Ministry of Environmental Protection and Agriculture of Georgia

# NATIONAL GREENHOUSE GAS INVENTORY

## REPORT OF GEORGIA

## 1990-2017

**National Inventory Report**

Under the United Nations Framework Convention on Climate Change

2021

# National Greenhouse Gas Inventory Report of GEORGIA 1990-2017

Tbilisi, 2021

**The Ministry of Environmental Protection and Agriculture of Georgia has been in charge of coordinating the preparation of The National Inventory Report of GHG emissions to the UNFCCC.**

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## Abbreviations and Symbols

**AD –** Activity Data
**AWDS –** Animal Waste Disposal Site
**BOD –** Biological Oxygen Demand
**COD –** Chemical Oxygen Demand
**COP –** Conference of Parties (of the UNFCCC)
**DOC –** Degradable Organic Carbon
**EF –** Emission Factor
**EIA –** Environmental Impact Assessment
**FAOSTAT –** Food and Agriculture Organization Statistics Office
**GAM –** Global Average Method
**GEOSTAT –** National Statistics Office of Georgia
**GHG –** Greenhouse Gas
**GPG –** Good Practice Guidelines
**IEA –** International Energy Agency
**IPCC –** Intergovernmental Panel on Climate Change
**KfW –** German Development Bank
**LULUCF –** Land Use, Land-Use Change and Forestry
**MCF –** Methane Correction Factor
**MEPA –** Ministry of Environmental Protection and Agriculture of Georgia
**MSW –** Municipal Solid Waste
**NG –** Natural Gas
**NIR –** National Inventory Report of GHGs emissions
**NMVO –** Non-Methane Volatile Organic Compounds
**SNC –** Second National Communication
**TNC –** Third National Communication
**UNFCCC –** United Nations Framework Convention on Climate Change

**C –** Carbon
**CaO –** Lime
**$CH_4$ –** Methane
**CO –** Carbon Monoxide
**$CO_2$ –** Carbon Dioxide
**HFC –** Hydrofluorocarbons
**$N_2O$ –** Nitrous Oxide
**PFC –** Perfluorocarbons
**$SF_6$ –** Sulphur Hexafluoride
**$SO_2$ –** Sulphur Dioxide
**Gg –** Gigagram ($10^9$ grams=1000 ton)
**hl –** Hectoliter (100 Liter)
**PJ –** Peta Joule ($10^{15}$ Joule)
**TJ –** Tera Joule ($10^{12}$ Joule)

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# Chapter 1. Introduction

## 1.1. A Description of Georgia's National Inventory Arrangements

### 1.1.1. Overview

Georgia joined the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and the parliament ratified the Kyoto Protocol on May 28, 1999 with the resolution N 1995. "The ultimate goal of this Convention is to achieve stabilization of greenhouse gas concentrations in the atmosphere at the level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

On June 7, 2017, Georgia ratified Paris Agreement and started preparing its Nationally Determined Contribution (NDC) document to be submitted in 2020. Simultaneously, the Ministry of Environmental Protection and Agriculture of Georgia develops "Climate Action Plan 2021-2030" with the technical assistance of GIZ which will be ready in 2020.

The ability of the International Community to achieve the set objective by reducing Greenhouse Gases (GHGs) emission, depends on the knowledge and understanding of the trends in GHG emissions. According to Article 4(1) (a) and Article 12(1) (a) of the Convention, all parties are required to provide the supreme body of the Convention – the Conference of the Parties[1] – with the information about national GHGs emissions and sources of their removal. Up to 2010[2], National Communication was the main reporting mechanism for Non-Annex 1 countries of the Convention. A decision[3] taken by the 16th Conference of the Parties held in Cancun (2010), requires all countries, starting 2014, to present a biennial independent and complete report (BUR- Biennial Update Report) including the trends of national GHG emissions.

In Georgia, the first GHG inventory was performed based on the 1980-1996 data, as a part of the preparation of the First/Initial National Communication (FNC, during 1997-1999). The Second National Communication (SNC, during 2006-2009) comprised GHG inventory data for the period of 1997-2006. The 2007-2011 GHG inventory was performed as a part of the Third National Communication (TNC, during 2012-2015). The First Biennial Update Report (FBUR, during 2015-2017) of Georgia to UNFCCC comprised GHG inventory data for the period of 2012-2013. The 2014-2015 GHG inventory was prepared as a part of the Second Biennial Update Report (SBUR, during 2018-2019). The Fourth National Communication (during 2019-2021) comprised GHG inventory data for the period of 2016-2017. In the latest national GHGs inventory the figures of the previous years were recalculated and adjusted in all the sectors, due to the use of IPCC 2006 guidelines and more reliable activity data.

The present report describes the results of the Sixth National Inventory of greenhouse gases for the period of 1990-2017. The Inventory is based on the Intergovernmental Panel on Climate Change (IPCC) Methodology that is comprised of the following key documents (hereafter jointly referred to as the IPCC methodology). These are:

- 2006 IPCC Guidelines for National Greenhouse Gas Inventories[4] (hereafter referred to as IPCC 2006);

[1]Conference of the Parties (COP) - is the supreme decision-making body of the Convention. All States that are Parties to the Convention are represented at the COP.
[2]In 2010, 16th Conference of the Parties of the UNFCCC was held in Cancun, Mexico, where the decision was made to have separate reporting on inventories and climate change mitigation activities.
[3] 1/CP16; http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2.
[4]IPCC 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Egleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. http://www.ipcc-nGgip.iges.or.jp/public/2006gl/index.html

- 2003 IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (hereafter referred to as IPCC GPG-LULUCF);
- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories[5] (hereafter referred to as IPCC 1996);
- IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)[6] (hereafter referred to as IPCC GPG).

Inventory Software Ver 2.69 (released in September 2019[7], for energy sector) and excel based worksheets (for IPPU, Agriculture, LULUCF, Waste sectors) were used for the compilation of the inventory. The inventory covers the following sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry, and other Land Use (AFOLU, in separate chapters); and Waste.

The UN Framework Convention on Climate Change requires reporting the gases listed below:

Carbon Dioxide ($CO_2$);
Methane ($CH_4$);
Nitrous Oxide ($N_2O$);
Hydrofluorocarbons (HFCs);
Perfluorocarbons (PFCs);
Sulphur Hexafluoride ($SF_6$).

The Sixth National Inventory of Georgia reviews all the above-listed direct gases stipulated by the Convention as well as indirect greenhouse gases, such as: Nitrogen Oxides ($NO_X$), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCs) as well as Sulphur Dioxide ($SO_2$).

According to the UNFCCC reporting guidelines on annual inventories[8], the Global Warming Potentials (GWP) provided by the IPCC in its Second Assessment Report ("1995 IPCC GWP Values") based on the effects of GHGs over a 100-year time horizon was used for expressing GHG emissions and removals in $CO_2$ equivalents. The values of the GWP of greenhouse gases are shown in the Table below[9].

Table 1-1 Global Warming Potential (GWP) of Direct Greenhouse Gases

| Gas | Lifetime, Years | 100-years Horizon GWP | Gas | Lifetime, Years | 100-years Horizon, GWP |
|---|---|---|---|---|---|
| $CO_2$ | variable (50-200) | 1 | HFC-227ea | 36.5 | 2.900 |
| $CH_4$ | 12±3 | 21 | HFC-236fa | 209 | 6.300 |
| $N_2O$ | 120 | 310 | HFC-245ca | 6.6 | 560 |
| **HFC:** | | | **PFC:** | | |
| HFC-23 | 264 | 11.700 | PFC, $CF_4$ | 50000 | 6.500 |
| HFC-32 | 5.6 | 650 | PFC-116, $C_2F_6$ | 10000 | 9.200 |
| HFC-125 | 32.6 | 2.800 | PFC-218, $C_3F_8$ | 2600 | 7.000 |
| HFC-134a | 10.6 | 1.300 | PFC 31-10, $C_4F_{10}$ | 2600 | 7.000 |
| HFC-143a | 48.3 | 3.800 | PFC 51-14, $C_6F_{14}$ | 3200 | 7.400 |
| HFC-152a | 1.5 | 140 | $SF_6$ | 3200 | 23.900 |

5 IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories. Reference manual. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK. http://www.ipcc-nGgip.iges.or.jp/public/gl/invs1.html

6 IPCC, 2000: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan. http://www.ipcc-nGgip.iges.or.jp/public/gp/english/

7 https://www.ipcc-nggip.iges.or.jp/software/index.html

8 Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention, III B.

9 IPCC Second Assessment - Climate Change 1995. IPCC, Geneva, Switzerland. pp 64

### 1.1.2. Institutional Arrangement of the National GHG Inventory

The Government of Georgia is a body accountable to the UNFCCC. The Ministry of Environmental Protection and Agriculture of Georgia elaborates and implements the policy in climate change[10]. The Department of Environment and Climate Change is a structural unit of the Ministry; the subunit of the above Department – The Climate Change Division, along with other functions, is responsible for coordination of periodic compilation of inventory report and its submission to the Convention Secretariat.

There is an independent non-commercial legal entity under public law of Georgia, the LEPL Environmental Information and Education Centre[11], in the structure of the Ministry of Environmental Protection and Agriculture. One of the functions of this Entity implies development of a unified environmental data base and support of its publicity. Furthermore, the Centre prepares National Greenhouse Gas Emissions Inventory reports with the assistance of independent international and local experts.

The present NIR has been prepared under the project: "The Fourth National Communication and Second Biennial Update Report to the UN Framework Convention on Climate Change". The Climate Change Division of the Ministry of Environmental Protection and Agriculture leads and coordinates the report development. UNDP Georgia operates as an implementing agency for the Global Environment Facility (GEF) project and assists Georgia during the whole program implementation process; it also monitors and supervises the project on behalf of the GEF. An executive council was formed at the initial phase of the project. The council consists of the representatives of the Ministry of Environmental Protection and Agriculture, the Ministry of Economy and Sustainable Development, UNDP, GIZ and Greens Movement (NGO). The council makes important decisions about the project, reviews and submits the work plans and changes in the budget; it is responsible for timely implementation of the project, as well as its quality.

There is an active cooperation on data exchange between the Ministry of Environmental Protection and Agriculture and National Statistics Office of Georgia based on the MoU singed in 2014.

[10] The resoulution of The Government of Georgia – on Approval of the Statute of Ministry of Environmental Protection and Agriculture of Georgia, N112, 6 March, 2018.

[11] www.eiec.gov.ge

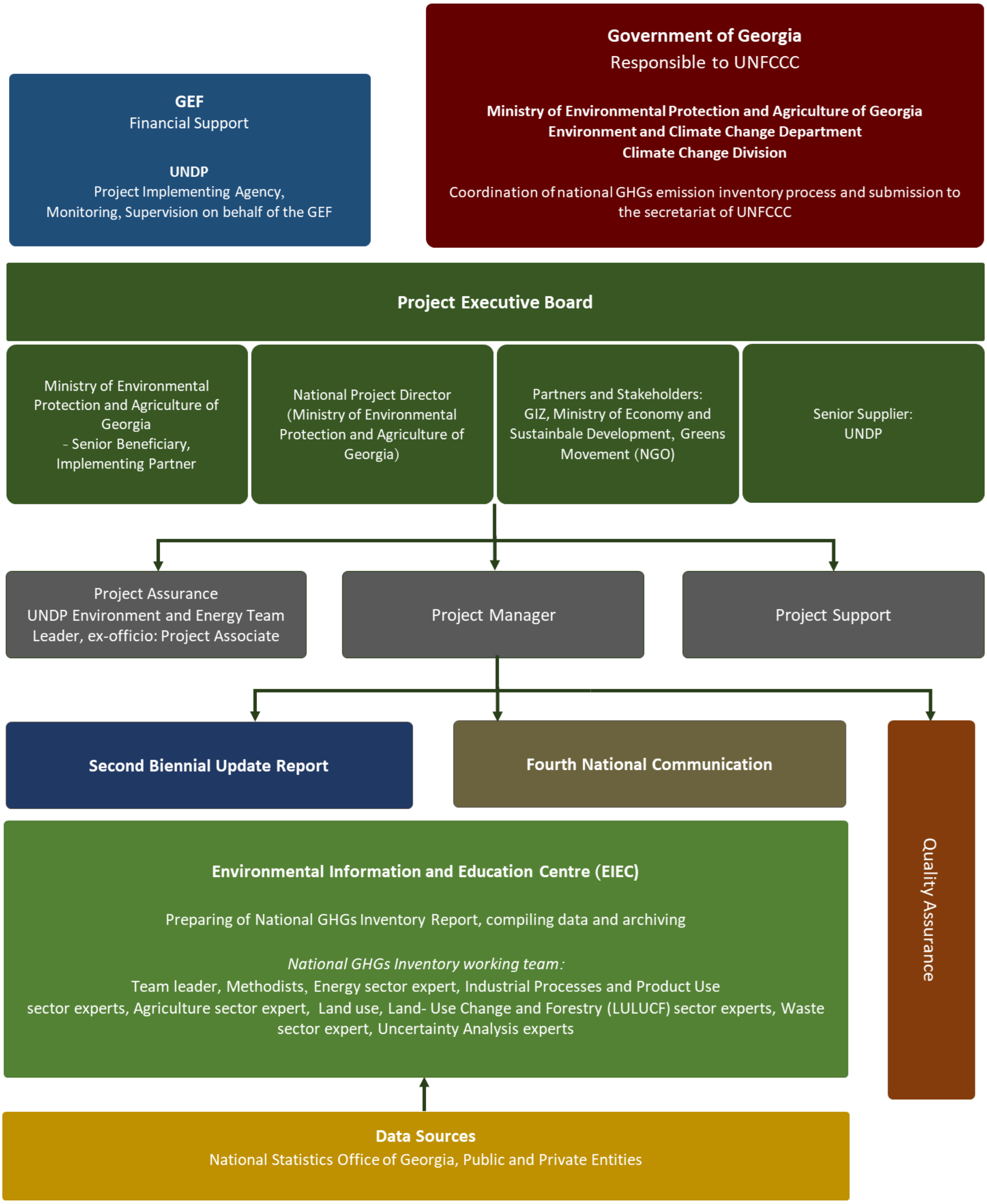


*Figure 1-1 Institutional Framework of the National GHG Inventory in Georgia*

### 1.1.3. Quality Assurance and Quality Control

The QC is carried out through a system of routine technical activities that monitor and maintain the quality of the inventory, throughout its development process. In accordance with Table 6.1, Chapter 6, Vol.1 of the 2006 IPCC Guidelines, basic QC procedures include the general items to be confirmed, related to the calculation, data processing, completeness, and documentation applicable to all emission source and sink categories. The QC activities are carried out by a team of experts involved during the preparation of the GHG NIR and by the project coordinator during the compilation and development of the GHG NIR of Georgia.

Quality Assurance (QA), as defined by the 2006 IPCC Guideline is a planned system of review procedures conducted by the personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon completion of inventory following the QC procedures in order to verify that data quality objectives are met, ensure that the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability, and support the effectiveness of the QC programme.

The external review of this NIR was coordinated by the UNDP-UNEP Global Support Programme (GSP) and was conducted from 16 to 22 March 2020 by Dr. Carlos Lopez, consultant in national GHG emissions inventories.

### 1.1.4. Treatment of the Confidential Information

Part of the AD, EFs and other parameters obtained from GEOSTAT or the private sector correspond to confidential information. These are listed and archived. At the stage of obtaining and archiving data, as well as during the QC process, confidential files are distinguished from others, and restricted access is ensured. At the stage of UN reporting, the minimum level of aggregation of the above with other sub-categories is performed, and the notation key “C” (confidential) is used.

## 1.2. Description of Key Categories

Chapter 4 of 2006 IPCC Guidelines for the National GHG Inventories provides rules for methodological choice and identification of key categories. According to the guideline, “a key category is one that is prioritized within the national inventory system because its estimate has a significant influence on a country’s total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Whenever the term key category is used, it includes both source and sink categories.”

This sub-chapter provides the analysis of key source/sink of GHG emission/removals in Georgia for the period of 1990-2017, related to absolute values of emissions/removals (level analysis), as well as for the trends, Approach 1. The key category analysis was performed using excel worksheets.

For the identification of key source/sink categories, the share of individual categories (converted to CO2 eq.) in total emissions/removals is calculated according to the absolute level of emissions/removals (level assessment). Following the calculation of contribution percentage of each source/sink category, they are summed in descending order of magnitude, adding up to 95% of the total value of all key categories.

According to the trend assessment method, a source/sink category is considered a key category if it significantly contributes to the total trend of national emissions and removals. For this assessment, the trend of a category is calculated for each source/sink category as the difference of the values of emissions/removals derived from the particular source/sink category, between current and base years for the inventory, divided by the value of current year emission/removal. Furthermore, the trend of total value of inventory is calculated by dividing the difference between the total emissions of current and base years, by current year total emission.

To assess the actual significance of the difference between the category and total trends in the outcomes of the overall inventory, these differences are weighed according to the assessment of the share of absolute value of a category of emission, i.e., a level assessment is performed. Specifically, the total emission trend is subtracted from the assessed category trend and is multiplied by the value of the level (share), obtained for this category by the “level assessment” calculated for the base year. Derived values for all categories are summed and the share of each category, as part of this total, is calculated. Thus, a key category would include a category for which the difference between the total inventory trend and the source category trend, according to the category “level” in the base year, is significant.

The current inventory was conducted for the 1990-2017 period. Hence, 1990 was considered base year for trend assessment. The derived results were arranged in a descending order and cumulative totals were calculated. The sources with the cumulative total equaling to, or higher than 95% of the overall emission (in $CO_2$ eq.) were determined to be a key category in terms of the trend. The identified key categories are presented in Table below.

Table 1-2 Key Categories of Georgia’s GHG Inventory According to Level and Trend Assessment, Approach 1

| IPCC Category code | IPCC Category | Greenhouse gas | Reasons to select as Key-category |
|---|---|---|---|
| 3.B.1.a | Forest land Remaining Forest land | $CO_2$ | Level, Trend |
| 1.A.3.b | Road Transportation | $CO_2$ | Level, Trend |
| 3.B.3.a | Grassland Remaining Grassland | $CO_2$ | Level, Trend |
| 1.A.4 | Other Sectors - Gaseous Fuels | $CO_2$ | Level, Trend |
| 3.B.2.a | Cropland Remaining Cropland | $CO_2$ | Level, Trend |
| 3.A.1 | Enteric Fermentation | $CH_4$ | Level, Trend |
| 1.B.2.b | Natural Gas | $CH_4$ | Level, Trend |
| 4.A | Solid Waste Disposal | $CH_4$ | Level, Trend |
| 1.A.1 | Energy Industries - Gaseous Fuels | $CO_2$ | Level, Trend |
| 3.C.4 | Direct N2O Emissions from managed soils | $N_2O$ | Level, Trend |
| 1.A.2 | Manufacturing Industries and Construction - Solid Fuels | $CO_2$ | Level, Trend |
| 2.A.1 | Cement production | $CO_2$ | Level, Trend |
| 1.A.1 | Energy Industries - Solid Fuels | $CO_2$ | Level, Trend |
| 3.C.5 | Indirect N2O Emissions from managed soils | $N_2O$ | Level, Trend |
| 2.C.2 | Ferroalloys Production | $CO_2$ | Level, Trend |
| 2.B.1 | Ammonia Production | $CO_2$ | Level, Trend |
| 4.D | Wastewater Treatment and Discharge | $CH_4$ | Level, Trend |
| 3.A.2 | Manure Management | $N_2O$ | Level, Trend |
| 1.A.2 | Manufacturing Industries and Construction - Gaseous Fuels | $CO_2$ | Level, Trend |
| 2.B.2 | Nitric Acid Production | N2O | Level, Trend |
| 1.A.3.e | Other Transportation | $CO_2$ | Level |
| 2.F.1 | Refrigeration and Air Conditioning | HFCs, PFCs | Level |
| 1.A.4 | Other Sectors - Liquid Fuels | $CO_2$ | Trend |
| 2.C.1 | Iron and Steel Production | $CO_2$ | Trend |
| 1.A.2 | Manufacturing Industries and Construction - Liquid Fuels | $CO_2$ | Trend |
| 1.B.1 | Solid Fuels | $CH_4$ | Trend |
| 1.A.1 | Energy Industries - Liquid Fuels | $CO_2$ | Trend |

## 1.3. Uncertainty Assessment

The uncertainty analysis is one of the main activities of the inventory process. Performance of this analysis is stipulated by the Convention Reporting Guidelines and is one of the specific functions performed by the National system (Decision 20 / CP.7).

Uncertainty estimates are an essential element of a complete inventory of greenhouse gas emissions and removals. Uncertainty information is intended not for disputing the validity of the inventory estimates, but rather for supporting, prioritizing efforts to improve the accuracy of inventories and guide decisions on the methodological choice. This analysis, using appropriate analytical methods can only be carried out, for key categories.

There are two methods of uncertainty estimation stipulated by the IPCC GPG: (1) the basic method (Tier 1), which is mandatory and (2) the analytical method (Tier 2).

Tier 2 methodology is based on the Monte-Carlo analysis. The principle of the Monte-Carlo analysis is to select random values for emission factors within frames of density functions of their individual probability and calculate the corresponding emission values. This procedure is repeated several times. The results of this calculation are the probability density function of emissions values. The Monte-Carlo analysis can be performed on each source-category's level, on the level of any source-category's community, or on the total inventory's level. The Monte Carlo analysis is rather detailed one and requires considerable resources and time.

For uncertainty assessment of the Georgian inventory, the relatively simple approach of Tier 1 was applied, based on the following formulae (see annex):

- A and B show the IPCC category and greenhouse gas.
- C and D are the inventory estimates in the base year and the current year respectively, for the category and gas specified in Columns A and B, expressed in $CO^2$ equivalents.
- E and F contain the uncertainties for the activity data and emission factors respectively, derived from a mixture of empirical data and expert judgment as previously described in this chapter, entered as half the 95 percent confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95 percent confidence interval is that the value entered in Columns E and F corresponds to the familiar plus or minus value when uncertainties are loosely quoted as 'plus or minus *x* percent', so expert judgments of this type can be directly entered in the spreadsheet. If uncertainty is known to be highly asymmetrical, the larger percentage difference between the mean and the confidence limit should be entered.
- G is the combined uncertainty by category derived from the data in Columns E and F using the error propagation equation. The entry in Column G is therefore the square root of the sum of the squares of the entries in Columns E and F.

$$G_x = \sqrt{E_x^2 + F_x^2}$$

- H shows the uncertainty in Column G as a percentage of total national emissions in the current year. The entry in each row of Column H is the square of the entry in Column G multiplied by the square of the entry in Column D, divided by the square of total at the foot of Column D. The value at the foot of Column H is an estimate of the percentage uncertainty in total national net emissions in the current year, calculated from the entries above using Equation 3.1. This total is obtained by summing the entries in Column H and taking the square root.
- Contribution to Variance by Category in Year 2017:

$$H_x = \frac{(G_x * D_x)^2}{(\sum D_i)^2}$$

Total emissions uncertainty using error propagation equation:

$$H_{tot} = \sqrt{\sum_x H_x^2}$$

Where,

*X* is an index that indicates the source-category,

$G_x$ is combined uncertainty of x source-category,

$E_x$ is activity data uncertainty of x source-category,

$F_x$ is uncertainty of gas emission factor from x source-category,

$H_x$ is percentage of combined uncertainty of 2017 in total emissions

$D_x$ is emission of 2017 from x source-category,

$H_{tot}$ is total uncertainty of emissions

In addition, the formula below **($I_x$)** was used to estimate the uncertainty of the trend, which shows A type sensitivity.

$I_x$ = percentage trend if source category x is increased by 1% in both years – percentage trend without increase

$$\frac{0.01 \bullet D_x + \sum D_i - (0.01 \bullet C_x + \sum C_i)}{(0.01 \bullet C_x + \sum C_i)} \bullet 100 - \frac{\sum D_i - \sum C_i}{\sum C_i} \bullet 100$$

This equation shows the change in emissions between the base year (1990) and the year t (2017) in response to a 1% increase in emissions of source category x emissions in the base year and year t. This shows the sensitivity of the trend in emissions to a systematic uncertainty in the emission estimate – i.e. one that is correlated between the base year and year t. This sensitivity is described as type A sensitivity.

To estimate the uncertainty of the trend, the formula presented below **($J_x$),** was used, which shows B type sensitivity.

$J_x$ = percentage trend if source category x is increased by 1% in year t – percentage trend without increase

$$J_x \frac{D_x}{\sum C_i}$$

This equation shows the changes in emissions between the base year (1990) and year t (2017) in response to a 1% increase in the emissions of source category x in the year t only. This shows the sensitivity of the trend in emissions to a random uncertainty error in the emissions estimate – i.e. one that is not correlated between the base year and year Y. This sensitivity is described as type B sensitivity.

In order to estimate the uncertainty in national emissions due to an uncertainty of emission factors (column K) the following approach, advised by the IPCC methodology, was applied:

Assuming that the same emission factor is used in both years, and that the actual emission factors are fully correlated, hence, the % error is introduced equally in both years. Therefore, the formula for the uncertainty introduced on the trend by the emission factor is:

$$K_x = \text{sensitivity A} * \text{uncertainty of emission factor} = I_x * F_x$$

In case no correlation between emission factors is assumed, sensitivity B should be used, and the K is increased by √2, for the reason given below, in the main derivation for column L:

$$K_x = \text{sensitivity B} * \text{uncertainty of emission factor} * \sqrt{2} = J_x * \mathbf{F_x} * \sqrt{\mathbf{2}}$$

To estimate uncertainty in national emissions due to uncertain activity data (column L), the following approach, according to the IPCC methodology, was used:

The trend is the difference between emissions in the base year and in the year t. Therefore, the uncertainty of the activity data of the base year and t has to be taken into account. The two uncertainties combined, using the error propagation equation and the assumption that the uncertainty is the same in the base year and year t, we use the following formula:

$$L_x = \sqrt{(\text{uncertainty (activity data, base year)})^2 + (\text{uncertainty (activity data, year t)})^2}$$

$$\approx \sqrt{\text{uncertainty (activity data, year t)})^2 * 2} = E_x * \sqrt{2}$$

Since activity data in both years are assumed to be independent, column L equals:

$$L_x = \text{ sensitivity B} * \text{combined uncertainty of activity data of both years} = J_x * E_x * \sqrt{2}$$

In case correlation between activity data is assumed, sensitivity A should be used and the $\sqrt{2}$ factor does not apply:

$$L_x = I_x * E_x$$

To estimate the uncertainty trend in national emission (column M), the following approach was used:

Column M combines the uncertainty introduced in the trend by the uncertainty in the activity data and the emission factor:

$$M_x = \sqrt{K_x^2 + L_x^2}$$

The entries Mi in column M are combined to obtain the total uncertainty of the trend, using the error propagation equation, as following:

$$M_{tot} = \sqrt{M_1^2 + M_2^2 + \cdots + M_n^2}$$

According to the general methodology, uncertainty shall be assessed on the levels of each emission subcategory and activity data, and for each emission factor. However, when the sub-categories have no correlation or interdependence between each other (for example if emission factors or activity data are the same or interdependent for different categories), it is recommended to carry out an uncertainty analysis on the aggregate level were interdependence is negligible. This approach has the advantage that the aggregated categories can be selected allowing them to match key categories analysis and, therefore, serve their purpose; it implies identification of categories (during the uncertainty assessment, as well as analysis of key categories) which requires special focus during the inventory.

Most of the countries use the aggregated categories in the uncertainty analysis, and Georgia has selected the same approach in this inventory.

The uncertainty analysis in the inventory of Georgia's National Communication is based on the Tier 1 approach and covers all source-categories and all direct greenhouse gases, where 2017 was taken for the uncertainty assessment, and 1990 as the base year. The uncertainty estimation for the activity data and emission factors was based on typical values of the IPCC and on experts' judgment. A detailed description and calculations of the uncertainty are presented in Annex B. Uncertainty Analysis.

The results revealed that the level of emissions' uncertainty (percentage uncertainty in total inventory) is within 22.85%, and the uncertainty trend – 11.99%. The highest uncertainty assessments fall on fugitive emissions from solid fuel, oil and gas extraction, also nitrous oxide emissions from civil and international aviation. Uncertainty is also relatively high in case of nitrous oxide emissions from commercial/institutional services, residential and stationary activities.

**The Energy Sector**

**Fuel combustion (1A)**

Uncertainty estimates are an essential element of a complete emission inventory. Uncertainty information is intended not for disputing the validity of the inventory estimates, but rather for supporting, prioritizing efforts to improve the accuracy of inventories and guide decisions on methodological choice.

For the fuel combustion source-category (1A) uncertainty was assessed using the Tier 1 approach, which is reviewed in detail in Annex A.

According the IPCC methodology, overall uncertainty in activity data is a combination of both systematic and random errors. Most developed countries prepare balances of fuel supply and deliveries, which provides a check on systematic errors. In these circumstances, overall systematic errors are likely to be small. Experts believe that uncertainty resulting from the two errors is probably within the range of ±5%. For countries with less well-developed energy data systems, this could be considerably larger, probably about ±10%. Informal activities may increase the uncertainty up to as much as 50% in some sectors for certain countries[12].

The uncertainty associated with EFs and NCVs results from two main elements, viz. the accuracy with which the values are measured, and the variability in the source of supply of the fuel and quality of the sampling of available supplies. There are few mechanisms to account for systematic errors in the measurement of the above properties. Consequently, it can be considered that the errors are basically random. For traded fuels, the uncertainty is likely to be less than 5%. For non-traded fuels, the uncertainty will be higher and will result, mostly, from variability in the fuel composition[13].

The IPCC typical value of uncertainty for countries with under-developed energy data systems, where there is no good practice for creation of energy balances, is 10%; in case of countries with well-developed energy data systems the uncertainty is 5%. A complete official energy balance - according to international standards and requirements - was developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies and was not fully in line with EU requirements. Despite this, the uncertainty was set as 5%.

According to IPCC GHG uncertainty for main activity - electricity and heat production, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is less than 1%. In case of Georgia, the uncertainty was set at 1%[14]. Uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%.

The data on consumption of firewood have high level of uncertainty. The data are based on survey results of consumption of energy forms, which was conducted by the National Statistics Office of Georgia (GEOSTAT), as well as data from Georgia's Energy Balance. Compared to the 2013 inventory report, more reliable data on consumption of firewood are available, which have been collected by GEOSTAT since 2014 through household surveys and surveys in other sectors (industry, construction etc.). As mentioned above, the standard IPCC value of uncertainty for countries with under developed energy data systems, where energy balances creation is not well practiced, is 10%; in case of countries with a well-developed

[12] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg. 2.40)

[13] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg. 2.38)

[14] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (table 2.15).

energy data system, the uncertainty is 5%. Since firewood is mainly consumed by the household sector, survey respondents may assess and indicate inaccurate (approximately) volumes of consumed firewood, especially when consumed firewood is not purchased. That is why the 18.7% uncertainty value was selected.

As for emission factors, for different type of fuels, the following values of uncertainty were selected:

- for Liquid Fuels – 6.1%
- for Gaseous Fuels - 3.9
- for Solid Fuels – 12.4%
- for Biomass – 18.7%

A more detailed overview of the methods of selection of activity data for fuel combustion source category and emission factors uncertainty values is provided in chapter 3.

**Fugitive emissions (1B)**

In this sub-category, uncertainty assessments of activity data and emission factors were based on the expert judgments and IPCC default values[15]. Uncertainty values and their determining method are detailed in Annex B.

## Industrial Processes

**Cement Production (2A1)**

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

The activity data is sufficiently accurate, their uncertainty is about 5%. According 2006 IPCC GHG methodology, where a clinker production data is estimated from cement production, the uncertainty of the activity data can be as high as about 35 percent. For Tier 2, the uncertainty in data on a clinker production tonnage, when available, is about 1-2 percent. Collecting data from individual producers (if complete) rather than using national totals will reduce the uncertainty of the estimate because these data will account for variations in conditions at the plant level[16].

As for the emission factor, major source of uncertainty is associated with determining the CaO content of a clinker. If a clinker data are available, the uncertainty of the emission factor is equal to the uncertainty of the CaO fraction and the assumption that it was all derived from CaCO3 (Table 2.3)[17]. According to the methodology, it is assumed that the content of CaO is standard, associated with 4-8% of uncertainty. That is why, the uncertainty of emission factors is about 5%. Consequently, the combined uncertainty is 7.07%.

**Lime Production (2A2)**

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.

The stoichiometric ratio is an exact value and, therefore, the uncertainty of the emission factor is the uncertainty of lime composition, in particular of the share of hydraulic lime that has 15% uncertainty in the

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15 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/ V2_4_Ch4_Fugitive_Emissions.pdf (table 4.2.4, table 4.2.5)

16 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (pg. 2.16)

17 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (pg. 2.17)

emission factor (2% uncertainty in the other types). Therefore, the total uncertainty is 15% at most (see Table 2.25), where default uncertainty values for lime production are given)[18].

The uncertainty for the activity data is likely to be much higher than for the emission factors, based on the experience in gathering lime data.

In Georgia, since lime production is practiced by many small enterprises, there is certain risk related to full coverage. However, the National Statistics Office of Georgia (GEOSTAT), which is the source for the above data, significantly improved data coverage in this area, but according to the IPCC methodology this uncertainty could be quite high. Consequently, based on experts' assessment, the uncertainty of activity data from this source is estimated as 20%.

Consequently, the combined uncertainty (boundaries of emission assessment) is 25% derived from the error propagation equation.

**Glass production (2A3)**

Glass production is estimated based on the carbonate input (Tier 3), the emission factor uncertainty (1-3 percent) is relatively low because the emission factor is based on a stoichiometric ratio[19].

Since emissions are estimated based on the quantity of melted glass in each manufacturing process and default emission factors, the uncertainty of Tier 2 is higher than Tier 3. The emission factors can be expected to have an uncertainty of +/- 10 percent.

Like cement and lime production, the uncertainty associated with weighing or proportioning of the raw materials under the Tier 3 approach is approximately 1-3 percent. Glass production data are typically measured accurately (+/-5 percent) for Tier 1 and Tier 2.

Consequently, the combined uncertainty (boundaries of emission assessment) is 11.18%, which is derived from the error propagation equation.

**Ammonia Production (2B1)**

According to the IPCC methodology[20], where activity data are obtained from plants, uncertainty estimates can be obtained from producers. These activity data are likely to be highly accurate (i.e., with uncertainty as low as ±2 percent). This will include uncertainty estimates for fuel use, uncertainty estimates for ammonia production and CO2 recovered. Data that are obtained from national statistical agencies usually do not include uncertainty estimates. It is good practice to consult with national statistical agencies to obtain the information on any sampling errors. In cases when national statistical agencies collect data from the ammonia production facilities, uncertainties in national statistics are not expected to differ from uncertainties established as a result of plant-level consultations. In case the uncertainty values are not available from other sources, a default value of ±5 percent can be used.

In Georgia’s case, activity data were collected from the National Statistics Office of Georgia (GEOSTAT), as well as from the enterprise – Rustavi Chemical Fertilizers Plant, and are quite accurate. Emissions are calculated based on the consumed natural gas volume, as well as based on the produced ammonia amount. According to the expert judgment their uncertainty is within 5%.

[18] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (pg. 2.25)

[19] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (pg. 2.31)

[20] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf (pg. 3.17)

Uncertainties for the default values[21] are estimates based on data from EFMA (2000a; p.21) and de Beer, Phylipsen and Bates (2001; p.21). In general, default emission factors for gaseous inputs and outputs have higher uncertainties than those for solid or liquid inputs and outputs. Mass values for gaseous substances are influenced by temperature and pressure variations and gases tend to have higher losses through process leaks. It is a good practice to obtain uncertainty estimates at the plant level, which should be lower than uncertainty values associated with default values. Default emission factor uncertainties reflect variations between plants across different locations.

According to the new Guidelines (2006 edition), the Tier 1 approach for determining CO2 emission parameters, fuel uncertainty needed only for unit weight of the ammonia production, (which is about 6-7%), was used to estimate the coefficient. However, such an important parameter as the carbon content in natural gas, which varies according to the specific gas consumed, is crucial as well.

In the case of Georgia's energy sector, where this parameter is used, the standard value - 15.3 kg C / GJ was taken. Whereas the carbon content for specific gas is not taken into account with the ammonia coefficient, expert judgment on the overall uncertainty of CO2 emission in case of Georgia, set the coefficient at 6% or more.

Consequently, the combined uncertainty is 7.81% based on the error propagation equation.

**Cast Iron and Steel Production (2C1)**

According to the 2006 IPCC methodology[22] the default emission factors used for iron and steel production may have an uncertainty of ± 25 percent (see table 4.4).

In terms of uncertainty for activity data, the most important type of activity data is the amount of steel produced using each method. According to the guideline, National statistics should be available and likely have an uncertainty of ± 10 percent.

Consequently, the combined uncertainty (boundaries of emissions assessment) is 26.93% based of error propagation equation.

Time series are agreed since calculation of emissions for each year was performed using the same methodological approach and emission factors.

**Ferroalloys Production (2C2)**

According to the IPCC methodology, the most important type of activity data is the amount of ferroalloy production by product type and national statistics should be available and likely have an uncertainty less than 5 percent[23]. The activity data were collected from the National Statistics Office of Georgia (GEOSTAT), as well as from the Metallurgy research Institute of Georgia. Therefore, the data are rather accurate. Based on expert assessment, their uncertainty value is 5%.

Applying the Tier I approach, the uncertainty of default emission factors are evaluated within 25% range.

Consequently, the combined uncertainty (boundaries of emissions assessment) is 25.5% based on the error propagation equation.

[21] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf (table 3.1)

[22] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf (pg. 4.30)

[23] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf (pg. 4.40)

**Nitric Acid Production (2B2)**

According to the 2006 IPCC methodology[24], if activity data are collected from plants, uncertainty estimates can be obtained from producers. Data that are obtained from national statistical agencies usually do not include uncertainty estimates. It is a good practice to consult with national statistical agencies to get the information on any sampling errors. Whenever national statistical agencies collect data from the population of nitric acid production facilities, uncertainties in national statistics are not expected to differ from uncertainties established as a result of plant-level consultations. In case uncertainty values are not available from other sources, a default value of ±2 percent can be applied.

The data are accurate and based on expert judgment, their uncertainty does not exceed 5%.

The uncertainty of emission factor of nitrogen oxides emission for this process is high, as the real value is largely determined by parameters of the specific production. 2006 IPCC guidelines for plants with medium-pressure technology give standard limits of about 20% for uncertainty estimation[25].

Consequently, the combined uncertainty (boundaries of emissions assessment) is 20.62% based on the error propagation equation.

The time series are agreed, since calculating emissions for each year were performed using the same methodological approach and emission factors.

## Agriculture

**Enteric Fermentation**

The activity data was obtained from the official statistical publication and is reliable. Though, classification and distribution of cattle is not entirely consistent with the IPCC standard on dairy and non-dairy cattle, but it could be assumed, that the data provided by GEOSTAT about “cows” and “other cattle” are in conformity with the classification of "dairy" and “non-dairy cattle”, as cows were intended for exactly dairy production purpose in case of Georgia, and the rest - for meat production. Therefore, the uncertainty of activity data is moderate and does not exceed 10%.

As the emission factors for the Tier 1 method are not based on country-specific data, they may not accurately represent a country’s livestock characteristics, and as a result, may be highly uncertain. Emission factors estimated using the Tier 1 method are unlikely to be known more precisely than ± 30% and may be uncertain to ± 50%. In case of Georgia uncertainty of 30% was stated; as for activity data (heads of cattle by species), they should be considered as reliable, since they are based on Official Statistical Data from GEOSTAT.

Due to the mentioned, and based on the error propagation equation, the methane emission uncertainty is about 31.62%.

**Manure Management**

**Methane Emissions from Manure Management**

Uncertainty of the data of activity related to number of the animals is assessed at 10%, since it is based on official statistical data. According to the IPCC GPG, 50% is stated for methane emission-related uncertainty. Consequently, the combined uncertainty is approximately 51%.

[24] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf (pg. 3.24)

[25] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf (table 3.3)

**Nitrous oxide Emissions from Manure Management**

The uncertainty of activity data for nitrous oxide emission calculation in manure management sector was estimated at 50%, as there is no accurate information about the management systems. According to the IPCC GPG, uncertainty for emission factors was estimated at 100%. Consequently, the combined uncertainty of nitrous oxide emissions is 111.8%.

**Direct soil emissions**

The activity data were obtained from the National Statistics Office of Georgia (GEOSTAT), which is a competent source and hence the data are quite accurate. Therefore, 10% was selected as the indicator of uncertainty.

The uncertainty for the emission coefficient was taken from the IPCC GPG standard range and was estimated based on expert assessment, which equals to 25%. Consequently, the combined uncertainty for this source-category is approximately 26.93%.

**Indirect soil emissions**

According to the IPCC methodology information about emission factors, leaching and volatilization fractions are sparse and highly variable. Expert judgment indicates that emission factor uncertainties are at least in order of magnitude and volatilization fraction is about +/−50%. Uncertainties in activity data estimates should be taken from the corresponding direct emissions source categories[26].

The uncertainty of activity data is also quite high and is related to the assumption of the percentage leached. In addition, the nitrogen content in fertilizers also carries uncertainty. Finally, the uncertainty of activity data was set at 50%. Consequently, the combined uncertainty is much higher (app. 71%).

**Land Use Land, Use Change and Forestry (LULUCF) (CRF sector 5)**

**Source category: Forest land**

**Emission and removal factors**

FAO (2006) provides uncertainty estimates for forest carbon factors; basic wood density (10 to 40%); annual increment in managed forests of industrialized countries (6%); growing stock (industrialized countries - 8%, non-industrialized countries -30%); combined natural losses for industrialized countries (15%); wood and fuel wood removals (industrialized countries - 20%).

In Finland, the uncertainty of basic wood density of pine, spruce and birch trees is under 20% in studies of Hakkila (1968, 1979). The variability between forest stands of the same species should be lower than or at most the same as for individual trees of the same species. In Finland, the uncertainty of biomass expansion factors for pine, spruce, and birch was approximately 10% (Lehtonen et al., 2003).

In eight Amazon tropical forest inventory plots, combined measurement errors led to errors of 10-30% in estimates of basal area change over periods of less than 10 years (Phillips et al., 2002)[27].

The overall uncertainty of country-specific basic wood density values should be about 20%.

[26] http://www.ipcc-nggip.iges.or.jp/public/gp/english/4_Agriculture.pdf (pg.4.75)

[27] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf (4.19)

**Activity data**

According to the IPCC methodology, area data should be obtained using the guidance provided under Chapter 3 or from FAO (2000). Industrialized countries set an uncertainty in forest area estimates as approximately 3% (FAO, 2000)[28].

In Georgia's case 5% uncertainty was selected.

**Cropland**

The sources of uncertainty when using the Tier 1 method include the degree of accuracy in land area estimates and in the default biomass carbon increment and loss rates. Uncertainty is likely to be low (<10%) for estimates of area under different cropping systems since most countries annually estimate cropland area using reliable methods. A published compilation of research on carbon stocks in agroforestry systems was used to derive the default data provided in Table 5.1 (Schroeder, 1994). While defaults were derived from multiple studies, their associated uncertainty ranges were not included in the publication. Therefore, a default uncertainty level of +75% of the parameter value has been set based on IPCC methodology and the expert judgment[29].

**Grassland**

Area data and estimates of uncertainty should be obtained using the methods provided under Chapter 3. Tiers 2 and 3 approaches may also use finer resolution activity data, such as area estimates for different climatic regions or for grassland management systems within national boundaries. The finer-resolution data will reduce uncertainty levels when associated with carbon accumulation factors defined for those finer-scale land databases. If using aggregate land-use area statistics for activity data (e.g., FAO data), the inventory agency may have to apply a default level of uncertainty for the land area estimates (±50%). However, it is a good practice for the inventory compiler to derive uncertainties from country-specific activity data rather than using a default level. Therefore, in case of Georgia, activity data is quite accurate and is based on the expert assessment; its uncertainty value is within 10%.

In terms of uncertainty of emission factors, according to the IPCC methodology[30] and based on the expert judgment, a default uncertainty value of 75% was selected.

**Waste**

**Solid Waste Disposal**

The uncertainty in waste disposal data depends on the way the data is obtained. Uncertainty can be reduced when the amounts of waste in the SWDS are weighed. If the estimates are based on waste delivery vehicle capacity or visual estimation, uncertainty will be higher. Estimates based on default activity data will have the highest uncertainties.

If waste scavenging takes place at the SWDS, it needs to be taken into account while operating with the waste disposal data, otherwise, the uncertainty in waste disposal data will increase. Scavenging will also increase uncertainties in the composition of waste disposed in the SWDS, and hence also in the total DOC in the waste.

[28] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf (4.20)

[29] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf

[30] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_06_Ch6_Grassland.pdf

Uncertainty estimates for Total Municipal Solid Waste ($MSW_T$) and Fraction of MSW sent to SWDS ($MSW_F$), as well as the default model parameters are given in Table 3.5[31]. The estimates are based on the expert judgment.

According to the IPCC methodology, the uncertainty range for Total Municipal Solid Waste (MSWT) is Country-specific: 30% is a typical value for countries which collect waste generation data on regular basis; ±10% for countries with high quality data (e.g., weighing at all SWDS and other treatment facilities). For countries with poor quality data: more than a factor of two.

Total uncertainty range of Waste composition is between ±10% for countries with high quality data (e.g., regular sampling at representative SWDS). ±30% for countries with country-specific data based on studies including periodic sampling. For countries with poor quality data: more than a factor of two[32].

Finally, for the value of uncertainty for emission factor 30% was chosen.

**Industrial Wastewater handling**

The activity data for industrial wastewater is the amount of manufactured produce and the volume of wastewater consumed for manufacturing the produce. According to the expert's judgment and the IPCC Guidelines, the uncertainty limits for them are estimated as following[33]:

- For Industrial Production - 25% (uncertainty limits should be discussed within the recommended limits, according IPCC, as statistical data related this sector is good quality)
- The uncertainty of industrial wastewater volume (Wastewater/unit production) according to the experts' estimation is no less than 50%
- For COD (chemical oxygen demand) concentration (COD/unit wastewater) - no less than 50%.

According IPCC 2006 guideline, these data can be very uncertain as the same sector might use different waste handling procedures at different plants and in different countries. The product of the parameters (W•COD) is expected to have less uncertainty. An uncertainty value can be attributed directly to kg COD/tonne of product. –50 %, +100% is suggested.

The combined uncertainty of this source-category, based on uncertainties of emission factors and activity data, equals to 58.31%.

**Domestic Wastewater handling**

The data of domestic and commercial wastewater (Domestic Wastewater handling) includes the number of the population and the share of anaerobic treated wastewater. The uncertainty of standard limits of all values are based on the experts' judgments and the 2006 IPCC methodology[34].

IPCC methodology provides default uncertainty ranges for emission factor and activity data of domestic wastewater. According to the guideline, for identifying emission factor uncertainty, uncertainty range for maximum CH4 producing capacity (Bo) is ± 30%. Consequently, the final uncertainty of emission factors was set at 30%.

[31] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf (pg. 3.27)

[32] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf (pg. 3.27)

[33] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf (ph. 6.23)

[34] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf (pg. 6.16)

According to the IPCC methodology[35]:

- Uncertainty for the human population is within 5% limit
- For BOD per person ± 30%
- For fraction of the population income group, when good quality data on urbanization are available however, the distinction between urban high income and urban low income may have to be based on the expert judgment - ± 15%.

The only national value for the emission calculation formula is the number of the populations, for which the uncertainty is estimated within 5% limits and, consequently, emission uncertainty estimation from this source is based on the standard factor evaluation given in the 2006 IPCC methodology.

Large uncertainties are associated with the IPCC default emission factors for $N_2O$ from effluent. Currently available field data is insufficient to improve this factor. In addition, the $N_2O$ emission factor for plants is uncertain because it is based on one field test[36].

These ranges of activity data and emission uncertainty factor are used to calculate the total uncertainty in methane and nitrous oxide emissions, which makes 58.31% for industrial waste water and 30.41% for domestic waste water; IPCC methodology includes uncertainty ranges based on the expert judgment.

Tables of Uncertainty Analysis and Uncertainty values of Activity Data and Emission Factors are provided in annex B.

# Chapter 2. Trends in GHG emissions and removals

## 2.1. Description and Interpretation of Emission and Removal Trends for Aggregate GHGs

Greenhouse gases ($CO_2$, $CH_4$, $N_2O$, HFCs and $SF_6$) emission trends for 1990-2017, without consideration of the LULUCF sector, are provided in table below. In 1990, these emissions totaled 45,813 Gigagrams in $CO_2$ equivalent. Due to the collapse of the economic system of the Soviet period, emissions started to fall sharply. In 2017, GHG emissions amounted to 17,766 Gg. $CO_2$ equivalent[37].

Table 2-1 GHG Emission Trends in Georgia During 1990-2017 (Gg $CO_2$ eq.) excluding LULUCF

| Gas/Year | $CO_2$ | $CH_4$ | $N_2O$ | HFC-134a | HFC-125 | HFC-143a | HFC-32 | PFCs | $SF_6$ | NF3 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 34,097.77 | 9,288.91 | 2,426.51 | NA | NA | NA | NA | NA | NE | NA | **45,813** |
| 1991 | 25,692.44 | 8,540.44 | 2,152.57 | NA | NA | NA | NA | NA | NE | NA | **36,385** |
| 1992 | 20,496.33 | 7,819.22 | 1,802.06 | NA | NA | NA | NA | NA | NE | NA | **30,118** |
| 1993 | 15,726.21 | 6,972.08 | 1,698.80 | NA | NA | NA | NA | NA | NE | NA | **24,397** |
| 1994 | 10,255.88 | 4,057.05 | 1,432.52 | NA | NA | NA | NA | NA | NE | NA | **15,745** |
| 1995 | 7,208.45 | 3,944.06 | 1,543.04 | NA | NA | NA | NA | NA | NE | NA | **12,696** |
| 1996 | 6,332.33 | 4,521.04 | 2,109.23 | NA | NA | NA | NA | NA | C | NA | **12,963** |
| 1997 | 5,385.22 | 4,373.06 | 2,234.49 | NA | NA | NA | NA | NA | C | NA | **11,993** |
| 1998 | 4,776.89 | 4,405.12 | 1,836.76 | NA | NA | NA | NA | NA | C | NA | **11,019** |
| 1999 | 4,371.96 | 3,830.09 | 2,153.86 | NA | NA | NA | NA | NA | C | NA | **10,356** |
| 2000 | 4,874.75 | 4,204.08 | 1,844.25 | NA | NA | NA | NA | NA | C | NA | **10,923** |

35 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf (pg. 6.16)

36 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf (pg. 6.26)

37 The discrepancies may appear in total values due to rounding effect.

| Gas/Year | $CO_2$ | $CH_4$ | $N_2O$ | HFC-134a | HFC-125 | HFC-143a | HFC-32 | PFCs | $SF_6$ | NF3 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 3,741.50 | 3,953.12 | 1,896.87 | 0.11 | 0.05 | 0.06 | 0.00[38] | NE | C | NA | **9,592** |
| 2002 | 3,278.30 | 5,326.10 | 2,149.07 | 0.46 | 0.19 | 0.20 | 0.01 | NE | C | NA | **10,754** |
| 2003 | 3,458.88 | 5,924.18 | 2,230.22 | 1.46 | 0.64 | 0.47 | 0.07 | NE | C | NA | **11,616** |
| 2004 | 3,870.84 | 5,914.30 | 1,917.07 | 2.43 | 1.42 | 0.99 | 0.17 | NE | C | NA | **11,707** |
| 2005 | 4,759.76 | 4,459.33 | 1,940.05 | 4.59 | 2.33 | 1.73 | 0.27 | NE | C | NA | **11,168** |
| 2006 | 5,441.69 | 5,638.35 | 2,010.66 | 4.69 | 2.22 | 1.53 | 0.27 | NE | C | NA | **13,099** |
| 2007 | 6,499.91 | 5,340.34 | 1,774.80 | 5.31 | 2.14 | 1.45 | 0.26 | NE | C | NA | **13,624** |
| 2008 | 5,837.42 | 4,511.38 | 1,840.29 | 7.81 | 3.09 | 2.71 | 0.30 | NE | C | NA | **12,203** |
| 2009 | 6,192.01 | 4,133.36 | 1,856.39 | 12.84 | 4.07 | 3.61 | 0.39 | NE | C | NA | **12,203** |
| 2010 | 7,004.96 | 4,798.58 | 1,830.52 | 26.41 | 12.86 | 13.91 | 0.89 | NE | C | NA | **13,688** |
| 2011 | 8,898.12 | 5,276.69 | 1,787.43 | 30.54 | 17.31 | 14.54 | 1.82 | NE | C | NA | **16,027** |
| 2012 | 9,320.10 | 5,587.74 | 1,926.17 | 56.77 | 19.06 | 15.01 | 2.14 | NE | C | NA | **16,927** |
| 2013 | 8,711.96 | 4,957.75 | 2,190.26 | 65.07 | 21.33 | 15.24 | 2.62 | NE | C | NA | **15,964** |
| 2014 | 9,582.52 | 5,034.74 | 2,122.72 | 68.38 | 30.71 | 16.94 | 4.52 | NE | C | NA | **16,861** |
| 2015 | 10,250.94 | 5,645.66 | 2,177.69 | 77.83 | 37.61 | 17.98 | 5.97 | NE | C | NA | **18,214** |
| 2016 | 10,507.79 | 5,739.05 | 2,151.97 | 73.16 | 40.16 | 14.61 | 7.13 | NE | C | NA | **18,534** |
| 2017 | 10,688.51 | 4,941.06 | 1,980.96 | 81.69 | 48.85 | 15.92 | 8.87 | NE | C | NA | **17,766** |

## 2.2. Description and Interpretation of Emission and Removal Trends by Categories

Emission trends by sectors over 1990-2017 years period are provided in the Table 1.5. As it is clear from the table, energy is the dominant sector, and it accounts for more than half of the total emissions over the entire period, excluding LULUCF. Following the disintegration of the Soviet Union, the contribution of the agricultural sector in the total emissions grows gradually, and it ranks second over the period of 1990-2017. IPPU and Waste sectors are on the third and fourth places in ranking, excluding LULUCF.

In Georgia, LULUCF sector had a net sink of greenhouse gases during 1990-2017 years period. The sink capacity of the LULUCF sector fluctuates between (-4,145) Gg $CO_2$ eq and (-6,625) Gg $CO_2$ eq. In 2017 greenhouse gas emissions in Georgia totaled 17,766 Gg in $CO_2$ equivalent without consideration of the LULUCF sector, and 12,842 Gg $CO_2$ eq when taking this sector into account.

Table 2-2 GHGs Emission Trends by Sectors in 1990-2015 (Gg $CO_2$ eq.)

| Sector | Energy | IPPU | Agriculture | Waste | LULUCF (Net removals) | Total (excluding LULUCF) | Total (including LULUCF) |
|---|---|---|---|---|---|---|---|
| 1990 | 36,698 | 3,879 | 4,102 | 1,135 | (6,353) | **45,813** | **39,460** |
| 1991 | 28,529 | 3,038 | 3,713 | 1,106 | (6,416) | **36,385** | **29,970** |
| 1992 | 24,224 | 1,705 | 3,079 | 1,110 | (6,312) | **30,118** | **23,805** |
| 1993 | 19,678 | 776 | 2,831 | 1,112 | (6,548) | **24,397** | **17,849** |
| 1994 | 11,558 | 414 | 2,683 | 1,091 | (6,625) | **15,745** | **9,120** |
| 1995 | 8,319 | 447 | 2,805 | 1,125 | (6,273) | **12,696** | **6,423** |
| 1996 | 7,931 | 535 | 3,344 | 1,153 | (6,022) | **12,963** | **6,941** |
| 1997 | 6,783 | 504 | 3,526 | 1,180 | (5,965) | **11,993** | **6,028** |
| 1998 | 6,125 | 502 | 3,184 | 1,208 | (5,521) | **11,019** | **5,498** |
| 1999 | 4,849 | 710 | 3,560 | 1,237 | (5,324) | **10,356** | **5,032** |
| 2000 | 5,612 | 725 | 3,317 | 1,269 | (5,031) | **10,923** | **5,892** |
| 2001 | 4,391 | 439 | 3,474 | 1,288 | (4,889) | **9,592** | **4,703** |
| 2002 | 5,139 | 591 | 3,719 | 1,305 | (4,778) | **10,754** | **5,976** |
| 2003 | 5,763 | 699 | 3,833 | 1,321 | (4,407) | **11,616** | **7,209** |
| 2004 | 6,086 | 846 | 3,436 | 1,339 | (4,145) | **11,707** | **7,562** |

[38] 0.00345

| Sector | Energy | IPPU | Agriculture | Waste | LULUCF (Net removals) | Total (excluding LULUCF) | Total (including LULUCF) |
|---|---|---|---|---|---|---|---|
| 2005 | 5,396 | 957 | 3,461 | 1,354 | (4,163) | **11,168** | **7,006** |
| 2006 | 7,258 | 1,136 | 3,329 | 1,376 | (4,257) | **13,099** | **8,843** |
| 2007 | 7,888 | 1,314 | 3,022 | 1,400 | (4,362) | **13,624** | **9,263** |
| 2008 | 6,267 | 1,383 | 3,132 | 1,421 | (4,357) | **12,203** | **7,846** |
| 2009 | 6,580 | 1,106 | 3,061 | 1,456 | (4,727) | **12,203** | **7,476** |
| 2010 | 7,707 | 1,443 | 3,055 | 1,483 | (4,537) | **13,688** | **9,151** |
| 2011 | 9,743 | 1,794 | 2,981 | 1,509 | (4,864) | **16,027** | **11,163** |
| 2012 | 10,294 | 1,872 | 3,223 | 1,538 | (4,750) | **16,927** | **12,178** |
| 2013 | 8,949 | 1,892 | 3,582 | 1,542 | (4,834) | **15,964** | **11,130** |
| 2014 | 9,642 | 2,035 | 3,633 | 1,551 | (4,609) | **16,861** | **12,252** |
| 2015 | 10,849 | 2,058 | 3,745 | 1,562 | (4,617) | **18,214** | **13,597** |
| 2016 | 11,355 | 1,822 | 3,798 | 1,559 | (4,797) | **18,534** | **13,738** |
| 2017 | 10,726 | 1,990 | 3,488 | 1,562 | (4,924) | **17,766** | **12,842** |

In the table below GHG emissions and removals from LULUCF sector are provided in Gg $CO_2$ equivalent.

Table 2-3 GHG Emissions and Removals from LULUCF sector (Gg CO2 eq.)

| Source | Emission (GG $CO_2$ eq.) | Removal (GG $CO_2$) | Net removals |
|---|---|---|---|
| 1990 | 3,394 | 9,747 | **-6,353** |
| 1991 | 3,432 | 9,848 | **-6,416** |
| 1992 | 3,519 | 9,831 | **-6,312** |
| 1993 | 3,398 | 9,946 | **-6,548** |
| 1994 | 3,435 | 10,061 | **-6,625** |
| 1995 | 3,546 | 9,819 | **-6,273** |
| 1996 | 3,579 | 9,601 | **-6,022** |
| 1997 | 3,532 | 9,498 | **-5,965** |
| 1998 | 3,750 | 9,270 | **-5,521** |
| 1999 | 3,702 | 9,025 | **-5,324** |
| 2000 | 3,747 | 8,779 | **-5,031** |
| 2001 | 3,726 | 8,615 | **-4,889** |
| 2002 | 3,673 | 8,451 | **-4,778** |
| 2003 | 3,881 | 8,288 | **-4,407** |
| 2004 | 3,977 | 8,122 | **-4,145** |
| 2005 | 4,050 | 8,213 | **-4,163** |
| 2006 | 4,083 | 8,340 | **-4,257** |
| 2007 | 4,090 | 8,452 | **-4,362** |
| 2008 | 4,160 | 8,517 | **-4,357** |
| 2009 | 3,879 | 8,606 | **-4,727** |
| 2010 | 4,016 | 8,554 | **-4,537** |
| 2011 | 3,825 | 8,689 | **-4,864** |
| 2012 | 3,754 | 8,503 | **-4,750** |
| 2013 | 3,835 | 8,669 | **-4,834** |
| 2014 | 3,866 | 8,475 | **-4,609** |
| 2015 | 3,905 | 8,522 | **-4,617** |
| 2016 | 3,772 | 8,569 | **-4,797** |
| 2017 | 3,813 | 8,737 | **-4,924** |

## 2.3. Description and Interpretation of Emission Trends for Precursors

Tables below show direct GHG emissions and precursors by sectors and sub-sectors for 1990 and 2017.

Table 2-4 Direct GHG Emissions and Precursors by Sectors and Sub-Sectors in 1990 (Gg)

| Greenhouse Gas Source and Sink Categories | $CO_2$ Emissions (Gg) | $CO_2$ Removals (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | NOx (Gg) | CO (Gg) | NMVOCs (Gg) | SOx (Gg) |
|---|---|---|---|---|---|---|---|---|
| **Total National Emissions and Removals for 1990** | **37,492** | **9,747** | **1,438** | **63** | **115** | **386** | **72** | **106** |
| **1. Energy** | **30,368.23** | **NO** | **294.84** | **0.46** | **103.81** | **354.44** | **59.86** | **105.23** |
| A. Fuel Combustion (sectoral approach) | 30,294 | | 8.56 | 0.46 | 103.81 | 354.44 | 59.86 | 105.23 |
| 1. Energy Industries | 13,731.86 | | 0.41 | 0.09 | 36.46 | 3.43 | 0.99 | 51.95 |
| 2. Manufacturing Industries and Construction | 7,534.96 | | 0.45 | 0.07 | 20.65 | 6.37 | 0.98 | 27.11 |
| 3. Transport | 3,744.54 | | 0.99 | 0.19 | 35.06 | 237.63 | 44.84 | 11.84 |
| 4. Other Sectors | 5,282.99 | | 5.58 | 0.09 | 11.64 | 107.01 | 13.05 | 14.33 |
| 5. Non-Specified | 0 | | 1.13 | 0.02 | 0 | 0 | 0 | 0 |
| B. Fugitive Emissions from Fuels | 73.88 | | 286.28 | | NE | NE | NE | NE |
| 1. Solid Fuels | 62.20 | | 32.21 | | NE | NE | NE | NE |
| 2. Oil and Natural Gas | 11.68 | | 254.07 | | NE | NE | NE | NE |
| C. CO2 transport and storage | NO | NO | | | | | | |
| **2. Industrial Processes** | **C** | **NA** | **0.04** | **C** | **NO** | **1.58** | **11.92** | **0.39** |
| A. Mineral Products | 571.93 | | | | NA | NA | NA | 0.39 |
| B. Chemical Industry | C | | NA | C | NA | 1.58 | 0.94 | 0.01 |
| C. Metal Production | 2,633.05 | | 0.04 | NA | NA | NA | NA | NA |
| D. Non-Energy Products from Fuel and Solvent Use | 0 | | NA | NA | NA | NA | NA | NA |
| E. Electronic Industry | NO | | NO | NO | NO | NO | NO | NO |
| F. Product Uses as Substitutes for ODS | | | | | | | | |
| G. Other Product Manufacture and Use | C | | NA | C | NA | NA | NA | NA |
| H. Other (please specify) | NA | | NA | NA | NA | NA | 10.98 | NA |
| **3. Agriculture** | **NA** | **NA** | **95.98** | **6.72** | **10.70** | **0.50** | **NE** | **NE** |
| A. Enteric Fermentation | | | 89.67 | | | | | |
| B. Manure Management | | | 5.80 | 1.17 | | | NE | |
| C. Rice Cultivation | | | NO | | | | NO | |
| D. Agricultural Soils | | | NE | 5.54 | | | NE | |
| E. Prescribed Burning of Savannahs | | | NO | NO | NO | NO | NO | |
| F. Field Burning of Agricultural Residues | | | 0.51 | 0.01 | 10.70 | 0.50 | NE | |
| G. Other | | | NO | NO | NO | NO | NO | |
| **4. Land-use Change and Forestry** | **3,393.66** | **9,746.73** | **2.01** | **0.02** | **0.16** | **29.07** | **NA** | **NA** |
| A. Changes in Forest and Other Woody Biomass Stocks | 492.67 | 6,716.84 | | | | | | |
| B. Forest and Grassland conversion | NE | NE | NE | NE | NE | NE | | |

| Greenhouse Gas Source and Sink Categories | $CO_2$ Emissions (Gg) | $CO_2$ Removals (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | NOx (Gg) | CO (Gg) | NMVOCs (Gg) | SOx (Gg) |
|---|---|---|---|---|---|---|---|---|
| C. Abandonment of Managed Lands | | NE | | | | | | |
| D. CO2 Emissions and Removals from Soil | 2,900.99 | 3,029.89 | | | | | | |
| E. Other | NE | NE | 2.01 | 0.02 | 0.16 | 29.07 | | |
| **5. Waste** | **NA** | **NA** | **1,045.00** | **55.00** | **NE** | **NE** | **NE** | **NO** |
| A. Solid Waste Disposal on Land | | | 619.00 | | NE | | NE | |
| B. Waste-water Handling | | | 426.00 | 55.00 | NE | NE | NE | |
| C. Waste Incineration | | | | | NO | NO | NO | NO |
| D. Other | | | NO | NO | NO | NO | NO | NO |
| **6. Other** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** |
| **Memo items** | | | | | | | | |
| **International Bunkers** | **608.63** | | **0.00** | **0.02** | **NE** | **NE** | **NE** | **NE** |
| Aviation | 608.63 | | 0.004 | 0.017 | NE | NE | NE | NE |
| Marine | NE | | NE | NE | NE | NE | NE | NE |
| **CO2 Emissions from Biomass** | **2,149** | | | | | | | |

Table 2-5 Anthropogenic Emissions of HFCs, PFCs and SF6 in 1990 (Gg)

| Greenhouse Gas Source and Sink Categories | HFCs (Gg) | | | | PFCs (Gg) | | | $SF_6$ (Gg) |
|---|---|---|---|---|---|---|---|---|
| | **HFC-23** | **HFC-134** | **HFC-125** | **HFC-143a** | **CF4** | **C2F6** | **Other** | |
| **Total National Emissions and Removals 1990** | **NE** | **NE** | **NE** | **NO** | **NE** | **NE** | **NE** | **NE** |
| **1. Energy** | | | | | | | | |
| A. Fuel Combustion (sectoral approach) | | | | | | | | |
| 1. Energy Industries | | | | | | | | |
| 2. Manufacturing Industries and Construction | | | | | | | | |
| 3. Transport | | | | | | | | |
| 4. Other Sectors | | | | | | | | |
| 5. Other | | | | | | | | |
| B. Fugitive Emissions from Fuels | | | | | | | | |
| 1. Solid Fuels | | | | | | | | |
| 2. Oil and Natural Gas | | | | | | | | |
| C. CO2 transport and storage | | | | | | | | |

| Greenhouse Gas Source and Sink Categories | | | HFCs (Gg) | | | | PFCs (Gg) | | | SF₆ (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | HFC-23 | HFC-134 | HFC-125 | HFC-143a | CF4 | C2F6 | Other | |
| **2. Industrial Processes** | | | **NO, NA, NE** | **NO, NA, NE** | **NO, NA, NE** | **NO, NA** | **NO, NE** | **NO, NE** | **NO, NE** | **NO, NE** |
| | A. Mineral Products | | | | | | | | | |
| | B. Chemical Industry | | | | | | | | | |
| | C. Metal Production | | NO | NO | NO | NO | NO | NO | NO | NO |
| | D. Non-Energy Products from Fuel and Solvent Use | | | | | | | | | |
| | E. Electronic Industry | | NO | NO | NO | NO | NO | NO | NO | NO |
| | F. Product Uses as Substitutes for ODS | | NA | NA | NA | NA | NE | NE | NE | NE |
| | G. Other Product Manufacture and Use | | NE | NE | NE | | NE | NE | | NE |
| | H. Other (please specify) | | | | | | | | | |
| **3. Agriculture** | | | | | | | | | | |
| | A. Enteric Fermentation | | | | | | | | | |
| | B. Manure Management | | | | | | | | | |
| | C. Rice Cultivation | | | | | | | | | |
| | D. Agricultural Soils | | | | | | | | | |
| | E. Prescribed Burning of Savannahs | | | | | | | | | |
| | F. Field Burning of Agricultural Residues | | | | | | | | | |
| | G. Other | | | | | | | | | |
| **4. Land-use Change and Forestry** | | | | | | | | | | |
| | A. Changes in Forest and Other Woody Biomass Stocks | | | | | | | | | |
| | B. Forest and Grassland Conversion | | | | | | | | | |
| | C. Abandonment of Managed Lands | | | | | | | | | |
| | D. CO2 Emissions and Removals from Soil | | | | | | | | | |
| | E. Other | | | | | | | | | |
| **5. Waste** | | | | | | | | | | |
| | A. Solid Waste Disposal on Land | | | | | | | | | |
| | B. Waste-water Handling | | | | | | | | | |
| | C. Waste Incineration | | | | | | | | | |
| | D. Other | | | | | | | | | |
| **6. Other (please specify)** | | | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** |
| **Memo Items** | | | | | | | | | | |
| | International Bunkers | | | | | | | | | |
| | | Aviation | | | | | | | | |
| | | Marine | | | | | | | | |

| Greenhouse Gas Source and Sink Categories | | HFCs (Gg) | | | | PFCs (Gg) | | | SF6 (Gg) |
|---|---|---|---|---|---|---|---|---|---|
| | | HFC-23 | HFC-134 | HFC-125 | HFC-143a | CF4 | C2F6 | Other | |
| | CO2 Emissions from Biomass | | | | | | | | |

Table 2-6 Direct GHG Emissions and Precursors by Sectors and Sub-Sectors in 2017 (Gg)

| Greenhouse Gas Sources and Sink Categories | | | $CO_2$ Emissions (Gg) | $CO_2$ Removals (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | NOx (Gg) | CO (Gg) | NMVOCs (Gg) | SOx (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total National Emissions and Removals for 2017** | | | **14,501** | **8,737** | **1,702** | **66** | **61** | **1,439** | **54** | **19** |
| **1. Energy** | | | **9,083** | **NO** | **74** | **0.2920** | **50** | **296** | **50** | **18** |
| | A. Fuel Combustion (sectoral approach) | | 9,070.91 | | 6.58 | 0.29 | 49.96 | 296.42 | 49.88 | 18.00 |
| | | 1. Energy Industries | 1,529.88 | | 0.02 | 0.01 | 2.93 | 0.38 | 0.09 | 0.30 |
| | | 2. Manufacturing Industries and Construction | 1,009.68 | | 0.08 | 0.01 | 4.22 | 1.97 | 0.26 | 5.37 |
| | | 3. Transport | 4,044.00 | | 1.69 | 0.21 | 38.58 | 215.60 | 40.11 | 11.58 |
| | | 4. Other Sectors | 2,487.35 | | 4.78 | 0.07 | 4.23 | 78.47 | 9.42 | 0.75 |
| | | 5. Non-Specified | NO | | NO | NO | NO | NO | NO | NO |
| | B. Fugitive Emissions from Fuels | | 12.15 | | 67.37 | | NE | NE | NE | NE |
| | | 1. Solid Fuels | 10.06 | | 0 | | NE | NE | NE | NE |
| | | 2. Oil and Natural Gas | 2.09 | | 67.37 | | NE | NE | NE | NE |
| | C. CO2 transport and storage | | NO | NO | | | | | | |
| **2. Industrial Processes** | | | **C** | **NA** | **NA** | **C, NA, NO** | **NA, NO** | **1.67** | **4.10** | **0.60** |
| | A. Mineral Products | | 727.25 | | | | NA | NA | 0.36 | 0.59 |
| | B. Chemical Industry | | C | | NA | C | NA | 1.66 | 0.99 | 0.01 |
| | C. Metal Production | | 463.69 | | 0.003 | NA | NA | NA | NA | NA |
| | D. Non-Energy Products from Fuel and Solvent Use | | 10.25 | | NA | NA | NA | 0.01 | 0.04 | NA |
| | E. Electronic Industry | | NO | | NO | NO | NO | NO | NO | NO |
| | F. Product Uses as Substitutes for ODS | | | | | | | | | |
| | G. Other Product Manufacture and Use | | C | | NA | C | NA | NA | NA | NA |
| | H. Other (please specify) | | NA | | NA | NA | NA | NA | 2.71 | NA |
| **3. Agriculture** | | | **NA** | **NA** | **89.78** | **5.17** | **4.80** | **0.20** | **NE** | **NA** |
| | A. Enteric Fermentation | | | | 87.12 | | | | | |
| | B. Manure Management | | | | 2.43 | 1.09 | | | NE | |
| | C. Rice Cultivation | | | | NO | | | | NO | |

| Greenhouse Gas Sources and Sink Categories | $CO_2$ Emissions (Gg) | $CO_2$ Removals (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | NOx (Gg) | CO (Gg) | NMVOCs (Gg) | SOx (Gg) |
|---|---|---|---|---|---|---|---|---|
| D. Agricultural Soils | | | NE | 4.07 | | | NE | |
| E. Prescribed Burning of Savannahs | | | NO | NO | NO | NO | NO | |
| F. Field Burning of Agricultural Residues | | | 0.23 | 0.01 | 4.80 | 0.20 | NE | |
| G. Other | | | NO | NO | NO | NO | NO | |
| **4. Land-use Change and Forestry** | **3,812.72** | **8,736.57** | **78.97** | **0.97** | **6.14** | **1,140.66** | **NA** | **NA** |
| A. Changes in Forest and Other Woody Biomass Stocks | 900.62 | 6,478.75 | | | | | | |
| B. Forest and Grassland conversion | NE | NE | NE | NE | NE | NE | | |
| C. Abandonment of Managed Lands | | NE | | | | | | |
| D. CO2 Emissions and Removals from Soil | 2,912.10 | 2,257.82 | | | | | | |
| E. Other | NE | NE | 78.97 | 0.97 | 6.14 | 1,140.66 | | |
| **5. Waste** | **NA** | **NA** | **1,459.00** | **59.00** | **NE** | **NE** | **NE** | **NO** |
| A. Solid Waste Disposal on Land | | | 1,073.00 | | NE | | NE | |
| B. Waste-water Handling | | | 386.00 | 59.00 | NE | NE | NE | |
| C. Waste Incineration | | | | | NO | NO | NO | NO |
| D. Other | | | NO | NO | NO | NO | NO | NO |
| **6. Other** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** |
| **Memo items** | | | | | | | | |
| **International Bunkers** | **296.92** | | **0.002** | **0.008** | **NE** | **NE** | **NE** | **NE** |
| Aviation | 292.23 | | 0.0020 | 0.0082 | NE | NE | NE | NE |
| Marine | 4.69 | | 0.0004 | 0.0001 | NE | NE | NE | NE |
| **CO2 Emissions from Biomass** | **1,702** | | | | | | | |

Table 2-7 Anthropogenic Emissions of HFCs, PFCs and SF6 in 2017 (Gg)

| Greenhouse Gas Source and Sink Categories | HFCs (Gg) | | | | PFCs (Gg) | | | $SF_6$ (Gg) |
|---|---|---|---|---|---|---|---|---|
| | HFC-23 | HFC-134 | HFC-125 | HFC-143a | CF4 | C2F6 | Other | |
| **Total National Emissions and Removals 2017** | **0.063** | **0.017** | **0.004** | **0.014** | **NE** | **NE** | **NE** | **C** |
| **1. Energy** | | | | | | | | |
| A. Fuel Combustion (sectoral approach) | | | | | | | | |
| 1. Energy Industries | | | | | | | | |
| 2. Manufacturing Industries and Construction | | | | | | | | |

| Greenhouse Gas Source and Sink Categories | | | HFCs (Gg) | | | | PFCs (Gg) | | | $SF_6$ (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | HFC-23 | HFC-134 | HFC-125 | HFC-143a | CF4 | C2F6 | Other | |
| | | 3. Transport | | | | | | | | |
| | | 4. Other Sectors | | | | | | | | |
| | | 5. Other | | | | | | | | |
| | B. Fugitive Emissions from Fuels | | | | | | | | | |
| | | 1. Solid Fuels | | | | | | | | |
| | | 2. Oil and Natural Gas | | | | | | | | |
| | C. CO2 transport and storage | | | | | | | | | |
| **2. Industrial Processes** | | | **0.06** | **0.02** | **0.004** | **0.01** | **NO, NE** | **NO, NE** | **NO, NE** | **NO, NE, C** |
| | A. Mineral Products | | | | | | | | | |
| | B. Chemical Industry | | | | | | | | | |
| | C. Metal Production | | NO | NO | NO | NO | NO | NO | NO | NO |
| | D. Non-Energy Products from Fuel and Solvent Use | | | | | | | | | |
| | E. Electronic Industry | | NO | NO | NO | NO | NO | NO | NO | NO |
| | F. Product Uses as Substitutes for ODS | | 0.06 | 0.02 | 0.004 | 0.01 | NE | NE | NE | NE |
| | G. Other Product Manufacture and Use | | NE | NE | NE | | NE | NE | | C |
| | H. Other (please specify) | | | | | | | | | |
| **3. Agriculture** | | | | | | | | | | |
| | A. Enteric Fermentation | | | | | | | | | |
| | B. Manure Management | | | | | | | | | |
| | C. Rice Cultivation | | | | | | | | | |
| | D. Agricultural Soils | | | | | | | | | |
| | E. Prescribed Burning of Savannahs | | | | | | | | | |
| | F. Field Burning of Agricultural Residues | | | | | | | | | |
| | G. Other | | | | | | | | | |
| **4. Land-use Change and Forestry** | | | | | | | | | | |
| | A. Changes in Forest and Other Woody Biomass Stocks | | | | | | | | | |
| | B. Forest and Grassland Conversion | | | | | | | | | |
| | C. Abandonment of Managed Lands | | | | | | | | | |
| | D. CO2 Emissions and Removals from Soil | | | | | | | | | |
| | E. Other | | | | | | | | | |
| **5. Waste** | | | | | | | | | | |

| Greenhouse Gas Source and Sink Categories | | | HFCs (Gg) | | | | PFCs (Gg) | | | SF₆ (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | HFC-23 | HFC-134 | HFC-125 | HFC-143a | CF4 | C2F6 | Other | |
| | A. Solid Waste Disposal on Land | | | | | | | | | |
| | B. Waste-water Handling | | | | | | | | | |
| | C. Waste Incineration | | | | | | | | | |
| | D. Other | | | | | | | | | |
| **6. Other (please specify)** | | | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** |
| **Memo Items** | | | | | | | | | | |
| | International Bunkers | | | | | | | | | |
| | | Aviation | | | | | | | | |
| | | Marine | | | | | | | | |
| | CO2 Emissions from Biomass | | | | | | | | | |

# Chapter 3. Energy (CRF Sector 1)

## 3.1. Overview of the Sector

Emissions from the energy sector consist of two main categories: fuel combustion and fugitive emissions from fuels. Fuel combustion includes emissions released into the atmosphere when fossil fuels (e.g., coal, oil products and natural gas) are combusted. Fugitive emissions are intentional or unintentional releases of gases from fossil fuels by anthropogenic activities.

In Georgia, fossil fuels are used to produce energy for a wide variety of purposes (e.g., production, transportation, and consumption of energy products) and as a result $CO_2$ (Carbon Dioxide), $CH_4$ (Methane), $N_2O$ (Nitrous Oxide), $NO_X$ (Nitrogen Oxide), CO (Carbon Monoxide), and NMVOC (Non-Methane Volatile Organic Compounds) are emitted in the process.

The methodologies are shown in the *Table 3-1* below.

Table 3-1 Methodologies used in the energy sector

| Categories | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| **1.A - Fuel Combustion** | T1 | D | T1 | D | T1 | D |
| **1.A.1 - Energy Industries** | T1 | D | T1 | D | T1 | D |
| **1.A.2 - Manufacturing Industries and Construction** | T1 | D | T1 | D | T1 | D |
| **1.A.3 – Transport** | T1 | D | T1 | D | T1 | D |
| **1.A.4 - Other Sectors** | T1 | D | T1 | D | T1 | D |
| 1.A.4.a - Commercial/Institutional | T1 | D | T1 | D | T1 | D |
| 1.A.4.b – Residential | T1 | D | T1 | D | T1 | D |
| 1.A.4.c - Agriculture/Forestry/ Fishing/Fish Farms | T1 | D | T1 | D | T1 | D |
| **1.A.5 Non-Specified** | T1 | D | T1 | D | T1 | D |
| **1.B - Fugitive Emissions from Fuels** | T1 | D | T1, T2 | D, CS | T1 | D |
| **1.B.1 - Solid Fuels** | T1 | D | T1 | D | NA | NA |
| **1.B.2 - Oil and Natural Gas** | T1 | D | T1, T2 | D, CS | T1 | D |
| 1.B.2.a – Oil | T1 | D | T1 | D | T1 | D |
| 1.B.2.b - Natural Gas | T1 | D | T2 | CS | T1 | D |
| 1.C. CO2 transport and storage | NA | NA | | | | |

Note: D: IPCC default, T1: Tier1, T2: Tier2, T3: Tier3, CS: country specific method or EF

In 2017, GHG emissions ($CO_2$, $CH_4$, $N_2O$) from the energy sector amounted to 10,726 Gg $CO_2$ equivalent, which is about 60% of Georgia's total GHG emissions (excluding LULUCF). In 2017, the following source categories had the largest shares in the total GHG emissions from the Energy Sector: Transport – 39%, Other Sectors – 24%, Oil and Natural Gas – 13%, Energy Industries – 14%, Manufacturing Industries and Construction – 9%. Compared to 1990, the total GHG emissions from the energy sector had decreased by 71%.

Table 3-2 Energy Sectoral Table for 1990 and 2017

| Categories | 1990 Emissions (Gg) | | | 2017 Emissions (Gg) | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ | $CH_4$ | $N_2O$ |
| **1 – Energy** | 30,368.23 | 294.84 | 0.44 | 9,083.06 | 73.95 | 0.29 |
| **1.A - Fuel Combustion** | 30,294.35 | 8.55 | 0.44 | 9,070.91 | 6.58 | 0.29 |

| Categories | 1990 Emissions (Gg) | | | 2017 Emissions (Gg) | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ | $CH_4$ | $N_2O$ |
| **1.A.1 - Energy Industries** | 13,731.86 | 0.41 | 0.09 | 1,529.88 | 0.02 | 0.01 |
| **1.A.2 - Manufacturing Industries and Construction** | 7,534.96 | 0.45 | 0.07 | 1,009.68 | 0.08 | 0.01 |
| **1.A.3 – Transport** | 3,744.54 | 0.99 | 0.19 | 4,044.00 | 1.69 | 0.21 |
| **1.A.4 - Other Sectors** | 5,282.99 | 5.58 | 0.09 | 2,487.35 | 4.78 | 0.07 |
| 1.A.4.a - Commercial/Institutional | 1,076.52 | 0.45 | 0.01 | 417.08 | 0.09 | 0.00 |
| 1.A.4.b – Residential | 3,688.24 | 4.89 | 0.07 | 1,777.79 | 4.67 | 0.06 |
| 1.A.4.c - Agriculture/Forestry/ Fishing | 518.23 | 0.24 | 0.00 | 292.47 | 0.03 | 0.00 |
| **1.A.5 Non-Specified** | 0.00 | 1.13 | 0.02 | NO | NO | NO |
| **1.B - Fugitive Emissions from Fuels** | 73.88 | 286.29 | 0.00 | 12.15 | 67.369 | 0.00 |
| **1.B.1 - Solid Fuels** | 62.20 | 32.21 | 0.00 | 10.06 | 0.00 | 0.00 |
| **1.B.2 - Oil and Natural Gas** | 11.68 | 254.07 | 0.00 | 2.09 | 67.369 | 0.00 |
| **1.B.3 - Other emissions from Energy Production** | NO | NO | NO | NO | NO | NO |
| **1.C - CO2 Transport and Storage** | NO | NO | NO | NO | NO | NO |

A significant fall in GHG emissions in the 1990s is due to the collapse of the Soviet Union and fundamental changes in the economy of the country. However, the national economy started to grow since 2000 and the average annual growth of real GDP amounted to 8.4% prior to 2008. During 2008-2009, economic growth of Georgia has slowed down due to the Russian-Georgian war. Starting in 2010, the real GDP of the country began to increase again by 4.7% on average until 2018[39].

In 2010, hydro generation reached its maximum capacity, while the generation from thermal power plants was the lowest in the past decade. Since 2011 emissions in the energy sector increased mainly due to the increased thermal power generation and improvement of the economic situation. Table below shows the $CO_2$ equivalent of the emissions in the energy sector. The Global Warming Potentials used to convert from GHG to $CO_2$ eq are reflected in the second assessment report.

Table 3-3 GHG Emissions from the Energy Sector (Gg, $CO_2$ eq.)

| Year | 1A - Fuel Combustion | 1B - Fugitive Emissions from Fuels | 1C - CO2 Transport and Storage | Total from Energy Sector |
|---|---|---|---|---|
| 1990 | 30,612 | 6,086 | NO | 36,698 |
| 1991 | 23,030 | 5,499 | NO | 28,529 |
| 1992 | 19,191 | 5,033 | NO | 24,225 |
| 1993 | 15,454 | 4,224 | NO | 19,678 |
| 1994 | 10,032 | 1,527 | NO | 11,559 |
| 1995 | 7,063 | 1,256 | NO | 8,319 |
| 1996 | 6,255 | 1,676 | NO | 7,930 |
| 1997 | 5,254 | 1,529 | NO | 6,782 |
| 1998 | 4,598 | 1,528 | NO | 6,125 |
| 1999 | 4,030 | 820 | NO | 4,850 |
| 2000 | 4,508 | 1,104 | NO | 5,611 |
| 2001 | 3,580 | 810 | NO | 4,390 |

[39] GEOSTAT – Real Growth of GDP.

| Year | 1A - Fuel Combustion | 1B - Fugitive Emissions from Fuels | 1C - CO2 Transport and Storage | Total from Energy Sector |
|---|---|---|---|---|
| 2002 | 3,027 | 2,112 | NO | 5,138 |
| 2003 | 3,110 | 2,653 | NO | 5,762 |
| 2004 | 3,390 | 2,697 | NO | 6,087 |
| 2005 | 4,123 | 1,274 | NO | 5,397 |
| 2006 | 4,659 | 2,600 | NO | 7,259 |
| 2007 | 5,558 | 2,331 | NO | 7,889 |
| 2008 | 4,822 | 1,446 | NO | 6,267 |
| 2009 | 5,470 | 1,111 | NO | 6,581 |
| 2010 | 6,014 | 1,693 | NO | 7,707 |
| 2011 | 7,565 | 2,180 | NO | 9,745 |
| 2012 | 7,932 | 2,363 | NO | 10,295 |
| 2013 | 7,394 | 1,554 | NO | 8,949 |
| 2014 | 8,154 | 1,489 | NO | 9,643 |
| 2015 | 8,818 | 2,032 | NO | 10,849 |
| 2016 | 9,252 | 2,103 | NO | 11,355 |
| 2017 | 9,300 | 1,427 | NO | 10,726 |

As can be seen from the Table, a large share of the emissions from the energy sector is due to fuel combustion (87% in 2017) and the remaining 13% is caused by fugitive emissions. Among emission source-categories, the highest growth relative to 2000 was noted in fugitive emissions from the transformation of solid fuel (5 Gg $CO_2$ eq. in 2000, 132 Gg $CO_2$ eq. in 2016), which took place as a result of the intensification of coal mining works in recent years. However, since 2017 coal mining has significantly decreased due to the technical inspection of safety norms of mines, following the deadly workplace accidents[40].

Emissions by greenhouse gases are shown in table below.

Table 3-4 GHG Emissions from the Energy Sector (Gg)

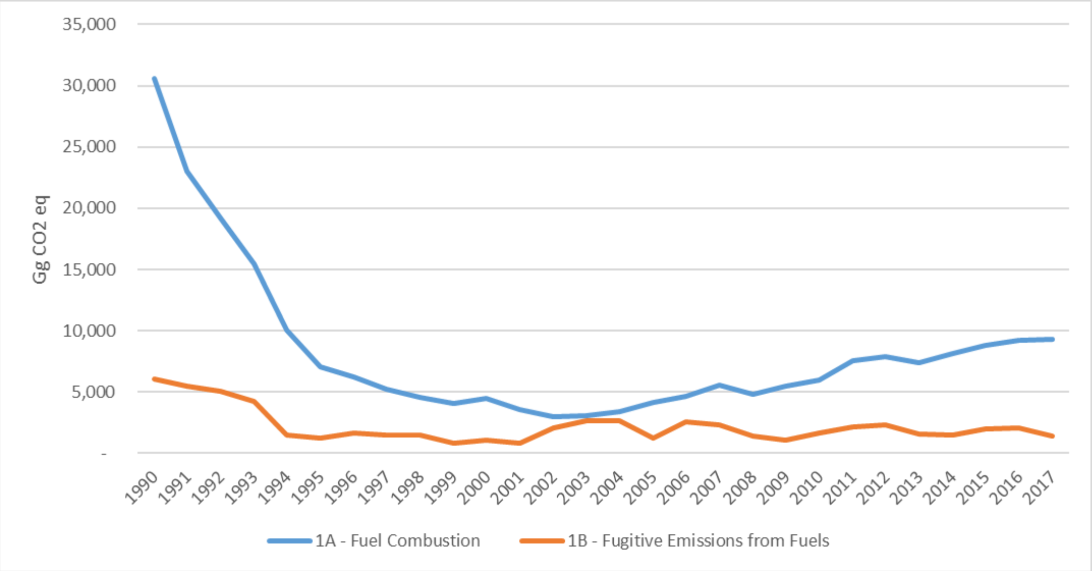
| Gas | $CO_2$ | $CH_4$ | CH4 in $CO_{2eq}$ | $N_2O$ | N2O in $CO_{2eq}$ | Total $CO_2$eq |
|---|---|---|---|---|---|---|
| 1990 | 30,368 | 294.86 | 6,192 | 0.44 | 138 | **36,698** |
| 1991 | 22,803 | 267.85 | 5,625 | 0.33 | 101 | **28,529** |
| 1992 | 18,894 | 249.21 | 5,233 | 0.31 | 97 | **24,224** |
| 1993 | 15,053 | 215.25 | 4,520 | 0.34 | 105 | **19,678** |
| 1994 | 9,887 | 77.11 | 1,619 | 0.17 | 52 | **11,559** |
| 1995 | 6,820 | 68.57 | 1,440 | 0.19 | 59 | **8,319** |
| 1996 | 5,894 | 92.66 | 1,946 | 0.29 | 91 | **7,931** |
| 1997 | 4,968 | 82.94 | 1,742 | 0.24 | 73 | **6,782** |
| 1998 | 4,352 | 81.62 | 1,714 | 0.19 | 59 | **6,125** |
| 1999 | 3,796 | 47.54 | 998 | 0.18 | 55 | **4,850** |
| 2000 | 4,290 | 60.49 | 1,270 | 0.17 | 52 | **5,612** |
| 2001 | 3,359 | 46.62 | 979 | 0.17 | 53 | **4,391** |

[40] Miners' Deaths Spark Protests In Georgia

| Gas | $CO_2$ | $CH_4$ | CH4 in $CO_{2eq}$ | $N_2O$ | N2O in $CO_{2eq}$ | Total $CO_2$eq |
|---|---|---|---|---|---|---|
| 2002 | 2,804 | 108.66 | 2,282 | 0.17 | 53 | **5,138** |
| 2003 | 2,891 | 134.22 | 2,819 | 0.17 | 53 | **5,763** |
| 2004 | 3,169 | 136.40 | 2,864 | 0.17 | 53 | **6,087** |
| 2005 | 3,977 | 65.52 | 1,376 | 0.14 | 43 | **5,396** |
| 2006 | 4,504 | 129.02 | 2,709 | 0.15 | 45 | **7,259** |
| 2007 | 5,384 | 116.73 | 2,451 | 0.17 | 53 | **7,889** |
| 2008 | 4,659 | 74.28 | 1,560 | 0.15 | 48 | **6,267** |
| 2009 | 5,300 | 58.33 | 1,225 | 0.18 | 55 | **6,581** |
| 2010 | 5,840 | 85.94 | 1,805 | 0.20 | 62 | **7,707** |
| 2011 | 7,412 | 108.16 | 2,271 | 0.20 | 60 | **9,744** |
| 2012 | 7,782 | 116.52 | 2,447 | 0.21 | 65 | **10,295** |
| 2013 | 7,169 | 80.91 | 1,699 | 0.26 | 80 | **8,949** |
| 2014 | 7,913 | 78.11 | 1,640 | 0.29 | 89 | **9,643** |
| 2015 | 8,591 | 103.25 | 2,168 | 0.29 | 90 | **10,850** |
| 2016 | 9,020 | 106.52 | 2,237 | 0.32 | 98 | **11,355** |
| 2017 | 9,083 | 73.95 | 1,553 | 0.29 | 90 | **10,726** |

During 2000-2017, GHGs emissions from the manufacturing industry and transport sectors increased about 1.5 and 4.4 times, respectively. In the transport sector, GHG emissions increased due to the growing auto-park and a majority share of second-hand cars in the park. In Georgia, the number of motor vehicles in 2002-2016 period increased from 319,600 to 1,126,470[41]. Since 2006, the development of energy transit pipelines (South Caucasus Gas Pipeline, Baku-Tbilisi-Erzurum oil Pipeline) through Georgia required additional gas and diesel for the pipeline operation. Figure 1 shows GHG emission trends in 1990-2017 years period in the energy sector.

*Figure 3-1 Trend of GHG Emissions from The Energy Sector 1990-2017 (Gg $CO_2$ eq.)*




Results of uncertainty analysis in energy sector is provided in sub-chapter 1.3

[41] Ministry of Internal Affairs, 2016

### Non-$CO_2$ Emissions from Energy Sector

Non-$CO_2$ emissions, such as CO, NOx, NMVOC and $SO_2$, were calculated using the Tier 1 approach in fuel combustion. The Tier 1 methodology for non-$CO_2$ gases estimates emissions by applying Emission Factors to fuel statistics, which are organized by sector. Emissions of these gases depend on the fuel type used, combustion technology, operating conditions, control technology, and on maintenance and age of the equipment. However, since Georgia does not have such detailed data, the Tier 1 methodology was used, ignoring these refinements. Table below provides estimates of non-$CO_2$ emissions from fuel combustion for the period of 1990-2017.

Table 3-5 Precursor Gas Emissions in Energy Sector

| Non-$CO_2$ From Fuel Combustion (Tier 1) Gg | CO | NOx | NMVOCs | SO2 |
|---|---|---|---|---|
| **1990** | 354 | 104 | 60 | 105 |
| **1991** | 310 | 71 | 52 | 42 |
| **1992** | 305 | 63 | 47 | 51 |
| **1993** | 358 | 53 | 52 | 40 |
| **1994** | 157 | 37 | 25 | 34 |
| **1995** | 201 | 30 | 28 | 27 |
| **1996** | 444 | 40 | 70 | 14 |
| **1997** | 354 | 32 | 55 | 13 |
| **1998** | 260 | 26 | 39 | 14 |
| **1999** | 244 | 22 | 36 | 11 |
| **2000** | 209 | 22 | 30 | 10 |
| **2001** | 245 | 19 | 37 | 5 |
| **2002** | 249 | 18 | 38 | 5 |
| **2003** | 251 | 18 | 38 | 4 |
| **2004** | 239 | 19 | 36 | 5 |
| **2005** | 200 | 23 | 33 | 7 |
| **2006** | 205 | 25 | 33 | 7 |
| **2007** | 242 | 28 | 40 | 9 |
| **2008** | 215 | 23 | 35 | 9 |
| **2009** | 225 | 28 | 36 | 12 |
| **2010** | 246 | 32 | 41 | 15 |
| **2011** | 227 | 37 | 38 | 16 |
| **2012** | 308 | 39 | 47 | 17 |
| **2013** | 257 | 40 | 41 | 16 |
| **2014** | 262 | 46 | 42 | 16 |
| **2015** | 266 | 50 | 44 | 18 |
| **2016** | 326 | 54 | 55 | 19 |
| **2017** | 296 | 50 | 50 | 18 |

In 2017, the transport and the residential sectors contributed about 73% and 26% respectively in CO emissions. While transport sector (77%) was a key contributor in NOx emissions. 80% and 18% respectively was the share of the transport and the residential sectors in NMVOC emissions in the same year. Manufacturing industry and the transport sectors had 30% and 64% shares respectively in $SO_2$ emission.

## 3.2. Fuel Combustion (1.A.)

### *a) Source-category description and calculated emissions*

Emissions of greenhouse gases from the Fuel Combustion source-category totaled 9,300 Gg in $CO_2$eq in 2017. In that year, carbon dioxide, methane and nitrous oxide accounted for 85%, 14%, and 1% of emissions from fuel combustion source-category, respectively. The transport sector has the highest share of 39% in GHGs emissions from the source. The residential sector has the highest contribution in methane emissions, and transport sector - in nitrous oxide emissions.

### *b) Methodological issues*

- ***Estimation Method***

Emissions in the source-category are calculated using the IPCC methodology Tier 1 – sectoral approach. The sectoral approach for assessing emissions from Fuel Combustion Stationary Source-categories is based on the data on actual consumption of fuel combusted in the source category provided in the country's energy balance and emission factor. Emission Factors are derived from the default values provided together with associated uncertainty range.

The following equation is used to calculate greenhouse gas emissions from stationary combustion according to the sectoral approach:

$$Emissions_{GHG,fuel} = Fuel\ Consumption_{fuel} \times Emission\ Factor_{GHG,fuel}$$

Where:

$Emissions_{GHG,\ fuel}$ – Emissions of a given GHG by type of fuel (kg GHG)

$Fuel\ Consumption_{fuel}$ – Amount of fuel combusted (TJ)

Emission Factor $_{GHG,\ fuel}$ – Default emission factor of a given GHG by type of fuel (kg gas/TJ). For CO2, it includes the carbon oxidation factor, assumed to be 1.

Not all fuel supplied to an economy is combusted for heat energy. Certain volume is used as a feedstock for manufacturing of products, such as plastics or in a non-energy use (e.g. bitumen for road construction), without oxidation (emissions) of carbon. This is called stored carbon and is deducted from the carbon emissions calculation. The estimation of the stored carbon requires data for fuel consumption by activities using the fuel as raw material.

Recalculations in GHGs emission inventories for previous years were carried out are mainly due to shifting from IPCC 1996 to IPCC 2006 guidelines and availability of the new data sources.

- ***Emission Factors***

The emission factor is a coefficient that relates the Activity Data to the amount of the chemical compound, which is the source of later emissions. Emission Factors for $CO_2$ from fossil fuel combustion are expressed on a per unit energy basis, since the carbon content of fuels is generally less variable when expressed on a per unit energy basis, compared to per unit mass basis. Therefore, net calorific values (NCVs) are used to convert fuel consumption data on a per unit mass or volume basis, to data on a per unit energy basis. Country specific NCV-s of different fuels were obtained from the GEOSTAT energy balance (2013-2017).

Table 3-6 Conversion Factors and Carbon Emission Factors for Various Types of Fuel

| Fuel type | Unit | Net Calorific Values (TJ/Unit) | Carbon content (kg C/GJ) |
|---|---|---|---|
| Crude Oil | 1000 t | 42.5 | 20.0 |
| Motor Gasoline | 1000 t | 44.0 | 18.9 |
| Jet Kerosene | 1000 t | 43.2 | 19.5 |
| Other Kerosene | 1000 t | 43.2 | 19.6 |
| Gas/Diesel Oil | 1000 t | 43.3 | 20.2 |
| Residual Fuel Oil | 1000 t | 40.4 | 21.1 |
| LPG | 1000 t | 45.0 | 17.2 |
| Naphtha | 1000 t | 44.5 | 20.0 |
| Bitumen | 1000 t | 38.0 | 22.0 |
| Lubricants | 1000 t | 38.0 | 20.0 |
| Fuel Oil | 1000 t | 41.9 | 20.0 |
| Other Oil Products | 1000 t | 43.3 | 20.0 |
| Anthracite | 1000 t | 29.3 | 26.8 |
| Lignite | 1000 t | 17.0 | 27.6 |
| Sub-Bituminous Coal | 1000 t | 18.9 | 26.2 |
| Other-Bituminous Coal | 1000 t | 25.0 | 25.8 |
| Coking Coal | 1000 t | 28.2 | 25.8 |
| Coke Oven/Gas Coke | 1000 t | 29.3 | 29.2 |
| Natural Gas (Ng) | 1 000 000 $m^3$ | 35.0 | 15.3 |
| Fuel Wood | 1000 $m^3$ | 7.8 | 30.5 |
| Petroleum Coke | 1000 t | 32.5 | 26.6 |
| Charcoal | 1000 t | 30.8 | 26.6 |
| Patent Fuel | 1000 t | 29.0 | 26.6 |
| Other Primary Solid Biomass | 1000 t | 18.0 | 27.3 |

Emission Factors for $CO_2$ are in units of kg $CO_2$/GJ on a net calorific value basis and reflect the carbon content of the fuel. $CO_2$ Emission Factors for all Tiers reflect the full carbon content of the fuel less any non-oxidized fraction of carbon retained in the ash, particulates, or soot. Since this fraction is generally small, the Tier 1 default Emission Factors neglect this effect by assuming a complete oxidation of the carbon contained in the fuel (carbon oxidation factor equal to 1). Emission Factors for $CH_4$ and $N_2O$ for different source categories differ due to the differences in combustion technologies applied in the various source categories. The default factors presented for Tier 1 apply to technologies without emission controls[42].

- ***Activity Data***

Generally, in the energy sector the national energy balance is the basis for the assessment of greenhouse gas emissions during fuel combustion. In production of fuel, its import, export, changes in stocks and consumption, energy balance is provided in physical units (tons or $m^3$) or in energy units (terajoules or kilo tons of oil equivalent). For comparison of data in the energy balance, physical units are converted into energy units using fuel specific net calorific values (NCV).

In 2014, the National Statistics Office of Georgia (GEOSTAT) published its first energy balance for 2013. Quality of the data is improving year after year. Activity Data have been obtained from various sources.

The following data were provided from different sources:

- Energy balances for 2013-2017 were provided by the National Statistics Office of Georgia (GEOSTAT)[43];
- Energy balances for 1990-2012 were provided by the International Energy Agency (IEA);

[42] The Emission Factor Database (EFDB)
[43] GEOSTAT - Energy Statistics

- Natural gas balances for 2010-2012, jet kerosene and firewood supply, and consumption data were obtained from the Ministry of Energy of Georgia;
- Information on the natural gas and crude oil transit were provided by the Georgian Oil and Gas Corporation (GOGC)[44];
- Electricity balances for 2007-2017 years were obtained from the Electricity Market Operator (ESCO)[45];
- Natural gas transmission and distribution losses were provided by the Georgian National Energy and Water Supply Regulatory Commission (GNERC)[46];
- Data for natural gas and diesel consumption in operations of energy transit pipelines for 2010-2017 years period were provided by the British Petroleum Georgia[47].

Based on the data provided, aggregated energy balances were developed for the period of 1990-2012 years.

### 3.2.1. The Sectoral Approach vs the Reference Approach

This chapter explains a comparison between the reference approach and the sectoral approach in accordance with the UNFCCC Inventory Reporting Guidelines (Decision 24/CP.19 Annex I, paragraph 40). The Reference Approach is a top-down approach, using a country's energy supply data to calculate the emissions of $CO_2$ from combustion of mainly fossil fuels. The Reference Approach is a straightforward method that can be applied on the basis of relatively easily available energy supply statistics. Improved comparability between the sectoral and the reference approaches continues to allow a country to produce a second independent estimate of $CO_2$ emissions from fuel combustion with limited additional effort and data requirements. The Reference Approach provides an upper bound to $CO_2$ emissions inferred from the country's supply of fossil fuels by identifying the carbon content, subtracting from it the excluded carbon - carbon stored in non-energy products and products made from fuels used as raw material, adjusting for carbon, which remains unburnt, and multiplying by 44/12. Under the Reference Approach, carbon dioxide emissions are calculated using the following formula:

$$Carbon\ dioxide\ emission\ (Gg\ CO_2) = \sum_i \left\{ \left[ \begin{array}{c} Apparent\ Consuption\ of\ fuel\ (Units) \\ \times\ Calorific\ value\ of\ fuel\left(\frac{TJ}{Unit}\right) \\ \times\ Carbon\ emission\ factor\ \frac{\left(\frac{tC}{TJ}\right)}{1000} - Excluded\ carbon \end{array} \right] \times Fraction\ of\ carbon\ oxidized \right\} \times \frac{44}{12}$$

Where the lower index *i* refers to the type of fuel, and apparent consumption for each primary fuel is calculated as:

$$Apparent\ Consumption\ = Production\ + Imports\ - Exports\ - International\ Bunkers\ - Stock\ Change$$

While for secondary fuels, apparent consumption is calculated as:

$$Apparent\ Consumption\ = Imports\ - Exports\ - International\ Bunkers\ - Stock\ Change$$

Usually the value of fraction of carbon oxidized is 1, reflecting complete oxidation.

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44 www.gogc.ge
45 www.esco.ge
46 www.gnerc.org
47 www.bpgeorgia.ge

Excluded carbon is calculated using the formula:

$$Excluded\ Carbon\ (Gg\ C) = Non-energy\ use\ (10^3 t) \times\ Calorific\ value\ of\ fuel \left(\frac{TJ}{10^3 t}\right) \times Carbon\ emission\ factor \left(t \frac{C}{TJ}\right) \times Fraction\ of\ excluded\ carbon \times 10^3$$

The Reference approach is an upper bound, as some of the carbon will be emitted in forms other than $CO_2$, in part because complete combustion of the fuel is not always the case, and in addition, fuels may leak or evaporate. Consequently, the $CO_2$ emissions figure obtained from the Reference Approach will include carbon emitted as $CH_4$, CO, $N_2O$ or NMVOC.

The Reference Approach uses a simple assumption: once carbon is brought into the national economy in fuel, it is either saved in some way or it must be released to the atmosphere. To calculate the carbon released, it is not necessary to know exactly how the fuel was used or what intermediate transformations it underwent. In this respect, the methodology may be termed a "top-down" approach compared with the "bottom-up" methods used for other gases. The "bottom-up" methods are a higher-level approach when the information about fuel consumption and Emission Factors is collected at the level of specific enterprises. The sectoral approach is an intermediate approach between these two approaches since it uses information about fuel consumption at the level of economic sectors. The difference between carbon dioxide emissions calculated using the Reference approach and sectoral approach, should not exceed 2%, otherwise the explanation for the difference should be provided.

Table below shows carbon dioxide emissions in 2016-2017, calculated using these two approaches for different types of fuel, followed by the explanation of differences.

Table 3-7 Comparison of $CO_2$ Emissions Calculated Using the Reference and the Sectoral Approaches

| Fuel type | Year | 2016 | 2017 |
|---|---|---|---|
| **Liquid Fuel** | Reference approach, Gg | 3,935 | 3,479 |
| | Sectoral approach, Gg | 3,967 | 3,489 |
| | Difference, % | -0.82% | -0.28% |
| **Solid Fuel** | Reference approach, Gg | 1,113 | 1,237 |
| | Sectoral approach, Gg | 1,114 | 1,235 |
| | Difference, % | -0.09% | 0.15% |
| **Gas Fuel** | Reference approach, Gg | 4,192 | 4,310 |
| | Sectoral approach, Gg | 3,925 | 4,347 |
| | Difference, % | 6.81% | -0.85% |
| **Other Fossil Fuels** | Reference approach, Gg | 0 | 0 |
| | Sectoral approach, Gg | 0 | 0 |
| | Difference, % | 0.00% | 0.00% |
| **Peat** | Reference approach, Gg | 0 | 0 |
| | Sectoral approach, Gg | 0 | 0 |
| | Difference, % | 0.00% | 0.00% |
| **Total** | Reference approach, Gg | 9,240 | 9,026 |
| | Sectoral approach, Gg | 9,007 | 9,071 |
| | Difference, % | 2.60% | -0.49% |

6.81% difference in gas fuel in 2016 is due to the natural gas losses at the time of transportation and distribution, which is treated as methane emission, while under the reference approach it is treated as combusted and transformed into carbon dioxide.

### 3.2.2. International Bunker Fuels

All emissions from fuels used for international aviation and water-borne navigation (bunkers) are to be excluded from national totals and reported separately as memo items. Emissions from international aviation are defined as emissions from flights that depart in one country and arrive in a different country, including take-offs and landings for these flight stages.

Emissions from international water-borne navigation are sourced from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. It includes emissions from journeys that depart in one country and arrive in a different country.

Table below provides emissions from the International Aviation and Marine Bunkers.

Table 3-8 GHG emissions from international bunkers

| Year | International Aviation Bunkers | | | | | International Marine Bunkers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Jet Kerosene, TJ | $CO_2$ (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | Total in Gg CO2 eq | Diesel, Fuel Oil, TJ | $CO_2$ (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | Total in Gg $CO_2$ eq |
| 1990 | 8,512 | 609 | 0.004 | 0.017 | **614** | NE | NE | NE | NE | NE |
| 1991 | 8,256 | 590 | 0.004 | 0.017 | **596** | 5,102 | 392 | 0.04 | 0.01 | **395** |
| 1992 | 7,095 | 507 | 0.004 | 0.014 | **512** | 3,644 | 280 | 0.03 | 0.01 | **282** |
| 1993 | 5,418 | 387 | 0.003 | 0.011 | **391** | 2,466 | 189 | 0.02 | 0.01 | **191** |
| 1994 | 2,765 | 198 | 0.001 | 0.006 | **200** | 2,168 | 166 | 0.02 | 0.00 | **168** |
| 1995 | 172 | 12 | 0.00 | 0.000 | **12** | 2,061 | 158 | 0.01 | 0.00 | **160** |
| 1996 | 3,354 | 240 | 0.002 | 0.007 | **242** | NE | NE | NE | NE | NE |
| 1997 | 2,967 | 212 | 0.001 | 0.006 | **214** | NE | NE | NE | NE | NE |
| 1998 | 4,128 | 295 | 0.002 | 0.008 | **298** | NE | NE | NE | NE | NE |
| 1999 | 3,483 | 249 | 0.002 | 0.007 | **251** | NE | NE | NE | NE | NE |
| 2000 | 648 | 46 | 0.000 | 0.001 | **46** | NE | NE | NE | NE | NE |
| 2001 | 559 | 40 | 0.000 | 0.001 | **40** | NE | NE | NE | NE | NE |
| 2002 | 989 | 71 | 0.000 | 0.002 | **71** | 809 | 60 | 0.01 | 0.00 | **61** |
| 2003 | 1,118 | 80 | 0.001 | 0.002 | **81** | NE | NE | NE | NE | NE |
| 2004 | 1,591 | 114 | 0.001 | 0.003 | **115** | NE | NE | NE | NE | NE |
| 2005 | 1,599 | 114 | 0.001 | 0.003 | **115** | NE | NE | NE | NE | NE |
| 2006 | 1,591 | 114 | 0.001 | 0.003 | **115** | NE | NE | NE | NE | NE |
| 2007 | 2,021 | 145 | 0.001 | 0.004 | **146** | NE | NE | NE | NE | NE |
| 2008 | 1,720 | 123 | 0.001 | 0.003 | **124** | NE | NE | NE | NE | NE |
| 2009 | 1,720 | 123 | 0.001 | 0.003 | **124** | NE | NE | NE | NE | NE |
| 2010 | 1,673 | 120 | 0.001 | 0.003 | **121** | NE | NE | NE | NE | NE |
| 2011 | 1,512 | 108 | 0.001 | 0.003 | **109** | NE | NE | NE | NE | NE |
| 2012 | 2,949 | 211 | 0.001 | 0.006 | **213** | NE | NE | NE | NE | NE |
| 2013 | 3,656 | 261 | 0.002 | 0.007 | **263** | NE | NE | NE | NE | NE |
| 2014 | 3,470 | 248 | 0.002 | 0.007 | **250** | 41 | 3 | 0.00 | 0.00 | **3** |
| 2015 | 3,002 | 215 | 0.002 | 0.006 | **217** | 61 | 5 | 0.00 | 0.00 | **5** |

| Year | International Aviation Bunkers | | | | | International Marine Bunkers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Jet Kerosene, TJ | $CO_2$ (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | Total in Gg CO2 eq | Diesel, Fuel Oil, TJ | $CO_2$ (Gg) | $CH_4$ (Gg) | $N_2O$ (Gg) | Total in Gg $CO_2$ eq |
| 2016 | 3,048 | 218 | 0.002 | 0.006 | **220** | 24 | 2 | 0.00 | 0.00 | **2** |
| 2017 | 4,087 | 292 | 0.002 | 0.008 | **295** | 63 | 5 | 0.00 | 0.00 | **5** |

Due to the lack of data, information on GHG emissions from the consumption of fuel by international marine bunkers is only available for 1991-1995- and 2014-2017-years periods. Data for the 1991-1995 period were provided by IEA, while the data for the latest period were obtained from the Transport and Logistics Development Policy Department of the Ministry of Economy and Sustainable Development.

### 3.2.3. Feedstocks and Non-Energy Use of Fuels

Not all fuel supplied to an economy is burned for heat energy. Certain volume is used as a feedstock for manufacturing products such as plastics, or in a non-energy use (e.g. bitumen for road construction, natural gas for ammonia, naphtha, ethane, paraffin and candle production), without oxidation (emissions) of carbon. This is called excluded/stored carbon and is deducted from the carbon emissions calculation. The values of the consumption of fossil fuel products for non-energy purposes are provided in the table below.

Table 3-9 The Consumption of Fossil Fuel for Non-Energy Purposes (TJ)

| Year | Lubricants (TJ) | Bitumen (TJ) | Natural gas (TJ) | Year | Lubricants (TJ) | Bitumen (TJ) | Natural gas (TJ) |
|---|---|---|---|---|---|---|---|
| 1990 | 4,560 | 9,880 | 6,000 | 2004 | 462 | 1,443 | 3,815 |
| 1991 | 7,266 | 3,861 | 6,000 | 2005 | 380 | 2,584 | 7,385 |
| 1992 | 5,586 | 3,861 | 3,410 | 2006 | 630 | 2,613 | 7,273 |
| 1993 | 5,586 | 3,471 | 2,841 | 2007 | 714 | 3,900 | 2,902 |
| 1994 | 2,698 | 1,748 | 2,000 | 2008 | 714 | 3,783 | 3,052 |
| 1995 | 420 | 78 | 2,273 | 2009 | 0 | 312 | 3,070 |
| 1996 | 966 | 0 | 0 | 2010 | 386 | 3,542 | 4,078 |
| 1997 | 336 | 390 | 2,313 | 2011 | 520 | 2,273 | 4,422 |
| 1998 | 462 | 390 | 4,489 | 2012 | 644 | 3,878 | 4,646 |
| 1999 | 378 | 312 | 6,427 | 2013 | 571 | 3,005 | 8,798 |
| 2000 | 304 | 342 | 0 | 2014 | 638 | 3,105 | 9,058 |
| 2001 | 210 | 858 | 3,429 | 2015 | 755 | 3,378 | 9,539 |
| 2002 | 126 | 1,014 | 2,868 | 2016 | 796 | 3,980 | 7,784 |
| 2003 | 210 | 1,170 | 3,256 | 2017 | 699 | 3,990 | 8,593 |

Carbon emissions from the use of fuels listed above as feedstock are reported within the source categories of the Industrial Processes and Product Use (IPPU) chapter. Lubricating oil statistics usually cover use of lubricants in engines, as well as oils and greases for industrial purposes and heat transfer and cutting oils. Bitumen/asphalt is used for road paving and roof covering and the carbon it contains remains stored for long periods of time. Consequently, there are no fuel combustion emissions arising from the deliveries of bitumen within the year of the inventory. Natural gas is mainly used in production of fertilizers.

### 3.2.4. Energy Industries (1.A.1.)

***a) Source-category description and calculated emissions***

The energy industry source category comprises emissions from fuels combusted by the fuel extraction or energy-producing industries, including the following sub-categories:

- Main Activity Electricity and Heat Production includes emissions from main activity producers of electricity generation, combined heat and power generation, and heat plants. Main activity producers (formerly known as public utilities) are defined as undertakings which produce electricity and heat as their principal activity and supply it to the public. They may be in public or private ownership.
- Petroleum refining covers all combustion activities supporting the refining of petroleum products including on-site combustion for the generation of electricity and heat for own use.
- Manufacture of Solid Fuels and Other Energy Industries - combustion emissions from fuel use during manufacturing secondary and tertiary products from solid fuels including production of charcoal. Emissions from own on-site fuel use should be included. Also includes combustion for the generation of electricity and heat for own use in these industries.
- Emissions from fuel combustion in coke ovens within the iron and steel industry should be reported under other energy industries (1A1c) rather than within manufacturing industry[48].

Currently, in Georgia, electric energy is produced mainly by hydropower plants (HPP) and gas thermal power plants (TPP). Georgia is a country rich with hydro resources and the largest share of power generation falls on hydropower plants. In 2017, the country has 76 HPPs (3,176 MW), 4 gas TPPs (911.2 MW), 1 coal TPP (13.2 MW) and 1 wind power plant (20.7 MW)[49].

The largest share of hydro power production – 93% in total power generation, can be noticed in 2010 due to the high level of precipitation. Starting from 2013 with increasing power consumption, thermal power generation increased. During 2010-2017, the average annual electricity consumption growth rate was 5%[50]. In 2013, four new hydro power plants with 46 MW installed capacity (250 GWh annual generation) were completed. In 2015 new Gardabani gas thermal power plant (230 MW installed capacity) was completed. Ten new HPPs were commissioned for 2015-2017 years period.

As for heat production, during the Soviet period, prior to 1991, centralized heating systems were operated in large cities of Georgia; these systems used natural gas and heavy fuel oil as fuel. Later, these systems gradually became fully useless; hence, greenhouse gas emissions from this subsector dropped to almost zero. Currently, most of the population uses firewood and natural gas for heating. Emissions from the consumption of these fuels are reflected in the residential sub-category.

Table 3-10 GHGs Emissions from the Energy Industry (Gg)

| **Gas/Sub-sectors** | **$CO_2$ in Gg** | **$CH_4$** | **CH4 in $CO_{2eq}$** | **$N_2O$** | **N2O in $CO_{2eq}$** | **Total in $CO_{2eq}$.** | **Electricity Generation (Gg in CO2eq.)** | **Heat Plants (Gg in CO2eq.)** | **Other Energy Industries (Gg in CO2eq.)** |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 13,732 | 0.41 | 8.61 | 0.087 | 26.97 | **13,768** | 6,217 | 7,551 | 0 |
| 1991 | 8,750 | 0.258 | 5.418 | 0.058 | 17.98 | **8,773** | 5,099 | 3,674 | 0 |
| 1992 | 8,035 | 0.221 | 4.641 | 0.046 | 14.26 | **8,054** | 3,779 | 4,275 | 0 |
| 1993 | 5,345 | 0.152 | 3.192 | 0.028 | 8.68 | **5,357** | 2,755 | 2,602 | 0 |
| 1994 | 4,078 | 0.128 | 2.688 | 0.023 | 7.13 | **4,088** | 2,737 | 1,351 | 0 |
| 1995 | 4,342 | 0.138 | 2.898 | 0.025 | 7.75 | **4,352** | 3,336 | 1,016 | 0 |
| 1996 | 1,199 | 0.031 | 0.651 | 0.005 | 1.55 | **1,201** | 1,201 | 0 | 0 |
| 1997 | 1,092 | 0.027 | 0.567 | 0.004 | 1.24 | **1,093** | 1,048 | 0 | 45.574 |
| 1998 | 1,284 | 0.03 | 0.63 | 0.004 | 1.24 | **1,286** | 1,252 | 0 | 33.743 |
| 1999 | 1,190 | 0.027 | 0.567 | 0.004 | 1.24 | **1,192** | 1,192 | 0 | 0 |

[48] IPCC 2006, Table 8.2
[49] GEOSTAT, Energy Balance 2017
[50] Electricity Market Operator (ESCO) – Electricity Balance

| Gas/Sub-sectors | $CO_2$ in Gg | $CH_4$ | CH4 in $CO_{2eq}$ | $N_2O$ | N2O in $CO_{2eq}$ | Total in $CO_{2eq.}$ | Electricity Generation (Gg in CO2eq.) | Heat Plants (Gg in CO2eq.) | Other Energy Industries (Gg in CO2eq.) |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 1,445 | 0.03 | 0.63 | 0.004 | 1.24 | **1,447** | 1,447 | 0 | 0 |
| 2001 | 1,160 | 0.022 | 0.462 | 0.003 | 0.93 | **1,162** | 923 | 5 | 233.784 |
| 2002 | 782 | 0.016 | 0.336 | 0.003 | 0.93 | **783** | 377 | 205.522 | 200.777 |
| 2003 | 812 | 0.017 | 0.357 | 0.002 | 0.62 | **813** | 382 | 238 | 192.541 |
| 2004 | 1,018 | 0.021 | 0.441 | 0.003 | 0.93 | **1,019** | 541 | 255.416 | 223.466 |
| 2005 | 1,198 | 0.03 | 0.63 | 0.003 | 0.93 | **1,200** | 652 | 176 | 371 |
| 2006 | 1,521 | 0.029 | 0.609 | 0.003 | 0.93 | **1,523** | 1,042 | 96.197 | 384.662 |
| 2007 | 1,753 | 0.033 | 0.693 | 0.004 | 1.24 | **1,755** | 1283.564 | 148.784 | 322.787 |
| 2008 | 975 | 0.019 | 0.399 | 0.002 | 0.62 | **976** | 642 | 143.96 | 190.298 |
| 2009 | 1,352 | 0.029 | 0.609 | 0.004 | 1.24 | **1,354** | 824.849 | 349.21 | 179.807 |
| 2010 | 559 | 0.01 | 0.21 | 0.002 | 0.62 | **560** | 560 | 0 | 0 |
| 2011 | 1,273 | 0.02 | 0.42 | 0.003 | 0.93 | **1,274** | 1,274 | 0 | 0 |
| 2012 | 1,378 | 0.03 | 0.63 | 0.002 | 0.62 | **1,379** | 1,379 | 0 | 0 |
| 2013 | 999 | 0.02 | 0.42 | 0.002 | 0.62 | **1,000** | 953 | 0 | 47 |
| 2014 | 1,531 | 0.02 | 0.42 | 0.008 | 2.48 | **1,534** | 1,130 | 0 | 404 |
| 2015 | 1,619 | 0.03 | 0.63 | 0.007 | 2.17 | **1,622** | 1,275 | 0 | 347 |
| 2016 | 1,470 | 0.022 | 0.462 | 0.008 | 2.48 | **1,473** | 1,071 | 0 | 400.599 |
| 2017 | 1,530 | 0.023 | 0.483 | 0.009 | 2.79 | **1,533** | 1,088 | 0 | 444.794 |

***b) Methodological issues***

- ***Estimation Method***

Emissions have been calculated using the IPCC Tier 1 Sectoral Approach explained in the Paragraph above.

- ***Emission Factor***

Country specific net calorific values were used to convert the amount of consumed fuel from physical units into energy units (Table *3-6*). The following default Emission Factors are provided in the table below[51].

Table 3-11 Default Emission Factors for Stationary Combustion in The Energy Industries (kg GHG/TJ on a Net Calorific basis)

| Fuels\GHGs | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| **Natural Gas** | 56,100 | 1.0 | 0.1 |
| **Diesel** | 74,100 | 3.0 | 0.6 |
| **Lignite** | 101,000 | 1 | 1.5 |

- ***Activity Data***

Data were taken from the energy balances (See Annex A).

### 3.2.5. Manufacturing Industries and Construction (1.A.2.)

[51] IPCC 2006, Volume 2, table 2.2 - default emission factors for stationary combustion in the energy industries

### a) *Source-category description and calculated emissions*

Manufacturing industries and the construction sub-sector, comprise emissions produced by the burning of fuel from various industries, such as cast iron and steel production, ferroalloys, chemicals, paper, food products, drinks and tobacco production, etc., as well as emissions from construction materials production.

After the disintegration of the Soviet Union, almost 1/3 of Georgian factories ceased production. But since 1995 the political stabilization and establishment of new industrial contacts has led to the relative stability of the main industrial indicators and GDP growth.

Heavy manufacturing industry in Georgia is one of the most important sectors in terms of value added to exports and employment. In 2018, manufacturing industries and construction sectors accounted for 10.2% and 8.3% of GDP, respectively. Together they accounted for 14% of the employment in Georgia[52]. The most important sub-sectors of heavy manufacturing are ferroalloy, steel/iron, fertilizers and cement production.

Four factories operate in the field of ferroalloys production – Georgian Manganese (the same as Zestaphoni ferroalloy factory), Chiatura Manganese[53], Rusmetal[54] and GTM Group[55]. Zestaphoni ferro-alloy factory is the largest producer of silicon-manganese. Its annual productivity is about 185,000 tons.

Steel and iron production take place in three factories - Geosteel[56], Rustavi Metallurgical Plant[57] and Iberia Steel. In this factory the steel is produced in electric ovens by melting scrap metal and slag; the biggest share (80-85%) is produced through melting scrap metal (Secondary steel production).

Fertilizers is one of the largest export products of Georgia. ‘Rustavi Azoti’ is the largest chemical enterprise of mineral fertilizers and industrial chemicals in Trans-Caucasus[58].

The largest company in nonmetallic building materials in Georgia - Heidelberg cement, owns three plants of cement production– one in Kaspi and two in Rustavi. Annual production capacity of the company is about 2mln tons of cement and 1.4 mln tons of clinker[59].

Emissions from fuel combustion in coke ovens within the iron and steel industry are reported under 1A1c rather than within manufacturing industry.

*Table 3-12* provides GHGs emissions from the manufacturing industries and construction. GHGs emissions decreased about 7.5 times from 1990 to 2017 from the source category.

Table 3-12 GHGs Emissions from the Manufacturing Industries and Construction (Gg)

| Year/Gas | $CO_2$ | $CH_4$ | CH4 in $CO_{2eq}$ | $N_2O$ | N2O in $CO_{2eq}$ | Total in $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1990 | 7,535 | 0.45 | 9.45 | 0.07 | 21.70 | **7,566** |
| 1991 | 6,463 | 0.25 | 5.33 | 0.04 | 11.78 | **6,480** |
| 1992 | 3,851 | 0.14 | 2.86 | 0.02 | 6.20 | **3,860** |
| 1993 | 2,968 | 0.11 | 2.39 | 0.02 | 5.27 | **2,976** |
| 1994 | 2,145 | 0.12 | 2.52 | 0.02 | 5.27 | **2,153** |
| 1995 | 787 | 0.04 | 0.76 | 0.01 | 1.55 | **790** |

[52] National Statistics Office of Georgia www.geostat.ge
[53] Georgian American Alloys – www.gaalloys.com
[54] Rusmetal www.rusmetali.com
[55] Ferro-Alloy Plant www.gtmgroup.ge
[56] Geosteal www.geosteel.com.ge
[57] Rustavi Metallurgical Plant http://www.rmp.ge/en/
[58] www.rustaviazot.ge
[59] Heidelberg cement Georgia www.heidelbergcement.ge

| Year/Gas | $CO_2$ | $CH_4$ | CH4 in $CO_{2eq}$ | $N_2O$ | N2O in $CO_{2eq}$ | Total in $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1996 | 1,212 | 0.06 | 1.16 | 0.01 | 2.48 | **1,216** |
| 1997 | 814 | 0.05 | 1.13 | 0.01 | 2.48 | **817** |
| 1998 | 518 | 0.05 | 1.13 | 0.01 | 2.48 | **522** |
| 1999 | 289 | 0.05 | 1.03 | 0.01 | 2.17 | **292** |
| 2000 | 684 | 0.06 | 1.26 | 0.01 | 2.79 | **688** |
| 2001 | 276 | 0.05 | 1.11 | 0.01 | 2.17 | **279** |
| 2002 | 220 | 0.05 | 1.07 | 0.01 | 2.17 | **223** |
| 2003 | 243 | 0.05 | 1.09 | 0.01 | 2.17 | **246** |
| 2004 | 256 | 0.05 | 1.09 | 0.01 | 2.17 | **259** |
| 2005 | 302 | 0.01 | 0.21 | 0.00 | 0.31 | **303** |
| 2006 | 424 | 0.01 | 0.21 | 0.00 | 0.31 | **424** |
| 2007 | 482 | 0.01 | 0.23 | 0.00 | 0.31 | **483** |
| 2008 | 626 | 0.02 | 0.48 | 0.00 | 0.93 | **628** |
| 2009 | 636 | 0.02 | 0.50 | 0.00 | 0.93 | **637** |
| 2010 | 906 | 0.06 | 1.26 | 0.01 | 2.79 | **910** |
| 2011 | 1,644 | 0.12 | 2.52 | 0.02 | 5.58 | **1,652** |
| 2012 | 2,021 | 0.15 | 3.15 | 0.02 | 6.82 | **2,031** |
| 2013 | 1,505 | 0.13 | 2.77 | 0.02 | 6.20 | **1,514** |
| 2014 | 1,020 | 0.09 | 1.89 | 0.01 | 4.03 | **1,026** |
| 2015 | 1,058 | 0.09 | 1.89 | 0.01 | 4.03 | **1,064** |
| 2016 | 910 | 0.07 | 1.55 | 0.01 | 3.41 | **915** |
| 2017 | 1,010 | 0.08 | 1.70 | 0.01 | 3.72 | **1,015** |

According to the IPCC 2006 guidelines emissions from fuel combustion in coke ovens within the iron and steel industry should be reported under other energy industries (1A1c) rather than within manufacturing industry.

***b) Methodological issues***

- ***Estimation Method***

Emissions were calculated using the IPCC Tier 1 sectoral approach.

- ***Emission Factor***

Country specific net calorific values were used to convert the amount of consumed fuel from physical units into energy units (Table *3-6*). The following default Emission Factors are provided in the Table *3-13*[60].

Table 3-13 Default Emission Factors for Stationary Combustion in Manufacturing Industries and Construction (kg/TJ on a Net Calorific Basis)

| Fuels\GHGs | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| **Natural Gas** | 56100 | 1 | 0.1 |
| **Diesel** | 74100 | 3 | 0.6 |
| **Anthracite** | 98300 | 10 | 1.5 |

[60] IPCC 2006, Volume 2, table 2.3 - default emission factors for stationary combustion in manufacturing industries and construction

| Fuels\GHGs | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| **Other Bituminous Coal** | 94600 | 10 | 1.5 |
| **Lignite** | 101000 | 10 | 1.5 |
| **Liquefied Petroleum Gases** | 63100 | 1 | 0.1 |
| **Kerosene** | 71900 | 3 | 0.6 |
| **Residual Fuel Oil** | 77400 | 3 | 0.6 |
| **Wood/Wood Waste** | 112000 | 30 | 4 |
| **Other Primary Solid Biomass** | 100000 | 30 | 4 |
| **Coke Oven Gas** | 107000 | 10 | 1.5 |
| **Charcoal** | 112000 | 200 | 4 |

- ***Activity Data***

Data were taken from the energy balances (See Annex A).

### 3.2.6. Transport (1.A.3.)

***a) Source-category description and calculated emissions***

Georgia is the transportation hub for the South Caucasus region (Georgia, Armenia, and Azerbaijan) and Central Asia (Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, and Turkmenistan), providing routes to Russia, Turkey and (over the Black Sea) to Europe. Georgia's oil and gas pipelines, the Black Sea ports, developed railway system, and airports with direct air services to more than 20 destinations are also playing an increasingly important role in linking East and West.

The transport sector in Georgia, similarly to the majority of the world's countries, is one of the most significant emitters of greenhouse gases, and therefore major focus is made on the inventory of emissions from this sector and on the implementation of mitigation measures.

In Georgia, the growth of emissions from the transport sector is mainly due to several factors: annual growth of vehicle fleet, large share of second-hand cars in this fleet, and the growth of transit. Since Georgia is a transit country, the number of transit trucks consuming fuel purchased in Georgia is increasing along with the growth of local vehicles fleet. Annual growth of both local and transit transport causes the increase of carbon dioxide and other greenhouse gases, as well as local pollutants which seriously affect human health. In addition, energy transit pipelines Baku-Tbilisi-Supsa (WREP), Baku-Tbilisi-Ceyhan (BTC) oil and South Caucasus Gas (SCP) pipelines pass through the territory of Georgia. Service Company British Petroleum uses natural gas and diesel at the substations to operate the pipelines.

Under the transport sector, Georgia's GHGs Inventory includes road transport, rail transport, civil aviation, domestic navigation, and pipelines.

The trends of greenhouse gases from the transport sector are provided in *Table 3-14* and *Table 3-15*. As can be seen from the tables, similar to other source-categories of fuel combustion, carbon dioxide is the dominant greenhouse gas in this sector, accounting for 98% of the emissions in 2017.

Table 3-14 GHG Emissions from the Transport Sector (Gg)

| Year/Gas | $CO_2$ in Gg | $CH_4$ in Gg | CH4 in Gg $CO_{2eq}$ | $N_2O$ in Gg | N2O in Gg $CO_{2eq}$ | Total in Gg $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1990 | 3,745 | 0.99 | 20.71 | 0.19 | 57.35 | **3,823** |
| 1991 | 2,709 | 0.82 | 17.14 | 0.13 | 41.23 | **2,767** |
| 1992 | 2,305 | 0.62 | 13.02 | 0.11 | 35.34 | **2,353** |
| 1993 | 1,962 | 0.54 | 11.42 | 0.10 | 31.00 | **2,004** |
| 1994 | 1,390 | 0.36 | 7.56 | 0.07 | 21.70 | **1,419** |
| 1995 | 827 | 0.21 | 4.31 | 0.04 | 13.33 | **845** |
| 1996 | 2,455 | 0.99 | 20.87 | 0.12 | 35.96 | **2,512** |
| 1997 | 1,889 | 0.77 | 16.23 | 0.09 | 27.28 | **1,933** |
| 1998 | 1,203 | 0.45 | 9.53 | 0.06 | 17.67 | **1,230** |
| 1999 | 1,091 | 0.41 | 8.67 | 0.05 | 16.12 | **1,116** |
| 2000 | 925 | 0.31 | 6.51 | 0.05 | 13.95 | **945** |
| 2001 | 1,154 | 0.49 | 10.25 | 0.05 | 16.74 | **1,181** |
| 2002 | 1,214 | 0.51 | 10.65 | 0.06 | 17.67 | **1,242** |
| 2003 | 1,239 | 0.51 | 10.77 | 0.06 | 17.98 | **1,268** |
| 2004 | 1,203 | 0.47 | 9.79 | 0.06 | 17.67 | **1,230** |
| 2005 | 1,503 | 0.55 | 11.55 | 0.07 | 22.63 | **1,537** |
| 2006 | 1,572 | 0.55 | 11.61 | 0.08 | 23.25 | **1,607** |
| 2007 | 1,972 | 0.69 | 14.39 | 0.09 | 29.14 | **2,016** |
| 2008 | 1,685 | 0.60 | 12.64 | 0.08 | 24.80 | **1,723** |
| 2009 | 2,061 | 0.60 | 12.54 | 0.10 | 31.31 | **2,104** |
| 2010 | 2,529 | 0.69 | 14.49 | 0.12 | 35.96 | **2,579** |
| 2011 | 2,513 | 0.69 | 14.49 | 0.11 | 35.34 | **2,563** |
| 2012 | 2,617 | 0.70 | 14.70 | 0.13 | 40.61 | **2,672** |
| 2013 | 3,223 | 1.45 | 30.39 | 0.15 | 47.43 | **3,301** |
| 2014 | 3,641 | 1.78 | 37.38 | 0.19 | 57.35 | **3,735** |
| 2015 | 4,037 | 1.89 | 39.69 | 0.20 | 62.00 | **4,139** |
| 2016 | 4,547 | 1.89 | 39.63 | 0.23 | 70.99 | **4,658** |
| 2017 | 4,044 | 1.69 | 35.45 | 0.21 | 63.55 | **4,143** |

Greenhouse gases emissions by subcategories in 1990-2017 are provided by subsectors in *Table 3-15*. Road transport is the dominant subsector. (95% of the emissions in 2017). As railway transport is fully electrified effectively in Georgia, its contribution is insignificant in terms of the emissions. GHG emissions in civil aviation (during 1990-2010), domestic navigation (during 1990-2011) and other transportation sub-categories (1995, 1998-2000, 2005) are not estimated due to the lack of data.

Table 3-15 GHGs Emissions from Transport Sub-Categories (Gg $CO_2$ eq)

| Year/Sub-categories | 1A3a Civil aviation total in Gg $CO_{2eq.}$ | 1A3b Road Transportation total in Gg $CO_{2eq.}$ | 1A3c Railways total in Gg $CO_{2eq.}$ | 1A3d National Navigation total in Gg $CO_{2eq.}$ | 1A3e Other Transportation (pipelines, off road) total in Gg CO2eq. | Total from sector in Gg $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1990 | NE | 3,678 | 43.58 | NE | 101 | **3,822** |

| Year/Sub-categories | 1A3a Civil aviation total in Gg $CO_{2eq.}$ | 1A3b Road Transportation total in Gg $CO_{2eq.}$ | 1A3c Railways total in Gg $CO_{2eq.}$ | 1A3d National Navigation total in Gg $CO_{2eq.}$ | 1A3e Other Transportation (pipelines, off road) total in Gg CO2eq. | Total from sector in Gg $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1991 | NE | 2,623 | 43.70 | NE | 101 | **2,767** |
| 1992 | NE | 2,204 | 43.60 | NE | 106 | **2,353** |
| 1993 | NE | 1,935 | 14.46 | NE | 55 | **2,004** |
| 1994 | NE | 1,337 | 29.26 | NE | 53 | **1,419** |
| 1995 | NE | 844 | 0.89 | NE | NE | **845** |
| 1996 | NE | 2,506 | 0.04 | NE | 5 | **2,512** |
| 1997 | NE | 1,916 | 12.01 | NE | 5 | **1,933** |
| 1998 | NE | 1,223 | 7.27 | NE | NE | **1,230** |
| 1999 | NE | 1,116 | 0.04 | NE | NE | **1,116** |
| 2000 | NE | 945 | 0.04 | NE | NE | **945** |
| 2001 | NE | 1,171 | 0.00 | NE | 9 | **1,181** |
| 2002 | NE | 1,235 | 0.00 | NE | 8 | **1,242** |
| 2003 | NE | 1,259 | 1.00 | NE | 9 | **1,269** |
| 2004 | NE | 1,220 | 0.00 | NE | 10 | **1,230** |
| 2005 | NE | 1,537 | 0.00 | NE | NE | **1,537** |
| 2006 | NE | 1,585 | 1.00 | NE | 21 | **1,608** |
| 2007 | NE | 1,991 | 0.00 | NE | 25 | **2,016** |
| 2008 | NE | 1,695 | 0.00 | NE | 27 | **1,723** |
| 2009 | NE | 2,094 | 0.00 | NE | 11 | **2,104** |
| 2010 | NE | 2,390 | 0.02 | NE | 190 | **2,580** |
| 2011 | 56.2 | 2,291 | 0.00 | NE | 215 | **2,563** |
| 2012 | 1.8 | 2,459 | 3.45 | 4.20 | 204 | **2,672** |
| 2013 | 2.2 | 3,103 | 0.04 | 4.08 | 191 | **3,301** |
| 2014 | 2.5 | 3,500 | 3.76 | 2.19 | 227 | **3,735** |
| 2015 | 2.0 | 3,912 | 2.19 | 2.10 | 221 | **4,139** |
| 2016 | 3.3 | 4,427 | 3.76 | 2.12 | 222 | **4,658** |
| 2017 | 1.8 | 3,941 | 4.07 | 6.02 | 190 | **4,143** |

### *b) Methodological issues*

- ***Estimation Method***

In the transport sector, emissions for all subcategories were calculated using the IPCC Tier 1 sectoral approach. For this sector, carbon dioxide emissions were calculated based on the consumed fuel statistics using the Tier 1 (top down) approach, since the carbon dioxide emission factor is dependent on the type of consumed fuel only, rather than  the type of transport that has combusted the fuel. Methane and nitrous oxide emissions are dependent on the motor vehicle type, catalyzer type and the mode of operation, and higher-tier methods are recommended for calculating their emissions. Such detailed information is not available in Georgia; therefore, the Tier 1 sectoral approach was applied for all greenhouse gases.

- ***Emission Factor***

Country specific net calorific values were used to convert the amount of consumed fuel from physical units into energy units (Table 5). The following default Emission Factors are provided in Table *3-16*[61].

Table 3-16 Default Emission Factors for Mobile category (kg/TJ on a Net Calorific Basis)

| Fuels\GHGs | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| **Civil Aviation** | | | |
| Jet Kerosene | 71,500 | 0.5 | 2 |
| **Road Transportation** | | | |
| Gasoline | 69,300 | 33 | 3.2 |
| Diesel | 74,100 | 3.9 | 3.9 |
| Natural Gas | 56,100 | 92 | 3 |
| LPG | 63,100 | 62 | 0.2 |
| **Railways** | | | |
| Sub-bituminous Coal | 96,100 | 2 | 1.5 |
| Other Petroleum Products | NA | 5 | 0.6 |
| **Water-borne Navigation** | | | |
| Diesel | 74,100 | 7 | 2 |
| **Pipelines** | | | |
| Natural Gas | 56,100 | 1 | 0.1 |
| Diesel | 74,100 | 3 | 0.6 |
| **Off-road** | | | |
| Gasoline | 69,300 | 80 | 2 |
| Diesel | 74,100 | 4.15 | 28.6 |

- ***Activity Data***

Data are provided in the energy balances (see Annex A).

### 3.2.7. Other Sectors (1.A.4.)

***a) Source-category description and calculated emissions***

Emissions in this source-category comprise emissions from the following subsectors:

- Commercial and Public Services.
- Residential.
- Agriculture, Fishing and Forestry.

Greenhouse gases emissions from this source category are provided in Table *3-17***.** The shares of methane (3.9% in 2017) and nitrous oxide (0.8% in 2017) are high, compared to other source categories; this is due to firewood consumption in the residential sector.

Table 3-17 GHG Emissions from The Other Sectors (Gg)

| Year/Gas | $CO_2$ | $CH_4$ | $CH_4$ in $CO_{2eq}$ | $N_2O$ | $N_2O$ in $CO_{2eq}$ | Total in $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1990 | 5,283 | 5.58 | 117.18 | 0.09 | 26.97 | **5,427** |
| 1991 | 4,847 | 6.33 | 132.89 | 0.10 | 30.07 | **5,010** |

[61] IPCC 2006, Volume 2, table 3.2.1, 3.2.2, - Road transport default co2, ch4, n2o emission factors.

| Year/Gas | $CO_2$ | $CH_4$ | $CH_4$ in $CO_{2eq}$ | $N_2O$ | $N_2O$ in $CO_{2eq}$ | Total in $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1992 | 4,686 | 9.35 | 196.27 | 0.13 | 41.54 | **4,924** |
| 1993 | 4,769 | 13.72 | 288.06 | 0.19 | 59.83 | **5,117** |
| 1994 | 2,265 | 4.25 | 89.29 | 0.06 | 18.60 | **2,372** |
| 1995 | 860 | 8.58 | 180.08 | 0.12 | 36.27 | **1,076** |
| 1996 | 937 | 11.96 | 251.16 | 0.16 | 50.53 | **1,238** |
| 1997 | 1,164 | 9.70 | 203.62 | 0.14 | 41.85 | **1,410** |
| 1998 | 1,339 | 8.70 | 182.78 | 0.12 | 37.82 | **1,560** |
| 1999 | 1,145 | 8.31 | 174.49 | 0.11 | 35.34 | **1,355** |
| 2000 | 1,228 | 7.88 | 165.52 | 0.11 | 33.48 | **1,427** |
| 2001 | 735 | 7.76 | 163.04 | 0.11 | 32.55 | **931** |
| 2002 | 560 | 7.74 | 162.58 | 0.10 | 32.24 | **754** |
| 2003 | 562 | 7.74 | 162.58 | 0.10 | 32.24 | **757** |
| 2004 | 655 | 7.76 | 162.88 | 0.11 | 32.55 | **851** |
| 2005 | 970 | 4.51 | 94.63 | 0.06 | 19.22 | **1,084** |
| 2006 | 970 | 4.82 | 101.30 | 0.07 | 20.46 | **1,092** |
| 2007 | 1,128 | 5.15 | 108.13 | 0.07 | 22.01 | **1,258** |
| 2008 | 1,252 | 4.96 | 104.18 | 0.07 | 21.08 | **1,377** |
| 2009 | 1,074 | 4.96 | 104.10 | 0.07 | 21.08 | **1,199** |
| 2010 | 1,592 | 5.00 | 104.90 | 0.07 | 20.46 | **1,718** |
| 2011 | 1,880 | 4.09 | 85.97 | 0.06 | 17.98 | **1,984** |
| 2012 | 1,748 | 3.89 | 81.71 | 0.05 | 16.74 | **1,846** |
| 2013 | 1,424 | 6.17 | 129.63 | 0.08 | 25.73 | **1,579** |
| 2014 | 1,708 | 6.00 | 125.90 | 0.08 | 25.11 | **1,859** |
| 2015 | 1,863 | 5.17 | 108.53 | 0.07 | 21.70 | **1,993** |
| 2016 | 2,079 | 5.04 | 105.82 | 0.07 | 21.39 | **2,206** |
| 2017 | 2,487 | 4.78 | 100.46 | 0.07 | 20.46 | **2,608** |

Greenhouse gas emissions by subcategories in the period of 1990-2017 are provided in Table *3-18*. The residential sector is a dominant subsector (73% in 2017), while GHGs emissions from commercial and agricultural sub-sectors amounted to 16% and 11% respectively.

Table 3-18 GHG Emissions from Commercial/Institutional/Residential/Agriculture/Fishing/ Forestry Source-Categories, By Sub-Categories (Gg $CO_2$ eq)

| Year/ Category | 1A4a - Commercial total in $CO_{2eq.}$ | 1A4b - Residential total in $CO_{2eq.}$ | 1A4c - Agriculture/ Forestry/ Fishing total in $CO_{2eq.}$ | Total from sector in $CO_{2eq.}$ |
|---|---|---|---|---|
| 1990 | 1,090 | 3,812 | 524 | **5,427** |
| 1991 | 1,107 | 3,046 | 857 | **5,010** |
| 1992 | 899 | 3,374 | 651 | **4,924** |
| 1993 | 895 | 3,699 | 523 | **5,117** |
| 1994 | 600 | 1,305 | 467 | **2,372** |
| 1995 | 126 | 675 | 275 | **1,076** |
| 1996 | 110 | 770 | 358 | **1,238** |
| 1997 | 343 | 733 | 334 | **1,410** |

| Year/ Category | 1A4a - Commercial total in $CO_{2eq.}$ | 1A4b - Residential total in $CO_{2eq.}$ | 1A4c - Agriculture/ Forestry/ Fishing total in $CO_{2eq.}$ | Total from sector in $CO_{2eq.}$ |
|---|---|---|---|---|
| 1998 | 255 | 981 | 324 | **1,560** |
| 1999 | 66 | 1,059 | 230 | **1,355** |
| 2000 | 181 | 1,064 | 182 | **1,427** |
| 2001 | 69 | 786 | 76 | **931** |
| 2002 | 59 | 614 | 83 | **755** |
| 2003 | 66 | 628 | 64 | **757** |
| 2004 | 77 | 678 | 95 | **851** |
| 2005 | 124 | 680 | 280 | **1,084** |
| 2006 | 75 | 714 | 304 | **1,092** |
| 2007 | 97 | 774 | 387 | **1,258** |
| 2008 | 182 | 1,005 | 190 | **1,377** |
| 2009 | 202 | 832 | 165 | **1,199** |
| 2010 | 226 | 1,184 | 307 | **1,717** |
| 2011 | 373 | 1,281 | 330 | **1,984** |
| 2012 | 562 | 1,210 | 74 | **1,846** |
| 2013 | 270 | 1,278 | 32 | **1,579** |
| 2014 | 466 | 1,367 | 25 | **1,859** |
| 2015 | 413 | 1,542 | 38 | **1,993** |
| 2016 | 415 | 1,722 | 69 | **2,206** |
| 2017 | 419 | 1,895 | 293 | **2,608** |

### *b) Methodological issues*

- ***Estimation Method***

Emissions were calculated using the IPCC Tier 1 sectoral approach.

- ***Emission Factor***

Country specific net calorific values were used to convert the amount of consumed fuel from physical units into energy units (Table *3-6*). The following default Emission Factors are provided in the Table *3-19*[62].

Table 3-19 Default Emission Factors for commercial/institutional and residential and agriculture/forestry/fishing categories (kg/TJ on a Net Calorific Basis)

| Fuels\GHGs | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| **Commercial/Institutional** | | | |
| Anthracite | 98,300 | 10 | 1.5 |
| Lignite | 101,000 | 10 | 1.5 |
| Wood | 112,000 | 300 | 4 |
| Other primary solid biomass | 100,000 | 300 | 4 |
| Natural Gas | 56,100 | 5 | 0.1 |
| LPG | 63,100 | 5 | 0.1 |
| Residual fuel oil | 77,400 | 10 | 0.6 |
| **Residential** | | | |
| Lignite | 101,000 | 300 | 1.5 |
| Wood | 112,000 | 300 | 4 |

[62] IPCC 2006, Volume 2, table 2.4, 2.5

| Fuels\GHGs | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| Other primary solid biomass | 100,000 | 300 | 4 |
| Natural Gas | 56,100 | 5 | 0.1 |
| LPG | 63,100 | 5 | 0.1 |
| Other Kerosene | 71,900 | 10 | 0.6 |
| Charcoal | 112,000 | 200 | 1 |
| **Agriculture/Forestry/Fishing** | | | |
| Wood | 112,000 | 300 | 4 |
| Natural Gas | 56,100 | 5 | 0.1 |
| Anthracite | 98,300 | 10 | 1.5 |
| Lignite | 101,000 | 300 | 1.5 |
| Gasoline | 69300 | 10 | 0.6 |
| Diesel | 74100 | 10 | 0.6 |
| LPG | 63100 | 5 | 0.1 |

- ***Activity Data***

Data were taken from the energy balances (See Annex A).

### 3.2.8. Non-Specified (1.A.5.)

Includes all remaining emissions from fuel combustion that are not specified elsewhere. The same emission factors were used here as in commercial and residential sectors.

Table 3-20 GHG Emissions from Non-specified Source-Category (Gg)

| Year/Gas | $CO_2$ | $CH_4$ | $CH_4$ in $CO_{2eq}$ | $N_2O$ | $N_2O$ in $CO_{2eq}$ | Total in $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 1990 | NO | 1.13 | 23.69 | 0.02 | 4.65 | 28.34 |
| 1991 | NO | NO | NO | NO | NO | 0.00 |
| 1992 | NO | NO | NO | NO | NO | 0.00 |
| 1993 | NO | NO | NO | NO | NO | 0.00 |
| 1994 | NO | NO | NO | NO | NO | 0.00 |
| 1995 | NO | NO | NO | NO | NO | 0.00 |
| 1996 | 88.17 | 0.01 | 0.19 | 0.00 | 0.00 | 88.36 |
| 1997 | NO | NO | NO | NO | NO | 0.00 |
| 1998 | NO | NO | NO | NO | NO | 0.00 |
| 1999 | 75.71 | 0.01 | 0.17 | 0.00 | 0.31 | 76.18 |
| 2000 | NO | NO | NO | NO | NO | 0.00 |
| 2001 | 27.49 | 0.00 | 0.04 | 0.00 | 0.00 | 27.53 |
| 2002 | 23.00 | 0.00 | 0.04 | 0.00 | 0.01 | 23.06 |
| 2003 | 26.09 | 0.00 | 0.04 | 0.00 | 0.00 | 26.13 |
| 2004 | 30.58 | 0.00 | 0.06 | 0.00 | 0.00 | 30.64 |
| 2005 | NO | NO | NO | NO | NO | 0.00 |
| 2006 | 12.68 | 0.00 | 0.02 | 0.00 | 0.00 | 12.70 |
| 2007 | 43.99 | 0.07 | 1.45 | 0.00 | 0.62 | 46.06 |
| 2008 | 115.79 | 0.07 | 1.55 | 0.00 | 0.62 | 117.97 |
| 2009 | 169.72 | 0.19 | 4.05 | 0.00 | 1.24 | 175.01 |
| 2010 | 240.61 | 0.23 | 4.89 | 0.01 | 1.86 | 247.37 |
| 2011 | 85.72 | 0.22 | 4.56 | 0.00 | 1.24 | 91.52 |

| Year/Gas | $CO_2$ | $CH_4$ | $CH_4$ in $CO_{2eq}$ | $N_2O$ | $N_2O$ in $CO_{2eq}$ | Total in $CO_{2eq.}$ |
|---|---|---|---|---|---|---|
| 2012 | 0.00 | 0.13 | 2.77 | 0.00 | 0.62 | 3.39 |
| 2013 | NO | NO | NO | NO | NO | 0.00 |
| 2014 | NO | NO | NO | NO | NO | 0.00 |
| 2015 | NO | NO | NO | NO | NO | 0.00 |
| 2016 | NO | NO | NO | NO | NO | 0.00 |
| 2017 | NO | NO | NO | NO | NO | 0.00 |

### 3.2.9. Emissions from waste incineration with energy recovery

Incinerating waste for energy recovery is not carried out in Georgia.

## 3.3. Fugitive Emissions from Fuels (1.B.)

Fugitive emissions include all intentional or unintentional release of greenhouse gases (mainly methane) during the extraction, processing, and transportation of fossil fuels to the point of final use. Fugitive emissions were calculated from the following categories and sub-categories:

Solid fuels (coal mining and handling, underground mines)

- Coal mining
- Post-mining seam gas emissions
- Abandoned underground mines.

Oil

- Venting
- Flaring
- Oil production and upgrading
- Oil transportation
- Natural Gas
- Venting
- Flaring
- Production
- Transmission and storage
- Distribution.

GHG emissions trend from the fugitive emissions in subsectors are provided in the *Table 3-21*.

Table 3-21 Fugitive Emissions (Gg)

| Year/ Category | 1B1 Solid fuel total in $CO_{2eq.}$ | $CO_2$ | CH4 in $CO_{2eq}$ | 1B2a Oil total in $CO_{2eq.}$ | $CO_2$ | CH4 in $CO_{2eq}$ | N2O in $CO_{2eq}$ | 1B2b Natural Gas total in $CO_{2eq.}$ | $CO_2$ | CH4 in $CO_{2eq}$ | N2O in $CO_{2eq}$ | Total fugitive emissions in $CO_{2eq.}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1990** | **738.70** | 62.20 | 676.50 | **160.46** | 11.41 | 149.00 | 0.05 | **5,186.87** | 0.27 | 5,186.60 | 0.0005 | **6,086** |
| **1991** | **23.07** | 23.07 | 0.00 | **18.06** | 11.54 | 6.47 | 0.05 | **5,457.83** | 0.30 | 5,457.53 | 0.0005 | **5,499** |
| **1992** | **8.35** | 8.35 | 0.00 | **112.19** | 8.08 | 104.08 | 0.04 | **4,912.87** | 0.26 | 4,912.61 | 0.0004 | **5,033** |

| Year/ Category | 1B1 Solid fuel total in $CO_{2eq}$. | $CO_2$ | CH4 in $CO_{2eq}$ | 1B2a Oil total in $CO_{2eq}$. | $CO_2$ | CH4 in $CO_{2eq}$ | N2O in $CO_{2eq}$ | 1B2b Natural Gas total in $CO_{2eq}$. | $CO_2$ | CH4 in $CO_{2eq}$ | N2O in $CO_{2eq}$ | Total fugitive emissions in $CO_{2eq}$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1993** | **5.98** | 5.98 | 0.00 | **35.62** | 2.55 | 33.06 | 0.01 | **4,182.32** | 0.23 | 4,182.09 | 0.0004 | **4,224** |
| **1994** | **81.98** | 6.90 | 75.08 | **39.23** | 2.82 | 36.39 | 0.01 | **1,405.85** | 0.05 | 1,405.80 | 0.0000 | **1,527** |
| **1995** | **15.67** | 1.32 | 14.35 | **42.05** | 3.04 | 39.00 | 0.01 | **1,198.54** | 0.04 | 1,198.50 | 0.0001 | **1,256** |
| **1996** | **7.39** | 0.62 | 6.77 | **102.71** | 3.03 | 99.67 | 0.01 | **1,565.53** | 0.06 | 1,565.47 | 0.0000 | **1,676** |
| **1997** | **2.31** | 0.19 | 2.11 | **112.58** | 8.14 | 104.41 | 0.04 | **1,413.65** | 0.05 | 1,413.60 | 0.0000 | **1,529** |
| **1998** | **6.92** | 0.58 | 6.33 | **99.98** | 7.23 | 92.72 | 0.03 | **1,420.84** | 0.05 | 1,420.79 | 0.0000 | **1,528** |
| **1999** | **7.39** | 0.62 | 6.77 | **76.47** | 5.53 | 70.92 | 0.03 | **735.71** | 0.03 | 735.69 | 0.0000 | **820** |
| **2000** | **4.91** | 0.41 | 4.49 | **93.34** | 6.75 | 86.56 | 0.03 | **1,005.42** | 0.15 | 1,005.27 | 0.0006 | **1,104** |
| **2001** | **2.31** | 0.19 | 2.11 | **83.18** | 6.01 | 77.14 | 0.03 | **724.97** | 0.08 | 724.89 | 0.0003 | **810** |
| **2002** | **2.78** | 0.23 | 2.54 | **62.19** | 4.49 | 57.67 | 0.02 | **2,047.00** | 0.11 | 2,046.89 | 0.0001 | **2,112** |
| **2003** | **3.70** | 0.31 | 3.38 | **117.63** | 8.50 | 109.09 | 0.04 | **2,531.44** | 0.13 | 2,531.31 | 0.0001 | **2,653** |
| **2004** | **3.70** | 0.31 | 3.38 | **82.36** | 5.95 | 76.38 | 0.03 | **2,610.47** | 0.12 | 2,610.35 | 0.0001 | **2,697** |
| **2005** | **2.23** | 0.19 | 2.04 | **56.86** | 4.11 | 52.73 | 0.02 | **1,214.70** | 0.07 | 1,214.63 | 0.0001 | **1,274** |
| **2006** | **4.14** | 0.35 | 3.79 | **53.78** | 3.89 | 49.87 | 0.02 | **2,542.15** | 0.12 | 2,542.02 | 0.0001 | **2,600** |
| **2007** | **10.61** | 0.89 | 9.72 | **51.77** | 3.48 | 48.27 | 0.02 | **2,268.75** | 0.12 | 2,268.63 | 0.0001 | **2,331** |
| **2008** | **14.76** | 1.24 | 13.51 | **49.14** | 3.24 | 45.89 | 0.02 | **1,381.69** | 0.10 | 1,381.59 | 0.0001 | **1,446** |
| **2009** | **56.74** | 4.78 | 51.96 | **48.60** | 3.12 | 45.46 | 0.01 | **1,005.99** | 0.08 | 1,005.92 | 0.0001 | **1,111** |
| **2010** | **119.27** | 10.04 | 109.23 | **49.36** | 3.18 | 46.17 | 0.01 | **1,524.34** | 0.10 | 1,524.24 | 0.0001 | **1,693** |
| **2011** | **157.23** | 13.24 | 143.99 | **47.55** | 3.09 | 44.45 | 0.01 | **1,975.14** | 0.11 | 1,975.03 | 0.0000 | **2,180** |
| **2012** | **187.93** | 15.82 | 172.11 | **42.41** | 2.73 | 39.67 | 0.01 | **2,132.58** | 0.11 | 2,132.47 | 0.0000 | **2,363** |
| **2013** | **184.00** | 15.20 | 168.80 | **45.66** | 2.96 | 42.69 | 0.01 | **1,324.49** | 0.10 | 1,324.39 | 0.0000 | **1,554** |
| **2014** | **133.52** | 11.23 | 122.29 | **41.45** | 2.64 | 38.80 | 0.01 | **1,313.90** | 0.11 | 1,313.78 | 0.0001 | **1,489** |
| **2015** | **136.28** | 11.47 | 124.80 | **39.41** | 2.49 | 36.91 | 0.01 | **1,856.10** | 0.13 | 1,855.97 | 0.0001 | **2,032** |
| **2016** | **132.10** | 11.12 | 120.98 | **37.93** | 2.39 | 35.53 | 0.01 | **1,933.08** | 0.13 | 1,932.95 | 0.0001 | **2,103** |
| **2017** | **10.06** | 10.06 | 0.00 | **32.27** | 1.98 | 30.28 | 0.00 | **1,384.57** | 0.10 | 1,384.47 | 0.0001 | **1,427** |

As can be seen from the table, natural gas is the dominant subsector, where high emissions are caused by high losses of natural gas in the process of transportation and distribution. Over the years, emissions from the mining and processing of coal also increased, as a result of intensification of mining of this fuel in Georgia. Below all source subcategories are described separately.

### 3.3.1. Solid Fuels (1.B.1.)

#### *a) Source-category description and calculated emissions*

Although mining of coal from underground layers was well developed in Georgia during the Soviet period, later coal mining decreased considerably. Starting from 2009, coal mining started to grow again and, respectively, fugitive emissions from this sub-category also increased. However, since 2017 coal mining has significantly decreased due to the technical inspection of safety norms of mines, following the deadly workplace accidents. Emissions data are provided in the *Table 3-22*.

Table 3-22 Methane Emissions from Underground Mines During Coal Mining and Treatment (Gg)

| Source | 1B1 Solid fuel total in $CO_{2eq.}$ | 1B1ai1 Mining total in $CO_{2eq.}$ | 1B1ai2 Post-mining seam gas emissions total in $CO_{2eq.}$ | 1B1ai3 Abandoned underground mines total in $CO_{2eq.}$ |
|---|---|---|---|---|
| 1990 | **738.70** | 637.80 | 100.90 | 0.000002 |
| 1991 | **23.70** | 20.81 | 2.89 | 0.000002 |
| 1992 | **8.35** | 7.33 | 1.02 | 0.000002 |
| 1993 | **5.98** | 5.25 | 0.73 | 0.000002 |
| 1994 | **81.98** | 70.78 | 11.20 | 0.000002 |
| 1995 | **15.66** | 13.53 | 2.14 | 0.000002 |
| 1996 | **7.38** | 6.38 | 1.00 | 0.000002 |
| 1997 | **2.32** | 2.00 | 0.32 | 0.000002 |
| 1998 | **6.93** | 5.97 | 0.95 | 0.000002 |
| 1999 | **7.38** | 6.38 | 1.00 | 0.000002 |
| 2000 | **4.89** | 4.23 | 0.66 | 0.000002 |
| 2001 | **2.32** | 2.00 | 0.32 | 0.000002 |
| 2002 | **2.78** | 2.39 | 0.39 | 0.000002 |
| 2003 | **3.69** | 3.19 | 0.50 | 0.000002 |
| 2004 | **3.69** | 3.19 | 0.50 | 0.000002 |
| 2005 | **2.23** | 1.93 | 0.30 | 0.000002 |
| 2006 | **4.15** | 3.58 | 0.57 | 0.000002 |
| 2007 | **10.62** | 9.16 | 1.45 | 0.000002 |
| 2008 | **14.77** | 12.75 | 2.02 | 0.000002 |
| 2009 | **56.73** | 48.99 | 7.74 | 0.000002 |
| 2010 | **119.26** | 102.98 | 16.28 | 0.000002 |
| 2011 | **157.24** | 135.76 | 21.48 | 0.000002 |
| 2012 | **187.92** | 162.26 | 25.66 | 0.000002 |
| 2013 | **184.32** | 159.14 | 25.18 | 0.000002 |
| 2014 | **133.36** | 115.15 | 18.21 | 0.000002 |
| 2015 | **136.28** | 117.66 | 18.62 | 0.000002 |
| 2016 | **132.10** | 114.05 | 18.05 | 0.000002 |
| 2017 | **10.06** | 8.83 | 1.23 | 0.000002 |

Coal deposits in Georgia are mainly located in three regions where coal extraction is underway for 158 years: in Tkibuli-Shaori since 1847; in Tkvarcheli since 1929 and in Akhaltsikhe since 1947[63]. Surface mining of coal is only carried out in Tkvarcheli. However, information about the volume, technology and manufacturers is not available since the entire region is occupied by Russia[64].

There are only 6 abandoned underground mines except Tkvarcheli - two in Tkibuli and four in Akhaltsikhe.

### b) *Methodological issues*

- ***Estimation Method***

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63 ქვანახშირის მოპოვება საქართველოში და მისი განვითარების პერსპექტივები - მწვანე ალტერნატივა / Coal Production and its Development Perspective – Green Alternative

64 ღია წესით ქვანახშირის მოპოვება საქართველოში და მასთან დაკავშირებული პრობლემები - მწვანე ალტერნატივა / Surface mining of coal in Georgia and Related Problems – Green Alternative

In all sub-sectors of solid fuel fugitive emissions were calculated using the IPCC Tier 1 sectoral approach. The Tier 1 approach requires that countries choose from the global average range of Emission Factors and use country-specific Activity Data to calculate total emissions.

Below is the general form of the equation for estimating emissions for Tier 1 approach, based on coal production Activity Data from underground coal mining and post-mining emissions:

**Estimating emissions from underground coal mines for tier 1 and tier 2 approaches without adjustment for methane utilization or flaring**

$$Greenhouse\ gas\ emissions = Raw\ coal\ production \times\ Emission\ factor \times Units\ convertion\ factor$$

The basic equation for estimating emissions from abandoned underground coal mines is shown below:

**General equation for estimating fugitive emissions from abandoned underground coal mines**

$$CH_4 emissions = Emissions\ from\ abandoned\ mines - CH_4 emissions\ recovered$$

- ***Emission Factors***

Tier 1 Emission Factors for underground mining are shown below.

**Tier 1: Global Average Method – Underground Mining – prior to Adjustment for Any Methane Utilization or Flaring**

$$CH_4 Emissions = CH_4 Emission\ Factor \times Underground\ Coal\ Productio \times Conversion\ Factor$$

Where units are:

*Methane Emissions* (Gg/year)

*$CH_4$ Emission Factor* ($m^3$/tons)

*Underground Coal Production* (tons/year)

Emission Factor:

Low $CH_4$ Emission Factor = 10 $m^3$/tons

Average $CH_4$ Emission Factor =18 $m^3$/tons

High $CH_4$ Emission Factor = 25 $m^3$/tons

*Conversion Factor:*

This is the density of $CH_4$ and converts volume of $CH_4$ to mass of $CH_4$. The density is taken at 20˚C and 1 atmosphere pressure and has a value of $0.67 \times 10^{-6}$ Gg/$m^3$.

Countries using the Tier 1 approach should consider country-specific variables such as the depth of major coal seams to determine the emission factor to be used. As gas content of coal usually grows with increase of the depth, the low end of the range should be chosen for average mining depths <200 m, whereas the high value is appropriate for depths > 400 m. For intermediate depths, average values can be used. In Georgia, average mining depths is about 800-1200m, based on the information provided by Georgian Industrial Group (GIG), therefore High $CH_4$ Emission Factor = 25 $m^3$/tons was stated.

For a Tier 1 approach the post-mining emissions factors are shown below together with the estimation method:

TIER 1: GLOBAL AVERAGE METHOD – POST-MINING EMISSIONS – UNDERGROUND MINES

$$Methane\ emissions = CH_4 Emission \times Underground\ Coal\ Productio \times Conversion\ Factor$$

Where units are:

*Methane Emissions* (Gg/year)

*$CH_4$ Emission Factor* ($m^3$/tons)

*Underground Coal Production* (tons/year)

Emission Factor:

Low $CH_4$ Emission Factor = 0.9 $m^3$/tons

Average $CH_4$ Emission Factor =2.5 $m^3$/tons

High $CH_4$ Emission Factor = 4.0 $m^3$/tons

*Conversion Factor:*

This is the density of $CH_4$ and converts volume of $CH_4$ to mass of $CH_4$. The density is taken at 20˚C and 1 atmosphere pressure and has a value of $0.67\times10^{-6}$ Gg/$m^3$.

Developing emissions estimates from abandoned underground coal mines requires historical records. The two key parameters used to estimate abandoned mine emissions for each mine (or group of mines) are the time (in years) elapsed since the mine was abandoned, relative to the year of the emissions inventory, and Emission Factors that take into account the mine's gassiness. Tier 1 approach includes default values and broader time intervals. For a Tier 1 approach, the emissions for a given inventory year can be calculated from the Equation below:

**Tier 1 approach for abandoned underground mines**

$$Methane\ Emissions = Number\ of\ Abandoned\ Coal\ Mines\ remaining\ unflooded \times Fraction\ of gassy \times Coal\ Mines\ Emission\ Factor \times Conversion\ Factor$$

Where units are:

Methane Emissions (Gg/year)

Emission Factor ($m^3$/year)

Note: The Emission Factor has different units here compared with the definitions for underground, surface, and post-mining emissions. The reason for this is that the different method is applied for estimating emissions from abandoned mines compared with underground or surface mining.

This equation is applied for each time interval, and emissions from each time interval are added to calculate the total emissions.

***Conversion Factor:***

This is the density of $CH_4$ and converts volume of $CH_4$ to mass of $CH_4$. The density is taken at 20˚C and 1 atmosphere pressure and has a value of 0.67×10-6 Gg/$m^3$.

A Tier 1 approach for determining emissions from abandoned underground mines is described below and is largely based on methods developed by the USEPA (Franklin et al, 2004).

Since six underground mines were abandoned in Georgia during 1976-2000 period, default values - percentage of coal mines that are gassy were assumed to be 30%, selected from the range 8%-100% (IPCC 2006, volume 2, table 4.1.5). As for the Emission Factors, they are obtained from the table 4.1.6 of IPCC 2006, volume 2.

- ***Activity Data***

Information about coal mining and its specificities were obtained from the National Statistics Office of Georgia (GEOSTAT).

### 3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2.)

***a) Source-category description and calculated emissions***

The sources of fugitive emissions in oil and gas systems include, but are not limited to, equipment leaks, evaporation and flashing losses, venting, flaring, incineration, and accidental releases. While some of these emission sources are engineered or intentional and therefore relatively well characterized, the quantity and composition of the emissions is generally subject to significant uncertainty due to the limited use of measurement systems. in these cases.

Fugitive emissions are calculated from the following sub-categories:

Oil

- Venting - Emissions from venting of associated gas and waste gas/vapor streams at oil facilities;
- Flaring - Emissions from flaring of natural gas and waste gas/vapor streams at oil facilities;
- Oil production and upgrading - Fugitive emissions from oil production (excluding venting and flaring) occur at the oil wellhead through to the starting point of the oil transmission system. This includes fugitive emissions related to well servicing, transportation of untreated production to treating or extraction facilities, activities at extraction and upgrading facilities, associated gas re-injection systems, and produced water disposal systems. Fugitive emissions from upgraders are grouped with those from production sites rather than those from refining facilities since the upgraders are often integrated with extraction facilities and their relative emission contributions are difficult to be established;
- Oil transportation - Fugitive emissions (excluding venting and flaring) related to the transportation of marketable crude oil to upgraders and refineries. The transportation systems may comprise pipelines, marine tankers, tank trucks and rail cars. Evaporation losses from storage, filling and unloading activities, as well as fugitive equipment leaks are the primary sources of these emissions.
- Natural Gas;
- Venting - Emissions from venting of natural gas and waste gas/vapor streams at gas facilities;
- Flaring - Emissions from flaring of natural gas and waste gas/vapor streams at gas facilities;
- Production - Fugitive emissions (excluding venting and flaring) from the gas wellhead through to the inlet of gas processing plants, or, where processing is not required, to the tie-in points on gas transmission systems. This includes fugitive emissions related to well servicing, gas gathering, processing and associated waste water and acid gas disposal activities;
- Transmission and storage - Fugitive emissions from systems used to transport processed natural gas to market. Fugitive emissions from natural gas storage systems should also be included in this category;
- Distribution - Fugitive emissions (excluding venting and flaring) during the distribution of natural gas to end users.

Table 3-23 GHG Emissions from Oil and Natural Gas Related Activities (Gg)

| Source | 1B2 Oil and Natural Gas total in $CO_{2eq}$. | 1B2ai Oil venting total in $CO_{2eq}$. | 1B2aii Oil flaring total in $CO_{2eq}$. | 1B2aiii2 Oil production and upgrading total in $CO_{2eq}$. | 1B2aiii3 Oil transport total in $CO_{2eq}$. | 1B2aiii4 Oil Refining total in CO2 eq. | 1B2bi Natural gas venting total in $CO_{2eq}$. | 1B2bii Natural gas flaring total in $CO_{2eq}$. | 1B2biii2 Natural gas production total in $CO_{2eq}$. | 1B2biii4 Natural gas transmission and storage total in $CO_{2eq}$. | 1B2biii5 Natural gas distribution total in $CO_{2eq}$. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | **5,347** | 4.19 | 11.09 | 142.45 | NO | 2.60 | 44.88 | 0.08 | 15.10 | 1,476 | 3,651 |
| 1991 | **5,476** | 4.25 | 11.21 | 0.46 | NO | 2.10 | 41.88 | 0.08 | 15.11 | 1,006 | 4,395 |
| 1992 | **5,025** | 2.97 | 7.88 | 100.85 | NO | 0.49 | 41.35 | 0.07 | 12.47 | 994 | 3,865 |
| 1993 | **4,218** | 0.94 | 2.49 | 31.85 | NO | 0.35 | 33.31 | 0.07 | 12.47 | 810 | 3,326 |
| 1994 | **1,445** | 1.04 | 2.75 | 35.23 | NO | 0.21 | 15.99 | 0.00 | 0.66 | 526 | 863 |
| 1995 | **1,241** | 1.12 | 2.96 | 37.92 | NO | 0.05 | 9.80 | 0.01 | 2.63 | 695 | 491 |
| 1996 | **1,668** | 2.86 | 2.75 | 97.08 | NO | 0.03 | 8.58 | 0.00 | 0.83 | 282 | 1,274 |
| 1997 | **1,526** | 2.99 | 7.94 | 101.61 | NO | 0.04 | 7.37 | 0.00 | 0.00 | 243 | 1,164 |
| 1998 | **1,521** | 2.66 | 7.05 | 90.24 | NO | 0.04 | 7.52 | 0.00 | 0.00 | 247 | 1,166 |
| 1999 | **812** | 2.03 | 5.39 | 69.01 | NO | 0.05 | 7.24 | 0.00 | 0.00 | 238 | 490 |
| 2000 | **1,099** | 2.48 | 6.58 | 84.26 | NO | 0.02 | 9.49 | 0.11 | 20.36 | 312 | 663 |
| 2001 | **808** | 2.21 | 5.86 | 75.08 | NO | 0.03 | 8.00 | 0.06 | 10.12 | 263 | 444 |
| 2002 | **2,109** | 1.65 | 4.38 | 56.12 | NO | 0.03 | 6.69 | 0.02 | 4.28 | 220 | 1,816 |
| 2003 | **2,649** | 3.12 | 8.29 | 106.18 | NO | 0.04 | 7.60 | 0.03 | 4.69 | 250 | 2,269 |
| 2004 | **2,693** | 2.19 | 5.80 | 74.33 | NO | 0.04 | 8.90 | 0.02 | 3.04 | 293 | 2,306 |
| 2005 | **1,272** | 1.51 | 4.01 | 51.32 | NO | 0.02 | 10.46 | 0.03 | 4.69 | 344 | 856 |
| 2006 | **2,596** | 1.43 | 3.79 | 48.50 | NO | 0.02 | 13.58 | 0.03 | 4.69 | 447 | 2,077 |
| 2007 | **2,321** | 1.27 | 3.38 | 43.22 | 3.85 | 0.05 | 40.02 | 0.02 | 4.13 | 449 | 1,775 |
| 2008 | **1,431** | 1.18 | 3.13 | 40.19 | 4.57 | 0.06 | 65.02 | 0.02 | 3.31 | 351 | 963 |
| 2009 | **1,055** | 1.14 | 3.02 | 38.68 | 5.74 | 0.02 | 63.42 | 0.01 | 1.93 | 352 | 589 |
| 2010 | **1,574** | 1.16 | 3.08 | 39.41 | 5.72 | 0.00 | 58.12 | 0.01 | 2.07 | 295 | 1,169 |
| 2011 | **2,023** | 1.13 | 2.99 | 38.26 | 5.18 | 0.00 | 59.72 | 0.01 | 1.49 | 459 | 1,455 |
| 2012 | **2,175** | 0.99 | 2.64 | 33.78 | 5.00 | 0.00 | 60.39 | 0.01 | 1.38 | 485 | 1,586 |
| 2013 | **1,370** | 1.08 | 2.86 | 36.66 | 5.06 | 0.00 | 66.15 | 0.01 | 1.34 | 55 | 1,202 |
| 2014 | **1,355** | 0.96 | 2.55 | 32.66 | 5.29 | 0.00 | 84.75 | 0.01 | 2.63 | 230 | 996 |
| 2015 | **1,896** | 0.91 | 2.40 | 30.79 | 5.31 | 0.00 | 84.89 | 0.02 | 2.91 | 360 | 1,408 |
| 2016 | **1,971** | 0.87 | 2.31 | 29.53 | 5.15 | 0.07 | 86.14 | 0.01 | 1.69 | 317 | 1,528 |
| 2017 | **1,417** | 0.72 | 1.90 | 24.50 | 5.10 | 0.02 | 88.55 | 0.01 | 2.19 | 464 | 830 |

### b) *Methodological issues*

- ***Estimation Method***

Fugitive emissions from oil and natural gas systems are often difficult to quantify accurately. This is largely due to the diversity of the industry, the large number and variety of potential emission sources, the wide variations in emission-control levels and the limited availability of emission-source data.

In Georgia, oil and natural gas are extracted at a small scale, and this fact has been considered in the process of the methodology selection. For assessing fugitive emissions in the course of oil extraction, the Tier 1 method was used; Tier 1 method implies the application of appropriate default Emission Factors to a representative activity parameter (usually throughput) for each applicable segment or subcategory of a country's oil and natural gas industry. Tier 1 approach is performed using equations presented below:

**Tier 1: ESTIMATING FUGITIVE EMISSIONS FROM AN INDUSTRY SEGMENT**

$$E_{gas,industry\ segment} = A_{industry\ segment} \times EF_{gas,industry\ segment}$$

**Tier 1: TOTAL FUGITIVE EMISSIONS FROM INDUSTRY SEGMENTS**

$$E_{gas} = \sum_{industry\ segments} E_{gas,industry\ segment}$$

Where:

$E_{gas,\ industry\ segment}$ = Annual emissions (Gg)

$EF_{gas,\ industry\ segment}$ = Emission factor (Gg/unit of activity)

$A_{industry\ segment}$ = Activity value (units of activity)

Emissions during natural gas transmission and distribution were calculated using the value of losses in the transmission and distribution systems, based on the following formula:

$$CH_4Emissions(Gg) = Gas\ Loss(10^6\ m^3) \times Methan\ Content\ in\ Gas(\%) \times Conversion\ Factor(t\frac{CH_4}{m^3CH_4}) \times 1000$$

This methodology corresponds to the one recommended for the calculation of emissions from natural gas losses under the Clean Development Mechanism (CDM). In the formula, a conversion factor, methane density (ρ), converts methane volume into weight. A value (0.64512 Gg CH4/mln.m3) accepted in the CDM Methodology in standard conditions (at 0°C temperature and 101.3 kPa pressure conditions), ρ= 0.0007168 (t $CH_4$/$m^3$ $CH_4$) was used. In total 90% was taken as the value of methane content in natural gas[65].

- ***Emission Factors***

The available Tier 1 default Emission Factors are presented in table Table *3-24*[66]. All the presented Emission Factors are expressed in units of mass emissions per unit volume of oil or gas throughput. Furthermore, throughput statistics are the most consistently available Activity Data to be used in Tier 1 calculations. The Emission Factors apply to systems in developing countries and countries with economies in transition where there are much greater amounts of fugitive emissions per unit of activity (often by an order of magnitude or more). The reasons for the greater emissions in these cases may include less stringent design standards, use of lower quality components, restricted access to natural gas markets, and, in some cases, artificially low energy pricing resulting in reduced energy conservation.

Table 3-24 Emission Factors for Fugitive Emissions (Including Venting and Flaring) From Oil and Gas Operations

| Category | Sub-Category | Emission Source | $CH_4$ Value | $CO_2$ Value | $N_2O$ Value | Units of Measure |
|---|---|---|---|---|---|---|
| Gas production | All | Fugitives | 1.2E-02 | 9.7E-05 | - | Gg per mln. m3 gas production |
| | | Flaring | 8.8E-07 | 1.4E-03 | 2.5E-08 | Gg per mln. m3 gas production |
| Gas Transmission & Storage | Transmission | Fugitives | 0.64512 | 5.04E-06 | - | Gg per mln. m3 of transported gas |
| | | Venting | 3.9E-04 | 5.2E-06 | - | Gg per mln. m3 of marketable gas |

[65] Project 2404 : Leak Reduction in Above Ground Gas Distribution Equipment in the KazTransgaz-Tbilisi Gas Distribution System- Tbilisi, Georgia
[66] From IPCC 2006, Volume 2, table 4.2.5

| Category | Sub-Category | Emission Source | $CH_4$ Value | $CO_2$ Value | $N_2O$ Value | Units of Measure |
|---|---|---|---|---|---|---|
| Gas Distribution | All | All | 0.64512 | 5.73E-04 | - | Gg per mln. m3 of distributed gas |
| Oil Production | Conventional Oil | Fugitives | 3.0E-02 | 2.0E-03 | - | Gg per $10^3$ m3 conventional oil production |
| | | Venting | 8.5E-04 | 1.1E-04 | - | Gg per $10^3$ m3 conventional oil production |
| | | Flaring | 2.95E-05 | 4.8E-02 | 7.6E-07 | Gg per $10^3$ m3 conventional oil production |
| Oil Transport | Pipelines | All | 5.4E-06 | 4.9E-07 | - | Gg per $10^3$ m3 oil transported by pipeline |
| | Tanker Trucks and Rail Cars | Venting | 2.5E-05 | 2.3E-06 | - | Gg per $10^3$ m3 oil transported by Tanker Truck |

- ***Activity Data***

Information about oil and natural gas production, transmission and distribution were obtained from the National Statistics Office of Georgia (GEOSTAT) and Georgian Oil and Gas Corporation (GOGC).

Assessments regarding natural gas losses were made based on the information obtained from the energy balances provided by GEOSTAT. According to the information, natural gas losses in the transportation system were about 1.49% of the domestic supply in 2017. Gas transmission losses have been assumed to be 2% of the domestic supply in previous years based on the expert judgment.

Natural gas losses are quite high in the gas distribution systems of Georgia. These losses are made up of operational (technological and accident-related) and commercial losses. The amount of losses in gas pipelines depends on several factors – gas pressure, gas pipeline diameter and length, its technical state, number of gas-control points, etc. It is almost impossible to obtain such data in Georgia.

Under the Decree N26 of November 18, 2010, the Georgian National Energy and Water Regulatory Commission, approved the Rule of Calculation of the Amount of standard losses in the natural gas distribution network. This rule is based on statistical data, expert assessments, and gas dynamics postulates. Standard losses were established for natural gas supply licenses according to this rule.

GNERC's annual reports (2012 and 2013 years), state that gas distribution losses amounted to about 9% of distributed natural gas in Georgia. This figure has been used for the calculation of gas distribution losses for the previous years in the GHGs emission inventory.

#### 3.3.2.1. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d.)

In Georgia electricity is not produced with the geothermal power generation and hence there is no related fugitive emissions.

## 3.4. $CO_2$ transport and storage (1.C.)

$CO_2$ transport and storage do not take place in Georgia.

# Chapter 4. Industrial processes and product use (CRF Sector 2)

## 4.1. Overview of Sector

The Chapter 4 comprises description of methodologies used for estimating GHG emissions as well as information on references to Activity Data and Emission Factors reported under CRF Sector 2 –Industrial Processes for the period 1990 to 2017.

The GHG Emissions from this sector cover emissions from the following categories: Mineral Products (2A), Chemical Industry (2B), Metal Production (2C), Non-Energy Products from Fuels and Solvent Use (2D), Electronics Industry (2E), Product Uses as Substitutes for ODS (2F) Other Product Manufacture and Use (2G) and Other Industries such as paper, drinks and food production (2H) Table *4-1*.The GHG Emissions by gases from the sector are presented in *Table* 4-2.

To the extent that confidentiality concerns allow, relative information is shown in the tables under each sub-category. Emissions by each sub-category and by gas are shown in the first table of each category.

Table 4-1 Emissions from the Industrial Processes and Product use in Georgia in 1990-2017 (Gg-$CO_2$ eq.)

| Year | Mineral Products | Chemical Industry | Metal Production | Non-Energy Products from Fuels and Solvent Use | Electronics industry | Product Uses as Substitutes for ODS | Other Product Manufacture and Use | Other Industries such as paper, drinks and food production | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 2A | 2B | 2C | 2D | 2E | 2F | 2G | 2H | |
| 1990 | 572 | C | 2635 | 0 | NA | NA | C | NO | 3879 |
| 1991 | 357 | C | 2035 | 0 | NA | NA | C | NO | 3038 |
| 1992 | 211 | C | 1053 | 0 | NA | NA | C | NO | 1705 |
| 1993 | 110 | C | 276 | 0 | NA | NA | C | NO | 776 |
| 1994 | 45 | C | 116 | 0 | NA | NA | C | NO | 414 |
| 1995 | 32 | C | 94 | 0 | NA | NA | C | NO | 447 |
| 1996 | 48 | C | 81 | 0 | NA | NA | C | NO | 535 |
| 1997 | 42 | C | 106 | 0 | NA | NA | C | NO | 504 |
| 1998 | 84 | C | 111 | 0 | NA | NA | C | NO | 502 |
| 1999 | 138 | C | 62 | 0 | NA | NA | C | NO | 710 |
| 2000 | 143 | C | 46 | 0 | NA | NA | C | NO | 725 |
| 2001 | 146 | C | 71 | 0 | NA | 0.2 | C | NO | 439 |
| 2002 | 161 | C | 61 | 0 | NA | 0.9 | C | NO | 591 |
| 2003 | 161 | C | 111 | 0 | NA | 2.6 | C | NO | 699 |
| 2004 | 188 | C | 187 | 0 | NA | 5.0 | C | NO | 846 |
| 2005 | 226 | C | 200 | 0 | NA | 8.9 | C | NO | 957 |
| 2006 | 332 | C | 214 | 0 | NA | 8.7 | C | NO | 1136 |
| 2007 | 521 | C | 207 | 0 | NA | 9.2 | C | NO | 1314 |
| 2008 | 585 | C | 235 | 0 | NA | 14 | C | NO | 1383 |
| 2009 | 328 | C | 224 | 0 | NA | 21 | C | NO | 1106 |
| 2010 | 413 | C | 362 | 0 | NA | 54 | C | NO | 1443 |
| 2011 | 625 | C | 438 | 0 | NA | 64 | C | NO | 1794 |
| 2012 | 625 | C | 473 | 0 | NA | 93 | C | NO | 1872 |
| 2013 | 639 | C | 465 | 9 | NA | 104 | C | NO | 1892 |
| 2014 | 752 | C | 482 | 10 | NA | 121 | C | NO | 2035 |
| 2015 | 759 | C | 438 | 11 | NA | 139 | C | NO | 2058 |
| 2016 | 714 | C | 387 | 12 | NA | 135 | C | NO | 1822 |
| 2017 | 727 | C | 464 | 10 | NA | 155 | C | NO | 1990 |

Table 4-2 Emissions from the Industrial Processes and Product use by gases in Georgia in 1990-2017 (Gg)

| Year | $CO_2$ | $CH_4$ | $N_2O$ | HFCs | PFCs | $SF_6$ | $NF_3$ |
|---|---|---|---|---|---|---|---|

| | | | $CO_2$ eq. | | $CO_2$ eq. | $CO_2$ eq. | $CO_2$ eq. | | $CO_2$ eq. | | $CO_2$ eq. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 3730 | 0.0433 | 0.9094 | C | C | NA | NA | C | C | NE | NE |
| 1991 | 2889 | 0.0208 | 0.4361 | C | C | NA | NA | C | C | NE | NE |
| 1992 | 1602 | 0.0107 | 0.2248 | C | C | NA | NA | C | C | NE | NE |
| 1993 | 673 | 0.0037 | 0.0773 | C | C | NA | NA | C | C | NE | NE |
| 1994 | 369 | 0.0023 | 0.0477 | C | C | NA | NA | C | C | NE | NE |
| 1995 | 388 | 0.0027 | 0.0573 | C | C | NA | NA | C | C | NE | NE |
| 1996 | 438 | 0.0020 | 0.0416 | C | C | NA | NA | C | C | NE | NE |
| 1997 | 417 | 0.0028 | 0.0586 | C | C | NA | NA | C | C | NE | NE |
| 1998 | 425 | 0.0057 | 0.1198 | C | C | NA | NA | C | C | NE | NE |
| 1999 | 576 | 0.0044 | 0.0930 | C | C | NA | NA | C | C | NE | NE |
| 2000 | 585 | 0.0036 | 0.0755 | C | C | NA | NA | C | C | NE | NE |
| 2001 | 382 | 0.0055 | 0.1155 | C | C | 0.22 | NE | C | C | NE | NE |
| 2002 | 474 | 0.0047 | 0.0986 | C | C | 0.86 | NE | C | C | NE | NE |
| 2003 | 568 | 0.0086 | 0.1803 | C | C | 2.64 | NE | C | C | NE | NE |
| 2004 | 702 | 0.0145 | 0.3035 | C | C | 5.01 | NE | C | C | NE | NE |
| 2005 | 783 | 0.0155 | 0.3254 | C | C | 8.91 | NE | C | C | NE | NE |
| 2006 | 938 | 0.0165 | 0.3474 | C | C | 8.71 | NE | C | C | NE | NE |
| 2007 | 1116 | 0.0160 | 0.3363 | C | C | 9.16 | NE | C | C | NE | NE |
| 2008 | 1178 | 0.0182 | 0.3822 | C | C | 13.91 | NE | C | C | NE | NE |
| 2009 | 892 | 0.0173 | 0.3635 | C | C | 20.91 | NE | C | C | NE | NE |
| 2010 | 1165 | 0.0276 | 0.5799 | C | C | 54.07 | NE | C | C | NE | NE |
| 2011 | 1486 | 0.0329 | 0.6907 | C | C | 64.20 | NE | C | C | NE | NE |
| 2012 | 1538 | 0.0354 | 0.7429 | C | C | 92.99 | NE | C | C | NE | NE |
| 2013 | 1542 | 0.0343 | 0.7209 | C | C | 104.26 | NE | C | C | NE | NE |
| 2014 | 1670 | 0.0351 | 0.7380 | C | C | 120.56 | NE | C | C | NE | NE |
| 2015 | 1660 | 0.0313 | 0.6574 | C | C | 139.38 | NE | C | C | NE | NE |
| 2016 | 1488 | 0.0024 | 0.0514 | C | C | 135.06 | NE | C | C | NE | NE |
| 2017 | 1606 | 0.0030 | 0.0620 | C | C | 155.33 | NE | C | C | NE | NE |

Only non-energy industrial activities related emissions are considered in this sector. Emissions due to fuel combustion in manufacturing industries are allocated to IPCC Sub-category 1A2 – Fuel Combustion Activities – Manufacturing Industries and Construction (see Chapter 3).

In 2017, total GHG emissions from this sector amounted to approximately 1,990.2 Gg-$CO_2$ eq., accounting for 11% of national total emissions (excluding LULUCF) in Georgia. The emissions of $CO_2$, $CH_4$, and $N_2O$ from this sector have decreased by 53% compared to 1990. The emissions of HFCs, PFCs, $SF_6$, and $NF_3$ from this sector have increased712 times compared to 2001.

The main driving factors for the reduction of emissions in this sector since 1990 are the decrease in steel production due to economic transition.. However, HFC emissions from the product uses as ODS substitutes have largely increased. The methodological tiers used in the IPPU sector are as shown in the Table 4-3 below.

Table 4-3 The methodological tiers used in the IPPU sector

| **GHG Source and Sink Categories** | **$CO_2$** | | **$CH_4$** | | **$N_2O$** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Method applied** | **Emission factor** | **Method applied** | **Emission factor** | **Method applied** | **Emission factor** | | |
| 2.A Mineral industry | D,T2 | D | | | | | | |
| 2.B Chemical industry | D,T2 | D,PS | NA,NO | NA,NO | D,T2 | D | | |
| 2.C Metal industry | D,T2 | PS | D,T1 | D | NA,NO | NA,NO | | |
| 2.D Non-energy products from fuel and solvent use | D,T1 | D | NA,NO | NA,NO | NA,NO | NA,NO | | |
| 2.E Electronic industry | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2.F Product uses as ODS substitutes | | | | | | | | |
| 2.G Other product manufacture and use | | | | | | | | |
| 2.H Other | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | | |

| GHG Source and Sink Categories | HFCs | | PFCs | | $SF_6$ | | $NF_3$ | |
|---|---|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| 2.A Mineral industry | | | | | | | | |
| 2.B Chemical industry | | | | | | | | |
| 2.C Metal industry | | | | | | | | |
| 2.D Non-energy products from fuel and solvent use | NA, NO | NA, NO | NA, NO | NA, NO | NA, NO | NA, NO | NA, NO | NA, NO |
| 2.E Electronic industry | | | | | | | | |
| 2.F Product uses as ODS substitutes | D,T1 | D | NE | NE | NE | NE | NE | NE |
| 2.G Other product manufacture and use | NA,NE | NA,NE | NA,NE | NA,NE | D,T1 | D | NA, NE | NA,NE |
| 2.H Other | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO |

D: IPCC default, T1-T3: IPCC Tier 1-3, CS: country specific, PS: plant specific, OTH: other.

Furthermore, the chapter includes information on emissions of indirect GHGs such as non-methane volatile organic compounds (NMVOCs), carbon monoxide, nitrogen oxides (*Table 4-4*).

Table 4-4 Precursor Emissions from the Industrial Processes and Product use in Georgia in 1990-2017 (Gg)

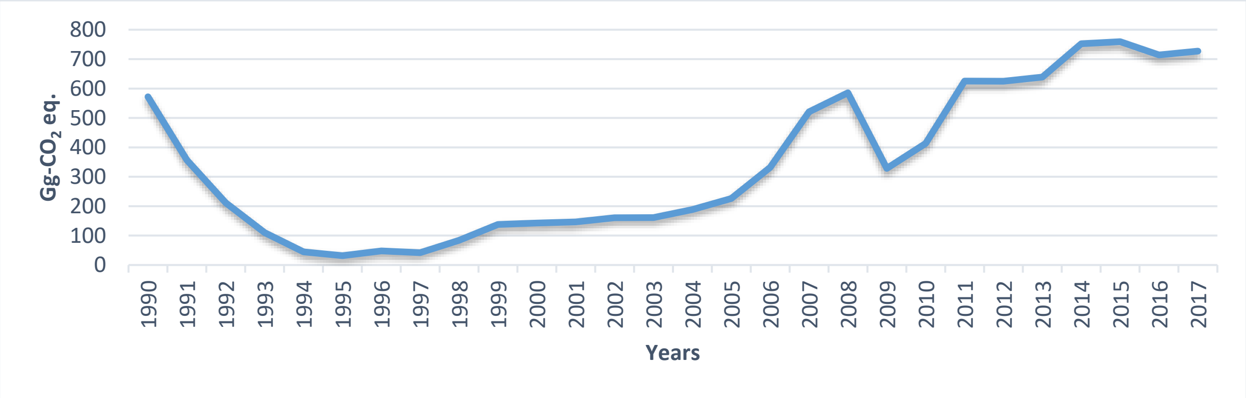
| Year | CO | NOx | NMVOC | $SO_2$ | Year | CO | NOx | NMVOC | $SO_2$ |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1.6 | 2.85 | 11.92 | 0.40 | 2004 | 1.0 | 2.69 | 2.04 | 0.13 |
| 1991 | 1.5 | 2.86 | 12.93 | 0.26 | 2005 | 1.2 | 3.19 | 2.16 | 0.17 |
| 1992 | 0.9 | 1.98 | 9.22 | 0.14 | 2006 | 1.4 | 3.67 | 2.29 | 0.25 |
| 1993 | 0.8 | 1.99 | 7.65 | 0.07 | 2007 | 1.4 | 3.65 | 2.41 | 0.39 |
| 1994 | 0.4 | 0.86 | 5.92 | 0.03 | 2008 | 1.5 | 3.68 | 2.02 | 0.42 |
| 1995 | 0.5 | 1.12 | 3.79 | 0.02 | 2009 | 1.4 | 3.72 | 2.22 | 0.27 |
| 1996 | 0.7 | 1.86 | 3.38 | 0.03 | 2010 | 1.6 | 4.33 | 2.87 | 0.28 |
| 1997 | 0.0 | 1.67 | 2.25 | 0.03 | 2011 | 1.7 | 4.69 | 3.29 | 0.46 |
| 1998 | 0.6 | 1.49 | 2.31 | 0.06 | 2012 | 1.8 | 4.65 | 3.22 | 0.47 |
| 1999 | 1.0 | 2.59 | 1.90 | 0.10 | 2013 | 1.7 | 4.73 | 3.34 | 0.50 |
| 2000 | 1.1 | 2.71 | 1.90 | 0.10 | 2014 | 1.7 | 4.72 | 3.58 | 0.50 |
| 2001 | 0.5 | 1.08 | 1.27 | 0.10 | 2015 | 1.9 | 4.99 | 3.59 | 0.54 |
| 2002 | 0.9 | 2.25 | 1.52 | 0.10 | 2016 | 1.5 | 3.85 | 3.81 | 0.56 |
| 2003 | 1.0 | 2.48 | 1.64 | 0.10 | 2017 | 1.7 | 4.43 | 4.10 | 0.63 |

## 4.2. Mineral Industry (2.A.)

The Sub-sector of the mineral products considers the direct GHG emissions from the Cement Production (2.A.1), Lime Production (2.A.2) and Glass Production (2.A.3) source-categories. The non-direct GHG emission was additionally estimated for the source category of Asphalt Processing. In 2017 the GHG emissions from the sub-sector of the mineral products was 37% of total emissions from the Industrial Processes and Product use.

The highest emissions from the sub-sector of mineral products were estimated in 2015; it was about 759 Gg-$CO_2$ eq. mainly caused by performance improvement in clinker production. The emissions value at the end of estimation period (727 Gg-$CO_2$ eq. in 2017) was 21% higher than the value estimated in 1990 (571 Gg-$CO_2$ eq.). Other peaking years of emissions were 2008 and 2011. The emissions from the sub-sector have significantly declined since1990 for next five years. Although the production processes of all three categories have been reduced, the steep depletion of the GHG emission is mainly related to the sharp decline of clinker production. The recovery of the construction markets for chemical industries has taken more than a decade. The transformation period was characterized with a few crises in economic development translated into the lowest level of GHG emissions from the sub-sector. The collapse of socialist system has resulted in the reduction of production of construction goods more than twenty times. In 1995 the emissions dropped by 95% comparing to the 1990 level and reached its lowest level for the whole time series period - 32 Gg-$CO_2$ eq. The emissions have declined from 2008 to 2009 due to the economic crisis in the construction market in Georgia. The emissions have increased between 2009- and 2015-years period by approximately 57%. The largest upturn was recorded in 2009-2011years period from 328 to 625 Gg-$CO_2$ eq. Afterwards, the emissions have steadily increased by 2%. At the end of the period the emissions have dropped by 6%, comparing the value calculated for the year of 2015. The emissions trend is illustrated in the Figure 4-1 beneath.

*Figure 4-1 GHG Emissions from mineral production*




### 4.2.1. Cement Production (2.A.1.)

***a) Source-category description and calculated emissions***

$CO_2$ is emitted in the process of the calcination of limestone, the main component of which is calcium carbonate, during the production of clinker - an intermediate product of cement, the main component of which is calcium oxide.

The clinker in Georgia is produced by two different methods called dry and wet methods in three factories. The dry method is used in Rustavi Factory, while the wet method is used both in Rustavi and Kaspi factories.

In 2014 the emissions reached the highest value for the whole time series. In 2016 the emissions declined by 10 per cent[67]. The emissions estimated for the year of 1990 were about 29 %lower than in 2014. Following five years the emissions trend was declining. During the two decades since the restitution of independence of Georgia there was another low production level identified due to the economic crisis. In 2009 the emissions dropped by 48% compared to the 2008 level and y 43%compared to the 1990 level mainly caused by the economic crisis in the international market. The emissions during 2009-2015 have increased by 146%. In 2017 the emissions from the clinker production were about 8% lower compared to 2014, since the production slightly slowed down due to the market saturation.

2A1 - Cement Production is a key source-category regarding $CO_2$ emissions. It has been a key source without interruption since 1990: see Table 1-2

[67]The value was calculated based on the date expressed in thousandths

The calculated $CO_2$ emissions from the clinker production are presented in Table 4-5 beneath.

Table 4-5 $CO_2$ emissions from clinker production (Gg) in 1990-2017

| Year | Quantity of Clinker or Cement Produced (t) | Emission Factor (t $CO_2$/t clinker or cement produced) | CKD Correction Factor | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|
| 1990 | C | 0.51025 | 1.02 | C | C |
| 1991 | C | 0.51025 | 1.02 | C | C |
| 1992 | C | 0.51025 | 1.02 | C | C |
| 1993 | C | 0.51025 | 1.02 | C | C |
| 1994 | C | 0.51025 | 1.02 | C | C |
| 1995 | C | 0.51025 | 1.02 | C | C |
| 1996 | C | 0.51025 | 1.02 | C | C |
| 1997 | C | 0.51025 | 1.02 | C | C |
| 1998 | C | 0.51025 | 1.02 | C | C |
| 1999 | C | 0.51025 | 1.02 | C | C |
| 2000 | C | 0.51025 | 1.02 | C | C |
| 2001 | C | 0.51025 | 1.02 | C | C |
| 2002 | C | 0.51025 | 1.02 | C | C |
| 2003 | C | 0.51025 | 1.02 | C | C |
| 2004 | C | 0.51025 | 1.02 | C | C |
| 2005 | C | 0.51025 | 1.02 | C | C |
| 2006 | C | 0.51025 | 1.02 | C | C |
| 2007 | C | 0.51025 | 1.02 | C | C |
| 2008 | C | 0.51025 | 1.02 | C | C |
| 2009 | C | 0.51025 | 1.02 | C | C |
| 2010 | C | 0.51025 | 1.02 | C | C |
| 2011 | C | 0.51025 | 1.02 | C | C |
| 2012 | C | 0.51025 | 1.02 | C | C |
| 2013 | C | 0.51025 | 1.02 | C | C |
| 2014 | C | 0.51025 | 1.02 | C | C |
| 2015 | C | 0.51025 | 1.02 | C | C |
| 2016 | C | 0.51025 | 1.02 | C | C |
| 2017 | C | 0.51025 | 1.02 | C | C |

The calculated emissions of Sulfur dioxide from the cement production are shown in the Table *4-6* beneath.

Table 4-6 $SO_2$ emissions (Gg) from cement and clinker production in 1990-2017

| Year | Quantity of Cement Produced (Gg) | Emission Factor (t $SO_2$ /Gg cement produced) | $SO_2$ Emitted (t) | $SO_2$ Emitted (Gg) |
|---|---|---|---|---|
| 1990 | 1290 | 0.3 | 387.0 | 0.39 |
| 1991 | 821 | 0.3 | 246.3 | 0.25 |
| 1992 | 451 | 0.3 | 135.2 | 0.14 |
| 1993 | 227 | 0.3 | 68.3 | 0.07 |
| 1994 | 89 | 0.3 | 26.6 | 0.03 |
| 1995 | 59 | 0.3 | 17.7 | 0.02 |
| 1996 | 85 | 0.3 | 25.5 | 0.03 |
| 1997 | 94 | 0.3 | 28.2 | 0.03 |
| 1998 | 199 | 0.3 | 59.6 | 0.06 |
| 1999 | 341 | 0.3 | 102.4 | 0.10 |
| 2000 | 348 | 0.3 | 104.3 | 0.10 |
| 2001 | 335 | 0.3 | 100.6 | 0.10 |
| 2002 | 347 | 0.3 | 104.0 | 0.10 |
| 2003 | 345 | 0.3 | 103.4 | 0.10 |
| 2004 | 442 | 0.3 | 132.5 | 0.13 |
| 2005 | 530 | 0.3 | 158.9 | 0.16 |
| 2006 | 790 | 0.3 | 236.9 | 0.24 |

| Year | Quantity of Cement Produced (Gg) | Emission Factor (t $SO_2$ /Gg cement produced) | $SO_2$ Emitted (t) | $SO_2$ Emitted (Gg) |
|---|---|---|---|---|
| 2007 | 1264 | 0.3 | 379.1 | 0.38 |
| 2008 | 1351 | 0.3 | 405.3 | 0.41 |
| 2009 | 870 | 0.3 | 261.1 | 0.26 |
| 2010 | 907 | 0.3 | 272.1 | 0.27 |
| 2011 | 1502 | 0.3 | 450.6 | 0.45 |
| 2012 | 1546 | 0.3 | 463.7 | 0.46 |
| 2013 | 1619 | 0.3 | 485.6 | 0.49 |
| 2014 | 1619 | 0.3 | 485.6 | 0.49 |
| 2015 | 1759 | 0.3 | 527.6 | 0.53 |
| 2016 | 1844 | 0.3 | 553.2 | 0.55 |
| 2017 | 2058 | 0.3 | 617.3 | 0.62 |

### b) *Methodological issues*

- ***Estimation Method***

$CO_2$ emissions from cement production are estimated using the IPCC 2006 Tier 2 approach. In accordance with the Tier 2 method $CO_2$ emissions can be calculated from based on the clinker production:

$$CO_2 Emissions = M_{cl} \times EF_{cl} \times CF_{ckd}$$

Where:

$M_{cl}$ = weight (mass) of clinker produced, tonnes
$EF_{cl}$ = emission factor for clinker, tonnes $CO_2$/tonne of clinker
$CF_{ckd}$ = emissions correction factor for CKD, dimensionless

The Cement Kiln Dust (CDK) Correction Factor equals to 1.02.
The emission factor calculation is represented beneath:

$$EF_{cl} = 0.785 \times 0.65^{*} = 0.51025$$

** The default value of the CaO content for clinker*

- ***Emission factors***

According to the IPCC 2006 emission factor is calculated as follows: EF = CaO fraction × 0.785 (molecular weight ratio of $CO_2$ / CaO = 44.01 / 56.08). The default value of the CaO content in clinker is equal to 65%. Accordingly, EF = 0.65 × 0.785 = 0.51025 t $CO_2$ /t clinker. For clinker EF = 0.51 $CO_2$ tonne / tonne of produced clinker[68].

In this sub-sector sulfur dioxide ($SO_2$) emissions are also calculated, according to the IPCC 1996 its emission rate is 0.3 kg of $SO_2$ / tonne of product.

- ***Activity data***

In Georgia, three clinker production plants operate (two plants in Rustavi City and One in Kaspi City). During the production of clinker, limestone, which is mainly calcium carbonate ($CaCO_3$), is calcined to produce lime (CaO) and $CO_2$ as a by-product.

[68] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Activity data – figures of clinker production is obtained from the Factories. All three factories are owned by one company. Accordingly, the production data are confidential (*Table 4-7*).

Table 4-7 The Activity Data of Clinker Production

| Clinker Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 1990 | C | 2000 | C | 2010 | C |
| 1991 | C | 2001 | C | 2011 | C |
| 1992 | C | 2002 | C | 2012 | C |
| 1993 | C | 2003 | C | 2013 | C |
| 1994 | C | 2004 | C | 2014 | C |
| 1995 | C | 2005 | C | 2015 | C |
| 1996 | C | 2006 | C | 2016 | C |
| 1997 | C | 2007 | C | 2017 | C |
| 1998 | C | 2008 | C | | |
| 1999 | C | 2009 | C | | |

***c) Uncertainties and Time-series Consistencies***

- ***Uncertainty***

The default value given in the 2006 IPCC Guidelines was applied for the uncertainty of the $CO_2$ emission factor and activity data for cement production. As a result, the uncertainty of emissions was estimated to be 4%.

- ***Time-series Consistency***

Georgia applies for tier 2 method for estimation of GHG emissions from cement production. clinker production data delivered from three factories cover the period of 2008 to 2017. To keep time-series consistency since the activity data at the factory level are available since 2008, $CO_2$ emissions from cement production between the years 1990 and 2007 is estimated by using overlap method. The cement production data series have been applied as previously used method for estimation of emissions from clinker production between the years 1990 and 2007.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvements***

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: "Georgia's Integrated Transparency Framework for Implementation of Paris Agreement".

### 4.2.2. Lime Production (2.A.2.)

***a) Source-category description and calculated emissions***

$CO_2$ is emitted during the calcination of $CaCO_3$, $MgCO_3$ in limestone used as raw material to produce quicklime.

In 2014 the emissions were about 31 Gg $CO_2$ the lowest value for the recent five years. In 2016 the emissions increased by 49 per cent[69] to 60 Gg $CO_2$. with highest emissions from the Lime Production in Georgia during the whole time series for the period of 1990 to 2017. In 2017 the emissions dropped approximately by12 per cent. The emissions estimated for the year of 1990 (37 Gg $CO_2$) were about 21% lower than in 2017. Following four years the emissions trend was descending and it reached the level of 1.3 Gg $CO_2$ (depletion by 63 per cent). During the two decades since the restitution of independence of Georgia another low production level has occurred due to the economic crisis. In 1997 the emissions dropped by 148 times compared to 1996-year level mainly caused by the economic crisis in the country. In 2004 the emissions dropped by 55% compared to the previous year estimation resulted by the economic changes in the country. In 2008 the growth of Lime production was stopped due to the war, accordingly the emissions slightly declined -by 14% (17 Gg $CO_2$) compared to the 2007-year level. The international market crisis has not significantly affected the Lime Production sector since the goods produced are mostly used domestically. In 2009 the emissions reached 40 Gg $CO_2$. The increase of $CO_2$ emissions is 57% higher than in 2008.

The calculated carbon dioxide emissions from lime production in Georgia are presented in the *Table 4-8* beneath.

Table 4-8 $CO_2$ emissions from lime production in 1990-2017

| Year | Quantity of Lime Produced (t) | Emission Factor (t $CO_2$/t Quicklime produced) | LKD | Water correction factor | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|
| 1990 | 49,400.00 | 0.75 | 1.02 | 0.97[70] | 36,657.3 | 36.66 |
| 1991 | 18,500.00 | 0.75 | 1.02 | 0.97 | 13,727.9 | 13.73 |
| 1992 | 11,100.00 | 0.75 | 1.02 | 0.97 | 8,236.8 | 8.24 |
| 1993 | 5,000.00 | 0.75 | 1.02 | 0.97 | 3,710.3 | 3.71 |
| 1994 | 1,800.00 | 0.75 | 1.02 | 0.97 | 1,335.7 | 1.34 |
| 1995 | 4,300.00 | 0.75 | 1.02 | 0.97 | 3,190.8 | 3.19 |
| 1996 | 14,800.00 | 0.75 | 1.02 | 0.97 | 10,982.3 | 10.98 |
| 1997 | 100.00 | 0.75 | 1.02 | 0.97 | 74.2 | 0.07 |
| 1998 | 3,200.00 | 0.75 | 1.02 | 0.97 | 2,374.6 | 2.37 |
| 1999 | 400.00 | 0.75 | 1.02 | 0.97 | 296.8 | 0.30 |
| 2000 | 3,100.00 | 0.75 | 1.02 | 0.97 | 2,300.4 | 2.30 |
| 2001 | 13,300.00 | 0.75 | 1.02 | 0.97 | 9,869.3 | 9.87 |
| 2002 | 26,300.00 | 0.75 | 1.02 | 0.97 | 19,515.9 | 19.52 |
| 2003 | 27,600.00 | 0.75 | 1.02 | 0.97 | 20,480.6 | 20.48 |
| 2004 | 12,400.00 | 0.75 | 1.02 | 0.97 | 9,201.4 | 9.20 |
| 2005 | 16,400.00 | 0.75 | 1.02 | 0.97 | 12,169.6 | 12.17 |
| 2006 | 22,200.00 | 0.75 | 1.02 | 0.97 | 16,473.5 | 16.47 |
| 2007 | 23,790.00 | 0.75 | 1.02 | 0.97 | 19,546.6 | 19.55 |
| 2008 | 22,390.78 | 0.75 | 1.02 | 0.97 | 33,504.2 | 33.50 |
| 2009 | 28,241.83 | 0.75 | 1.02 | 0.97 | 39,707.1 | 39.71 |
| 2010 | 14,954.11 | 0.75 | 1.02 | 0.97 | 32,251.4 | 32.25 |
| 2011 | 33,610.48 | 0.75 | 1.02 | 0.97 | 46,128.3 | 46.13 |
| 2012 | 8,438.37 | 0.75 | 1.02 | 0.97 | 29,314.0 | 29.31 |
| 2013 | 13,238.62 | 0.75 | 1.02 | 0.97 | 33,328.4 | 33.33 |

[69]The value was calculated based on the data expressed in thousands

[70]In case of factory specific data, the water correction factor equals to 0.986

| Year | Quantity of Lime Produced (t) | Emission Factor (t $CO_2$/t Quicklime produced) | LKD | Water correction factor | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|
| 2014 | 20,058.47 | 0.75 | 1.02 | 0.97 | 30,831.2 | 30.83 |
| 2015 | 37,259.64 | 0.75 | 1.02 | 0.97 | 45,857.3 | 45.86 |
| 2016 | 54,691.60 | 0.75 | 1.02 | 0.97 | 60,654.4 | 60.65 |
| 2017 | 41,939.00 | 0.75 | 1.02 | 0.97 | 53,385.2 | 53.39 |

2A2 – Lime Production is a key source-category regarding $CO_2$ emissions. It has been a key source since 2002. see Table 1-2

***b) Methodological Issues***

- ***Estimation Method***

In accordance with the GPG 2000 the $CO_2$ emissions from the Lime production is calculated based on the following equation:

$$CO_2 Emissions = M_l \times EF_l \times CF_{ckd} \times CF_w$$

Where:

$M_l$ = weight (mass) of lime produced, tonnes
$EF_l$= emission factor for lime, tonnes $CO_2$/tonne lime (0.75)
$CF_{lkd}$ = emissions correction factor for LKD, dimensionless (1.02)
$CF_w$ = water correction factor (0.97)
$CF_w$ = factory specific water correction factor (0.986)

- ***Emission factors***

In theory, assuming that calcination of the raw material is 100%, the emission factor for lime is equal to 785 kg of $CO_2$ per a tonne of lime. Furthermore, since the wet production technology is used to produce the largest amount of lime in Georgia the default hydrated lime correction factor of 0.97 was used in calculations.

- ***Activity data***

A major producer of lime in Georgia is JSC "Heidelberg Cement." It owns approximately 72% of the lime production in Georgia. In Georgia lime is also produced by several small enterprises, such as small plants in Kutaisi, Surami, Dzirula, Ozurgeti, and Zugdidi. All of them mainly use limestone as raw material. There is no accurate statistics on data of consumed raw materials. According to data supplied by a manufacturer[71] approximately 1.75 tons of raw materials is needed to produce 1 tonne of lime. Production technology is mostly based on the wet method.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 2% in the 2006 IPCC Guidelines was used. For the uncertainty of activity data, the default value of 3% in the 2006 IPCC Guidelines was used. As a result, the uncertainty for emissions was estimated as 4%.

[71] industria_kiri@posta.ge; contacts@rustavisteel.com

- ***Time-series Consistency***

Lime production data at an aggregated level have been provided by the Statistics Office of Georgia. Since 2007 one factory has been providing factory specific activity data. Accordingly, in order to avoid any double counting the amount of produced lime from the reported factory has been deducted from the aggregated data delivered by the Statistics office of Georgia.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the2006 IPCC Guidelines. General inventory QC focuses on checking the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvements***

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: “Georgia’s Integrated Transparency Framework for Implementation of Paris Agreement”.

### 4.2.3. Glass production (2.A.3.)

***a) Source-category description and calculated emissions***

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$; dolomite contains $CaCO_3$ and $MgCO_3$. Heating of limestone and dolomite releases $CO_2$ derived from $CaCO_3$ and $MgCO_3$. Similarly, $CO_2$ is emitted from soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate.

This subcategory implies productions and technologies, related to thermal processing of carbonate. One of such technologies is in the glass production. The $CO_2$ emissions from the glass production are included in this category.

The emissions from the source-category of Glass Production are rather low in Georgia. In 2017 the emissions were about C Gg $CO_2$. In 2015 the emissions increased by 9.7%[72] to C Gg $CO_2$. Since 2012 the emissions gradually increased to the end of the calculation period. The highest emissions from the Glass production in Georgia were noted in 1990 - C Gg of $CO_2$ during the whole time series from 1990 to 2017. During next four years there was downward emissions trend and it reached the level of C Gg $CO_2$ (depletion by 88 %). The lowest level of emissions was estimated in 2009 - about 2 Gg $CO_2$ due to the war. Afterwards the emitted amount of $CO_2$ has increased steadily and at the end of the estimation period it was 86% higher compared to the year of 2009.

The calculated quantities of emitted NMVOCs and $CO_2$ from glass production of Georgia are presented in Table 4-9 and *Table 4-10*.

Table 4-9 $CO_2$ emissions from glass production

[72]The value was calculated based on the data expressed in thousands

| Year | Glass production (t) | EF of glass production (t $CO_2$/t glass) | Cullet (ratio) | CO2 emission (t) | CO2 emission (Gg) |
|---|---|---|---|---|---|
| 1990 | C | 0.21 | NE | C | C |
| 1991 | C | 0.21 | NE | C | C |
| 1992 | C | 0.21 | NE | C | C |
| 1993 | C | 0.21 | NE | C | C |
| 1994 | C | 0.21 | NE | C | C |
| 1995 | C | 0.21 | NE | C | C |
| 1996 | C | 0.21 | NE | C | C |
| 1997 | C | 0.21 | NE | C | C |
| 1998 | C | 0.21 | NE | C | C |
| 1999 | C | 0.21 | NE | C | C |
| 2000 | C | 0.21 | NE | C | C |
| 2001 | C | 0.21 | NE | C | C |
| 2002 | C | 0.21 | NE | C | C |
| 2003 | C | 0.21 | 0.70 | C | C |
| 2004 | C | 0.21 | 0.65 | C | C |
| 2005 | C | 0.21 | 0.65 | C | C |
| 2006 | C | 0.21 | 0.70 | C | C |
| 2007 | C | 0.21 | 0.65 | C | C |
| 2008 | C | 0.21 | 0.70 | C | C |
| 2009 | C | 0.21 | 0.70 | C | C |
| 2010 | C | 0.21 | 0.70 | C | C |
| 2011 | C | 0.21 | 0.65 | C | C |
| 2012 | C | 0.21 | 0.70 | C | C |
| 2013 | C | 0.21 | 0.65 | C | C |
| 2014 | C | 0.21 | 0.65 | C | C |
| 2015 | C | 0.21 | 0.65 | C | C |
| 2016 | C | 0.21 | 0.91 | C | C |
| 2017 | C | 0.21 | 0.91 | C | C |

Table 4-10 NMVOCs emissions from glass production in 1990-2017

| Year | Glass production (Gg) | Emission factor (t NMVOCs /Gg glass) | NMVOCs emissions (t) | NMVOCs emissions (Gg) |
|---|---|---|---|---|
| 1990 | C | NE | NE | C |
| 1991 | C | NE | NE | C |
| 1992 | C | NE | NE | C |
| 1993 | C | NE | NE | C |
| 1994 | C | NE | NE | C |
| 1995 | C | NE | NE | C |
| 1996 | C | NE | NE | C |
| 1997 | C | NE | NE | C |
| 1998 | C | NE | NE | C |
| 1999 | C | NE | NE | C |
| 2000 | C | NE | NE | C |
| 2001 | C | NE | NE | C |
| 2002 | C | NE | NE | C |
| 2003 | C | 4.5 | 177.1 | C |
| 2004 | C | 4.5 | 205.3 | C |
| 2005 | C | 4.5 | 217.3 | C |
| 2006 | C | 4.5 | 191.9 | C |
| 2007 | C | 4.5 | 209.0 | C |
| 2008 | C | 4.5 | 152.7 | C |

| Year | Glass production (Gg) | Emission factor (t NMVOCs /Gg glass) | NMVOCs emissions (t) | NMVOCs emissions (Gg) |
|---|---|---|---|---|
| 2009 | C | 4.5 | 63.3 | C |
| 2010 | C | 4.5 | 85.4 | C |
| 2011 | C | 4.5 | 117.4 | C |
| 2012 | C | 4.5 | 106.7 | C |
| 2013 | C | 4.5 | 130.4 | C |
| 2014 | C | 4.5 | 228.9 | C |
| 2015 | C | 4.5 | 253.6 | C |
| 2016 | C | 4.5 | 304.8 | C |
| 2017 | C | 4.5 | 356.1 | C |

2A7 – Glass Production is not a key source-category regarding $CO_2$ emissions. It has been a key source since 2003. see Table 1-2

***b) Methodological Issues***

- ***Estimation Method***

The IPCC 1996 methodology was used, according to which, only NMVOCs emissions from this sub-sector will be considered. Since 2006 the IPCC methodology also includes the $CO_2$ emissions Three levels are used for the calculation purposes. Based on the Tier 1 approach $CO_2$ emissions are calculated by the following formula:

$$CO_2 Emissions = M_g \times EF \times (1 - CR)$$

Where:

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

Estimation of NMVOCs emission is carried out by multiplying emission factor (tonnes of NMVOCs emitted from glass production) by the number of tonnes of glass produced during the year.

- ***Emission factors***

NMVOCs emission is determined by the weight of melted glass mass. A similar blend composition is mainly used at a plant and the glass is produced using the same technology. The IPCC 1996 Methodology proposes emission coefficient of 4.5 kg of NMVOCs / tonne of produced glass.

The IPCC 2006 methodology provides $CO_2$ emission factor - 0.21 tonne of $CO_2$ / a tonne of glass, which is exactly the same value of the $CO_2$ emission coefficient calculated on the basis of chemical composition of glass blend, used at Ksani plant (a tonne of raw materials produces 0.85 tonne of glass and the mass loss is about 17.85%, so the emission coefficient is 0.17 / 0.85 = 0.21 tonne of $CO_2$ / a tonne of produced glass).

- ***Activity data***

In Georgia, the glass production is run by JSC “Mina” - Ksani glass factory, located in Mtskheta region, in Ksani. Currently the plant uses 4 recipes of blend for green, antique green, blue and light green glass bottle making. Ksani glass factory started its activities in 1987 with 3 furnaces and 8 production lines and its annual capacity was 40 thousand tonnes. during the period of 1992-97 due to the ongoing processes in the country the plant's capacity was reduced to a single oven. In 1997, the Turkish industrial holding "Shishejam" bought the plant’s control package of shares and the plant’s capacity increased up to 18 thousand tonnes. At the end of 2002, the second furnace was launched with 2 production lines and the plant's capacity became 48 thousand tonnes / year. In 2008, the first furnace stopped working due to the lapse of the operational life. Presently the second furnace is operating, and the plant capacity is 35 thousand tonnes / year.

The activity data and the cullet content data was provided by the Ksani Glass Factory for the years of 2003 -2015 (*Table 4-11*).

Table 4-11 The activity data of glass production

| Glass Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 2003 | C | 2008 | C | 2013 | C |
| 2004 | C | 2009 | C | 2014 | C |
| 2005 | C | 2010 | C | 2015 | C |
| 2006 | C | 2011 | C | 2016 | C |
| 2007 | C | 2012 | C | 2017 | C |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The default value of 5% provided in the 2006 IPCC Guidelines was applied for the uncertainty of the emission factor. The default value of 3% provided in the 2006 IPCC Guidelines was applied for the uncertainty of activity data. As a result, the uncertainty for emissions was estimated as 6%.

- ***Time-series consistency***

Georgia applies for tier 1 method for estimation of GHG emissions from glass production. Glass production data has been delivered by the factory for the period of 2003 to 2017. To keep time-series consistency, as the activity data at the factory level is only available since 2003, $CO_2$ emissions from glass production between 1990 and 2002 were estimated by using overlap method. The bottle consumption data series have been applied as previously used method for estimation of emissions from glass production between 1990 and 2003.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Recalculations have not been applied for this submission.

### *f) Category-specific Planned Improvements*

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: "Georgia's Integrated Transparency Framework for Implementation of Paris Agreement".

#### 4.2.4. Other process uses of carbonates (2.A.4.)

##### 4.2.4.1. Ceramics (2.A.4.a)

The ceramic production is the only one from this source category, carried out in Georgia; this production is characterized as carbon free process in accordance to the laboratory analysis provided by the plant.

##### 4.2.4.2. Other uses of soda ash (2.A.4.b)

This source category does not exist in Georgia.

##### 4.2.4.3. Non-metallurgical magnesium production (2.A.4.c)

This source category does not exist in Georgia.

##### 4.2.4.4. Other (2.A.4.d)

This source category does not exist in Georgia.

### 4.3. Chemical Industry (2.B.)

The Sub-sector of the chemical industry in Georgia considers emissions from the Ammonia Production (2.B.1) and Nitric Acid Production (2.B.2) source-categories. In 2017 the GHG emissions from the sub-sector of the chemical industry amounted to 32% of the total emissions from the Industrial Processes and Product use.

The highest emissions from the sub-sector of chemical industry was estimated in 2015 - about C Gg of $CO_2$ eq., mainly caused by performance improvement in both production lines. In 2016 the emissions declined by 19% followed by 10% increase in 2017. The emissions value at the end of the estimation period was 4.65% higher than the value estimated in 1990 (C Gg-$CO_2$ eq.). 1996, 2000 and 2007 were also peaking years of emissions. The emissions from the sub-sector have significantly declined since 1990 during next four years. Although the production processes of both chemicals have been reduced, the steep depletion of the GHG emission is mainly related to the sharp cut of number of ammonia customers. Seeking new markets for chemical industries has taken more than a decade. The transformation period was characterized with a few crises in economic development translated into the lowest level of GHG emissions from the sub-sector. The collapse of socialism system has caused the reduction of production of chemical goods more than twice. In 1994 the emissions dropped by 62% compared to the 1990 level. In 2001 the emissions reached its lowest level for the whole time series period - C Gg-$CO_2$ eq. (only 33% of 1990 level). The emissions declined from 2008 to 2010 due to the economic crisis in the industry market. The emissions increased between 2010 and 2015 period by approximately 15%. The largest upturn was recorded in 2011 from C Gg to C Gg- $CO_2$ eq. Later, the emissions slightly declined (by 1.6%) due to the decrease in production of nitric acid. At the end of the period the emissions increased again by 6% compared to the value calculated for the year of 2014. The emissions trend is illustrated in the

*Figure* 4-2 GHG Emissions from Chemical Industry

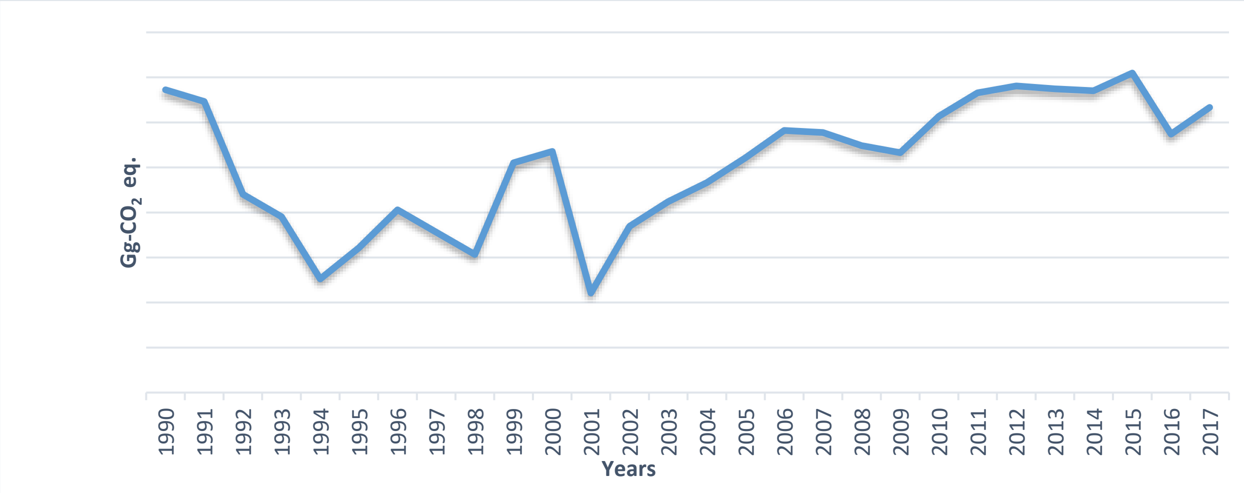
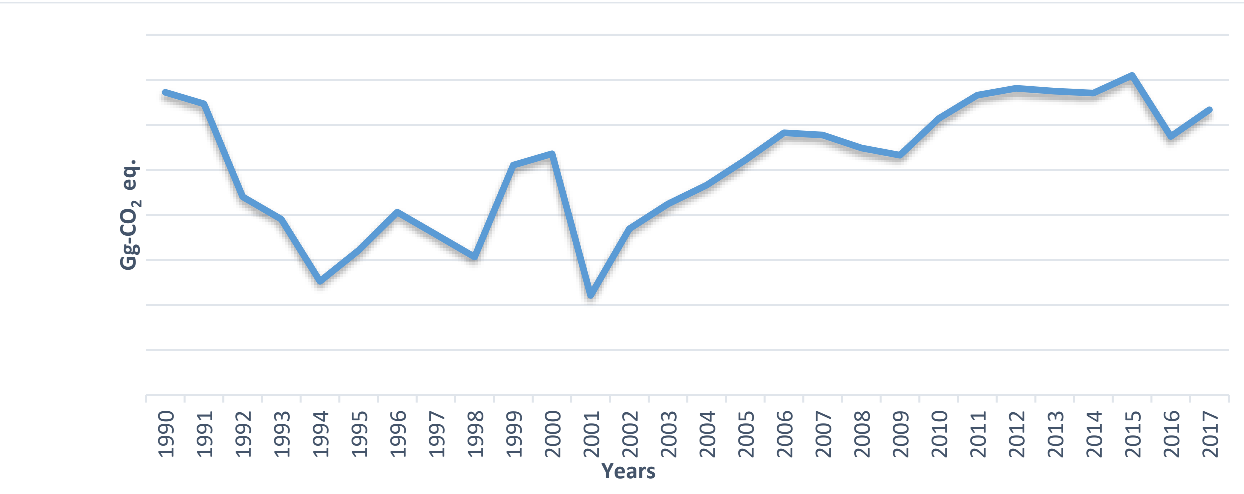



figure beneath.

*Figure 4-2 GHG Emissions from Chemical Industry*




### 4.3.1. Ammonia Production (2.B.1.)

#### *a) Source-category description and calculated emissions*

In ammonia production, $CO_2$ is emitted when hydrocarbon feedstock is broken down for producing $H_2$.

Most of the ammonia in Georgia is produced through the Haber-Bosch process called a synthesis of ammonia: nitrogen and hydrogen enter into a reaction. The required hydrogen is a product of natural gas conversion.

Ammonia is obtained at 25-29 MPa pressure and 470-550° C temperature from nitrogen and hydrogen mixture with iron catalyst in place.

The carbon dioxide resulted from the production of ammonia has been used for obtaining the dry ice. Taking into account the fact that the solid carbon dioxide almost immediately coverts into atmosphere gas after dry ice is used, the intermediate retention of $CO_2$ in products and production processes will not be considered.

In 2015 the emissions were about C Gg $CO_2$, the highest value since 1991. In 2016 the emissions declined by 17 % followed by 7 % increase in 2017. In 2014 the emissions slightly dropped (by 0.87 per cent)[73] - from C Gg $CO_2$ to C Gg $CO_2$. The highest emissions were estimated in 1990 - about C Gg $CO_2$. During next four years the emissions trend was descending and it reached the level of C Gg $CO_2$ (depletion by 60.38%). During the first decade after the restitution of independence of Georgia there were two more times when the production levels reached their minimum due to the economic crisis. In 1998 the emissions dropped by 56% (C Gg $CO_2$) compared to the 1990 level and in 2001 the emission level was reduced by 69% compared to the 1990 emission estimation. The emissions declined by 12%[74] since 2007 for two years mainly due to the economic crisis in the international market. The emissions have increased from C Gg $CO_2$ (in 2009) up to C (in 2015) by 33%.

Table 4-12 $CO_2$ emissions from the ammonia production calculated on the basis of products quantity in 1990-2017

| Year | Total natural gas requirement (Gj) | Carbon content factor of the natural gas (kg C/GJ) | carbon oxidation factor of the natural gas (fraction) | $CO_2$ recovered for downstream use (kg) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|
| 1990 | C | 143,120,974 | 1[75] | 1 | C |
| 1991 | C | 136,052,006 | 1 | 1 | C |
| 1992 | C | 92,235,615 | 1 | 1 | C |
| 1993 | C | 78,466,560 | 1 | 1 | C |
| 1994 | C | 56,705,411 | 1 | 1 | C |
| 1995 | C | 71,765,384 | 1 | 1 | C |
| 1996 | C | 84,481,522 | 1 | 1 | C |
| 1997 | C | 73,644,584 | 1 | 1 | C |
| 1998 | C | 62,807,646 | 0.9981 | 1 | C |
| 1999 | C | 103,072,457 | 0.9963 | 1 | C |
| 2000 | C | 108,739,284 | 0.9916 | 1 | C |
| 2001 | C | 45,199,898 | 0.9970 | 1 | C |
| 2002 | C | 69,148,138 | 0.9981 | 1 | C |
| 2003 | C | 80,822,499 | 0.9984 | 1 | C |
| 2004 | C | 89,538,650 | 0.9964 | 1 | C |
| 2005 | C | 97,726,551 | 0.9956 | 1 | C |
| 2006 | C | 107,393,555 | 0.9966 | 1 | C |
| 2007 | C | 107,067,960 | 0.9900 | 1 | C |
| 2008 | C | 98,510,924 | 0.9915 | 1 | C |
| 2009 | C | 94,366,870 | 0.9834 | 1 | C |
| 2010 | C | 108,253,165 | 0.9837 | 1 | C |
| 2011 | C | 117,287,868 | 0.9842 | 1 | C |
| 2012 | C | 120,595,044 | 0.9970 | 1 | C |
| 2013 | C | 118,539,665 | 0.9903 | 1 | C |
| 2014 | C | 119,054,086 | 0.9774 | 1 | C |
| 2015 | C | 124,961,924 | 0.9866 | 1 | C |
| 2016 | C | 104,058,266 | 0.9830 | 1 | C |
| 2017 | C | 111,947,336 | 0.9850 | 1 | C |

The value was calculated based on the data expressed in thousands

[74]The comparison of the emission levels between the years of 2007 and 2009.
[75]The default data is used due to the absence of the factory specific data

Table 4-13 NMVOCs, CO and $SO_2$ reflects emissions from ammonia production calculated for 2010-2011 years period.

Table 4-13 NMVOCs, CO and $SO_2$ emissions from ammonia production in 1990-2017

| Year | Quantity of Ammonia Produced (t) | Emission Factor (Kg pollutant/t Ammonia produced) | NMVOC (Gg) | CO (Gg) | $SO_2$ (Gg) |
|---|---|---|---|---|---|
| 1990 | C | 4.7, 7.9, 0.03 | 0.94 | 1.58 | C |
| 1991 | C | 4.7, 7.9, 0.03 | 0.88 | 1.48 | C |
| 1992 | C | 4.7, 7.9, 0.03 | 0.50 | 0.85 | C |
| 1993 | C | 4.7, 7.9, 0.03 | 0.47 | 0.79 | C |
| 1994 | C | 4.7, 7.9, 0.03 | 0.25 | 0.42 | C |
| 1995 | C | 4.7, 7.9, 0.03 | 0.30 | 0.50 | C |
| 1996 | C | 4.7, 7.9, 0.03 | 0.44 | 0.74 | C |
| 1997 | C | 4.7, 7.9, 0.03 | NE | NE | C |
| 1998 | C | 4.7, 7.9, 0.03 | 0.36 | 0.61 | C |
| 1999 | C | 4.7, 7.9, 0.03 | 0.60 | 1.00 | C |
| 2000 | C | 4.7, 7.9, 0.03 | 0.64 | 1.08 | C |
| 2001 | C | 4.7, 7.9, 0.03 | 0.27 | 0.46 | C |
| 2002 | C | 4.7, 7.9, 0.03 | 0.52 | 0.88 | C |
| 2003 | C | 4.7, 7.9, 0.03 | 0.58 | 0.98 | C |
| 2004 | C | 4.7, 7.9, 0.03 | 0.62 | 1.04 | C |
| 2005 | C | 4.7, 7.9, 0.03 | 0.72 | 1.20 | C |
| 2006 | C | 4.7, 7.9, 0.03 | 0.81 | 1.36 | C |
| 2007 | C | 4.7, 7.9, 0.03 | 0.83 | 1.40 | C |
| 2008 | C | 4.7, 7.9, 0.03 | 0.87 | 1.46 | C |
| 2009 | C | 4.7, 7.9, 0.03 | 0.81 | 1.36 | C |
| 2010 | C | 4.7, 7.9, 0.03 | 0.94 | 1.58 | C |
| 2011 | C | 4.7, 7.9, 0.03 | 1.03 | 1.74 | C |
| 2012 | C | 4.7, 7.9, 0.03 | 1.04 | 1.75 | C |
| 2013 | C | 4.7, 7.9, 0.03 | 1.04 | 1.74 | C |
| 2014 | C | 4.7, 7.9, 0.03 | 1.04 | 1.74 | C |
| 2015 | C | 4.7, 7.9, 0.03 | 1.10 | 1.85 | C |
| 2016 | C | 4.7, 7.9, 0.03 | 0.86 | 1.45 | C |
| 2017 | C | 4.7, 7.9, 0.03 | 0.99 | 1.66 | C |

### b) *Methodological Issues*

- ***Estimation Method***

The Tier 2 approach of the IPCC 2006 guideline was used for the calculation of the emissions from the Ammonia Production source-category. The approach is based on the factory specific data from ammonia production process.

- ***Emission factors***

The carbon content factor recommended by the IPCC 2006 is 15.3 kg of carbon per Gj of used natural gas. The carbon oxidation factor of natural gas has been provided by the Plant for the years of 1996, 1998-2015. The default value[76] has been applied for other years as recommended by the IPCC 2006. Other gases, such as NOx, NMVOCs, CO and $SO_2$. Are also emitted into the atmosphere as a result of ammonia production. These emissions are calculated using default emission factors proposed in the IPCC 1996 methodology. Emission coefficients of trace admixtures applied are given in *Table 4-14*.

[76]2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, Chapter 3: Chemical Industry Emissions, p.3.15, Table 3.1)

Table 4-14 Emission coefficients of trace admixtures emitted from ammonia production[77]
(kg of gas / tonne of ammonia)

| Gases emitted | NMNMVOCs | CO | $SO_2$ |
|---|---|---|---|
| EF | 4.7 | 7.9 | 0.03 |

- ***Activity data***

Natural gas consumption data are obtained from Ammonia producing plant in Rustavi - "Azoti." The performance of ammonia production factory in 1990-2015 years period is given in *Table 4-15*.

Table 4-15 Ammonia production data

| Natural Gas in Ammonia Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (Million $m^3$)** | **Year** | **Activity Data (Million $m^3$)** | **Year** | **Activity Data (Million $m^3$)** |
| 1990 | C | 2000 | C | 2010 | C |
| 1991 | C | 2001 | C | 2011 | C |
| 1992 | C | 2002 | C | 2012 | C |
| 1993 | C | 2003 | C | 2013 | C |
| 1994 | C | 2004 | C | 2014 | C |
| 1995 | C | 2005 | C | 2015 | C |
| 1996 | C | 2006 | C | 2016 | C |
| 1997 | C | 2007 | C | 2017 | C |
| 1998 | C | 2008 | C | | |
| 1999 | C | 2009 | C | | |

- ***Point to Note***

Fuel consumption in this category has been deducted from energy sector activity data (see Chapter 3).

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

The uncertainty of each fuel was estimated. For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence interval for the carbon emission factors were applied. For the uncertainty of the activity data, the same values were applied as in fuel combustion. As a result, the uncertainty of emissions is  the following: natural gas -1 - +1%.

- ***Time-series Consistency***

For activity data, the same sources were used throughout the time series. The factory has provided activity data since 1990. The factory level data was not available for the year of 1997. To provide time-series consistency the interpolation method has been applied for recovery of the data in 1997. Therefore, $CO_2$ emission from ammonia production has been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

[77] http://www.ipcc-nggip.iges.or.jp/public/gl/invs5b.html (page 2.14, Table 2.4)

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvements***

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: “Georgia’s Integrated Transparency Framework for Implementation of Paris Agreement”.

### 4.3.2. Nitric Acid Production (2.B.2.)

***a) Source-category description and calculated emissions***

$N_2O$ is emitted when nitric acid ($HNO_3$) is produced from ammonia.

Nitric acid ($HNO_3$) is produced as a result of catalytic oxidation of ammonia with an oxygen of air at high temperature. During this process nitrous oxide ($N_2O$) and nitrogen oxides (NOx-s) are produced as indirect products. The indirect gases absorbed by the vapor condensate[78]. The quantity of emitted gases is proportional to the quantity of consumed ammonia. Their concentration in exhaust gases depends on a type of plant’s technology and a level of emissions control.

In 2014 the emissions were about C Gg $CO_2$ - one of the high values for the recent five years. The highest emission from the Nitric Acid Production in Georgia during the whole time series from 1990 to 2017 was estimated for the year of 2015 - 5%[79] higher than in the previous year (C Gg $CO_2$). In 2016 the emissions declined by 22% followed by 13% increase in 2017. The emissions estimated for the year of 1990 (C Gg $CO_2$) were about 43% lower compared to 2015. During three years after 1991 the emissions trend was descending, and it reached the level of 45 Gg $CO_2$ (depletion by 70%). During the two decades since the restitution of independence of Georgia the emissions dropped by 2.5 times compared to the 2000 level mainly due to the economic instability in the country. In 2010 the increase of the emissions from the Nitric Acid production was about 14% compared to the 2009 level. After this significant effect of emissions enlargement related to improvement of the factory performance the emissions upward trend steadily continued to grow and in 2015 the emissions level was 14% higher compared to the level of 2010.

Considering the available statistical data and above assumptions the calculated of nitrogen oxide emissions are given in *Table 4-16.*

Table 4-16 Nitrogen oxides emissions from nitric acid production in 1990-2017

| Year | Quantity of Nitric Acid Produced (t) | Emission Factor (kg $N_2O$/t Nitric Acid produced) | $N_2O$ Emitted (Gg) | $CO_2$ eq. Emitted (Gg) | Emission Factor (kg $N_2O$/t Nitric Acid produced) | NOx (Gg) |
|---|---|---|---|---|---|---|
| 1990 | C | 2 | C | C | 12 | C |
| 1991 | C | 2 | C | C | 12 | C |
| 1992 | C | 2 | C | C | 12 | C |
| 1993 | C | 2 | C | C | 12 | C |
| 1994 | C | 2 | C | C | 12 | C |
| 1995 | C | 2 | C | C | 12 | C |
| 1996 | C | 2 | C | C | 12 | C |

[78] Factory technology description paper.

[79] The value was calculated based on the data expressed in thousands

| Year | Quantity of Nitric Acid Produced (t) | Emission Factor (kg $N_2O$/t Nitric Acid produced) | $N_2O$ Emitted (Gg) | $CO_2$ eq. Emitted (Gg) | Emission Factor (kg $N_2O$/t Nitric Acid produced) | $NO_X$ (Gg) |
|---|---|---|---|---|---|---|
| 1997 | C | 2 | C | C | 12 | C |
| 1998 | C | 2 | C | C | 12 | C |
| 1999 | C | 2 | C | C | 12 | C |
| 2000 | C | 2 | C | C | 12 | C |
| 2001 | C | 2 | C | C | 12 | C |
| 2002 | C | 2 | C | C | 12 | C |
| 2003 | C | 2 | C | C | 12 | C |
| 2004 | C | 2 | C | C | 12 | C |
| 2005 | C | 2 | C | C | 12 | C |
| 2006 | C | 2 | C | C | 12 | C |
| 2007 | C | 2 | C | C | 12 | C |
| 2008 | C | 2 | C | C | 12 | C |
| 2009 | C | 2 | C | C | 12 | C |
| 2010 | C | 2 | C | C | 12 | C |
| 2011 | C | 2 | C | C | 12 | C |
| 2012 | C | 2 | C | C | 12 | C |
| 2013 | C | 2 | C | C | 12 | C |
| 2014 | C | 2 | C | C | 12 | C |
| 2015 | C | 2 | C | C | 12 | C |
| 2016 | C | 2 | C | C | 12 | C |
| 2017 | C | 2 | C | C | 12 | C |

2B2 – Nitric Acid Production is a key source-category with regard to $CO_2$ eq. emissions. see Table 1-2

### b) *Methodological Issues*

- ***Estimation Method***

The tier 1 methodology is used for calculation of emissions from the source-category of nitric acid production, since the activity data cover the amount of nitric acid produced per annum, in accordance with the IPCC 2006 Guideline.

- ***Emission factors***

According to the IPCC 2006[80] for factories with Non-Selective Catalytic Reduction (NSCR) technology the emission coefficient for nitrous oxide ($N_2O$) is equal to 2 kg of $N_2O$ / tonne of $HNO_3$. The estimation presented in First BUR considered emission factor of 6.75 kg of $N_2O$ / tonne of $HNO_3$ calculated as an average of medium pressure production default emission factors. The change of emission factor is caused by the technology line description provided by the factory. The Rustavi synthetic fertilizer's plant uses the NSCR technology for abatement of the nitrogen oxides ($NO_x$). The $N_2O$ is further removed in this catalyst bed.

- ***Activity data***

The source of Nitric acid production data is nitric acid production - Rustavi synthetic fertilizer's plant. The so-called weak nitric acid is produced by catalytic oxidation of ammonia with oxygen from the air, followed by the absorption of oxides generated with water vapor at medium pressure.

[80] http://www.ipcc-nggip.iges.or.jp/public/gl/invs5b.html (page 2.16, Table 2.5 and 2.6)

Table 4-17. Nitric acid production data

| Nitric Acid Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 1990 | C | 2000 | C | 2010 | C |
| 1991 | C | 2001 | C | 2011 | C |
| 1992 | C | 2002 | C | 2012 | C |
| 1993 | C | 2003 | C | 2013 | C |
| 1994 | C | 2004 | C | 2014 | C |
| 1995 | C | 2005 | C | 2015 | C |
| 1996 | C | 2006 | C | 2016 | C |
| 1997 | C | 2007 | C | 2017 | C |
| 1998 | C | 2008 | C | | |
| 1999 | C | 2009 | C | | |

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

As for the uncertainty of the emission factor, the standard deviation was calculated from the emission factors and production amounts and was assessed to be 73%. For the uncertainty of activity data, the default value of 2%, provided by the 2006 IPCC Guidelines was applied. As a result, the uncertainty of emissions was estimated as 73%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The factory has provided activity data since 1990. The factory level data was not available for the year of 1997. to provide time-series consistency the interpolation method has been applied for recovery of the data in 1997. Therefore, $CO_2$ emission from nitric acid production has been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvements***

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: “Georgia’s Integrated Transparency Framework for Implementation of Paris Agreement”.

### 4.3.3. Adipic Acid Production (2.B.3.)

This source category does not exist in Georgia.

### 4.3.4. Caprolactam, glyoxal and glyoxylic acid production (2.B.4.)

This source category does not exist in Georgia.

#### 4.3.4.1. Caprolactam Production (2.B.4.a)

This source category does not exist in Georgia.

#### 4.3.4.2. Caprolactam Production (2.B.4.a)

This source category does not exist in Georgia.

#### 4.3.4.3. Glyoxylic acid Production (2.B.4.c)

This source category does not exist in Georgia.

### 4.3.5. Carbide Production (2.B.5.)

This source category does not exist in Georgia.

#### 4.3.5.1. Silicon Carbide Production (2.B.5.a)

This source category does not exist in Georgia.

#### 4.3.5.2. Calcium Carbide Production and Use (2.B.5.b)

This source category does not exist in Georgia.

### 4.3.6. Calcium Carbide Production and Use (2.B.5.b)

This source category does not exist in Georgia.

### 4.3.7. Soda Ash Production (2.B.7.)

This source category does not exist in Georgia.

### 4.3.8. Petrochemical and Carbon Black Production (2.B.8.)

This source category does not exist in Georgia.

#### 4.3.8.1. Methanol Production (2.B.8.a)

This source category does not exist in Georgia.

#### 4.3.8.2. Ethylene Production (2.B.8.b)

This source category does not exist in Georgia.

#### 4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c)

This source category does not exist in Georgia.

#### 4.3.8.4. Ethylene oxide Production (2.B.8.d)

This source category does not exist in Georgia.

#### 4.3.8.5. Acrylonitrile Production (2.B.8.e)

This source category does not exist in Georgia.

#### 4.3.8.6. Carbon Black Production (2.B.8.f)

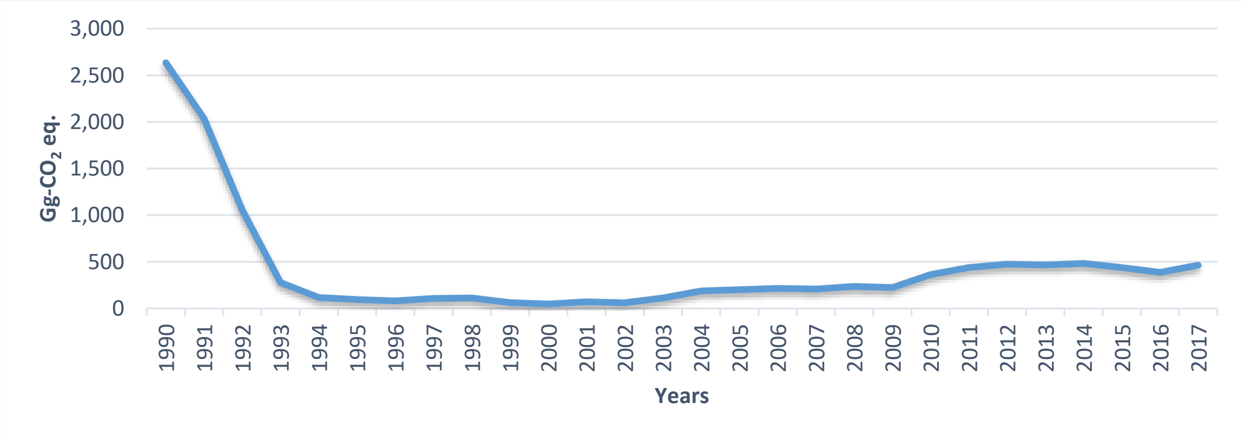
This source category does not exist in Georgia.

## 4.4. Metal Industry (2.C.)

The sub-sector of the metal production covers steel (2.C.1) and ferroalloys (2.C.2) processing in Georgia. In 2017 the GHG emissions from the sub-sector of the metal production was 23% of total emissions from the Industrial Processes and Product use.

The emissions from the ferroalloys production are about 26 times higher than the emissions from the steel production. The significant difference in produced emissions between the source-categories mostly relates to the technology used in steel production. In Georgia, the steel manufacturing uses Electric Arc Furnace characterized as low emitter. By contrast, the steel production was the biggest contributor in GHG emissions in 90's. Accordingly, since 2000 the emission trend for the Metal Production sub-sector was mostly maintained by the ferroalloys production source-category, while the steel production was the leader in the past. The trend is illustrated in the *Figure 4-3* beneath.

*Figure 4-3 The emission trend from the metal production*




The highest emissions from the sub-sector of metal production was estimated in 1990 and was about 2635 Gg- $CO_2$ eq.; it was mainly caused by performance improvement in both production lines. The emissions value at the end of the estimation period was 83% lower compare to the value estimated in 1990. The emissions from the sub-sector significantly declined for four years following 1990. Although the production processes of both types of metal industry have been reduced, the steep depletion of the GHG emission mainly relates to the termination of the sinter and cast-iron productions. The transformation period was characterized with a crisis in economic development translated into the lowest level of GHG emissions from the sub-sector for the period between 1996 and 2003. The collapse of socialist system has caused the reduction of production of steel goods more than nineteen times. In 1996 the emissions dropped by 97% compared to the 1990 level. In 2000 the emissions reached its lowest level for the whole time series period - 46 Gg-$CO_2$ eq. (only 1.7% of 1990 level). The emissions increased between 2002 and 2006 by approximately 72%. The largest upturn was recorded in 2009-2012 - from 224 Gg to 473 Gg-$CO_2$ eq. At the end of the period the emissions slightly declined (by 9%) compared to the value calculated for the year of 2014. In 2016 the emissions declined by 12% compared to the previous year followed by 17% increase in 2017.The emissions trend is illustrated in the *Figure 4-3* above.

### 4.4.1. Iron and Steel Production (2.C.1.)

Currently, the Steel production is carried out by two major factories - LTD Georgia Rustavi Steel and Geosteel using Electric Arc Furnace. In the recent past the steel was produced by the only metallurgical factory in Georgia - LTD Georgia Rustavi Steel. In 1990 the several technological lines were operated in the factory, particularly it had a sinter production, pig iron production and steel production via marten kiln lines. In 1993 the pig iron production was terminated. The sinter production was closed in the following year. The use of marten kilns was terminated in 1999. During 2000 - 2010 years period the factory produced steel by melting the cast iron, which is not characterized by the industrial GHG emissions.

Since 2010 the steel production through the EAF was launched by Geosteel and two years later the Rustavi Steel joined it. During the recent few years, the trend was characterized by the significantly low emissions compared to the emissions related to the years of 1990-1992.

In 2017 the emissions were about C Gg $CO_2$ - the highest value for the recent eight years. It has increased by 90 per cent[81] compared to the value of the year of 2010. The emission had an upward trend between 2010- and 2017-years period. The highest emissions from the Cast Iron and Steel production in Georgia were estimated in 1990 - C Gg of $CO_2$ during the whole time series from 1990 to 2017. Following nine years the emissions trend was descending and it reached the level of 0 Gg $CO_2$ in 2000. The emission in 2017 was C times lower than it used to be in 1990.

#### 4.4.1.1. Steel Production (2.C.1.a)

#### 4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a)

***a) Source-category description and calculated emissions***

"In a majority of scrap charged EAF, $CO_2$ emissions are mainly associated with consumption of the carbon electrodes. All carbon used in EAFs and other steelmaking processes should be considered process related IPPU emissions"[82].

In 2017 the emissions were about C Gg $CO_2$ - the highest value for the recent eight years. It increased by 90%[83] compared to the value of the year 2010. The emission had an upward trend between 2010- and 2017-years period. The highest emissions from the Cast Iron and Steel production in Georgia were estimated in 1990 - C Gg of $CO_2$ during the whole time series from 1990 to 2017. Following nine years the emissions trend was descending and it reached the level of 0 Gg $CO_2$ in 2000. The emission in 2017 was C times lower than it used to be in 1990.

The emissions calculated, based on statistical data provided in this subsector and on the emission coefficients provided in the methodological instructions of the IPCC 2006 Guidelines, are presented in the Table *4-21*, Table *4-22*, Table *4-23*, Table *4-24*.

[81] The value was calculated based on the data expressed in thousands
[82] 2006 IPCC Guidelines Volume 3, Chapter 4 Metal Industry, p. 4.12
[83] The value was calculated based on the data expressed in thousands

Table 4-18 $CO_2$ emissions from the steel production by EAF in 1990 - 2017

| Year | Amount of Steel Produced (Gg) | Amount of Coke input (Gg) | Amount of natural gas input (Pj) | Amount of limestone input (Gg) | Amount of Heavy oil input (Gg) | Amount of Graphite input (Gg) | Amount of Ferrosilicon input (Gg) | Amount of Silicomanganum input (Gg) | Amount of Sinter input (Gg) | Amount of Pig Iron input (Gg) | Amount of Rust input (Gg) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | C | 338.4 | 3,537.4 | 139.4 | 155.6 | 1.95 | 3.89 | 12.96 | 1,134.4 | NO | 648.2 | C |
| 1991 | C | 249.9 | 2,613.0 | 103.0 | 144.9 | 1.44 | 2.87 | 9.58 | 837.9 | NO | 478.8 | C |
| 1992 | C | 137.4 | 1,449.2 | 56.6 | 63.2 | 0.79 | 1.58 | 5.27 | 460.7 | NO | 26.3 | C |
| 1993 | C | 0.2 | 121.2 | 21.7 | 26.0 | 0.33 | 0.65 | 2.17 | NO | 108.4 | 108.4 | C |
| 1994 | C | 0.1 | 67.2 | 12.0 | 2.4 | 0.18 | 0.36 | 1.19 | NO | 59.9 | 59.9 | C |
| 1995 | C | 0.1 | 49.3 | 8.7 | 10.5 | 0.13 | 0.26 | 0.87 | NO | 43.7 | 43.7 | C |
| 1996 | C | 0.1 | 46.8 | 8.2 | 9.9 | 0.12 | 0.25 | 0.83 | NO | 41.3 | 41.3 | C |
| 1997 | C | 0.1 | 59.3 | 10.4 | 12.5 | 0.16 | 0.31 | 0.10 | NO | 52.1 | 52.1 | C |
| 1998 | C | 0.01 | 32.2 | 5.6 | 6.8 | 0.09 | 0.17 | 0.56 | NO | 28.2 | 28.2 | C |
| 1999 | C | 0.084 | 4.0 | 0.7 | 0.8 | 0.01 | 0.02 | 0.07 | NO | 3.5 | 3.5 | C |
| 2000 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2001 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2002 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2003 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2004 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2005 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2006 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2007 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2008 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2009 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2010 | C | 0.62 | NO | 0.2 | 0.10 | NO | 0.36 | 106.24 | 2.12 | NO | NO | NO |
| 2011 | C | 2.99 | NO | 0.5 | 0.57 | NO | 0.70 | 134.47 | 1.04 | NO | NO | NO |

[84] 0.007

| Year | Amount of Steel Produced (Gg) | Amount of Coke input (Gg) | Amount of natural gas input (Pj) | Amount of limestone input (Gg) | Amount of Heavy oil input (Gg) | Amount of Graphite input (Gg) | Amount of Ferrosilicon input (Gg) | Amount of Silicomanganum input (Gg) | Amount of Sinter input (Gg) | Amount of Pig Iron input (Gg) | Amount of Rust input (Gg) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | C | 3.63 | NO | 0.8 | 2.13 | 0.03 | 0.78 | 159.88 | 1.45 | 2.0 | 3.0 | C |
| 2013 | C | 4.57 | NO | 1.1 | 0.92 | 0.13 | 1.22 | 177.85 | 2.60 | 5.6 | 15.9 | C |
| 2014 | C | 6.11 | NO | 1.4 | 1.00 | 0.20 | 1.48 | 204.73 | 2.40 | 8.0 | 24.1 | C |
| 2015 | C | 7.38 | NO | 1.6 | 1.56 | 0.26 | 1.77 | 228.78 | 2.65 | 10.3 | 31.8 | C |
| 2016 | C | 8.61 | NO | 1.9 | 1.37 | 0.28 | 2.01 | 252.59 | 2.77 | 10.9 | 33.8 | C |
| 2017 | C | 9.82 | NO | 2.2 | 1.50 | 0.28 | 2.23 | 276.46 | 2.85 | 9.5 | 33.8 | C |

***b) Methodological Issues***

- ***Estimation Method***

The Tier 2 approach of the IPCC 2006 Guideline is applied; the approach calculates the emissions by multiplication of the quantity of process inputs and outputs for steel making via EAF.

$$E_{CO2} = [PC \times C_{PC} + NG \times C_{NG} + L \times C_L + HO \times C_{HO} + G \times C_G + F \times C_F + SM \times C_{SM} + S \times C_S + PI \times C_{PI} + R \times C_R - St \times C_{St}] \times \frac{44}{12}$$

Where:

$E_{CO2}$ = Emissions from the steel production via EAF
$PC$ = Quantity of coke used for steel production
$C_{PC}$ = Carbon content in the consumed coke
$NG$ = Quantity of natural gas used for steel production
$C_{NG}$ = Carbon content in the consumed natural gas
$L$ = Quantity of limestone used for steel production
$C_L$ = Carbon content in the consumed limestone
$HO$ = Quantity of heavy oil used for steel production
$C_{HO}$ = Carbon content in the consumed heavy oil
$G$ = Quantity of graphite used for steel production
$C_G$ = Carbon content in the consumed graphite
$F$ = Quantity of ferrosilicon used for steel production
$C_F$ = Carbon content in the consumed ferrosilicon
$SM$ = Quantity of silicomanganese used for steel production
$C_{SM}$ = Carbon content in the consumed silicomanganese
$S$ = Quantity of sinter used for steel production
$C_S$ = Carbon content in the consumed sinter
$PI$ = Quantity of pig iron used for steel production
$C_{PI}$ = Carbon content in the consumed pig iron
$R$ = Quantity of rust used for steel production
$C_R$ = Carbon content in the consumed rust
$St$ = Quantity of steel produced through the EAF
$C_{St}$ = Carbon content in the produced steel

- ***Emission factors***

The process inputs and outputs carbon content data for the steel production have been obtained from the factories.

- ***Activity Data***

The factories: LTD Georgia Rustavi Steel and Geosteel are the sources for the steel production data (*Table 4-19*).

Table 4-19. Steel production data

| Steel Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 1990 | C | 2000 | C | 2010 | C |
| 1991 | C | 2001 | C | 2011 | C |
| 1992 | C | 2002 | C | 2012 | C |
| 1993 | C | 2003 | C | 2013 | C |
| 1994 | C | 2004 | C | 2014 | C |
| 1995 | C | 2005 | C | 2015 | C |
| 1996 | C | 2006 | C | 2016 | C |
| 1997 | C | 2007 | C | 2017 | C |
| 1998 | C | 2008 | C | | |
| 1999 | C | 2009 | C | | |

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

The factory specific values were applied for the uncertainty of the $CO_2$ emission factor and activity data for steel production. As a result, the uncertainty of emissions was estimated to be 4%.

- ***Time-series Consistency***

Emissions throughout the time series are consistently estimated using the activity data provided by the factories.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvements***

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: “Georgia’s Integrated Transparency Framework for Implementation of Paris Agreement”.

#### 4.4.1.3. Pig Iron Production (2.C.1.b)

This source category does not exist in Georgia.

#### 4.4.1.4. Direct reduced iron production (2.C.1.c)

This source category does not exist in Georgia.

#### 4.4.1.5. Sinter Production (2.C.1.d)

In 1990 the emissions were about C Gg $CO_2$ the highest value for the four years period. The emissions declined steadily and in 1995 the sinter production was terminated in Georgia.

This source category does not exist in Georgia.

Table 4-20 $CO_2$ emissions from the sinter production in 1990 - 2017

| Year | Amount of Sinter Produced (t) | EF ($CH_4$ kg/t Sinter) | $CH_4$ Emissions (t) | $CH_4$ Emissions (Gg) | $CO_2$ eq. Emissions (Gg) |
|---|---|---|---|---|---|
| 1990 | C | 0.07 | C | C | C |
| 1991 | C | 0.07 | C | C | C |
| 1992 | C | 0.07 | C | C | C |
| 1993 | C | 0.07 | C | C | C |
| 1994 | C | 0.07 | C | C | C |
| 1995 | NA | NA | NA | NA | NA |
| 1996 | NA | NA | NA | NA | NA |
| 1997 | NA | NA | NA | NA | NA |
| 1998 | NA | NA | NA | NA | NA |
| 1999 | NA | NA | NA | NA | NA |
| 2000 | NA | NA | NA | NA | NA |
| 2001 | NA | NA | NA | NA | NA |
| 2002 | NA | NA | NA | NA | NA |
| 2003 | NA | NA | NA | NA | NA |
| 2004 | NA | NA | NA | NA | NA |
| 2005 | NA | NA | NA | NA | NA |
| 2006 | NA | NA | NA | NA | NA |
| 2007 | NA | NA | NA | NA | NA |
| 2008 | NA | NA | NA | NA | NA |
| 2009 | NA | NA | NA | NA | NA |
| 2010 | NA | NA | NA | NA | NA |
| 2011 | NA | NA | NA | NA | NA |
| 2012 | NA | NA | NA | NA | NA |
| 2013 | NA | NA | NA | NA | NA |
| 2014 | NA | NA | NA | NA | NA |
| 2015 | NA | NA | NA | NA | NA |
| 2016 | NA | NA | NA | NA | NA |
| 2017 | NA | NA | NA | NA | NA |

#### 4.4.1.6. Pellet Production (2.C.1.e)

This source category does not exist in Georgia.

### 4.4.2. Ferroalloys Production (2.C.2.)

***a) Source-category description and calculated emissions***

The ferroalloy plants produce the enriched alloys that are transmitted to the steel producing plants for manufacturing steel alloy. Ferroalloys production includes the metallurgical reduction process that causes significant emission of $CO_2$ and minor emission of $CH_4$. The ferroalloys including Ferro silicomanganese, Ferrosilicon, and Ferromanganese are produced by several plants in Georgia. The dominant product is silicomanganese - with about 82% share, followed by ferrosilicon - with 14% share and ferromanganese - with 4 per cent share.

In 2015 the emissions were about 405 Gg $CO_2$ eq. - the lowest value for the recent five years. It slightly declined (by 11 per cent)[85] compared to the value of 2014. In 2016 the emissions declined by 14 % followed by 18 % increase in 2017. The emission had a fluctuating trend between 2011 and 2017 period. The highest emissions from the ferroalloys production in Georgia during the whole time series from 1990 to 2017 were estimated in 2012 - 457 Gg of $CO_2$ eq. At the beginning of the period the emission was 74 % lower than in 2017. During the following six years the emissions trend was descending and it reached the level of 25 Gg $CO_2$ eq. in 1996, the minimum level of emissions for the whole estimating period.

The emissions calculated based on statistical data provided in this subsector and on the emission coefficients provided in the methodological instructions of the IPCC 2006 Guidelines, are presented in the Table *4-21*, Table *4-22*, Table *4-23*, Table *4-24*.

Table 4-21 $CO_2$ emissions (Gg) from production of the Ferro silicomanganese in 1990-2017

| Year | Amount of Ferrosilicomanganese Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) | Year | Amount of Ferrosilicomanganese Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 67,363 | 1.4 | 94,308 | 94.31 | 2004 | 88,062 | 1.4 | 123,286 | 123.29 |
| 1991 | 45,595 | 1.4 | 63,833 | 63.83 | 2005 | 94,430 | 1.4 | 132,201 | 132.20 |
| 1992 | 20,529 | 1.4 | 28,741 | 28.74 | 2006 | 100,797 | 1.4 | 141,116 | 141.12 |
| 1993 | 22,420 | 1.4 | 31,388 | 31.39 | 2007 | 97,589 | 1.4 | 136,625 | 136.63 |
| 1994 | 13,835 | 1.4 | 19,368 | 19.37 | 2008 | 110,892 | 1.4 | 155,249 | 155.25 |
| 1995 | 16,640 | 1.4 | 23,295 | 23.30 | 2009 | 105,480 | 1.4 | 147,672 | 147.67 |
| 1996 | 12,061 | 1.4 | 16,885 | 16.89 | 2010 | 168,270 | 1.4 | 235,578 | 235.58 |
| 1997 | 17,015 | 1.4 | 23,821 | 23.82 | 2011 | 200,435 | 1.4 | 280,610 | 280.61 |
| 1998 | 34,751 | 1.4 | 48,652 | 48.65 | 2012 | 215,569 | 1.4 | 301,797 | 301.80 |
| 1999 | 26,992 | 1.4 | 37,789 | 37.79 | 2013 | 209,200 | 1.4 | 292,880 | 292.88 |
| 2000 | 21,919 | 1.4 | 30,687 | 30.69 | 2014 | 214,141 | 1.4 | 299,798 | 299.80 |
| 2001 | 33,523 | 1.4 | 46,932 | 46.93 | 2015 | 190,757 | 1.4 | 267,060 | 267.06 |
| 2002 | 28,605 | 1.4 | 40,047 | 40.05 | 2016 | 239,701 | 1.4 | 335,581 | 335.58 |
| 2003 | 52,314 | 1.4 | 73,239 | 73.24 | 2017 | 289,142 | 1.4 | 404,799 | 404.80 |

Table 4-22 $CO_2$ emissions (Gg) from production of the Ferromanganese in 1990-2017

| Year | Amount of Ferromanganeses Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) | Year | Amount of Ferromanganeses Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 3,165 | 1.3 | 4,115 | 4.12 | 2004 | 4,138 | 1.3 | 5,379 | 5.38 |
| 1991 | 2,143 | 1.3 | 2,785 | 2.79 | 2005 | 4,437 | 1.3 | 5,768 | 5.77 |
| 1992 | 965 | 1.3 | 1,254 | 1.25 | 2006 | 4,737 | 1.3 | 6,157 | 6.16 |
| 1993 | 1,054 | 1.3 | 1,370 | 1.37 | 2007 | 4,586 | 1.3 | 5,962 | 5.96 |
| 1994 | 650 | 1.3 | 845 | 0.85 | 2008 | 5,211 | 1.3 | 6,774 | 6.77 |
| 1995 | 782 | 1.3 | 1,016 | 1.02 | 2009 | 4,957 | 1.3 | 6,444 | 6.44 |
| 1996 | 567 | 1.3 | 737 | 0.74 | 2010 | 7,907 | 1.3 | 10,279 | 10.28 |
| 1997 | 800 | 1.3 | 1,039 | 1.04 | 2011 | 9,419 | 1.3 | 12,244 | 12.24 |
| 1998 | 1,633 | 1.3 | 2,123 | 2.12 | 2012 | 10,130 | 1.3 | 13,169 | 13.17 |
| 1999 | 1,268 | 1.3 | 1,649 | 1.65 | 2013 | 9,830 | 1.3 | 12,780 | 12.78 |
| 2000 | 1,030 | 1.3 | 1,339 | 1.34 | 2014 | 10,063 | 1.3 | 13,081 | 13.08 |
| 2001 | 1,575 | 1.3 | 2,048 | 2.05 | 2015 | 8,964 | 1.3 | 11,653 | 11.65 |
| 2002 | 1,344 | 1.3 | 1,747 | 1.75 | 2016 | 2,446 | 1.3 | 3,180 | 3.18 |

[85] The value was calculated based on the data expressed in thousands

| Year | Amount of Ferromanganeses Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) | Year | Amount of Ferromanganeses Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|---|---|---|
| 2003 | 2,458 | 1.3 | 3,196 | 3.20 | 2017 | 2,950 | 1.3 | 3,836 | 3.84 |

Table 4-23 $CO_2$ emissions (Gg) from production of the Ferrosilicon in 1990-2017

| Year | Amount of Ferrosilicon Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) | Year | Amount of Ferrosilicon Produced (t) | Emission Factor (t $CO_2$/t Ferroalloy Produced) | $CO_2$ Emitted (t) | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 11,054 | 4 | 44,218 | 44.22 | 2004 | 14,451 | 4 | 57,805 | 57.80 |
| 1991 | 7,482 | 4 | 29,929 | 29.93 | 2005 | 15,496 | 4 | 61,985 | 61.98 |
| 1992 | 3,369 | 4 | 13,476 | 13.48 | 2006 | 16,541 | 4 | 66,165 | 66.16 |
| 1993 | 3,679 | 4 | 14,717 | 14.72 | 2007 | 16,015 | 4 | 64,059 | 64.06 |
| 1994 | 2,270 | 4 | 9,081 | 9.08 | 2008 | 18,198 | 4 | 72,791 | 72.79 |
| 1995 | 2,731 | 4 | 10,922 | 10.92 | 2009 | 17,310 | 4 | 69,238 | 69.24 |
| 1996 | 1,979 | 4 | 7,917 | 7.92 | 2010 | 27,614 | 4 | 110,455 | 110.45 |
| 1997 | 2,792 | 4 | 11,169 | 11.17 | 2011 | 32,892 | 4 | 131,568 | 131.57 |
| 1998 | 5,703 | 4 | 22,811 | 22.81 | 2012 | 35,376 | 4 | 141,502 | 141.50 |
| 1999 | 4,429 | 4 | 17,718 | 17.72 | 2013 | 34,330 | 4 | 137,322 | 137.32 |
| 2000 | 3,597 | 4 | 14,388 | 14.39 | 2014 | 35,141 | 4 | 140,565 | 140.57 |
| 2001 | 5,501 | 4 | 22,005 | 22.00 | 2015 | 31,304 | 4 | 125,216 | 125.22 |
| 2002 | 4,694 | 4 | 18,777 | 18.78 | 2016 | 2,446 | 4 | 9,784 | 9.78 |
| 2003 | 8,585 | 4 | 34,339 | 34.34 | 2017 | 2,950 | 4 | 11,802 | 11.80 |

Table 4-24 $CH_4$ emissions (Gg) from production of the Ferrosilicon in 1990-2017

| Year | Amount of Ferrosilicon Produced (t) | Emission Factor (t $CH_4$/t Ferroalloy Produced) | $CH_4$ Emitted (t) | $CH_4$ Emitted (Gg) | $CO_2$ eq. Emitted (Gg) | Year | Amount of Ferrosilicon Produced (t) | Emission Factor (t $CH_4$/t Ferroalloy Produced) | $CH_4$ Emitted (t) | $CH_4$ Emitted (Gg) | $CO_2$ eq. Emitted (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 11,054 | 0.001 | 11.05 | 0.011 | 0.23 | 2004 | 14,451 | 0.001 | 14.45 | 0.014 | 0.30 |
| 1991 | 7,482 | 0.001 | 7.48 | 0.007 | 0.16 | 2005 | 15,496 | 0.001 | 15.50 | 0.015 | 0.33 |
| 1992 | 3,369 | 0.001 | 3.37 | 0.003 | 0.07 | 2006 | 16,541 | 0.001 | 16.54 | 0.017 | 0.35 |
| 1993 | 3,679 | 0.001 | 3.68 | 0.004 | 0.08 | 2007 | 16,015 | 0.001 | 16.01 | 0.016 | 0.34 |
| 1994 | 2,270 | 0.001 | 2.27 | 0.002 | 0.05 | 2008 | 18,198 | 0.001 | 18.20 | 0.018 | 0.38 |
| 1995 | 2,731 | 0.001 | 2.73 | 0.003 | 0.06 | 2009 | 17,310 | 0.001 | 17.31 | 0.017 | 0.36 |
| 1996 | 1,979 | 0.001 | 1.98 | 0.002 | 0.04 | 2010 | 27,614 | 0.001 | 27.61 | 0.028 | 0.58 |
| 1997 | 2,792 | 0.001 | 2.79 | 0.003 | 0.06 | 2011 | 32,892 | 0.001 | 32.89 | 0.033 | 0.69 |
| 1998 | 5,703 | 0.001 | 5.70 | 0.006 | 0.12 | 2012 | 35,376 | 0.001 | 35.38 | 0.035 | 0.74 |
| 1999 | 4,429 | 0.001 | 4.43 | 0.004 | 0.09 | 2013 | 34,330 | 0.001 | 34.33 | 0.034 | 0.72 |
| 2000 | 3,597 | 0.001 | 3.60 | 0.004 | 0.08 | 2014 | 35,141 | 0.001 | 35.14 | 0.035 | 0.74 |
| 2001 | 5,501 | 0.001 | 5.50 | 0.006 | 0.12 | 2015 | 31,304 | 0.001 | 31.30 | 0.031 | 0.66 |
| 2002 | 4,694 | 0.001 | 4.69 | 0.005 | 0.10 | 2016 | 2,446 | 0.001 | 2.45 | 0.002 | 0.05 |
| 2003 | 8,585 | 0.001 | 8.58 | 0.009 | 0.18 | 2017 | 2,950 | 0.001 | 2.95 | 0.003 | 0.06 |

2C2 – Ferroalloys Production is a key source-category regarding $CO_2$ emissions. see Table 1-2

***b) Methodological Issues***

- ***Estimation Method***

The Tier I approach of the IPCC 2006 Guideline is applied. The approach calculates the emissions by multiplication of the quantity of produced ferroalloys and typical emission factors for each type of ferroalloys.

$$E_{CO2} = F \times EF$$

Where:

$E_{CO2}$ – $CO_2$ emissions from Ferroalloys production
F – Amount of Ferroalloys produced
EF – Emission Factor related to the ferroalloys production

- ***Emission factors***

The default EFs for the ferrosilicon, ferromanganese, and silicomanganese have been taken from the 2006 Guidelines. Accordingly, 4 tonnes of $CO_2$/tonne of produced ferrosilicon, 1.3 tonne of $CO_2$/tonne of produced ferromanganese, 1.4 tonne of $CO_2$/tonne of produced silicomanganese.

- ***Activity Data***

The State National Statistics Office is the source for the ferroalloy production data. Only silicon manganese, ferromanganese and ferrosilicon were produced; 30-40 kg of carbon electrodes was consumed, 2.5 tonnes of 25-40% rich iron ore was processed, 450-500 kg of reducer was consumed for production of 1 tonne of the silicon manganese (Table 4-25, Table 4-26, Table 4-27).

Table 4-25. Ferro silicomanganese production data

| Ferro silicomanganese Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 1990 | 67,363 | 2000 | 21,919 | 2010 | 168,270 |
| 1991 | 45,595 | 2001 | 33,523 | 2011 | 200,435 |
| 1992 | 20,529 | 2002 | 28,605 | 2012 | 215,569 |
| 1993 | 22,420 | 2003 | 52,314 | 2013 | 209,200 |
| 1994 | 13,835 | 2004 | 88,062 | 2014 | 214,141 |
| 1995 | 16,640 | 2005 | 94,430 | 2015 | 190,757 |
| 1996 | 12,061 | 2006 | 100,797 | 2016 | 239,701 |
| 1997 | 17,015 | 2007 | 97,589 | 2017 | 289,142 |
| 1998 | 34,751 | 2008 | 110,892 | | |
| 1999 | 26,992 | 2009 | 105,480 | | |

Table 4-26. Ferromanganese production data

| Ferromanganese Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 1990 | 3,165 | 2000 | 1,030 | 2010 | 7,907 |
| 1991 | 2,143 | 2001 | 1,575 | 2011 | 9,419 |
| 1992 | 965 | 2002 | 1,344 | 2012 | 10,130 |
| 1993 | 1,054 | 2003 | 2,458 | 2013 | 9,830 |
| 1994 | 650 | 2004 | 4,138 | 2014 | 10,063 |
| 1995 | 782 | 2005 | 4,437 | 2015 | 8,964 |
| 1996 | 567 | 2006 | 4,737 | 2016 | 2,446 |
| 1997 | 800 | 2007 | 4,586 | 2017 | 2,950 |
| 1998 | 1,633 | 2008 | 5,211 | | |
| 1999 | 1,268 | 2009 | 4,957 | | |

Table 4-27. Ferrosilicon production data

| Ferrosilicon Production | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 1990 | 11,054 | 2000 | 3,597 | 2010 | 27,614 |
| 1991 | 7,482 | 2001 | 5,501 | 2011 | 32,892 |
| 1992 | 3,369 | 2002 | 4,694 | 2012 | 35,376 |
| 1993 | 3,679 | 2003 | 8,585 | 2013 | 34,330 |
| 1994 | 2,270 | 2004 | 14,451 | 2014 | 35,141 |
| 1995 | 2,731 | 2005 | 15,496 | 2015 | 31,304 |
| 1996 | 1,979 | 2006 | 16,541 | 2016 | 2,446 |
| 1997 | 2,792 | 2007 | 16,015 | 2017 | 2,950 |
| 1998 | 5,703 | 2008 | 18,198 | | |
| 1999 | 4,429 | 2009 | 17,310 | | |

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

The default value provided in the *2006 IPCC Guidelines* was applied for the uncertainty of the $CO_2$ emission factor and activity data for cement production. . As a result, the uncertainty of emissions was estimated to be 4%.

- ***Time-series Consistency***

Emissions throughout the time series are consistently estimated using the activity data provided by the Statistics Office of Georgia.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the2006 IPCC Guidelines. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvements***

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: “Georgia’s Integrated Transparency Framework for Implementation of Paris Agreement”.

### 4.4.3. Aluminum Production (2.C.3.)

This source category does not exist in Georgia.

### 4.4.4. Magnesium Production (2.C.4.)

This source category does not exist in Georgia.

### 4.4.5. Lead production (2.C.5.)

This source category does not exist in Georgia.

### 4.4.6. Zinc production (2.C.6.)

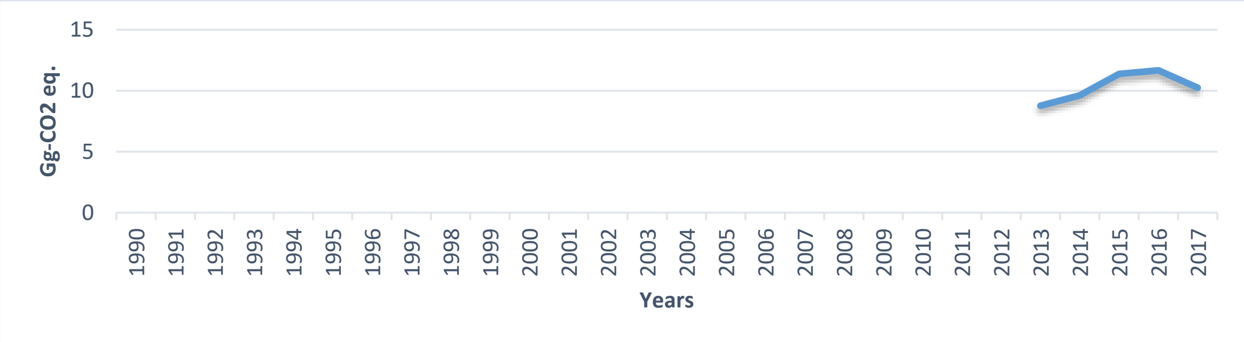
This source category does not exist in Georgia.

## 4.5. Non-energy products from fuels and solvent use (2.D.)

The Sub-sector of the Non-energy products from fuels and solvent use in Georgia considers emissions from the Lubricants (2.D.1) and Paraffin Wax use (2.D.2) source-categories. In 2017 the GHG emissions from the sub-sector of the chemical industry was 0.5% of total emissions from the Industrial Processes and Product use.

The activity data on the usage of Lubricants and wax for non-energy purposes has been collected since the national statistics office launched the energy balance processing. Accordingly, the emissions have been estimated for the period of years of 2013 – 2017. In 2016 the emissions were 10.25 Gg-$CO_2$ eq. - the highest level during the estimation period followed by 12% decrease in 2017. The biggest contributor to the upward trend within this period was the amount of consumed lubricants. The emissions trend is illustrated in the *Figure 4-4* beneath.

*Figure 4-4 The emissions trend from the Non-energy products from fuels and solvent use*




### 4.5.1. Lubricant use (2.D.1.)

***a) Source-category description and calculated emissions***

In 2015 the emissions were about 11.07 Gg $CO_2$ eq. - the highest value for the recent three years. It slightly increased (by 15%)[86] compared to the value of 2014. The emission had an upward trend between 2013 and 2015 years period. At the beginning of the period the emission was 24% lower than in 2015.

The emissions calculated based on statistical data provided in this subsector and on the emission coefficients provided in the methodological instructions of the IPCC 2006 Guidelines, are presented in the *Table 4-28*.

Table 4-28 $CO_2$ Emissions from lubricant use 2013-2017

| Year | Total Lubricant consumed (TJ) | Carbon content factor of the lubricant (kg C/GJ) | ODU factor of the lubricant (fraction) | Mass ration of $CO_2$/C | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|
| 2013 | 570.7 | 20 | 0.2 | 44/12 | 8.37 |
| 2014 | 638.4 | 20 | 0.2 | 44/12 | 9.36 |
| 2015 | 754.8 | 20 | 0.2 | 44/12 | 11.07 |
| 2016 | 795.7 | 20 | 0.2 | 44/12 | 11.67 |

[86]The value was calculated based on the date expressed in thousandths

| Year | Total Lubricant consumed (TJ) | Carbon content factor of the lubricant (kg C/GJ) | ODU factor of the lubricant (fraction) | Mass ration of $CO_2/C$ | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|
| 2017 | 698.8 | 20 | 0.2 | 44/12 | 10.25 |

### b) *Methodological Issues*

- ***Estimation Method***

The Tier I approach of the IPCC 2006 guideline is applied; the approach calculates the emissions by multiplication of the quantity of used lubricants and typical emission factor.

$$CO_2Emissions = LC \times CC_{Lubricant} \times ODU_{Lubricant} \times 44/12$$

Where:

$CO_2\ Emissions$ = $CO_2$ emissions from lubricants, tonne $CO_2$
$LC$ = total lubricant consumption, TJ
$CC_{Lubricant}$ = carbon content of lubricants (default), tonne C/TJ (= kg C/GJ)
$ODU_{Lubricant}$ = ODU factor (based on default composition of oil and grease), fraction
$44/12$ = mass ratio of $CO_2/C$

- ***Emission Factors***

The default carbon content factor (20 kg C/GJ) for lubricants and ODU factor (0.2) have been taken from the 2006 Guidelines[87].

- ***Activity Data***

The State National Statistics Office is the source for the Lubricant use data for the non-energy purposes.

Table 4-29. Lubricant consumption data

| Lubricant consumed | | | | | |
|---|---|---|---|---|---|
| Year | Activity Data (TJ) | Year | Activity Data (TJ) | Year | Activity Data (TJ) |
| 2013 | 570.7 | 2015 | 754.8 | 2017 | 698.8 |
| 2014 | 638.4 | 2016 | 795.7 | | |

### c) *Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of emission factors, a 50% default value provided in the 2006 IPCC Guidelines was applied for both lubricants and grease. For the uncertainty of the activity data, a 5% default value provided in the 2006 IPCC Guidelines was applied for both lubricants and grease. As a result, the uncertainty of emissions was assessed to be 50% for both lubricants and grease.

- ***Time-series Consistency***

[87]2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol.3 Chapter 5, Table 5.2 p.5.9

The Statics office of Georgia started producing energy balance in 2013. Emissions for the period of 2013 and 2017 are consistently estimated using the activity data provided by the Statistics Office of Georgia.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the2006 IPCC Guidelines. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvementsto***

Georgia is going to advance these assumptions by addressing its national circumstances and provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: "Georgia's Integrated Transparency Framework for Implementation of Paris Agreement".

### 4.5.2. Paraffin wax use (2.D.2.)

***a) Source-category description and calculated emissions***

In 2015 the emissions were about 0.3 Gg $CO_2$ eq.  - the average value for the recent three years. It slightly increased (by 17%)[88] compared to the value of 2014. The emission had an upward trend between 2014- and 2015-years period. At the beginning of the period the emission was 23% higher than in 2015.

The emissions calculated based on statistical data provided in this subsector and on the emission coefficients provided in the methodological instructions of the IPCC 2006 Guidelines, are presented in the Table *4-30*.

Table 4-30 $CO_2$ Emissions from paraffin wax use 2013-2017

| Year | Total Paraffin Wax consumed (TJ) | Carbon content factor of the paraffin wax (kg C/GJ) | ODU factor of the paraffin wax (fraction) | Mass ration of $CO_2$/C | $CO_2$ Emitted (Gg) |
|---|---|---|---|---|---|
| 2013 | 26.9 | 20 | 0.2 | 44/12 | 0.39 |
| 2014 | 17.1 | 20 | 0.2 | 44/12 | 0.25 |
| 2015 | 20.6 | 20 | 0.2 | 44/12 | 0.30 |
| 2016 | NE | NE | NE | NE | NE |
| 2017 | NE | NE | NE | NE | NE |

***b) Methodological Issues***

- ***Estimation Method***

The Tier I approach of the IPCC 2006 Guideline is applied; the approach calculates the emissions by multiplication of the quantity of used paraffin waxes and typical emission factors.

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

[88] The value was calculated based on the data expressed in thousands

Where:

$CO_2$ *Emissions* = $CO_2$ emissions from waxes, tonne $CO_2$

*PW* = total wax consumption, TJ

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

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

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

- ***Emission Factors***

The default carbon content factor (20 kg C/GJ) for lubricants and ODU factor (0.2) have been taken from the 2006 Guidelines[89].

- ***Activity Data***

The State National Statistics Office is the source for the wax use data for the non-energy purposes.

Table 4-31. Paraffin wax consumption data

| **Paraffin Wax consumed** | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (TJ)** | **Year** | **Activity Data (TJ)** | **Year** | **Activity Data (TJ)** |
| 2013 | 26.9 | 2015 | 20.6 | 2017 | NE |
| 2014 | 17.1 | 2016 | NE | | |

### c) Uncertainties and Time-series Consistency

- ***Uncertainty***

A 100% default value provided in the 2006 IPCC Guidelines was applied for the uncertainty of emission factors; a 5% default value provided in the 2006 IPCC Guidelines was applied for the uncertainty of the activity data. As a result, the uncertainty of emissions was assessed to be 100%.

- ***Time-series Consistency***

The Statics Office of Georgia started the production of energy balance in 2013. Emissions for the period of 2013 and 2015 are consistently estimated using the activity data provided by the Statistics Office of Georgia.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the2006 IPCC Guidelines. General inventory QC focuses on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

Recalculations have not been applied for this submission.

### f) Category-specific Planned Improvements

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category

[89] 2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol.3 Chapter 5, p.5.12

under the project: “Georgia’s Integrated Transparency Framework for Implementation of Paris Agreement”.

### 4.5.3. Solvent Use (2.D.3.)

This source category does not exist in Georgia.

### 4.5.4. Other (2.D.4.)

#### 4.5.4.1. Asphalt Production and Use

***a) Source-category description and calculated emissions***

Georgia is mainly producing artificial asphalt. The calculated carbon monoxide and NMVOCs emissions from asphalt production are presented in *Table 4-32*.

Table 4-32 CO and NMVOCs emissions from asphalt production in 1990-2017

| Year | Asphalt-concrete production | Emission factor (t CO /Gg asphalt) | CO emission (t) | CO emission (Gg) | Emission factor (t NMVOCs /Gg asphalt) | NMVOCs emission (t) | NMVOCs emission (Gg) |
|---|---|---|---|---|---|---|---|
| 1990 | NO | NO | NO | NO | NO | NO | NO |
| 1991 | NO | NO | NO | NO | NO | NO | NO |
| 1992 | NO | NO | NO | NO | NO | NO | NO |
| 1993 | NO | NO | NO | NO | NO | NO | NO |
| 1994 | NO | NO | NO | NO | NO | NO | NO |
| 1995 | NO | NO | NO | NO | NO | NO | NO |
| 1996 | NO | NO | NO | NO | NO | NO | NO |
| 1997 | 21.9 | 0.0095 | 0.21 | 0.0002 | 0.0475 | 1.04 | 0.0010 |
| 1998 | 20.9 | 0.0095 | 0.20 | 0.0002 | 0.0475 | 0.99 | 0.0010 |
| 1999 | 10.0 | 0.0095 | 0.10 | 0.0001 | 0.0475 | 0.48 | 0.0005 |
| 2000 | 19.7 | 0.0095 | 0.19 | 0.0002 | 0.0475 | 0.94 | 0.0009 |
| 2001 | 24.7 | 0.0095 | 0.23 | 0.0002 | 0.0475 | 1.17 | 0.0012 |
| 2002 | 25.1 | 0.0095 | 0.24 | 0.0002 | 0.0475 | 1.19 | 0.0012 |
| 2003 | 70.6 | 0.0095 | 0.67 | 0.0007 | 0.0475 | 3.35 | 0.0034 |
| 2004 | 117.5 | 0.0095 | 1.12 | 0.0011 | 0.0475 | 5.58 | 0.0056 |
| 2005 | 293.4 | 0.0095 | 2.79 | 0.0028 | 0.0475 | 13.94 | 0.0139 |
| 2006 | 228.4 | 0.0095 | 2.17 | 0.0022 | 0.0475 | 10.85 | 0.0108 |
| 2007 | 189.1 | 0.0095 | 1.80 | 0.0018 | 0.0475 | 8.98 | 0.0090 |
| 2008 | 183.2 | 0.0095 | 1.74 | 0.0017 | 0.0475 | 8.70 | 0.0087 |
| 2009 | 181.4 | 0.0095 | 1.72 | 0.0017 | 0.0475 | 8.62 | 0.0086 |
| 2010 | 371.6 | 0.0095 | 3.53 | 0.0035 | 0.0475 | 17.65 | 0.0177 |
| 2011 | 173.3 | 0.0095 | 1.65 | 0.0016 | 0.0475 | 8.23 | 0.0082 |
| 2012 | 444.4 | 0.0095 | 4.22 | 0.0042 | 0.0475 | 21.11 | 0.0211 |
| 2013 | 464.6 | 0.0095 | 4.41 | 0.0044 | 0.0475 | 22.07 | 0.0221 |
| 2014 | 325.4 | 0.0095 | 3.09 | 0.0031 | 0.0475 | 15.46 | 0.0155 |
| 2015 | 627.4 | 0.0095 | 5.96 | 0.0060 | 0.0475 | 29.80 | 0.0298 |
| 2016 | 815.9 | 0.0095 | 7.75 | 0.0078 | 0.0475 | 38.76 | 0.0388 |
| 2017 | 866.2 | 0.0095 | 8.23 | 0.0082 | 0.0475 | 41.15 | 0.0411 |

***b) Methodological Issues***

- ***Estimation Method***

The methodology used in the IPCC 1996 has been applied, according to which only NMVOCs and CO emissions will be considered in this sub-sector, since it is believed that the direct effects of the greenhouse gas emissions from asphalt production is negligible. Emission rate is calculated by emission factors (gases emitted during production of a tonne of asphalt) multiplied by tonnes of produced asphalt.

- ***Emission Factors***

Emissions from asphalt production are calculated on the national level only for CO and NMVOCs. Emission factors are taken from the EMER / CORINAIR (SNAP 40610) guidelines,[90] The technology of the asphalt production - saturation without emission. for NMVOCs - 0.0475, while for CO - 0.0095 kg / tonne of asphalt.

- ***Activity data***

This sub-sector considers asphalt producing enterprises (oil refineries are not included) and its consumption. In Georgia asphalt production technology is as follows: after processing of oil products the remaining mass Bitumen and fillers (cement, lime) are stirred in mobile or stationary units about 30-50 km away from the place where asphalt is used. Asphalt products are also used as binder and hermetic material, for example for foundations, etc. Asphalt surface for roads is condensed, contains compact fillers and bitumen connecting. Liquid asphalt is characterized by a relatively high level of emissions. There are bitumen and asphalt emulsions. The latter is mainly composed of water and a small or zero amounts of solvents. During the discussed period in Georgia the main volume of asphalt was produced by several large and small enterprises. They produced the so-called hot asphalt mixture using almost the same technology. The data has been provided by Georgian statistics office.

## 4.6. Electronics industry (2.E.)

This source category does not exist in Georgia.

### 4.6.1. Semiconductor (2.E.1.)

This source category does not exist in Georgia.

### 4.6.2. Liquid Crystals (2.E.2.)

This source category does not exist in Georgia.

### 4.6.3. Photovoltaics (2.E.3.)

This source category does not exist in Georgia.

### 4.6.4. Heat transfer fluid (2.E.4.)

This source category does not exist in Georgia.

## 4.7. Product uses as substitutes for ODS (2.F.)

The Sub-sector of the Product uses as substitutes for ODS in Georgia covers HFC and PFC emissions from the Refrigeration and air conditioning (2.F.1). In 2017 the GHG emissions from the sub-sector of the

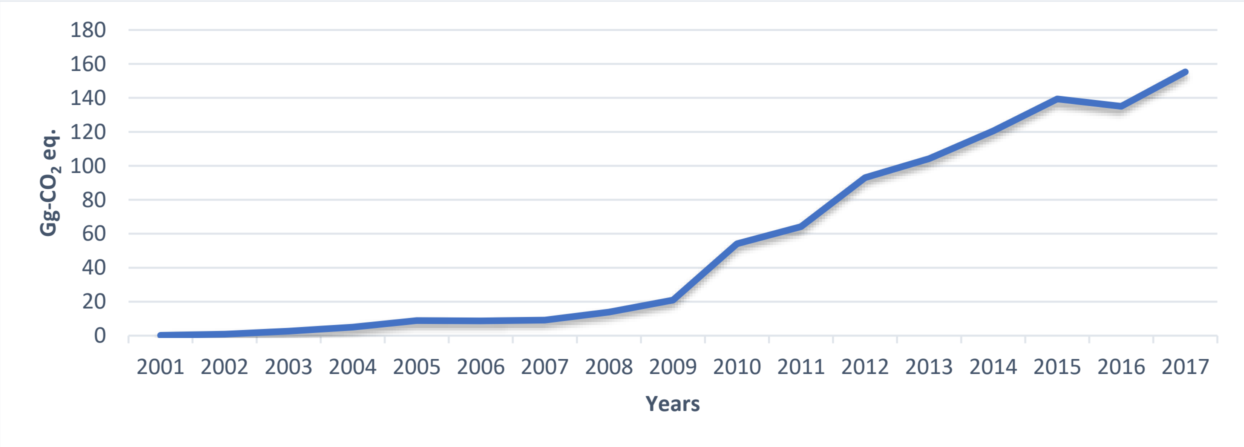
[90] EMEP/CORINAR (SNAP A0 610), Atmosperic emission inventory guidebook. Second edition 2009. http://eea.europa.eu/publications/Emep CORINARS 5

Product uses as substitutes for ODS was 7.8% of the total emissions from the Industrial Processes and Product use.

Nowadays, the industrial gases (hydrofluorocarbons -HFCs, perfluorocarbons -PFCs and Sulphur hexafluoride -SF6) are only imported for utilization. Accordingly, the emissions are only specified by their usage. Calculation of halocarbons is important as they are characterized by stability and high global warming potential (GWP).

The emissions trend is illustrated in the *Figure 4-5* beneath.

*Figure 4-5 The emissions trend from the Product uses as substitutes for ODS*




### 4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)

***a) Source-category description and calculated emissions***

The emissions from the consumption of HFCs have been estimated based on the halogens imported to Georgia. These compounds and mixtures are: HFC-134a, R-404A, R-407C, R-507A, R-410A. The composition analysis of these mixtures reveals that mostly four different compounds of HFCs are accounted for in the period between 2001 and 2015. The emissions from the HFCs consumption counts from the year of 2001 due to the appearance in imported goods.

In general, the emission from the HFCs consumption has an upward trend in Georgia. The highest emissions were in 2017 - about 155 Gg $CO_2$ eq. In 2014 the emissions were 14 per cent lower than in 2015. The lowest emissions from the HFCs consumption in Georgia were estimated in 2001 - 0.2 Gg of $CO_2$ eq. - almost 700 times less compared to the end of the period.

The actual emissions from the f-gases in Refrigerators and Air conditioners are represented in the *Table 4-33, Table 4-34, Table 4-35, Table 4-36* beneath.

Table 4-33 HFC-134a actual emissions in Georgia in 2001-2017

| Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) | Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) |
|---|---|---|---|---|---|---|---|
| 2001 | 0.08 | 1300 | 0.11 | 2010 | 20.31 | 1300 | 26.41 |
| 2002 | 0.36 | 1300 | 0.46 | 2011 | 23.49 | 1300 | 30.54 |
| 2003 | 1.13 | 1300 | 1.46 | 2012 | 43.67 | 1300 | 56.77 |
| 2004 | 1.87 | 1300 | 2.43 | 2013 | 50.06 | 1300 | 65.07 |
| 2005 | 3.53 | 1300 | 4.59 | 2014 | 52.60 | 1300 | 68.38 |
| 2006 | 3.61 | 1300 | 4.69 | 2015 | 59.87 | 1300 | 77.83 |
| 2007 | 4.09 | 1300 | 5.31 | 2016 | 56.28 | 1300 | 73.16 |
| 2008 | 6.01 | 1300 | 7.81 | 2017 | 62.84 | 1300 | 81.69 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2009 | 9.88 | 1300 | 12.84 | | | | |

Table 4-34 HFC-125 actual emissions in Georgia in 2001-2017

| Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) | Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) |
|---|---|---|---|---|---|---|---|
| 2001 | 0.02 | 2800 | 0.05 | 2010 | 4.59 | 2800 | 12.86 |
| 2002 | 0.07 | 2800 | 0.19 | 2011 | 6.18 | 2800 | 17.31 |
| 2003 | 0.23 | 2800 | 0.64 | 2012 | 6.81 | 2800 | 19.06 |
| 2004 | 0.51 | 2800 | 1.42 | 2013 | 7.62 | 2800 | 21.33 |
| 2005 | 0.83 | 2800 | 2.33 | 2014 | 10.97 | 2800 | 30.71 |
| 2006 | 0.79 | 2800 | 2.22 | 2015 | 13.43 | 2800 | 37.61 |
| 2007 | 0.76 | 2800 | 2.14 | 2016 | 14.34 | 2800 | 40.16 |
| 2008 | 1.10 | 2800 | 3.09 | 2017 | 17.44 | 2800 | 48.85 |
| 2009 | 1.45 | 2800 | 4.07 | | | | |

Table 4-35 HFC-143a actual emissions in Georgia in 2001-2017

| Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) | Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) |
|---|---|---|---|---|---|---|---|
| 2001 | 0.02 | 3800 | 0.06 | 2010 | 3.66 | 3800 | 13.91 |
| 2002 | 0.05 | 3800 | 0.20 | 2011 | 3.83 | 3800 | 14.54 |
| 2003 | 0.12 | 3800 | 0.47 | 2012 | 3.95 | 3800 | 15.01 |
| 2004 | 0.26 | 3800 | 0.99 | 2013 | 4.01 | 3800 | 15.24 |
| 2005 | 0.46 | 3800 | 1.73 | 2014 | 4.46 | 3800 | 16.94 |
| 2006 | 0.40 | 3800 | 1.53 | 2015 | 4.73 | 3800 | 17.98 |
| 2007 | 0.38 | 3800 | 1.45 | 2016 | 3.84 | 3800 | 14.61 |
| 2008 | 0.71 | 3800 | 2.71 | 2017 | 4.19 | 3800 | 15.92 |
| 2009 | 0.95 | 3800 | 3.61 | | | | |

Table 4-36 HFC-32 actual emissions in Georgia in 2001-2017

| Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) | Year | Quantity of Pollutant (t) | GWP | $CO_2$ eq. (Gg) |
|---|---|---|---|---|---|---|---|
| 2001 | 0.00[91] | 650 | 0.00[92] | 2010 | 1.37 | 650 | 0.89 |
| 2002 | 0.02 | 650 | 0.01 | 2011 | 2.79 | 650 | 1.82 |
| 2003 | 0.11 | 650 | 0.07 | 2012 | 3.30 | 650 | 2.14 |
| 2004 | 0.26 | 650 | 0.17 | 2013 | 4.03 | 650 | 2.62 |
| 2005 | 0.41 | 650 | 0.27 | 2014 | 6.96 | 650 | 4.52 |
| 2006 | 0.42 | 650 | 0.27 | 2015 | 9.18 | 650 | 5.97 |
| 2007 | 0.41 | 650 | 0.26 | 2016 | 10.96 | 650 | 7.13 |
| 2008 | 0.46 | 650 | 0.30 | 2017 | 13.65 | 650 | 8.87 |
| 2009 | 0.60 | 650 | 0.39 | | | | |

### *b) Methodological Issues*

- ***Estimation Method***

According to the IPCC 2006 Guideline the Tier 1a/b method was used for estimation of actual emissions. The spreadsheet contained in the 2006 Guidelines has been used for the calculations.

In accordance with the national circumstances of Georgia there is no domestic production of HFCs so far. Subsequently, production is zero. There is the same situation in relation of export. Accordingly, the

[91] 0.00345
[92] 0.00224

emissions from the sub-sector of Consumption of Halocarbons correspond to the imported gases and equipment mostly for the air conditioning and refrigerants.

- ***Emission Factors***

According to the IPCC 2000 GPG, the imported or produced halocarbons and perfluorocarbons are emitted completely and consequently their emission coefficient is equal to 1.

- ***Activity data***

Since the Customs Service possesses the most accurate data on imported goods, the data on the HFC gases are obtained from the above agency. The aggregated values were separated in 4 different compounds: HFC-134a, HFC-125, HFC-143a, and HFC-32 by the expert judgment (Table 4-37, Table 4-38, Table 4-39, and Table 4-40).

Table 4-37. Imported data of HFC-134a

| Imported HFC-134a | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 2001 | 70.52 | 2007 | 6.80 | 2013 | 70.52 |
| 2002 | 65.78 | 2008 | 16.92 | 2014 | 65.78 |
| 2003 | 0.24 | 2009 | 31.80 | 2014[93] | 0.24 |
| 2004 | 73.92 | 2010 | 79.44 | 2015 | 73.92 |
| 2005 | 89.55 | 2011 | 39.05 | 2016 | 89.55 |
| 2006 | 92.25 | 2012 | 152.19 | 2017 | 92.25 |

Table 4-38. Imported data of HFC-125

| Imported HFC-125 | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 2001 | 0.11 | 2007 | 0.60 | 2013 | 8.77 |
| 2002 | 0.35 | 2008 | 3.03 | 2014 | 26.10 |
| 2003 | 1.14 | 2009 | 3.44 | 2014[94] | 0.18 |
| 2004 | 2.08 | 2010 | 22.39 | 2015 | 25.41 |
| 2005 | 2.67 | 2011 | 14.68 | 2016 | 35.22 |
| 2006 | 0.59 | 2012 | 9.31 | 2017 | 35.37 |

Table 4-39. Imported data of HFC-143a

| Imported HFC-143a | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 2001 | 0.10 | 2007 | 0.26 | 2013 | 3.22 |
| 2002 | 0.26 | 2008 | 2.60 | 2014 | 4.91 |
| 2003 | 0.52 | 2009 | 2.29 | 2014[95] | 0.08 |
| 2004 | 1.04 | 2010 | 19.02 | 2015 | 4.39 |
| 2005 | 1.56 | 2011 | 4.31 | 2016 | 5.99 |
| 2006 | 0.10 | 2012 | 3.98 | 2017 | 6.14 |

[93] destroyed amount of HFC-134a
[94] destroyed amount of HFC-134a
[95] destroyed amount of HFC-134a

Table 4-40. Imported data of HFC-32

| Imported HFC-32 | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 2001 | 0.02 | 2007 | 0.35 | 2013 | 5.90 |
| 2002 | 0.12 | 2008 | 0.76 | 2014 | 21.62 |
| 2003 | 0.64 | 2009 | 1.38 | 2014[96] | 0.11 |
| 2004 | 1.10 | 2010 | 5.75 | 2015 | 21.39 |
| 2005 | 1.24 | 2011 | 10.76 | 2016 | 29.73 |
| 2006 | 0.46 | 2012 | 5.72 | 2017 | 29.74 |

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainties of the activity data, the 10% value of the Tier 1 method for metal industry provided in the *2006 IPCC Guidelines* was applied for all production, use, and disposal. As a result, the uncertainties of the emissions were determined to be 32% for production and use and 10% - for disposal.

- ***Time-series Consistency***

Emissions throughout the time series are consistently estimated using the activity data provided by the refrigerant's association.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the2006 IPCC Guidelines. The focus of general inventory QC is made on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Recalculations have not been applied for this submission.

***f) Category-specific Planned Improvements***

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: "Georgia's Integrated Transparency Framework for Implementation of Paris Agreement".

### 4.7.2. Foam Blowing Agents (2.F.2.)

The emissions from this source-category is going to be estimated using the methods delivered under the project: "Georgia's Integrated Transparency Framework for Implementation of the Paris Agreement" for the period of 2020-2022.

### 4.7.3. Fire Protection (2.F.3.)

The emissions from this source-category is going to be estimated using the methods delivered under the project: "Georgia's Integrated Transparency Framework for Implementation of the Paris Agreement" for the period of 2020-2022.

### 4.7.4. Aerosols (2.F.4.)

[96] destroyed amount of HFC-134a

The emissions from this source-category is going to be estimated using the methods delivered under the project: “Georgia’s Integrated Transparency Framework for Implementation of the Paris Agreement” for the period of 2020-2022.

#### 4.7.5. Solvents (2.F.5.)

The emissions from this source-category is going to be estimated using the methods delivered under the project: “Georgia’s Integrated Transparency Framework for Implementation of the Paris Agreement for the period of 2020-2022.

#### 4.7.6. Other applications (2.F.6.)

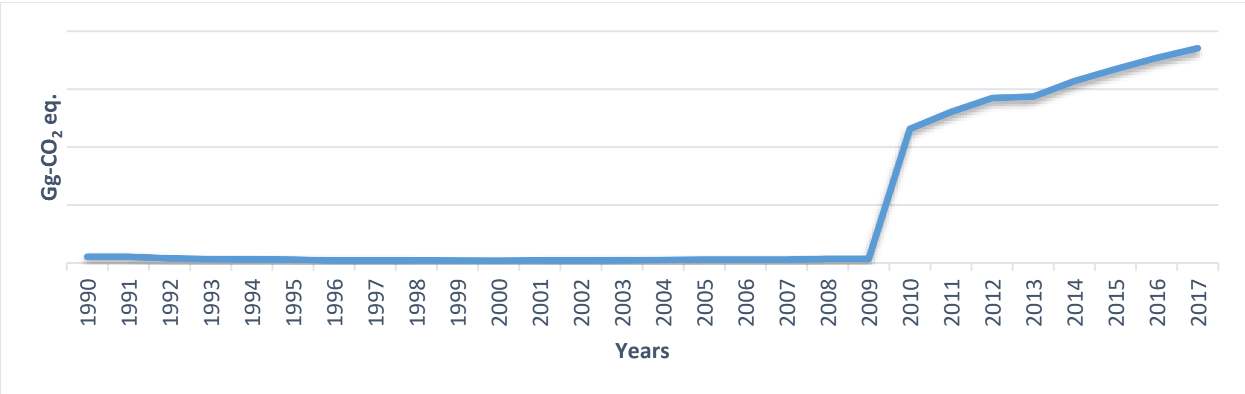
In case of relevance the emissions from this source-category is going to be estimated using the methods delivered under the project: “Georgia’s Integrated Transparency Framework for Implementation of the Paris Agreement” for the period of 2020-2022.

### 4.8. Other product manufacture and use (2.G.)

The Sub-sector of the Other product manufacture and use in Georgia considers emissions from the Electrical Equipment (2.G.1) and $N_2O$ from product uses (2.G.3) source-categories. In 2017 the GHG emissions from the sub-sector of the other product manufacture and use was 0.02% of the total emissions from the Industrial Processes and Product use.

The emissions trend is illustrated in the *Figure 4-6* beneath.

*Figure 4-6 The emissions trend from the other product manufacture and use*




#### 4.8.1. Electrical Equipment (2.G.1.)

***a) Source-category description and calculated emissions***

Only $SF_6$ equipment was operated in Georgia during the reporting period. At energy facilities $SF_6$ is used in communication equipment. According to official information provided by the State Electricity specialists, namely, they were installed since 1997 at various voltage breakers. Currently number of "Elegas Breakers" on the balance of JSC "GSE" consists of 304 sets, and the total volume of $SF_6$ in them is C kg. The equipment used in breakers is hermetic; their operational lifetimes 30-40 years. It should be noted that according to experts reports in recent years, quality (hermitization) of this type of equipment has significantly improved, which means that $SF_6$ emissions from electric utilities were subsequently reduced (50-90%). . Amount of $SF_6$ released in Georgia during working processes of electrical equipment is calculated for 1997-2013. The results of calculations are presented in *Table 4-41* below.

Table 4-41 $SF_6$ quantities released from electrical equipment in Georgia in 2010-2017

| **Year** | **Consumed $SF_6$, tons** | **Rate of $SF_6$ losses** | **$SF_6$ emission, tons** | **$SF_6$ emission, Gg** | **$SF_6$ emission, Gg $CO_2$eq.** |
|---|---|---|---|---|---|
| 2010 | C | 0.002 | C | C | C |
| 2011 | C | 0.002 | C | C | C |
| 2012 | C | 0.002 | C | C | C |
| 2013 | C | 0.002 | C | C | C |
| 2014 | C | 0.002 | C | C | C |
| 2015 | C | 0.002 | C | C | C |
| 2016 | C | 0.002 | C | C | C |
| 2017 | C | 0.002 | C | C | C |

Calculations demonstrated that $SF_6$ emission from using equipment in energy system of Georgia is practically insignificant. The emission reached its maximum in 2015 and amounted to C Gg or C Gg $CO_{2eq}$.

### b) *Methodological Issues*

- ***Estimation Method***

For calculation of $SF_6$ emission the Methodology from IPCC-2006 Guideline was used as it provides the spreading coefficients according to the regions and to the types of devices (airproof, closed).

- ***Emission Factors***

According to the IPCC 2006, the following coefficients are provided for the specific types of devices and according to the regions in the *Table 4-42* beneath.

Table 4-42 The coefficients of $SF_6$ emissions according to the regions and to the types of devices

| Region/ Phase | Airproof / leakage per year, % | Closed / leakage per year, % |
|---|---|---|
| Europe | 0.002 | 0.026 |

- ***Activity data***

Statistics of installed $SF_6$ breakers in JSC "Georgian State Electro system" from 2010-2017 is presented in Table *4-43*.

Table 4-43 Number of breakers that contain $SF_6$ installed in the state electricity system in 2010-2017

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| Amount | 85 | 31 | 14 | 1 | 15 | 21 | 14 | 12 |

### c) *Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the activity data, the 10% value of the Tier 1 method for Electrical Equipment in the *2006 IPCC Guidelines* was applied for all production, use, and disposal. As a result, the uncertainties of the emissions for production and use were determined to be 32%, and for disposal- 10%.

- ***Time-series Consistency***

Emissions throughout the time series are consistently estimated using the activity data provided by the JSC "GSE".

*d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the2006 IPCC Guidelines. The focus of general inventory QC is made on checking of the parameters for activity data and emission factors and archiving of reference materials. QA/QC activities are summarized in Chapter 1.

*e) Category-specific Recalculations*

Recalculations have not been applied for this submission.

*f) Category-specific Planned Improvements*

Georgia is going to advance these assumptions by addressing its national circumstances and to provide relevant information in its forthcoming submissions in accordance with the study of the source-category under the project: "Georgia's Integrated Transparency Framework for Implementation of Paris Agreement".

**4.8.2. SF6 and PFCs from other product use (2.G.2.)**

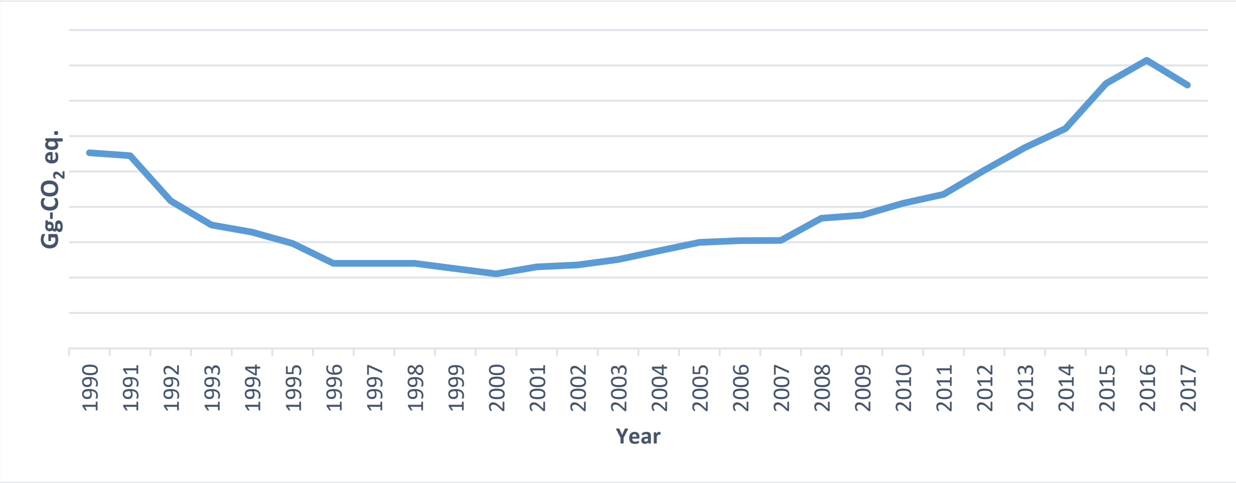
The emissions from this source-category is going to be estimated by using the methods delivered under the project: "Georgia's Integrated Transparency Framework for Implementation of the Paris Agreement" for the period of 2020-2022.

**4.8.3. $N_2O$ from product uses (2.G.3.)**

*a) Source-category description and calculated emissions*

In general, one of major sources of greenhouse gas emissions is solvents and their associated components. This sector considers nitrous oxide ($N_2O$) emissions, the main source of its use being anesthesia in the medical field.

*Figure 4-7 The emissions from the Solvent and Other Product Use*




Average annual emissions of $N_2O$ used for anesthesia in Healthcare system during the discussed period amounted to C Gg/year, or slightly less.

$N_2O$ emissions in 2010-2017 in this subsector are estimated specifically for anesthesia in medical field. Nitrogen monoxide ($N_2O$) emissions are released from various sources (agriculture, industry, transport) and one of the fields, which also contribute to the emission of nitric oxide, is Healthcare system.

Nitrogen monoxide-containing substances are most actively used during anesthesia in medical sector. In addition, most inhalational anesthetics contain $N_2O$.

Table 4-44 Emission of $N_2O$ from the subsector "Solvents and other product use" in 1990-2017

| Year | Number of medical operations conducted | EF (kg $N_2O$ /per surgery) | $N_2O$ emission (Gg) | $CO_2$ eq. emission (Gg) |
|---|---|---|---|---|
| 1990 | C | 1.96E-04 | C | C |
| 1991 | C | 1.96E-04 | C | C |
| 1992 | C | 1.96E-04 | C | C |
| 1993 | C | 1.96E-04 | C | C |
| 1994 | C | 1.96E-04 | C | C |
| 1995 | C | 1.96E-04 | C | C |
| 1996 | C | 1.96E-04 | C | C |
| 1997 | C | 1.96E-04 | C | C |
| 1998 | C | 1.96E-04 | C | C |
| 1999 | C | 1.96E-04 | C | C |
| 2000 | C | 1.96E-04 | C | C |
| 2001 | C | 1.96E-04 | C | C |
| 2002 | C | 1.96E-04 | C | C |
| 2003 | C | 1.96E-04 | C | C |
| 2004 | C | 1.96E-04 | C | C |
| 2005 | C | 1.96E-04 | C | C |
| 2006 | C | 1.96E-04 | C | C |
| 2007 | C | 1.96E-04 | C | C |
| 2008 | C | 1.96E-04 | C | C |
| 2009 | C | 1.96E-04 | C | C |
| 2010 | C | 1.96E-04 | C | C |
| 2011 | C | 1.96E-04 | C | C |
| 2012 | C | 1.96E-04 | C | C |
| 2013 | C | 1.96E-04 | C | C |
| 2014 | C | 1.96E-04 | C | C |
| 2015 | C | 1.96E-04 | C | C |
| 2016 | C | 1.96E-04 | C | C |
| 2017 | C | 1.96E-04 | C | C |

### b) *Methodological Issues*

- ***Estimation Method***

Calculations assumed that $N_2O$ used for anesthesia is fully emitted into the atmosphere or, in other words, emission of $N_2O$ is equal to its use.

It was assumed that consumed $N_2O$ is proportional to a total number of surgical operations conducted in the country. These data and the results of the calculations are presented in *Table 4-45*.

- ***Emission Factor***

Emission factor is 0.196*10-3 kg[97].

- ***Activity data***

[97] EMEP/CORINAR (EEA-2009); (page 5.18, Table 8.11- coefficients for European countries)

Surgery visits in Georgia during the period of 1990-2017were used for calculation; the information was provided by the Ministry of Health and Social Security and National Statistics Office of Georgia. The number of medical operations is represented in the Table 4-45.

Table 4-45. Number of medical operations

| Medical operations | | | | | |
|---|---|---|---|---|---|
| **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** | **Year** | **Activity Data (t)** |
| 1990 | C | 2000 | C | 2010 | C |
| 1991 | C | 2001 | C | 2011 | C |
| 1992 | C | 2002 | C | 2012 | C |
| 1993 | C | 2003 | C | 2013 | C |
| 1994 | C | 2004 | C | 2014 | C |
| 1995 | C | 2005 | C | 2015 | C |
| 1996 | C | 2006 | C | 2016 | C |
| 1997 | C | 2007 | C | 2017 | C |
| 1998 | C | 2008 | C | | |
| 1999 | C | 2009 | C | | |

#### 4.8.3.1. Medical applications (2.G.3.a)

#### 4.8.3.2. Other (2.G.3.b)

## 4.9. Other (2.H.)

***a) Source-category description and calculated emissions***

This category includes production of pulp and paper (2.H.1), as well as of food and drinks (2.H.2). Presently there is no wood processing in Georgia. The paper is produced in Tserovani Plant, but it uses imported raw materials and this production does not cause the GHG emissions into the atmosphere.

### 4.9.1. Food and beverages industry (2.H.2.)

The direct greenhouse gases are not produced from the source category of Food and Drinks Production and therefore only indirect gases and NMVOCs were estimated. Various enterprises of food industry operated in Georgia during the discussed period; the major ones among them were: meat and fish processing, corn drying and milling, bakery, confectionary, sugar, wine, spirit, beer, soft drinks, dairy products, coffee roasting and milling. The non-methane volatile organic compounds emissions (NMVOCs) from just this subcategory are calculated here.

The emissions calculated based on statistical data provided in this subsector and on the emission, factors offered by the methodological instructions of IPCC 1996, are given in the Table 3-28.

According to the conducted calculations it is obvious that the volume of NMVOCs released into the atmosphere from foods and drinks production at the territory of Georgia during 1990-2015 is significant and 200 times exceeds the emissions from the asphalt production (see the *Table 4-46*).

Table 4-46. NMVOCs Emissions from The Food and Drinks Production in 1990-2017 in Georgia (Gg)

| Year | Meat and semi-prepared meat food (t) | Fish and fish product (t) | Margarine and similar products (t) | Drying and grinding of wheat (t) | Bread baking (t) | Confectionary (t) | Sugar (t) | Milling and roasting of coffee (t) | Forage for domestic animals (t) | Sparkling wine (hl) | White wine (hl) | Beer (hl) | Spirit, vodka (hl) | Brandy (hl) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 0.0133 | 0.0179 | C | 1.2372 | 8.5557 | 0.0595 | C | NO | 1.0797 | 0.00012 | 0.0006 | 0.0003 | 0.0123 | 0.0076 |
| 1991 | 0.0044 | 0.0120 | C | 1.1008 | 10.0493 | 0.0253 | C | NO | 0.8385 | 0.00009 | 0.0004 | 0.0002 | 0.0116 | 0.0051 |
| 1992 | 0.0014 | 0.0007 | C | 0.7521 | 7.6031 | 0.0019 | C | NO | 0.3467 | 0.00006 | 0.0007 | 0.0001 | 0.0097 | 0.0048 |
| 1993 | 0.0002 | 0.0001 | C | 0.6013 | 6.3951 | 0.0019 | C | NO | 0.1611 | 0.00004 | 0.0005 | 0.0000 | 0.0178 | 0.0036 |
| 1994 | 0.0001 | 0.0001 | C | 0.5465 | 4.9833 | 0.0005 | C | NO | 0.1356 | 0.00001 | 0.0002 | 0.0000 | 0.0034 | 0.0010 |
| 1995 | 0.0001 | 0.0002 | C | 0.4346 | 2.9635 | 0.0003 | C | NO | 0.0843 | 0.00000 | 0.0001 | 0.0000 | 0.0022 | 0.0006 |
| 1996 | 0.0001 | 0.0002 | C | 0.2747 | 2.6230 | 0.0004 | C | 0.0005 | 0.0374 | 0.00001 | 0.0001 | 0.0000 | 0.0029 | 0.0005 |
| 1997 | 0.0003 | 0.0004 | C | 0.2342 | 1.9866 | 0.0002 | C | 0.0017 | 0.0220 | 0.00001 | 0.0001 | 0.0000 | 0.0065 | 0.0003 |
| 1998 | 0.0003 | 0.0000 | C | 0.1918 | 1.7389 | 0.0003 | C | 0.0009 | 0.0110 | 0.00000 | 0.0001 | 0.0000 | 0.0041 | 0.0001 |
| 1999 | 0.0004 | 0.0000 | C | 0.1482 | 1.1359 | 0.0002 | C | 0.0008 | 0.0048 | 0.00001 | 0.0001 | 0.0000 | 0.0077 | 0.0001 |
| 2000 | 0.0003 | 0.0000 | C | 0.1339 | 1.1134 | 0.0001 | C | 0.0008 | 0.0027 | 0.00001 | 0.0001 | 0.0001 | 0.0078 | 0.0002 |
| 2001 | 0.0001 | 0.0000 | C | 0.1037 | 0.8814 | 0.0001 | C | 0.0006 | 0.0001 | 0.00001 | 0.0001 | 0.0001 | 0.0109 | 0.0003 |
| 2002 | 0.0002 | 0.0000 | C | 0.1013 | 0.8884 | 0.0001 | C | 0.0002 | 0.0000 | 0.00001 | 0.0001 | 0.0001 | 0.0043 | 0.0003 |
| 2003 | 0.0003 | 0.0000 | C | 0.0939 | 0.7701 | 0.0003 | C | 0.0003 | 0.0013 | 0.00001 | 0.0001 | 0.0001 | 0.0058 | 0.0005 |
| 2004 | 0.0007 | 0.0000 | C | 0.1829 | 1.0013 | 0.0003 | C | 0.0003 | 0.0007 | 0.00001 | 0.0001 | 0.0002 | 0.0161 | 0.0007 |
| 2005 | 0.0008 | 0.0001 | C | 0.2545 | 0.9294 | 0.0003 | C | 0.0005 | 0.0006 | 0.00002 | 0.0001 | 0.0002 | 0.0200 | 0.0008 |
| 2006 | 0.0012 | 0.0000 | C | 0.3997 | 0.8390 | 0.0007 | C | 0.0007 | 0.0156 | 0.00001 | 0.0001 | 0.0003 | 0.0172 | 0.0005 |
| 2007 | 0.0018 | 0.0001 | C | 0.4696 | 0.8244 | 0.0009 | C | 0.0005 | 0.0484 | 0.00001 | 0.0001 | 0.0002 | 0.0139 | 0.0003 |
| 2008 | 0.0023 | 0.0001 | C | 0.2837 | 0.6746 | 0.0017 | C | 0.0003 | 0.0098 | 0.00001 | 0.0001 | 0.0002 | 0.0147 | 0.0005 |
| 2009 | 0.0017 | 0.0003 | C | 0.4977 | 0.8085 | 0.0020 | C | 0.0006 | 0.0080 | 0.00001 | 0.0000 | 0.0002 | 0.0189 | 0.0004 |
| 2010 | 0.0030 | 0.0003 | C | 0.5219 | 1.2609 | 0.0065 | C | 0.0011 | 0.0032 | 0.00001 | 0.0001 | 0.0003 | 0.0214 | 0.0003 |
| 2011 | 0.0046 | 0.0006 | C | 0.6226 | 1.4564 | 0.0146 | C | 0.0013 | 0.0034 | 0.00001 | 0.0001 | 0.0003 | 0.0245 | 0.0008 |
| 2012 | 0.0062 | 0.0005 | C | 0.6350 | 1.3521 | 0.0153 | C | 0.0014 | 0.0056 | 0.00001 | 0.0002 | 0.0003 | 0.0262 | 0.0012 |
| 2013 | 0.0079 | 0.0004 | C | 0.5728 | 1.5141 | 0.0156 | C | 0.0014 | 0.0067 | 0.00001 | 0.0002 | 0.0004 | 0.0294 | 0.0008 |
| 2014 | 0.0083 | 0.0006 | C | 0.5817 | 1.6456 | 0.0163 | C | 0.0012 | 0.0169 | 0.00001 | 0.0004 | 0.0003 | 0.0213 | 0.0010 |
| 2015 | 0.0086 | 0.0006 | C | 0.5567 | 1.5941 | 0.0176 | C | 0.0013 | 0.0191 | 0.00001 | 0.0003 | 0.0003 | 0.0143 | 0.0011 |
| 2016 | 0.0100 | 0.0006 | C | 0.5163 | 2.0146 | 0.0211 | C | 0.0016 | 0.0158 | 0.00001 | 0.0003 | 0.0004 | 0.0247 | 0.0013 |
| 2017 | 0.0106 | 0.0006 | C | 0.5755 | 1.9033 | 0.0260 | C | 0.0019 | 0.1636 | 0.00003 | 0.0003 | 0.0003 | 0.0256 | 0.0032 |

In this sector the food production is the major emitter of NMVOCs, contributing to approximately 98% of the total volume of emitted NMVOCs.

### *b) Methodological Issues*

- ***Estimation Method***

It is recommended to conduct the calculations according to Tier 2 approach, that provides taking into consideration the production technology designed for each separate product. As for Tier 3 approach, it implies including the modeling into the calculation process. The Tier 2 approach was applied for calculations.

- ***Emission Factors***

The emission coefficients offered in the IPCC Guidelines are provided in the Table 23 and are calculated based on the following assumptions:

- 0.15 tonne of grains is consumed for producing of 1-tonne beer;
- Brandy fermentation takes 3 years, but other alcohol drinks do not require fermentation;
- It is assumed that content of alcohol in the beer is 4%, , provided the mass of 1m3 is 1 tonne;
- The spirit has 40% of alcohol content;
- The density of the ethyl alcohol is 789 kg/m3.

Table 4-47. Coefficients of NMVOCs Emissions for the Subcategory "Food and Drinks Production"

| **Food** | **EF kg NMVOCs/t food production** | **Beverages** | **EF Kg NMVOCs/hl drink production** |
|---|---|---|---|
| Meat and meat semi-prepared food | 0.3 | Sparkling wine | 0.080 |
| Fish and fish product | 0.3 | White wine | 0.035 |
| Margarine and similar products | 10.0 | Beer | 0.035 |
| Drying and grinding of wheat | 1.3 | Spirit, vodka | 15.000 |
| Bread baking | 10.0 | Brandy | 3.500 |
| Confectionary | 1.0 | Alcohol free drinks | 0.400 |
| Sugar | 10.0 | | |
| Milling and roasting of coffee | 0.6 | | |
| Forage for domestic animals | 1.0 | | |

- ***Activity Data***

The subsector of food and drinks production comprises the complete cycle of food production: thermal processing of fats, baking, fermentation, cooking, drying, corn drying and milling processes. These activities imply emission of various volatile compounds, but only NMVOCs emissions will be discussed here according to the IPCC Methodological Guidelines. The emissions from processing of dairy products or oils are not discussed in this sector, as their processing technologies do not require heating, and consequently the emissions are not significant. In drinks (beer, wine, alcohol) production uses grapes, fruits and corn, which should be matured prior to being processed. During this process, the starch is turned into sugar and the sugar turns into the ethyl spirit with participation of yeast microbes. This process is called fermentation. Sometimes the technological process requires preparing raw materials before the fermentation (for example, for beer production, preparing of malt, for spirit production – distillation of the fermented liquid). The technological process of preparing food products and drinks includes roasting of raw materials, fermentation, and distillation. The fermentation process determines the sugar content of drinks and is the main cause of the emission of NMVOCs.

*Table 4-48* demonstrates the data on the food production in Georgia during 1990-2017.

*Table 4-48. The Food Products (tonne) and Drinks Produced in Georgia in 1990-2017*

| Year | Meat and semi-prepared meat food (t) | Fish and fish product (t) | Margarine and similar products (t) | Drying and grinding of wheat (t) | Bread baking (t) | Confectionary (t) | Sugar (t) | Milling and roasting of coffee (t) | Forage for domestic animals (t) | Sparkling wine (hl) | White wine (hl) | Beer (hl) | Spirit, vodka (hl) | Brandy (hl) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 44235 | 59678 | C | 951699 | 855572 | 59504 | C | NO | 1079685 | 1451 | 16283 | 9477 | 822 | 2165 |
| 1991 | 14728 | 39901 | C | 846748 | 1004925 | 25281 | C | NO | 838505 | 1104 | 12616 | 6011 | 774 | 1460 |
| 1992 | 4509 | 2190 | C | 578534 | 760311 | 1924 | C | NO | 346695 | 779 | 21011 | 2352 | 647 | 1358 |
| 1993 | 555 | 386 | C | 462506 | 639512 | 1859 | C | NO | 161144 | 443 | 14003 | 1204 | 1187 | 1023 |
| 1994 | 246 | 188 | C | 420421 | 498331 | 466 | C | NO | 135550 | 171 | 7000 | 632 | 229 | 282 |
| 1995 | 235 | 518 | C | 334288 | 296351 | 346 | C | NO | 84303 | 49 | 4229 | 653 | 145 | 158 |
| 1996 | 410 | 622 | C | 211346 | 262305 | 378 | C | 784 | 37406 | 95 | 2697 | 476 | 196 | 135 |
| 1997 | 938 | 1457 | C | 180183 | 198657 | 235 | C | 2830 | 22045 | 76 | 3600 | 785 | 435 | 82 |
| 1998 | 1155 | 31 | C | 147529 | 173886 | 277 | C | 1484 | 11034 | 40 | 2304 | 971 | 271 | 38 |
| 1999 | 1423 | 3 | C | 113980 | 113590 | 154 | C | 1318 | 4811 | 67 | 1939 | 1258 | 514 | 31 |
| 2000 | 995 | 63 | C | 102977 | 111335 | 144 | C | 1411 | 2701 | 88 | 1665 | 2345 | 522 | 71 |
| 2001 | 417 | 13 | C | 79734 | 88141 | 101 | C | 997 | 99 | 115 | 1976 | 2572 | 729 | 73 |
| 2002 | 603 | 4 | C | 77900 | 88842 | 105 | C | 349 | NE | 118 | 2012 | 2735 | 286 | 74 |
| 2003 | 1011 | 10 | C | 72215 | 77009 | 336 | C | 418 | 1318 | 160 | 2308 | 2842 | 388 | 142 |
| 2004 | 2261 | 57 | C | 140688 | 100126 | 287 | C | 483 | 691 | 164 | 2666 | 4762 | 1071 | 193 |
| 2005 | 2640 | 299 | C | 195754 | 92938 | 348 | C | 758 | 603 | 189 | 3906 | 5864 | 1337 | 227 |
| 2006 | 3965 | 155 | C | 307454 | 83899 | 656 | C | 1204 | 15599 | 137 | 2118 | 7337 | 1147 | 152 |
| 2007 | 5842 | 457 | C | 361223 | 82443 | 885 | C | 796 | 48389 | 162 | 1438 | 7087 | 927 | 87 |
| 2008 | 7830 | 259 | C | 218256 | 67460 | 1669 | C | 466 | 9773 | 160 | 1670 | 6246 | 977 | 151 |
| 2009 | 5815 | 943 | C | 382884 | 80853 | 2016 | C | 1073 | 7995 | 122 | 1400 | 6854 | 1261 | 124 |
| 2010 | 9987 | 1002 | C | 401483 | 126086 | 6464 | C | 1889 | 3207 | 114 | 2476 | 8279 | 1427 | 100 |
| 2011 | 15353 | 2152 | C | 478916 | 145640 | 14560 | C | 2207 | 3446 | 139 | 2905 | 7874 | 1634 | 226 |
| 2012 | 20537 | 1507 | C | 488460 | 135211 | 15345 | C | 2401 | 5628 | 124 | 4499 | 9903 | 1748 | 338 |

| Year | Meat and semi-prepared meat food (t) | Fish and fish product (t) | Margarine and similar products (t) | Drying and grinding of wheat (t) | Bread baking (t) | Confectionary (t) | Sugar (t) | Milling and roasting of coffee (t) | Forage for domestic animals (t) | Sparkling wine (hl) | White wine (hl) | Beer (hl) | Spirit, vodka (hl) | Brandy (hl) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | 26492 | 1375 | C | 440589 | 151412 | 15596 | C | 2411 | 6720 | 165 | 6552 | 10090 | 1963 | 229 |
| 2014 | 27773 | 1970 | C | 447428 | 164562 | 16339 | C | 1956 | 16894 | 181 | 10869 | 9965 | 1421 | 286 |
| 2015 | 28544 | 2005 | C | 428262 | 159409 | 17598 | C | 2167 | 19139 | 128 | 7554 | 8606 | 950 | 323 |
| 2016 | 33303 | 2049 | C | 397152 | 201457 | 21103 | C | 2731 | 15787 | 160 | 9001 | 10238 | 1644 | 362 |
| 2017 | 35346 | 2145 | C | 442715 | 190334 | 25991 | C | 3157 | 163646 | 353 | 8702 | 8849 | 1709 | 912 |

Agriculture (CRF Sector 3)

## 4.10. Overview of Sector

This chapter provides the information about the estimation of greenhouse gas (GHG) emissions from Agriculture Sector for the period 1990-2017.

According to the "Agriculture census 2014", in Georgia 73.1% of farms manage land lots up to 1 ha, 25% land lots from 1 ha to 5 ha and only 1.5% of the farms manage land lots larger than 5 ha. The agricultural lands area of Georgia comprises 2.55 million hectares, which is about 37% of the total territory (forestry is about 41%, other area - about 23%). The shares of various agricultural activities are as follows: Land under annual crops – 220,300 ha, Permanent cropland – 226,100 ha, Pastures, and grasslands - 1,776,000 ha.

The agriculture sector of Georgia as source of GHG emissions comprises three subcategories: Enteric fermentation, Manure management and Agricultural Soils. The other IPCC subcategories of rice cultivation and prescribed burning of savannas are not relevant for Georgia and therefore are not considered. GHG emissions are estimated for 2016-2017 years period. For previous 1990-2015 years GHG emissions from agriculture sectors are recalculated applying specified data on cattle distribution by breeds (provided by Head of the Department of Zootechny of the Agrarian University of Georgia Mr. Levan Tortladze), using tier 2 approach for methane emissions from manure management, estimating GHG emissions from enteric fermentation in donkeys and horses (during 2006-2017 years) and estimating GHG emissions from field burning of agricultural residues.

The GHG emissions from the agricultural sector are presented in *Table 4-49*, and *Figure 4-8 - Figure 4-11*. It clearly shows that enteric fermentation is the largest source for methane emissions within this sector, while "Agriculture soils" is the largest emitter of nitrous oxide.

Table 4-49 Methane and Nitrous Oxide emissions (in Gg) from agriculture sector in 1990-2017 years

| Year | $CH_4$ | | | | $N_2O$ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Enteric fermentation (3.A)** | **Manure management (3.B)** | **Field burning of Agricultural Residues (3.F)** | **CH4 total** | **Manure management – direct (3.B)** | **Manure management – indirect (3.B)** | **Agricultural soils (3.D)** | **Direct soil emissions (3.D.a)** | **Synthetic fertilizers (3.D.a.1)** | **Organic N fertilizers (3.D.a.2)** | **Urine & dung from grazing animals (3.D.a.3)** | **Crop residue decomposition (3.D.a.4)** | **Indirect soil emissions (3.D.b)** | **Atmospheric deposition (3.D.b.1)** | **Nitrogen leaching & run-off (3.D.b.2)** | **Field burning of Agricultural Residues (3.F)** | **$N_2O$ total** |
| 1990 | 89.67 | 5.80 | 0.51 | 95.99 | 0.96 | 0.22 | 5.54 | 3.49 | 1.19 | 3.40 | 3.77 | 0.20 | 2.05 | 0.33 | 1.72 | 0.01 | 6.73 |
| 1991 | 83.28 | 5.05 | 0.44 | 88.77 | 0.88 | 0.20 | 4.87 | 3.07 | 0.98 | 2.92 | 3.23 | 0.17 | 1.80 | 0.30 | 1.50 | 0.01 | 5.96 |
| 1992 | 68.96 | 3.55 | 0.39 | 72.90 | 0.71 | 0.16 | 4.11 | 2.59 | 0.90 | 2.54 | 2.82 | 0.15 | 1.52 | 0.25 | 1.28 | 0.01 | 4.99 |
| 1993 | 63.25 | 3.00 | 0.32 | 66.56 | 0.66 | 0.15 | 3.81 | 2.39 | 0.90 | 0.30 | 1.08 | 0.12 | 1.42 | 0.23 | 1.19 | 0.01 | 4.63 |
| 1994 | 63.53 | 3.01 | 0.38 | 66.92 | 0.67 | 0.15 | 3.30 | 2.08 | 0.61 | 0.30 | 1.04 | 0.13 | 1.22 | 0.20 | 1.01 | 0.01 | 4.13 |
| 1995 | 65.16 | 3.01 | 0.38 | 68.54 | 0.69 | 0.15 | 3.56 | 2.24 | 0.76 | 0.31 | 1.06 | 0.12 | 1.32 | 0.22 | 1.11 | 0.01 | 4.41 |
| 1996 | 67.06 | 2.98 | 0.46 | 70.50 | 0.71 | 0.15 | 5.14 | 3.18 | 1.66 | 0.31 | 1.06 | 0.14 | 1.96 | 0.29 | 1.67 | 0.01 | 6.01 |
| 1997 | 68.13 | 3.01 | 0.64 | 71.79 | 0.72 | 0.16 | 5.61 | 3.47 | 1.87 | 0.32 | 1.07 | 0.21 | 2.15 | 0.31 | 1.84 | 0.02 | 6.51 |
| 1998 | 69.84 | 3.04 | 0.44 | 73.32 | 0.73 | 0.16 | 4.40 | 2.74 | 1.21 | 0.32 | 1.05 | 0.16 | 1.66 | 0.25 | 1.41 | 0.01 | 5.30 |
| 1999 | 74.78 | 3.33 | 0.57 | 78.67 | 0.79 | 0.17 | 5.18 | 3.21 | 1.56 | 0.34 | 1.13 | 0.19 | 1.97 | 0.29 | 1.67 | 0.02 | 6.16 |
| 2000 | 78.26 | 3.50 | 0.31 | 82.07 | 0.82 | 0.18 | 4.13 | 2.59 | 0.93 | 0.35 | 1.17 | 0.13 | 1.54 | 0.25 | 1.29 | 0.01 | 5.14 |
| 2001 | 78.88 | 3.55 | 0.56 | 82.98 | 0.83 | 0.18 | 4.56 | 2.85 | 1.13 | 0.36 | 1.20 | 0.17 | 1.71 | 0.27 | 1.44 | 0.01 | 5.58 |
| 2002 | 81.42 | 3.60 | 0.50 | 85.52 | 0.86 | 0.19 | 5.15 | 3.21 | 1.43 | 0.37 | 1.24 | 0.17 | 1.94 | 0.30 | 1.64 | 0.01 | 6.21 |
| 2003 | 83.37 | 3.76 | 0.56 | 87.68 | 0.88 | 0.19 | 5.34 | 3.33 | 1.49 | 0.38 | 1.27 | 0.18 | 2.02 | 0.31 | 1.71 | 0.02 | 6.43 |
| 2004 | 79.96 | 3.76 | 0.51 | 84.23 | 0.84 | 0.18 | 4.34 | 2.73 | 0.94 | 0.37 | 1.26 | 0.16 | 1.61 | 0.26 | 1.35 | 0.01 | 5.37 |
| 2005 | 80.89 | 3.61 | 0.53 | 85.03 | 0.85 | 0.19 | 4.36 | 2.74 | 0.91 | 0.37 | 1.26 | 0.21 | 1.62 | 0.26 | 1.36 | 0.01 | 5.41 |
| 2006 | 73.40 | 2.95 | 0.24 | 76.60 | 0.76 | 0.17 | 4.62 | 2.88 | 1.32 | 0.33 | 1.13 | 0.10 | 1.74 | 0.27 | 1.47 | 0.01 | 5.56 |
| 2007 | 71.24 | 1.99 | 0.31 | 73.54 | 0.72 | 0.15 | 3.88 | 2.43 | 0.92 | 0.31 | 1.09 | 0.11 | 1.45 | 0.23 | 1.21 | 0.01 | 4.76 |
| 2008 | 73.14 | 1.94 | 0.33 | 75.41 | 0.74 | 0.16 | 4.08 | 2.56 | 1.01 | 0.31 | 1.11 | 0.12 | 1.53 | 0.24 | 1.28 | 0.01 | 4.99 |
| 2009 | 69.45 | 2.06 | 0.27 | 71.78 | 0.71 | 0.15 | 4.15 | 2.59 | 1.13 | 0.30 | 1.05 | 0.10 | 1.56 | 0.24 | 1.32 | 0.01 | 5.02 |
| 2010 | 72.32 | 2.01 | 0.18 | 74.51 | 0.74 | 0.16 | 3.90 | 2.44 | 0.99 | 0.31 | 1.07 | 0.07 | 1.46 | 0.24 | 1.22 | 0.01 | 4.81 |
| 2011 | 71.61 | 1.96 | 0.30 | 73.87 | 0.73 | 0.16 | 3.71 | 2.33 | 0.85 | 0.31 | 1.06 | 0.11 | 1.38 | 0.22 | 1.16 | 0.01 | 4.61 |
| 2012 | 76.24 | 2.44 | 0.28 | 78.95 | 0.79 | 0.17 | 4.09 | 2.56 | 0.97 | 0.33 | 1.15 | 0.11 | 1.52 | 0.25 | 1.28 | 0.01 | 5.06 |
| 2013 | 81.54 | 2.50 | 0.35 | 84.38 | 0.84 | 0.18 | 4.81 | 3.00 | 1.27 | 0.36 | 1.24 | 0.13 | 1.80 | 0.28 | 1.52 | 0.01 | 5.84 |
| 2014 | 87.69 | 2.50 | 0.26 | 90.46 | 0.91 | 0.19 | 4.48 | 2.82 | 1.00 | 0.38 | 1.32 | 0.11 | 1.67 | 0.27 | 1.39 | 0.01 | 5.59 |
| 2015 | 91.08 | 2.56 | 0.27 | 93.91 | 0.94 | 0.20 | 4.57 | 2.87 | 0.98 | 0.40 | 1.37 | 0.12 | 1.69 | 0.28 | 1.42 | 0.01 | 5.72 |
| 2016 | 92.47 | 2.48 | 0.32 | 95.27 | 0.96 | 0.20 | 4.63 | 2.91 | 1.00 | 0.40 | 1.39 | 0.12 | 1.72 | 0.28 | 1.43 | 0.01 | 5.80 |
| 2017 | 87.12 | 2.43 | 0.23 | 89.78 | 0.90 | 0.19 | 4.07 | 2.57 | 0.78 | 0.38 | 1.32 | 0.09 | 1.50 | 0.26 | 1.24 | 0.01 | 5.17 |

Table 4-50 GHG emissions (in Gg $CO_2$-eq) from agriculture sector in1990 -2017 years

| Year | $CH_4$ | | | | $N_2O$ | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Enteric fermentation (3.A)** | **Manure management (3.B)** | **Field burning of Agricultural Residues (3.F)** | **$CH_4$ total** | **Manure management – direct (3.B)** | **Manure management – Indirect (3.B)** | **Agricultural soils (3.D)** | **Direct soil emissions (3.D.a)** | **Synthetic fertilizers (3.D.a.1)** | **Organic N fertilizers (3.D.a.2)** | **Urine & dung from grazing animals (3.D.a.3)** | **Crop residue decomposition (3.D.a.4)** | **Indirect soil emissions (3.D.b)** | **Atmospheric deposition (3.D.b.1)** | **Nitrogen leaching & run-off (3.D.b.2)** | **Field burning of Agricultural Residues (3.F)** | **$N_2O$ total** | **Total Agriculture sector** |
| 1990 | 1,883 | 122 | 11 | 2,016 | 297 | 68 | 1,717 | 1,080 | 370 | 140 | 508 | 62 | 637 | 103 | 534 | 4 | 2,086 | 4,102 |
| 1991 | 1,749 | 106 | 9 | 1,864 | 274 | 62 | 1,509 | 952 | 303 | 129 | 467 | 52 | 557 | 92 | 466 | 4 | 1,849 | 3,713 |
| 1992 | 1,448 | 75 | 8 | 1,531 | 221 | 50 | 1,274 | 801 | 279 | 102 | 375 | 45 | 473 | 76 | 396 | 3 | 1,548 | 3,079 |
| 1993 | 1,328 | 63 | 7 | 1,398 | 204 | 45 | 1,181 | 741 | 278 | 92 | 335 | 36 | 440 | 71 | 369 | 3 | 1,433 | 2,831 |
| 1994 | 1,334 | 63 | 8 | 1,405 | 207 | 46 | 1,022 | 645 | 189 | 93 | 324 | 40 | 377 | 62 | 314 | 3 | 1,278 | 2,683 |
| 1995 | 1,368 | 63 | 8 | 1,439 | 213 | 47 | 1,103 | 694 | 235 | 95 | 327 | 36 | 409 | 67 | 343 | 3 | 1,366 | 2,805 |
| 1996 | 1,408 | 63 | 10 | 1,480 | 220 | 48 | 1,592 | 985 | 513 | 97 | 330 | 45 | 607 | 90 | 517 | 4 | 1,864 | 3,344 |
| 1997 | 1,431 | 63 | 14 | 1,508 | 224 | 49 | 1,740 | 1,075 | 580 | 99 | 330 | 66 | 666 | 95 | 571 | 5 | 2,018 | 3,526 |
| 1998 | 1,467 | 64 | 9 | 1,540 | 227 | 49 | 1,364 | 850 | 376 | 98 | 327 | 49 | 515 | 78 | 436 | 4 | 1,644 | 3,184 |
| 1999 | 1,570 | 70 | 12 | 1,652 | 244 | 53 | 1,606 | 997 | 482 | 105 | 351 | 58 | 609 | 90 | 519 | 5 | 1,908 | 3,560 |
| 2000 | 1,643 | 74 | 7 | 1,723 | 256 | 56 | 1,279 | 803 | 289 | 109 | 363 | 41 | 477 | 77 | 400 | 3 | 1,594 | 3,317 |
| 2001 | 1,656 | 74 | 12 | 1,743 | 257 | 56 | 1,413 | 884 | 349 | 111 | 371 | 54 | 530 | 83 | 447 | 5 | 1,731 | 3,474 |
| 2002 | 1,710 | 76 | 11 | 1,796 | 265 | 58 | 1,596 | 994 | 443 | 114 | 385 | 51 | 602 | 92 | 510 | 4 | 1,923 | 3,719 |

| Year | CH₄ | | | | N₂O | | | | | | | | | | | | | Total Agriculture sector |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Enteric fermentation (3.A) | Manure management (3.B) | Field burning of Agricultural Residues (3.F) | $CH_4$ total | Manure management – direct (3.B) | Manure management – Indirect (3.B) | Agricultural soils (3.D) | Direct soil emissions (3.D.a) | Synthetic fertilizers (3.D.a.1) | Organic N fertilizers (3.D.a.2) | Urine & dung from grazing animals (3.D.a.3) | Crop residue decomposition (3.D.a.4) | Indirect soil emissions (3.D.b) | Atmospheric deposition (3.D.b.1) | Nitrogen leaching & run-off (3.D.b.2) | Field burning of Agricultural Residues (3.F) | $N_2O$ total | |
| 2003 | 1,751 | 79 | 12 | 1,841 | 272 | 59 | 1,656 | 1,031 | 462 | 117 | 395 | 57 | 625 | 95 | 530 | 5 | 1,992 | 3,833 |
| 2004 | 1,679 | 79 | 11 | 1,769 | 260 | 57 | 1,346 | 846 | 290 | 114 | 392 | 50 | 500 | 81 | 420 | 4 | 1,667 | 3,436 |
| 2005 | 1,699 | 76 | 11 | 1,786 | 262 | 57 | 1,351 | 849 | 281 | 113 | 390 | 65 | 502 | 80 | 422 | 5 | 1,675 | 3,461 |
| 2006 | 1,541 | 62 | 5 | 1,609 | 235 | 51 | 1,432 | 892 | 409 | 101 | 351 | 30 | 540 | 84 | 456 | 2 | 1,720 | 3,329 |
| 2007 | 1,496 | 42 | 6 | 1,544 | 224 | 48 | 1,203 | 755 | 285 | 95 | 339 | 35 | 448 | 72 | 376 | 3 | 1,478 | 3,022 |
| 2008 | 1,536 | 41 | 7 | 1,584 | 230 | 49 | 1,266 | 793 | 312 | 97 | 345 | 38 | 473 | 75 | 398 | 3 | 1,548 | 3,132 |
| 2009 | 1,459 | 43 | 6 | 1,507 | 220 | 47 | 1,285 | 802 | 351 | 93 | 326 | 31 | 483 | 76 | 408 | 2 | 1,554 | 3,061 |
| 2010 | 1,519 | 42 | 4 | 1,565 | 229 | 49 | 1,210 | 757 | 306 | 97 | 333 | 22 | 453 | 73 | 379 | 2 | 1,490 | 3,055 |
| 2011 | 1,504 | 41 | 6 | 1,551 | 228 | 48 | 1,151 | 722 | 264 | 96 | 328 | 34 | 429 | 69 | 359 | 3 | 1,430 | 2,981 |
| 2012 | 1,601 | 51 | 6 | 1,658 | 244 | 52 | 1,267 | 794 | 301 | 104 | 356 | 33 | 473 | 76 | 396 | 2 | 1,565 | 3,223 |
| 2013 | 1,712 | 52 | 7 | 1,772 | 261 | 56 | 1,490 | 931 | 393 | 111 | 385 | 41 | 560 | 88 | 472 | 3 | 1,810 | 3,582 |
| 2014 | 1,842 | 53 | 6 | 1,900 | 281 | 60 | 1,390 | 874 | 309 | 119 | 410 | 35 | 517 | 85 | 432 | 2 | 1,733 | 3,633 |
| 2015 | 1,913 | 54 | 6 | 1,972 | 293 | 62 | 1,416 | 891 | 304 | 124 | 425 | 38 | 525 | 87 | 439 | 2 | 1,773 | 3,745 |
| 2016 | 1,942 | 52 | 7 | 2,001 | 297 | 63 | 1,434 | 902 | 311 | 125 | 430 | 36 | 532 | 88 | 444 | 3 | 1,797 | 3,798 |
| 2017 | 1,830 | 51 | 5 | 1,885 | 280 | 60 | 1,261 | 796 | 242 | 119 | 408 | 27 | 465 | 79 | 386 | 2 | 1,603 | 3,488 |

*Figure 4-8 Methane emissions in 1990-2017 years*

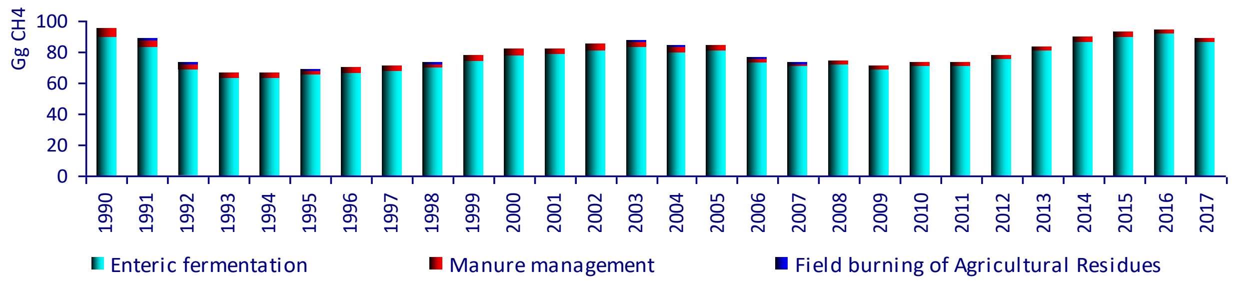



*Figure 4-9 Nitrous Oxide emissions in 1990-2017 years*

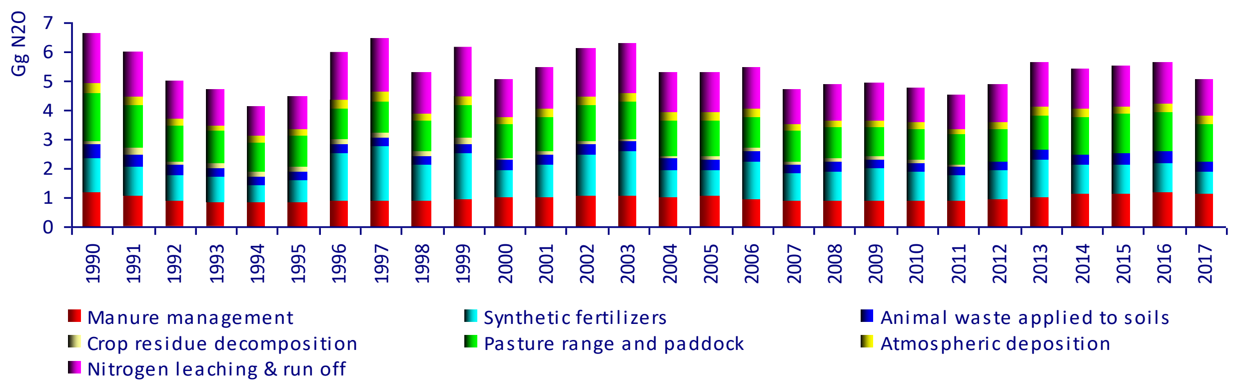


*Figure 4-10 GHG emissions from Agriculture sector by sources in 1990-2017 years*

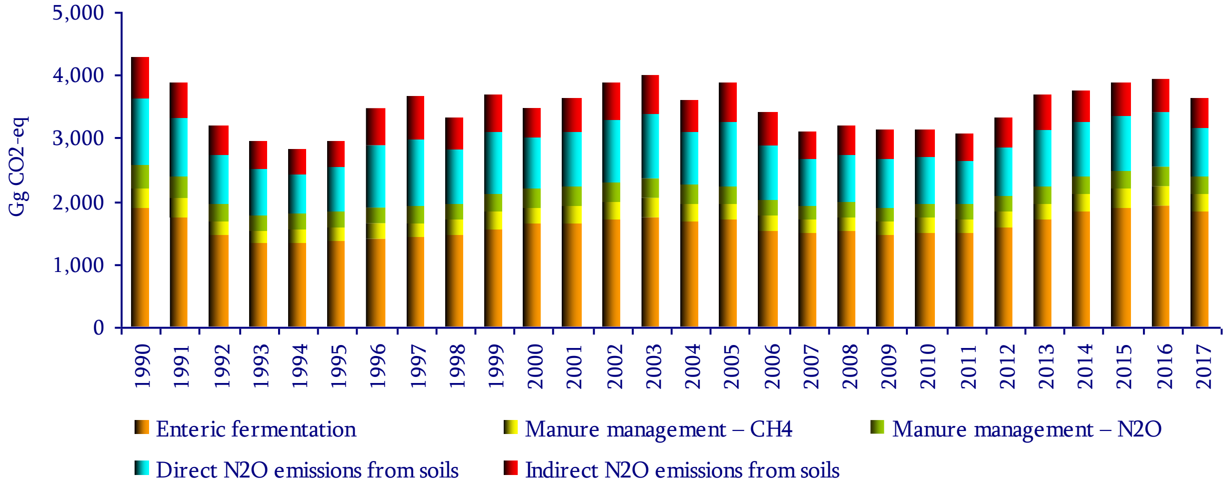
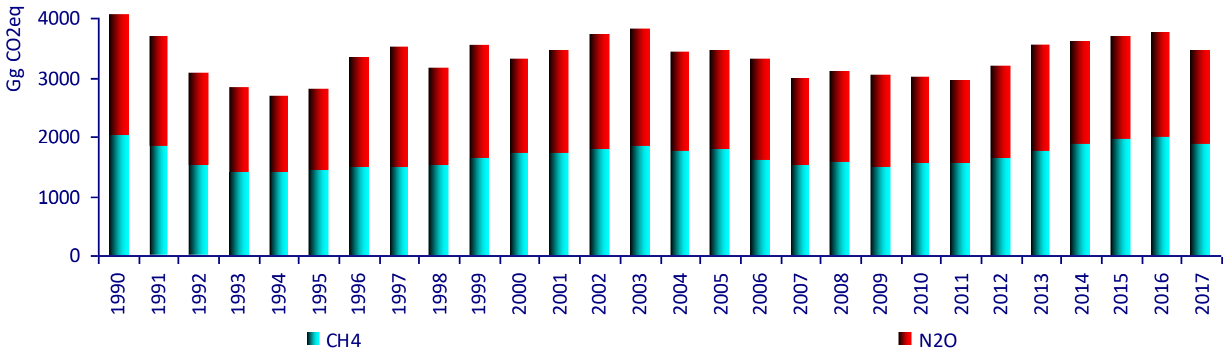



*Figure 4-11 GHG emissions by gases in 1990-2017 years*




The shares of gases in agriculture sector emissions as well as share of sub-categories emissions in agriculture sector emissions are presented in *Table 4-51.* According to this table share of methane varies within 43–54 percent. Enteric fermentation is the largest source for emission. s. The share of nitrous oxide varies within 46-57 percent.

Table 4-51 Share of sub-categories emissions in agriculture sector emissions (in %)

| Year | $CH_4$ | | | | $N_2O$ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Enteric fermentation (3.A)** | **Manure management (3.B)** | **Field burning of Agricultural Residues (3.F)** | **$CH_4$ total** | **Manure management (3.B)** | **Agricultural soils (3.D)** | **Direct soil emissions (3.D.a)** | **Synthetic fertilizers (3.D.a.1)** | **Organic N fertilizers (3.D.a.2)** | **Urine & dung from grazing animals (3.D.a.3)** | **Crop residue decomposition (3.D.a.4)** | **Indirect soil emissions (3.D.b)** | **Atmospheric deposition (3.D.b.1)** | **Nitrogen leaching & run-off (3.D.b.2)** | **Field burning of Agricultural Residues (3.F)** | **$N_2O$ total** | **Total Agriculture sector** |
| 1990 | 46 | 3 | 0.3 | **49** | 9 | 42 | 26 | 9 | 3 | 2 | 12 | 16 | 3 | 13 | 0.1 | **51** | **100** |
| 1991 | 47 | 3 | 0.3 | **50** | 9 | 41 | 26 | 8 | 3 | 1 | 13 | 15 | 2 | 13 | 0.1 | **50** | **100** |
| 1992 | 47 | 2 | 0.3 | **50** | 9 | 41 | 26 | 9 | 3 | 1 | 12 | 15 | 2 | 13 | 0.1 | **50** | **100** |
| 1993 | 47 | 2 | 0.3 | **49** | 9 | 42 | 26 | 10 | 3 | 1 | 12 | 16 | 2 | 13 | 0.1 | **51** | **100** |
| 1994 | 50 | 2 | 0.3 | **52** | 9 | 38 | 24 | 7 | 3 | 1 | 12 | 14 | 2 | 12 | 0.1 | **48** | **100** |
| 1995 | 49 | 2 | 0.3 | **51** | 9 | 39 | 25 | 8 | 3 | 1 | 12 | 15 | 2 | 12 | 0.1 | **49** | **100** |

| Year | $CH_4$ | | | | $N_2O$ | | | | | | | | | | | | Total Agriculture sector |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Enteric fermentation (3.A) | Manure management (3.B) | Field burning of Agricultural Residues (3.F) | $CH_4$ total | Manure management (3.B) | Agricultural soils (3.D) | Direct soil emissions (3.D.a) | Synthetic fertilizers (3.D.a.1) | Organic N fertilizers (3.D.a.2) | Urine & dung from grazing animals (3.D.a.3) | Crop residue decomposition (3.D.a.4) | Indirect soil emissions (3.D.b) | Atmospheric deposition (3.D.b.1) | Nitrogen leaching & run-off (3.D.b.2) | Field burning of Agricultural Residues (3.F) | $N_2O$ total | |
| 1996 | 42 | 2 | 0.2 | **44** | 8 | 48 | 29 | 15 | 3 | 1 | 10 | 18 | 3 | 15 | 0.1 | **56** | **100** |
| 1997 | 41 | 2 | 0.2 | **43** | 8 | 49 | 31 | 16 | 3 | 2 | 9 | 19 | 3 | 16 | 0.1 | **57** | **100** |
| 1998 | 46 | 2 | 0.2 | **48** | 9 | 43 | 27 | 12 | 3 | 2 | 10 | 16 | 2 | 14 | 0.1 | **52** | **100** |
| 1999 | 44 | 2 | 0.2 | **46** | 8 | 45 | 28 | 14 | 3 | 2 | 10 | 17 | 3 | 15 | 0.1 | **54** | **100** |
| 2000 | 50 | 2 | 0.2 | **52** | 9 | 39 | 24 | 9 | 3 | 1 | 11 | 14 | 2 | 12 | 0.1 | **48** | **100** |
| 2001 | 48 | 2 | 0.3 | **50** | 9 | 41 | 25 | 10 | 3 | 2 | 11 | 15 | 2 | 13 | 0.1 | **50** | **100** |
| 2002 | 46 | 2 | 0.2 | **48** | 9 | 43 | 27 | 12 | 3 | 1 | 10 | 16 | 2 | 14 | 0.1 | **52** | **100** |
| 2003 | 46 | 2 | 0.2 | **48** | 9 | 43 | 27 | 12 | 3 | 1 | 10 | 16 | 2 | 14 | 0.1 | **52** | **100** |
| 2004 | 49 | 2 | 0.2 | **51** | 9 | 39 | 25 | 8 | 3 | 1 | 11 | 15 | 2 | 12 | 0.1 | **49** | **100** |
| 2005 | 49 | 2 | 0.3 | **52** | 9 | 39 | 25 | 8 | 3 | 2 | 11 | 14 | 2 | 12 | 0.1 | **48** | **100** |
| 2006 | 46 | 2 | 0.3 | **48** | 9 | 43 | 27 | 12 | 3 | 1 | 11 | 16 | 3 | 14 | 0.1 | **52** | **100** |
| 2007 | 50 | 1 | 0.2 | **51** | 9 | 40 | 25 | 9 | 3 | 1 | 11 | 15 | 2 | 12 | 0.1 | **49** | **100** |
| 2008 | 49 | 1 | 0.2 | **51** | 9 | 40 | 25 | 10 | 3 | 1 | 11 | 15 | 2 | 13 | 0.1 | **49** | **100** |
| 2009 | 48 | 1 | 0.2 | **49** | 9 | 42 | 26 | 11 | 3 | 1 | 11 | 16 | 2 | 13 | 0.1 | **51** | **100** |
| 2010 | 50 | 1 | 0.1 | **51** | 9 | 40 | 25 | 10 | 3 | 1 | 11 | 15 | 2 | 12 | 0.1 | **49** | **100** |
| 2011 | 50 | 1 | 0.2 | **52** | 9 | 39 | 24 | 9 | 3 | 1 | 11 | 14 | 2 | 12 | 0.1 | **48** | **100** |
| 2012 | 50 | 2 | 0.2 | **51** | 9 | 39 | 25 | 9 | 3 | 1 | 11 | 15 | 2 | 12 | 0.1 | **49** | **100** |
| 2013 | 48 | 1 | 0.2 | **49** | 9 | 42 | 26 | 11 | 3 | 1 | 11 | 16 | 2 | 13 | 0.1 | **51** | **100** |
| 2014 | 51 | 1 | 0.2 | **52** | 9 | 38 | 24 | 9 | 3 | 1 | 11 | 14 | 2 | 12 | 0.1 | **48** | **100** |
| 2015 | 51 | 1 | 0.2 | **53** | 9 | 38 | 24 | 8 | 3 | 1 | 11 | 14 | 2 | 12 | 0.1 | **47** | **100** |
| 2016 | 51 | 1 | 0.2 | **53** | 9 | 38 | 24 | 8 | 3 | 1 | 11 | 14 | 2 | 12 | 0.1 | **47** | **100** |
| 2017 | 52 | 1 | 0.1 | **54** | 10 | 36 | 23 | 7 | 3 | 1 | 12 | 13 | 2 | 11 | 0.1 | **46** | **100** |

**Comparison of recalculated GHG emissions with relevant values from SBUR**

For years 1990, 1994, 2000, 2005, 2011-2015 the recalculated values have been compared with relevant values from Second Biennial Update Report (SBUR). Differences are provided in *Table 4-52*. According to this table the difference between FNC and SBUR varies within 5%-15%. Enteric fermentation and manure management bear the largest difference among the categories. As mentioned above, compared to the previous inventory, specified data on cattle distribution by breeds are used. Besides, tier 2 approach for methane emissions from manure management was applied.

Table 4-52 Difference (in %) between FNC and Second BUR

| Year | $CH_4$ | | | | $N_2O$ | | | | | | | | | | | | Total Agriculture total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Enteric fermentation | Manure management | Field burning of Agricultural Residues | $CH_4$ total | Manure management | Agricultural soils | Direct soil emissions | Synthetic fertilizers | Animal waste applied to soils | Crop residue decomposition | Pasture range and paddock | Indirect emissions | Atmospheric deposition | Nitrogen leaching & run off | Field burning of Agricultural Residues | $N_2O$ total | |
| 1990 | 16 | -36 | - | 16 | -3 | -1 | -1 | 0 | -3 | 0 | -2 | -1 | -2 | -1 | - | 0 | **5** |
| 1994 | 23 | -42 | - | 23 | 1 | 1 | 1 | 0 | 2 | -1 | 1 | 0 | 1 | 0 | - | 2 | **10** |
| 2000 | 24 | -44 | - | 24 | 2 | 1 | 1 | 0 | 2 | -1 | 2 | 1 | 1 | 1 | - | 2 | **10** |
| 2005 | 25 | -43 | - | 25 | 3 | 2 | 1 | 0 | 3 | 0 | 2 | 2 | 2 | 1 | - | 4 | **11** |
| 2010 | 28 | -55 | - | 28 | 5 | 4 | 4 | 0 | 5 | -1 | 7 | 3 | 5 | 3 | - | 4 | **13** |
| 2011 | 27 | -56 | - | 27 | 4 | 4 | 4 | 0 | 4 | 11 | 7 | 4 | 3 | 4 | - | 5 | **13** |

| Year | $CH_4$ | | | | $N_2O$ | | | | | | | | | | | | Total Agriculture total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Enteric fermentation | Manure management | Field burning of Agricultural Residues | $CH_4$ total | Manure management | Agricultural soils | Direct soil emissions | Synthetic fertilizers | Animal waste applied to soils | Crop residue decomposition | Pasture range and paddock | Indirect emissions | Atmospheric deposition | Nitrogen leaching & run off | Field burning of Agricultural Residues | $N_2O$ total | |
| 2012 | 28 | -52 | - | 28 | 5 | 4 | 4 | 0 | 5 | 17 | 7 | 4 | 5 | 4 | - | 5 | **13** |
| 2013 | 28 | -52 | - | 28 | 6 | 4 | 4 | 0 | 6 | 0 | 7 | 3 | 4 | 3 | - | 5 | **13** |
| 2014 | 29 | -54 | - | 29 | 6 | 4 | 4 | 0 | 6 | 1 | 8 | 4 | 5 | 4 | - | 5 | **14** |
| 2015 | 30 | -54 | - | 30 | 7 | 5 | 5 | 0 | 7 | 0 | 9 | 4 | 6 | 4 | - | 6 | **15** |

## 4.11. Enteric Fermentation (3.A.)

The emissions source category "enteric fermentation" consists of the following sub-sources: cattle, buffalos, sheep, goats (multi-chamber stomachs), horses, asses, and swine (monogastric stomachs). Camels and mules are not relevant for Georgia. For 1900-2017 years period GHG emissions mainly varied according to the livestock population.

Methane emissions in Gg from enteric fermentation in livestock are presented in *Table 4-53*. Major "Key source" is enteric fermentation by cattle, which contributes about 90% of the total emissions from enteric fermentation. Data on number of asses for several years are absent.

Table 4-53 Methane emissions (in Gg) from enteric fermentation in livestock

| Year | Cattle 3.A.1 | Buffalos 3.A.2 | Sheep 3.A.3 | Goats 3.A.4 | Horses 3.A.5.1 | Asses 3.A.5.2 | Swine 3.A.6 | Total in Gg CH4 | Total in Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 78.32 | 2.02 | 7.75 | 0.34 | 0.35 | NE | 0.88 | **89.67** | **1,883** |
| 1991 | 73.07 | 1.81 | 7.06 | 0.29 | 0.33 | NE | 0.73 | **83.28** | **1,749** |
| 1992 | 60.57 | 1.65 | 5.73 | 0.23 | 0.3 | NE | 0.48 | **68.96** | **1,448** |
| 1993 | 56.4 | 1.35 | 4.6 | 0.19 | 0.35 | NE | 0.37 | **63.25** | **1,328** |
| 1994 | 57.59 | 1.22 | 3.77 | 0.2 | 0.39 | NE | 0.37 | **63.53** | **1,334** |
| 1995 | 59.53 | 1.22 | 3.37 | 0.25 | 0.43 | NE | 0.35 | **65.16** | **1,368** |
| 1996 | 61.76 | 1.23 | 3 | 0.26 | 0.47 | NE | 0.33 | **67.06** | **1,408** |
| 1997 | 63.04 | 1.25 | 2.62 | 0.3 | 0.5 | 0.09 | 0.33 | **68.13** | **1,431** |
| 1998 | 64.63 | 1.25 | 2.61 | 0.33 | 0.55 | 0.11 | 0.37 | **69.84** | **1,467** |
| 1999 | 69.21 | 1.25 | 2.77 | 0.4 | 0.61 | 0.12 | 0.41 | **74.78** | **1,570** |
| 2000 | 72.74 | 1.31 | 2.73 | 0.4 | 0.63 | NE | 0.44 | **78.26** | **1,643** |
| 2001 | 72.99 | 1.34 | 2.84 | 0.46 | 0.69 | 0.11 | 0.45 | **78.88** | **1,656** |
| 2002 | 75.39 | 1.32 | 3.06 | 0.44 | 0.77 | NE | 0.45 | **81.42** | **1,710** |
| 2003 | 77.18 | 1.33 | 3.14 | 0.47 | 0.78 | NE | 0.47 | **83.37** | **1,751** |
| 2004 | 73.2 | 1.32 | 3.45 | 0.58 | 0.8 | 0.13 | 0.48 | **79.96** | **1,679** |
| 2005 | 74.23 | 1.23 | 3.6 | 0.48 | 0.77 | 0.13 | 0.46 | **80.89** | **1,699** |
| 2006 | 67.35 | 1.21 | 3.48 | 0.46 | 0.47 | 0.08 | 0.34 | **73.4** | **1,541** |
| 2007 | 65.58 | 1.07 | 3.56 | 0.43 | 0.41 | 0.09 | 0.11 | **71.24** | **1,496** |
| 2008 | 67.61 | 1.01 | 3.45 | 0.4 | 0.5 | 0.08 | 0.09 | **73.14** | **1,536** |
| 2009 | 64.38 | 0.98 | 3.01 | 0.36 | 0.52 | 0.07 | 0.14 | **69.45** | **1,459** |
| 2010 | 67.35 | 0.93 | 2.98 | 0.29 | 0.55 | 0.11 | 0.11 | **72.32** | **1,519** |
| 2011 | 66.81 | 0.93 | 2.88 | 0.27 | 0.53 | 0.08 | 0.11 | **71.61** | **1,504** |
| 2012 | 70.77 | 0.94 | 3.44 | 0.27 | 0.55 | 0.06 | 0.2 | **76.24** | **1,601** |
| 2013 | 75.43 | 1 | 3.98 | 0.3 | 0.55 | 0.08 | 0.19 | **81.54** | **1,712** |
| 2014 | 81.7 | 0.65 | 4.33 | 0.27 | 0.51 | 0.07 | 0.17 | **87.69** | **1,842** |
| 2015 | 84.96 | 0.85 | 4.21 | 0.25 | 0.61 | 0.04 | 0.16 | **91.08** | **1,913** |

| Year | Cattle 3.A.1 | Buffalos 3.A.2 | Sheep 3.A.3 | Goats 3.A.4 | Horses 3.A.5.1 | Asses 3.A.5.2 | Swine 3.A.6 | Total in Gg CH4 | Total in Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|
| 2016 | 86.28 | 0.92 | 4.38 | 0.3 | 0.41 | 0.04 | 0.14 | **92.47** | **1,942** |
| 2017 | 81.21 | 0.8 | 4.28 | 0.26 | 0.4 | 0.03 | 0.15 | **87.12** | **1,830** |

### 4.11.1. Cattle (3.A.1.)

Georgian Mountain and Red Mingrelian are native cattle breeds prevailing in Georgia. Georgian Mountain and Red Mingrelian are late maturing breeds, characterized by small weight, low productivity, and high fattiness of milk. Since the 30-ies of the 20th century several high-productive early maturing breeds have been imported. According to estimations, the characteristics and accordingly the emission factors of early maturing breeds are slightly (by 3-4%) different. Therefore, averaged value of emission factors has been applied and 3 breeds have been considered: Early maturing, Georgian Mountain and Red Mingrelian. Specified data on cattle distribution by breeds are provided by Head of the Department of Zootechny of the Agrarian University of Georgia Mr. Levan Tortladze.

Table 4-54 Cattle distribution by breeds

| Year | Breed | | | | | | Total number |
|---|---|---|---|---|---|---|---|
| | Early maturing | | Georgian Mountain | | Red Mingrelian | | |
| | % | Number | % | Number | % | Number | |
| 1990 | 60.2 | 806,576 | 23.8 | 318,879 | 16.0 | 214,372 | 1,339,828 |
| 1991 | 60.5 | 755,266 | 23.6 | 295,080 | 15.8 | 197,615 | 1,247,961 |
| 1992 | 60.8 | 628,438 | 23.5 | 242,636 | 15.7 | 161,861 | 1,032,935 |
| 1993 | 61.2 | 587,289 | 23.3 | 224,075 | 15.5 | 148,887 | 960,251 |
| 1994 | 61.5 | 601,940 | 23.2 | 226,951 | 15.3 | 150,191 | 979,083 |
| 1995 | 61.8 | 624,476 | 23.0 | 232,663 | 15.2 | 153,340 | 1,010,479 |
| 1996 | 62.1 | 650,242 | 22.9 | 239,392 | 15.0 | 157,117 | 1,046,752 |
| 1997 | 62.4 | 666,105 | 22.7 | 242,322 | 14.8 | 158,365 | 1,066,792 |
| 1998 | 62.8 | 685,340 | 22.6 | 246,356 | 14.7 | 160,306 | 1,092,002 |
| 1999 | 63.1 | 736,507 | 22.4 | 261,595 | 14.5 | 169,474 | 1,167,576 |
| 2000 | 63.4 | 776,787 | 22.3 | 272,610 | 14.4 | 175,818 | 1,225,216 |
| 2001 | 63.7 | 782,173 | 22.1 | 271,220 | 14.2 | 174,123 | 1,227,516 |
| 2002 | 64.0 | 810,779 | 21.9 | 277,771 | 14.0 | 177,500 | 1,266,051 |
| 2003 | 64.4 | 832,828 | 21.8 | 281,901 | 13.9 | 179,286 | 1,294,015 |
| 2004 | 64.7 | 792,621 | 21.6 | 265,065 | 13.7 | 167,764 | 1,225,451 |
| 2005 | 65.0 | 806,547 | 21.5 | 266,471 | 13.5 | 167,824 | 1,240,841 |
| 2006 | 65.3 | 734,208 | 21.3 | 239,641 | 13.4 | 150,169 | 1,124,017 |
| 2007 | 65.6 | 717,400 | 21.2 | 231,319 | 13.2 | 144,212 | 1,092,931 |
| 2008 | 66.0 | 742,032 | 21.0 | 236,357 | 13.0 | 146,584 | 1,124,972 |
| 2009 | 66.3 | 708,967 | 20.9 | 223,077 | 12.9 | 137,611 | 1,069,655 |
| 2010 | 66.6 | 744,115 | 20.7 | 231,279 | 12.7 | 141,896 | 1,117,289 |
| 2011 | 68.0 | 748,949 | 20.1 | 221,264 | 11.9 | 130,967 | 1,101,180 |
| 2012 | 69.4 | 804,547 | 19.5 | 225,820 | 11.1 | 128,477 | 1,158,844 |
| 2013 | 70.8 | 869,385 | 18.9 | 231,705 | 10.3 | 126,161 | 1,227,252 |
| 2014 | 72.3 | 954,302 | 18.3 | 241,349 | 9.5 | 125,121 | 1,320,772 |
| 2015 | 73.7 | 1,005,441 | 17.7 | 241,124 | 8.7 | 118,287 | 1,364,852 |
| 2016 | 73.7 | 1,021,077 | 17.7 | 244,874 | 8.7 | 120,127 | 1,386,077 |
| 2017 | 73.7 | 961,055 | 17.7 | 230,479 | 8.7 | 113,065 | 1,304,600 |

According to IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (further referred to as IPCC GPG), in case enteric fermentation is a key source category for the animal categories that represent a large portion of the country's total emissions the Tier 2 approach should be used. For 1990-2015 years period methane emissions from cattle constituted about 90% of the total methane emissions from "Enteric fermentation". Consequently, for this category tier 2 approach is used.

**Methodology:**

Tier 2 represents more complicated approach, which requires detailed characteristics of cattle (breed, age, weight, milk yield, birth etc.). Emission factor for each selected animal category (type) was assessed based on these data. Afterwards, emissions were calculated for each group of cattle by multiplying a population of cattle (grouping is made according to breed and age) by corresponding emission factor and summing up calculated emissions.

**Activity data:**

Methane emissions from enteric fermentation in cattle depends on cattle characteristics. Cattle has been classified by age based on the scientific information obtained from zoological veterinary experts. The classification has been performed separately for early maturing and late maturing breeds as their growth characteristics are different.

*Table 4-55* presents Georgian Mountain cattle distribution by age.

*Table 5-8* presents Red Mingrelian cattle distribution by age

Table 4-57 presents early maturing cattle distribution by age

Table 4-55 Georgian Mountain cattle distribution by age

| | Population, thousand heads | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| **Age, year** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **4-5** | **5-6** | **5-6** | **>6** | **>6** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **5-6** | **>6** | |
| 1990 | 35.6 | 27.6 | 24.6 | 24.1 | 10.4 | 11.2 | 9.8 | 10.6 | 83.3 | 41.0 | 11.0 | 9.6 | 7.7 | 6.4 | 2.6 | 2.1 | 1.3 | 318.9 |
| 1991 | 32.9 | 25.5 | 22.8 | 22.3 | 9.6 | 10.4 | 9.1 | 9.8 | 77.1 | 38.0 | 10.2 | 8.9 | 7.2 | 5.9 | 2.4 | 2.0 | 1.2 | 295.1 |
| 1992 | 27.1 | 21.0 | 18.7 | 18.3 | 7.9 | 8.5 | 7.4 | 8.0 | 63.4 | 31.2 | 8.3 | 7.3 | 5.9 | 4.9 | 2.0 | 1.6 | 1.0 | 242.6 |
| 1993 | 25.0 | 19.4 | 17.3 | 16.9 | 7.3 | 7.9 | 6.9 | 7.4 | 58.5 | 28.8 | 7.7 | 6.8 | 5.4 | 4.5 | 1.9 | 1.5 | 0.9 | 224.1 |
| 1994 | 25.3 | 19.6 | 17.5 | 17.1 | 7.4 | 8.0 | 7.0 | 7.5 | 59.3 | 29.2 | 7.8 | 6.9 | 5.5 | 4.6 | 1.9 | 1.5 | 0.9 | 227.0 |
| 1995 | 25.9 | 20.1 | 17.9 | 17.6 | 7.6 | 8.2 | 7.1 | 7.7 | 60.8 | 29.9 | 8.0 | 7.0 | 5.6 | 4.7 | 1.9 | 1.5 | 1.0 | 232.7 |
| 1996 | 26.7 | 20.7 | 18.5 | 18.1 | 7.8 | 8.4 | 7.3 | 7.9 | 62.5 | 30.8 | 8.2 | 7.2 | 5.8 | 4.8 | 2.0 | 1.6 | 1.0 | 239.4 |
| 1997 | 27.0 | 20.9 | 18.7 | 18.3 | 7.9 | 8.5 | 7.4 | 8.0 | 63.3 | 31.2 | 8.3 | 7.3 | 5.9 | 4.9 | 2.0 | 1.6 | 1.0 | 242.3 |
| 1998 | 27.5 | 21.3 | 19.0 | 18.6 | 8.0 | 8.7 | 7.6 | 8.2 | 64.3 | 31.7 | 8.5 | 7.5 | 6.0 | 5.0 | 2.0 | 1.6 | 1.0 | 246.4 |
| 1999 | 29.2 | 22.6 | 20.2 | 19.7 | 8.5 | 9.2 | 8.0 | 8.7 | 68.3 | 33.7 | 9.0 | 7.9 | 6.3 | 5.3 | 2.2 | 1.7 | 1.1 | 261.6 |
| 2000 | 30.4 | 23.6 | 21.0 | 20.6 | 8.9 | 9.6 | 8.4 | 9.0 | 71.2 | 35.1 | 9.4 | 8.2 | 6.6 | 5.5 | 2.3 | 1.8 | 1.1 | 272.6 |
| 2001 | 30.2 | 23.4 | 20.9 | 20.5 | 8.8 | 9.6 | 8.3 | 9.0 | 70.8 | 34.9 | 9.3 | 8.2 | 6.6 | 5.5 | 2.2 | 1.8 | 1.1 | 271.2 |
| 2002 | 31.0 | 24.0 | 21.4 | 21.0 | 9.0 | 9.8 | 8.5 | 9.2 | 72.5 | 35.8 | 9.6 | 8.4 | 6.7 | 5.6 | 2.3 | 1.8 | 1.2 | 277.8 |
| 2003 | 31.4 | 24.4 | 21.7 | 21.3 | 9.2 | 9.9 | 8.6 | 9.3 | 73.6 | 36.3 | 9.7 | 8.5 | 6.8 | 5.7 | 2.3 | 1.9 | 1.2 | 281.9 |
| 2004 | 29.6 | 22.9 | 20.4 | 20.0 | 8.6 | 9.3 | 8.1 | 8.8 | 69.2 | 34.1 | 9.1 | 8.0 | 6.4 | 5.3 | 2.2 | 1.8 | 1.1 | 265.1 |
| 2005 | 29.7 | 23.0 | 20.5 | 20.1 | 8.7 | 9.4 | 8.2 | 8.8 | 69.6 | 34.3 | 9.2 | 8.1 | 6.5 | 5.4 | 2.2 | 1.8 | 1.1 | 266.5 |
| 2006 | 26.7 | 20.7 | 18.5 | 18.1 | 7.8 | 8.4 | 7.4 | 7.9 | 62.6 | 30.8 | 8.2 | 7.3 | 5.8 | 4.8 | 2.0 | 1.6 | 1.0 | 239.6 |
| 2007 | 25.8 | 20.0 | 17.8 | 17.5 | 7.5 | 8.2 | 7.1 | 7.7 | 60.4 | 29.8 | 8.0 | 7.0 | 5.6 | 4.7 | 1.9 | 1.5 | 1.0 | 231.3 |
| 2008 | 26.4 | 20.4 | 18.2 | 17.8 | 7.7 | 8.3 | 7.2 | 7.8 | 61.7 | 30.4 | 8.1 | 7.2 | 5.7 | 4.8 | 2.0 | 1.6 | 1.0 | 236.4 |
| 2009 | 24.9 | 19.3 | 17.2 | 16.8 | 7.3 | 7.9 | 6.8 | 7.4 | 58.3 | 28.7 | 7.7 | 6.8 | 5.4 | 4.5 | 1.8 | 1.5 | 0.9 | 223.1 |

| | Population, thousand heads | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| **Age, year** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **4-5** | **5-6** | **5-6** | **>6** | **>6** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **5-6** | **>6** | |
| 2010 | 25.8 | 20.0 | 17.8 | 17.4 | 7.5 | 8.1 | 7.1 | 7.7 | 60.4 | 29.8 | 8.0 | 7.0 | 5.6 | 4.6 | 1.9 | 1.5 | 1.0 | 231.3 |
| 2011 | 24.7 | 19.1 | 17.1 | 16.7 | 7.2 | 7.8 | 6.8 | 7.3 | 57.8 | 28.5 | 7.6 | 6.7 | 5.4 | 4.4 | 1.8 | 1.5 | 0.9 | 221.3 |
| 2012 | 25.2 | 19.5 | 17.4 | 17.0 | 7.3 | 8.0 | 6.9 | 7.5 | 59.0 | 29.1 | 7.8 | 6.8 | 5.5 | 4.5 | 1.9 | 1.5 | 0.9 | 225.8 |
| 2013 | 25.8 | 20.0 | 17.9 | 17.5 | 7.5 | 8.2 | 7.1 | 7.7 | 60.5 | 29.8 | 8.0 | 7.0 | 5.6 | 4.7 | 1.9 | 1.5 | 1.0 | 231.7 |
| 2014 | 26.9 | 20.9 | 18.6 | 18.2 | 7.9 | 8.5 | 7.4 | 8.0 | 63.0 | 31.1 | 8.3 | 7.3 | 5.9 | 4.9 | 2.0 | 1.6 | 1.0 | 241.3 |
| 2015 | 26.9 | 20.8 | 18.6 | 18.2 | 7.8 | 8.5 | 7.4 | 8.0 | 63.0 | 31.0 | 8.3 | 7.3 | 5.8 | 4.8 | 2.0 | 1.6 | 1.0 | 241.1 |
| 2016 | 27.3 | 21.2 | 18.9 | 18.5 | 8.0 | 8.6 | 7.5 | 8.1 | 63.9 | 31.5 | 8.4 | 7.4 | 5.9 | 4.9 | 2.0 | 1.6 | 1.0 | 244.9 |
| 2017 | 25.7 | 19.9 | 17.8 | 17.4 | 7.5 | 8.1 | 7.1 | 7.6 | 60.2 | 29.7 | 7.9 | 7.0 | 5.6 | 4.6 | 1.9 | 1.5 | 1.0 | 230.5 |

Table 4-56 Red Mingrelian cattle distribution by age

| | Population, thousand heads | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| **Age, year** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **4-5** | **5-6** | **5-6** | **>6** | **>6** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **5-6** | **>6** | |
| 1990 | 23.9 | 18.5 | 16.5 | 16.2 | 7.0 | 7.6 | 6.6 | 7.1 | 56.0 | 27.6 | 7.4 | 6.5 | 5.2 | 4.3 | 1.8 | 1.4 | 0.9 | 214.4 |
| 1991 | 22.0 | 17.1 | 15.2 | 14.9 | 6.4 | 7.0 | 6.1 | 6.6 | 51.6 | 25.4 | 6.8 | 6.0 | 4.8 | 4.0 | 1.6 | 1.3 | 0.8 | 197.6 |
| 1992 | 18.0 | 14.0 | 12.5 | 12.2 | 5.3 | 5.7 | 5.0 | 5.4 | 42.3 | 20.8 | 5.6 | 4.9 | 3.9 | 3.3 | 1.3 | 1.1 | 0.7 | 161.9 |
| 1993 | 16.6 | 12.9 | 11.5 | 11.2 | 4.8 | 5.2 | 4.6 | 4.9 | 38.9 | 19.2 | 5.1 | 4.5 | 3.6 | 3.0 | 1.2 | 1.0 | 0.6 | 148.9 |
| 1994 | 16.7 | 13.0 | 11.6 | 11.3 | 4.9 | 5.3 | 4.6 | 5.0 | 39.2 | 19.3 | 5.2 | 4.5 | 3.6 | 3.0 | 1.2 | 1.0 | 0.6 | 150.2 |
| 1995 | 17.1 | 13.3 | 11.8 | 11.6 | 5.0 | 5.4 | 4.7 | 5.1 | 40.0 | 19.7 | 5.3 | 4.6 | 3.7 | 3.1 | 1.3 | 1.0 | 0.6 | 153.3 |
| 1996 | 17.5 | 13.6 | 12.1 | 11.9 | 5.1 | 5.5 | 4.8 | 5.2 | 41.0 | 20.2 | 5.4 | 4.8 | 3.8 | 3.2 | 1.3 | 1.0 | 0.7 | 157.1 |
| 1997 | 17.7 | 13.7 | 12.2 | 11.9 | 5.2 | 5.6 | 4.9 | 5.3 | 41.4 | 20.4 | 5.4 | 4.8 | 3.8 | 3.2 | 1.3 | 1.1 | 0.7 | 158.4 |
| 1998 | 17.9 | 13.9 | 12.4 | 12.1 | 5.2 | 5.6 | 4.9 | 5.3 | 41.9 | 20.6 | 5.5 | 4.9 | 3.9 | 3.2 | 1.3 | 1.1 | 0.7 | 160.3 |
| 1999 | 18.9 | 14.6 | 13.1 | 12.8 | 5.5 | 6.0 | 5.2 | 5.6 | 44.3 | 21.8 | 5.8 | 5.1 | 4.1 | 3.4 | 1.4 | 1.1 | 0.7 | 169.5 |
| 2000 | 19.6 | 15.2 | 13.6 | 13.3 | 5.7 | 6.2 | 5.4 | 5.8 | 45.9 | 22.6 | 6.0 | 5.3 | 4.3 | 3.5 | 1.5 | 1.2 | 0.7 | 175.8 |
| 2001 | 19.4 | 15.0 | 13.4 | 13.1 | 5.7 | 6.1 | 5.3 | 5.8 | 45.5 | 22.4 | 6.0 | 5.3 | 4.2 | 3.5 | 1.4 | 1.2 | 0.7 | 174.1 |
| 2002 | 19.8 | 15.3 | 13.7 | 13.4 | 5.8 | 6.3 | 5.4 | 5.9 | 46.4 | 22.8 | 6.1 | 5.4 | 4.3 | 3.6 | 1.5 | 1.2 | 0.7 | 177.5 |
| 2003 | 20.0 | 15.5 | 13.8 | 13.5 | 5.8 | 6.3 | 5.5 | 5.9 | 46.8 | 23.1 | 6.2 | 5.4 | 4.3 | 3.6 | 1.5 | 1.2 | 0.7 | 179.3 |
| 2004 | 18.7 | 14.5 | 12.9 | 12.7 | 5.5 | 5.9 | 5.1 | 5.6 | 43.8 | 21.6 | 5.8 | 5.1 | 4.1 | 3.4 | 1.4 | 1.1 | 0.7 | 167.8 |
| 2005 | 18.7 | 14.5 | 12.9 | 12.7 | 5.5 | 5.9 | 5.1 | 5.6 | 43.8 | 21.6 | 5.8 | 5.1 | 4.1 | 3.4 | 1.4 | 1.1 | 0.7 | 167.8 |
| 2006 | 16.7 | 13.0 | 11.6 | 11.3 | 4.9 | 5.3 | 4.6 | 5.0 | 39.2 | 19.3 | 5.2 | 4.5 | 3.6 | 3.0 | 1.2 | 1.0 | 0.6 | 150.2 |
| 2007 | 16.1 | 12.5 | 11.1 | 10.9 | 4.7 | 5.1 | 4.4 | 4.8 | 37.7 | 18.6 | 5.0 | 4.4 | 3.5 | 2.9 | 1.2 | 1.0 | 0.6 | 144.2 |
| 2008 | 16.3 | 12.7 | 11.3 | 11.1 | 4.8 | 5.2 | 4.5 | 4.9 | 38.3 | 18.9 | 5.0 | 4.4 | 3.6 | 2.9 | 1.2 | 1.0 | 0.6 | 146.6 |
| 2009 | 15.3 | 11.9 | 10.6 | 10.4 | 4.5 | 4.8 | 4.2 | 4.6 | 35.9 | 17.7 | 4.7 | 4.2 | 3.3 | 2.8 | 1.1 | 0.9 | 0.6 | 137.6 |
| 2010 | 15.8 | 12.3 | 10.9 | 10.7 | 4.6 | 5.0 | 4.4 | 4.7 | 37.1 | 18.3 | 4.9 | 4.3 | 3.4 | 2.9 | 1.2 | 0.9 | 0.6 | 141.9 |
| 2011 | 14.6 | 11.3 | 10.1 | 9.9 | 4.3 | 4.6 | 4.0 | 4.3 | 34.2 | 16.9 | 4.5 | 4.0 | 3.2 | 2.6 | 1.1 | 0.9 | 0.5 | 131.0 |
| 2012 | 14.3 | 11.1 | 9.9 | 9.7 | 4.2 | 4.5 | 3.9 | 4.3 | 33.6 | 16.5 | 4.4 | 3.9 | 3.1 | 2.6 | 1.1 | 0.9 | 0.5 | 128.5 |
| 2013 | 14.1 | 10.9 | 9.7 | 9.5 | 4.1 | 4.4 | 3.9 | 4.2 | 32.9 | 16.2 | 4.3 | 3.8 | 3.1 | 2.5 | 1.0 | 0.8 | 0.5 | 126.2 |
| 2014 | 14.0 | 10.8 | 9.6 | 9.4 | 4.1 | 4.4 | 3.8 | 4.1 | 32.7 | 16.1 | 4.3 | 3.8 | 3.0 | 2.5 | 1.0 | 0.8 | 0.5 | 125.1 |
| 2015 | 13.2 | 10.2 | 9.1 | 8.9 | 3.8 | 4.2 | 3.6 | 3.9 | 30.9 | 15.2 | 4.1 | 3.6 | 2.9 | 2.4 | 1.0 | 0.8 | 0.5 | 118.3 |
| 2016 | 13.4 | 10.4 | 9.3 | 9.1 | 3.9 | 4.2 | 3.7 | 4.0 | 31.4 | 15.5 | 4.1 | 3.6 | 2.9 | 2.4 | 1.0 | 0.8 | 0.5 | 120.1 |
| 2017 | 12.6 | 9.8 | 8.7 | 8.5 | 3.7 | 4.0 | 3.5 | 3.7 | 29.5 | 14.6 | 3.9 | 3.4 | 2.7 | 2.3 | 0.9 | 0.7 | 0.5 | 113.1 |

Table 4-57 Early maturing cattle distribution by age

| | Population, thousand heads | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| **Age, year** | **0-1** | **1-2** | **2-3** | **3-4** | **3-4** | **4-5** | **4-5** | **>5** | **>5** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **>5** | |
| 1990 | 109.0 | 95.3 | 86.6 | 34.1 | 36.8 | 36.1 | 39.1 | 183.8 | 90.6 | 35.1 | 24.4 | 18.4 | 8.7 | 4.7 | 4.0 | 806.6 |
| 1991 | 102.0 | 89.2 | 81.1 | 31.9 | 34.4 | 33.8 | 36.6 | 172.1 | 84.8 | 32.9 | 22.8 | 17.2 | 8.1 | 4.4 | 3.8 | 755.3 |
| 1992 | 84.9 | 74.2 | 67.5 | 26.6 | 28.6 | 28.1 | 30.5 | 143.2 | 70.6 | 27.3 | 19.0 | 14.3 | 6.8 | 3.6 | 3.1 | 628.4 |
| 1993 | 79.3 | 69.4 | 63.0 | 24.8 | 26.8 | 26.3 | 28.5 | 133.9 | 66.0 | 25.6 | 17.8 | 13.4 | 6.3 | 3.4 | 2.9 | 587.3 |
| 1994 | 81.3 | 71.1 | 64.6 | 25.4 | 27.4 | 26.9 | 29.2 | 137.2 | 67.6 | 26.2 | 18.2 | 13.7 | 6.5 | 3.5 | 3.0 | 601.9 |
| 1995 | 84.4 | 73.8 | 67.0 | 26.4 | 28.5 | 28.0 | 30.3 | 142.3 | 70.1 | 27.2 | 18.9 | 14.2 | 6.7 | 3.6 | 3.1 | 624.5 |
| 1996 | 87.8 | 76.8 | 69.8 | 27.5 | 29.6 | 29.1 | 31.5 | 148.2 | 73.0 | 28.3 | 19.7 | 14.8 | 7.0 | 3.8 | 3.2 | 650.2 |
| 1997 | 90.0 | 78.7 | 71.5 | 28.2 | 30.4 | 29.8 | 32.3 | 151.8 | 74.8 | 29.0 | 20.2 | 15.2 | 7.2 | 3.9 | 3.3 | 666.1 |
| 1998 | 92.6 | 80.9 | 73.6 | 29.0 | 31.2 | 30.7 | 33.2 | 156.2 | 77.0 | 29.8 | 20.7 | 15.6 | 7.4 | 4.0 | 3.4 | 685.3 |
| 1999 | 99.5 | 87.0 | 79.1 | 31.1 | 33.6 | 33.0 | 35.7 | 167.9 | 82.7 | 32.0 | 22.3 | 16.8 | 7.9 | 4.3 | 3.7 | 736.5 |
| 2000 | 104.9 | 91.7 | 83.4 | 32.8 | 35.4 | 34.8 | 37.7 | 177.1 | 87.2 | 33.8 | 23.5 | 17.7 | 8.4 | 4.5 | 3.9 | 776.8 |
| 2001 | 105.7 | 92.4 | 84.0 | 33.1 | 35.7 | 35.0 | 37.9 | 178.3 | 87.8 | 34.0 | 23.7 | 17.8 | 8.4 | 4.5 | 3.9 | 782.2 |
| 2002 | 109.5 | 95.8 | 87.0 | 34.3 | 37.0 | 36.3 | 39.3 | 184.8 | 91.1 | 35.3 | 24.5 | 18.5 | 8.7 | 4.7 | 4.0 | 810.8 |
| 2003 | 112.5 | 98.4 | 89.4 | 35.2 | 38.0 | 37.3 | 40.4 | 189.8 | 93.5 | 36.2 | 25.2 | 19.0 | 9.0 | 4.8 | 4.1 | 832.8 |
| 2004 | 107.1 | 93.6 | 85.1 | 33.5 | 36.1 | 35.5 | 38.4 | 180.7 | 89.0 | 34.5 | 24.0 | 18.1 | 8.5 | 4.6 | 3.9 | 792.6 |
| 2005 | 109.0 | 95.3 | 86.6 | 34.1 | 36.8 | 36.1 | 39.1 | 183.8 | 90.6 | 35.1 | 24.4 | 18.4 | 8.7 | 4.7 | 4.0 | 806.5 |
| 2006 | 99.2 | 86.7 | 78.8 | 31.0 | 33.5 | 32.9 | 35.6 | 167.3 | 82.5 | 31.9 | 22.2 | 16.7 | 7.9 | 4.3 | 3.7 | 734.2 |
| 2007 | 96.9 | 84.7 | 77.0 | 30.3 | 32.7 | 32.1 | 34.8 | 163.5 | 80.6 | 31.2 | 21.7 | 16.4 | 7.7 | 4.2 | 3.6 | 717.4 |
| 2008 | 100.2 | 87.6 | 79.6 | 31.4 | 33.8 | 33.2 | 36.0 | 169.1 | 83.3 | 32.3 | 22.4 | 16.9 | 8.0 | 4.3 | 3.7 | 742.0 |
| 2009 | 95.8 | 83.7 | 76.1 | 30.0 | 32.3 | 31.7 | 34.4 | 161.6 | 79.6 | 30.9 | 21.4 | 16.2 | 7.6 | 4.1 | 3.5 | 709.0 |
| 2010 | 100.5 | 87.9 | 79.9 | 31.5 | 33.9 | 33.3 | 36.1 | 169.6 | 83.6 | 32.4 | 22.5 | 17.0 | 8.0 | 4.3 | 3.7 | 744.1 |
| 2011 | 101.2 | 88.5 | 80.4 | 31.7 | 34.1 | 33.5 | 36.3 | 170.7 | 84.1 | 32.6 | 22.7 | 17.1 | 8.1 | 4.3 | 3.7 | 748.9 |
| 2012 | 108.7 | 95.0 | 86.4 | 34.0 | 36.7 | 36.0 | 39.0 | 183.4 | 90.4 | 35.0 | 24.3 | 18.3 | 8.7 | 4.7 | 4.0 | 804.5 |
| 2013 | 117.5 | 102.7 | 93.3 | 36.7 | 39.6 | 38.9 | 42.2 | 198.2 | 97.6 | 37.8 | 26.3 | 19.8 | 9.4 | 5.0 | 4.3 | 869.4 |
| 2014 | 128.9 | 112.7 | 102.4 | 40.3 | 43.5 | 42.7 | 46.3 | 217.5 | 107.2 | 41.5 | 28.9 | 21.8 | 10.3 | 5.5 | 4.7 | 954.3 |
| 2015 | 135.8 | 118.8 | 107.9 | 42.5 | 45.8 | 45.0 | 48.8 | 229.2 | 112.9 | 43.8 | 30.4 | 22.9 | 10.8 | 5.8 | 5.0 | 1,005.4 |
| 2016 | 137.9 | 120.6 | 109.6 | 43.2 | 46.5 | 45.7 | 49.5 | 232.7 | 114.7 | 44.4 | 30.9 | 23.3 | 11.0 | 5.9 | 5.1 | 1,021.1 |
| 2017 | 129.8 | 113.5 | 103.2 | 40.6 | 43.8 | 43.0 | 46.6 | 219.1 | 107.9 | 41.8 | 29.1 | 21.9 | 10.4 | 5.6 | 4.8 | 961.1 |

**Emission factor:**

Emission factors for this category were calculated as described in the IPCC GPG - Tier 2 approach. Equation 10.21 from IPCC 2006 (Chapter 10, p. 10.31) was used to estimate $CH_4$ Emission Factor for enteric fermentation from cattle:

$$EF = \left[ \frac{GE \times \left( \frac{Y_m}{100} \right) \times 365}{55.65} \right]$$

Where:

*EF* emission factor, kg CH4/head/year

*GE* gross energy intake, MJ/head/day

$Y_m$ methane conversion factor, % of gross energy in feed converted to methane. Default value for Eastern Europe $Y_m$ =0.065 is used (IPCC 2006, Chapter 10, p.10.72, table 10A.1).

The factor 55.65 (MJ/kg CH4) is the energy content of methane.

Equation 10.16 from IPCC 2006 (Chapter 10, p.10.21) is used for calculating GE.

$$GE = \frac{\left(\frac{NE_m + NE_a + NE_1 + NE_{work} + NE_p}{REM}\right) + \left(\frac{NE_g}{REG}\right)}{\frac{DE\%}{100}}$$

where:

*GE* gross energy, MJ/day

$NE_m$ Net energy for maintenance (MJ/day). $NE_m = Cf_i \times (weight)^{0.75}$. $Cf_i$=0.322 for non- lactating cattle and $Cf_i$ =0.386 for lactating cattle (IPCC 2006, Chapter 10, p.10.16, table 10.4).

$NE_a$ Net energy for animal activity (MJ/day). $NE_a = C_a \times NE_m$. $C_a$ coefficient corresponds to animal feeding conditions. In Georgia cattle usually grazes on pastures and hilly areas, hence much energy is wasted in feeding.
According to IPCC 2006 (Chapter 10,p.10.17, Table 10.5)) in these conditions $C_a$=0.36.

$NE_l$ Net energy for lactation (MJ/day). $NE_l$=daily milk amount× (1.47+0.40×fattiness) IPCC 2006 (Chapter 10, p.10.18, equation 10.8). Daily milk means daily milk yield. Fattiness is fat content of milk (%)

$NE_{work}$ Net energy for work, MJ/day. $NE_w = 0.10 \times NE_m \times$ hours of work per day (IPCC 2006, Chapter 10, p.10.11, equation 10.11). It was assumed that bulls work for 1 hour per day.

$NE_p$ Net energy required for pregnancy (MJ/day). $NE_p = C_{pregnancy} \times NE_m$ (IPCC 2006, Chapter 10, p.10.20, Equation 10.13), $C_{pregnancy}$ is pregnancy coefficient. For cattle $C_{pregnancy}$ =0.1 (IPCC 2006, Chapter 10, p.10.20, table 10.7).

*REM* Ratio of net energy available in a diet for maintenance to digestible energy consumed

$$REM = \left[1.123 - (4.092 \times 10^{-3} \times DE\%) + [1.126 \times 10^{-5} \times (DE\%)^2] - \left(\frac{25.4}{DE\%}\right)\right]$$

(IPCC 2006, Chapter 10, p.10.20, Equation 10.14)

*DE%* digestible energy expressed as a percentage of gross energy. Based on estimates for the former USSR, default value DE =60% (IPCC 2006, Chapter 10, p.10.72, table 10A.1) is used.

$NE_g$ net energy needed for growth, MJ/day.

$$NE_g = 22.02 \times \left(\frac{BW}{C \times MW}\right)^{0.75} \times WG^{1.097}$$

(IPCC 2006, Chapter 10, p.10.17, equation 10.6)

*BW* The average live body weight (BW) of the animals in the population, kg

*C* A coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls

*WG* The average daily weight gain of the animals in the population, kg day-1

$REG$ Ratio of net energy available for growth in a diet to digestible energy consumed. (IPCC 2006, Chapter 10, p.10.21, Eq. 10.15)

$$REG = \left[1.164 - (5.160 \times 10^{-3} \times DE\%) + \left[1.308 \times 10^{-5} \times (DE\%)^2 - \left(\frac{37.4}{DE\%}\right)\right]\right]$$

**Actvity data:**
Necessary data for calculations are given in Table 4-58 - Table 4-60.

Table 4-58 Females live-weight standards

| Breed | live weight by moths, kg | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Newborn | 6 | 7 | 8 | 9 | 10 | 12 | 15 | 18 | 24 | 30 | 36 | 48 | 60 | 72 |
| Georgian Mountain | 13 | 55 | 60 | 70 | 80 | 85 | 100 | 115 | 130 | 135 | 157 | 169 | 180 | 200 | 210 |
| Red Mingrelian | 15 | 75 | 85 | 95 | 105 | 115 | 130 | 160 | 190 | 200 | 217 | 234 | 250 | 280 | 300 |
| Early maturing | 32 | 152 | 168 | 187 | 203 | 220 | 250 | 297 | 345 | 397 | 420 | 443 | 487 | 520 | 520 |

Table 4-59 Males live-weight standards

| Breed | live weight by moths, kg | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Newborn | 6 | 7 | 8 | 9 | 10 | 12 | 15 | 18 | 24 | 30 | 36 | 48 | 60 | 72 |
| Georgian Mountain | 13 | 60 | 65 | 75 | 85 | 95 | 110 | 140 | 160 | 190 | 220 | 255 | 290 | 320 | 320 |
| Red Mingrelian | 15 | 80 | 90 | 100 | 110 | 125 | 160 | 200 | 210 | 310 | 350 | 390 | 460 | 480 | 480 |
| Early maturing | 32 | 170 | 195 | 225 | 240 | 263 | 310 | 385 | 458 | 543 | 613 | 693 | 773 | 820 | 820 |

Table 4-60 Average milk production and average fat content for cows

| Breed | Fat, % | Milk production, kg | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Averaged in herd | | 1st lactation | | 2nd lactation | | 3rd and more lactation | |
| | | Per year | Per day | Per year | Per day | Per year | Per day | Per year | Per day |
| Georgian Mountain | 4.3 | 1,358 | 3.7 | 1,228 | 3.4 | 1,302 | 3.6 | 1,376 | 3.8 |
| Red Mingrelian | 4.3 | 1,460 | 4.0 | 1,047 | 2.9 | 1,269 | 3.5 | 1,491 | 4.1 |
| Early maturing | 3.7 | 2,610 | 7.1 | 2,349 | 6.4 | 2,597 | 7.1 | 2,845 | 7.8 |

**Emission factors:**
The calculated emission factors for cattle are given in *Table 4-61*.

Table 4-61 Estimated methane emission factors

| Cattle category | Age, year | Emission factor, kgCH₄/head | |
|---|---|---|---|
| | | Georgian mountain | Red Mingrelian |
| Calf – females | 0-1 | 13 | 16 |
| Heifer | 1-2 | 29 | 40 |
| Heifer | 2-3 | 34 | 43 |
| Heifer | 3-4 | 34 | 44 |
| Cow | 4-5 | 37 | 49 |
| Lactating cow | 4-5 | 52 | 61 |
| Cow | 5-6 | 38 | 50 |
| Lactating cow | 5-6 | 53 | 66 |
| Cow | >6 | 37 | 49 |
| Lactating cow | >6 | 53 | 65 |
| Calf – males | 0-1 | 13 | 17 |
| Bullock | 1-2 | 36 | 53 |
| Bullock | 2-3 | 45 | 63 |
| Bullock | 3-4 | 49 | 71 |
| Bull (castrate) | 4-5 | 56 | 76 |
| Bull (castrate) | 5-6 | 55 | 75 |
| Bull (castrate) | >6 | 55 | 65 |

| Cattle category | Age, year | Emission factor, kgCH₄/head |
|---|---|---|
| | | Early maturing |
| Calf – females | 0-1 | 28 |
| Heifer | 1-2 | 70 |
| Heifer | 2-3 | 70 |
| Cow | 3-4 | 74 |
| Lactating cow | 3-4 | 90 |
| Cow | 4-5 | 77 |
| Lactating cow | 4-5 | 94 |
| Cow | >5 | 74 |
| Lactating cow | >5 | 94 |
| Calf – males | 0-1 | 30 |
| Bullock | 1-2 | 85 |
| Bullock | 2-3 | 101 |
| Bull (castrate) | 3-4 | 112 |
| Bull (castrate) | 4-5 | 114 |
| Bull (castrate) | >5 | 111 |

**Emissions:**

The estimated emissions from cattle are given in Table *4-62 - Table 4-64.*

Table 4-62 Estimated methane emissions for Georgian Mountain cattle in 1990-2017 years

| | **Emissions, Gg $CH_4$** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| **Age, year** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **4-5** | **5-6** | **5-6** | **>6** | **>6** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **5-6** | **>6** | |
| 1990 | 0.46 | 0.80 | 0.84 | 0.82 | 0.38 | 0.58 | 0.37 | 0.56 | 3.08 | 2.18 | 0.14 | 0.35 | 0.35 | 0.31 | 0.15 | 0.12 | 0.07 | **11.60** |
| 1991 | 0.43 | 0.74 | 0.77 | 0.76 | 0.36 | 0.54 | 0.34 | 0.52 | 2.85 | 2.01 | 0.13 | 0.32 | 0.32 | 0.29 | 0.14 | 0.11 | 0.07 | **10.70** |
| 1992 | 0.35 | 0.61 | 0.64 | 0.62 | 0.29 | 0.44 | 0.28 | 0.43 | 2.34 | 1.66 | 0.11 | 0.26 | 0.26 | 0.24 | 0.11 | 0.09 | 0.06 | **8.80** |
| 1993 | 0.32 | 0.56 | 0.59 | 0.57 | 0.27 | 0.41 | 0.26 | 0.39 | 2.17 | 1.53 | 0.10 | 0.24 | 0.24 | 0.22 | 0.10 | 0.08 | 0.05 | **8.10** |
| 1994 | 0.33 | 0.57 | 0.59 | 0.58 | 0.27 | 0.42 | 0.26 | 0.40 | 2.19 | 1.55 | 0.10 | 0.25 | 0.25 | 0.22 | 0.11 | 0.08 | 0.05 | **8.20** |
| 1995 | 0.34 | 0.58 | 0.61 | 0.60 | 0.28 | 0.43 | 0.27 | 0.41 | 2.25 | 1.59 | 0.10 | 0.25 | 0.25 | 0.23 | 0.11 | 0.08 | 0.05 | **8.40** |
| 1996 | 0.35 | 0.60 | 0.63 | 0.61 | 0.29 | 0.44 | 0.28 | 0.42 | 2.31 | 1.63 | 0.11 | 0.26 | 0.26 | 0.24 | 0.11 | 0.09 | 0.05 | **8.70** |
| 1997 | 0.35 | 0.61 | 0.64 | 0.62 | 0.29 | 0.44 | 0.28 | 0.43 | 2.34 | 1.65 | 0.11 | 0.26 | 0.26 | 0.24 | 0.11 | 0.09 | 0.06 | **8.80** |
| 1998 | 0.36 | 0.62 | 0.65 | 0.63 | 0.30 | 0.45 | 0.29 | 0.43 | 2.38 | 1.68 | 0.11 | 0.27 | 0.27 | 0.24 | 0.11 | 0.09 | 0.06 | **8.90** |
| 1999 | 0.38 | 0.66 | 0.69 | 0.67 | 0.31 | 0.48 | 0.30 | 0.46 | 2.53 | 1.78 | 0.12 | 0.28 | 0.29 | 0.26 | 0.12 | 0.10 | 0.06 | **9.50** |
| 2000 | 0.40 | 0.68 | 0.71 | 0.70 | 0.33 | 0.50 | 0.32 | 0.48 | 2.63 | 1.86 | 0.12 | 0.30 | 0.30 | 0.27 | 0.13 | 0.10 | 0.06 | **9.90** |
| 2001 | 0.39 | 0.68 | 0.71 | 0.70 | 0.33 | 0.50 | 0.32 | 0.48 | 2.62 | 1.85 | 0.12 | 0.30 | 0.30 | 0.27 | 0.13 | 0.10 | 0.06 | **9.80** |
| 2002 | 0.40 | 0.70 | 0.73 | 0.71 | 0.33 | 0.51 | 0.32 | 0.49 | 2.68 | 1.89 | 0.12 | 0.30 | 0.30 | 0.27 | 0.13 | 0.10 | 0.06 | **10.10** |
| 2003 | 0.41 | 0.71 | 0.74 | 0.72 | 0.34 | 0.52 | 0.33 | 0.50 | 2.72 | 1.92 | 0.13 | 0.31 | 0.31 | 0.28 | 0.13 | 0.10 | 0.06 | **10.20** |
| 2004 | 0.38 | 0.66 | 0.69 | 0.68 | 0.32 | 0.49 | 0.31 | 0.47 | 2.56 | 1.81 | 0.12 | 0.29 | 0.29 | 0.26 | 0.12 | 0.10 | 0.06 | **9.60** |
| 2005 | 0.39 | 0.67 | 0.70 | 0.68 | 0.32 | 0.49 | 0.31 | 0.47 | 2.57 | 1.82 | 0.12 | 0.29 | 0.29 | 0.26 | 0.12 | 0.10 | 0.06 | **9.70** |
| 2006 | 0.35 | 0.60 | 0.63 | 0.61 | 0.29 | 0.44 | 0.28 | 0.42 | 2.32 | 1.63 | 0.11 | 0.26 | 0.26 | 0.24 | 0.11 | 0.09 | 0.05 | **8.70** |
| 2007 | 0.34 | 0.58 | 0.61 | 0.59 | 0.28 | 0.42 | 0.27 | 0.41 | 2.24 | 1.58 | 0.10 | 0.25 | 0.25 | 0.23 | 0.11 | 0.08 | 0.05 | **8.40** |
| 2008 | 0.34 | 0.59 | 0.62 | 0.61 | 0.28 | 0.43 | 0.28 | 0.42 | 2.28 | 1.61 | 0.11 | 0.26 | 0.26 | 0.23 | 0.11 | 0.09 | 0.05 | **8.60** |
| 2009 | 0.32 | 0.56 | 0.58 | 0.57 | 0.27 | 0.41 | 0.26 | 0.39 | 2.16 | 1.52 | 0.10 | 0.24 | 0.24 | 0.22 | 0.10 | 0.08 | 0.05 | **8.10** |
| 2010 | 0.34 | 0.58 | 0.61 | 0.59 | 0.28 | 0.42 | 0.27 | 0.41 | 2.23 | 1.58 | 0.10 | 0.25 | 0.25 | 0.23 | 0.11 | 0.08 | 0.05 | **8.40** |
| 2011 | 0.32 | 0.55 | 0.58 | 0.57 | 0.27 | 0.41 | 0.26 | 0.39 | 2.14 | 1.51 | 0.10 | 0.24 | 0.24 | 0.22 | 0.10 | 0.08 | 0.05 | **8.00** |
| 2012 | 0.33 | 0.57 | 0.59 | 0.58 | 0.27 | 0.41 | 0.26 | 0.40 | 2.18 | 1.54 | 0.10 | 0.25 | 0.25 | 0.22 | 0.10 | 0.08 | 0.05 | **8.20** |
| 2013 | 0.34 | 0.58 | 0.61 | 0.59 | 0.28 | 0.42 | 0.27 | 0.41 | 2.24 | 1.58 | 0.10 | 0.25 | 0.25 | 0.23 | 0.11 | 0.08 | 0.05 | **8.40** |
| 2014 | 0.35 | 0.60 | 0.63 | 0.62 | 0.29 | 0.44 | 0.28 | 0.42 | 2.33 | 1.65 | 0.11 | 0.26 | 0.26 | 0.24 | 0.11 | 0.09 | 0.06 | **8.80** |
| 2015 | 0.35 | 0.60 | 0.63 | 0.62 | 0.29 | 0.44 | 0.28 | 0.42 | 2.33 | 1.64 | 0.11 | 0.26 | 0.26 | 0.24 | 0.11 | 0.09 | 0.05 | **8.70** |
| 2016 | 0.35 | 0.61 | 0.64 | 0.63 | 0.29 | 0.45 | 0.29 | 0.43 | 2.37 | 1.67 | 0.11 | 0.27 | 0.27 | 0.24 | 0.11 | 0.09 | 0.06 | **8.90** |
| 2017 | 0.33 | 0.58 | 0.60 | 0.59 | 0.28 | 0.42 | 0.27 | 0.41 | 2.23 | 1.57 | 0.10 | 0.25 | 0.25 | 0.23 | 0.11 | 0.08 | 0.05 | **8.40** |

Table 4-63 Estimated methane emissions for Red Mingrelian cattle in 1990-2017 years

| | **Emissions, Gg $CH_4$** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| Age, year | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **4-5** | **5-6** | **5-6** | **>6** | **>6** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **5-6** | **>6** | |
| 1990 | 0.38 | 0.74 | 0.71 | 0.71 | 0.34 | 0.46 | 0.33 | 0.47 | 2.74 | 1.79 | 0.13 | 0.34 | 0.33 | 0.31 | 0.14 | 0.11 | 0.06 | **10.10** |
| 1991 | 0.35 | 0.68 | 0.66 | 0.66 | 0.32 | 0.42 | 0.30 | 0.43 | 2.53 | 1.65 | 0.12 | 0.32 | 0.30 | 0.28 | 0.12 | 0.10 | 0.05 | **9.30** |
| 1992 | 0.29 | 0.56 | 0.54 | 0.54 | 0.26 | 0.35 | 0.25 | 0.35 | 2.07 | 1.35 | 0.09 | 0.26 | 0.25 | 0.23 | 0.10 | 0.08 | 0.04 | **7.60** |
| 1993 | 0.27 | 0.51 | 0.49 | 0.49 | 0.24 | 0.32 | 0.23 | 0.33 | 1.91 | 1.25 | 0.09 | 0.24 | 0.23 | 0.21 | 0.09 | 0.07 | 0.04 | **7.00** |
| 1994 | 0.27 | 0.52 | 0.50 | 0.50 | 0.24 | 0.32 | 0.23 | 0.33 | 1.92 | 1.26 | 0.09 | 0.24 | 0.23 | 0.21 | 0.09 | 0.07 | 0.04 | **7.10** |
| 1995 | 0.27 | 0.53 | 0.51 | 0.51 | 0.24 | 0.33 | 0.24 | 0.34 | 1.96 | 1.28 | 0.09 | 0.25 | 0.23 | 0.22 | 0.10 | 0.08 | 0.04 | **7.20** |
| 1996 | 0.28 | 0.54 | 0.52 | 0.52 | 0.25 | 0.34 | 0.24 | 0.34 | 2.01 | 1.31 | 0.09 | 0.25 | 0.24 | 0.22 | 0.10 | 0.08 | 0.04 | **7.40** |
| 1997 | 0.28 | 0.55 | 0.53 | 0.53 | 0.25 | 0.34 | 0.24 | 0.35 | 2.03 | 1.32 | 0.09 | 0.25 | 0.24 | 0.23 | 0.10 | 0.08 | 0.04 | **7.50** |

| | Emissions, Gg $CH_4$ | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| Age, year | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **4-5** | **5-6** | **5-6** | **>6** | **>6** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **5-6** | **>6** | |
| 1998 | 0.29 | 0.55 | 0.53 | 0.53 | 0.26 | 0.34 | 0.25 | 0.35 | 2.05 | 1.34 | 0.09 | 0.26 | 0.24 | 0.23 | 0.10 | 0.08 | 0.04 | **7.50** |
| 1999 | 0.30 | 0.59 | 0.56 | 0.56 | 0.27 | 0.36 | 0.26 | 0.37 | 2.17 | 1.42 | 0.10 | 0.27 | 0.26 | 0.24 | 0.11 | 0.08 | 0.05 | **8.00** |
| 2000 | 0.31 | 0.61 | 0.58 | 0.58 | 0.28 | 0.38 | 0.27 | 0.38 | 2.25 | 1.47 | 0.10 | 0.28 | 0.27 | 0.25 | 0.11 | 0.09 | 0.05 | **8.30** |
| 2001 | 0.31 | 0.60 | 0.58 | 0.58 | 0.28 | 0.37 | 0.27 | 0.38 | 2.23 | 1.46 | 0.10 | 0.28 | 0.27 | 0.25 | 0.11 | 0.09 | 0.05 | **8.20** |
| 2002 | 0.32 | 0.61 | 0.59 | 0.59 | 0.28 | 0.38 | 0.27 | 0.39 | 2.27 | 1.48 | 0.10 | 0.28 | 0.27 | 0.25 | 0.11 | 0.09 | 0.05 | **8.40** |
| 2003 | 0.32 | 0.62 | 0.59 | 0.60 | 0.29 | 0.39 | 0.27 | 0.39 | 2.29 | 1.50 | 0.10 | 0.29 | 0.27 | 0.26 | 0.11 | 0.09 | 0.05 | **8.40** |
| 2004 | 0.30 | 0.58 | 0.56 | 0.56 | 0.27 | 0.36 | 0.26 | 0.37 | 2.15 | 1.40 | 0.10 | 0.27 | 0.26 | 0.24 | 0.11 | 0.08 | 0.05 | **7.90** |
| 2005 | 0.30 | 0.58 | 0.56 | 0.56 | 0.27 | 0.36 | 0.26 | 0.37 | 2.15 | 1.40 | 0.10 | 0.27 | 0.26 | 0.24 | 0.11 | 0.08 | 0.05 | **7.90** |
| 2006 | 0.27 | 0.52 | 0.50 | 0.50 | 0.24 | 0.32 | 0.23 | 0.33 | 1.92 | 1.26 | 0.09 | 0.24 | 0.23 | 0.21 | 0.09 | 0.07 | 0.04 | **7.10** |
| 2007 | 0.26 | 0.50 | 0.48 | 0.48 | 0.23 | 0.31 | 0.22 | 0.32 | 1.85 | 1.21 | 0.08 | 0.23 | 0.22 | 0.21 | 0.09 | 0.07 | 0.04 | **6.80** |
| 2008 | 0.26 | 0.51 | 0.49 | 0.49 | 0.23 | 0.32 | 0.22 | 0.32 | 1.88 | 1.23 | 0.09 | 0.24 | 0.22 | 0.21 | 0.09 | 0.07 | 0.04 | **6.90** |
| 2009 | 0.25 | 0.48 | 0.46 | 0.46 | 0.22 | 0.30 | 0.21 | 0.30 | 1.76 | 1.15 | 0.08 | 0.22 | 0.21 | 0.20 | 0.09 | 0.07 | 0.04 | **6.50** |
| 2010 | 0.25 | 0.49 | 0.47 | 0.47 | 0.23 | 0.30 | 0.22 | 0.31 | 1.82 | 1.19 | 0.08 | 0.23 | 0.22 | 0.20 | 0.09 | 0.07 | 0.04 | **6.70** |
| 2011 | 0.23 | 0.45 | 0.43 | 0.43 | 0.21 | 0.28 | 0.20 | 0.29 | 1.68 | 1.10 | 0.08 | 0.21 | 0.20 | 0.19 | 0.08 | 0.07 | 0.04 | **6.20** |
| 2012 | 0.23 | 0.44 | 0.43 | 0.43 | 0.20 | 0.28 | 0.20 | 0.28 | 1.64 | 1.07 | 0.08 | 0.21 | 0.20 | 0.18 | 0.08 | 0.06 | 0.03 | **6.00** |
| 2013 | 0.23 | 0.44 | 0.42 | 0.42 | 0.20 | 0.27 | 0.19 | 0.28 | 1.61 | 1.06 | 0.07 | 0.20 | 0.19 | 0.18 | 0.08 | 0.06 | 0.03 | **5.90** |
| 2014 | 0.22 | 0.43 | 0.41 | 0.42 | 0.20 | 0.27 | 0.19 | 0.27 | 1.60 | 1.05 | 0.07 | 0.20 | 0.19 | 0.18 | 0.08 | 0.06 | 0.03 | **5.90** |
| 2015 | 0.21 | 0.41 | 0.39 | 0.39 | 0.19 | 0.25 | 0.18 | 0.26 | 1.51 | 0.99 | 0.07 | 0.19 | 0.18 | 0.17 | 0.07 | 0.06 | 0.03 | **5.60** |
| 2016 | 0.21 | 0.42 | 0.40 | 0.40 | 0.19 | 0.26 | 0.18 | 0.26 | 1.54 | 1.00 | 0.07 | 0.19 | 0.18 | 0.17 | 0.08 | 0.06 | 0.03 | **5.70** |
| 2017 | 0.20 | 0.39 | 0.37 | 0.38 | 0.18 | 0.24 | 0.17 | 0.25 | 1.45 | 0.95 | 0.07 | 0.18 | 0.17 | 0.16 | 0.07 | 0.06 | 0.03 | **5.30** |

Table 4-64 Estimated methane emissions for early maturing cattle in 1990-2017 years

| | Emissions, Gg $CH_4$ | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle category** | **Calf – females** | **Heifer** | **Heifer** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Cow** | **Lactating cow** | **Calf – males** | **Bullock** | **Bullock** | **Bull (castrate)** | **Bull (castrate)** | **Bull (castrate)** | **Total** |
| **Age, year** | **0-1** | **1-2** | **2-3** | **3-4** | **3-4** | **4-5** | **4-5** | **>5** | **>5** | **0-1** | **1-2** | **2-3** | **3-4** | **4-5** | **>5** | |
| 1990 | 3.05 | 6.67 | 6.06 | 2.52 | 3.31 | 2.78 | 3.68 | 13.60 | 8.52 | 1.05 | 2.07 | 1.86 | 0.97 | 0.53 | 0.45 | **56.70** |
| 1991 | 2.86 | 6.24 | 5.67 | 2.36 | 3.10 | 2.60 | 3.44 | 12.74 | 7.97 | 0.99 | 1.94 | 1.74 | 0.91 | 0.50 | 0.42 | **53.10** |
| 1992 | 2.38 | 5.20 | 4.72 | 1.97 | 2.58 | 2.17 | 2.86 | 10.60 | 6.63 | 0.82 | 1.62 | 1.45 | 0.76 | 0.42 | 0.35 | **44.20** |
| 1993 | 2.22 | 4.86 | 4.41 | 1.84 | 2.41 | 2.02 | 2.68 | 9.91 | 6.20 | 0.77 | 1.51 | 1.35 | 0.71 | 0.39 | 0.32 | **41.30** |
| 1994 | 2.28 | 4.98 | 4.52 | 1.88 | 2.47 | 2.07 | 2.74 | 10.15 | 6.35 | 0.79 | 1.55 | 1.39 | 0.73 | 0.40 | 0.33 | **42.30** |
| 1995 | 2.36 | 5.16 | 4.69 | 1.95 | 2.56 | 2.15 | 2.85 | 10.53 | 6.59 | 0.82 | 1.61 | 1.44 | 0.75 | 0.41 | 0.34 | **43.90** |
| 1996 | 2.46 | 5.38 | 4.89 | 2.03 | 2.67 | 2.24 | 2.96 | 10.97 | 6.86 | 0.85 | 1.67 | 1.50 | 0.78 | 0.43 | 0.36 | **45.70** |
| 1997 | 2.52 | 5.51 | 5.00 | 2.08 | 2.73 | 2.30 | 3.04 | 11.24 | 7.03 | 0.87 | 1.71 | 1.53 | 0.80 | 0.44 | 0.37 | **46.80** |
| 1998 | 2.59 | 5.67 | 5.15 | 2.14 | 2.81 | 2.36 | 3.12 | 11.56 | 7.24 | 0.89 | 1.76 | 1.58 | 0.83 | 0.45 | 0.38 | **48.20** |
| 1999 | 2.79 | 6.09 | 5.53 | 2.30 | 3.02 | 2.54 | 3.36 | 12.42 | 7.78 | 0.96 | 1.89 | 1.70 | 0.89 | 0.49 | 0.41 | **51.80** |
| 2000 | 2.94 | 6.42 | 5.84 | 2.43 | 3.19 | 2.68 | 3.54 | 13.10 | 8.20 | 1.01 | 2.00 | 1.79 | 0.94 | 0.51 | 0.43 | **54.60** |
| 2001 | 2.96 | 6.47 | 5.88 | 2.45 | 3.21 | 2.70 | 3.56 | 13.19 | 8.26 | 1.02 | 2.01 | 1.80 | 0.94 | 0.52 | 0.43 | **55.00** |
| 2002 | 3.07 | 6.70 | 6.09 | 2.54 | 3.33 | 2.79 | 3.70 | 13.68 | 8.56 | 1.06 | 2.08 | 1.87 | 0.98 | 0.54 | 0.45 | **57.00** |
| 2003 | 3.15 | 6.89 | 6.26 | 2.61 | 3.42 | 2.87 | 3.80 | 14.05 | 8.79 | 1.09 | 2.14 | 1.92 | 1.01 | 0.55 | 0.46 | **58.50** |
| 2004 | 3.00 | 6.55 | 5.96 | 2.48 | 3.25 | 2.73 | 3.61 | 13.37 | 8.37 | 1.03 | 2.04 | 1.82 | 0.96 | 0.52 | 0.44 | **55.70** |
| 2005 | 3.05 | 6.67 | 6.06 | 2.52 | 3.31 | 2.78 | 3.68 | 13.60 | 8.51 | 1.05 | 2.07 | 1.86 | 0.97 | 0.53 | 0.45 | **56.70** |
| 2006 | 2.78 | 6.07 | 5.52 | 2.30 | 3.01 | 2.53 | 3.35 | 12.38 | 7.75 | 0.96 | 1.89 | 1.69 | 0.89 | 0.49 | 0.41 | **51.60** |
| 2007 | 2.71 | 5.93 | 5.39 | 2.24 | 2.94 | 2.47 | 3.27 | 12.10 | 7.57 | 0.94 | 1.84 | 1.65 | 0.87 | 0.47 | 0.40 | **50.40** |

| | Emissions, Gg $CH_4$ | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cattle category | Calf – females | Heifer | Heifer | Cow | Lactating cow | Cow | Lactating cow | Cow | Lactating cow | Calf – males | Bullock | Bullock | Bull (castrate) | Bull (castrate) | Bull (castrate) | Total |
| Age, year | 0-1 | 1-2 | 2-3 | 3-4 | 3-4 | 4-5 | 4-5 | >5 | >5 | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | >5 | |
| 2008 | 2.81 | 6.13 | 5.58 | 2.32 | 3.04 | 2.56 | 3.38 | 12.52 | 7.83 | 0.97 | 1.91 | 1.71 | 0.90 | 0.49 | 0.41 | **52.10** |
| 2009 | 2.68 | 5.86 | 5.33 | 2.22 | 2.91 | 2.44 | 3.23 | 11.96 | 7.48 | 0.93 | 1.82 | 1.63 | 0.86 | 0.47 | 0.39 | **49.80** |
| 2010 | 2.81 | 6.15 | 5.59 | 2.33 | 3.05 | 2.56 | 3.39 | 12.55 | 7.86 | 0.97 | 1.91 | 1.71 | 0.90 | 0.49 | 0.41 | **52.30** |
| 2011 | 2.83 | 6.19 | 5.63 | 2.34 | 3.07 | 2.58 | 3.41 | 12.63 | 7.91 | 0.98 | 1.93 | 1.72 | 0.90 | 0.50 | 0.41 | **52.60** |
| 2012 | 3.04 | 6.65 | 6.04 | 2.52 | 3.30 | 2.77 | 3.67 | 13.57 | 8.49 | 1.05 | 2.07 | 1.85 | 0.97 | 0.53 | 0.44 | **56.50** |
| 2013 | 3.29 | 7.19 | 6.53 | 2.72 | 3.57 | 3.00 | 3.96 | 14.66 | 9.18 | 1.13 | 2.24 | 2.00 | 1.05 | 0.58 | 0.48 | **61.10** |
| 2014 | 3.61 | 7.89 | 7.17 | 2.99 | 3.92 | 3.29 | 4.35 | 16.10 | 10.07 | 1.25 | 2.45 | 2.20 | 1.15 | 0.63 | 0.53 | **67.10** |
| 2015 | 3.80 | 8.31 | 7.55 | 3.15 | 4.13 | 3.47 | 4.58 | 16.96 | 10.61 | 1.31 | 2.59 | 2.31 | 1.21 | 0.67 | 0.56 | **70.70** |
| 2016 | 3.86 | 8.44 | 7.67 | 3.19 | 4.19 | 3.52 | 4.65 | 17.22 | 10.78 | 1.33 | 2.63 | 2.35 | 1.23 | 0.68 | 0.56 | **71.80** |
| 2017 | 3.64 | 7.95 | 7.22 | 3.01 | 3.94 | 3.31 | 4.38 | 16.21 | 10.15 | 1.25 | 2.47 | 2.21 | 1.16 | 0.64 | 0.53 | **67.50** |

Methane emissions from enteric fermentation in cattle estimated on the basis of tier 2 approach are presented in summary *Table 4-65*.

Table 4-65 Methane emissions in Gg from enteric fermentation in cattle

| Year | Methane emissions | | | | |
|---|---|---|---|---|---|
| | Early maturing | Georgian Mountain | Red Mingrelian | Total, Gg $CH_4$ | Total, Gg $CO_2$eq |
| 1990 | 56.68 | 11.56 | 10.08 | **78.32** | **1,645** |
| 1991 | 53.07 | 10.70 | 9.30 | **73.07** | **1,534** |
| 1992 | 44.16 | 8.80 | 7.61 | **60.57** | **1,272** |
| 1993 | 41.27 | 8.12 | 7.00 | **56.40** | **1,184** |
| 1994 | 42.30 | 8.23 | 7.07 | **57.59** | **1,209** |
| 1995 | 43.88 | 8.44 | 7.21 | **59.53** | **1,250** |
| 1996 | 45.69 | 8.68 | 7.39 | **61.76** | **1,297** |
| 1997 | 46.81 | 8.79 | 7.45 | **63.04** | **1,324** |
| 1998 | 48.16 | 8.93 | 7.54 | **64.63** | **1,357** |
| 1999 | 51.75 | 9.48 | 7.97 | **69.21** | **1,453** |
| 2000 | 54.58 | 9.88 | 8.27 | **72.74** | **1,528** |
| 2001 | 54.96 | 9.83 | 8.19 | **72.99** | **1,533** |
| 2002 | 56.97 | 10.07 | 8.35 | **75.39** | **1,583** |
| 2003 | 58.52 | 10.22 | 8.43 | **77.18** | **1,621** |
| 2004 | 55.70 | 9.61 | 7.89 | **73.20** | **1,537** |
| 2005 | 56.68 | 9.66 | 7.90 | **74.23** | **1,559** |
| 2006 | 51.59 | 8.69 | 7.06 | **67.35** | **1,414** |
| 2007 | 50.41 | 8.39 | 6.78 | **65.58** | **1,377** |
| 2008 | 52.14 | 8.57 | 6.90 | **67.61** | **1,420** |
| 2009 | 49.82 | 8.09 | 6.47 | **64.38** | **1,352** |
| 2010 | 52.29 | 8.38 | 6.68 | **67.35** | **1,414** |
| 2011 | 52.63 | 8.02 | 6.16 | **66.81** | **1,403** |
| 2012 | 56.54 | 8.19 | 6.04 | **70.77** | **1,486** |
| 2013 | 61.09 | 8.40 | 5.94 | **75.43** | **1,584** |
| 2014 | 67.06 | 8.75 | 5.89 | **81.70** | **1,716** |
| 2015 | 70.65 | 8.74 | 5.56 | **84.96** | **1,784** |
| 2016 | 71.75 | 8.88 | 5.65 | **86.28** | **1,812** |
| 2017 | 67.53 | 8.36 | 5.32 | **81.21** | **1,705** |

### 4.11.2. Buffalo, Sheep, Goats, Horses, Asses & Swine (3.A.2, 3.A.3, 3.A.4, 3.A.5.1, 3.A.5.2, 3.A.6 )

**Methodology:**

The IPCC 2006 methodology is used for estimating methane emissions from enteric fermentation for Buffalo, Sheep, Goats, Horses, Asses and Swine,. The amount of methane emitted by a population of animals is calculated by multiplying the emission rate per animal by the number of animals.

$$EN_i = EF_i \times Pop_i$$

Where:

- $EM_i$ emissions from animal type i
- $i$ index refers to animal type
- $EF_i$ methane emission factor for animal type i
- $Pop_i$ quantity of animal type i

**Activity data**:

Numbers of animals in 1990-2017 years are given in Table *4-66*.

Table 4-66 The number of animals (thousand heads)

| Year | Buffalos 3.A.2 | Sheep 3.A.3 | Goats 3.A.4 | Horses 3.A.5.1 | Asses 3.A.5.2 | Swine 3.A.6 | Poultry |
|---|---|---|---|---|---|---|---|
| 1990 | 37 | 1,550 | 68 | 20 | NE | 880 | 21,760 |
| 1991 | 33 | 1,411 | 59 | 18 | NE | 733 | 20,167 |
| 1992 | 30 | 1,146 | 45 | 17 | NE | 476 | 11,210 |
| 1993 | 24 | 920 | 38 | 20 | NE | 365 | 11,857 |
| 1994 | 22 | 754 | 39 | 21 | NE | 367 | 12,290 |
| 1995 | 22 | 674 | 51 | 24 | NE | 353 | 13,847 |
| 1996 | 22 | 600 | 52 | 26 | NE | 333 | 14,645 |
| 1997 | 23 | 525 | 59 | 28 | 9 | 330 | 15,542 |
| 1998 | 23 | 522 | 65 | 30 | 11 | 366 | 8,240 |
| 1999 | 23 | 553 | 80 | 34 | 12 | 411 | 8,473 |
| 2000 | 24 | 547 | 81 | 35 | NE | 443 | 7,826 |
| 2001 | 24 | 568 | 92 | 39 | 11 | 445 | 8,495 |
| 2002 | 24 | 611 | 88 | 43 | NE | 446 | 8,899 |
| 2003 | 24 | 629 | 93 | 43 | NE | 474 | 9,201 |
| 2004 | 24 | 689 | 116 | 44 | 13 | 484 | 9,836 |
| 2005 | 22 | 720 | 96 | 43 | 13 | 455 | 7,482 |
| 2006 | 22 | 697 | 92 | 26 | 8 | 344 | 5,401 |
| 2007 | 19 | 711 | 86 | 23 | 9 | 110 | 6,150 |
| 2008 | 18 | 690 | 79 | 28 | 8 | 86 | 6,682 |
| 2009 | 18 | 602 | 72 | 29 | 7 | 135 | 6,675 |
| 2010 | 17 | 597 | 57 | 31 | 11 | 110 | 6,522 |
| 2011 | 17 | 577 | 54 | 29 | 8 | 105 | 6,360 |
| 2012 | 17 | 688 | 54 | 31 | 6 | 204 | 6,159 |
| 2013 | 18 | 796 | 61 | 31 | 8 | 191 | 6,761 |
| 2014 | 12 | 866 | 54 | 28 | 7 | 170 | 6,658 |
| 2015 | 15 | 842 | 50 | 34 | 4 | 162 | 8,309 |
| 2016 | 17 | 876 | 61 | 23 | 4 | 136 | 8,238 |
| 2017 | 15 | 856 | 51 | 22 | 3 | 151 | 8,386 |

**Emission factors:**

Emission factors are taken according to default values for developing countries with temperate climate [IPCC 2006, Chapter 10, p. 10.28, table 10.10].

**Emissions**:

$CH_4$ emissions from enteric fermentation for Buffalos, Sheep, Goats, Horses, Asses and Swine, are presented in *Table 4-67*.

Table 4-67 Methane emissions (in Gg) from enteric fermentation in Buffalos, Sheep, Goats, Horses, Asses and Swine

| Year | Buffalos 3.A.2 | Sheep 3.A.3 | Goats 3.A.4 | Horses 3.A.5.1 | Asses 3.A.5.2 | Swine 3.A.6 | Total | Total Gg-$CO_2$eq |
|---|---|---|---|---|---|---|---|---|
| 1990 | 2.02 | 7.75 | 0.34 | 0.35 | NE | 0.88 | 11.35 | 238 |
| 1991 | 1.81 | 7.06 | 0.29 | 0.33 | NE | 0.73 | 10.22 | 215 |
| 1992 | 1.65 | 5.73 | 0.23 | 0.30 | NE | 0.48 | 8.39 | 176 |
| 1993 | 1.35 | 4.60 | 0.19 | 0.35 | NE | 0.37 | 6.85 | 144 |
| 1994 | 1.22 | 3.77 | 0.20 | 0.39 | NE | 0.37 | 5.94 | 125 |
| 1995 | 1.22 | 3.37 | 0.25 | 0.43 | NE | 0.35 | 5.63 | 118 |
| 1996 | 1.23 | 3.00 | 0.26 | 0.47 | NE | 0.33 | 5.30 | 111 |
| 1997 | 1.25 | 2.62 | 0.30 | 0.50 | 0.09 | 0.33 | 5.09 | 107 |
| 1998 | 1.25 | 2.61 | 0.33 | 0.55 | 0.11 | 0.37 | 5.20 | 109 |
| 1999 | 1.25 | 2.77 | 0.40 | 0.61 | 0.12 | 0.41 | 5.56 | 117 |
| 2000 | 1.31 | 2.73 | 0.40 | 0.63 | NE | 0.44 | 5.52 | 116 |
| 2001 | 1.34 | 2.84 | 0.46 | 0.69 | 0.11 | 0.45 | 5.89 | 124 |
| 2002 | 1.32 | 3.06 | 0.44 | 0.77 | NE | 0.45 | 6.03 | 127 |
| 2003 | 1.33 | 3.14 | 0.47 | 0.78 | NE | 0.47 | 6.19 | 130 |
| 2004 | 1.32 | 3.45 | 0.58 | 0.80 | 0.13 | 0.48 | 6.76 | 142 |
| 2005 | 1.23 | 3.60 | 0.48 | 0.77 | 0.13 | 0.46 | 6.66 | 140 |
| 2006 | 1.21 | 3.48 | 0.46 | 0.47 | 0.08 | 0.34 | 6.05 | 127 |
| 2007 | 1.07 | 3.56 | 0.43 | 0.41 | 0.09 | 0.11 | 5.66 | 119 |
| 2008 | 1.01 | 3.45 | 0.40 | 0.50 | 0.08 | 0.09 | 5.53 | 116 |
| 2009 | 0.98 | 3.01 | 0.36 | 0.52 | 0.07 | 0.14 | 5.07 | 107 |
| 2010 | 0.93 | 2.98 | 0.29 | 0.55 | 0.11 | 0.11 | 4.97 | 104 |
| 2011 | 0.93 | 2.88 | 0.27 | 0.53 | 0.08 | 0.11 | 4.80 | 101 |
| 2012 | 0.94 | 3.44 | 0.27 | 0.55 | 0.06 | 0.20 | 5.47 | 115 |
| 2013 | 1.00 | 3.98 | 0.30 | 0.55 | 0.08 | 0.19 | 6.11 | 128 |
| 2014 | 0.65 | 4.33 | 0.27 | 0.51 | 0.07 | 0.17 | 6.00 | 126 |
| 2015 | 0.85 | 4.21 | 0.25 | 0.61 | 0.04 | 0.16 | 6.12 | 129 |
| 2016 | 0.92 | 4.38 | 0.30 | 0.41 | 0.04 | 0.14 | 6.19 | 130 |
| 2017 | 0.80 | 4.28 | 0.26 | 0.40 | 0.03 | 0.15 | 5.91 | 124 |

## 4.12. Manure Management (3.B.)

During handling or storage of livestock manure, both $CH_4$ and $N_2O$ are emitted. The magnitude of the emissions depends upon the quantity of manure handled, the manure properties, and the type of manure management system. Typically, poorly aerated manure management systems generate large quantities of $CH_4$ but smaller amounts of $N_2O$, while well-aerated systems generate little $CH_4$ but larger volume of $N_2O$.

### 4.12.1. Methane Emissions from Manure Management (3.B.1)

Shortly after manure is excreted, it begins to decompose. If little oxygen is present, the decomposition will be mainly anaerobic and thus produces $CH_4$. The quantity of $CH_4$ produced depends on the type of waste management system, the degree of aeration, and the quantity of manure.

Methane emissions from cattle manure management are estimated using the IPCC Tier 2 approach.

$$EF_{(T)} = \left(VS_{(T)} \times 365\right) \times \left[B_{o(T)} \times 0.67 kg/m^3 \times \sum_{S,k} \frac{MCF_{S,k}}{100} \times MS_{(T,S,k)}\right]$$

Where:

| | |
|---|---|
| $EF_{(T)}$ | annual $CH_4$ emission factor for livestock category *T*, kgCH4/animal/year |
| $VS_{(T)}$ | daily volatile solid excreted for livestock category *T*, kg dry matter/animal/day |
| 365 | basis for calculating annual VS production, days yr-1 |

| | |
|---|---|
| *Bo(T)* | maximum methane producing capacity for manure produced by livestock category *T*, m3 $CH_4$ kg-1 of VS excreted |
| 0.67 | conversion factor of $m^3$ $CH_4$ to kilograms $CH_4$ |
| *MCF(S,k)* | methane conversion factors for each manure management system *S* by climate region *k*, % |
| *MS(T,S,k)* | fraction of livestock category *T*'s manure handled using manure management system *S* in climate region *k*, dimensionless |

For other types of animals the IPCC Tier 1 approach was used. This approach relies on default emission factors.

**Activity Data:**
The animal population data are the same as those used for the Enteric Fermentation emission estimates (Table *4-54*and Table *4-66*).

**Emission factors:**
Due to absence of country specific data on VS and Bo, default values from the 2006 IPCC (Reference Manual, chapter 10, tables 10A4, 10A5) have been used. Emission factors for buffalo and swine were taken according to default values for Asia region [IPCC 2006, Chapter 10, p. 10.38-10.39, table 10.14]. For other types of animals (goats, horses, asses and poultry) emission factors are taken according to default values for developing countries with temperature from 15°C to 25°C (temperate climate) [IPCC 2006, Chapter 10, p. 10.40, table 10.15].

**Emissions:**
Calculated methane emissions from manure management are presented in *Table 4-68*.

Table 4-68 Methane emissions (in Gg) from manure management

| Year | Cattle 3.B.1.1 | Buffalos 3.B.1.2 | Sheep 3.B.1.3 | Goats 3.B.1.4 | Horses 3.B.1.5.a | Asses 3.B.1.5.b | Swine 3.B.1.6 | Poultry 3.B.1.7 | Total | Total Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1.50 | 0.07 | 0.23 | 0.01 | 0.03 | NE | 3.52 | 0.44 | 5.80 | 122 |
| 1991 | 1.40 | 0.07 | 0.21 | 0.01 | 0.03 | NE | 2.93 | 0.40 | 5.05 | 106 |
| 1992 | 1.16 | 0.06 | 0.17 | 0.01 | 0.03 | NE | 1.90 | 0.22 | 3.55 | 75 |
| 1993 | 1.07 | 0.05 | 0.14 | 0.01 | 0.03 | NE | 1.46 | 0.24 | 3.00 | 63 |
| 1994 | 1.09 | 0.04 | 0.11 | 0.01 | 0.04 | NE | 1.47 | 0.25 | 3.01 | 63 |
| 1995 | 1.13 | 0.04 | 0.10 | 0.01 | 0.04 | NE | 1.41 | 0.28 | 3.01 | 63 |
| 1996 | 1.17 | 0.04 | 0.09 | 0.01 | 0.04 | NE | 1.33 | 0.29 | 2.98 | 63 |
| 1997 | 1.19 | 0.05 | 0.08 | 0.01 | 0.05 | 0.01 | 1.32 | 0.31 | 3.01 | 63 |
| 1998 | 1.22 | 0.05 | 0.08 | 0.01 | 0.05 | 0.01 | 1.46 | 0.16 | 3.04 | 64 |
| 1999 | 1.31 | 0.05 | 0.08 | 0.01 | 0.06 | 0.01 | 1.64 | 0.17 | 3.33 | 70 |
| 2000 | 1.37 | 0.05 | 0.08 | 0.01 | 0.06 | NE | 1.77 | 0.16 | 3.50 | 74 |
| 2001 | 1.37 | 0.05 | 0.09 | 0.02 | 0.06 | 0.01 | 1.78 | 0.17 | 3.55 | 74 |
| 2002 | 1.42 | 0.05 | 0.09 | 0.02 | 0.07 | NE | 1.78 | 0.18 | 3.60 | 76 |
| 2003 | 1.45 | 0.05 | 0.09 | 0.02 | 0.07 | NE | 1.90 | 0.18 | 3.76 | 79 |
| 2004 | 1.37 | 0.05 | 0.10 | 0.02 | 0.07 | 0.01 | 1.94 | 0.20 | 3.76 | 79 |
| 2005 | 1.39 | 0.04 | 0.11 | 0.02 | 0.07 | 0.01 | 1.82 | 0.15 | 3.61 | 76 |
| 2006 | 1.26 | 0.04 | 0.10 | 0.02 | 0.04 | 0.01 | 1.37 | 0.11 | 2.95 | 62 |
| 2007 | 1.22 | 0.04 | 0.11 | 0.01 | 0.04 | 0.01 | 0.44 | 0.12 | 1.99 | 42 |
| 2008 | 1.26 | 0.04 | 0.10 | 0.01 | 0.05 | 0.01 | 0.35 | 0.13 | 1.94 | 41 |
| 2009 | 1.20 | 0.04 | 0.09 | 0.01 | 0.05 | 0.01 | 0.54 | 0.13 | 2.06 | 43 |
| 2010 | 1.25 | 0.03 | 0.09 | 0.01 | 0.05 | 0.01 | 0.44 | 0.13 | 2.01 | 42 |
| 2011 | 1.23 | 0.03 | 0.09 | 0.01 | 0.05 | 0.01 | 0.42 | 0.13 | 1.96 | 41 |
| 2012 | 1.30 | 0.03 | 0.10 | 0.01 | 0.05 | 0.01 | 0.82 | 0.12 | 2.44 | 51 |
| 2013 | 1.37 | 0.04 | 0.12 | 0.01 | 0.05 | 0.01 | 0.76 | 0.14 | 2.50 | 52 |
| 2014 | 1.48 | 0.02 | 0.13 | 0.01 | 0.05 | 0.01 | 0.68 | 0.13 | 2.50 | 53 |
| 2015 | 1.53 | 0.03 | 0.13 | 0.01 | 0.06 | NE | 0.65 | 0.17 | 2.56 | 54 |
| 2016 | 1.55 | 0.03 | 0.13 | 0.01 | 0.04 | NE | 0.54 | 0.16 | 2.48 | 52 |
| 2017 | 1.46 | 0.03 | 0.13 | 0.01 | 0.04 | NE | 0.60 | 0.17 | 2.43 | 51 |

### 4.12.2. Nitrous oxide emissions from manure management (3.B.2)

#### 4.12.2.1. Direct $N_2O$ emissions from Manure Management

The production of $N_2O$ during storage and treatment of animal waste occurs during nitrification and denitrification of nitrogen contained in the manure. Nitrification is the oxidation of ammonium ($NH_4$+) to nitrate ($NO_3$-), and denitrification is the reduction of ($NO_3$-) to $N_2O$ or nitrogen ($N_2$). Generally, as the degree of aeration of the waste increases, so does the amount of $N_2O$ produced.

The Animal Waste Management System (AWMS) is an important regulating factor in $N_2O$ emissions. $N_2O$ emissions from some types of AWMS (Anaerobic lagoons; Liquid systems; Solid storage and drylot; and other systems) are reported under Manure Management, while stable manure that is applied to agricultural soils (e.g., daily spread) and dung and urine deposited by grazing animals on fields (pasture range and paddock) is referred in the methodology for estimating direct emissions from agricultural soils. Manure used for fuel is considered an energy-related emission.

**Methodology:**
IPCC tier 1 method is used. Direct nitrous oxide emissions from manure management are estimated by multiplying the total amount of N excretion (from all livestock species/categories) in each type of manure management system by an emission factor for that type of manure management system. Emissions are then summed over all manure management systems. IPCC default $N_2O$ emission factors, default nitrogen excretion data, and default manure management system data are used. The methodology is based on the following formulae:

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}\right)\right] \times EF_{3(S)}\right] \times \frac{44}{28}$$

Where:

| | |
|---|---|
| $N_T$ | number of head of livestock category T in the country |
| $Nex_{(T)}$ | annual average N excretion per head of species/category T in the country, \ kgN/animal/year |
| $MS_{(T,S)}$ | fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless |
| $EF_{3(S)}$ | emission factor for direct $N_2O$ emissions from manure management system S in the country, kg$N_2O$-N/kg N in manure management system S |
| $S$ | manure management system |
| $T$ | species/category of livestock |
| 44/28 | conversion of $N_2O$-N emissions to $N_2O$ emissions |

**Activity data:**
Animal population data and distribution by categories are taken from Table *4-54* and Table *4-66*.

**Emission factors:**
The average daily nitrogen excretion rates for domestic animals are taken according to default values for Asia region [IPCC 2006, Chapter 10, p.10.59, Table 10.19]. Herd average weight for cattle was estimated based on cattle distribution by age (Table *4-55*

Table 4-57) and cattle weight by age (*Table 4-58, Table 4-59*). For other animal's default values are used (IPCC 2006, Chapter 10, p.10.59, Table 10.19). $EF_3$ are taken from the IPCC 2006 (Chapter 10, p.10.62, Table 10.21). During 1990-2017 Cattle Herd average weight varies within the range of 336.8-365 kg and Nex varies within 41.8-45.3 (average 43.2). Nex for other animals is presented in *Table 4-69*.

Table 4-69 Nitrogen Excretion rate (Nex) for animal types

| Animal | Cattle | Sheep | Goats | Swine | Buffalo | Horses | Asses | Poultry |
|---|---|---|---|---|---|---|---|---|
| Weight, kg | 348 | 28 | 30 | 28 | 380 | 238 | 130 | 0.9 |
| Nex, kg N/head/day/1000kg | 0.34 | 1.17 | 1.37 | 0.42 | 0.32 | 0.46 | 0.46 | 1.1 |
| Nex, kg N/head/year | 43.2 | 12 | 15 | 4.3 | 44.4 | 40 | 21.8 | 0.4 |

The fraction of nitrogen available for conversion into $N_2O$ is estimated by applying system-specific values to the manure nitrogen handled by each management system. The IPCC default values for Asia region are used here [IPCC 2006, Chapter 10, pp. 10.78-10.81, tables 10A-5-10A-8], with adjustments based on the national agriculture expert (Head of the Zootechny department of the Agrarian University of Georgia Mr. Levan Tortladze) judgment (*Table 4-70*).

Table 4-70 Fraction of manure nitrogen in different management systems

| Animal | Anaerobic Lagoons | Liquid Systems | Solid Storage | Drylot | Daily Spread | Pasture Range And Paddock | Other systems |
|---|---|---|---|---|---|---|---|
| Cattle | - | - | - | 0.46 | 0.02 | 0.50 | 0.02 |
| Poultry | - | - | - | - | - | 0.44 | 0.56 |
| Sheep | - | - | - | - | - | 0.83 | 0.17 |
| Swine | - | - | - | 0.54 | - | - | 0.46 |
| Others | - | - | - | - | - | 0.95 | 0.05 |

Only insignificant portion of manure nitrogen transforms into nitrous oxide. $N_2O$ emission factors (kg $N_2O$-N/kg emitted nitrogen) for various manure management systems are provided in *Table 4-71*. IPCC Default values are used [IPCC 2006, Chapter 10, p.10.62, table 10.21].

Table 4-71 $N_2O$ emission factors from manure management systems (kg $N_2O$-N/kg emitted nitrogen)

| AWMS | Anaerobic Lagoons | Liquid Systems | Solid Storage | Drylot | Daily Spread | Pasture Range And Paddock | Other systems |
|---|---|---|---|---|---|---|---|
| Emission factor - EF3 | 0 | 0.001 | 0.005 | 0.02 | 0.0 | 0.02 | 0.005 |

**Emissions:** Direct $N_2O$ Emissions from different manure management systems are provided in Table *4-72*.

Table 4-72 Direct $N_2O$ emissions (in Gg) from manure management systems

| Year | Drylot | | Other systems | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle 3.B.2.1 | Swine 3.B.2.6 | Cattle 3.B.2.1 | Buffalos 3.B.2.2 | Sheep 3.B.2.3 | Goats 3.B.2.4 | Swine 3.B.2.6 | Poultry 3.B.2.7 | Total, Gg N_N2O | Total, Gg $N_2O$ | Total, Gg $CO_2$eq |
| 1990 | 0.515 | 0.041 | 0.006 | 0 | 0.016 | 0 | 0.009 | 0.022 | 0.609 | **0.96** | **297** |
| 1991 | 0.481 | 0.034 | 0.005 | 0 | 0.014 | 0 | 0.007 | 0.020 | 0.563 | **0.88** | **274** |
| 1992 | 0.399 | 0.022 | 0.004 | 0 | 0.012 | 0 | 0.005 | 0.011 | 0.453 | **0.71** | **221** |
| 1993 | 0.371 | 0.017 | 0.004 | 0 | 0.009 | 0 | 0.004 | 0.012 | 0.418 | **0.66** | **204** |
| 1994 | 0.380 | 0.017 | 0.004 | 0 | 0.008 | 0 | 0.004 | 0.012 | 0.425 | **0.67** | **207** |
| 1995 | 0.392 | 0.016 | 0.004 | 0 | 0.007 | 0 | 0.003 | 0.014 | 0.438 | **0.69** | **213** |
| 1996 | 0.407 | 0.015 | 0.004 | 0 | 0.006 | 0 | 0.003 | 0.015 | 0.452 | **0.71** | **220** |
| 1997 | 0.416 | 0.015 | 0.005 | 0 | 0.005 | 0 | 0.003 | 0.016 | 0.461 | **0.72** | **224** |
| 1998 | 0.427 | 0.017 | 0.005 | 0 | 0.005 | 0 | 0.004 | 0.008 | 0.466 | **0.73** | **227** |
| 1999 | 0.457 | 0.019 | 0.005 | 0 | 0.006 | 0 | 0.004 | 0.009 | 0.500 | **0.79** | **244** |
| 2000 | 0.481 | 0.021 | 0.005 | 0 | 0.006 | 0 | 0.004 | 0.008 | 0.525 | **0.82** | **256** |
| 2001 | 0.482 | 0.021 | 0.005 | 0 | 0.006 | 0 | 0.004 | 0.009 | 0.528 | **0.83** | **257** |
| 2002 | 0.499 | 0.021 | 0.005 | 0 | 0.006 | 0 | 0.004 | 0.009 | 0.545 | **0.86** | **265** |
| 2003 | 0.511 | 0.022 | 0.006 | 0 | 0.006 | 0 | 0.005 | 0.009 | 0.559 | **0.88** | **272** |

| Year | Drylot | | Other systems | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle 3.B.2.1 | Swine 3.B.2.6 | Cattle 3.B.2.1 | Buffalos 3.B.2.2 | Sheep 3.B.2.3 | Goats 3.B.2.4 | Swine 3.B.2.6 | Poultry 3.B.2.7 | Total, Gg N_N2O | Total, Gg $N_2O$ | Total, Gg $CO_2$eq |
| 2004 | 0.484 | 0.022 | 0.005 | 0 | 0.007 | 0 | 0.005 | 0.010 | 0.535 | **0.84** | **260** |
| 2005 | 0.492 | 0.021 | 0.005 | 0 | 0.007 | 0 | 0.004 | 0.008 | 0.538 | **0.85** | **262** |
| 2006 | 0.446 | 0.016 | 0.005 | 0 | 0.007 | 0 | 0.003 | 0.005 | 0.483 | **0.76** | **235** |
| 2007 | 0.435 | 0.005 | 0.005 | 0 | 0.007 | 0 | 0.001 | 0.006 | 0.460 | **0.72** | **224** |
| 2008 | 0.448 | 0.004 | 0.005 | 0 | 0.007 | 0 | 0.001 | 0.007 | 0.472 | **0.74** | **230** |
| 2009 | 0.427 | 0.006 | 0.005 | 0 | 0.006 | 0 | 0.001 | 0.007 | 0.453 | **0.71** | **220** |
| 2010 | 0.447 | 0.005 | 0.005 | 0 | 0.006 | 0 | 0.001 | 0.007 | 0.471 | **0.74** | **229** |
| 2011 | 0.444 | 0.005 | 0.005 | 0 | 0.006 | 0 | 0.001 | 0.006 | 0.468 | **0.73** | **228** |
| 2012 | 0.471 | 0.009 | 0.005 | 0 | 0.007 | 0 | 0.002 | 0.006 | 0.501 | **0.79** | **244** |
| 2013 | 0.503 | 0.009 | 0.005 | 0 | 0.008 | 0 | 0.002 | 0.007 | 0.535 | **0.84** | **261** |
| 2014 | 0.546 | 0.008 | 0.006 | 0 | 0.009 | 0 | 0.002 | 0.007 | 0.577 | **0.91** | **281** |
| 2015 | 0.569 | 0.007 | 0.006 | 0 | 0.009 | 0 | 0.002 | 0.008 | 0.601 | **0.94** | **293** |
| 2016 | 0.578 | 0.006 | 0.006 | 0 | 0.009 | 0 | 0.001 | 0.008 | 0.609 | **0.96** | **297** |
| 2017 | 0.544 | 0.007 | 0.006 | 0 | 0.009 | 0 | 0.001 | 0.008 | 0.576 | **0.90** | **280** |

### 4.12.2.2. Indirect $N_2O$ emissions from Manure Management

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia ($NH_3$) and nitrogen oxides ($NO_x$). Nitrogen losses begin at the point of excretion in housings and other animal production areas.

**Methodology:**
Tier 1 method is used. Calculation of N volatilization in forms of $NH_3$ and $NO_x$ from manure management systems implies multiplication of the amount of nitrogen excreted (from all livestock categories) and managed in each manure management system by a fraction of volatilized nitrogen (IPCC 2006, Chapter 10, Equation 10.26). N losses are then summed over all manure management systems. The Tier 1 method is applied using nitrogen excretion data from Table *4-69* and manure management system data from Table *4-70*.

According to the IPCC 2006, due to extremely limited measurement data on leaching and runoff losses from various manure management systems, "estimation of N losses from leaching and runoff from manure management should be considered part of a Tier 2 or Tier 3 method".

N losses due to volatilization from manure management are estimated using formula

$$N_{volatilization-MMS} = \sum_S \left[ \sum_T \left[ \left( N_{(T)} \times Nex_{(T)} \times MS_{(T,S)} \right) \times \left( \frac{Frac_{GaMS}}{100} \right)_{(T,S)} \right] \right]$$

Where:

| | |
|---|---|
| $N_{volatilization\text{-}MMs}$ | amount of manure nitrogen that is lost due to volatilization of NH3 and NOx, kg N/year |
| $N_{(T)}$ | number of head of livestock species/category T in the country |
| $Nex_{(T)}$ | annual average N excretion per head of species/category T in the country, kgN/animal/year |
| $MS_{(T,S)}$ | fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless |
| $Frac_{GasMS}$ | percent of managed manure nitrogen for livestock category T that volatilizes as $NH_3$ and $NO_x$ in the manure management system S, % |

$$N_2O_{G(mm)} = (N_{volatilization\text{-}MMs} \times EF_4) \times 44/28$$

Where:

| | |
|---|---|
| $N_2O_{G(mm)}$ | indirect $N_2O$ emissions due to volatilization of N from Manure Management in the country, kg $N_2O$/year |
| $EF_4$ | emission factor for $N_2O$ emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg $N_2O$-N (kg $NH_3$-N + $NO_x$-N volatilized). |

**Activity data:**
Animal population data and distribution by categories are obtained from Table *4-54* and Table *4-66*.

**Emission factors:**
$Nex_{(T)}$ and $MS_{(T,S)}$ are presented respectively in tables 4.25 and 4.26. For $EF_4$ default value 0.01 kg $N_2O$–N (kg $NH_3$–N + $NO_x$–N volatilized) is used [IPCC 2006, Chapter 11, p.11.24, Table 11.3]. $Frac_{GasMS}$ = 0.2 [IPCC 2006, Chapter 11, p.11.24, Table 11.3]. Default values of fractions of N losses from manure management systems due to volatilization are used (IPCC 2006, Chapter 10, p. 10.65, Table 10.22).

**Emissions.**
Indirect $N_2O$ Emissions from different manure management systems are given in *Table 4-73*.

Table 4-73 Indirect $N_2O$ emissions (in Gg) from Manure Management

| Year | Drylot | | Other systems | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle 3.B.2.1 | Swine 3.B.2.6 | Cattle 3.B.2.1 | Buffalos 3.B.2.2 | Sheep 3.B.2.3 | Goats 3.B.2.4 | Swine 3.B.2.6 | Poultry 3.B.2.7 | Total, Gg N_N₂O | Total | Total, in Gg $CO_2$eq |
| 1990 | 0.103 | 0.010 | 0.004 | 0 | 0.008 | 0 | 0.009 | 0.004 | 0.139 | 0.22 | 68 |
| 1991 | 0.096 | 0.008 | 0.004 | 0 | 0.007 | 0 | 0.007 | 0.004 | 0.128 | 0.20 | 62 |
| 1992 | 0.080 | 0.006 | 0.003 | 0 | 0.006 | 0 | 0.005 | 0.002 | 0.102 | 0.16 | 50 |
| 1993 | 0.074 | 0.004 | 0.003 | 0 | 0.005 | 0 | 0.004 | 0.002 | 0.093 | 0.15 | 45 |
| 1994 | 0.076 | 0.004 | 0.003 | 0 | 0.004 | 0 | 0.004 | 0.002 | 0.094 | 0.15 | 46 |
| 1995 | 0.078 | 0.004 | 0.003 | 0 | 0.003 | 0 | 0.003 | 0.003 | 0.096 | 0.15 | 47 |
| 1996 | 0.081 | 0.004 | 0.004 | 0 | 0.003 | 0 | 0.003 | 0.003 | 0.098 | 0.15 | 48 |
| 1997 | 0.083 | 0.004 | 0.004 | 0 | 0.003 | 0 | 0.003 | 0.003 | 0.100 | 0.16 | 49 |
| 1998 | 0.085 | 0.004 | 0.004 | 0 | 0.003 | 0 | 0.004 | 0.002 | 0.101 | 0.16 | 49 |
| 1999 | 0.091 | 0.005 | 0.004 | 0 | 0.003 | 0 | 0.004 | 0.002 | 0.109 | 0.17 | 53 |
| 2000 | 0.096 | 0.005 | 0.004 | 0 | 0.003 | 0 | 0.004 | 0.002 | 0.114 | 0.18 | 56 |
| 2001 | 0.096 | 0.005 | 0.004 | 0 | 0.003 | 0 | 0.004 | 0.002 | 0.115 | 0.18 | 56 |
| 2002 | 0.100 | 0.005 | 0.004 | 0 | 0.003 | 0 | 0.004 | 0.002 | 0.119 | 0.19 | 58 |
| 2003 | 0.102 | 0.005 | 0.004 | 0 | 0.003 | 0 | 0.005 | 0.002 | 0.122 | 0.19 | 59 |
| 2004 | 0.097 | 0.006 | 0.004 | 0 | 0.004 | 0 | 0.005 | 0.002 | 0.117 | 0.180 | 57 |
| 2005 | 0.098 | 0.005 | 0.004 | 0 | 0.004 | 0 | 0.004 | 0.002 | 0.118 | 0.185 | 57 |
| 2006 | 0.089 | 0.004 | 0.004 | 0 | 0.004 | 0 | 0.003 | 0.001 | 0.105 | 0.170 | 51 |
| 2007 | 0.087 | 0.001 | 0.004 | 0 | 0.004 | 0 | 0.001 | 0.001 | 0.098 | 0.154 | 48 |
| 2008 | 0.090 | 0.001 | 0.004 | 0 | 0.004 | 0 | 0.001 | 0.001 | 0.100 | 0.160 | 49 |
| 2009 | 0.085 | 0.002 | 0.004 | 0 | 0.003 | 0 | 0.001 | 0.001 | 0.097 | 0.152 | 47 |
| 2010 | 0.089 | 0.001 | 0.004 | 0 | 0.003 | 0 | 0.001 | 0.001 | 0.100 | 0.157 | 49 |
| 2011 | 0.089 | 0.001 | 0.004 | 0 | 0.003 | 0 | 0.001 | 0.001 | 0.099 | 0.156 | 48 |
| 2012 | 0.094 | 0.002 | 0.004 | 0 | 0.003 | 0 | 0.002 | 0.001 | 0.108 | 0.170 | 52 |
| 2013 | 0.101 | 0.002 | 0.004 | 0 | 0.004 | 0 | 0.002 | 0.001 | 0.115 | 0.180 | 56 |
| 2014 | 0.109 | 0.002 | 0.005 | 0 | 0.004 | 0 | 0.002 | 0.001 | 0.123 | 0.194 | 60 |
| 2015 | 0.114 | 0.002 | 0.005 | 0 | 0.004 | 0 | 0.002 | 0.002 | 0.128 | 0.200 | 62 |
| 2016 | 0.116 | 0.002 | 0.005 | 0 | 0.004 | 0 | 0.001 | 0.002 | 0.130 | 0.200 | 63 |
| 2017 | 0.109 | 0.002 | 0.005 | 0 | 0.004 | 0 | 0.001 | 0.002 | 0.123 | 0.190 | 60 |

#### 4.12.2.3. Other

Not occurring (NO)

## 4.13. Rice Cultivation (3.C.)

Rice is not cultivated in Georgia (NO).

## 4.14. Agricultural Soils (3.D.)

Nitrous oxide emissions from agricultural soils consist of direct and indirect sources. Direct source emissions result from nitrogen that has entered the soil from synthetic fertilizer, nitrogen from animal manure, nitrogen from crop residue decomposition and nitrogen deposited by grazing animals on fields (pasture range and paddock). Emissions from indirect sources are emitted off site through volatilization and leaching of synthetic fertilizer and manure nitrogen.

### 4.14.1. Direct Soil Emissions (3.D.a.)

$N_2O$ direct emissions from soils (kg N/year) are calculated by the following formula:

$$N_2O_{Direct} - N = N_2O - N_{N\ inputs} + N_2O - N_{OS} + N_2O - N_{PRP}$$

$$N_2O - N_{Ninput} = \begin{bmatrix} [(F_{SN+}F_{ON} + F_{CR} + F_{SOM}) \times EF_1] + \\ [(F_{SN} + F_{ON} + F_{CR} + F_{SOM})_{FR} \times EF_{1FR}] \end{bmatrix}$$

$$N_2O - N_{OS} = \begin{bmatrix} (F_{OS,CG,Temp} \times EF_{2CG,Temp}) + (F_{OS,CG,Trop} \times EF_{2CG,Trop}) + \\ (F_{OS,F,Temp,NR} \times EF_{2F,Temp,NR}) + (F_{OS,F,Temp,NP} \times EF_{2F,Temp,NP}) + \\ (F_{OS,F,Trop} \times \mathrm{EF}_{2\mathrm{F,Trop}}) \end{bmatrix}$$

$$N_2O - N_{PRP} = [(F_{PRP,CPP} \times EF_{3PRP,CPP}) + (F_{PRP,SO} \times EF_{3PRP,SO})]$$

Notes:

The subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor respectively;
The subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and other animals, respectively;
The subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and other animals, respectively;

Where:

| | |
|---|---|
| $N_2O_{Direct} - N$ | annual direct $N_2O$–N emissions produced from managed soils, kg $N_2O$–N/year |
| $N_2O–N_{N\ inputs}$ | annual direct $N_2O$–N emissions from N inputs to managed soils, kg $N_2O$–N/year |
| $N_2O–N_{OS}$ | annual direct $N_2O$–N emissions from managed organic soils, kg $N_2O$–N/year |
| $N_2O–N_{PRP}$ | annual direct $N_2O$–N emissions from urine and dung inputs to grazed soils, kg$N_2O$–N/year |
| $F_{SN}$ | annual amount of synthetic fertilizer N applied to soils, kg N/year |
| $F_{ON}$ | annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N/year |
| $F_{CR}$ | annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N/year |
| $F_{SOM}$ | annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kgN/year |
| $F_{OS}$ | annual area of managed/drained organic soils, ha |
| $F_{PRP}$ | annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N/year |
| $EF_1$ | emission factor for $N_2O$ emissions from N inputs, kg $N_2O$–N/(kg N input) |
| $EF_{1FR}$ | emission factor for $N_2O$ emissions from N inputs to flooded rice, kg $N_2O$–N/(kg N input) |

| | |
|---|---|
| *$EF_2$* | emission factor for $N_2O$ emissions from drained/managed organic soils, kg $N_2O$ – N/ha/year |
| *$EF3_{PRP}$* | emission factor for $N_2O$ emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg $N_2O$–N/(kg N input) |

#### 4.14.1.1. Inorganic N Fertilizers (3.D.a.1.)

Synthetic fertilizers add large quantities of nitrogen to agricultural soils. This added nitrogen undergoes nitrification and denitrification, and releases $N_2O$. Emission rates associated with fertilizer application will depend on many factors such as the quantity and type of nitrogen fertilizers, crop types, soil types, climate, and other environmental conditions.

**Methodology:**
Tier 1 approach is used. $N_2O$ emissions are calculated by multiplying fertilizer consumption by the non-volatilized fraction (available for nitrification and denitrification) and by an emission factor:

$$N_2O_{SN} = F_{SN} \times EF_1$$

Where:

| | |
|---|---|
| *$F_{SN}$* | annual amount of synthetic fertilizer N applied to soils, kg N/year |
| *$EF_1$* | emission factor for $N_2O$ emissions from N inputs, kg $N_2O$–N/kg N input |

According to the IPCC 2006, for the Tier 1 approach, the amount of applied mineral nitrogen fertilizer is not adjusted for the amounts of $NH_3$ and $NO_x$ volatilization after application to soil. This is different from the methodology described in the 1996 IPCC Guidelines.

**Activity data:**
Data on synthetic N fertilizers applied to soil are provided by the National Statistics Office of Georgia. Data on Synthetic N fertilizers applied to soil is presented in Table *4-74*.

**Emission factor:**
The IPCC default emission factor $EF_1$=0.0125 kg$N_2O$-N/kgN is used (IPCC GPG, p.4.60, table 4.17).

**Emissions:**
$N_2O$ emissions from synthetic N fertilizers applied to soil are presented in Table *4-74*.

Table 4-74 $N_2O$ Direct emissions from synthetic N fertilizers applied to soils in 2004-2017 years

| **Year** | **Synthetic fertilizer N applied, Gg** | **Amount of N input, Gg N** | **Emission, Gg $N_2O$** | **Emission in Gg $CO_2$-eq** | **Year** | **Synthetic fertilizer N applied, Gg** | **Amount of N input, Gg N** | **Emission, Gg $N_2O$** | **Emission in Gg $CO_2$-eq** |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 60.8 | 0.76 | 1.19 | 370 | 2004 | 47.7 | 0.60 | 0.94 | 290 |
| 1991 | 49.8 | 0.62 | 0.98 | 303 | 2005 | 46.2 | 0.58 | 0.91 | 281 |
| 1992 | 45.9 | 0.57 | 0.90 | 279 | 2006 | 67.2 | 0.84 | 1.32 | 409 |
| 1993 | 45.7 | 0.57 | 0.90 | 278 | 2007 | 46.8 | 0.59 | 0.92 | 285 |
| 1994 | 31.1 | 0.39 | 0.61 | 189 | 2008 | 51.2 | 0.64 | 1.01 | 312 |
| 1995 | 38.6 | 0.48 | 0.76 | 235 | 2009 | 57.7 | 0.72 | 1.13 | 351 |
| 1996 | 84.3 | 1.05 | 1.66 | 513 | 2010 | 50.2 | 0.63 | 0.99 | 306 |
| 1997 | 95.2 | 1.19 | 1.87 | 580 | 2011 | 43.3 | 0.54 | 0.85 | 264 |
| 1998 | 61.7 | 0.77 | 1.21 | 376 | 2012 | 49.5 | 0.62 | 0.97 | 301 |
| 1999 | 79.2 | 0.99 | 1.56 | 482 | 2013 | 64.6 | 0.81 | 1.27 | 393 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 47.5 | 0.59 | 0.93 | 289 | 2014 | 50.8 | 0.64 | 1.00 | 309 |
| 2001 | 57.3 | 0.72 | 1.13 | 349 | 2015 | 49.9 | 0.62 | 0.98 | 304 |
| 2002 | 72.8 | 0.91 | 1.43 | 443 | 2016 | 51.0 | 0.64 | 1.00 | 311 |
| 2003 | 75.8 | 0.95 | 1.49 | 462 | 2017 | 39.7 | 0.50 | 0.78 | 242 |

#### 4.14.1.2. Organic Fertilizer (3.D.a.2.)

Organic N fertilizer includes applied animal manure, sewage sludge, compost and other organic amendments applied to soils. The application of organic N fertilizers to soils can increase the rate of nitrification and denitrification and result in enhanced $N_2O$ emissions from agricultural soils. As a rule, all the manure from manure management systems is applied to agricultural soils. Manure deposited on land by grazing animals is considered separately.

**Methodology:**
Emissions are calculated by multiplying the amount of organic nitrogen applied to agricultural soils by the non-volatilized fraction by an emission factor:

$$N_2O_{ON} = F_{ON} \times EF_1$$

$$F_{ON} = F_{AM} + F_{SEW} + F_{COMP} + F_{OOA}$$

Where:

$F_{ON}$ = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, kgN/year
$EF_1$ = emission factor for $N_2O$ emissions from N inputs, kg $N_2O$–N/kg N input
$F_{AM}$ = annual amount of animal manure N applied to soils, kg N/year
$F_{SEW}$ = annual amount of total sewage N that is applied to soils, kg N/year
$F_{COMP}$ = annual amount of total compost N applied to soils, kg N/year
$F_{OOA}$ = annual amount of other organic amendments used as fertilizer (e.g., rendering waste, guano, brewery waste, etc.), kg N/year

In Georgia sewage, compost and other organic amendments practically/actually are not used as N fertilizer. Consequently, $F_{SEW}$, $F_{COMP}$ and $F_{OOA}$ are not considered.

For calculating annual amount of animal manure applied to soils the following formula is used:

$$F_{AM} = N_{MMSAvb} \times [1 - (Frac_{FEED} + Frac_{FUEL} + Frac_{CNST})]$$

Where:

$F_{AM}$ = annual amount of animal manure N applied to soils, kg N/year
$N_{MMS\,Avb}$ = amount of managed manure N available for soil application, feed, fuel or construction, kgN/year
$Frac_{FEED}$ = fraction of managed manure used for feed
$Frac_{FUEL}$ = fraction of managed manure used for fuel
$Frac_{CNST}$ = fraction of managed manure used for construction

In Georgia, only insignificant amount of manure is used as fuel, and none of it is used for feed and construction purposes.

The estimate of managed manure nitrogen available for application to managed soils is based on the following equation:

$$N_{MMS\_Avb} = \sum_{(S)} \left\{ \sum_{(T)} \left[ \left( N_{(T)} \times Nex_{(T)} \times MS_{(T,S)} \right) \times \left( 1 - \frac{Frac_{lossMS}}{100} \right) \right] \right\}$$

Where:

| | |
|---|---|
| $N_{(T)}$ | number of head of livestock species/category T in the country |
| $Nex_{(T)}$ | annual average N excretion per animal of species/category T in the country, kgN/animal/year |
| $MS_{(T,S)}$ | fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless |
| $Frac_{LossMS}$ | amount of managed manure nitrogen for livestock category T that is lost in the manure management system S, % |
| $S$ | manure management system |
| $T$ | species/category of livestock |

According to the IPCC 2006, for the Tier 1 approach, the amount of applied organic nitrogen fertilizers is not adjusted for the amounts of $NH_3$ and $NO_x$ volatilization after application to soil. This is a difference from the methodology described in the 1996 IPCC Guidelines.

Activity data: The animal population data are the same as those used for the Enteric Fermentation estimates (Table *4-54*, Table *4-66*).

**Emission factor:**
The IPCC 2006 default emission factor $EF_1$=0.0125 kg$N_2$O-N/kgN (IPCC GPG, p.4.60, table 4.17) and default values of parameter $Frac_{LossMS}$ are used [IPCC 2006, Chapter 10, p.10.67, Table 10.23]. Nitrogen Excretion rate (Nex) for animal types are presented in Table *4-69*.

**Calculated Emissions**:
Estimated nitrous oxide emissions from Organic N fertilizers applied to soil are presented in *Table 4-75*.

Table 4-75 Estimated nitrous oxide emissions (in Gg) from manure applied to soil in years 1990-2017

| Year | Dry lot | | Other systems | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle 3.B.2.1 | Swine 3.B.2.6 | Cattle 3.B.2.1 | Buffalos 3.B.2.2 | Sheep 3.B.2.3 | Goats 3.B.2.4 | Swine 3.B.2.6 | Horses | Assess | Poultry 3.B.2.7 | Total, Gg N | Total, Gg $N_2O$ | Total, Gg $CO_2$eq |
| 1990 | 0.193 | 0.018 | 0.008 | 0.001 | 0.030 | 0.0005 | 0.015 | 0.0004 | NE | 0.022 | 0.288 | 0.45 | 140 |
| 1991 | 0.18 | 0.015 | 0.008 | 0.001 | 0.027 | 0.0004 | 0.013 | 0.0003 | NE | 0.02 | 0.264 | 0.42 | 129 |
| 1992 | 0.15 | 0.01 | 0.007 | 0.001 | 0.022 | 0.0003 | 0.008 | 0.0003 | NE | 0.011 | 0.208 | 0.33 | 102 |
| 1993 | 0.139 | 0.007 | 0.006 | 0.001 | 0.018 | 0.0003 | 0.006 | 0.0004 | NE | 0.012 | 0.190 | 0.30 | 92 |
| 1994 | 0.142 | 0.007 | 0.006 | 0.0005 | 0.014 | 0.0003 | 0.006 | 0.0004 | NE | 0.012 | 0.190 | 0.30 | 93 |
| 1995 | 0.147 | 0.007 | 0.006 | 0.0005 | 0.013 | 0.0004 | 0.006 | 0.0004 | NE | 0.014 | 0.195 | 0.31 | 95 |
| 1996 | 0.153 | 0.007 | 0.007 | 0.0005 | 0.011 | 0.0004 | 0.006 | 0.0005 | NE | 0.015 | 0.199 | 0.31 | 97 |
| 1997 | 0.156 | 0.007 | 0.007 | 0.0005 | 0.010 | 0.0004 | 0.006 | 0.001 | 0.0001 | 0.016 | 0.202 | 0.32 | 99 |
| 1998 | 0.160 | 0.007 | 0.007 | 0.0005 | 0.010 | 0.0005 | 0.006 | 0.001 | 0.0001 | 0.008 | 0.201 | 0.32 | 98 |
| 1999 | 0.171 | 0.008 | 0.007 | 0.0005 | 0.011 | 0.001 | 0.007 | 0.001 | 0.0001 | 0.009 | 0.215 | 0.34 | 105 |
| 2000 | 0.180 | 0.009 | 0.008 | 0.0005 | 0.010 | 0.001 | 0.008 | 0.001 | NE | 0.008 | 0.225 | 0.35 | 109 |
| 2001 | 0.181 | 0.009 | 0.008 | 0.001 | 0.011 | 0.001 | 0.008 | 0.001 | 0.0001 | 0.009 | 0.227 | 0.36 | 111 |
| 2002 | 0.187 | 0.009 | 0.008 | 0.0005 | 0.012 | 0.001 | 0.008 | 0.001 | NE | 0.009 | 0.234 | 0.37 | 114 |
| 2003 | 0.191 | 0.010 | 0.008 | 0.001 | 0.012 | 0.001 | 0.008 | 0.001 | NE | 0.009 | 0.241 | 0.38 | 117 |
| 2004 | 0.182 | 0.010 | 0.008 | 0.001 | 0.013 | 0.001 | 0.008 | 0.001 | 0.0001 | 0.010 | 0.233 | 0.37 | 114 |
| 2005 | 0.184 | 0.009 | 0.008 | 0.0005 | 0.014 | 0.001 | 0.008 | 0.001 | 0.0001 | 0.008 | 0.233 | 0.37 | 113 |
| 2006 | 0.167 | 0.007 | 0.007 | 0.0005 | 0.013 | 0.001 | 0.006 | 0.0005 | 0.0001 | 0.005 | 0.208 | 0.33 | 101 |
| 2007 | 0.163 | 0.002 | 0.007 | 0.0004 | 0.014 | 0.001 | 0.002 | 0.0004 | 0.0001 | 0.006 | 0.195 | 0.31 | 95 |
| 2008 | 0.168 | 0.002 | 0.007 | 0.0004 | 0.013 | 0.001 | 0.001 | 0.001 | 0.0001 | 0.007 | 0.200 | 0.31 | 97 |
| 2009 | 0.160 | 0.003 | 0.007 | 0.0004 | 0.011 | 0.001 | 0.002 | 0.001 | 0.0001 | 0.007 | 0.192 | 0.30 | 93 |

| Year | Dry lot | | Other systems | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle 3.B.2.1 | Swine 3.B.2.6 | Cattle 3.B.2.1 | Buffalos 3.B.2.2 | Sheep 3.B.2.3 | Goats 3.B.2.4 | Swine 3.B.2.6 | Horses | Assess | Poultry 3.B.2.7 | Total, Gg N | Total, Gg $N_2O$ | Total, Gg $CO_2$eq |
| 2010 | 0.168 | 0.002 | 0.007 | 0.0004 | 0.011 | 0.0004 | 0.002 | 0.001 | 0.0001 | 0.007 | 0.198 | 0.31 | 97 |
| 2011 | 0.167 | 0.002 | 0.007 | 0.0004 | 0.011 | 0.0004 | 0.002 | 0.001 | 0.0001 | 0.006 | 0.197 | 0.31 | 96 |
| 2012 | 0.177 | 0.004 | 0.008 | 0.0004 | 0.013 | 0.0004 | 0.004 | 0.001 | 0.0001 | 0.006 | 0.213 | 0.33 | 104 |
| 2013 | 0.189 | 0.004 | 0.008 | 0.0004 | 0.015 | 0.0004 | 0.003 | 0.001 | 0.0001 | 0.007 | 0.228 | 0.36 | 111 |
| 2014 | 0.205 | 0.003 | 0.009 | 0.0002 | 0.017 | 0.0004 | 0.003 | 0.001 | 0.0001 | 0.007 | 0.244 | 0.38 | 119 |
| 2015 | 0.213 | 0.003 | 0.009 | 0.0003 | 0.016 | 0.0004 | 0.003 | 0.001 | 0.0004 | 0.008 | 0.254 | 0.40 | 124 |
| 2016 | 0.217 | 0.003 | 0.009 | 0.0003 | 0.017 | 0.0004 | 0.002 | 0.0004 | 0.0004 | 0.008 | 0.257 | 0.40 | 125 |
| 2017 | 0.204 | 0.003 | 0.009 | 0.0003 | 0.016 | 0.0004 | 0.003 | 0.0004 | 0.0003 | 0.008 | 0.244 | 0.38 | 119 |

### 4.14.1.3. Urine and dung deposited by grazing animals (3.D.a.3.)

Emissions from manure dropped on the soil during grazing on grasslands are reported under this subcategory. When manure is excreted on pasture and paddock from grazing animals, nitrogen in the manure undergoes transformations. During these transformation processes, $N_2O$ is produced.

**Methodology:**
The annual amount of $N_2O$ from Urine and dung from grazing animals are calculated for each animal category by multiplying the animal population by the appropriate nitrogen excretion rate and by the fraction of manure nitrogen available for conversion to $N_2O$.

Methodology is based on the following formulas:

$$N_2O - N_{PRP} = \left[\left(F_{PRP,CPP} \times EF_{3PRP,CPP}\right) + \left(F_{PRP,SO} \times EF_{3PRP,SO}\right)\right]$$

$$F_{PRP} = \sum_{T}\left[\left(N_{(T)} \times Nex_{(T)}\right) \times MS_{(T,PRP)}\right]$$

Where:

$EF_{3PRP}$ = emission factor for $N_2O$ emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg $N_2O$–N/(kg N input). The subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and other animals, respectively.

$F_{PRP}$ = annual amount of urine and dung N deposited on pasture, range and paddock by grazing animals, kgN/year

$N_{(T)}$ = number of head of livestock species/category T in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N/animal/year

$MS_{(T,PRP)}$ = fraction of total annual N excretion for each livestock species/category T that is deposited on pasture, range and paddock

$T$ = type of animal category.

**Activity data**:
The animal population data are the same as those used in the Enteric Fermentation emission estimates (Table *4-54* and Table *4-66*). The average annual nitrogen excretion rates for domestic animals are taken from the Table *4-69*. Fraction of total annual N excretion for each livestock species/category T that is deposited on pasture, range and paddock is given in Table *4-70*.

**Emission factors:**

The default value for $EF_{3PRP}$ is 0.02 of the N deposited by all animal types except sheep [IPCC 2006, Chapter 11, p.11.11, Table 11.1].

**Emissions:**
$N_2O$ emissions from urine and dung N deposited on pastures and paddocks are given in *Table 4-76*.

Table 4-76 $N_2O$ emissions from urine and dung N deposited on pastures and paddocks in 1990-2017

| Year | kg $N_2O$-N | | | | | | | | | Gg $N_2O$ in total | Gg CO2eq |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle | Buffalo | Swine | Poultry | Sheeps | Goats | Horses | Assess | Total | | |
| 1990 | 0.56 | 0.03 | 0.04 | 0.07 | 0.31 | 0.02 | 0.01 | NE | **1.04** | **1.64** | **508** |
| 1991 | 0.52 | 0.03 | 0.03 | 0.06 | 0.28 | 0.02 | 0.01 | NE | **0.96** | **1.51** | **467** |
| 1992 | 0.43 | 0.03 | 0.02 | 0.04 | 0.23 | 0.01 | 0.01 | NE | **0.77** | **1.21** | **375** |
| 1993 | 0.40 | 0.02 | 0.02 | 0.04 | 0.18 | 0.01 | 0.01 | NE | **0.69** | **1.08** | **335** |
| 1994 | 0.41 | 0.02 | 0.02 | 0.04 | 0.15 | 0.01 | 0.02 | NE | **0.66** | **1.04** | **324** |
| 1995 | 0.43 | 0.02 | 0.02 | 0.04 | 0.13 | 0.01 | 0.02 | NE | **0.67** | **1.06** | **327** |
| 1996 | 0.44 | 0.02 | 0.02 | 0.05 | 0.12 | 0.01 | 0.02 | NE | **0.68** | **1.06** | **330** |
| 1997 | 0.45 | 0.02 | 0.02 | 0.05 | 0.10 | 0.02 | 0.02 | 0.004 | **0.68** | **1.07** | **330** |
| 1998 | 0.46 | 0.02 | 0.02 | 0.03 | 0.10 | 0.02 | 0.02 | 0.005 | **0.67** | **1.05** | **327** |
| 1999 | 0.50 | 0.02 | 0.02 | 0.03 | 0.11 | 0.02 | 0.03 | 0.005 | **0.72** | **1.13** | **351** |
| 2000 | 0.52 | 0.02 | 0.02 | 0.02 | 0.11 | 0.02 | 0.03 | NE | **0.75** | **1.17** | **363** |
| 2001 | 0.52 | 0.02 | 0.02 | 0.03 | 0.11 | 0.03 | 0.03 | 0.001 | **0.76** | **1.20** | **371** |
| 2002 | 0.54 | 0.02 | 0.02 | 0.03 | 0.12 | 0.03 | 0.03 | NE | **0.79** | **1.24** | **385** |
| 2003 | 0.55 | 0.02 | 0.02 | 0.03 | 0.12 | 0.03 | 0.03 | NE | **0.81** | **1.27** | **395** |
| 2004 | 0.53 | 0.02 | 0.02 | 0.03 | 0.14 | 0.03 | 0.03 | 0.01 | **0.8** | **1.26** | **392** |
| 2005 | 0.53 | 0.02 | 0.02 | 0.02 | 0.14 | 0.03 | 0.03 | 0.01 | **0.8** | **1.26** | **390** |
| 2006 | 0.48 | 0.02 | 0.02 | 0.02 | 0.14 | 0.03 | 0.02 | 0.003 | **0.72** | **1.13** | **351** |
| 2007 | 0.47 | 0.02 | 0.01 | 0.02 | 0.14 | 0.02 | 0.02 | 0.004 | **0.7** | **1.09** | **339** |
| 2008 | 0.49 | 0.02 | 0.004 | 0.02 | 0.14 | 0.02 | 0.02 | 0.003 | **0.71** | **1.11** | **345** |
| 2009 | 0.46 | 0.02 | 0.01 | 0.02 | 0.12 | 0.02 | 0.02 | 0.003 | **0.67** | **1.05** | **326** |
| 2010 | 0.49 | 0.01 | 0.01 | 0.02 | 0.12 | 0.02 | 0.02 | 0.005 | **0.68** | **1.07** | **333** |
| 2011 | 0.48 | 0.01 | 0.005 | 0.02 | 0.11 | 0.02 | 0.02 | 0.003 | **0.67** | **1.06** | **328** |
| 2012 | 0.51 | 0.01 | 0.01 | 0.02 | 0.14 | 0.02 | 0.02 | 0.002 | **0.73** | **1.15** | **356** |
| 2013 | 0.55 | 0.02 | 0.01 | 0.02 | 0.16 | 0.02 | 0.02 | 0.003 | **0.79** | **1.24** | **385** |
| 2014 | 0.59 | 0.01 | 0.01 | 0.02 | 0.17 | 0.02 | 0.02 | 0.003 | **0.84** | **1.32** | **410** |
| 2015 | 0.62 | 0.01 | 0.01 | 0.03 | 0.17 | 0.01 | 0.03 | 0.002 | **0.87** | **1.37** | **425** |
| 2016 | 0.63 | 0.01 | 0.01 | 0.03 | 0.17 | 0.02 | 0.02 | 0.002 | **0.88** | **1.39** | **430** |
| 2017 | 0.59 | 0.01 | 0.01 | 0.03 | 0.17 | 0.01 | 0.02 | 0.001 | **0.84** | **1.32** | **408** |

#### 4.14.1.4. Crop Residues (3.D.a.4.)

After harvesting, part of agricultural crop residues is left in the field and decomposed. They represent nitrogen source. As a result of transformation nitrous oxide is formed.

**Methodology**:
Georgia uses the IPCC 2006 Tier 1 methodology for emission calculation. Annual amount of N in crop residues, $F_{CR}$, the sum of the above-and below-ground N contents, is provided by the Equation:

$$N_2O\text{-}N_{N\,inputs} = F_{CR} \times EF_1$$

$$F_{CR} = \sum_T \left\{ \begin{matrix} Crop_{(T)} \times \left(Area_{(T)} - Area\ burnt_{(T)} \times C_f\right) \times Frac_{Renew(T)} \times \\ \left[R_{AG(T)} \times N_{AG(T)} \times \left(1 - Frac_{Remove(T)}\right) + R_{BG(T)} \times N_{BG(T)}\right] \end{matrix} \right\}$$

Where:

$F_{CR}$ annual amount of nitrogen in crop residues (above and below ground), including N-fixing crops,as well as from forage/pasture renewal, returned to soils annually, kg N/year

$EF_1$ emission factor for $N_2O$ emissions from N inputs, kg $N_2O$–N /(kg N inputs)

$Crop_{(T)}$ harvested annual dry matter yield for crop T, kg d.m./ha.

$$Crop_{(T)} = Yield\ Fresh_{(T)} \times DRY$$

$Crop_{(T)}$ = Yield $Fresh_{(T)}$ ×DRY
Yield_$Fresh_{(T)}$ = harvested fresh yield for crop T, kg fresh weight/ha
DRY = dry matter fraction of harvested crop T, kg d.m./(kg fresh weight)
$Area_{(T)}$ = total annual area harvested of crop T, ha/year
$Area\ burnt_{(T)}$ = annual area of crop T burnt, ha/year
$C_f$ = combustion factor (dimensionless)
$Frac_{Renew(T)}$ = fraction of total area under crop T that is renewed annually
$R_{AG(T)}$ = ratio of above-ground residues dry matter ($A_{GDM(T)}$) to harvested yield ($Crop_{(T)}$), kgd.m./(kg d.m.)
$R_{AG(T)} = A_{GDM(T)} \times 1000 / Crop_{(T)}$;
$A_{GDM(T)} = (Crop_{(T)}/1000) \times slope_{(T)} + intercept_{(T)}$
$N_{AG(T)}$ = N content of above-ground residues for crop T, kg N/(kg d.m.)
$Frac_{Remove(T)}$ = fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction, kg N/(kg crop-N).
$R_{BG(T)}$ = ratio of below-ground residues to harvested yield for crop T, kg d.m./kg d.m.
$R_{BG(T)} = R_{BG-BIO(T)} \times [(A_{GDM(T)} \times 1000 + Crop_{(T)}) / Crop_{(T)}]$
$N_{BG(T)}$ = N content of below-ground residues for crop T, kg N/kg d.m.
$T$ = crop or forage type

**Activity data:**
Data on agriculture crop production are provided by The National Statistics Office of Georgia.

**Emission factors:**
For emission factor IPCC GDP default value is used - $EF_1$=0.0125 kg($N_2O$-N)/(kgN inputs). For annual crops $Frac_{Renew}$ = 1. Data for $Frac_{Remove}$ are not available in Georgia, therefore, $Frac_{Remove(T)}$ = 0. Other input factors used for estimation of N from crop residues added to soils are used according to the IPCC 2006 [IPCC 2006, Chapter 11, P.11.17, table 11.2, Chapter 2, p.2.49, table 2.6].

Table 4-77 Input factors used for estimation of N from crop residues added to soils

| Crop | Dry matter fraction of harvested crop DRY, kg d.m./ kg fresh weight | N content of above-ground residues NAG , kg N/kg d.m. | Ratio of belowground residues to above-ground biomass RBG-BIO , kg d.m./kg d.m. | N in below-ground residues NBG , kgN/kg d.m | Slope | Intercept | Combustion factor CF |
|---|---|---|---|---|---|---|---|
| Wheat | 0.89 | 0.006 | 0.24 | 0.009 | 1.51 | 0.52 | 0.9 |
| Barley | 0.89 | 0.007 | 0.22 | 0.014 | 0.98 | 0.59 | 0.9 |
| Maize | 0.87 | 0.006 | 0.22 | 0.007 | 1.03 | 0.61 | 0.8 |
| Oats | 0.89 | 0.007 | 0.25 | 0.008 | 0.91 | 0.89 | 0.8 |
| Potatoes | 0.22 | 0.019 | 0.20 | 0.014 | 0.10 | 1.06 | 0.8 |
| Dry Beans | 0.9 | 0.01 | 0.19 | 0.01 | 1.36 | 0.68 | 0.8 |

**Emissions:** $N_2O$ emissions from crop residue decomposition are given in Table *4-78*.

Table 4-78 $N_2O$ emissions from crop residue decomposition

| Year | GHG emission | | Year | GHG emission | |
|---|---|---|---|---|---|
| | Gg $N_2O$ | in Gg $CO_2$-eq | | Gg $N_2O$ | in Gg $CO_2$-eq |
| 1990 | 0.20 | 62 | 2004 | 0.16 | 50 |
| 1991 | 0.17 | 52 | 2005 | 0.21 | 65 |

| Year | GHG emission | | Year | GHG emission | |
|---|---|---|---|---|---|
| | Gg $N_2O$ | in Gg $CO_2$-eq | | Gg $N_2O$ | in Gg $CO_2$-eq |
| 1992 | 0.14 | 45 | 2006 | 0.08 | 25 |
| 1993 | 0.11 | 35 | 2007 | 0.10 | 30 |
| 1994 | 0.13 | 40 | 2008 | 0.10 | 31 |
| 1995 | 0.12 | 36 | 2009 | 0.09 | 27 |
| 1996 | 0.14 | 45 | 2010 | 0.07 | 22 |
| 1997 | 0.21 | 66 | 2011 | 0.11 | 34 |
| 1998 | 0.16 | 49 | 2012 | 0.11 | 33 |
| 1999 | 0.19 | 58 | 2013 | 0.13 | 41 |
| 2000 | 0.13 | 41 | 2014 | 0.11 | 35 |
| 2001 | 0.17 | 54 | 2015 | 0.12 | 38 |
| 2002 | 0.17 | 51 | 2016 | 0.12 | 36 |
| 2003 | 0.18 | 57 | 2017 | 0.09 | 27 |

Table 4-79 Direct $N_2O$ emissions from soils

| Year | Source | | | | Total | |
|---|---|---|---|---|---|---|
| | Synthetic N fertilizers | Organic N fertilizers | Urine and dung deposition | Crop residues decomposition | Gg$N_2O$ | Gg$CO_2$eq |
| 1990 | 1.19 | 0.45 | 1.64 | 0.20 | 3.49 | 1,080 |
| 1991 | 0.98 | 0.42 | 1.51 | 0.17 | 3.07 | 951 |
| 1992 | 0.90 | 0.33 | 1.21 | 0.14 | 2.58 | 801 |
| 1993 | 0.90 | 0.30 | 1.08 | 0.11 | 2.39 | 740 |
| 1994 | 0.61 | 0.30 | 1.04 | 0.13 | 2.08 | 645 |
| 1995 | 0.76 | 0.31 | 1.06 | 0.12 | 2.24 | 694 |
| 1996 | 1.66 | 0.31 | 1.06 | 0.14 | 3.18 | 985 |
| 1997 | 1.87 | 0.32 | 1.07 | 0.21 | 3.47 | 1,075 |
| 1998 | 1.21 | 0.32 | 1.05 | 0.16 | 2.74 | 850 |
| 1999 | 1.56 | 0.34 | 1.13 | 0.19 | 3.21 | 997 |
| 2000 | 0.93 | 0.35 | 1.17 | 0.13 | 2.59 | 803 |
| 2001 | 1.13 | 0.36 | 1.20 | 0.17 | 2.85 | 884 |
| 2002 | 1.43 | 0.37 | 1.24 | 0.17 | 3.21 | 994 |
| 2003 | 1.49 | 0.38 | 1.27 | 0.18 | 3.33 | 1,031 |
| 2004 | 0.94 | 0.37 | 1.26 | 0.16 | 2.73 | 846 |
| 2005 | 0.91 | 0.37 | 1.26 | 0.21 | 2.74 | 849 |
| 2006 | 1.32 | 0.33 | 1.13 | 0.08 | 2.86 | 887 |
| 2007 | 0.92 | 0.31 | 1.09 | 0.10 | 2.42 | 749 |
| 2008 | 1.01 | 0.31 | 1.11 | 0.10 | 2.54 | 786 |
| 2009 | 1.13 | 0.30 | 1.05 | 0.09 | 2.57 | 798 |
| 2010 | 0.99 | 0.31 | 1.07 | 0.07 | 2.44 | 757 |
| 2011 | 0.85 | 0.31 | 1.06 | 0.11 | 2.33 | 722 |
| 2012 | 0.97 | 0.33 | 1.15 | 0.11 | 2.56 | 794 |
| 2013 | 1.27 | 0.36 | 1.24 | 0.13 | 3.00 | 931 |
| 2014 | 1.00 | 0.38 | 1.32 | 0.11 | 2.82 | 874 |
| 2015 | 0.98 | 0.40 | 1.37 | 0.12 | 2.87 | 891 |
| 2016 | 1.00 | 0.40 | 1.39 | 0.12 | 2.91 | 902 |
| 2017 | 0.78 | 0.38 | 1.32 | 0.09 | 2.57 | 796 |

### 4.14.2. Indirect Emissions (3.D.b.)

A fraction of the fertilizer nitrogen (from synthetic and organic N fertilizers and urine and dung deposition from grazing animals) that is applied to agricultural fields will be removed off-site either through volatilization and subsequent re-deposition or leaching, erosion and runoff. The nitrogen that is transported from the agricultural field in this manner will provide additional nitrogen for subsequent nitrification and denitrification to produce $N_2O$. The nitrogen leaving an agricultural field may not be available for the process of nitrification and denitrification for many years, particularly in the case of nitrogen leaching into groundwater.

#### 4.14.2.1. Atmospheric Deposition (3.D.b.1.)

**Methodology**:
IPCC 2006 Tier 1 methodology is used to estimate indirect $N_2O$ emissions due to volatilization and re-deposition of nitrogen from applied to soil N.

The $N_2O$ emissions from atmospheric deposition of N volatilized from managed soil are estimated using the following Equation:

$$N_2O_{(ATD)} - N = \left[(F_{SN} \times Frac_{GASF}) + \left((F_{ON+}F_{PRP}) \times Frac_{GASM}\right)\right] \times EF_4$$

Where:

| | |
|---|---|
| $N_2O_{(ATD)}$ | annual amount of $N_2O$–N produced from atmospheric deposition of N volatilized from managed soils, kg $N_2O$–N/year |
| $F_{SN}$ | annual amount of synthetic fertilizer N applied to soils, kg N/year |
| $Frac_{GASF}$ | fraction of synthetic fertilizer N that volatilizes as $NH_3$ and $NO_x$, kg N volatilized/(kg N applied) |
| $F_{ON}$ | annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N/year |
| $F_{PRP}$ | annual amount of urine and dung N deposited by grazing animals on pasture range and paddock, kgN/year |
| $Frac_{GASM}$ | fraction of applied organic N fertilizer materials ($F_{ON}$) and of urine and dung N Deposited by grazing animals ($F_{PRP}$) that volatilizes as $NH_3$ and $NO_x$, (kg N volatilized)/(kg of N applied or deposited) |
| $N_2O_{(ATD)}$ | $N_2O_{(ATD)}$–N × 44/28 |

**Activity data:**
The data on amount of N fertilizers is obtained from the State Statistics Office of Georgia.

**Emission factors:**
The IPCC 2006 default emission factor is applied to derive the $N_2O$ emission estimate, $EF_4$ =0.01 kg($N_2O$-N)/kgN [IPCC 2006, Chapter 11, p. 11.24, table 11.3).

$Frac_{GASF}$ = 0.10 (kg N volatilized)/(kg N applied) and $Frac_{GASM}$ = 0.2 (kg NH3–N + NOx–N)/(kg N applied) [IPCC 2006, Chapter 11, p. 11.24, table 11.3).

**Emissions:**
Estimated GHG emissions are presented in *Table 4-80*

Table 4-80 Estimated $N_2O$ emissions from volatilization and re-deposition in 1990–2017

| Year | $F_{SN}$ | $Frac_{GASF}$ | $F_{ON}$ | $F_{PRP}$ | $Frac_{GASM}$ | $EF_4$ | $N_2O_{(ATD)}$–N | Gg $N_2O$ | Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 61 | 0.1 | 23 | 52 | 0.2 | 0.1 | 0.211 | **0.332** | **103** |
| 1991 | 50 | 0.1 | 21 | 48 | 0.2 | 0.1 | 0.188 | **0.295** | **92** |
| 1992 | 46 | 0.1 | 17 | 38 | 0.2 | 0.1 | 0.156 | **0.245** | **76** |
| 1993 | 46 | 0.1 | 15 | 34 | 0.2 | 0.1 | 0.145 | **0.228** | **71** |
| 1994 | 31 | 0.1 | 15 | 33 | 0.2 | 0.1 | 0.128 | **0.201** | **62** |
| 1995 | 39 | 0.1 | 16 | 34 | 0.2 | 0.1 | 0.137 | **0.215** | **67** |
| 1996 | 84 | 0.1 | 16 | 34 | 0.2 | 0.1 | 0.184 | **0.289** | **90** |
| 1997 | 95 | 0.1 | 16 | 34 | 0.2 | 0.1 | 0.195 | **0.307** | **95** |
| 1998 | 62 | 0.1 | 16 | 34 | 0.2 | 0.1 | 0.161 | **0.253** | **78** |
| 1999 | 79 | 0.1 | 17 | 36 | 0.2 | 0.1 | 0.186 | **0.292** | **90** |
| 2000 | 48 | 0.1 | 18 | 37 | 0.2 | 0.1 | 0.158 | **0.248** | **77** |
| 2001 | 57 | 0.1 | 18 | 38 | 0.2 | 0.1 | 0.170 | **0.267** | **83** |

| Year | $F_{SN}$ | $Frac_{GASF}$ | $F_{ON}$ | $F_{PRP}$ | $Frac_{GASM}$ | $EF_4$ | $N_2O_{(ATD)}$−N | Gg $N_2O$ | Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|
| 2002 | 73 | 0.1 | 19 | 39 | 0.2 | 0.1 | 0.189 | **0.297** | **92** |
| 2003 | 76 | 0.1 | 19 | 41 | 0.2 | 0.1 | 0.195 | **0.307** | **95** |
| 2004 | 48 | 0.1 | 19 | 40 | 0.2 | 0.1 | 0.165 | **0.260** | **81** |
| 2005 | 46 | 0.1 | 19 | 40 | 0.2 | 0.1 | 0.163 | **0.257** | **80** |
| 2006 | 67 | 0.1 | 17 | 36 | 0.2 | 0.1 | 0.173 | **0.271** | **84** |
| 2007 | 47 | 0.1 | 16 | 35 | 0.2 | 0.1 | 0.148 | **0.232** | **72** |
| 2008 | 51 | 0.1 | 16 | 35 | 0.2 | 0.1 | 0.154 | **0.242** | **75** |
| 2009 | 58 | 0.1 | 15 | 33 | 0.2 | 0.1 | 0.155 | **0.244** | **76** |
| 2010 | 50 | 0.1 | 16 | 34 | 0.2 | 0.1 | 0.150 | **0.236** | **73** |
| 2011 | 43 | 0.1 | 16 | 34 | 0.2 | 0.1 | 0.142 | **0.223** | **69** |
| 2012 | 50 | 0.1 | 17 | 37 | 0.2 | 0.1 | 0.157 | **0.246** | **76** |
| 2013 | 65 | 0.1 | 18 | 40 | 0.2 | 0.1 | 0.180 | **0.283** | **88** |
| 2014 | 51 | 0.1 | 20 | 42 | 0.2 | 0.1 | 0.174 | **0.273** | **85** |
| 2015 | 50 | 0.1 | 20 | 44 | 0.2 | 0.1 | 0.178 | **0.279** | **87** |
| 2016 | 51 | 0.1 | 21 | 44 | 0.2 | 0.1 | 0.180 | **0.284** | **88** |
| 2017 | 40 | 0.1 | 20 | 42 | 0.2 | 0.1 | 0.163 | **0.255** | **79** |

#### 4.14.2.2. Nitrogen Leaching and Run-off (3.D.b.2.)

When synthetic fertilizer or manure nitrogen is applied to cropland, a portion of this nitrogen is lost through leaching, runoff, and erosion. The quantity of this nitrogen loss depends on a number of factors, such as rates, methods and time of nitrogen application, crop type, soil texture, rainfall, landscape, etc. This portion of lost nitrogen can further undergo transformations, such as nitrification and denitrification, thus producing $N_2O$ emissions off site.

**Methodology**:

The IPCC 2006 Tier 1 methodology estimates for $N_2O$ emissions from runoff and leaching of nitrogen is used. The $N_2O$ emissions from leaching and runoff are estimated using the following Equation:

$$N_2O_L - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$$

Where:

- $N_2O_{(L)}-N$ annual amount of $N_2O$–N produced from leaching and runoff of N additions to managed soils, kg $N_2O$–N/year
- $F_{SN}$ annual amount of synthetic fertilizer N applied to soils, kgN/ year
- $F_{ON}$ annual amount of managed animal manure, compost, sewage sludge and other organic N applied to soils, kg N/year
- $F_{PRP}$ annual amount of urine and dung N deposited by grazing animals, kg N/year
- $F_{CR}$ amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N/year
- $F_{SOM}$ annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kgN/year. In Georgia $N_2O$ emissions from this source category are occurring only on a very small scale
- $Frac_{LEACH-(H)}$ fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N/(kg of N additions)
- $EF_5$ emission factor for $N_2O$ emissions from N leaching and runoff, kg N N O–N (kg N leached and runoff)

**Activity data:**

Data on nitrogen applied are the same as used in Direct $N_2O$ emissions from managed soil.

**Emission factor:**

Fraction of all N added to soils that is lost through leaching and runoff, kg N/(kg of N additions), $Frac_{LEACH-(H)}$ = 0.30 is used [IPCC 2006, Chapter 11, p.11.24, Table 11.3]. IPCC 1996 recommends default value for emission factor - $EF_5$ = 0.025 kg $N_2O$-N/(kg N leaching and runoff).. The latter one is more appropriate for conditions of Georgia.

**Emissions:**

$N_2O$ emissions from Leaching and Runoff of N during 1990-2017 years period are provided in *Table 4-81*.

Table 4-81 $N_2O$ emissions from leaching and runoff in 1990-2017 years

| Year | $F_{SN}$ | $F_{ON}$ | $F_{PRP}$ | $F_{CR}$ | $Frac_{LEACH-(H)ASM}$ | $EF_5$ | $N_2O_{(ATD)}$–N | Gg $N_2O$ | Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 61 | 23 | 52 | 10 | 0.3 | 0.025 | 1.10 | **1.72** | **534** |
| 1991 | 50 | 21 | 48 | 9 | 0.3 | 0.025 | 0.96 | **1.50** | **466** |
| 1992 | 46 | 17 | 38 | 7 | 0.3 | 0.025 | 0.81 | **1.28** | **396** |
| 1993 | 46 | 15 | 34 | 6 | 0.3 | 0.025 | 0.76 | **1.19** | **369** |
| 1994 | 31 | 15 | 33 | 6 | 0.3 | 0.025 | 0.65 | **1.01** | **314** |
| 1995 | 39 | 16 | 34 | 6 | 0.3 | 0.025 | 0.70 | **1.11** | **343** |
| 1996 | 84 | 16 | 34 | 7 | 0.3 | 0.025 | 1.06 | **1.67** | **517** |
| 1997 | 95 | 16 | 34 | 11 | 0.3 | 0.025 | 1.17 | **1.84** | **571** |
| 1998 | 62 | 16 | 34 | 8 | 0.3 | 0.025 | 0.90 | **1.41** | **436** |
| 1999 | 79 | 17 | 36 | 10 | 0.3 | 0.025 | 1.07 | **1.67** | **519** |
| 2000 | 48 | 18 | 37 | 7 | 0.3 | 0.025 | 0.82 | **1.29** | **400** |
| 2001 | 57 | 18 | 38 | 9 | 0.3 | 0.025 | 0.92 | **1.44** | **447** |
| 2002 | 73 | 19 | 39 | 8 | 0.3 | 0.025 | 1.05 | **1.64** | **510** |
| 2003 | 76 | 19 | 41 | 9 | 0.3 | 0.025 | 1.09 | **1.71** | **530** |
| 2004 | 48 | 19 | 40 | 8 | 0.3 | 0.025 | 0.86 | **1.35** | **420** |
| 2005 | 46 | 19 | 40 | 11 | 0.3 | 0.025 | 0.87 | **1.36** | **422** |
| 2006 | 67 | 17 | 36 | 4 | 0.3 | 0.025 | 0.93 | **1.46** | **453** |
| 2007 | 47 | 16 | 35 | 5 | 0.3 | 0.025 | 0.77 | **1.2** | **373** |
| 2008 | 51 | 16 | 35 | 5 | 0.3 | 0.025 | 0.81 | **1.27** | **394** |
| 2009 | 58 | 15 | 33 | 4 | 0.3 | 0.025 | 0.83 | **1.31** | **405** |
| 2010 | 50 | 16 | 34 | 4 | 0.3 | 0.025 | 0.78 | **1.22** | **379** |
| 2011 | 43 | 16 | 34 | 6 | 0.3 | 0.025 | 0.74 | **1.16** | **359** |
| 2012 | 50 | 17 | 37 | 5 | 0.3 | 0.025 | 0.81 | **1.28** | **396** |
| 2013 | 65 | 18 | 40 | 7 | 0.3 | 0.025 | 0.97 | **1.52** | **472** |
| 2014 | 51 | 20 | 42 | 6 | 0.3 | 0.025 | 0.89 | **1.39** | **432** |
| 2015 | 50 | 20 | 44 | 6 | 0.3 | 0.025 | 0.90 | **1.42** | **439** |
| 2016 | 51 | 21 | 44 | 6 | 0.3 | 0.025 | 0.91 | **1.43** | **444** |
| 2017 | 40 | 20 | 42 | 4 | 0.3 | 0.025 | 0.79 | **1.24** | **386** |

## 4.15. Prescribed Burning of Savannas (clearance of land by prescribed burning) (3.E.)

Land clearance by prescribed burning is not practiced in Georgia (NO).

## 4.16. Field Burning of Agricultural Residues (3.F.)

Burning of agricultural residues (crop residues is not thought to be a net source of carbon dioxide because the carbon released to the atmosphere during burning is reabsorbed during the next growing season). Calculations are carried out applying 1996 IPCC methodology.

Crop residue burning is a net source of $CH_4$ and $N_2O$. $CH_4$ and $N_2O$ emissions from field burning of agriculture residues are not key sources for Georgia. In 1990-2017 share of methane emissions from this source in sectoral emissions was within 0.3–0.6% and share of Nitrous oxide emissions was within 0.1–0.3%. Carbon monoxide and nitrogen oxides are also emitted during field burning of crop residues.

$$\text{Total carbon released (tonnes of carbon)} = \sum_{all\ crop\ types} \text{annual production (tonnes of biomass per year)} \times \text{the ratio of residue to crop product (fraction)} \times \text{the average dry matter fraction of residue} \left(\frac{\text{tonnes of dry matter}}{\text{tonnes of biomass}}\right) \times \text{the fraction actually burned in the field} \times \text{the fraction oxidized} \times \text{the carbon fraction} \left(\frac{\text{tonnes of carbon}}{\text{tonnes of dry matter}}\right)$$

Trace gas emissions from burning is summarized as follows:

$CH_4$ Emissions = Carbon Released × (emission ratio) x 16/12

CO Emissions = Carbon Released × (emission ratio) x 28/12

$N_2O$ Emissions = Carbon Released × (N/C ratio) x (emission ratio) x 44/28

$NO_x$ Emissions = Carbon Released × (N/C ratio) x (emission ratio) x 46/14

There is no statistics about area burnt available in Georgia. According to the IPCC 1996 default value 0.25 was used (IPCC 1996, Reference manual, Agriculture, table 4.19)

IPCC 1996 default values are used for Dry Matter Fraction, Carbon Fraction, Nitrogen-Carbon Ratio and emission ratios (IPCC 1996, Reference manual, Agriculture, tables 4.16 and 4.17).

**Emissions:**
Methane and nitrous oxide emissions and carbon monoxide and nitrogen oxides emissions are presented in *Table 4-82* and *Table 4-83*.

Table 4-82 GHG Emissions from field burning of crop residues

| Year | Gg $CH_4$ | Gg $N_2O$ | in Gg $CO_2$-eq | Year | Gg $CH_4$ | Gg $N_2O$ | in Gg $CO_2$-eq |
|---|---|---|---|---|---|---|---|
| 1990 | 0.51 | 0.09 | 15 | 2004 | 0.51 | 0.08 | 15 |
| 1991 | 0.44 | 0.07 | 13 | 2005 | 0.53 | 0.09 | 16 |
| 1992 | 0.39 | 0.06 | 11 | 2006 | 0.24 | 0.04 | 7 |
| 1993 | 0.32 | 0.05 | 9 | 2007 | 0.31 | 0.05 | 9 |
| 1994 | 0.38 | 0.06 | 11 | 2008 | 0.33 | 0.06 | 10 |
| 1995 | 0.38 | 0.06 | 11 | 2009 | 0.27 | 0.04 | 8 |
| 1996 | 0.46 | 0.08 | 14 | 2010 | 0.18 | 0.03 | 5 |
| 1997 | 0.64 | 0.11 | 19 | 2011 | 0.30 | 0.05 | 9 |
| 1998 | 0.44 | 0.07 | 13 | 2012 | 0.28 | 0.05 | 8 |
| 1999 | 0.57 | 0.09 | 17 | 2013 | 0.35 | 0.06 | 11 |
| 2000 | 0.31 | 0.05 | 9 | 2014 | 0.26 | 0.04 | 8 |
| 2001 | 0.56 | 0.09 | 16 | 2015 | 0.27 | 0.05 | 8 |
| 2002 | 0.50 | 0.08 | 15 | 2016 | 0.32 | 0.05 | 9 |
| 2003 | 0.56 | 0.09 | 7 | 2017 | 0.23 | 0.04 | 7 |

Table 4-83 NOx and CO Emissions from field burning of crop residues

| Year | Gg CO | Gg NOx | Year | Gg CO | Gg NOx |
|---|---|---|---|---|---|
| 1990 | 10.7 | 0.5 | 2004 | 10.6 | 0.5 |
| 1991 | 9.2 | 0.4 | 2005 | 11.1 | 0.5 |
| 1992 | 8.1 | 0.4 | 2006 | 5.1 | 0.2 |
| 1993 | 6.6 | 0.3 | 2007 | 6.4 | 0.3 |
| 1994 | 8.0 | 0.4 | 2008 | 6.9 | 0.3 |
| 1995 | 7.9 | 0.4 | 2009 | 5.6 | 0.3 |
| 1996 | 9.6 | 0.5 | 2010 | 3.7 | 0.2 |
| 1997 | 13.5 | 0.6 | 2011 | 6.3 | 0.3 |
| 1998 | 9.2 | 0.5 | 2012 | 5.8 | 0.3 |
| 1999 | 11.9 | 0.6 | 2013 | 7.3 | 0.4 |

| Year | Gg CO | Gg NOx |
|---|---|---|
| 2000 | 6.6 | 0.3 |
| 2001 | 11.7 | 0.5 |
| 2002 | 10.5 | 0.5 |
| 2003 | 11.7 | 0.6 |

| Year | Gg CO | Gg NOx |
|---|---|---|
| 2014 | 5.5 | 0.3 |
| 2015 | 5.7 | 0.3 |
| 2016 | 6.7 | 0.3 |
| 2017 | 4.8 | 0.2 |

# Chapter 5. Land use, land-use change and forestry (CRF Sector 4)

## 5.1. Overview of the Sector

The greenhouse gas inventory in the sector has been prepared in accordance with the new 2006 IPCC Guidelines. The old (1990-2015) and the new (2016-17) emissions / absorption estimates have also been updated.

The greenhouse inventory (GHGI) for the LULUCF sector covers the following source/sink categories: 1) Forest land (5A); 2) Cropland (5B); 3) Grassland (5C); 4) Wetlands (5D); 5) Settlements (5E) and 6) Other land (5F). In this GHGI, emissions and absorptions have been estimated for three source/sink categories: forest land, cropland, and grassland. The above mentioned categories are the key source-categories in Georgia; in addition there is sufficient data available (e.g. databases) for carrying out calculations in these categories (unlike other source/sink categories); this allows to obtain the annual parameters for greenhouse gases emissions and absorptions in order to determine the trend of annual changes.

The calculations of emissions and absorptions in the LULUCF sector have been carried out using default values of Emission Factors (Tier I approach), which correspond to the climatic conditions of Georgia according to the methodological explanations of IPCC guidelines. Carbon dioxide emissions and absorptions for each source/sink category, as well as the total sum values for 1990-2017 years period are provided in Table 6-4. Figure –6-1 presents the trend of calculated total emissions and absorptions for the entire LULUCF sector as well as specifically for the forest land category, respectively. The methodology of calculations, Activity Data and Emission Factors are described in detail further in the respective chapters. The methodological tiers used in the LULUCF sector are as shown in the Table 6-1 below.

Table 5-1 The methodological tiers used in the LULUCF sector

| GHG Source and Sink Categories | $CO_2$ | | $CH_4$ | | $N_2O$ | | NOx | | CO | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| 5.A Forest land | D,T1 | D, PS | D,T1 | D | D,T1 | D | D,T1 | D | D,T1 | D |
| 5.B Cropland | D,T1 | D,PS | NE | NE | NE | NE | NE | NE | NE | NE |
| 5.C Grassland | D,T1 | D,PS | NE | NE | NE | NE | NE | NE | NE | NE |
| 5.D Wetlands | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| 5.E Settlements | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| 5.F Other land | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |

D: IPCC default, T1-T3: IPCC Tier 1-3, PS: plant specific.

## 5.2. Land-use definitions, the classification systems used and their correspondence to the land use, land-use change and forestry categories

Greenhouse gas inventories in the source categories were carried out taking into account the land use classifications specified in the IPCC Guidelines - *Table 5-2****2***.

Table 5-2 Land-use definitions and the classification

| Land-use definitions | Land-use classification |
|---|---|
| **Forest Land** | This category includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently fall below but could potentially reach the threshold values used by the country to define the Forest Land category. |
| **Cropland** | This category includes cropped land, including rice fields, and agroforestry systems where the vegetation structure falls below the threshold used for the Forest Land category. |
| **Grassland** | This category includes rangelands and pastureland that are not considered cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pasture systems, consistent with national definitions. |
| **Wetlands** | This category includes areas of peat extraction and land that is covered or saturated by water the whole or part of the year (e.g., peatlands) and does not fall under the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions. |
| **Settlements** | This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included in any of other categories. This should be consistent with national definitions. |
| **Other Land** | This category includes bare soil, rock, ice, and all land areas that do not fall under any of the other five categories. It allows the total of identified land areas to match the national area, where data is available. If data is available, countries are encouraged to classify unmanaged lands by the above land-use categories (e.g., into Unmanaged Forest Land, Unmanaged Grassland, and Unmanaged Wetlands). This will improve transparency and enhance the ability to track land-use conversions from specific types of unmanaged lands into the categories above. |

## 5.3. Approaches for estimating land areas and land-use database used for the inventory preparation

Indicators of changes in land and land use are mainly based on data from the National Statistics Office and FAOSATA. Data from the Ministry of Environment and Agriculture of Georgia and the Ajara Forestry Agency are used as well.

### 5.3.1. Survey methods of major land area statistics

Presently, statistics on land categories are difficult to obtain, given that the most recent property survey was conducted in Georgia in 2003. Forest registration has also been suspended for years. All this makes it difficult to obtain reliable data.

### 5.3.2. Land area estimation methods

As we have already mentioned, the greenhouse gas inventory report contains six source/sink categories (land use categories), for which GHG emissions and absorptions are determined separately, per each change in land use categories, that are calculated by the following formula:

$$\Delta C_{AFOLU} = \Delta C_{FL} + \Delta C_{CL} + \Delta C_{GL} + \Delta C_{WL} + \Delta C_{SL} + \Delta C_{OL}$$

Where:

$\Delta C_{AFOLU}$ = carbon stock change
Indices denote the following land-use categories:
FL = Forest land
CL = Cropland

GL = Grassland
WL = Wetlands
SL = Settlements
OL = Other land

The methodology of greenhouse gas inventory is based on the so-called Good Practice Guidance principles that implies carrying out calculations according to tiers. In particular, there are the following tiers: Tier 1 approach is feasible even when country-specific Activity Data and emission/absorption factors are not available, and works when changes of the carbon pool in biomass on *Forest Land Remaining Forest Land* are relatively small. The method requires the biomass carbon loss to be subtracted from the biomass carbon gain. The annual change in carbon stocks in biomass can be estimated using the gain-loss method; Tier 2 approach can be used in countries where country-specific Activity Data and emission/absorption factors are available or can be gathered at reasonable cost. The Tier 3 approach for biomass carbon stock change estimation allows for a variety of methods, including process- based models. Implementation may differ from one country to another, due to differences in inventory methods, forest conditions and Activity Data.

The selection of the tier methodology acceptable for calculations depends on availability of the necessary data. While selecting the appropriate tier for improving the process of inventory development, attention must be paid to those source/sink categories (land use categories) of emissions/absorptions, where changes in carbon stock are significant in comparison with others, so that they may be considered as a key source category.

### 5.3.3. Land-use transition matrix

According to IPCC requirements, the existence of annual Activity Data on land use and land-use changes is important and essential for the inventory in this sector.

Proceeding from these requirements, *Table 5-3* was compiled based mainly on data from the National Statistics Office and the Ministry of Environmental Protection and Agriculture, indicating the respective areas of land use categories determined by IPCC guidelines and changes occurred in them in years 1990-2017. To obtain certain data, taking into account the unavailability of information from the above-mentioned institutions, the FAOSTAT database has also been used.

During the inventory development process, changes in the land use category were noted in various directions. There is a trend of decline in forest lands and croplands. Cropland has been significantly reduced; namely in 2017 the total area (including areas covered by perennials) decreased by 21% compared to 1990.

Generally, it can be said that changes in land use areas are minimal. It is noteworthy that the small change in the total forest area of Georgia is due to the fact that no clear cut is carried out there and the tendency to transfer forest lands to other land use categories is insignificant.

Table 5-3 Distribution of the Territory of Georgia According to Various Land Use Categories (following IPCC classification), (including Abkhazia and South Ossetia), thousand ha

| Year | Land use subcategories | | | | | | Total area of Georgia (Including territorial waters) |
|---|---|---|---|---|---|---|---|
| | 5A. | 5B. | 5C. | 5D. | 5E. | 5F. | |
| | Forest land | Cropland | Grassland | Wetlands | Settlements | Other land | |
| 1990 | 2752.3 | 1147.9 | 1956.5 | 835.1 | 211.2 | 725.4 | 7628.4 |
| 1991 | 2752.3 | 1143.4 | 1961.5 | 835.1 | 211.2 | 724.9 | 7628.4 |
| 1992 | 2752.3 | 1125.3 | 1966.6 | 835.1 | 211.2 | 737.9 | 7628.4 |

| Year | Land use subcategories | | | | | | Total area of Georgia (Including territorial waters) |
|---|---|---|---|---|---|---|---|
| | 5A. | 5B. | 5C. | 5D. | 5E. | 5F. | |
| | Forest land | Cropland | Grassland | Wetlands | Settlements | Other land | |
| 1993 | 2752.3 | 1124.3 | 1971.6 | 835.1 | 211.2 | 733.9 | 7628.4 |
| 1994 | 2752.3 | 1123.3 | 1976.5 | 835.1 | 211.2 | 730.0 | 7628.4 |
| 1995 | 2752.3 | 1099.6 | 1978.1 | 835.1 | 211.2 | 752.1 | 7628.4 |
| 1996 | 2752.3 | 1078.9 | 1979.7 | 835.1 | 211.2 | 771.2 | 7628.4 |
| 1997 | 2752.3 | 1073.2 | 1981.3 | 835.1 | 211.2 | 775.3 | 7628.4 |
| 1998 | 2773.4 | 1049.1 | 1982.9 | 835.1 | 211.2 | 776.7 | 7628.4 |
| 1999 | 2773.4 | 1025.0 | 1984.5 | 835.1 | 211.2 | 799.2 | 7628.4 |
| 2000 | 2773.4 | 1001.0 | 1986.5 | 835.1 | 211.2 | 821.2 | 7628.4 |
| 2001 | 2773.4 | 977.4 | 1988.1 | 835.1 | 211.2 | 843.2 | 7628.4 |
| 2002 | 2773.4 | 953.8 | 1989.7 | 835.1 | 211.2 | 865.2 | 7628.4 |
| 2003 | 2773.4 | 930.2 | 1991.3 | 835.1 | 211.2 | 887.2 | 7628.4 |
| 2004 | 2773.4 | 906.4 | 1992.9 | 835.1 | 211.2 | 909.4 | 7628.4 |
| 2005 | 2772.4 | 918.1 | 1994.5 | 835.1 | 211.2 | 897.1 | 7628.4 |
| 2006 | 2772.4 | 924.1 | 1996.5 | 835.1 | 211.2 | 889.1 | 7628.4 |
| 2007 | 2772.4 | 922.1 | 1996.5 | 835.1 | 211.2 | 891.1 | 7628.4 |
| 2008 | 2772.4 | 923.1 | 1996.5 | 835.1 | 211.2 | 890.1 | 7628.4 |
| 2009 | 2772.4 | 933.1 | 1996.5 | 835.1 | 211.2 | 880.1 | 7628.4 |
| 2010 | 2733.8 | 933.1 | 1996.5 | 835.1 | 211.2 | 918.7 | 7628.4 |
| 2011 | 2733.8 | 933.1 | 1996.5 | 835.1 | 211.2 | 918.7 | 7628.4 |
| 2012 | 2732.8 | 933.1 | 1996.5 | 835.1 | 211.2 | 919.7 | 7628.4 |
| 2013 | 2732.8 | 938.1 | 1996.5 | 835.1 | 211.2 | 914.7 | 7628.4 |
| 2014 | 2733.9 | 918.1 | 1996.5 | 835.1 | 211.2 | 933.6 | 7628.4 |
| 2015 | 2746.5 | 918.1 | 1996.5 | 835.1 | 211.2 | 921.0 | 7628.4 |
| 2016 | 2746.5 | 918.1 | 1996.5 | 835.1 | 211.2 | 921.0 | 7628.4 |
| 2017 | 2747.1 | 928.9 | 1996.5 | 835.1 | 211.2 | 909.6 | 7628.4 |

## 5.4. Parameters for estimating carbon stock changes from land use conversions

Table 5-4 Carbon Stock Changes and Net $CO_2$ Emissions and Absorptions in the LULUCF Sector

| Year | Forest lands | | Croplands | | | | Grasslands | | Net emission/absorption | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Perennial crops | | Arable lands | | | | | |
| | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ |
| 1990 | 1697.5 | -6224.2 | 748.9 | -2746.0 | 77.4 | -283.9 | -791.2 | 2901.0 | 1732.7 | -6353.1 |
| 1991 | 1697.7 | -6224.8 | 730.0 | -2676.5 | 114.5 | -419.9 | -792.5 | 2905.8 | 1749.6 | -6415.4 |
| 1992 | 1704.1 | -6248.4 | 663.4 | -2432.4 | 148.0 | -542.6 | -793.9 | 2911.0 | 1721.6 | -6312.5 |
| 1993 | 1701.0 | -6237.0 | 697.2 | -2556.4 | 181.5 | -665.4 | -793.8 | 2910.5 | 1785.9 | -6548.2 |
| 1994 | 1692.0 | -6204.0 | 695.1 | -2548.7 | 214.9 | -788.1 | -795.1 | 2915.3 | 1806.9 | -6625.5 |
| 1995 | 1711.6 | -6276.0 | 592.2 | -2171.4 | 201.5 | -739.0 | -794.5 | 2913.3 | 1710.8 | -6273.0 |
| 1996 | 1696.2 | -6219.5 | 552.3 | -2025.1 | 188.1 | -689.8 | -794.3 | 2912.4 | 1642.4 | -6022.0 |
| 1997 | 1677.0 | -6149.1 | 569.1 | -2086.7 | 174.7 | -640.7 | -794.0 | 2911.4 | 1626.8 | -5965.1 |
| 1998 | 1660.9 | -6089.9 | 477.2 | -1749.6 | 161.3 | -591.6 | -793.8 | 2910.5 | 1505.6 | -5520.5 |
| 1999 | 1673.7 | -6136.9 | 423.8 | -1553.8 | 147.9 | -542.4 | -793.5 | 2909.5 | 1451.9 | -5323.5 |
| 2000 | 1661.2 | -6091.0 | 370.5 | -1358.4 | 134.6 | -493.7 | -794.1 | 2911.7 | 1372.2 | -5031.3 |
| 2001 | 1666.1 | -6109.1 | 317.1 | -1162.6 | 143.3 | -525.5 | -793.3 | 2908.6 | 1333.3 | -4888.6 |
| 2002 | 1681.0 | -6163.7 | 263.8 | -967.1 | 152.0 | -557.4 | -793.6 | 2910.0 | 1303.2 | -4778.2 |
| 2003 | 1624.4 | -5956.2 | 210.5 | -771.7 | 160.7 | -589.2 | -793.8 | 2910.6 | 1201.8 | -4406.6 |
| 2004 | 1598.9 | -5862.5 | 156.2 | -572.9 | 169.4 | -621.1 | -794.0 | 2911.2 | 1130.5 | -4145.3 |
| 2005 | 1499.2 | -5497.2 | 252.0 | -924.0 | 178.1 | -653.1 | -794.1 | 2911.8 | 1135.2 | -4162.5 |
| 2006 | 1490.3 | -5464.5 | 256.2 | -939.4 | 208.6 | -764.8 | -794.2 | 2912.1 | 1160.9 | -4256.6 |

| Year | Forest lands | | Croplands | | | | Grasslands | | Net emission/absorption | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Perennial crops | | Arable lands | | | | | |
| | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ | Thousand tC | Gg $CO_2$ |
| 2007 | 1488.5 | -5457.8 | 235.2 | -939.4 | 239.0 | -876.5 | -794.2 | 2912.1 | 1189.5 | -4284.7 |
| 2008 | 1469.4 | -5387.9 | 243.6 | -893.2 | 269.5 | -988.2 | -794.2 | 2912.1 | 1188.3 | -4357.2 |
| 2009 | 1546.0 | -5668.6 | 237.3 | -870.1 | 300.0 | -1099.9 | -794.2 | 2912.1 | 1289.1 | -4593.9 |
| 2010 | 1466.1 | -5375.6 | 235.2 | -862.4 | 330.4 | -1211.4 | -794.2 | 2912.1 | 1237.4 | -4537.3 |
| 2011 | 1564.6 | -5736.7 | 228.9 | -839.3 | 327.3 | -1200.1 | -794.2 | 2912.1 | 1326.6 | -4864.0 |
| 2012 | 1531.9 | -5616.9 | 228.9 | -839.3 | 328.8 | -1205.6 | -794.2 | 2912.1 | 1295.4 | -4749.7 |
| 2013 | 1580.3 | -5794.3 | 231.0 | -847.0 | 301.3 | -1104.8 | -794.2 | 2912.1 | 1318.4 | -4834.0 |
| 2014 | 1499.5 | -5498.3 | 231.0 | -847.0 | 320.6 | -1175.4 | -794.2 | 2912.1 | 1256.9 | -4608.6 |
| 2015 | 1495.7 | -5484.3 | 231.0 | -847.0 | 326.6 | -1197.5 | -794.2 | 2912.1 | 1259.1 | -4616.8 |
| 2016 | 1532.0 | -5617.4 | 231.0 | -847.0 | 339.4 | -1244.4 | -794.2 | 2912.1 | 1308.2 | -4796.6 |
| 2017 | 1521.3 | -5578.1 | 276.4 | -1013.4 | 339.4 | -1244.4 | -794.2 | 2912.1 | 1342.8 | -4923.8 |

*Figure 5-1 Dynamics of net $CO_2$ emissions/absorption in the "Land Use, Land-Use Change and Forestry" sector*

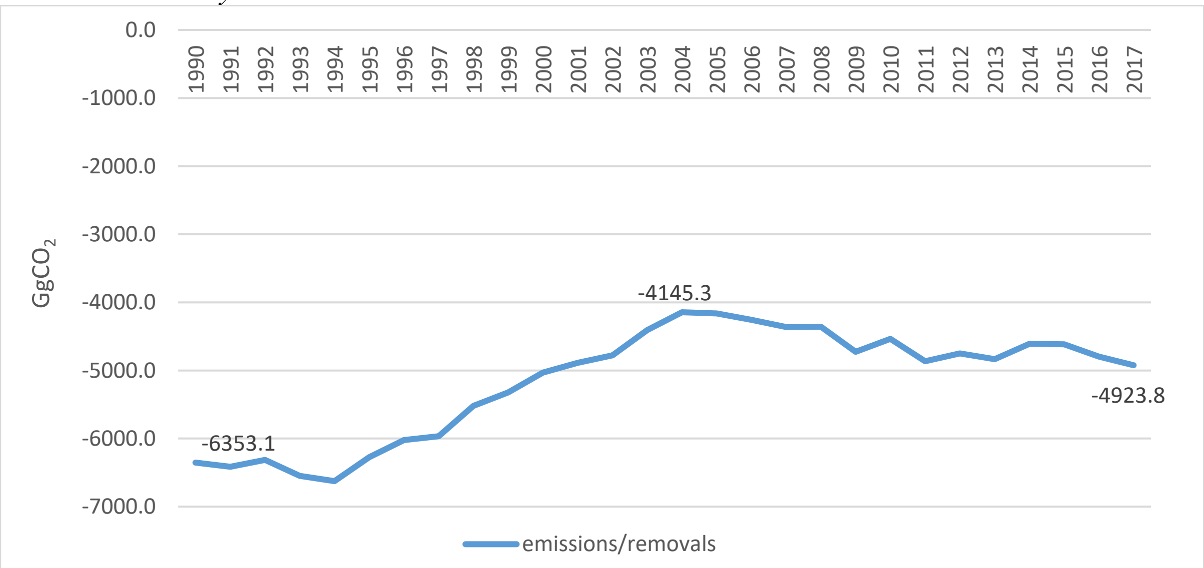



*Figure 5-2 Dynamics of net $CO_2$ emissions/absorptions in the forest land (on territories covered with forest)*

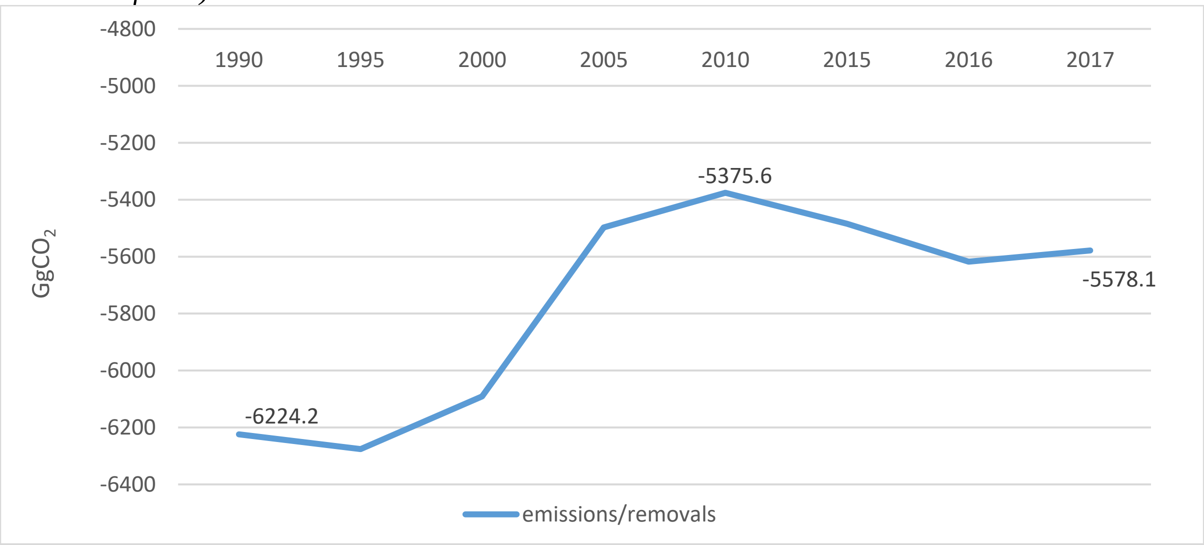


*Figure 5-3 Dynamics of net $CO_2$ emissions/absorptions in the croplands*

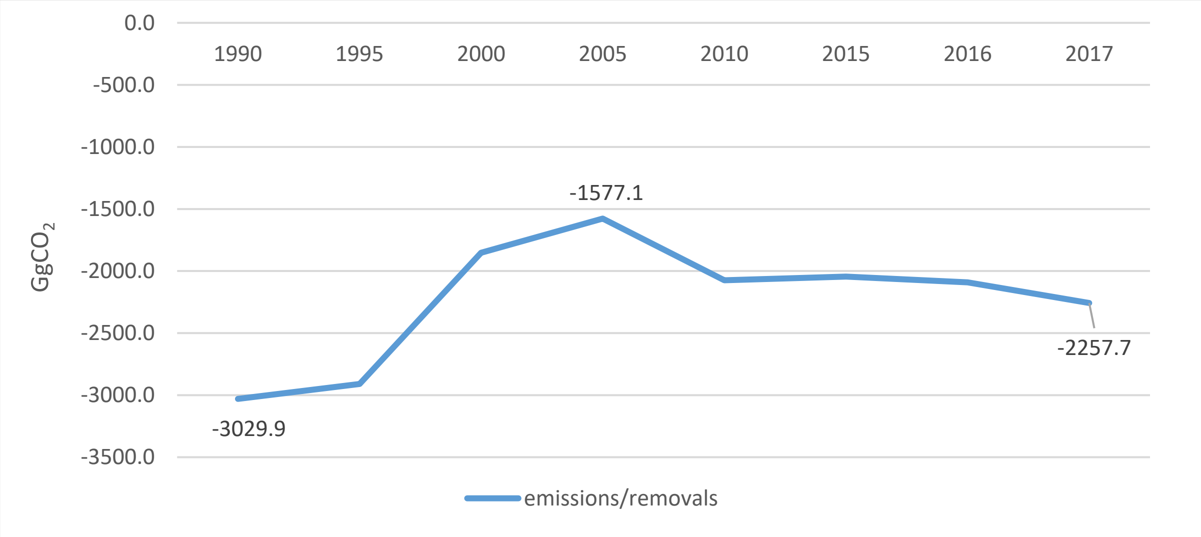
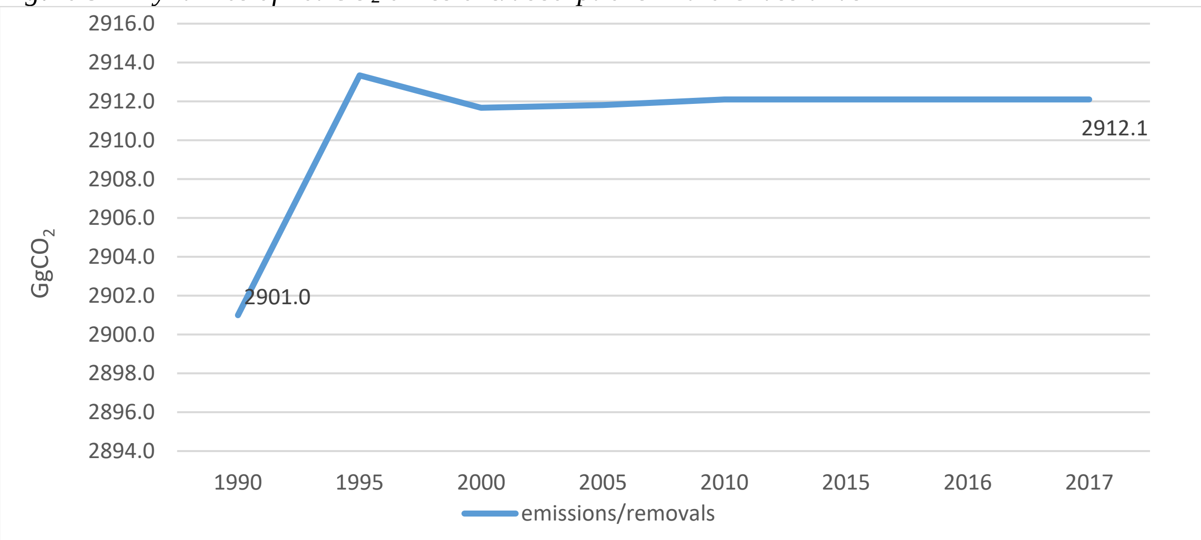



*Figure 5-4 Dynamics of net $CO_2$ emissions/absorptions in the Grasslands*




As seen in the given graphs, the sector accumulates carbon dioxide, although a trend of decline is obvious. Namely in 1990 the accumulated volume was about 6353.1 $GgCO_2$, while in 2017 net emissions decreased by 23 %, amounting to 4923.8Gg $CO_2$.

## 5.5. Forest land (4.A.)

### *a) Source-category description and calculated emissions*

Within the framework of this report, greenhouse gas inventories for Georgian forests were carried out on an entire forest area, regardless of forest management regime (active or passive). Specifically, the calculations include part of the forest area within protected areas where any forest use measures (eg Nature strict reserve IUCN category 1) are prohibited by Georgian legislation, since these areas are considered to be managed forests despite passive management. Exceptions are forests in areas not controlled by Georgia (Abkhazia, so called South Ossetia), which are not included in the calculation due to the lack of relevant data.

The aim of calculations is to elucidate what a forest is – an absorber or, on the contrary, an emitter of carbon dioxide, which determines balance of volume of reduction of biomass, the biomass growth and volume of reforestation, forest yield.

Using the necessary Activity Data for the inventory and Emission Factors, the work sheets have been filled in and emissions and absorptions have been calculated. According to the obtained results the values of carbon dioxide emissions and absorptions are provided in *Table 5-5*.

With regard to $CO_2$ emissions as a result of forest fires, emissions of other greenhouse gases obtained by calculations are provided in *Table 5-6*.

Table 5-5 Carbon Stock Changes and $CO_2$ net Emissions from Living Biomass in Forest Lands in Georgia

| Year | forest land, thousand ha | Carbon gains, thousand tons C | Carbon losses thousand tons C | Net carbon stock change, thousand tons C | Carbon dioxide net emissions/absorptions, Gg $CO_2$ |
|---|---|---|---|---|---|
| 1990 | 2127.5 | 1831.9 | 134.4 | 1697.5 | 6224.2 |
| 1991 | 2127.5 | 1831.9 | 134.2 | 1697.7 | 6224.8 |
| 1992 | 2127.5 | 1831.9 | 127.8 | 1704.1 | 6248.4 |
| 1993 | 2127.5 | 1831.9 | 130.9 | 1701.0 | 6237.0 |
| 1994 | 2127.5 | 1831.7 | 139.7 | 1692.0 | 6204.0 |
| 1995 | 2127.5 | 1831.7 | 120.1 | 1711.6 | 6276.0 |
| 1996 | 2127.5 | 1831.7 | 135.5 | 1696.2 | 6219.5 |
| 1997 | 2127.5 | 1831.7 | 154.7 | 1677.0 | 6149.1 |
| 1998 | 2150.3 | 1836.5 | 175.6 | 1660.9 | 6089.9 |
| 1999 | 2150.3 | 1836.5 | 162.8 | 1673.7 | 6136.9 |
| 2000 | 2150.3 | 1835.8 | 174.6 | 1661.2 | 6091.0 |
| 2001 | 2150.3 | 1835.8 | 169.6 | 1666.1 | 6109.1 |
| 2002 | 2150.3 | 1835.8 | 154.8 | 1681.0 | 6163.7 |
| 2003 | 2150.3 | 1835.8 | 211.3 | 1624.4 | 5956.2 |
| 2004 | 2150.3 | 1835.8 | 236.9 | 1598.9 | 5862.5 |
| 2005 | 2149.3 | 1809.8 | 310.5 | 1499.2 | 5497.2 |
| 2006 | 2149.3 | 1809.8 | 319.5 | 1490.3 | 5464.5 |
| 2007 | 2149.3 | 1809.8 | 321.3 | 1488.5 | 5457.8 |
| 2008 | 2149.3 | 1809.8 | 340.3 | 1469.4 | 5387.9 |
| 2009 | 2149.3 | 1809.8 | 263.8 | 1546.0 | 5668.6 |
| 2010 | 2110.7 | 1765.1 | 299.0 | 1466.1 | 5375.6 |
| 2011 | 2110.7 | 1809.3 | 244.8 | 1564.6 | 5736.7 |
| 2012 | 2109.7 | 1759.3 | 227.4 | 1531.9 | 5616.9 |
| 2013 | 2109.7 | 1831.9 | 251.6 | 1580.3 | 5794.3 |
| 2014 | 2110.8 | 1759.7 | 260.1 | 1499.5 | 5498.3 |
| 2015 | 2123.4 | 1766.6 | 270.9 | 1495.7 | 5484.3 |
| 2016 | 2123.4 | 1766.6 | 234.6 | 1532.0 | 5617.4 |
| 2017 | 2124.0 | 1766.9 | 245.6 | 1521.3 | 5578.1 |

Table 5-6 Greenhouse Gas Emissions as a Result of Forest Fires in Forest land of Georgia

| Year | Greenhouse gas emission $10^{-3}$ Gg | | | |
|---|---|---|---|---|
| | $CH_4$ | CO | $N_2O$ | $NO_X$ |
| 1990 | 2.01 | 29.07 | 0.02 | 0.16 |
| 1991 | 0.61 | 8.78 | 0.01 | 0.05 |
| 1992 | NE | NE | NE | NE |
| 1993 | 5.51 | 79.56 | 0.07 | 0.43 |
| 1994 | 48.37 | 698.61 | 0.59 | 3.76 |
| 1995 | 1.42 | 20.48 | 0.02 | 0.11 |
| 1996 | 32.40 | 468.00 | 0.40 | 2.52 |
| 1997 | 15.31 | 221.13 | 0.19 | 1.19 |

| Year | Greenhouse gas emission $10^{-3}$ Gg | | | |
|---|---|---|---|---|
| | $CH_4$ | CO | $N_2O$ | $NO_X$ |
| 1998 | 31.21 | 450.74 | 0.38 | 2.43 |
| 1999 | 6.76 | 97.67 | 0.08 | 0.53 |
| 2000 | 18.93 | 273.49 | 0.23 | 1.47 |
| 2001 | 2.01 | 29.07 | 0.15 | 0.16 |
| 2002 | 36.88 | 532.64 | 0.45 | 2.87 |
| 2003 | 4.21 | 60.84 | 0.05 | 0.33 |
| 2004 | 5.18 | 74.88 | 0.06 | 0.40 |
| 2005 | 1.81 | 26.21 | 0.02 | 0.14 |
| 2006 | 124.37 | 1796.42 | 1.52 | 9.67 |
| 2007 | 0.24 | 3.42 | 0.00 | 0.02 |
| 2008 | 362.17 | 5231.36 | 4.43 | 28.17 |
| 2009 | 2.01 | 29.07 | 0.53 | 0.16 |
| 2010 | 30.06 | 434.19 | 0.37 | 2.34 |
| 2011 | 0.28 | 4.10 | 0.00 | 0.02 |
| 2012 | 12.07 | 174.40 | 0.15 | 0.94 |
| 2013 | 2.01 | 29.07 | 0.09 | 0.16 |
| 2014 | 58.51 | 845.09 | 0.72 | 4.55 |
| 2015 | 2.01 | 29.07 | 0.20 | 0.16 |
| 2016 | 11.15 | 161.02 | 0.14 | 0.87 |
| 2017 | 78.97 | 1140.66 | 0.97 | 6.14 |

### *b) Methodological issues*

- ***Estimation Method***

In accordance with the IPCC methodology, carbon in the forest sector is accumulated in or released from the so called “pools”: 1) living biomass (above-ground and below-ground); 2) dead organic matter (dead wood, litter); 3) soils (mineral and organic). Explanation of these pools is provided in *Table 5-7*.

Based on materials needed for inventory obtained in advance, and the IPCC guidelines the key category for calculations has been selected, namely, “Forest land; remaining forest land”. As we have already noted, this was stipulated by the fact that in Georgia the number of cases of forest area conversions into areas of other categories or vice versa is negligible. A “living biomass” has been selected from the carbon pools, since based on conditions in the forestry sector of Georgia and natural-ecological state this is where the main changes in carbon stocks take place.

As it has already been mentioned, calculations were made according to the Tier 1 approach, and calculations were made for living biomass.  Calculations were not carried out in relation of dead organic material and soil carbon reservoirs. This is in line with the forest management system in Georgia, in other words in most cases clear logging does not take place in forests of Georgia and accordingly no significant changes occur in the mentioned two pools.

Table 5-7 Explanation of Carbon Pools

| № | Carbon “reservoirs” | | Explanation |
|---|---|---|---|
| 1 | Living Biomass | Above ground biomass | All living above ground biomass (timber, stumps, branches, bark, leaves, etc.). |
| | | Below ground biomass | All living biomass of live root system |
| 2 | Dead Organic Matter | Dead wood | All dead wood fallen down on the soil not decayed |
| | | Litter | All dead cover (humus) on about 10 centimeters depth |
| 3 | Soils | Organic matter of soil | Organic carbon in determined depth of mineral and organic soils (including peats). |

The schematic diagram of formulas needed for calculation of carbon accumulation and release in the remaining forest land is provided in *Figure 5-5* The System of Equations For Calculation Of The Amount Of Carbon Accumulation In Biomass. At this stage, the calculation has only been carried out for the "above-ground and below ground biomass", based on the available materials i.e. in the pool of living biomass. As it was mentioned, calculations were made for so called living biomass (Tier 1 approach).

*Figure 5-5 The System of Equations For Calculation Of The Amount Of Carbon Accumulation In Biomass*

$$\Delta C_{FF} = (\Delta C_{FF_{LB}} + \Delta C_{FF_{DOM}} + \Delta C_{FF_{SOILS}})$$

$$\Delta C_{FF_{LB}} = (\Delta C_{FF_G} - \Delta C_{FF_L})$$

$$C_{FF_G} = (A \cdot G_{TOTAL}) \cdot CF$$

$$\Delta C_{FF_L} = L_{fellings} + L_{fuelwood} + L_{other\ losses}$$

$$G_{TOTAL} = G_W \cdot (1 + R)$$

$$G_W = I_V \cdot D \cdot BEF_1$$

$$L_{fellings} = H \cdot D \cdot BEF_2 \cdot (1 - F_{BL}) \cdot CF$$

$$L_{fuelwood} = FG \cdot D \cdot BEF_2 \cdot CF$$

$$L_{other\ losses} = A_{DISTURBANCE} \cdot B_W \cdot (1 - F_{BL}) \cdot CF$$

Where:

ΔCFF annual change in carbon stocks from forest land remaining forest land, tonnes C yr-1;

$\Delta C_{FFLB}$ annual change in carbon stocks in living biomass (includes above- and belowground biomass) in forest land remaining forest land; tonnes C yr-1;

$\Delta C_{FFDOM}$ annual change in carbon stocks in dead organic matter (includes dead wood and litter) in forest land remaining forest land; tonnes C yr-1;

$\Delta C_{FFSOILS}$ annual change in carbon stocks in soils in forest land remaining forest land; tonnes C yr-1;

$\Delta C_{FFG}$annual increase in carbon stocks due to biomass growth, tonnes C yr-1;

$\Delta C_{FFL}$- annual decrease in carbon stocks due to biomass loss, tonnes C yr-1;

A - Area of remaining forest land, by forest type, ha;

$G_{TOTAL}$- average annual increment rate in total biomass in units of dry matter, by forest type and climatic zone, tonnes d.m. ha-yr;

CF-carbon fraction of dry matter (default = 0.5), tons C (tonnes d.m.)-1;

$G_W$-average annual aboveground biomass increment, tonnes d.m. ha-1 yr-1;

$I_V$- =average annual net increment in volume suitable for industrial processing, m3 ha-1 yr-1;

D-basic wood density, tonnes d.m. m-3;

$BEF_1$- biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment, dimensionless.

R – root-to-shoot ratio appropriate to increments, dimensionless.

$L_{fellings}$ – annual carbon loss due to commercial felling, tonnes C yr-1

$L_{fuelwood}$- annual carbon loss due to fuelwood gathering, tonnes C yr-1

$L_{other\ losses}$ –annual other losses of carbon, tonnes C yr-1

H-annually extracted volume, roundwood, m3 yr-1;

$BEF_2$-biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark), dimensionless.

$F_{BL}$- fraction of biomass left to decay in forest (transferred to dead organic matter);

FG- annual volume of fuelwood gathering, m3 yr-1;

$B_W$-average biomass stock of forest areas, tonnes d.m. ha-1;

In addition to the natural processes that take place on forest lands and changes in carbon stock due to timber production, emissions of $CO_2$ and other greenhouse gases into the atmosphere resulting from forest fires have also been calculated.

$CH_4$, $N_2O$, CO, and $NO_X$ gases are also emitted along with carbon because of forest fires.

The available methodology allows to determine quantities of greenhouse gases ($CH_4$, $N_2O$), other than carbon dioxide released due to forest fires.

As for estimation of other greenhouse gases ($CH_4$, $N_2O$) the following equation[98] is used:

$$L_{FIRE} = A \times B \times C \times D \times 10^{-6}$$

Where:

A area burnt, ha;
B-mass of ‘available’ fuel, kg d.m. ha-1;
C-combustion efficiency (or fraction of the biomass combusted), dimensionless.
D-emission factor, g (kg d.m.)-1;

The mentioned formulas allow calculating quantities of all greenhouse gases separately, since emission factors for various gases differ (see the *Table 5-14*).

- ***Emission factors***

Absolute dry volume weight of timber (D) has been calculated for forest massifs with different climate in Western and Eastern Georgia and also for coniferous and deciduous species separately.

Data on dominating forest species in all three regions have been used for the calculations. The obtained values for volume weight of timber are provided in *Table 5-8, Table 5-9* and *Table 5-10*.

[98]Good Practice Guidance for Land Use, Land-Use Change and Forestry, Chapter 3, GREENHOUSE GAS EMISSIONS FROM BIOMASS BURNING, IPCC 2003,http://www.ipcc-nggip.iges.or.jp

Table 5-8 Basic Wood Density and Volumes of Reserves of Deciduous and Coniferous Forests in West Georgia (Humid Continental Climate) Volumes of Reserves Are Obtained by Averaging Data for 2006[99]

| Dominant forest species | Reserves of dominating species ($m^3$) and share in total reserves (%) | Basic wood density timber, t dm/m3[100] |
|---|---|---|
| **Deciduous** | | |
| Beech | 71 170 (52%) | 0.58 |
| Chestnut | 30 792 (22%) | 0.48 |
| Alder | 19 426 (14%) | 0.45 |
| Oak | 9 009 (6%) | 0.66 |
| Hornbeam | 6 015 (4%) | 0.74 |
| **Total** | 136 412 (100%) | |
| | **Basic wood density** | **0.55** |
| **Coniferous** | | |
| Fir | 49 236 (76%) | 0.41 |
| Spruce | 14 258 (22%) | 0.44 |
| Pine | 1 253 (2%) | 0.48 |
| **Total** | 64 747 (100%) | |
| | **Basic wood density** | **0.42** |

Table 5-9 Basic Wood Density and Volumes of Reserves of Deciduous and Coniferous Forests in East Georgia (Dry Continental Climate) Volumes of Reserves Are Obtained based on Average Data of 2006[101]

| Dominant forest species | Reserves of dominating species ($m^3$) and share in total reserves (%) | Basic wood density timber, t dm/m3[33] |
|---|---|---|
| **Deciduous** | | |
| Beech | 65 569 (37%) | 0.58 |
| Oak | 61 085 (34%) | 0.66 |
| Hornbeam | 39 250 (22%) | 0.74 |
| Oriental hornbeam | 9 369 (5%) | 0.74 |
| Maple | 4 025 (2%) | 0.65 |
| **Total** | 179 298 (100%) | |
| | **Basic wood density** | **0.65** |
| **Coniferous** | | |
| Spruce | 21 365 (61%) | 0.48 |
| Pine | 10 025 (30%) | 0.41 |
| Fir | 3 258 (9%) | 0.44 |
| **Total** | 34 648 (100%) | |
| **Basic wood density** | | **0.45** |

[99] Georgian Statistical Yearbook of Forestry, Ministry of Environment and Natural Resources of Georgia, Forestry Department, Tbilisi, 2006;

[100]Makhviladze S.E. Wood science, Tbilisi 1962 (in Georgian); Боровиков А.М., Уголев Б.Н. Справочник по древесине. “Лесная Промышленность”, Москва, 1989;

[101] Georgian Statistical Yearbook of Forestry, Ministry of Environment and Natural Resources of Georgia, Forestry Department, Tbilisi, 2006;

Table 5-10 Basic Wood Density and Volumes of Reserves of Deciduous and Coniferous Forests in Ajara AR

| Dominant forest species | Reserves of dominating species ($m^3$) and share in total reserves (%) | Basic wood density timber, t/m3[33] |
|---|---|---|
| **Deciduous** | | |
| **Beech** | 24170 (73%) | 0.58 |
| **Chestnut** | 5792 (18%) | 0.48 |
| **Alder** | 1426(4%) | 0.45 |
| **Hornbeam** | 1009(3%) | 0.74 |
| **Oak** | 715(2%) | 0.66 |
| **Total** | 33112(100%) | |
| | **Basic wood density** | **0.56** |
| **Coniferous** | | |
| **Fir** | 8386(50%) | 0.415 |
| **Spruce** | 8051(48%) | 0.44 |
| **Pine** | 298(2%) | 0.48 |
| **Total** | 16735(100%) | |
| **Basic wood density** | | **0.43** |

The percentage distribution of stocks of dominating species has been taken into consideration in calculations of average volume weights provided in the Tables. It should be noted that in accordance with IPCC Guidelines the values of volume weight of dominating species in the countries of moderate climate in fact coincide with the country specific values of dominating species of Georgia. IPCC value for deciduous species (species -beech) equals 0.58 t dm/$m^3$, and for coniferous ones (species -fir tree) - 0.40 t dm/$m^3$.

With regard to the value of volume weight used in calculations of biomass losses, it was obtained taking into account the main species of timber produced in Georgia. Since volume of timber produced by cutting are not identified by species on a national scale in Georgia, therefore expert estimation has been used to determine percentage values of the main species, used by population as timber and firewood. In particular, the following species are produced in Georgia as timber: beech - 70%, fir-tree - 15%, spruce - 10% and other - 5%, and as firewood: beech - 35%, hornbeam - 30%, oriental hornbeam - 20% and other - 15%. Taking into consideration the above-mentioned percentage values, the average value of volume weight of absolutely dry timber has been calculated (*Table 5-11*).

Table 5-11 Absolutely Dry Volume of Commercial Timber and Fire Wood Produced in Georgia

| Dominant forest species | Share in total reserves (%) | Basic wood density timber, t dm/m3[102] |
|---|---|---|
| **Roundwood** | | |
| Beech | 70 | 0.58 |
| Spruce | 15 | 0.48 |
| Fir | 10 | 0.41 |
| Other | 5 | NO |
| | 100 | |
| **Basic wood density** | | **0.52** |
| **Firewood** | | |
| Beech | 35 | 0.58 |
| Hornbeam | 30 | 0.74 |
| Oriental hornbeam | 20 | 0.74 |

[102]Makhviladze. Timbers, Tbilisi 1962; Боровиков А.М., Уголев Б.Н. Справочникподревесине. "ЛеснаяПромышленность", Москва, 1989.

| Dominant forest species | Share in total reserves (%) | Basic wood density timber, t dm/m3[102] |
|---|---|---|
| Other | 15 | NO |
| | 100 | |
| **Basic wood density** | | **0.57** |

The majority of parameters indicated in the equations provided on the *Figure 5-5* The System of Equations For Calculation Of The Amount Of Carbon Accumulation In Biomass have been taken from IPCC methodology from Tables designed for countries with moderate climate. *Table 5-12* demonstrates a list of certain parameters, used in the calculations indicating the respective source.

Table 5-12 Parameters Used in Inventory and Their Values

| Factors | West Georgia | | East Georgia | | AR of Ajara | | Source |
|---|---|---|---|---|---|---|---|
| | Deciduous | Coniferous | Deciduous | Coniferous | Deciduous | Coniferous | |
| CF- carbon fraction of dry matter, tonnes C (tonnes d.m.) | 0.48 | 0.51 | 0.48 | 0.51 | 0.48 | 0.51 | Agriculture, Forestry and Other Land Use (AFOLU), Forest land, Table 4.3 |
| $BEF_1$- biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment, dimensionless; | 1.20 | 1.15 | 1.20 | 1.05 | 1.20 | 1.15 | (IPCC 2003), Table 3A.1.10 |
| R – root-to-shoot ratio appropriate to increments, dimensionless | 0.23 | 0.29 | 0.23 | 0.29 | 0.23 | 0.29 | Agriculture, Forestry and Other Land Use (AFOLU), Forest land, Table 4.4 |
| $BEF_2$ -biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark) | 1.35 | | | | | | (IPCC 2003), Table 3A.1.10 |

According to the data obtained from the National Forestry Agency and Forestry Agency of Adjara, forest fires of various intensity were registered on forest areas during the period of inventory. As a result, various volumes of biomass, enveloped in flames have been burnt on these areas. The burnt areas are provided in *Table 5-13*.

Table 5-13 Burnt Areas Registered in Georgia in 1990-2017[103]

| Year | Number of fire cases | Burnt areas, ha | Average above-ground biomass of areas affected, tonnes dm ha$^{-1}$ | Year | Number of fire cases | Burnt areas, ha | Average above-ground biomass of areas affected, tonnes dm ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| 1990 | 1 | 14.2 | 35 | 2004 | 21 | 32.0 | 40 |
| 1991 | 1 | 10.0 | 15 | 2005 | 16 | 44.9 | 10 |
| 1992 | NE | NE | NE | 2006 | 87 | 767.7 | 40 |
| 1993 | 7 | 34.0 | 40 | 2007 | 1 | 3.9 | 15 |
| 1994 | 10 | 341.2 | 35 | 2008 | 32 | 1277.5 | 70 |
| 1995 | 1 | 7.0 | 50 | 2009 | 15 | 717.4 | 15 |
| 1996 | 7 | 200.0 | 40 | 2010 | 6 | 371.1 | 20 |
| 1997 | 11 | 108.0 | 35 | 2011 | 4 | 7.0 | 10 |

[103] Georgian Statistical Yearbook, Ministry of Environment Protetion and Agriculture of Georgia, National Forestry Agency.

| Year | Number of fire cases | Burnt areas, ha | Average above-ground biomass of areas affected, tonnes dm $ha^{-1}$ | Year | Number of fire cases | Burnt areas, ha | Average above-ground biomass of areas affected, tonnes dm $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| 1998 | 31 | 308.2 | 25 | 2012 | 12 | 198.7 | 15 |
| 1999 | 13 | 37.1 | 45 | 2013 | 35 | 87.6 | 20 |
| 2000 | 34 | 85.0 | 55 | 2014 | 66 | 722.3 | 20 |
| 2001 | 28 | 148.0 | 20 | 2015 | 72 | 205.4 | 20 |
| 2002 | 36 | 607.0 | 15 | 2016 | 42 | 183.5 | 15 |
| 2003 | 5 | 52.0 | 20 | 2017 | 55 | 1299.9 | 15 |

Volumes of greenhouse gases emitted due to fires were calculated, as we have already mentioned, based on the IPCC equation 3.2.20[104].

Since substantiated values of factors, needed for calculations, are not available in Georgia, calculations for this source-category have been carried out by the Tier 1 approach. The coefficients have been taken from methodological Tables: IPCC Table 3A.1.12; Table 3A.1.16 Values implied for countries with moderate climate from these Tables have been used, in particular:

C- combustion efficiency =0.45 (IPCC Table 3A.1.12)

As for the emission factors, their values are provided in Table *5-14*.

Table 5-14 Values of Emission Factors for Individual Greenhouse Gases (IPCC Table 3A.1.16)

| Gas | (Emission factor, g/kg d.m.) |
|---|---|
| $CH_4$ | 9.00 |
| CO | 130.00 |
| $N_2O$ | 0.11 |
| $NO_X$ | 0.70 |

- ***Activity Data***

The areas covered by state forests in Georgia in 1990-2017 years period are provided in *Table 5-15*. Forest areas in the western and eastern parts of the country are identified separately, since the natural and climatic conditions of Western and Eastern Georgia differ from each other, therefore forest covers differ as well. Western Georgia is characterized by a humid subtropical climate; once we move from the Black sea to eastern direction, reduction of precipitation occurs simultaneously with the climate transformation into moderately dry continental climate. It should be noted that in these two parts of the country there are regions with distinguished climate or forest characteristics (e.g. Upper Svaneti).

Unfortunately, it is impossible to carry out inventory of greenhouse gases on forest areas per separate climatic zones, due to unavailability of necessary statistical or taxation data. Therefore, the calculations have been carried out according to units of regional management, namely forest plots under the National Forestry Agency, based on inventory data for these plots. From the available data on those forest plots it became clear, which climate parameters and forest cover (dominating species, growth parameters) relatively differ from adjacent regions; calculations for these plots have been carried out separately. For example, separate calculations have been carried out for Upper Svaneti (Mestia) and Borjomi-Bakuriani

[104] Good Practice Guidance for Land Use, Land-Use Change and Forestry, Chapter 3, EQUATION 3.2.20. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf

forests. Forest areas in the protected areas of Georgia and the forests under the management of Ajara AR have also been treated separately for the GHGI.

The data on average forest yield for forest types located in various climatic zones have been treated separately, based on unified forest inventory data, 2003 (*Table 5-17*).

Table 5-15 Forest areas of Georgia, According to Different Climatic Zones in Regions, ha

| **Year** | **Forest land (National Forestry Agency), ha** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **West Georgia** | | | | | **East Georgia** | | | | | **Total** |
| | **humid continental climate (Upper Svaneti -Mestia)** | | **humid subtropical climate[105]** | | **Total** | **dry continental climate[106]** | | **humid continental climate (Borjomi-Bakuriani)** | | **Total** | **(6+11)** |
| | **coniferous** | **deciduous** | **Coniferous** | **deciduous** | | **coniferous** | **deciduous** | **coniferous** | **deciduous** | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1990 | 46050 | 36183 | 82621 | 692953 | 857807 | 129166 | 749345 | 28813 | 21966 | 929290 | 1787097 |
| 1991 | 46050 | 36183 | 82621 | 692953 | 857807 | 129166 | 749345 | 28813 | 21966 | 929290 | 1787097 |
| 1992 | 46050 | 36183 | 82621 | 692953 | 857807 | 129166 | 749345 | 28813 | 21966 | 929290 | 1787097 |
| 1993 | 46050 | 36183 | 82621 | 692953 | 857807 | 129166 | 749345 | 28813 | 21966 | 929290 | 1787097 |
| 1994 | 46050 | 36183 | 82621 | 692953 | 857807 | 129223 | 750288 | 28756 | 21023 | 929290 | 1787097 |
| 1995 | 46050 | 36183 | 82621 | 692953 | 857807 | 129223 | 750288 | 28756 | 21023 | 929290 | 1787097 |
| 1996 | 46050 | 36183 | 82621 | 692953 | 857807 | 129223 | 750288 | 28756 | 21023 | 929290 | 1787097 |
| 1997 | 46050 | 36183 | 82621 | 692953 | 857807 | 129223 | 750288 | 28756 | 21023 | 929290 | 1787097 |
| 1998 | 46050 | 36183 | 80004 | 678123 | 840360 | 126010 | 734601 | 28756 | 21023 | 910390 | 1750750 |
| 1999 | 46050 | 36183 | 80004 | 678123 | 840360 | 126010 | 734601 | 28756 | 21023 | 910390 | 1750750 |
| 2000 | 46050 | 36183 | 80004 | 678123 | 840360 | 128177 | 735299 | 26589 | 20325 | 910390 | 1750750 |
| 2001 | 46050 | 36183 | 80004 | 678123 | 840360 | 128177 | 735299 | 26589 | 20325 | 910390 | 1750750 |
| 2002 | 46050 | 36183 | 80004 | 678123 | 840360 | 128177 | 735299 | 26589 | 20325 | 910390 | 1750750 |
| 2003 | 46050 | 36183 | 80004 | 678123 | 840360 | 128177 | 735299 | 26589 | 20325 | 910390 | 1750750 |
| 2004 | 46050 | 36183 | 80004 | 678123 | 840360 | 128177 | 735299 | 26589 | 20325 | 910390 | 1750750 |
| 2005 | 46050 | 36183 | 73994 | 644066 | 800293 | 121955 | 699272 | 25432 | 20325 | 866984 | 1667277 |
| 2006 | 46050 | 36183 | 73994 | 644066 | 800293 | 121955 | 699272 | 25432 | 20325 | 866984 | 1667277 |
| 2007 | 46050 | 36183 | 73994 | 644066 | 800293 | 121955 | 699272 | 25432 | 20325 | 866984 | 1667277 |
| 2008 | 46050 | 36183 | 73994 | 644066 | 800293 | 121955 | 699272 | 25432 | 20325 | 866984 | 1667277 |
| 2009 | 46050 | 36183 | 73994 | 644066 | 800293 | 121955 | 699272 | 25432 | 20325 | 866984 | 1667277 |
| 2010 | 46050 | 36183 | 73994 | 644066 | 800293 | 123267 | 699272 | 24120 | 20325 | 866984 | 1667277 |
| 2011 | 46050 | 36183 | 73994 | 644066 | 800293 | 123490 | 699272 | 23897 | 20325 | 866984 | 1667277 |
| 2012 | 46050 | 36183 | 73981 | 643994 | 800208 | 123608 | 699195 | 23764 | 20325 | 866892 | 1667100 |
| 2013 | 46050 | 36183 | 73981 | 643994 | 800208 | 123694 | 699195 | 23678 | 20325 | 866892 | 1667100 |
| 2014 | 46050 | 36183 | 73981 | 643994 | 800208 | 124307 | 699508 | 23065 | 20012 | 866892 | 1667100 |
| 2015 | 46050 | 36183 | 73981 | 643994 | 800208 | 124471 | 699952 | 22901 | 19568 | 866892 | 1667100 |
| 2016 | 46050 | 36183 | 73981 | 643994 | 800208 | 124471 | 699952 | 22901 | 19568 | 866892 | 1667100 |
| 2017 | 46050 | 36183 | 73981 | 643994 | 800208 | 124471 | 699952 | 22901 | 19568 | 866892 | 1667100 |

| **year** | **Ajara AR, ha** | | | **Abkhazia and South Ossetia, ha** | **Forest areas that exist on the protected sites** | **Total area of forest of Georgia(12+16+17+18), thousand ha** |
|---|---|---|---|---|---|---|
| | **coniferous** | **deciduous** | **Total** | | | |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 1990 | 54630 | 127470 | 182,100 | 624787 | 158316 | **2752300** |

105 Racha-Lechkhumi and Lower Svaneti; Imereti; Guria; part of Samegrelo-Upper Svaneti

106 Inner Kartli; Samtskhe-Javakheti; Mtskheta-Mtianeti; Lower Kartli; Kakheti

| | | | | | | |
|---|---|---|---|---|---|---|
| 1991 | 54630 | 127470 | 182,100 | 624787 | 158316 | **2752300** |
| 1992 | 54630 | 127470 | 182100 | 624787 | 158316 | **2752300** |
| 1993 | 54630 | 127470 | 182100 | 624787 | 158316 | **2752300** |
| 1994 | 54630 | 127470 | 182100 | 624787 | 158316 | **2752300** |
| 1995 | 54630 | 127470 | 182100 | 624787 | 158316 | **2752300** |
| 1996 | 54630 | 127470 | 182100 | 624787 | 158316 | **2752300** |
| 1997 | 54630 | 127470 | 182100 | 624787 | 158316 | **2752300** |
| 1998 | 56100 | 130900 | 187000 | 623087 | 212563 | **2773400** |
| 1999 | 56100 | 130900 | 187000 | 623087 | 212563 | **2773400** |
| 2000 | 56100 | 130900 | 187000 | 623087 | 212563 | **2773400** |
| 2001 | 56100 | 130900 | 187000 | 623087 | 212563 | **2773400** |
| 2002 | 56100 | 130900 | 187000 | 623087 | 212563 | **2773400** |
| 2003 | 56100 | 130900 | 187000 | 623087 | 212563 | **2773400** |
| 2004 | 56100 | 130900 | 187000 | 623087 | 212563 | **2773400** |
| 2005 | 56100 | 130900 | 187000 | 623087 | 295036 | **2772400** |
| 2006 | 56100 | 130900 | 187000 | 623087 | 295036 | **2772400** |
| 2007 | 56100 | 130900 | 187000 | 623087 | 295036 | **2772400** |
| 2008 | 56100 | 130900 | 187000 | 623087 | 295036 | **2772400** |
| 2009 | 56100 | 130900 | 187000 | 623087 | 295036 | **2772400** |
| 2010 | 42288 | 106092 | 148380 | 623087 | 295036 | **2733780** |
| 2011 | 42288 | 106092 | 148380 | 623087 | 295036 | **2733780** |
| 2012 | 40498 | 99149 | 139647 | 623087 | 302939 | **2732773** |
| 2013 | 40498 | 99149 | 139647 | 623087 | 302939 | **2732773** |
| 2014 | 40498 | 99149 | 139647 | 623087 | 304090 | **2733924** |
| 2015 | 40498 | 99149 | 139647 | 623087 | 316673 | **2746507** |
| 2016 | 40498 | 99149 | 139647 | 623087 | 316673 | **2746507** |
| 2017 | 40498 | 99149 | 139647 | 623087 | 317234 | **2747068** |

Table 5-16 Average Annual Increment of Forest Areas in $m^3$/ha yr[107]

| Species | West Georgia | | East Georgia | | Ajara AR humid subtropical climate |
|---|---|---|---|---|---|
| | humid continental climate | humid subtropical climate | dry continental climate | humid continental climate | |
| Coniferous | 2.3 | 3.1 | 2.0 | 2.9 | 3.5 |
| Deciduous | 1.9 | 2.5 | 1.7 | 2.3 | 2.9 |

The *Table 5-17* provides volumes of timber and firewood annually produced in Georgia. (Source of data: Georgian Statistical Yearbook of Forestry 1990-2017).

Table 5-17 Firewood and Timber Produced (in their number, by illegal logging) in Georgia (Abkhazia and South Ossetia are not included) in 1990-2017[108]

| Year | Firewood $m^3$ | Roundwood$m^3$ | Total $m^3$ | Year | Firewood $m^3$ | Roundwood$m^3$ | Total $m^3$ |
|---|---|---|---|---|---|---|---|
| 1990 | 317845.0 | 79461.2 | 397306.2 | 2004 | 532018.0 | 133004.6 | 665022.6 |
| 1991 | 301994.0 | 75498.6 | 377492.6 | 2005 | 698703.0 | 174675.8 | 873378.8 |
| 1992 | 287633.0 | 71908.2 | 359541.2 | 2006 | 679338.0 | 179834.6 | 859172.6 |
| 1993 | 293214.0 | 73303.6 | 366517.6 | 2007 | 723278.0 | 180819.6 | 904097.6 |
| 1994 | 301936.0 | 75484.0 | 377420.0 | 2008 | 671650.0 | 167912.4 | 839562.4 |
| 1995 | 269810.0 | 67452.4 | 337262.4 | 2009 | 582516.0 | 145629.0 | 728145.0 |
| 1996 | 296590.0 | 74147.6 | 370737.6 | 2010 | 665454.0 | 166363.4 | 831817.4 |
| 1997 | 346109.0 | 84027.2 | 430136.2 | 2011 | 550983.0 | 137745.8 | 688728.8 |
| 1998 | 387242.0 | 96810.6 | 484052.6 | 2012 | 519917.0 | 114979.2 | 634896.2 |
| 1999 | 364759.0 | 91189.8 | 455948.8 | 2013 | 565936.0 | 141484.0 | 707420.0 |
| 2000 | 388129.0 | 97032.2 | 485161.2 | 2014 | 570397.0 | 142599.2 | 712996.2 |

[107] Unified forest inventory data,2003
[108] Georgian Statistical Yearbook of Forestry 1990-2017

| Year | Firewood $m^3$ | Roundwoodm$^3$ | Total $m^3$ | Year | Firewood $m^3$ | Roundwoodm$^3$ | Total $m^3$ |
|---|---|---|---|---|---|---|---|
| 2001 | 378790.0 | 94697.6 | 473487.6 | 2015 | 605558.0 | 151389.6 | 756947.6 |
| 2002 | 416652.0 | 104163.0 | 520815.0 | 2016 | 525297.0 | 131324.2 | 656621.2 |
| 2003 | 474705.0 | 118676.2 | 593381.2 | 2017 | 532387.0 | 133096.8 | 665483.8 |

### 5.5.1. Forest land remaining Forest land (4.A.1.)

No calculations were performed for this source category due to lack of relevant data.

### 5.5.2. Land converted to Forest land (4.A.2)

No calculations were performed for this source category due to lack of relevant data

## 5.6. Cropland (4.B)

The quantity of carbon that is accumulated on croplands depends on the kinds of crops grown, the management practices (e.g. fallow lands) and climatic conditions. Harvesting of annual crops (cereals, vegetables) takes place every year, therefore, in accordance with IPCC guidelines there is no net accumulation of biomass carbon stocks. In the case of perennial crops (fruit gardens, vineyards etc.) carbon is accumulated annually, that allows accumulation of carbon stock over the long period.

With regard to carbon stock changes in soils, those depend on operating practices on cultivable lands, in particular, ploughing of soil, drainage, use of organic and mineral fertilizers.

### 5.6.1. Cropland remaining Cropland (4.B.1)

***a) Source-category description and calculated emissions***

Conversion of areas designated for other purposes into the cropland category may affect the carbon stocks. Conversion of forest lands, grasslands, and wetlands into croplands usually causes loss in carbon stocks. However, there are exceptions - namely, when areas with scarce vegetable cover and sometimes totally denuded of biomass supply is converted into croplands causing an increase in carbon stock.

Since the calculations have been carried out according to Tier 1 methodology and the data provided in the methodology in default form may be used for all countries with moderate climate (all moderately humid or dry climates are included there), therefore the calculations have been conducted on areas of perennial crops in Georgia with the same factor. During the inventory period the areas covered with perennial crops mainly were showing a decreasing tendency, whereas values of emissions obtained as a result of carbon stock changes are given in *Table 5-18*.

Table 5-18 Changes in Carbon Stocks in the Biomass of Perennial Crops

| Year | Area thousand ha | Reduction of areas compared to previous year, thousand ha | Carbon gains, thousand t C | Carbon losses, thousand t C | Net carbon stock change in cropland, thousand t C | Carbon dioxide net emissions/removals in cropland, $GgCO_2$ |
|---|---|---|---|---|---|---|
| 1990 | 356.6 | NE | 748.9 | NE | 748.9 | 2746.0 |
| 1991 | 352.1 | 4.5 | 739.4 | 9.45 | 730.0 | 2676.5 |
| 1992 | 334.0 | 18.1 | 701.4 | 38.01 | 663.4 | 2432.4 |
| 1993 | 333.0 | 1.0 | 699.3 | 2.1 | 697.2 | 2556.4 |
| 1994 | 332.0 | 1.0 | 697.2 | 2.1 | 695.1 | 2548.7 |
| 1995 | 307.0 | 25.0 | 644.7 | 52.5 | 592.2 | 2171.4 |
| 1996 | 285.0 | 22.0 | 598.5 | 46.2 | 552.3 | 2025.1 |
| 1997 | 278.0 | 7.0 | 583.8 | 14.7 | 569.1 | 2086.7 |
| 1998 | 252.6 | 25.4 | 530.5 | 53.3 | 477.1 | 1749.6 |

| Year | Area thousand ha | Reduction of areas compared to previous year, thousand ha | Carbon gains, thousand t C | Carbon losses, thousand t C | Net carbon stock change in cropland, thousand t C | Carbon dioxide net emissions/removals in cropland, $GgCO_2$ |
|---|---|---|---|---|---|---|
| 1999 | 227.2 | 25.4 | 477.1 | 53.3 | 423.8 | 1553.8 |
| 2000 | 201.8 | 25.4 | 423.8 | 53.3 | 370.4 | 1358.4 |
| 2001 | 176.4 | 25.4 | 370.4 | 53.3 | 317.1 | 1162.6 |
| 2002 | 151.0 | 25.4 | 317.1 | 53.3 | 263.8 | 967.1 |
| 2003 | 125.6 | 25.4 | 263.8 | 53.3 | 210.4 | 771.7 |
| 2004 | 100.0 | 25.6 | 210.0 | 53.8 | 156.2 | 572.9 |
| 2005 | 110.0 | NE | 252.0 | NE | 252.0 | 924.0 |
| 2006 | 116.0 | NE | 256.2 | NE | 256.2 | 939.4 |
| 2007 | 114.0 | 2.0 | 239.4 | 4.2 | 235.2 | 939.4 |
| 2008 | 115.0 | NE | 243.6 | NE | 243.6 | 893.2 |
| 2009 | 114.0 | 1.0 | 239.4 | 2.1 | 237.3 | 870.1 |
| 2010 | 113.0 | 1.0 | 237.3 | 2.1 | 235.2 | 862.4 |
| 2011 | 111.0 | 2.0 | 233.1 | 4.2 | 228.9 | 839.3 |
| 2012 | 110.0 | 1.0 | 231.0 | 2.1 | 228.9 | 839.3 |
| 2013 | 110.0 | NE | 231.0 | NE | 231.0 | 847.0 |
| 2014 | 110.0 | NE | 231.0 | NE | 231.0 | 847.0 |
| 2015 | 110.0 | NE | 231.0 | NE | 231.0 | 847.0 |
| 2016 | 110.0 | NE | 231.0 | NE | 231.0 | 847.0 |
| 2017 | 120.8 | NE | 276.4 | NE | 276.4 | 1013.4 |

With regard to emissions and absorptions in croplands, in particular, in mineral soils, as we have already noted, the factors have been taken from the respective Tables of IPCC guidelines; the results obtained by the calculations are provided in *Table 5-19*.

Table 5-19 Carbon Stock Changes and $CO_2$ emissions/absorptions in Croplands (in mineral soils)

| Land use | Area, thousand ha | Annual change in carbon stocks in mineral soils | Carbon dioxide net emissions |
|---|---|---|---|
| | | thousand t C/year | $GgCO_2$/year |
| **1990** | | | |
| Cultivated | 701.9 | 29.2 | 107.1 |
| Represents temporary set aside of annually cropland | 89.4 | 51.8 | 190.1 |
| Total | 791.3 | 81.0 | 297.1 |
| **1991** | | | |
| Cultivated | 639.7 | 26.6 | 97.6 |
| Represents temporary set aside of annually cropland | 151.6 | 87.9 | 322.3 |
| Total | 791.3 | 114.5 | 419.9 |
| **1992** | | | |
| Cultivated | 577.5 | 24.0 | 88.1 |
| Represents temporary set aside of annually cropland | 213.8 | 124.0 | 454.5 |
| Total | 791.3 | 148.0 | 542.6 |
| **1993** | | | |
| Cultivated | 515.3 | 21.4 | 78.6 |
| Represents temporary set aside of annually cropland | 276.0 | 160.0 | 586.8 |
| Total | 791.3 | 181.5 | 665.4 |
| **1994** | | | |
| Cultivated | 453.1 | 18.8 | 69.1 |
| Represents temporary set aside of annually cropland | 338.2 | 196.1 | 719.0 |
| Total | 791.3 | 214.9 | 788.1 |
| **1995** | | | |
| Cultivated | 479.4 | 19.9 | 73.1 |

| Land use | Area, thousand ha | Annual change in carbon stocks in mineral soils | Carbon dioxide net emissions |
|---|---|---|---|
| | | thousand t C/year | $GgCO_2$/year |
| Represents temporary set aside of annually cropland | 313.2 | 181.6 | 665.8 |
| Total | 792.6 | 201.5 | 739.0 |
| **1996** | | | |
| Cultivated | 505.7 | 21.0 | 77.1 |
| Represents temporary set aside of annually cropland | 313.2 | 167.1 | 612.7 |
| Total | 818.9 | 188.1 | 689.8 |
| **1997** | | | |
| Cultivated | 532.0 | 22.1 | 81.1 |
| Represents temporary set aside of annually cropland | 263.2 | 152.6 | 559.5 |
| Total | 795.2 | 174.7 | 640.7 |
| **1998** | | | |
| Cultivated | 558.3 | 23.2 | 85.2 |
| Represents temporary set aside of annually cropland | 238.2 | 138.1 | 506.4 |
| Total | 796.5 | 161.3 | 591.6 |
| **1999** | | | |
| Cultivated | 584.6 | 24.3 | 89.2 |
| Represents temporary set aside of annually cropland | 213.2 | 123.6 | 453.2 |
| Total | 801.8 | 298.9 | -1095.9 |
| **2000** | | | |
| Cultivated | 610.8 | 25.4 | 93.2 |
| Represents temporary set aside of annually cropland | 188.4 | 109.2 | 400.5 |
| Total | 799.2 | 134.6 | 493.7 |
| **2001** | | | |
| Cultivated | 596.6 | 24.8 | 91.0 |
| Represents temporary set aside of annually cropland | 204.4 | 118.5 | 434.5 |
| Total | 801.0 | 143.3 | 525.5 |
| **2002** | | | |
| Cultivated | 582.4 | 24.2 | 88.8 |
| Represents temporary set aside of annually cropland | 220.4 | 127.8 | 468.6 |
| Total | 802.8 | 152.0 | 557.4 |
| **2003** | | | |
| Cultivated | 568.2 | 23.6 | 86.7 |
| Represents temporary set aside of annually cropland | 236.4 | 137.1 | 502.6 |
| Total | 804.6 | 160.7 | 589.2 |
| **2004** | | | |
| Cultivated | 554 | 23.0 | 84.5 |
| Represents temporary set aside of annually cropland | 252.4 | 146.3 | 536.6 |
| Total | 806.4 | 169.4 | 621.1 |
| **2005** | | | |
| Cultivated | 539.6 | 22.4 | 82.3 |
| Represents temporary set aside of annually cropland | 268.5 | 155.7 | 570.8 |
| Total | 808.1 | 178.1 | 653.1 |
| **2006** | | | |
| Cultivated | 483.0 | 20.1 | 73.7 |
| Represents temporary set aside of annually cropland | 325.1 | 188.5 | 691.1 |
| Total | 808.1 | 208.6 | 764.8 |
| **2007** | | | |
| Cultivated | 426.4 | 17.7 | 65.0 |
| Represents temporary set aside of annually cropland | 381.7 | 221.3 | 811.5 |
| Total | 808.1 | 239.0 | 876.5 |
| **2008** | | | |
| Cultivated | 369.8 | 15.4 | 56.4 |
| Represents temporary set aside of annually cropland | 438.3 | 254.1 | 931.8 |
| Total | 808.1 | 269.5 | 988.2 |
| **2009** | | | |

| Land use | Area, thousand ha | Annual change in carbon stocks in mineral soils | Carbon dioxide net emissions |
|---|---|---|---|
| | | thousand t C/year | $GgCO_2$/year |
| Cultivated | 313.2 | 13.0 | 47.8 |
| Represents temporary set aside of annually cropland | 494.9 | 286.9 | 1052.1 |
| Total | 808.1 | 300.0 | 1099.9 |
| **2010** | | | |
| Cultivated | 256.7 | 10.7 | 39.2 |
| Represents temporary set aside of annually cropland | 551.4 | 319.7 | 1172.2 |
| Total | 808.1 | 330.4 | 1211.4 |
| **2011** | | | |
| Cultivated | 262.4 | 10.9 | 40.0 |
| Represents temporary set aside of annually cropland | 545.7 | 316.4 | 1160.1 |
| Total | 808.1 | 327.3 | 1200.1 |
| **2012** | | | |
| Cultivated | 259.6 | 10.8 | 39.6 |
| Represents temporary set aside of annually cropland | 548.5 | 318.0 | 1166.1 |
| Total | 808.1 | 328.8 | 1205.7 |
| **2013** | | | |
| Cultivated | 310.7 | 12.9 | 47.4 |
| Represents temporary set aside of annually cropland | 497.4 | 288.4 | 1057.4 |
| Total | 808.1 | 301.3 | 1104.8 |
| **2014** | | | |
| Cultivated | 274.9 | 11.4 | 41.9 |
| Represents temporary set aside of annually cropland | 533.2 | 309.1 | 1133.5 |
| Total | 808.1 | 320.6 | 1175.5 |
| **2015** | | | |
| Cultivated | 263.7 | 11.0 | 40.2 |
| Represents temporary set aside of annually cropland | 544.4 | 315.6 | 1157.4 |
| Total | 808.1 | 326.6 | 1197.6 |
| **2016** | | | |
| Cultivated | 240.0 | 10.0 | 36.6 |
| Represents temporary set aside of annually cropland | 568.1 | 329.4 | 1207.7 |
| Total | 808.1 | 339.4 | 1244.4 |
| **2017** | | | |
| Cultivated | 220.3 | 9.2 | 33.6 |
| Represents temporary set aside of annually cropland | 587.8 | 340.8 | 1249.6 |
| Total | 808.1 | 350.0 | 1283.2 |

Facts of cropland liming besides 1990, have been registered in Zugdidi Municipality, namely, in the Village Kakhati the private company “Nergeta " has limed kiwi plantations in 2011-2012 and 2014-2015, in total 44 ha. Using the mentioned data, the calculations have been carried out following Tier 1 methodology and the obtained results are provided in *Table 5-20*. No such facts have been reported in recent years.

Table 5-20 $CO_2$, Emissions, Due to Lime Application

| Year | Type of lime applied in the area | Limed area, ha | Amount of limestones applied to the area t limestones/year | Emission factor[109], tC/t limestones | Carbon emissions as a result of liming , t C/year | $CO_2$ emission $10^{-3}$ Gg/year |
|---|---|---|---|---|---|---|
| 1990 | Limestones $CaCO_3$ | 3000 | 30000 | 0.12 | 3600 | 13.20 |
| 2011 | Limestones $CaCO_3$ | 14 | 140 | 0.12 | 17 | 0.06 |

[109] Chapter 3: LUCF Sector Good Practice Guidance, EQUATION 3.3.6. Tier 1.

| Year | Type of lime applied in the area | Limed area, ha | Amount of limestones applied to the area t limestones/year | Emission factor[109], tC/t limestones | Carbon emissions as a result of liming , t C/year | $CO_2$ emission $10^{-3}$ Gg/year |
|---|---|---|---|---|---|---|
| 2012 | Limestones $CaCO_3$ | 10 | 100 | 0.12 | 12 | 0.04 |
| 2014 | Limestones $CaCO_3$ | 10 | 100 | 0.12 | 12 | 0.04 |
| 2015 | Limestones $CaCO_3$ | 10 | 100 | 0.12 | 12 | 0.04 |

### b) *Methodological issues*

- ***Estimation Method***

The equation given below is the basis for the calculation of carbon accumulation and release from croplands (which do not change a land use, namely remaining cropland), in accordance with IPCC guidelines (IPCC 2003):

$$\Delta C_{CC}=\Delta C_{CCLB}+\Delta C_{CCsoils}$$

Where:

$\Delta C_{CC}$ - annual change in carbon stocks in cropland remaining cropland, tonnes C yr-1
$\Delta C_{CCLB}$ - annual change in carbon stocks in living biomass, tonnes C yr-1
$\Delta C_{CCsoils}$ - annual change in carbon stocks in soils, tonnes C yr-1

According to the methodology, areas covered with perennial crops are included in the cropland land-use category; calculation of changes in carbon stocks in the above-ground biomass is carried out for these areas. Carbon is accumulated in biomass of perennial crops, such as fruit gardens, tea plantations etc. For annual crops, increase in biomass stocks in a single year is assumed to be equal to biomass losses from harvest and mortality in that same year, thus there is no net accumulation of biomass carbon stocks.

The amount of changes in carbon stocks in biomass of perennial crops is calculated by the methodology, designed for the forest land, namely, based on the equation for estimating changes of carbon stocks, existing in forest biomass from the sub-category “remaining forest land”. It should be noted here that in accordance with the IPCC guidance, unlike the forestry sector, the calculation for perennial crops is only carried out for the above-ground biomass (calculations are not conducted for the below-ground biomass).

The calculations for perennial crops have been conducted following the Tier 1 methodology, using the default factors provided by the IPCC guidelines (IPCC 2003), tailored for the climatic zones of Georgia.

The year’s decrease of a biomass caused by annual decrease of areas of crops is subtracted from the year’s growth of a biomass on the areas covered with perennial crops.

Regarding the calculation of $CO_2$ emissions and absorption in soil, it is carried out both for mineral and organic soils. In addition, losses of carbon from soils because of liming have been estimated.

Annual carbon stock changes in soils are calculated using the following formula:

$$\Delta C_{CCsoils} = \Delta C_{CCmineral} - \Delta C_{CCorganic} - \Delta C_{CClime}$$

**Mineral soils**

The methodology for calculations for mineral soils is based on identifying changes of carbon stocks contained in soils as a result of changes in the management of soils over a certain period.

$$\Delta C_{CCMineral} = [(SOC_0 – SOC_{(0-T)}) \times A] / T,$$

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I,$$

Where:

$\Delta C_{CCmineral}$ -annual change in carbon stocks in mineral soils, tonnes C yr-1
$SOC_0$ -soil organic carbon stock in the inventory year, tons C ha-1
$SOC_{(0-T)}$ – soil organic carbon stock T years prior to the inventory, tonnes C ha-1;
T- Inventory time period, yr (default is 20 yr);
A - Land area of each parcel, ha
$SOC_{REF}$- the reference carbon stock, tonnes C ha-1;
$F_{LU}$- stock change factor for land use or land-use change type, dimensionless;
$F_{MG}$- stock change factor for management regime, dimensionless;

$F_I$- stock change factor for input of organic matter, dimensionless.

**Organic Soils**

According to the methodology, dried peat bed where agricultural activities take place is classified as organic soil. When organic soils are dried (peatland) and agricultural activities begin, oxidation of organic soils is stimulated in this process. That results in releasing carbon from soil (emissions).

It should be noted that peat lands are mainly located on wetlands of Western Georgia (Kolkheti national park), which are not used as agricultural cultivable lands (in their number croplands). As for agricultural wetlands, where the drainage works have started in recent years, they are presented mainly by mineral soils. It should also be noted l that in the mentioned areas the drainage works were carried out since the 60-ies of the XX century and the process was ended in the 90-ies, due to the deplorable situation that arose in the country in this period; as a result the areas underwent secondary flooding. At present the company "Georgian amelioration Ltd" (100% state owned company), is implementing rehabilitation and reconstruction of amelioration systems in the entire Georgia. On the basis of IPCC guidelines, in particular, taking into account the 20-year period of conversion (reference index), the estimated values of emissions resulted from drainage works on agricultural cultivable lands, being implemented at present, are not included in the calculations.

**Liming of Croplands**

Lime-containing carbonates, e.g. limestone's ($CaCO_3$), or dolomites ($CaCO_3 \times MgCO_3$) are included in the calculations. They are used in agriculture and represent a source of carbon dispersion.

The humid subtropical soils spread in Western Georgia are characterized by high acidity (pH=3.0-5.5). These soils are distinguished by physical and chemical properties unfavorable for plants, therefore there is limited normal growth of plants, assimilation of nutritional chemicals and substance exchange on these lands. On the mentioned soils the yield of annual crops as well as citruses and other perennial crops is very low, therefore liming activities are required for increasing the fertility of these soils and improving their productivity.

- ***Emission Factors***

In order to calculate carbon stock changes in perennial crops according to the IPCC methodology, the data for moderate climatic zones was taken for Georgia. In particular the accumulation rate of carbon in the above-ground biomass is 2.1 t C/ha annually, whereas on 1 ha of perennial crops 63 t of carbon is accumulated at harvest (by the methodology, this value is acceptable for both, warm humid and dry climates). Losses are calculated every year according to data, obtained because of decreasing areas covered with crops (dying or cutting of crops). In this case it is implied that the carbon stock contained earlier on the areas has been totally emitted into the atmosphere. Carbon losses (1 ha=63 t C) caused by decreasing of areas are subtracted from carbon increment in perennial crops (1 ha=2.1 t C/year). Over the given years abrupt changes has taken place in areas of perennial crops the areas covered with perennial crops decreased by 240 thousand ha - down to 110 thousand ha in 2015 as compared with 1990 data.

For calculations in croplands the reference value of carbon stock has been used (for soils), was obtained on the basis of the research carried out in Georgia ("Carbon stock in the region of Inner Kartli", Gizo Gogichaishvili). In particular, based on the research carried out in Eastern Georgia, according to the type of soil dominating on croplands in Georgia (Cambisols and Calcic Kastanozems) it has been identified that the carbon stock is 52 ton 1 ha C (soil depth 0-30 cm.). It should be noted here that by the classification of soils provided in the respective Table of the IPCC methodology, and taking into account the types of soils spread in Georgia, the reference carbon stock for Georgia is 38 t C/ha.

For mineral soils the calculations of changes of carbon stock have been made following the Tier 1 methodology, therefore the default stock change factor values have been taken from the Table[110] provided in the IPCC methodology. It should be noted that the data for cultivated lands by regions (for western relatively humid and eastern relatively dry zones) are not available. Since 70% of arable lands are located in Eastern Georgia, values for countries with dry climate were taken. As it was already mentioned the scale of changes of carbon stock in soil depends on a management regime of croplands; Therefore, appropriate stock change factor values have been chosen according to management types. Certain part of croplands in Georgia are not cultivated (*Table 5-21*) and as a result management regimes of arable lands differ from each other, therefore the calculations were carried out separately on these two types of arable lands with different management regimes. .

Table 5-21 Values of Emission Factors used in calculations

| **Emission Factors** | **$SOC_{(0-T)}$ - soil organic carbon stock T years prior to the inventory, tonnes C ha-1;** | | **$SOC_0$- soil organic carbon stock in the inventory year, tonnes C ha-1** | |
|---|---|---|---|---|
| | **Cultivated** | **Represents temporary set aside of annually cropland** | **Cultivated** | **Represents temporary set aside of annually cropland** |
| $SOC_{REF}$- the reference carbon stock, tons C ha | 52 | | | |
| $F_{LU}$ - stock change factor for land use or land-use change type, dimensionless | 0.80 | 0.93 | 0.80 | 0.80 |
| $F_{MG}$ - stock change factor for management regime, dimensionless (cultivated) | 1 | - | 1.02 | - |
| $F_{MG}$ - stock change factor for management regime, dimensionless (Represents temporary set aside of annually cropland) | - | 1.10 | - | 1 |
| $F_I$ - stock change factor for input of organic matter, dimensionless | 1 | 1.37 | 1 | 1 |

- ***Activity Data***

The croplands and the areas covered with perennial crops in Georgia over 1990-2017 years period are distributed as presented in *Table 5-22*.

[110]AFOLU, Cropland, Table 5.5. https://www.ipcc- nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf

Table 5-22 Cropland Area

| Year | Total, thousand ha | Arable land,[111] thousand ha | | | Perennial plantations[112], thousand ha |
|---|---|---|---|---|---|
| | | Total, thousand ha | Represents temporary set aside of annually cropland | Cultivated | |
| 1990 | 1147.9 | 791.3 | 89.4 | 701.9 | 356.6 |
| 1991 | 1143.4 | 791.3 | 151.6 | 639.7 | 352.1 |
| 1992 | 1125.3 | 791.3 | 213.8 | 577.5 | 334.0 |
| 1993 | 1124.3 | 791.3 | 276.0 | 515.3 | 333.0 |
| 1994 | 1123.3 | 791.3 | 338.2 | 453.1 | 332.0 |
| 1995 | 1099.6 | 792.6 | 313.2 | 479.4 | 307.0 |
| 1996 | 1078.9 | 793.9 | 288.2 | 505.7 | 285.0 |
| 1997 | 1073.2 | 795.2 | 263.2 | 532.0 | 278.0 |
| 1998 | 1049.1 | 796.5 | 238.2 | 558.3 | 252.6 |
| 1999 | 1025.0 | 797.8 | 213.2 | 584.6 | 227.2 |
| 2000 | 1001.0 | 799.2 | 188.4 | 610.8 | 201.8 |
| 2001 | 977.4 | 801.0 | 204.4 | 596.6 | 176.4 |
| 2002 | 953.8 | 802.8 | 220.4 | 582.4 | 151.0 |
| 2003 | 930.2 | 804.6 | 236.4 | 568.2 | 125.6 |
| 2004 | 906.4 | 806.4 | 252.4 | 554.0 | 100.0 |
| 2005 | 918.1 | 808.1 | 268.5 | 539.6 | 110.0 |
| 2006 | 924.1 | 808.1 | 325.1 | 483.0 | 116.0 |
| 2007 | 922.1 | 808.1 | 381.7 | 426.4 | 114.0 |
| 2008 | 923.1 | 808.1 | 438.3 | 369.8 | 115.0 |
| 2009 | 922.1 | 808.1 | 494.9 | 313.2 | 114.0 |
| 2010 | 921.1 | 808.1 | 551.4 | 256.7 | 113.0 |
| 2011 | 919.1 | 808.1 | 545.7 | 262.4 | 111.0 |
| 2012 | 918.1 | 808.1 | 548.5 | 259.6 | 110.0 |
| 2013 | 918.1 | 808.1 | 497.4 | 310.7 | 110.0 |
| 2014 | 918.1 | 808.1 | 533.2 | 274.9 | 110.0 |
| 2015 | 918.1 | 808.1 | 544.4 | 263.7 | 110.0 |
| 2016 | 918.1 | 808.1 | 568.1 | 240.0 | 110.0 |
| 2017 | 928.9 | 808.1 | 587.8 | 220.3 | 120.8 |

As for liming activities, they began in Georgia in the 60-ies of the past century and mainly covered acid soils in Western Georgia. The works were carried out annually on the area of 10-12 thousand ha. Liming was renewed in Georgia every 6-7 years and it was controlled by the state. At present the facts of liming are rare and they are not accounted for appropriately. According to the available materials, liming in Georgia has been conducted in 1990 - on an area of 3000 ha and in 1992 - on an area of 500 ha[113]. Since then liming was recorded in 2011 in Zugdidi municipality. The private company "Nergeta" started kiwi plantations in the village Kakhati. During this process the company carried out liming of various intensity on its own area, namely, in 2011 it limed 14 ha, in 2012 - 10 ha and in 2014-2015 in total (10 ha annually) the company limed the area up to 20 ha.

### 5.6.2. Land converted to Cropland (4.B.2)

No calculations were performed for this source category due to lack of relevant data.

## 5.7. Grassland (4.C)

***a) Source-category description and calculated emissions***

[111]National Statistics Service of Georgia, http://www.geostat.ge/ ;
[112] Statistical data of UN Food and Agriculture Organization, http://www.fao.org/faostat/en/#data/RL
[113] Roza Lortkipanidze, Soils and agriculture of Imereti, Tbilisi 1997.

In accordance with the IPCC methodology Grassland comprises rangelands and pastureland that are not considered cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pasture systems, consistent with national definitions.

In this category the calculations have been conducted for the soil pool using the equation that was used for soils of arable land. The calculations have shown that the state of hay lands is stable and thus no emissions take place, whereas the areas of pastures are the source of emission.

The values obtained by calculations on grasslands of Georgia during the inventory period are provided in Table *5-23*.

Table 5-23 Carbon Stock Changes and $CO_2$ emissions/removals in Grassland

| Land use | Area, thousand ha | Annual change in carbon stocks in mineral soils | Carbon dioxide emissions |
|---|---|---|---|
| | | thousand t C/year | $GgCO_2$/year |
| 1990 | | | |
| Grassland | 1826.0 | -892.6 | -3272.8 |
| Hayland | 130.0 | 101.4 | 371.8 |
| Total | 1956.0 | -791.2 | -2901.0 |
| 1991 | | | |
| Grassland | 1830.0 | -892.6 | -3272.8 |
| Hayland | 131.0 | 101.4 | 371.8 |
| Total | 1961.0 | -791.2 | -2901.0 |
| 1992 | | | |
| Grassland | 1835.0 | -896.9 | -3288.5 |
| Hayland | 132.0 | 103.0 | 377.5 |
| Total | 1967.0 | -793.9 | -2911.0 |
| 1993 | | | |
| Grassland | 1838.0 | -897.0 | -3289.0 |
| Hayland | 134.0 | 104.5 | 383.2 |
| Total | 1972.0 | -792.5 | -2905.8 |
| 1994 | | | |
| Grassland | 1842.0 | -900.4 | -3301.4 |
| Hayland | 135.0 | 105.3 | 386.1 |
| Total | 1977.0 | -795.1 | -2915.3 |
| 1995 | | | |
| Grassland | 1842.3 | -900.5 | -3301.7 |
| Hayland | 135.8 | 105.9 | 388.4 |
| Total | 1978.1 | -794.5 | -2913.3 |
| 1996 | | | |
| Grassland | 1843.1 | -900.8 | -3303.1 |
| Hayland | 136.6 | 106.5 | 390.7 |
| Total | 1979.7 | -794.3 | -2912.4 |
| 1997 | | | |
| Grassland | 1843.9 | -901.2 | -3304.4 |
| Hayland | 137.4 | 107.2 | 393.0 |
| Total | 1981.3 | -794.0 | -2911.4 |
| 1998 | | | |
| Grassland | 1844.7 | -901.6 | -3305.7 |
| Hayland | 138.2 | 107.8 | 395.3 |
| Total | 1982.9 | -793.8 | -2910.5 |
| 1999 | | | |
| Grassland | 1845.5 | -901.9 | -3307.1 |
| Hayland | 139.0 | 108.4 | 397.5 |
| Total | 1984.5 | -793.5 | -2909.5 |

| Land use | Area, thousand ha | Annual change in carbon stocks in mineral soils | Carbon dioxide emissions |
|---|---|---|---|
| | | thousand t C/year | $GgCO_2$/year |
| 2000 | | | |
| Grassland | 1846.4 | -902.5 | -3309.2 |
| Hayland | 139.0 | 108.4 | 397.54 |
| Total | 1985.4 | -794.1 | -2911.7 |
| 2001 | | | |
| Grassland | 1846.0 | -902.5 | -3309.0 |
| Hayland | 139.0 | 109.2 | 400.4 |
| Total | 1985.0 | -793.3 | -2908.6 |
| 2002 | | | |
| Grassland | 1848.6 | -903.7 | -3313.5 |
| Hayland | 141.1 | 110.1 | 403.5 |
| Total | 1989.7 | -793.6 | -2910.0 |
| 2003 | | | |
| Grassland | 1849.7 | -904.2 | -3315.6 |
| Hayland | 141.6 | 110.4 | 405.0 |
| Total | 1991.3 | -793.8 | -2910.6 |
| 2004 | | | |
| Grassland | 1850.8 | -904.8 | -3317.6 |
| Hayland | 142.1 | 110.8 | 406.4 |
| Total | 1992.9 | -794.0 | -2911.2 |
| 2005 | | | |
| Grassland | 1851.9 | -905.4 | -3319.6 |
| Hayland | 142.6 | 111.2 | 407.8 |
| Total | 1994.5 | -794.1 | -2911.8 |
| 2006 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2007 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2008 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 574.5 | 111.7 | 409.5 |
| Total | 2427.8 | -794.2 | -2912.1 |
| 2009 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2010 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2011 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2012 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2013 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |

| Land use | Area, thousand ha | Annual change in carbon stocks in mineral soils | Carbon dioxide emissions |
|---|---|---|---|
| | | thousand t C/year | $GgCO_2$/year |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2014 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2015 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2016 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |
| 2017 | | | |
| Grassland | 1853.3 | -905.9 | -3321.7 |
| Hayland | 143.2 | 111.7 | 409.5 |
| Total | 1996.5 | -794.2 | -2912.1 |

Since information about areas converted into grasslands from other land-use categories (forest lands, wetlands etc.) for the inventory is not available, the calculations were not conducted in this case. It should be noted, however, that in Georgia there are no facts of large-scale conversion of various categories of areas into grasslands; neither large-scale misappropriation of areas (for future use as pastures) have occurred.

**Methodological issues**

- ***Estimation Method***

The below-ground carbon stocks prevail on grasslands. The carbon stock is accumulated mainly in the root system and organic mass of soil.

The carbon stock contained in grasslands is affected by anthropogenic activity and natural phenomena. Annual accumulation of biomass on grasslands may result in high volumes, but due to rapid losses (grazing, mowing, fires etc.) the grasslands become the source of emission.

The calculations have been carried out following the Tier 1 methodology. In this case the methodology defines that calculations are carried out only on carbon stocks contained in the soil. Taking this into account, the calculation has been carried out correspondingly, by the equation[114] used for croplands, but the factors have been taken from the Table[115] designated for grasslands.

Despite the fact that grasslands and hay lands are included jointly in this land-use category, , the regimes of their management radically differ from each other. Thus, calculations of carbon stock changes in soils implied for grasslands and hay lands have been carried out separately.

**Mineral soils**

The formula for calculation of changes in carbon stocks in mineral soils is given below:

$$\Delta C_{GGMineral} = [(SOC_0 - SOC_{(0-T)}) \times A] / T,$$

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I,$$

[114]http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html(equi. 3.3.3.)
[115] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_06_Ch6_Grassland.pdf , TABLE 6.2

Where:

$\Delta C_{GGMineral}$ = annual change in carbon stocks in mineral soils, tonnes C yr-1
$SOC_0$ = soil organic carbon stock in the inventory year, tons C ha-1
$SOC_{(0-T)}$= soil organic carbon stock T years prior to the inventory, tonnes C ha-1
T = inventory time period, yr (default is 20 yr)
A= land area of each parcel, ha
$SOC_{REF}$ = the reference carbon stock, tonnes C ha-1;
$F_{LU}$ = stock change factor for land use or land-use change type, dimensionless;
$F_{MG}$ = stock change factor for management regime, dimensionless;
$F_I$ = stock change factor for input of organic matter, dimensionless.

**Organic soils**
Calculations on grasslands and hay lands existing on organic soils are usually carried out when drainage works are carried out. In Georgia, the drainage works on wet grasslands and hay lands are not conducted, therefore the calculations were not made.

It should also be noted, that due to unavailability of data for liming of grasslands and hay lands (areas of limed grasslands) the calculations were not conducted for this category.

- ***Emission Factors***

Since the calculations for soils have been carried out mainly following the Tier 1 approach, the significant part of Emission Factors has been taken from the Table 6.2 provided in the methodology:[116]. With regard to the value of the reference carbon stock for grasslands, similarly to croplands the data have been taken from research conducted in Georgia and it equals to 52 t C/ha.

Since an essential degradation of grasslands is noted in Georgia, a stock change factor corresponding to abrupt degradation has been taken for Eastern Georgia[117] for the regime of areas management ($F_{MG}$), and a factor envisaged for average degradation - for Western Georgia.

Hay lands as compared to grasslands undergo less degradation and therefore their state is more stable. Respectively, different factors (of less degradation) have been applied for them (Table *5-24*).

Table 5-24 Emission Coefficients Used in Calculations (grassland -1990)

| **Emission Factors** | **$SOC_{(0-T)}$ - soil organic carbon stock T years prior to the inventory, tons C ha-1;** | | **$SOC_0$- soil organic carbon stock in the inventory year, tons C ha-1** | |
|---|---|---|---|---|
| | **West Georgia, temperate warm, humid** | **East Georgia, temperate warm and dry** | **West Georgia, temperate warm, humid** | **East Georgia, temperate warm and dry** |
| $SOC_{REF}$- the reference carbon stock, tons C ha | 52 | | | |
| $F_{LU}$ - stock change factor for land use or land-use change type | 1 | 1 | 1 | 1 |
| $F_{MG}$ - stock change factor for management regime | 1 | 1 | 0.95 | 0.70 |
| $F_I$ - stock change factor for input of organic matter | 1 | 1 | 1 | 1 |

[116]AFOLU, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_06_Ch6_Grassland.pdf ,GRASSLAND, Table 6.2.
[117] http://www.moe.gov.ge/ka/%E1%83%97%E1%83%94%E1%83%9B%E1%83%94%E1%83%91%E1%83%98/mica

- ***Activity Data***

The distribution of grasslands and hay lands in Georgia is provided in Table *5-25*. Since the condition of grasslands (in contrast to hay lands) on the territories of Western and Eastern Georgia drastically differs from each other (the grasslands of Eastern Georgia undergo intense degradation), therefore, in order to increase the accuracy, calculations were carried out separately for Western and Eastern Georgia.

Table 5-25 Areas of Grasslands and Hay Lands

| Years | Total, thousand ha | Hayland, thousand ha | Grassland, thousand ha | | |
|---|---|---|---|---|---|
| | | | Total, thousand ha | Temperate warm, humid | Temperate warm, dry |
| 1990 | 1956.5 | 130.0 | 1826.5 | 566.2 | 1260.3 |
| 1991 | 1961.5 | 131.2 | 1830.3 | 567.4 | 1262.9 |
| 1992 | 1966.6 | 132.5 | 1834.1 | 568.6 | 1265.5 |
| 1993 | 1971.6 | 133.7 | 1837.9 | 569.8 | 1268.1 |
| 1994 | 1976.5 | 135.0 | 1841.5 | 570.9 | 1270.6 |
| 1995 | 1978.1 | 135.8 | 1842.3 | 571.2 | 1271.1 |
| 1996 | 1979.7 | 136.6 | 1843.1 | 571.5 | 1271.6 |
| 1997 | 1981.3 | 137.4 | 1843.9 | 571.8 | 1272.1 |
| 1998 | 1982.9 | 138.2 | 1844.7 | 572.1 | 1272.6 |
| 1999 | 1984.5 | 139.0 | 1845.5 | 572.4 | 1273.1 |
| 2000 | 1986.5 | 140.1 | 1846.4 | 572.3 | 1274.1 |
| 2001 | 1988.1 | 140.6 | 1847.5 | 572.6 | 1274.9 |
| 2002 | 1989.7 | 141.1 | 1848.6 | 572.9 | 1275.7 |
| 2003 | 1991.3 | 141.6 | 1849.7 | 573.2 | 1276.5 |
| 2003 | 1992.9 | 142.1 | 1850.8 | 573.5 | 1277.3 |
| 2004 | 1994.5 | 142.6 | 1851.9 | 573.8 | 1278.1 |
| 2005 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2006 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2007 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2008 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2009 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2010 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2011 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2012 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2013 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2014 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2015 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2016 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |
| 2017 | 1996.5 | 143.2 | 1853.3 | 574.5 | 1278.8 |

### 5.7.1. Grassland remaining Grassland (4.C.1)

No calculations were performed for this source category due to lack of relevant data.

### 5.7.2. Land converted to Grassland (4.C.2)

No calculations were performed for this source category due to lack of relevant data.

## 5.8. Wetlands (4.D)

### 5.8.1. Wetlands remaining Wetlands (4.D.1)

Wetlands, in their number marshes, in Georgia due to specific landscape and climatic conditions are mainly presented in Kolkheti and Javakheti, though it should be noted, that despite high anthropogenic impact, the fragments and habitats of watery areas are also preserved in Eastern Georgia. In total, wetlands cover 51,500 ha of Georgian territory. The areas of wetlands are provided in Table *5-26*.

Table 5-26 Wetlands

| Major lakes | |
|---|---|
| **Name** | **Ha** |
| Bazaleti | 122 |
| Lisi | 47 |
| Paliastomi | 1820 |
| Ritsa | 149 |
| Saghamo | 481 |
| Tabatskuri | 1420 |
| Paravani | 3750 |
| Khozafin, Kartsakhi | 2630 |
| Jandar | 1250 |
| Khadik | 14 |
| Santi | 73 |
| Chanchal | 1330 |
| Madatap | 878 |
| Keli | 128 |
| Tobavarchkhili | 21 |
| Grdzeli | 17 |
| Ertso | 31 |
| Kochebis | 38 |
| Mrude | 26 |
| Abulis | 90 |
| Bugdasheni | 39 |
| Paskias | 177 |
| Bareti | 124 |
| Didi gldani | 20 |
| **Total** | **14675** |
| **Major reservoirs, ha** | |
| **Name** | **Ha** |
| Gali | 803 |
| Enguri | 1350 |
| Jinvali | 1150 |
| Samgori | 1180 |
| Sioni | 1200 |
| Tkibuli | 1150 |
| Shaori | 1320 |
| Tsalka | 3370 |
| Vartsikhe | 510 |
| Gumati | 240 |
| Algeti | 230 |
| Lajanuri | 160 |
| Nadarbazevi | 118 |
| Zonkari | 140 |
| **Total** | **12921** |
| **Total lakes and reservoirs** | **27596** |
| | |

| | |
|---|---|
| **Swamps** | **51500** |
| | |
| **Total (Major lakes, reservoirs and swamps)** | **79096** |
| | |
| **Other internal water fund** | **76,604** |
| Black Sea territorial waters of Georgia | 679400 |
| | |
| **SUM** | **835100** |

### 5.8.2. Land converted to Wetlands (4.D.2)

No calculations were performed for this source category due to lack of relevant data.

## 5.9. Settlements (4.E)

### 5.9.1. Settlements remaining Settlements (4.E.1)

Since the data needed for calculations (such as: areas covered by timber plants (ha) in all settlements (cities, villages and settlements), in all years, as well as the volume of annual accumulation of carbon in the mentioned crops (t C/year), and average age of woody plants in composition of cover (year)),were not available in Georgia, the calculations were not conducted. Only limited data on planting provided in the sustainable energy action plans for several self-governed cities are available, which is not sufficient to represent and reflect the general situation in Georgia.

Table 5-27 Settlements

| **Settlements, thousand ha** | | **88.4** |
|---|---|---|
| E.g. Major cities | | |
| | Population (year) | Area, ha |
| Tbilisi | 1 118 300 (2015) | 50200 |
| Batumi | 152 839 (2015) | 1937 |
| Kutaisi | 147 635 (2015) | 5600 |
| Kutaisi | 125 103 (2015) | 6000 |
| Gori | 49 700 (2015) | 2320 |
| Zugdidi | 42 998 (2015) | 2180 |
| Rustavi | 19 629(2015) | 1963 |
| Poti | 41 465 (2015) | 6900 |
| | **Total** | 77100 |
| **Infrastructure, thousand ha** | | **122.8** |
| E.g. Highways | | |
| | Length, km | Area, ha |
| Of international significance | 1595.0 | 15950.0 |
| Of domestic importance | 5372.6 | 37608.2 |
| Total | 6967.6 | 53558.2 |
| E.g. Area covered by railway tracks | | |
| Length of main rails | 1441.7 | 4,325.0 |
| | **Total** | 57,883 |
| **Total settlements and infrastructure, thousand ha** | | **211.2** |

### 5.9.2. Land converted to Settlements (4.E.2)

No calculations were performed for this source category due to lack of relevant data.

## 5.10. Other land (4.F)

According to the IPCC methodology, calculations are not conducted for this category, since it is considered that normally these are unmanaged areas. As for the lands converted into the other land category (forest lands, wetlands etc.) there is lack of the statistical data in Georgia on  such conversions, , consequently carbon stock change estimation for these land-use conversion category has not been conducted.

### 5.10.1. Other land remaining Other land (4.F.1)

No calculations were performed for this source category due to lack of relevant data.

### 5.10.2. Land converted to Other land (4.F.2)

No calculations were performed for this source category due to lack of relevant data.

## 5.11. Harvested Wood Products (4.G)

No calculations were performed for this source category due to lack of relevant data.

### 5.11.1. Buildings

No calculations were performed for this source category due to lack of relevant data.

### 5.11.2. Wood used for other than buildings

No calculations were performed for this source category due to lack of relevant data.

### 5.11.3. Paper and paperboard

No calculations were performed for this source category due to lack of relevant data.

## 5.12. Direct $N_2O$ emissions from N inputs to managed soils (4. (I))

No calculations were performed for this source category due to lack of relevant data.

## 5.13. Emissions and Removals from Drainage and Rewetting and Other Management of Organic and Mineral soils (4.(II))

No calculations were performed for this source category due to lack of relevant data.

## 5.14. Direct $N_2O$ emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (4.(III))

No calculations were performed for this source category due to lack of relevant data.

## 5.15. Indirect nitrous oxide ($N_2O$) emissions from managed soils (4.(IV))

No calculations were performed for this source category due to lack of relevant data.

## 5.16. Biomass burning (4.(V))

The calculations for this source category, based on currently available data, were only carried out in the forest land section. In particular, the magnitude of $CO_2$ and other greenhouse gas emissions from biomass combustion during forest fires was estimated by years (*Table 5-6*).

# Chapter 6. Waste (CRF Sector 5)

## 6.1. Overview of Sector

Waste Management is still an environmental challenge for Georgia - poor waste management leads to one of the most important environmental problems.

Georgia makes efforts to improve the situation. In 2015 Solid Waste Management Code of Georgia entered into force. The Code aimed at establishing a legal framework in the field of solid waste management for implementing measures that will facilitate waste prevention and its increased re-use as well as environmentally safe treatment of waste (which includes recycling and separation of secondary raw materials, energy recovery from waste and safe disposal of waste).

Solid Waste Management Company of Georgia (SWMCG) intends to construct new regional landfills and systems of connected transfer stations to assure a fully integrated solid waste management system in Georgia in the future. The core mission of SWMCG is to replace all former municipal landfills over the period of about 10 years with a system of regional landfills and a network of connected transfer stations. A certain number of former municipal landfills will be closed, and some of them will be transformed into transfer stations.

Untreated municipal wastewater is a major cause of surface water pollution in Georgia. Water used in households and industry contains a huge amount of toxins that gravely degrade the natural environment, flora and fauna, and the quality of life of the population.

The centralized sewage system exists in 45 towns in Georgia. The systems are, however, in poor condition. The plants are typically 30-45 years old; some are still uncompleted, and most them are not maintained. Most of the wastewater treatment plants cannot provide sewage treatment with high efficiency. None of the existing plants (excluding Adlia plant) provide actual biological treatment since the technical facilities are out of order.

In Adlia treatment plant wastewater is cleaned in several mechanical and chemical stages. At primary mechanical cleaning stage wastewater is cleaned of sand, fat and residue. Silt is collected and stabilized. At biological cleaning stage ammonium transforms into nitrate and protein and hydrocarbons are reduced. At secondary mechanical cleaning silt is removed.

The estimated GHG emissions from waste sector are provided in *Table 6-1* and *Table 6-2*

Table 6-1 Methane and Nitrous Oxide emissions (in Gg) from Waste sector in 1990-2017

| **Year** | **$CH_4$** | | | | **$N_2O$** |
|---|---|---|---|---|---|
| | **Solid Waste Disposal Sites (5.A)** | **Domestic W/W Handling (5.D.1)** | **Industrial W/W Handling (5.D.2)** | **Total** | **Domestic W/W Handling** |
| 1990 | 31.15 | 11.45 | 8.84 | 51.44 | 0.18 |
| 1991 | 32.78 | 11.5 | 5.83 | 50.11 | 0.18 |
| 1992 | 34.27 | 11.48 | 4.47 | 50.22 | 0.18 |
| 1993 | 35.63 | 11.22 | 3.34 | 50.19 | 0.19 |
| 1994 | 36.94 | 10.29 | 1.96 | 49.19 | 0.19 |
| 1995 | 38.18 | 9.99 | 2.52 | 50.69 | 0.19 |
| 1996 | 39.27 | 9.71 | 3.12 | 52.10 | 0.19 |
| 1997 | 40.25 | 9.46 | 3.76 | 53.47 | 0.18 |
| 1998 | 41.13 | 9.32 | 4.32 | 54.77 | 0.18 |
| 1999 | 41.97 | 9.23 | 4.99 | 56.19 | 0.19 |
| 2000 | 42.95 | 9.14 | 5.59 | 57.68 | 0.19 |

| Year | $CH_4$ | | | | $N_2O$ |
|---|---|---|---|---|---|
| | Solid Waste Disposal Sites (5.A) | Domestic W/W Handling (5.D.1) | Industrial W/W Handling (5.D.2) | Total | Domestic W/W Handling |
| 2001 | 43.82 | 9.06 | 5.78 | 58.66 | 0.18 |
| 2002 | 44.59 | 8.99 | 5.87 | 59.45 | 0.18 |
| 2003 | 45.28 | 8.87 | 6.05 | 60.20 | 0.18 |
| 2004 | 45.94 | 8.74 | 6.3 | 60.98 | 0.19 |
| 2005 | 46.62 | 8.61 | 6.53 | 61.76 | 0.18 |
| 2006 | 47.33 | 8.49 | 7.04 | 62.86 | 0.18 |
| 2007 | 48.14 | 8.36 | 7.5 | 64.00 | 0.18 |
| 2008 | 48.94 | 8.23 | 7.91 | 65.08 | 0.18 |
| 2009 | 49.71 | 8.19 | 8.8 | 66.70 | 0.18 |
| 2010 | 50.37 | 8.13 | 9.46 | 67.96 | 0.18 |
| 2011 | 50.68 | 8.08 | 10.45 | 69.21 | 0.18 |
| 2012 | 51.93 | 8 | 10.66 | 70.59 | 0.18 |
| 2013 | 52.29 | 7.96 | 10.51 | 70.76 | 0.18 |
| 2014 | 52.59 | 7.95 | 10.6 | 71.14 | 0.18 |
| 2015 | 52.80 | 7.97 | 10.91 | 71.68 | 0.18 |
| 2016 | 53.00 | 7.98 | 10.47 | 71.45 | 0.19 |
| 2017 | 53.17 | 7.97 | 10.42 | 71.56 | 0.19 |

*Table 6-2* Methane and Nitrous Oxide emissions (in Gg $CO_2$eq) from Waste sector in 1990-2017 years

| Year | Solid Waste Disposal Sites-$CH_4$ | Domestic W/W Handling-$CH_4$ | Industrial W/W Handling-$CH_4$ | Domestic W/W Handling-$N_2O$ | Total |
|---|---|---|---|---|---|
| 1990 | 654 | 240 | 186 | 55 | **1,135** |
| 1991 | 688 | 241 | 122 | 55 | **1,106** |
| 1992 | 720 | 241 | 94 | 55 | **1,110** |
| 1993 | 748 | 236 | 70 | 58 | **1,112** |
| 1994 | 776 | 216 | 41 | 58 | **1,091** |
| 1995 | 802 | 210 | 53 | 60 | **1,125** |
| 1996 | 825 | 204 | 66 | 58 | **1,153** |
| 1997 | 845 | 199 | 79 | 57 | **1,180** |
| 1998 | 864 | 196 | 91 | 57 | **1,208** |
| 1999 | 881 | 194 | 105 | 57 | **1,237** |
| 2000 | 902 | 192 | 117 | 58 | **1,269** |
| 2001 | 920 | 190 | 121 | 57 | **1,288** |
| 2002 | 936 | 189 | 123 | 57 | **1,305** |
| 2003 | 951 | 186 | 127 | 57 | **1,321** |
| 2004 | 965 | 184 | 132 | 58 | **1,339** |
| 2005 | 979 | 181 | 137 | 57 | **1,354** |
| 2006 | 994 | 178 | 148 | 56 | **1,376** |
| 2007 | 1,011 | 176 | 158 | 55 | **1,400** |
| 2008 | 1,028 | 173 | 166 | 54 | **1,421** |
| 2009 | 1,044 | 172 | 185 | 55 | **1,456** |
| 2010 | 1,058 | 171 | 199 | 55 | **1,483** |
| 2011 | 1,064 | 170 | 220 | 55 | **1,509** |
| 2012 | 1,090 | 168 | 224 | 56 | **1,538** |
| 2013 | 1,098 | 167 | 221 | 56 | **1,542** |
| 2014 | 1,104 | 167 | 223 | 57 | **1,551** |
| 2015 | 1,109 | 167 | 229 | 57 | **1,562** |
| 2016 | 1,113 | 168 | 220 | 58 | **1,559** |
| 2017 | 1,117 | 167 | 219 | 59 | **1,562** |

The shares of different source categories in waste sector emissions are presented in *Table 6-3*. Methane emissions from Solid Waste Disposal Sites are dominant.

Table 6-3 Share of different source categories in GHG emissions from waste sector

| Year | Solid Waste Disposal Sites-$CH_4$ | Domestic W/W Handling-$CH_4$ | Industrial W/W Handling-$CH_4$ | Domestic W/W Handling-$N_2O$ | Total |
|---|---|---|---|---|---|
| 1990 | 56 | 22 | 17 | 5 | 100 |
| 1991 | 61 | 22 | 11 | 5 | 100 |
| 1992 | 64 | 22 | 9 | 5 | 100 |
| 1993 | 66 | 22 | 7 | 5 | 100 |
| 1994 | 70 | 20 | 4 | 5 | 100 |
| 1995 | 70 | 19 | 5 | 5 | 100 |
| 1996 | 71 | 18 | 6 | 5 | 100 |
| 1997 | 71 | 17 | 7 | 5 | 100 |
| 1998 | 71 | 17 | 8 | 5 | 100 |
| 1999 | 70 | 16 | 9 | 5 | 100 |
| 2000 | 70 | 16 | 10 | 5 | 100 |
| 2001 | 71 | 15 | 10 | 5 | 100 |
| 2002 | 71 | 15 | 10 | 4 | 100 |
| 2003 | 71 | 14 | 10 | 4 | 100 |
| 2004 | 71 | 14 | 10 | 4 | 100 |
| 2005 | 71 | 14 | 10 | 4 | 100 |
| 2006 | 71 | 13 | 11 | 4 | 100 |
| 2007 | 71 | 13 | 12 | 4 | 100 |
| 2008 | 72 | 13 | 12 | 4 | 100 |
| 2009 | 71 | 12 | 13 | 4 | 100 |
| 2010 | 71 | 12 | 14 | 4 | 100 |
| 2011 | 70 | 11 | 15 | 4 | 100 |
| 2012 | 70 | 11 | 15 | 4 | 100 |
| 2013 | 70 | 11 | 15 | 4 | 100 |
| 2014 | 70 | 11 | 15 | 4 | 100 |
| 2015 | 70 | 11 | 15 | 4 | 100 |
| 2016 | 71 | 11 | 15 | 4 | 100 |
| 2017 | 71 | 11 | 14 | 4 | 100 |

### Comparison of recalculated GHG emissions with relevant values from SBUR

For 1990, 1994, 2000, 2005, 2011-2015 years the recalculated values have been compared with relevant values from Second Biennial Update Report (SBUR). Differences are provided in *Table 6-4*. According to this table the difference between FNC and SBUR varies within the range of 0%-10%. Solid Waste Disposal Sites reflect the most significant difference among the categories. Differences are caused mainly due to application of specified activity data. In case of SWDS delay in time was taken into account.

Table 6-4 Difference (in %) between FNC and Second BUR

| Year | CH4 / Solid Waste Disposal Sites | Previous inventories (SBUR) | Difference, in % | CH4 / Domestic Waste Water Handling | Previous inventories (SBUR) | Difference, in % | CH4 / Industrial Waste Water | Previous inventories (SBUR) | Difference, in % | $N_2O$ / Domestic Waste Water Handling | Previous inventories (SBUR) | Difference, in % | $CO_2$-eq emissions from Waste sector | Previous inventories (SBUR) | Difference, in % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 654 | 558 | 17 | 240 | 227 | 6 | 186 | 263 | -29 | 55 | 57 | -4 | **1,135** | **1,105** | **3** |
| 1994 | 776 | 663 | 17 | 216 | 218 | -1 | 41 | 42 | -3 | 58 | 54 | 7 | **1,091** | **977** | **12** |
| 2000 | 902 | 764 | 18 | 192 | 191 | 0 | 117 | 117 | 0 | 58 | 53 | 9 | **1,269** | **1,125** | **13** |
| 2005 | 979 | 824 | 19 | 181 | 183 | -1 | 137 | 139 | -2 | 57 | 54 | 6 | **1,354** | **1,200** | **13** |
| 2010 | 1,058 | 881 | 20 | 171 | 183 | -7 | 199 | 211 | -6 | 55 | 55 | 0 | **1,483** | **1,330** | **11** |
| 2011 | 1,064 | 891 | 19 | 170 | 183 | -7 | 220 | 233 | -6 | 55 | 55 | 0 | **1,509** | **1,362** | **11** |
| 2012 | 1,090 | 893 | 22 | 168 | 181 | -7 | 224 | 246 | -9 | 56 | 55 | 2 | **1,538** | **1,375** | **12** |
| 2013 | 1,098 | 894 | 23 | 167 | 181 | -8 | 221 | 244 | -10 | 56 | 56 | 0 | **1,542** | **1,375** | **12** |
| 2014 | 1,104 | 895 | 23 | 167 | 183 | -9 | 223 | 243 | -8 | 57 | 57 | 0 | **1,551** | **1,378** | **13** |
| 2015 | 1,109 | 894 | 24 | 167 | 183 | -9 | 229 | 253 | -10 | 57 | 58 | -2 | **1,562** | **1,388** | **13** |
| 2016 | 1,113 | | | 168 | | | 220 | | | 58 | | | **1,559** | | |
| 2017 | 1,117 | | | 167 | | | 219 | | | 59 | | | **1,562** | | |

## 6.2. Solid Waste Disposal (5.A.)

Presently there are 56 municipal landfills in Georgia. Solid Waste Management Company of Georgia manages 53 landfills, 2 landfills are managed by Municipality of Batumi city in Adjara Autonomous Republic and Didi Lilo landfill is managed by Tbilisi municipality.

The methane emissions from landfills in Georgia are estimated based on the IPCC First order decay (FOD) method. The IPCC FOD method assumes that the degradable organic component/degradable organic carbon (DOC) in waste decays slowly throughout a few decades, during which CH4 and CO2 are produced.

**IPCC First order decay (FOD) method:**

According to the 2006 IPCC "The FOD method requires data to be collected or estimated for historical disposals of waste over a time period of 3 to 5 half-lives in order to achieve an acceptably accurate result". This requirement is fulfilled for majority of landfills.

$$CH_{4generated,t} = \{DDOCm_t \times [1 - exp(-k)] + H_{t-1} \times [1 - exp(-k)]\} \times 16/12 \times F_t$$

$$H_t = DDOCm_t \times \exp(-k) + H_{t-1} \times \exp(-k), \qquad H_0 = 0$$

$$DDOCm_t = W_t \times DOC_t \times DOCF_t \times MCF_t$$

Production of CH4 does not begin immediately after disposal of the waste.

DDOCm decomp = DDOCm0 x {1 – exp[-k x DL) / 12] }

Where

DL- time delay in months

$$W_t = Pop_t \times GR_t \times MSW_{F,t}$$

Where:

| | |
|---|---|
| $CH_{4\,generated,t}$ | $CH_4$ generated in year t |
| $t$ | year of inventory |
| $DDOC_{mt}$ | mass of decomposable DOC deposited in year t (Gg) |
| $k=ln(2)/t_{1/2}$ | methane generation rate constant |
| $t_{1/2}$ | half life |
| $F_t$ | fraction by volume of $CH_4$ in landfill gas |
| $DOC_t$ | degradable organic carbon in year t |
| $DOC_{F,t}$ | fraction of DOC dissimilated in year t |
| $MCF_t$ | methane correction factor in year t |
| $W_t$ | amount of waste deposited in landfills in year t |
| $Pop_t$ | population whose waste goes to SWDS (habitants) |
| $GR_t$ | MSW generation rate in year t (kg per capita) |
| $MSW_{F,t}$ | fraction of MSW disposed at SWDS in year t |

**Activity data:**

Solid Waste Management Company of Georgia is the source of data on the amount of waste annually deposited in landfills.

**Methane Recovery**

Methane recovery from landfills is not practiced in Georgia.

**MSW generation rate in year t (kg per capita)**

The following values are used for the calculatios: 2006 IPCC default value for Eastern Europe (1.04 kg/capita/day) for 2000-2017 years, 0.85 kg/capita/day (1996 IPCC, Generation rate for Greece) for years prior to 1990 and linear interpolated values for years 1991-1999.

**Fraction of MSW disposed to SWDS**

The following values are used: 2006 IPCC default value for Eastern Europe $MSW_F$ = 0.9 for 2000-2017 years, 0.93 for years before 1990 (1996 IPCC, MSWF for Greece, nearby comparable country) and linear interpolated values for 1991-1999 years.

**Methane correction factor (MCF)**

MCF accounts for the fact that unmanaged SWDS produce less $CH_4$ from a given amount of waste than managed SWDS, since a larger fraction of waste decomposes aerobically in the top layers of unmanaged SWDS.

Table 6-5 MCF default values for different types of landfills

| Landfill type | MCF default values |
|---|---|
| Managed | 1.0 |
| Unmanaged – deep ( >5 m) | 0.8 |
| Unmanaged – shallow ( <5 m) | 0.4 |
| Non categorized | 0.6 |

**Solid waste composition:** There is very scare information about the composition of solid waste disposed in landfills of Georgia. Since 2014 waste composition has been determined for several landfills. Data in Table *5-6* are provided by Solid Waste Management Company of Georgia. Default values for Eastern Europe from the 2006 IPCC are used for other landfills.

Table 6-6 Solid waste composition

| Component /Landfill | Tbilisi | Rustavi | Batumi | Kutaisi | Others |
|---|---|---|---|---|---|
| Food waste | 71 | 42 | 41.2 | 47 | 30.1 |
| Paper/cardboards | 5.6 | 17 | 17.4 | 10 | 21.8 |
| Textiles | 3.2 | | 3.3 | | 4.7 |
| Wood | 2.6 | | 0.5 | | 7.5 |
| Rubber/leather | | | | | 1.4 |
| Other | 17.6 | 41 | 37.6 | 43 | 34.5 |

**Degradable organic carbon (DOC)** is the portion of organic carbon present in solid waste that is susceptible to biochemical decomposition[118]. Data from laboratory experiments conducted by Dr.Barlaz[119] are used for DOC values of specific materials Experiments provided data on the amount of $CH_4$ generated by each type of organic material. DOC for waste components ($DOC^k_{100\%}$) is presented in *Table 6-7*. Data

[118] DOC and $DOC_f$ have been estimated based on "Methodology for estimating of DOC and DOCF". Methodology was examined and approved within the UNDP/GEF Regional Project RER/01/G31" Capacity Building for Improving National GHG Inventories" (Attachment 12 to the Georgia's National Project Report)".

[119] M.A.Barlaz. 1997. "Biodegradative Analysis of Municipal Solid Waste in Laboratory-Scale Landfills", EPA 600/R-97-071. Solid Waste Management and Greenhouse Gases. A Life-Cycle Assessment of Emissions and Sinks. 2nd EDITION. EPA 530-R-02-006.

from this table are used in calculations of DOC containing in k component ($DOC^k_p$) of waste and DOC in total.

$$DOC_p^k = DOC_{100\%}^k \times \frac{P}{100}; \quad DOC = \sum_k DOC_p^k$$

Table 6-7 Estimated DOC for solid waste disposed on landfills

| **Component /Landfill** | **Tbilisi** | **Rustavi** | **Batumi** | **Kutaisi** | **Others** |
|---|---|---|---|---|---|
| DOC | 0.146 | 0.126 | 0.145 | 0.105 | 0.188 |

Table 6-8 Details of DOC estimation (case of other landfills)

| **Component** | **Dry-wet Ratio** | **$DOC^k_{100\%}$** | | **Waste composition, %** | **$DOC^k_p$** |
|---|---|---|---|---|---|
| | | **Dry** | **wet** | | |
| | **A** | **B** | **C=A*B** | **D** | **E=C*D/100** |
| Second Food | 0.300 | 0.458 | 0.137 | 30.1 | 0.0414 |
| Broad Definition for Mixed Paper | 0.945 | 0.425 | 0.402 | 21.8 | 0.0876 |
| Textiles | 0.900 | 0.550 | 0.495 | 4.7 | 0.0233 |
| Wood | 0.800 | 0.492 | 0.394 | 7.5 | 0.0295 |
| Leather | 0.800 | 0.600 | 0.480 | 1.4 | 0.0067 |
| Other | | | | 34.0 | |
| $\Sigma_k DOC^k_p$ | | | | 100 | **0.1884** |

**Fraction of degradable organic carbon dissimilated ($DOC_F$)** is the portion of DOC that is converted to landfill gas. It is a good practice to use a value of 0.5 – 0.6 (including lignin C) as the default. According to GPG, national values for $DOC_F$ can be used, but they should be based on well-documented research. For the maximum digestibility of lignocellulosic materials a log-linear relationship of Van Soest and data from Barlaz's experiment were used. $DOC_F$ for mix of materials (municipal solid waste) was calculated by formula:

$$DOC_F = \sum_k \frac{(DOC_k \times DOC_{Fk})}{DOC}$$

Table 6-9 Estimated $DOC_F$ for solid waste disposed on landfills

| **Component /Landfill** | **Tbilisi** | **Rustavi** | **Batumi** | **Kutaisi** | **Others** |
|---|---|---|---|---|---|
| $DOC_F$ | 0.627 | 0.581 | 0.573 | 0.616 | 0.521 |

Table 6-10 Details of $DOC_F$ estimation (case of other landfills)

| | **$DOC_i$** | **$DOC_{Fi}$** | **$DOC_i$*$DOC_{Fi}$** | **$DOC_F$** |
|---|---|---|---|---|
| Second Food | 0.0414 | 0.7010 | 0.0290 | |
| Broad Definition for Mixed Paper | 0.0876 | 0.4800 | 0.0420 | |
| Textiles | 0.0233 | 0.5500 | 0.0128 | |
| Wood | 0.0295 | 0.3600 | 0.0106 | |
| Leather | 0.0067 | 0.5500 | 0.0037 | |
| Σ | 0.1884 | | 0.0981 | **0.5208** |

**Fraction of $CH_4$ in landfill gas (F):**

The Extended Buswell Equation[120] was used for calculating the fraction of volume of $CH_4$ in landfill gas

[120] Buswell A.M., Hatfield W.D. (ed.) (1937): Anaerobic Fermentations. State of Illinois, Department of Registration and Education, Bulletin No. 32.

Table 6-11 Estimated fraction of $CH_4$ in landfill gas

| Component /Landfill | Tbilisi | Rustavi | Batumi | Kutaisi | Others |
|---|---|---|---|---|---|
| Fraction of $CH_4$ in landfill gas | 0.537 | 0.531 | 0.532 | 0.535 | 0.531 |

**Half life (t1/2):**

The half-life value is the time taken for the DOCm in waste to decay to half its initial mass. k = ln(2)/t1/2. For cities located in Western Georgia k=0.09 (t1/2=7.7) and for cities in Eastern Georgia k=0.06 (t1/2=11.55).

**Time delay:**

It is supposed that CH4 production will begin 6 months after waste disposal, i.e. DL = 6 months.

### The estimated methane emissions

Estimated methane emissions from the SWDSs of Georgia are provided in Table 6-12.

Table 6-12 Methane emissions from SWDSs of Georgia

| Year | Tbilisi | | | | Kutaisi | Rustavi | | Batumi | Gori | Poti | Zygdidi | | Hypothetic | | GHG emissions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Didi Lilo | Gldani (closed) | Iagludji (closed) | Lilo (closed) | | Closed | New | | | | Closed | New | I (MCF=0.4) | II (MCF=0.8) | $GgCH_4$ | $GgCO_2eq$ |
| 1990 | | 13.33 | 2.43 | 0.35 | 4.11 | 1.84 | | 3.46 | 0.38 | 0.89 | | | 3.82 | 0.55 | 31.15 | 654 |
| 1991 | | 13.69 | 2.86 | 0.57 | 4.21 | 1.89 | | 3.54 | 0.43 | 0.91 | | | 4.07 | 0.60 | 32.78 | 688 |
| 1992 | | 14.03 | 3.29 | 0.78 | 4.30 | 1.86 | | 3.63 | 0.49 | 0.93 | | | 4.31 | 0.64 | 34.27 | 720 |
| 1993 | | 14.35 | 3.72 | 0.98 | 4.40 | 1.75 | | 3.73 | 0.54 | 0.94 | | | 4.55 | 0.67 | 35.63 | 748 |
| 1994 | | 14.62 | 4.13 | 1.18 | 4.49 | 1.65 | | 3.84 | 0.59 | 0.96 | | | 4.77 | 0.70 | 36.94 | 776 |
| 1995 | | 14.84 | 4.51 | 1.39 | 4.59 | 1.56 | | 3.95 | 0.64 | 0.97 | | | 4.99 | 0.73 | 38.18 | 802 |
| 1996 | | 15.03 | 4.86 | 1.59 | 4.68 | 1.46 | | 4.04 | 0.68 | 0.99 | | | 5.19 | 0.76 | 39.27 | 825 |
| 1997 | | 15.18 | 5.17 | 1.78 | 4.75 | 1.38 | | 4.12 | 0.73 | 1.00 | | | 5.37 | 0.78 | 40.25 | 845 |
| 1998 | | 15.30 | 5.44 | 1.96 | 4.82 | 1.30 | | 4.18 | 0.77 | 1.01 | | | 5.55 | 0.80 | 41.13 | 864 |
| 1999 | | 15.40 | 5.70 | 2.12 | 4.88 | 1.22 | | 4.24 | 0.80 | 1.03 | | | 5.73 | 0.84 | 41.97 | 881 |
| 2000 | | 15.49 | 5.95 | 2.27 | 4.93 | 1.15 | | 4.31 | 0.83 | 1.03 | 0.16 | | 5.90 | 0.91 | 42.95 | 902 |
| 2001 | | 15.57 | 6.19 | 2.42 | 4.97 | 1.08 | | 4.36 | 0.86 | 1.04 | 0.27 | | 6.09 | 0.97 | 43.82 | 920 |
| 2002 | | 15.64 | 6.40 | 2.55 | 4.99 | 1.02 | | 4.41 | 0.88 | 1.05 | 0.37 | | 6.26 | 1.03 | 44.59 | 936 |
| 2003 | | 15.70 | 6.61 | 2.67 | 4.99 | 0.96 | | 4.45 | 0.90 | 1.06 | 0.45 | | 6.41 | 1.08 | 45.28 | 951 |
| 2004 | | 15.93 | 6.80 | 2.65 | 4.99 | 0.91 | | 4.47 | 0.92 | 1.07 | 0.53 | | 6.55 | 1.13 | 45.94 | 965 |
| 2005 | | 16.33 | 6.98 | 2.50 | 4.97 | 0.85 | | 4.49 | 0.94 | 1.08 | 0.60 | | 6.71 | 1.17 | 46.62 | 979 |
| 2006 | | 16.71 | 7.16 | 2.35 | 4.95 | 0.80 | | 4.50 | 0.97 | 1.08 | 0.67 | | 6.91 | 1.22 | 47.33 | 994 |
| 2007 | | 17.06 | 7.36 | 2.21 | 4.93 | 0.76 | | 4.52 | 0.99 | 1.09 | 0.74 | | 7.19 | 1.30 | 48.14 | 1,011 |
| 2008 | | 17.41 | 7.55 | 2.08 | 4.89 | 0.71 | | 4.52 | 1.01 | 1.10 | 0.79 | | 7.48 | 1.39 | 48.94 | 1,028 |
| 2009 | | 17.74 | 7.76 | 1.96 | 4.85 | 0.67 | | 4.53 | 1.03 | 1.11 | 0.85 | | 7.75 | 1.46 | 49.71 | 1,044 |
| 2010 | | 18.06 | 7.96 | 1.85 | 4.80 | 0.63 | | 4.53 | 1.06 | 1.11 | 0.84 | | 8.00 | 1.54 | 50.37 | 1,058 |
| 2011 | | 17.70 | 8.16 | 1.74 | 4.74 | 0.60 | | 4.53 | 1.08 | 1.12 | 0.77 | 0.42 | 8.22 | 1.60 | 50.68 | 1,064 |
| 2012 | 2.25 | 16.67 | 7.69 | 1.64 | 4.68 | 0.56 | 0.22 | 4.52 | 1.11 | 1.12 | 0.70 | 0.64 | 8.46 | 1.67 | 51.93 | 1,090 |
| 2013 | 3.64 | 15.70 | 7.24 | 1.54 | 4.62 | 0.53 | 0.36 | 4.52 | 1.13 | 1.13 | 0.64 | 0.83 | 8.70 | 1.72 | 52.29 | 1,098 |
| 2014 | 4.92 | 14.78 | 6.82 | 1.45 | 4.54 | 0.50 | 0.50 | 4.52 | 1.16 | 1.13 | 0.59 | 0.97 | 8.93 | 1.78 | 52.59 | 1,104 |
| 2015 | 6.11 | 13.92 | 6.42 | 1.37 | 4.47 | 0.47 | 0.64 | 4.51 | 1.18 | 1.14 | 0.54 | 1.09 | 9.13 | 1.82 | 52.80 | 1,109 |
| 2016 | 7.24 | 13.11 | 6.05 | 1.29 | 4.40 | 0.44 | 0.77 | 4.51 | 1.21 | 1.14 | 0.49 | 1.17 | 9.32 | 1.87 | 53.00 | 1,113 |

| Year | Tbilisi | | | | Kutaisi | Rustavi | | Batumi | Gori | Poti | Zygdidi | | Hypothetic | | GHG emissions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Didi Lilo | Gldani (closed) | Iagludji (closed) | Lilo (closed) | | Closed | New | | | | Closed | New | I (MCF=0.4) | II (MCF=0.8) | $GgCH_4$ | $GgCO_2eq$ |
| 2017 | 8.31 | 12.35 | 5.70 | 1.21 | 4.33 | 0.42 | 0.90 | 4.50 | 1.23 | 1.15 | 0.45 | 1.23 | 9.49 | 1.90 | 53.17 | 1,117 |

### 6.2.1. Managed Disposal Sites (5.A.1.)

All 56 landfills of Georgia are managed. 12 biggest landfills are in 7 cities with the population larger than 50,000. Methane emissions from these landfills are provided in Table 7-12. In 14 landfills waste layer is very shallow and methane is not generated. The rest 30 landfills are classified according to their MCF. Two hypothetic landfills are incorporating all these landfills. In order to calculate the methane emission the simplifying assumption was made that all the waste from landfills with shallow waste layer (<5m) are disposed on hypothetic landfill I and waste from landfills with deep waste layer (≥5m) are disposed on another hypothetic landfill II.

### 6.2.2. Unmanaged Waste Disposal Sites (5.A.2.)

No unmanaged landfills in Georgia.

### 6.2.3. Uncategorized Waste Disposal Sites (5.A.3.)

1357 illegal landfills have been identified within the frames of the project *Clean up Georgia*[121] in 2013,. According to this project the number of illegal landfills decreased to 333 in 2018.

## 6.3. Biological Treatment of Solid Waste (5.B.)

### 6.3.1. Composting (5.B.1)

NO - composting is not practiced in Georgia

### 6.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.)

NO - Anaerobic digesters absent in Georgia

## 6.4. Incineration and Open Burning of Waste (5.C.)

NO - Incineration plants absent in Georgia

NE - In Georgia, no statistics concerning "Open burning of waste".

## 6.5. Wastewater Treatment and Discharge (5.D.)

The water used in households and industry contains a huge amount of toxins that significantly damage the environment. Wastewater handling systems transfer wastewater from its source to a disposal site. Wastewater treatment systems are used to biologically stabilize the wastewater prior to disposal. At the first stage of the wastewater treatment (primary treatment) larger solids from the wastewater are removed.

[121] Implemented by NGO consortium Greens Movement of Georgia/Friends of the Earth Georgia, Georgian Society of Nature Explorers "Orchis, "Ecological Awareness and Waste Management" with financial support of Swedish Government and in collaboration with the Ministry of Environment and Natural Resources Protection of Georgia and Solid Waste Management Company.

Remaining particulates are then allowed to settle. At the next stage treatment comprises the combination of biological processes that promote biodegradation by microorganisms.

Sludge is produced at both stages of treatment. Sludge is produced during the primary treatment consists of solids that are removed from the wastewater. Sludge produced during the secondary treatment is a result of biological growth in the biomass, as well as the collection of small particles. This sludge should be further treated before it can be safely disposed of. Methods of sludge treatment include aerobic and anaerobic stabilization (digestion), conditioning, centrifugation, composting, and drying.

$CH_4$ is produced when wastewater or sludge is anaerobically treated. The methane emissions from aerobic systems are negligible. Wastewater treatment systems generate $N_2O$ through the nitrification and denitrification of sewage nitrogen.

### 6.5.1. Domestic Wastewater (5.D.1.)

**Methodological issues:**

$CH_4$ emissions directly depend on the content of the degradable organic material (DC) in the wastewater. The amount of DC in the wastewater is characterized by the BOD (Biochemical Oxygen Demand) or by COD (Chemical Oxygen Demand). The BOD concentration only reflects the amount of carbon that is aerobically biodegradable. The COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable).

The methane generation also depends on the type of the handling systems and temperature. Systems that provide anaerobic environments will generally produce $CH_4$ whereas systems that provide aerobic environments will normally produce little or no methane. With increases in temperature, the rate of $CH_4$ production increases. $CH_4$ production typically requires the temperature higher than 15°C.

To estimate total emissions from wastewater, the selected emissions factors are multiplied by the associated organic wastewater production and summed.

The following equation is used:

$$CH_4Emission = \left[\sum_{i,j}\left(U_i \times T_{i,j} \times EF_j\right)\right](TOW - S) - R$$

Where:

| | |
|---|---|
| $CH_4$ *Emissions* | $CH_4$ emissions in inventory year, kg $CH_4$/yr |
| $U_i$ | fraction of the population in income group i in inventory year |
| $T_{i,j}$ | degree of utilization of treatment/discharge pathway or system, *j*, for each income group fraction *i* in inventory year |
| $i$ | income group: rural, urban high income and urban low income |
| j | each treatment/discharge pathway or system |
| $EF_j$ | emission factor, kg $CH_4$ / kg BOD |
| $TOW$ | total organics in wastewater in inventory year, kg BOD/yr |
| $S$ | organic component removed as sludge in inventory year, kg BOD/yr |
| $R$ | amount of $CH_4$ recovered in inventory year, kg $CH_4$/yr |

The emission factor for a wastewater treatment and discharge pathway and system is a function of the maximum $CH_4$ producing potential (Bo) and the methane correction factor (MCF) for the wastewater treatment and discharge system.

$$EF_j = B_0 \times MCF_j$$

Where:

| | |
|---|---|
| $j$ | each treatment/discharge pathway or system |
| $Bo$ | maximum $CH_4$ producing capacity, kg $CH_4$/kg BOD |
| $MCF_j$ | methane correction factor (fraction) |

(TOW) is a function of human population and BOD generation per person. It is expressed in terms of biochemical oxygen demand (kg BOD/year). The equation for TOW is:

$$TOW = P \times BOD \times 0.001 \times I \times 365$$

Where:

$TOW$ total organics in wastewater in inventory year, kg BOD/yr
$P$ country population in inventory year, (person)
$BOD$ country-specific per capita BOD in inventory year, g/person/day,
I correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00.)

According to the 2006 IPCC it is a good practice to treat the three categories of residents: rural population, urban high-income population, and urban low-income population. Data on distribution of urban population by income is unavailable in Georgia. It means that summation by I index is only applicable to urban (in total) and rural population.

It is a good practice to use a default value of 0.25 kg$CH_4$/kgCOD or a default value of 0.6 kg$CH_4$/kgBOD (2006 IPCC, chapter 6, p.6.12). I = 1.0.

**Emissions Factors:**

When country-specific data are not available IPCC 2006 recommends selecting a BOD default value from a nearby comparable country. Greece default value BOD = 0.057 kg BOD/cap/day (20,805 kgBOD/1000 persons/yr) was used. Methane conversion factor, MCF varies within 10-80%. Calculations were carried out applying parameter MCF=50%. In villages of Georgia commonly small family latrines (3-5 persons) are used, for rural areas MCF=10%. T varies within 0.1-0.8. T=0.45 for urban and T=1 for rural areas.

**Activity data:**

Data on urban and rural population whose wastewater is handled are provided by the National Statistic Office of Georgia.

Table 6-13 Urban and rural population in 1990-2017 years

| Year | Urban | Rural | Total, thousand habitants |
|---|---|---|---|
| 1990 | 2,999 | 2,426 | 5,424 |
| 1991 | 3,005 | 2,449 | 5,453 |
| 1992 | 2,983 | 2,484 | 5,467 |
| 1993 | 2,914 | 2,432 | 5,346 |
| 1994 | 2,653 | 2,277 | 4,930 |
| 2004 | 2,252 | 1,935 | 4,186 |
| 2005 | 2,238 | 1,863 | 4,102 |
| 2006 | 2,225 | 1,792 | 4,017 |
| 2007 | 2,212 | 1,720 | 3,932 |
| 2008 | 2,199 | 1,649 | 3,848 |

| Year | Urban | Rural | Total, thousand habitants | Year | Urban | Rural | Total, thousand habitants |
|---|---|---|---|---|---|---|---|
| 1995 | 2,568 | 2,226 | 4,794 | 2009 | 2,188 | 1,641 | 3,829 |
| 1996 | 2,483 | 2,191 | 4,675 | 2010 | 2,172 | 1,628 | 3,800 |
| 1997 | 2,413 | 2,146 | 4,558 | 2011 | 2,157 | 1,617 | 3,774 |
| 1998 | 2,366 | 2,139 | 4,505 | 2012 | 2,137 | 1,602 | 3,739 |
| 1999 | 2,338 | 2,132 | 4,470 | 2013 | 2,125 | 1,593 | 3,718 |
| 2000 | 2,308 | 2,127 | 4,435 | 2014 | 2,124 | 1,593 | 3,717 |
| 2001 | 2,293 | 2,102 | 4,395 | 2015 | 2,127 | 1,595 | 3,722 |
| 2002 | 2,278 | 2,078 | 4,356 | 2016 | 2,131 | 1,598 | 3,729 |
| 2003 | 2,265 | 2,006 | 4,271 | 2017 | 2,130 | 1,597 | 3,726 |

Table 6-14 $CH_4$ emissions from domestic & commercial wastewater handling

| Year | CH4 from urban population | CH4 from rural population | Emission in $GgCH_4$ | Emission in $GgCO_2eq$ | Year | $CH_4$ from urban population | $CH_4$ from rural population | Emission in $GgCH_4$ | Emission in $GgCO_2eq$ |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 8.42 | 3.03 | 11.45 | 240 | 2004 | 6.32 | 2.42 | 8.74 | 184 |
| 1991 | 8.44 | 3.06 | 11.50 | 241 | 2005 | 6.29 | 2.33 | 8.61 | 181 |
| 1992 | 8.38 | 3.10 | 11.48 | 241 | 2006 | 6.25 | 2.24 | 8.49 | 178 |
| 1993 | 8.18 | 3.04 | 11.22 | 236 | 2007 | 6.21 | 2.15 | 8.36 | 176 |
| 1994 | 7.45 | 2.84 | 10.29 | 216 | 2008 | 6.18 | 2.06 | 8.23 | 173 |
| 1995 | 7.21 | 2.78 | 9.99 | 210 | 2009 | 6.15 | 2.05 | 8.19 | 172 |
| 1996 | 6.97 | 2.74 | 9.71 | 204 | 2010 | 6.10 | 2.03 | 8.13 | 171 |
| 1997 | 6.78 | 2.68 | 9.46 | 199 | 2011 | 6.06 | 2.02 | 8.08 | 170 |
| 1998 | 6.65 | 2.67 | 9.32 | 196 | 2012 | 6.00 | 2.00 | 8.00 | 168 |
| 1999 | 6.57 | 2.66 | 9.23 | 194 | 2013 | 5.97 | 1.99 | 7.96 | 167 |
| 2000 | 6.48 | 2.66 | 9.14 | 192 | 2014 | 5.97 | 1.99 | 7.95 | 167 |
| 2001 | 6.44 | 2.62 | 9.06 | 190 | 2015 | 5.97 | 1.99 | 7.97 | 167 |
| 2002 | 6.40 | 2.59 | 8.99 | 189 | 2016 | 5.99 | 1.99 | 7.98 | 168 |
| 2003 | 6.36 | 2.50 | 8.87 | 186 | 2017 | 5.98 | 1.99 | 7.97 | 167 |

### 6.5.2. Nitrous Oxide from Human Sewage

Consumption of foodstuffs by humans results in the production of sewage. Main source of nitrogen from human sewage is protein, a complex, high-molecular-mass, organic compound that consists of amino acids joined by peptide bonds.

Sewage nitrogen production can be estimated based on FAO per capita protein consumption data and human population counts. FAO Statistics Division provides per person protein consumption data for Georgia for years 1990-1992 (56 g/person/day), 1995-1997 (69 g/person/day), 2000-2002 (72 g/person/day) and 2005-2007 (77 g/person/day). Protein consumption for years 2008-2017 was estimated assuming that by 2017 it had increased by 1 g/person/day annually.

The emissions of $N_2O$ from human sewage are calculated by the formula:

$$N_2O(S) = Protein \times \text{fracNPR} \times NR_{people} \times EF_6$$

Where:

| | |
|---|---|
| $N_2O(s)$ | $N_2O$ emissions from human sewage (kg $N_2O$-N/yr) |
| *Protein* | annual per capita protein intake (kg/person/yr) |
| $NR_{PEOPLE}$ | number of people in the country |
| $EF_6$ | emissions factor [default 0.01 (0,002-0,12) kg $N_2O$-N/kg sewage-N produced |
| *FracNPR* | fraction of nitrogen in protein, default value =0.16 kg N/kg protein |

Table 6-15 $N_2O$ emissions (in Gg) from humane sewage in 1990-2017 years

| Year | Population | Protein consumption | $N_2O$ emission in Gg | in $CO_2$eq | Year | Population | Protein consumption | $N_2O$ emission in Gg | in $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 5,424 | 56 | 0.18 | **55** | 2004 | 4,186 | 76 | 0.19 | **58** |
| 1991 | 5,453 | 56 | 0.18 | **55** | 2005 | 4,102 | 77 | 0.18 | **57** |
| 1992 | 5,467 | 56 | 0.18 | **55** | 2006 | 4,017 | 77 | 0.18 | **56** |
| 1993 | 5,346 | 60 | 0.19 | **58** | 2007 | 3,932 | 77 | 0.18 | **55** |
| 1994 | 4,930 | 65 | 0.19 | **58** | 2008 | 3,848 | 78 | 0.18 | **54** |
| 1995 | 4,794 | 69 | 0.19 | **60** | 2009 | 3,829 | 79 | 0.18 | **55** |
| 1996 | 4,675 | 69 | 0.19 | **58** | 2010 | 3,800 | 80 | 0.18 | **55** |
| 1997 | 4,558 | 69 | 0.18 | **57** | 2011 | 3,774 | 81 | 0.18 | **55** |
| 1998 | 4,505 | 70 | 0.18 | **57** | 2012 | 3,739 | 82 | 0.18 | **56** |
| 1999 | 4,470 | 71 | 0.19 | **57** | 2013 | 3,718 | 83 | 0.18 | **56** |
| 2000 | 4,435 | 72 | 0.19 | **58** | 2014 | 3,717 | 84 | 0.18 | **57** |
| 2001 | 4,395 | 72 | 0.18 | **57** | 2015 | 3,722 | 85 | 0.18 | **57** |
| 2002 | 4,356 | 72 | 0.18 | **57** | 2016 | 3,729 | 86 | 0.19 | **58** |
| 2003 | 4,271 | 74 | 0.18 | **57** | 2017 | 3,726 | 87 | 0.19 | **59** |

### 6.5.3. Industrial Wastewater (5.D.2.)

Assessment of $CH_4$ production potential from industrial wastewater streams is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater and the wastewater treatment system.

**Methodology:**

The method for calculating emissions from industrial wastewater is similar to the method used for domestic wastewater, but the development of emission factors and activity data is more complex since there are many types of wastewater, and many different industries to track. The most accurate estimates of emissions for this source category are based on measured data from point sources. Due to the high costs of measurements and the potentially large number of point sources, comprehensive measurement data are absent in Georgia.

COD is the appropriate DC indicator for industrial wastewater streams.2006 IPCC provides default COD values for various industries by region. Default values of the wastewater produced per unit product by industry in m3/tonne of product are also provided in IPCC GPG.

The equation to estimate CH4 emissions from industrial wastewater is as follows:

$$CH_4 Emissions = \sum_i [(TOW_i - S_i) \times EF_i - R_i]$$

Where:

- $TOW_i$ total organically degradable material in wastewater from industry I in inventory year, kg COD/year
- $I$ industrial sector
- $S_i$ organic component removed as sludge in inventory year, kg COD/year
- $EF_i$ emission factor for industry i, kg $CH_4$/kg CODr
- $R_i$ amount of CH4 recovered in inventory year, kg $CH_4$/year

**Emission Factor:**

Emission factor depends on the maximum CH4 producing capacity (Bo) in each industry, and on methane correction factor (MCF).

$$EF_j = B_0 \times MCF_j$$

Where:

| | |
|---|---|
| $EF_j$ | emission factor for each treatment/discharge pathway or system, kg $CH_4$/kg COD |
| $j$ | each treatment/discharge pathway or system |
| $B_o$ | maximum $CH_4$ producing capacity, kg CH/kg COD |
| $MCF_j$ | methane correction factor (fraction) |

If no country-specific data are available, it is a good practice to use the IPCC COD-default factor for Bo (0.25 kg $CH_4$/kg COD). MCF=0.3. Organic components are not removed and $CH_4$ is not recovered, i.e. S=0 and R=0.

The total organic wastewater (TOWI) for the industry is calculated by the formulae:

$$TOW = P_i \times W_i \times COD_i$$

Where:

$TOWi$ = total organically degradable material in wastewater for industry i, kg COD/yr

| | |
|---|---|
| $i$ | industrial sector |
| $P_i$ | total industrial product for industrial sector i, t/yr |
| $W_i$ | wastewater generated, m3/t product |
| $COD_i$ | chemical oxygen demand (industrial degradable organic component in wastewater), kg COD/$m^3$ |

**Activity data:**

Specified production data for different industries provided by The National Statistics Office of Georgia.

GHG emissions from industrial wastewater handling are presented in Table *6-16*.

Table 6-16 $CH_4$ emissions from industrial wastewater handling in 1990-2017 years

| Year | Alcohol Refining | Beer & Malt | Dairy Products | Meat & Poultry | Organic Chemicals | Pulp & Paper (combined) | Veget, Fruits & Juices | Wine & Vinegar | Soft drinks | Canneries | Total in Gg $CH_4$ | Total in Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 0.16 | 0.06 | 0.18 | 0.30 | 6.60 | 1.45 | 0.004 | 0.04 | 0.04 | 0.000 | 8.84 | 186 |
| 1991 | 0.15 | 0.04 | 0.11 | 0.03 | 5.42 | 0.03 | 0.002 | 0.03 | 0.02 | 0.000 | 5.83 | 122 |
| 1992 | 0.13 | 0.02 | 0.02 | 0.01 | 4.24 | 0.01 | 0.000 | 0.05 | 0.01 | 0.000 | 4.47 | 94 |
| 1993 | 0.23 | 0.01 | 0.01 | 0.001 | 3.06 | - | 0.000 | 0.03 | 0.002 | 0.000 | 3.34 | 70 |
| 1994 | 0.05 | 0.004 | 0.01 | 0.000 | 1.88 | - | 0.000 | 0.02 | 0.001 | 0.000 | 1.96 | 41 |
| 1995 | 0.02 | 0.004 | 0.003 | 0.000 | 2.48 | 0.002 | 0.000 | 0.01 | 0.002 | 0.000 | 2.52 | 53 |
| 1996 | 0.03 | 0.003 | 0.003 | 0.001 | 3.07 | 0.002 | 0.000 | 0.01 | 0.005 | 0.000 | 3.12 | 66 |
| 1997 | 0.05 | 0.01 | 0.004 | 0.002 | 3.67 | 0.003 | 0.000 | 0.01 | 0.01 | 0.000 | 3.76 | 79 |
| 1998 | 0.02 | 0.01 | 0.005 | 0.002 | 4.27 | 0.002 | 0.000 | 0.01 | 0.01 | 0.000 | 4.32 | 91 |
| 1999 | 0.09 | 0.01 | 0.003 | 0.003 | 4.87 | 0.003 | 0.000 | 0.01 | 0.01 | 0.000 | 4.99 | 105 |
| 2000 | 0.09 | 0.02 | 0.003 | 0.004 | 5.46 | 0.004 | 0.000 | 0.004 | 0.01 | 0.000 | 5.59 | 117 |
| 2001 | 0.10 | 0.02 | 0.003 | 0.001 | 5.63 | 0.001 | 0.000 | 0.01 | 0.01 | 0.000 | 5.78 | 121 |
| 2002 | 0.03 | 0.02 | 0.01 | 0.001 | 5.80 | - | 0.000 | 0.01 | 0.01 | 0.000 | 5.87 | 123 |
| 2003 | 0.02 | 0.02 | 0.004 | 0.002 | 5.97 | - | 0.000 | 0.01 | 0.02 | 0.000 | 6.05 | 127 |
| 2004 | 0.09 | 0.03 | 0.005 | 0.005 | 6.14 | | 0.000 | 0.01 | 0.03 | 0.000 | 6.30 | 132 |
| 2005 | 0.11 | 0.04 | 0.01 | 0.01 | 6.31 | 0.003 | 0.000 | 0.01 | 0.04 | 0.000 | 6.53 | 137 |
| 2006 | 0.15 | 0.05 | 0.01 | 0.01 | 6.74 | - | 0.02 | 0.01 | 0.05 | 0.004 | 7.04 | 148 |

| Year | Alcohol Refining | Beer & Malt | Dairy Products | Meat & Poultry | Organic Chemicals | Pulp & Paper (combined) | Veget, Fruits & Juices | Wine & Vinegar | Soft drinks | Canneries | Total in Gg $CH_4$ | Total in Gg $CO_2$eq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 0.13 | 0.05 | 0.01 | 0.01 | 7.17 | - | 0.07 | 0.004 | 0.05 | 0.01 | 7.50 | 158 |
| 2008 | 0.16 | 0.04 | 0.01 | 0.02 | 7.60 | - | 0.02 | 0.005 | 0.04 | 0.01 | 7.91 | 166 |
| 2009 | 0.12 | 0.05 | 0.28 | 0.01 | 8.03 | 0.24 | 0.03 | 0.004 | 0.04 | 0.01 | 8.80 | 185 |
| 2010 | 0.11 | 0.06 | 0.30 | 0.02 | 8.46 | 0.43 | 0.03 | 0.01 | 0.04 | 0.01 | 9.46 | 199 |
| 2011 | 0.13 | 0.05 | 0.36 | 0.03 | 9.21 | 0.53 | 0.07 | 0.01 | 0.04 | 0.02 | 10.45 | 220 |
| 2012 | 0.13 | 0.07 | 0.37 | 0.04 | 9.18 | 0.73 | 0.06 | 0.01 | 0.05 | 0.02 | 10.66 | 224 |
| 2013 | 0.08 | 0.07 | 0.34 | 0.05 | 9.26 | 0.57 | 0.05 | 0.02 | 0.05 | 0.02 | 10.51 | 221 |
| 2014 | 0.08 | 0.07 | 0.35 | 0.06 | 9.25 | 0.59 | 0.09 | 0.03 | 0.06 | 0.02 | 10.60 | 223 |
| 2015 | 0.05 | 0.06 | 0.34 | 0.06 | 9.80 | 0.45 | 0.04 | 0.02 | 0.06 | 0.03 | 10.91 | 229 |
| 2016 | 0.02 | 0.07 | 0.32 | 0.07 | 9.34 | 0.48 | 0.06 | 0.02 | 0.06 | 0.04 | 10.47 | 220 |
| 2017 | 0.03 | 0.06 | 0.35 | 0.07 | 8.95 | 0.76 | 0.08 | 0.02 | 0.07 | 0.03 | 10.42 | 219 |

# Chapter 7. Other (CRF Sector 6)

Indirect $N_2O$ emissions from the atmospheric deposition of nitrogen in $NO_x$ and $NH_3$ is not estimated due to the lack of data.

Emissions from the other (5B) category has not occurred during this period.

# Chapter 8. Recalculation of GHG emissions

During this inventory GHG emissions and removals were calculated using 2006 IPCC guidelines for the years 1991-1993, 1995-1999, 2001-2004, 2006-2009, 2016 and 2017, and figures were recalculated for all the previous years (1990, 1994, 2000, 2005, 2010-2015) in all sectors except for the IPPU sector where GHG emissions had been recalculated for all previous years during the last inventory.

Table 8-1 Difference in total GHG emissions in the latest and the previous national inventories

| National GHG emissions, CO2 eq. | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **1994** | **2000** | **2005** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** |
| Total (excluding LULUCF)-2017 | 45,813 | 15,745 | 10,923 | 11,168 | 13,688 | 16,027 | 16,927 | 15,964 | 16,861 | 18,214 |
| Total (excluding LULUCF)-2015 | 45,607 | 15,415 | 10,479 | 10,684 | 13,208 | 15,563 | 16,549 | 15,487 | 16,278 | 17,589 |
| Difference-% | **0%** | **2%** | **4%** | **5%** | **4%** | **3%** | **2%** | **3%** | **4%** | **4%** |
| Total (including LULUCF)-2017 | 39,461 | 9,121 | 5,892 | 7,006 | 9,151 | 11,163 | 12,178 | 11,130 | 12,252 | 13,597 |
| Total (including LULUCF)-2015 | 38,768 | 8,685 | 5,472 | 5,926 | 9,595 | 10,490 | 12,738 | 10,750 | 13,780 | 13,707 |
| Difference-% | **2%** | **5%** | **8%** | **18%** | **-5%** | **6%** | **-4%** | **4%** | **-11%** | **-1%** |

More specific information on differences in results by sectors are provided below.

**Energy**

Table 8-2 Category-specific documentation of recalculations (Transport-1A3)

| Transport Sector/CO2 eq. | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 3,822 | 1,419 | 945 | 1,537 | 2,580 | 2,563 | 2,672 | 3,301 | 3,735 | 4,139 |
| Previous Data | 3,822 | 1,420 | 945 | 1,537 | 2,601 | 2,585 | 2,690 | 3,380 | 3,758 | 4,162 |
| Difference % | 0.0% | 0.0% | 0.0% | 0.0% | -0.8% | -0.9% | -0.7% | -2.3% | -0.6% | -0.6% |
| **Documentation Reason for Recalculation:** British Petroleum Georgia provided specified data of natural gas and diesel consumption which is used in the oil and gas transit pipeline substations. Also, The Ministry of Economy and Sustainable Development provided data on oil products consumption by international Bunkers (Navigation). Those data were previously unknown and aggregated in the transport sector and in recent inventory it was extracted. | | | | | | | | | | |

## Agriculture

Table 8-3 Category-Specific Documentation of Recalculations (Enteric fermentation)

| Enteric fermentation / $CH_4$ | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 89.7 | 63.5 | 78.3 | 80.9 | 72.3 | 71.6 | 76.2 | 81.5 | 87.7 | 91.1 |
| Previous Data | 77.1 | 51.8 | 62.9 | 64.7 | 56.4 | 56.4 | 59.8 | 63.6 | 68.1 | 70.1 |
| Difference % | 16% | 23% | 24% | 25% | 28% | 27% | 27% | 28% | 29% | 30% |
| **Documentation Reason for Recalculation:** The specified data on cattle distribution by breeds has been provided by the highly experienced person Mr. Levan Tortladze - Head of the Department of Zootechny of the Agrarian University of Georgia. Emission factor for enteric fermentation significantly depends on cattle breed. | | | | | | | | | | |

Table 8-4 Category-Specific Documentation of Recalculations (Manure management)

| Manure management / $CH_4$ | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 5.8 | 3 | 3.5 | 3.6 | 2 | 2 | 2.4 | 2.5 | 2.5 | 2.6 |
| Previous Data | 9 | 5.2 | 6.2 | 6.4 | 4.4 | 4.4 | 5 | 5.2 | 5.5 | 5.6 |
| Difference % | -36% | -42% | -44% | -44% | -55% | -55% | -52% | -52% | -55% | -54% |
| **Documentation Reason for Recalculation:** In case of enteric fermentation, specified data on cattle distribution by breeds was used. More significantly, recalculations were performed applying Tier 2 approach. | | | | | | | | | | |

Table 8-5 Category-Specific Documentation of Recalculations (Manure management)

| Manure management / $N_2O$ | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 1.17 | 0.81 | 1 | 1.03 | 0.9 | 0.89 | 0.96 | 1.02 | 1.1 | 1.15 |
| Previous Data | 1.21 | 0.8 | 0.98 | 1 | 0.85 | 0.85 | 0.91 | 0.96 | 1.04 | 1.07 |
| Difference % | -3% | 1% | 2% | 3% | 6% | 5% | 5% | 6% | 6% | 7% |
| **Documentation Reason for Recalculation:** In case of enteric fermentation, specified data on cattle distribution by breeds was used. Nitrogen excretion rate depends on amount of managed manure N available for soil application, i.e. on cattle breed. | | | | | | | | | | |

Table 8-6 Category-Specific Documentation of Recalculations (Direct emissions from managed soils)

| Direct emissions from managed soils / $N_2O$ | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 3.49 | 2.08 | 2.59 | 2.74 | 2.44 | 2.33 | 2.56 | 3 | 2.82 | 2.87 |
| Previous Data | 3.54 | 2.07 | 2.56 | 2.7 | 2.35 | 2.24 | 2.45 | 2.9 | 2.7 | 2.74 |
| Difference % | -1% | 0% | 1% | 1% | 4% | 4% | 4% | 3% | 4% | 5% |
| **Documentation Reason for Recalculation:**<br>In case of enteric fermentation, specified data on cattle distribution by breeds was used. Amount of animal manure applied to soils and amount of urine and dung deposited by grazing animals on pasture, range and paddock depends on cattle breed. | | | | | | | | | | |

Table 8-7 Category-Specific Documentation of Recalculations (Indirect emissions from managed soils)

| Indirect emissions from managed Soils / $N_2O$ | Emissions in Gg $CO_2$eq | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 637 | 377 | 477 | 502 | 453 | 429 | 473 | 560 | 517 | 525 |
| Previous Data | 645 | 375 | 472 | 494 | 438 | 414 | 455 | 542 | 498 | 503 |
| Difference % | -1% | 1% | 1% | 2% | 3% | 4% | 4% | 3% | 4% | 4% |
| **Documentation Reason for Recalculation:**<br>In case of enteric fermentation, specified data on cattle distribution by breeds was used. Atmospheric deposition of N volatilized from managed soils and Nitrogen leaching/runoff from managed soils depends on amount of animal manure applied to soils and amount of urine and dung deposited by grazing animals on pasture, range and paddock, i.e. on cattle breed. | | | | | | | | | | |

## Land-use, Land Use Change and Forestry

Table 8-8 Category-Specific Documentation of Recalculations (Forest lands)

| Forest lands/CO2 | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | (6,224) | (6,204) | (6,091) | (5,497) | (5,375) | (5,736) | (5,616) | (5,794) | (5,498) | (5,484) |
| Previous Data | (6,458) | (6,374) | (6,174) | (5,896) | (5,790) | (6,078) | (5,831) | (5,774) | (5,646) | (5,621) |
| Difference % | -3.6% | -2.7% | -1.3% | -6.8% | -7.2% | -5.6% | -3.7% | 0.3% | -2.6% | -2.4% |
| Documentation Reason for Recalculation:<br>Activity data and the emissions factors has been updated and specified. | | | | | | | | | | |

Table 8-9 Category-Specific Documentation of Recalculations (Perennial crops)

| Perennial crops/CO2 | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | (2,746) | (2,549) | (1,358) | (924) | (862) | (839) | (839) | (847) | (847) | (847) |
| Previous Data | (2,695) | (2,417) | (1,586) | (1,163) | (924) | (655) | (963) | (1,001) | (693) | (847) |
| Difference % | 1.9% | 5.5% | -14.4% | -20.6% | -6.7% | 28.1% | -12.9% | -15.4% | 22.2% | 0.0% |
| Documentation Reason for Recalculation:<br>Activity data and the emissions factors has been updated and specified. | | | | | | | | | | |

Table 8-10 Category-Specific Documentation of Recalculations (Arable lands)

| Arable lands/CO2 | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | (283) | (788) | (494) | (653) | (1,211) | (1,200) | (1,206) | (1,105) | (1,175) | (1,198) |
| Previous Data | (570) | (775) | (480) | (640) | (1,198) | (1,187) | (1,192) | (1,091) | (1,080) | (1,096) |
| Difference % | -50.4% | 1.7% | 2.9% | 2.0% | 1.1% | 1.1% | 1.2% | 1.3% | 8.8% | 9.3% |
| **Documentation Reason for Recalculation:**<br>Activity data and the emissions factors has been updated and specified. | | | | | | | | | | |

Table 8-11 Category-Specific Documentation of Recalculations (Grasslands)

| Grassland/CO2 | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 2,901 | 2,915 | 2,912 | 2,912 | 2,912 | 2,912 | 2,912 | 2,912 | 2,912 | 2,912 |
| Previous Data | 2,800 | 2,813 | 2,810 | 2,811 | 2,811 | 2,811 | 2,811 | 2,811 | 2,811 | 2,811 |
| Difference % | 3.6% | 3.6% | 3.6% | 3.6% | 3.6% | 3.6% | 3.6% | 3.6% | 3.6% | 3.6% |
| **Documentation Reason for Recalculation:**<br>Activity data and the emissions factors has been updated and specified. | | | | | | | | | | |

**Waste**

Table 8-12 Category-Specific Documentation of Recalculations (Emissions from Solid Waste Disposal Sites)

| Emissions from Solid Waste Disposal Sites / CH4 | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 31.2 | 36.9 | 42.9 | 46.6 | 48.5 | 49.3 | 49.7 | 50.1 | 50.5 | 50.7 |
| Previous Data | 26.6 | 31.6 | 36.4 | 39.2 | 42 | 42.4 | 42.5 | 42.6 | 42.6 | 42.6 |
| Difference % | 17% | 17% | 18% | 19% | 15% | 16% | 17% | 18% | 19% | 19% |
| | | | | | | | | | | |
| **Documentation Reason for Recalculation:**<br>Compared to previous inventory, time Delay - the period between deposition of the waste and full production of CH4 is considered. Specified data on amount of solid waste disposal on landfills was used. | | | | | | | | | | |

Table 8-13 Category-Specific Documentation of Recalculations (CH4 Emissions from Domestic Wastewater Handling)

| Domestic Wastewater Handling / $CH_4$ | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 11.5 | 10.3 | 9.1 | 8.6 | 8.1 | 8.1 | 8 | 8 | 8 | 8 |
| Previous Data | 10.8 | 10.4 | 9.1 | 8.7 | 8.7 | 8.7 | 8.6 | 8.6 | 8.7 | 8.7 |
| Difference % | 6% | -1% | 0% | -1% | -7% | -7% | -7% | -7% | -8% | -8% |
| **Documentation Reason for Recalculation:**<br>Data on rural and urban population was specified. | | | | | | | | | | |

Table 8-14 Category-Specific Documentation of Recalculations (N2O Emissions from Domestic Wastewater Handling)

| Domestic Wastewater Handling / $N_2O$ | Emissions in Gg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1994 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Latest Data | 11.5 | 10.3 | 9.1 | 8.6 | 8.1 | 8.1 | 8 | 8 | 8 | 8 |
| Previous Data | 10.8 | 10.4 | 9.1 | 8.7 | 8.7 | 8.7 | 8.6 | 8.6 | 8.7 | 8.7 |
| Difference % | 6% | -1% | 0% | -1% | -7% | -7% | -7% | -7% | -8% | -8% |
| **Documentation Reason for Recalculation:** Corrected data on per capita protein consumption was used | | | | | | | | | | |

# ANNEX A. THE NATIONAL ENERGY BALANCE FOR THE 2016 AND 2017 YEAR

| Georgia 2016 (TJ) | Anthracite | Other Bit. Coal | Lignite/Brown Coal | Coke Oven Coke | Charcoal | Fuel wood | Other vegetal materials and residual | Natural Gas | Crude Oil | Liquefied Petroleum Gases | Motor Gasoline | Kerosene type Jet Fuel | Kerosene | Road diesel | Heating and other gas oil | Fuel oil-low sulphur ( < 1%) | Lubricants | Bitumen | Non-specified Petroleum Prods. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | - | - | 5,041 | - | 9 | 16,007 | 225 | 231 | 1,639 | - | - | - | - | - | - | - | - | - | - |
| Imports | 202 | 2,415 | - | 4,308 | 8 | - | - | 82,281 | 1,813 | 578 | 25,351 | 3,056 | 1 | 27,608 | 434 | 1,776 | 834 | 3,937 | 342 |
| Exports | - | - | 26 | - | - | 55 | - | - | 770 | - | - | - | - | 16 | - | 764 | 76 | - | 3,675 |
| International Marine Bunkers | | | | | | | | | | | | | | 23.6 | | | | | |
| International Aviation Bunkers | - | - | - | - | - | - | - | - | - | - | - | 3,048 | - | - | - | - | - | - | - |
| Stock Changes | (118) | (125) | (151) | (606) | (3) | - | - | - | 15 | 162 | 625 | 39 | - | (699) | - | 936 | 38 | 43 | (132) |
| **Domestic Supply** | **84** | **2,290** | **4,863** | **3,701** | **14** | **15,953** | **225** | **82,512** | **2,697** | **740** | **25,976** | **47** | **1** | **26,870** | **434** | **1,948** | **796** | **3,980** | **(3,464)** |
| **Statistical Differences** | - | - | - | - | - | (0) | - | 0 | 0 | (0) | (1) | 0 | 0 | 0 | (0) | 0 | - | - | 1 |
| **Transformation Sector - Input** | - | - | 450 | - | - | - | - | 18,256 | 2,697 | - | - | - | - | - | - | 2,210 | - | - | - |
| MA Thermal Electricity Plants | - | - | 450 | - | - | - | - | 18,256 | - | - | - | - | - | - | - | - | - | - | - |
| Petroleum Refineries | - | - | - | - | - | - | - | - | 2,697 | - | - | - | - | - | - | 2,210 | - | - | - |
| **Transformation Sector - Production** | - | - | - | - | - | - | - | - | - | - | 311 | - | - | 400 | - | 327 | - | - | 3,804 |
| MA Thermal Electricity Plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Petroleum Refineries | - | - | - | - | - | - | - | - | - | - | 311 | - | - | 400 | - | 327 | - | - | 3,804 |
| **Energy Sector** | - | - | 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Coal Mines | - | - | 19 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oil and Gas Extraction | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Petroleum Refineries | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Transmission Losses** | | | | | | | | **819** | | | | | | | | | | | |
| **Distribution Losses** | - | - | - | - | - | - | - | **3,948** | - | - | - | - | - | - | - | - | - | - | - |
| **Final Consumption** | **84** | **2,290** | **4,394** | **3,701** | **14** | **15,953** | **225** | **59,488** | **-** | **740** | **26,288** | **47** | **1** | **27,269** | **435** | **64** | **796** | **3,980** | **338** |
| **Industry Sector** | 56 | 2,290 | 4,349 | 3,701 | - | 63 | - | 4,039 | - | 1 | - | - | - | - | - | 20 | - | - | 287 |
| Iron and steel | - | - | - | 3,701 | - | - | - | 459 | - | - | - | - | - | - | - | 2 | - | - | - |
| Chemical (including petrochemical) | - | - | - | - | - | - | - | 144 | - | - | - | - | - | - | - | - | - | - | - |
| Non-ferrous metals | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-metallic minerals | - | 2,290 | 4,342 | - | - | - | - | 1,344 | - | - | - | - | - | - | - | 12 | - | - | 287 |
| Transport equipment | - | - | - | - | - | - | - | 14 | - | - | - | - | - | - | - | - | - | - | - |
| Machinery | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - |
| Mining and quarrying | - | - | - | - | - | - | - | 70 | - | - | - | - | - | - | - | - | - | - | - |
| Food, beverages and tobacco | 56 | - | - | - | - | 63 | - | 1,337 | - | - | - | - | - | - | - | - | - | - | - |
| Paper, pulp and printing | - | - | - | - | - | - | - | 74 | - | - | - | - | - | - | - | - | - | - | - |
| Wood and wood products | - | - | 8 | - | - | - | - | 11 | - | - | - | - | - | - | - | - | - | - | - |
| Construction | - | - | - | - | - | - | - | 508 | - | - | - | - | - | - | - | 6 | - | - | - |
| Textiles and leather | - | - | - | - | - | - | - | 35 | - | - | - | - | - | - | - | - | - | - | - |
| Not elsewhere specified (Industry) | - | - | - | - | - | - | - | 42 | - | 1 | - | - | - | - | - | - | - | - | - |
| **Transport Sector** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **13,005** | **-** | **32** | **26,251** | **47** | **-** | **26,677** | **-** | **18** | **-** | **-** | **-** |
| Road | - | - | - | - | - | - | - | 9,660 | - | 32 | 26,251 | - | - | 25,758 | - | - | - | - | - |
| Rail | - | - | - | - | - | - | - | - | - | - | - | - | - | 430 | - | 18 | - | - | - |
| Domestic aviation | - | - | - | - | - | - | - | - | - | - | - | 47 | - | - | - | - | - | - | - |
| Domestic navigation | - | - | - | - | - | - | - | - | - | - | - | - | - | 29 | - | - | - | - | - |
| Pipeline transport | - | - | - | - | - | - | - | 3,345 | - | - | - | - | - | 460 | | - | - | - | - |
| Not elsewhere specified (Transport) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Other Sectors** | **28** | **-** | **45** | **-** | **14** | **15,889** | **225** | **34,661** | **-** | **707** | **37** | **-** | **1** | **592** | **435** | **26** | **-** | **-** | **-** |
| Commercial and public services | 16 | - | 11 | - | 14 | 167 | 14 | 6,678 | - | - | - | - | - | - | 430 | 26 | - | - | - |
| Residential | 7 | - | 28 | - | - | 15,722 | 211 | 27,615 | - | 707 | - | - | 1 | - | - | - | - | - | - |
| Agriculture/forestry | 4 | - | 6 | - | - | 0 | - | 368 | - | - | 37 | - | - | 592 | 4 | - | - | - | - |
| Fishing | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Not elsewhere specified (Other) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Non-Energy Use** | - | - | - | - | - | - | - | 7,784 | - | - | - | - | - | - | - | - | 796 | 3,980 | 51 |

| Georgia 2017 (TJ) | Anthracite | Other Bit. Coal | Lignite/Brown Coal | Coke Oven Coke | Charcoal | Fuel wood | Other vegetal materials and residual | Natural Gas | Crude Oil | Liquefied Petroleum Gases | Motor Gasoline | Kerosene type Jet Fuel | Kerosene | Road diesel | Heating and other gas oil | Fuel oil-low sulphur ( < 1%) | Lubricants | Bitumen | Non-specified Petroleum Prods. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | - | - | 4,558 | - | 3 | 15,115 | 162 | 298 | 1,360 | - | - | - | - | - | - | - | - | - | - |
| Imports | 434 | 3,685 | - | 3,954 | - | - | - | 85,120 | 2,531 | 699 | 23,487 | 4,326 | - | 23,494 | 997 | 3,503 | 866 | 3,952 | 53 |
| Exports | - | - | 37 | 375 | - | 66 | - | - | 3,029 | - | 62 | - | - | 473 | - | 3,740 | 167 | - | |
| International Marine Bunkers | | | | | | | | | | | | | | 63.22 | | | | | |
| International Aviation Bunkers | - | - | - | - | - | - | - | - | - | - | - | 4,087 | - | - | - | - | - | - | - |
| Stock Changes | (241) | (245) | (32) | 519 | - | - | - | - | 200 | 60 | 88 | (213) | - | 588 | - | (52) | (0) | 38 | (49) |
| **Domestic Supply** | **193** | **3,440** | **4,488** | **4,098** | **3** | **15,049** | **162** | **85,418** | **1,062** | **759** | **23,514** | **26** | **-** | **23,546** | **997** | **(289)** | **699** | **3,990** | **4** |
| Statistical Differences | - | - | - | - | - | 0 | 0 | - | (0) | - | - | 0 | - | 0 | - | (0) | - | - | 0 |
| **Transformation Sector - Input** | **-** | **-** | **634** | **-** | **-** | **-** | **-** | **18,235** | **1,063** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** |
| MA Thermal Electricity Plants | - | - | 634 | - | - | - | - | 18,235 | - | - | - | - | - | - | - | - | - | - | - |
| Petroleum Refineries | - | - | - | - | - | - | - | - | 1,063 | - | - | - | - | - | - | - | - | - | - |
| **Transformation Sector - Production** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **97** | **-** | **-** | **425** | **-** | **352** | **-** | **-** | **129** |
| MA Thermal Electricity Plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Petroleum Refineries | - | - | - | - | - | - | - | - | - | - | 97 | - | - | 425 | - | 352 | - | - | 129 |
| **Energy Sector** | **-** | **-** | **15** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** |
| Coal Mines | - | - | 15 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oil and Gas Extraction | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Petroleum Refineries | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Transmission Losses** | | | | | | | | 1,199 | | | | | | | | | | | |
| **Distribution Losses** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **2,144** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** |
| **Final Consumption** | **193** | **3,440** | **3,839** | **4,098** | **3** | **15,048** | **162** | **63,840** | **-** | **759** | **23,610** | **26** | **-** | **23,971** | **997** | **63** | **699** | **3,990** | **133** |
| **Industry Sector** | **167** | **3,440** | **3,808** | **4,098** | **-** | **46** | **0** | **4,851** | **-** | **-** | **-** | **-** | **-** | **-** | **59** | **40** | **-** | **-** | **57** |
| Iron and steel | - | 38 | - | 4,098 | - | - | - | 571 | - | - | - | - | - | - | 8 | - | - | - | - |
| Chemical (including petrochemical) | - | - | - | - | - | - | - | 200 | - | - | - | - | - | - | - | - | - | - | - |
| Non-ferrous metals | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-metallic minerals | - | 3,402 | 3,808 | - | - | 1 | - | 1,362 | - | - | - | - | - | - | - | 20 | - | - | 49 |
| Transport equipment | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - |
| Machinery | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | - | - | - | - |
| Mining and quarrying | - | - | - | - | - | - | - | 32 | - | - | - | - | - | - | - | - | - | - | - |
| Food, beverages and tobacco | 167 | - | - | - | - | 44 | 0 | 1,726 | - | - | - | - | - | - | - | 20 | - | - | - |
| Paper, pulp and printing | - | - | - | - | - | - | - | 63 | - | - | - | - | - | - | - | - | - | - | - |
| Wood and wood products | - | - | - | - | - | 1 | - | 25 | - | - | - | - | - | - | - | - | - | - | - |
| Construction | - | - | - | - | - | 1 | - | 742 | - | - | - | - | - | - | 51 | - | - | - | - |
| Textiles and leather | - | - | - | - | - | - | - | 49 | - | - | - | - | - | - | - | - | - | - | - |
| Not elsewhere specified (Industry) | - | - | - | - | - | - | - | 77 | - | - | - | - | - | - | - | - | - | - | 8 |
| **Transport Sector** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **12,166** | **-** | **129** | **23,553** | **26** | **-** | **23,464** | **520** | **18** | **-** | **-** | **-** |
| Road | - | - | - | - | - | - | - | 8,785 | - | 129 | 23,553 | - | - | 23,121 | - | - | - | - | - |
| Rail | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 439 | 18 | - | - | - |
| Domestic aviation | - | - | - | - | - | - | - | - | - | - | - | 26 | - | - | - | - | - | - | - |
| Domestic navigation | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 81 | - | - | - | - |
| Pipeline transport | - | - | - | - | - | - | - | 3,381 | - | - | - | - | - | 342 | | - | - | - | - |
| Not elsewhere specified (Transport) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Other Sectors** | **26** | **-** | **31** | **-** | **3** | **15,002** | **162** | **38,231** | **-** | **630** | **57** | **-** | **-** | **507** | **418** | **4** | **-** | **-** | **-** |
| Commercial and public services | 15 | - | 9 | - | 3 | 144 | 12 | 6,853 | - | - | - | - | - | - | 405 | 4 | - | - | - |
| Residential | 6 | - | 17 | - | - | 14,857 | 150 | 30,940 | - | 630 | - | - | - | - | - | - | - | - | - |
| Agriculture/forestry | 5 | - | 5 | - | - | 1 | - | 438 | - | - | 57 | - | - | 507 | 13 | - | - | - | - |
| Fishing | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Not elsewhere specified (Other) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Non-Energy Use** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **8,593** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **699** | **3,990** | **76** |

## *ANNEX B. UNCERTAINTY ANALYSIS*

### Results of the Uncertainty Analysis

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2006 IPCC Categories** | Gas | Emissions of 1990 | Emissions of 2017 | Uncertainty of activity data | Emission factor / estimation parameter uncertainty | Combined uncertainty | Contribution to Variance by Category in Year 2017 | A type sensitivity | B type 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 |
| | | | Input data | Input data | Input data (Note A) | Input data (Note A) | $\sqrt{E^2+F^2}$ | $\frac{(G \bullet D)^2}{(\sum D)^2}$ | Note B | $\left\lvert \frac{D}{\sum C} \right\rvert$ | I * F Note C | J* E * $\sqrt{2}$ Note D | $K^2 + L^2$ |
| | | | **Gg CO2-eq.** | **Gg CO2-eq.** | **%** | **%** | **%** | **%** | **%** | **%** | **%** | **%** | **%** |
| 1A1 | Electricity and Heat Production - Liquid Fuels | **$CO_2$** | 8172.17 | 0.00 | 1 | 6.1 | 6.18 | 0.00 | -0.08 | 0.00 | 0.00 | -0.08 | 0.01 |
| 1A1 | Electricity and Heat Production - Gaseous fuels | **$CO_2$** | 4604.23 | 1022.98 | 1 | 3.9 | 4.03 | 0.07 | -0.02 | 0.03 | 0.14 | -0.02 | 0.02 |
| 1A1 | Heat Production and other Energy Industries - Solid Fuels | **$CO_2$** | 955.46 | 506.90 | 1 | 12.4 | 12.44 | 0.17 | 0.00 | 0.01 | 0.22 | 0.00 | 0.05 |
| 1A2 | Manufacturing Industries and Construction - solid fuels | **$CO_2$** | 3519.07 | 722.80 | 5 | 12.4 | 13.37 | 0.41 | -0.02 | 0.02 | 0.32 | -0.08 | 0.10 |
| 1A2 | Manufacturing Industries and Construction - biomass | **$CO_2$** | 0.00 | 5.20 | 5 | 18.7 | 19.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Manufacturing Industries and Construction - liquid fuels | **$CO_2$** | 2008.10 | 14.70 | 5 | 6.1 | 7.89 | 0.00 | -0.02 | 0.00 | 0.00 | -0.09 | 0.01 |
| 1A2 | Manufacturing Industries and Construction - Gaseous Fuels | **$CO_2$** | 2007.79 | 272.20 | 5 | 3.9 | 6.34 | 0.01 | -0.01 | 0.01 | 0.04 | -0.06 | 0.01 |
| 1A3a | Civil aviation | **$CO_2$** | 0.00 | 1.80 | 5 | 4.2 | 6.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A3a i | International Aviation (International Bunkers) - Liquid Fuels | **$CO_2$** | 608.63 | 292.23 | 5 | 4.2 | 6.53 | 0.02 | 0.00 | 0.01 | 0.04 | 0.01 | 0.00 |
| 1A3b | Road Transportation - Liquid Fuels | **$CO_2$** | 3603.22 | 3353.65 | 5 | 3.1 | 5.88 | 1.69 | 0.05 | 0.08 | 0.37 | 0.25 | 0.19 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A3b | Road transportation - Gaseous Fuels | $CO_2$ | 0.00 | 492.84 | 5 | 3.9 | 6.34 | 0.04 | 0.01 | 0.01 | 0.07 | 0.06 | 0.01 |
| 1A3c | Other transportation | $CO_2$ | 141.32 | 195.70 | 5 | 5 | 7.07 | 0.01 | 0.00 | 0.00 | 0.03 | 0.02 | 0.00 |
| 1A3d | International water-borne navigation (International bunkers) - Liquid Fuels | $CO_2$ | 0.00 | 4.68 | 5 | 4.2 | 6.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4a | Commercial/Institutional- solid fuels | $CO_2$ | 85.85 | 2.30 | 5 | 12.4 | 13.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4a | Commercial/Institutional-liquid fuels | $CO_2$ | 762.45 | 30.33 | 5 | 6.1 | 7.89 | 0.00 | -0.01 | 0.00 | 0.01 | -0.03 | 0.00 |
| 1A4a | Commercial/Institutional-Gaseous Fuels | $CO_2$ | 228.21 | 384.45 | 5 | 3.9 | 6.34 | 0.03 | 0.01 | 0.01 | 0.05 | 0.04 | 0.00 |
| 1A4a | Commercial/Institutional-biomass | $CO_2$ | 122.19 | 17.71 | 5 | 18.7 | 19.36 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 1A4b | Residential - solid fuels | $CO_2$ | 73.83 | 2.29 | 5 | 12.4 | 13.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4b | Residential - liquid fuels | $CO_2$ | 986.76 | 39.77 | 5 | 6.1 | 7.89 | 0.00 | -0.01 | 0.00 | 0.01 | -0.04 | 0.00 |
| 1A4b | Residential - Gaseous Fuels | $CO_2$ | 2627.65 | 1735.73 | 5 | 3.9 | 6.34 | 0.53 | 0.02 | 0.04 | 0.24 | 0.09 | 0.07 |
| 1A4b | Residential - biomass | $CO_2$ | 1605.97 | 1679.00 | 5 | 18.7 | 19.36 | 4.58 | 0.03 | 0.04 | 1.10 | 0.13 | 1.24 |
| 1A4c | Stationary - solid fuels | $CO_2$ | 56.76 | 1.05 | 5 | 12.4 | 13.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4c | Stationary - Liquid Fuels | $CO_2$ | 390.99 | 42.50 | 5 | 6.1 | 7.89 | 0.00 | 0.00 | 0.00 | 0.01 | -0.01 | 0.00 |
| 1A4c | Stationary - Gaseous Fuels | $CO_2$ | 70.48 | 248.94 | 5 | 3.9 | 6.34 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 | 0.00 |
| 1A4c | Stationary - biomass | $CO_2$ | 421.12 | 0.12 | 5 | 18.7 | 19.36 | 0.00 | 0.00 | 0.00 | 0.00 | -0.02 | 0.00 |
| 1B1 | Fugitive Emissions from Solid Fuel Mining and transformation | $CO_2$ | 62.20 | 10.10 | 5 | 300 | 300.04 | 0.04 | 0.00 | 0.00 | 0.11 | 0.00 | 0.01 |
| 1B2 | Fugitive Emissions from Fuels - Oil and Natural Gas (Flaring, production, distribution) | $CO_2$ | 11.68 | 2.09 | 5 | 300 | 300.04 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| 2A1 | Cement Production | $CO_2$ | 504.97 | 658.74 | 5 | 5 | 7.07 | 0.09 | 0.01 | 0.02 | 0.12 | 0.06 | 0.02 |
| 2A2 | Lime Production | $CO_2$ | 36.66 | 53.39 | 20 | 15 | 25.00 | 0.01 | 0.00 | 0.00 | 0.03 | 0.02 | 0.00 |
| 2A3 | Glass production | $CO_2$ | 30.30 | 15.12 | 5 | 10 | 11.18 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 2B1 | Ammonia Production | $CO_2$ | 524.78 | 404.32 | 5 | 6 | 7.81 | 0.04 | 0.01 | 0.01 | 0.09 | 0.03 | 0.01 |
| 2C1 | Cast Iron and Steel Production | $CO_2$ | 2492.08 | 43.25 | 10 | 25 | 26.93 | 0.01 | -0.02 | 0.00 | 0.04 | -0.22 | 0.05 |
| 2C2 | Ferroalloys Production | $CO_2$ | 142.87 | 420.50 | 5 | 25 | 25.50 | 0.50 | 0.01 | 0.01 | 0.37 | 0.05 | 0.14 |
| 2D1 | Lubricant Use | $CO_2$ | 0 | 10.25 | 5 | 50 | 50.25 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5A | Forest land | $CO_2$ | -6224.20 | -5578.10 | 5 | 20 | 20.62 | 57.38 | -0.08 | -0.14 | -3.92 | -0.40 | 15.55 |
| 5B | Cropland | $CO_2$ | -3029.90 | -2257.80 | 10 | 75 | 75.66 | 126.64 | -0.03 | -0.06 | -5.95 | -0.28 | 35.53 |
| 5C | Grassland | $CO_2$ | 901.00 | 2912.10 | 10 | 75 | 75.66 | 210.68 | 0.06 | 0.07 | 7.68 | 0.64 | 59.38 |
| 1A1 | Stationary fuel combustion | $CH_4$ | 8.59 | 0.48 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Fuel combustion | $CH_4$ | 9.44 | 1.69 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 1A3a | Civil aviation | $CH_4$ | 0.09 | 0.00 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A3b | Road transportation | $CH_4$ | 20.60 | 35.36 | 5 | 40 | 40.31 | 0.01 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 |
| 1A3c | Other transportation | $CH_4$ | 0.07 | 0.13 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4a | Commercial/Institutional | $CH_4$ | 9.50 | 1.81 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 1A4b | Residential | $CH_4$ | 102.61 | 98.00 | 5 | 100 | 100.12 | 0.42 | 0.00 | 0.00 | 0.34 | 0.01 | 0.12 |
| 1A4c | Stationary | $CH_4$ | 28.72 | 0.66 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1B1 | Fugitive Emissions from Solid Fuel Mining and transformation | $CH_4$ | 676.51 | 0.00 | 5 | 300 | 300.04 | 0.00 | -0.01 | 0.00 | 0.00 | -0.03 | 0.00 |
| 1B2 | Fugitive Emissions from oil Extraction | $CH_4$ | 66.89 | 96.53 | 5 | 300 | 300.04 | 3.64 | 0.00 | 0.00 | 1.02 | 0.01 | 1.04 |
| 1B2 | Fugitive Emissions from oil and natural gas production | $CH_4$ | 142.02 | 24.43 | 5 | 300 | 300.04 | 0.23 | 0.00 | 0.00 | 0.26 | 0.00 | 0.07 |
| 1B2 | Fugitive Emissions from oil and natural gas Transmission and distribution | $CH_4$ | 5126.65 | 1293.79 | 10 | 100 | 100.50 | 73.36 | -0.02 | 0.03 | 4.55 | -0.16 | 20.72 |
| 4A | Enteric fermentation | $CH_4$ | 1883.0 | 1656.0 | 10 | 30 | 31.62 | 11.90 | 0.02 | 0.04 | 1.75 | 0.23 | 3.11 |
| 4B | Manure management | $CH_4$ | 122.0 | 74.0 | 10 | 50 | 50.99 | 0.06 | 0.00 | 0.00 | 0.13 | 0.01 | 0.02 |
| 3F | Field burning of Agricultural Residues (3.F) | $CH_4$ | 11.0 | 12.0 | 10 | 50 | 50.99 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| 6A | Solid Waste Disposal Sides | $CH_4$ | 619.0 | 1073.0 | 30 | 30 | 42.43 | 8.99 | 0.02 | 0.03 | 1.13 | 0.63 | 1.67 |
| 6B1 | Industrial Waste Water handling | $CH_4$ | 186.0 | 219.0 | 50 | 30 | 58.31 | 0.71 | 0.00 | 0.01 | 0.23 | 0.18 | 0.09 |
| 6B2 | Domestic Waste Water handling | $CH_4$ | 240.0 | 167.0 | 5 | 30 | 30.41 | 0.11 | 0.00 | 0.00 | 0.18 | 0.01 | 0.03 |
| 1A1 | Stationary fuel combustion | $N_2O$ | 26.89 | 2.77 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 1A2 | Fuel combustion | $N_2O$ | 21.56 | 3.67 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 1A3a | Civil aviation | $N_2O$ | 0.00 | 0.00 | 5 | 150 | 150.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A3a i | International Aviation | $N_2O$ | 5.28 | 2.53 | 5 | 150 | 150.08 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A3b | Road transportation | **$N_2O$** | 54.90 | 59.50 | 5 | 50 | 50.25 | 0.04 | 0.00 | 0.00 | 0.10 | 0.00 | 0.01 |
| 1A3c | Other transportation | **$N_2O$** | 2.55 | 4.09 | 5 | 100 | 100.12 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 1A4a | Commercial/Institutional | **$N_2O$** | 3.70 | 0.49 | 5 | 150 | 150.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4b | Residential | **$N_2O$** | 22.49 | 19.71 | 5 | 150 | 150.08 | 0.04 | 0.00 | 0.00 | 0.10 | 0.00 | 0.01 |
| 1A4c | Stationary | **$N_2O$** | 5.33 | 0.14 | 5 | 150 | 150.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2B2 | Nitric Acid Production | **$N_2O$** | 147.50 | 228.94 | 5 | 20 | 20.62 | 0.10 | 0.00 | 0.01 | 0.16 | 0.02 | 0.03 |
| 2G3 | Medical Surgeries | **$N_2O$** | 11.06 | 14.884 | 5 | 10 | 11.18 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 4B | Manure management | **$N_2O$** | 365.0 | 313.0 | 50 | 100 | 111.80 | 5.31 | 0.00 | 0.01 | 1.10 | 0.22 | 1.26 |
| 4D1 | Direct soil emissions | **$N_2O$** | 1080.0 | 884.0 | 10 | 25 | 26.93 | 2.46 | 0.01 | 0.02 | 0.78 | 0.12 | 0.62 |
| 4D3 | Indirect soil emissions | **$N_2O$** | 637.0 | 530.0 | 50 | 50 | 70.71 | 6.09 | 0.01 | 0.01 | 0.93 | 0.36 | 1.00 |
| 3F | Field burning of Agricultural Residues | **$N_2O$** | 26.0 | 29.0 | 10 | 50 | 50.99 | 0.01 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 |
| 6B2 | Domestic Waste Water handling | **$N_2O$** | 55.0 | 59.0 | 5 | 70 | 70.18 | 0.07 | 0.00 | 0.00 | 0.15 | 0.00 | 0.02 |
| 2F | Consumption of halocarbons and sulfur hexafluoride (Refrigeration and Air Conditioning Equipments) | **HFC** | 0.00 | 155.33 | 5 | 25 | 25.50 | 0.07 | 0.00 | 0.00 | 0.14 | 0.02 | 0.02 |
| 2F | Consumption of halocarbons and sulfur hexafluoride (Emissions from Appliances (electrical equipment) | **SF6** | 0.00 | 355.76 | 5 | 100 | 100.12 | 5.51 | 0.01 | 0.01 | 1.25 | 0.04 | 1.57 |
| | **Total emissions:** | | **40221.66** | **15180.54** | | **Percentage uncertainty in total inventory:** | | **522.10** | | | | | **143.79** |
| | | | | | | | | **22.85** | | | | **Trend uncertainty:** | **11.99** |

## *ANNEX C. UNCERTAINTY VALUES OF ACTIVITY DATA AND EMISSION FACTORS*

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| 1A1 | Electricity and Heat Production - Liquid Fuels | **$CO_2$** | According to IPCC GHG uncertainty for main activity electricity and heat production, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is less than 1%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/ V2_2_Ch2_Stationary_Combustion.pdf (table 2.15). Therefore, the uncertainty was set at 1%. | According to the IPCC Guidelines, selecting a typical value for emission factors is within the 95%; confidence interval and uncertainty is less than 5%. Therefore, a value of 5% was selected. |
| 1A1 | Electricity and Heat Production - Gaseous fuels | **$CO_2$** | According to IPCC GHG uncertainty for main activity electricity and heat production, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is less than 1%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/ V2_2_Ch2_Stationary_Combustion.pdf (table 2.15). Therefore, the uncertainty was set at 1%. | According to the IPCC Guidelines, selecting a typical value for emission factors is within the 95%; confidence interval and uncertainty is less than 5%. Therefore, a value of 5% was selected. |
| 1A1 | Heat Production and other Energy Industries - Solid Fuels | **$CO_2$** | According to IPCC GHG uncertainty for main activity electricity and heat production, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is less than 1%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/ V2_2_Ch2_Stationary_Combustion.pdf (table 2.15). Therefore, the uncertainty was set at 1%. | According to the IPCC Guidelines, selecting a typical value for emission factors is within the 95%; confidence interval and uncertainty is less than 5%. Therefore, a value of 5% was selected. |
| 1A2 | Manufacturing Industries and Construction - solid fuels | **$CO_2$** | According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according to international standards and requirements was developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies, and was not fully in line with EU requirements. Therefore, the uncertainty was set at 5%. | According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected |
| 1A2 | Manufacturing Industries and | **$CO_2$** | According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according to international standards and requirements was | According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | Construction - biomass | | developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies and was not fully in line with EU requirements. Despite this, the uncertainty was set at 5%. | |
| 1A2 | Manufacturing Industries and Construction - liquid fuels | **$CO_2$** | According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according to international standards and requirements was developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies and was not fully in line with EU requirements. Despite this, the uncertainty was set at 5%. | According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected |
| 1A2 | Manufacturing Industries and Construction - Gaseous Fuels | **$CO_2$** | According to IPCC GHG uncertainty for Industrial combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 2-5%, but when data are based on extrapolation, uncertainty is about 3-10%. A complete official energy balance, according international standards and requirements was developed by the National Statistics Office of Georgia (GEOSTAT) in 2014 (for the 2013 reference period). The energy balance for 1990 was also developed by Official Statistics Office, however it was mostly based on soviet standards and methodologies and was not fully in line with EU requirements. Despite this, the uncertainty was set at 5%. | According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected |
| 1A3a | Civil aviation | **$CO_2$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (3.69). Therefore, a value of 5% was selected. | According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 4.2% was selected |
| 1A3ai | International Aviation (International Bunkers) - Liquid Fuels | **$CO_2$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (3.69). Therefore, a value of 5% was selected. | According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 4.2% was selected |
| 1A3b | Road Transportat | **$CO_2$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc- | According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 3.1% was selected |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | ion - Liquid Fuels | | nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected. | |
| 1A3b | Road transportation - Gaseous Fuels | **$CO_2$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected. | According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 3.9% was selected |
| 1A3c | Other transportation | **$CO_2$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected. | Typical 5%. |
| 1A3d | International water-borne navigation (International bunkers) - Liquid Fuels | **$CO_2$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf. Therefore, a value of 5% was selected. | According to the IPCC Guidelines and based of the expert assessment, uncertainty value of 4.2% was selected |
| 1A4a | Commercial/Institutional - solid fuels | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected |
| 1A4a | Commercial/Institutional - liquid fuels | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected |
| 1A4a | Commercial/Institutional - Gaseous Fuels | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected |
| 1A4a | Commercial/Institution | **$CO_2$** | According IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when | According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | al - biomass | | data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | |
| 1A4b | Residential - solid fuels | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected |
| 1A4b | Residential - liquid fuels | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected |
| 1A4b | Residential - Gaseous Fuels | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected |
| 1A4b | Residential - biomass | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected |
| 1A4c | Stationary - solid fuels | **$CO_2$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for solid fuels, the value of 12.4% for uncertainty was selected |

|  | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| 1A4c | Stationary-Liquid Fuels | $CO_2$ | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for liquid fuels, the value of 6.1% for uncertainty was selected |
| 1A4c | Stationary - Gaseous Fuels | $CO_2$ | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for gaseous fuels, the value of 3.9% for uncertainty was selected |
| 1A4c | Stationary - Biomass | $CO_2$ | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC Guidelines, for biomass, the value of 18.7% for uncertainty was selected |
| 1B1 | Fugitive Emissions from Solid Fuel Mining and transformation | $CO_2$ | Coal mining data provided by GEOSTAT is reliable and, therefore, the uncertainty value of 5% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/ V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16) | According to the IPPC methodology, using the typical emission factor for this category has a huge uncertainty value. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16) |
| 1B2 | Fugitive Emissions from Fuels - Oil and Natural Gas (Flaring, production, distribution) | $CO_2$ | Data on Oil and Natural Gas was provided by the Oil and Gas Corporation and is reliable. Therefore, an uncertainty value of 5% was chosen | According to the IPPC methodology, using the typical emission factor for this category has huge uncertainty value. Due to the complexity of the oil and gas industry, it is difficult to quantify the net uncertainties in the overall inventories, emission factors and activity data. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (table 4.2.4, table 4.2.5) |
| 2A1 | Cement Production | $CO_2$ | Activity data is quite accurate; therefore, its uncertainty value is within 5%. | Major source for emission factor uncertainty is associated with determining the CaO content of clinker. If clinker data are available, the uncertainty of the emission factor is equal to the uncertainty of the CaO fraction and the assumption is that it was all derived from |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | | | | CaCO3 (Table 2.3)122. According to the methodology, it is assumed that the content of CaO is standard, associated with 4-8% of uncertainty. That's why, the uncertainty of emission factors is about 5%. |
| 2A2 | Lime Production | **$CO_2$** | In Georgia, as far as lime production is scattered in many small enterprises, there is certain risk regarding full coverage. However, the National Statistics Office of Georgia (GEOSTAT),being the source for these data, has significantly improved data coverage in this area; nevertheless, according to the IPCC methodology the uncertainty could still be quite hig. Consequently, based on the experts' assessment, the uncertainty of activity data from this source is estimated as 20%. | The stoichiometric ratio is a precisenumber and, therefore, the uncertainty of the emission factor is the uncertainty of lime composition, in particular of the share of hydraulic lime that has 15% uncertainty in the emission factor (2% uncertainty in the types). Therefore, the total uncertainty value is 15% |
| 2A3 | Glass production | | Glass production data are typically measured fairly accurately (+/-5 percent) for Tier 1 and Tier 2 approaches. | Because emissions are estimated based on quantity of melted glass in each manufacturing process and default emission factors, the uncertainty of Tier 2 is higher than Tier 3. The emission factors can be expected to have an uncertainty of +/- 10 percent. |
| 2B1 | Ammonia Production | **$CO_2$** | Activity data was collected from the National Statistics Office of Georgia (GEOSTAT), as well as from the enterprise Rustavi Chemical Fertilizers Plant, which are rather accurate data. Emissions are calculated based on the volume of consumed natural gas, as well as based on the produced ammonia amount. Based on the expert judgment, their uncertainty is within 5%. | Based on the 2006 IPCC, the only required fuel uncertainty is estimated from determining the parameters of the $CO_2$ emissions coefficient for manufacturing the unit weight ammonia, which is about 6-7%, when using the Tier 1 approach. In Georgia's case, based on the expert assessment, the overall uncertainty of the $CO_2$ emission coefficient is around 6%. |
| 2C1 | Cast Iron and Steel Production | **$CO_2$** | According to guideline, the most important type of activity data is the amount of steel produced; each method is applicable and national statistics should be available and likely have an uncertainty of ± 10 percent. Therefore, uncertainty value of 10% was selected. | According to the 2006 IPCC methodology[123] the default emission factors for iron and steel production usedmay have an uncertainty of ± 25 percent (see table 4.4). |
| 2C2 | Ferroalloys Production | **$CO_2$** | According to IPCC methodology, the most important type of activity data is the amount of ferroalloy production by product type and national statistics should be available and likely have an uncertainty less than 5 percent. The activity data were collected from the National Statistics Office of Georgia (GEOSTAT), as well as from the Metallurgy research Institute of Georgia. Therefore, the data are rather accurate. Based on the expert assessment, their uncertainty value is 5%. | In case of using the Tier 1 method, the uncertainty of emission standard coefficients is estimated within the25% range. |

[122] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (pg. 2.17)

[123] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf (pg. 4.30)

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| 2D1 | Lubricant Use | **$CO_2$** | Much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used in individual countries, for which a default of 5 percent may be used in countries with well-developed energy statistics and 10-20 percent in other countries (PG. 5.10) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_5_Ch5_Non_Energy_Products.pdf | The default ODU factors developed are very uncertain, as they are based on limited knowledge of typical lubricant oxidation rates. Expert judgment suggests using a default uncertainty of 50 percent. |
| 5A | Forest land | **$CO_2$** | According to the IPCC methodology, uncertainties vary between 1-15% in 16 European countries (Laitat et al. 2000). Area data should be obtained using the guidance in Chapter 3 or from FAO (2000). Industrialized countries estimated an uncertainty in forest area as approximately 3%. In Georgia's case 5% uncertainty was selected. | In Finland, the uncertainty of basic wood density of pine, spruce and birch trees is up to 20% in studies of Hakkila (1968, 1979). The variability between forest stands of the same species should be lower or at most the same as for individual trees of the same species. In Finland, the uncertainty of biomass expansion factors for pine, spruce, and birch was approximately 10% (Lehtonen et al., 2003).<br>In eight Amazon tropical forest inventory plots, combined measurement errors led to errors of 10-30% in estimates of basal area change over periods of less than 10 years (Phillips et al., 2002).<br>The overall uncertainty of country-specific basic wood density values should be about 20% |
| 5B | Cropland | **$CO_2$** | Activity data are quite accurate. Based on the expert assessment, its uncertainty value is within 10%. | The sources of uncertainty when using the Tier 1 method include the degree of accuracy in land area estimates and in the default biomass carbon increment and loss rates. Uncertainty is likely to be low (<10%) in estimates of area under different cropping systems since most countries annually estimate cropland area using reliable methods. A published compilation of research on carbon stocks in agroforestry systems was used to derive the default data provided in Table 5.1 (Schroeder, 1994). While defaults were derived from multiple studies, their associated uncertainty ranges were not included in the publication. Therefore, a default uncertainty level of +75% of the parameter value has been assigned based on IPCC methodology and expert judgment. |
| 5C | Grassland | **$CO_2$** | Activity data are quite accurate. Based on the expert assessment, its uncertainty value is within 10%. | According to the IPCC methodology and based on the expert judgment, the default uncertainty value of 75% was selected. |
| 1A1 | Stationary fuel combustion | **$CH_4$** | Typical 5%. | According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate at 100% was selected. |

|  | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
|  |  |  |  | https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf |
| 1A2 | Fuel combustion | **$CH_4$** | Typical 5%. | According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate at 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf |
| 1A3a | Civil aviation | **$CH_4$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (3.69). Therefore, a value of 5% was selected. | According to IPCC GHG methodology, the uncertainty of the CH4 emission factor may range between -57 and +100 percent. In Georgia's case, uncertainty value of 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.69) |
| 1A3b | Road transportation | **$CH_4$** | Typical 5%. | Methane usually contributes less than 1% of the CO2-equivalent emissions from the transportation sector. Experts believe that there is an uncertainty of ±40% in the CH4 estimate. That's why uncertainty value of 40% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.29) |
| 1A3c | Other transportation | **$CH_4$** | Typical 5%. | Typical 100%. |
| 1A4a | Commercial/Institutional | **$CH_4$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC GPG document, Table 2.12, the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38) |
| 1A4b | Residential | **$CH_4$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about | According to the IPCC GPG document, Table 2.12, the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate 100% was selected. https://www.ipcc- |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | | | 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38) |
| 1A4c | Stationary | **$CH_4$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC GPG document, Table 2.12, the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38) |
| 1B1 | Fugitive Emissions from Solid Fuel Mining and transformation | **$CH_4$** | Coal mining data provided by GEOSTAT are reliable and, therefore, the uncertainty value of 5% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16), (table 4.2.4, table 4.2.5) | According to the IPPC methodology, using the typical emission factor for this category has a huge uncertainty value. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.15, 4.16), (table 4.2.4, table 4.2.5) |
| 1B2 | Fugitive Emissions from oil Extraction | **$CH_4$** | Data on Oil extraction are provided by the Oil and Gas Corporation and are reliable. Therefore, the uncertainty value of 5% was chosen. | According to the IPPC methodology, using the typical emission factor for this category has huge uncertainty value. Due to the complexity of the oil and gas industry, it is difficult to quantify the net uncertainties in the overall inventories, emission factors and activity data. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (table 4.2.4, table 4.2.5) |
| 1B2 | Fugitive Emissions from oil and natural gas production | **$CH_4$** | Data on gas production were provided by the Oil and Gas Corporation and are reliable. Therefore, an uncertainty value of 5% was chosen. | According to the IPPC methodology, using the typical emission factor for this category has huge uncertainty value. Due to the complexity of the oil and gas industry, it is difficult to quantify the net uncertainties in the overall inventories, emission factors and activity data. Therefore, an uncertainty value of 300% was chosen. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (table 4.2.4, table 4.2.5) |
| 1B2 | Fugitive Emissions from oil and natural gas | **$CH_4$** | The data were calculated using analytical method, they were based on estimation and, therefore, an uncertainty value of 10% was chosen. | According to the IPPC methodology, 100% value of uncertainty was chosen for emission factors. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf (pg. 4.49, 4.50) |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | Transmission and distribution | | | |
| 4A | Enteric fermentation | **$CH_4$** | The activity data were taken from the official statistical publication and are reliable. Classification and distribution of cattle is not entirely consistent with the IPCC standard on dairy and non-dairy cattle, however, it could be assumed, that the data provided by GEOSTAT about "cows" and "other cattle" are in conformity with the classification of "dairy" and "non-dairy cattle", as cows were intended for exactly dairy purpose in the case of Georgia, and the rest for beef production. Therefore, the uncertainty of activity data is moderate and does not exceed of 10%. | As the emission factors for the Tier 1 method are not based on country-specific data, they may not accurately represent a country's livestock characteristics, and may be highly uncertain as a result. Emission factors estimated using the Tier 1 method are unlikely to be known more precisely than ± 30% and may be uncertain to ± 50%. In case of Georgia uncertainty of 30% was selected, as for activity data (heads of cattle by species), they should be considered as reliable, since they are based on Official Statistical Data from GEOSTAT. |
| 4B | Manure management | **$CH_4$** | The uncertainty of activity data related to animal number is estimated at 10%, as it is based on official statistical data. | According to the IPCC GPG, 50% is taken for methane emissions-related uncertainty. |
| 3F | Field burning of Agricultural Residues (3.F) | **$CH_4$** | According to IPCC 2006 methodology and based on expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 10% was selected. | According to IPCC 2006 methodology and based on the expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 50% was selected. |
| 6A | Solid Waste Disposal Sides | **$CH_4$** | Calculations were made based on the IPCC 2006 methodology, Table 3.5; The final uncertainty of the activity data was estimated at 30%. https://www.ipccnggip.iges.or.jp/public/ 2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf (pg. 3.27) | Calculations were made based on the IPCC 2006 methodology, Table 3.5; and similar calculations were performed in the SNC. The value of uncertainty for emission factor 30% was chosen. |
| 6B1 | Industrial Waste Water handling | **$CH_4$** | Calculations were made based on the IPCC 2006 methodology, Table 6.10 and similar calculations were performed in the SNC. The final uncertainty of the activity data was set at 50%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf (pg. 6.23) | Calculations were made based on the IPCC 2006 methodology, Table 6.10 and similar calculations were performed in the SNC. The final uncertainty in emission factors was set at 30%. |
| 6B2 | Domestic Waste Water handling | **$CH_4$** | Calculations were made based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 6.7; The final uncertainty of the activity data was set at 5%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf | Calculations were made based on the 2006 IPCC Guidelines (Table 6.7) and similar calculations were performed in the SNC. The final uncertainty in emission factors was set at 30%. |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | | | V5_6_Ch6_Wastewater.pdf (pg. 6.17) | |
| 1A1 | Stationary fuel combustion | **$N_2O$** | Typical 5%. | According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate at 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf |
| 1A2 | Fuel combustion | **$N_2O$** | Typical 5%. | According to the IPCC GPG document, Table 2.12 reads that the uncertainty boundary is within the 50%-150% interval. In Georgia's case the intermediate of 100% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf |
| 1A3a | Civil aviation | **$N_2O$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent). Therefore, a value of 5% was selected. | according to IPCC GHG methodology, the uncertainty of the N2O emission factor may range between -70 and +150 percent. Based on the expert assessment, uncertainty value of 150% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.69) |
| 1A3ai | International aviation | **$N_2O$** | According to the IPCC Guidelines, with complete survey data, the uncertainty may be very low (less than 5 percent). Therefore, a value of 5% was selected. | According to IPCC GHG methodology, the uncertainty of the N2O emission factor may range between -70 and +150 percent. Based on the expert assessment, uncertainty value of 150% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.69) |
| 1A3b | Road transportation | **$N_2O$** | Typical 5%. | Typical 50% https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf (pg. 3.29). Nitrous oxide usually contributes approximately 3% to the CO2-equivalent emissions from the transportation sector. Theexpert judgment suggests that the uncertainty of the N2O estimate may be more than ±50%. The major source of uncertainty is related to the emission factors. |
| 1A3c | Other transportation | **$N_2O$** | Typical 5% | Typical 100% |
| 1A4a | Commercial/Institutional | **$N_2O$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is | According to the IPCC GPG document, Table 2.12, uncertainty ranges from one-tenth of the mean value, to ten times the mean value that should be applied. In this case, an uncertainty value of 150% was |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| | | | about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38) |
| 1A4b | Residential | **$N_2O$** | According to IPCC GHG uncertainty for commercial, institutional, residential combustion, for countries with well-developed statistical systems, when data are based on surveys (or administrative sources), is about 3-5%, but when data are based on extrapolation, uncertainty is about 5-10%. In Georgia's case uncertainty of 5% was chosen, as comprehensive energy data collection system for official statistics exists since 2014. | According to the IPCC GPG document, Table 2.12, uncertainty ranges from one-tenth of the mean value, to ten times the mean value that should be applied. In this case, an uncertainty value of 150% was selected. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38) |
| 1A4c | Stationary | **$N_2O$** | uncertainty of 5% was chosen | According to the IPCC methodology https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf (pg.2.38), an uncertainty value of 150% was selected. |
| 2B2 | Nitric Acid Production | **$N_2O$** | The activity data are rather accurate. Based on the expert judgment its uncertainty value does not exceed 5%. | A new IPCC manual allows standard boundaries of 20% uncertainty assessment for medium-pressure technology plants |
| 2G3 | Medical Surgeries | **$N_2O$** | According to IPCC 2006 manual, activity data uncertainties are estimated based on the expert judgment. Uncertainty value of 5% was estimated https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf (pg. 8.37) | According to IPCC 2006 manual, uncertainties are estimated byased on the expert judgment. Uncertainty value was estimated at 10%. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf (pg. 8.37) |
| 4B | Manure management | **$N_2O$** | The uncertainty of activity data for nitrous oxide emissions calculation in the manure management sector were estimated at 50%, as there is no exact information about the management systems. | According to IPCC GPG, the uncertainty for emission factors was estimated at 100% |
| 4D1 | Direct soil emissions | **$N_2O$** | The activity data were collected from National Statistics Office of Georgia (GEOSTAT), which is a competent source and quite accurate. Therefore, 10% was selected as the indicator of uncertainty. | The uncertainty for emission factors were taken from the standard range of the IPCC GPG, there were alsobased on the expert assessment and are equal to 25%. |
| 4D3 | Indirect soil emissions | **$N_2O$** | The uncertainty of activity data is also quite high and related to the assumption on the percentage leached. In addition, the nitrogen content in fertilizers also has uncertainty. Finally, the uncertainty of activity data was set at 50%. | According to IPCC methodology and expert judgment emission factor uncertainties are at least in order of magnitude and volatilisation fractions of about +/−50%. |
| 3F | Field burning of Agricultural Residues (3.F) | **$N_2O$** | According to IPCC 2006 methodology and based on expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 10% was selected. | According to IPCC 2006 methodology and based the on expert assessment https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf (table 2.27, table 2.5, table 2.6), the value of 50% was selected. |

| | IPCC source-category | Gas | Uncertainty values in activity data and its selection reasons | Uncertainty in emission factors and its selection reasons |
|---|---|---|---|---|
| 6B2 | Domestic Waste Water handling | **$N_2O$** | The only national value for the emission calculation formula is the number of the populations, for which the uncertainty is estimated within 5% limits. Consequently, 5% of uncertainty value was chosen. | According to IPCC methodology and the expert judgment, emission factor uncertainties are estimated at 70%. |
| 2F | Consumption of halocarbons and sulfur hexafluoride (Refrigeration and Air Conditioning Equipment) | **HFC** | Activity dataare relatively accurate. Based on the expert judgment, its uncertainty value is 5% | According to the IPCC GPG, the uncertainty level for standard coefficients of emission is estimated at 25%. |
| 2F | Consumption of halocarbons and sulfur hexafluoride (Emissions from Appliances (electrical equipment) | **SF6** | Activity data are relatively accurate. Based on the expert judgment, its uncertainty value is 5% | According to the IPCC GPG, tier 1 estimates are set at an uncertainty level of 100% or more, representing an estimate of actual emissions. Therefore, the value of 100% was selected. |

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