surged in 2019, reaching 18,148.15 tons [AFOLURef-8, AFOLURef-9].

Flooded lands

Flooded lands in Armenia are almost entirely represented by reservoirs built for hydropower generation, irrigation and potable water extraction.

The 2006 IPCC Guidelines recommend Equation 7.10 [Gen-1, Volume 4] to estimate CO_2 emissions from areas converted to wetlands. Since 2017, there have been no land conversions from any land category to wetlands, so no emissions have been recorded.

Selection of emission factors

Peatlands

The total emissions from peatlands are assumed to be constant for the entire period due to the lack of data on the status of industrial peatlands ready for extraction.

Due to changes in the carbon stocks consequent to drainage, the emission factor is 2.8 tons C ha^{-1} $year^{-1}$, and the carbon content of air-dried peat is 0.45 tons per ton of C. Since Armenia's peat is in high demand in the horticultural sector and is quite expensive, it is assumed that all peat mined is used as fertilizer.

Emissions estimation

Carbon emissions are estimated using the $CO_2 – C^2$ formula for the emissions from managed peatlands [Gen-1, Volume 4, Equation 7.3].

4.3.5.2.5 Settlements (3B5)

This category is not a major source of emissions/removals. According to the Guidelines, the *Settlements* category includes natural soils, perennial vegetation, such as public and private gardens and groves, trees in rural areas, along streets, around suburban cottages, and such – provided they are not included in other land use categories.

In the National GHG Inventory of Armenia, according to with "The Procedure for the Classification of the Land Coverage of the Republic of Armenia" (approved by the GoA decision #431-N of April 11, 2019), home garden plots and areas under orchards are included into the *Cropland* category, and lands for public development, mixed development and general use are a part of *Grassland* category, because their characteristics are considered relevant.

In the *Settlements Remaining Settlements* category, carbon pools are aboveground and belowground biomass, dead organic matter, and soils. For all pools in this category, emissions are estimated using *the Tier-1 method*, which assumes no change in carbon stocks, according to the 2006 IPCC Guidelines, in other words that the Gain-Loss conditions are balanced.

The *Land Converted to Settlements* category implies origination of new emissions and removals. Carbon losses and removals due to land conversions to the *Settlements* category is estimated using *the Tier-1 method* and accounting for all carbon pools, that is, aboveground and belowground biomass and dead organic matter.

4.3.5.2.6 Other Lands (3B6)

In accordance with "The Procedure for the Classification of the Land Coverage of the Republic of Armenia" (approved by the GoA decision #431-N of April 11, 2019), lands considered as without vegetation (shores of lakes and rivers, sand dunes, bare rocks and bedrocks) are now included in this category of land use: 80 percent of other agricultural lands, 80 percent of land plots in other forest lands, a part of for entrails-use and special purpose lands, areas of natural lakes and ponds in specially protected areas, coastal areas of water lands, areas of rivers and canals, reserve lands and other lands not subject to management, which are not included in the previous five categories.

Data availability enables verification and adjustment of the areas of common land plots, matching them to the entire surface of the country. For instance, other agricultural lands are other lands intended for agricultural purposes, but not used: salt marshes, sand dunes, gorges, ravines, stony areas, as well as field roads. This category also includes unused/unmanaged forest lands as well as unmanaged water areas.

4.3.5.3 General pattern of emissions/removals from the *Lands* sub-sector

In 2018 and 2019, as in the previous years, the *Lands* category generally functioned as a sink with the net removals at -458.07 and -375.83 CO2 eq., respectively (Table 4.65 and 4.66), consequent to Armenia’s forests being CO_2 sinks, expectedly.

The results are presented according to the Good Practice Guidance 2003 for the *Land Use, Land Use Change and Forestry* sector [Gen-7].

Table 4.65 Emissions/removals of CO_2 and non-CO_2 gases in the *Land Use and Land Use Change* category in 2018

Land use categories			Annual change in carbon stock and CO_2 emissions				CH_4	N_2O	NOx	CO
Previous land use	Land use in the reporting year	IPCC Guidelines	Biomass	Dead organic matter	Natural soils	CO_2 emissions/removals D = (A+B+C) • (-44/12)	(Gg)	(Gg)	(Gg)	(Gg)
			A	B	C	D				
			ΔCLF_{LB}	ΔCLF_{DOM}	ΔCLF_{SOM}					
Forest land	Forest land	5A	141.480			-518.761				
Cropland	Forest land	5A, 5C, 5D	0.464	1.317		-6.527				
Grassland	Forest land	5A, 5C, 5D								
Wetlands	Forest land	5A, 5C, 5D								
Settlements	Forest land	5A, 5C, 5D								
Other Land	Forest land	5A, 5C, 5D								
		Total Forest land	**141.944**	**1.317**		**-525.288**				
Cropland	Cropland	5A, 5D	-0.183			0.670				
Forest land	Cropland	5B, 5D								
Grassland	Cropland	5B, 5D			2.029	-7.438				
Wetlands	Cropland	5D								
Settlements	Cropland	5D			-0.012	0.042				
Other Land	Cropland	5D								
		Total Cropland	**-0.183**		**2.017**	**-6.726**				
Grassland	Grassland	5A, 5D								
Forest land	Grassland	5B, 5D								
Cropland	Grassland	5C, 5D	-5.009			18.366				
Wetlands	Grassland	5C, 5D								
Settlements	Grassland	5C, 5D								
Other Land	Grassland	5C, 5D								
		Total Grassland	**-5.009**			**18.366**				
Wetlands	Wetlands	5A, 5E				11.554		0.0014		
Forest land	Wetlands	5B								
Cropland	Wetlands	5E								
Grassland	Wetlands	5B								
Settlements	Wetlands	5E								
Other Land	Wetlands	5E								
		Total Wetlands				**11.554**		0.0014		
Settlements	Settlements	5A								
Forest land	Settlements	5B								
Cropland	Settlements	5E								
Grassland	Settlements	5B	-4.624		0.040	16.809				
Wetlands	Settlements	5E								
Other Land	Settlements	5E								
		Total Settlements	**-4.624**	**0.000**	**0.040**	**16.809**				
Other Land	Other Land	5A								
Forest land	Other Land	5B	-7.140			26.180				

Land use categories			Annual change in carbon stock and CO_2 emissions				CH_4	N_2O	NOx	CO
Previous land use	Land use in the reporting year	IPCC Guidelines	Biomass	Dead organic matter	Natural soils	CO_2 emissions/removals D = (A+B+C) • (-44/12)	(Gg)	(Gg)	(Gg)	(Gg)
			A	B	C	D				
			ΔCLF_{LB}	ΔCLF_{DOM}	ΔCLF_{SOM}					
Cropland	Other Land	5E								
Grassland	Other Land	5B								
Wetlands	Other Land	5E								
Settlements	Other Land	5E	-0.941			3.449				
		Total Other Land	**-8.081**			**29.629**				
		TOTAL	**124.047**	**1.354**	**2.057**	**-455.655**		**0.0014**		

Table 4.66 Emissions/removals of CO_2 and non-CO_2 gases in the *Land Use and Land Use Change* category in 2019

Land use categories			Annual change in carbon stock and CO_2 emissions				CH_4	N_2O	NOx	CO
Previous land use	Land use in the reporting year	IPCC Guidelines	Biomass	Dead organic matter	Natural soils	CO_2 emissions/removals D = (A+B+C) • (-44/12)	(Gg)	(Gg)	(Gg)	(Gg)
			A	B	C	D				
			ΔCLF_{LB}	ΔCLF_{DOM}	ΔCLF_{SOM}					
Forest land	Forest land	5A	121.848			-446.778				
Cropland	Forest land	5A, 5C, 5D	0.464	1.317		-6.527				
Grassland	Forest land	5A, 5C, 5D								
Wetlands	Forest land	5A, 5C, 5D								
Settlements	Forest land	5A, 5C, 5D								
Other Land	Forest land	5A, 5C, 5D								
		Total Forest land		**1.317**		**-453.305**				
Cropland	Cropland	5A, 5D	-0.183			0.670				
Forest land	Cropland	5B, 5D								
Grassland	Cropland	5B, 5D			2.029	-7.438				
Wetlands	Cropland	5D								
Settlements	Cropland	5D			-0.012	0.042				
Other Land	Cropland	5D								
		Total Cropland			**2.017**	**-6.726**				
Grassland	Grassland	5A, 5D								
Forest land	Grassland	5B, 5D								
Cropland	Grassland	5C, 5D	-5.009			18.366				
Wetlands	Grassland	5C, 5D								
Settlements	Grassland	5C, 5D								
Other Land	Grassland	5C, 5D								
		Total Grassland		**0.000**	**0.000**	**18.366**				
Wetlands	Wetlands	5A, 5E				31.917		0.0014		
Forest land	Wetlands	5B								
Cropland	Wetlands	5E								
Grassland	Wetlands	5B								
Settlements	Wetlands	5E								
Other Land	Wetlands	5E								
		Total Wetlands				**31.917**		**0.0014**		
Settlements	Settlements	5A								
Forest land	Settlements	5B								
Cropland	Settlements	5E								
Grassland	Settlements	5B	-1.897		0.063	6.727				
Wetlands	Settlements	5E								
Other Land	Settlements	5E								
		Total Settlements			**0.063**	**6.727**				

Land use categories			Annual change in carbon stock and CO_2 emissions				CH_4	N_2O	NOx	CO
Previous land use	Land use in the reporting year	IPCC Guidelines	Biomass	Dead organic matter	Natural soils	CO_2 emissions/removals D = (A+B+C) • (-44/12)	(Gg)	(Gg)	(Gg)	(Gg)
			A	B	C	D				
			ΔCLF_{LB}	ΔCLF_{DOM}	ΔCLF_{SOM}					
Other Land	Other Land	5A								
Forest land	Other Land	5B	-0.941			3.449				
Cropland	Other Land	5E	-7.140			26.180				
Grassland	Other Land	5B								
Wetlands	Other Land	5E								
Settlements	Other Land	5E								
		Total Other Land	**-8.081**			**29.629**				
		TOTAL	**107.142**	**1.317**	**2.080**	**-373.392**		**0.0014**		

Table 4.67 shows the assessment of net GHG flows from the *Land* category in 2018 and 2019 expressed in CO_2 equivalent.

Table 4.67 Estimates of emissions/removals from the *Land* sub-category in 2018 and 2019

Categories	2018 (Gg)			2019 (Gg)		
	Net CO_2 emissions/removals	Emissions CH_4	N_2O	Net CO_2 emissions/removals	Emissions CH_4	N_2O
3.B Land	-455.65		0.0014	-373.39		0.0014
3.B.1 Forest land	-525.29			-453.30		
3.B.1.a Forest land Remaining Forest land	-518.76			-446.78		
3.B.1.b Land Converted to Forest land	-6.53			-6.53		
3.B.1.b.i Cropland Converted to Forest land	-6.53			-6.53		
3.B.2 Cropland	-6.73			-6.73		
3.B.2.a Cropland Remaining Cropland	0.67			0.67		
3.B.2.b Land Converted to Cropland	-7.40			-7.40		
3.B.2.b.i Forest Land converted to Cropland	0.0			0.0		
3.B.2.b.ii Grassland converted to Cropland	-7.44			-7.44		
3.B.2.b.iii Wetlands converted to Cropland	0.0			0.0		
3.B.3.b.iv Settlements converted to Cropland	0.04			0.04		
3.B.2.b.v Other Land converted to Cropland	0.0			0.0		
3.B.3 Grassland	18.37			18.37		
3.B.3.a Grassland Remaining Grassland	0.0			0.0		
3.B.3.b Land Converted to Grassland	18.37			18.37		
3.B.3.b.i Forest Land converted to Grassland	0.0			0.0		
3.B.3.b.ii Cropland converted to Grassland	18.37			18.37		
3.B.3.b.iii Wetlands converted to Grassland	0.0			0.0		
3.B.3.b.iv Settlements converted to Grassland	0.0			0.0		
3.B.3.b.v Other land converted to Grassland	0.0			0.0		
3.B.4 Wetlands	11.55		0.014	31.92		0.014
3.B.4.a Wetlands Remaining Wetlands	11.55		0.014	31.92		0.014
3.B.4.a.i Peatlands remaining peatlands	11.55		0.014	31.92		0.014
3.B.5 Settlements	16.81			6.73		
3.B.5.a - Settlements Remaining Settlements						
3.B.5.b - Land Converted to Settlements	16.81			6.73		
3.B.5.b.ii - Cropland converted to Settlements	0.0			0.0		
3.B.5.b.iii Grassland converted to Settlements	16.81			6.73		
3.B.6 Other land	29.63			29.63		
3.B.6.b - Land Converted to Other land	29.63			29.63		
3.B.6.b.i - Forest land converted to Other Land	3.45			3.45		
3.B.6.b.ii - Cropland converted to Other Land	26.18			26.18		

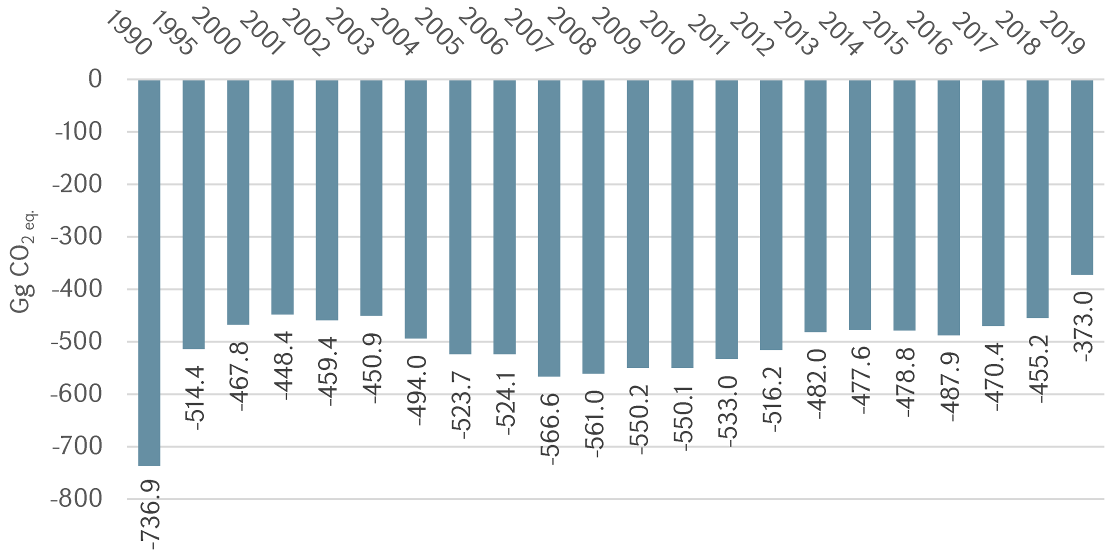


Figure 4.54 Time series of emissions/removals from the *Land* sub-category in 1990-2019, Gg $CO_{2\ eq.}$

4.3.5.4 Quality Control/Quality Assurance procedures

The quality in the *Land* category is strongly influenced by the level of uncertainty in the baseline data.

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, total 9 categories. The alignment with the GHG Inventory categories and data estimation are performed based on the official statistics on the agricultural lands as published by the SC and Ministry of Economy of the RA. With the help of the same data, the distribution of the *Cropland* is distributed according to the types of crops, actual unused areas, climatic zoning, and such.

4.3.5.5 Completeness of data and uncertainty analysis

Uncertainties in the *Forestry* sub-category is mostly due to the lack of complete and accurate information on the changes in the forest covered areas, as well as because of the high uncertainty of the fuelwood volumes, which is the key challenge for the GHG Inventory. The lack of a coordinated mechanism for forest inventory has a negative impact on forest management planning, as well as on comprehensive reflection of the current qualitative and quantitative changes in the *Forestry* sub-category (in particular, on forest logging, afforestation, forest rehabilitation, burned forests, area exposed to infection and pests, etc.)

Uncertainties in *Other Land Use* are consequent to the ambiguities in the areas of land plots, also by the fact that the Government publishes the RA Land Balances as of July 1 each year, so some of the changes are left out of the balance of a given inventory year. In addition, while the results of the cadastral mapping and the data published by the Statistical Committee are the primary data source for the land balances approved by the Government, there are often differences between the two, as the experience shows, from which more uncertainties ensue. Other sources of uncertainties include the errors made during the cadastral mapping, double-counting, and the changes in the land use already made, but still pending registration.

4.3.6 Aggregate Sources and Non-CO_2 Emissions Sources on Land (3C)

Estimation methodology and selection of emission factors

This category provides estimations of methane, nitrous oxide, carbon monoxide emissions from burning biomass and vegetation residue in forest-covered areas, cropland and grassland, and of direct and indirect nitrous oxide emissions in managed lands from the application of organic and synthetic fertilizers to the natural soils and vegetation residue decomposition.

The estimations are performed using *the Tier 1 method*.

4.3.6.1 GHG Emissions from Biomass Burning (3C1)

Methane, nitrous oxide, and carbon monoxide emissions are estimated for forest lands (3C1a), croplands (3C1b), and grasslands (3C1c), using the data on forest lands and grasslands fires, also on the burning crops residue in croplands [AFOLURef-8, AFOLURef-9] and applying *the Tier-1 method*.

Table 4.68 GHG *Emissions from Biomass Burning* (3C1) in 2018

Categories	Activity data		Emissions					Information on carbon emissions in the form of CH_4 and CO	
	Unit	Value	CO_2, Gg	CH4, Gg biomass	N_2O, Gg	CO, Gg biomass	NOx, Gg	Biomass C Gg	DOM C Gg
3.C.1 Emissions from biomass burning				**0.154**	**0.005**	**5.118**	**0.143**	**2.309**	
3.C.1.a - Biomass burning in forest lands				0.010	0.001	0.228	0.006	0.105	
Area				0.010	0.001	0.228	0.006	0.105	
Irregular fires	ha	239		0.010	0.001	0.228	0.006	0.105	
3.C.1.b Biomass burning in cropland				0.141	0.004	4.790	0.130	2.158	
Biomass burning in Cropland category				0.141	0.004	4.790	0.130	2.158	
Controlled combustion	ha	13016		0.141	0.004	4.790	0.130	2.158	
3.C.1.c Biomass burning in grasslands				0.004	0.000	0.100	0.006	0.046	
Grassland Remaining Grassland sub-category				0.004	0.000	0.100	0.006	0.046	
Irregular combustion	ha	376.2		0.004	0.000	0.100	0.006	0.046	

Table 4.69 GHG *Emissions from Biomass Burning* (3C1) in 2019

Categories	Activity data		Emissions					Information on carbon emissions in the form of CH_4 and CO	
	Unit	Value	CO_2, Gg	CH4, Gg biomass	N_2O, Gg	CO, Gg biomass	NOx, Gg	Biomass C Gg	DOM C Gg
3.C.1 Emissions from biomass burning				**0.215**	**0.0083**	**6.411**	**0.181**	**2.909**	
3.C.1.a - Biomass burning in forest lands				0.079	0.0044	1.793	0.050	0.828	
Area				0.079	0.0044	1.793	0.050	0.828	
Irregular fires	ha	1880.8		0.079	0.0044	1.793	0.050	0.828	
3.C.1.b Biomass burning in cropland				0.131	0.0034	4.459	0.121	2.009	
Biomass burning in Cropland category				0.131	0.0034	4.459	0.121	2.009	
Controlled combustion	ha	12118		0.131	0.0034	4.459	0.121	2.009	
3.C.1.c Biomass burning in grasslands				0.006	0.0005	0.159	0.010	0.072	
Grassland Remaining Grassland sub-category				0.006	0.0005	0.159	0.010	0.072	
Irregular combustion	ha	596.2		0.006	0.0005	0.159	0.010	0.072	

4.3.6.2 Urea application (3C3)

Emissions of carbon dioxide, CO2, from the *Urea Application* sub-category are calculated using *the Tier-1 method*. Activity data on the synthetic fertilizers' application are used for the estimations, namely: volumes of urea (product code: 3102 10, 3102 90) from the product group of imported mineral or chemical nitrogen fertilizer (the assumption of the Guidelines is that all fertilizers are used within the year of their import), and the emission factors from urea application recommended by the Guidelines (Annex 3.4, Tables 3.4.1 and 3.4.2).

4.3.6.3 Direct N_2O Emissions from Managed Soils (3C4)

The following sources of nitrous oxide emissions, N_2O, are considered in this sub-category:

- Artificial nitrogen fertilizer – relying on the import volumes of chemical nitrogen were used [Ref-5], product code: 3102210000 – 3102900000) and N_2O emission factors from chemical nitrogen recommended by the Guidelines;
- Organic nitrogen used as fertilizer in the form of animal manure (including urine) – relying on the estimates of manure use as organic fertilizer (specific weights by total manure mass) and N_2O emission factors from organic manure recommended by the Guidelines;
- Nitrogen from manure, urine and poultry droppings remaining in the pastures – using the specific weight of the mass of manure and poultry droppings according to their management method and N_2O emission factors recommended by the Guidelines;
- Nitrogen in vegetation residues, including from nitrogen-fixing crops and forage crops; to obtain an estimate of vegetation residue volumes, the data on land plots and collected dry mass are used with the emission factors provided by the Guidelines (Appendix 3.4, Tables 3.4.1 and 3.4.2).

Table 4.70 *Direct N_2O Emissions from Managed Soils* (3C4) in 2018, by category

Categories	Activity data		Emissions
	Total amout of applied nitrogen (kg N/year)	Area (ha)	N_2O (Gg)
3.C.4 - Direct N_2O Emissions from Managed Soils	**92,215,306.6**	**1,678,673.4**	**2.069**
Synthetic N fertilizers application	33,524,616.7		0.527
Organic N applied as fertilizer (animal manure and wastewater sludge)	13,548,301.5		0.213
Urine and dung N deposited on pasture, range and paddock by grazing animals	43,377,835.6		1.275
N in crop residues	1,764,552.8		0.028
N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils		1,678,673.4	0.026
Drainage/management of organic soils (i.e., histosols)			

Table 4.71 *Direct N_2O Emissions from Managed Soils* (3C4) in 2019, by category

Categories	Activity data		Emissions
	Total amout of applied nitrogen (kg N/year)	Area (ha)	N_2O (Gg)
3.C.4 - Direct N_2O Emissions from Managed Soils	**130,447,181.9**	**1,729,033.6**	**2.668**
Synthetic N fertilizers application	71,087,094.7		1.117
Organic N applied as fertilizer (animal manure and wastewater sludge)	14,432,841.77		0.227
Urine and dung N deposited on pasture, range and paddock by grazing animals	43,245,626.58		1.270
N in crop residues	1,681,618.8		0.026
N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils		1,729,033.6	0.027
Drainage/management of organic soils (i.e., histosols)			

The sharp increase in emissions in 2019 is due to a nearly two-fold growth in the volumes (activity data are presented in Annex 3.4, Tables 3.4.1 and 3.4.2).

4.3.6.4 Indirect N_2O Emissions from Managed Soils (3C5, 3C6)

The following sources of nitrous oxide emissions, N_2O, are considered in this sub-category:

- mineral or chemical N fertilizers;
- organic N applied as fertilizer (for instance, animal manure, compost, organic waste and others);
- urea and dung N deposited on pasture, range and paddock by grazing animals;
- N in crop residues, including N-fixing crops and forage crops.

N_2O emissions from atmospheric deposition of volatile nitrogen from croplands are estimated by formula 11.9, and N_2O emissions from leaching and runoff – by formula 11.10 [Gen-1, Volume 4, Chapter 11].

Indirect N_2O emissions due to leaching and runoff from manure management were 52,603.46 kg N_2O/year in 2018 and 53,226.12 kg N_2O/year in 2019.

In 2018 and 2019, the volumes of both urea and chemical nitrogen fertilizer rose significantly in comparison to the indicators of previous years; consequently, the nitrous oxide emissions also increased.

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 nitrate has a leading role among 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 nitrate can be used for fertilizing all agricultural crops. For example, the proportion of nitrogen fertilizers for grains/cereals 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 recorded in Armenia in recent years, the expansion of export opportunities, state support (for instance, subsidies for fertilizer procurement), and increase in farm incomes have contributed to the rising volumes of synthetic fertilizers' application in plant cultivation.

Table 4.72 Indirect N_2O Emissions from Managed Soils and from Manure Management (3C5, 3C6) in 2018

Categories	Activity data	Emissions
	Total amount of applied / leached nitrogen (kg N / year)	N_2O (Gg)
3.C.5 - Indirect N_2O Emissions from Managed Soils		**0.564**
N_2O emissions from atmospheric deposition of volatile nitrogen from croplands due to agricultural inputs (synthetic N fertilizers; organic N applied as fertilizer; urine and dung N deposited on pasture, range and paddock by grazing animals).	90.451	0.232
N from managed soils due to leaching/runoff (i.e. synthetic N fertilizers, organic N as fertilizer, urine and dung N accumulated in pasture, range and paddock from grazing animals; N in crop residues; N mineralization/immobilization due to loss/gain of soil organic matter resulting from change of land use or management of mineral soils)	93.894	0.332
3.C.6 - Indirect N_2O Emissions from Manure Management		0.115

Table 4.73 Indirect N_2O Emissions from Managed Soils and from Manure Management (3C5, 3C6) in 2019

Categories	Activity data	Emissions
	Total amount of applied / leached nitrogen (kg N / year)	N_2O (Gg)
3.C.5 - Indirect N_2O Emissions from Managed Soils		**0.760**
N_2O emissions from atmospheric deposition of volatile nitrogen from croplands due to agricultural inputs (synthetic N fertilizers; organic N applied as fertilizer; urine and dung N deposited on pasture, range and paddock by grazing animals).	128.766	0.293
N from managed soils due to leaching/runoff (i.e. synthetic N fertilizers, organic N as fertilizer, urine and dung N accumulated in pasture, range and paddock from grazing animals; N in crop residues; N mineralization/immobilization due to loss/gain of soil organic matter resulting from change of land use or management of mineral soils)	132.176	0.467
3.C.6 - Indirect N_2O Emissions from Manure Management		0.116

Summary of emissions data

Tables 4.74 and 4.75 show the resulting data on the emissions from the *Aggregate Sources and Non-CO_2 Emissions Sources on Land* category in 2018 and 2019, expressed in CO_2 equivalent.

Table 4.74 Emissions from the *Aggregate Sources and Non-CO_2 Emissions Sources on Land* sector in 2018

IPCC Categories	Net CO_2 emissions/ removals	Emissions			
		CH_4	N_2O	NOx	CO
3.C Aggregate sources and non-CO_2 emissions sources on land	4.426	0.154	2.753	0.143	5.118
3.C.1 Emissions from biomass burning		0.154	0.005	0.143	5.118
3.C.1.a Biomass burning in forest lands		0.010	0.001	0.006	0.228
3.C.1.b Biomass burning in cropland		0.141	0.004	0.130	4.790
3.C.1.c Biomass burning in grasslands		0.004	0.0003	0.006	0.100
3.C.3 Urea application	4.426				
3.C.4 Direct N_2O Emissions from managed soils			2.070		
3.C.5 Indirect N_2O Emissions from managed soils			0.564		
3.C.6 Indirect N2O Emissions from manure management			0.115		

Table 4.75 Emissions from the *Aggregate Sources and Non-CO_2 Emissions Sources on Land* sector in 2019

IPCC Categories	Net CO_2 emissions/ removals	Emissions			
		CH_4	N_2O	NOx	CO
3.C Aggregate sources and non-CO_2 emissions sources on land	5.507	0.215	3.553	0.181	6.411
3.C.1 Emissions from biomass burning		0.215	0.008	0.181	6.411
3.C.1.a Biomass burning in forest lands		0.079	0.004	0.050	1.793
3.C.1.b Biomass burning in cropland		0.131	0.003	0.121	4.459
3.C.1.c Biomass burning in grasslands		0.006	0.0005	0.010	0.159
3.C.3 Urea application	5.507				
3.C.4 Direct N_2O Emissions from managed soils			2.668		
3.C.5 Indirect N_2O Emissions from managed soils			0.760		
3.C.6 Indirect N2O Emissions from manure management			0.116		

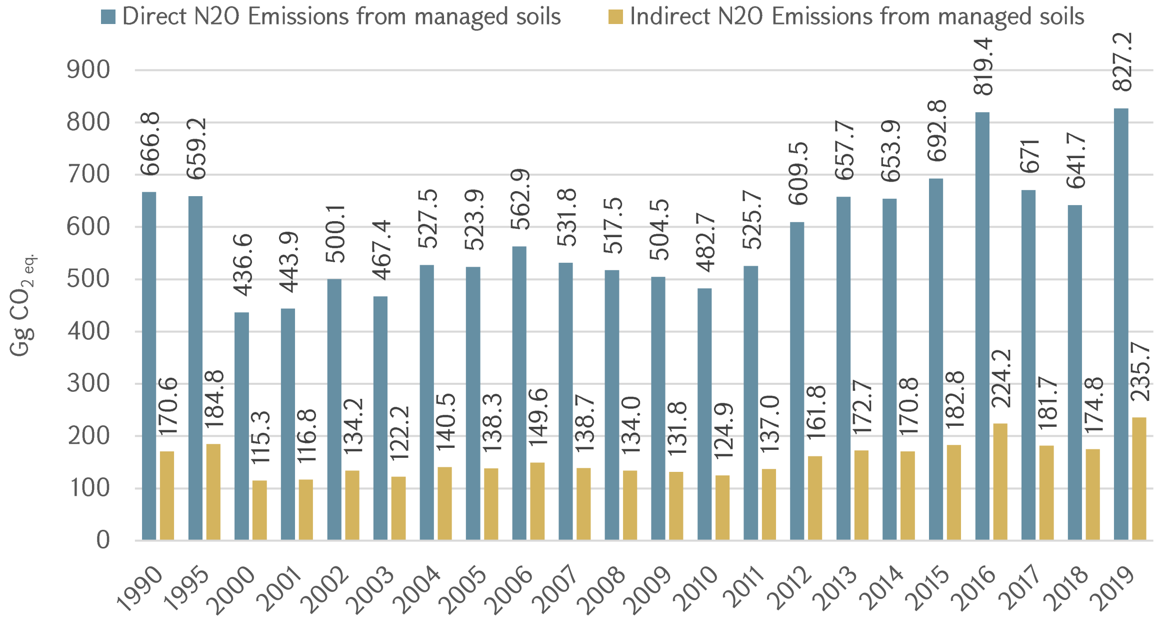


Figure 4.55 Dynamics of direct and indirect N_2O emissions in 1990-2019, Gg $CO_{2\ eq.}$

GHG emissions in CO_2 equivalent

Table 4.76 GHG emissions/removals from the *Agriculture, Forestry and Other Land Use* sector in 2018, in CO_2 equivalent (by classification format of the main sources)

IPCC Category Codes	Categories	GHG	2018 Ex,t (Gg $CO_{2\ eq}$)
3.A.1	Enteric Fermentation	CH_4	902.420
3.C.4	Direct N_2O Emissions from managed soils	N_2O	641.358
3.B.1.a	Forest land Remaining Forest land	CO_2	- 518.761
3.C.5	Indirect N_2O Emissions from managed soils	N_2O	174.708
3.A.2	Manure Management	N_2O	54.292
3.C.6	Indirect N_2O Emissions from manure management	N_2O	35.586
3.A.2	Manure Management	CH_4	34.544
3.B.6.b	Land Converted to Other land	CO_2	29.629
3.D.1	Harvested wood products	CO_2	-22.090
3.B.3.b	Land Converted to Grassland	CO_2	18.366
3.B.5.b	Land Converted to Settlements	CO_2	16.809
3.B.4.a.i	Peatlands remaining peatlands	CO_2	11.554
3.B.2.b	Land Converted to Cropland	CO_2	-7.396
3.B.1.b	Land Converted to Forest land	CO_2	-6.527
3.C.3	Urea application	CO_2	4.426
3.C.1	Emissions from biomass burning	CH_4	3.237
3.C.1	Emissions from biomass burning	N_2O	1.402
3.B.2.a	Cropland Remaining Cropland	CO_2	0.670
3.B.4.a.i	Peatlands remaining peatlands	N_2O	0.429

Table 4.77 GHG emissions/removals from the *Agriculture, Forestry and Other Land Use* sector in 2019, in CO_2 equivalent (by classification format of the main sources)

IPCC Category Codes	Categories	GHG	2019 Ex,t (Gg $CO_{2\ eq}$)
3.A.1	Enteric Fermentation	CH_4	900.624
3.C.4	Direct N_2O Emissions from managed soils	N_2O	827.044
3.B.1.a	Forest land Remaining Forest land	CO_2	-446.778
3.C.5	Indirect N_2O Emissions from managed soils	N_2O	235.699
3.A.2	Manure Management	N_2O	54.941

IPCC Category Codes	Categories	GHG	2019 Ex,t (Gg $CO_{2\ eq}$)
3.A.2	Manure Management	CH_4	36.996
3.C.6	Indirect N_2O Emissions from manure management	N_2O	36.083
3.B.4.a.i	Peatlands remaining peatlands	CO_2	31.917
3.B.6.b	Land Converted to Other land	CO_2	29.629
3.B.3.b	Land Converted to Grassland	CO_2	18.366
3.B.2.b	Land Converted to Cropland	CO_2	-7.396
3.B.1.b	Land Converted to Forest land	CO_2	-6.731
3.B.5.b	Land Converted to Settlements	CO_2	6.527
3.D.1	Harvested wood products	CO_2	-5.669
3.C.3	Urea application	CO_2	5.507
3.C.1	Emissions from biomass burning	CH_4	4.520
3.C.1	Emissions from biomass burning	N_2O	2.562
3.B.2.a	Cropland Remaining Cropland	CO_2	0.670
3.B.4.a.i	Peatlands remaining peatlands	N_2O	0.429

4.3.7 Harvested wood products (3D)

Sub-category description

According to 2006 IPCC Guidelines, there are different approaches to estimating emissions/removals from the production of harvested wood, based on the differences between the time period and location of carbon stocks in different wood species. According to the Guidelines, countries are free to choose their approach, although the production approach is preferred for GHG Inventory reporting under the Paris Agreement (PA). Estimates of emissions/removals from *Harvested wood products* (HWP) in this report are made using the production approach [Gen-1] (Volume 4, Chapter 12).

Harvested wood products create a separate carbon stock. The time carbon is held in wood products varies depending on the product and its uses. For example, fuelwood and mill residue may be burned in the year of harvest; many types of paper are likely to have a use life of less than 5 years which may include recycling of paper; and sawnwood or panels used in buildings may be held for decades. Discarded HWP can be deposited in solid waste disposal sites (SWDS) where they may persist for long periods of time. Due to this storage in products in use and in SWDS, the oxidation of harvested wood products in a given year could be less, or potentially more, than the total amount of wood harvested in that year.

Estimates of HWP contribution to the total emissions and removals volumes are designed to be consistent with those for other GHG sectors, specifically:

1. All CO_2 released from HWP is included in the AFOLU Sector;
2. CO_2 released from wood burnt for energy in the Energy Sector is not included in the Energy Sector totals (although CO_2 emissions from biofuels are reported as a memo item for QA/QC purposes). CH_4 and other gases from HWP used for energy is included in the Energy Sector;
3. CO_2 released from HWP in SWDS is not included in the totals of the Waste Sector's emissions/removals although CH_4 emissions from HWP are included.

Activity data and information sources

To estimate the contribution of harvested wood products to the total volumes of emissions/removals, the following **activity** data are used as collected from the publication of the country's official statistics.

1. Annual change in carbon stock in HWP in the reporting country, including HWP stocks from both domestic harvest and imports (Gg of carbon per year);

2. Annual change in carbon stock in HWP made from wood harvested in the reporting country including annual change in carbon stock in HWP exported to other countries (Gg of carbon per year);
3. Annual imports of all types of wood and paper material (Gg of carbon per year);
4. Annual exports of all types of wood and paper material (Gg of carbon per year);
5. Annual harvest for wood products (Gg of carbon per year).

Assessment method and estimation approach

Estimates of carbon release and storage from harvested wood products, according to the Production approach recommended by the Guidelines, are carried out based on the activity data of 1990-2019, using the first-order decay method (the software package allows to perform the calculations automatically and to use other approaches as well).

Activity data and estimation results are shown in Table 4.78.

Table 4.78 Carbon storage/release in Harvested Wood Products in 1990-2019[10]

Year	1A Annual Change in stock of HWP in use from consumption	1B Annual Change in stock of HWP in SWDS from consumption	2A Annual Change in stock of HWP in use produced from domestic harvest	2B Annual Change in stock of HWP in SWDS produced from domestic harvest	3 Annual Imports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/chips	4 Annual Exports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/chips	5 Annual Domestic Harvest	6 Annual release of carbon to the atmosphere from HWP consumption (from fuelwood & products in use and products in SWDS)	7 Annual release of carbon to the atmosphere from HWP (including fuelwoood) where wood came from domestic harvest (from products in use and products in SWDS)	8 HWP Contribution to AFOLU CO_2 emissions/removals
	ΔC HWP IU DC	ΔC HWP SWDS DC	ΔC HWP IU DH	ΔC HWP SWDS DH	Pim	Pex	H	↑C HWP DC	↑C HWP DH	
1990	0.011	0.003	0.002	0.009	0.014	0.005	0.000	-0.004	-0.011	-40.240
1991	0.011	0.003	0.002	0.010	0.014	0.005	0.000	-0.004	-0.012	-42.832
1992	0.011	0.003	0.002	0.010	0.015	0.005	0.000	-0.004	-0.012	-44.421
1993	0.011	0.003	0.002	0.012	0.016	0.005	0.000	-0.003	-0.013	-49.353
1994	0.011	0.003	0.002	0.013	0.017	0.005	0.000	-0.003	-0.014	-52.805
1995	0.012	0.003	0.002	0.014	0.017	0.005	0.000	-0.003	-0.016	-57.841
1996	0.013	0.003	0.003	0.015	0.019	0.005	0.000	-0.003	-0.018	-65.047
1997	0.014	0.003	0.003	0.017	0.020	0.006	0.000	-0.003	-0.020	-72.716
1998	0.016	0.003	0.004	0.018	0.022	0.006	0.000	-0.004	-0.022	-82.311
1999	0.017	0.004	0.005	0.020	0.024	0.007	0.000	-0.003	-0.024	-89.581
2000	0.019	0.003	0.006	0.021	0.026	0.007	0.000	-0.003	-0.026	-97.145
2001	0.022	0.003	0.007	0.022	0.030	0.008	0.000	-0.003	-0.030	-108.312
2002	0.010	0.003	0.007	0.025	0.027	0.014	0.000	-0.001	-0.032	-118.846
2003	0.021	0.003	0.008	0.026	0.025	0.004	0.000	-0.004	-0.035	-126.576
2004	0.026	0.003	0.007	0.021	0.033	0.005	0.000	-0.001	-0.028	-101.391
2005	0.031	0.003	0.005	0.014	0.041	0.004	0.000	0.004	-0.019	-69.758
2006	0.053	0.003	0.007	0.015	0.063	0.002	0.000	0.005	-0.021	-77.666
2007	0.055	0.003	0.002	0.013	0.071	0.002	0.000	0.010	-0.015	-56.069
2008	0.131	0.003	-0.007	0.002	0.159	0.001	0.000	0.024	0.004	15.507
2009	0.033	0.003	-0.005	0.007	0.063	0.001	0.000	0.026	-0.001	-4.374
2010	0.048	0.003	-0.002	0.004	0.099	0.001	0.000	0.046	-0.003	-10.840
2011	0.046	0.003	-0.004	0.003	0.075	0.000	0.000	0.025	0.001	4.393
2012	0.047	0.003	-0.003	0.004	0.079	0.000	0.000	0.029	0.000	-1.651
2013	0.040	0.003	0.000	0.005	0.073	0.000	0.000	0.030	-0.005	-16.515
2014	0.088	0.003	0.001	0.002	0.137	0.001	0.000	0.046	-0.003	-10.719
2015	0.036	0.003	0.001	0.005	0.080	0.002	0.000	0.039	-0.006	-22.068
2016	0.124	0.003	0.004	0.003	0.166	0.003	0.000	0.036	-0.007	-25.166
2017	0.079	0.000	0.003	0.004	0.124	0.003	0.000	0.042	-0.006	-24.086
2018	0.185	0.000	0.004	0.002	0.233	0.002	0.000	0.047	-0.006	-22.090
2019	0.187	0.000	0.001	0.001	0.245	0.002	0.000	0.056	-0.002	-5.669

[10] Approach used to estimate HWP Contribution: Production approach

4.3.8 General pattern of emissions from the Agriculture, Forestry and Other Land Use Sector

Tables 4.79 and 4.80 show the GHG emissions from the AFOLU sector in years 2018 and 2019, respectively.

Table 4.81 provides the time series of the emissions from the AFOLU sector.

Table 4.79 GHG emissions/removals from the Agriculture, Forestry and Other Land Use Sector in 2018

IPCC Category Codes	Categories	Emissions, Gg				
		Net CO_2 emissions/ removals	by gas			
			CH_4	N_2O	NOx	CO
3	**Agriculture, Forestry, and Other Land Use**	**- 473.319**	**44.771**	**2.928**	**0.143**	**5.118**
3.A	**Livestock**		44.617	0.175		
3.A.1	**Enteric Fermentation**		42.972			
3.A.1.a	Cattle		37.355			
3.A.1.a.i	Dairy Cows		20.690			
3.A.1.a.ii	Other Cattle		16.666			
3.A.1.b	Buffalo		0.050			
3.A.1.c	Sheep		4.773			
3.A.1.d	Goats		0.155			
3.A.1.f	Horses		0.187			
3.A.1.g	Mules and Asses		0.017			
3.A.1.h	Swine		0.419			
3A1j	Other (Rabbits, Fur bearing animals)		0.016			
3.A2	**Manure Management**		1.645	0.175		
3.A.2.a	Cattle		0.543	0.013		
3.A.2.a.i	Dairy Cows		0.292	0.006		
3.A.2.a.ii	Other Cattle		0.251	0.007		
3.A.2.b	Buffalo		0.001	0.00004		
3.A.2.c	Sheep		0.152	0.138		
3.A.2.d	Goats		0.003	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		0.838	0.010		
3.A.2.i	Poultry		0.080	0.012		
3A2j	Other (Rabbits, Fur bearing animals)		0.016	0.000		
3.B	**Land**	-455.655		0.0014		
3.B.1	**Forest land**	-525.288				
3.B.1.a	Forest land Remaining Forest land	-518.761				
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	0.000				
3.B.1.b.iii	Wetlands Converted to Forest land	0.000				
3.B.1.b.iv	Settlements Converted to Forest land	0.000				
3.B.1.b.v	Other Land Converted to Forest land	0.000				
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	0.000				
3.B.2.b.ii	Grassland converted to Cropland	-7.438				
3.B.2.b.iii	Wetlands converted to Cropland	0.000				
3.B.2.b.iv	Settlement converted to Croplands	0.042				
3.B.2.b.v	Other Land converted to Cropland	0.000				
3.B.3	**Grassland**	18.366				
3.B.3.a	Grassland Remaining Grassland	0.000				
3.B.3.b	Land Converted to Grassland	18.366				
3.B.3.b.i	Forest Land converted to Grassland	0.000				
3.B.3.b.ii	Cropland converted to Grassland	18.366				
3.B.3.b.iii	Wetlands converted to Grassland	0.000				
3.B.3.b.iv	Settlements converted to Grassland	0.000				
3.B.3.b.v	Other Land converted to Grassland	0.000				
3.B.4	**Wetlands**	11.554		0.0014		

IPCC Category Codes	Categories	Emissions, Gg				
		Net CO_2 emissions/ removals	by gas			
			CH_4	N_2O	NOx	CO
3.B.4.a	Wetlands Remaining Wetlands	11.554		0.0014		
3.B.4.a.i	Peatlands remaining peatlands	11.554		0.0014		
3.B.5	**Settlements**	16.809				
3.B.5.a	Settlements Remaining Settlements	0.000				
3.B.5.b	Land Converted to Settlements	16.809				
3.B.5.b.ii	Cropland converted to Settlements	0.000				
3.B.5.b.iii	Grassland converted to Settlements	0.000				
3.B.6	**Other land**	29.629				
3.B.6.a	Other land Remaining Other land					
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	26.180				
3.C	**Aggregate sources and non-CO_2 emissions sources on land**	4.426	0.154	2.752	0.143	5.118
3.C.1	Emissions from biomass burning		0.154	0.005	0.143	5.118
3.C.1a	Biomass burning in forest lands		0.010	0.001	0.006	0.228
3.C.1.b	Biomass burning in cropland		0.141	0.004	0.130	4.790
3.C.1.c	Biomass burning in grasslands		0.004	0.0003	0.006	0.100
3.C.3	Urea application	4.426				
3.C.4	Direct N_2O Emissions from managed soils			2.069		
3.C.5	Indirect N_2O Emissions from managed soils			0.564		
3.C.6	Indirect N_2O Emissions from manure management			0.115		
3.D	**Other**	**-22.090**				
3.D.1	Harvested wood products	-22.090				

Table 4.80 GHG emissions/removals from the *Agriculture, Forestry and Other Land Use* Sector in 2019

IPCC Category Codes	Categories	Emissions, Gg				
		Net CO_2 emissions/ removals	by gas			
			CH_4	N_2O	NOx	CO
3	**Agriculture, Forestry, and Other Land Use**	**- 373.555**	**44.864**	**3.731**	**0.181**	**6.411**
3.A	**Livestock**		44.649	0.177		
3.A.1	**Enteric Fermentation**		42.887			
3.A.1.a	Cattle		37.194			
3.A.1.a.i	Dairy Cows		20.567			
3.A.1.a.ii	Other Cattle		16.627			
3.A.1.b	Buffalo		0.049			
3.A.1.c	Sheep		4.777			
3.A.1.d	Goats		0.161			
3.A.1.f	Horses		0.199			
3.A.1.g	Mules and Asses		0.016			
3.A.1.h	Swine		0.478			
3A1j	Other (Rabbits, Fur bearing animals)		0.013			
3.A2	**Manure Management**		1.762	0.177		
3.A.2.a	Cattle		0.540	0.013		
3.A.2.a.i	Dairy Cows		0.290	0.006		
3.A.2.a.ii	Other Cattle		0.250	0.007		
3.A.2.b	Buffalo		0.001	0.00005		
3.A.2.c	Sheep		0.152	0.138		
3.A.2.d	Goats		0.004	0.003		
3.A.2.f	Horses		0.012	0.000		
3.A.2.g	Mules and Asses		0.001	0.000		
3.A.2.h	Swine		0.955	0.012		
3.A.2.i	Poultry		0.084	0.012		
3A2j	Other (Rabbits, Fur bearing animals)		0.013	0.00		
3.B	**Land**	-373.392		0.0014		
3.B.1	**Forest land**	-453.305				

IPCC Category Codes	Categories	Emissions, Gg				
		Net CO_2 emissions/ removals	by gas			
			CH_4	N_2O	NOx	CO
3.B.1.a	Forest land Remaining Forest land	-446.778				
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	0.000				
3.B.1.b.iii	Wetlands Converted to Forest land	0.000				
3.B.1.b.iv	Settlements Converted to Forest land	0.000				
3.B.1.b.v	Other Land Converted to Forest land	0.000				
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	0.000				
3.B.2.b.ii	Grassland converted to Cropland	-7.438				
3.B.2.b.iii	Wetlands converted to Cropland	0.000				
3.B.2.b.iv	Settlement converted to Croplands	0.042				
3.B.2.b.v	Other Land converted to Cropland	0.000				
3.B.3	**Grassland**	18.366				
3.B.3.a	Grassland Remaining Grassland	0.000				
3.B.3.b	Land Converted to Grassland	18.366				
3.B.3.b.i	Forest Land converted to Grassland	0.000				
3.B.3.b.ii	Cropland converted to Grassland	18.366				
3.B.3.b.iii	Wetlands converted to Grassland	0.000				
3.B.3.b.iv	Settlements converted to Grassland	0.000				
3.B.3.b.v	Other Land converted to Grassland	0.000				
3.B.4	**Wetlands**	31.917		0.0014		
3.B.4.a	Wetlands Remaining Wetlands	31.917		0.0014		
3.B.4.a.i	Peatlands remaining peatlands	31.917		0.0014		
3.B.5	**Settlements**	6.727				
3.B.5.a	Settlements Remaining Settlements	0.000				
3.B.5.b	Land Converted to Settlements	6.727				
3.B.5.b.ii	Cropland converted to Settlements	0.000				
3.B.5.b.iii	Grassland converted to Settlements	0.000				
3.B.6	**Other land**	29.629				
3.B.6.a	Other land Remaining Other land					
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	26.180				
3.C	**Aggregate sources and non-CO_2 emissions sources on land**	5.507	0.215	3.553	0.181	6.411
3.C.1	Emissions from biomass burning		0.215	0.008	0.181	6.411
3.C.1a	Biomass burning in forest lands		0.079	0.004	0.050	1.793
3.C.1.b	Biomass burning in cropland		0.131	0.003	0.121	4.459
3.C.1.c	Biomass burning in grasslands		0.006	0.001	0.010	0.159
3.C.3	Urea application	5.507				
3.C.4	Direct N_2O Emissions from managed soils			2.668		
3.C.5	Indirect N_2O Emissions from managed soils			0.760		
3.C.6	Indirect N_2O Emissions from manure management			0.116		
3.D	**Other**	**-5.530**				
3.D.1	Harvested wood products	-5.530				

Table 4.81 GHG emissions from the AFOLU sector in 1990-2019, Gg $CO_{2\ eq.}$

Category / Year	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
3A - Livestock	1,296.69	1,033.86	788.50	922.07	891.32	1,063.47	1,188.40	1,194.15	1,065.70	991.26	992.56
3B - Land	-736.89	-514.37	-467.77	-523.74	-550.08	-516.21	-477.61	-487.87	-470.43	-455.23	-372.96
3C - Aggregate sources and non-CO_2 emissions sources on land	789.03	898.40	585.48	699.50	643.58	811.42	870.35	1,089.44	900.29	860.72	1,111.41
3D1 Harvested wood products	-40.24	-57.84	-97.14	-69.76	-10.84	-1.65	-10.72	-25.17	-24.09	-22.09	-5.67
Total	1,308.59	1,360.05	809.07	1,028.07	973.98	1,357.03	1,570.42	1,770.55	1,471.48	1,374.66	1,725.34

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 incineration and 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 628.65 Gg $CO_{2\ eq.}$ in 2018 and 628.70 Gg $CO_{2\ eq}$ in 2019, which respectively makes 6.0% and 5.6 % of Armenia's total emissions.

4.4.2 Waste Sector description

The most part of emissions are methane emissions from the decomposition of municipal solid waste, making up 68% of Waste sector emissions and 5.3% of the country's total emissions in 2018 and 67% of Waste sector emissions and 4.9% of the country's total emissions in 2019.

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

- (4.A) Solid Waste Disposal (CH_4 emissions)
- (4.C) Incineration and Open Burning of Waste
  - (4.C.1) Incineration of Waste (CO_2, CH_4 and N_2O emissions)
  - (4.C.2) Open Burning of Waste (CO_2, CH_4, and N_2O emissions)
- (4.D) Wastewater Treatment and Discharge (CH_4,and N_2O emissions)
  - (4.D.1) Domestic Wastewater Treatment and Discharge (CH_4, N_2O emissions)
  - (4.D.2) Industrial Wastewater Treatment and Discharge (CH_4 emissions)

Other sources mentioned in IPCC 2006 Guideline are missing in Armenia.

4.4.3 Improvements

The following improvements were implemented within the framework of this report:

- *Improved accuracy*
  - Activity data of *Industrial Wastewater Treatment and Discharge* sub-category were adjusted during the calculations data on "Meat and Poultry", "Dairy Products", "Soap and Detergents", as well as "Starch Production" industrial sectors were checked and recalculation was performed for the entire time series.
- *Improved completeness*
  - A new sub-category *Incineration of Waste* (4.C.1) has been considered, where CO_2, CH_4 and N_2O emissions are assessed.
  - As a result of the conducted studies and official surveys, it was found out that *Biological Treatment of Solid Waste* (category 4.B) was not implemented in RA during the reporting period.

4.4.4 Key categories

In 2018 and 2019 Solid Waste Disposal (methane emissions) and *Wastewater Treatment and Discharge* (methane and nitrous oxide emissions) are identified as the key source categories of greenhouse gas (CH_4) emissions both with level and trend assessment.

4.4.5 Methane emissions from Solid Waste Disposal Site (4.A)

Choice of method

To estimate CH_4 emissions from Solid Waste Disposal (SWDS), the First Order Decay (hereinafter FOD) method is to be applied, considering the recommendation provided by the IPCC 2006 Guidelines [Gen-1, Volume 5]. This method assumes that the generation of methane in airless conditions changes over time, initially (up to 3-5 years) it has a minimum value, then increases, reaching its maximum value, and then decreases within 25-30 years. Half-lives for different types of waste may vary from a few years to several decades or longer.

According to IPCC 2006 Guideline [Gen-1], It is good practice to use disposal data for at least 50 years. This means that in order to avoid underestimated values for a given year, it is necessary to start the calculation by taking into account the waste deposited 50 years earlier. In Armenia, the lack of required activity data does not allow to make such accurate assessment for the Soviet period up to 90s.

FOD calculation is based on 3.1, 3.2, 3.4-3.7 equations [Gen-1, Volume 5, Chapter 3].

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 in the given year reliable local data on MSW morphology are required. In recent decades, an increase in the 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 (DOCf) was selected 0.5 [Gen-1, Volume 5, Chapter 3, 3.2.3., FRACTION OF DEGRADABLE ORGANIC CARBON WHICH DECOMPOSES DOCF, page 3.13], fraction of methane in landfill gas (F) is 0.5 [Gen-1, Volume 5, Chapter 3, Table 3.1].
- 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, Chapter 3, Table 3.3].
- 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 deep-layer anaerobic managed SWDS[11] ("Nubarashen" SWD site is the largest in RA); MCF = 1.0

[11] With depth of more than 5 m

- Capital City of Yerevan – 30 % of solid waste of SWDS in 2018 was disposed to Jrvezh, Spandaryan and Masis dumpsites and 2019 – to Masis deep-layer unmanaged SWDS, MCF = 0.8.
- Gyumri and Vanadzor cities – deep-layer unmanaged SWDS, MCF = 0.8.
- Other 45 cities and towns of the country – unmanaged shallow SWDS[12], MCF = 0.4.

Activity data

When selecting activity data, 2006 IPCC Guidelines' provision stating that if there is no reliable data on waste collection in rural areas, then the calculation of waste volumes disposed in SWDS is based on the number of urban population, was followed [Gen-1, Volume 5, Chapter 2, Table 2.1, 2A.1].

- The numbers of urban population of 2018-2019 was taken from the bulletins of official statistics [Wref-2, Wref-3].
- Per capita waste generation rate for MSW selected for Yerevan is 0.315 tonnes/capita/year [WRef-4], for Gyumri and Vanadzor - 0.274 tonnes/capita/year [WRef-5] and for other cities - 0.219 tonnes/capita/year [WRef-5]. 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 2018-2019 (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-4 /3.5.1/ and WRef-5] for Yerevan, Gyumri and Vanadzor and 0.75 [WRef-5] for other cities. In this case again, upon the same approach the average value of this factor has been calculated, equaling 0.86 (IPCC default value for the Russian Federation is 0.9).

According to the assessments in frames of "Nubarashen" CDM project, 6.077 Gg $CO_{2\ eq.}$ and 12.765 Gg $CO_{2\ eq.}$ were captured and flared in 2018 and 2019 [WRef-6].

Considering that country-specific data were used as activity data, while default values were mainly used for the parameters, it can be stated that Tier 2 method was applied for emissions assessment.

Completeness

From the waste types mentioned in the Guidelines [Gen-1, Volume 5, Chapter 3.5], Municipal Solid Waste - 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. 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,

[12] With depth of less than 5 m

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 4.56.

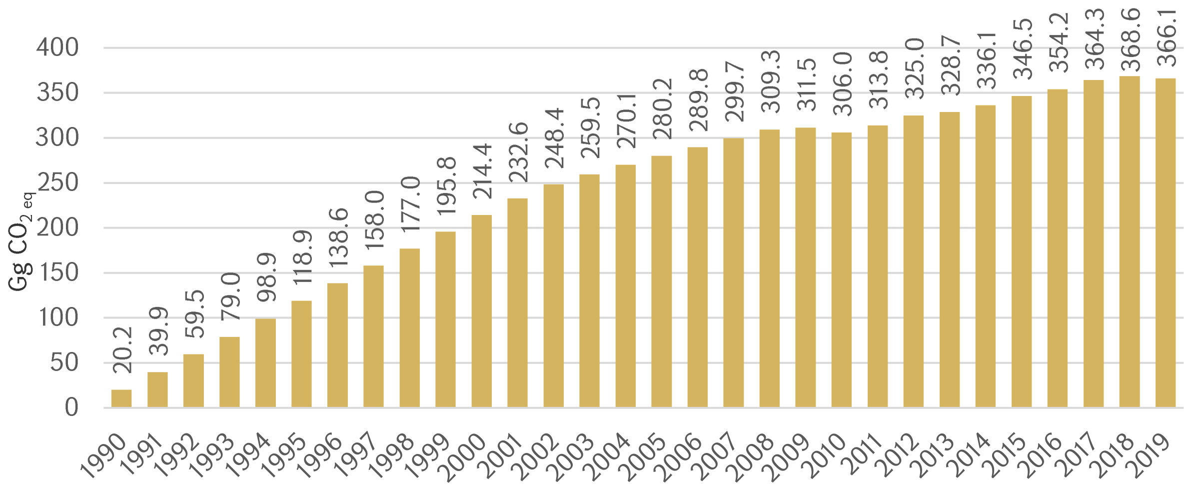


Figure 4.56 (A) Methane emissions from SWDSs, calculated since 1990

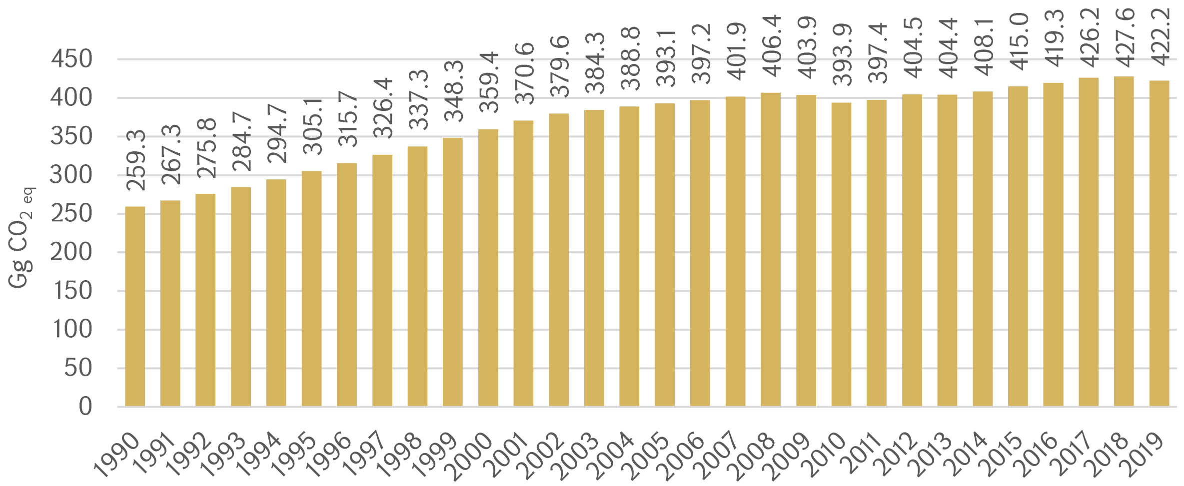


Figure 4.56 (B) Methane emissions from SWDSs calculated since 1950

As it was expected, figures calculated since 1990 are underestimated.

The methane emissions distribution (percentage) according to the landfill classification is presented in Figure 4.57. 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".

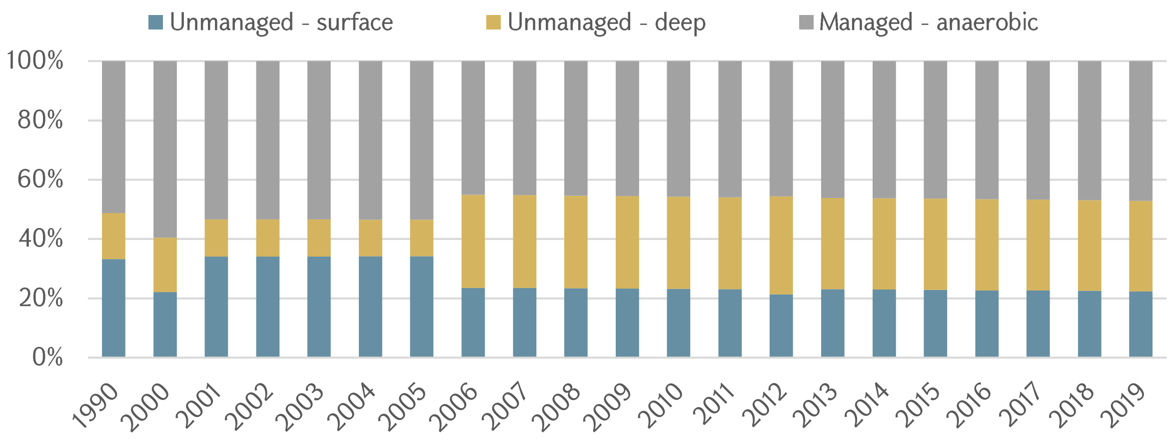


Figure 4.57 Methane emissions distribution (percentage) according to landfill classification

Uncertainty assessment

The uncertainties of methane emissions from Solid Waste Disposal Sites are related to:

- Uncertainty related to the methods,
- Uncertainty related to the data and parameters estimates.

However, it should be taken into account that the FOD method is a simple model of a very complex and poorly researched system and has several sources of uncertainty. However, uncertainty is mainly caused by the activity data and emission factors.

In the Table 4.82 the uncertainty estimates selected from IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 3, Table 3.5] are provided.

Table 4.82 Uncertainty of activity data and parameters

Activity data and parameters	Uncertainty range
Total Municipal Solid Waste (MSW_T)	±30%
Fraction of MSWT disposed at SWDS	±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 Landfill Gas	±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] with the following results:

- Activity data: 70%
- Emission factors: 30%
- General uncertainty: 76%

4.4.6 Waste incineration (4.C.1)

According to the 2006 IPCC Guidelines [Gen-1, Volume 5, Chapter 5] Waste incineration is defined as the combustion of solid and liquid waste in controlled incineration facilities. Emissions from waste incineration without energy recovery are reported in the current chapter, while emissions from waste incineration with energy recovery should be considered in the Energy Sector. Emissions from agricultural residue burning are considered in the agriculture, forestry and other land use sectors. Waste incineration, like other types of combustion, are sources of GHG emissions. Relevant gases emitted include methane, nitrous oxide and carbon dioxide. Normally, emissions of carbon dioxide are more significant than that of methane and nitrous oxide. According to Guideline [Gen-1, Volume 5, Chapter 5], calculation of CO_2 emissions from open burning or incineration based on waste types/material (paper, wood, plastics) is considered to be a good practice for SWDs, as shown in Equation 5.2.

Method

Consistent with the IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 5] a more accurate estimate of emissions from waste incineration can be achieved by estimating emissions for each incineration facility separately and/or by dividing the waste into separate categories. Both of the above-mentioned approaches were used within the framework of this report. The most important factor affecting carbon dioxide emissions is the estimated mineral/fossil carbon in the incinerated waste. Methane and nitrogen oxide emissions are more dependent on the technology and conditions during the incineration process. The general approach to calculate GHG emissions from waste incineration is to obtain the amount of dry weight of waste incinerated (dry mass) (preferably differentiated by waste type) and to investigate the related greenhouse gas emission factors (preferably relying on country-specific data if available). According to IPCC 2006 Guideline [Gen-1, Volume 5, Chapter 5.2] the basic approach for GHG emissions estimation in the given category are as follows:

- Identification of incinerated waste types,
- Estimation of incinerated waste quantity,
- Use of default emission factors given in IPCC 2006 Guideline Gen-1, Volume 5, Chapter 5.4.1.3 and Chapter 2.3 for different waste types,
- Calculation of GHG emissions
- Providing data in the worksheets of Appendix 1, Volume 5.

Since there is no information on the emission factors of incinerated/open-burned waste in Armenia (required for the level 2b calculation), the following approach was used when compiling this report:

a) Accurate country-specific (by incineration plant level) activity data on the type and amount of waste incinerated was collected and used in the calculations, and

b) default emission factors.

Choice of Method

Consistent with the IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 5] the common method for estimating CO_2 emissions from incineration and open burning of waste is based on an estimate of the fossil carbon content in the waste combusted, multiplied by the oxidation factor, and converting the product (amount of fossil carbon oxidised) to CO_2. The activity data are the waste inputs placed in the incinerator or the amount of waste open-burned, and the emission factors are based on the oxidized carbon content of the incinerated waste. Relevant data includes the dry matter content, the total carbon content in the dry matter, the fossil carbon fraction and the oxidation factor.

Consistent with the IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 5] when calculating CO_2 emissions with the mentioned method applying Tier 1 and Tier 2 approaches Equations 5.1 and 5.2 [Gen-1, Volume 5, Chapter 5.2.1.1, Equations 5.1 and 5.2] are used. Besides, if there is data on individual waste types, the use of 5.2 equation is considered to be the best practice, which has been done within the framework of compiling the current report for assessing CO_2 emissions resulting from solid waste incineration in the mentioned category. The calculation has been made with the application of IPCC 2006 Software. In IPCC 2006 Guideline the fossil-based liquid wastes are defined as industrial and municipal residues based on mineral oils, natural gas or other fossil fuels. Regarding the estimation of CO_2 emissions from the liquid waste incineration, Equation 5.3 [Chapter 5.2.1.4, Eqaution 5.3. p. 5.10] has been used. As to the default emission factors, quantities from Gen-I, Volume 5, Chapter 5.4.1, Table 5.2 and from Gen-1, Volume 5, Chapter 2, Tables 2.3-2.6 and also those from IPCC Software have been used, respectively.

CH_4 emissions from waste incineration are the result of incomplete combustion. Important factors affecting the emissions are combustion temperature, residence time and air ratio. The latter are relevant to applied technology. According to IPCC 2006 Guideline [Gen-1, Volume 5, Chapter 5] calculation of CH_4 with Tier 1 and Tier 2 methods is based on the quantity of burned wastes and corresponding emissions factor. In both cases Equation 5.4 [Gen-1, volume 5, Chapter 5.2.2.1, Equation 5.4, p. 5.12] has been used within the frame of compiling the current report for estimation of CH_4 emissions from the waste incineration in the given category. The default factors described in Gen-1, Volume 5, Chapter 5.4.2, Table 5.3, p. 5.20 have been used. The quantity and composition of wastes used in the equation is consistent with the activity data used in the estimations of CO_2 emissions resulting from incineration.

Nitrous oxide is emitted in combustion processes at relatively low combustion temperatures between 500 and 900°C. Other important factors affecting emissions are the type of air pollution control device, the waste type and its nitrogen content, and also the fraction of excess air. According to IPCC 2006 Guideline [Gen-1, Volume 5, Chapter 5] the calculation of N_2O emissions using Tier 1 and Tier 2 approaches with the given method is based on the quantity of wastes burnt in the furnace, as well as on the default emission factors. In both cases Equation 5.5 [Gen-1, Volume 5, Chapter 5.2.3.1, Equation 5.5, p. 5.14] has been applied and it was also used in the current report for estimating N_2O emissions from incineration in the discussed category. Default factors from Gen-1, Volume 5, Chapter 5.4, Table 5.6, p. 5.22 have been used, respectively. The quantity and composition of wastes used in the Equation corresponds to the activity data applied in the calculation of CO_2 and CH_4 emissions resulting from incineration.

Activity data

Consistent with IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 5.1] the incinerated waste types include Municipal Solid Waste (MSW), industrial waste, hazardous waste, medical waste and sewage sludge. Medical waste is the prevailing part of incinerated waste (GHG emissions from incineration have to be estimated according to IPCC 2006 Guideline) in Armenia, however some quantities of industrial and hazardous wastes[13] are also being subjected to incineration. According to IPCC 2006 Guideline [Gen-1, Volume 5, Chapter 5.3], at best, together with activity data collection, data on the quantities and types of incinerated waste should be provided, which has been done within the scope of this report compilation. The use of hazardous waste in Armenia belongs to the range of activities subject to licensing, so it can be carried out only by organizations with the appropriate license. Taking into account the above stated fact, data on the types and quantity of waste incinerated in Armenia during the reporting period was obtained from the relevant licensed organizations based on written official requests.

On the basis of written inquiries and additional corrections, identification of waste was carried out according to the specific waste types listed in IPCC Guideline, 2006. The summary information is introduced in the Table below (Table 4.83). The information presented in the table includes the data of all stations operating in RA during the reporting period.

Table 4.83 Collected activity data by waste types and years

2018		2019	
Waste type	Mass/t	Waste type	Mass/t
Medical	334.92	Medical	405.873
Plastic	68.956	Plastic	105.493
Textile	7.252	Textile	20.046
Paper	0.834	Paper	3.108
Food	223.172	Food	238.501
		Rubber	10.836
		Waste oil	0.229

[13] In this sentence, the term "hazardous waste" is used as defined in the 2006 IPCC Guidelines. Medical wastes and the most part of industrial wastes (all wastes of I-IV class) are considered to be hazardous wastes in Armenia.

As already mentioned, according to IPCC 2006 Guidelines [Gen-1, Volume 5, Capter 5] the good practice for Municipal Solid Waste is considered to be CO_2 emissions calculation resulted from open burning or incineration based on waste types/materials such as paper, wood, plastics, as shown in Equation 5.2. The estimation has been made by applying IPCC 2006 software.

Completeness

Consistent with IPCC 2006 Guidelines [Gen-1, Volume 5, Chapter 5.5] completeness depends on the reporting of types and amounts of waste incinerated. If the method is implemented at the facility-level, and then summed across facilities, it is good practice to ensure that all waste incineration plants are covered, which has been done within the frame of the current reporting years. All incineration plants operating during the reporting period were included and individual approach (at institutional level) has been demonstrated at the stage of activity data collection both in terms of types and amounts of waste incinerated. Thus, it can be stated that completeness for this category has been ensured at a proper level.

The calculations of GHG emissions from waste incineration for 2018-2019 are presented in Tables 4.82, 4.83 and 4.84.

Table 4.84 Calculations of incineration-induced emissions per GHGs and years

Year	CO_2/Gg	CH_4/Gg	N_2O/Gg	Total $CO_{2\,eq.}$
2018	0,35	3,8*10^{-5}	5,15*10^{-5}	0,4
2019	0,47	4,7*10^{-5}	6,4*10^{-5}	0,5

4.4.7 Open Burning of Waste (4C2)

In the rural areas, green waste (tree branches, 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 or transported to a dumping site, where open burning is implemented.

Relevant gases *emitted from open burning of waste* include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

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 1.076.9 thousand in 2018 and 1.070.4 thousand in 2019 [WRef-2, WRef-3].

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-5, Table 2].

Default values were applied for waste parameters (dry matter content, carbon content and other input parameters) [Gen-1].

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].

Total dry matter (dm_i) content in the MSW is 0.78 [Gen-1, Volume 5, Chapter 5, p. 5.17].

Carbon content (CF_i) in the dry waste type is 0.34 [Gen-1, Volume 5, Chapter 5, p. 5.17-18].

Fraction of fossil carbon (FCF_i) in the total carbon content of the MSW is 0.08 [Gen-1, Volume 5, Chapter 5, p. 5.19-20].

Oxidation factor (OF_i) is 0.58 [Gen-1, Volume 5, Chapter 5, Table 5.2, p. 5.18].

CH_4 emission factor is 6500 g / t MSW wet weight [Gen-1, Volume 5, Chapter 5.4.2, p. 5.20].

N_2O emission factor is 150 g N_2O / t MSW dry weight [Gen-1, Volume 5, Chapter 5.4., p. 5.22].

Calculated greenhouse gas emissions from the *Waste* sector are presented in Tables 4.85 and 4.86.

Time series of GHG emissions are introduced in Figure 4.58.

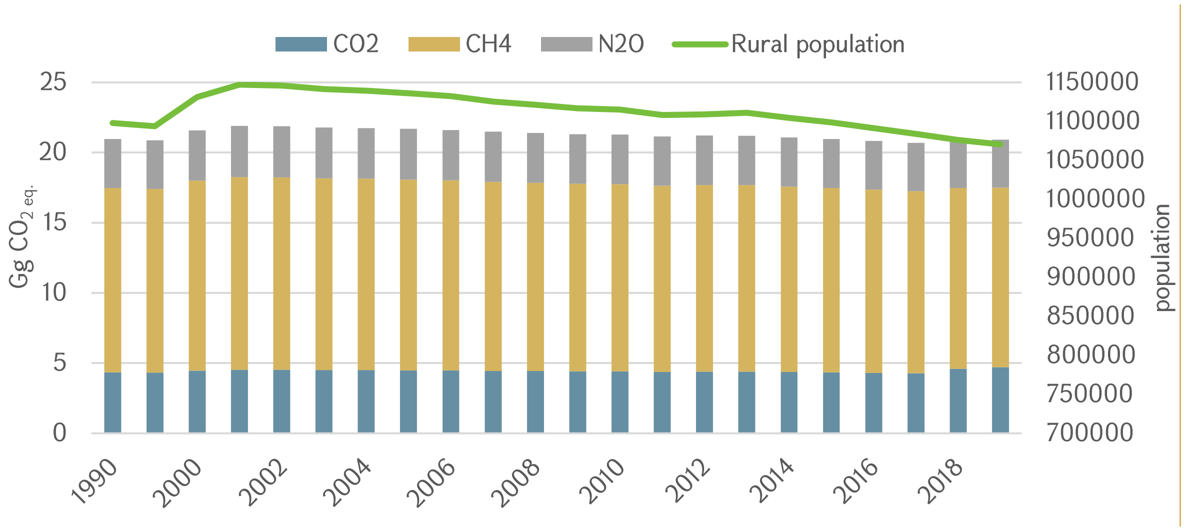


Figure 4.58 GHG emissions from open burning of waste

Table 4.85 GHG emissions from *Waste* sector, 2018

Categories	Emissions, Gg		
	CO_2	CH_4	N_2O
4 - Waste	4.600	26.153	0.241
4.A – Solid Waste Disposal		20.360	
4.A.1 - Managed Waste Disposal Sites			
4.A.2 - Unmanaged Waste Disposal Sites			
4.A.3 - Uncategorised Waste Disposal Sites			
4.B - Biological Treatment of Solid Waste			
4.C - Incineration and Open Burning of Waste	4.600	0.613	0.011
4.C.1 - Waste Incineration	0.346	0.00004	0.00005
4.C.2 - Open Burning of Waste	4.253	0.613	0.011
4.D - Wastewater Treatment and Discharge		5.180	0.230
4.D.1 - Domestic Wastewaster Treatment and Discharge		3.255	0.230
4.D.2 - Industrial Wastewater Treatment and Discharge		1.925	

Table 4.86 GHG emissions from *Waste* sector, 2019

Categories	Emissions, Gg		
	CO_2	CH_4	N_2O
4 - Waste	4.706	26.158	0.241
4.A – Solid Waste Disposal		20.105	
4.A.1 - Managed Waste Disposal Sites			
4.A.2 - Unmanaged Waste Disposal Sites			
4.A.3 - Uncategorised Waste Disposal Sites			
4.B - Biological Treatment of Solid Waste			
4.C - Incineration and Open Burning of Waste	4.706	0.610	0.011
4.C.1 - Waste Incineration	0.475	0.00005	0.00006
4.C.2 - Open Burning of Waste	4.231	0.610	0.011
4.D - Wastewater Treatment and Discharge		5.444	0.230
4.D.1 - Domestic Wastewaster Treatment and Discharge		3.247	0.230
4.D.2 - Industrial Wastewater Treatment and Discharge		2.197	

4.4.8 Wastewater Treatment and Discharge (4D)

Greenhouse gas emissions sources from wastewater are (4D):

- Methane and nitrous oxide emissions from domestic and commercial wastewaters (4D1),
- Methane emission from industrial wastewaters (4D2).

Given the lack of reliable activity 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 (Statistical Committee and the Ministry of Environment).

4.4.9 Methane Emission from Domestic and Commercial Wastewaters (4D1)

Currently, Armenia has a limited sewer service area. There are few wastewater treatment plants and only mechanical treatment is performed. There is no centralized biological treatment for domestic and commercial wastewaters, sludge removal and methane recovery.

Throughout 2018-2019, in large cities and towns the domestic and commercial wastewaters were discharged mostly by the existing sewer system and in the rural communities - mostly by the latrines and holes.

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] and the calculations were made per corresponding emission factors and activity data.

Choice of Emission Factors

Methane emissions were estimated by applying IPCC 2006 Tier 1 method and the following default values of emission factors were used:

- **Maximum methane producing capacity:** Bo=0.6 kg CH_4/kg BOD, default factor, [Gen-1, Volume 5, Chapter 6, Table 6.2].
- **I = 1 default factor for additional industrial BOD discharged into sewers (**organic production and/or industrial residues) has been selected [Gen-1, Volume 5, Chapter 6, p. 6.14]) since methane emissions from organic residues of industrial origin have been calculated in the category of Industrial Wastewater (4D2).
- **Methane correction factor (fraction) - MCF_J.** MCF = 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]. MCF = 0.1 In the case of latrines was selected for MCFj 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].

Collection of activity data

Consistent with IPCC 2006 Guidelines, estimation of methane emissions from domestic and commercial wastewaters and selection of method is carried out for different population groups (urban, rural and/or high, middle and low-income population groups) based on the country-specific removal/treatment system.

For developing countries, the IPCC 2006 Guidelines suggest that population of large cities with centralized and branched sewerage systems should be viewed as high income population group, town population – as middle income and rural population should be considered as low income population group [Gen-1]. From this perspective in the current report the population of Yerevan, Gyumri and Vanadzor cities have been considered as high income, the population of other cities - as middle income, and the rural population – as low-income population groups [Gen-1, Volume 5, Chapter 6]. The number of individual population groups are taken from the data bank of the RA SC official website [WRef-9, WRef-10]. Those data are also reported in the RA SC yearbook.

Based on the Guidelines' data and the country practice developed for domestic and commercial wastewaters removal/treatment system and expert judgment thereabout, the following fractions of sewerage use among different population groups have been applied for further calculations:

- For large cities (Yerevan, Gyumri, Vanadzor) the share of sewerage is 0.95 (95%), public and other latrines - 0.05 (5%),

- For other cities of the republic 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-11, WRef-8).

Country-specific per capita BOD in inventory year, g/person/day in domestic/commercial wastewaters = 18,250 kg/1000persons/year (which is equivalent to 50g/person/day). No values as the choice of these calculation parameters is recommended by IPCC Guidelines for South Caucasus or former USSR countries, thus, the value of 18,250 kg/1000persons/year (50 g/person/day) recommended by IPCC 1996 [Gen-8, p. 6.23] for former USSR countries have been used for all calculations, which was also used for all previous calculations in National Greenhouse Gas Inventory.

Sludge removal and methane recovered. 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.

Time series

Time series of methane emissions from domestic and commercial wastewater, along with population dynamics, are provided in Figure 4.59 for the entire observation period (1990-2019).

Figure 4.59 shows that the reduction of methane emissions from domestic and commercial wastewater is due to the decrease in the country's population.

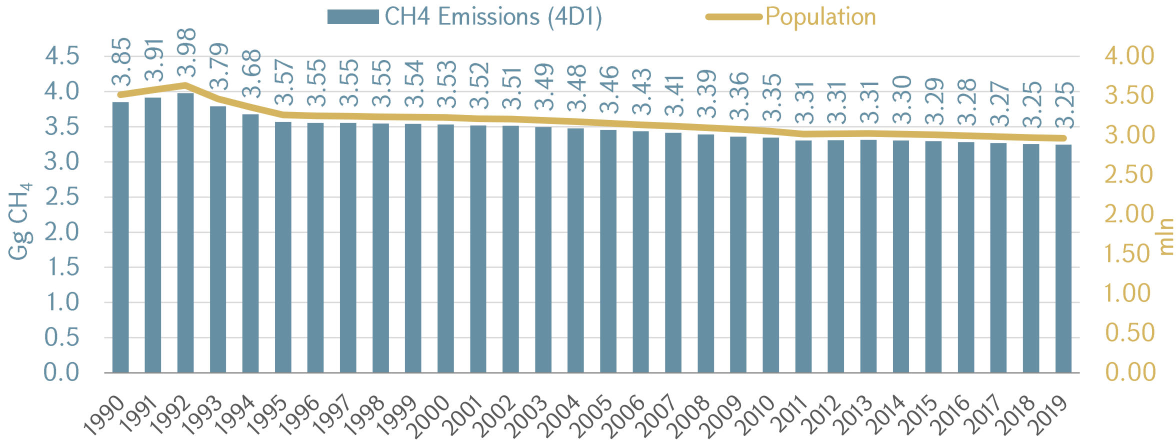


Figure 4.59 Methane CH_4 emissions from domestic and commercial wastewater (Gg) and population dynamics

Figure 4.60 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. The data indicate that throughout the entire observation period large cities were the main source of methane emissions from domestic and commercial wastewaters.

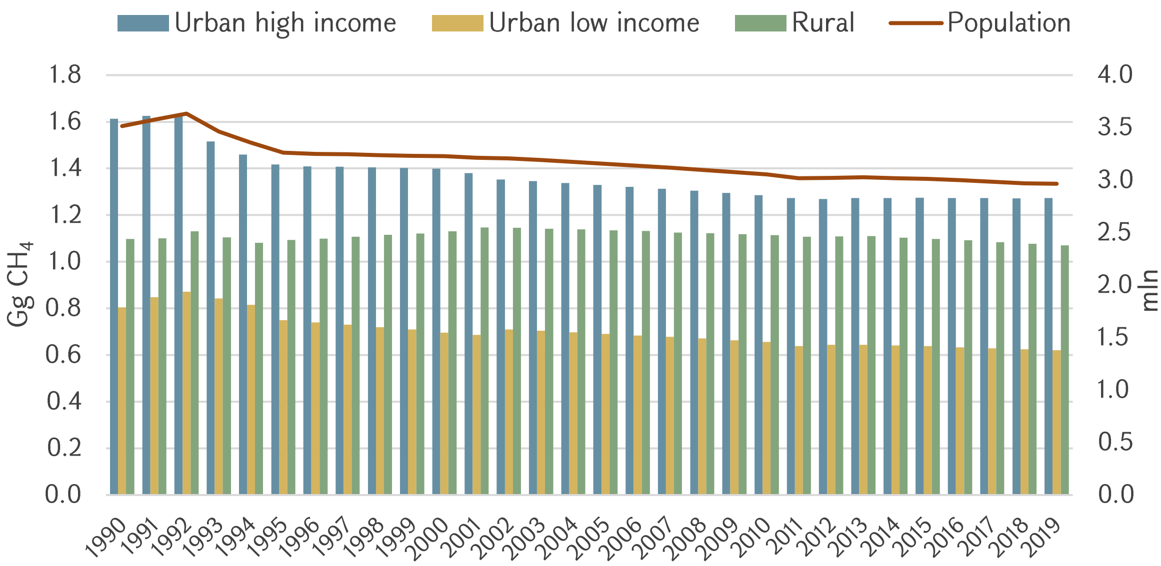


Figure 4.60 Methane emissions from domestic and commercial wastewater by population groups, Gg

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%.

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%, default factor of maximum methane producing capacity makes ±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%
- total uncertainty - 68.74%.

4.4.10 Industrial Wastewater (4D2)

Methane emissions

The need for wastewater treatment/discharge is one of the primary conditions (fixed by law) for the activity of industrial enterprises in Armenia.

For the assessment of methane emissions from industrial wastewater, the volumes of specific product ranges published by SC come forth as the source of reliable and complete activity data in Armenia. Anyhow, considering that the information required for the calculation of country-based emission factors is missing, methane emissions from the industrial wastewater were estimated using IPCC Tier 1 Approach. According to the mentioned approach the estimations were made by 3 stages using Equations 6.4, 6.5 and 6.6 of IPCC 2006 Guideline [Gen-1, Volume 5].

Choice of emission factors

The following default values [Gen-1] for calculation of methane emissions from industrial wastewater were used per Tier 1 approach of IPCC:

Methane correction factor (fraction). MCF = 0.1 (for collected and untreated industrial wastewater that are eventually discharged in rivers, lakes and river mouths) [Gen-1, Volume 5, Chapter 6, Table 6.8].

Maximum methane producing capacity: Bo = 0.25 (kg CH_4/kg COD) (default value) [Gen-1, Volume 5, Chapter 6, p. 6.21].

Chemical oxygen demand by industry type (COD_i), kg COD/m^3, values are from [Gen-1, Volume 5, Chapter 6, Table 6.9] default factors.

Wastewater amount generated by industry type (W_i), m^3/t, values were taken from [Gen-1, Volume 5, Chapter 6, Table 6.9] default factors.

Removed sludge from industrial wastewater of industry type for the given year: **$S_i = 0$** (default value [Gen-1, Volume 5, Chapter 6]). Sludge-related emissions are not considered, since on the basis of survey data it can be concluded that such activity is missing in Armenia.

Utilized/removed methane amount: **$R_i = 0$** (default value, [Gen-1, Volume 5, Chapter 6]. There is no activity of methane utilization/removal from industrial wastewater in Armenia.

Collection of activity data

According to the Guidelines, for the assessment of methane emissions from industrial wastewater, the annual volumes of products with organically degradable material in the wastewater have been used as source activity data. The IPCC Guidelines 2006 suggest considering a number of industry types, which are introduced in Table 4.87 with relevant calculation factors and default values [Gen-1, Volume 5, Chapter 6, Table 6.9].

Table 4.87 Estimation factors of methane emissions from industrial wastewater per industry types

Industry type	Wastewater generation, W_i, (m^3/t)	Chemical Oxygen Demand, COD (kg/m^3)
Milk, Dairy Products, including Cheese	7	2.7
Fruits, Canned Vegetables, Juices	20	5.0
Alcoholic Beverages, Spirits	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, Canned Fish	8	2.5
Sugar Processing	4	3.2

Table 4.88 presents the quantities of output from which the wastewater were generated, by production type and by year. The required activity data were obtained from the periodically published bulletins [WRef-9] of RA SC publications, such as “Output of Main Commodities in the Industrial Organizations (in Kind)”, as well as from RA SC database publications “RA national food balance per commodity range/types, indicators and years” [WRef-10].
The activity data of “Dairy Product”, “Meat and Poultry”, “Soap and Detergents” sectors have been corrected and recalculated for the whole observation period. The “Starch Production” sector has been removed from the overall industry list.

Table 4.88 Production volumes (thousand t/year) by years, 2000-2019

Industry sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Alcohol distillation	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	39.19	51.20
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	23.82	26.52
Dairy Products	196.04	202.63	212.79	226.03	354.75	594.6	620	641.2	661.9	615.7	600.9	601.5	618.2	657	700.4	728.6	754.2	758.2	697.70	667.90
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	0.27	0.19
Meat & Poultry	41.66	39.47	39.78	42.78	44.98	56	66.8	69.7	70.9	70.7	69.5	71.7	73.9	83.4	92.7	100.4	106.1	109	108.20	107.30
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	25.65	27.42
Pulp & Paper	0.00	0.24	0.65	1.61	1.61	1.81	1.72	1.35	2.00	2.14	3.37	10.48	10.66	13.53	17.68	14.91	16.97	19.54	21.66	28.02
Soap & Detergents	0	0.5884	0.5603	0.4888	0.8543	3.2362	3.5739	2.854	2.2733	2.3825	2.4147	2.207	1.973	2.5029	1.6826	1.5656	2.0999	4.2972	4.75	5.38
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	1.45	1.79
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	145.07	133.90
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	10.38	13.69
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	57.99	59.98

Time series

To ensure consistency, time series of methane emissions from industrial wastewater for the period of 2000-2019 have been recalculated, the results of which are introduced in Figure 4.61.

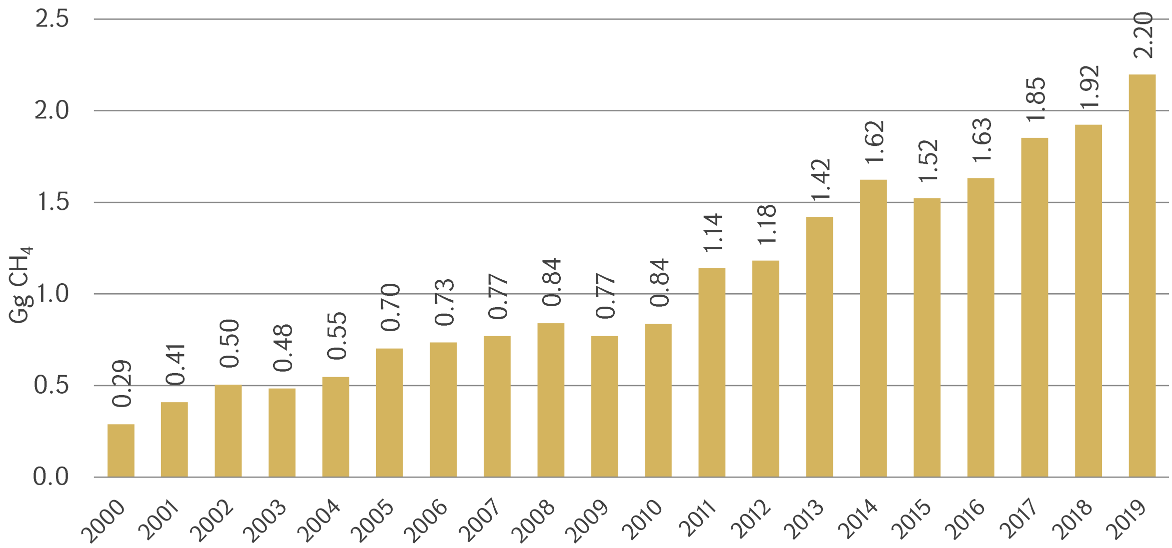


Figure 4.61 Methane emissions from industrial wastewater, Gg

The shares of methane emissions from industrial wastewater per industry type for the period of 2000-2019 are given in Figure 4.62.

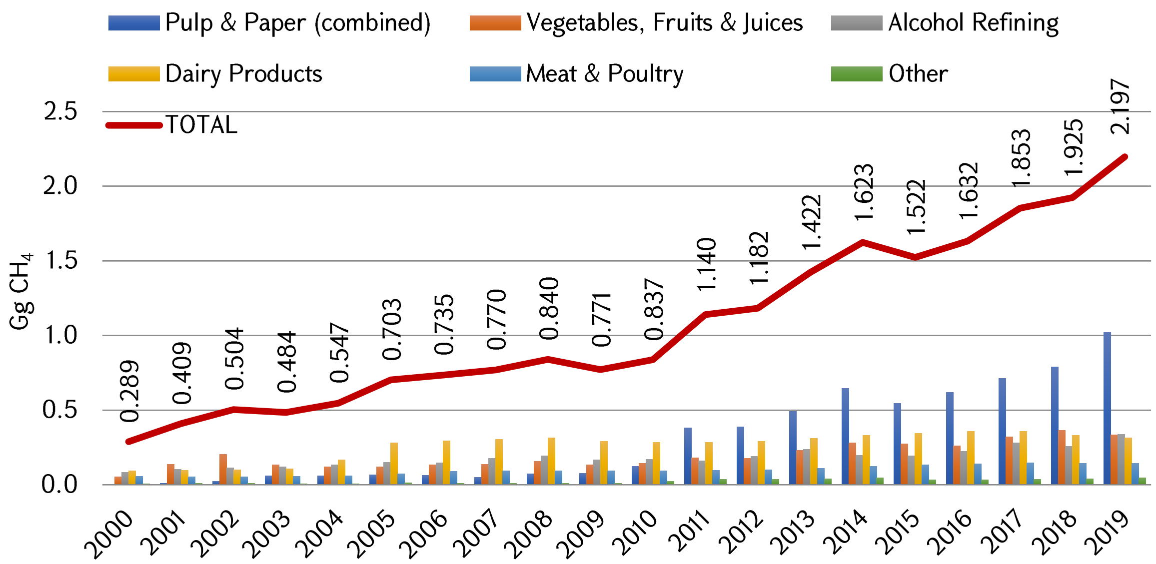


Figure 4.62 Methane emissions from industrial wastewater per industry types, Gg

Methane emissions from domestic, commercial and industrial wastewater and the time series of their summary values are given in Figure 4.63.

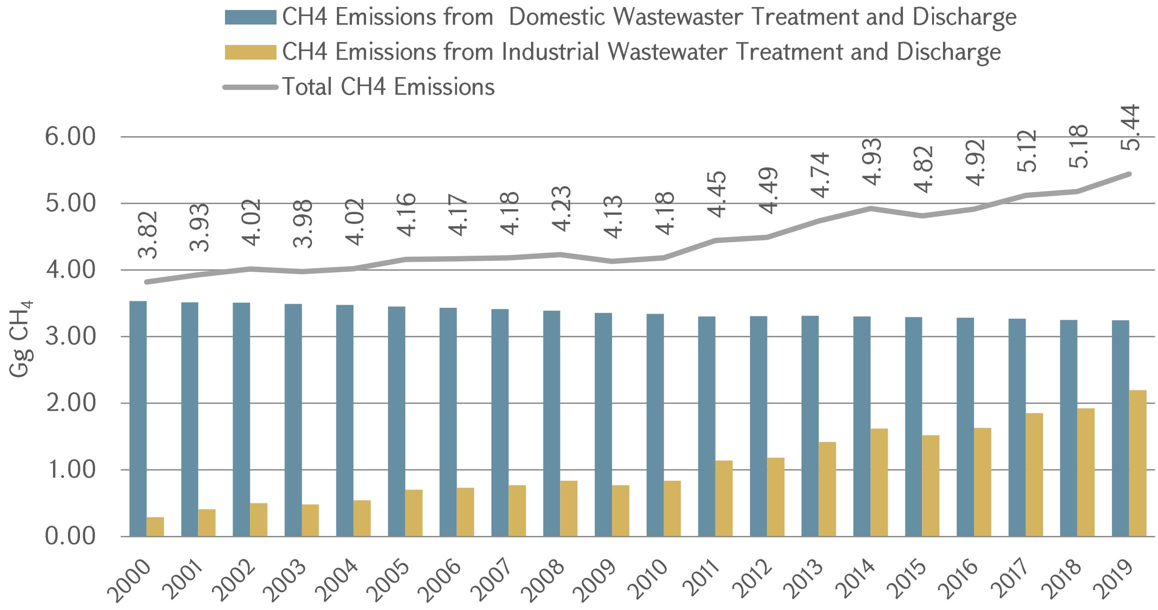


Figure 4.63 Methane emissions per wastewater sub-categories, Gg

It is obvious from Figure 4.63, that methane emissions from domestic and commercial wastewaters predominate in total wastewater emissions.

Uncertainty assessment

The uncertainty assessment of estimated methane emissions from industrial wastewater has been carried out based on the default values of uncertainty range given in Table 6.10 of IPCC 2006 Guidelines [Gen-1]. COD per industry types include the most uncertain data for assessing methane emissions from industrial wastewater. The uncertainty in the wastewater/output unit ratio in the calculation of industrial wastewater is too high, due to different wastewater management approaches in different plants. COD wastes may have less uncertainties, which can be assumed as -50 %, +100% [Gen-1].

The uncertainty range of Maximum Methane Producing Capacity (Bo) factor makes 30 %, Methane Correction Factor (MCF) - 0-1 %, production volume - 25%.

Activity data, emission factors and total uncertainties have been calculated with [Gen-1, Volume 1, 3.1] Equation. The following values have been obtained:

- Activity data: 75.00%
- Emission factors: 58.31%
- Total uncertainties: 95.00%.

4.4.11 Nitrous oxide emissions 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, thus the stage of method choice is missing in this sector. 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 with 2 calculation steps based on Equations 6.7 and 6.8 [Gen-1, Volume 5, Chapter 6].

The following default values were used for the calculations:

N_2O nitrous oxide emission factor: $EF_{EFFLUENT}$ = 0.005 (kg N2O-N/kg N) [Gen-1, Volume 5, Chapter 6, Table 6.11].

Fraction of nitrogen in protein: F_{NPR} = 0.16 (kg N/kg protein) [Gen-1, Volume 5, Chapter 6].

Non-consumed protein in wastewater: $F_{NON\text{-}CON}$ = 1.40. This default value is recommended by the Guideline for the developed countries, where waste disposal systems are available [Gen-1, Volume 5, Chapter 6, Table 6.11]. For the developing countries, like Armenia, the default value $F_{NON\text{-}CON}$ = 1.1 is recommended by the Guidelines. However, taking into account that waste disposal and wastewater treatment/removal through sewer system is being implemented in Armenia, the default value **$F_{NON\text{-}CON}$ = 1.40** is used in calculations.

The share of industrial and commercial protein discharged into sewer: $F_{IND\text{-}COM}$ = 1. 25 [Gen-1, Volume 5, Chapter 6, Table 6.11].

Nitrogen removed with sludge: N_{SLUDGE} = 0. As in the previous two sections referring to the wastewater, in this section as well, 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) in the given country. 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-7] were used within the frame of this inventory report, which are introduced in Table 4.89 and served as basis for calculations.

Table 4.89 Per capita daily protein consumption

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	2017-19
Per capita consumption protein (g/person/day)	65.3	65.3	67	70.3	74	77.3	79.7	83	84.3	86	87	89	91	89.7	96

Time series and uncertainty assessment

To ensure time series consistency, GHG/nitrogen oxide emissions from wastewater have been recalculated with the same methodology for all reporting years.

Time series of the nitrogen oxide emissions from wastewater, depending on protein consumption and population number, are given in Figures 4.64 and 4.65.

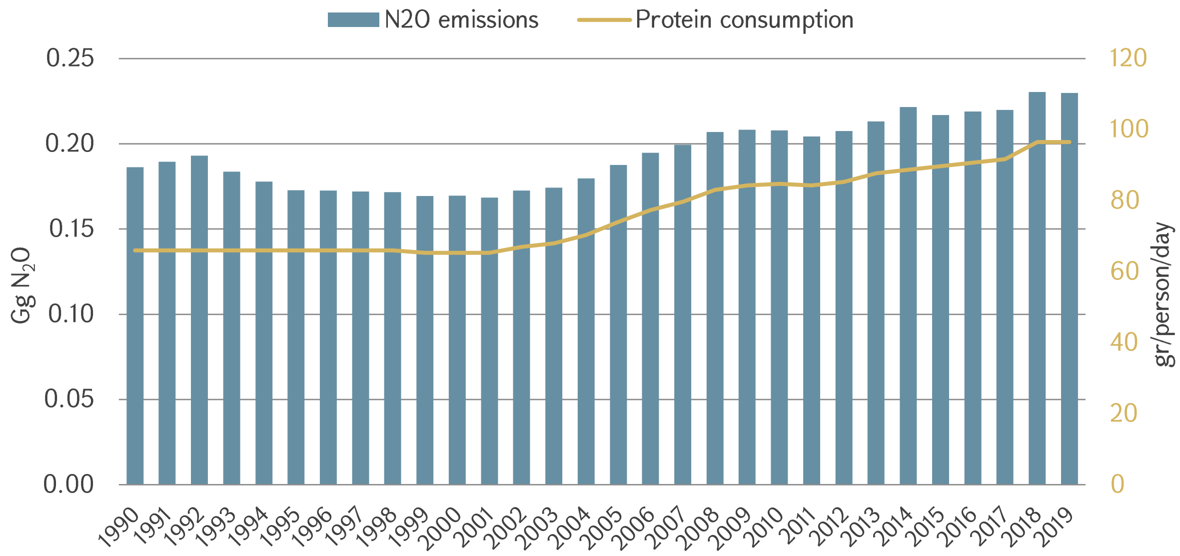


Figure 4.64 Nitrogen oxide emissions from wastewater and protein consumption

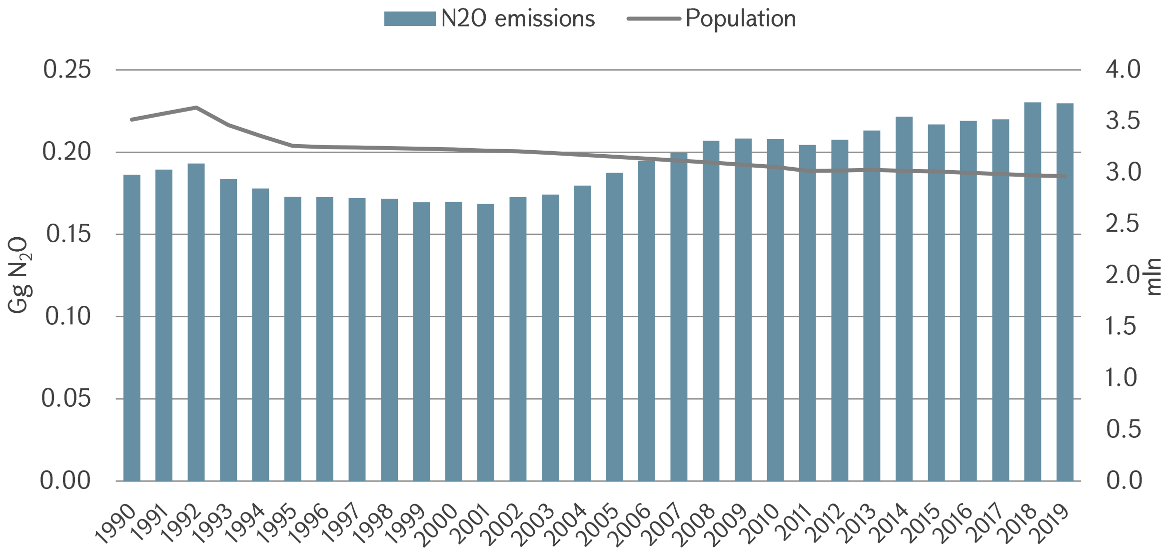


Figure 4.65 Nitrogen oxide emissions from wastewater and population number

Time series show that nitrous oxide emissions change depending on dynamics of population number and protein consumption. The effect of consumed proteins is obviously higher than that of population number.

Currently it is not possible to estimate the uncertainty of the nitrogen oxide emissions from wastewater, as the corresponding studies are very limited, while the recommended range for the emission factors is very large, in particular N_2O emission factor (kg N_2O-N/kg N) uncertainty range is - $EF_{EFFLUENT}$: 0.0005 - 0.25 [Gen-1, Volume 5, Table 6.11].

Quality Assurance/ Quality Control

The sources of activity data and their reliability were specified prior to the calculations.

During the calculation multifold quality control and relevance analysis for both activity data and the main calculation parameters were implemented followed by the quality control of the results of calculation and analysis of time series.

In each calculation step, the use of default values of the main calculation parameters ar their compliance with the formed country standards were monitored.

The calculations were also done by Excel and compared to the results received by the running 2006 IPCC Inventory Software.

Time series of calculation results was compiled, their internal consistency was checked and comparative analysis with previous results was carried out.

4.4.12 Possible Inventory 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, which will determine the actual number of the population, the number of the population in urban and rural settlements, and their 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. The study of technological processes and treatment systems of organizations with organic substance discharge, as well as collecting information about treatment plants, can also provide improvement. Information should be continuously updated.

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ANNEXES

Annex 1. Key Category Analysis and Uncertainty Assessment

Annex 1.1 Key Category Analysis - Level Assessment

A IPCC Category code	B IPCC Category	C Gas	D 2019 Ex,t (Gg $CO_{2\ eq}$)	E |Ex,t| (Gg $CO_{2\ eq}$)	F Lx,t	G Cumulative Total of Column F
1.A.1	**Energy Industries - Gaseous Fuels**	**CO_2**	**1,364.95**	**1,364.95**	**11.66%**	**11.66%**
1.A.4.b	**Residential- Gaseous Fuels**	**CO_2**	**1,318.75**	**1,318.75**	**11.26%**	**22.92%**
1.A.3.b	**Road Transportation - Gaseous Fuels**	**CO_2**	**1,138.30**	**1,138.30**	**9.72%**	**32.64%**
1.B.2.b	**Fugitive emissions from Natural Gas transportation and distribution**	**CH_4**	**1,122.51**	**1,122.51**	**9.59%**	**42.22%**
2.F.1	**Refrigeration and Air Conditioning**	**HFCs**	**927.87**	**927.87**	**7.92%**	**50.15%**
1.A.3.b	**Road Transportation - Liquid Fuels**	**CO_2**	**901.17**	**901.17**	**7.70%**	**57.84%**
3.C.4	**Direct N2O Emissions from managed soils**	**N_2O**	**827.04**	**827.04**	**7.06%**	**64.90%**
3.A.1.a	**Enteric Fermentation - Cattle**	**CH_4**	**781.07**	**781.07**	**6.67%**	**71.57%**
1.A.4.a	**Commercial/institutional - Gaseous Fuels**	**CO_2**	**482.04**	**482.04**	**4.12%**	**75.69%**
3.B.1.a	**Forest land Remaining Forest land**	**CO_2**	**-446.78**	**446.78**	**3.82%**	**79.50%**
4.A	**Solid Waste Disposal**	**CH_4**	**422.20**	**422.20**	**3.61%**	**83.11%**
1.A.2	**Manufacturing Industries and Construction - Gaseous Fuels**	**CO_2**	**382.86**	**382.86**	**3.27%**	**86.38%**
2.A.1	**Cement production**	**CO_2**	**258.95**	**258.95**	**2.21%**	**88.59%**
3.C.5	**Indirect N2O Emissions from managed soils**	**N_2O**	**235.70**	**235.70**	**2.01%**	**90.60%**
1.A.4.c	**Agriculture/Forestry/Fishing/Fish Farms - Gaseous Fuels**	**CO_2**	**144.95**	**144.95**	**1.24%**	**91.84%**
3.A.1.b-j	**Enteric Fermentation - Other**	**CH_4**	**119.56**	**119.56**	**1.02%**	**92.86%**
4.D	**Wastewater Treatment and Discharge**	**CH_4**	**114.33**	**114.33**	**0.98%**	**93.84%**
4.D	**Wastewater Treatment and Discharge**	**N_2O**	**71.23**	**71.23**	**0.61%**	**94.45%**
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	**67.05**	**67.05**	**0.57%**	**95.02%**
3.A.2	Manure Management	N_2O	54.94	54.94	0.47%	95.49%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	54.07	54.07	0.46%	95.95%
1.A.3.b	Road Transportation	CH_4	46.14	46.14	0.39%	96.34%
2.A.2	Lime production	CO_2	39.59	39.59	0.34%	96.68%
3.A.2	Manure Management	CH_4	37.00	37.00	0.32%	97.00%
3.C.6	Indirect N2O Emissions from manure management	N_2O	36.08	36.08	0.31%	97.31%
1.A.3.e	Other Transportation	CO_2	31.97	31.97	0.27%	97.58%
3.B.4.a.i	Peatlands remaining peatlands	CO_2	31.92	31.92	0.27%	97.85%
1.A.3.b	Road Transportation	N_2O	31.20	31.20	0.27%	98.12%
3.B.6.b	Land Converted to Other land	CO_2	29.63	29.63	0.25%	98.37%
2.F.2	Foam Blowing Agents	HFCs	28.86	28.86	0.25%	98.62%

1.A.4	Other Sectors - Biomass	CH_4	28.68	28.68	0.24%	98.86%
3.B.3.b	Land Converted to Grassland	CO_2	18.37	18.37	0.16%	99.02%
4.C	Incineration and Open Burning of Waste	CH_4	12.80	12.80	0.11%	99.13%
2.F.4	Aerosols	HFCs	12.10	12.10	0.10%	99.23%
1.A.4	Other Sectors - Solid Fuels	CO_2	10.54	10.54	0.09%	99.32%
3.B.2.b	Land Converted to Cropland	CO_2	-7.40	7.40	0.06%	99.39%
2.A.3	Glass Production	CO_2	7.06	7.06	0.06%	99.45%
3.B.5.b	Land Converted to Settlements	CO_2	6.73	6.73	0.06%	99.50%
3.B.1.b	Land Converted to Forest land	CO_2	-6.53	6.53	0.06%	99.56%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	5.71	5.71	0.05%	99.61%
3.D.1	Harvested Wood Products	CO_2	-5.67	5.67	0.05%	99.66%
1.A.4	Other Sectors - Biomass	N_2O	5.62	5.62	0.05%	99.70%
3.C.3	Urea application	CO_2	5.51	5.51	0.05%	99.75%
4.C	Incineration and Open Burning of Waste	CO_2	4.71	4.71	0.04%	99.79%
3.C.1	Emissions from biomass burning	CH_4	4.52	4.52	0.04%	99.83%
1.A.4	Other Sectors - Gaseous Fuels	CH_4	3.61	3.61	0.03%	99.86%
4.C	Incineration and Open Burning of Waste	N_2O	3.42	3.42	0.03%	99.89%
2.G	Other Product Manufacture and Use	SF_6	3.29	3.29	0.03%	99.92%
3.C.1	Emissions from biomass burning	N_2O	2.56	2.56	0.02%	99.94%
2.C.1	Iron and Steel Production	CO_2	1.18	1.18	0.01%	99.95%
1.A.4	Other Sectors - Gaseous Fuels	N_2O	1.07	1.07	0.01%	99.96%
1.A.1	Energy Industries - Gaseous Fuels	N_2O	0.75	0.75	0.01%	99.97%
2.F.3	Fire Protection	HFCs	0.71	0.71	0.01%	99.97%
3.B.2.a	Cropland Remaining Cropland	CO_2	0.67	0.67	0.01%	99.98%
1.A.3.e	Other Transportation	N_2O	0.52	0.52	0.00%	99.98%
1.A.1	Energy Industries - Gaseous Fuels	CH_4	0.51	0.51	0.00%	99.99%
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	0.21	0.21	0.00%	99.99%
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.17	0.17	0.00%	99.99%
1.A.4	Other Sectors - Solid Fuels	CH_4	0.17	0.17	0.00%	99.99%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CH_4	0.14	0.14	0.00%	100.00%
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.14	0.14	0.00%	100.00%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.13	0.13	0.00%	100.00%
1.B.2.b	Natural Gas	CO_2	0.11	0.11	0.00%	100.00%
1.A.4	Other Sectors - Solid Fuels	N_2O	0.05	0.05	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	0.04	0.04	0.00%	100.00%
Total			**10,777.82**	**11,710.56**	**100%**	

Annex 1.2 Key Category Analysis - Trend Assessment

A	B	C	D	E	F	G	H	I	J
IPCC Category code	IPCC Category	Gas	2000 Year Estimate Ex0, Gg $CO_{2\,eq}$	2019 Year Estimate Ext, Gg $CO_{2\,eq}$	2000 Year Estimate (absolute) |Ex0|, Gg $CO_{2\,eq}$	2019 Year Estimate (absolute) |Ext|, Gg $CO_{2\,eq}$	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column I
1.A.1	**Energy Industries - Gaseous Fuels**	**CO_2**	**1696.99**	**1364.95**	**1696.99**	**1364.95**	**0.230**	**20.05%**	**20.05%**
1.A.3.b	**Road Transportation - Gaseous Fuels**	**CO_2**	**55.20**	**1138.30**	**55.20**	**1138.30**	**0.152**	**13.24%**	**33.29%**
1.A.4.b	**Residential- Gaseous Fuels**	**CO_2**	**170.43**	**1318.75**	**170.43**	**1318.75**	**0.149**	**12.99%**	**46.28%**
2.F.1	**Refrigeration and Air Conditioning**	**HFCs**	**0.90**	**927.87**	**0.90**	**927.87**	**0.135**	**11.76%**	**58.04%**
1.B.2.b	**Fugitive emissions from Natural Gas transportation and distribution**	**CH_4**	**1106.49**	**1122.51**	**1106.49**	**1122.51**	**0.116**	**10.12%**	**68.16%**
1.A.4.a	**Commercial/institutional - Gaseous Fuels**	**CO_2**	**35.16**	**482.04**	**35.16**	**482.04**	**0.061**	**5.35%**	**73.51%**
3.B.1.a	**Forest land Remaining Forest land**	**CO_2**	**-470.82**	**-446.78**	**470.82**	**446.78**	**0.047**	**4.09%**	**77.60%**
3.A.1.a	**Enteric Fermentation - Cattle**	**CH_4**	**634.96**	**781.07**	**634.96**	**781.07**	**0.047**	**4.07%**	**81.67%**
1.A.2	**Manufacturing Industries and Construction - Gaseous Fuels**	**CO_2**	**345.63**	**382.86**	**345.63**	**382.86**	**0.032**	**2.75%**	**84.42%**
4.A	**Solid Waste Disposal**	**CH_4**	**359.38**	**422.20**	**359.38**	**422.20**	**0.029**	**2.56%**	**86.98%**
1.A.3.b	**Road Transportation - Liquid Fuels**	**CO_2**	**626.80**	**901.17**	**626.80**	**901.17**	**0.027**	**2.37%**	**89.34%**
1.A.4.c	**Agriculture/Forestry/Fishing/Fish Farms - Gaseous Fuels**	**CO_2**	**0.00**	**144.95**	**0.00**	**144.95**	**0.021**	**1.84%**	**91.18%**
1.A.2	**Manufacturing Industries and Construction - Liquid Fuels**	**CO_2**	**89.23**	**54.07**	**89.23**	**54.07**	**0.015**	**1.28%**	**92.46%**
3.C.4	**Direct N2O Emissions from managed soils**	**N_2O**	**436.57**	**827.04**	**436.57**	**827.04**	**0.010**	**0.88%**	**93.35%**
3.A.1.b-j	**Enteric Fermentation - Other**	**CH_4**	**93.09**	**119.56**	**93.09**	**119.56**	**0.006**	**0.53%**	**93.88%**
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	**62.27**	**67.05**	**62.27**	**67.05**	**0.006**	**0.52%**	**94.40%**
3.C.5	**Indirect N2O Emissions from managed soils**	**N_2O**	**115.32**	**235.70**	**115.32**	**235.70**	**0.005**	**0.45%**	**94.85%**
1.A.3.b	**Road Transportation**	**CH_4**	**7.30**	**46.14**	**7.30**	**46.14**	**0.005**	**0.43%**	**95.28%**
2.A.2	Lime production	CO_2	3.95	39.59	3.95	39.59	0.005	0.42%	95.69%
3.B.6.b	Land Converted to Other land	CO_2	-0.02	29.63	0.02	29.63	0.004	0.38%	96.07%
2.F.2	**Foam Blowing Agents**	HFCs	0.00	28.86	0.00	28.86	0.004	0.37%	96.43%
3.B.4.a.i	Peatlands remaining peatlands	CO_2	1.97	31.92	1.97	31.92	0.004	0.36%	96.80%
4.D	Wastewater Treatment and Discharge	CH_4	80.26	114.33	80.26	114.33	0.004	0.32%	97.11%
3.D.1	Harvested Wood Products	CO_2	-97.14	-5.67	97.14	5.67	0.003	0.25%	97.37%

4.D	Wastewater Treatment and Discharge	N_2O	52.60	71.23	52.60	71.23	0.003	0.25%	97.62%
3.A.2	Manure Management	N_2O	42.33	54.94	42.33	54.94	0.003	0.23%	97.86%
3.B.3.b	Land Converted to Grassland	CO_2	0.00	18.37	0.00	18.37	0.003	0.23%	98.09%
2.A.1	Cement production	CO_2	138.85	258.95	138.85	258.95	0.003	0.23%	98.32%
1.A.3.b	Road Transportation	N_2O	9.99	31.20	9.99	31.20	0.002	0.18%	98.50%
3.C.6	Indirect N2O Emissions from manure management	N_2O	28.49	36.08	28.49	36.08	0.002	0.17%	98.66%
1.A.4	Other Sectors - Biomass	CH_4	24.20	28.68	24.20	28.68	0.002	0.17%	98.83%
1.A.3.e	Other Transportation	CO_2	10.84	31.97	10.84	31.97	0.002	0.17%	99.00%
1.A.1	Energy Industries - Liquid Fuels	CO_2	6.57	0.00	6.57	0.00	0.002	0.14%	99.15%
4.C	Incineration and Open Burning of Waste	CH_4	13.52	12.80	13.52	12.80	0.002	0.14%	99.28%
1.A.4	Other Sectors - Solid Fuels	CO_2	0.04	10.54	0.04	10.54	0.002	0.13%	99.41%
2.F.4	Aerosols	HFCs	3.06	12.10	3.06	12.10	0.001	0.09%	99.50%
3.C.3	Urea application	CO_2	0.00	5.51	0.00	5.51	0.001	0.07%	99.57%
2.A.3	Glass Production	CO_2	1.50	7.06	1.50	7.06	0.001	0.06%	99.63%
4.C	Incineration and Open Burning of Waste	CO_2	4.47	4.71	4.47	4.71	0.000	0.04%	99.67%
4.C	Incineration and Open Burning of Waste	N_2O	3.59	3.42	3.59	3.42	0.000	0.04%	99.70%
1.A.4	Other Sectors - Biomass	N_2O	4.76	5.62	4.76	5.62	0.000	0.03%	99.73%
2.G	Other Product Manufacture and Use	SF_6	0.04	3.29	0.04	3.29	0.000	0.04%	99.78%
3.A.2	Manure Management	CH_4	18.12	37.00	18.12	37.00	0.001	0.07%	99.85%
1.A.4	Other Sectors - Gaseous Fuels	CH_4	0.38	3.61	0.38	3.61	0.000	0.04%	99.88%
3.C.1	Emissions from biomass burning	CH_4	3.68	4.52	3.68	4.52	0.000	0.02%	99.91%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	4.30	5.71	4.30	5.71	0.000	0.02%	99.93%
2.C.1	Iron and Steel Production	CO_2	0.00	1.18	0.00	1.18	0.000	0.02%	99.94%
1.A.4	Other Sectors - Gaseous Fuels	N_2O	0.11	1.07	0.11	1.07	0.000	0.01%	99.96%
1.A.1	Energy Industries - Gaseous Fuels	N_2O	0.92	0.75	0.92	0.75	0.000	0.01%	99.97%
1.A.1	Energy Industries - Gaseous Fuels	CH_4	0.62	0.51	0.62	0.51	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%	99.98%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.23	0.13	0.23	0.13	0.000	0.00%	99.99%
1.A.3.e	Other Transportation	N_2O	0.18	0.52	0.18	0.52	0.000	0.00%	99.99%
1.A.4	Other Sectors - Solid Fuels	CH_4	0.00	0.17	0.00	0.17	0.000	0.00%	99.99%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	N_2O	0.19	0.21	0.19	0.21	0.000	0.00%	99.99%
3.C.1	Emissions from biomass burning	N_2O	1.42	2.56	1.42	2.56	0.000	0.00%	99.99%
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	0.14	0.13	0.14	0.000	0.00%	100.00%

1.B.2.b	Natural Gas	CO_2	0.11	0.11	0.11	0.11	0.000	0.00%	100.00%
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.14	0.17	0.14	0.17	0.000	0.00%	100.00%
1.A.4	Other Sectors - Solid Fuels	N_2O	0.00	0.05	0.00	0.05	0.000	0.00%	100.00%
3.B.2.b	Land Converted to Cropland	CO_2	0.00	-7.40	0.00	7.40	0.000	0.00%	100.00%
3.B.5.b	Land Converted to Settlements	CO_2	0.00	6.73	0.00	6.73	0.000	0.00%	100.00%
3.B.1.b	Land Converted to Forest land	CO_2	0.00	-6.53	0.00	6.53	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 - Liquid Fuels	N_2O	0.09	0.14	0.09	0.14	0.000	0.00%	100.00%
1.A.3.e	Other Transportation	CH_4	0.01	0.04	0.01	0.04	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%
2.F.3	Fire Protection	HFCs	0.00	0.71	0.00	0.71	0.000	0.00%	100.00%
1.A.2	Manufacturing Industries and Construction - Biomass	CH_4	0.00	0.00	0.00	0.00	0.000	0.00%	100.00%
Total			**5,730.59**	**10,777.82**	**6,866.55**	**11,710.56**	**1.218**	**100.00%**	

Annex 1.3 Uncertainty Assessment

IPCC Code	Category	Gas	Base year Emissions or removals (2000), Gg $CO_{2\ eq.}$	Last year emissions or removals (2019), Gg $CO_{2\ eq.}$	Activity Data Uncert-ainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in last year (2019)	Type A Sens-itivity	Type B Sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
1.A.1	Energy Industries - Gaseous Fuels	CO_2	1696.99	1364.95	3%	3%	4%	0.000029	31.7816%	23.8186%	0.9534%	1.0105%	0.0193%
1.A.1	Energy Industries - Gaseous Fuels	CH_4	0.62	0.51	3%	100%	100%	0.000000	0.0116%	0.0089%	0.0116%	0.0004%	0.0000%
1.A.1	Energy Industries - Gaseous Fuels	N_2O	0.92	0.75	3%	500%	500%	0.000000	0.0172%	0.0131%	0.0858%	0.0006%	0.0001%
1.A.1	Energy Industries - Liquid Fuels	CO_2	6.57	0.00	5%	3%	6%	-	0.2155%	0.0000%	0.0065%	0.0000%	0.0000%
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	N_2O	0.02	0.00	5%	1000%	1000%	-	0.0005%	0.0000%	0.0052%	0.0000%	0.0000%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	89.23	54.07	20%	5%	21%	0.000001	1.9847%	0.9435%	0.0992%	0.2669%	0.0008%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.08	0.05	20%	100%	102%	0.000000	0.0017%	0.0008%	0.0017%	0.0002%	0.0000%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.23	0.13	20%	1000%	1000%	0.000000	0.0051%	0.0023%	0.0513%	0.0007%	0.0000%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	345.63	382.86	5%	3%	6%	0.000004	4.6597%	6.6810%	0.1398%	0.4724%	0.0024%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CH_4	0.13	0.14	5%	100%	100%	0.000000	0.0017%	0.0025%	0.0017%	0.0002%	0.0000%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	N_2O	0.19	0.21	5%	1000%	1000%	0.000000	0.0025%	0.0037%	0.0250%	0.0003%	0.0000%
1.A.3.b	Road Transportation - Liquid Fuels	CO_2	626.80	901.17	20%	5%	21%	0.000297	4.8404%	15.7256%	0.2420%	4.4479%	0.1984%
1.A.3.b	Road Transportation - Liquid Fuels	CH_4	5.43	7.25	20%	300%	301%	0.000004	0.0516%	0.1265%	0.1548%	0.0358%	0.0003%
1.A.3.b	Road Transportation - Liquid Fuels	N_2O	9.09	12.48	20%	300%	301%	0.000012	0.0807%	0.2177%	0.2420%	0.0616%	0.0006%
1.A.3.b	Road Transportation - Gaseous Fuels	CO_2	55.20	1138.30	5%	3%	6%	0.000038	18.0501%	19.8636%	0.5415%	1.4046%	0.0227%
1.A.3.b	Road Transportation - Gaseous Fuels	CH_4	1.87	38.89	5%	1500%	1500%	0.002930	0.6174%	0.6787%	9.2608%	0.0480%	0.8576%
1.A.3.b	Road Transportation - Gaseous Fuels	N_2O	0.90	18.72	5%	2500%	2500%	0.001886	0.2972%	0.3267%	7.4297%	0.0231%	0.5520%

1.A.3.e	Other Transportation - Liquid Fuels	CO_2	10.84	31.97	20%	5%	21%	0.000000	0.2022%	0.5579%	0.0101%	0.1578%	0.0003%
1.A.3.e	Other Transportation - Liquid Fuels	CH_4	0.01	0.04	20%	100%	102%	0.000000	0.0002%	0.0006%	0.0002%	0.0002%	0.0000%
1.A.3.e	Other Transportation - Liquid Fuels	N_2O	0.18	0.52	20%	1000%	1000%	0.000000	0.0033%	0.0091%	0.0330%	0.0026%	0.0000%
1.A.4	Other Sectors - Liquid Fuels	CO2	62.27	67.05	20%	5%	21%	0.000002	0.8735%	1.1700%	0.0437%	0.3309%	0.0011%
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.14	0.17	20%	100%	102%	0.000000	0.0015%	0.0030%	0.0015%	0.0009%	0.0000%
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.09	0.14	20%	1000%	1000%	0.000000	0.0005%	0.0024%	0.0047%	0.0007%	0.0000%
1.A.4	Other Sectors - Solid Fuels	CO_2	0.04	10.54	40%	10%	41%	0.000000	0.1826%	0.1840%	0.0183%	0.1041%	0.0001%
1.A.4	Other Sectors - Solid Fuels	CH_4	0.00	0.17	40%	100%	108%	0.000000	0.0028%	0.0029%	0.0028%	0.0016%	0.0000%
1.A.4	Other Sectors - Solid Fuels	N_2O	0.00	0.05	40%	1000%	1001%	0.000000	0.0009%	0.0009%	0.0090%	0.0005%	0.0000%
1.A.4	Other Sectors - Gaseous Fuels	CO_2	205.58	1945.74	5%	3%	6%	0.000111	27.1967%	33.9535%	0.8159%	2.4009%	0.0643%
1.A.4	Other Sectors - Gaseous Fuels	CH_4	0.38	3.61	5%	100%	100%	0.000000	0.0506%	0.0630%	0.0506%	0.0045%	0.0000%
1.A.4	Other Sectors - Gaseous Fuels	N_2O	0.11	1.07	5%	1000%	1000%	0.000001	0.0150%	0.0186%	0.1495%	0.0013%	0.0002%
1.A.4	Other Sectors - Biomass	CH_4	24.20	28.68	100%	100%	141%	0.000014	0.2937%	0.5005%	0.2937%	0.7078%	0.0059%
1.A.4	Other Sectors - Biomass	N_2O	4.76	5.62	100%	1000%	1005%	0.000027	0.0582%	0.0981%	0.5822%	0.1387%	0.0036%
1.B.2.b	Natural Gas	CO_2	0.11	0.11	5%	5%	7%	0.000000	0.0016%	0.0020%	0.0001%	0.0001%	0.0000%
1.B.2.b	Natural Gas	CH_4	1106.49	1122.51	5%	5%	7%	0.000054	16.6943%	19.5881%	0.8347%	1.3851%	0.0262%
2.A.1	Cement production	CO_2	138.85	258.95	5%	20%	21%	0.000025	0.0381%	4.5188%	0.0076%	0.3195%	0.0010%
2.A.2	Lime production	CO_2	3.95	39.59	5%	6%	8%	0.000000	0.5611%	0.6909%	0.0337%	0.0489%	0.0000%
2.A.3	Glass Production	CO_2	1.50	7.06	5%	40%	40%	0.000000	0.0741%	0.1233%	0.0296%	0.0087%	0.0000%
2.C.1	Iron and Steel Production	CO_2	0.00	1.18	10%	25%	27%	0.000000	0.0207%	0.0207%	0.0052%	0.0029%	0.0000%
2.D	Non-Energy Products from Fuels and Solvent Use	CO_2	4.30	5.71	5%	50%	50%	0.000000	0.0416%	0.0997%	0.0208%	0.0070%	0.0000%
2.F.1	Refrigeration and Air Conditioning	HFC	0.90	927.87	30%	25%	39%	0.001130	16.1621%	16.1915%	4.0405%	6.8695%	0.6352%
2.F.2	Foam Blowing Agents	HFC	0.00	28.86	50%	25%	56%	0.000002	0.5036%	0.5036%	0.1259%	0.3561%	0.0014%
2.F.3	Fire Protection	HFC	0.00	0.71	40%	25%	47%	0.000000	0.0123%	0.0123%	0.0031%	0.0070%	0.0000%
2.F.4	Aerosols	HFC	3.06	12.10	30%	25%	39%	0.000000	0.1107%	0.2111%	0.0277%	0.0896%	0.0001%
2.G	Other Product Manufacture and Use	SF_6	0.04	3.29	5%	30%	30%	0.000000	0.0560%	0.0574%	0.0168%	0.0041%	0.0000%
3.A.1.a	Enteric Fermentation - Cattle	CH_4	634.96	781.07	10%	20%	22%	0.000263	7.2013%	13.6298%	1.4403%	1.9275%	0.0579%
3.A.1.b-j	Enteric Fermentation - Other	CH_4	93.09	119.56	20%	40%	45%	0.000025	0.9687%	2.0863%	0.3875%	0.5901%	0.0050%
3.A.2	Manure Management	N_2O	42.33	54.94	25%	30%	39%	0.000004	0.4304%	0.9587%	0.1291%	0.3390%	0.0013%
3.A.2	Manure Management	CH_4	18.12	37.00	25%	30%	39%	0.000002	0.0507%	0.6456%	0.0152%	0.2282%	0.0005%
3.B.1.a	Forest land Remaining Forest land	CO_2	-470.82	-446.78	5%	105%	105%	0.001899	7.6620%	7.7964%	8.0451%	0.5513%	0.6503%
3.B.1.b	Land Converted to Forest land	CO_2	0.00	-6.53	5%	105%	105%	0.000000	0.1139%	0.1139%	0.1196%	0.0081%	0.0001%
3.B.2.a	Cropland Remaining Cropland	CO_2	0.67	0.67	5%	50%	50%	0.000000	0.0103%	0.0117%	0.0051%	0.0008%	0.0000%
3.B.2.b	Land Converted to Cropland	CO_2	0.00	-7.40	5%	50%	50%	0.000000	0.1291%	0.1291%	0.0645%	0.0091%	0.0000%
3.B.3.b	Land Converted to Grassland	CO_2	0.00	18.37	5%	50%	50%	0.000001	0.3205%	0.3205%	0.1602%	0.0227%	0.0003%
3.B.4.a.i	Peatlands remaining peatlands	CO_2	1.97	31.92	5%	50%	50%	0.000002	0.4922%	0.5570%	0.2461%	0.0394%	0.0006%
3.B.4.a.i	Peatlands remaining peatlands	N_2O	0.43	0.43	5%	50%	50%	0.000000	0.0066%	0.0075%	0.0033%	0.0005%	0.0000%
3.B.5.b	Land Converted to Settlements	CO_2	0.00	6.73	5%	50%	50%	0.000000	0.1174%	0.1174%	0.0587%	0.0083%	0.0000%
3.B.6.b	Land Converted to Other land	CO_2	-0.02	29.63	5%	50%	50%	0.000002	0.5176%	0.5170%	0.2588%	0.0366%	0.0007%
3.C.1	Emissions from biomass burning	CH_4	3.68	4.52	5%	105%	105%	0.000000	0.0419%	0.0789%	0.0440%	0.0056%	0.0000%
3.C.1	Emissions from biomass burning	N_2O	1.42	2.56	5%	105%	105%	0.000000	0.0020%	0.0447%	0.0021%	0.0032%	0.0000%
3.C.3	Urea application	CO_2	0.00	5.51	5%	10%	11%	0.000000	0.0960%	0.0961%	0.0096%	0.0068%	0.0000%
3.C.4	Direct N2O Emissions from managed soils	N_2O	436.57	827.04	20%	180%	181%	0.019314	0.1041%	14.4321%	0.1874%	4.0820%	0.1670%
3.C.5	Indirect N2O Emissions from managed soils	N_2O	115.32	235.70	20%	210%	211%	0.002128	0.3282%	4.1130%	0.6892%	1.1633%	0.0183%
3.C.6	Indirect N2O Emissions from manure management	N_2O	28.49	36.08	25%	30%	39%	0.000002	0.3053%	0.6297%	0.0916%	0.2226%	0.0006%
3.D.1	Harvested Wood Products	CO_2	-97.14	-5.67	50%	50%	71%	0.000000	3.0898%	0.0989%	1.5449%	0.0700%	0.0239%
4.A	Solid Waste Disposal	CH_4	359.38	422.20	70%	30%	76%	0.000890	4.4244%	7.3674%	1.3273%	7.2934%	0.5496%
4.C	Incineration and Open Burning of Waste	CO_2	4.47	4.71	40%	40%	57%	0.000000	0.0646%	0.0821%	0.0258%	0.0465%	0.0000%
4.C	Incineration and Open Burning of Waste	CH_4	13.52	12.80	40%	40%	57%	0.000000	0.2205%	0.2234%	0.0882%	0.1264%	0.0002%
4.C	Incineration and Open Burning of Waste	N_2O	3.59	3.42	40%	40%	57%	0.000000	0.0582%	0.0597%	0.0233%	0.0338%	0.0000%
4.D	Wastewater Treatment and Discharge	CH_4	80.26	114.33	36%	58%	68%	0.000052	0.6390%	1.9951%	0.3706%	1.0157%	0.0117%
4.D	Wastewater Treatment and Discharge	N_2O	52.60	71.23	35%	500%	501%	0.001097	0.4832%	1.2430%	2.4159%	0.6153%	0.0622%
	Total		**5730.59**	**10777.82**				**0.0323**					**0.0394**
			Percentage Uncertainty in total inventory					**17.96%**				**Trend Uncertainty**	**19.86%**

Annex 2. The Energy Sector

Annex 2.1 Main indicators of the gas supply system in 2018 and 2019

Main indicators of the gas supply system in 2018, mln m³

#	Indicator	October	Novem-ber	Decem-ber	IV quarter	Total in 2018
1	**Imported Natural Gas, including:**	**229.8**	**244.3**	**248.0**	**722.1**	**2463.4**
1.1	From Russian Federation	179.2	195.1	196.6	570.9	1939.6
1.2	From the Islamic Republic of Iran	50.6	49.2	51.4	151.2	523.8
2	**Taken from gas pipelines and Gas Underground Storage Facility (GUSF)**	**0.5**	**8.8**	**14.5**	**23.9**	**60.2**
3	**Gas for own needs in the transmission system**	**1.2**	**0.6**	**0.1**	**1.8**	**3.2**
4	**Gas losses in the own transmission system, including:**	**7.3**	**8.7**	**8.7**	**24.7**	**96.4**
4.1	Technological inevitable losses in gas pipelines	7.3	8.7	8.7	24.7	96.1
4.2	Accidental losses	0.0	0.0	0.0	0.0	0.3
5	**Injected into gas pipelines and GUSF**	**19.5**	**8.3**	**0.0**	**27.8**	**39.4**
6	**The volume of gas transmitted**	**202.4**	**235.5**	**253.7**	**691.6**	**2384.5**
6.1	Other consumers	10.5	7.3	30.6	48.4	197.5
6.2	Distribution system	191.9	228.1	223.2	643.2	2187.0
7	**Gas for own needs in the distribution system**	**0.0**	**0.1**	**0.6**	**0.7**	**2.8**
8	**Recovered gas**	**0.1**	**0.0**	**0.0**	**0.2**	**0.7**
9	**Gas losses in the distribution system**	**2.0**	**2.4**	**4.0**	**8.3**	**27.5**
10	**Natural gas sales in the distribution system, including:**	**189.8**	**225.6**	**218.6**	**634.0**	**2156.1**
10.1	Residential	29.4	66.0	94.4	189.7	554.1
10.2	Energy Generation	73.0	64.7	19.0	156.6	629.9
10.3	Industry	26.1	17.8	16.8	60.7	226.4
10.4	Auto gas filling compressor station	52.3	50.5	52.1	154.9	552.7
10.5	Budgetary organizations	0.6	7.1	9.9	17.6	43.8
10.6	Other consumers	8.4	19.6	26.4	54.4	149.1

Main indicators of the gas supply system in 2019, mln m³

#	Indicator	October	Novem-ber	Decem-ber	IV quarter	Total in 2019
1	**Imported Natural Gas. including:**	**158.0**	**246.0**	**301.1**	**705.1**	**2545.4**
1.1	From Russian Federation	125.7	214.9	268.9	609.5	2166.9
1.2	From the Islamic Republic of Iran	32.3	31.2	32.2	95.7	378.5
2	**Taken from gas pipelines and Gas Underground Storage Facility (GUSF)**	**0.1**	**0.4**	**2.3**	**2.8**	**30.3**
3	**Gas for own needs in the transmission system**	**0.1**	**0.3**	**0.2**	**0.5**	**1.6**
4	**Gas losses in the own transmission system. including:**	**7.1**	**8.0**	**8.4**	**23.4**	**86.8**
4.1	Technological inevitable losses in gas pipelines	7.1	8.0	8.4	23.4	86.8
4.2	Accidental losses	0.0	0.0	0.0	0.0	0.0
5	**Injected into gas pipelines and GUSF**	**0.1**	**3.7**	**1.2**	**5.1**	**11.7**
6	**The volume of gas transmitted**	**150.8**	**234.4**	**293.7**	**678.9**	**2475.5**
6.1	Other consumers	24.3	16.3	15.5	56.1	242.4
6.2	Distribution system	126.4	218.2	278.1	622.8	2233.1
7	**Gas for own needs in the distribution system**	**0.0**	**0.2**	**0.8**	**1.0**	**2.7**
8	**Recovered gas**	**0.0**	**0.0**	**0.1**	**0.1**	**0.615**
9	**Gas losses in the distribution system**	**2.1**	**3.3**	**4.3**	**9.7**	**27.4**
10	**Natural gas sales in the distribution system, including:**	**124.3**	**214.7**	**273.0**	**611.9**	**2202.4**
10.1	Residential	29.1	75.7	103.3	208.1	668.7
10.2	Energy Generation	17.8	32.1	63.7	113.6	501.0
10.3	Industry	16.3	24.3	15.1	55.7	208.6
10.4	Auto gas filling compressor station	50.6	48.4	49.9	149.0	577.2
10.5	Budgetary organizations	0.5	7.3	9.9	17.7	52.2
10.6	Other consumers	9.9	26.8	31.0	67.8	194.7

Annex 2.2 The Energy Balance of the RA in 2019 (in the format of the International Energy Agency)

Yerevan **25.02.2021**

ENERGY BALANCE OF THE REPUBLIC OF ARMENIA, 2019
(FORMAT OF IEA)

1000 tonnes of oil equivalent (1000 t. o. e.)

N		Total	BROWN COAL	Anthracite	Bituminous coal	Liquefied petroleum gases (LPG)	Motor Gasoline excl. bio	Gasoline type jet fuel	White spirit & SBP	Kerosene Type Jet Fuel excl. bio	Other Kerosene	Gas/Diesel Oil excl. bio	Fuel Oil	Lubricants	Paraffin Waxes	Bitumen	Other oil products	Natural Gas	Hydro power	Wind power	Solar PV	Solar Thermal	Fire wood	Solid biomass	Other biomass	Nuclear heat	Derived heat	Electricity
1.1	Production	934.2																	203.9	0.3	6.2	8.5	49.2		21.9	644.2		
1.2	Imports	2 665.4	0.3	2.3	0.1	34.1	185.7	0.2	0.7	72.4	0.9	137.9	0.3	9.1	0.2	60.6	3.1	2 120.3					0.1	11.5	0.4			25.2
1.3	International aviation bunker	-72.7						-0.2		-72.4																		
1.4	Exports	-109.2										-0.5		0.0		-0.1	0.0							0.0	-1.1			-107.6
1.5	Stock changes	-13.8														-30.0		15.5							0.7			
1	**TPES (Total primary energy supply)**	**3 403.9**	**0.3**	**2.3**	**0.1**	**34.1**	**185.7**		**0.7**		**0.9**	**137.4**	**0.3**	**9.1**	**0.2**	**30.5**	**3.1**	**2 135.8**	**203.9**	**0.3**	**6.2**	**8.5**	**49.3**	**11.5**	**21.9**	**644.2**		**-82.4**
2	**Transfers**																											
3	**Statistical differences**	**0.0**									**0.0**							**0.0**										**0.0**
4	**Transformation processes**	**-768.8**																**-576.2**	**-203.9**	**-0.3**	**-6.2**					**-644.2**	**0.7**	**661.3**
4.1	*Electricity plants*	-455.2																	-203.9	-0.3	-6.2					-644.2		399.4

N		Total	BROWN COAL	Anthracite	Bituminous coal	Liquefied petroleum gases (LPG)	Motor Gasoline excl. bio	Gasoline type jet fuel	White spirit & SBP	Kerosene Type Jet Fuel excl. bio	Other Kerosene	Gas/Diesel Oil excl. bio	Fuel Oil	Lubricants	Paraffin Waxes	Bitumen	Other oil products	Natural Gas	Hydro power	Wind power	Solar PV	Solar Thermal	Fire wood	Solid biomass	Other biomass	Nuclear heat	Derived heat	Electricity
4.1.1	*Nuclear power stations (MA El. Gen.)*	-455.2																								-644.2		189.0
4.1.2	*Hydro power stations (MA El. Gen.)*																		-121.7									121.7
4.1.3	*Small hydro power stations (MA El. Gen.)*																		-82.2									82.2
4.1.4	*Wind power stations (MA El. Gen.)*																			-0.3								0.3
4.1.5	*Solar power stations (MA El. Gen.)*																				-6.2							6.2
4.2	*Thermal power stations (MA El. Gen.)*	-312.5																-573.7										261.2
4.3	*Combined heat and power stations (CHP)*	-1.1																-2.5									0.7	0.7
4.4	*Other stations*																											
5	**Energy industry own use**	**-32.3**																**-3.6**									**0.0**	**-28.7**
5.1	*Nuclear power stations*	-14.5																										-14.5
5.2	*Termal power stations (El. Gen., CHP)*	-10.9																									0.0	-10.8
5.3	*Hydro power stations*	-3.4																										-3.4
5.4	*Wind power stations*	0.0																										0.0
5.5	*Gas transportation*	-3.6																-3.6										
5.6	*Other stations*	0.0																										0.0
6	**Distribution losses**	**-143.2**																**-95.6**									**-0.4**	**-47.1**
7	**Total final consumption**	**2 459.6**	**0.3**	**2.3**	**0.1**	**34.1**	**185.7**		**0.7**		**0.9**	**137.4**	**0.3**	**9.1**	**0.2**	**30.5**	**3.1**	**1 460.4**				**8.5**	**49.3**	**11.5**	**21.9**		**0.2**	**503.1**
7.1	**Final energy consumption**	**2 413.4**	**0.3**	**2.3**		**34.1**	**185.6**		**0.1**		**0.9**	**136.2**	**0.0**					**1 460.4**				**8.5**	**49.3**	**11.5**	**20.8**		**0.2**	**503.1**

N		Total	BROWN COAL	Anthracite	Bituminous coal	Liquefied petroleum gases (LPG)	Motor Gasoline excl. bio	Gasoline type jet fuel	White spirit & SBP	Kerosene Type Jet Fuel excl. bio	Other Kerosene	Gas/Diesel Oil excl. bio	Fuel Oil	Lubricants	Paraffin Waxes	Bitumen	Other oil products	Natural Gas	Hydro power	Wind power	Solar PV	Solar Thermal	Fire wood	Solid biomass	Other biomass	Nuclear heat	Derived heat	Electricity
7.1.1	Industry	**313.0**				**0.2**	**0.1**		**0.1**			**17.1**	**0.0**					**161.7**					**0.0**	**0.0**				**133.8**
7.1.1.1	*Iron and steel*	*19.9*				*0.0*												*13.9*										*6.0*
7.1.1.2	*Chemical and petrochemical*	*3.7*										*0.2*						*2.2*										*1.3*
7.1.1.3	*Non-ferrous metals*	*24.3*										*5.0*						*0.7*										*18.6*
7.1.1.4	*Non-metallic minerals*	*81.7*				*0.0*	*0.0*		*0.0*			*0.5*						*69.8*										*11.4*
7.1.1.5	*Transport equipment*	*0.1*																*0.1*										*0.0*
7.1.1.6	*Machinery*	*2.9*				*0.0*												*0.8*						*0.0*				*2.0*
7.1.1.7	*Mining and quarrying*	*84.2*				*0.0*						*10.8*						*8.4*						*0.0*				*64.9*
7.1.1.8	*Food, beverages and tobacco*	*75.1*				*0.0*						*0.0*						*56.2*					*0.0*					*18.9*
7.1.1.9	*Paper, pulp and printing*	*5.7*																*3.8*										*2.0*
7.1.1.10	*Wood and wood products*	*0.1*																*0.0*					*0.0*					*0.1*
7.1.1.11	*Textiles and leather*	*2.3*																*0.7*					*0.0*					*1.6*
7.1.1.12	*Construction*	*8.0*				*0.2*	*0.1*		*0.0*			*0.7*	*0.0*					*3.9*										*3.1*
7.1.1.13	*Non-specified (Industry)*	*5.1*				*0.0*	*0.0*		*0.0*			*0.0*						*1.2*										*3.8*
7.1.2	Transport	**806.6**				**28.4**	**185.6**					**103.1**						**480.8**										**8.7**
7.1.2.1	*Rail, metro, other electric transport*	*6.6*																										*6.6*
7.1.2.2	*Road*	*797.8*				*28.4*	*185.6*					*103.1*						*480.8*										
7.1.2.3	*Aviation*	*1.5*																										*1.5*
7.1.2.4	*Non-specified (Transport)*	*0.7*																										*0.7*
7.1.3	Other sectors	**1 293.9**	**0.3**	**2.3**		**5.5**					**0.9**	**16.1**						**817.8**				**8.5**	**49.3**	**11.5**	**20.8**		**0.2**	**360.6**

N		Total	BROWN COAL	Anthracite	Bituminous coal	Liquefied petroleum gases (LPG)	Motor Gasoline excl. bio	Gasoline type jet fuel	White spirit & SBP	Kerosene Type Jet Fuel excl. bio	Other Kerosene	Gas/Diesel Oil excl. bio	Fuel Oil	Lubricants	Paraffin Waxes	Bitumen	Other oil products	Natural Gas	Hydro power	Wind power	Solar PV	Solar Thermal	Fire wood	Solid biomass	Other biomass	Nuclear heat	Derived heat	Electricity
7.1.3.1	*Households*	812.7	0.3	0.5		0.4						0.4						557.0				4.3	49.3	11.5	20.8		0.2	168.0
7.1.3.2	*Agriculture*	29.8									0.9	15.7																13.2
7.1.3.3	*Services*	451.4		1.8		5.1												260.8				4.3						179.4
7.2	**Non-energy use**	**46.2**			**0.1**		**0.0**		**0.7**			**1.1**	**0.3**	**9.1**	**0.2**	**30.5**	**3.1**								**1.1**			
7.2.1	Chemical Industry	1.8							0.7			1.1																
7.2.2	Other sectors	44.3			0.1		0.0						0.3	9.1	0.2	30.5	3.1								1.1			

Note:
The discrepancy between the totals and sum in some cases can be explaind by using rounded data.
The energy balance of the Republic of Armenia in 2019 is compiled by the Ministry of territorial administration and infrastructure of the Republic of Armenia.
The methodology of the energy balance is available on the website
http://www.minenergy.am/storage/files/pages/pg_8282982648982_2.2EDRC-Explanatory_Notes_on_Energy_Balance_of_Armenia_for_2015_a.docx
The explanatory notes of energy balance of Armenia for 2019 is located by the following link:
http://www.mtad.am/u_files/file/energy/2_Armenia%20%20Energy%20Balance%202019_ENG.pdf in mtad.am website (armenian and english languages)

Annex 2.3 Main indicators of the electrical energy system in 2018 and 2019

Main indicators of the electrical energy system in 2018, mln kWh

#	Electrical Energy Produced and Supplied	October	November	December	IV quarter	II semester	Total in 2018
1	**Electrical energy generation, including:**	**653.1**	**676.4**	**671.5**	**2000.9**	**3924.1**	**7776.9**
1.1	ANPP	157.7	196.0	289.0	642.7	934.9	2076.1
1.2	Hrazdan TPP	19.4	0.0	35.8	55.1	293.0	314.0
1.3	"Gazprom Armenia" CJSC Hrazdan-5 TPP	211.1	153.2	0.0	364.4	1007.5	1615.0
1.4	Yerevan CCGT	126.3	157.0	157.6	440.9	599.4	1431.4
1.5	International energy corporation HPP	9.2	14.2	20.9	44.4	217.9	412.2
1.6	ContourGlobal HPP	77.1	96.3	104.7	278.2	498.0	901.9
1.7	Combined Heat and Power Production (Cogeneration)	0.3	2.6	2.6	5.4	6.1	15.2
1.8	Power plants using renewable energy resources (up to 30 MW)	51.9	57.0	60.9	169.8	367.2	1011.1
1.8.1	*Small HPPs*	51.1	56.4	60.0	167.6	363.0	1004.0
1.8.2	*Solar power plants*	0.7	0.4	0.3	1.4	3.2	5.2
1.8.3	*Wind power plants*	0.1	0.2	0.5	0.8	0.9	1.9
2	**Own needs of the generating plants, including:**	**32.3** **5.0%**	**31.7** **4.7%**	**32.1** **4.8%**	**96.1** **4.8%**	**186.0** **4.7%**	**353.8** **4.5%**
2.1	ANPP	15.5 9.8%	17.8 9.1%	21.4 7.4%	54.7 8.5%	83.8 9.0%	178.0 8.6%
2.2	Hrazdan TPP	1.4 7.4%	0.0 0.0%	2.8 7.7%	4.2 7.6%	21.5 7.3%	23.0 7.3%
2.3	"Gazprom Armenia" CJSC Hrazdan-5 TPP	8.9 4.2%	6.4 4.2%	0.0 0.0%	15.3 4.2%	43.4 4.3%	65.9 4.1%
2.4	Yerevan CCGT	4.2 3.3%	5.1 3.2%	5.2 3.3%	14.4 3.3%	20.0 3.3%	47.4 3.3%
2.5	International energy corporation HPP	0.5 5.2%	0.5 3.3%	0.5 2.6%	1.5 3.4%	5.3 2.4%	10.4 2.5%
2.6	ContourGlobal HPP	0.4 0.6%	0.5 0.5%	0.6 0.6%	1.5 0.5%	3.0 0.6%	5.9 0.7%
2.7	Combined Heat and Power Production (Cogeneration)	0.0 0.0%	0.1 5.5%	0.1 5.1%	0.3 5.0%	0.3 4.5%	0.6 3.8%
2.8	Power plants using renewable energy resources (up to 30 MW), excluding autonomous generation	1.4 2.6%	1.4 2.4%	1.5 2.5%	4.2 2.5%	8.7 2.4%	22.7 2.2%
3	**Electricity supply from generation plants (1-2+3.8.3), including:**	**620.9**	**644.7**	**639.0**	**1904.6**	**3738.5**	**7423.8**
3.1	ANPP	142.2	178.2	267.6	588.0	851.1	1898.1
3.2	Hrazdan TPP	17.9	0.0	33.0	50.9	271.6	291.0
3.3	"Gazprom Armenia" CJSC Hrazdan-5 TPP	202.2	146.8	0.0	349.1	964.1	1549.1
3.4	Yerevan CCGT	122.1	152.0	152.4	426.5	579.4	1384.1
3.5	International energy corporation HPP	8.8	13.7	20.4	42.9	212.6	401.8
3.6	ContourGlobal HPP	76.7	95.8	104.1	276.7	495.1	896.0
3.7	Combined Heat and Power Production (Cogeneration). including:	0.3	2.4	2.5	5.2	5.9	14.6
3.7.1	*Yerevan Medical University CHP plant*	0.0005	0.9	1.2	2.1	2.1	5.2
3.7.2	*ArmRosCogeneration CHP plant*	0.3	1.6	1.2	3.1	3.8	9.4
3.8	Power plants using renewable energy resources (up to 30 MW). including:	50.7	55.6	59.0	165.3	358.8	989.1
3.8.1	*Small HPPs*	49.8	55.0	58.6	163.4	354.3	981.5
3.8.2	*Solar power plants*	0.6	0.4	0.3	1.4	3.2	5.1
3.8.3	*Reciprocal currents' share of the autonomous generation*	0.1	0.02	-0.4	-0.2	0.4	0.7
3.8.4	*Wind power plants*	0.1	0.2	0.5	0.8	0.9	1.8
4	**Import, including:**	10.2	5.9	17.8	33.9	59.2	203.8
4.1	Artsakh	9.6	4.3	6.0	19.9	33.5	97.1
4.2	The Islamic Republic of Iran	0.4	1.6	11.8	13.9	15.5	24.4
4.3	Georgia	0.2	0.0	0.0	0.2	10.2	82.3
5	**Inflow to the high voltage network (3.1+3.2+3.3+3.4+3.5+3.6+4)**	**580.2**	**592.5**	**595.3**	**1768.0**	**3433.1**	**6623.9**
6	**Losses in the high voltage network (% ratio to the inflows), including:**	**14.1** **2.4%**	**11.7** **2.0%**	**8.5** **1.4%**	**34.3** **1.9%**	**66.1** **1.9%**	**137.3** **2.1%**
6.1	Armenian Electric Networks CJSC	10.5	8.9	7.4	26.8	53.2	103.4
6.2	Yerevan CCGT	3.6	2.8	1.1	7.4	12.9	33.9
7	**Delivery from High Voltage Networks (5+3.7+3.8-6), including:**	**617.0**	**638.9**	**648.4**	**1904.3**	**3731.6**	**7490.3**
7.1	Domestic consumption	466.9	492.7	564.5	1524.1	3052.3	5863.0
7.2	Artsakh	6.3	9.5	10.1	25.9	45.7	79.9

#	Electrical Energy Produced and Supplied	October	November	December	IV quarter	II semester	Total in 2018
7.3	The Islamic Republic of Iran	143.8	136.8	73.7	354.3	633.6	1539.6
7.4	Georgia	0.0	0.0	0.0	0.0	0.0	7.8
7.4.1	*High Voltage Networks CJSC*	0.0	0.0	0.0	0.0	0.0	0.3
7.4.2	*EnergyImpEx CJSC*	0.0	0.0	0.0	0.0	0.0	7.6
8	**Total losses in distribution networks (% ratio to the inflows) (8/7.1), including:**	**34.5**	**37.9**	**58.6**	**131.0**	**245.2**	**474.7**
		7.4%	**7.7%**	**10.4%**	**8.6%**	**8.0%**	**8.1%**
8.1	technological losses	34.8	38.3	48.3	121.4	238.0	469.2
		7.4%	7.8%	8.6%	8.0%	7.8%	8.0%
8.2	commercial losses	0.2	-0.5	10.3	9.6	7.2	5.6
		-0.05%	-0.1%	1.8%	0.6%	0.2%	0.1%
9	**Electricity supplied by Armenian Electric Networks CJSC (by consumer group) (7.1-8)**	**432.3**	**454.812**	**505.9**	**1393.1**	**2807.1**	**5388.3**
9.1	Residential	139.3	166.8	186.8	492.8	931.0	1815.2
9.2	Budgetary organizations	14.8	22.2	23.8	60.8	100.9	211.6
9.3	Industry	115.3	95.0	117.9	328.3	635.1	1265.8
9.4	Transport	7.7	8.3	8.6	24.6	49.0	96.2
9.5	Irrigation	9.1	2.1	0.4	11.6	115.5	170.3
9.6	Water supply and sanitation	4.8	4.1	4.1	13.0	35.4	62.2
9.7	Other consumers	141.3	156.3	164.4	462.0	940.2	1766.9

Main indicators of the electrical energy system in 2019, mln kWh

#	Electrical Energy Produced and Supplied	October	November	December	IV quarter	II semester	Total in 2019
1	**Electrical energy generation, including:**	**603.0**	**613.5**	**765.2**	**1981.7**	**3989.5**	**7632.3**
1.1	ANPP	289.8	290.3	298.0	878.1	994.3	2197.8
1.2	Hrazdan TPP	42.1	39.9	69.3	151.4	395.8	500.7
1.3	“Gazprom Armenia” CJSC Hrazdan-5 TPP	0.0	0.2	97.1	97.3	713.8	944.5
1.4	Yerevan CCGT	128.9	150.6	155.3	434.8	845.5	1593.0
1.5	International energy corporation HPP	4.9	10.3	19.3	34.5	168.0	424.3
1.6	ContourGlobal HPP	82.8	69.5	75.0	227.3	509.3	991.1
1.7	Combined Heat and Power Production (Cogeneration)	0.0	1.2	1.1	2.3	2.3	8.6
1.8	Power plants using renewable energy resources (up to 30 MW)	54.4	51.5	50.1	156.0	360.6	972.2
1.8.1	*Small HPPs*	53.1	50.2	48.8	152.0	351.8	955.6
1.8.2	*Solar power plants*	1.1	1.1	1.0	3.2	7.3	13.4
1.8.3	*Wind power plants*	0.2	0.2	0.4	0.8	1.5	3.2
2	**Own needs of the generating plants, including:**	**30.0**	**30.7**	**37.1**	**97.8**	**174.3**	**334.0**
		5.0%	**5.0%**	**4.8%**	**4.9%**	**4.4%**	**4.4%**
2.1	ANPP	20.9	20.5	21.2	62.5	72.7	168.8
		7.2%	7.1%	7.1%	7.1%	7.3%	7.7%
2.2	Hrazdan TPP	2.8	2.8	4.8	10.4	26.6	34.0
		6.7%	7.0%	6.9%	6.9%	6.7%	6.8%
2.3	“Gazprom Armenia” CJSC Hrazdan-5 TPP	0.0	0.04	3.5	3.6	30.3	39.3
		0.0%	23.0%	3.6%	3.7%	4.2%	4.2%
2.4	Yerevan CCGT	4.1	5.0	5.0	14.1	27.3	51.9
		3.2%	3.3%	3.2%	3.2%	3.2%	3.3%
2.5	International energy corporation HPP	0.2	0.3	0.4	0.9	4.8	10.8
		4.9%	2.8%	1.9%	2.6%	2.8%	2.5%
2.6	ContourGlobal HPP	0.7	0.6	0.6	1.8	3.9	7.4
		0.8%	0.8%	0.8%	0.8%	0.8%	0.7%
2.7	Combined Heat and Power Production (Cogeneration)	0.0	0.1	0.1	0.2	0.2	0.7
		0.0%	10.5%	9.8%	10.2%	10.5%	7.6%
2.8	Power plants using renewable energy resources (up to 30 MW), excluding autonomous generation	1.4	1.4	1.5	4.3	8.5	21.1
		2.5%	2.8%	2.9%	2.7%	2.4%	2.2%
3	**Electricity supply from generation plants (1-2+3.8.3), including:**	**574.4**	**583.8**	**728.7**	**1886.8**	**3821.8**	**7308.5**
3.1	ANPP	269.0	269.8	276.8	815.6	921.6	2029.0
3.2	Hrazdan TPP	39.3	37.1	64.5	140.9	369.2	466.7
3.3	“Gazprom Armenia” CJSC Hrazdan-5 TPP	0.0	0.1	93.6	93.7	683.5	905.2
3.4	Yerevan CCGT	124.8	145.6	150.2	420.7	818.2	1541.1
3.5	International energy corporation HPP	4.7	10.0	18.9	33.6	163.2	413.5
3.6	ContourGlobal HPP	82.1	69.0	74.4	225.5	505.5	983.6
3.7	Combined Heat and Power Production (Cogeneration). including:	0.0	1.0	1.0	2.1	2.1	8.0
3.7.1	*Yerevan Medical University CHP plant*	0.0	1.0	1.0	2.0	2.0	7.0
3.7.2	*ArmRosCogeneration CHP plant*	0.0	0.0	0.0	0.0	0.0	0.9
3.7.3	*Lusastgh CJSC*	0.0	0.0	0.0	0.0	0.01	0.01
3.8	Power plants using renewable energy resources (up to 30 MW). including:	54.4	51.0	49.3	154.7	358.6	961.3
3.8.1	*Small HPPs*	51.7	48.8	47.3	147.8	343.4	934.8

#	Electrical Energy Produced and Supplied	October	November	December	IV quarter	II semester	Total in 2019
3.8.2	*Solar power plants*	1.1	1.0	1.0	3.1	7.2	13.1
3.8.3	*Reciprocal currents' share of the autonomous generation*	1.4	1.0	0.6	3.0	6.6	10.1
3.8.4	*Wind power plants*	0.2	0.2	0.4	0.8	1.4	3.2
4	**Import, including:**	**14.9**	**25.1**	**16.5**	**56.5**	**97.9**	**292.6**
4.1	Artsakh	14.1	9.1	8.0	31.2	61.8	154.5
4.2	The Islamic Republic of Iran	0.8	16.0	8.4	25.3	30.8	78.8
4.3	Georgia	0.0	0.0	0.0	0.0	5.4	59.3
4.4	High Voltage Networks CJSC	0.0	0.0	0.0	0.0	0.0	0.0
4.5	EnergyImpEx CJSC	0.0	0.0	0.0	0.0	5.4	40.9
4.6	Armenian Electric Networks CJSC	0.0	0.0	0.0	0.0	0.0	18.4
5	**Inflow to the high voltage network (3.1+3.2+3.3+3.4+3.5+3.6+4)**	**534.9**	**556.8**	**694.9**	**1786.5**	**3559.0**	**6631.8**
6	**Losses in the high voltage network (% ratio to the inflows), including:**	**8.7**	**7.0**	**11.5**	**27.2**	**56.4**	**106.0**
		1.6%	**1.3%**	**1.7%**	**1.5%**	**1.6%**	**1.6%**
6.1	Armenian Electric Networks CJSC	7.0	6.5	9.6	23.1	46.6	87.1
6.2	Yerevan CCGT	1.6	0.5	1.9	4.1	9.7	18.1
6.3	Imports from Georgia	0.0	0.0	0.0	0.0	0.0	0.8
6.4	High Voltage Networks CJSC	0.0	0.0	0.0	0.0	0.0	0.0
7	**Delivery from High Voltage Networks (5+3.7+3.8-6), including:**	**580.6**	**601.9**	**733.6**	**1916.1**	**3863.4**	**7495.0**
7.1	Domestic consumption	480.7	555.6	611.6	1647.9	3253.9	6244.0
7.2	Artsakh	2.4	8.4	7.3	18.2	29.3	68.8
7.3	The Islamic Republic of Iran	97.4	37.9	114.7	250.0	580.2	1182.3
7.4	Georgia	0.0	0.0	0.0	0.0	0.0	0.0005
8	**Total losses in distribution networks (% ratio to the inflows) (8/7.1), including:**	**33.1**	**37.9**	**46.8**	**117.9**	**227.3**	**442.0**
		6.9%	**6.8%**	**7.7%**	**7.2%**	**7.0%**	**7.1%**
8.1	technological losses	33.2	38.6	46.5	118.2	228.0	453.5
		6.9%	7.0%	7.6%	7.2%	7.0%	7.3%
8.2	commercial losses	-0.1	-0.7	0.4	-0.4	-0.7	-11.5
		-0.01%	-0.1%	0.1%	-0.02%	-0.02%	-0.2%
9	**Electricity supplied by Armenian Electric Networks CJSC (by consumer group) (7.1-8)**	**447.6**	**517.6**	**564.8**	**1530.1**	**3026.6**	**5802.0**
9.1	Residential	137.8	174.2	207.0	519.0	956.1	1928.9
9.2	Budgetary organizations	14.2	21.9	24.6	60.7	100.6	216.7
9.3	Industry	119.4	132.5	129.7	381.7	752.9	1365.5
9.4	Transport	8.2	9.1	9.5	26.8	53.1	101.6
9.5	Irrigation	8.8	2.9	0.4	12.1	98.9	153.7
9.6	Water supply and sanitation	5.0	4.4	4.3	13.7	35.7	64.9
9.7	Other consumers	154.1	172.7	189.3	516.1	1029.3	1970.7

Annex 2.4 Information of the electrical energy system indicators in 2018 and 2019

REPUBLIC OF ARMENIA
PUBLIC SERVICES REGULATORY COMMISSION
COMMISSION MEMBER

R A, Y E R E V A N, 2 2 S A R Y A N, T E L.: (3 7 4 - 1 0) 5 6 6 4 7 1, F A X: (3 7 4 - 1 0) 5 2 5 5 6 3

« 15 » September 2020

№ AA/34.3-M2-8/3947-2020

To: Diana Harutyunyan
Climate Change Programme Coordinator
UNDP Armenia

In response to your №BUR3-006
dated 01.09.2020

Dear Mrs. Harutyunyan,

Please find herewith attached the information on natural gas consumed by thermal power plants in 2017-2019, and on the new power plants that entered into the power system from January 1st, 2016 to December 31st, 2019.

Attachment: 2 electronic files.

X [signature]
SERGEY AGHINYAN

S.Aghinyan

Executed by: L.Hovhannisyan ☎ 010 52-85-90 (326)

DATA SUMMARY

On consumption of natural gas by power plants in 2017-2019 and caloric value of the fuel

No	Names	Unit of measurement	2017	2018	2019
1	**Hrazdan TPP OJSC**				
	Natural gas	thousand cubic meters	91,143.7	92,185.0	143,186.3
		kcal/cubic meters	8,364.0	8,306.6	8,333.2
2	**Gazprom Armenia CJSC's Hrazdan-5 plant generating electricity by steam-gas cycle**				
	Natural gas	thousand cubic meters	226,112.5	372,979.7	222,851.0
		kcal/cubic meters	8,490.7	8,251.0	8,367.0
3	**Yerevan TPP CJSC's Combined Cycle Co-generation Power Unit**				
	Natural gas	thousand cubic meters	315,180.4	298,538.0	322,749.0
		kcal/cubic meters	8,456.0	8,211.0	8,316.0
4	**Yerevan State Medical University after Mkhitar Heratsi Foundation CHP power plant**				
	Natural gas	thousand cubic meters	2,176.9	1,665.3	1,933.9
		kcal/cubic meters	8,334.8	8,222.2	8,275.2
5	**ArmRuskogeneratsia CJSC Co-generation Power Plant**				
	Natural gas	thousand cubic meters	2,913.0	2,560.0	1,012.7
		kcal/cubic meters	8,410.5	8,271.2	8,271.4

1) According to the reports submitted to the Commission by “Lus Astgh” LLC, the plant did not use natural gas during the mentioned period.
2) “Yerfrez” OJSC’s electricity (power) generation license was nullified since December 23rd, 2013.
3) “Lusakert Biogas Plant” CJSC is a plant generating electricity from biological mass (renewable energy resource), does not use natural gas for electricity production.

Annex 2.5 Estimation of country-specific CO_2 emission factors for the stationary combustion of natural gas

CO_2 emissions from stationary combustion for the generation of electrical and thermal energy are estimated based on the physical and chemical parameters of natural gas: composition and density, and relying on them: net calorific value of natural gas (per weight) and its carbon content.

The sequence of the estimation steps is provided below:

1. Carbon (C) content (mol. %) is calculated per the 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. %) is calculated per the components' share of natural gas:

   % 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. To obtain the carbon content in natural gas by weight (g/m^3), the carbon content value (mol, %) obtained in point 3 above is multiplied by the average annual value of natural gas density (see Annex 2.1).

5. The net calorific value of the natural gas as received in kcal/m^3 (Annex 2.6) is re-estimated in MJ/m^3 units, that is, multiplied by 4.1868/1000.

6. To express the carbon content of the natural gas in kg/GJ units, the carbon content value in g/m^3 (obtained in point 4) is multiplied by 1000 and divided on natural gas annual average calorific value in MJ/m^3 (obtained in point 5). This was performed to enable the comparison with the reference values provided in the 2006 IPCC Guidelines.

7. According to the 2006 IPCC Guidelines, to get the CO_2 emission factor from stationary combustion of natural gas in kg/TJ units, the carbon content in kg/GJ units (obtained in point 6) should be multiplied by 1000 and by 44/12.

The estimation of the country-specific CO_2 emission factors for natural gas imported from RF, mixture (Yerevan gas distribution station 2 and weighted average) and from Iran, is presented in the table below.

Table 2.5-1 Carbon content values and country-specific CO_2 emission factors estimated based on the physical and chemical parameters of the natural gas imported to Armenia

Imported natural gas	Density	Net calorific values (NCV) [Default value: 48 TJ/Gg. confidence intervals limits: 46.5 - 50.4]			Carbon content [Default value: 15.3 kg/GJ; upper and lower intervals limits: 14.8 -15.9]			CO_2 emission factors [Default value: 56100 kg/TJ; 95 % confidence intervals limits: 54300-58300]
	kg/m^3	kcal/m^3	MJ/m^3	TJ/Gg	kg/m^3	kcal/m^3	MJ/m^3	TJ/Gg
2011								
Imported from the 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 the Russian Federation	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 the Russian Federation	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 the Russian Federation	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 the Russian Federation	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 the Russian Federation	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 the Russian Federation	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
2018								
Imported from the Russian Federation	0.7186	8,282	34.67	48.25	74.1659	0.5330	15.37	56,356.67
Mixture GDS-2	0.7235	8,186	34.27	47.37	73.3249	0.5305	15.48	56,755.47
Mixture (weighted average)	0.7222	8,227	34.44	47.70	73.6849	0.5321	15.45	56,643.25
Imported from Iran	0.7354	8,025	33.60	45.69	71.9037	0.5288	15.74	57,705.74

Imported natural gas	Density	Net calorific values (NCV) [Default value: 48 TJ/Gg. confidence intervals limits: 46.5 - 50.4]			Carbon content [Default value: 15.3 kg/GJ; upper and lower intervals limits: 14.8 -15.9]			CO_2 emission factors [Default value: 56100 kg/TJ; 95 % confidence intervals limits: 54300-58300]
	kg/m^3	kcal/m^3	MJ/m^3	TJ/Gg	kg/m^3	kcal/m^3	MJ/m^3	TJ/Gg
2019								
Imported from the Russian Federation	0.7265	8,383	35.10	48.31	74.2618	0.5395	15.37	56,362.62
Mixture GDS-2	0.7259	8,314	34.81	47.95	73.9255	0.5366	15.42	56,526.24
Mixture (weighted average)	0.7278	8,330	34.88	47.92	73.9040	0.5378	15.42	56,545.70
Imported from Iran	0.7350	8,027	33.61	45.72	71.8555	0.5281	15.71	57,621.33

Annex 2.6 Information on the average physical and chemical characteristics of natural gas in 2017-2020

Закрытое акционерное общество
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(ЗАО «Газпром Армения»)

ЗАМЕСТИТЕЛЬ ГЕНЕРАЛЬНОГО ДИРЕКТОРА ГЛАВНЫЙ ИНЖЕНЕР

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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
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«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 ԳԲԿ-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

Տեղեկատվություն

2017 և 2018 թ.թ. ընթացքում ՌԴ-ից ու ԻԻՀ-ից ներկրված և «Երևանի ԳԲԿ-2»-ից մատակարարված, բնական գազի բաղադրամասերի և ֆիզիկաքիմիական պարամետրերի տարեկան միջին ցուցանիշների վերաբերյալ

h/h	Բաղադրամասերը մոլ. %	2017 թ.			2018 թ.		
		ՌԴ	ԻԻՀ	ԳԲԿ-2	ՌԴ	ԻԻՀ	ԳԲԿ-2
1	Թթվածին O_2	0.0097	0.0098	0.0089	0.0025	0.0104	0.0080
2	Ածխածնի երկօքսիդ CO_2	0.1390	0.6732	0.2321	0.2034	0.5406	0.3196
3	Ազոտ N2	1.5882	4.2709	2.0438	1.4713	4.2198	2.4011
4	Էթան C_2H_6	7.9975	3.4648	6.7487	4.5036	3.3929	3.9664
5	Պրոպան C_3H_8	1.9953	1.0219	1.6705	0.9284	0.9532	0.9251
6	Իզո-բութան i - C_4H_{10}	0.1384	0.1796	0.1374	0.0829	0.1714	0.1096
~~7~~	~~Ն-բութան n-C4H10~~	~~0.1176~~	~~0.2520~~	~~0.1411~~	~~0.0881~~	~~0.2352~~	~~0.1366~~
8	Պենտան C_5H_{12} և C_5+	0.0405	0.0796	0.0385	0.0481	0.0676	0.0438
9	Մեթան CH_4	87.9738	90.0481	88.9789	92.7551	90.4923	92.0900
10	Խտություն ρ (կգ / մ^3)	0.7535	0.7397	0.7460	0.7186	0.7354	0.7235

Ֆիզիկաքիմիական ցուցանիշներ							
1	Ստորին այրման ջերմությունը (միջին), Կկալ/մ^3 (ստանդարտ պայմաններում՝ t = 20^{0}C, P=101.325 կՊա)	8647	8030	8469	8282	8025	8186
2	Ստորին այրման ջերմությունը (միջին), Մջ/մ^3	36.20	33.62	35.46	34.67	33.60	34.27
4	Վոբբեի թվի արժեքը , Մջ/մ^3	50.65	47.54	49.93	49.64	47.64	48.98
5	Ծծմբաջրածնի զանգվածային խտությունը, գ/մ^3	0.0014	0.0017	0.0015	0.0025	0.0018	0.0021
6	Մերկապտանային ծծմբի ~~զանգվածային խտությունը, գ/մ^3~~	0.0042	0.0063	0.0048	0.0069	0.0096	0.0088
7	Մեխանիկական խառնուկների զանգվածը, գ/մ^3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

«Գազպրոմ Արմենիա» ՓԲԸ
փորձարկման լաբորատորիայի
գլխավոր մասնագետ

Ա. Հախինյան

Закрытое акционерное общество
«Газпром Армения»
(ЗАО «Газпром Армения»)

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(«Գազպրոմ Արմենիա» ՓԲԸ)

ԳԼԽԱՎՈՐ ՏՆՕՐԵՆԻ
ՏԵՂԱԿԱԼ
ԳԼԽԱՎՈՐ ՃԱՐՏԱՐԱԳԵՏ

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«01» 12 2021г.

№ 02/19.2/3170-2021

ՀՀ Շրջակա միջավայրի
նախարարի տեղակալ
տիկին Ա. Մազմանյանին

Հարգելի տիկին Մազմանյան

Ի պատասխան 24.11.2021թ. № 3/15.2/14028 գրության Ձեզ է ներկայացվում ՀՀ գազափոխադրման համակարգում՝ 2019թ. և 2020թ. ընթացքում, ՌԴ-ից ու ԻԻՀ-ից ներկրված և «Երևանի ԳԲԿ-2»-ից մատակարարված բնական գազի բաղադրամասերի և ֆիզիկաքիմիական պարամետրերի տարեկան միջին ցուցանիշների վերաբերյալ տեղեկատվություն:

Առդիր՝ տեղեկատվություն – 1 թերթից:

Հարգանքով՝

Ա. Հակոբյան

Ա. Զարզարյան
Հեռ. 29-47-83

ՏԵՂԵԿԱՆՔ

2019-2020թթ. ՌԴ-ից, ԻԻՀ-ից ներկրված և ԵԳԲԿ-2 -ից մատակարարված բնական գազի բաղադրամասերի ու ֆիզիկաքիմիական ցուցանիժների միջին տարեկան արժեքնեքները

հ/հ	Բաղադրամասերը , մոլ. %	2019 թ.			2020 թ.		
		ՌԴ-ից	*ԻԻՀ-ից*	*ԵԳԲԿ-2-ից*	*ՌԴ-ից*	*ԻԻՀ-ից*	*ԵԳԲԿ-2-ից*
1	Հելիում He	0,0258	0,0539	0,0281	0,02162	0,05232	0,0262
2	Ջրածին H_2	0,0017	0,0032	0,0015	0,00172	0,00353	0,0020
3	Թթվածին O_2	0,0024	0,0116	0,0069	0,0058	0,0117	0,0082
4	Ածխածնի երկօքսիդ CO_2	0,2425	0,5583	0,2985	0,1996	0,5442	0,2627
5	Ազոտ N2	1,2818	4,1362	1,6566	1,2039	3,9072	1,6845
6	Էթան C_2H_6	5,2418	3,6246	4,8817	4,7658	3,6821	4,2617
7	Պրոպան C_3H_8	1,1787	0,8756	1,1022	1,0060	0,9774	0,9582
8	Իզո-բութան i - C_4H_{10}	0,0961	0,1510	0,0960	0,0923	0,1849	0,1076
9	Ն-բութան n-C4H10	0,0948	0,2031	0,0988	0,0886	0,2465	0,1142
10	Պենտան C_5H_{12} և C_5+	0,0483	0,0859	0,0410	0,0401	0,0863	0,0413
11	Մեթան CH_4	91,7862	90,2967	91,7887	92,5746	90,3038	92,5335
	Ֆիզիկաքիմիական ցուցանիշներ						
1	Խտություն ρ (կգ / մ^3)	**0,7265**	**0,7350**	**0,7259**	**0,7202**	**0,7372**	**0,7208**
2	Ստորին այրման ջերմությունը (միջին), Կկալ/մ^3 (ստանդարտ պայմաններում՝ t = 20^{0}C, P=101.325 կՊա)	**8383**	**8027**	**8314**	**8337**	**8079**	**8264**
3	Ստորին այրման ջերմությունը (միջին), Մջ/մ^3	35,10	33,61	34,81	34,91	33,83	34,60
4	Վոբբեի թվի արժեքը , Մջ/մ^3	50,04	47,66	49,66	49,98	47,91	49,54
5	Ծծմբաջրածնի զանգվածային խտությունը, գ/մ^3	0,0018	0,0028	0,0018	0,0015	0,0010	0,0013
6	Մերկապտանային ծծմբի զանգվածային խտությունը, գ/մ^3	0,0044	0,0080	0,0050	0,0057	0,0072	0,0064
7	Մեխանիկական խառնուկների զանգվածը, գ/մ^3	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Attachments to the two letters above: Data summary of annual average indices of the physical and chemical parameters and components of the natural gas imported from Russia and Iran and supplied by "Yerevan GDC-2" in 2017, 2018, 2019 and 2020

#	Components mol %	**2017**			**2018**		
		Russia	Iran	GDC-2	Russia	Iran	GDC-2
1.	Oxygen O_2	0.0097	0.0098	0.0089	0.0025	0.0104	0.0080
2.	Carbon Dioxide CO_2	0.1390	0.6732	0.2321	0.2034	0.5406	0.3196
3.	Nitrogen N_2	1.5882	4.2709	2.0438	1.4713	4.2198	2.4011
4.	Ethane C_2H_6	7.9975	3.4648	6.7487	4.5036	3.3929	3.9664
5.	Propane C_3H_8	1.9953	1.0219	1.6705	0.9284	0.9532	0.9251
6.	Isobutane i-C_4H_{10}	0.1384	0.1796	0.1374	0.0829	0.1714	0.1096
7.	N-butane n-C_4H_{10}	0.1176	0.2520	0.1411	0.0881	0.2352	0.1366
8.	Pentane C_5H_{12} and C_5+	0.0405	0.0796	0.0385	0.0481	0.0676	0.0438
9.	Methane CH_4	87.9738	90.0481	88.9789	92.7551	90.4923	92.0900
10.	Density (kg/m^3)	0.7535	0.7397	0.7460	0.7186	0.7354	0.7235

Physical and chemical parameters							
1.	Lower temperature of combustion (average), kcal/m^3 (in standard conditions: t=20°C, P=101.325 kPa)	8647	8030	8469	8282	8025	8186
2.	Lower temperature of combustion (average), MJ/m^3	36.20	33.62	35.46	34.67	33.60	34.27
4.	Value of Wobbe index, MJ/m^3	50.65	47.54	49.93	49.64	47.64	48.98
5.	Mass density of hydrogen sulphide, g/m^3	0.0014	0.0017	0.0015	0.0025	0.0018	0.0021
6.	Mass density of mercaptan sulfur, g/m^3	0.0042	0.0063	0.0048	0.0069	0.0096	0.0088
7.	Mass of mechanical mixtures, g/m^3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

***Source**: GazProm Armenia CJSC*

#	Components mol %	**2019**			**2020**		
		Russia	Iran	GDC-2	Russia	Iran	GDC-2
1.	Helium, He	0.0258	0.0539	0.0281	0.02162	0.05232	0.0262
2.	Hydrogen, H_2	0.0017	0.0032	0.0015	0.00172	0.00353	0.0020
3.	Oxygen O_2	0.0024	0.0116	0.0069	0.0058	0.0117	0.0082
4.	Carbon Dioxide CO_2	0.2425	0.5583	0.2985	0.1996	0.5442	0.2627
5.	Nitrogen N_2	1.2818	4.1362	1.6566	1.2039	3.9072	1.6845
6.	Ethane C_2H_6	5.2418	3.6246	4.8817	4.7658	3.6821	4.2617
7.	Propane C_3H_8	1.1787	0.8756	1.1022	1.0060	0.9774	0.9582
8.	Isobutane i-C_4H_{10}	0.0961	0.1510	0.0960	0.0923	0.1849	0.1076
9.	N-butane n-C_4H_{10}	0.0948	0.2031	0.0988	0.0886	0.2465	0.1142
10.	Pentane C_5H_{12} and C_5+	0.0483	0.0859	0.0410	0.0401	0.0863	0.0413
11.	Methane CH_4	91.7862	90.2967	91.7887	92.5746	90.3038	92.5335

Physical and chemical parameters							
1.	Density, ρ, kg/m^3	0.7265	0.7350	0.7259	0.7202	0.7372	0.7208
2.	Lower temperature of combustion (average), kcal/m^3 (in standard conditions: t=20°C, P=101.325 kPa)	8383	8027	8314	8337	8079	8264
3.	Lower temperature of combustion (average), MJ/m^3	35.10	33.61	34.81	34.91	33.83	34.60
4.	Value of Wobbe index, MJ/m^3	50.04	47.66	49.66	49.98	47.91	49.54
5.	Mass density of hydrogen sulphide, g/m^3	0.0018	0.0028	0.0018	0.0015	0.0010	0.0013
6.	Mass density of mercaptan sulfur, g/m^3	0.0044	0.0080	0.0050	0.0057	0.0072	0.0064
7.	Mass of mechanical mixtures, g/m^3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

***Source**: GazProm Armenia CJSC*

Annex 3. Agriculture

Annex 3.1 Data used to assess the livestock populations

Table 3.1.1 Livestock populations (heads) in all the country's farms[14] as of January 01 of 2018, 2019 and 2020

2018	Cattle		*of which: Dairy Cows*		Swine		*of which: Sows*		Sheep and goats, total		Sheep	
	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %
Total in the RA	**590,585**	**90.1**	**266,815**	**90.1**	**166,757**	**95.0**	**31,612**	**96.9**	**660,059**	**90.8**	**637,978**	**91.2**
Commercial enterprises	5,005	91.4	2,300	85.2	16,503	135.7	4,227	134.5	2,597	33.7	2,447	32.4
Population's farms	585,580	90.0	264515	90.2	150,254	92.0	27,385	92.9	657,462	91.4	635,531	91.8

	of which: Ewes		Goats		*of which: Nanny goats*		Horses		Poultry, total		*of which: Laying hens*	
	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %	01.01.18	Ratio to the previous year %
Total in the RA	**452,775**	**94.8**	**22,081**	**80.2**	**16,126**	**81.7**	**10,049**	**94.5**	**4,406,374**	**115.5**	**2,628,110**	**97.7**
Commercial enterprises	881	15.8	150	88.8	130	113.0	67	100.0	2,233,834	129.6	998,380	93.7
Population's farms	451,894	95.7	21,931	80.2	15,996	81.6	9,982	94.5	2,172,540	103.9	1,629,730	100.3

[14] Food safety and poverty in Armenia in 2018-2020, statistical handbook, the SC of the RA, 2019, 2020

2019	Cattle		*of which: Dairy Cows*		Swine		*of which: Sows*		Sheep and goats, total		Sheep	
	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %
Total in the RA	**571,861**	**96.8**	**253,990**	**95.2**	**197,877**	**118.7**	**39,371**	**124.5**	**638,257**	**96.7**	**615,705**	**96.5**
Commercial enterprises	4,967	99.2	2,045	88.9	21,343	129.3	5,345	126.4	2,392	92.1	2,295	93.8
Population's farms	566,894	96.8	2 519 45	95.2	176,534	117.5	34,026	124.3	635,865	96.7	613,410	96.5

	of which: Ewes		Goats		*of which: Nanny goats*		Horses		Poultry, total		*of which: Laying hens*	
	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %	01.01.19	Ratio to the previous year %
Total in the RA	**429,766**	**94.8**	**22,552**	**102.1**	**16,349**	**101.4**	**10,748**	**107**	**4,152,052**	**94.2**	**2,706,018**	**103**
Commercial enterprises	1,329	93.5	97	64.7	72	55.4	34	50.7	2,156,308	96.5	1,242,606	124.5
Population's farms	428,437	94.8	22,455	102.4	16,277	101.8	10,714	107.3	1,995,744	91.9	1,463,412	89.8

2020	Cattle		*of which: Dairy Cows*		Swine		*of which: Sows*		Sheep and goats, total		Sheep	
	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %
Total in the RA	**579,256**	**101.3**	**251,716**	**99.1**	**223,252**	**112.8**	**42,796**	**108.7**	**662,532**	**103.8**	**639,598**	**103.9**
Commercial enterprises	4,511	90.8	2,117	103.5	32,706	153.2	11,221	209.9	2,000	83.6	2,000	87.1
Population's farms	574,745	101.4	249,599	99.1	190,546	107.9	31,575	92.8	660,532	103.9	637,598	103.9

	of which: Ewes		Goats		*of which: Nanny goats*		Horses		Poultry, total		*of which: Laying hens*	
	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %	01.01.20	Ratio to the previous year %
Total in the RA	**452,646**	**105.3**	**22,934**	**101.7**	**15,828**	**96.8**	**11,367**	**105.8**	**4,568,083**	**110.0**	**2,868,672**	**106.0**
Commercial enterprises	1,213	91.3	0	0.0	0	0.0	57	167.6	2,453,237	113.8	1,253,420	100.9
Population's farms	451,433	105.4	22,934	102.1	15,828	97.2	11,310	105.6	2,114,846	106.0	1,615,252	110.4

Table 3.1.2 Output of the main products of animal husbandry[15], 1000 ton

	2018	2019
Animals and poultry sold for slaughter (in slaughter weight),	108.2	107.3
including:		
Veal and beef	68.8	68.1
Pork	16.3	16.1
Lamb and goat's meat	10.8	10.7
Poultry	12.3	12.4
Milk produced	697.7	667.9
Wool produced	1,032	981

Table 3.1.3 Imported high-breed cattle populations (heads) in 2014-2019

Code	2014	2015	2016	2017	2018	2019
102211000	32	321	451	439	164	363
102213000						33
102219000					846	134
102292900					3,184	-
102294100					796	-
102295100					55	-
102296100					102	-
102297100					41	
102902000						5
102909900			6		1,592	0
Total	**32**	**321**	**457**	**439**	**6,780**	**535**

Table 3.1.4 Livestock populations published by the SC of the RA for 2018 and 2019

Livestock (as of January 01)	2018	2019	2020
Buffalos	722	670	690
Mules and Asses	1,793	1,600	1,509
Rabbits	27,771	30,553	35,769
Fur bearing animals	14,186	17,945	3,329

Annex 3.2 Data used to estimate the country-specific emission factors from the livestock enteric fermentation

Table 3.2.1 Baseline data to estimate the emission factors

#	Indicator	Unit of measure	2018	2019
1	Cows average live weight	kg	407**	407**
2	Bulls average live weight	kg	530	531
3	The young (calves) average live weight	kg	164**	164**
4	The young (calves) average live weight	gram	470	470
5	The young (calves) standard weight	kg	322*	322*
6	Cows average live weight *	kg	-	-
7	Bulls average live weight *	kg	-	-
8	The young (calves) Average live weight *	kg	-	-
9	Cows fertility	%	88	88
10	Cows Digestion Energy (feed digestion coefficient)	%	67**	67**
11	Bulls Digestion Energy (feed digestion coefficient)	%	57	57
12	The young (calves) digestion energy (feed digestion coefficient)	%	59	59
13	Cow milk fat content	%	3,7	3,7
14	Sheep average live weight	kg	47	47
15	Sheep feed digestion coefficient	%	-	-
16	Cattle upkeep methods, *including:*	day	-	-
16.1	Nursery regime	day	210-240	210-240
16.2	Grazing regime	day	125-155	125-155
17	Manure excrement per 1 cattle head	ton/year	5,6	5,6
18	Cattle manure share in pastures	%	27	27
19	Sheep and goats manure share in pastures	%	45	45

[15] Statistical Yearbook 2020 of the RA, the SC of the RA, 2021, p. 365

Notes:

* The values of the above-listed indicators vary depending on the animal's nourishment, which ranges from 45 to 55% of its live weight.

Source: The Ministry of Economy of the RA (the information is received in response to the inquiry by the Minisrty of Environment).

** The data was adjusted based on the decisions reflected in the joint meeting minutes of "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Report" UNDP-GEF/00096445 project's experts and the Ministry of Agriculture of the RA held on June 18, 2019.

Annex 3.3 The Land Balance of the RA

Relying on the report "On the availability and distribution of the land fund of the RA (the land balance) as of July 01 of 2018 and 2019" by the State Committee of the Real Estate Cadastre adjunct to the RA Government, the changes of the Land Fund according to the target uses is as follows.

The area of the **agricultural lands** increased by 1.35 thousand hectares in total in 2018, including:

0.04 thousand hectares converted from settlements, 0.01 thousand hectares – from industry, for entrails-use and other production, 0.02 thousand hectares – from energy, transport, communication, public utility infrastructure, 0.14 thousand hectares – from specially protected areas (the state-owned environmental lands in Kajaran community of Syunik marz), 0.02 thousand hectares – from forest lands, and 1.12 thousand hectares came from special importance areas and lands under water (the land balance of Armavir marz included 1,115 hectares in excess with 1,062 hectares of special importance areas and 53 hectares of lands under water; this was corrected for the land balance of 2018 based on the data yielded from the strengthening of the administrative borders of the marz and communities and balancing the geodetic network).

At the same time, **agricultural lands** decreased by 0.68 thousand hectares in 2018, including:

0.04 thousand hectares converted to settlements;

0.45 thousand hectares – to industry, for entrails-use and other production (distribution by marzes: 11 hectares in Aragatsotn, 49 hectares in Ararat, 10 hectares in Armavir, 2 hectares in Lori, 17 hectares in Kotayk, 44 hectares in Shirak, 240 hectares in Syunik and 77 hectares in Vayots Dzor);

0.11 thousand hectares – to energy, transport, communication, public utility infrastructure (distribution by marzes: 9 hectares in Aragatsotn, 5 hectares in Armavir, 80 hectares in Gegharkunik, 2 hectares in Kotayk, 4 hectares in Shirak, 1 hectares in Syunik, 3 hectares in Vayots Dzor and 4 hectares in Tavush – mainly for the purposes of utility infrastructure and high voltage electrical networks' transmission lines);

0.05 thousand hectares – to specially protected areas, mainly to the historical and cultural reserve "Amberd" in Aragatsotn marz;

0.03 thousand hectares – to forest lands, namely, about 6 hectares in Shirak marz and about 23 hectares in Syunik marz.

The area of the **agricultural lands** increased by 0.03 thousand hectares (i.e., 35 hectares) in 2019, including:

21.0 hectares converted from industry, for entrails-use and other production, 10.0 hectares – from special importance areas, and the rest – from specially protected areas (0.67 ha of privatized arable land in Aknashen community was mistakenly counted as communally-owned historical-cultural land) and settlements, mainly in Ararat, Armavir and Lori marzes.

At the same time, **agricultural lands** decreased by 0.29 thousand hectares (i.e., 293 hectares) in 2019, including:

0.04 thousand hectares (i.e., 56 hectares) converted to settlements, mainly in Ararat, Gegharkunik, Kotayk and Tavush marzes;

0.15 thousand hectares (i.e., 148 hectares) – to industry, for entrails-use and other production (distribution by marzes: 11 hectares in Aragatsotn, 38 hectares in Ararat, 16 hectares in Armavir, 2 hectares in Gegharkunik, 20 hectares in Kotayk, 1 hectares in Shirak, 20 hectares in Syunik, 2 hectares in Vayots Dzor and 38 hectares in Tavush);

0.08 thousand hectares (i.e., 75 hectares) – to energy, transport, communication, public utility infrastructure (distribution by marzes: 49 hectares in Aragatsotn, 19 hectares in Gegharkunik, 1 hectares in Lori, 1 hectares in Syunik and 5 hectares in Vayots Dzor – mainly for the purposes of utility infrastructure and high voltage electrical networks' transmission lines);

0.01 thousand hectares (i.e., 7 hectares) – to specially protected areas, mainly to the community-owned recreational and historical-cultural lands of Ararat, Armavir and Syunik marzes;

0.01 thousand hectares (i.e., 7 hectares) – to special importance areas, namely, 5 hectares in Shirak marz and 2 hectares in Syunik marz.

Table 3.3.1 Baseline density factors of wood

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

Table 3.3.2 Average annual biomass growth

Dominating tree species	Average annual regrowth (m^3/ha per year)
	Revised in 2010 [Ref-8, LUCFref.1, LUCFref.2, 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

Dominating tree species	Average annual regrowth (m^3/ha per year) Revised in 2010 [Ref-8, LUCFref.1, LUCFref.2, LUCFref.10, LUCFref.11, LUCFref.12, LUCFref.20, LUCFref.22]
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 (the RA forests)	**1.5**

Annex 3.4 Import volumes of mineral or chemical nitrogen fertilizers

Table 3.4.1 Import volumes of mineral or chemical nitrogen fertilizers in 2018

Commodity name, its section, group, sub-group and 10-digit code in accordance with the EEU Commodity Nomenclature of External Economic Activity	Unit of measure	IMPORTS	
		amount, kg	weight, ton
		2018	
Mineral or chemical nitrogen fertilizer		X	86,104.8
3102101000	kg N	2,692,996.3	5,868.1
3102109000	kg N	72,611.8	167.3
3102210000	kg N	317.7	1.5
3102290000	kg N	8,510.0	23.0
3102301000	kg N	176.6	1.5
3102309000	kg N	33,262,947.5	78,427.1
3102600000	kg N	254,467.2	1,596.0
3102900000	kg N	6,707.8	20.4
Total	kg N	**33,533,126.71**	**6,035.4**

Table 3.4.2 Import volumes of mineral or chemical nitrogen fertilizers in 2019

Commodity name, its section, group, sub-group and 10-digit code in accordance with the EEU Commodity Nomenclature of External Economic Activity	Unit of measure	IMPORTS	
		amount, kg	weight, ton
		2019	
Mineral or chemical nitrogen fertilizer		X	69,339.8
3102101000	kg N	3,379,840.6	7,384.5
3102109000	kg N	47,942.1	124.5
3102210000	kg N	1,233.4	5.9
3102301000	kg N	727.3	4.5
3102309000	kg N	70,864,905.0	60,518.9
3102401000	kg N	175.2	2.0
3102500000	kg N	2,300.2	2.3
3102600000	kg N	196,638.3	1,238.3
3102800000	kg N	7,513.0	21.8
3102900000	kg N	13,602.4	37.1
Total	kg N	71,087,094.73	7,509.1

Annex 4. Summary information of the equipment containing SF_6

Annex 4.1 Summary information of charging equipment containing SF_6

Year	220 kV equipment		110 kV equipment		35 kV equipment		Total per year		Sum across the years	
	Number of equipment installed (item)	Number of charging SF_6 (kg)	Number of equipment installed (item)	Number of charging SF_6 (kg)	Number of equipment installed (item)	Number of charging SF_6 (kg)	Number of equipment installed (item)	Number of charging SF_6 (kg)	Number of equipment installed (item)	Number of charging SF_6 (kg)
1999	0	0.00	8	68.00	0	0.00	8	68.00	8	68.00
2000	0	0.00	0	0.00	0	0.00	0	0.00	8	68.00
2001	0	0.00	0	0.00	0	0.00	0	0.00	8	68.00
2002	5	110.00	0	0.00	3	14.40	8	124.40	16	192.40
2003	12	281.10	28	318.00	0	0.00	40	599.10	56	791.50
2004	32	768.00	45	398.80	2	9.20	79	1,176.00	135	1,967.50
2005	2	47.00	0	0.00	0	0.00	2	47.00	137	2,014.50
2006	15	392.60	8	48.00	0	0.00	23	440.60	160	2,455.10
2007	0	0.00	0	0.00	0	0.00	0	0.00	160	2,455.10
2008	0	0.00	0	0.00	0	0.00	0	0.00	160	2,455.10
2009	0	0.00	29	290.00	43	215.00	72	505.00	232	2,960.10
2010	10	259.00	32	314.30	43	215.00	85	788.30	317	3748.40
2011	0	0.00	3	25.50	0	0.00	3	25.50	320	3,773.90
2012	0	0.00	22	138.60	0	0.00	22	138.60	342	3,912.50
2013	8	160.00	0	0.00	0	0.00	8	160.00	350	4,072.50
2014	0	0.00	11	91.30	0	0.00	11	91.30	361	4,163.80
2015	0	0.00	0	0.00	0	0.00	0	0.00	361	4,163.80
2016	0	0.00	0	0.00	0	0.00	0	0.00	361	4,163.80
2017	0	0.00	0	0.00	0	0.00	0	0.00	361	4,163.80
2018	8	168.00	19	133.00	13	64.70	40	365.70	401	4,529.50
2019	20	482.00	28	196.00	13	64.70	61	742.70	462	5,272.20
Total	**112**	**2,667.70**	**233**	**2,021.50**	117	**583.00**			**462**	**5,272.20**

Annex 4.2 Summary information on hermetically sealed equipment containing SF_6

Year	Number of equipment installed, item	SF_6 amount, kg	Sum across the years	
			Number of equipment installed, item	SF_6 bank, kg
1999	0	0.00	0	0.00
2000	0	0.00	0	0.00
2001	0	0.00	0	0.00
2002	0	0.00	0	0.00
2003	2	18.20	2	18.20
2004	0	0.00	2	18.20
2005	0	0.00	2	18.20
2006	2	18.20	4	36.40
2007	0	0.00	4	36.40
2008	0	0.00	4	36.40
2009	0	0.00	4	36.40
2010	65	88.73	69	125.13
2011	0	0.00	69	125.13
2012	0	0.00	69	125.13
2013	0	0.00	69	125.13
2014	0	0.00	69	125.13
2015	0	0.00	69	125.13
2016	0	0.00	69	125.13
2017	0	0.00	69	125.13
2018	3	50.60	72	175.73
2019	3	50.60	75	226.33
Total			**75**	**226.33**

Annex 5. Time series of country-specific emissions in 1990-2019 period

Annex 5.1 Time series of emissions in CO_2 equivalent

Categories	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
	Gg CO_2 eq.										
Total National Emissions and Removals	**25,077.64**	**6,756.11**	**5,730.59**	**7,236.67**	**7,939.40**	**9,547.11**	**10,029.75**	**9,802.71**	**10,133.51**	**9,999.79**	**10,777.84**
1 - Energy	**22,719.35**	**4,819.12**	**4,255.09**	**5,252.55**	**5,809.63**	**6,891.84**	**7,041.52**	**6,623.41**	**7,087.43**	**6,822.29**	**7,138.47**
1.A - Fuel Combustion Activities	**21,057.00**	**3,739.82**	**3,148.49**	**3,962.17**	**4,366.57**	**5,385.71**	**5,467.00**	**5,042.64**	**5,460.37**	**5,552.47**	**6,015.84**
1.A.1 - Energy Industries	11,534.50	2,117.27	1,705.12	1,185.07	841.71	1,617.75	1,581.06	1,183.69	1,299.14	1,499.32	1,366.20
1.A.2 - Manufacturing Industries and Construction	2,065.35	455.98	435.49	716.18	600.96	685.70	617.76	440.81	470.44	428.18	437.46
1.A.3 - Transport	3,810.42	847.16	710.31	1,147.73	1,556.17	1,591.48	1,728.14	1,652.66	1,788.76	1,885.00	2,149.33
1.A.4 - Other Sectors	3,646.72	319.41	297.57	913.19	1,367.72	1,490.78	1,540.05	1,765.48	1,902.02	1,739.97	2,062.84
1.A.5 - Non-Specified	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.B - Fugitive emissions from fuels	**1,662.35**	**1,079.30**	**1,106.60**	**1,290.37**	**1,443.06**	**1,506.12**	**1,574.52**	**1,580.77**	**1,627.07**	**1,269.81**	**1,122.63**
1.B.1 - Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.B.2 - Oil and Natural Gas	1,662.35	1,079.30	1,106.60	1,290.37	1,443.06	1,506.12	1,574.52	1,580.77	1,627.07	1,269.81	1,122.63
1.C - Carbon dioxide Transport and Storage	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2 - Industrial Processes and Product Use	**630.91**	**122.47**	**152.60**	**395.79**	**588.56**	**713.85**	**816.46**	**797.40**	**951.94**	**1,174.19**	**1,285.32**
2.A - Mineral Industry	**630.33**	**120.00**	**144.30**	**341.02**	**311.14**	**305.12**	**273.59**	**151.80**	**258.34**	**337.04**	**305.61**
2.B - Chemical Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.C - Metal Industry	**0.00**	**0.00**	**0.00**	**0.82**	**1.10**	**1.14**	**1.41**	**1.26**	**1.44**	**1.40**	**1.18**
2.D - Non-Energy Products from Fuels and Solvent Use	**0.59**	**2.45**	**4.30**	**7.62**	**7.37**	**7.24**	**7.12**	**4.05**	**4.24**	**4.91**	**5.71**
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F - Product Uses as Substitutes for Ozone Depleting Substances	**0.00**	**0.02**	**3.96**	**45.08**	**266.61**	**397.91**	**531.74**	**637.70**	**685.34**	**828.02**	**969.53**
2.G - Other Product Manufacture and Use	**0.00**	**0.00**	**0.04**	**1.25**	**2.34**	**2.44**	**2.59**	**2.59**	**2.59**	**2.82**	**3.29**
2.H - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3 - Agriculture, Forestry, and Other Land Use	**1,308.59**	**1,360.05**	**809.07**	**1,028.07**	**973.98**	**1,357.03**	**1,570.42**	**1,770.55**	**1,471.48**	**1,374.66**	**1,725.34**
3.A - Livestock	1,296.69	1,033.86	788.50	922.07	891.32	1,063.47	1,188.40	1,194.15	1,065.70	991.26	992.56
3.A.1 - Enteric Fermentation	1,144.21	927.71	728.05	853.40	827.13	981.75	1,094.07	1,095.35	973.50	902.42	900.62
3.A.2 - Manure Management	152.48	106.14	60.45	68.67	64.19	81.72	94.32	98.80	92.20	88.84	91.94
3.B - Land	**-736.89**	**-514.37**	**-467.77**	**-523.74**	**-550.08**	**-516.21**	**-477.61**	**-487.87**	**-470.43**	**-455.23**	**-372.96**
3.B.1 - Forest land	-739.26	-516.74	-470.82	-526.80	-553.13	-527.00	-539.78	-547.24	-530.44	-525.29	-453.30
3.B.2 - Cropland	0.67	0.67	0.67	0.67	0.67	10.31	-6.73	-6.73	-6.73	-6.73	-6.73
3.B.3 - Grassland	0.00	0.00	0.00	0.00	0.00	-1.97	18.37	18.37	18.37	18.37	18.37
3.B.4 - Wetlands	1.72	1.72	2.40	2.40	2.40	2.40	6.15	8.05	18.75	11.98	32.35
3.B.5 - Settlements	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.81	6.73
3.B.6 - Other Land	-0.016133	-0.02	-0.02	-0.02	-0.02	0.05	44.38	39.68	29.63	29.63	29.63
3.C - Aggregate sources and non-CO_2 emissions sources on land	**789.03**	**898.40**	**585.48**	**699.50**	**643.58**	**811.42**	**870.35**	**1,089.44**	**900.29**	**860.72**	**1,111.41**
3.C.1 - Emissions from biomass burning	0.05	5.52	5.10	5.08	6.45	5.38	5.14	5.18	7.64	4.64	7.08
3.C.2 - Liming	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.C.3 - Urea application	0.00	2.72	0.002	0.002	0.97	0.43	0.68	1.03	2.72	4.43	5.51
3.C.4 - Direct N2O Emissions from managed soils	666.81	659.25	436.57	523.87	482.66	609.51	653.88	819.41	671.00	641.36	827.04
3.C.5 - Indirect N2O Emissions from managed soils	170.64	184.85	115.32	138.32	124.90	160.84	170.83	224.20	181.67	174.71	235.70
3.C.6 - Indirect N2O Emissions from manure management	122.18	46.07	28.49	32.22	28.60	35.26	39.82	39.62	37.26	35.59	36.08
3.C.7 - Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.C.8 - Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Categories	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
	Gg $CO_{2\ eq.}$										
3.D - Other	**-40.24**	**-57.84**	**-97.14**	**-69.76**	**-10.84**	**-1.65**	**-10.72**	**-25.17**	**-24.09**	**-22.09**	**-5.67**
3.D.1 - Harvested Wood Products	-40.24	-57.84	-97.14	-69.76	-10.84	-1.65	-10.72	-25.17	-24.09	-22.09	-5.67
3.D.2 - Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 - Waste	**418.79**	**454.47**	**513.83**	**560.26**	**567.24**	**584.40**	**601.34**	**611.35**	**622.65**	**628.65**	**628.70**
4.A - Solid Waste Disposal	**259.26**	**305.06**	**359.38**	**393.12**	**393.91**	**404.54**	**408.13**	**419.32**	**426.22**	**427.57**	**422.21**
4.B - Biological Treatment of Solid Waste	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4.C - Incineration and Open Burning of Waste	**20.96**	**20.88**	**21.59**	**21.69**	**21.28**	**21.22**	**21.08**	**20.83**	**20.69**	**20.90**	**20.93**
4.D - Wastewater Treatment and Discharge	**138.57**	**128.54**	**132.86**	**145.46**	**152.04**	**158.64**	**172.14**	**171.19**	**175.74**	**180.19**	**185.56**
4.E - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
5 - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo Items											
International Bunkers	**412.51**	**90.72**	**91.33**	**112.67**	**137.37**	**128.74**	**128.70**	**137.85**	**170.20**	**196.83**	**219.42**
1.A.3.a.i - International Aviation (International Bunkers)	412.51	90.72	91.33	112.67	137.37	128.74	128.70	137.85	170.20	196.83	219.42
1.A.3.d.i - International water-borne navigation (International bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A.5.c - Multilateral Operations	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total $CO_{2\ eq}$ without Lands	**25,814.53**	**7,270.48**	**6,198.36**	**7,760.41**	**8,489.48**	**10,063.32**	**10,507.36**	**10,290.58**	**10,603.94**	**10,455.02**	**11,150.80**
Total $CO_{2\ eq}$ with Lands	**25,077.64**	**6,756.11**	**5,730.59**	**7,236.67**	**7,939.40**	**9,547.11**	**10,029.75**	**9,802.71**	**10,133.51**	**9,999.79**	**10,777.84**

Annex 5.2 Time series of CO_2 emissions

Categories	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
	Gg										
Total National Emissions and Removals	**20,759.84**	**3,244.68**	**2,686.99**	**3,659.33**	**4,050.87**	**5,095.74**	**5,167.70**	**4,595.69**	**5,137.57**	**5,320.04**	**5,840.41**
1 - Energy	**20,902.02**	**3,687.71**	**3,099.26**	**3,899.31**	**4,287.23**	**5,295.71**	**5,369.29**	**4,946.71**	**5,361.50**	**5,445.41**	**5,896.76**
1.A - Fuel Combustion Activities	**20,901.86**	**3,687.60**	**3,099.15**	**3,899.18**	**4,287.09**	**5,295.55**	**5,369.09**	**4,946.53**	**5,361.31**	**5,445.30**	**5,896.64**
1.A.1 - Energy Industries	11,507.12	2,114.29	1,703.55	1,183.99	840.94	1,616.28	1,579.61	1,182.60	1,297.95	1,497.94	1,364.95
1.A.2 - Manufacturing Industries and Construction	2,061.69	455.27	434.87	715.40	600.26	684.92	617.02	440.25	469.86	427.70	436.93
1.A.3 - Transport	3,726.54	826.99	692.84	1,115.07	1,505.23	1,535.35	1,665.16	1,591.58	1,723.69	1,814.60	2,071.44
1.A.4 - Other Sectors	3,606.50	291.05	267.89	884.72	1,340.65	1,459.00	1,507.31	1,732.10	1,869.81	1,705.06	2,023.33
1.A.5 - Non-Specified	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.B - Fugitive emissions from fuels	**0.16**	**0.11**	**0.11**	**0.13**	**0.14**	**0.16**	**0.20**	**0.18**	**0.19**	**0.11**	**0.11**
1.B.1 - Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.B.2 - Oil and Natural Gas	0.16	0.11	0.11	0.13	0.14	0.16	0.20	0.18	0.19	0.11	0.11
1.C - Carbon dioxide Transport and Storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2 - Industrial Processes and Product Use	**630.91**	**122.45**	**148.60**	**349.46**	**319.61**	**313.50**	**282.13**	**157.11**	**264.01**	**343.35**	**312.50**
2.A - Mineral Industry	**630.33**	**120.00**	**144.30**	**341.02**	**311.14**	**305.12**	**273.59**	**151.80**	**258.34**	**337.04**	**305.61**
2.B - Chemical Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.C - Metal Industry	**0.00**	**0.00**	**0.00**	**0.82**	**1.10**	**1.14**	**1.41**	**1.26**	**1.44**	**1.40**	**1.18**
2.D - Non-Energy Products from Fuels and Solvent Use	**0.59**	**2.45**	**4.30**	**7.62**	**7.37**	**7.24**	**7.12**	**4.05**	**4.24**	**4.91**	**5.71**
2.E - Electronics Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.F - Product Uses as Substitutes for Ozone Depleting Substances	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.G - Other Product Manufacture and Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.H - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3 - Agriculture, Forestry, and Other Land Use	-777.44	-569.80	-565.34	-593.93	-560.38	-517.86	-488.08	-512.44	-492.22	-473.32	-373.55
3.A - Livestock	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Categories	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
	Gg										
3.B - Land	**-737.20**	**-514.68**	**-468.19**	**-524.17**	**-550.51**	**-516.64**	**-478.04**	**-488.30**	**-470.86**	**-455.65**	**-373.39**
3.B.1 - Forest land	-739.26	-516.74	-470.82	-526.80	-553.13	-527.00	-539.78	-547.24	-530.44	-525.29	-453.30
3.B.2 - Cropland	0.67	0.67	0.67	0.67	0.67	10.31	-6.73	-6.73	-6.73	-6.73	-6.73
3.B.3 - Grassland	0.00	0.00	0.00	0.00	0.00	-1.97	18.37	18.37	18.37	18.37	18.37
3.B.4 - Wetlands	1.41	1.41	1.97	1.97	1.97	1.97	5.72	7.62	18.32	11.55	31.92
3.B.5 - Settlements	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.81	6.73
3.B.6 - Other Land	-0.02	-0.02	-0.02	-0.02	-0.02	0.05	44.38	39.68	29.63	29.63	29.63
3.C - Aggregate sources and non-CO_2 emissions sources on land	**0.00**	**2.72**	**0.00**	**0.00**	**0.97**	**0.43**	**0.68**	**1.03**	**2.72**	**4.43**	**5.51**
3.C.3 - Urea application	0.00	2.72	0.00	0.00	0.97	0.43	0.68	1.03	2.72	4.43	5.51
3.D - Other	**-40.24**	**-57.84**	**-97.14**	**-69.76**	**-10.84**	**-1.65**	**-10.72**	**-25.17**	**-24.09**	**-22.09**	**-5.67**
3.D.1 - Harvested Wood Products	-40.24	-57.84	-97.14	-69.76	-10.84	-1.65	-10.72	-25.17	-24.09	-22.09	-5.67
3.D.2 - Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 - Waste	**4.34**	**4.32**	**4.47**	**4.49**	**4.41**	**4.39**	**4.36**	**4.31**	**4.28**	**4.60**	**4.71**
4.A - Solid Waste Disposal	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4.B - Biological Treatment of Solid Waste	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4.C - Incineration and Open Burning of Waste	**4.34**	**4.32**	**4.47**	**4.49**	**4.41**	**4.39**	**4.36**	**4.31**	**4.28**	**4.60**	**4.71**
4.D - Wastewater Treatment and Discharge	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4.E - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
5 - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo Items											
International Bunkers	**408.91**	**89.93**	**90.53**	**111.68**	**136.17**	**127.62**	**127.57**	**136.61**	**168.68**	**195.11**	**217.50**
1.A.3.a.i - International Aviation (International Bunkers)	408.91	89.93	90.53	111.68	136.17	127.62	127.57	136.61	168.68	195.11	217.50
1.A.3.d.i - International water-borne navigation (International bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A.5.c - Multilateral Operations	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Annex 5.3 Time series of CH_4 emissions

Categories	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
	Gg										
Total National Emissions and Removals	**156.26**	**117.60**	**111.54**	**128.71**	**135.33**	**147.14**	**156.92**	**157.92**	**154.87**	**134.80**	**128.26**
1 - Energy	**82.71**	**52.98**	**54.25**	**63.35**	**71.11**	**74.53**	**78.04**	**78.32**	**80.58**	**63.88**	**57.24**
1.A - Fuel Combustion Activities	**3.56**	**1.59**	**1.56**	**1.91**	**2.40**	**2.82**	**3.07**	**3.05**	**3.11**	**3.41**	**3.79**
1.A.1 - Energy Industries	0.35	0.05	0.03	0.02	0.01	0.03	0.03	0.02	0.02	0.03	0.02
1.A.2 - Manufacturing Industries and Construction	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1.A.3 - Transport	1.54	0.40	0.35	0.75	1.31	1.52	1.75	1.72	1.81	2.01	2.20
1.A.4 - Other Sectors	1.62	1.13	1.18	1.12	1.06	1.25	1.29	1.31	1.26	1.37	1.55
1.A.5 - Non-Specified	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.B - Fugitive emissions from fuels	**79.15**	**51.39**	**52.69**	**61.44**	**68.71**	**71.71**	**74.97**	**75.27**	**77.47**	**60.46**	**53.45**
1.B.2 - Oil and Natural Gas	79.15	51.39	52.69	61.44	68.71	71.71	74.97	75.27	77.47	60.46	53.45
1.C - Carbon dioxide Transport and Storage	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2 - Industrial Processes and Product Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.A - Mineral Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.B - Chemical Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.C - Metal Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.D - Non-Energy Products from Fuels and Solvent Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Categories	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
	Gg										
2.E - Electronics Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.F - Product Uses as Substitutes for Ozone Depleting Substances	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.G - Other Product Manufacture and Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.H - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3 - Agriculture, Forestry, and Other Land Use	**56.73**	**45.91**	**35.71**	**41.84**	**40.65**	**48.22**	**53.89**	**54.10**	**48.25**	**44.77**	**44.86**
3.A - Livestock	**56.73**	**45.72**	**35.53**	**41.66**	**40.44**	**48.04**	**53.71**	**53.92**	**48.01**	**44.62**	**44.65**
3.A.1 - Enteric Fermentation	54.49	44.18	34.67	40.64	39.39	46.75	52.10	52.16	46.36	42.97	42.89
3.A.2 - Manure Management	2.24	1.54	0.86	1.02	1.05	1.29	1.61	1.76	1.65	1.64	1.76
3.B - Land	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3.C - Aggregate sources and non-CO_2 emissions sources on land	**0.001**	**0.188**	**0.175**	**0.175**	**0.211**	**0.183**	**0.176**	**0.177**	**0.243**	**0.154**	**0.215**
3.C.1 - Emissions from biomass burning	0.001	0.188	0.175	0.175	0.211	0.183	0.176	0.177	0.243	0.154	0.215
3.D - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3.D.1 - Harvested Wood Products	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 - Waste	**16.82**	**18.72**	**21.58**	**23.52**	**23.57**	**24.39**	**24.99**	**25.51**	**26.04**	**26.15**	**26.16**
4.A - Solid Waste Disposal	**12.35**	**14.53**	**17.11**	**18.72**	**18.76**	**19.26**	**19.43**	**19.97**	**20.30**	**20.36**	**20.11**
4.B - Biological Treatment of Solid Waste	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4.C - Incineration and Open Burning of Waste	**0.63**	**0.62**	**0.64**	**0.65**	**0.63**	**0.63**	**0.63**	**0.62**	**0.62**	**0.61**	**0.61**
4.D - Wastewater Treatment and Discharge	**3.85**	**3.57**	**3.82**	**4.16**	**4.17**	**4.49**	**4.93**	**4.92**	**5.12**	**5.18**	**5.44**
4.E - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
5 - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo Items											
International Bunkers	**0.0029**	**0.0006**	**0.0006**	**0.0008**	**0.0010**	**0.0009**	**0.0009**	**0.0010**	**0.0012**	**0.0014**	**0.0015**
1.A.3.a.i - International Aviation (International Bunkers)	0.0029	0.0006	0.0006	0.0008	0.0010	0.0009	0.0009	0.0010	0.0012	0.0014	0.0015
1.A.3.d.i - International water-borne navigation (International bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A.5.c - Multilateral Operations	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Annex 5.4 Time series of N_2O emissions

Category	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
	Gg										
Total National Emissions and Removals	**3.34**	**3.36**	**2.25**	**2.67**	**2.51**	**3.10**	**3.33**	**4.03**	**3.41**	**3.28**	**4.10**
1 - Energy	**0.26**	**0.06**	**0.05**	**0.07**	**0.09**	**0.10**	**0.11**	**0.10**	**0.11**	**0.11**	**0.13**
1.A - Fuel Combustion Activities	**0.26**	**0.06**	**0.05**	**0.07**	**0.09**	**0.10**	**0.11**	**0.10**	**0.11**	**0.11**	**0.13**
1.A.1 - Energy Industries	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2 - Manufacturing Industries and Construction	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3 - Transport	0.17	0.04	0.03	0.05	0.08	0.08	0.08	0.08	0.09	0.09	0.10
1.A.4 - Other Sectors	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
1.B - Fugitive emissions from fuels	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
1.C - Carbon dioxide Transport and Storage	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2 - Industrial Processes and Product Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.A - Mineral Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.B - Chemical Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.C - Metal Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.D - Non-Energy Products from Fuels and Solvent Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.E - Electronics Industry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Category	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019
						Gg					
2.F - Product Uses as Substitutes for Ozone Depleting Substances	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.G - Other Product Manufacture and Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2.H - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3 - Agriculture, Forestry, and Other Land Use	**2.89**	**3.12**	**2.01**	**2.40**	**2.20**	**2.78**	**2.99**	**3.70**	**3.07**	**2.93**	**3.73**
3.A - Livestock	**0.34**	**0.24**	**0.14**	**0.15**	**0.14**	**0.18**	**0.19**	**0.20**	**0.19**	**0.18**	**0.18**
3.A.1 - Enteric Fermentation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.A.2 - Manure Management	0.34	0.24	0.14	0.15	0.14	0.18	0.19	0.20	0.19	0.18	0.18
3.B - Land	**0.0010**	**0.0010**	**0.0014**	**0.0014**	**0.0014**	**0.0014**	**0.0014**	**0.0014**	**0.0014**	**0.0014**	**0.0014**
3.B.4 - Wetlands	0.0010	0.0010	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
3.C - Aggregate sources and non-CO_2 emissions sources on land	**2.55**	**2.88**	**1.88**	**2.24**	**2.06**	**2.60**	**2.79**	**3.50**	**2.88**	**2.75**	**3.55**
3.C.1 - Emissions from biomass burning	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01
3.C.4 - Direct N2O Emissions from managed soils	2.15	2.13	1.41	1.69	1.56	1.97	2.11	2.64	2.16	2.07	2.67
3.C.5 - Indirect N2O Emissions from managed soils	0.00	0.60	0.37	0.45	0.40	0.52	0.55	0.72	0.59	0.56	0.76
3.C.6 - Indirect N2O Emissions from manure management	0.39	0.15	0.09	0.10	0.09	0.11	0.13	0.13	0.12	0.11	0.12
3.D - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
3.D.1 - Harvested Wood Products	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 - Waste	**0.20**	**0.18**	**0.18**	**0.20**	**0.22**	**0.22**	**0.23**	**0.23**	**0.23**	**0.24**	**0.24**
4.A - Solid Waste Disposal	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4.B - Biological Treatment of Solid Waste	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4.C - Incineration and Open Burning of Waste	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
4.D - Wastewater Treatment and Discharge	**0.19**	**0.17**	**0.17**	**0.19**	**0.21**	**0.21**	**0.22**	**0.22**	**0.22**	**0.23**	**0.23**
4.E - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
5 - Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Memo Items											
International Bunkers	**0.011**	**0.003**	**0.003**	**0.003**	**0.004**	**0.004**	**0.004**	**0.004**	**0.005**	**0.005**	**0.006**
1.A.3.a.i - International Aviation (International Bunkers)	0.011	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006
1.A.3.d.i - International water-borne navigation (International bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A.5.c - Multilateral Operations	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**

Annex 5.5 Time series of F-gases' emissions

Category	2000	2005	2010	2012	2014	2016	2017	2018	2019
HFC emissions, Gg CO_2 eq.	**3.96**	**45.08**	**266.61**	**397.91**	**531.74**	**637.70**	**685.34**	**828.02**	**969.53**
HFC-32	0.02	1.32	8.48	13.07	18.08	22.72	25.09	33.67	42.40
HFC-125	0.23	11.49	82.99	127.95	172.88	211.75	230.71	288.91	344.72
HFC-134a	3.36	22.97	99.71	141.34	189.48	223.14	237.13	288.14	344.51
HFC-152a	0.14	0.35	0.88	1.06	1.22	1.37	1.44	1.66	1.94
HFC-143a	0.21	8.90	74.37	114.22	149.56	178.12	190.34	214.96	235.25
HFC-227ea	0.00	0.05	0.17	0.28	0.53	0.60	0.64	0.67	0.71
SF_6	0.04	1.25	2.34	2.44	2.59	2.59	2.59	2.82	3.29
Total emissions of F-gases, Gg CO_2 eq.	**4.00**	**46.33**	**268.94**	**400.35**	**534.34**	**640.30**	**687.93**	**830.85**	**972.82**